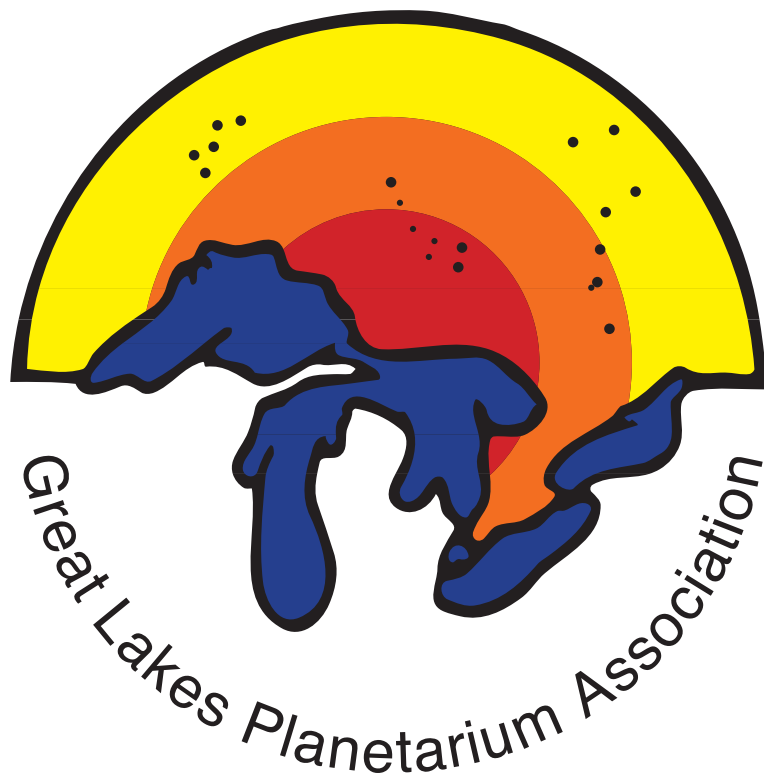


**PROCEEDINGS OF THE 55TH ANNUAL
G.L.P.A. CONFERENCE**



**EAST LANSING, MICHIGAN
OCTOBER 10-13, 2018**

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In future volumes of this series, we request all authors to carefully observe directions and deadlines supplied in the Instructions to Authors in order to expedite preparation of the Proceedings.

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LIVING AMONG THE STARS

2018 Armand Spitz Lecture

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Abstract: Armand Spitz is introduced through several of his quotes. Natural interpretation as the National Park Service defines it is described, with parallels drawn to planetarium presentations. Diversity is discussed using research on the notions of “white privilege” and “unconscious bias.” The importance of random events in a person’s life is explored. Prof. Steven Pinker’s reliance on data to offer an optimistic view of the world is noted, with webpage references provided. A strategy planetarians might consider to help ease the public’s distrust of science is offered. The importance of people feeling a part of the universe at large is declared.

I’ve been given an hour to offer my thoughts and perspective. Let’s look at this realistically. You’ve been here for little more than two days, two jam packed days that start early and go late. Most civilized conferences end each day with the evening meal, but GLPA has to make sure you get your money’s worth! There’s a full schedule after dinner... and that’s followed by the hospitality suite until who knows when. I understand some of you might lose focus here. That’s ok. I’ve been in those shoes. Remember the *Proceedings* will be available. I’m aware that I’m holding up the hospitality suite. So let’s get moving.

It’s a pleasure to be with you and asked to give the Spitz Lecture, named after the pioneer of the small planetarium. I find it humbling to honor the name of Armand Spitz. His enthusiasm for and dedication to promoting astronomy to the “masses” was unparalleled in his time. When I see the planetariums of today and the multitude of educational activities associated with planetariums I can’t help but wonder, what would Armand think? How could he not be proud?

For newer members, who may not be that familiar with Armand Spitz, you can find a particularly good overview of his life written by Brent Abbatantuono, as part of a master’s thesis and printed in the March 1995 IPS *Planetarian*. It is freely available on the web also.

That *Planetarian* article opens with a quote from Armand. It says a great deal about the man, I think, and is pertinent to this occasion. So I’ll read it.

“I never expected to make any substantial contribution to astronomy or science, but what greater satisfaction can I have, than to have one very famous astronomer tell me that he gained his first interest in astronomy through viewing a Spitz planetarium when he was a small boy. I can only hope that in whatever celestial book-keeping there is, I will be given indirect credit for helping along the knowledge of the heavens.”

I find that a statement to which we all can aspire.

It also sets a nice tone to begin my talk.

Right off I should confess that I was previously asked to present the Spitz Lecture, but at that time I felt I didn’t possess the credentials to do the job. My vision of the ideal lecturer was someone who had a history of accomplishments in the profession, an elder statesman or stateswoman figure. Well, now I’m here. I possess half of the requirements I deemed necessary; I am elder. I will attempt to wing the statesman part. One advantage I found: it is true what they say about growing older. I have become more philosophical/reflective with the years.

GLPA as family

First, I must say how impressed I am by GLPA. As a professional organization it’s a wonder to behold. The number and quality of resources and activities available are remarkable, both for those who attend the conferences and state meetings and those who are unable. The camaraderie is inspirational.

And all of this is run by volunteers!—most of whom have taxing full time jobs. The kind of effort put forth by this group can only occur through a deep passion for and strong belief in what the group is doing. I say thank you for all I have received over the years. Being a part of GLPA has enriched my professional life in many ways.

I’ve come to think of GLPA as a family and these gatherings as large family reunions, as many of you do. To me the comparisons between family reunion and GLPA conference are curious. For instance, no matter how infrequently we may contact each other between conferences, there’s an immediate affinity for each other, whether longtime friends or new acquaintances. It’s like we share DNA. It’s also the place to exchange the latest news ... and gossip. There are even people at conferences who take on roles associated with families. For example, what family would be complete without a “crazy uncle”? I think we’ll agree that we have those in GLPA. You know who you are.

And I've always been amazed at how quickly members are willing to help out each other, whether it's sharing a new technique or loaning a piece of equipment, as examples. No jealousy, no competition in this family! A word to newcomers, in case you haven't discovered already. Don't hesitate to jump right in and partake. Ask questions or ask for advice. And don't overlook the social hours, better known as hospitality suites. If some groups seem like cliques to you, they aren't. Go introduce yourself.

Enough of the family analogy. Let me just say you should all be extremely proud of the Great Lakes Planetarium Association.

I'd like to cite a personal example of GLPA's value. The first GLPA conference I attended was the second one ever held (I missed being a founding member by one meeting, but I had no idea about that at the time). It convened in Cincinnati in 1966. (I know what you are thinking, he doesn't look that old, right.) Ralph Ewers was the director there as well as our conference host. At that time I was a senior in college. I was an astronomy TA. My college had installed a planetarium (Spitz AP3) the previous year. I had learned the bare rudiments of how to use it. My astronomy professor invited me and another student to attend the conference with him because he thought we would benefit from exposure to GLPA. Clearly he was right in my case. There I was captivated by the almost magical quality of the planetarium demos I saw, and the impressive creativity of the people who presented them. It's also there that I first grasped the understanding that people got paid to do this. Planetariuming was a real honest-to-goodness profession, a career! And a bunch of years later, here I am.

Moving on.

Interpreter of Science

Another Armand Spitz quote makes a nice introduction to my next topic:

"I am not a mathematical astronomer. I don't get along with mathematical equations. I am not very much of a scientist. You can call me an interpreter of science if you want to."

Remember that phrase "interpreter of science."

Early in my career I had the good fortune to be part of a project to bring astronomy to the National Parks. It will come as no surprise to many of you that Von Del Chamberlain was the principal investigator on the grant. I like to think Von Del started the movement that is now common within the parks, but I'll allow the possibility that other people, some here in fact, independently saw the value of using the night skies of the parks for public astronomy.

Through that experience I became acquainted with a number of naturalists (most people know them as rangers; they tend to call themselves interpreters and their interactions with the visitors, interpretation). I also learned about their thinking regarding the presentations they make to the visitors and realized there is much in common between what they do and what we undertake in our planetariums.

At that time the National Park Service philosophy for naturalist interpreters was summarized in the book entitled *Interpreting Our Heritage* by Freeman Tilden. It is no longer in print but freely available on the web. (Just search for the title.) For this talk I dug out my dog-eared copy and looked at my underlinings for nuggets of wisdom to share.

In the margin on one of the pages I found a note I had written to myself. It said "I am an astronomy interpreter." That reinforced my intent to tell you about the book.

So here are Freeman Tilden's Six Principles of Interpretation, around which the first half of the book is based:

Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile.

Information, as such, is not Interpretation. Interpretation is revelation based upon information. But they are entirely different things. However, all interpretation includes information.

Interpretation is an art, which combines many arts, whether the materials presented are scientific, historical or architectural. Any art is in some degree teachable.

The chief aim of Interpretation is not instruction, but provocation.

Interpretation should aim to present a whole rather than a part, and must address itself to the whole person (man) rather than any phase.

Interpretation addressed to children (say, up to the age of twelve) should not be a dilution of the presentation to adults, but should follow a fundamentally different approach. To be at its best it will require a separate program.

We are astronomy interpreters.

A few more tidbits from the book:

This quote comes from Anatole France, a French poet/novelist who won the Nobel prize for literature in 1922.

"Do not try to satisfy your vanity by teaching a great many things. Awaken people's curiosity. It is enough to open minds; do not overload them. "Put there just a spark. If there is some good inflammable stuff, it will catch fire."

The number one fault I see in myself, particularly in the early days, and others of us in the trade, is presenting too many facts, too much material. It's a natural tendency, of course. When we are passionate for a subject we want to share it with others. We figure if we can just give them enough information, they will begin to like it too.

Another:

"The most common error... derives from the fact that the writer has in mind the question: 'What do I wish to say?' ... It is of no importance whatever, ... The important thing is what does the audience wish to hear?"

"Education is knowledge treated imaginatively."

I had to think about the word "imaginatively" in this age of "alternate truths." To me the point is, acquiring information in a planetarium setting should always be a pleasant experience, at minimum.

"It is elementary that participation in our programming must be physical."

The writer was referring to programs at historical parks, I think, but I firmly believe there should be a physical component in planetarium activities when possible. I always considered the planetarium as a means to an end, the end being for the visitors to physically connect to the real nighttime sky. We, at Abrams, would try to provide that opportunity with outdoor observing using naked eye, binoculars, and telescopes when possible. I still vividly remember my first view of Saturn through a friend's telescope. I was 11 years old at the time. To me that's a powerful statement for the physical aspect.

"Cultivate the power that lies in understatement." Somewhat related to this, I use to wonder if we, Abrams, and other planetariums oversell astronomical events with exclamations like 'It's the closest full Moon in five centuries!!!' which may be technically true, but to the public not noticeably different than next month's full Moon.

"Whatever is delivered without enthusiasm will be received without interest."

That's enough to give you the flavor. Many more tidbits await. Download a copy of the book and browse it for yourself.

Diversity

I was pleased to notice recently that IPS is forming a Working Group for Equity, Diversity, and Inclusion. And I also spotted a session on this conference schedule exploring with the same topic, I think. I'm glad to see the subject getting a formal treatment in our profession. I also see the importance of each of us continually examining the issue on a personal basis. I admit being a bit late to this realization. I blame it on living in this liberal bubble known as East Lansing. I always tried to be sensitive to issues of diversity, but mostly I was naive.

The notion of "white privilege" woke me up. Upon first encountering that viewpoint, I found myself defensive. An odd feeling for someone who supports diversity, I thought. And then I read an analogy that mixed bicycle riding and white privilege. I enjoy bike riding but seldom do so on busy streets—too

dangerous. I've long thought the laws equating bicycles to cars are poor, unrealistic. In my opinion, every busy street should have a dedicated bike lane with a physical barrier between car and bike.

The gist of the analogy is that bikes have to ride on a system designed for cars, which means drivers take for granted that the system is theirs—a natural assumption, really, particularly if you don't ride a bike. The bikes are likely considered interlopers, consciously or unconsciously. Further, the system allows drivers to intimidate and hassle bikers without them ever being aware they are doing it (not giving the biker enough space, turning without attention to bike presence, for example. Since I'm both a rider and a driver, the experience really hit home.

White people operate in a system designed by them and largely for them without realizing it. The system could naturally allow unintended harassment of non-whites without whites having a clue. That was a powerful recognition for me. Understand also that this reasoning applies to gender issues, the disabled, and so forth, in essence any majority/minority situation.

That realization led me to the concept of "unconscious bias." The key word here is "unconscious."

Jennifer Eberhardt, a social psychology professor at Stanford, produced some of the early ground breaking research on unconscious bias. In one experiment she had students look at a screen and see how quickly they could identify various images that slowly came into focus. What the students didn't know is they were first subliminally shown a burst of human faces. For one group the faces were black, the other white.

For most images the students were shown there was little difference in how quickly the two groups recognized the object. But when the object was a gun, the students who were exposed to the black faces identified the weapon significantly sooner.

Much research now exists on the presence and nature of unconscious or implicit bias. The effect is real.

The important point for each of us is to be aware that unconscious bias exists; it is a common human circumstance. It is not a deep moral failing that requires punishment. Instead we should try to root it out in ourselves and our organizations, and attempt to manage its consequences.

Luck

The topic of biases and privileges leads me to the concept of, for lack of a better term, "luck." Perhaps my least favorite expression is "self-made man" (or woman or person, although almost always man). I cringe whenever I hear or read it. There is no such person. I find the notion egotistical at least and certainly delusional. It is fine to celebrate an important accomplishment but to imply it was solely through the efforts of one individual is to completely dismiss anyone else's effort or influence and what I will call the notion of luck.

To be clear, I don't mean any hocus pocus supernatural incident, no four leaf clovers or tea leaves. The definition of "luck" I'm using: *It's a chance event, not brought on by the individual's action.*

If each of us took the time to examine in some detail how we got to where we are, we'd find luck played a significant role.

Since I've been retired I've had time to reflect, and I traced my planetarium path. Allow me to briefly elaborate in the hope that it might prod you to think about your own situation.

I was born in a democratic country (luck), to a middle class mother and father who were supportive and loving (luck). I was a child at an impressionable age near the beginning of the space age (luck). As a teenager I witnessed the launch of Sputnik and the early space race (luck). I was able to attend college (luck). The college I chose installed a planetarium (luck). I was picked to be an astronomy lab assistant (luck). My astronomy instructor was (and still is) an exceptional teacher (luck). I was taken to a GLPA conference when I was a student (luck). While in grad school my draft number came up (luck). Before serving, I was hired into a job that allowed a teaching deferment (luck). The job was in an outstanding planetarium with an exceptional staff (luck).

You get the point. Each of you has your own random walk of luck, and every one of our trails ended, to this point, in a planetarium. To my way of thinking, an exceptional piece of good luck.

I think an examination of luck is a powerful tool that would benefit anyone. I'd like to see it more widely used and discussed. We can all endure a little more humility.

We are in trying times, with relentless negativity and deep divisions. For most of us it's an unsettling experience, a time of uncertainty. A time when it's easy to think the country if not the world is going to hell in the proverbial hand basket. I admit to being caught up in the pessimism. I have been known to say the situation is so difficult and immense it seems that a revolution may be required to recover. I was at least half serious. I'm not alone. Many polls have shown that people think the world is getting worse. And it's not just an American opinion. Most other people around the world believe the same way.

How did we get to this state? One theory suggests the trend began with the Vietnam War and Watergate when we as a country began to question our leaders, eventually spreading to the current state where everything is aggressively questioned.

News reporting and social media are certainly one reason for this negative attitude. By its nature news deals with the extraordinary, the exceptional, which is usually not the optimistic. The same goes for social media. Sensationalism is more attention grabbing and more likely to be passed on without scrutiny.

Or perhaps it's simply because in the early days of human evolution, to be fearful provided a better chance of survival. A less concerned approach more often resulted in death and the loss of those genes to the gene pool.

An Optimistic View of the World

Psychologists offer a bit more insight:

They have known for some time that people see their own lives more favorably than average. We think we are less likely to be divorced, get ill, be laid off, etc. But when asked about society as a whole we are more pessimistic.

Psychologists also observe that what can be recalled most easily from memory is what people believe will most likely occur. That's why the endless negativity on media has such a pervasive effect on society. It is part of what they refer to as the availability heuristic.

The more I contemplated, the more I focused on the notion of a revolution. I think my wife was beginning to worry about me. Then I realized that, indeed, we already are in the midst of a revolution, the "digital revolution." I recalled the general circumstances of the Industrial Revolution from my high school history. I remember it was a time of general upheaval. People's lives changed dramatically in a couple of generations. But the key point that struck me was that the big picture over time was positive. Individuals were hurt but civilization advanced. Would that pattern repeat for our current revolution? I simplistically began to think there was hope.

Then, I happened across a TED [Technology, Entertainment, Design] talk by Harvard psychology professor, Steven Pinker. I'd run across the name before but hadn't paid much attention. He's well known in the field of psycholinguistics. He's also written a number of popular science books that have received acclaim. His latest book is *Enlightenment Now*, subtitled *The Case For Reason, Science, Humanism, and Progress*. Incidentally, he's also a Fellow of the Committee for Skeptical Inquiry that, among other things, publishes the *Skeptical Inquirer*. I realize a number of you are familiar with this organization but if you aren't, I highly recommend you look them up and consider subscribing to *Skeptical Inquirer* or read it in the library. (These days I find myself more likely to read *Skeptical Inquirer* cover to cover than I am *Sky & Telescope*.)

Prof. Pinker offers a radically optimistic viewpoint. He insists that by almost any measure of human progress the world is better than ever. And he wields the data to prove it.

To counteract our negatively skewed thinking Pinker says we merely need to pay attention to the numbers. And boy, does he mean numbers. His style of bulldozing you with facts may be overwhelming and off-putting to some, but he offers plenty of sources for confirmation on line to view at leisure. His three favorite websites are: ourworldindata.org (Max Roser); humanprogress.org (Marian Tupy of Cato Institute); gapminder.org (Hans Rosling). For me he provides a strong antidote to the negativity.

How We Know What We Know

On that happier note, I move to the "elephant in the room."

I'd feel remiss if I didn't bring up the topic: I refer to the "war on science." It's part of a larger threat to change the way we think about truth—primarily for political reasons, as I see it. How we got to this point and the role politics plays is beyond the scope of this talk. But thinking about what we as planetariums can do about it is not. I don't know to what extent the planetarium community has been actively involved with this problem, so pardon me if I come across as naive.

Clearly the loss of trust in science is an enormous problem, possibly earth-shattering, literally, with many and hard-to-pinpoint causes. Admittedly planetariums are a small part of the science field. But because we are a significant contact with the public it seems worth our effort to do something.

One idea to consider, in my view, is to be more open about how we know what we know in our presentations and in interactions with visitors. Most visitors will think that what they hear or see from us is hard fact unless we are careful to indicate otherwise. This, of course, is due to a lack of the general public's understanding about how science works. I, like most of you, have been hanging out in this science shell since college, if not before. Empirical truth is second nature to us. Incidentally, I prefer to call it contingent truth. I think that term is easier for non-science folks to understand, and immediately says something about the process involved. I am amazed at how many well-educated people don't get how science works. We have to be more deliberate in our interactions and our programming.

It's a difficult balance between engaging and overwhelming our audiences. I personally think an entire planetarium show could be devoted to how we know, with well-chosen examples to illustrate the scientific/empirical/contingent approach.

I was once invited to give a talk to an adult inquiry club. I was asked to talk about some of the astronomy topics recently in the news and explain about how we know. I chose the Big Bang, Dark Matter, Dark Energy, and a few other "hot topics." Preparing for the presentation was a chore, to be sure, but valuable. It let me update my own knowledge as well as work to construct simpler explanations. It was an informative experience for me and one that made me wonder why we don't do more of that. I'll pass that question on to you.

I'm curious if there has been any discussion or papers within GLPA regarding this approach. I'm thinking an analogy-sharing effort among members could be useful.

Enough trying to solve the world's problems. Time to end on a more positive note.

Living Among the Stars

Have you realized or thought recently about what a great job you have? Sure, there are the usual day-to-day issues: long hours, inadequate budgets, middle school classes from Dante's *Inferno*, a person who has "purchased" a star and wants you to show them where to find it. But think about it: how many people get to say everyday, they work with the universe. We get to mix education, science, and art. (and play with gadgets! These days the gadgets

are mostly digital but they are still gadgets.)

When I was starting out in this field, I use to declare "Everyone is interested in astronomy. You just have to find what part tickles their fancy." I still believe that. I was once at a planetarium conference, I can't remember which one, where Carl Sagan was an invited speaker. He gave a public talk to which we were also invited. After the speech, a dozen or so planetarium people cornered him to ask questions. I don't remember what question prompted the response, but my hero Carl said children should not be taught the constellations; they should be introduced to, what I took to be astrophysics, from his description, but at a level, of course, that they could understand. I was floored. To me, one of the great attributes of astronomy is that it embraces so many topics.

A simple definition of astronomy is "the study of stars, planets, and space." But we all know it embodies so much more. Certainly there's Carl's astrophysics—pretty much all branches of physics, in fact, as well as chemistry, biology, mathematics, optics, space exploration/travel, timekeeping, navigation. There's history, cultural ideas—that's where I'd put constellations—literature, music, art (van Gogh immediately comes to my mind) ... you fill in some more.

Something for everyone, I say.

To me contemplating the many topics of astronomy is both an exhilarating and humbling experience. And for you, too, I'm sure. What's even more important, I think, is that our planetarium visitors share that same exhilarating/humbling response. You've seen it yourselves, on their faces, in their reactions, in the questions they ask. It's what Carl Sagan called the Cosmic Perspective. I suggest the term "Living Among the Stars." To me that phrase evokes a more personal experience.

Why should we be concerned that our patrons understand that they are living among the stars? I think it's absolutely imperative to the human experience to have that viewpoint. Particularly now, the way this country (and world) finds itself, with "alternative facts," distrust of science, and extreme polarization, akin to tribal warfare. That sense of humility that is gained by coming face to face with the enormity of the universe and understanding that each one of us is connected to it, and to each other, is a strong antidote. We have the ability, allow me to say, the responsibility, to promote that sensitivity wherever and whenever possible. Imagine what the country might be like if every Representative and Senator, or even just the majority of Congress, had that connection of living among the stars.

Living among the stars.

What I'm saying is yes, our work is interesting. It's also important. I think it should be considered vital to the future of humankind. I bid you: continue the good work, among the stars.

It's been great sharing the universe with you, tonight, and for the last several (four or five) decades. Thanks for your attention.

VIRTUAL TOUR OF THE NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY

Zachary Constan

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Abstract: The “Virtual Tour” of the Facility for Rare Isotope Beams and National Superconducting Cyclotron Laboratory includes full-dome images of the experimental vaults, 3D models of equipment, and animations that demonstrate how our research gets done. Using MSU’s Abrams Planetarium, we can “go” places in the lab that most visitors never see! The tour will be conducted by NSCL outreach coordinator Zach Constan and introduced by Professor Jaideep Singh, whose career grant from the National Science Foundation funded the creation and implementation of this project.

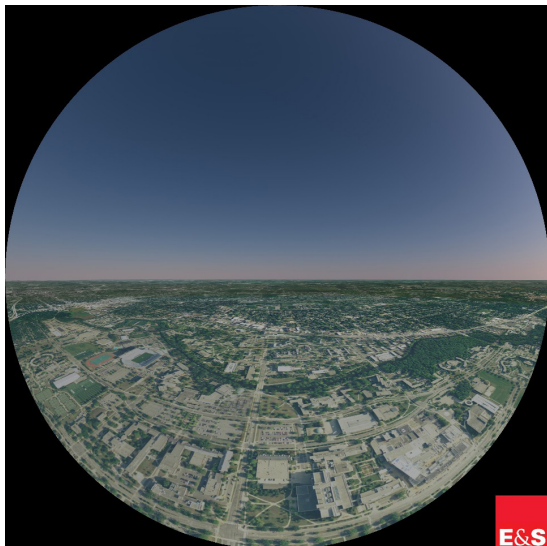
Good morning! I’m Zach Constan, the Outreach Coordinator for the National Superconducting Cyclotron Laboratory at Michigan State University. My job is to explain to people what goes on in that building on campus. Our outreach activities include tours, public talks, science festivals, summer camps, open houses, etc.

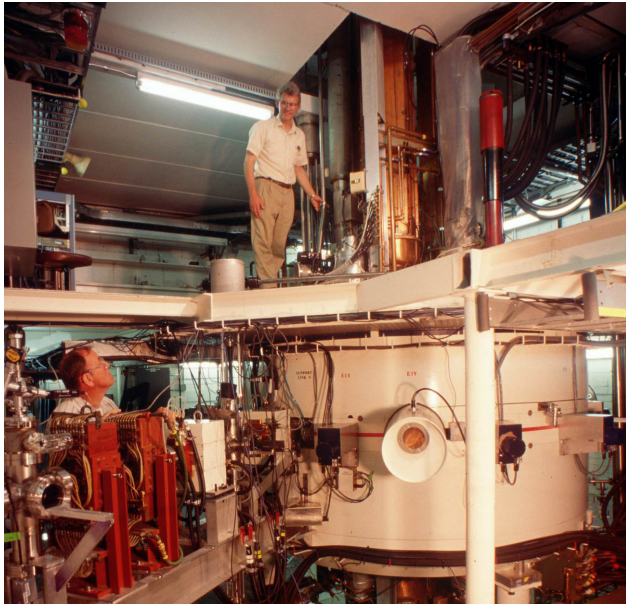
We give tours to ~3500 people per year at the lab, but there are many groups that cannot tour—maybe they have too many visitors, or the walking part is a barrier, or they don’t have enough time. Developing this “virtual tour” with Abrams Planetarium has made it possible to put those guests “inside” the laboratory in a different way... indeed, they get to see areas of the lab that regular tour groups cannot go to! We’re tremendously happy to have this show available for guests, and Catherine Hermanson is currently working on an updated version to premiere at the next MSU Science Festival in April. This is generously funded by the broader impacts portion of Dr. Jaideep Singh’s NSF CAREER award.

The show starts with a high-level view of East Lansing. You can see most of MSU here, and the NSCL is one unassuming building less than a block from Abrams. Thousands of people walk by it every day and have no idea what’s going on inside... in fact, I used to be one of those students. Let’s go inside to our first stop: the Atrium.

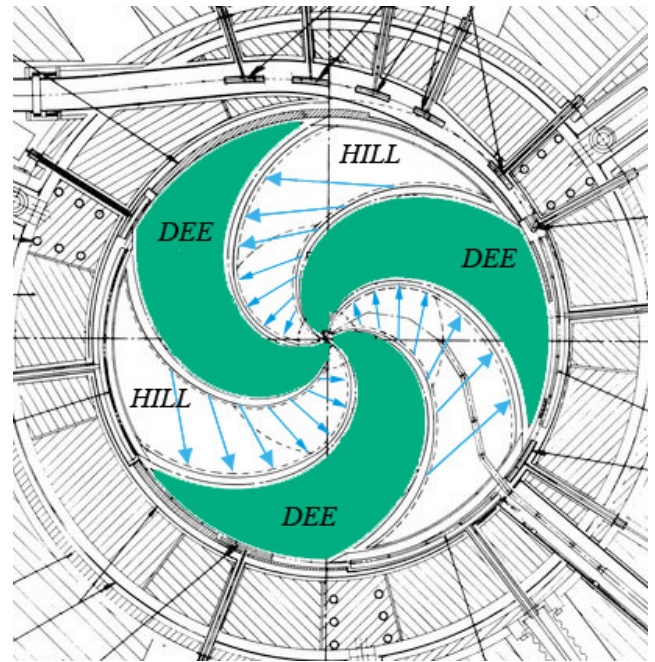


The Atrium is our lunchroom, basically. This photosphere lets us look around it, and I can turn the view around. It’s very disorienting, especially when you’re standing up. Those plants are real, by the way. On one wall is a big mural, and behind that wall are the cyclotrons. Yes, we eat lunch (or ice cream, or bagels) next to the accelerators. Let’s go to the K500 cyclotron now.

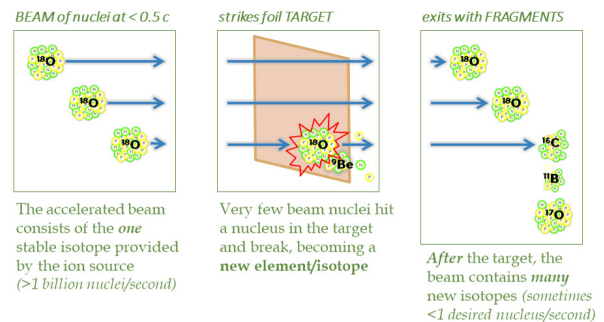
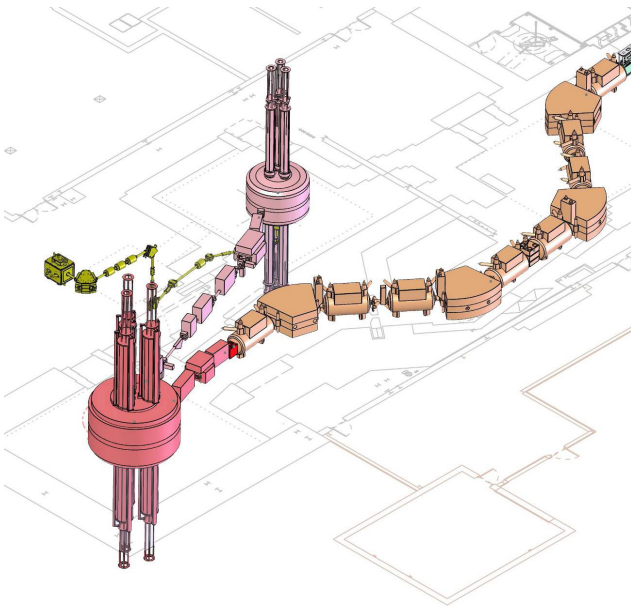




You're looking at the world's first superconducting cyclotron, invented here at MSU. That helps explain why a farm school like us now has the number one nuclear science program in the country! This machine runs 24 hours a day for most of the year—I almost never get to show it off to anyone, but you always get to see it on the virtual tour! That white cylinder is 10 feet across and five stories tall. Stable nuclei are fed up into it from below, and then the cyclotron accelerates them in a circle (hence, “cyclo”). When they spiral to the edge and escape this machine, they're traveling 30,000 miles per second. That's not fast enough.

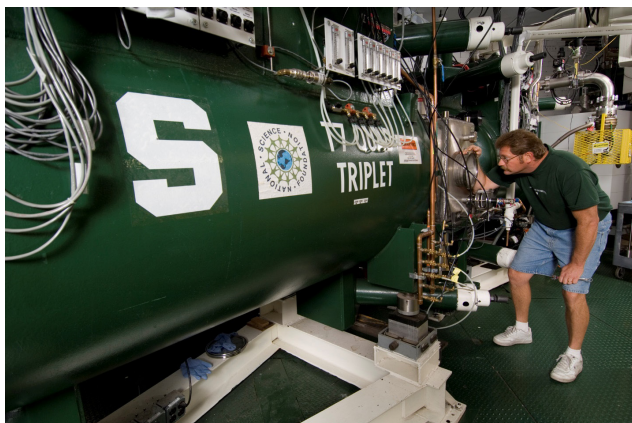


This is a simple animation of what is happening in the cyclotron. The spiral objects that look like fan blades are called “dees”, and a nucleus enters in the middle. The nucleus travels in a circle because of a strong magnetic field, while the “dees” charge to 140 thousand volts. That high electric field accelerates the nucleus so it spirals out to the edge. When it gets to the edge, it escapes the cyclotron at incredible speed, traveling down a pipe to the next step.

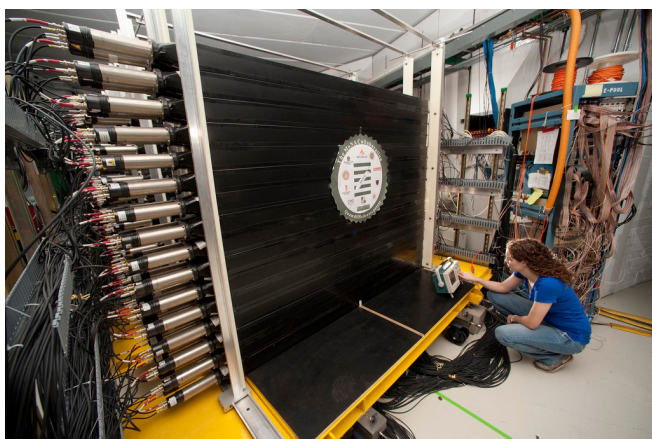


In this next animation, a target Beryllium-9 nucleus is stationary, while an Oxygen-18 nucleus is coming at it from the cyclotrons at half the speed of light. When the two nuclei collide, they are shattered (we call it fragmentation) and result in many pieces of nuclei. The various combinations of protons and neutrons are new, hopefully radioactive/rare nuclei that we might want to study. One possible fragment is Lithium-11, a short-lived but very interesting nucleus that will decay in less than a second. This is something we want to learn about! Our job at the lab is to smash nuclei very hard and study the pieces left over ... before they decay, if possible.

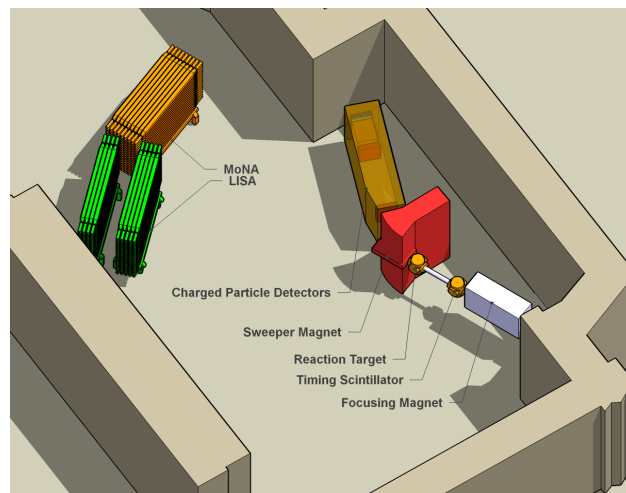
Now we're looking at a 3D model of the cyclotrons, made by our mechanical designers. Nuclei feed from the K500 cyclotron to the bigger one, the K1200. Bigger is more powerful, at least in this case. The K1200 can accelerate the nuclei to half the speed of light, which is equivalent to four times around the Earth per second.



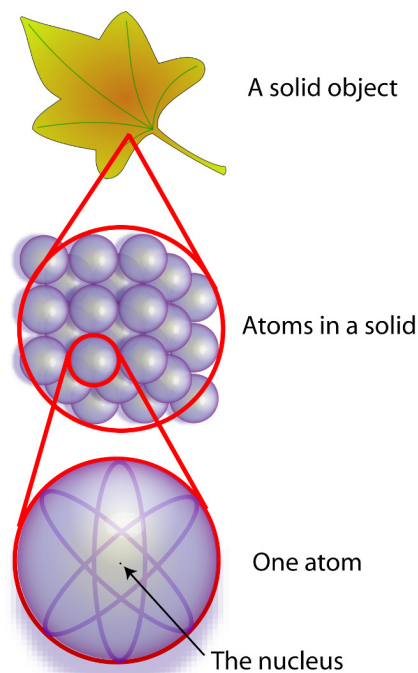
Once you've broken the nucleus and made some interesting new ones, you need to filter out all the pieces that are unnecessary. This image shows our fragment separator, a 35-meter-long series of magnets that can separate the nuclei of interest from everything else while they're traveling through at half the speed of light. It's like a mass spectrometer that chemists use to separate elements, except that this has to do so while the particles travel through at half the speed of light—thus, it's bigger. The grey magnets are kind of like a prism that splits white light into a rainbow of colors, except they're separating nuclei. The green magnets (with a big Spartan "S") are kind of like lenses, focusing the nuclei into a tight beam so they continue in the right direction. As a whole, this separator can select one interesting nucleus out of a million billion others.



Once you've selected the nuclei you want to study (maybe one out of every billion), you send them to a detector to be measured. This image shows a concrete vault of 6-foot-thick walls where we housed two detectors: MoNA and LISA. Coming up with those acronyms was very important. They're made of 288 black bars, each 2 meters long. Nuclei come in from the right, down a pipe, and particles fly across the room into those bars. They're made of a special plastic called a scintillator ... when particles hit it, the plastic in the bar glows purple. "Observing" a nucleus is impossible—the best microscopes on Earth can barely "see" an atom, and the nucleus is 10,000 times smaller! Our detectors measure the nucleus by using some material that reacts to the nucleus in a way we can measure. A great analogy is how you can't see air, but you can see wind because it moves the trees. We cannot observe the nucleus directly, but evidence like purple light allows us to know something about it.



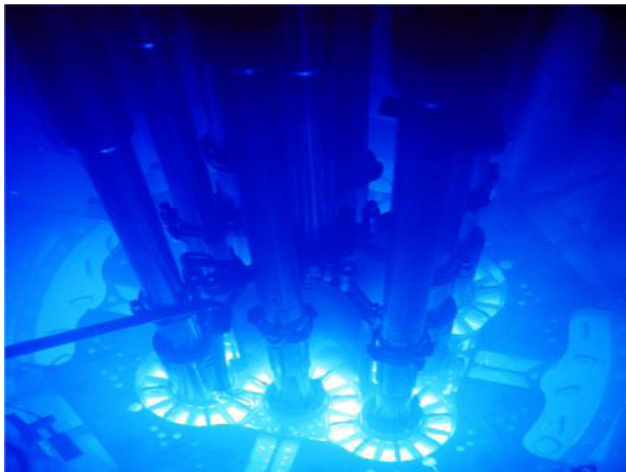
Next is a 3D model of MoNA LISA, which lets the designers (and experimenters) understand where things are and how they fit. During an experiment, the 288 bars can be configured in many different ways to measure different values (e.g. energy/speed, trajectory) more efficiently.



Our laboratory is dedicated to measuring the nucleus of the atom, which is of course the basis of matter in general. Any matter is made of atoms, which all must have a nucleus core. Understanding the nucleus is one key to understanding the things around us, from shoes to stars. We do research because we're curious. But you might be wondering: who cares? How does learning about the nucleus help us?



The same detectors that have been invented to measure the nucleus are now known by different names: MRI, CAT scan, X-ray, PET scan. Someone along the way realized that your body is also made of nuclei, so now we can look inside your body without cutting it open. You're welcome! Particle accelerators invented to study nuclei are now being used to bombard cells in a tumor, so nuclear science is also helping to cure cancer.



Twenty percent of electricity in this country is provided by nuclear power, so that's a big benefit. One of my favorite examples of nuclear science in action is the smartphone—you can't build the electronics that small without the last 50 years of basic nuclear research. Labs like ours learned about the nucleus, and we weren't trying to make a phone, but that's what we got. Again, you're welcome! While our research is trying to understand the nature of the nucleus, what we're really doing is saving lives and changing the world.

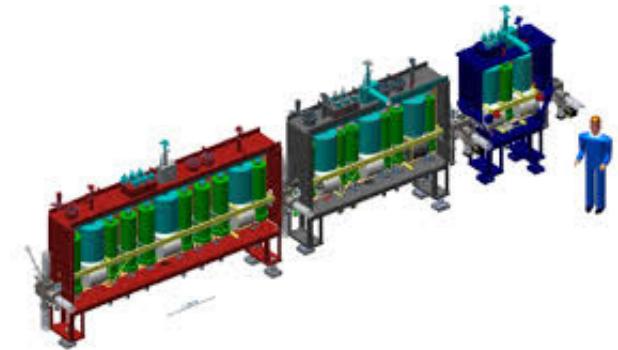


Hopefully, you're convinced that nuclear research is important. Our laboratory has been doing this for over 50 years and must always be improving to do new and more difficult experiments. Science is a moving target! This image shows the inside of another building, one where I can't take visitors at all. We're next to a

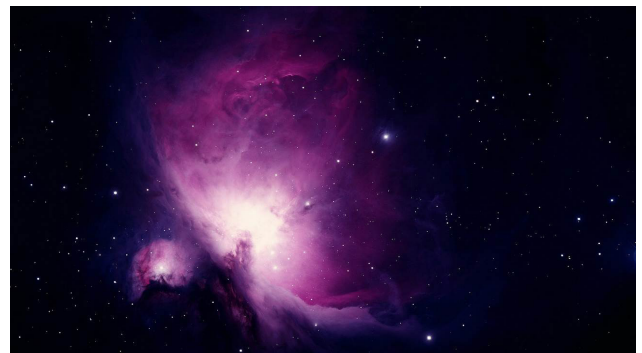
clean room, inside of which are some vertical metal cylinders on a cart. Those are next-generation accelerators that we've invented, and we're building some of the first ones ever to further upgrade our laboratory.



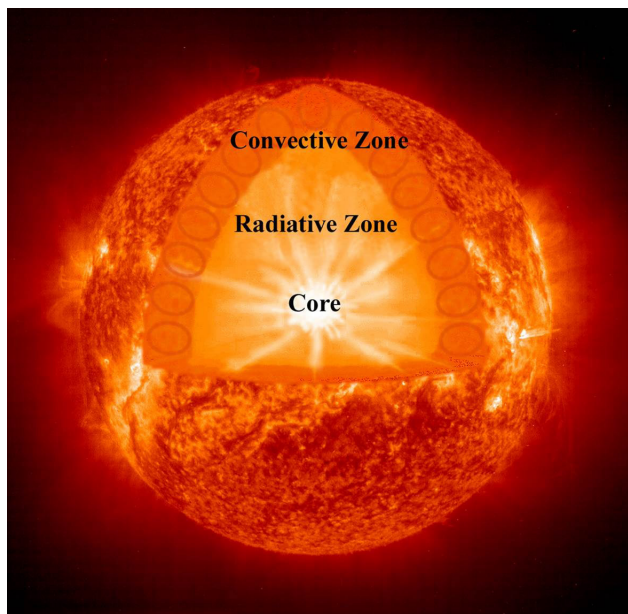
Now we're in a tunnel, 35 feet underground. We're in the process of building 300 of those cylinders (at \$100,000 apiece) for a new accelerator. It will completely replace our cyclotrons—in about two years we will tear them out and plug in this new one. The cylinders will be lined up underground to make a 400-yard-long linear accelerator (linac) folded twice to fit in this tunnel. It's part of a \$730 million project called the "Facility for Rare Isotope Beams" or FRIB. The new accelerator will push hundreds of times as many nuclei per second, smashing more, and producing more rare radioactive nuclei. An experiment that would take two weeks with our current cyclotrons would take less than one hour with the new linac. This project, funded by the US Department of Energy, will let our lab make nuclei that have never been observed, do experiments no one else can do, and become the number one rare isotope laboratory in the world. It's on track to be complete in 2021, or 2022 at the latest.



This 3D model shows a smaller linear accelerator that is based on the same technology. In fact, to show that these new accelerator cylinders can work, we built this small linac with just 15 of them in a row to get nuclei to star-like energies. This accelerator has been running for three years, so the tech has been well established. But the little accelerator's ability to make nuclei travel like they were in a star lets us do experiments that aren't possible anywhere else!



Speaking of stars, here's the night sky. Zooming in below Orion's belt shows the Orion Nebula, a stellar nursery. New stars are forming and beginning fusion in this giant cloud. One of our laboratory's primary goals is to study nuclear astrophysics (how nuclei determine the behavior of stars), from star birth, through its normal lifetime, and death.

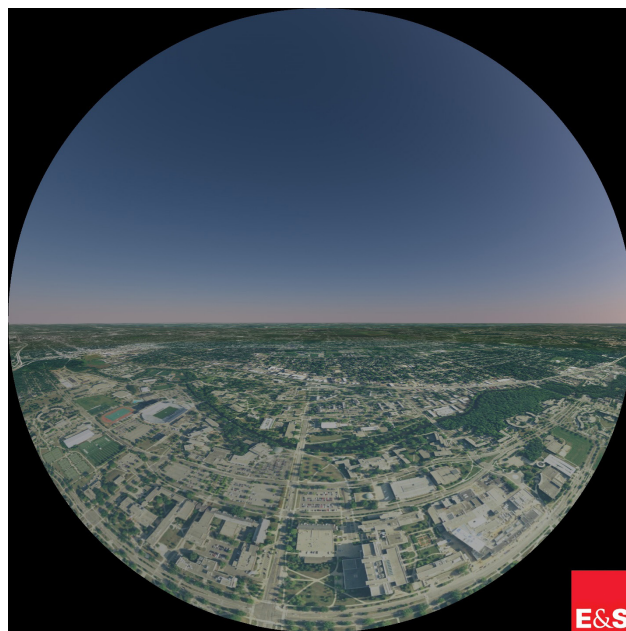


Planetarium shot of cutaway star?

We're very interested in how fusion powers a star ... the nuclear reactions in the core are why it shines, and what provides most of the energy on Earth. We can study that by reproducing those reactions in the laboratory, which is much cheaper than going to the star, and safer, too.



Towards the end of the star's life, new reactions take over as heavier nuclei are fused. In the case of our sun, helium is fused to carbon, but more massive stars can fuse all the way up to iron. When our Sun becomes a white dwarf and throws off gas into a planetary nebula, this will introduce new and heavier nuclei into the galaxy. The creation of heavier elements in stars has enriched our universe with new nuclei beyond hydrogen and helium ... this is called the chemical evolution of the universe. But fusion stops at iron, element 26. One of the biggest unanswered questions in science is: why do elements beyond iron exist at all? Our lab is studying supernovae and neutron star mergers (some of the most violent stellar events) to figure it out.



Now we're back at MSU, and you know far more about what goes on in the NSCL building than almost anyone on campus. This is an old picture, without the FRIB accelerator or any of the other recent additions. We keep changing to do the latest, greatest research, so come by sometime to see our work! Learn more at www.nscl.msu.edu/public/education. There you'll find out how to arrange tours, download our video game, etc. Our outreach programs are free to the public, so if you or someone you know is interested, please contact me!

FUTURE OF PLANETARIUMS: PEOPLE MATTER

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Abstract: Planetariums are places of joy and excitement to spread love and connection with the night sky for everyone. For us to stay relevant and thrive, we need to appeal to a wide range of people and actively talk about how we work to include everyone in our audiences and as practitioners in our field. Led by Dr. Garcia, this interactive at GLPA 2018 session explored the universal phenomenon of implicit bias: what it is, why and how it happens, and when it is most likely to occur. Participants also explored their own implicit bias and how it impacts the ways in which they interact with audiences and peers and considered some of the ways to reduce the incidence of bias, both professionally and personally, within the Planetarium field.

Introduction

As planetarians, we appreciate and love the work we do using immersive domed theaters to teach people about the universe. We also want to share our love and appreciation of the night sky and everything in the universe with others. However, it is always good to take a hard look at ourselves to make sure that we are inviting and welcoming to everyone who comes into our field as practitioners or through our doors as audiences. Diversity in practitioners leads to greater innovation, new ideas, and creating more welcoming environments for all. Welcoming diverse audiences helps planetariums thrive in a world where are often hit by budget shortfalls and lack of support. Even if, on the whole, we are welcoming, we still need to ask if we can do better. The interactive presentation help at GLPA 2018 was a chance for us to start examining our field as a whole and find those gaps and help each other do better. Even if you feel you are very welcoming and inclusive, everyone is always learning.

To prepare for this presentation, our speaker (Dr. Jessica Garcia) needed some data to build her work on. What is the climate of inclusivity like in our field? What are our demographics? How do our demographics line up with our audiences? Unfortunately, we did not have these answers because there had been little, if any, previous quantitative research done in this area. Simply by looking at group photos of past conferences, we can see that our field has long been dominated by white, able-bodied men. We are seeing those demographics shift as well, with many more young (mostly white) women entering the field. However, this is still fairly anecdotal. As a result, we surveyed planetarians in order to begin to identify that climate as well as understand our

demographics for both our audiences as well as those of us who work in the planetarium field.

A summary of the results most relevant to this presentation at GLPA 2018 are revealed here. More results and deeper analysis of the data will be shared through another means that is yet to be determined. The results are presented as-is with little interpretation of what they mean. We request that people consider the data with an open mind and use these results as a starting point for discussions that can help us improve the work we do and how we interact with our audiences and our colleagues. The intention is not to use this information to make assumptions or generalizations about any particular groups or about what this data means.

These results will be followed by a summary of the main takeaway points from Dr. Garcia's portion of the presentation on implicit bias, how it affects us all, and how we can be more aware of our own biases and better promote inclusion, equity, and diversity in the Planetarium field.

Summary of Survey Results

Overview of Survey

In September of 2018, a survey was sent to planetarians via the Dome Dialogues Facebook page, Dome-L Google groups, and the GLPA email list. This survey was meant to give us a sense of what the climate in the field was like regarding diversity and inclusion. We also surveyed people to get a sense of our field's current demographics, both of our members and our audiences.

The survey was modeled after other climate surveys that have

been administered at other institutions of higher education. It was shortened and modified to fit our particular field. The group working on this survey included myself, Geoff Holt (president of GLPA), Keith Davis (Digital Visualization Theater at University of Notre Dame) and Dani LeBlanc (Museum of Science, Boston). The evaluation team at the Museum of Science and Dr. Jessica Garcia of the Michigan State University Office of Inclusion and Intercultural Initiatives also read through the survey to help ensure it was appropriate.

A total of 101 respondents completed the survey prior to analysis. Though the survey was sent out widely, some respondents may not have been in the United States and approximately 76% of the respondents were members of GLPA at the time they submitted the survey. At no point was a question required to continue the survey. The survey began with a statement of the purpose of the survey and that results would not be shared with anyone except as a summarized version of the data.

This is a summary of the results of this survey, broken down by various subgroups. Note subgroups related to race and sexual orientation were not analyzed separately as we had too few respondents that did not identify as white or straight. Any subgroups could have been identified as individuals. Results from subgroups that have clear trends different from the full sample are presented. Statistical analysis to check for significance was not performed on these data. It is shown in its raw format.

Respondent Demographic Results

Respondents were asked about their personal demographics to give a sense of who is represented in our field.

Age:

The field is fairly evenly split across age bands except for the youngest (under 25) and oldest (70 and older) members (Figure 1).

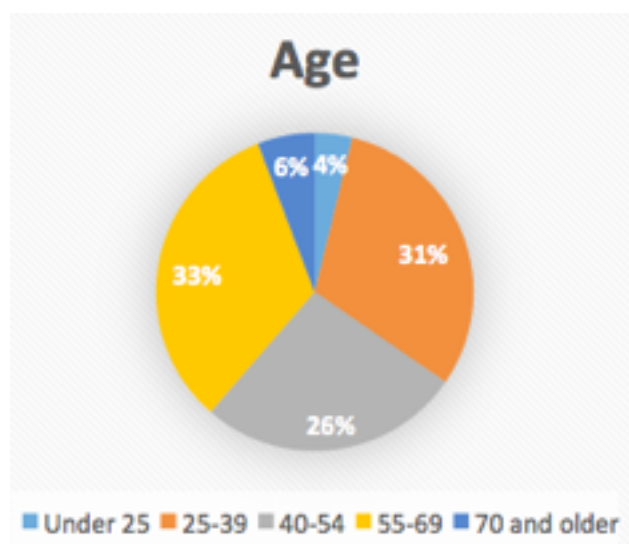


Figure 1

Sex:

Respondents were asked with which sex they identify. The majority of respondents identified as male, with a 60%-40% split between male and female (Figure 2).



Figure 2.

Sexual Orientation:

The respondents were asked how they identify their sexuality. Within our field and with the number of respondents, we could not summarize the results according to all answers as it would be too identifying for some individuals, so results are summarized as either heterosexual or non-heterosexual. A majority of respondents identified as heterosexual or straight (Figure 3). However, 13% of our respondents identified as non-heterosexual or not straight. This is a significantly higher proportion than the United States as a whole, which has only 4.5% of people identify as LGBT (Newport, 2018). However that estimate of 4.5% does not include those who identify as queer, questioning, or asexual.

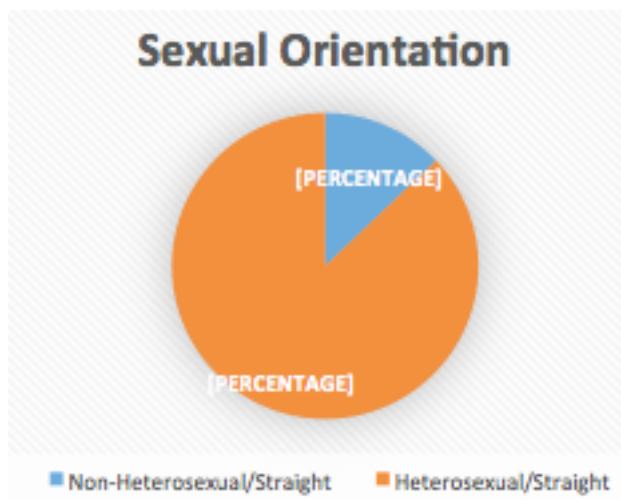


Figure 3

Race:

The respondents were asked to identify with which race and ethnic groups they identify. As before, we had such an overwhelming majority of white respondents that individuals could possibly be identified. As a result, we summarize the results here as either white or non-white (Figure 4). 91% of our respondents identified as white/non-Hispanic or Latino which is significantly higher than the U.S. population of 61.3% (U.S. Census Bureau).

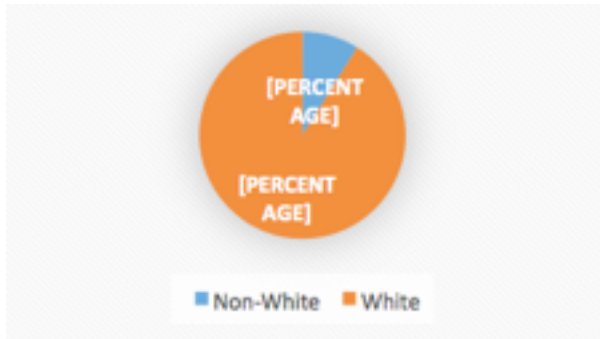


Figure 4

Generation Status:

We asked respondents for their generation status as this can give a sense of how many people are immigrants or the children of immigrants. This survey was sent out to all planetarians via Dome-L and Dome Dialogues. So keep in mind that some people responding may be planetarians outside of the U.S. Though a majority of folks were members of GLPA and U.S. based planetarians. A majority of the respondent answers suggest that they are grandchildren or children of immigrants to the U.S (Figure 5).

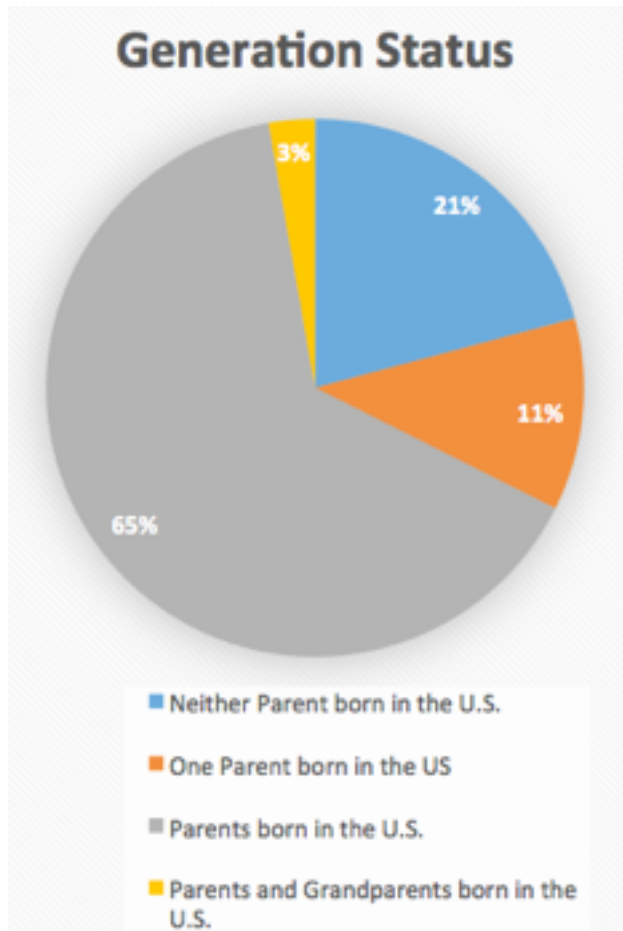


Figure 5

Religion:

Respondents were asked their religion as an open-ended question and were categorized as broadly as possible so as not to identify individuals. About a quarter of people identify as Christian, a third identified as not having a religion/atheist, and a third did not answer.

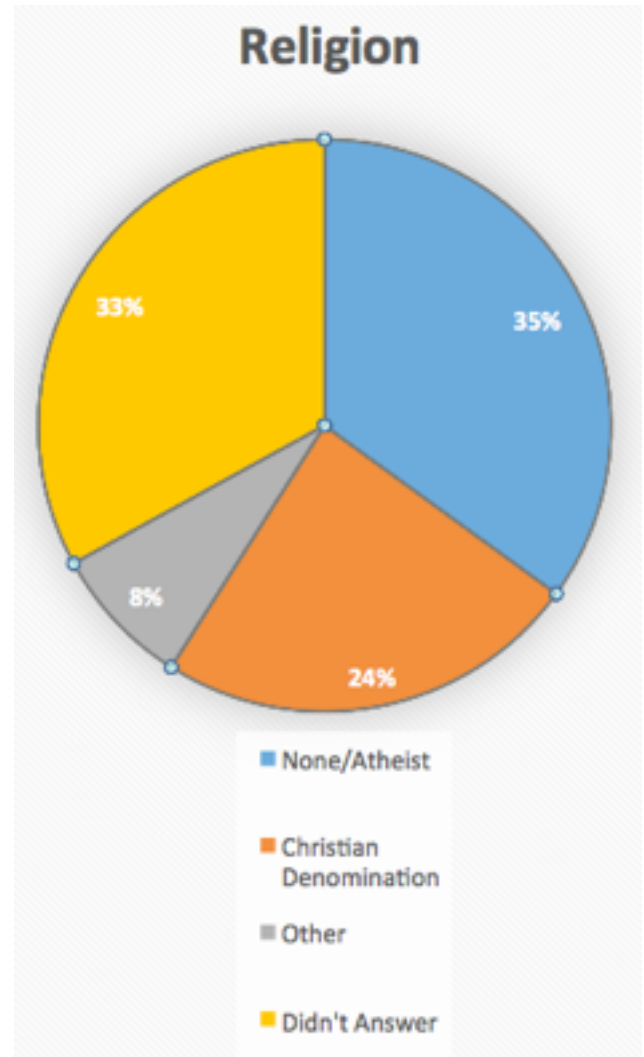


Figure 6

Professional Breakdown of Respondents:

In addition to asking people about their personal background we asked people about their role in the planetarium field. To better understand the professional background and diversity of the respondents in terms of skillsets.

Highest Degree:

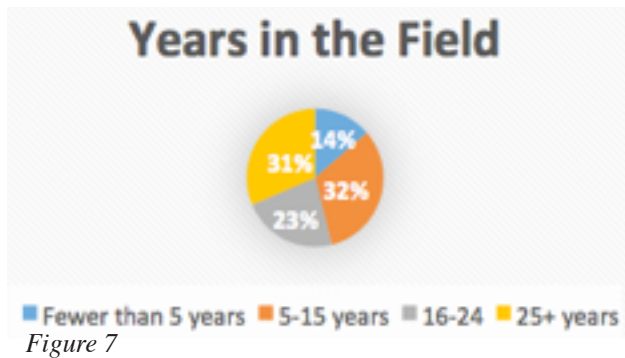
Respondents were asked which was the highest degree they had earned. The response was closely split between Master's Degrees and 4-year/Bachelors degrees. The remaining were a mix of doctoral degrees, GED, trade school, Associate's Degree, or students still in college (Table 1).

Table 1

Highest Degree	Percentage
High School Diploma/ GED	4.9%
Two-year college/ Associate's Degree	2.9%
Four-year college/ Bachelor's Degree	37.9%
Master's Degree	42.7%
Doctoral Degree	8.7%
Trade School	1.1%
In College	1.8%

Years in the Field:

We asked respondents how many years they have been in the field. The results were fairly evenly distributed. However, there is fairly equal representation between those who have been in the field for 5-15 years, so established in their planetarium careers but still on the early side and those who are veterans of the field at 25 or more years (Figure 7).



Types of Positions:

Respondents were able to answer more than one answer for this and so the percentages do not add up to 100%.

Table 2

Position Type	Percentage
Management/Executive	46%
Education	55%
Technical	21%
Production	23%
Marketing/Sales	13%
Other	11%

The Planetarium's Role in Supporting Diversity, Inclusion and Equity:

Respondents were asked "Do you feel that promoting diversity, inclusion, and equity is the responsibility of the planetarium community?" A large majority answered that it was our responsibility and a majority of the remainder thought it was maybe our responsibility (Figure 8). As a field, we largely feel that we have the job of promoting diversity, inclusion, and equity. What that means to each individual can mean different things.

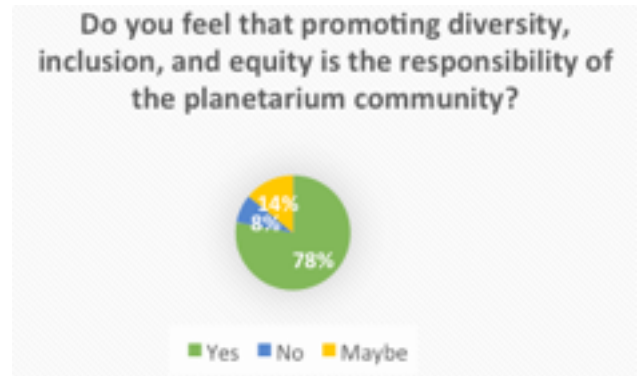


Figure 8

Climate Results

Climate in this context refers to how people feel about their position, role, and acceptance in the larger planetarium field. This is a pared-down summary of all the questions that were asked as part of the survey.. Results that were most relevant to Dr. Garcia's portion of the presentation are presented here.

Description of the Planetarium Community:

Respondents were asked several Likert-style questions where they answered the question "In general, how much do you agree or disagree with the following statements" on a 6-point scale of strongly disagree to strongly agree. Below are the results of several of those statements with key results.

1. I have considered leaving the planetarium field because I have felt isolated or unwelcome:

Most people disagreed or strongly disagreed that they have ever considered leaving because they felt isolated or unwelcome in the field. While these results are generally positive, it is important to note that 10% of respondents did agree at least slightly that they have considered leaving (Figure 9). Though the percentage is low, it is still significant that people have not felt welcome.

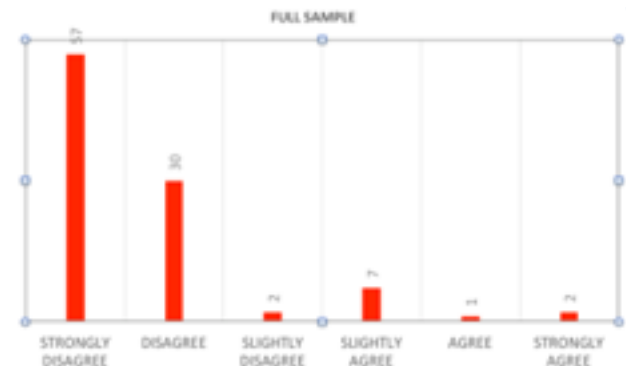


Figure 9

2. *I have to work harder than others to be taken seriously in the planetarium field:*

For this statement there was a clear difference between those who identified as male versus female. Men were more likely to disagree they had to work harder, with a majority disagreeing at least somewhat. However, when we look at women, we see clearly two camps with a slight majority of women agreeing at least slightly that they need to work harder (Figure 10).



Figure 10.

3. *The planetarium community has a strong commitment to diversity, equity and inclusion:*

There was a very clear generational divide on this question. Respondents under 39 trended toward disagreeing while those over 55 trended toward agreeing with this statement (Figure 11). This is a good reminder that what diversity, equity, and inclusion mean can be very different.

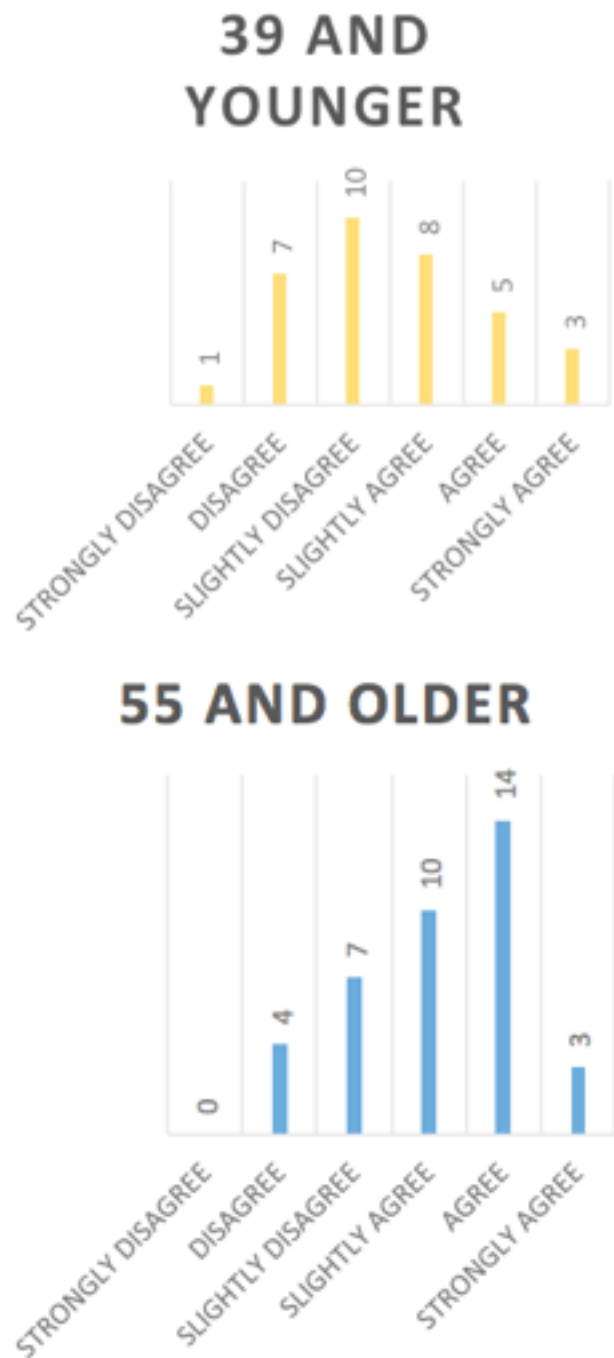
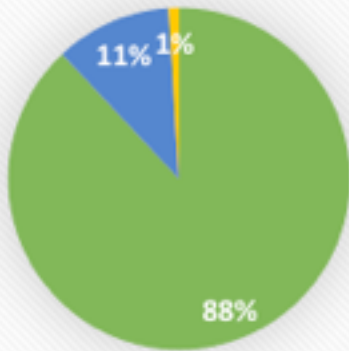


Figure 11

Discriminatory Events

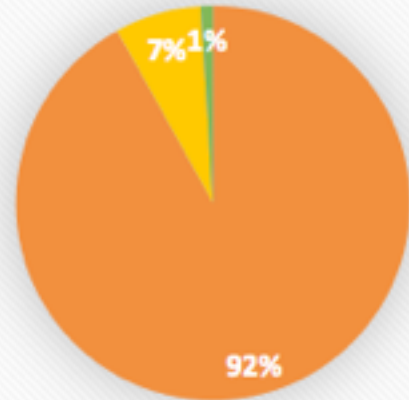
We asked respondents “Have you personally experienced discriminatory events within the planetarium community” due to several different factors. A vast majority of people have not experienced any discriminatory events. However, there was never a category where no one had ever experienced a discriminatory event. So the fact that there are non-zero responses for discriminatory events means we are not always welcoming or supportive of our colleagues (Figure 12 with eight parts).

Political Orientation



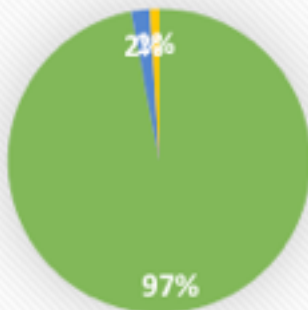
■ Never ■ 1 or 2 times ■ 3 or more times

Ability/Disability



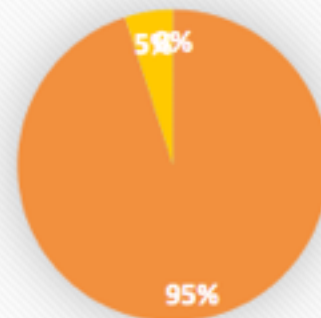
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Race



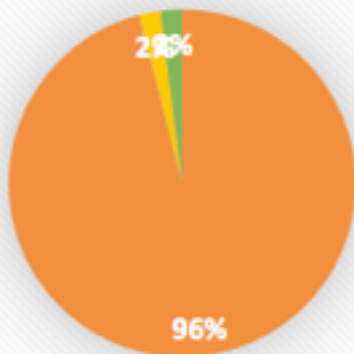
■ Never ■ 1 or 2 times ■ 3 or more times

Religion



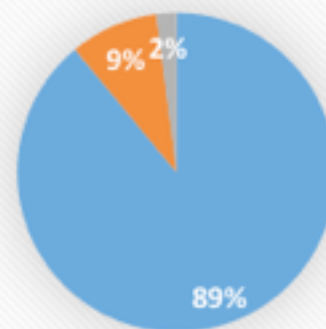
■ Never ■ 1 or 2 times ■ 3 or more times

Gender Identity or Expression



■ Never ■ 1 or 2 times ■ 3 or more times

Height or Weight



■ Never ■ 1 or 2 times ■ 3 or more times

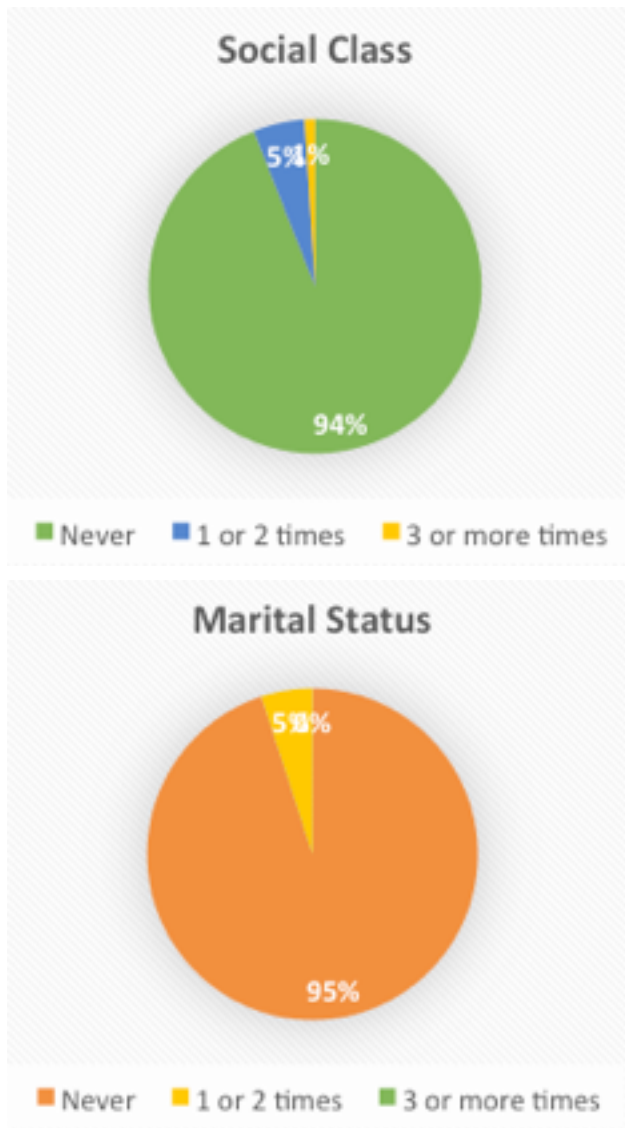
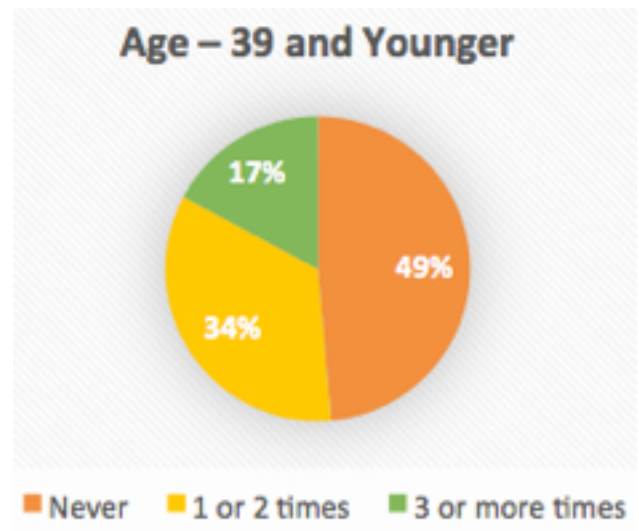


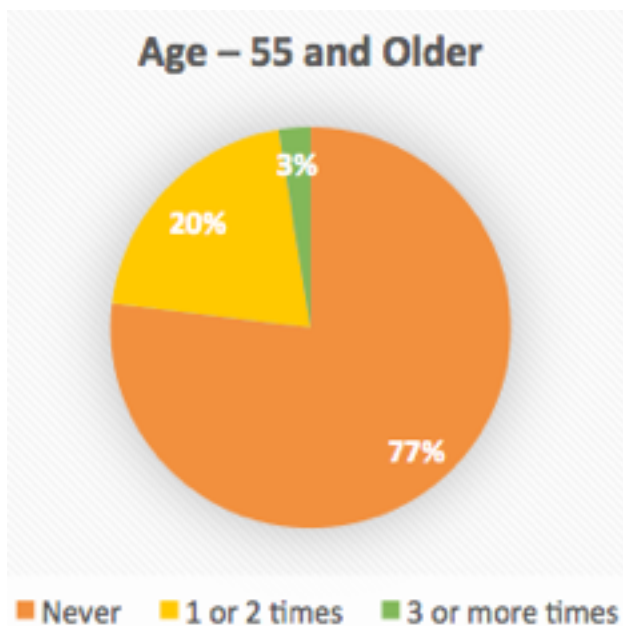
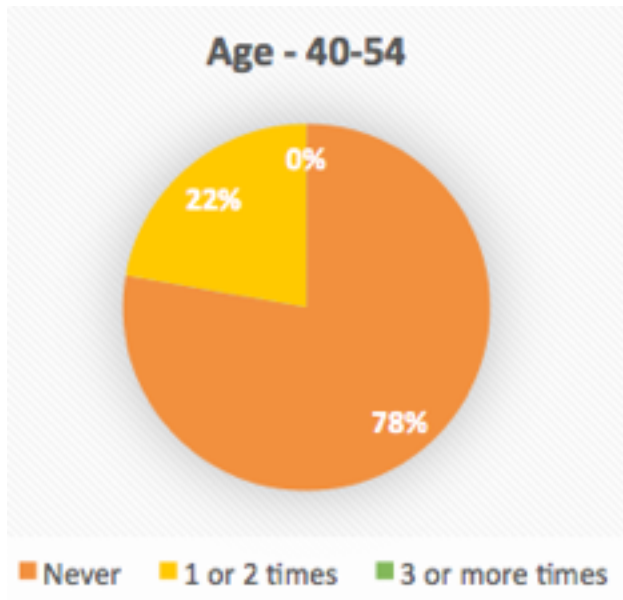
Figure 12

Regarding marital status, again the majority has overwhelmingly never experienced a discriminatory event due to this status. However, it is important to note that the 5% who reported having experienced a discriminatory event due to marital status were all women (bottom right of figure 12).

When asked specifically if respondents have ever experienced a discriminatory event due to their sex, there were significantly more non-zero answers. As our field is more evenly split between men and women, these responses were analyzed according to one's sex. There was a very clear and overwhelming difference between male and female respondents. Again, the answers from men were non-zero, though a vast majority answered they had never experienced a discriminatory event due to their sex. However, nearly two thirds of the female respondents have experienced at least one discriminatory event and nearly one third have experienced three or more discriminatory events (Figure 13)

Respondents were also asked if they had ever experienced discriminatory events based on their age. Since our respondents were fairly evenly split by age as well, we looked at the results by age. For respondents older than 40 years of age, nearly a quarter of respondents have experienced at least one discriminatory event based on age. For those 39 and younger, slightly over half have experienced a discriminatory event based on age. This shows that ageism goes both ways within the field, though there appears to be a stronger effect for younger planetarians.





Audience Demographics:

We asked respondents for the demographics of the audiences they serve. The reason we asked this was because part of our job is to make everyone feel welcome not only in the field but also those who visit our planetarium. We also know that people, children especially, are going to feel more confident and motivated to learn science if they see themselves portrayed in science (Lepper & Henderlong, 2000). So it is critical that in our programming we make an effort for representation of everyone that comes through our doors. It's also important for us to have representation within the field of practitioners so kids can see themselves as someone who can work in a planetarium or do science. This is to see and understand what the demographics of our audiences are so we can make sure we can represent that well.

What the results show are that many respondents don't know

what the demographics are for their audience. In the comments it was clear that people were unsure how to best do that without being intrusive or making possibly inaccurate judgments. Most answers were coming from estimates or from district data for those planetariums in school districts.

What we can glean from this data is that a majority of respondents do work with audiences that are a majority white. This is unsurprising as we can look at Table 3, we can see the estimated demographics by race and ethnicity for the United State. We are a majority white country. However, we can see that several respondents have audiences that do not follow the same demographics as the U.S. For instance about 18% of respondents have audiences that are 25% or more African American/Black and 13% of respondents work with audiences that are more than 25% Latino. However, based on the demographics of our respondents, it is likely that many of those respondents themselves are white.

Figure 15

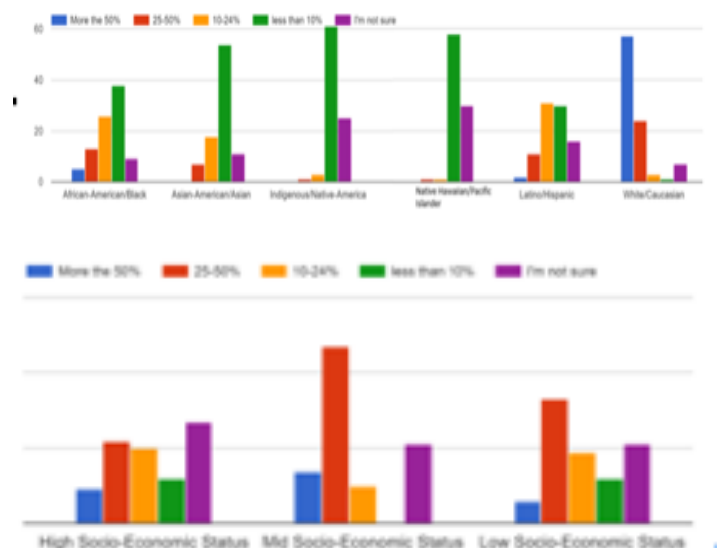


Table 3

Race	Percentage of U.S. Population – Estimate from U.S. Census Bureau
White alone	76.7
Black or African American, alone	13.4
American Indian or Alaskan Native, alone	1.3
Asian alone	5.8
Native Hawaiian or other Pacific Islander alone	0.2%
Two or more races	2.7%
Hispanic or Latino	18.1%
White alone, not Hispanic or Latino	60.7%

Future work

Bibliography:

Lepper, M. R., & Henderlong, J. (2000). Turning “play” into “work” into “play”: 25 years of research on intrinsic versus extrinsic motivation. In *Intrinsic and extrinsic motivation: The search for optimal motivation and performance*.

Newport, F. (2018). “In U.S., Estimate of LGBT Population Rises to 4.5%.” <https://news.gallup.com/poll/234863/estimate-lgbt-population-rises.aspx>

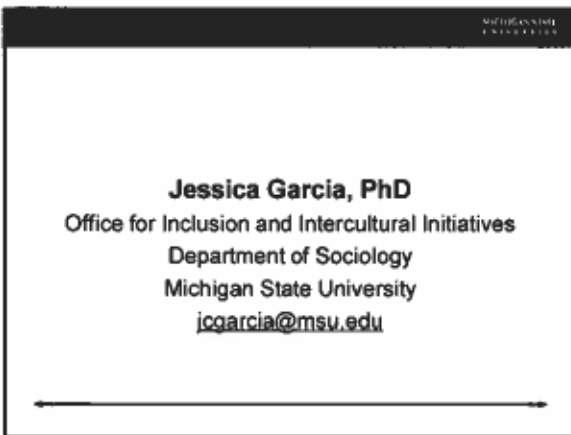
U.S. Census Bureau. <https://www.census.gov/quickfacts/fact/table/US/PST045217#PST045217>

Editor’s Note: The text above was prepared by Dr. Schmoll. Dr. Garcia’s part of the oral presentation used the notes on the following pages.

This survey is just the beginning to more work ahead for our field. The results open many questions. One is what does “promoting diversity, inclusion, and equity” mean to planetarians and how are those interpretations different between individuals? What additional data do we need to get a more complete picture? What techniques can we employ to be more effective? What conversations should we be having to make our field more welcoming?

The survey results also show a clear generational divide in if we feel we are already striving to promote diversity and inclusion. We can ask why those views are so different across generations and what can each generation learn from the other?

Also, keep in mind, that of our respondents, 91% are white and 88% are heterosexual/straight. The field does not have a lot of representation from marginalized groups. This means that a majority of people who are responding are in a field that is like themselves leaving less room for discrimination. We can start also asking questions such as why do we not have representation from marginalized groups? How do we discriminate—whether intentional or not—against our colleagues?



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The Future of Planetariums: People Matter

GLPA Annual Conference
October 12, 2018
Jessica Garcia PhD
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Participation Guidelines

- Listen respectfully
- Speak from experience and avoid generalizations
- Step up/Step back
- Disagree respectfully
- Honor confidences
- Expect/Accept discomfort – view it as a learning opportunity
- Allow each other room to make mistakes while learning; apologize if you make a mistake
- Expect non-closure

4

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Introduction: Outline

1

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Part I: Creating an Inclusive Environment

1

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Great Lakes Planetarium Association Code of Conduct

As members of the community,

- We pledge to treat all people with respect and provide a harassment and bullying-free environment, regardless of sex, sexual orientation and/or gender identity, disability, physical appearance, body size, race, nationality, ethnicity, and religion. In particular, sexual language and imagery, sexist, racist, or otherwise exclusionary jokes are not appropriate. We will treat those outside our community with the same respect as people within our community.
- We pledge that all discussions between members of the community should be done with respect, and we pledge to take proactive measure to ensure that all participants are heard and feel confident that they can freely express their opinions.
- We pledge to help the entire community follow the code of conduct and to act accordingly when we note violations.

<https://glpa.org/wp-content/uploads/2018/01/Code-of-Conduct.pdf>

1

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Benefits of an Inclusive Environment

Inclusion → open lines of communication; trust; accountability; transparency; a sense of belonging; commitment to the success of the unit

- Increases sense of belonging, commitment, and retention
- Improves camaraderie, climate, and morale
- Capitalizes on talent, ideas, and collaborative problem-solving
- Reduces conflict
- Strengthens teams, improves trust
- Enhances physical health and well-being

1

Inclusion in the Workplace

- Companies with greater racial/ethnic and gender diversity among their management have significantly higher financial returns than industry means
- Organizations with at least one female board member yield significantly higher returns on equity and higher net income growth
- Diverse teams think more critically, consider more perspectives, are more objective, more innovative, and more productive

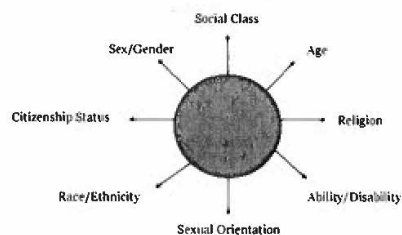
RACE/ETHNICITY	Non-Hispanic Whites	Blacks, Latinx, Asians, Native Americans, Arab Americans, Mixed Race
SEX/GENDER	Men, Cisgender	Women, Transgender, Intersex
CLASS	1 percent, Upper Middle Class	Lower Middle Class, Working Class, Poor
SEXUAL ORIENTATION	Heterosexuals	Lesbians, Gays, Bisexuals
CITIZENSHIP STATUS	US Born	Undocumented, Naturalized, Visa, Green Card
RELIGION	Christians	Jews, Muslims, Hindus, Atheists
ABILITY	Able-bodied	Persons with Disabilities (physical, cognitive, emotional, etc.)
AGE	Young and Middle-Aged Adults	Children, Elderly

Inclusion in the Workplace

- From a business perspective
 - Diversity is about reputation management and compliance
 - Inclusion is about growth, renewal, and reinvention
 - "If a brand doesn't have a multicultural strategy, it doesn't have a growth strategy." Andrew McCaskill, Nielsen's Senior Vice President, Global Communications and Multicultural Marketing
- Policies have to align with messaging in order for diversity trainings to work
- In order for inclusion to work, it must be centered within an organization, not relegated to HR

Forms of Oppression	Groups with More Power	Groups with Less Power
RACISM	White	Blacks, Latinx, Asians, Native Americans, Arab Americans, Multiracial
SEXISM, TRANSPHOBIA	Men, Cisgender	Women, Transgender, Intersex
CLASSISM	1 Percent, Upper Middle Class	Lower Middle Class, Working Class, Poor
HETEROSEXISM, HOMOPHOBIA	Heterosexuals	Lesbians, Gays, Bisexuals
NATIVISM	US Born	Undocumented, Naturalized, Visas, Green Cards
ANTISEMITISM, ISLAMOPHOBIA	Christian	Jews, Muslims, Hindu, Atheists
ABLEISM	Persons without Disabilities	Persons with Disabilities
AGEISM	Young and Middle-Aged Adults	Children, Elderly

Social Identity Model



Griffin, Pat. 1997. "Introductory Module for the Single Issues Courses." Pp. 81-81 in *Teaching for Diversity and Social Justice: A Sourcebook*, edited by Mounissa Adams, Lee Anne Bell and Pat Griffin. New York: Routledge.

Standpoint

- Multiple identities "intersect" and influence the ways in which we view the world around us, interact with others, and how others interact with us
 - This intersection is our standpoint (our "lens")
- This standpoint can lead to bias, both explicit and implicit

Part II: Introduction to Implicit Bias

Why is there bias?

- Amygdala → primitive regions of the brain associated with fear
 - Unconscious associations may only indicate cultural assumptions, perhaps without prejudice
- Heuristics → mental shortcuts
 - Simple, efficient thinking strategies that enable us to live and make routine decisions and judgments with minimal effort
 - Our brains fill in any "gaps" of information
 - Chief Executive Officer

Definitions: Bias

- Strongly held beliefs favoring (or not) one over another
- Conscious/explicit or unconscious/implicit
- Influences interactions and behaviors in subtle and overt ways
- Benefits some and disadvantages others
- Universal—we all have biases of some sort

The Unconscious Mind

- Thinking, Fast, and Slow
- Research shows 2 systems of thought
 - System 1 [automatic processing] -- thinking happens fast (intuitive, impulse)
 - System 2 [controlled processing] -- thinking very slow (more deliberate, weighing)

Kahneman, D. (2011). *Thinking, Fast, and Slow*. New York: Farrar, Straus and Groux.

Characteristics of Implicit Bias

- Pervasive and robust
 - Everyone possesses them
- May contradict our declared beliefs
- Impacts our behaviors
- Tends to favor our own "group"
 - "Group" covers many identities
 - Marginalized group members often share the same implicit biases

Where Does Implicit Bias Come From?

- Direct and indirect messages
- Evident at a very young age
- Environment: Family, peers, community, media (may be distorted, but, reinforced over time and internalized)

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When Does Bias Emerge?

- Altruism decreases and prejudice increases (when we are most likely to rely on automatic processing):
 - Ambiguous or incomplete information
 - Time constraints
 - Fatigue & High Emotion
- When we have a lot on our minds, we tend to default to unconscious response/reaction (i.e. automatic processing)

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Part III: Consequences of Bias and Discrimination

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How Does Bias Impact Behavior?

- Level of service (excellent, good, adequate)
- Length of time you spend with the person
- Interactions (telephone, face-to-face, and email)

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Impact of Bias in the Workforce

- Employment & Race-Coding Names
- Stereotyping (positive or negative)
 - Common cognitive bias
 - Impacts how we evaluate individuals/groups
 - Influences our interactions with them

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Harvard's Implicit Association Test (IAT)

- Web based, measures strength of biases
 - Over 14 million participants
 - Uses reaction times to measure how quickly people associate concepts
 - Easier pairings (faster response times) are taken to indicate stronger unconscious associations
- To learn more about Implicit Association and/or to take the IAT visit:
 - <https://implicit.harvard.edu/implicit/takeatest.html>
 - <https://implicit.harvard.edu/implicit/iatdetails.html>

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Job Applications

- Hiring is the most vulnerable stage of employment to racial (and other) bias (e.g. wage setting, promotions, termination decisions)
 - Objective information is limited, discrimination is less easily detected
- Meta-analysis of every field experiment on racial and ethnic discrimination in the labor force from 1989-2015 (n=24)
 - Whites receive on average 36% more callbacks than African Americans and 24% more than Latinos
 - There were no significant changes for African Americans and only modest improvement for Latinos

Source: (O'Flaherty, Pager, Harrell, and Mabeen 2017)

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Job Applications

- Hiring committees actively consider women's (but not men's) relationship status when selecting hires
- Committee members assumed heterosexual women whose partners held academic or high-status jobs were not "movable," and excluded offers when there were viable male or single female alternatives (Rivera 2017)

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Metastereotypes

- Metastereotype refers to the belief that others see your group negatively
 - This is a coping mechanism; it enables the individual to ascertain the potential for and the intensity of emotional, psychological, and/or physical threats
- Can lead to negative consequences
 - Preparing for encounters is stressful; constant state of fight/flight
 - Increased cortisol, heart rate, and blood pressure; greater psychological distress (Stevenson 2014, Salles, Mueller, and Cohen 2016)
 - Can also lead to self-fulfilling prophecies if internalized (Steele and Aronson 1995)

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Other Research: Faculty More Likely to Respond to White Males

- Would-be graduate students sent letters to faculty members expressing interest in professor's work and asking about research opportunities (6,548 professors at 259 U.S. institution)
- Letter asked for a 10-minute discussion
- Names on letters: Brad Anderson, Keisha Thomas, Raj Singh, Mei Chen or Juanita Martinez
- Lower response rate to women and minorities than to white men
 - Health Services: 57% v. 71%
 - Life Sciences: 61% v. 72%
 - Natural and physical sciences and math: 64% v. 73%

Velez, K., et al (2016). Women's Academic Beliefs and Expectations: How Pay and Representation of Colleagues' Status Bias Hiring Outcomes and Organizational Climate. *Journal of Applied Psychology*

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Stereotype Threat

- Situations where people are (or feel themselves to be) at risk of conforming to stereotypes about themselves (Steele and Aronson 1995)
- Heightened when people expect discrimination due to their identification with a negatively stereotyped group are asked to perform complex and demanding tasks
 - Often exacerbated when a person belongs to multiple marginalized groups
- Repeated experiences of stereotype threat can lead to diminished confidence, poor performance, and loss of interest in achievement
- Example: Girls math scores drop when they are reminded of their gender (Shapiro and Williams 2011)

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Other Research: Science Faculty Subtle Gender Biases Favor Male Students

- Applications for lab manager position
- Application material from students randomly assigned a male or female name
- Science faculty from research intensive universities in U.S. rated application material
- Male applicants rated as significantly more competent and hireable than the (identical) female applicant
- Offered higher starting salary to male applicant

Voss-Ruesch, Corinne A. et al. (2013). Proceedings of the National Academy of Sciences of the United States of America. 110 (12): 41, 19474-19479

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Consequences of Discrimination

- Everyday experiences of discrimination lead to an increase in stress hormones and disrupted sleep (Adam et al 2014)
- Dysregulated cortisol levels are linked to higher fatigue, worse mental health, cognitive decline, worsened memory, CVD, and mortality
 - These effects are cumulative: The more discrimination people experience across adolescence and early adulthood, the more dysregulated their cortisol rhythms are by age 32
- Shorter sleep is related to fatigue, increased depression, compromised immune systems, increased obesity, diabetes, and heart problems, impaired attention and memory

Part IV: Microaggressions

Microaggressions: Gender

- Referring to a woman's behavior as "bitchy" or "bossy" and a man's behavior as an example of "strong leadership"
- Men are more likely to interrupt and talk over women
- Asking someone who is transgender, "What are you?" or using the wrong pronoun when referring to them

Microaggressions

- Microaggressions: small subtle, often unspoken and unconscious behaviors that communicate dispositions, attitudes, biases, and sentiments
 - Body language, voice tone, and facial expressions can impact positively or negatively, putting some within the organization at a disadvantage and others at an advantage

Sue Chen's Airing (2013) Microaggressions in everyday life: race, gender, and sexual orientation matters (p. 2). Wiley.

Microaggressions: Sexual Orientation

- Using the phrase "gay" to refer to something weird, unusual, or boring
- Microaggressions can happen within groups, not only across them
 - You don't look/act [fill in the blank]

Microaggressions: Race

- Referring to an African American student as articulate
- A US born Asian American student is complimented by a White student for speaking such "good English."
 - Where Are You From?
- Someone who is mixed race is asked, "What are you?"
 - Individuals with ambiguous identities are frequently interrogated
- Mispronouncing names

Microaggressions: Other Groups

- Joking with a Muslim student wearing a hijab, "I hope you don't have a bomb under there"
 - Humor in general is tricky
- Insisting on "helping" a person with disabilities that has not asked for help

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Microaggressions

- Persons of color and women:
 - Often experience the campus climate as isolating, alienating, extremely stressful, risky and invalidating
 - More likely to experience being "the only one" that leads to feelings of isolation and loneliness
 - Lack mentors who possess knowledge of the "minority experience"

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Recommendations: Reducing Bias

- Evidence that neuroplasticity allows for reducing bias
 - The brain is continually reorganizing itself, creating new connections between neurons throughout the lifespan
 - Awareness and intentionality moves from automatic processing to controlled processing until it becomes automatic again

Hanson, R. (2013). *Hardwiring happiness: The new brain science of contentment, calm, and confidence*

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Part V: Reducing Bias

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Recommendations: Reducing Bias

- Learn to recognize your own biases
 - How do your experiences and your identity shape your interactions with others?
 - <https://implicit.harvard.edu/implicit/takeatest.html>
- Know yourself and your own triggers
- Recognize impact of:
 - Ambiguous or incomplete information → get to know people
 - Time constraints – Quick decisions
 - Fatigue & High Emotion
 - When we have a lot on our minds, we tend to default to unconscious response/reaction

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Debiasing

- "The key isn't to feel guilty about our (implicit) biases—guilt tends toward inaction. It's to become consciously aware of them, minimize them to the greatest extent possible, and constantly check in with ourselves to ensure we are acting based on a rational assessment of the situation rather than on stereotypes and prejudice." ~Kirwan Institute, 2015

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Recommendations: Reducing Bias

- Intergroup Contact
- Taking the perspective of others (empathy building)
 - Become an outsider
- Counterstereotypical Examples – success is mixed, can also lead to increased stereotyping
- Training – learning to remove, overcome, or dismantle bias and its influence on us
- Be open to feedback from others
- Practice
- Encourage others to do the same work

ASTRONOMY UPDATE FOR THE PLANETARIAN 2018

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Abstract: Once again, the rate of scientific discoveries has made it impossible to review even a fraction of them. So, there was a lot of selectivity involved in this Astronomy Update. Last July we witnessed a solar system fly-through of an interstellar asteroid (or was it a comet?). The Japanese space agency put three robotic landers on an asteroid. Jupiter has 10 newly discovered moons, bringing the total to 79. Its magnetic field has been traced with puzzling results. An underground Martian lake of liquid water has been detected. Mars also has exposed water ice in rock outcrops. The Curiosity rover has found complex organic molecules in the rocks of Gale Crater. The Opportunity rover has been silent since June when a planet-wide dust storm made its solar panels ineffective. Water ice has been found on the Moon in the shadow of craters near the poles. This is not new, but it now appears that the ice may be exposed on, or very near, the surface. The composition of the geyser material that is ejected by Saturn's moon Enceladus contains very large organic molecules. This indicates the possibility of microbial life beneath the moon's ice crust. The strange hexagonal pattern in the north polar region of Saturn extends hundreds of miles above the cloud tops. A new small object has been seen in the outer solar system. Its orbit is consistent with the existence of an unseen ninth planet. The studies of exoplanets are finding strange possibilities including Earth-sized planets with surfaces entirely covered with water, rogue planets that float through space without a host star, a planet so hot it has atoms of iron and titanium floating in its atmosphere, images of a forming planet and the possible detection of the first exomoon. The Gaia space probe indicates that the colorful star pair called Albireo is not really a binary system. There will be no explosion from merging stars in the year 2022 after all—it was all just a typo. There were several examples of stars exploding in ways that do not match our ideas about the workings of supernovae. Astronomers may have witnessed the formation of jets coming from a super-massive black hole. We began a new age of multi-messenger astronomy where observations made in the electromagnetic spectrum are combined with those of gravitational waves or streams of subatomic particles. General Relativity's prediction of gravitational redshifts was tested using the massive black hole at the Milky Way's center. Finally, deep space observations reveal baffling behaviors when the universe was young. Chief among these is the great speed with which stars, galaxies, and supermassive black holes formed.

People

Jocelyn Bell Burnell has received a Special Breakthrough Prize in Fundamental Physics. The \$3 million award recognizes her 1967 discovery of pulsars and her scientific leadership in the 50 years since then. She plans to use this money to fund research students especially students from under-represented groups in physics.

Stephen Hawking, renowned physicist, famed science communicator, and inspiration, passed away at the age of 76. He taught us how black holes work.

Solar System

An Interstellar Visitor

For the first time astronomers have seen an object that came from outside our Solar System. This moving target was first detected by the robotic telescope Pan-STARRS in Hawaii. Observations established the orbit to be hyperbolic and moving far too fast (maximum speed of 87.71 km/s relative to the Sun) to be captured by the Sun's gravity. It was named 'Oumuamua, the root word in Hawaiian for "scout." Classifying this has proven to be difficult. At first it was thought to be a comet. But deep images failed to detect any coma. It was then classified as an asteroid. With time its orbital path showed variations like those seen for comets when they get close to the Sun and vent gas jets of sublimating ice. So it seemed that 'Oumuamua was a comet after all. But astronomer Roman Rafikov argued that if it released enough gas to change its trajectory, its spin would increase because any gas jets are not likely to be acting directly on the object's center of mass. But observations show a steady, tumbling and rotation of roughly once every eight and a half hours. It is unclear why the orbit is changing.

'Oumuamua is a small oblong-shaped object, estimated to be about a half mile long and only a few hundred feet wide. This shape is estimated from the way light varies as it tumbles. It has a dark red color, like objects in the outer Solar System. 'Oumuamua was likely ejected from a forming planetary system by a collision.

Rovers on Asteroid Ryugu

The Japanese space probe Hayabusa 2 has entered an orbit about the asteroid Ryugu. It has dropped three landers onto the surface of the asteroid. Two of these are rovers. But because the surface is so irregular they do not use wheels to move about. Instead they hop from place to place. They are powered by solar panels. The third lander has a different set of instruments and it is stationary on the asteroid. It operated for 17 hours until its batteries died. The orbiting Hayabusa 2 will descend to the asteroid and collect three rock samples. This will happen in late October 2018, February 2019 and April-May 2019. For the last sample a projectile will first be shot into the asteroid to create a fresh impact crater so the material from the interior can be collected. The samples will be returned to earth in December 2020.

Jupiter has 10 new moons

Jupiter now has 10 new moons. That brings the total to 79. These new ones are all less than 3 km wide. They were discovered by the 6.5-m Magellan-Baade reflector at Las Campanas and the 4.0-m Blanco reflector on Cerro Tololo in Chile. Jupiter's small, outer moons have retrograde orbits compared to the inner moons. These outer moonlets also seem to be members of orbital families suggesting they are fragments of larger bodies that were shattered by collisions.

Jupiter's Magnetic Field—very strange

Jupiter has a magnetic field 20,000 times that of Earth. It appears to have the basic form of a dipole field, like that of a simple bar magnet. But all these impressions were based on measurements made at a considerable distance from the planet. Jupiter's magnetic field has a belt of trapped radiation surrounding its equator. Until recently all space probes have stayed well outside this region in order not to "cook" their electronics. However, the Juno probe has a polar orbit that allows it to pass inside the donut-shaped radiation field and get to within 2600 miles of the planet's cloud tops. The magnetic field has now been mapped in detail close to the planet. The magnetic field of Jupiter is not a simple dipole. In the northern hemisphere the field lines are not concentrated at a narrow pole, but rather are spread across the wide region. These field lines extend to a South Pole region and to another pole located just south of the equator. The planet appears to have a broad north pole and two south poles.

The magnetic field of the earth is produced by charged flows in its core. Jupiter doesn't have a concentrated core. Its magnetic field appears to be the product of circulating conductive fluid streams at relatively shallow depths within the planet. Even knowing this, Jupiter's magnetic field is hard to explain.

A Martian Lake

The European Space Agency (ESA) has announced the possible discovery of a *liquid* water lake on present-day Mars. However, this lake will not be easy to get to. The discovery was made by the ESA's Mars orbiter called the Mars Express which carries an instrument designed to see beneath the surface of Mars. The Mars Advanced Radar for Subsurface and Ionosphere Sounding or MARSIS transmits radio waves to Mars using a pair of boom antennas, each 20 meters long.

These radio waves penetrate many kilometers into the planet that reflect off structures and layers. A strong reflective boundary was detected about 1,500 meters beneath the surface at a location near the South Pole. The signature appears to be that of a buried lake of liquid water. However, the predicted temperature at the location of this lake is -68°C . The freezing point of water can be lowered if the water contains high concentrations of salts. Salts of sodium, magnesium, and calcium can decrease the freezing point to as low as -74°C . Salts are known to exist on the Martian surface. Perchlorates are particularly common. So, there could be a very salty lake beneath Mars' southern polar cap.

Visible Martian Water Ice

Water ice is known to exist beneath the surface of Mars. The Phoenix lander found water ice just a few centimeters below the Martian soil at its location near the North Pole. Pure water ice that is exposed will sublimate quickly in the low atmospheric pressure. That is why the announcement of exposed water ice visible from orbit was surprising. NASA's Mars Reconnaissance Orbiter found several outcrops in locations in both the hemispheres of Mars. These locations are cliff faces and the walls of craters where deeper layers of the surface are exposed. The infrared spectrometer aboard the orbiter confirmed that these layers are strongly enriched in water ice. This ice is not a seasonal frost coating, but rather permanent ice layers located at depths ranging from a few meters down to more than 100 meters. The ability to reach water so easily will be a major benefit to future human explorers of the planet.

Organic Compounds on Mars

The NASA Curiosity Rover has found that the mudstone rock in Gale crater has organic compounds. Organic molecules contain carbon and hydrogen, and may include oxygen, nitrogen, and other elements. While commonly associated with life, organic molecules also can be created by non-biological processes and are not necessarily indicators of life. But their discovery on Mars suggests the planet could have supported ancient life. The Curiosity rover has uncovered clays and sedimentary rocks formed in streams. This is evidence that a lake and conditions supportive of life existed billions of years ago in Gale Crater.

Opportunity, please call home

Last summer Mars became engulfed in an intense and enormous dust storm. The Opportunity rover went quiet in June. The rover uses solar panels to power its instruments and charge its batteries that power heaters that allow the rover to survive the plunging nighttime temperatures. While the dust storm has now ended it seems likely the rover's solar panels are covered with a thick layer of dust. Three times a week, every week since June, earth-based controllers have been sending out signals hoping for a response. So far they have only been met with silence. There is a very small chance that strong winds, perhaps in the form of a dust devil, could clean the solar panels. All we can do is wait and listen for a call from Mars.

Water Ice on the Moon

There are now indications that in at least a few locations water ice exists on the surface of the Moon. These detections were made by NASA's Moon Mineralogy Mapper (M3) instrument, which flew aboard India's Chandrayaan-1 spacecraft. A team led by Shuai Li of the University of Hawaii and Brown University studied M3 data. They found the distinctive signature of water ice in the reflectance spectra.

Most of the water ice lies in the shadows of craters near the poles, where the warmest temperatures never reach above -250 degrees Fahrenheit. Because of the small tilt of the Moon's rotation axis, sunlight never reaches these locations.

This is the first definitive evidence of water ice on the Moon's surface. With ice sitting within the top few millimeters of the surface, water would be accessible to future expeditions and lunar colonies.

Life on Enceladus?

Saturn's small (300 miles diameter) moon Enceladus expels jets of water from cracks in its ice crust. It is suspected that tidal heating keeps the interior ocean from freezing and supplying the energy to power the jets. There is good reason to suspect there are hot, geothermal vents at the bottom of the oceans of Enceladus. Prior to the end of its mission the Cassini probe passed through the jets of Enceladus to sample their content. In addition to detecting salty water, large organic molecules above 200 atomic mass units were discovered. This supports the hypothesis that, under the ice crust, there could be simple marine life, clustered around hydrothermal vents.

Christopher Glein of the Southwest Research Institute said, "With complex organic molecules emanating from its liquid water ocean, this moon is the only body besides Earth known to simultaneously satisfy all of the basic requirements for life as we know it."

High Flying Hexagon

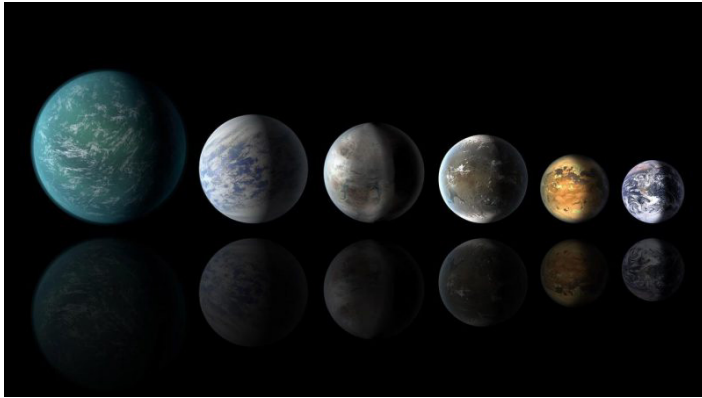
Prior to the end of Cassini's mission researchers were able to use its infrared spectrometer to study Saturn's northern stratosphere for the first time. To their great surprise they found that the hexagon structure in Saturn's troposphere extends upward into the stratosphere. A cloud structure like the northern polar hexagon should remain trapped in the lower troposphere. The hexagon structure is made by an atmospheric jet stream with winds blowing up to 300 miles per hour. It measures 20,000 miles across. We now know it also towers hundreds of miles above the clouds.

Goblin in the Outer Solar System

The object 2015 TG₃₈₇, nicknamed the Goblin, orbits between 65 and 2300 AU from Sun. This is a region beyond the Kuiper Belt extending to the inner Oort Cloud. This object is estimated to be 300 km in diameter. Scott Sheppard, Chadwick Trujillo, and David Tholen discovered 2015 TG₃₈₇ with the 8.2-meter Subaru Telescope in Hawai'i. Astronomers give small objects in the outer solar system a lot of attention. Their orbits are unaffected by the gravitational influences of the planets in the inner solar system. That makes them sensitive probes for the gravitational effects of unknown objects in the outer solar system. For example, astronomers Konstantin Batygin and Mike Brown have noted that the alignment of the orbits of these outer objects suggests the presence of a ninth planet several times as massive as Earth. The orbit of 2015 TG₃₈₇ is consistent with the presence of a possible Planet-9.

Exoplanets

Watery Super-Earths



Artist's concept of some known habitable-zone super-Earth planets. Some or even all of them could have oceans. Earth itself is at the right. Image via NASA.

A new study suggests that exoplanets between two and four times the size of Earth are likely to have a lot of water. Li Zeng at Harvard University and collaborators used the average densities of the planets to put constraints on their compositions and internal structures. Based on data from the Kepler Space Telescope and the Gaia mission, they showed that many of these planets could contain as much as 50 percent water. The water content of Earth is only 0.02 percent (by weight). The largest of these exoplanets could be water worlds, where the entire surface is covered by deep oceans, with no land masses.

Rogue Planet with Auroras

Planet SIMP J01365663+0933473 is a free-floating rogue planet that has a very strong magnetic field. This planet was not discovered in the usual ways because it doesn't have a host star that can be studied for Doppler wobbles or light drops due to planet transits. Instead it was discovered with the Very Large Array radio telescope. This exoplanet has strong auroral radio emission that requires a magnetic field 200 times the strength of Jupiter's magnetic field. Also, it is very near the limit between being a planet or a brown dwarf star. It has 12.7 times the mass and 1.2 times the radius of Jupiter. Brown dwarfs are also known to have strong magnetic fields with strong radio emission. It's not clear why this should be.

There are currently 17 known or suspected rogue planets. Given that they are hard to detect this large number suggests they may be very common in interstellar space.

Binary Rogue Planets

The object 2MASS J11193254-1137466 was originally classified as a rogue planet. Recently, a team of scientists led by William Best using the Keck Telescope discovered that it is two objects orbiting each other. The pair is thought to be a member of the TW Hydrae Association, a group of roughly two dozen young stars of a common age moving through space together. The distance to the group of 160 light-years allowed the astronomers to

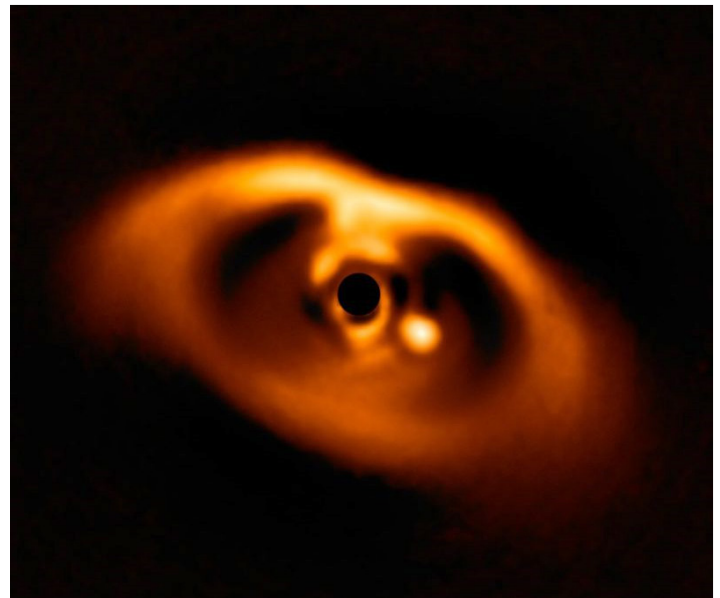
estimate the binary's separation as about 3.9 AU and each planet is about 3.7 times the mass of Jupiter.

Exoplanet Kelt-9b has Iron and Titanium in its Atmosphere

A research team lead by Jens Hoeijmakers has for the first time found iron and titanium in the atmosphere of an exoplanet. Named KELT-9b, it is the hottest planet ever discovered. It can reach temperatures of up to 7,800 degrees F (4,300 degrees C); hotter than some stars. It has three times the mass and twice the diameter of Jupiter. Astronomers have known that iron and titanium should exist on exoplanets where they are chemically bound in molecules. However, at the high temperatures of the atmosphere of KELT-9b the molecules are broken apart and the individual atoms are free in the atmosphere.

Seeing a Newly-Born Planet

Young, forming stars are surrounded by an accretion disk of dust and gas. Much of this material falls into the star and some condenses into planets orbiting around the star's equator. As the young planets move through the disk they sweep up material, growing in mass and creating a gap in the disk. These disks have been imaged around several young stars, and some show gaps. But the planets have not been unambiguously seen; these planet candidates could just have been features in the disk, not forming planets.



This image from ESO's Very Large Telescope is the first clear image of a planet being born. The planet is visible as a bright point to the right of the center of the image, which is blacked out by the coronagraph mask used to block the light of the central star. Image via ESO/A. Müller et al.

A significant gap was discovered in the disk of young star PDS 70 in 2012. Researchers from the Max Planck Institute for Astronomy and the European Southern Observatory decided to search for a baby planet. They used the planet-hunting instrument SPHERE on the European Southern Observatory's Very Large Telescope. This instrument has a coronagraph that blocks the glaring light of the star. They then obtained a long time series of

images in which any planets would appear to move as they orbit their star. Computer algorithms were used to isolate and enhance any moving object in the images while suppressing light from unchanging details.

A very large planet was detected in the gap in PDS 70's accretion disk. It has a mass that is several times that of Jupiter, and orbits about 22 AU from its host star. The orbital period is 120 years and its surface temperature is estimated to be 1,200 K.

TESS is operational

The Transiting Exoplanet Survey Satellite (TESS) was launched in April. It reached its operational orbit in July and promptly began operation. It has already discovered two new exoplanets. TESS differs from the Kepler Space Telescope in that TESS will survey the entire sky, not just a limited number of star fields. It will search for planets of bright, nearby stars, while Kepler concentrated on faint, distant stars. Over the course of its initial two-year mission, TESS is expected to find about 20,000 exoplanets.

An Exomoon?

David Kipping and Alex Teachey may have discovered the first exomoon. They used data from Kepler spacecraft and the Hubble Space Telescope to find a candidate exomoon. The star Kepler-1625 has a planet, Kepler-1625b, that orbits every 287 days making a 19-hour transit in front of the star as seen from Earth. Some of the transit light curves appear to have an extra drop in light just before or just after the planet's transit. This is what you would expect to see if the planet has a companion moon. If this drop in light is caused by a moon, it would be a Neptune-sized and orbiting a planet several times larger than Jupiter. Many more observations will be required to confirm this.

Stars

Albireo is NOT a binary star

The European Space Agency's Gaia spacecraft is now returning measurements of the position and motion of a billion stars in the Milky Way. One tiny piece of the scientific return is the resolution of a long-standing question of night-sky watchers. Is the colorful star pair known as Albireo an actual binary pair? Are they physically bound by gravity with an orbital period so long that astronomers have been unable to see them move? The Gaia positional data is of such high precision that the actual space motion of the two stars is now known. They have different space motions, i.e. they are not a traveling pair. They are just a very pretty optical double, a chance alignment seen in our summer skies.

No Explosion in 2022

In last year's Astronomy Update I mentioned the prediction that stars in a binary system called KIC 9832227 would collide and merge in the year 2022. Lawrence Molnar (Calvin College) and his colleagues predicted this merger and a resulting explosion producing a nova.

This prediction was based on timing data that indicated the orbital speeds were increasing as you would expect if the stars were spiraling toward each other. The researchers relied on published timing data as well as new observations. It turns out that one of the published references had a typo, throwing off the calculations for binary system. This error was discovered by a team led by graduate student Quentin Socia. They found the 2004 catalog had different Julian dates listed in the preprint version than the final, published version.

Never forget, science is done by mere humans.

A Star That Won't Die

Astronomers know that a massive star ends its life by undergoing a supernova explosion. While the exact details are not fully known it seems very clear that a star can only have one supernova explosion. The star is either destroyed or it becomes a neutron star or a black hole that is incapable of another explosion. That is why the case of star iPTF14hls is so strange. This star has been observed going supernova twice, once in 1954 and again in 2014. Its behavior in 2014 was a series of several supernova-size events. Calculations suggest the star was at least 50 solar masses. Perhaps this size is the reason that our conventional theory fails to explain explosions of this object. It may be some entirely different physical processes are involved.

A Super-Supernova

Astronomers have seen a new type of cosmic explosion, believed to be 10 to 100 times more energetic than an ordinary supernova. This explosion, designated AT2018cow, was seen in a galaxy 200 million light-years away. Another unusual aspect of the outburst was its speed; it reached its peak brightness in two days. Supernovae usually take weeks to become their brightest. Most of the light for a supernova's afterglow is from the radioactive decay of nickel produced in the supernova. The AT2018cow event was too bright and too fast for that. Its spectrum was smooth, unlike most supernovae that have distinct absorption lines. Observational data are still being collected as the outburst continues to fade.

Fast Something-or-Others

There is at least one more new type of supernova-like event. Miika Pursiainen and his research team have reported on the discovery of explosive events that are much faster than ordinary supernovae. They are called Fast-Evolving Luminous Transients (FELTs). While they resemble supernovae in their peak luminosity, they fade away in just a few days where supernovae take weeks. These astronomers have seen 72 different FELTs outbursts.

Black Holes

Black Hole Eats Star While We Watch

Scientists have known for decades that massive black holes can expel jets of gas at speeds of a quarter the speed of light. It is believed that the formation of the jets occurs when the black hole ingests a cloud or a nearby star. These objects are shredded and

form a swirling accretion disk around the black hole. The jets are likely formed by matter from the disk that is directed along the magnetic field lines of the rotating black hole.

While astronomers have seen these jets in operation, they had not seen one form. That has now changed. Galaxies Arp 299 A and Arp 299 B are a colliding pair. The massive black hole at the center of Arp 299 B is 20 million solar masses. Radio observations of this black hole seem to show the results of a star falling into the black hole. Material is seen expanding in one direction, at about one-quarter the speed of light. This is consistent with a jet of material being ejected from the disk surrounding the black hole. These observations involved 36 scientists from 26 institutions around the world.

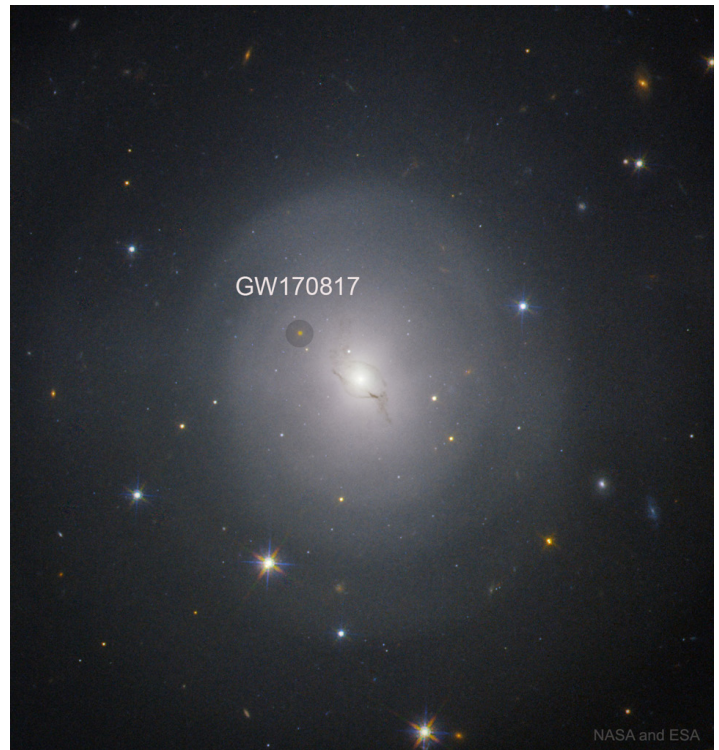
Era of Multi-Messenger Astronomy Begins

(Multi-messenger astronomy, the study of the universe using fundamentally different types of emission.)

Example 1: Gravitation Wave Detection GW170817

LIGO made its fifth confirmed gravitational-wave event. But this one lasted much longer than the previous ones. Instead of a fraction of a second duration this new one lasted ninety seconds. This is the expected gravitational wave signature from a merging pair of neutron stars. The gravitational waves emitted drained the system of orbital energy, and two neutron stars eventually collided.

The gravitational wave data indicated a distance to the source of roughly 150 million light-years. Optical astronomers then began a search in the location indicated by the gravitational wave observatories. Within the search area there were only a few galaxies at this distance range. Astronomers checked the galaxies one by one to see if they could find an optical transient. Galaxy NGC 4993 showed a nova-like event. Its redshift distance is 130 million light-years. The explosion is labeled a kilonova because it is less luminous than a supernova, but about 1000 times brighter than a normal nova. This matches the expected luminosity of merging neutron stars.



This Hubble Space Telescope image shows the kilonova outburst in NGC 4993. This explosion was due to the collision and merger of two neutron stars.

Spectroscopy of the kilonova showed heavy metals like platinum, lead, and gold. These observations confirm that the majority of elements more massive than iron are produced by neutron star collisions, rather than in supernova explosions. The merger of two neutron stars may produce ten times the mass of the Moon in pure gold. Just two seconds after the LIGO detection the Fermi Gamma-ray Space Telescope recorded a short gamma-ray burst. This confirms that short gamma-ray bursts are produced by colliding neutron stars.

Based on gravitational-wave observations, the neutron stars were 1.48 and 1.26 solar masses. Their merger produced an object of about 2.7 solar masses. An object of this mass doesn't have an identity; it is either the most massive neutron star known, or the least massive black hole known.

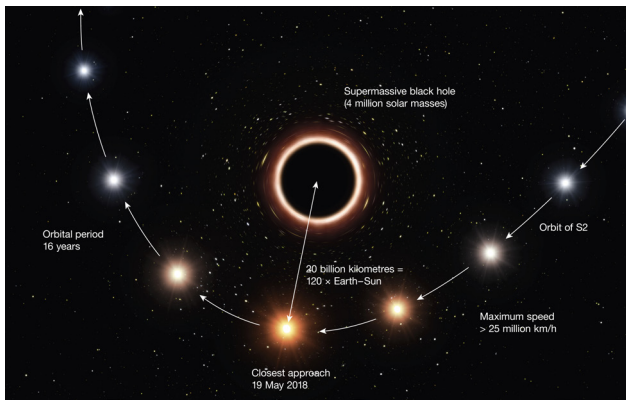
Example 2: IceCube Neutrino 170922A

The world's largest neutrino detector is called IceCube in part because it is in Antarctica. A large array of light detectors is buried in the ice where they can record light scintillations produced by high energy neutrinos arriving from space. A major goal is to relate these neutrinos to their source in the cosmos.

On September 22, 2017 IceCube alerted astronomers of a detection of a high-energy neutrino that could be traced to a small patch of sky in the constellation Orion. About 20 observatories on Earth and in space made follow-up observations. They detected an outburst from the blazar TXS 0506+056. This object is a galaxy 3.7 billion light-years from Earth containing a billion-solar-mass black hole. We now know that massive black holes that are ingesting matter can somehow produce high energy neutrinos.

Testing General Relativity

Astronomers at the European Southern Observatory have been conducting a 26-year study of the motions of the stars near the center of the Milky Way galaxy. This has required infrared imaging (because of the interstellar dust), adaptive optics, and interferometry (to achieve the necessary resolution). These observations were made by combining the light of the four 8-meter telescopes that make up the Very Large Telescope (VLT). Many stars can be seen orbiting about a seemingly empty place where a 4 million solar mass black hole resides. One star, called S2, reached its closest point to the black hole this last summer. At a distance of just 17 light *hours* from the black hole it was traveling at almost 3% the speed of light. General Relativity predicts that light that leaves a strong gravitational field will be redshifted. This is in addition to any redshift created by relative motion. The passage of star S2 was used to test General Relativity and in fact the light from S2 was redshifted by the exact amount predicted.



An illustration of the close passage of the star S2 to the central black hole of the Milky Way galaxy. The change in the star's color due to gravitational redshift was confirmed. From the European Southern Observatory.

The Universe Did Crazy Things When It Was Young

1. Blue-Dot Galaxies

Astronomers Debra and Bruce Elmegreen discovered a unique galaxy type by exploring archival Hubble Telescope data. They noticed several galaxies that stand out as tiny, bright, blue objects that are nearly unresolved points. These galaxies are just a few hundred light-years across and the mass of gas and dust exceeds that of stars by a factor of five. Their blue color indicates a high rate of star formation. What are these? In the early universe did they merge to make larger galaxies, or did they become small things like globular star clusters?

2. Early Spinners

A research team led by Renske Smit used the Atacama Large Millimeter/submillimeter Array (ALMA) to study galaxies that existed just 800 million years after the Big Bang. They were surprised to find these young galaxies are rotating. They formed when gravity caused gas to flow rapidly into them and forming lots of new stars. This resulted in many supernovae that made the

surrounding gas turbulent. So there is an expectation of chaos in these early galaxies not organized rotation.

3. Galaxies Without Stars

When you hear the word “galaxy” a pinwheel of stars immediately comes to mind. So, it may seem very odd to hear that galaxies in the early universe had few stars and in some cases no stars at all. Some theoretical models of the early universe predict a time period after the Big Bang where denser pockets of gas have pulled together as the first stage of galaxy formation. But stars have not yet formed. These star-less galaxies, also known as dark galaxies, might be a very early stage of galactic formation. They were just concentrations of gas. A large research team centered at the Physics Department of ETH Zurich believes they have detected some dark galaxies. The trick was to look for these objects in places close to quasars. The UV light from the quasar will cause the gas in the dark galaxies to glow by fluorescence. So far they have found six dark galaxies.

4. Super-Massive Black Holes formed Super Early

A team led by astrophysicist Eduardo Bañados has found a quasar with a redshift of 7.54, corresponding to a time just 690 million years after the Big Bang. This quasar contains the most distant supermassive black hole yet found. This black hole is 800 million solar masses. The existence of such massive black holes so soon after the Big Bang challenges our understanding of how supermassive black holes and their host galaxies form. It takes a lot of time to move and compress such huge quantities of matter.

5. Stars Formed Quickly Too

After the Big Bang there would have been a time where the universe contained only gas, and stars had not yet formed. New observations suggest stars formed quickly and this cosmic dark age might have lasted no more than 250 million years.

Takuya Hashimoto and collaborators used the Atacama Large Millimeter/submillimeter Array (ALMA) to study a galaxy whose light was emitted 550 million years after the big bang. The spectrum of this galaxy contains the spectral signature of oxygen. The Big Bang produced only hydrogen, helium and a very small amount of lithium. All the other elements, including oxygen, were produced in stars. The presence of oxygen in this early galaxy means that 550 million years after the Big Bang at least one generation of stars had already formed and died producing heavy elements that were incorporated in the next generation of stars.

Closing Comments

This is my tenth year of presenting the Astronomy Update for the GLPA. This is also my last Astronomy Update. I feel it is time for me to retire. I sincerely hope the members have enjoyed the conference presentations and the write-ups for the Proceedings. I have enjoyed presenting the Updates and interacting with the GLPA members. I want to thank the GLPA Executive Committee for its faith in me, the Proceedings Editor Dale Smith for catching my mistakes and working with my late submissions, and my friend Gary Tomlinson—those introductions were great fun.

DARK TWIST ON PLANETARIUM STORYTELLING

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Abstract: Sometimes technology challenges planetarians - hardware and software sometimes fail. We are in an awkward position - we have no stars! But, we are anxious to teach students. We have a program set up with the elementary school's technology specialist, putting third graders into groups, and having them build constellation projectors from oatmeal boxes. We will include some of the dimmer stars in the constellation diagrams we will provide to them; they are not likely to recognize the constellations. Students will write a story, tell it in the planetarium dome, and then listen to several stories about the constellation.

HI! My name is Sue. I am a planetarian. I haven't shown a planetarium show for almost three years.

All right. Seriously, when I retired in January 2016, I gave up my planetarium in a large high school and moved to the "country." I live so far out of town, even the people that live in the boonies say I live in the boonies. I did start preparing for this retirement and my new (almost ready to go) portable planetarium business, however. I got a great deal on a portable dome and have it stored in my barn. I am working on a couple of different ways to find enough money to get a projector for the dome so I can be back in business. However, I recently came across a way to use my dome without the projector, and thought you might find this interesting.

I was speaking to the local school librarian about my dome. She goes to my church and we meet socially often. I said, maybe we could just put up the dome and bring the kids inside and just tell stories. She thought it would be wonderful to have an alternative space for the kids to think about stories. So we put our heads together to come up with an idea.

We eventually decided to give the students a chance to try out storytelling for themselves. Since we don't have a star projector to fill the sky, I thought we could let the kids make their own single constellation star projectors and see how that would work. The librarian thought that would be great. So here's our plan.

WAIT! If you try this, you need to know that librarians have weird schedules. Our three elementary schools have two classes each of grades 1 through 5. The librarian spends one day in each elementary school, and two days doing technology coordination and visiting our kindergartens. That means she sees her students every other week. It also means I will have to take the dome to each school twice to get all of the students in the dome one time. OH! Don't think there is any important order to her schedule, either. She does not see the grades in order, nor does she see both classes in the same grade on the same day, except for 5th grade and 2nd grade in one of the three schools.

Anyway, here is our plan.

She is going to work with third, fourth, and fifth grade students. She is going to group them into fours and will have between five and eight groups in each class. Then she will have the fifth graders make oatmeal box projectors. You have probably seen them. Kids poke holes in the end of an oatmeal box in the shape of a constellation and then use a flashlight inside the box to shine the stars onto the ceiling, or in this case, dome. I supplied the constellations, sized for her oatmeal boxes, and with the images flipped so they will project correctly. I chose constellations with brighter stars, and added in some dimmer stars that are not often included in the drawings students see. I did not include any lines, or even names of the constellations. I don't think they will recognize them, but they could.

The librarian will take the students into a dark room at school and the kids will project their constellations on the wall or ceiling and make a drawings of them. Remember, this will be just the stars and they don't know the name of the constellation they were given. Then, they will take their star drawing and create their own constellation by connecting some of the stars.

As a group, at their next meeting (two weeks later), they will make up a story about the star picture that will last about two minutes. They are to use some dialog in the story, and the librarian will explain how to put quotation marks in their writing. The group of four will write the story and edit in this class period.

When the stories are ready, I will bring the dome to school and we will take each class into the portable dome. I will have a light source for them as they enter and when I turn it out, there will be red string lights around the edge of the dome so the librarian and maybe their teacher can see the kids. It should still be pretty dark, and there should be no problem seeing the projected stars. Each group will present their story. One student will be in charge of the projector (flashlight and oatmeal box), one will connect the stars with a laser pointer, one will tell the story with the fourth adding the dialog voices. This should take two minutes. I will then have

two minutes to point out the “accepted” star picture and tell them the Greek or Roman story and one other culture’s story for that collection of stars. Even with eight groups, we should have just enough time to finish everyone.

The constellations I have chosen to use are Ursa Major, Cygnus, Scorpius, Pegasus, Orion, Draco, Gemini, and Boötes.

OK. Now the bad news. When I submitted the proposal, I thought we would have completed the project by now. I didn’t count on the long time it would take to see every class and how long before she could attempt a project like this.

So. I am scheduled to go to the school in two (and three) weeks to see how the kids have done. That will mean taking the dome to all three schools on four different days. All I can say is, tune in next year for how this all comes out. I’ll present part II, How Students React to Using a Dome without a Projector!

PROCESSING AND STORYTELLING WITH GAIA DR2 DATA

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Abstract: This year saw the Gaia team release their Data Release 2 from the Gaia satellite, one of the largest stellar databases ever seen. One of the largest but most interesting challenges in recent years, we were eager to tackle the dataset at Morrison Planetarium. Here's a review of the processes and work we did to get Gaia's data into our software, presentations and lessons we've already used it for, and what we hope to use it for in the future.

Introduction

Since the emergence of the first digital planetariums in the final decades of the 20th century, one of the leaps beyond the traditional starball was the ability to present the stars in three dimensions, accurately placing them in their locations (to the best of our knowledge) in the Universe and being able to fly and explore the starfield not just as the firmament above our heads, but as an expanse extending hundreds of light-years into the Milky Way. Digital planetariums didn't just extend the starfield into the third dimension, they expanded into the fourth. With proper motion measurements of the stars their future and past motions could be extrapolated and presented to an audience. The coincidence that creates our familiar constellations could be fully understood, watching them deform not only as the planetarium became a spaceship, propelling audiences to see the familiar stars from a new perspective, but also a time machine, deforming our seemingly constant asterisms over the eons of past and future, beyond our cultural memory and even our species' existence.

The ability to present these datasets has relied on massive catalogs compiled by astronomers performing exacting parallax measurements as the Earth orbited the Sun to trigonometrically determine the positions of these stars, as well as tracking their small, subtle motions across the sky to measure their velocities relative to the Sun. The most significant update to these datasets came with the age of satellite observatories and computerized data processing. In 1989 the European Space Agency launched the *Hipparcos* satellite, named for Greek mathematician and astronomer Hipparchus, credited with the invention of trigonometry and discovery of astronomical parallax (although he only applied it to lunar and solar measurements; stellar parallax, and thus, the ability to measure the distance to the stars would not be discovered for another 2000 years). During its four-year mission *Hipparcos* measured the parallax of some 118,000 stars giving us an unprecedented three-dimensional understanding of our local universe. Combined with additional photometry results and cross-referenced with the *Tycho star catalog* (Hog, Kuzmin and Bastian) (containing the celestial and photometric positions of a million stars) the *HIPPARCOS Catalogue* (Perryman, Lindegren and Kovalevsky) was published in 1997 and since has become

a heavily utilized and referenced astronomical catalog, further improved with additional cross-referencing against other stellar catalogues. *Hipparcos* and its 2000s successor the *Extended Hipparcos Catalogue (XHIP)* (Erik Anderson) are generally the source catalog for defining the stellar simulation in most digital planetarium and space simulation software.

But *Hipparcos* is not without its limitations. 118,000 stars, although an impressive update from the few thousand visible to the naked eye (and available in most optomechanical star projectors), are hardly a comprehensive survey of the Milky Way, and *Hipparcos* does not extend beyond a few hundred light years, excepting some extremely luminous, distant stars. Nor does it include the majority of faint stars, a cross-reference and augment with additional surveys, such as *Gliese-Jahreiss Catalogue of Nearby Stars*, which can be used to supplement *Hipparcos* with a portion of the local red dwarf population not observed by the satellite. In addition, although *Hipparcos* is generally reliable and highly accurate, some of its measurements, particularly of the Pleiades star cluster, do not agree with other parallax measurements taken from Earth. And, of course, the nature of science always requires further questing and knowledge.

20 years later, *Hipparcos* has now been followed up by a successor mission, also from the European Space Agency: *Gaia*. Launched in 2014, *Gaia* was sent far beyond the Earth orbit used for *Hipparcos*. It was placed at LaGrange Point 2, about a million miles further from the Sun than Earth. *Gaia*'s mission goals are far more ambitious than those of *Hipparcos* by several orders of magnitude: *Gaia* seeks to measure over one billion objects, delivering high-quality photometry and position and velocity data for millions of stars giving us an unprecedented view of our Milky Way (and beyond).

Even before its first year of observations were complete, the *Gaia* team released their first dataset, Data Release 0 (DR0), containing millions of stellar observations. This extremely incomplete observational data was cross-referenced with the *Tycho-2 star catalog* (Høg, Fabricius and Makarov) (a 2.5 million star catalog and successor to *Tycho* used with *Hipparcos*) resulting in the *Tycho-Gaia Astrometric Solution (TGAS)* (Michalik, Lindegren

and Hobbs). *TGAS* represented the first chance to attempt to tackle a very small subset of the enormous amount of astronomical data that would be coming from *Gaia* and the first chance to present it in the planetarium. At the California Academy of Sciences we were excited to face this challenge and began to map out a data processing workflow with the hopes of combining *TGAS* with *Hipparcos* to expand our stellar catalog by an order of magnitude. This step would be necessary to make *Gaia* a useful catalog as the satellite currently has not made observations of many bright, nearby stars, and thus cannot provide a complete stellar catalog on its own and must be cross-referenced and merged with *Hipparcos* to be complete. Ultimately, however, we spent significant amounts of time looking into what would be the best software solution for such a large dataset (with much discussion whether python would be sufficient or if R was worth investigation), rather than actually doing the processing work and left the process ignored. Despite our lack of action, we shared our plans with other interested planetarians and *TGAS* has subsequently been implemented in other planetarium software.

Process and Implementation

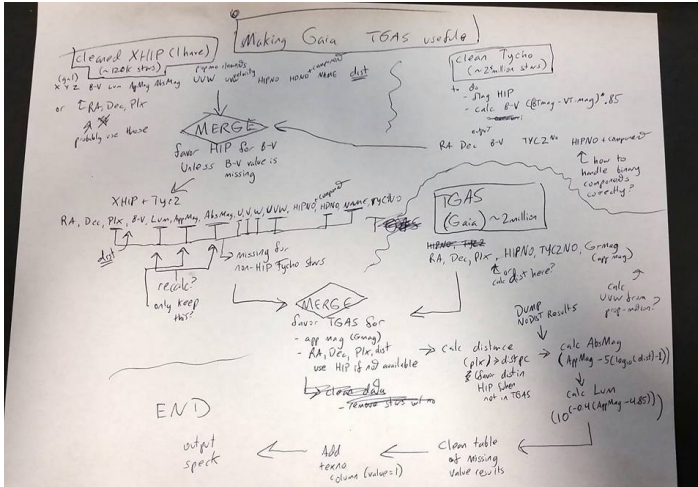


Figure 1. A Proposed Merge Solution for *TGAS* and *XHIP*.

We did not revisit the problem again through the 2017 release of *Data Release 1* (DR1), and started discussing it again with *Data Release 2* (DR2) (Gaia Collaboration: Brown, A. G. A.; Vallenari, A.; Prusti, T.; de Bruijne, J. H. J.; Babusiaux, C.; Bailer-Jones, C. A. L.; Biermann, M.; Evans, D. W.; Eyer, L.; Jansen, F.; Jordi, C.; Klioner, S. A.; Lammers, U.; Lindgren, L.; Luri, X.; Mignard, F.; Pa) in May of 2018. Our interest in the dataset was specifically prompted by communication with Dr. Jacqueline Faherty, of the American Museum of Natural History. Faherty has lectured at the Academy of Sciences and has frequently shared her research data with us, sometimes in exchange for visualizations for her own use. This was no exception; Faherty had begun processing reductions of *Gaia* DR2 and was interested in our assistance in producing visualizations of her data. We confessed to her that although we had done some initial planning we hadn't made any preparations for handling the final dataset. She offered us some reductions to start working with and we dove right into it.

Initially, to avoid the daunting task of the entire DR2 we began with a smaller subsample of just stars within 20 parsecs of the Sun,

about 5400 stars. Having previously done work on reprocessing the *XHIP* catalog and the Gliese-Jahreiss *Nearby Stars* we had some workflows in place for handling stellar data, but we wanted to investigate what was in DR2 thoroughly so we began our processing journey with Microsoft Excel, which would allow us to quickly see the results of our equations and transformations before we applied a more programmatic approach to processing larger datasets.

Unfiltered, DR2 contains an enormous amount of data, not all of which would be immediately useful to us. Other data were useful, but significantly different from how *Hipparcos* handled it, and, of course, plenty of data were missing, as the mission is still ongoing. Our primary simulation software at the California Academy of Sciences is Sciss's *Uniview* software, and this paper will describe the work we did to process the data for *Uniview*; however, the techniques, applications and caveats may be useful to others wishing to process this data for their own software.

Since our final goal would be the four-dimensional simulation of the dataset, including the three-dimensional positions of stars along with their motions in space over time, the very first step would just be to make sure we could get the stars into their current position correctly. DR2 provided stellar positions for epoch J2015.5 in both right ascension and declination (RA & Dec) and galactic longitude and latitude (l & b). With distance measurements obtained from parallax these celestial measurements can be converted to Cartesian X, Y, Z coordinates useful for a 3D simulation. *Uniview* creates its simulated Universe by building a series of nested coordinate spheres with appropriate transformations placed on them as one advances outward into space. Thus, the Earth and Earth-centered satellites are in the celestial equatorial coordinate system most Earth-based astronomers are familiar with. Solar System objects are in ecliptic coordinates aligned to the Earth's orbit, extrasolar objects in galactic coordinates along the Milky Way's plane, and extragalactic objects in the extragalactic reference system expanding beyond the galactic. Many astronomical datasets give position in RA and Dec and a transformation must be applied to reproject them into galactic coordinates. However, because galactic coordinates were provided, the Cartesian position was relatively easy to calculate trigonometrically without the need to apply further transformations. Although we applied distance from the inversion of parallax, we were subsequently informed that beyond 300 parsecs *Gaia* data obtains very high errors in measurement. Bailer-Jones *et al.* have used galactic modeling as well as statistical techniques to produce a distance table to improve on as much as possible these errors (C.A.L. Bailer-Jones (MPIA)), thus improvements can be made on subsequent processing of DR2.

Although this requires trig formulas in Excel, working in an actual astronomy data processing environment like *AstroPy* will let you accomplish this in a single step.

With distance complete, we turned our attention to how to handle proper motion. Although *XHIP* directly provided the Cartesian galactic velocities (U, V, W), *Gaia*, like many catalogues, provided celestial terms: proper motion in right ascension (pmra) (actually $pmra \cdot \cos(\text{Dec})$), proper motion in declination (pmdec) and radial velocity (rv) (the velocity component of the star's orbit around the Milky Way center, in heliocentric reference

frame). Of course, these terms can be converted, although it took a little bit of hunting to come across the right formula. We ultimately found and used the formula from Johnson and Soderblom (Johnson and Soderblom) shown in figure 2.

where the transformation matrix is given by

$$T = \begin{bmatrix} +\cos\theta_0 & +\sin\theta_0 & 0 & 0 & +\cos\delta_{NGP} & -\sin\delta_{NGP} & 0 \\ +\sin\theta_0 & -\cos\theta_0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & +1 & +\cos\delta_{NGP} & 0 & +\sin\delta_{NGP} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & +1 \end{bmatrix}$$

Using the above definitions of α_{NGP} , δ_{NGP} , and θ_0

$$T = \begin{bmatrix} -0.06699 & -0.87276 & -0.48354 \\ +0.49273 & -0.45035 & +0.74458 \\ -0.86760 & -0.18837 & +0.46020 \end{bmatrix}$$

We also define a coordinate matrix

$$A = \begin{bmatrix} +\cos\alpha\cos\delta & -\sin\alpha & -\cos\alpha\sin\delta \\ +\sin\alpha\cos\delta & +\cos\alpha & -\sin\alpha\sin\delta \\ +\sin\delta & 0 & +\cos\delta \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ \sin\alpha & -\cos\alpha & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} \cos\delta & 0 & -\sin\delta \\ 0 & -1 & 0 \\ -\sin\delta & 0 & -\cos\delta \end{bmatrix}$$

The Galactic space-velocity components are then

$$\begin{bmatrix} U \\ V \\ W \end{bmatrix} = B \begin{bmatrix} \rho \\ \mu_{\alpha}/\pi \\ \mu_{\delta}/\pi \end{bmatrix}, \quad (1)$$

ities, which are now being measured to better than 1 km s⁻¹ (e.g., Beavers and Eitter 1986).

V. CORRECTION FOR THE SOLAR MOTION

Figure 2. Calculating UVW from Johnson and Soderblom

Unfortunately for one of the authors, Dan Tell, this formula requires a matrix transformation from equatorial to galactic coordinates and Tell never did well at matrices in high school Algebra, managing to skate by the rest of his educational career without fully learning them. Fortunately, other resources were available to assist in creation of linear versions of the equation that we could enter into Excel to test our UVW conversions. We used the source code from David Rodriguez (Rodriguez) which itself was based on the NASA IDL Astronomy Users Library (Landsman). With this we were able to generate linear equations for UVW conversion, as shown in figure 3.

$$u = -1 * (((0.0548755604 * \cos(RA)) * \cos(Dec)) + (0.8734370902 * \sin(RA)) * \cos(Dec)) + (0.4838350155 * \sin(Dec))) * RV + (((-0.0548755604 * \sin(RA))) + (0.8734370902 * \cos(RA))) * (4.74047 * \text{pmRA}/\text{parallax})) + (((-0.0548755604 * \cos(RA)) * \sin(Dec)) - (0.8734370902 * \sin(RA)) * \sin(Dec)) + (0.4838350155 * \cos(Dec))) * (4.74047 * \text{pmDec}/\text{parallax}));$$

$$v = (((0.4941094279 * \cos(RA)) * \cos(Dec)) + (-0.4448296300 * \sin(RA)) * \cos(Dec)) + (0.7469822445 * \sin(Dec))) * RV + (((-0.4941094279 * \sin(RA))) + (-0.4448296300 * \cos(RA))) * (4.74047 * \text{pmRA}/\text{parallax})) + (((-0.4941094279 * \cos(RA)) * \sin(Dec)) - (-0.4448296300 * \sin(RA)) * \sin(Dec)) + (0.7469822445 * \cos(Dec))) * (4.74047 * \text{pmDec}/\text{parallax}));$$

$$w = (((-0.8676661490 * \cos(RA)) * \cos(Dec)) + (-0.1980763734 * \sin(RA)) * \cos(Dec)) + (0.4559837762 * \sin(Dec))) * RV + (((-0.8676661490 * \sin(RA))) + (-0.1980763734 * \cos(RA))) * (4.74047 * \text{pmRA}/\text{parallax})) + (((-0.8676661490 * \cos(RA)) * \sin(Dec)) - (-0.1980763734 * \sin(RA)) * \sin(Dec)) + (0.4559837762 * \cos(Dec))) * (4.74047 * \text{pmDec}/\text{parallax}));$$

Figure 3. Linearized UVW equations

With our coordinates set up, we still had a few more steps to apply to get a usable version of the dataset. As the initial 20pc sample was so small we wanted to get as many stars in our test dataset as possible into *Uniview*, however, many Gaia stars do not yet have fully complete photometry. A common value missing that is vital for *Uniview* to render stars is luminosity, quite literally, how much light a star generates. *Uniview* uses luminosity as its primary driver for star rendering. By its nature, luminosity has a relationship to stellar magnitude. Typically astronomers may use magnitude measurements from the V or visual band according to the Johnson-Morgan UBV photometry system (Johnson and Morgan), centered on 551 nm. However, *Gaia* uses G-band magnitudes (we are hopefully assuming it is calibrated to the G “green” band), which is a slightly lower wavelength of 464 nm and a slightly broader band. Although the equations defining the relationships remain the same, some of the terms must change, particularly luminosity, which uses the Sun as reference, as the Sun has a slightly different G-band absolute magnitude than the V-band. Substituting the Sun’s G-band magnitude we approximate the luminosity of stars that were missing this term to ensure we could test with as many stars as possible, even if luminosity was

not perfectly accurate.

Similarly, we assign color in *Uniview* using the B-V color system (as it sounds, Johnson B magnitude (blue filter) minus V magnitude). Although *Gaia* also has B and R (red) band photometry that could be used to make new colormaps, we did not at this time want to rewrite our colormap, and although we knew B-G would not be accurate we used it as an immediate substitute. We would make further corrections as we moved into our python environment for final processing.

Even with these steps we were not able to account for all stars. Stars with missing B-magnitudes, for example, were thrown out in our final processing before loading our results into *Uniview*.

In our initial test of this small dataset in *Uniview* we successfully positioned our stars and had approximate luminosities and colors and proper motion. We then moved on to a slightly larger dataset containing all stars within 100 parsecs, a much larger dataset of 700000 stars—already substantially more than the entirety of *XHIP*. Again we performed the same conversions and loaded our result into *Uniview*. We had found that our 20pc dataset was not a particularly good test for actually ensuring we had done everything right; since *Gaia* does not have many measurement for close, bright stars, and has many faint stars not included in *XHIP*, we were not able to clearly distinguish that proper motion was moving correctly. Fortunately, the 100pc dataset includes one of the most easily visible and obvious moving groups in nearby space: the Hyades. Immediately we discovered that in our processing the Hyades (as well as the Ursa Major moving group, many stars of which were in the 100pc dataset) were diverging significantly from the proper motion values in *XHIP*. Luckily this problem was easy to correct: in our first pass of processing we had failed to apply the transformation matrix given above (as mentioned, Tell is not good with matrices) resulting in wildly incorrect moving group motion. A reprocessing that successfully applied this matrix resolved the issue, and motions roughly agreed with existing *XHIP* values where present (although presumably with finer precision) and we were able to perform several test cases, which will be outlined in the stories below.

Demoing this for Faherty, we were warned that we should be cautious with another assumption we made: several *Gaia* stars do not have radial velocity measurements. We assigned an RV value of 0 for all stars missing radial velocity, which still applied their pmra* and pmdec for proper motion; however, she pointed out, the lack of RV would cause clusters in which some stars had this measurement and others did not to shear apart over time, inaccurately. Further improvements on this will have to wait for subsequent *Gaia* releases with improved measurements.

Importantly: we had achieved our goal: accurately (within the limits of the source data) representing (a portion) of *Gaia Data Release 2* data in a simulation environment to explore the past, present, and future of the nearby Milky Way.

Confident our processing was sufficient for our initial purposes we turned our attention to a larger dataset. We were certain *Uniview* would not be able to display one billion stars, but also knowing there were many missing values we simplified our work

by making data requests for only stars in DR2 that had all values we were interested in using, namely, parallax, distance, B-magnitude, G-magnitude, luminosity, etc., which would also remove some of our assumptions. We made our initial requests from Université de Strasbourg's *VizieR* system and these parameters gave us a file of approximately 58 million stars. With this new dataset in hand we set about creating a Python script to process the dataset to apply the necessary transformations to render it in 4D in *Uniview*. Having some experience with *AstroPy* (<http://www.astropy.org/>) we believed it would provide most of the tools we needed to achieve our goals, although we ultimately had to include some functions from *PyAstronomy* (<https://www.hs-uni-hamburg.de/DE/Ins/Per/Czesla/PyA/PyA/index.html>). Milan Bhatt's far greater programming expertise and Python experience was mixed with Tell's understanding of the astronomical terms to generate this script. In addition, Tell and Bhatt worked together to try to find a better solution for getting more accurate color in *Uniview*. Many stars in DR2 have a calculated effective temperature value (teff) from their other terms. Teff has a relationship with stellar color (although giant stars follow this relationship somewhat differently from main sequence stars), and it was therefore hoped even if B-V color could not be calculated that a new colormap could be generated that relied on teff, instead of B-V color (accepting some inaccuracy might be in place for giants). However, we discovered that *PyAstronomy* provided some tools that utilized research into the mathematical relationships behind the teff and B-V color relationship (Ramírez and Meléndez) (Ballesteros) which DR2 had sufficient data to approximate B-V color calculation. Overall, most of the large functions we wrote for our test case in Excel could be replaced by relatively simple commands in *AstroPy*.

```
def reset_icrs_rep(self):
    del(self.icrs_rep)
    #self.icrs_rep = ICRS()

def create_galactic_rep(self):
    self.galactic_rep = self.icrs_rep.transform_to(Galactic)
    self.x = self.galactic_rep.cartesian.x
    self.y = self.galactic_rep.cartesian.y
    self.z = self.galactic_rep.cartesian.z

    self.u = self.galactic_rep.velocity.d_x
    self.v = self.galactic_rep.velocity.d_y
    self.w = self.galactic_rep.velocity.d_z

def reset_galactic_rep(self):
    del(self.galactic_rep)
    #self.galactic_rep = Galactic()

def reset_class_variables(self):
    del(self.ra, self.dec, self.parallax, self.distance,
         self.pmra_cosdec, self.pmdec, self.radial_velocity,
         self.designation, self.pscol, self.gmag, self.bpmag,
         self.glon, self.glat, self.teff, self.bvcolor,
         self.radius, self.luminosity, self.x, self.y, self.z,
         self.u, self.v, self.w)

def calculate_bvcolor(self, method='ballesteros'):
    #teff_list = self.teff
    if (method == 'ballesteros'):
        b = pyasl.BallesterosBV_I()
        m = map(lambda t: b.t2bv(t), self.teff)
        self.bvcolor = list(m)
    else:
        r = pyasl.Ramirez2005()
        m = map(lambda t: r.teffToColor("B-V", t, 0.0), self.teff)
        self.bvcolor = list(m)

def output_speck_file(self, file_name):
    #num_cols = fits.hdu[0].header['TFIELDS']
    file_writer = open(file_name, mode='w', newline='\n',
                       encoding='cp1252', buffering=1024)
    header = \
'''
CAS Stars - Processed through Astropy 3.0.3 and PyAstronomy
Milan Bhatt, California Academy of Sciences
stavar 0 Bvcolor
stavar 1 luminosity
stavar 2 gmag
'''
```

Figure 4 and 5. Preview of Python script.

Of course, a 58 million star dataset is enormous: our raw request was approximately 10 gigabytes. As such our next challenge was actually loading it into memory and applying all the desired transformations. Our initial starting file was an ASCII tab separated value (TSV) document, which we quickly found was not the most memory-efficient input format for our Python script. Unfortunately, we found our requests from *VizieR* or directly from the *Gaia Archive* would time out when requesting the binary FITS format files that would run much more efficiently. Ultimately we made use of conversion utilities within *AstroPy* to rewrite our TSV into FITS to improve performance. However, we found the enormity of the file was still daunting for computers. We relied on a machine in our render farm with 64 GB of RAM to process our data and frequently would get part way through the dataset before it would crash. Bhatt's programming and optimization expertise allowed him to improve the data handling and ultimately we were able to improve our routine and process the entire input file in a little under ten minutes.

Once we had the data reliably able to be processed we then had the challenge of loading it into *Uniview*. At the Academy we primarily still use *Uniview 2.0* and its subsequent patches as we were continuing to test and verify the function of the more recent *Uniview 3.0* release. *Uniview 2.0* is a 32-bit application and we knew this would impose a limit on how much data we could load into RAM, so we avoided an output file larger than four gigabytes. To have the best available sample set we thresholded our data by luminosity, making subsets containing only the most luminous stars. We found, however, that although we could successfully load profiles with DR2 subsets approaching 4GB, *Uniview 2.0* would not successfully draw more than about 3 million stars, a subset file that was only about 600 megabytes in size, and realtime

performance was very poor with this large dataset.

Determining that 32-bit architecture was not sufficient for our purposes we began testing implementation in *Uniview 3.0*, which is a 64-bit application and does not have the same limits imposed by that architecture. Immediately we found we could load all of our earlier subsets into *Uniview 3.0* with no performance issues and thus began generating larger and larger files to test performance. Ultimately we found we could successfully load the entire 58 million star dataset (a 10.9 GB file in our reduction) with only minor performance issues on our test machine (although this dataset used up most of the available 16GB of RAM in the machine). In the process of testing these large datasets we discovered *VizieR* had timed out on our download and we were using a significantly incomplete version of the dataset. A new query direct from the Gaia Archive returned a more complete dataset of stars with no missing values of about 72 million objects, which provided more complete sky coverage.

Storytelling with Gaia DR2

With *Gaia DR2* datasets implemented in our software, the question was now: what could we do with it? Daily use of the entire DR2 dataset was impractical (since it uses up most of the RAM on the 16GB machines in our cluster it would not allow much memory for adding other modules to our show profiles), since we had not done a complete cross-reference with *XHIP* to remove redundant stars and update values it also did not provide a complete starfield on its own, even though it substantially increased the depth with which one could fly through a realistic sky simulation. In addition, we had not yet fully installed *Uniview 3.0* in our dome, limiting our public planetarium presentations to smaller subsets of the data.

Our first applications ended up being for our *Universe Update* program series. *Universe Update* is a monthly, live planetarium presentation shown as part of the Academy's *nightlife* 21-and-over evening event, usually presented by Director of Morrison Planetarium and Science Visualization, Ryan Wyatt. In the late spring and summer of 2018 Morrison Planetarium also collaborated on content and domecast our *Universe Updates* with Adler Planetarium at their *Adler After Dark* 21-and-over evening event, with the show presented at 6:30 PDT, 8:30 CDT allowing for back-and-forth presentation and conversation with Adler's Space Visualization Laboratory Director, Mark SubbaRao. We were able to process initial reductions of the *Gaia* data for presentation in our May *Universe Update*, taking the audience through the motion of the local stellar neighborhood from one million years before the present, to one million years into the future, in addition to featuring the allsky maps released by the *Gaia* team, and a model of the spacecraft from the German Aerospace Center (DLR, *Deutsches Zentrum für Luft- und Raumfahrt e.V.*) provided via Tim Florian Horn, Director of the Stiftung Planetarium Berlin. Additional *Gaia* data on the motions of Globular Clusters were processed for the presentation by SubbaRao and the Adler team for the presentation, as well.

With this first presentation down we began considering other uses for *Gaia* data. Our fall programming schedule planned for a return of the American Museum of Natural History's production *Journey to the Stars* and, as with all presentations at Morrison

Planetarium, we planned to insert a live break in the show when the presenter could expand on the show topics with some of the latest research available. We decided a story related to *Gaia* would make the most sense and working with Faherty as our science advisor we planned a live section that would focus on current research using *Gaia*, focused on brown dwarfs and moving groups.

For this storyline we used existing data on brown dwarfs and rogue planets provided to us by Faherty (Faherty, Riedel, and Cruz) and combined it with new analysis of moving groups and co-moving stars (Faherty, Bochanski, and Gagné). Implementing the new moving groups into *Uniview* and color-coding them allowed the presenter to conclude their live section with a discussion of the stellar life cycle and the evidence we see for it around us. *Journey to the Stars* introduces the audience to star birth in nebulae, that stars are not born individually, but are born as parts of clusters that eventually fall apart, featuring a hypothetical pre-solar nebula and companions to our infant Sun. The audience can then see the evidence for this in the live section as the presenter can demonstrate the motion of not just moving groups, but also several pairs and triplets of co-moving stars identified in the *Gaia* data. Faherty, and researchers before her, have observed that co-moving binaries and triplets are actually the remains of moving groups, which are themselves stars that retain their gravitational affiliation from their birth in open clusters. Observing both larger groups and smaller co-moving affiliations lets researchers understand the history of the life cycles of stars and of our Milky Way.

Researchers are continuing to discover more moving groups and other associations using *Gaia* data. We have been fortunate to help in the assistance in visualizing some of these additional discoveries and hope to present more in the planetarium environment in the future.

Similarly, *Gaia* can be used to demonstrate stellar flybys of our Solar System. Although vast distances generally separate the stars, they do occasionally pass relatively nearby each other, sometimes bringing their interstellar distance down from light years to a few thousand astronomical units and proper motion data are valuable in the relative short term (thousands of years) for making relatively accurate predictions of these flybys. In 2015, measurements of Scholz's star, a red dwarf, show it likely passed within about 52,000 astronomical units of the Sun about 70,000 years ago (Mamajek, Barenfeld and Ivanov), passing within the Oort Cloud. Although the authors of that study estimate that the close passage of Scholz's Star was very fast and far from the denser, inner Oort Cloud, and thus unlikely to generate a significant increase in the flux of long period comets, it shows that these events do happen, and may happen with greater frequency than might be expected.

Unfortunately, Scholz's Star was not observed in DR2 and its flyby cannot be simulated using that dataset. But other stars are available for interest, and it is relatively easy to use even the 100pc *Gaia* sample to illustrate the future flyby of Gliese 710. Using *Hipparcos* data it was estimated that in approximately 1.35 million years Gliese 710 would approach within a light year of the Solar System (García-Sánchez, Preston, and Jones). DR2 refines these measurements significantly showing that Gliese 710 has an extremely high likelihood of passing within 17000 AU of the Sun, well within the Oort Cloud (C.A.L. Bailer-Jones) and close enough

for this relatively faint star to shine as bright as the nearby planets, possibly significantly impacting the Oort Cloud and dispersing a large number of comets into the inner solar system. This flyby of Gliese 710 can be demonstrated in software with relative ease and precision. Bailer-Jones *et al.* also demonstrate that many other flybys can be predicted from DR2, although they note the data are somewhat spurious for many sources owing to the lack of radial velocity measurements for many small stars, and imprecision in parallax for others—although they cannot quantify the scale of these errors they show a rate from current data of almost 20 flybys within one parsec every million years. It is likely as *Gaia* data continue to be refined we may discover more stellar flybys have occurred in our astronomically recent past and will occur in the future.

We are hopeful to pursue future applications of *Gaia* in the planetarium. Other possibilities we have begun investigating are using *Gaia* to generate a non-photographic simulation of the visible appearance of the Milky Way from Earth. The richness of the *Gaia* starfield does allow for a simulated representation of the Milky Way composed entirely out of the blended light of stars, exactly as it is in reality (as *Gaia* is not an infrared observatory it does not see through the Milky Way's dust lanes and, as such, they correctly appear as black voids in the Milky Way).

In addition to use as a source for a two dimensional representation, *Gaia* data are, of course, also three-dimensional and with proper culling (particularly reducing the dataset just to O and B stars) the three dimensional structure of the nearby Milky Way can be seen, which has potential visualization, teaching, and research applications.

Gaia data also certainly have applications in the production of rendered fulldome films, being able to dramatically extend the starfield and more accurately represent the local Milky Way and infer the greater structure of the Milky Way itself. The data have obvious applications for better producing shows that explore the *Kepler* and *K2* fields, which contain many stars not observed by *Hipparcos*, as well as improving the distribution of small, faint stars in any depiction of our stellar neighborhood. Beyond these obvious three-dimensional applications, the data will also continue to expand our ability to understand our Universe throughout time, allowing for more accurate depictions of the sky over time that we may better understand the skies of our ancestors and our descendants.

Conclusion

Gaia, by increasing the amount of stellar position data we have by several orders of magnitude, is a massive improvement over *Hipparcos* and the adaptation of it to planetarium environments may be one of the first Data2Dome projects that has immediate utility to planetarium presentation, education, research, visualization and production. We hope that the work we have done starting on this dataset will inspire more planetarians to work with and explore DR2 in their own domes and refine and reduce the dataset in meaningful new ways to expand our audiences' and research partners' understanding of the vastness of the cosmos in space and time.

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QUALITY CONTROL IN ACTIVITIES AND PROGRAMS

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Abstract: When we design an astronomy activity or a planetarium program, there are many factors that need to be considered. One critically important area of concern is quality control. Quality control includes accuracy, respect for all persons, appropriate levels of explanations and humor, attention to whether the material is dated, appropriate level of complication, and clean and nonviolent humor. An activity or planetarium presentation may be interactive or not, but I believe that quality implies that there is a goal of stimulating reflecting thinking. This paper covers these different aspects of quality control.

My perspective for offering recommendations about what constitutes “Quality” are derived from experience in planning and giving planetarium programs and preparing astronomy activities for a wide variety of audiences over many years. Important to my ideas are the reactions to many programs, both live and recorded, at conferences. I have listened to comments of students, teachers, administrators, and colleagues about both my own and others’ programs and activities and I have read accounts of projects in which there was some type of evaluation. My own doctoral research, research by others, and expert guidance on doing planetarium research (from Shannon Schmoll, Julia Plummer, Chrysta Ghent, and Ka Chun Yu) have also helped me come to my conclusions about quality.

Each of us brings to a viewing of the same program a unique background and set of expectations. This summer, at the Full-dome Festival that preceded IPS2018 in Toulouse, France, the audience of planetarium educators, program developers, and technical experts, immediately following a showing, were asked to rate programs with a button system installed on seat arms. Results were tabulated to select a popular audience award. Ratings by different planetarians varied, confirming that there are differences in value judgments.

Still, I believe that there are some factors that we all can consider as we write or select for programs and activities. I think that quality control should be consciously applied and that these factors are important:

- 1) Scientific and other types of accuracy in both words and visuals;
- 2) Everyone involved or mentioned in the program or activity—audience or participants, presenters, and people or groups referenced—are shown respect;
- 3) Explanations or activity actions are not too complicated, extensive, or confusing for the group intended;
- 4) The show or activity is not out of date;

- 5) The program or activity employs clean and nonviolent humor and promotes positive attitudes; the program or activity may or may not be physically interactive, but questions, alternative answers, and pauses encourage critical thinking;
- 6) The presentation appeals to different senses and to different styles of learning. I know this is a tall list, but striving to meet these ideals greatly increases the probability that an activity or program when and where presented will be of high quality.

There are other factors that interact with quality that we all consider when we prepare or select programs and activities. These include:

- audience or participant age and cognitive level;
- national and local STEM standards and goals, technical capabilities and materials available;
- location, including area size;
- possible disabilities of participants, cultural expectations, including languages;
- the time to give a program or activity;
- if help is available or not;
- and, for a live show or activity, the knowledge and innate skills of the presenter.

I believe that accuracy—scientific and other types—is a very important aspect of quality. It is a big disappointment for me to see incorrect visuals, such as Earth rotation reversed, either in the sky above or on a globe. I’ve seen a solar eclipse and a lunar eclipse both shown in reverse in planetariums. Frequently I note that scale is treated poorly, although I congratulate those who try hard to convey proper scale. Occasionally a small slip in a fact—billions for trillions or Celsius for Fahrenheit—appears. I

know this can happen to us all in live presentations, but we need to review our facts carefully to minimize this and certainly scripts for recorded full dome shows need careful study to get visuals and facts correct. Remember Phillip Sadler's "Project Universe?" Harvard University graduates in caps and gowns recounted reasons for lunar phases and seasons. And their carefully- and thoughtfully-articulated reasons were incorrect! Although we might initially believe that information is correct, that information should be checked before sharing it with others. Members of the IPS Education Committee, which I chair, have found that a number of online activities, even an occasional ones on NASA and other reputable websites, have things wrong and confusing.

When we use models, it is important to point out what is right and what is wrong with them. This includes both physical models, such as an orrery of the solar system in which size and distance are clearly wrong, as well as visual aspects of the planetarium. We can't always show things absolutely right. My planetarium's Sun and Moon projections are too large; I try to remember to mention that in programs. We speed up rotation, revolution and planet motion, and other motions. We need to let audiences know that we are doing this.

This is not to say that artistic license should never be used. If it is known that a literary story is being presented, this is different. *The Little Prince*, the famous story written by Antoine de Saint-Exupery in 1943, for example, shows unbelievable planets, incorrect scale, and people and animal breathing without air—but we all accept this as a story. Cultural myths have many unnatural depictions and happenings, but if everyone understands that this is a story, it is fine.

Respect shown to all involved is another important quality control factor. Gender, race, religion, disabilities, or unusual human physical features (such as albinism, recently in the news) need respect in words and actions.

We all recognize the following as false ideas: astrology, Creationism, dinosaurs and humans co-existing, and aliens invading Earth. Our inclination is categorically dismiss them, perhaps with vehemence, perhaps with sarcasm. But logical development of ideas, with a non-judgmental tone, does more to help people who hold these ideas start to question them. You may not sway anyone who is firmly committed to Creationism as you discuss ideas of deep time, including radioactive dating, but you can keep an adult or student following other things you have to say instead of categorically rejecting everything else you present.

Words, explanations, analogies, visual demonstrations, and humor all need to be adapted to be appropriate for an intended group. Also, the topic itself should be both interesting and cognitive-appropriate for the age, ages, or special group. For example, a program about stellar evolution will be confusing for normal first-grade children. An H-R diagram will be meaningless to them. However, fast-forward to fourth and fifth grades—children of 9 and 10 years often are very curious about the birth and evolution of the Solar System. And this is true regardless of previous classroom astronomy experience. When I was in Rio de Janeiro a few years ago, I observed many groups of children 10 years old visiting a planetarium. I was involved with one session.

At the end of a full-dome program, the children asked me in-depth questions about the birth and life of the Sun, although they had no lessons about this topic in school. (The planetarium astronomer translated from their questions in Portuguese and my answers back into Portuguese.)

Other examples of cognitive level...An explanation of the term "light year" starts to be understood by most at about age 9 or fourth grade, when children can mentally go back and forth between the separate ideas of distance and time. And complex ideas like dark matter and dark energy, and ways scientists have for thinking that they exist, are confusing for average thinkers until ages 13 and up.

One can "explain" many things at different levels, but we need to realize differences of ability for different ages. We can teach things about phases of the Moon and seasons to very young children. First grade children usually can put cards with phase shapes in order or sequence and identify differences from one phase to the next in the sky (although some are dyslexic and get crescents, quarters, and gibbous phases reversed). Third grade children can draw the differences as they see them in the sky and they can use a model to show that the Moon revolves about the Earth while the Sun is shining from one direction. What almost all cannot do is match the phase with the position of the Moon in the Sun-Earth-Moon model. I found that this latter skill, a complete coordination of the phase we see with the Moon position in its orbit was not possible by students 13 years old, even after in-depth planetarium teaching. Julia Plummer has found some different results with young children and Pierre Chastenay has found some exciting different results with older students using a digital planetarium. However the cognitive level needed for full understanding of Moon phases is higher than once believed, evidenced in part by the Harvard graduates in Sadler's "Private Universe."

If you are starting to work with very young children, I recommend watching "Sesame Street" for ideas on analogies, amount of repetition, humor, and time spent on a topic. The Sesame Street planetarium program, "One World, One Sky" also incorporates quality teaching. At last summer's IPS2018 meeting Linda Shore, current Director of the Astronomical Society of the Pacific, presented some appropriate astronomy activities for very young children. See the ASP website for her ideas. A recent NOVA television program featured the importance of rhythm in learning and using language. Research therefore points to preparing programs and activities for very young children that involve rhythmic language. In all quality programs and activities for very young children, you will find features of physical interaction, and individual discovery.

Movies, television programs and advertisements, recent local, country, and world news, current popular and music provide many sources of analogy and reference appropriate for older students and adults.

And what besides cognitive level can be confusing? Methods of presentation. In planetarium programs, this includes visuals that are not correctly paired with narration, poor analogies that lead to misconceptions, music that overpowers the narration, too many visuals occurring simultaneously. For activities both in and

out of the dome, this can be incomplete instructions, an activity that is too complex, insufficient materials for all, and inability of all to see and hear.

I have found that children of all ages currently seem less patient than years ago, most probably due to cell phones and other technology. This narrowing of attention-span is something we need to recognize. I do not know if we should cater to it to have quality presentations—making our discussions and activity sessions shorter—or rather if we should try to make something so engrossing, so interesting, that we keep students on task. Perhaps we can perform a service in reversing a trend.

I think that humor at the expense of others in any program or activity is very wrong. In a children's full-dome program I viewed in Toulouse, there were frequent animations of children hitting other children and animals. Comments between the children in this program often were sarcastic. I believe the violence and sarcasm were intended as humor. Some would argue that this is part of culture in many places. However, I think that our planetarium community should commit to a standard of promoting positive attitude. Programs that convey peace and cooperation are to be valued and used, and there are some wonderful full-dome shows that do that.

If humor is clean, nonviolent, and not at the expense of others, it can be a wonderful tool for involving the audience. Puns, silly analogies, and unusual accents and music—can provide enjoyable moments for audience and activity participants. The old expression of "Use humor in which people laugh *with* you; not *at* you," is a good one to remember.

However, another quality control factor may affect use of these sources. It is important that a program (particularly a recorded show) not be out of date. References to movies, TV programs, and popular music can easily cause a recorded show to go out of date. Even particular word usage or slang can change over a decade.

If scientific discoveries and advances in scientific theory on the topic discussed have been made past the date when the program was prepared, this critically dates a program. Mention of a political leader or country can also change (Think of the change of a country's president and the change of Soviet Union to Russia and other countries). Quality control means not using a dated program.

An activity is certainly interactive, but a planetarium program may be interactive or not. The Lawrence Hall of Science has published many fine participatory planetarium programs—physical activities that take place within a planetarium presentation. But incorporating a physical activity, although often a desirable procedure that focuses interest, is not essential for a quality presentation.

What is important is whether the program or activity stimulates reflective thinking. This can be accomplished in some different ways. Dayna Thompson gave a wonderful paper in the Toulouse planetarium last summer, "Communicating With Your Audience: Tips to Presenting Live, Interactive Programming." Dayna stimulates reflective thinking in live programming in a number of ways. I'm summarizing her ideas here because I think so much of them and that they are great ways to include the reflective thinking requirement of a quality program.

Dayna concentrates on having a two-way conversation with her audience. She notes that she checks with her audience throughout her presentation. She uses phrases, "I want you to do something for me..." or "I know that many of you may be thinking that..." or "How would it make you feel if..." She uses this technique with audiences of all sizes. She calls the audience "friends." She asks questions and tries to use a positive response for every answer. She sometimes puts questions and multiple-response answers on the dome, asking audience members to hold up fingers to show their choice. Often she asks people to "think-pair-share"—that is discuss their answer with their neighbor. Dayna suggests something they can do right away after they leave the planetarium, such as find a planet in the real sky and even give a demonstration that she suggests be tried at home.

I think another way to channel reflective thinking is through music—not sound effects but music that evokes feelings that are representative of the topic development. Mark Petersen, Jonn Serrie, and others have composed pieces representing planetarium topics, but also there are many classical and semi-classical works that can give an emotional experience to a program. When emotion and concrete and abstract thinking are involved, reflective thinking can be tapped.

My last requirement for quality in a presentation is that it appeals to different senses and different styles of learning. Using senses in addition to seeing and hearing can produce focused effects. Ken Perkins and others have advocated use of different odors in the planetarium, such as pine for Christmas holiday programs and evoking a feeling of being in a forest. (Do ask about allergies in a group before using scents). Ken also used a fan for wind and a swaying lantern for a ferry crossing a river in a Huck Finn story—complex sense experiences.

These are my ideas about what makes a quality offering. I welcome your ideas on this important subject. If we all strive for quality in our programs, we enhance the image of each individual planetarium and of planetariums generally. But most important, we are helping people have quality learning experiences.

DEALING WITH DARK DOME DISCIPLINE

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Abstract: Every planetarium educator tries to maintain some semblance of “law and order” under their dome. This paper will look at some recent initiatives here in Milwaukee to combat smart phone use, talking, clueless parents (when child crying), and flashing shoes.

Let me tell you a little story about discipline.

Now pay attention please, I don’t want to explain this twice.
Just kidding. ☺

About three years ago, a new sheriff (President) came to our town (museum). As head honcho, he got to do what he wanted to do. He had some good ideas for our little place. One of them was to make the planetarium free. Whoa...I thought to myself—this can’t be good. But I listened. And I implemented the new directions for free people in our dome.

By the way, the sheriff knew all about the bottom line. To gain back what he lost in planetarium revenue—he raised the overall museum price. Other sheriffs had done this.



The Good

Free stuff can draw a crowd. Our planetarium attendance exploded. In the first year, fannies in the seat jumped from 30,000 to 120,000. Crazy. Ok, part of that increase was changing the length of the planetarium show. They used to be 45 minutes long—with a canned show followed by live presenter showing the current sky. Now the shows were between 20 and 25 minutes. Half were push button programs. The other half were live sky tours.

This boost in attendance was nice. It meant more people getting in tune with the cosmos. More education—connecting the terrestrial and the celestial and all that. The new sheriff was a miracle worker. The increase in sky watchers is obviously good for the museum’s development department. They could boast

about all these planetarium people—and hopefully—raise more money.

The Bad

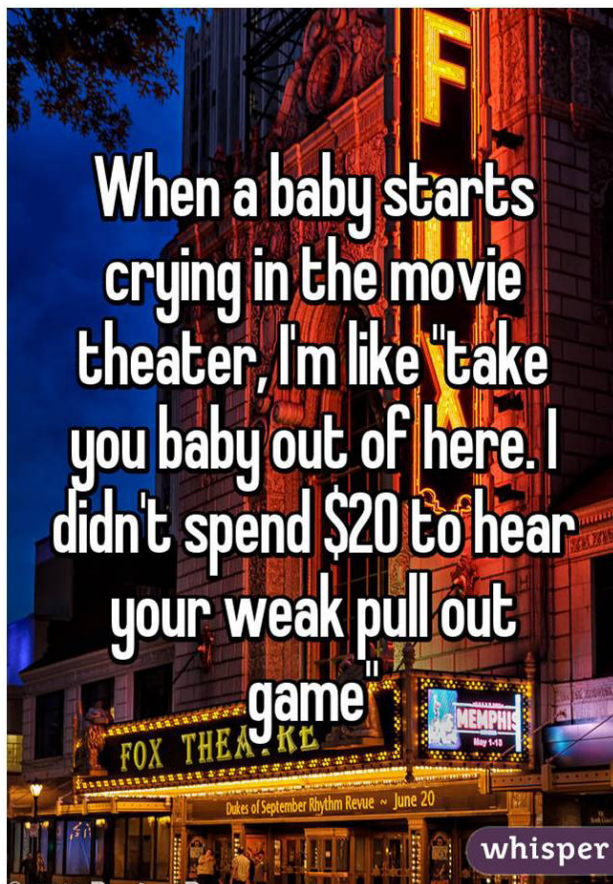


Free stuff draws people who really don’t give a rat’s rear about what’s free. They go because it’s free. Not everyone of course. But enough to say, “*hey, I’m here because of my kid...she likes the stars, but me...well, I need to check my phone because...well. I don’t know...I just do. Who cares if it bothers anybody...I’ll be quick.*”

Folks were the same way with talking. I can talk, no one will hear me.

Another policy change stated that any child age four and under was free too. Not only that, but we could not limit access to these young stargazers. Management’s thinking was, “*we don’t want to do anything to discourage our families coming to the Museum.*”

The Planetarium became stroller city like never before. Lots of youngsters means lots of crying—and lots of parents who think their kid will just quiet down. Which they do—only to start crying again in a constant up and down rolling wave of noise.



Kids with those blinking shoes can also a problem, but not nearly as bad as people on their phones or talking.

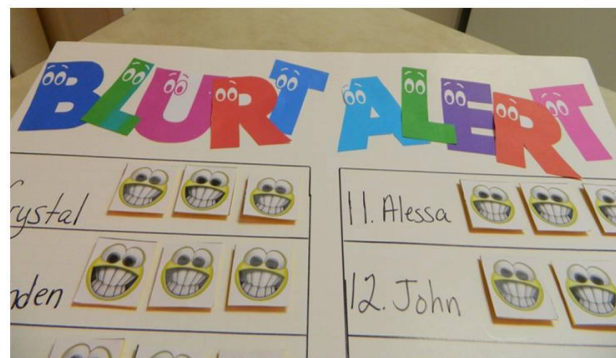
Before the new sheriff and his policies—back in the day when we charged dollars and attendance was more modest....people wanted to be in the planetarium. They were considerate. Nice. The star seekers shelled out their cash and wanted to see a great show.

Sure there were a few bad apples. Once in awhile we had to tell them to “knock it off” in a nice way or “pipe down.”

But the surge in non-astro folks had shattered the rote discipline procedures. They weren’t working.

The Ugly

The ugly is trying to figure out what to do. How do we combat all the phones, talking, shoes, and babies wailing? I did bring up to my boss to use tasers. But that idea got nixed.



I researched discipline. I looked for some gems that would alleviate our chatter clatter and smart phone light. It didn’t get me far. Most of best practices for control were for the classroom—formal education. Like the “Blurt Alert.” Where you add tally marks to a kids names each time they blurt. Besides not working in the planetarium, it seemed more like shaming.



I loved the “No” cartoon, but the thing is---you can give your “No....!” announcements before the Planetarium show, but too many simply do not hear you. They’re too busy checking their phones or talking.



Storytelling quiets a crowd wonderfully. The problem is presenting that smooth, low-key approach for the whole show. It works best for school group shows, but most of our issues have been with public shows—with a wide variety of ages. And all

storytelling all the time can be boring.

For school group discipline—I like to make a deal—especially when they are all rambunctious even before the show starts. So I believe (sometimes), it's ok for kids to talk and get excited! I mean—the planetarium has lots of cool stuff on the dome. For these types of school shows—I make a deal with them. It sort of goes like this.....

- *“Hey Everyone. Before we get started with the planetarium show...I have a few things to go over. Ok?”*
- *First....No talking when I’m talking there’s no _____! (let them say “talking.”) Excellent.*
- *I like to ask questions—and if you know the answer—then you can talk. But when you hear my voice on the microphone—(tap-tap on microphone)—voices down please.*
- *We are going to see some cool stuff on the big dome—I want you to get excited! But again, when you hear my voice (tap tap)—bring it down, ok?*
- *Are you ok with this deal everyone?*
- *Ok, great! Let’s shake on it! (I hold out my hand and we do “air shakes” of the hand.)*

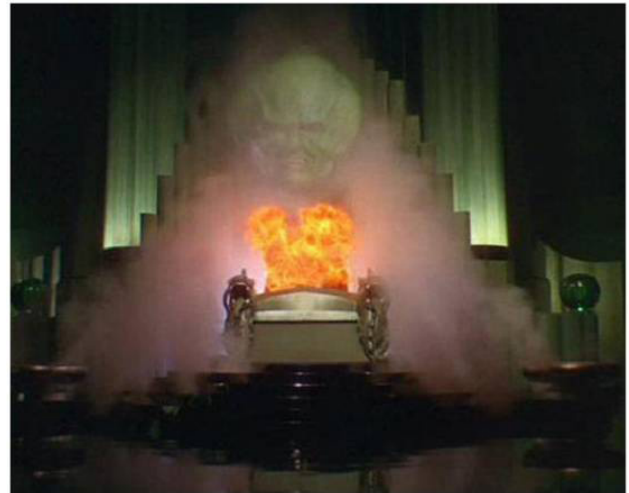
If they get too talkative during the show or the decibel meter rockets through the stratosphere, I mention, **“remember our deal?”**



Of course, it makes sense to have guidelines (aka: rules) posted somewhere—or as seating slides. These can help immensely. But too often are overlooked, or worse, not even looked at or understood.

Desperate Times Lead to Creative Measures:

Most of us planetarium people give live sky talks in our domes. Nothing can throw you off course more than someone talking or using their phone. Distractions disrupt your flow. They throw you off course and it seems the whole world is wrong. Well, for a moment.



Once I visited a planetarium in Wisconsin and the director had an audio file where the great and powerful Oz (from Wizard of Oz movie) would bellow, **“Silence Whippersnapper!”** This would be played if some kid(s) were a bit too loud in the planetarium. I thought this was a creative and clever way to silence the room. But on the flip side—teachers or parents could take offense to that “in your face” demand. Maybe they would say it was shouting at the children. The planetarium director I know no longer uses it.

So I still needed an effective solution. I discovered a new possibility at the cinema. They often have those funny PSAs (Public Service Announcements) before the movie starts that tell us to behave properly during the movie. I saw one with minions from the *Despicable Me* films. It was hilarious. And even better, I thought it was effective. The idea is pretty basic---use humor to get people not to talk or use their phones.



Then my low-wattage light bulb finally clicked on—**Minion Planets!** We were producing a new show on the Solar System using these fun animated planets. Why not use these planets to do a short 60-second PSA before the live Planetarium shows. So we did. We got our producer to voice Jupiter. My boss became Saturn. Educators became the Earth and the narrator. And our

animator's 4-year daughter did an amazing job as Pluto.

The results?

We achieved:

- No More Talking—Never.
- No More Texting—Never.
- All Angels All the Time

Ok, not that good. But the new Planet PSA has worked. We definitely notice better behavior under the dome.

Yeah.

A TALE OF TWO

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Abstract: I will be presenting a sample from an interactive show currently in production that is like a *Choose Your Own Adventure* for stardomes. My colleague John French and I hope to offer this show to other planetariums.

I along with my colleague John French have been working on an interactive show that we would like to present at Abrams Planetarium, before then offering it to other stardomes as well. This is a show called “A Tale of Two” that is in essence a space cruise gone wrong. A master of ceremonies “engineer” narrates the show as a silent player character (“the Captain”) makes the various choices. These choices are always in forks of two. The player character is to be an employee at the given planetarium, and have to do nothing more complex than press “A” or “B” at certain key junctures. They do not have to speak, as Mr. French and I have concluded that shows where live performers have to interact with pre-recorded dialogue are sometimes clunky or, when pulled off well, difficult to replicate.

We want this to be easy to replicate. The audience, for its part (the “passengers” on the cruise), are encouraged to shout out their preferences to the player—and this player will then make a rough estimate as to the audience’s preference. Mostly, it’s meant to make it *feel* as if the patrons are a part of the experience. The reason for presenting this in a stardome as opposed to a movie theatre is to take advantage of the immersive feeling one gets when a gigantic bubble envelops you overhead. There is huge potential for what planetariums can do as a medium, artistically and culturally. This is potential I would like to tap into.

In addition, Digistar offers a natural platform for an interactive element. When planetariums want to showcase something not strictly educational—such as when Abrams presents Pink Floyd’s *Dark Side of the Moon* laser show or a radio adaptation of Asimov’s “The Last Question”—we hope this to be an attractive possibility. The show is family-friendly in the sense that there is no profanity, nudity, or explicit/violent themes. However, it is unlikely that the story would be too engaging to anyone under the age of 13 or 12. Perhaps this is something to mention in promotional material.

MEET A SLOTH: LIVE ANIMALS IN THE DOME

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Abstract: The Boonshoft Astronomy and Live Animals departments collaborate to present “Meet a Sloth” shows in our planetarium. You too can meet “Patience” the Linne’s Two-Toed Sloth and her sweet potato dealer, Boonshoft’s Curator of Live Animals Stephanie Hylinski, via the wonders of video recording. Stephanie and I will discuss the hopes and concerns we each had as we began this program, and relate how over the past year these sloth shows have become both more successful and much easier than we expected.

Two years ago I developed a couple short shows that collaborated with our museum’s Education department, one about fireflies and one about spectroscopy. These were modeled after “science on a cart” activities, quick interactive demonstrations of a single topic. I provided graphics or video on the dome, a canvas that the educators couldn’t replicate out on the floor, to explain the topic. Then the educator had a hands-on activity: Luminol for fireflies or spectrum tubes and diffraction grating glasses for spectroscopy.

These programs were extremely well received by visitors and staff alike. Since the museum is also an accredited zoo, it was natural to wonder whether this sort of presentation might work with a live animal. Both the Live Animals and Education departments frequently have “Meet and Animal” shows. I pitched this to the Curator of Live Animals, Stephanie Hylinski, talking about how I could display maps on the dome, pictures or videos of the animal, and be a way to greatly increase the amount of information that could be presented about each animal. And I was taken aback by how cool the reception was! It turned out, though, that this had nothing to do with reluctance on Stephanie’s part, but rather my underestimation of just how many factors need to be assessed for the welfare of the animals. I’ll let Stephanie now explain what her thought process was as she contemplated this opportunity. She will also introduce Boonshoft’s sloth Patience to you—know the sloth is why you’re here!

[video transcript]

Hello my name is Stephanie Hylinski. I am the curator of live animals here at the Boonshoft Museum and I have Patience with me today. Patience is a Linne’s Two Fingered Sloth and lately it seems like sloths have gone viral! Everybody loves sloths, everybody wants to come and see Patience the sloth, but here at the museum Patience sleeps most of the day. She sleeps about 14 hours a day usually and up about 10 hours at night so a lot of our visitors even if they come to the museum weekly they only see her moving maybe once in a blue moon. It’s pretty rare to see her up and moving about during the daytime.

Joe in our astronomy department came to me and said, “We should do some kind of animal program in the planetarium.” So I thought about all the animals that we have for educational outreach. Most of the animals that we use for education are smaller and the planetarium is a pretty big space, so a small animal like a ferret or something like that wouldn’t really show up well in the planetarium. People wouldn’t really be able to see it very well. Patience does really well with small groups of people so she’s not an animal that we can normally bring out for school groups or normal visitors at the museum. She doesn’t like large crowds. Very loud groups especially kids can be a little scary to her sometimes, so I thought the planetarium would be a great sort a great place to do a sloth program where people can see but not touch Patience.

So in the dome Patience is up on her stand at the front of the planetarium. We have stanchions set up people can come up and see Patience at the very end of the program but they’re not allowed to touch her. For Patience that makes her a lot more comfortable that she has some distance between herself and the visitors. For our visitors it’s a really great opportunity for them to see Patience actually up and moving around when she comes out on her stand. We found some rainforest [full-domes] to enhance the program we say that we are transforming the planetarium into a virtual rainforest. Patience comes out and people are able to see her up close and learn a little bit more about her and her habitat. Rainforests are in big trouble right now so we thought it would be a great opportunity for us to raise awareness about bringing forests and conservation especially for sloths.

It’s also a great opportunity for us to get people to come into the museum to see Patience because we have a lot of people that will come to the museum almost just to see Patience. People are crazy about sloths and the planetarium programs have been really, really successful in promoting Patience, promoting our zoo, and also promoting conservation as well.

Patience is an amazing animal to bring out in our planetarium. As far as safety goes, some of our animals would not be safe to bring out in the planetarium; they might try to run off into the audience and it is a big space. So some animals we would be concerned about but Patience like all sloths if she doesn't have a branch to grab onto she's not going anywhere. So it works really well to bring her stand out in the planetarium we just make sure that she doesn't have the ability to grab onto any hanging overhanging bars or walls or anything like that. She's one of our best animals to bring out since she's slow and she's not really going anywhere anytime soon. She's pretty slow!

We thought the planetarium program would be a great way to raise some money for conservation. We have been collecting donations for the Sloth Conservation Foundation and so far Patience has raised about 300 dollars to help sloths in the wild. Our animals in the zoo are kept here nice and safe and also to educate people about the animals, but we also want to be helping out their cousins in the wild as well. Patience has been a great ambassador, a great way for us to raise money for conservation of wild sloths in the wild. Patience has been a real rock star; it's been a great program for us because people can't see her up moving around. She's one of our largest animals so she works really well in the planetarium so people can actually see her.

When Joe and I first started talking about this one of his concerns was they just got brand new carpet in the planetarium he asked me if she's going to poop on his carpet! [I was mostly joking.] Patience is one of the cleanest animals here at the museum so she only poops about once a week or so, so with about 99.9% certainty I told Joe she will not poop on your carpet she only poops about once a week so it'd be pretty rare for her to poop while she's out for her planetarium program.

So she's been a great hit a great way to raise conservation awareness for our guests and like I said people do get to come up see her up close and personal. We've had lots of people—members—come here to the museum all the time that have never seen her face. The planetarium show is a great opportunity for people to see Patience up close and personal awake and learn a little bit more about her

So here's a recap of the things Stephanie had to juggle as she decided how to respond to my invitation:

1. How will this stress the animal? Each animal is different in temperament, even within species.
2. How easy would it be to contain the animal if it gets loose? Will the animal try to get free when it's in an unfamiliar environment?
3. Is the animal charismatic enough to draw a crowd and make the effort worthwhile?
4. Is the animal large enough for a capacity crowd to all see it well?
5. Will this experience reinforce or undermine a training program for the animal?

It turned out that Patience was an ideal animal for a planetarium show. She was already on a training regimen to be acclimated to her stand that you saw in the video, so she was used to small groups. As Stephanie mentioned, there's no chance that Patience will try to get away, and if she did, who can't outrun a sloth? Patience is one of the most popular animals at the museum, so having an audience too small to justify the effort of the presentation wasn't a problem. She's also large enough to be seen all the way from the back of our 50-foot dome. Patience turned out to be quite fine with a large group of people, which was a pleasant surprise for Stephanie.

Stephanie alluded to one of my concerns: is the animal going to poop on my carpet? That was mostly in jest on both our parts; the planetarium is no different from any other floor that an animal might be presented on. Of more concern for me was the lighting. We are all well aware of how guests to our domes don't realize that the room needs to be dark to see anything projected on the dome. Stephanie wanted a rainforest scene with jungle sounds ambiance, had maps she wanted to show, a slideshow of all the different sloth species, and a sequence about deforestation. The audience wants to see Patience! I settled on green cove lighting that was 360° when Stephanie was talking and which dimmed at the front when a graphic was displayed.

Patience has been a big hit. She is a wonderful Animal Ambassador for the museum and for her species. It's unlikely that you have animals as large as Patience on site with you, but you are quite likely to have some organization in your community that uses animals in its outreach. A collaboration with them would be a boon for both of you. It is my hope that armed with this perspective on the concerns that the animal's caretakers will have, you will be better equipped to find success in this collaboration.

ADAPTING GIT TO THE PLANETARIUM WORKFLOW

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Abstract: In any planetarium where scripts are being edited by multiple people, often at multiple workstations, managing these changes can be difficult. Version control software can make this process considerably more failure-resistant. The most widely-adopted version control software, Git, can be successfully adapted into a Digistar 6 workflow. Though Git provides the planetarian with many benefits, including the opportunity to merge multiple versions of a file and the ability to roll back to a previous version of a project, it also comes with some obstacles, including compatibility with Digistar files and technical requirements.

Many modern planetariums rely heavily on scripts written by their staff. Some of these projects can be large enough that keeping track of changes made to them becomes burdensome, if not essentially impossible. This is especially true in cases where multiple staff members are working on a single project, sometimes from multiple workstations. This kind of problem, of course, is commonplace in the software development field, so a standard solution can be borrowed and adapted to the planetarium workflow: version control software.

Git (<https://git-scm.com>) is a version control system that can be used to track revisions to a codebase, set up multiple branches of a single project, and merge changes and branches from multiple users. Git is open-source software that is free to download and use, and is available for Windows, OS X, and Linux. Git eases the pain of developing large projects by allowing us to better manage the process of tracking changes. With Git, not only can we track changes, we can also revert to previous versions of our projects. Additionally, because Git is a distributed version control system, a full copy of any project can be put on any computer, making Git an efficient way to update projects on the Digistar host computer in the planetarium theater. Rather than loading everything onto removable storage and copying files over manually, projects can be updated with just a few commands.

Adapting Git for use in a Digistar planetarium is a relatively simple process. Git can be used locally, on a single computer, but there is a benefit to installing it onto a central server that workstations and the Digistar rack can connect to, either via a local network or the Internet. Once installed and set up, Git can be used to create a repository. A repository is a data structure that maintains information about a project that is being tracked by Git.

The workflow in Git has three essential parts: the working directory, the staging area, and the repository. The working directory is just that—all of the local files in your project that you are working on. When you make changes, you can use Git to add those files to the staging area. This prepares these files for the next step, the commit. Committing files to the repository records the state of those files, creating a sort of “snapshot” of your project. If Git is installed on a central server, these changes can be uploaded to the “remote”—the repository on the server, for other workstations to pull down and update their working copies.

There are two major problems I have found in using Git in a Digistar workflow. The first is technical in nature: Digistar, by default, encodes .ds files in UTF-16. Git, unfortunately, reads these as binary files, which effectively eliminates most of the benefit that Git can provide, including merging changes and tracking them in any useful way. Luckily, of course, there is a way around this. Digistar’s User Interface preferences can be set to encode files as UTF-8. Previously created files must be re-encoded. This can be a lengthy process, even with automation. Backing up all of the files to be re-encoded is wise.

The second problem is somewhat more difficult: teaching staff who may not come from a background that gives them confidence with command line tools how to use Git. This can be alleviated somewhat with a graphical user interface, but the only real solution to this problem is time and dedication. It is well worth it for the benefits Git can provide.

ENCOURAGING INDIGENOUS VOICES

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Abstract: I will discuss lessons learned from a fruitful collaboration between the staff at the Manfred Olson Planetarium and the members of the Electra Quinney Institute for American Indian Education, both at the University of Wisconsin-Milwaukee. Our work together resulted in a planetarium program that highlighted the culture, language, and sky-Earth connections for six Nations in Wisconsin. These types of collaborations are important because some of these cultures are at the brink of extinction if we don't encourage revitalization. I will give you specific suggestions that will help you build such a collaboration in your community.

For a decade now, faculty at the Electra Quinney Institute for American Indian Education (EQI) and I have wanted to study local Indigenous ways of understanding the night sky. Fortunately, we were able to establish a fruitful collaboration over time, which resulted in a show called “Indigenous Voices: Sharing the Wisconsin Sky”. Not only was the program attended by 850 people, but it helped many Native students involved to feel a stronger connection to their language and cultures. Although we were highlighting American Indian people in Wisconsin, we believe many of the lessons we learned could be useful elsewhere¹. We describe our experiences here to encourage other planetarians to reach out to Native or under-represented communities so that together they can highlight sky-Earth connections.

Starting

Involve people in your immediate community: Ask your colleagues whether they would be interested in building a coalition that connects Indigenous cultures with the stars. You will probably need to reach out more than once—people want to be sure that you are genuinely interested in a long-term project, in which they want to be equal partners. If possible, seek out Indigenous faculty who teach courses in Native American and Indigenous Studies in your area. I reached out to Dr. Margaret Noodin, Director of EQI, and Dr. Bernard Perley, Professor in the UWM Anthropology Department, and to Michael Zimmerman Jr., who incorporates study of the cosmos into his elementary and middle school Ojibwe classes. If you cannot find interested partners immediately, attend events in your vicinity such as a Pow Wow or a Native art exhibition in order to meet people.

¹ We found that Indigenous people prefer others to use their nation's specific name. Our project involved Ho-Chunk, Maliseet, Mohican, Odawa, Ojibwe, Oneida, and Potawatomi people. It is best to ask your collaborators what they prefer.

Gearing Up

Start with a pilot project to see how well you work together: We started in July 2014 with an evening summer program offered to students coming into the UWM American Indian Science Scholars Program. I talked about what causes the Northern Lights and Zimmerman discussed the words for aurora in different languages and what they signified to Indigenous people.

Double-check facts: Sometimes it is hard to get “simple” facts straight. Collaborators can help the planetarian avoid incorrect statements that could inadvertently alienate people. For example, I read that the Menominee people had always been in Wisconsin and were its original inhabitants. I then learned that the origin story of the Ho-Chunk Nation also started in Wisconsin, in the Green Bay area, and both groups consider themselves direct descendants of the population after the ice age. Another type of factual information that is crucial for the program is the ability to identify the Nations in your region. In parts of North America, one can determine nearby nations by using the Tribal Directory on the National Congress of American Indians website (<http://www.ncai.org/>).

The plan evolves over time: In Spring 2017, I discussed with Noodin and Perley the idea of a series of seven programs that would contain a brief overview of all local Nations, highlighting one each week with its culture and depiction of the night sky. By October 2017, we had concluded that EQI students would gather content on topics that could include celestial bodies, constellations, creation, the afterlife, and clan images. By mid-November, the significance of language had begun to emerge: the idea that we would hear words and maybe songs in the different languages was first discussed. By late February, the show had a shape: (i) a recorded welcome; (ii) a 20-minute presentation about all Nations, with maps, imagery and people talking different languages; (iii) a 15-minute stargazing session in the domed theater; and (iv) a discussion during which the audience could ask questions of the host and/or guest of the day.

Producing

Facing reality: During the months between our talks and production (February 2018), we got few responses from Indigenous people in the region, so it clearly would not be possible to have a full program for every Nation. Whereas we found no star stories or words for the Stockbridge-Munsee-Mohican Nation, we readily found information about the Ojibwe connections to the night sky.

Rely on liaisons to reach out to the Native communities: Our collaborators sometimes had to call in favors to have speakers come because Indigenous people can be unfamiliar, or even suspicious, of institutions and their intentions. This distrust is not surprising, as schools have historically been used to erase and suppress Indigenous language and culture. Noodin invited more than 15 people from a particular nation before one person accepted tentatively. She understood that he felt nervous about participating in the program because he couldn't speak his people's language, so we invited him to come to a program; he was more willing to participate when he understood the scope of our project and the planetarium's commitment to Indigenous culture.

Enable communication between guest and audience: Since most speakers did not know star stories, we sought to connect culture with the natural world through the question "What is your favorite season and why?" The prepared questions helped the audience ask questions as well; we found that audience members initially hesitated to ask questions, but once the discussion began, many questions were forthcoming.

Use what you can: When it became clear that for some tribes we had no star stories, we decided to highlight the different languages spoken in our region: we showed the words for the Earth, sky, Sun, Moon and stars in whatever languages we could (Menominee, Ojibwe, Oneida, and Potawatomi).

Morph loss into revitalization: During the process of collecting material, many Native American students felt heavily the loss of their culture and language. The students were helped when Perley articulated the role this program can play in revitalizing language and culture in these communities and getting more students engaged in the process.

Advertise the program widely and steer the conversation: Many news outlets are interested in this kind of programming if they know about it. On one occasion, the interviewer emphasized the conflict between science and the Indigenous sky stories without accepting that one of the delightful things we found during our collaboration was how science is incorporated into the language and stories.

Wrapping Up

Write about what worked: Not only were our programs sold out, they addressed a major need to make Indigenous peoples more visible. This project not only contributed to knowledge of the Indigenous world, it also added to the multicultural competency of the campus and our urban community as a whole. Everyone was reminded that citizens of the 573 Indigenous Nations in the United States represent a wide range of languages, traditions, historical circumstances, and physical features.

Write about what didn't work: Students might have been more active if their research had been part of their courses. The ideal scenario at our institution would be to plan a year in advance and work with the Undergraduate Research Program to ensure that students would at least earn credit for their research, which would help ensure that the time spent would be incorporated into their schedule.

The next steps: Our first step was to write how this program came together and share what we have learned with the planetarium community. Our next step is to promote the program to schools and libraries in the region. My collaborators and I imagine that these collaborations might look different in different contexts. We hope our experience will encourage you to build your own collaboration with Indigenous or under-represented peoples in your area; we look forward to reading what you learned from it.

For the full text of our paper, please see the 2018 December issue of the *Planetarian*, the journal of the International Planetarium Society (IPS).

TEACHING VIDEO GAME DESIGN USING SCRATCH

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Abstract: Scratch is a free, web-based design software that is ideal for teaching computer programming in an informal education setting. While designed to be a learning tool for students aged 8 to 16, Scratch is a powerful tool that can be quickly learned by anyone without a computer science background.

Scratch is a free, web-based design software that is ideal for teaching computer programming in an informal education setting. Scratch is a video game creation tool designed by the Lifelong Kindergarten Group at the MIT Media Lab. It can also be used to make video games, animations, and computer programs. While it is intended to be a learning tool for students aged 8 to 16, Scratch is a powerful tool that can be quickly learned by anyone without a computer science background.

Scratch was designed to teach the basics of computer programming using visual blocks instead of difficult-to-learn code. While this might seem limiting, it is still very powerful and advanced users could theoretically do anything with it. By using the visual code blocks, Scratch removes many early stumbling blocks and makes the process much less intimidating and frustrating for students. While many people might think it would be better to teach a real programming language, here I would like to compare Scratch to my experience learning computer programming in an informal education setting. When I was in middle school I took a summer camp class where I learned programming in Visual Basic. I really enjoyed it but it was slow going. At the end I didn't really have much to show for it—I could draw a circle and make some buttons but that was about it. Visual Basic was designed for professionals, not children. Often when schools teach programming languages like this, it turns into: the teacher writes a piece of code onto the board and the students copy it down without understanding the structure of the language.

Every programming language is different. Your students are going to forget the specifics in a week and the language will be obsolete in a decade anyway (as Visual Basic now is). They can learn real code later on. For now, it is good to learn how to think like a programmer and build confidence with concrete results that students can be excited about.

There is a lot of room for incorporating computer programming in your planetarium. Building this interest in computer programming is a great fit for our planetarium's educational mission. When children think of careers in space exploration, they think of astronauts and not the thousands of engineers and programmers who work on robotic exploration.

At Peoria Riverfront Museum, we have used Scratch in our summer camp classes and workshops. This December, we will take part in the Hour of Code, which is a world-wide learning event designed to demystify code and show that anyone can learn the basics of computer programming. At Peoria Riverfront Museum, we will use Scratch for a 1-hour introduction to computer programming, joining more than 200,000 educators across the world. I encourage you to look for ways to take part in the Hour of Code.

A METHOD TO MODEL SMALL 3D ROCKY BODIES IN 3DS MAX

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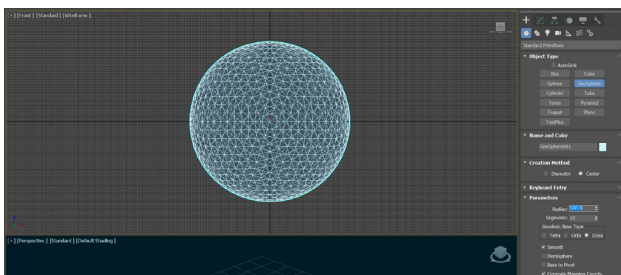
Salt Lake City, Utah 84101

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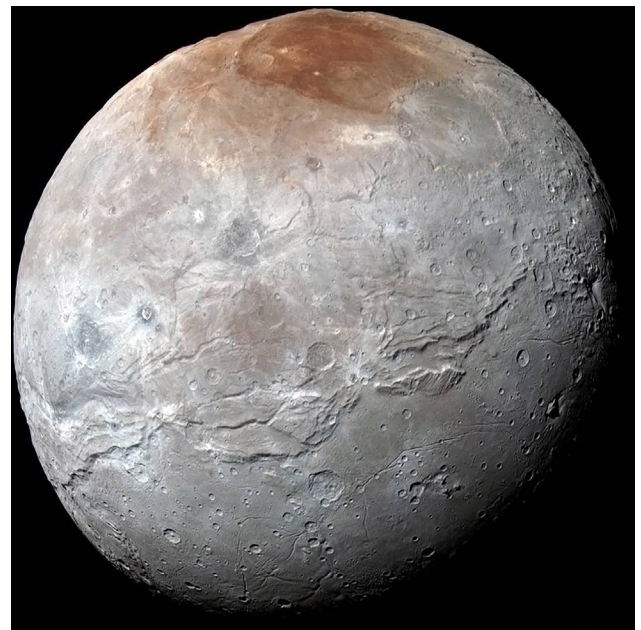
Abstract: When high-res photos of small rocky bodies become available from NASA or other sources, to use them in a 3D animation or show, it doesn't suffice to cut and paste on a flat plane. Mapping onto a sphere works, but lack of height detail is apparent to camera parallax. Bump map surface normals give apparent surface depth for facing portions, but do not alter the underlying geometry, so the smooth surface is obvious when edge normals are perpendicular to camera views. Spherical height maps displace geometry, but new height maps are low-res or nonexistent. This method is to model height.

This paper demonstrates a method to produce photo-realistic models of small rocky bodies in AUTODESK's 3DS MAX. This approach can be performed in other 3D modeling packages, but the tool names may differ.

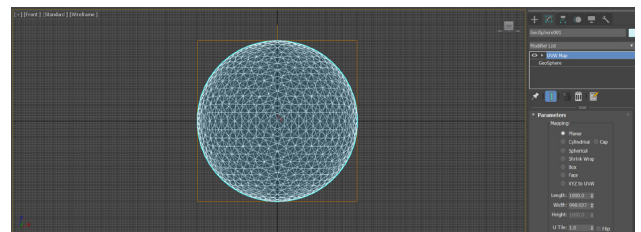
To begin, select CREATE>STANDARD PRIMITIVES>GEOSPHERE and drag out a new geosphere in the FRONT viewport. The new geosphere radius needs to be sufficiently large to have enough precision to keep accurate details between the many vertex points when it is extremely subdivided. It also needs to be small enough to avoid math distance precision trouble with physics, lights, and cameras. I typically use a value of between 500 and 1000 units. Initially set the segments count to 10, which is sufficient for rough, gross shaping of the rocky body geometry. The geosphere may be larger than the viewports, in which case ZOOM EXTENTS ALL in the bottom right menu will frame the object in the viewports.



In Adobe Photoshop or another image editing program open the photos of the rocky body, crop the image. If it is a smaller image, double the image resolution since photo editing software does a better job of pixel interpolation up-scaling than most 3D programs. If there are any obvious artifacts such as photo stitching blending lines they can be improved with various filters and brushes such as the healing brush. Tutorials on photo improvement methods can be found online.

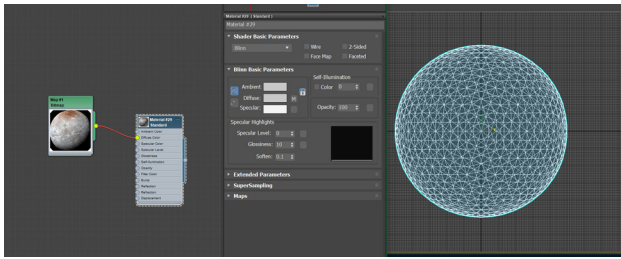


With the geosphere selected in the FRONT viewport, in the MODIFY tab apply a planar UVW map to the geosphere's modifier stack, then right click on the object in the viewport and CONVERT TO: >CONVERT TO EDITABLE POLY which collapses the modify stack, leaving an editable polygonal mesh geosphere.

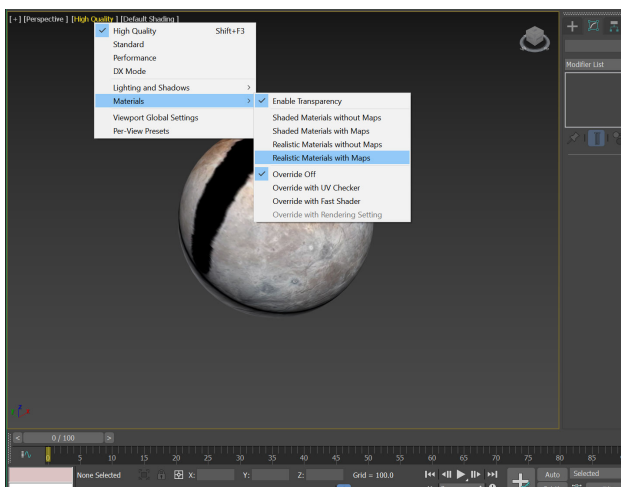


Open the material editor, create a scanline standard material, add a bitmap input to the diffuse channel, select your cropped image as the source for the bitmap. In the bitmap settings, set BLUR down to 0.1. Making sure the poly geosphere is selected, apply ASSIGN MATERIAL TO THE SELECTION in the material

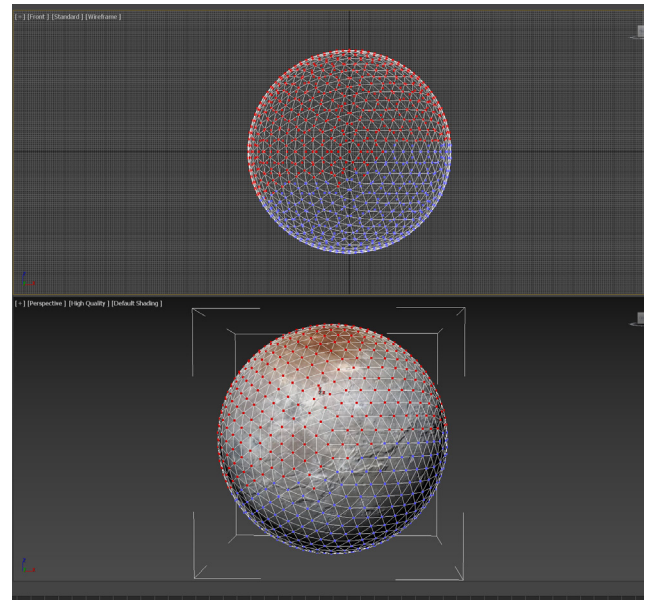
editor to the poly geosphere.



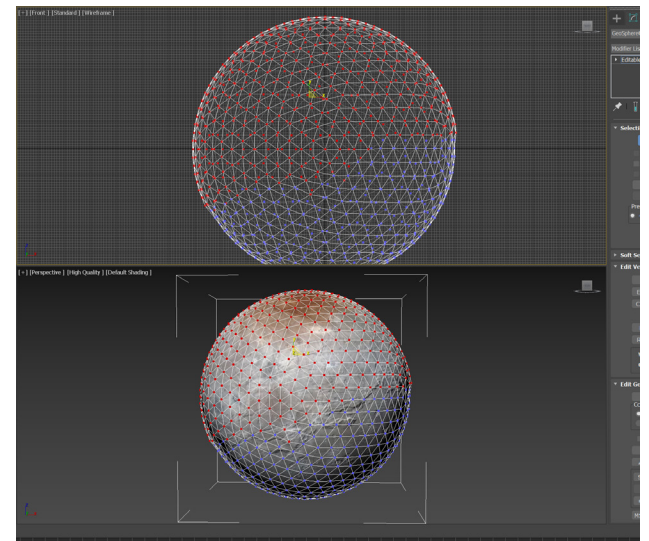
Select the PERSPECTIVE viewport and MAXIMIZE VIEWPORT TOGGLE, zoom out until the poly geosphere is nicely framed. On the top left of viewport controls change STANDARD>HIGH QUALITY and STANDARD>MATERIALS>REALISTIC MATERIALS WITH MAPS.



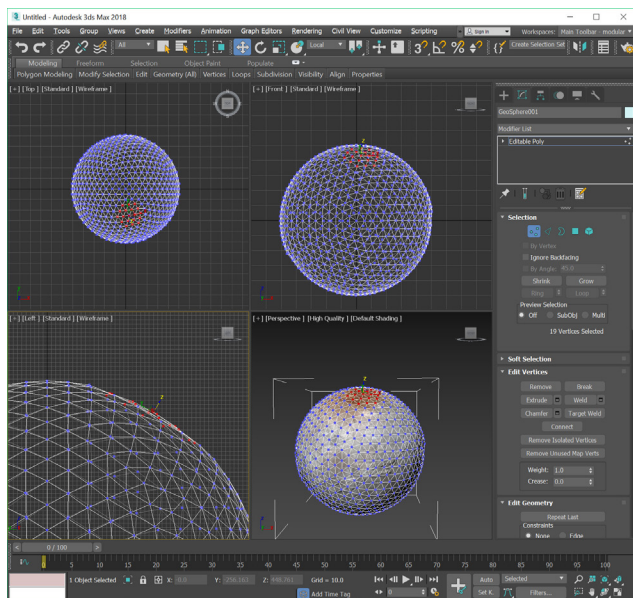
Rotate the viewport and examine the fit of the image onto the sphere and adjust the UVW map size gizmo if needed. Next we begin doing gross shape editing. For this example I am modeling Pluto's largest moon, Charon, which has a raised expanded northern hemisphere. Use the SELECT tool to add and subtract selected vertices on the model from the front viewport corresponding to the large raised areas of the photo.



Once you are satisfied with the selection for the large raised areas, use the UNIFORM SCALE tool to scale up the selected areas. In a similar manner for large depressed lower elevations you can select the lowered areas and slightly reduce the scale to lower their elevation. This gross adjustment does not need to be precise selections; this is just general shaping of the sphere. It is important to note that the scaling of the selected vertex points is toward the center of the selected vertices, not toward the center of the polygonal object. Scaling works best when large regions that encompass the body are being adjusted.

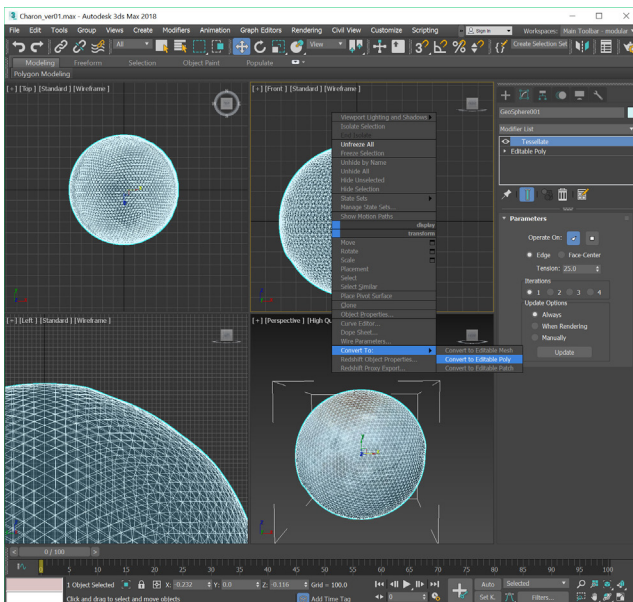


For large areas that do not encompass the body such as the large red colored crater on the north face of the Charon model, it is more effective and accurate to translate the vertices with the SELECT AND MOVE tool, using the LOCAL 'reference coordinate system' from the drop down menu, which allows movement of the vertices along the group normal, which roughly corresponds to elevation.



Now that some gross details have been added it is a good time to save a version before we build up the surface geometry. **SAVE>Charon_ver01.max**

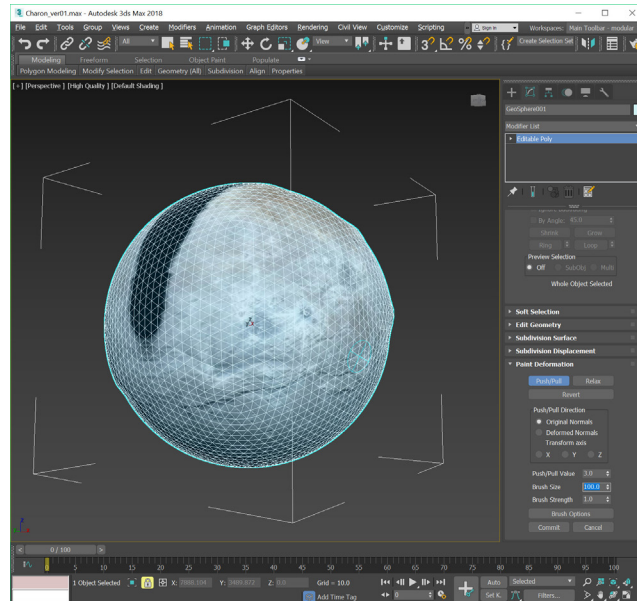
Next, increase the resolution of the polygonal mesh. Deselect sub-object mode on the poly geosphere, and add a **TESSELLATE** modifier to the modifier stack of the geosphere. It should be set to operate on **FACES**, with the **EDGE** radio button selected. Then right click the selected poly geosphere in a viewport and choose **CONVERT TO>CONVERT TO EDITABLE POLY**, which collapses the modifier stack and updates the poly geosphere.



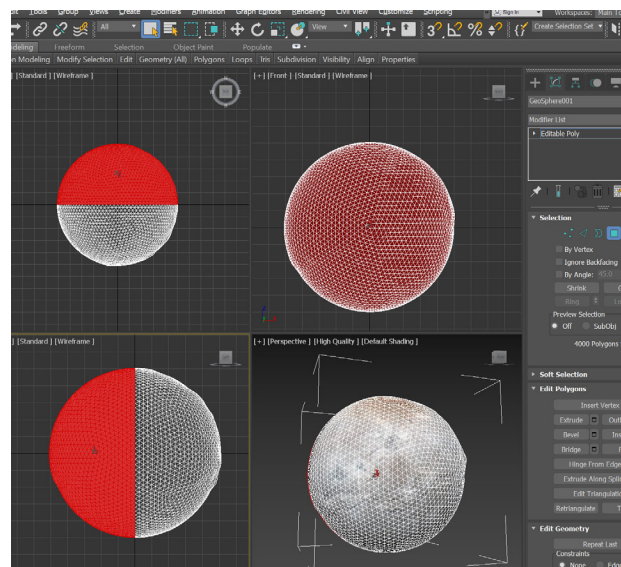
Select the **PERSPECTIVE** viewport and use the **MAXIMIZE VIEWPORT TOGGLE**.

The **MODIFY** menu for the poly geosphere has an option tool at the bottom of the modify roll-up named **PAINT DEFORMATION**. Zoom up on the poly geosphere and choose an oblique view angle. Set the **PAINT DEFORMATION** parameters to **PUSH/PULL** button selected, **PUSH/PULL VALUE 3**, **BRUSH SIZE 100**. Use

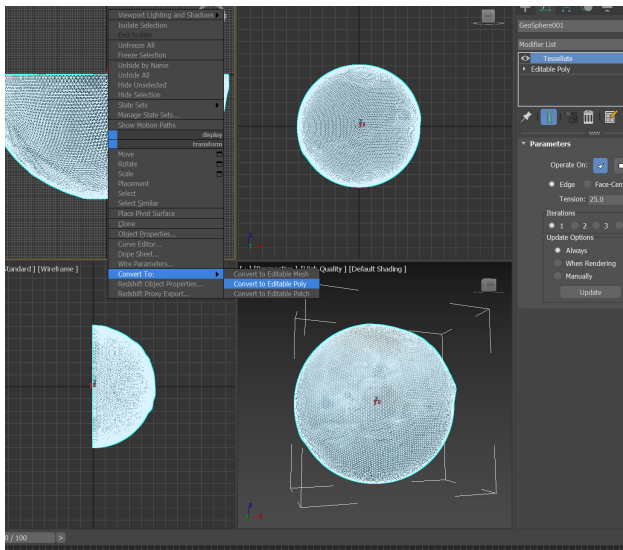
the **PUSH/PULL** brush to pull up the height of large ridges and mountain ranges using the left mouse button. Use **ALT+LMB** to depress large craters and valleys. At this level we are doing only moderately large details, refining the gross shape slightly, don't try to be too precise. Adjust and rotate the view in the viewport to see the height of the moderate detail heights you are adding to the model surface. Once you are satisfied with the moderate details, save the progress using **SAVE AS>Charon_ver02.max**



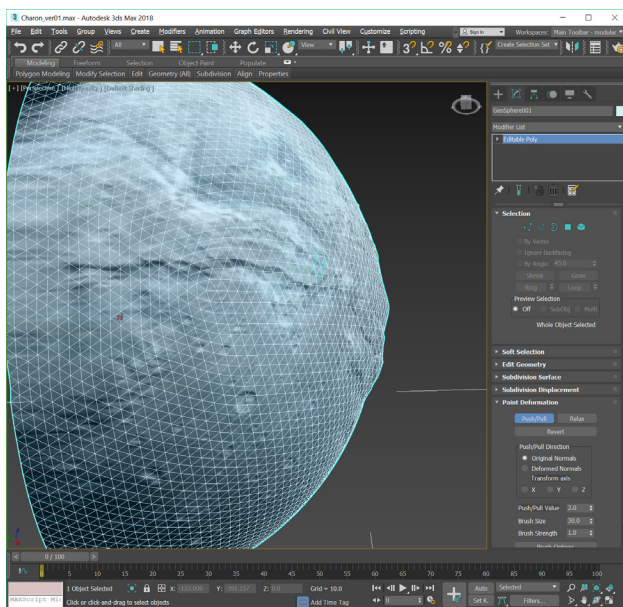
On the Charon model we only have high resolution photo data for one side. Before we increase the polygonal resolution again, remove the back half of the geosphere polygons to improve performance as the polygon count multiplies. Select sub-object **POLYGON** on the geosphere modify menu. Again use the **TOGGLE VIEWPORT** on the bottom right views menu to see the other viewports, and from the **TOP** viewport select all the polygons on the back and then delete them.



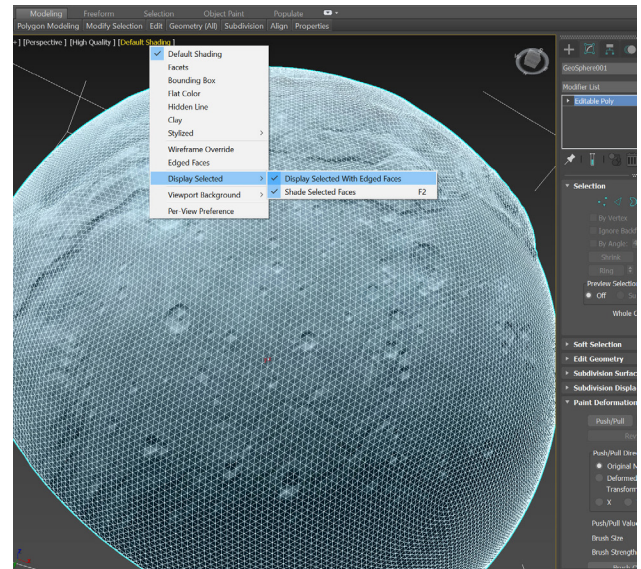
Again, add a **TESSELLATE** modifier to the poly geosphere, and again **CONVERT TO EDITABLE POLY**.



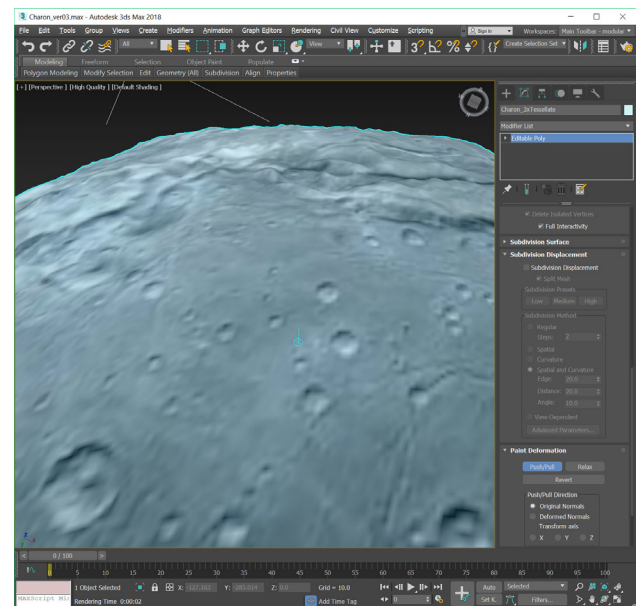
TOGGLE VIEWPORT again to the PERSPECTIVE and again using the PAINT DEFORMATION, set the PUSH/PULL VALUE to 3 and the BRUSH SIZE to 30. PULL up raised details and PUSH to depress areas such as craters. Because this brush is small compared to the granularity of the polygonal mesh, areas that become creased with sharp angles need to be smoothed with the RELAX button which is next to the PUSH/PULL button.



Continue to rotate the view to see the height details being created from different angles. Once the detail areas look decent it is again time to add a third TESSELLATE modifier and again collapse the modifier stack with CONVERT TO EDITABLE POLYGON.



At this high level of polygonal resolution, viewing the edges of the polygons interferes with seeing the material mapped onto the geosphere, so in the upper left of the PERSPECTIVE viewport, again choose DEFAULT SHADING>DISPLAY SELECTED>DISPLAY SELECTED WITH EDGED FACES to toggle edged faces off. Set the PAINT DEFORMATION tool settings to PUSH/PULL VALUE 2.0, BRUSH SIZE 10, and paint small details and clean up edges, raising and lowering areas and using the RELAX button brush to smooth out areas that become too distorted or angular.



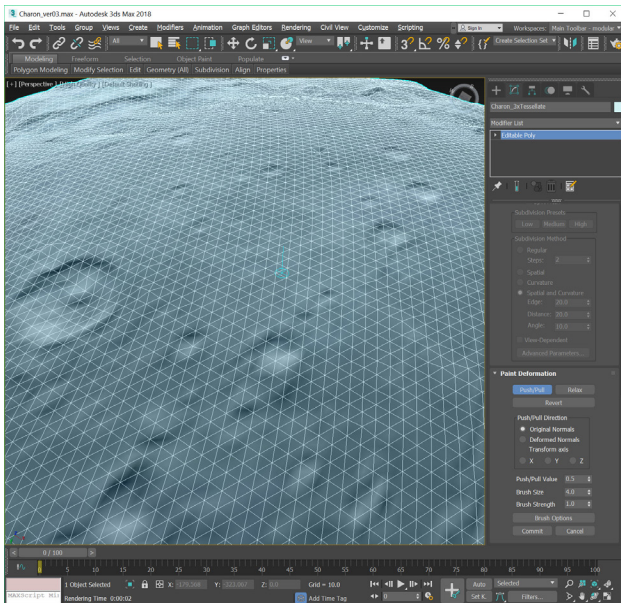
Trace out crater edges, small craters, cracks, collapsed lava tubes, lines and details pushing in depressions and pulling out elevated areas. There will be one more pass for the finest details so don't worry about the smallest craters and details.

This is a much more detailed process at this level—to make the terrain really believable at this level takes time. Expect to spend tens of minutes or even hours painting details, zooming in and out, rotating the view around the details as they are worked into the polygonal mesh.

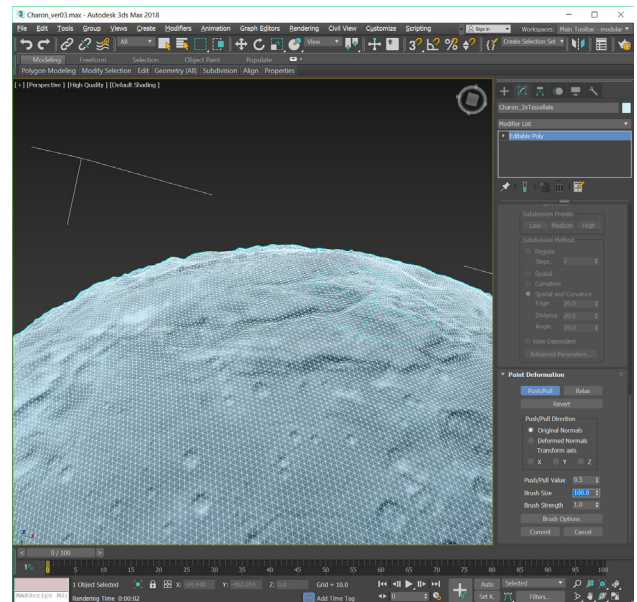
If the shot being created is from a distance and doesn't have too much parallax, the height painting will be complete enough at this stage and the model can be saved out, skip past the finest detail step below to the finishing and optimization steps.

This is a good time to SAVE>Charon_ver03.max

For a very detailed model add one more level of TESSELLATE modifier and again CONVERT TO EDITABLE POLY. Turn on the view edges under DISPLAY SELECTED WITH EDGED FACES to see the resolution that the smallest details will be height 'painted' with push/pull. It is useful to turn on and off the DISPLAY SELECTED WITH EDGED FACES several times during the final detail refinement so that the adjustments being made to the mesh are more clear.

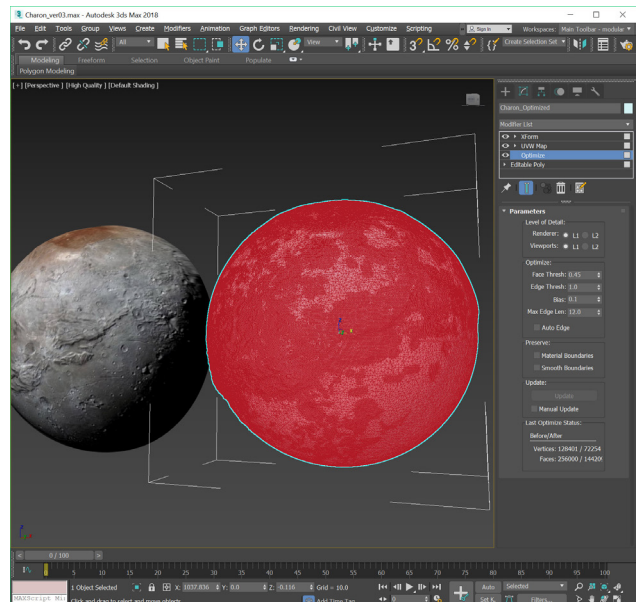


For this level of detail, a PUSH/PULL VALUE of 1 and BRUSH SIZE 4 will work well. Work over the surface of the model, a section at a time, turning on and off edged faces as you move from section to section, zooming in and out and rotating the view to see the height 'painting' from multiple angles of view. For the very finest smallest details turn the PUSH/PULL VALUE down to 0.5. This final height 'painting' step is where the smallest details are added to make the model able to be viewed with good height realism at medium and close distances. To height 'paint' this step properly will take hours of pushing and pulling the height for small craters, rills, mounds, ridges, valleys and other details. It is especially important to zoom out far enough to see if the detail being added makes sense in the scope and scale of the overall object.



Finishing & Optimization—rotate the model, zooming in and out looking for areas that now appear too high or too low. Adjust the brush size to a large brush at 0.5 brush strength that fits the area you want to adjust, using a very low value between 0.5-1 'nudge' the areas to the height that looks like it matches the image.

Make a clone copy of the surface and hide the original, apply a MODIFIER>OPTIMIZE to the modifier stack. I ended up using values of FACE THRESHOLD 0.45, EDGE THRESHOLD 1.0, BIAS 0.1, MAX EDGE LENGTH 12.0 for a final count of 144,209 faces from 256,000 original faces, 56% of the original. After optimization a new UVW MAP must be applied to the modifier stack since the mapping on the vertices will be displaced by the optimization. Collapse the stack with either a RESET XFORM on the modifier stack or a right click CONVERT TO EDITABLE POLYGON. Save again over Charon_ver03.max.



When the object is being rendered at a distance the optimized version is fast to render. When closeup work is being rendered, substitute and 'unhide' the full resolution version of the model.

When you render the model, the light direction must match the shadows shown on the material mapped to the model and the camera movement is limited to the portion that is actually created. A similar resolution geosphere can be cut in half and attached to the model if a backside is needed to obscure stars or other objects. It is possible to add detailed geometry on the backside from a different body to simulate data for circling or orbiting shots.

Feel free to email me with questions about this paper.

REACHING BEYOND THE DOME CONNECTING WITH THE COMMUNITY

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Abstract: Outreach to a community can be accomplished through countless mediums and depends on many variables. Self-promotion is a basic necessity to draw a crowd; however, it cannot sustain audience attention by itself. In this paper, we aim to provide examples of public outreach strategies that have succeeded for our planetarium in recent years to regain record attendance.

Introduction

In the planetarium field, we always strive to better ourselves as a whole. From the content we provide, to the number of guests we bring in, we look to improve in ways that reach the public's attention. The Ward Beecher Planetarium last year earned our highest attendance in the last 14 years, over 10,000 in public attendance, and over 18,000 in total. We have a couple ideas on how we improved, which we aim to share.

Self-promotion such as creating events on social media, distributing schedules through mail, and on site pick up are our primary sources of outreach; however, these strategies only go so far. These new ideas may not work for every planetarium, but they have in our recent past, and we look forward to the near future to see if our efforts continue to increase attendance.

We have reached beyond traditional public outreach through social media posts, library visits, and school activities. Firstly, we have moved towards public broadcasting; our planetarium engineer and lecturer have done a tremendous job keeping to task early morning interviews through both radio and television broadcast, and continue to work with the staff after interviews. Secondly, we have improved relations with our local astronomical society, and promote each other in various ways. Finally, and most importantly for a university planetarium, we include club activities and reach out to students as well as the local community.

Public Broadcast

Emphasis has been placed on reaching out to multiple platforms; because of this, we have increased our attendance in the past few years. One thing we take advantage of as a campus planetarium is the community. We deliver our brochures to local restaurants, libraries, businesses, and living quarters on and around our campus. This, accompanied by other strategies, has helped

us develop a relationship with those in a substantial radius of the area. Our planetarium engineer, Curt Spivey, has done multiple interviews and tours of our planetarium on local news stations. He has also received a regular time slot to present current astronomical events. This has developed a well-known presence for us in the community, and has helped a lot of people on and off campus learn about us. Both Curt and our planetarium lecturer, Tiffany Stone Wolbrecht, have created a radio presence as well to reach audiences on the go.

Our social media presence has also played a huge role in our attendance. The Ward Beecher Planetarium utilizes Facebook, Twitter, Instagram, and Snapchat to publicize upcoming events and programs to keep visitors up to date on the latest goings on under the dome. Although "interested" and "attending" number on event posts do not always equal actual numbers for attendance, we are able to gauge ourselves for a relative audience size. Our lecturer has also made numerous improvements to our website making it more visually appealing and informative to incoming visitors.

Astronomical Society

Throughout the past few years, we have strived to make a better connection with our local astronomical society. We have joined them in collaborative free public events such as star parties, but we have also included them in our yearly programs. The public has the opportunity to meet them twice a year before and after the holiday season as a way to learn how telescopes work and what equipment will be best for the budget they have.

The Mahoning Valley Astronomical Society has been a resourceful organization to work with, having decades of amateur astronomy experience to share with the community, they volunteer their time to further general knowledge of observational astronomy. For the 2017 Great American Eclipse, members of the

MVAS joined us in a free event that brought over 2000 visitors to observe the spectacle. We offered solar telescope sites, and free solar glasses to those who came to see us in collaboration with Mill Creek Metroparks at their experimental farm location. Although they aren't attached to YSU, we work closely with them, advertising for each other through social media and our own personal websites.

Collegiate Club Activities

The Ward Beecher Planetarium is a multifaceted entity ever present and ever growing in the community and beyond. It is nestled in the heart of Youngstown State University; and as such, interacts with thousands of college students every year. We will always offer planetarium programs to the public curious about the world above them, but one of the hallmarks of the Ward Beecher Planetarium is that we remain active beyond the dome. The planetarium has spanned across the general public to interacting with student organizations on YSU's campus.

One such organization is in the heart of the physics and astronomy department: The Society of Physics Students (SPS). It is the only group on campus dedicated to the success of the physics and astronomy majors and anyone with a passion for the field. It is the first obvious step to garnering a close relationship with the students that may one day become planetarium lecturers. The planetarium has partnered with SPS in many ways, the first being joint outreach to the community. Silly Science Sunday has become a yearly activity with the planetarium staff and students working aside volunteers from the Society of Physics Students to bring the wonder of science to approximately 5,000 people in the Youngstown community. SPS members brought some of their own telescopes to help some 2,000 people from across the region witness the Great American Eclipse. The planetarium has also allowed meetings to be held under the dome, ushering in a whole new era of immersive assemblies and demonstrations to SPS members and those who attend their events. The partnership between the planetarium and SPS has brought in speakers from other universities to give talks to members about the newest and most up to date discoveries in the field. Interest in working in the planetarium has skyrocketed as well, leading to countless new opportunities. In reaching out and partnering with SPS, a close connection has been cemented, creating a relationship that benefits the members of SPS, the planetarium and the community as a whole.

Science based student organizations aren't the only ones we have collaborated with. Ward Beecher has ventured into the realm of fantasy and fiction, lending a scientific view on some of the most popular aspects of today's culture. Room of Requirement is YSU's club dedicated to fans of the Harry Potter series and other fantasy interests. Working with the club has provided us with one of our most popular shows, Wizarding Weekend. Wizarding Weekend is a Harry Potter themed star talk, bringing the book series to light with the stars, showing how much of J. K. Rowling's inspiration originates in the night sky. The show brings in a large number of people, so much so that the planetarium reached capacity for all scheduled programs, facilitating the need to add extra shows. It caters to people of all ages, and guests are encouraged to come in costume. Visitors are sorted into houses upon arrival to the planetarium and fight for the honor of the house cup. Room of Requirement coordinates with the planetarium to help set up the show and provide fun activities for the crowds waiting for the next program. Students from the club also sit in and enjoy a show or two themselves. The inclusion of these collegiate groups has enabled us to incorporate new and exciting ideas into our public shows.

Conclusion

The planetarium strives to not only reach and educate as many people as possible but to reach new heights in education and inclusion in the field. In partnering with our local astronomical society, we can show the grandeur of distant stars and swirling galaxies utilizing instruments the first astronomers built when peering into the unknown. Our aim has always been to share this knowledge with the public, and our networking efforts have aided us in doing so. By pulling from diverse groups across the college campus, we have evolved the way we bring forth education of our shared knowledge in a manner that is inspiring to people from all walks of life. We will continue to connect with the community and venture beyond the dome to provide education, outreach and a starting place to ponder the vast universe we all share.

CORE CRITICAL IMPACT INDICATORS: EVALUATION ACROSS AN INSTITUTION

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Abstract: The Michigan Science Center, with generous funding from Denso, is working to evaluate our programming and exhibits across the institution. We are looking to gather input from other informal, hands-on STEM professionals as we review our current impact data and identify our Core Critical Impact Indicators or CCIIs. These CCIIs will help us better track our impact and engagement across the institution. This paper outlines the process that we have gone through so far, and our next steps as we progress in developing our Core Critical Impact Indicators.



The Michigan Science Center (MiSci) opened in 2012. During our first few years of operation, we inconstantly evaluated our programs, exhibits, and mission-aligned events. We surveyed guests following some programs, but later found, we weren't asking the right questions. All we learned was whether or not they were having fun and if they liked the food. The only programs we consistently evaluated were programs with grant requirements to perform an evaluation. Many of those programs came with evaluation tools, but each of those programs had very different tools and requirements. We weren't doing in-depth analysis of our programs in our infancy.

In 2017, MiSci adopted a new strategic plan. A large part of the strategic plan was to identify Core Critical Impact Indicators (CCII) to improve prediction and measurement of how hands-on, interactive experiences at MiSci encourage participants to consider STEM careers and drive greater interest in foundational STEM classes and skills. Thanks to generous funding from Denso, MiSci was able to begin to identify the key characteristics that define the most impactful science center experiences and track our engagement with and impact on our wide range of audiences.

One of our biggest struggles, and a large reason why we didn't have proper evaluation in the past, was not having a staff well versed in evaluating the work in informal settings. Fortunately, there is a lot of research and guidance readily available to assist us. One resource that has proven quite useful is *Learning Science in Informal Environments: People, Places, and Pursuits* created

by the National Research Council of the National Academies (Bell, 2009). This document identifies and discusses six strands of science learning and describes what guests do cognitively, socially, developmentally, and emotionally in informal learning environments (Bell, 2009). The strands are shown below.

Learners in informal environments:

Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.

Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.

Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.

Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.

Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (Bell, 2009)

Using the strands and MiSci's mission "to inspire curious minds of all ages to discover, explore, and appreciate STEM in a creative and dynamic learning environment", we developed the questions we would use to do an initial evaluation of our programs and exhibits.

- Does the exhibit or program have real world relevance?
- Was there a connection to a career or phenomenon?
- Does the program or exhibit generate curiosity?
- Is there interaction or engagement required?
- Is there an unexpected outcome?
- Does the exhibit or program produce an innovation mindset?
- Are the guests able to change the variables?
- Is the program or exhibit open ended with multiple solutions?

Because we were looking for a baseline, we only focused on things that could be observed by our staff in short periods of time. We also only focused on the exhibits first to make sure we were asking the right questions. This effort was intended to provide a more consistent approach when evaluating static exhibits and was later adapted to address interchangeable hands-on programs. Part-time educators and volunteers were given iPads to take to each exhibit and answer the questions. Five different people answered the questions at all exhibits to test for inter-rater reliability of the questions.

After analyzing all of our exhibits, we realized that “yes” and “no” answers were not enough. Some of our exhibits technically achieve one of the things that we are looking for, but not well. For example, one of our exhibits, mentions an engineer on the sign, but doesn’t provide much detail about how the exhibit relates to that career. Our next step along in this process will be to develop a Likert-type scale (Vagias, 2006), or something similar, to better understand where our exhibits fall along a spectrum of meeting a particular goal. This will allow us to better understand what improvements need to be made and how.

Through our initial evaluation and analysis, we have discovered that, though our long-term outcomes are the same across the variety of programs and exhibits, there are different ways to achieve those outcomes. For each program and exhibit type, we plan to develop logic models to better develop, create, and modify our exhibits and programs. Using resources, such as *Assessing the Impacts of STEM Learning Ecosystems: Logic Model Template & Recommendations for Next Steps*, we plan to make a logic model template for our institution to follow as we move forward in our evaluation plan (Traill & Traphagen, 2015).

One of our programs that needs particular evaluation is the STEMinista Project. It is a project to encourage 4th-8th grade girls to pursue STEM careers and maintain interest in STEM topics. After much success in this area, the Michigan Science Center was awarded the Ralph C. Wilson STEM2035 grant in mid-2018 which, among other things, allows the science center to participate in the Partnerships in Education and Resilience, or PEAR, Institute. We are excited to take part in training to use the PEAR Institute’s *Common Instrument Suite* and to be part of the accompanying Peer Learning Community (PLC). This will help us to improve our program development and evaluation processes for our STEMinista Project. Though the STEM2035 PLC is focused on the STEMinista Project, the information can be used to help us across our institution.

In summary, the Michigan Science Center’s next steps are to enhance our initial evaluation process with a Likert-type scale, learn more about the PEAR Institute and how we can use the *Common Instrument Suite* across the institution, and to create a logic model template for all of our program and exhibit types. We hope to have a better understanding of the work that we have ahead of us and have a plan for evaluation in place in early 2019.

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RED PLANET PIONEERS: A MISSION TO MARS

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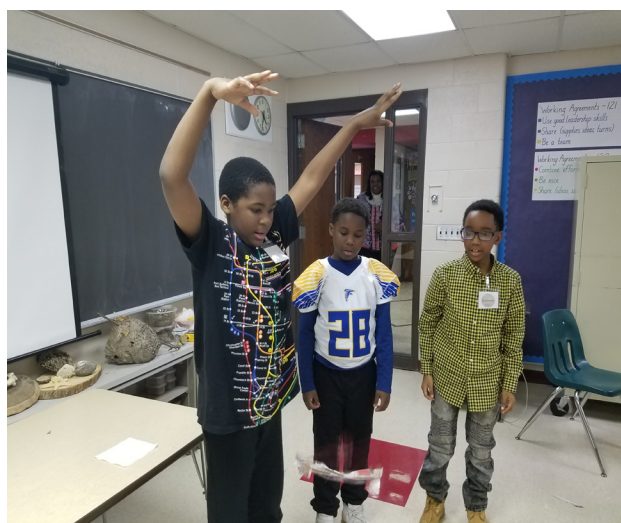
Abstract: In 2017, the Michigan Science Center was awarded a grant from the Michigan Space Grant Consortium. With this grant, the Michigan Science Center was able to develop and implement a Mars themed after school program for 3rd through 5th graders called the Red Planet Pioneers. The program focused on how we might get to the red planet Mars. This paper discusses the full scope of the project, including what went well, what we would have changed, and the full lesson plans implemented.

Project Overview

The Michigan Science Center's (MiSci) 2017-2018 Space Science focus: *Mission to Mars* was a network of dynamic programs including hands-on activities, Planetarium shows, speakers, and the development and implementation of a new afterschool program, *Young Astronauts*. Young Astronauts (later renamed *Red Planet Pioneers*) engaged interested students with space science projects tied to our themes. Additionally, this project included public outreach efforts that incorporate the continuation of our annual Space Week, a 6-day celebration of Space Science, Space Travel, and the spirit of exploration. This project also included embedded special supports to engage girls and minorities, Space, space exploration, and a mission to Mars. Institutions like the Michigan Science Center have the exciting job of creating experiences to engage the public with cutting edge science, new technology, and modern mysteries—experiences that may just launch our future explorers, engineers and home-grown geniuses to dedicate their lives to the challenges that need to be solved for a successful mission to Mars.

Red Planet Pioneer Overview (Young Astronauts)

Working with McIntyre Elementary school, the Michigan Science Center enrolled and engaged 64 third to fifth grade students to participate in special after school programming, exceeding the goal of 25 students. The Red Planet Pioneer program consisted of 19 female students. The school racial demographics are 96.4% African American, 0.2% Hispanic and 2.3% Caucasian. 55.1% of the students that attend McIntyre Elementary School are on free and reduced lunch. Due to our ability to offer the programming for free, the cost from the school was minimal and students that may not have been able to afford an after school program were able to participate.



In the early stages of the program, we renamed “Young Astronauts” to “Red Planet Pioneers” to differentiate our program and the Young Astronaut Program of the Reagan era. Originally, the plan was to create one cohort of students, but interest in the program was so great that we decided to split the grade levels and offer three different sessions.

The Michigan Science Center developed and adapted lessons for six sessions of the Red Planet Pioneers. Each session lasted 1.5 hours. The lessons followed six different themes. They included: teaching the fundamentals, the human experience, launching and landing, protecting the astronauts, and rovers and geology. The program focused on NASA's priority to expand the frontiers of knowledge and opportunity in space. Activities, namely those that were supported by the National Informal STEM Education Network were shared during an online workshop titled, “[Afterschool Programs: Advocating, Collaborating and bringing Earth and Space Content to Out-of-school Time](#)”. Lesson plans for the programs are available upon request. Contact Paulette.epstein@mi-sci.org for more information.

Meeting Times

	3 rd Grade	4 th Grade	5 th Grade
October 17 th	Gravity – Teaching the fundamentals	Space Collisions – Teaching the fundamentals	Projectile Motion – Teaching the fundamentals
November 21 st	M a r t i a n Weather – The human experience	Martian surface chemistry – The human experience	Forces During Launch – The human experience
December 19 th	Straw Rockets – Launching and Landing	Parachutes – Launching and Landing	Let it Glide – Launching and Landing
January 16 th	Invent a Space Suit – Protecting the astronauts	Inventing a Space Suit – Protecting the astronauts	Rocket Design – Protecting the astronauts
February 13 th	Egg Drop Challenge – Protecting the astronauts	G a i n i n g Traction on Mars – Rovers and Geology	R o c k e t Construction
March 20 th (6:30 -8:30)	Family Science Night w/ Ann Arbor Hands-on Museum	Family Science Night w/ Ann Arbor Hands-on Museum	Family Science Night w/ Ann Arbor Hands-on Museum
April 17 th	Magnetic Fields – Geology	G a i n i n g Traction on Mars – Rovers and Geology	Water on Mars
May 10 th (Thursday 6:00-8:30)	Potluck Dinner (STARLAB)	Potluck Dinner (STARLAB)	Potluck Dinner (STARLAB)

Theme 1: Teaching the Fundamentals

3rd Grade: Gravity—In this session, the students learned about the force that keeps us on the ground and orbiting around the Sun. They discovered patterns within our Solar System we demonstrated the relationship between the Sun, Earth, and Moon and how it might impact our journey to Mars.

4th Grade: Space Collisions—In this session, the students learned about how craters are formed. They dropped different sized objects from different heights and measured the impact sights. We discussed Asteroids, Meteoroids, and other flying debris and discussed what we might have to think about if we were trying to get to the red planet.

5th Grade: Projectile Motion - Students explored the content area of changes in motion, particularly how force affects motion, as they worked to solve the real-world problem of designing a catapult that could destroy an asteroid headed for Earth using projectiles. Students designed, tested, assessed, and modified a tool (catapult or otherwise) to repeatedly launch an object and accurately hit a target in the classroom.

Theme 2: The Human Experience

3rd Grade: Martian Weather—The students investigated the importance of density, temperature, and gravity with regards to air movement and weather by using water at different temperatures mixed with food coloring and making

observations. We then took a look at what might make Martian weather so much different than our Earth.

4th Grade: Martian Surface Chemistry—The students explored some of the chemical makeup of the Martian surface. The students used different solutions and steel wool to explore Iron Oxide. We did demonstrations with dry ice to learn a little more about what solid Carbon Dioxide might be like at the polar ice caps.

5th Grade: Rollercoasters—Students explored the most basic physical principles of roller coasters, which are crucial to the initial design process for engineers who create roller coasters. They learned about the possibilities and limitations of roller coasters within the context of energy conservation, frictional losses and other physical principles. We discussed how the forces may effect astronauts and energy consumption to get to the red planet.

Theme 3: Launching and Landing

3rd Grade: Straw Rockets—Using straws, cardstock and tape, students explored what it takes to launch a straw rocket. The students perfected their designs to see who could most accurately hit a target across the room. We discussed what kind of rocket design we would need to travel to Mars.

4th Grade: Parachutes—Using different materials, the students tested and perfected their designs for a parachute to land pennies safely back on the ground. We discussed the Martian atmosphere and how we might change our parachutes to make up for the thinner atmosphere.

5th Grade: Let it Glide (Adaption of NASA Glenn's EDC)—Using the Engineering Design Process, students will develop and build a shoebox glider, and then improve it in terms of aircraft and wing materials, shapes, and structure, to produce the greatest glide slope (the ratio of the distance traveled to decrease in altitude) possible.

Theme 4: Protecting the Astronauts

3rd Grade and 4th Grade: Invent a Space Suit—Students learned about the history and evolution of suit design within the American space flight program. They also exercised critical thinking skills and work as engineers to design new space suits to help astronauts thrive within different locales throughout the solar system.

3rd and 5th Grade: Egg Drop Challenge—The students put their engineering skills to the test as they designed a carrier to safely land an egg on the red planet. They had certain cost and weight parameters to make sure the egg landed safely for the least amount of money to the taxpayers.



Theme 5: Rovers and Geology

3rd Grade: Magnetic Fields—The students learned about magnets and their poles and worked together to make “Magnet Mazes” by using magnets to cause other magnets move through a course. Finally, the students concluded by reviewing what they learned about magnets, and why Mars’ differing magnetic field could make colonization hard in the future.

4th Grade: Invent a Rover—Students used household materials to invent and create a prototype of a rover to do research on the Martian surface. Each student was asked to make sure their rover could complete 3 simple tasks: gather soil samples, move around the surface, and transmit data back to Earth.

5th Grade: Water Pollution Clean-up—Students developed, tested, and revised a water treatment device to purify water, all while sticking to a budget and exploring how pollution impacts our watershed. We discussed why water is so important to life and some reasons why Mars may not have an abundant amount of liquid water.

Other parts of the Red Planet Pioneers Program

Teacher Professional Development: The Michigan Science Center offered two teacher professional development sessions for those interested in learning about the space and the Red Planet Pioneer curriculum. The first session, held June of 2017 brought together local *five* teachers to MiSci where they received materials for a variety of activities. The goal, in addition to providing resources, was to collect feedback on the activity set that was designed for Red Planet Pioneers. Feedback was positive, with all attendees agreeing

that the activities would promote positive engagement in space sciences.

The second professional development session was hosted with *twenty* Detroit Public School Community District teachers in August 2017. We again, discussed our space science offerings, both inside, and outside the building, and what is like to put together an after school program around space science.

Rocketry: Throughout the program, the 5th grade students were working on building Estes rockets to be launched at the end of the program. They launched them with the whole school watching. Everyone's rocket went up and no one's exploded on the launch pad.

InSight: Shortly before the program started, the Red Planet Pioneers signed up to have their name on the microchip that was sent to Mars with InSight. We were one of the more than 2.4 million names.

STARLAB: At the end of the program, we had a potluck where the families were able to experience our STARLAB portable planetarium. We also handed out certificates of completion and celebrated the end of the school year.

Evaluation

What the students learned

For the most part, students enjoyed the program and were more interested in space science because of it. Quite a few students communicated that they loved seeing the demos that we were able to provide (Liquid Nitrogen, Dry Ice, etc) that they have never seen in their classrooms before. When the students were asked at the end of the program how cold Dry Ice and Liquid Nitrogen were, the students were able to answer correctly.

What parents thought of the program

The parents were very grateful for the program. The school had a program like this in the past and they were worried that their students wouldn't have a place to learn about space science since it is not taught as much in the classrooms. We heard many great things about how much the students enjoyed the lessons as well. The parent volunteers were very excited about the lessons that they have never seen before and how they all tied together.

Lessons we learned

We went into the programming expecting to teach six sessions of combined 3rd-5th grade students. After being awarded the grant and talking to the school, they were expecting something different. We ended up creating a much larger program to accommodate the school's request by having six sessions of 3rd, 4th, and 5th grade separately. This had advantages and disadvantages. We were able to better target the lessons to the students and better link what we were learning in an informal setting to something that they might be learning in the classroom. We ended up having a lot more planning had to go into the lessons because there were three times

as many. We also discovered that some of the lessons that worked well at the science center were much harder to take on the road. Some of the activities would have worked much better had we scaled back. We also underestimated the amount of time required for the program, but that is probably because of the scope of what we originally had in mind and what the school had in mind. We also had issues finding parent volunteers for some of the age groups. It would have been much easier to find them in a mixed age classroom.



Space Month Programming and Outreach



During the Michigan Science Center Space month, our Sponsors of Science Program sponsored 609 students to attend the science center at no cost. This was over our goal of 400 students thanks to our other generous sponsors. The Sponsors of Science (SOS) Program offers sponsored field trips to students in underserved and under-resourced communities in Detroit and across the state. Historically, this funding primarily serves Detroit schools with field trips to MiSci—schools that generally have 80% or more of their students enrolled in the free and reduced lunch program. For school children, we assess free and reduced lunch eligibility program data.

In addition to the SOS program, MiSci is also committed to reaching female audiences through The STEMinista Project. During space week, a special workshop was offered to our STEMinista girls and reached twelve participants.

During space month, we exceeded our goal of reaching 3000 with 3791 children, students, and life-long learners through our programming provided. We offered planetarium shows, hands-on activities provided by the National Informal STEM Education Network, and special Spark!Lab activities centered on our future endeavors to Mars.

The original plan to host a forum was evaluated using registration data and feedback on past forums. We recognized the need to adjust our programming delivery method while maintaining program goals and objectives. Instead of the Forum, our Staff Astronomer Paulette Epstein gave four talks and open discussions. They were called *Illuminating Dark Matter* and the abstract is as follows:

Join Paulette Epstein, Planetarium Manager and Staff Astronomer at the Michigan Science Center, as she shines a light on “dark matter”. Find out why scientists think dark matter exists, what it could be made of, and the different detection methods available to scientists right now. Paulette will review the origins of our understanding of the stuff (including the foundational work of Vera Rubin), explore how scientific models of it have developed in the years since, and go deep into the work scientists are doing today to detect it.

Discussion was opened after every talk to discuss why we pursue space science knowledge, especially things that don’t seem to have an impact on our day to day. The dates of the talks were July 17, 2017; Feb 2, 2018; May 5, 2018; and May 7, 2018.

SHADOW PUPPETS ON THE DOME

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Abstract: This paper talks about a shadow puppet show presented in the planetarium by MSU professors Pia Banzhaf and Steve Baibak. The show was an adaptation of the book *The Three Astronauts* by Umberto Eco.

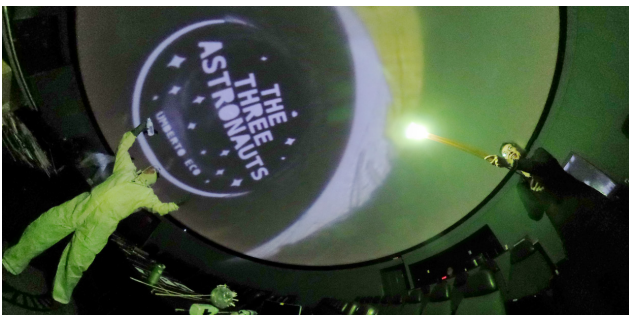
In the spring of 2018, the Abrams Planetarium hosted a shadow puppet show in the planetarium dome. The show was the brainchild of MSU professors Pia Banzhaf and Steve Baibak. The show was an adaptation of the classic 1966 children's book *The Three Astronauts* by Umberto Eco. *The Three Astronauts* tells the story of an American, a Russian, and a Chinese astronaut traveling to Mars. There they meet a Martian. They have to learn to trust each other and trust the Martian.

The puppeteers, Pia, Steve, and some students used very simple techniques to tell the story. With handheld L.E.D. flashlights, paper cut-outs, plastic bottles, and wire, they were able to create beautiful imagery on the dome.

The puppeteers rehearsed several times throughout the semester. The shadow techniques were reminiscent of the golden age of planetarium shows, when special effects were done using baby food jars, warped plastic disks and lenses from old filmstrip projectors.

The show was presented free of charge on a Sunday morning. It was well attended. After the show, the audience members were allowed to play with the shadow puppets and make their own shadows on the dome.

Here are some photos of the event:





NOTRE CIEL: BRINGING FRENCH LANGUAGE IMMERSION TO AN AMERICAN PLANETARIUM

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Abstract: In the spring of 2017, the James S. McDonnell Planetarium at the Saint Louis Science Center presented its first live, interactive planetarium show in French, *Notre Ciel*. Tying other academic subjects and real-life experiences into learning a world language is important for relevancy and vocabulary growth. As informal education settings, planetariums have a unique opportunity to reach students in ways that standard pedagogical methods may not. *Notre Ciel* has allowed the McDonnell Planetarium to reach out to a whole new audience: students learning French. This paper seeks to highlight best practices in bringing a world language under the dome.

Introduction

Depending on where one lives in the world, it may not be common practice for a planetarium to present live shows in multiple languages. In the United States of America, live shows offered in multiple languages seem to be somewhat uncommon, excepting perhaps some of the planetariums in more major cities, such as Morrison Planetarium in San Francisco, California which offers live shows in four languages several times a year. One might also find an institution in a smaller town here and there with an offering in a world language as does the Chaffee Planetarium at the Grand Rapids Public Museum in Michigan with its live Spanish show; however this may not be as common. In most cases for planetaria within the USA, a show in a language other than English is often a canned production with a dubbed track in the needed language, as is the case with *The Little Star That Could* and *Dynamic Earth* in Spanish at the Bechtel National Planetarium at Columbia Basin College in Pasco, Washington, or *Big Bird's Adventure: One World One Sky* in Spanish at the Adler in Chicago, Illinois. This is an unfortunate situation as the unique environment of the planetarium can lend itself well to teaching a world language, or helping visitors who may not be comfortable outside of their own language feel more comfortable. It is within the teaching of astronomy in a world language under the dome that meaningful language learning can occur for students—giving them the opportunity to explore multiple subjects at once and outside of a normal classroom environment. With a staff member capable of presenting a live planetarium show in French, the James S. McDonnell Planetarium at the Saint Louis Science Center in the United States has presented multiple bilingual French-English live shows, and took the leap in 2017 to present the first ever all live French show, *Notre Ciel*. This paper will look at how a planetarium can be beneficial to second language acquisition, welcome visitors who do not speak English as their primary language, and increase attendance through new group visits and partnerships.

A Language-Based Background

Perhaps this topic seems odd coming from a planetarian, so I would like to give some context as to my credentials. Today I am the Manager of the McDonnell Planetarium in Saint Louis, Missouri, but that was not where I started. My undergraduate studies were in French, German, and Vocal Performance. I also earned a K-12 professional educator's license (PEL), with endorsements to teach French and German, which continues to remain valid. As part of the requirement for the PEL, I studied Primary Language Acquisition, and especially Second Language Acquisition (SLA) theory. My plan was to become a high school French teacher when I fell in love with volunteering at the McDonnell Planetarium. I started working in museums and began earning a Masters degree in Museum Studies to support my work at the Planetarium. I never went back to classroom teaching and eventually became a fulltime planetarian.

For a while I figured my undergraduate degree would just go mostly unused. Periodically, we might get a visitor or two who speaks French or German and I will converse with them in their native language, but otherwise my most used subject from my undergraduate studies was music due to working with the symphony in the planetarium. After a few years of working at the McDonnell Planetarium, I noticed that about once a year we seemed to have a group of French speaking students come to a show as part of a class trip abroad. Every year the teacher would speak with me and tell me that the teens did not really speak much English. I would invite them to shout out remarks in French during my show to interact if they were more comfortable but they usually stayed silent while the rest of the audience would answer my questions and pose their own in their native English. This got me wondering how to potentially not only get them more involved, but also how to bring in others who speak or are learning a world language.

Why Bring a Language besides English into the Dome?

For students learning a world language, whether in an immersion school or in a class in a traditional school, the planetarium can provide a unique opportunity. One of the best ways to help second language (L2) acquisition is to provide meaningful input and allow the opportunity for interaction and output. According to Fred Genesee (2001) of McGill University, "Instruction for beginning language learners, in particular, should take into account their need for context-rich, meaningful environments" (para. 17). Meaningful input is language with communicative intent that is not a drill or activity specifically providing L2 learning instruction. Input is also considered in many language acquisition theories, to be the foundation for learning, comprehending and acquiring a language. By partnering with a teacher or school, a planetarium can provide meaningful input about astronomy in the L2 of the students, and in turn, provide the students an opportunity for output in a safe environment where they may not feel judged for speaking by other students. Bill VanPatten (2003) explains in *From Input to Output: A Teacher's Guide to Second Language Acquisition*, that

it is important, however, to note that we are not talking about learners practicing a form of structure in their output; we are talking about learners coming to the awareness that they need a form or structure because of their output (p.69).

By asking questions and allowing the students to answer, it also provides the students the opportunity to create (hopefully meaningful) output as well, which in the end could lead to better processing of the input.

To provide the most meaningful experience for the students, the presenter should communicate with the teacher before the visit if at all possible. Students who are in the beginning stages of SLA process for meaning first and foremost, as intake processing abilities of a new language learner are limited. Intake can become a part of the linguistic system as it is what is held and processed in working memory. If there are other environmental factors drawing on the attention of the learner, however, it makes intake and processing for meaning far more difficult (VanPatten, 2003). By working with the teacher beforehand and providing suggestions for pre-visit activities, the teacher can prepare the students with vocabulary and at least some content in the classroom. This approach means students will have at least some knowledge of astronomy in the L2 so that when they hear the vocabulary and content in context, scaffolding (building upon previous instances of learning a concept) can occur and the students will be able to better process the input for meaning with less of a drain on processing resources from any other input (i.e. the stars on the dome).

A world language show is an opportunity to bring a new audience into the dome. For school-based planetariums, this could be an easy fit. It gives world language instructors the opportunity to work with students in a different setting and create a fun and engaging way to teach the language, and they do not have to worry about travel costs as much as they would with a field trip outside of the school or school district. For both stand-alone planetaria and domes that are part of a museum campus, an opportunity lies within

this concept. As travel is difficult for most schools, particularly if there are not multiple classes attending the trip to make the cost of bus transportation worthwhile, the potential for Science and World Language teachers to partner and bring more students is strong. Any partnerships formed could also lead to more partnerships within the same school and district as well. This is a chance for planetariums to build new partnerships with teachers too, which will hopefully increase attendance (and when applicable, revenue) and become a repeat visit every year.

There is also a benefit in regards to native speakers, as a show in their native language can make an institution feel more welcoming to them. It also enables these visitors to be better engaged and hopefully increase stay time. Furthermore, if one taps into the tourist industry in the area, it is possible to have a new group of visitors to bring in from traveling groups passing through the city. In the end this could lead to a new revenue source for the institution.

Finally, a planetarium show in a world language opens up cultural opportunities to explore with the audience. Students study their own culture, perhaps the history of other cultures within the last 500 years, and primarily that of ancient civilizations in the United States. If they are taking a world language or international studies class, they may also study current cultures of other countries. By having a world language planetarium show, students can also experience that a different culture may view science, specifically astronomy, in a different way. This is the case, for example, while discussing the Big Dipper. Most American visitors who come to the planetarium are familiar with the Big Dipper, but are often unaware that other cultures call that asterism something else (i.e. the Great Plough in the U.K., *la Casserole* [the sauce pan] in France and *der Großer Wagen* [the large cart] in Germany). This lends itself to then discussing a new concept—not all star patterns are considered official constellations. This also allows for more stories from cultures other than the Greeks (which seem to be the most popular, particularly within the United States), leading to better engagement of the audience.

How Should the Show Flow?

Once approval has been given to have a 100% live world language show (and/or a bilingual shows), decisions have to be made on how to arrange the show for the audience. Lightbown and Spada (2006) note that it is important to provide a content-based, natural setting rather than a language classroom instructional setting, and to keep in mind that that

the focus of a lesson is... on the subject matter, such as history or [astronomy], which students are learning through the medium of the second language... the emphasis is on using the language rather than talking about it (p. 110).

By creating a planetarium show in the L2, the presenter is giving the students an opportunity to explore the language in a natural and meaningful way. The students are able to listen to, respond to, and interact with the L2 in a setting where they do not have to worry about a teacher grading them on their ability

to provide grammatically correct output or that they need to pass a test. Again though, presenters should remember to keep the astronomy content at the proper level for the students' age and grade, as focusing on the content and using normal L2 speech patterns will be most beneficial to them.

While one may be able to follow a normal show flow in the second language (L2), it may not be advantageous to the group in attendance. As with any live show, it is always best to gauge the audience (in advance of their arrival if possible). If the group in attendance is made up of native speakers or they have been studying the L2 for a year or more, it may be easier to provide a show in the L2 that is closer to a live show given in one's native language (L1) in terms of concepts and vocabulary. For more advanced users of the L2, (most likely older students who have had some astronomy previously in their Science courses), it may be possible to delve into more advanced topics such as the age of the universe, deep sky objects, and even black holes and quasars.

If the students in attendance are a group of novice learners, they may not have all of the necessary vocabulary to understand everything, and while content can and should be adjusted to be at the proper level of the group (VanPatten, 2003), one should not shy away from speaking normally. Beginning Astronomy topics can be covered even if the students know them in the L1 because this will give them an advantage for processing input, negotiating how the input is received, and producing meaningful output. Lee and VanPatten (2003) further these ideas, noting that communication in the L2 that is in person is helpful as

Comprehensible input derived from interaction, then, may be quite different from, say, input from the radio or the TV, where the speaker is in absolute and complete control of both what is said and how it is said, and the learner has no opportunity to negotiate comprehension (p. 32).

This also means that the presenter needs to be aware of the audience's responses (or lack thereof). Checking for comprehension with questions is always a good idea to ensure that the subject matter makes sense to the learner. If needed, circumlocution, the act of using a longer, more descriptive phrase to get a point across, rather than a shorter phrase with more advanced vocabulary, can be used to aid comprehension too.

It should be kept in mind too that students are most likely still new to the ideas presented in a planetarium, and that their L2 abilities may very well be limited, so grace is required. Lightbown and Spada (2006) remind educators that *"In these situations the emphasis is on getting meaning across clearly, and more proficient speakers tend to be tolerant of errors that do not interfere with meaning"* (p. 111). Therefore the presenter should not take it upon themselves to correct the language, but rather just allow for use of the language in a content-rich setting. Furthermore, the presenter should be sure to give plenty of wait-time, perhaps even longer than one would normally wait for visitors in an L1 show to respond, for the visitors to answer any questions posed to them in the L2. This is due to needing time to access and activate vocabulary and grammar in the L2 which comes slower than it would in their L1 (VanPatten, 2003).

While it is best to provide input only in the target L2 and accept output in the L2 as well, if the show is bilingual one will not have that luxury. In a bilingual show situation, saying every single phrase in both languages is not necessary. While some repetition between the languages may occur, if meaning can be perceived in both languages through context, then a cadence of switching back and forth without as much direct translation may be achievable. It is good to encourage the visitors learning an L2 to respond only in the L2 and not in the L1, even if a question was posed in the L1. While not an ideal situation, this will at least give them the opportunity to practice using the vocabulary (and the presenter can respond in the affirmative both in the L2 and L1 if desired to encourage continued L2 usage).

Lessons Learned from the McDonnell Planetarium and Notre Ciel

French live shows and bilingual French-English live shows at the James S. McDonnell Planetarium have been met with appreciation and positive feedback from attendees. These shows have been able to keep native speaking visitors, students learning a new language, teachers and non-French speaking chaperones engaged and learning about the night sky and the universe around them. Currently, most of the visitors have been younger elementary school aged students from the French immersion school; however, there have also been a few groups of teenage and adult native French speakers on vacation who have appreciated having some content in their L1.

When offering shows in a world language, it is important to only regularly schedule these shows when the presenters who can speak the needed language are available. Another option, which is the route the McDonnell Planetarium took, is to make the show available only through a group reservation for a day when a bilingual staff member is available. If the planetarium is a public institution, it should be well designated that the program will not be in the L1 anywhere a visitor might see the show schedule. All box office team members should also be aware of the language difference so they can make those purchasing tickets aware of the language differences. Finally, it is good to also announce at the beginning of the show that it will be presented in an L2 so that anyone who may have misunderstood has time to exchange their tickets for ones to a show they will better comprehend.

While many live show presenters present without a script and create their shows as they go based on a show's main ideas and audience feedback, as is done at the McDonnell Planetarium, in this instance it would be best practice for a presenter to prepare a script in advance. While this does not mandate the presenter to use the script in real time, it will force a potentially non-native speaker to think through what they want to say and how they want to say it so that they can model proper speech in the L2 for students. Also, as most world language instruction does not include a science unit or a large amount of astronomy vocabulary (most L2 instruction goes as far as giving the vocabulary for the Earth, Sun, Moon, planets, stars, and maybe galaxy), the presenter may find they need to research some vocabulary for themselves in advance. Having a script prepared, or at least an outline with key vocabulary, will help a presenter feel more prepared when the time comes to work with visitors in the L2 under the dome.

As mentioned earlier in the paper, talking with the teacher prior to the visit can help ensure that students get as much out of their visit as possible. The first group to attend *Notre Ciel* was comprised of first grade students from a Saint Louis Language Immersion School (SLLIS) who had been speaking French for a year and students new to the school who did not know a lot of French. After talking to the teacher, a communicative show was created to accommodate the young learners at their varying levels. The feedback from the show was positive from the teacher, the students who shouted out answers in French and English, and even the parent chaperones who were surprised to find they understood a lot of the show even though it was completely in French.

It can be difficult getting the word out to teachers about the shows, and even within the same immersion school, teachers may or may not know that a trip to the planetarium is an option. Reaching out to schools and world language teachers personally has seemed to work best. Other means of communication can include e-Blasts or email newsletters, a small description in a program book, listings on the organization's website, and asking reservation personnel to offer the show to those who are booking a visit. It should be noted though, that one should not assume that these later methods are a guaranteed way to capture groups; they do not appear to yield the same results. By speaking to a teacher or the principal personally, they learn of the presenter's interest in working with them and together they can plan a way to move forward with a field trip.

A recent example as to how personal communication can make a difference involved the SLLIS. The French School, Spanish School, and Chinese School all fall under the umbrella of SLLIS. A teacher who had brought her students in the spring of 2017 for *Notre Ciel* wound up with a mix of French and Chinese school students in her class during the 2017-2018 school year and felt she could not bring them as only half the students would understand the show in French. Before being able to discuss what could be worked out, they used their fieldtrip funds for the class to go somewhere else. A different teacher from the French School though, paired up with a teacher from the Chinese School to have enough students to bring to the Planetarium.

After a chat with the teachers prior to the start of their visit, it was decided that bilingual instruction would be helpful, and in the end, students thoroughly enjoyed a bilingual French-English show. The teachers were grateful that at least half the students could still be engaged in their L2, and the other students could still understand and participate in their L1. Students were engaged and responsive in both French and English, and the students from the French School were able to briefly converse about beginning concepts regarding stars and their temperatures, and the planets in French after the presentation. Being flexible allowed the students to benefit from the experience as much as possible, and the teachers are now discussing a French School field trip for the next school year.

Conclusion

Live French planetarium shows have been met with positive feedback at the James S. McDonnell Planetarium at the Saint Louis Science Center. The introduction of live world language planetarium shows has opened a new opportunity for world language classes, international visitors, and the planetarium itself. It is the chance to introduce a new group to other cultures. It is also an occasion to create partnerships with new teachers and schools to introduce meaningful and communicative world language learning in a practical setting. By offering a live world language option, a planetarium is able to welcome a new audience to learn about and find a love of the universe.

Acknowledgements

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Many thanks to Pamela Braasch for trusting me with this endeavor and giving the official approval to try something new in the dome with the *Notre Ciel* show and a new audience; even though there was a chance it might not reach anyone from our normal audiences.

Finally, my heartfelt appreciation to Valerie Sacks and John Lakey for the foundation that enabled me to create *Notre Ciel*.

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MAINTAINING RELEVANCE

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Abstract: Science centers in general, and Clark Planetarium specifically, have suffered from decreased attendance in recent years. We all face the challenge of remaining relevant to our visitors and constituencies—but how? Clark Planetarium underwent a series of internal and external evaluations to assess its brand, reputation, and relevance within its market area and demographics. Following the evaluation, a series of initiatives have aimed to increase brand awareness, relevance, and program attendance. This presentation will include a discussion of these issues and Clark’s initiatives in response, with the intent that other institutions learn from our example.

The Changing Landscape

Over the past several years, attendance to Clark Planetarium has declined significantly. An initial assessment of major factors in the decline showed three major factors:

1. The growing homeless population of Salt Lake City. Clark Planetarium is located several blocks away from the primary downtown homeless shelter.
2. The presence of drug use in the area around Clark Planetarium. This is highly correlated with the growing homeless population downtown.
3. Clark’s facility and exhibits had not been extensively renovated since the initial install in 2003.

In addition to long term institutional factors, some programs had seen new challenges. Ticket sales for the IMAX Theatre were also decreasing, primarily due to competition from new IMAX facilities within a 20-mile radius. One early attempt to boost IMAX sales brought entertainment-based IMAX films into the theaters for several years. Attendance did slightly increase but due to the required leasing costs for the films, there was a net financial loss that resulted in a return to the previous model.

In 2017, James Chung presented the ASTC webinar: “Disruption, Disintermediation, Re-invention: re-crafting the value chain”. While this presentation occurred after the Clark Planetarium project described here, it does provide additional data and background that could be of value to anyone considering this issue. Science centers must accept that market factors such as the national trend of fewer families having children and a distrust of science popularized by the media are leading to a shrinking market share under current practices.

Timeline

In 2009, Clark’s senior staff began a master planning process to address these issues. Initial steps included the design and prototyping of new exhibits for a major future renovation.

In 2012, the planning committee approached key stakeholders to begin fundraising for the renovation project. Stakeholders included additional Clark staff and board members, local government officials, consultants, and current visitors to Clark. Research projects began to survey overall constituency as well as current visitors, with the goal of assessing any other needed adjustments to our brand or business model.

By 2015, two-thirds of funding was secured.

In 2016, the new exhibit renovation was completed with a “Grand Reopening” in October 2016. In addition to the exhibits, major renovations updated the interior of the facility: redone lighting, repainting of the interior with a new and brighter palette, new carpeting, redesigned ticketing and concessions counters, and updated restrooms.

Research

A consultant was contracted to assess Clark’s internal and external brand perception. Survey methods included interviews with staff and board members, interviews with visitors and K-12 educators, as well as target audiences that were not visiting Clark.

- Internal Perception
 - * Science education
 - * Teaching about the thrill and awe of space/the universe
- External Focus Group Perception
 - * Mildly inspiring
 - * Edutainment
 - * School curriculum focus

- * **NOT** a top-of-mind destination

- Aspirational Brand
 - * Interactive
 - * Inspiring
 - * Educational
 - * A go-to resource in the community
 - * A cutting-edge science resource that inspires learning beyond our venue

The external focus groups were also asked about particular types of programming and what would bring them to Clark more often. Requests from guests:

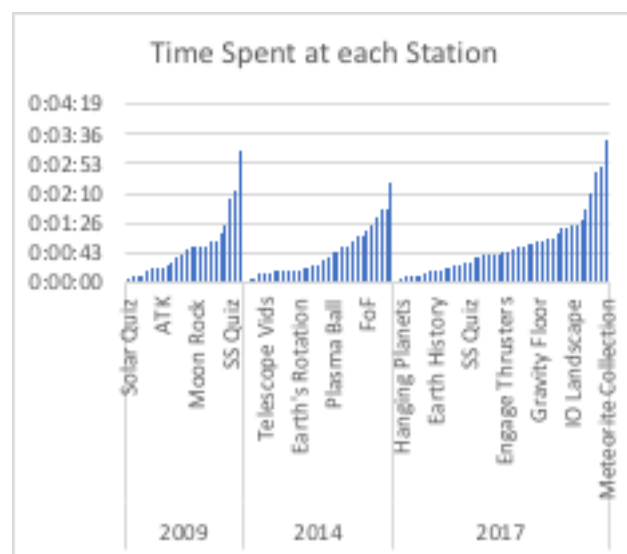
- A more rapidly changing IMAX schedule with newer shows, more variety
- Greater variety of programming in the dome
- Different types of experiences within the building, especially engaging experiences
- To engage with Clark off-site—at other locations throughout the community
- More interaction with staff or volunteers in exhibit spaces

Survey groups were asked about their preferences on exhibit-specific content. Results indicated that guests had specific content areas that they wanted to learn about, but the surveyed group had a very wide range of specific content areas that did not overlap. As a result, exhibit content was chosen to include a wide variety of astronomy, space science, and earth science themes, while maintaining significant variety and high quality within those themes.

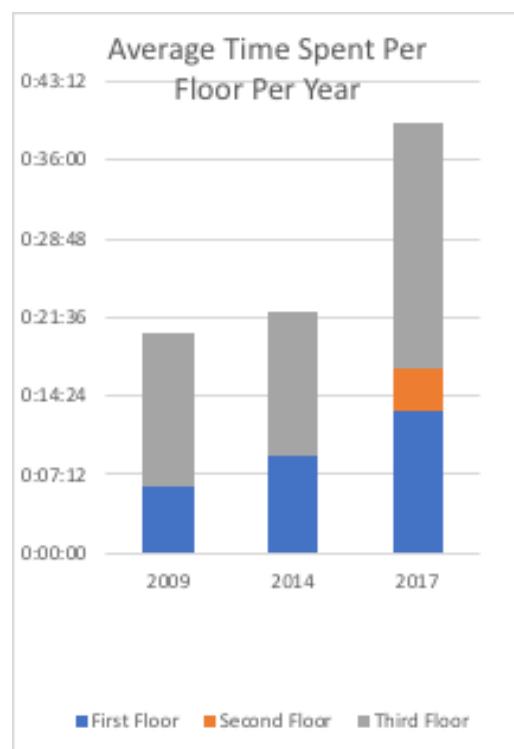
An additional finding was that the external focus groups were unaware that Clark already offered some of the programming that they were interested in. This led to a reassessment of marketing methods.

Results

After the research phase was completed, there was still a need for additional fund raising. To offset anticipated costs of exhibit production, several production staff were reassigned from dome show animation to interactive exhibit programming (“game designers”) to create content without resorting to contractors. In addition to internal restructuring, a partnership was formed with a local fabricator to create some of the exhibit components. The fabricator had valuable experience as an engineering firm doing research and development, and was able to provide affordable cabinets to use with the newly developed digital interactives.

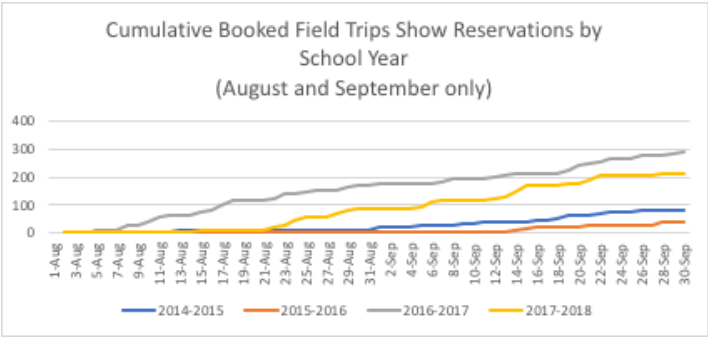


The final exhibit renovation plans included approximately double the number of exhibit components as were previously in the building. Following install, this created an unexpected concern: because many of the new exhibit components were so engaging, they “cannibalized” interactions from each other. Previous evaluations had indicated that some areas were not visited by visitors due to a lack of engaging qualities; the new components were actively “stealing” visitors from each other. A similar issue occurred with several of the new digital interactives. The interactive stations are so engaging that visitors will linger for an extended amount of time. While this is an overall positive, it did limit the number of people that can participate and can create queues through exhibit spaces. Several strategies were used to mitigate these concerns: the production of additional copies of each digital interactive station to allow for more users, and the adjustment of each interactive scenario to balance engagement timing and visitor flow.



Hold times within the exhibit spaces increased dramatically, nearly doubling the amount of time spent in the exhibit spaces. Based on the content specific to each floor of the museum, hold times increased in the expected areas. The first floor of exhibits has the highest concentration of collections and curated artifacts. The third floor is much larger and includes a broader array of interactives, both digital and otherwise. The second floor is relatively small, with only a small digital interactive area.

The renovations led to a heightened energy within the exhibit spaces that is apparent to both guests and staff. Guests are staying longer for longer visits, spending more time in the exhibits, spending more in the gift shop and theaters, and contributing to positive social media presence and brand growth.



PLANETARIUM CONTENT: DOME OPTIONAL

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Abstract: The Morrison Planetarium presenter team has had the opportunity to present and refine a variety of live and pre-rendered content both in the dome and throughout the California Academy of Sciences. Presentations have been given in the 3D theater, a panoramic planetarium, out on the public floor, and more. In this paper I will give an overview of these venues and share how we adapt our planetarium presentations for a variety of audiences and spaces outside the dome.

This year marks the tenth anniversary of the new California Academy of Sciences building and, along with that, the anniversary of the “new” Morrison Planetarium. Over the last decade our planetarium presentations have evolved in a number of ways. Early on we gave only one planetarium show, *Fragile Planet*, which was a pre-rendered show developed by the Morrison’s Visualization Studio and planetarium engineers. *Fragile Planet*, along with the many shows following it over the years, also has a short section in the middle and/or at the end of the show where a planetarium presenter can give live updates on science content. In the dome during these live sections the presenter team has been able to explore topics from exoplanets to earthquakes to brown dwarfs and much more. Consequently, having only these short (between one to five minutes) live sections did leave presenters with a desire to expand their opportunities to provide live content and interactions with guests. Not only do our presenters enjoy giving live planetarium programs, surveys we’ve conducted have shown that guests are five times more likely to rate satisfaction with their visit at a nine or ten when they’ve interacted one-on-one with Academy presenters or staff. One way the presenter team has been able to satisfy this desire for live content is by offering completely live planetarium shows during our weekly NightLife events and recently we’ve added a live show once at the end of each day. Alongside these dome presentations, the Morrison team has had the opportunity to develop presentations in a number of different venues. Presenting in these other spaces has given the presenter team the opportunity to be more versatile in our presentations and allowed us to explore different approaches to presenting planetarium content.

One of the first venues that was developed outside of the dome was our Hohfeld Hall space. At first, Hohfeld Hall was only used as a pre-show staging area where guests could start getting dark adapted and hear rules for the planetarium. The space includes a panoramic wall that acts as a screen with three projectors.



Hohfeld Hall pre-show loop

A couple years after the opening of the new Morrison Planetarium, the presenter team started to use the space for presentations as well. When Hohfeld Hall was first utilized as a presentation space, we were using Sky-Skan’s DigitalSky 2 for live presentations in the dome and decided to use it for Hohfeld as well. DigitalSky was used up until almost two years ago, when we moved away from DigitalSky in our venues and instead focused on using Uniview solely. Using an Ipad interface, the presenters have been able to give presentations in a more interactive way to smaller groups (up to ~150 people) than can fit in the dome (which fits 290 people). It also is a space that gives the opportunity to give presentations to guests of all ages. In the dome we have an age limit of kids four years old or older, and it’s recommended for guests ages seven or older. In Hohfeld, since it doesn’t have the safety limitations of a dark space with steep, concrete stairs, guests of all ages can be included. Hohfeld is a much more casual space than the dome, where we leave a door open so guests can come and go as they need and guests are encouraged to sit on the floor. Shows in Hohfeld Hall are generally done in time slots that fit in between dome shows, and so do have a limited amount of time at around 15-20 minutes.

Allowing such a wide range of audience types in Hohfeld does pose its challenges. Since shows can include groups with families including ages ranging from babies to senior citizens, school groups, camp groups, and more, we try to find topics that can be made accessible to everyone. Some topics that we've explored in our Hohfeld Hall shows have included infrared light, Hubble, and Mars.



Hohfeld Hall show: Curiosity on Mars

So far we have presented about twenty different shows, re-using certain shows as it made sense with our scheduling, programming themes throughout the museum or astronomical events. We try to provide presenters with enough content and background so that they can adapt shows depending on the audience. If we're presenting a show to five adults versus 50 elementary school kids, we want presenters to feel like they have the tools to present the show in a way that best addresses those particular audiences. Often the way we've approached this is by creating scripts that have more information than can fit into one individual show, but gives options for what the presenter can talk about. Presenters then adapt these initial scripts to fit their own presentation style and the audience. We hope to continue to give presenters more tools for how to adapt presentations; for example, I attended a Reflecting on Practice (ROP) three-day workshop that focused on how to present effectively and how guests learn. I then shared some of the practices that were covered in ROP at one of our presenter meetings. I also plan to bring back what I learn at the GLPA conference to our presenters, and hope to provide them with professional development opportunities in the future, so we can all continue to expand our skills and knowledge.

In addition to strictly astronomy programs, Hohfeld has also been an opportunity to explore topics related to exhibits at the Academy that are in other areas of science, often with an astronomy focus on those topics. Since it doesn't require as intensive of a production cycle as main dome shows, which can take as much as two plus years to make, we're able to create new shows for the space every few months and play into the different programming themes throughout the Academy. For example, when we rented AMNH's Pterosaurs: Flight in the Age of Dinosaurs exhibit we developed a show called *Impacts and Extinctions*, which explored major extinction events throughout Earth's history, what may have caused these events, and how Earth and its inhabitants have

changed over thousands or millions of years. Our most recent show, *Giants of Space*, was developed in parallel to the in-house permanent exhibition, *Giants of Land and Sea*. While *Giants of Land and Sea* explored the biggest animals and plants that we have in California, *Giants of Space* explores the biggest objects that we know of in the Universe.

While the majority of Hohfeld shows aim to reach guests spanning a wide range of ages, having a space that is open to all ages has given the opportunity to develop shows that are focused specifically for our youngest learners. Especially since we often do end up with shows that are best suited for elementary school-age kids or older, having an opportunity to give shows specifically for younger guests has been very well received. In the past with DigitalSky we've given a show called *Shapes in the Sky*, where we explore constellations and Moon phases, as well as a show called *Moon Explorers* where we would fly over to the Moon and pretend to be astronauts walking around on the Moon's surface.



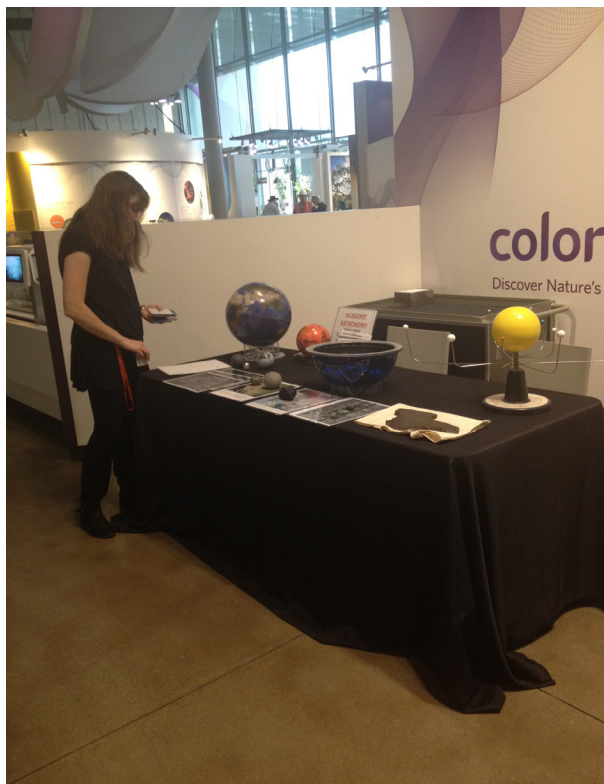
Hohfeld Hall show: Moon Explorers

We just revamped the *Moon Explorers* show in Uniview (started in October this year!) and have started by presenting it to our museum members on Tuesday mornings. With these shows presenters are able to get down to the kids' level by sitting on the floor with them, they point to different objects on the screen along with the kids, and mime or act things out with them such as putting on a space suit and walking/bouncing around on the Moon. We're hoping to continue giving this program after October and potentially expand its offerings to pre-school groups and the public during times outside of members-only hours.

During our shows in the dome we do try to incorporate interactive elements, but it can be difficult with the presenter being out of the line of sight of the audience. In Hohfeld we are able to be much more interactive with the guests and play off of their reactions and ask questions during shows. We are aiming to develop this interactive style even more in future presentations, such as with our upcoming show opening in January which will be focused on light and color. Previous Hohfeld presentations have been mostly lecture, with some back and forth with the audience through question and answer. With the next generation of Hohfeld presentations we want to get the audience even more involved and ask more open-ended questions that will help lead the presentation. We plan to have a Uniview presentation on the

panoramic screen as usual, but also are going to have hands on activities during the presentation where guests can learn about spectroscopy by looking at lights with diffraction gratings, feeling the temperature difference between a dark object and light object heated by a lightbulb, and showing an example of direct imaging by displaying a large and small light and having guests block out the light of the larger to see the smaller. No specifics have been decided on as far as what types of interactives we'll include in future shows, but we hope to develop that aspect of Hohfeld more over time, and maybe tap into some of what we've used out on the public floor.

Speaking of the public floor, Hohfeld Hall is not the first space where the presenter team has developed interactive activities. During our weekly NightLife events as well as various special events throughout the year, we've explored a variety of hands on interactives. Often these activities will involve two presenters at a table with a set of hands on objects surrounding an astronomical topic.



Tabling activities at NightLife

We do these activities fairly frequently, since they are our back-up if we're not able to have telescopes on our living roof during NightLife (and, being in San Francisco, that's a lot of the time). We're able to have short or lengthy discussions with guests depending on their level of interest and contextualize some concepts that aren't as easy to grasp with a planetarium show alone. During tabling activities guests can feel samples of simulated Moon and Mars dust, compare sizes of objects in the Solar System and relate their size and distance to places at the Academy or in California, explore how objects of different masses bend space, and more. These tabling activities have been a great tool at a variety of different events at the Academy, such as Astronomy Day,

weekly NightLife events, Penguins and Pajamas sleepovers, and special members nights. We recently began to incorporate some National Informal STEM Education (NISE) Network's activities into our tabling interactives as well. Some of the NISE kits we've used have allowed guests at our adult-only NightLife events on Thursdays to act out being a Mars rover and scientist guiding the rover, or explore extreme environments on Earth that could have parallels elsewhere in the Solar System.

Within the last year or so, we've also begun to explore pairing these hands on activities with planetarium visuals from Uniview, as well as Open Space and NASA Eyes, out on the public floor at our Science Today space. This area has benches that can sit a few dozen guests and has four flat screen monitors that combine into one where we can display using a laptop connection. We're still very much in the process of developing how we present in the space and are really excited for the possibilities and flexibility that it has. One of the pairings we've tried out so far has been using the NISE activity "Imagining Life", which explores animals that live in extreme environments around Earth.



Planetarium presenter, Christian, at Science Today

Guests are handed cards describing these animals and their home environments, then the presenter uses Uniview to show guests locations in our Solar System and beyond that have, or could potentially have, similar conditions to the ones that the animals live in, such as icy moons, exoplanets, or Io. Another pairing we've tried is bringing scale models of objects in our Solar System (Earth, Mars, Moon, Pluto, asteroids, etc) that we can use as reference while we fly around in Uniview.



Senior planetarium presenter, Mary, at Science Today

Presenters have been encouraged to start compiling a list of questions that guests commonly have so we can make a profile in the future that best fits guests' interests.

The last venue where we've been able to explore planetarium presentations outside the dome has been in our 3D theater. The 3D theater seats about 130 guests and uses Dolby 3D Digital Cinema glasses.



3D Theater

The 3D Theater can be one of the most challenging spaces that we present in outside of the dome, since it's open to guests of all ages but is in dark space with noisy stairs. We try to mitigate the number of people leaving in the middle of a show by being clear about how long the presentation will be and by encouraging people to stay seated through the whole show since it is a dark space. As far as interacting with the guests throughout presentations, the 3D theater tends to fall in between the dome and Hohfeld Hall or Science Today. The presenter is in front of the audience in the theater, so they're visible to guests and can have some back and forth with them. However it is a space that often has large audiences of a wide range of ages in a dark space, so the level of interactivity is limited.

As we often do in other venues throughout the Academy, the 3D theater has also been a space where we've been able to explore topics outside of astronomy. We produced a show focused on rainforests that was roughly half 3D movie and half live presentation. 3D Rainforest features footage of Academy scientists who work in rainforests and explores the different levels of rainforest ecosystems. The planetarium presenters then explored the effects of carbon dioxide in the atmosphere and deforestation, using data mapped onto the Earth's surface in Uniview. For this show we had the advantage of using a podium where presenters could reference a script, which was helpful given that our team generally didn't have a ton of background in rainforests or climate science. However, the majority of programs we've done in the 3D theater have been focused on astronomy, such as a tour of the Solar System for 3rd to 5th grade school groups and a tour of the Universe for general audiences. These presentations are fairly similar to shows that we've given in the planetarium dome, but with a fun twist of being in 3D.

One thing that all of these different venues have had in common has been providing some level of ability for interactions between presenters and Academy guests. There's the hard data from surveys showing that interaction is important to guests, and I've personally experienced this as a presenter. Any time I have the opportunity to chat with a guest about show content, answer their questions, or ask questions of them, I nearly always get the sense that they walk away from the interaction more informed and excited about science. Plus it often makes my day to have these interactions with guests, and I know my fellow presenters feel the same. We've been very grateful and fortunate to be able to explore different styles of presenting in a variety of different spaces. I believe this variety also helps to ensure that more guests will learn and grow by having different styles of learning and exploring science open to them. I hope to inspire you, my fellow planetarians, to explore the possibilities that your institutions have to offer you as well!

CONCERTS UNDER THE STARS: YEAR TWO

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Abstract: Following a successful pilot run in 2017, *Concerts Under the Stars* continued in 2018 at the Grand Rapids Public Museum's Roger B. Chaffee Planetarium for an equally successful second season. This paper will discuss the changes that took place between the first and second year, improvements to the series as a whole, reception and outcomes of the 2018 concert season, and plans for 2019.

Introduction: An Overview of 2017

In 2017, the Grand Rapids Public Museum started a new live music series in the Roger B. Chaffee Planetarium called *Concerts Under the Stars*. We booked exclusively local Grand Rapids musicians to perform in the planetarium, accompanied by a custom light show mixed live by a local video artist. During its first year, *Concerts Under the Stars* enjoyed immediate success, with four out of four sold out shows and a widespread reach to new planetarium audiences.

At its core, the overall intent of *Concerts Under the Stars* was to use the planetarium in a non-traditional way, thus attracting new audiences and challenging people's perceptions of how a planetarium can and should be used. But there were other, unexpected outcomes of the series, including our newfound reputation as a legitimate alternative music venue in Grand Rapids, and of course the things we learned throughout the process that allowed us to continue *Concerts Under the Stars* for a second year (and hopefully many more to come).

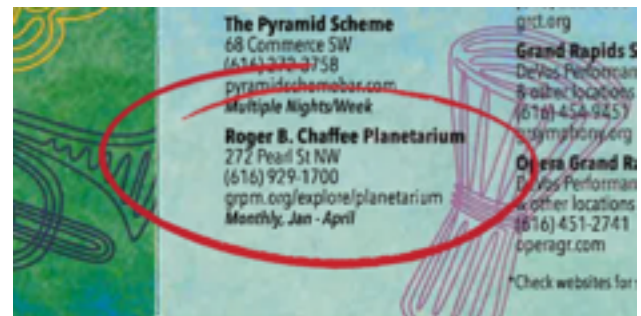


Figure 1. "Experience GR" brochure of music venues in Grand Rapids, including the Roger B. Chaffee Planetarium.

There were several things we did differently in 2018, some of which improved the shows and/or the general logistical structure of the events, and some that we probably won't try again. To name a few, we increased the number of performances from four to five (but we actually ended up with six), invested in some equipment to improve our efficiency running sound, had more variety in our visuals, partnered with a local radio station for advertising and promotion, and took bigger booking risks for genre and instrumentation.

Another Round of Local Performers

For Year Two of *Concerts Under the Stars*, we continued the trend of booking only Grand Rapids musicians. Logistically speaking, inviting local performers is simple; we would not have to worry about extra compensation for travel and lodging, we could schedule rehearsal time more freely, and (hypothetically) someone could quickly run home for a forgotten cable or cymbal. But more importantly, community support and collaboration is crucial to fostering good relationships between your institution and the rest of your city. There is no shortage of remarkable performers in Grand Rapids' ever-growing music scene, so why look somewhere else?

In 2017 we were somewhat reserved, and we booked bands with mostly electronic instrumentation and limited vocals, since we were concerned that feedback would be a major issue with our speaker setup. Our booking was more risky and diverse in 2018, with larger bands and a lot more equipment onstage. After the first



year we realized that our concerns were, while responsible, rather unnecessary.

The official lineup for *Concerts Under the Stars* 2018 was hi-ker (electronic indie pop), Edye Evans Hyde (jazz), Jes Kramer (one-woman indie band), Dan Rickabus (alternative folk ensemble), Major Murphy (rock and roll), and MERTLE (alternative rock/pop).

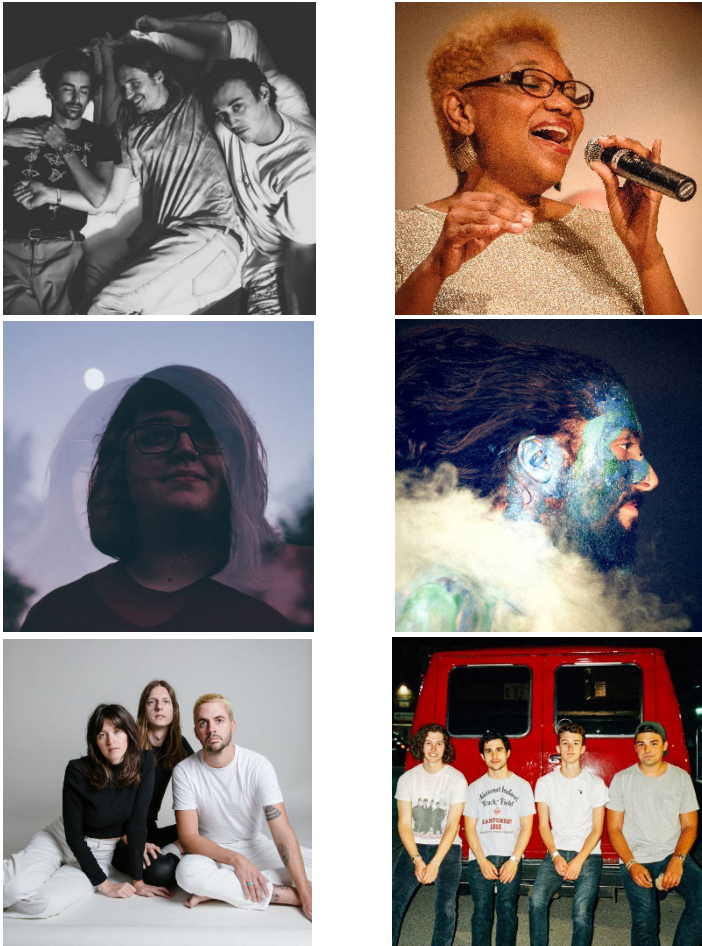


Figure 2. Publicity photos for all six bands for *Concerts Under the Stars* 2018.

Dan Rickabus was a particularly interesting and challenging show, and my personal favorite so far. Dan is the drummer of The Crane Wives, and he released a solo album called *Void/Journal* during the summer of 2017. He approached me about the possibility of performing with nine other musicians in the Chaffee Planetarium, to play the album in its entirety, beginning to end, as recorded, for the first time ever. We were intent on booking him, but I was skeptical about the ten-piece band until I saw them play a portion of *Void/Journal* at Lamplight Music Festival in a living room much smaller than our planetarium stage. After that we agreed to the idea and pulled it off remarkably well.

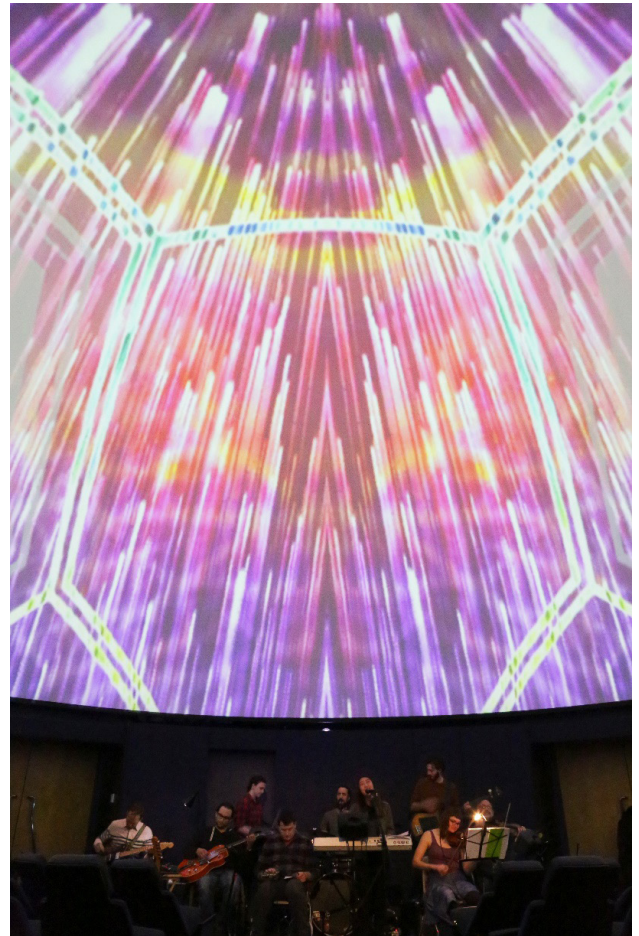


Figure 3. Dan Rickabus and his ensemble perform in the Chaffee Planetarium. Dome visuals by Nate Eizenga.

To improve efficiency in running sound for *Concerts Under the Stars* (especially for ten-piece bands), we installed a 16-channel snake that tucks neatly away under the wall behind the stage area. It was a simple investment, but it prevented us from having to run long cables back to our server room (and saved us a lot of wasted gaffer tape).

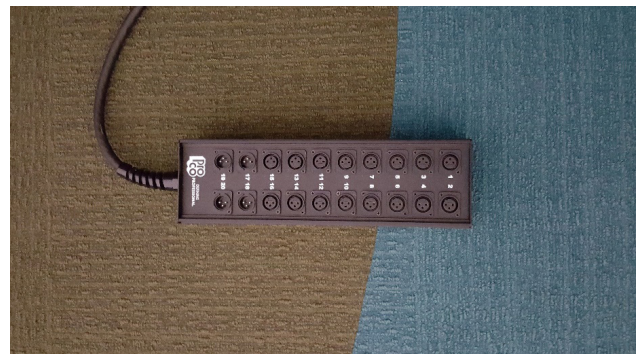


Figure 4. Pro Co SMA Series 16x4 Snake.

Custom Light Shows, Three Different Ways

For the first year of *Concerts Under the Stars*, we worked with one local video artist, Nate Eizenga. Nate provided live-mixed video for all four shows in 2017, harvesting royalty free videos, mixing them with a MIDI controller in a program called Resolume Arena, and projecting onto the dome with Digistar 5's

videoInputDisplay. Nate's process remained more or less the same in 2018, with an added degree of efficiency and experience under his belt. In 2018, Nate was available to work with us for two shows (hi-ker and Dan Rickabus).



Figure 5. Video artist Nate Eizenga practices at the console in the Chaffee Planetarium.

Two other shows (Jes Kramer and MERTLE) were accompanied by the video stylings of Meghan Moe Beitiks, a visiting visual arts professor at nearby Grand Valley State University. Moe was put in touch with Jes Kramer through mutual friends at GVSU, and following their show together, Moe was willing to work with us a second time a couple months later. In contrast to Nate's live performance, Moe produced looping videos to play start to finish as a backdrop to each song. She combined some of her own animation with royalty free video, largely from ESO's fulldome archive. However, she did also include a live/performative aspect to her work by utilizing our ChromaCove lights, choosing effects that suited the music throughout both of her shows with us. Moe's background in theater also inspired her to style a set for Jes Kramer, creating a cozy scene with pillows and floor lamps (modified so as not to cast light onto the dome, of course).



Figure 6. Jes Kramer performs in the Chaffee Planetarium. Dome visuals and set design by Meghan Moe Beitiks.

Visuals for the remaining two shows (Edye Evans Hyde and Major Murphy) were produced by us in-house. This process was a great test of our ability to produce 45-50 minutes worth of good looking abstract material in the span of just two or three weeks (twice). Some of the things we came up with included unused Digistar experiments from a previous light show production, Digistar cloud content, creations and presets from the software Magic, and—as is apparently customary—royalty free video. For Major Murphy's show, we also incorporated elements from their music videos, and John Foerch hooked up a MIDI-controlled microphone that could trigger lighting effects to react to the music.



Figure 7. Edye Evans Hyde and her ensemble perform in the Chaffee Planetarium.

All in all, the variety in the visuals was really positive, and added an extra layer of individuality to the shows. Although working with a video artist requires some degree of time investment to meet with them, test their ideas, and sometimes encode video, it pales in comparison to the time spent on producing visuals in-house. Ideally in future years, we hope to plan accordingly so that we collaborate with a visual artist for every show, lessening the amount of staff commitment and energy.

Advertising, Media, Budget, etc.

Since *Concerts Under the Stars* proved to be so successful in its pilot year, we were able to budget considerably higher for advertising, some equipment, and performer stipends. While most of our visibility still came from social media (both GRPM's and the performers') and word of mouth, the series was also picked up by a handful of local news outlets. Whenever possible, the musicians were interviewed on TV or radio within a week prior to their show. We partnered with community radio station 88.1 FM WYCE, which was our primary media sponsor. In addition to advertising the shows as part of their regular public service announcements, WYCE did ticket giveaways at the weekly radio show *GRLive*.



Figure 8. Two local news websites feature articles about Concerts Under the Stars.

The posters for these shows were created by regional designers Alex Barger and Daniel Deschaine. Alex worked with us on poster designs for the first year of *Concerts Under the Stars* when seeking a project as a student at Kendall College of Art and Design. We asked Alex to create another round of posters, and he collaborated with his colleague Daniel to create a cohesive geometric design theme that visualized each band's individual musical style. The physical posters hung in a few places throughout the Grand Rapids Public Museum, and variants of the design were used on our website and social media.

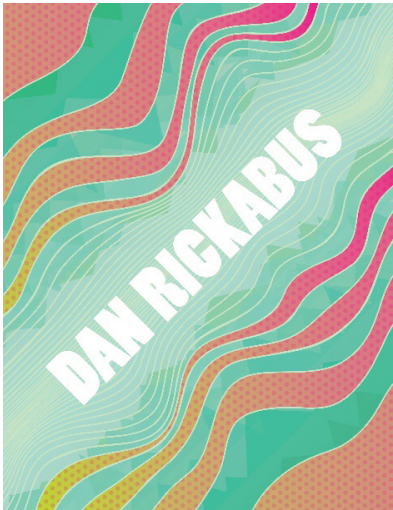
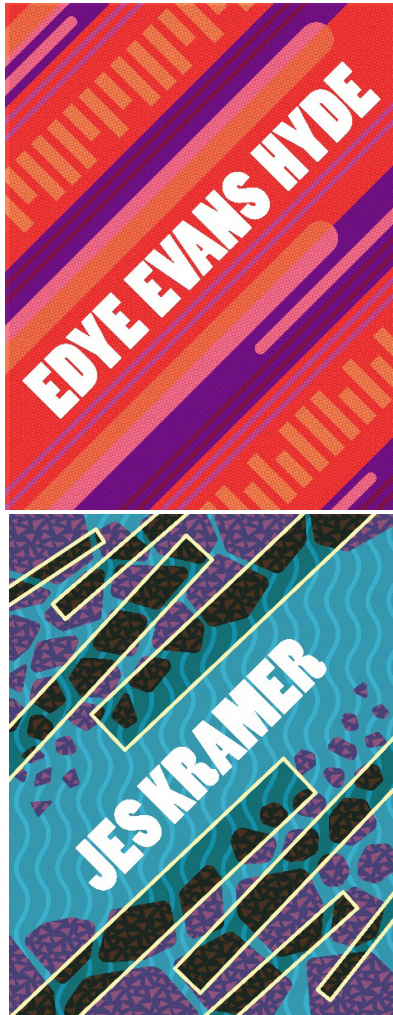


Figure 9. Three poster designs by Alex Barger and Daniel Deschaine.

The pricing structure stayed the same as it was the first year: \$10 for GRPM members, \$12 for non-members in advance, \$15 for non-members day-of-show. Having that advance ticket price seemed to encourage people to purchase tickets ahead of time, which drove up attendance considerably. The pricing structure may change for 2019, but this has not yet been finalized.

Showtime!

We require each band to schedule at least two rehearsals in the planetarium during the three weeks leading up to their performance. This allows us to get familiar with their stage plot and assess their audio equipment needs. Rehearsals tend to be most helpful for the video artists, who used the time to test their work on the dome and practice their set alongside the band. Occasionally we would schedule extra practice time if needed, but the required number is one regular rehearsal plus the dress rehearsal (often the night before the show, or sometime earlier in the week). It may seem demanding of everybody's time to require them to practice in our space, but all the performers seemed to find it genuinely helpful and productive, considering the acoustic uniqueness of the planetarium. The prep time that goes into each event allows us to anticipate potential problems and helps us put on the best show possible for our audiences.

Much of the general run of show stayed the same from the first year of concerts to the second. Doors opened at 6:30, and music started at 7:30 (although music was always delayed by about ten or fifteen minutes; people can never seem to be punctual for concerts, and even the Grand Rapids Public Museum succumbs to punk time). During the hour between doors and music, we played a playlist curated by the band in the planetarium and lobby area, and GRPM's Hospitality department provided a cash/credit bar. Each band prepared a 45-50 minute set, so each event as a whole ended up being about two hours total. Depending on the performers and depending on the audience, many people would stay and hang out with the musicians and artists after their set, while they packed up their gear and unloaded. Some bands also chose to sell merchandise before and after the show.

Once again, the concerts were immensely successful. Almost

all of them sold out; the only one that didn't was threatened by a snowstorm, but even then we were at 90% capacity. As mentioned, we initially scheduled five concerts, but for various reasons we ended up adding a sixth show to the lineup. Ultimately, it was marketed as a "by popular demand" addition, and was still well-attended and well-received despite its short notice and unexpected announcement.

One of the more notable accomplishments during the first year of *Concerts Under the Stars* was the unconventional audience that the series attracted. During a typical planetarium show, the audience is a fairly balanced mix of GRPM members and non-members (generally a higher percentage of GRPM members), but *Concerts Under the Stars* events were predominantly attended by non-members. As with any event that falls into the "alternative" category, we hoped to create something for demographics who don't necessarily show up during public hours, thus bringing in new audiences to the planetarium. This trend held true into the series' second year.

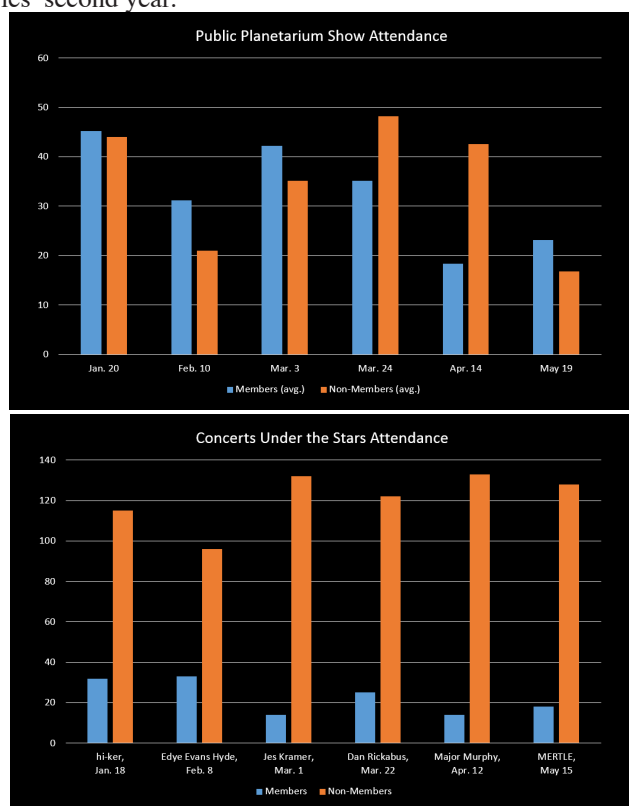


Figure 10. GRPM member vs. non-member attendance, a typical Saturday compared to Concerts Under the Stars.

Concerts Under the Stars 2019

Due to its popularity, *Concerts Under the Stars* will absolutely continue into the future. In our planning stages for 2019, some changes are already underway that we think will improve logistics and facilitation as well as visitors' experience.

During the first two years, the process for booking was not very formalized and always felt a little bit awkward to me. We have now formed a booking/planning committee that represents several departments within the Museum (some of which are directly involved in facilitating the events) and is comprised of people who have a connection to music in some way. I was also asked to invite

somebody from the community to join the committee, to offer their outside perspective and expertise. The person I invited is (among many other amazing things) the booking manager of one of the mid-size Grand Rapids music venues, a programmer on WYCE, and also happened to already be a big fan of *Concerts Under the Stars*.

Also new this year is a booking inquiry form on GRPM's website. Musicians in the past didn't necessarily know who to contact if they wanted to express their interest in performing in the planetarium, or if they did know who to contact it was usually in the form of a personal Facebook message rather than an email to my GRPM address. Now we can easily direct people to grpm.org/concerts-form, which has the added bonus of gathering all of the relevant contact information we need.

Returning to our roots, we are again planning four shows in 2019, concentrated from January through March. In 2017 and 2018, Spring Break during the first week of April caused scheduling conflicts and a strain on staff resources. Rather than force ourselves to work around it, in 2019 we will simply end *Concerts Under the Stars* before Spring Break begins, keeping "concert season" more contained to winter and allowing Spring Break to signal the start of a new season at the GRPM. With the Spring Break hassle and the addition of a sixth show, *Concerts Under the Stars* 2018 was a bit more sprawling than originally intended.

The structure of each event will also change slightly. Rather than perform one long set, bands will play two shorter sets with an intermission. We have observed that—even if they want to—people feel uncomfortable getting up during the show to return to the bar or use the restroom. Although certainly not disallowed, the occasional person exiting/entering is always a little disruptive for the rest of the audience (and disruptive to that person's experience as well). The intermission will increase the length of the experience overall, and will give visitors the opportunity to take care of their business without causing a distraction.

Earlier this year, the GRPM's Meijer Theater (which I manage in addition to the Chaffee Planetarium) received a grant for an A/V upgrade that included the purchase of several new condenser microphones. We intentionally chose equipment for the theater that could also be utilized in the planetarium for purposes such as this. That means less use of personal equipment, and more gear on-hand for those who need it. Since *Concerts Under the Stars* does not make a lot of revenue (the series more or less breaks even) it is hard to justify purchasing a lot of equipment that would be solely used for musical performances a few times a year. Being able to use brand new gear that was purchased in the context of an unrelated upgrade is very convenient and exciting.

At the time this paper is being written, we are in the planning stages for *Concerts Under the Stars* 2019. We intend to have the lineup booked and performance agreements signed by November 1 for an early December press release. With each year that we bring live local music into the Chaffee Planetarium, we hope to continue to improve upon what has already been very rewarding for both the Chaffee Planetarium and the broader Grand Rapids community.

UNDERSTANDING SMALL WORLDS IN THE SOLAR SYSTEM

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Abstract: NASA has provided the support to produce yet another tactile book highlighting the solar system. In this paper, we will review the content and features of this unique book that is tailored for stuents with and without visual impairments.

Since the beginning of our history, humans have looked up at the sky and marveled at what they saw. The changing face of the Moon, the brilliance of the Sun, and the movement of the planets. Today scientists understand more about these celestial bodies. Some of these bodies are extremely small while others are comparatively large.

In this book, we explore small bodies in our solar system, tapping into the interest our visitors have about small worlds. But what about those visitors who are blind or visually impaired (B/VI)? This paper will highlight the unique features of a book dedicated to the dynamics of small worlds, including the Oort Cloud, Comets, and the asteroid belt just to name a few. The book incorporates modern QR technology for the user to access the text that highlights the tactile book. For easy access the QR code is clearly marked by a raised box on the front of the book. Additional classroom material is being developed and will complement the book. Although it is specifically geared toward those who are blind and those with visual impairments, the newly released book, “Understanding Small Worlds in the Solar System” has appeal for all. It can be used in the regular classroom as well as at schools for the B/VI. The book was funded and supported through the NASA Solar System Exploration Research Virtual Institute (SSERVI), a grant in conjunction with the College of Charleston (CofC), and NASA Headquarters, Science Mission Directorate. It was written, produced and beta tested by Cass Runyon (CofC), David Hurd (Edinboro University of Pennsylvania), Joseph Minafra (NASA), Ken Quinn (Tactile Evaluator, Erie, PA), John Matelock (Tactile Illustrator, Edinboro, PA), Cynthia Hall (CofC), and Mariah Williams (Tactile Evaluator, CofC). Special thanks goes out to Joe Lang, Operations Manager for Connoisseur Media, Erie, PA for recording and narrating the text for the audio file.

NASA has taken great strides in providing ALL learners with the opportunity to explore the wonders of our solar system and universe. Their support of astronomy related material for the blind and visually impaired has been particularly noteworthy in the past and continues today. As a whole small bodies in our solar system provide a window into what the early solar system might

have looked like and the materials that formed it. Furthermore, the continued study of small bodies in our solar system will benefit humans by providing better methods for protecting our own planet and providing possible sources or resources in the future. Due to the complex nature of the multiple small worlds in our solar system, Cass Runyon of the College of Charleston and David Hurd of Edinboro University of Pennsylvania felt that the efforts to produce a tactile book highlighting these objects would benefit both sighted and visually impaired students.

The original plan was to provide a simple primer on small worlds with an emphasis on tactile diagrams to illustrate the primary types of small bodies and their formation. As beta testing began, it became apparent that more detailed written descriptions were necessary to help guide the user through complex features and subtleties often taken for granted by sighted persons. To this end, the book, *Understanding Small Worlds in the Solar System*, uses detailed written descriptors to help guide the users through each of the eight tactiles found in the book. In this book, the authors have also exaggerated relief for haptic effect and many tactiles are not to scale by size or distance, but all such divergences are detailed in the text.

The book comes complete with a Quick Response Code (QR code) to access the text and supplemental materials and audio files in both English and Spanish (Figures 1 and 2).



Figure 1: QR code for tactile books—give it a try!

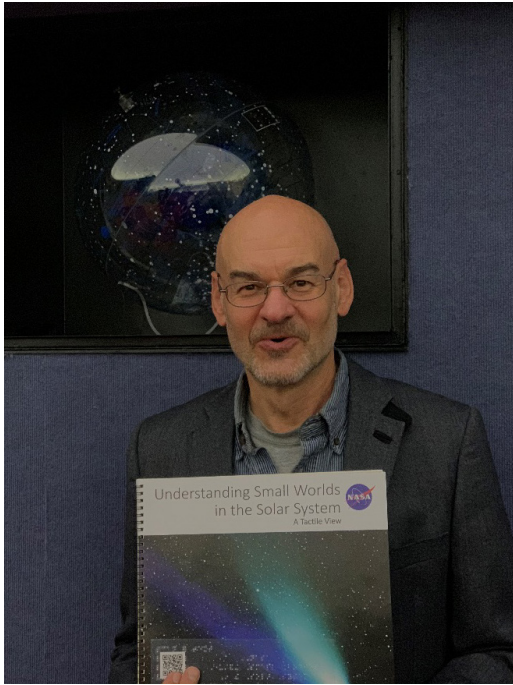


Figure 2: Book cover showing QR code in lower left

Although it is primarily geared toward those who are blind and those who are visually impaired, it can also be used effectively by sighted students through activities and inquiry-based opportunities for each learner. Many of these resources are currently being developed.

As can be seen in Figure 3, many features of small worlds (Pluto pictured here) can be explored tactilely.

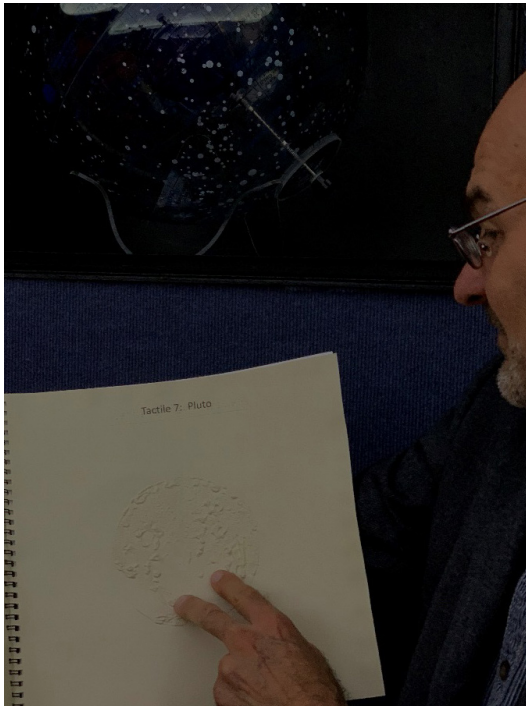


Figure 3: Pluto showing the “heart” shaped feature as seen by New Horizons.

Figure 4 highlights a tactile of our solar system that is not to scale by size or distance, but allows many learners to discover the relationship of the major and minor objects in our solar system. The next book the team hopes to develop will be on ocean worlds throughout our solar system.

Copies of the book can be acquired by contacting Ken Quinn (cj3639@gmail.com).

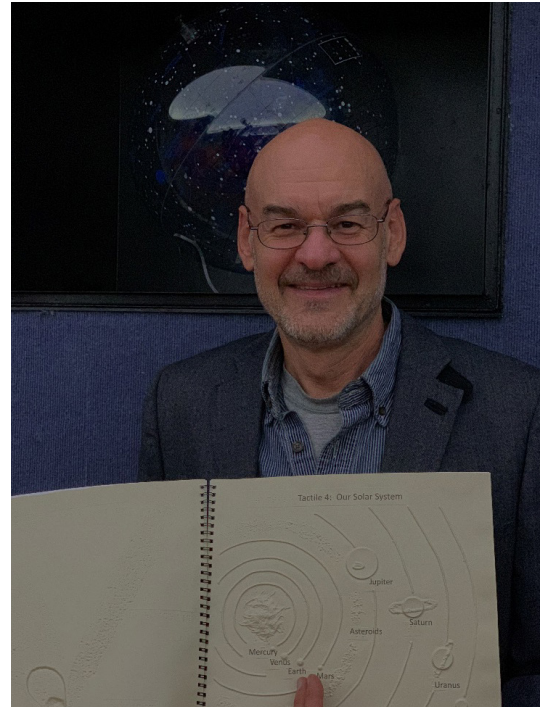


Figure 4.

THE MAN WHO PAINTED THE UNIVERSE

Francine Jackson

URI Planetarium

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Abstract: Whenever we do any type of program, we always hope someone in the audience will take our words to heart. Frank Kovac, after visiting the Adler Planetarium as a child, did much more than most: he built his own planetarium in his backyard.

We often hope that what we are saying in the planetarium is taken by members of the audience to heart, that they will somehow use the information at some future time. For Frank Kovac, going to a planetarium became a life-changing event.

When he was a child, Frank's father took him to the Adler Planetarium. He was so taken by his experiences that he was determined to make his own facility. As he grew up, Frank realized he was quite a handyman, so, upon buying a piece of property in Wisconsin, he set out to build his dream. Over a decade in time, and with \$100,000 of his own money, Frank, with virtually no help at all (just a neighbor who helped with the electrical wiring) built the Frank Kovac, Sr., Planetarium, named after his dad.

To say his final product is incredible does not come anywhere near what he has done. The dome is a 22-foot curved wooden structure, the largest of its kind ever built. Each star is a mix of day-glow paint, which he constantly updates to make sure that the individual stars are as near to reality as possible. He even spent

months adding a totally realistic Milky Way. After turning out the inside lights, the dome glows much as his real nighttime sky outside. And, moving the dome is a wonder: It's rotated by a 1/2 horse power DC gear motor powered from a variable speed control box. The entire globe is supported by two steel pivoting support arms with four 10-inch polyurethane wheels at a 45-degree angle (his latitude) along with a top bearing/spring support tied into the main building structure. The entire planetarium weighs about two tons.

The Kovac Planetarium has been listed by the State of Wisconsin as one of the must-see man-made features within the state. The local government even gave him a street sign. For years, groups came and enjoyed this incredible facility; unfortunately, though, the planetarium was not meeting expenses. At this time, Frank has had to return to work full time at the local paper mill just to keep his property paid for. It would be wonderful to be able to continue in keeping the Kovac Planetarium alive, but, at this time, it is closed, and there are no definite plans for it to reopen.

STARSHIP BRIDGE SIMULATOR IN YOUR DOME- THE NEXT GENERATION

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Abstract: You may remember a previous paper/workshop on Artemis, a software that recreates a futuristic starship bridge simulation. Planetariums have used this software for team building activities where groups work together controlling a ship to achieve missions. There's a new software title that has developed quickly in view of many un-addressed bugs and the closed source nature of Artemis software. Empty Epsilon is open source, completely free, highly modifiable, and in many ways superior to Artemis. I'll cover the basics of Empty Epsilon gaming and the differences/benefits relative to Artemis.

Why play in your dome?

- You are the "Space Place" in your community!
- Interactive Sci-Fi games fill a special niche (Special events)
- People can learn while having fun!
- Every major Sci-Fi convention (like GenCon) have starship bridge simulators as a game to play. People are attracted to this kind of gaming. They want to work with their friends and relive "Star Trek."

How do games in the dome "pay for themselves"?

If you have never heard of an "escape room" you should check them out. A team of people has one hour to solve a puzzle in a room in order to "win." They are extremely thought-provoking, cooperative, and popular. Admission to a typical escape room can be \$20-50 for an hour. A "Starship Bridge Experience" in your planetarium can potentially pay for itself by filling this style niche. Example: eight people paying \$50 each for a 1-2 hour experience. That's \$400 one time rental of your dome and can compete with any scout group fee. The catch is, as with any other program, upfront investment in hardware, props, software etc.

In previous GLPA presentations and workshops, I have talked about 'Artemis', a starship bridge simulator software. It encourages players to work together to solve problems and survive in space. My dome, and others have been using this software for special events or clubs for years now; however 'Artemis' is starting to show its age. The software graphically is ancient with limited Artificial intelligence, laggy network performance and bugs that remain unresolved. The software is closed source and rarely updated. What are those of us who want to command a more robust starship with a more comprehensive and educational story to do?

The Next Generation

A programmer (alias "Daid") overseas has had the same feeling and made an open source software project called 'Empty Epsilon.' It has many advantages.

Artemis	Empty Epsilon
Ancient graphics engine	New (Open Source/GL) engine
Ancient network comm	Modern – No LAG
Mods-Use outdated 3D format	Standard OBJ 3D models
Mission scripts XML (Restrictive)	Programming Language (LUA-Open Source)
"Arcade-y" Space Monsters	"Realism" – More to do!
PC Only	PC / Android / Linux
No Touchscreen support	Full Touchscreen support
Single 'Main Screen'	Multi-projector (angle) coverage 'Main Screen'
Closed Source (licensed)	Open Source (FREE to use and modify)

So, Empty Epsilon is so much better... what's the catch? Why haven't all 'Artemis' players switched over?

It's a newer program so knowledge of its existence is low. Also the lead programmer has fully acknowledged that he's writing this code to have fun and get other programmers to join in. He's got a fulltime job and has no intention of this software "going global" and supplanting his income. So the marketing end of the project is by word of mouth alone. As a result the number of game scripts is fairly low compared to Artemis.

What Can We Do?

In Wausau, there are ten students as planetarium assistants writing code, engineering steel bridge component props, and making Arduino driven effects.

Our intention is create a single, polished mission using actual NASA exoplanetary data and other science techniques for this kind of escape room experience for all domes who want to invest in a gaming niche style program.

What do we need from you?

Do you or do you know a person who is a "Star Trek" fan and can program in C++? Introduce this person to this project and us too! That person can join the global team of like-minded programmers to sail through the galaxy.

<http://daid.github.io/EmptyEpsilon/>

Are there no programmers in your life but you still want to play? Gather some of your PC geek, gaming students or friends. You will need some minimal level of expertise to get things set up and talking. We would very much like to provide our polished, single quality mission (as a first installment for you) when... it's actually built. So you will have to be patient and experiment with the software first if you aren't in a position to help code it.

WIN-WIN: PARTNERING WITH LOCAL INTERACTIVE MEDIA STUDENTS

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Abstract: The Peoria Riverfront Museum has partnered with our local university's Interactive Media department for the past five years to provide programming for our visitors. Students in the department create interactive games, short films, VR and IR experiences, and content for our planetarium. The projects are shown off at a free admission community day. This event provides programming that we are not able to create ourselves, gives the students valuable experience, and has strengthened the partnership between our two institutions. Learn how we got started, how the program has grown, and how you might be able to replicate this program in a way that works in your community.

Once a year, the Peoria Riverfront Museum is transformed into an interactive media paradise. Local students present a plethora of experiences to the public including short animated films, planetarium shorts, tabletop games, VR and IR experiences, green screen activities, touch table games, computer and online games, and even arcade games. This event, called FUSE, is free to the public, and usually draws about 1,500 visitors, about triple our typical Saturday attendance at that time of the year. The annual event is the result of a partnership between the Peoria Riverfront Museum and Bradley University's Interactive Media department (Figure 1). This partnership has benefited both parties, and is a model that could work in any community with a planetarium or museum, and a college or university.



Figure 1: IM students at FUSE 2018

Our museum has a long history of partnering with Bradley University, which is the largest institution of higher learning in town. We have partnered with their biology, chemistry, and engineering departments for events throughout the years, and many different classes visit the museum, including Astronomy 300, in which half the classes are taught in the planetarium (by Sheldon Schafer). In 2014, the museum was approached by the chair of the Interactive Media (IM) department to see if we would be open to

showing his senior animation students' capstone animation films in our Giant Screen Theater. Our theater has a 7-story wide, 5-story tall screen, and uses digital projection, so we can show almost anything. While we could have just rented the theater to them and charged them, we realized our visitors might be interested in the projects, so worked with leaders in the department to create a day full of programming for museum guests. The event would not have happened without the support of our museum director, whose top priority was deepening the museum's connections with the community. The event grew to include interactive experiences for museum guests showcasing all the types of media the students work on.

To prepare for the day, museum leaders visited the IM department's special topic class, specifically about the FUSE event. Members of the student production team and students from all grade levels who create the experiences attend this yearlong class. Museum leaders coached the students on how to talk to the public, and answered questions about what sorts of games would work well. Students drive the experiences created for FUSE. Students propose the interactive experiences, and then present them to the department. They are voted on and receive feedback from professors and other students, and some are selected to move forward. If a student's proposed project does not move forward, they join a team working on another project.

The night before the event, students bring their projects to the museum to set them up. Some are quite large, and most require computers or other technology to be set up. The students do all the moving and set up work, which minimizes the burden on the museum. On the day of the event, students help hand out museum wristbands, and act as docents for their projects, explaining them to guests and answering questions. At the end of the day, the students do all the work to clear away their projects and reset the museum's rooms.

The first event was seen as a success by the museum and the university. We have continued to hold it as an annual event, and the event has been built into the department's curriculum plan for

the year. Over the years, we have improved the event to make it work better for all parties. The first year, the students were not very prepared to speak to the museum guests. They made rookie mistakes such as turning their back on guests, mumbling, and not dressing professionally. Over the years, both the museum staff and department professors have coached the students on how to present to the public, and there has been a dramatic improvement. Students have also learned to shorten their presentations, and make their experiences more intuitive, so they need less instruction for first time users. The department realized we needed better wayfinding, so they created jobs for students—there is a student event producer, and students in charge of branding, materials and purchasing, scheduling, and making an event website.

In the first year, seniors presented their portfolios at the event. They were made to stand next to their presentations all day, which was boring for them and for most of our guests. This portion of the event has been dropped entirely. On the museum end, we improved by increasing our marketing of the event, and making the entire museum free for FUSE day, which helps draw a larger crowd.

Two years ago, we added the planetarium to FUSE. I approached one of the teachers, and asked him to visit the planetarium to see if it would be possible for students to create content for the dome. I showed him the software we use, and how images are projected on the dome. We have a ZEISS ZKP4 star projector with five digital projectors, and use ZEISS Powerdome, plus Uniview. After thinking about all the ways students might be able to create content, he decided the best fit would be to have sophomore students make short animated films for the planetarium. The students visited the planetarium early in the semester to see the space and learn how they needed to think about the shapes they were creating. We showed them the process that works best for our system—creating an image sequence with a separate audio file, which we then encode. While working on their films at school, students used the [dome viewer software](#) to preview how it would look. The students made a first draft, viewed it on the dome, and then submitted their final films just before the event. Students made any film they wanted, but we told them that if it was abstract, it might work well for us to use in our laser shows, so each year we get a handful that work their way into our regular programming (Figure 2).

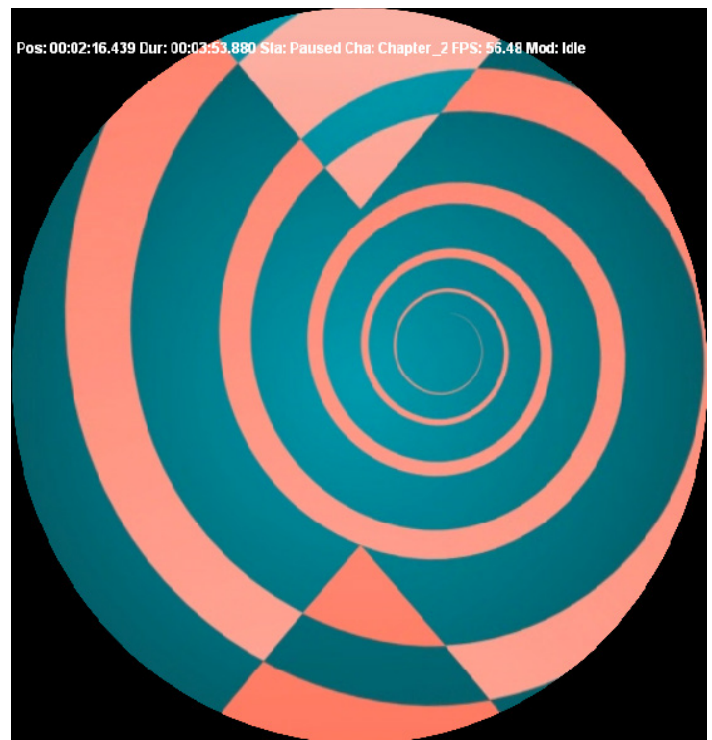


Figure 2: Still from a student animation made for FUSE that we use in laser shows

This annual event is beneficial to the students, the university, and the museum. Students lead the event. They get the experience of working for a client, planning a large event, working on long form projects, and presenting to diverse audiences—all experiences that will serve them well in a career. Professors identified that a key benefit is that students create these experiences from the beginning as something to be shared with the general project, forcing them to think about it differently from many projects they know will never leave school. Students have mentioned that this event helps them get to know each other—they are working with others from all grade levels on a long-term project, so they form new connections and friendships. Students are also presenting to their potential employers. In the past several years we have added a “VIP” event in which business and community leaders are invited to view the student work (Figure 3). At the VIP event and the public day, students are showing off their skills directly to potential buyers and doing market testing.



Figure 3: Students explaining their work to community business leaders

For the university, the event is a great way to reach out to the community and recruit potential students. They have a day in which they are celebrated and can show off to the community how innovative their students are. And for the museum, we get a day full of programming that we are not able to provide on our own (Figure 4). Students create unique films for our planetarium, some of which we are able to use throughout the year. The program has deepened our relationship with Bradley University, which is a key strategic partner in our community. Perhaps the largest benefit to us has been two stellar interns who have learned about our internship program because of this event.



Figure 4: Student-made multiplayer game

If this program sounds intriguing to you, I encourage you to reach out to your local university or college! If your planetarium is located in a university, partnering with your Interactive Media department would be a great way to show how the planetarium can be useful to many departments. Animations and films could be shown in the planetarium, and the lobby could be used to showcase other interactive projects created by students. If your planetarium is a stand alone or in a museum, reach out to the local universities and see if they are interested in collaborating. In our experience, the partnership is a win-win. You get creative, unique programming, and the university gets a community showcase and a great experience for their students.

SKYSHOW SUMMER CAMPS

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Abstract: For the past two years, Adler Planetarium has run a week-long skyshow camp for 6th and 7th graders. This camp engages students in the entire process of creating and presenting their own planetarium shows. The campers arrive on Monday with no planetarium experience and on Friday are presenting 5-minute shows of their own creation for their friends and family in the dome. We believe our model is successful and easily adaptable for other institutions.

Motivation

Informal learning has been moving increasingly toward a model in which the guest is the doer, and the staff's role is to facilitate. This model can be difficult in a planetarium, which is naturally set up to have a staff presenter and guests listening and observing. In order to make Adler's theater spaces more open and interactive, Tech Camp: Sky Show was created.

The goals for the camp are:

1. All campers learn and do all aspects of the show building process (programming, writing, performing)
2. Campers get to interact with experts and get "behind the scenes" access
3. Each group creates a final product that is interesting, unique, and watchable

Implementation

Tech Camp: Sky Show is a week long camp, Monday to Friday, 9:00 a.m. to 3:00 p.m. There are sixteen middle school aged participants per session.

The schedule is ambitious. The participants enter the week never having used The Worldwide Telescope, likely have never spoken publicly outside of their classroom, and vary widely in their interest in technology and/or astronomy. By Friday morning, they have become show creators.

To make it work, we've identified the critical factors that ensure that at the end of the week we have shows ready to go and participants who are confident and proud to share them.

On day one and throughout the week, the instructor is very clear about expectations and the timeline, allowing the participants to develop their goals and create show plans that are challenging

but realistic. Participants are given as much autonomy as they are able to handle: firm deadlines are given and they work within them, deciding when they need a break and how to manage their time. Some groups need heavier intervention, some only need occasional checks to ensure they are on track.

This program exists within the umbrella of camps at Adler. As a result, participants are not reliably present, though attendance is higher for this program than for the less content-heavy sessions. Every participant learns and does every part of the process to ensure that if a group is missing a member, they aren't stalled. This also helps the participants develop a more well-rounded set of skills.

Group size is an important factor as well. With sixteen participants, four groups of four has been the most successful configuration, but groups as small as three and as large as five have been successful. Any smaller, and groups have difficulty completing their shows, and with any more than five, participants do not consistently feel like integral parts of the group.

It is important to note that the goal of the institution does not necessarily match the goal(s) of the participants. The participants primarily want to have fun during their summer break, and even the most high-interest participants are bound by their developmental stage and needs. Middle schoolers are not known for their ability to sit still and focus for long periods of time, so many break times are built into the schedule. There is a long lunch with time built in for active games or other activities and campers either visit an exhibit or see a show at least once a day. Scheduled and add-in fun activities occur daily, including telescope viewing, stomp rockets, or activities pulled from other camp programs. There are always books, fidgets, and a daily break activity that campers can self-select as needed.

At first, we underestimated the importance of testing on a dome. Young teens aren't abstract thinkers. Because they cannot

envision the differences between viewing a show on a flat laptop screen and a dome, ample opportunity to gain concrete experience with presenting a dome show is required. It is often challenging to schedule time in the main theater, but if an institution has an inflatable dome or other minidome space, using it as often as possible is invaluable.

A solid, well-prepared staff is perhaps the biggest essential to a successful week. In addition to content experts, Adler utilizes an instructor, counselor, and teen volunteer. Present through the entire week, they keep the camp flowing, managing camper needs and assisting as needed in place of the experts. They see the big picture and ensure the groups are staying on track.

As one of the goals of this program was to give participants access to experts, we rely on Mark SubbaRao for WorldWide Telescope and show creation mentorship and on Nick Lake for scripting, presentation building, and performance skills. Additionally, members of Adler's Astronomy department visit to fact-check scripts and explain complex concepts. It is very possible to train non-expert staff to fill the content needs, but allowing the participants interaction with experts deepens their experiences and improves the final products.

Finally, a well-designed opportunity to share the shows improves the caregiver/parents' perception of the program. We introduce our team, recap the week, then let the campers take the lead. Their hard work shows clearly during their presentations.

The Worldwide Telescope

The Worldwide Telescope (www.worldwidetelescope.org) (WWT) is a powerful astronomical visualization environment. Originally developed by Microsoft Research, WWT is an open source project that is managed by the American Astronomical Society. The software is used by everyone from astronomy researchers to teachers, students, and astronomy enthusiasts. WWT is also capable of running planetariums, and works in a variety of types of digital systems including multi channel systems, single fisheye projectors, and mirror dome systems. The Adler Planetarium has collaborated with the WWT team from the beginning. In 2013 the Adler produced *Cosmic Wonder*, the first full length planetarium show produced (and played back) entirely inside the WWT software.

Through its tour feature WWT provides an intuitive platform for narrative storytelling using astronomical data. Like other planetarium software packages WWT has a rich set of tools for show creation, including a full keyframe editor. However, excellent tours can be constructed with only the slide editor, making WWT significantly easier to learn than others of the standard programs currently used in planetariums. We have been able to get the 5th and 6th grade students producing content after only one hour of instruction. As an example of how easy it is to create a tour, WWT initially shipped with a tour created by a the six year old (https://www.ted.com/talks/roy_gould_and_curtis_wong_preview_the_worldwide_telescope).

The WWT software runs both as a native Windows program and as a web application. Recent development has enabled near feature parity between the two clients, including tour creation functionality. While we have installed the WWT application on laptops running Windows, this program could just as easily be done in the web browser, without any software install. This also enables the students to take home a copy of what they created, something that would not be possible if we had used propriety planetarium software.

Prepping for Presentation

Due to the short timeline of the week, getting the presentations prepared by Friday morning is quite an undertaking. The schedule keeps moving, and while one aspect of the show might not be *quite* what a group wanted to achieve, there are more tasks at hand. Oftentimes there is a difference in emphasis between what the campers think is important and what is dictated by the schedule constraints. The camper in question might be interested in finding as many objects to talk about as possible or finding a "cooler" image of a deep sky object, whereas the task at hand is polishing the script and working on having something to say about the objects on the dome. One needs to be careful to not just tell them to stop what they are doing, but recognizing they may be trying to gain confidence in their presentation in another way and are seeing shortcomings they are trying to correct.

Setting realistic expectations for what the shows will look like and praising progress throughout the week are two important focus points. Friday morning is full enough of nerves and jitters about public speaking that having a solid show they are comfortable with is far better than having a perfect show they haven't had a chance to practice.

Starting Wednesday we lead the campers in a series of public speaking improv games designed to get them out of their comfort zones a bit and to start thinking about how they are presenting themselves. One that is particularly effective is drawing a series of index cards, each with a random noun on it. They then must tell a story that includes each of the words but also maintains a coherent, concise storyline. These exercises allow campers to stand in front of their peers, practice enunciation and projection, get a little goofy, and make mistakes in front of each other. It also allows them to get a bit lost in the subject matter and stop thinking about the fact they are doing public speaking. As they are deep in script-writing at this point there is some carryover regarding coherent storytelling and giving meaningful background on a subject.

The students are given two chances to practice their shows in the Grainger on Wednesday and Thursday mornings and the lessons learned and confidence gained between these two opportunities and the final presentation are amazing. The students aren't afraid to share their feedback on each others shows (it is important to encourage constructive feedback and positive comments) and the list of fixes and changes helps launch them into a session of productive work immediately following the practice session.

Conclusion

The major challenge of this camp is the tight schedule, which both keeps the campers motivated but also prevents them from spending even more time on the project and delivering a more polished show. We have considered making it a two-week camp, which would help immensely but also increase staffing time and cost.

There is heavy non-profit and for-profit competition in Chicago. To find Adler camps' place within that market, we focus on experiences that can't be found anywhere else in the city, which is how and why Tech Camp: Sky Show camp was created. It is likely that a similar program would be unique within your community as well.

We are aware of similar programs at other institutions, most notably American Museum of Natural History, Grand Rapids Public Museum, and Morehead Planetarium.

Overall, we believe this is a successful program and scalable for other institutions. The power of controlling the planetarium is exciting for the campers and their enthusiasm for the task is infectious. This program allows the campers to immerse themselves in a wide variety of topics over the week, including astronomy, mythology, physics, programming, public speaking, storytelling, improvisation, teamwork. The campers are inspired and engaged throughout the week, and are able to show off their hard work to their friends and family.

THE DOMES OF WESTERN NORTH CAROLINA

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Abstract: Madison County, Iowa, has its bridges, but western North Carolina has mountains, waterfalls ... and domes! For the past two years, I have been volunteering at Pisgah Astronomical Research Institute (PARI) in Rosman and Asheville Museum of Science (AMOS) in Asheville. At PARI, I present live programs within their “AdventureDome”; at AMOS, I present “Star Stories” within their StarDome. Each institution has undergone transformation over the past two years as has Mayland Community College, which hopes to build a new permanent dome at their Earth and Sky Park in Burnsville. This paper will describe planetarium activity and prospects at each site.

Of Mountains and Domes



Figure 1. Mountainside Club, Wolf Laurel

Madison County, Iowa, is famous for its bridges, thanks to a novel, a film, and a Broadway play. Western North Carolina is famous for its mountains, waterfalls, and craft beer. In addition to these attractions, Western North Carolina also sports a brace of planetarium domes, albeit portable ones. Since relocating to Weaverville in 2016, I have been volunteering in each of these domes and keeping tabs on prospects for a third. Their stories follow.

From NASA to DoD to PARI



Figure 2. PARI Entrance

In the early 1960s, as part of its new communications network, NASA constructed a 200-acre facility with twin 26-meter radio telescopes in Rosman, North Carolina. Dedicated in 1963, the Rosman Tracking Station began playing a vital role in communication with piloted orbital spacecraft like the Gemini capsules. It even figured prominently in transmissions to and from the Apollo 11 spacecraft.

By 1981, NASA no longer needed the Rosman facility and transferred it to the Department of Defense. The DoD used it to monitor transmissions to and from Russian spy satellites. To show the Russians that Rosman bore them no ill will, engineers painted a “smiley face” on one of the smaller radio dishes.

In 1995, after the end of the Cold War, the DoD closed the Station. The USDA Forest Service, which owned the land, dictated that the DoD remove or bury all of the structures at Rosman and return the area to its natural state. Don Cline, a retired telecommunications engineer and meteorite collector, intervened. He traded some land he owned to the Forest Service in exchange for the Rosman property and created the public nonprofit Pisgah Astronomical Research Institute—PARI.

Today PARI operates and maintains: the twin 26-meter radio telescopes, along with several smaller ones; automated optical telescopes on a high ridge; a nature center with an attached sky deck for use by portable telescopes; an extensive exhibit area with space artifacts and a large collection of minerals and meteorites; and, most recently, a small restaurant and set of cabins for overnight stays.

One of PARI’s buildings houses AdventureDome, a 22-foot inflatable Starlab dome; Inside, a Digitalis Digitarium Zeta Pro has replaced the earlier Starlab projector. Public and student visitors can enjoy live tours of the current evening sky. I present shows and help with telescope viewing several times a month.



Figure 3. AMOS Entrance

In 1960, the mineral collection of retired engineer and bank president Burnham S. Colburn formed the nucleus of a gem and mineral museum. After relocating in 1972, the museum became the independent nonprofit Colburn Gem and Mineral Museum. In July 1992, the Museum moved to the Pack Place Arts and Science Center and rebranded itself in 2002 as the Colburn Earth Science Museum to reflect a broader mission.

The need for more space, the desire for an even broader mission, and the growing untenability of the Pack Place location conspired to transform the Museum into the Asheville Science Museum—AMOS. The Museum moved into its current facility in the Wells Fargo building in 2016.

New exhibits include: a full-size dinosaur skeleton; the Colburn Hall of Minerals; an Elumenati GeoDome Panorama for simulated space travel; an interactive “Terra Box”; a “forest gym”; and an interactive model of the French Broad River. On Sunday afternoons, I become “Star Guy,” inflate a 4-meter Digitalis dome into the StarDome, and present live sky tours using a classic Starlab projector. (To tell the truth, although I like the versatility of the Digitalium Zeta Pro at PARI, I *much* prefer the realism of the Starlab star field at AMOS!) The system also travels to schools and day camps.

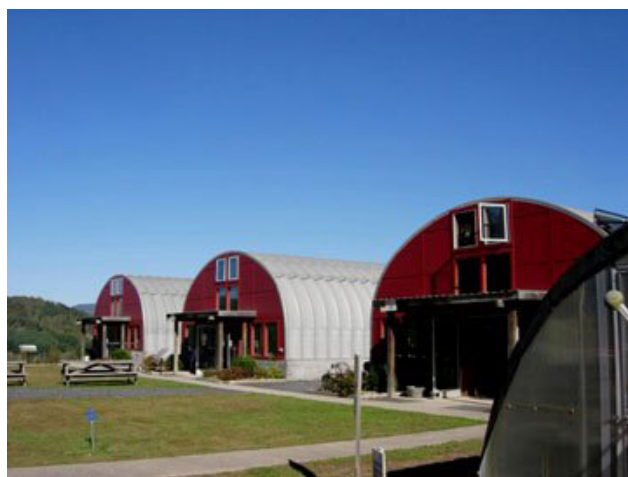


Figure 4. EnergyXchange Campus.

In 1994, a county landfill near Burnsville in western North Carolina closed. County leaders sought to use the space as well as the landfill gases. Five years later, the former landfill reopened as EnergyXchange. Natural gas drawn from the landfill provided fuel for such arts as glassblowing and ceramics; solar panels provided heat for a greenhouse as well as electricity for the buildings.

After a decade of operation, the methane supply proved too unreliable for the artists, and EnergyXchange closed. One of its partners, Mayland Community College, took over the site and began developing it as an Earth to Sky Park. The dark night skies over the location led them to apply for and receive designation as a Dark Sky Park from the International Dark-Sky Association.

Recently, private donors Warren and Larissa Bare provided funding for the Bare Dark Sky Observatory above the Park; it opened in spring 2017. The Observatory features a 34” f/3.6 StarStructure Newtonian telescope on a Dobsonian mount—the so-called Sam Scope. College staff and volunteers from the Blue Ridge Astronomical Society provide public observing throughout the year.

Prospecting

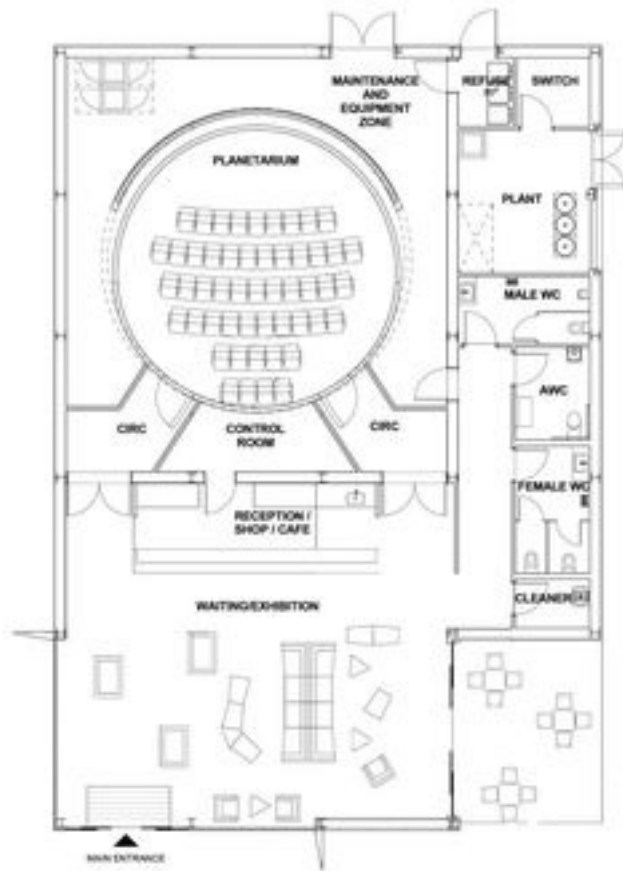


Figure 5. Planetarium Concept Drawing

Each of the facilities I have profiled has undergone profound transformation and is researching prospects for further development.

PARI is considering the construction of a new building to serve as its museum and, possibly, to house a permanent planetarium.

AMOS is considering expanding their footprint should Wells Fargo vacate the building, possibly including a permanent planetarium.

Finally, Mayland Community College is considering the construction of a permanent 63-seat planetarium within one of the Earth to Sky Park buildings.

I am monitoring each of these prospects and will let you know via the *GLPA Newsletter* if any of them begin to take shape.

TURNING DOME MASTER FRAMES INTO A FULLDOME MOVIE USING BLENDER

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Abstract: Blender has a powerful feature-rich built-in video editor that can handle a wide variety of formats, codecs, and frame types. Blender can even replace much if not all of your software production tools at a cost of nothing since it is free and open-source, easily downloaded and installed from blender.org. This talk will be entirely devoted to the powerful video mixer and how to take image frames and turn them into movies as well as demonstrate how to edit your movie, create transitions, and even adjust color, brightness, and contrast. How to truncate the final movie will also be covered.



Blender is a sophisticated software program and by itself can function as a complete software tool set that can meet your most common needs in planetarium production, processing, and editing. I see Blender as the “Swiss Army Knife” of software programs. This paper deals only with single projector configurations and will show you how to create playable movie files from frames. It is highly recommended that you use the .blend file I include as part of this paper. If you are reading this paper in the conference proceedings, you can email me (ken.murphy@smsu.edu) and I will send the Blender setup file that I’ve created where I’ve optimized Blender for video editing.

There are many window types available in Blender, most of which we won’t need. In the .blend setup file that I’ve prepared there are 3 important window types open: 1. Video Sequence Editor window, 2. Properties window, 3. Timeline window. As a side note, Blender users often refer to “windows” as “viewports”. See Fig. 1 below.

At the heart of image, audio, and video mixing is the Video Sequence Editor (VSE). This is the place where you manipulate “strips”. The strips are like pieces of film that are cut and laid out on a timeline. As the playhead moves it plays whatever it passes by. Strips can actually consist of audio, video, stills, and a set of numbered frames in a sequence.

When you have the .blend setup file, and you have downloaded and installed Blender from blender.org, just double click on the file I provide and it will open with all the settings you need. Go down the right-hand side and double check that the settings are right for your projector configuration. Here is a checklist:

1. Set Frame Limits (beginning and ending frames)
2. Set Resolution
3. Set Frames Per Second (FPS which is usually 30)
4. Set the Path location to where you want your output movie file to go
5. Make any additional adjustments such as changing the video format or if you wish to change bit rates etc. I have it set to output as an mp4 movie file as the default.
6. Hit ANIMATE at the top and watch the computer do the rest of the work for you! Note: Renders can take a long time; if you want to abort a render process hit the Escape key. The nice thing is that the partial movie file is perfectly playable up until the abort point.

Important Blender functions

Make sure that when you invoke a keyboard shortcut that you move the mouse over to the window where you expect your result to occur.

- **LMB**—Left Mouse Button—is used to select a strip in the Video Sequence Editor.
- **RMB**—Right Mouse Button click—to move or insert the play head along or onto the timeline. You can hold the RMB and drag back and forth on the timeline to scrub through video.
- **MMB**—Middle Mouse Button click—to grab and move or slide the timeline Left or Right. The mouse

roller wheel will zoom in and out on the timeline or the preview window.

- **Shift-A**—to Add Images, Movie file, Audio file, create Effects strip (the original strip must be selected). Be mindful that the mouse arrow is placed in the proper window. When trying to insert a frame strip, select **Insert Image** and then select **A** (for “all”) images making up the frame sequence.
- When you select a strip, you can hit **G** for grab to move the strip Right or Left on the timeline.
- You can also click and pull on the strip endpoints of movie, image, or frame strip to stretch it out.
- When a strip is selected and the play head (RMB) is placed in the right place you can hit **K** to create a split point in case you want to cut up a single strip into multiple strips or move them around independently or to apply an effect to a particular section (doesn’t work for an Effect strip, only the original strip).
- **Transitions** – select the first strip then Shift Click the 2nd strip, now hit Shift-A and select **Cross** to create a cross fade from one strip to the other. Pulling on the endpoints of the original strips can stretch or shrink the duration of the cross fade effect.
- **H**—when a strip is selected, hitting H will Hide the strip (very much like muting it out)
- **Alt-H**—will Unhide the strip (like unmuting the strip)
- If you wish to apply more effects such as slide your movie view Up Down Right or Left or to Scale, Crop, Rotate, or set Opacity, select the strip, hit Shift-A and add an effect. All the previously mentioned adjustments are now visible on the right.
- You can add **Text** to a movie strip by using Shift-A and selecting Text, you can edit the text, color, size, font, and placement in the settings section off to the right.
- If you click on an **Audio strip**, you can make adjustments to the section to the right such as volume settings, pan settings, pitch, etc.
- If you’d like to make color, contrast, brightness adjustments to a strip, select that strip, and look to the right, there are two sideways tabs, one says **Strip**, the other says **Modifiers**, select Modifiers and now click on **Add Strip Modifier** and select what visual adjustments you wish to make.
- If you use an image such as a .png with alpha channel (transparent parts of image), next to Blend you will need to change “Cross” under Edit Strip in the VSE to “Alpha Over”

- Play forward or reverse buttons are located at very bottom of the timeline window of your screen.

James Craig of “Planet of Mystery Productions” has created a series of blender tutorials demonstrating how to use the Video Sequence Editor. These tutorials are found on youtube at: <https://www.youtube.com/watch?v=TgXPeIP104I&list=PLewTlGgLnQDTE7AIsQ3PHRRivf4Oy3iM>. His website is: <http://planetofmystery.com/>.

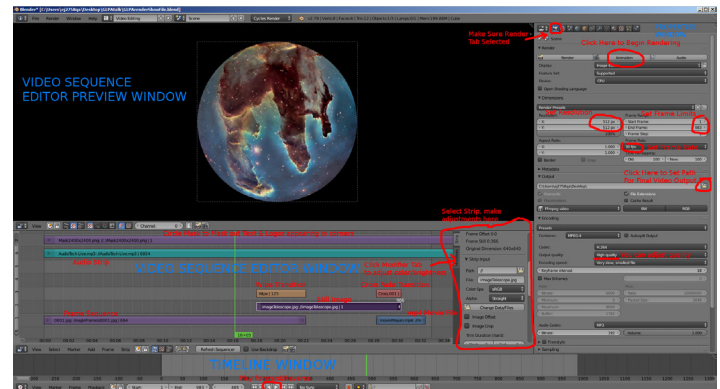


Fig. 1. Blender layout for video editing pointing out the important areas to possibly make adjustments and marking important settings.

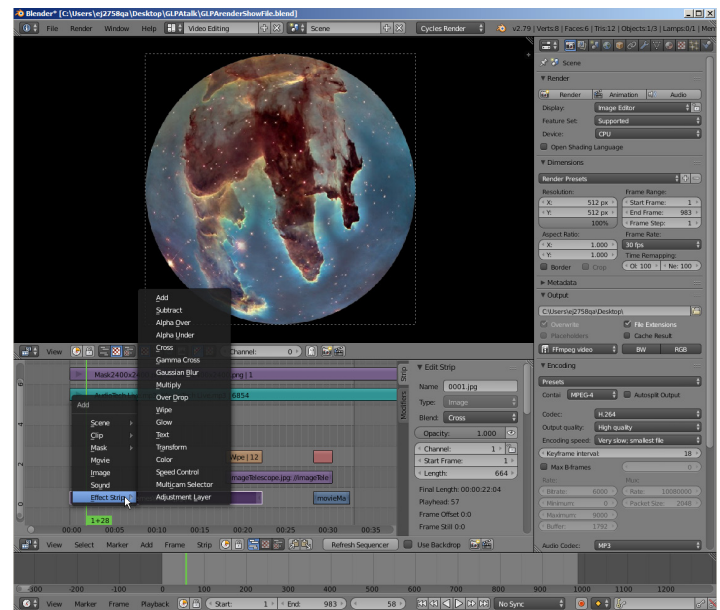


Fig. 2 shows the menus that appear when you right click on an image strip. Notice all the choices. The most common choices to use are “Cross” and “Transform”.

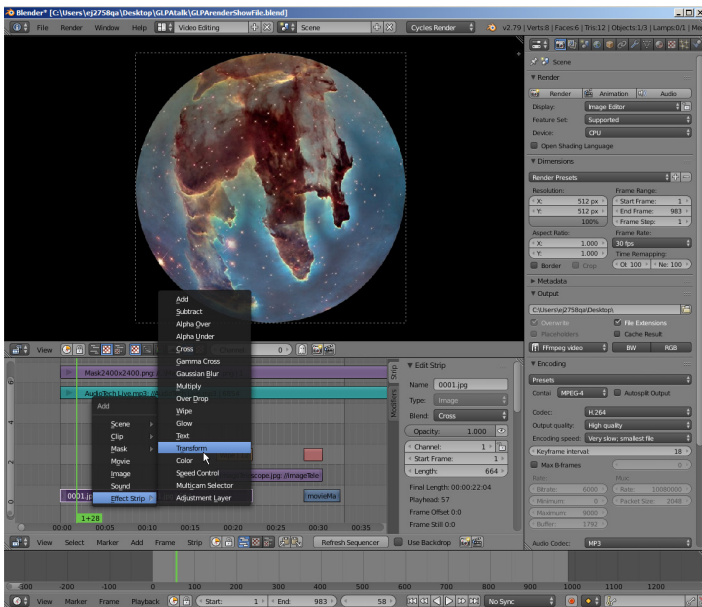


Fig. 3 shows the selection of the “Transform” effect.

(OPTIONAL) If you need to output a movie that truncates or crops the dome circle to some arbitrary amount the following instructions are for you:

First, you will need to select the frame sequence strip in the Video Sequence Editor window and create an Effect. Off to the right you will have to adjust the **Position** and **Scale** numbers. The formula below helps you do the calculation to get the appropriate numbers that fit your resolution configuration. There are two examples done for you to help you make sure you are doing the correct calculations. First you will need to click on the image sequence strip then **Shift-A** to add a **Transform** strip. In the Transform settings you will need to make the following adjustments to **Position:** and **Scale:**

You will need to calculate TWO numbers, the Y Position and the Y Scale values. Let X = your projector’s horizontal resolution (number of pixels) and let Y = your projector’s vertical resolution (number of pixels).

To calculate the second position number: $[(X - Y)/2]/Y \times 100$

To calculate the second scale number: X/Y

Example #1

X = 1400

Y = 1050

$[(1400-1050)/2]/1050 \times 100 = 16.667$

$1400/1050 = 1.333$

Position: 1, 16.667

Scale: 1, 1.333

Example #2

X = 2560

Y = 1600

Position: 1, 30

Scale: 1, 1.6

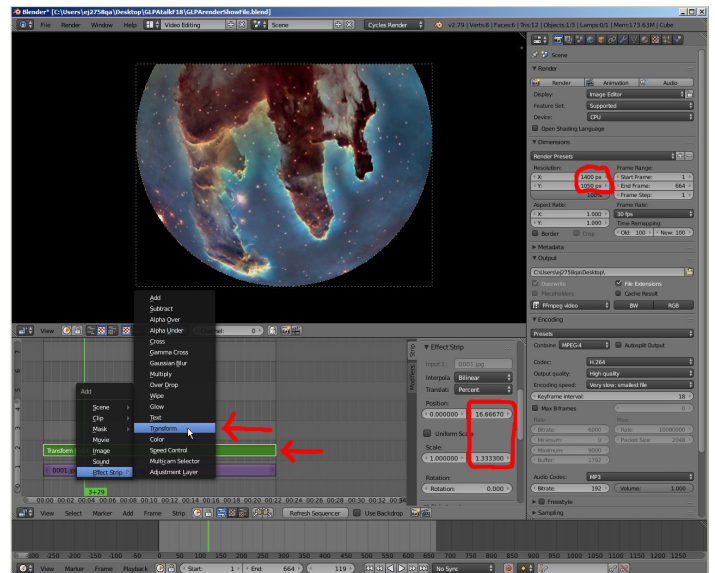


Fig. 4 demonstrates how to apply the settings for a “truncated” movie. Make necessary adjustments in the red highlighted areas.

USING THE GIANT PROTRACTOR TO UNDERSTAND THE SEASONS

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Abstract: We use the planetarium to teach students that the two key factors responsible for our Earthly seasons are the duration and the angle of insolation. Our full dome video system is capable of demonstrating the Sun's daily path including a history trail for each of the solstices and equinoxes. However, students struggle with understanding what the Sun's altitude has to do with the intensity. Our newly invented giant protractor offers a very effective method to help kids understand how the Sun's angle affects the intensity of the energy that reaches the ground.

A common misconception that many people have is that Earth's seasons are caused by our planet's changing distance from the Sun. As we know, they are actually caused by the tilt of our axis, our revolution around the Sun, and the parallelism of our axis. These result in changes in the duration and the angle of insolation. In the planetarium, we begin by showing the space-based view of Earth orbiting around the Sun. While kids can memorize what each orbital position represents, we felt that they did not have a deep understanding of why that actually caused the days to be warmer or cooler.

Our full dome video system is capable of demonstrating the Sun's daily path including a history trail for each of the solstices and equinoxes. With those lines on the dome, the students can really see the obvious difference in the first factor: the duration. They have no trouble seeing that the summer line is longer than the equinox line(s) and *much* longer than the winter line. Furthermore, we can change location and show how the effect is exaggerated or diminished at polar or tropical latitudes. However, they still didn't seem to get what the Sun's altitude had to do with the intensity. The human eye is so good at adapting to different light environments that we don't perceive that sunlight is actually brighter on the ground in summer than in winter.

We explained and showed the students diagrams, talked about shadow lengths, but we never really felt like they understood how the Sun's altitude affected the intensity. Teachers use illustrations like the one below to explain the concept, but test results demonstrated that understanding was still lacking. Furthermore, we can inadvertently reinforce a common misconception with such diagrams because students can think that the insignificantly longer distance the light travels to the polar region is responsible for the lower intensity.

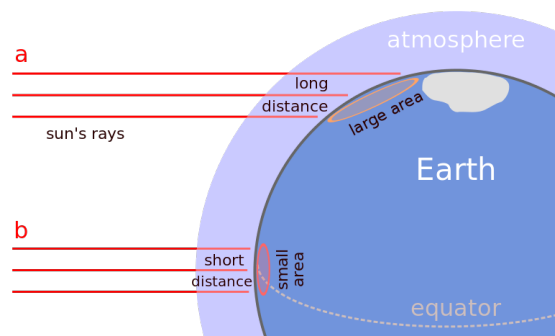


Image from Wikimedia https://commons.wikimedia.org/wiki/File:Oblique_rays_04_Pengo.svg

A few years ago, we had an idea for a new lab activity. We dreamed up an exercise that would involve tactile interaction and physical measurements by the students to really drive home the effect of the angle of incoming light. The activity required two novel devices: a giant protractor and a light that projected a crisply focused beam.

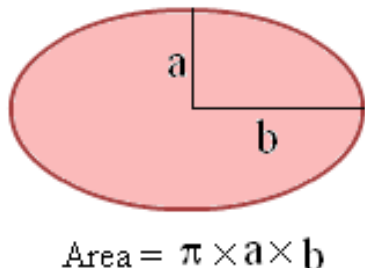
Thanks to leftover pieces of a musical set, Williamsville North's Stage Crew was able to create giant eight-foot wide protractors for our lab. We just had to find a light source that would project a tightly focused area. Every bulb, flashlight, or lamp we tried was insufficient because it did not provide illumination with a definite edge. We finally came across the "ETC Source 4 Mini" light fixture, which is a miniature version of stage lights called "ellipsoidals" or "leekos." It uses lenses to create the precise illumination control that we needed. We applied for and were awarded a grant to purchase two of the light fixtures, which cost about \$300.



Photo courtesy of ETC (Electronic Theatre Controls, Inc.)

While the difference in the light intensity is clearly apparent from higher or lower angles, we didn't have a way for the students to *quantify* the brightness. We thought about using solar cells and measuring the voltage, but that approach would get complicated. A Dome-L posting mentioned use of a smart phone app to measure light intensity as part of a different lab about the seasons. With this, we had a way for the students to collect numbers for graphing. The Lux Meter app by Crunchy ByteBox was our choice, but many others are out there.

We attached the light to the giant protractor over a series of angles (90, 75, 60, 45, 30 and 15 degrees) and aimed at the floor adjacent to the middle of the protractor. We had the students measure the circle or ellipse width and length, which conveniently fit within a meter stick. They calculated the area of the lighted area using the formula here:



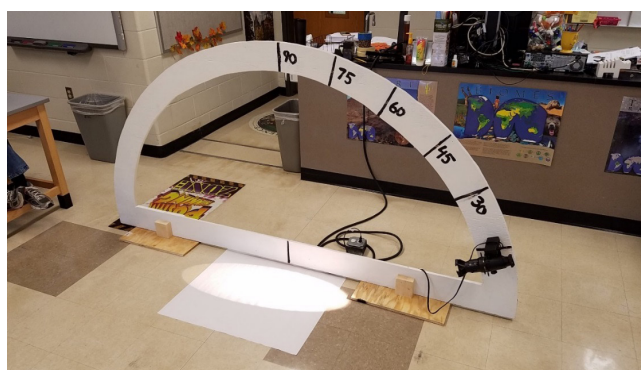
Next, they measured the light intensity with someone's smartphone. Not only could they see the difference in the illuminated area and brightness, but they had data for both that they could graph. The giant protractor method also helps dispel the distance misconception. The light fixture is the same distance from the projection area at each of the angles.

We hoped for better understanding, but were surprised at how very effective the lab was. Students enjoyed the experience and demonstrated deep understanding of the concept on their lab reports and subsequent tests. Students of *all* ability levels made graphs that showed the relationships clearly, and their written answers demonstrated mastery of the concept. Now we have a great way to really show the effect of the angle of insolation. We're just trying to think of what else we can measure with our giant protractors!

Here are some pictures by the authors of the setup and the students working with the giant protractor. (Note: The room lights are on for these pictures, but they were turned off during the data collection for better light meter results.)



This picture shows the circle of light from a 90 degree angle



This picture shows the ellipse of light from a low angle.



Students measuring the physical size of the projected area of light.



Students measuring the intensity of light with a smartphone app.

THE 2018 PERIHELIC OPPOSITION OF MARS— A SOUTHERN HEMISPHERE VIEW

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Abstract: There's a fascinating history of Mars observations from South Africa. The first color image of Mars was taken from what is now a major South African planetarium dome, the Lamont-Hussey Observatory on Naval Hill in Bloemfontein. Furthermore, the nearby Boyden Observatory houses a famous 13" Clark refractor used by William Pickering, and took the first black and white photographs of Mars in 1896. In this paper I visit this telescope for an historical tour of Boyden Observatory, its illustrious history, and report modern observations of Mars acquired by the author through this wonderful telescope.

Introduction

The 2018 perihelic opposition of Mars offered a rare opportunity to view the red planet at its best. The storied history of Mars observations, in particular the pre-space age efforts, includes names like Pickering, Lowell, and Slipher.

Since I was a teenager, I've had a personal goal of viewing Mars from the southern hemisphere with a fine refractor. I made such a trip this past summer, to the famous Boyden Observatory in South Africa, where I used a 13-inch Clark refractor, a telescope with its own remarkable historical Mars connection.

I also researched more detail about the fascinating history of Mars observations from Bloemfontein. The very first color images of Mars were taken from Bloemfontein by Earl Slipher, a Mars expert from Lowell Observatory in the USA.

The 13-inch refractor

Boyden Observatory houses a 13-inch Clark refractor, and has an historical connection to Mars dates back to the late 1880s, pre-dating Lowell's 24-inch Clark. William Pickering purchased the instrument from funds from Mrs. Draper, and it would eventually go to the original Harvard Observatory's Boyden Station in Arequipa, Peru.

William Pickering did show one visitor a view of Mars through one of Harvard's telescopes—maybe the 12-inch or perhaps this 13-inch. That visitor was Percival Lowell. It's certain that the Harvard telescopes and Pickering enthused Lowell, who later ordered a 24-inch refractor from Alvan Clark in 1895, and it remains in use at the Lowell Observatory in Flagstaff, Arizona.

The 13-inch telescope was used to take the first-ever black and white images of Mars, and one of the earliest examples is shown in Figure 1. This example is on loan to the University of the Free State (UFS), Bloemfontein, and seeing these original plates during my observational run with the same telescope was a thrill.

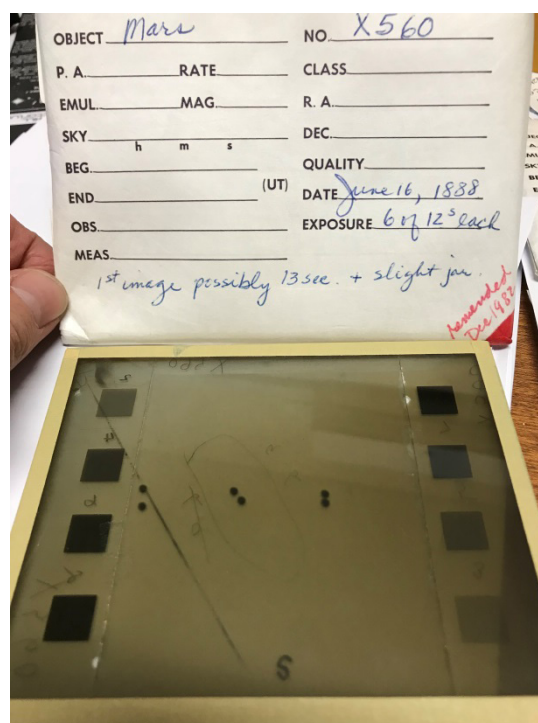


Figure 1: An original plate from the Harvard Observatory collection dated June 16, 1883, showing six black and white images of Mars, some of the first ever taken of the red planet. The number X refers to the 13-inch Clark refractor.

How and why Boyden Observatory for Mars

It was in July 2017, while writing an annual night sky guide for *Astronomy* magazine, that I realized the forthcoming perihelic opposition of Mars was the one I should and could make an effort to see from the southern hemisphere. The last perihelic opposition was in 2003, when I was running the CyberDome Theater at Exploration Place in Wichita, Kansas, and I couldn't travel. By the time of the next perihelic opposition in 15 years' time, I'll likely be retired and unable to travel.

Now was the time. I felt considerably lucky to have fine friends and colleagues connected to the Boyden Observatory, in Bloemfontein, South Africa, and had already used the 13-inch refractor on a previous visit.

My professional activities in the planetarium world have taken me to Bloemfontein, South Africa, many times for training staff at the Naval Hill Planetarium, operated by the Department of Physics, University of the Free State, and the same group operates the Boyden Observatory, which is located a few miles outside the town. The planetarium theater is housed inside an old Observatory dome that used to house a 27-inch refractor atop Naval Hill, located in the city. The Lamont-Hussey Observatory was operated by the University of Michigan from 1927 until 1972. This is the telescope used by Slipher to take the first color photographs of Mars. The building became re-used as a planetarium, the first digital planetarium in sub-Saharan Africa, and opened in November 2013.

I was interested in figuring out why I was so interested in doing this, so began to re-read the book *Lowell and Mars* by W. G. Hoyt, a fine history of Mars observations I first purchased and avidly read on my first visit to Lowell observatory in 1979. I found on page nine a reference to the Boyden station in Peru. In discussing the northern hemispheres newest observatories like the 36-inch refractor at Lick Observatory and Meudon's 32.5-inch refractor, Hoyt writes, "*There were several observatories too, most notably the Harvard College Observatory's **Boyden** (my emphasis) station ... far more favorably situated for the observing the 1892 opposition of Mars than the older established observatories in the northern hemisphere.*" The seed was planted.

Additionally, an article in *Sky and Telescope* (Sept, 1971, Vol 42, No 3, pp. 139-41) about the challenges of seeing and scintillation, references Boyden Observatory in Bloemfontein specifically as one of the places with fine seeing conditions for planetary observations.

So my destiny was set—I had to be in Bloemfontein for the 2018 perihelic opposition of Mars. Both the first black and white, and the first color images of Mars were taken with telescopes now located in Bloemfontein.

I made my visit immediately after the IPS 2018 conference in Toulouse, France, and stayed at Boyden Observatory for a week, from July 8-14.

Historical telescopes

The 13-inch Clark refractor has been located in Bloemfontein since 1927, along with other historic telescopes. (The telescope that photographed the Magellanic Clouds on plates that lead Henrietta Leavitt to her discovery of the Period Luminosity Law is located at Boyden Observatory).



Figure 2: The 13-inch Clark relocated to Boyden Observatory in 1927.



Figure 3: The 13-inch Clark as it is today, with the author.

Boyden Observatory also has a fine historical library and exhibition. In addition to the earlier mention of the historic black and white photographs of Mars taken with this 13-inch telescope, another remarkable find opened more of the Mars connection.

Some years ago staff discovered a brass tube in an original box from Lowell observatory, and quickly realized they had in their possession the actual camera used by Earl Slipher for the first color photographs of Mars, using the 27-inch refractor in the Lamont-Hussey observatory on Naval Hill. Figure 4 shows the camera, along with Slipher's landmark book on photograph of Mars.

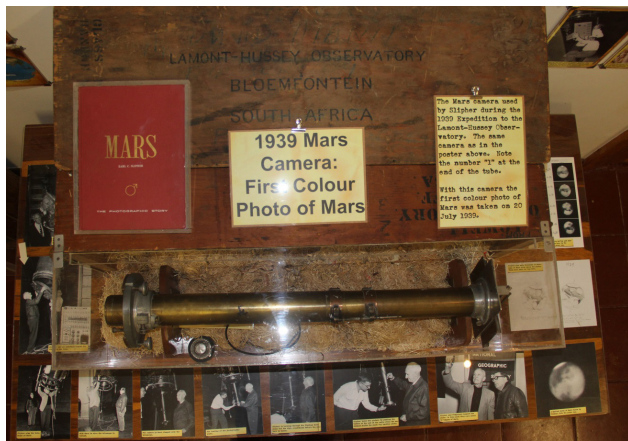


Figure 4: Earl Slipher's original camera used to take the first ever color photographs of Mars on July 20, 1939, and his book, "Mars, the Photographic story". This is on display at the Boyden Observatory, Bloemfontein, South Africa. Photograph by author.



Figure 5: The 27" Lamont-Hussey telescope tube shown prior to being mounted on display outside the original observatory building on Naval Hill, Bloemfontein, South Africa, now a planetarium. The original 27-inch lens is housed at the University of Michigan, Ann Arbor. Photograph by author.

My observations with the 13-inch

My observational goal was to use an advanced video camera on the 13" Clark to capture video frames while Mars, and also to view Mars and the center of the Milky Way in an ideal location—directly overhead. As luck would have it, Mars was undergoing a global dust storm, resulting in challenging observations of Mars, but nonetheless an amazing experience.



Figure 6: a modern digital video camera (ASI 178MM) attached to the famous 13-inch refractor. Photograph by author.



Figure 7: Mars in the early evening and the Boyden 13-inch refractor. Photograph by author.

Using this classic Clark telescope was as much a historical connection as well as a personal trip to photograph Mars. There were imaging challenges. The digital imaging system with a filter wheel provides a series of red, green, and blue filters for imaging. There is a significant variation in focus position for each filter, as is typical with old achromatic telescopes. Quickly turning the focus wheel between each filter change in cold temperatures (it's July in the southern hemisphere – winter!) created fatigue in my hands.

For four out of six nights I acquired video frames of Mars, as well as Jupiter and Saturn, through the 13-inch Clark refractor. It turned out to be the first time a modern digital video camera had been attached to the telescope to image Mars. We've come full circle from the first black and white images ever taken with the same telescope, spanning a history of over 130 years.



Figure 8: The red planet shrouded in dust, with a north polar hood and south polar cap clearly visible. Recorded as video through the Boyden 13-inch refractor, using RGB filters, and stacked with AutoStakkert!, processed in Registax and Adobe PhotoShop.

My observations of Mars during the dust storm proved interesting, and all images have been submitted to the Mars section of the British Astronomical Association.

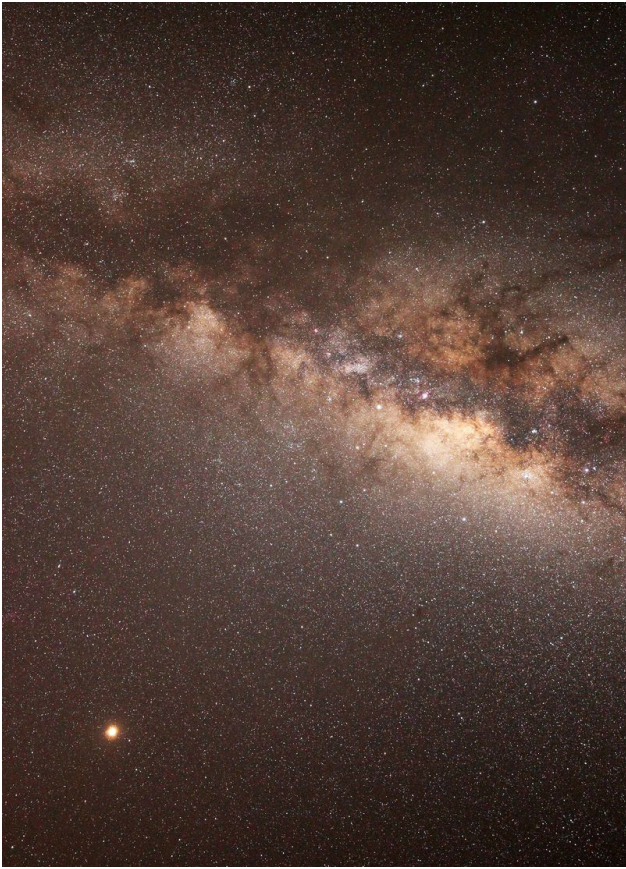


Figure 9: Mars and the Milky Way as seen from Boyden Observatory, South Africa. Photograph by author, Canon 60D, 14mm f/2.4 lens.

Acknowledgments

This paper, and the trip, would not have been possible without the valued friendship with colleagues Professor Matie Hoffman and Dawie van Jaarsveld, and Dr Daniel Wium, of Boyden Observatory and the UFS Physics/Astrophysics, as well as the staff of the observatory and of the Naval Hill planetarium.

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- Slipher, Earl C. *The Photographic Story of Mars*. Cambridge, MA; Sky Publishing Co., 1962.
- Young, A.T. *Seeing and Scintillation*. Sky & Telescope, Vol 42 (Sept), No 3, pp. 139-141, 1971.

PURSUIT OF A BETTER MOUSE TRAP: CONSTRUCTING AN EFFECTIVE ANALOG MONITOR FILTER FOR OUR PLANETARIUM CONSOLE

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Abstract: Since the early days of using a computer in a planetarium, people have employed a variety of methods to mitigate the amount of light spill around their consoles and domes. Within this paper, I will share my plans of how to construct an effective analog filter that is 1) Easy to make. 2) Can be easily added or removed and 3) Enables presenters to see a rich palette of colors on any monitor.

Introduction

Since the days of using an Apple IIgs to first control a multitude of slide projectors and special effect devices with a computer, I have had to battle light spill from computer monitors ever since. My efforts to curtail monitor light spill had largely fallen into two camps: using red cellophane or experimenting with transparent sheets of acrylic plastic. Within the scope of those two camps, I also experimented by trying different shades, material thickness, and ways to attach the filter media to the computer monitor. Some solutions were better than others were, but to be honest, I never truly liked any of them until my most recent iteration.

I recognize that many solutions exist that will mitigate the amount of light spill in the planetarium dome. It is my hope that the information provided within paper will help others who might wish to fabricate an effective, analog filter for their facility.

Historical Context

In the days before full-dome (BFD) systems, many of us would adjust the brightness levels on a monitor, place some type of physical filter in front of it, or perhaps change the color of the display text. Lines of text related to the programming code of various automation systems was one of the most common things displayed on a computer monitors at that time as shown in Figure 1. However, as banks of slide-projectors went away, emerging full-dome systems required operators to access much more than line after line of programming text that controlled a multitude of devices.



Figure 1. Lines of device control programming displayed on a monitor shielded by a red panel of acrylic plastic.

For example, a red filter effectively “turns” the text “red” for the viewer. This is because only the red wavelengths of light can pass through the filter media. Less light passing through also reduces the overall light spill into the planetarium. Since each filter color allows only certain wavelengths of light to pass through, it was not critical what the color of the text might “appear” to be. Did the filter reduce light spill and could I read the text displayed? Red filters have been common in planetariums because they are better at preserving the night vision for operators at the console. However, full-dome systems changed the game over device line programming because their native design was rich both in color and in content. In Figure 2, three monitors give feedback to an operator by a device-controlled platform and a full-dome system.

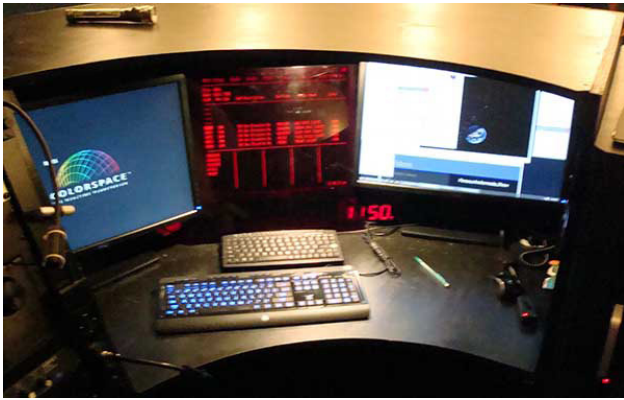


Figure 2. A device-controlled automation system monitor (red filter with red text) rests between two full-dome system monitors that displaying information in full-color. The deep console was constructed the monitors to minimize the amount of light that might spill into the planetarium.

Since full-dome systems provide dome-views of the night sky, show content, and libraries of celestial objects on a monitor, presenters must interact with the information displayed. During a presentation, an operator may need to start an audiovisual show, display the night sky, or navigate through an assortment of menus to illustrate an astronomical concept.

Furthermore, full-dome systems have enabled presenters to display constellation art, connect-the-dot patterns, and boundaries for different cultures. In addition, a variety of labels and symbols might designate different types of objects, such as extrasolar planets, asteroids, and satellites. The ability to change the color of the text or graphic on the computer screen so that it appears the same on the dome is advantageous. Full-dome in the author's opinion is best if the computer display is in color instead of a being only in "red" or some other monochromatic color. The problem with color is that most monitors were still too bright for use in the dome as captured in Figure 3.

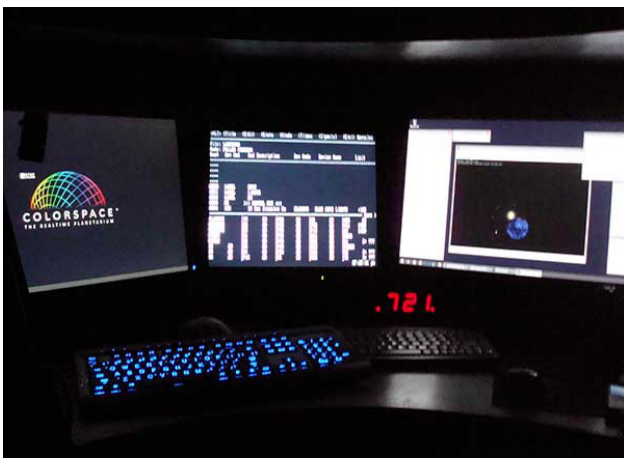


Figure 3. The same console from Figure 2 in use during a planetarium program. Note the varying levels of light spill for each color monitor and that the text appears white following the removal of the red filter that had covered the center monitor.

To get away from physical filters and yet preserve night vision, some full-dome vendors and makers of astronomy programs have built solutions within their software to toggle between full-color graphics and a screen that appears "red." This solution is simple to use and is satisfactory to many. For others, they have found monitors that work for their planetarium console or have chosen to modify theirs with electronic components at the risk of invalidating their monitor's warranty and/or shortening its life.

Lastly, some institutions have installed a software solution that will dim a monitor for low-light conditions. Since I did not have any experience using any of the software solutions, I am reluctant to mention any by name or inherently endorsing a given product. However, in the spirit of sharing information, a thread started by Rob Webb on the Dome Dialogues dated May 20, 2018 (Facebook.com) contains numerous opinions that are worth reading.

Given the many options and individual preferences, the best solution will depend largely on the needs of a facility, budget constraints, and the compatibilities that may exist between existing hardware. For my needs, I wanted something that allowed me and my planetarium operators to be able to see in color, preserve their night vision, was flexible in regard to use. It also needed to be reliable and could not spill too much light around the console or planetarium theater.

The Kalamazoo Solution

Following a comprehensive update that included the replacement of our full-dome projection system, cove lights, and sound system in November 2016, I felt that there had to be a better solution for mitigating the light spill from our three monitors at the console (Figure 4).

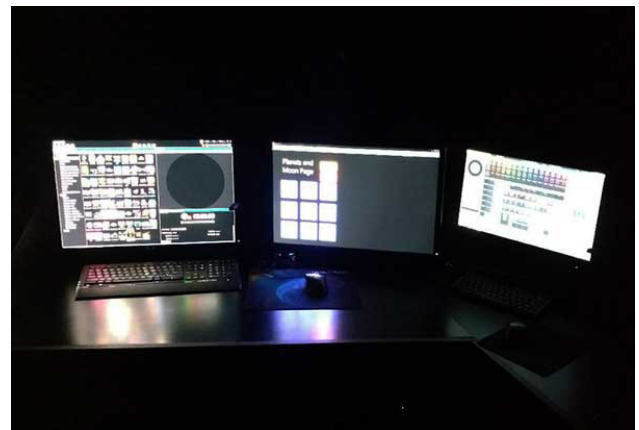


Figure 4. The Kalamazoo Valley Museum Planetarium console without any filter media to mitigate light spill.

Two of the monitors at our console had the ability to toggle between a full-color display and a red screen (Figure 5). The third monitor to the far right in Figure 4 did not have this function and was temporarily fitted with a red piece of cellophane.



Figure 5. The same Kalamazoo Valley Museum Planetarium depicting two monitors toggled to the “red” setting.

In practice, even with our monitors toggled to a red state and using a red gel, there was so much light cast that it made our presenters appear as if their face was “glowing” to their audiences (Figure 6). Adding to my dissatisfaction was the fact that despite having a system with tremendous capability, I was effectively limited to using color only for programming purposes. To me, the use of color was essential, and it was a waste not to be able to use it. I decided that there had to be a better way!



Figure 6. A “glowing” LaRue Russell from the Kalamazoo Valley Museum Planetarium demonstrates what an audience member sees from the middle of the dome when no monitor filters are used.

My goal was simple. I wanted to find a method of limiting the amount of light transmitted and yet see the color information displayed on our color monitors. After consulting with several plastic companies, I came upon *ePlastics* and was able to talk to a salesperson about their products. After describing what I was trying to accomplish, it was suggested that I purchase a sample packet of five, one-eighth inch thick acrylic plastic sheets (3.75 x 5.75 inches) in numbered shades of bronze (2370, 2404, and 2412)

and gray (2064 and 2074). Each would have a different light transmission value associated with it and the material thickness would NOT be an important consideration.

This packet of acrylic samples that I purchased proved to be more helpful than I had initially imagined. The samples gave me the opportunity to test each shade both individually and in combination with other samples in the planetarium. After I had completed my tests, I decided that I would sandwich a 1/8-inch sheet of bronze 2370 with a 1/8-inch sheet of bronze 2412 to make my filter. This combination reduced the amount of transmitted light overall and allowed me to see colors on my monitor screen.

Once I had identified the shades of acrylic plastic that I needed, measured the monitor faces, and inquired about shop fees, I was ready to work up my order. Since each shade of plastic would come in a 24-inch x 48-inch sheet, I had to decide whether I would pay to have the plastic cut to size and ship in a smaller package to our institution or arrange to have larger pieces shipped and cut in-house later. With some planning, I was able to have three monitor panels cut to size from a 24-inch x 48-inch sheet. In my opinion, the shop fee was worth the expense because I could then focus on how I wanted to attach the filter media to the monitor.

Over the years, I have seen filters draped over or attached to monitors with tape, Velcro, hooks, etc. In most cases, the filters are hard to remove, unsightly, or sticky from adhesives. I wanted a simple method that would enable an operator or programmer to remove the filter quickly should they need to. A trip to the hardware store inspired me with a method that I think is simple and yet practical in its application.

In addition to the two shades of bronze acrylic plastic, the following supplies and equipment are also needed or useful to have.

- 1) Aluminum “U” channel. That measures 3/8-inch x 1/2-inch with a 1/4-inch interior channel that is 7/16-inches deep. The channel needs to be a 1/4-inch so that it can sandwich the two shades of acrylic plastic together. Two pieces are required for each monitor filter built.
- 2) Aluminum flat stock. This should be 1/16-inch thick by 1.5 inches wide. One piece is required for each monitor filter built.
- 3) Flat Black Spray Paint
- 4) J-B Weld Cement
- 5) #6-32 x 3/4-Inch Round Head Machine Screws with Nuts
- 6) 600 Grit Sandpaper
- 7) Masking Tape
- 8) Four 1-inch Velcro Pads

- 9) Tools Needed—Hacksaw, Five Small C-Clamps, Drill Press or Mill, Fine Mill File, Drill Bits, Screwdriver, and Small Adjustable Wrench.

Constructing a KVM Monitor Filter

1. Measure both the horizontal and vertical screen dimensions of your monitor that you wish to cover.
2. Prior to making an order for filter media, decide if you would like to have it cut to size or buy sheet material that can be cut in-house.
3. Cut the aluminum flat stock to the appropriate length. It should be the same as the horizontal dimension of your plastic filter media and the width of your computer monitor.
4. Cut two pieces of aluminum U-channel to length. This measurement should be same width as your monitor and the same length as the aluminum flat stock cut in the previous step.
5. Using a drill press or preferably a mill, drill three holes completely through the sides of each piece of U-channel. Mark the location for each hole that needs to be bored. The first hole should be located halfway between each end of the channel and drilled a 1/4-inch from the top of the open side of the “U.” Mark the second and third holes about 1.5 inches from either end. They should also be bored a 1/4-inch from the top just like the first hole.

Please note that the three holes that are 1/4 -inch from the top of the open side will look centered when viewed from the wide sides of the channel.

For best results, use a smaller drill bit to make a pilot hole and then drill to a size that Drill each hole so that is slightly larger than the #6-32 machine screws that I have recommended.

6. Repeat Step 5 for the second piece of aluminum U-channel.
7. Deburr any ragged edges related to drilling. Afterward, lightly file any rough edges or saw marks that remain from an earlier step.
8. While working with the acrylic plastic during the construction process, leave the protective paper covering on to prevent any scratches prior to completion. This will be important in the next few steps.

Take each shade of acrylic plastic and sandwich it together. Mark on the paper covering which end will be the top and front sides. Insert the two plastic sheets into the one of the pieces of aluminum U-channel to form a top.

Square up the end pieces making sure that the plastic seats at the bottom of the U-channel before attaching two pieces of tape that wrap over the channel and secure it to the paper covering. This is a temporarily step to keep the metal and plastic parts place from moving relative to each other while the plastic in Step 9 is drilled.

Repeat this step by adding a second piece of U-channel that will form the bottom of the filter.

9. Carefully drill pilot holes through the acrylic plastic using a new or sharp drill bit that is smaller than the one use used to drill through the aluminum channel. Use the holes in the aluminum channel as your guide and use caution not to apply too much pressure while you drill. Too much pressure may cause the plastic to crack since the proximity of the hole is close to the edge of the acrylic sheet.
10. Remove the tape to carefully remove the top and bottom pieces of U-channel. Please note both the orientation and which piece is the top or bottom. Use a slightly larger drill bit to finish drilling the plastic holes to size. A slightly larger plastic hole will enable bolts to pass through the acrylic without stressing the plastic during assembly.
11. Place machine bolts through each of the six holes to test fit all of the pieces of the U-channel assembly.
12. Unbolt and remove the top piece of U-channel that you have identified. Please note the orientation of this piece so that you know which side will be the front or the back. This will help ensure that the holes and pieces assembled in the future will match up.
13. Check to see that the aluminum flat stock is the same length as your top piece of U-channel. If not, trim or file accordingly.
14. Prepare a mixture of J-B Weld and carefully apply it as per the directions to the metal surfaces to be bonded.

Be careful to position the bottom of the U-channel to flat stock to form a top plate that extends away from the front surface of the monitor as shown in Figures 7.



Figure 7. A cross section of the U-channel and aluminum flat stock after they were bonded.

The finished filter monitor is an acrylic sandwich made up of two shades of tinted plastic fastened together in a piece of U-channel as shown in Figure 8.

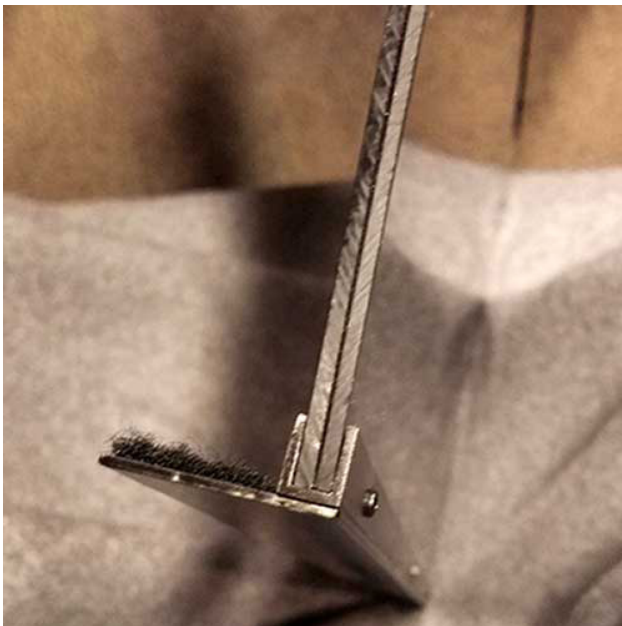


Figure 8. A cross section of the final assembly of the monitor filter.

The purpose of the aluminum flat stock fastened to the U-channel is to support the weight of the filter so that it can eventually hang in front of a monitor. Bolts run through the plastic and U-channel will keep the assembly together.

15. Position the U-channel to the flat stock as shown in Figure 7 and clamp the pieces together using five small C-clamps. Leave the C-clamps on for 1-2 days so that the J-B Weld

can fully cure.

16. Remove clamps and disassemble all remaining pieces. Please carefully note the how each piece of metal and plastic fit together. The specific orientation of the metal and plastic parts relative to the placement of each hole will help in reassembly.
17. Use 600 grit sandpaper to lightly sand any rough areas from excess J-B Weld and remove some of the sheen from each aluminum pieces so paint will better adhere.
18. Paint each of the metal pieces flat black including any hardware (nuts and bolts) needed to assemble the monitor filter.
19. Apply additional coats of paint if necessary. Let paint dry for at least 24 hours prior to any final assembly.
20. Remove the protective paper off each sheet of plastic and place sheets back together so that the front sides are the same and the holes match.
21. Reattach the U-channel pieces to both the top and bottom ends of the acrylic plastic sheet with machine screws and nuts as shown in Figure 9.



Figure 9. The purpose of the top-plate and U-channel assembly is to support the weight of the overall filter as it hangs down over the front of a monitor.

22. Trim excess screw lengths as needed and file any rough surfaces smooth. Apply touch-up paint if applicable.
23. Position the flat-aluminum/U-channel assembly of the filter so that it rests on top of your monitor as shown in Figure 10.



Figure 10. The author gently hanging a filter assembly over the front of one of his console monitors.

24. To keep the filter from sliding off, consider adding a small piece of Velcro to each corner. This will provide enough resistance to keep the filter from sliding off and yet make it easy to remove.
25. In Kalamazoo, we have also placed several small pads over the metal nuts as a cushion and to protect the monitor screen from being accidentally scratched.

Closing Comments

Since constructing three filters in the spring of 2017, I have found that our monitor filters have performed very well and look like they belong. In other words, their appearance does not detract from the console (Figure 11).

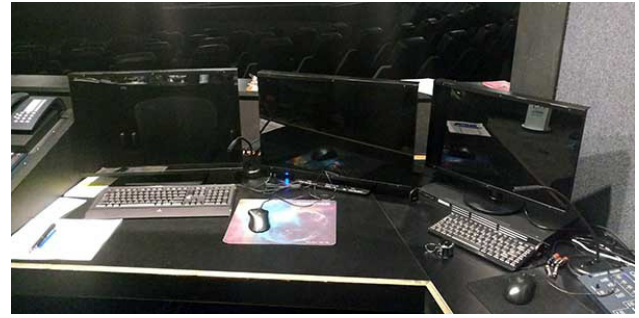


Figure 11. The Kalamazoo Valley Museum Console with the room lights following the installation of our new monitor filters.

The filters that we fabricated are effective in reducing the amount of light spill in the dome and the result is much improved. The difference between unfiltered and filter is significant. Figure 12 shows a direct comparison.

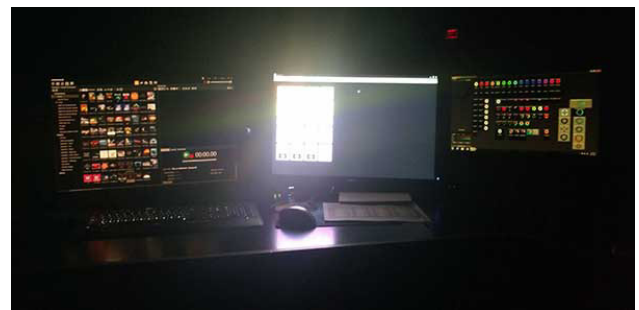


Figure 12. A direct comparison between monitors equipped with two of the filters we fabricated against one monitor without any filtration.

Furthermore, the filters are relatively simple regarding their design. They can be placed on or removed from a monitor with minimal effort and can be reused in the future if needed. Most of all, the monitor filters permit our operators to see any type of full-dome content and show play-back in full color as shown in Figure 13.



Figure 13. Kalamazoo Valley Museum Planetarium's monitor filters in action during a showing of the Clark Planetarium's production of "Let It Snow."

Lastly, the monitors are flexible enough, they can be left on for presenters who still prefer to see "red" or wish to have a darker console environment (Figure 14).

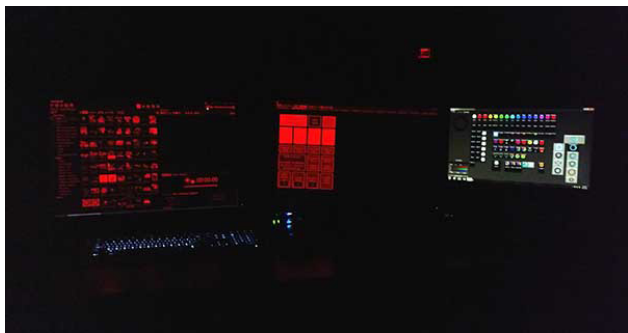


Figure 14. The “red” display toggled on the center and left monitors using our new filters. The monitor to the right does not have a “red” toggle and has been equipped with one of our new filters.

In conclusion, did I build a better “mousetrap” that everyone will want? Probably not! However, I will attest that the monitor filters that I have put together have met and exceeded my expectations in Kalamazoo! If you are looking for an analog solution, please contact me or check them out when we host GLPA in 2020!

Resources

ePlastics – Ridout Plastics
5535 Ruffin Road
San Diego, CA 92123
United States
858-560-1551
www.ePlastics.com
Contact: Rolando A. Walker

KEPLER'S THIRD LAW WITH SCIDOME

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Abstract: This planetarium exercise demonstrates Kepler's Third Law. The ecliptic serves as a calendar and protractor to measure dates of conjunction and quadrature and angles of maximum elongation. From these data, students compute orbital radii and sidereal periods. The exercise includes both inferior and superior planets. This exercise was originally developed using our Minolta opto-mechanical projector and is now adapted to our SciDome full-dome system.

Introduction

Kepler's Third Law describes planetary orbits with the well-known relationship $P^2 = a^3$, where P is the period in years and a is the semi-major axis in astronomical units. It is easy to demonstrate this law from an external viewpoint using an orrery or a video sequence. But this law, like all our other knowledge of celestial motions, was derived from Earth-based observations. With the help of the planetarium's sky, Kepler's Third Law can be quantitatively demonstrated from an Earth-based viewpoint. At Bowling Green, we developed such a laboratory-style exercise to do this for both the inner and outer planets, first using our Minolta star projector and now adapted to SciDome. This paper describes the exercise using SciDome, but the work could readily be adapted to other full-dome systems. The original paper using the Minolta was published in the 1990 GLPA Proceedings.

Basic measurements: using the ecliptic

The procedures are different for the inner and outer planets because the orbital geometry is different, so the inner and outer planets are done separately. The geometry and procedures involved are explained in detail in the student's lab packet (reproduced below), so are only briefly summarized here. Directions in the lab packet carefully guide the student through taking the data and using it to calculate the periods and radii.

Two types of data must be measured in order to calculate periods and radii: the dates of successive conjunctions and the angles of elongation between the Sun and planets on selected dates. These dates must bracket the times of maximum elongation for the inner planets and bracket the times of quadrature for the outer planets. Since the motions of the Sun and planets lie either on or close to the ecliptic, the ecliptic serves as the exercise's measuring tool. Deviations from the ecliptic are ignored.

First, the ecliptic is used as a calendar for recording the dates of conjunctions. Second, it is used as a calendar for recording the dates at which elongations (and quadratures) are measured. Since it is difficult to read calendar dates off SciDome's ecliptic

as projected on the dome, dates are read by the instructor off the computer screen.

Third, the ecliptic is used as a protractor to measure the elongation angle between the Sun and a planet. To do this, the ecliptic, ecliptic grid, and ecliptic meridian are turned on. The grid displays lines of ecliptic longitude and latitude. If the grid scale is set to "fine" the lines of ecliptic longitude are 10 degrees apart, so the ecliptic longitudes of the Sun and a planet can be estimated to one degree and then subtracted to yield the elongation angle. The medium and coarse settings do not yield sufficient accuracy.

I create SciDome favourites for all the planet motions to be measured. This helps me move the sky efficiently through the various conjunctions, elongations, and quadratures without operator error. A good web site for checking the dates of conjunctions, elongations, and quadratures is eco.mtk.nao.ac.jp from the National Observatory of Japan but in English.

In the favourites, set the planets to "celestial path" so the dots showing the position of a planet are visible. In the favorites, I set the time step size to 1 sidereal day and advance time by one step (one day) at a time, stopping every five or ten days to take a reading of elongations; for Jupiter and Saturn quadrature favourites, I set the step size to five sidereal days. These step sizes make efficient use of class time and help the student best see the celestial motion of the planet and Sun. Have just one planet at a time turned on to avoid confusing planets that may be close together. (At times, you may need to turn the whole sky in order to keep the Sun and planet above the horizon. In this case, use a step size of one minute to turn the whole sky and use the continuous motion tab.)

Method for the inner planets

The basic step in determining the period for Mercury and Venus is to observe and record the dates of two successive superior (or inferior) conjunctions. This measures the synodic period. The successive conjunctions occur at different places along the ecliptic. The angle between these two places is found by subtracting the ecliptic longitude of the planet on the two dates. Now knowing

the angle the planet has moved in orbit around the Sun (see Figure 1 in the student packet below) and how long it has taken to move through this angle, the student can readily determine the planet's angular rate of motion (degrees/day) in orbit around the Sun, and thus can easily calculate the sidereal period. Note that this procedure is purely geometric and does not resort to the common algebraic formula relating synodic and sidereal periods.

The procedure for measuring the orbit radius for Mercury and Venus is based on finding their angles of maximum elongation from the Sun. This is done by recording elongations at intervals of 5 days for Mercury or 10 days for Venus around the time of maximum elongation and then interpolating between these measurements to find the maximum elongation angle. Use of 5- or 10-day intervals is somewhat arbitrary, but measurements at 1-day intervals would greatly prolong the time required to obtain the necessary measurements. To compensate for orbital eccentricity, especially for Mercury, maximum elongations are found both east and west of the Sun and averaged. Since the triangle connecting the Sun, Earth, and planet at maximum elongation is a right triangle (see Figure 2 in the student packet), the sine of the maximum elongation angle directly gives the radius of the planet's orbit in A.U.

Method for the outer planets

The steps used to determine the periods of Mars, Jupiter, and Saturn are similar to the steps used for the inner planets. The dates and the longitudes on the ecliptic of two successive conjunctions are recorded (see Figure 3 in the student packet), thereby yielding the synodic period, the angular rate of motion in orbit, and thus the sidereal period.

The procedure for measuring the orbit radii of the outer planets is the most complex one in the exercise. It is different from the procedure used for the inner planets in that it involves measuring dates of quadrature (Sun and planet 90° apart). Quadrature is used because at quadrature (see Figure 4 in the student packet) the triangle connecting the Sun, Earth, and planet is a right triangle. In effect, the Earth is at maximum elongation as seen from the planet. If one of the acute angles in this triangle can be found, the radius of the planet's orbit in A.U. is easily calculated.

Quadrature is located by recording elongations at intervals of 5 days around the time of quadrature and then interpolating among these measurements to find the exact date of quadrature. Since the Sun moves eastward along the ecliptic faster than the planet does, the Sun gradually passes the planet, so the planet comes first to quadrature east of the Sun, then to conjunction, and last to quadrature west of the Sun. The dates of both quadratures are determined by examining the elongation measurements. Then the time interval between the conjunction and each quadrature is calculated by subtracting the dates, and the two intervals are averaged to compensate for orbital eccentricity. This mean time interval between conjunction and quadrature, together with the sidereal period and the ecliptic longitude angle between successive conjunctions (both of these quantities have already been determined) and a little geometry fixes the Sun-Earth-planet triangle at quadrature, and thus yields the radius of the planet's orbit in A.U.

Procedures for the taking the measurements and a sample set of star projector sequences

It is obvious that both the instructor and the student must be well-prepared for this exercise to work effectively. Though the exercise packet is self-contained, the student must already be familiar with the planetarium sky, with the ecliptic, and with the motions and configurations of the planets. If the students receive the exercise packet a few days ahead of time, everyone can read it in advance and understand the geometry, the data-taking, and the analysis. Most students catch on quickly to the data-taking procedure.

The measurements can be completed in about two class sessions of 50 minutes each, one for the inner planets and one for the outer planets. During the period when the measurements are being made, it was my practice for the sake of time efficiency and a uniform data set to read the positions of the Sun and planet to the class as they watched them, but other instructors may choose to let the class do all the reading. I also bring the room lights up dimly after each reading so students can record the data, though if everyone has a cell phone, they can provide their own light. Here is one sample set of movements.

Mercury (1st class period). Begin with the sky set to the superior conjunction of February 8, 2018 and then go to the next superior conjunction on June 6. Then for the maximum eastern elongation of November 6, measure the positions of the Sun and Mercury every five days from October 27 through November 16. Finally, for the maximum western elongation of December 15, measure the positions of the Sun and Mercury every five days from December 5 through December 25. It is important to choose maximum elongation dates where the elongation is near midway between the greatest maximum (28°) and the least maximum (18°); otherwise, the calculated radius R will be too large or too small and the R^3 will differ markedly from P^2 .

Venus (1st class period). Begin with the sky set to the superior conjunction of June 7, 2016. Then for the subsequent maximum western elongation of June 3, 2017 measure the positions of the Sun and Venus every five days from May 24 through June 23. Next go to the next superior conjunction on January 9, 2018. Then for the subsequent maximum eastern elongation of August 18, measure the positions of the Sun and Venus every five days from July 29 through September 7.

Mars (2nd class period). Begin with the sky set to the conjunction of June 15, 2015. Then for the eastern quadrature of September 14, 2016, measure the positions of the Sun and Mars every five days from September 4 through September 24. Then go to the conjunction of July 27, 2017. Finally, for the western quadrature of March 25, 2018, measure the positions of the Sun and Mars every five days from March 15 through April 4. These ranges allow the student to see the planets approaching and passing through the maximum elongations (for the inner planets) and quadratures (for the outer planets).

Jupiter (2nd class period). Begin with the sky set to the conjunction of October 27, 2017. Then for the eastern quadrature of August 7, 2018, measure the positions of the Sun and Jupiter

every five days from July 28 through August 17. Then go to the conjunction of November 26, 2018. Finally, for the western quadrature of March 14, 2019, measure the positions of the Sun and Jupiter every five days from March 4 through March 24.

Saturn (2nd class period). Begin with the sky set to the conjunction of December 22, 2017. Then for the eastern quadrature of September 26, 2018, measure the positions of the Sun and Saturn every five days from September 16 through October 6. Then go to the conjunction of January 2, 2019. Finally, for the western quadrature of March 10, 2019, measure the positions of the Sun and Saturn every five days from February 28 through March 20. Accurate quadrature readings are especially important for Jupiter and Saturn since the final step in computing the orbit radius involves taking the inverse of the cosine of an angle close to 90° , and a small error in the angle has a large effect on the derived radius.

Analysis

After taking the data in class, the students complete the remaining work at home individually or in groups, as they prefer. In the Minolta days, we tested various generations of this exercise on both small honors classes and large survey classes and found that most students are able to complete the analysis successfully. I would *not* encourage providing the students with a spreadsheet that does the calculations for them. I have tested the SciDome version on an advanced high school student doing an independent study with me.

Sample results

Once all the periods and radii have been calculated, then P , R , P^2 , and R^3 can be tabulated to illustrate Kepler's Third Law. Table 1 lists some typical results we have obtained using the dates above in SciDome. It shows that reasonably accurate periods and radii can be obtained with careful measurement despite the approximations in the methods.

Table 1. Sidereal periods and orbit radii

planet	-----measured values-----				---"real" values---	
	$P(\text{yr})$	$R(\text{AU})$	P^2	R^3	$p(\text{yr})$	$r(\text{AU})$
Mercury	0.23	0.37	0.053	0.050	0.24	0.39
Venus	0.61	0.73	0.37	0.38	0.62	0.72
Earth	1.00	1.00	1.00	1.00	1.00	1.00
Mars	1.89	1.55	3.57	3.72	1.88	1.52
Jupiter	12.99	5.67	169	182	11.9	5.2
Saturn	33.7	15.1	1136	3442	29.5	9.5

Students are also asked to plot P^2 vs. R^3 to show the relationship graphically. A labeled log-log grid is provided to accommodate the range of values. Finally, a few questions guide the student to see that P increases faster than R as one goes to greater distances from the Sun, and thus that the orbital speeds of more distant planets are slower, which in turn shows that the force of gravity weakens with increasing distance from the Sun.

One of the surprises in using data from SciDome rather than the opto-mechanical Minolta was that there was no improvement in the derived values for P and R , even though the dates of conjunctions and quadratures were verified by comparing with published ephemerides. In fact, the radius of Saturn's orbit based on Minolta data was more accurate.

The lesser accuracy with SciDome data for Saturn may reflect errors triggered by rounding the date of quadrature to the nearest whole day rather than taking it to a finer time scale and/or fortuitous rounding in reading dates on the Minolta. In fact, for Saturn a difference of one day in the measured interval between conjunction and quadrature can change the derived radius of orbit by 3 A.U.

Conclusion

This exercise provides the student with an experience in a quantitative and advanced use of the planetarium, illustrates the motions of the planets in a concrete way, and demonstrates the ability of a planetarium to show the complex motions of the planets as well as those of the Sun and Moon. The exercise also gives some practice in techniques of taking and analyzing data such as interpolation, graphing, and working through an extended analytical procedure. Finally, though it does not exactly replicate Kepler's original steps, it does show for one law how the god's-eye-view results we often show are derived from Earth-view measurements.

A copy of the student's lab packet follows. Of course, I would welcome suggestions on ways to improve this exercise.

KEPLER'S THIRD LAW

I. Introduction:

Background. Between 1576 and 1597 Tycho Brahe carried out precise observations of the positions of the planets and stars. Upon his death, his data went to his assistant Johannes Kepler, who spent many years analyzing Tycho's observations of Mars and finally arrived at three general "laws" that describe the motions of the planets. Later, Isaac Newton showed that Kepler's laws are consequences of the law of gravity.

Kepler's Third Law expresses the relationship between the period of a planet (the time it takes to complete one trip around its orbit) and the planet's distance from the Sun. This law can be discovered by observing the motion of the Sun and planets in the sky.

Today, we will re-discover Kepler's Third Law through the use of the planetarium. The planetarium reproduces the motions of the Sun and planets as seen in the Earth's sky. Most of the work in this exercise will be involved with measuring the positions of the Sun and planets in the Earth's sky and then using these measurements to learn how the planets move in their orbits around the Sun.

This is the same challenge that Kepler faced. He wanted to know how the planets moved in their orbits around the Sun. But all he (and we) could see were their positions in the sky as viewed from the Earth. Like Kepler, we will use these Earth-based measurements to deduce for each planet its period and its distance from the Sun.

The period P of a planet is the time the planet takes to circle once around the Sun. The period of the Earth is one year or 365 days. When we on the Earth try to measure the period of another planet by watching its motion in our sky, the situation is complicated because the Earth is also moving.

Measuring the radius R of a planet's orbit by watching its motion is also an indirect process. Our strategy will involve measuring angles of separation between the Sun and planets and using them to calculate a planet's distance from the Sun in terms of the Earth's distance, which is 1 Astronomical Unit (A.U.) or 93 million miles.

In using our measurements of the Sun's and planets' positions to calculate orbital periods and radii for the planets, we will assume all the orbits are circles in order to simplify the geometry. In fact, the orbits are ellipses, but they are very close to being circles. Since the geometry involved is different for planets inside and outside the Earth's orbit, we will deal with the planets in two separate sections.

Using the ecliptic to record the position of the Sun and planets. As we use the Planetarium to measure the positions of the Sun and planets against the background stars, you will see the Sun and planets move along the ecliptic. The ecliptic is the path the Sun follows through the star field over the course of a year, as seen from the Earth. In the planetarium, the ecliptic will appear as a circle projected on the sky against the background stars. The Sun returns to the same place on the ecliptic on the same date each year (because the Earth comes back to the same place in its orbit). So the ecliptic is calibrated in days to show the Sun's place in the star field on each day of the year. It is a kind of calendar that describes the Sun's motion. So you can record the date and the Sun's place in the star field on that date by simply noting the date on the ecliptic that the Sun is lined up with.

The planets' paths through the star field are very close to the ecliptic, so you can also use the ecliptic to record a planet's place in the star field. For this purpose, the ecliptic is calibrated in celestial longitude. These longitudes run from 0° to 360° , just like longitudes on the Earth's equator. You can record a planet's position along the ecliptic by noting its celestial longitude. Where needed, you can also record the Sun's celestial longitude.

II. Inner Planets: Mercury and Venus

1) Period

Look at Figure 1, which shows the orbits of Mercury (M) and the Earth (E) around the Sun (S). At time 1, all three objects form a straight line with Mercury between the Earth and Sun. This arrangement is called inferior conjunction. Seen from the Earth, Mercury would appear directly in line with the Sun.

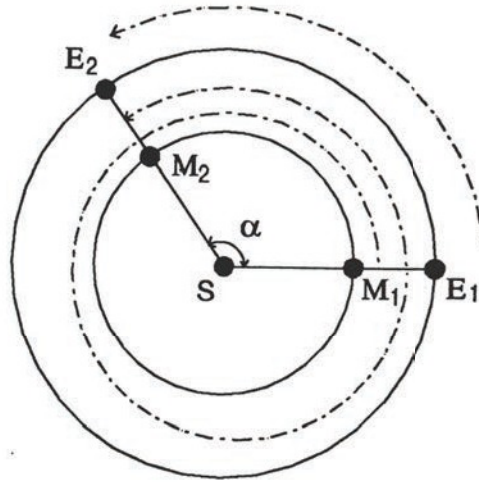


Figure 1. Inferior conjunctions of Mercury

But Mercury moves faster in its orbit than the Earth does, so it soon pulls ahead of the Earth, and eventually gains a full lap on the Earth. In fact, after the Earth has gone only about a third of the way around its orbit, Mercury has gone a full orbit plus another third and is once again lined up with the Earth and Sun in inferior conjunction. Seen from the Earth, it would again appear directly in line with the Sun, as at time 2. In the planetarium, we can observe the dates Mercury is at inferior conjunction.

By measuring the time interval between successive inferior conjunctions, we can calculate the period of Mercury as follows. Since the Earth moves about 1° per day in its orbit (360° in 365 days), the number of days between conjunctions equals the number of degrees the Earth has moved in that time, or the angle α in figure 1. Because Mercury has covered a full orbit and more, it has moved through an angle of $360^\circ + \alpha$ in the same time. Since we now know the angle Mercury has moved through and the time it took, we can calculate Mercury's rate of motion in degrees per day. Then we can easily compute the time Mercury needs to go exactly once around its orbit (i.e., to go 360°) by dividing 360° by the rate of motion. The result is the period, P.

In the planetarium, we will determine the periods of Mercury and Venus by measuring the dates of successive inferior conjunctions for each.

A. Period for Mercury

1st conjunction of Mercury on _____ (1) DATE
2nd conjunction of Mercury on _____ (2) DATE
Number of days between conj.: _____ days (3)
Angle α , which equals (3) _____ degrees (4a)
Add 360° to (4a): _____ degrees (4b) ANGLE MOVED
Divide (4b) by (3): _____ degrees/day (5) RATE OF MOTION
Divide 360° by (5): _____ days (6) PERIOD
Express the period in years: _____ years (7)

B. Period for Venus

1st conjunction of Venus on _____ (1) DATE
2nd conjunction of Venus on _____ (2) DATE
Number of days between conjunctions: 1 year and _____ days
= _____ days (3)
Angle α , which equals (3): _____ degrees (4a)
Add 360° to (4a): _____ degrees (4b) ANGLE MOVED
Divide (4b) by (3): _____ degrees/day (5) RATE OF MOTION
Divide 360° by (5): _____ days (6) PERIOD
Express the period in years: _____ years (7)

2) Distance from the Sun (radius of orbit)

At conjunction Mercury and Venus will be lined up with the Sun as viewed from Earth. At all other times they will be off to one side or the other of the Sun. The angle θ (see Fig. 2) by which they are separated from the Sun is called the elongation and is a maximum when the line of sight from Earth to the planet is tangent (grazing) to the planet's orbit, as drawn in Fig. 2. At any other time the line of sight cuts across the orbit and q is smaller, *i.e.*, the planet would appear closer to the Sun in our sky than in the arrangement in the Figure, where the planets are drawn at maximum elongation.

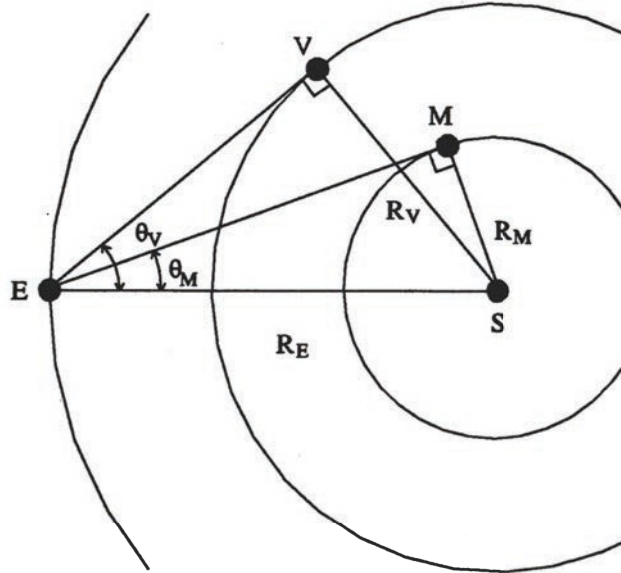


Fig. 2. Geometry used to determine orbital radii

When Mercury, for example, is at maximum elongation, the lines connecting it, the Earth, and the Sun form a right triangle. The hypotenuse of the triangle is the distance of the Earth from the Sun (R_E) and the short side is the distance of Mercury from the Sun (R_M). These distances and the maximum elongation angle q_M can be related by trigonometry:

$$R_M = R_E \sin q_M$$

If we can measure q_M and know the Earth's distance from the Sun (93 million miles or 1 Astronomical Unit, 1 A.U.), then it is easy to calculate Mercury's distance from the Sun in miles. It is even easier to express Mercury's distance in A.U.'s, *i.e.*, as a ratio to the Earth's distance.

$$R_M \text{ (in A.U.)} = \frac{R_M \text{ (in miles)}}{R_E \text{ (in miles)}} = \sin \theta_m$$

So if you measure the maximum elongation angle q_M , it is easy to calculate the orbital radius R_M in A.U.

The same procedure can be followed for Venus.

We will measure the maximum elongations θ_M and θ_V for Mercury and Venus in the planetarium. Because it is difficult to tell visually just when the maximum angle is reached, we will measure the elongation angle on a series of dates, then inspect the data to find the maximum angle.

To measure the elongation on a given date, record the celestial longitudes of the Sun and planet (Mercury or Venus) on the ecliptic. The difference between the celestial longitude of the Sun and the celestial longitude of the planet gives the planet's elongation. By inspecting the elongations measured in this way, you can easily locate the angle of maximum elongation.

Since the planets' orbits are not perfect circles, a planet's maximum elongation may depend on which side of the Sun the planet is on, *i.e.*, it may be different when the planet is east of the Sun from when it is west of the Sun. To allow for this effect, we will measure the maximum elongation for each planet both east and west of the Sun and average them. Then use the average maximum elongation for each planet to compute the radius of its orbit.

Mercury west of Sun

cel. long. of Sun	cel. long. of Mercury	elongation
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Mercury east of Sun

cel. long. of Sun	cel. long. of Mercury	elongation
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Venus west of Sun

Venus east of Sun

cel. long. of Sun	cel. long. of Venus	elongation	cel. long. of Sun	cel. long. of Venus	elongation
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

A. Radius of Mercury's orbit

Maximum elongation to east _____ degrees (1)

Maximum elongation to west _____ degrees (2)

Average of (1) and (2): _____ degrees (3)

Radius of Mercury's orbit: _____ A.U. (4)

Radius of Mercury's orbit: _____ miles (5)

B. Radius of Venus' orbit

Maximum elongation to east _____ degrees (1)

Maximum elongation to west _____ degrees (2)

Average of (1) and (2): _____ degrees (3)

Radius of Venus' orbit: _____ A.U. (4)

Radius of Venus' orbit: _____ miles (5)

III. Outer planets: Mars, Jupiter, and Saturn

1) Period

Look at Figure 3, which shows the orbits of the Earth (E) and Jupiter (P) around the Sun (S). At time 1, all three objects form a straight line with the Sun between the Earth and Jupiter. This arrangement is called conjunction. Seen from the Earth, Jupiter would appear directly in line with the Sun.

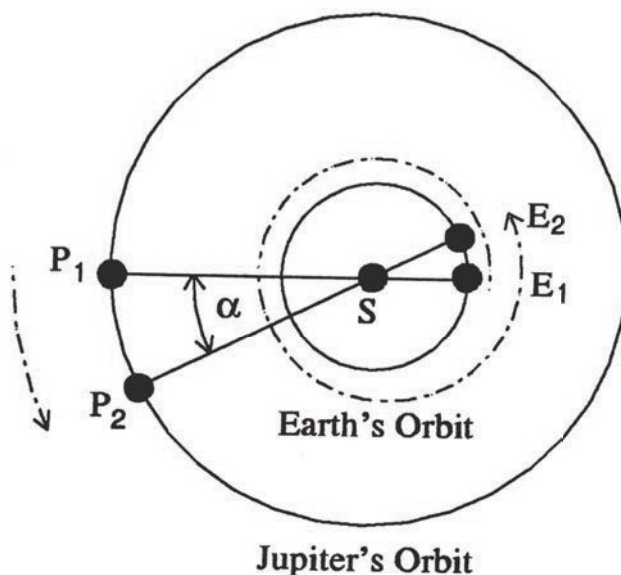


Figure 3. Conjunctions of Jupiter

But the Earth moves much faster in its orbit than Jupiter does, and eventually gains a full lap on Jupiter. In fact, after Jupiter has gone only about a twelfth of the way around its orbit, the Earth has gone a full orbit plus another twelfth and is once again lined up with Jupiter and the Sun at conjunction. Seen from the Earth, Jupiter would again appear directly in line with the Sun, as at time 2. In the planetarium, we can observe the dates Jupiter is at conjunction.

By measuring the time interval between successive conjunctions, we can calculate the period of Jupiter as follows. The interval between conjunctions will be 1 year plus an extra number of days, d . Since the Earth moves about 1° per day in its orbit (360° in 365 days), it will have moved through an angle $360^\circ + \alpha$ between conjunctions, where α (in degrees) equals the extra number of days, d . Jupiter, between conjunctions, will have moved only a° , as you can see by inspection from Figure 3. Since we now know the angle Jupiter has moved through and the time it took, we can calculate Jupiter's rate of motion in degrees per day. Then we can easily compute the time Jupiter needs to go exactly once around its orbit, *i.e.* to go 360° , by dividing 360° by the rate of motion. The result is the period, P . (Notice that once we have a , the procedure is identical to that for the inner planets.)

In the planetarium, we will determine the periods of Mars, Jupiter, and Saturn by measuring the dates of successive conjunctions for each.

A. Period for Mars

1st conjunction of Mars on _____ (1) DATE

2nd conjunction of Mars on _____ (2) DATE

Interval between conjunctions: 2 years plus _____ days (3A)

= _____ days (3B)

Angle α , which $= (3A) + 360$: _____ degrees (4) ANGLE MOVED

Divide (4) by (3B): _____ degrees/day (5) RATE OF MOTION

Divide 360° by (5): _____ days (6) PERIOD

Express the period in years: _____ years (7)

B. Period for Jupiter

1st conjunction of Jupiter on _____ (1) DATE

2nd conjunction of Jupiter on _____ (2) DATE

Interval between conjunctions: 1 year plus _____ days (3A)

= _____ days (3B)

Angle α , which equals (3A): _____ degrees (4) ANGLE MOVED

Divide (4) by (3B): _____ degrees/day (5) RATE OF MOTION

Divide 360° by (5): _____ days (6) PERIOD

Express the period in years: _____ years (7)

C. Period for Saturn

1st conjunction of Saturn on _____ (1) DATE

2nd conjunction of Saturn on _____ (2) DATE

Interval between conjunctions: 1 year plus _____ days (3A)

= _____ days (3B)

Angle α , which equals (3A): _____ degrees (4) ANGLE MOVED

Divide (4) by (3B): _____ degrees/day (5) RATE OF MOTION

Divide 360° by (5): _____ days (6) PERIOD

Express the period in years: _____ years (7)

2) Distance from the Sun (radius of orbit)

At conjunction Jupiter (or Mars or Saturn) will be lined up with the Sun as viewed from the Earth. At all other times it will be off to one side or the other of the Sun. The angle θ (see Fig. 4) between Jupiter and the Sun (as viewed from earth) is called the elongation and has a value of 90° when the line of sight from Earth to Jupiter is tangent (grazing) to the Earth's orbit, as drawn in Fig. 4. This configuration is called quadrature. The elongation reaches its maximum value, 180° , when the Earth passes between Jupiter and the Sun, a configuration called opposition.

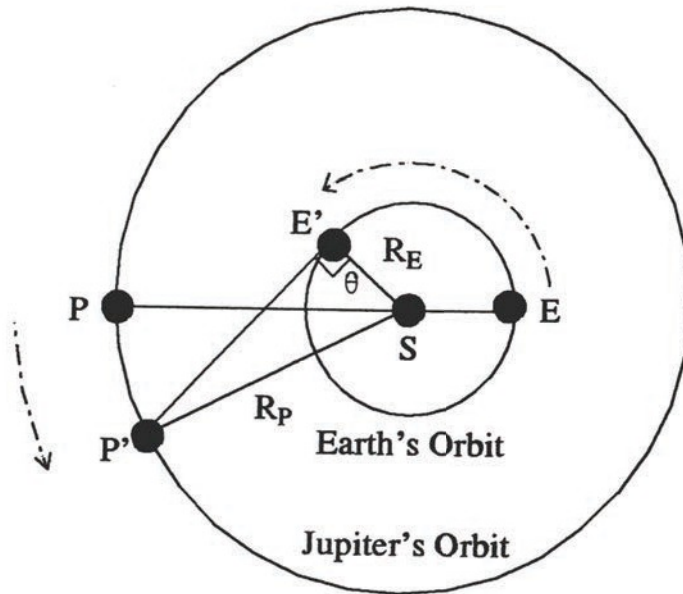


Fig. 4 Conjunction and quadrature of outer planet.

When Jupiter is at quadrature, the lines connecting it, the Earth, and the Sun form a right triangle, P'E'S, where the hypotenuse is Jupiter's distance from the Sun, R_P , and the short side is the Earth's distance, R_E . If we can determine the angle $E'SP'$, then we can calculate R_P in terms of R_E since they are all related by

$$\cos E'SP' = \frac{R_E}{R_P}$$

The angle $E'SP'$ can be determined from the following procedure. First, the dates of conjunction and quadrature must be measured in the planetarium. Then the time interval between conjunction and quadrature is calculated by subtracting the two dates.

Because Jupiter has moved from P to P', this interval between conjunction and quadrature is the same fraction of Jupiter's orbital period P that the angle $P'SP$ is of 360° , a whole orbit, so

$$\frac{\text{interval (in days)}}{P \text{ (in days)}} = \frac{\text{angle } P'SP \text{ (in degrees)}}{360^\circ}$$

Since we know P from the previous section and have just measured the interval between conjunction and quadrature, it is easy to compute angle $P'SP$.

Similarly, because the Earth has moved from E to E' in the time interval between conjunction and quadrature, this interval is the same fraction of Earth's orbital period (1 year) that the angle $E'SE$ is of 360° , a whole orbit, so

$$\frac{\text{interval (in days)}}{1 \text{ year (in days)}} = \frac{\text{angle } E'SE \text{ (in degrees)}}{360^\circ}$$

Since we know the length of the year and have just measured the interval between conjunction and quadrature, it is easy to compute angle E'SE .

Next, since the line PSE is a straight line, the angle PSE is 180° , so angle PSE' = 180° - angle E'SE. Now we can compute the desired angle E'SP' because angle E'SP' = angle P'SP + angle PSE'.

Then the right triangle P'E'S shows that

$$\frac{R_E}{R_P} = \cos E'SP'$$

which when inverted yields R_P in astronomical units (A.U.). That is,

$$R_P \text{ (in A.U.)} = \frac{R_P}{R_E} = \frac{1}{\cos E'SP'}$$

The same procedure can be followed for Mars and Saturn.

We will measure the dates of quadrature for Mars, Jupiter, and Saturn in the planetarium. Because it can be difficult to tell visually quadrature is reached, we measure the elongation angle on a series of dates, then inspect the data to find the date of 90° elongation, signifying quadrature.

To measure the elongation on a given date, record the date and the celestial longitudes of the Sun and planet on the ecliptic (the path they follow on the sky). The difference in celestial longitudes gives the elongation of the planet.

By inspecting the elongations measured in this way, you can locate the date of quadrature. Quadrature occurs when the elongation angle between the Sun and planet is 90° . Since the date of quadrature may not have fallen on a date of measurement, you will probably need to interpolate between the dates on which elongations were measured in order to determine the exact date of quadrature.

Since the planets' orbits are not perfect circles, the interval between conjunction and quadrature may depend on which side of the Sun the planet is on, *i.e.* it may be different when the planet is east of the Sun from when it is west of the Sun. To allow for this effect, we will measure the dates of quadrature both before and after the adjacent conjunction and average the two intervals (quadrature to conjunction and conjunction to quadrature) to determine the interval to be used in computing the radius of orbit.

Mars east of Sun
(quadrature before 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Mars</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Mars west of Sun
(quadrature after 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Mars</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Jupiter east of Sun
(quadrature before 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Jupiter</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Jupiter west of Sun
(quadrature after 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Jupiter</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Saturn east of Sun
(quadrature before 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Saturn</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Saturn west of Sun
(quadrature after 2nd conjunction)

<u>date</u>	<u>cel. long. of Sun</u>	<u>cel. long. of Saturn</u>	<u>elongation</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

A. Radius of Mars' orbit

Date of 2nd conjunction: _____ (1)
 Date of quad. before 2nd conj.: _____ (2A)
 Interval from quad. to 2nd conj.: _____ days (2B)
 Date of quad. after 2nd conj.: _____ (3A)
 Interval from conj. to 2nd quad.: _____ days (3B)
 Average of (2B) and (3B): _____ days (4) INTERVAL
 Orbital period P from earlier section: _____ days (5) P
 Angle P'SP: _____ degrees (6)
 Angle E'SE: _____ degrees (7)
 Angle PSE': _____ degrees (8)
 Angle E'SP': _____ degrees (9)
 Radius of orbit: _____ A.U. (10)

B. Radius of Jupiter's orbit

Date of 2nd conjunction: _____ (1)
 Date of quad. before 2nd conj.: _____ (2A)
 Interval from quad. to 2nd conj.: _____ days (2B)
 Date of quad. after 2nd conj.: _____ (3A)
 Interval from conj. to 2nd quad.: _____ days (3B)
 Average of (2B) and (3B): _____ days (4) INTERVAL
 Orbital period P from earlier section: _____ days (5) P
 Angle P'SP: _____ degrees (6)
 Angle E'SE: _____ degrees (7)
 Angle PSE': _____ degrees (8)
 Angle E'SP': _____ degrees (9)
 Radius of orbit: _____ A.U. (10)

C. Radius of Saturn's orbit

Date of 2nd conjunction: _____ (1)
 Date of quad. Before 2nd conj.: _____ (2A)
 Interval from quad. To 2nd conj.: _____ days (2B)
 Date of quad. after 2nd conj.: _____ (3A)
 Interval from conj. to 2nd quad.: _____ days (3B)
 Average of (2B) and (3B): _____ days (4) INTERVAL
 Orbital period P from earlier section: _____ days (5) P
 Angle P'SP: _____ degrees (6)
 Angle E'SE: _____ degrees (7)
 Angle PSE': _____ degrees (8)
 Angle E'SP': _____ degrees (9)
 Radius of orbit: _____ A.U. (10)

IV. Finding Kepler's Third Law

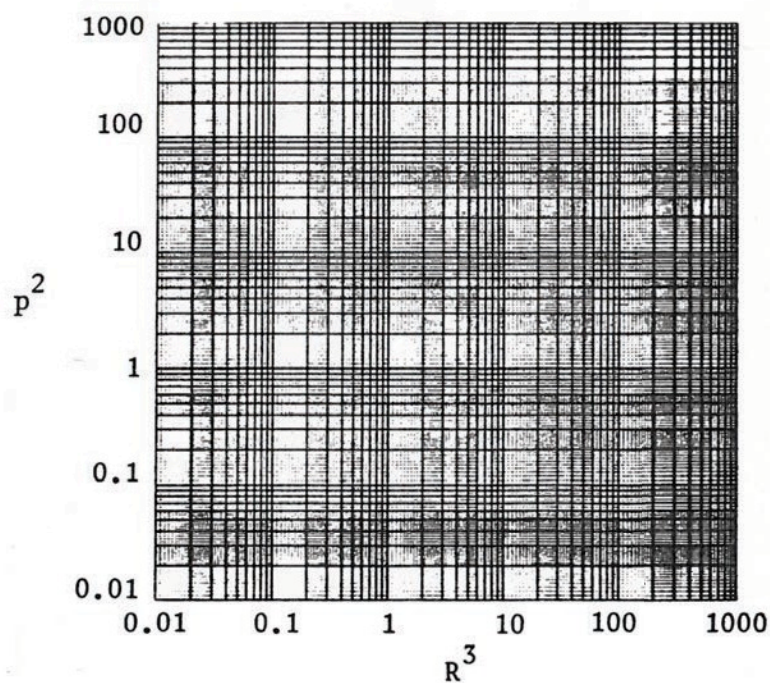
You have now measured the period (P) and orbit radius (R) for the five naked eye planets. Collect your results in the following table:

<u>Planet</u>	<u>P (in years)</u>	<u>R (in A.U.)</u>	<u>P²</u>	<u>R³</u>
Mercury	_____	_____	_____	_____
Venus	_____	_____	_____	_____
Earth	_____1_____	_____1_____	_____	_____
Mars	_____	_____	_____	_____
Jupiter	_____	_____	_____	_____
Saturn	_____	_____	_____	_____

Compare the values of P² and R³ for each planet.

Are they about the same? _____ If so, you have now re-discovered what Kepler first found almost four hundred years ago.

Next compare P² and R³ by plotting them on this graph.



Draw a smooth line through the points. If the line is straight, your data demonstrate Kepler's Third Law.

You can now use your values of P and R to gain some insight into comparative speeds of the different planets in their orbits. As you move outward from Mercury toward Saturn, both P and R increase. Which increases by a greater factor (*i.e.* by more times), P or R ? _____

What does this answer imply about the speed of a more distant planet compared with the speed of a planet nearer to the Sun? Explain your reasoning.

What does this result in turn demonstrate about the strength of the Sun's gravitational pull at different distances?

To Kepler, the relation between a planet's period and its distance from the Sun was a kind of mystic cosmic harmony. To us, it reflects that the motion of all the planets is controlled by just one force, the Sun's gravity, and helps reveal the effects of that force.

A STUDY ON VULNERABILITY, POWER, AND CONNECTION IN THE PLANETARIUM

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Abstract: In June 2018, I asked planetarians from the “Dome-L” Google Group and “The Dome Dialogues” Facebook Group to complete an anonymous, open-response survey. The survey included only three questions: “What makes you feel vulnerable when presenting to planetarium guests,” “What makes you feel powerful when presenting to planetarium guests,” and “In what ways do you feel connected with your audience?” The results were published in the September 2018 issue of *Planetarian* (Vol. 47, No. 3). In this paper I will summarize the results of the survey and discuss how they can open our eyes to personal struggle, responsibility, courage, and permissions.

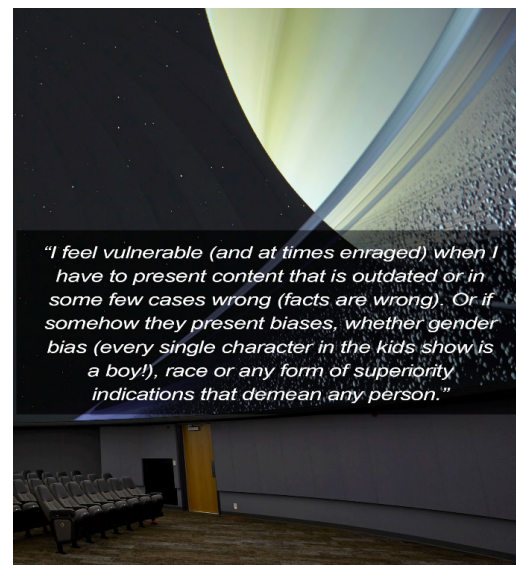
Introduction

In June 2018, I asked planetarians from the “Dome-L” Google Group and “The Dome Dialogues” Facebook Group to complete an anonymous, open-response survey through Google Forms. The survey included only three questions: “What makes you feel vulnerable when presenting to planetarium guests,” “What makes you feel powerful when presenting to planetarium guests,” and “In what ways do you feel connected with your audience?” If you did not respond to the survey, I recommend pausing here to answer the questions. Take your time.

What surprised me most about the survey responses was the honesty with which the questions were answered and the similarities between responses. Thank you to everyone who filled out the survey. I would love to talk to you about my own experiences with vulnerability, power, and connection, but this article is aimed at giving a voice to those who filled out the anonymous survey. Feel free to email, call, or talk with me in person and I promise to speak openly with you about the topic.

When the survey questions are asked separately, the responses can be informative and even enlightening. However, when asked together there are some interesting results. Many of the valuable survey responses appear throughout the article, but I encourage you to read through the full list of submissions here: <https://tinyurl.com/ycc8hvu5>. Note that some potential identifiers were removed, but the responses are otherwise left unaltered. In this article I will summarize the results of the survey and discuss how they can open our eyes to personal struggle, responsibility, courage, and permissions.

Vulnerability and personal struggle

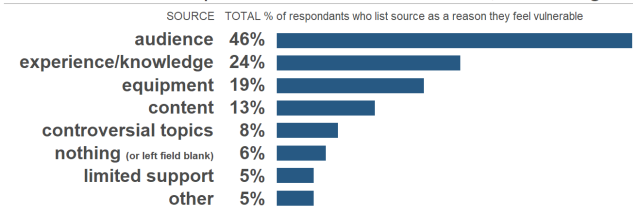


The first question of the survey asked, “What makes you feel vulnerable when presenting to planetarium guests? (This can be content that you present live, pre-recorded content that you’ve helped develop, or other types of content.)” Some may consider this a personal question; vulnerability is not something we often talk about as it is typically associated with weakness. After all, “vulnerable” is defined as “capable of being physically or emotionally wounded,” and “open to attack or damage” (2018). Think about the times when you feel most open to attack. For many people it is when we are exposed, especially in a public setting like when we speak in front of an audience, which is why it is not surprising that the fear of public speaking (glossophobia) is so wide-spread. In fact, an estimated 75% of people experience some degree of anxiety or nervousness with public speaking (Hamilton, 2008). To make matters worse for planetarians, we speak in our unique planetarium settings. Presenting in the planetarium offers its own anxiety-inducing effects with their specialized equipment,

room design, etc.

There were a total of 63 respondents (all planetarians in our community) who took the survey. Out of 63, three said “nothing” made them feel vulnerable when presenting to planetarium guests and one left the field blank. The other 59 respondents gave a range of responses that include some common sources that make them feel vulnerable when presenting to planetarium guests. These sources are summarized in **Table 1** and described in detail below.

Sources that make planetarians feel **vulnerable**, according to survey

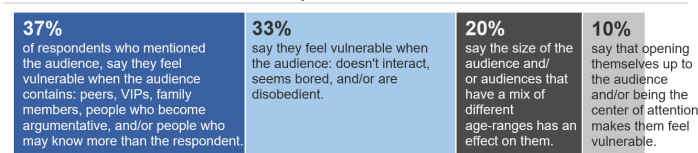


N = 63. Based on responses to the question, *What makes you feel vulnerable when presenting to planetarium guests? (This can be content that you present live, pre-recorded content that you've helped develop, or other types of content.)* Sources are based on submissions from an open-ended response survey conducted June 2018.

TABLE 1

Audience was mentioned most often (46% of respondents) as a source of vulnerability when presenting to planetarium guests. One respondent describes how the audience makes them feel vulnerable in their response: “When [guests] don’t laugh at my jokes, or ask purposefully misleading questions. I generally feel a little vulnerable the whole time, especially before the lights go off.” There were four main factors about the audience described in survey responses (see **Table 2**): threats (peers, VIPs, argumentative guests, etc.), distractions (bored/no interaction, disobedient), size (big/small, mixed audiences), and general (being the center of attention, opening themselves up to audience).

What about the audience makes planetarians feel **vulnerable**?



n = 29. Based on responses to the question, *What makes you feel vulnerable when presenting to planetarium guests?* Results are from submissions to an open-ended response survey conducted June 2018.

TABLE 2

Experience/knowledge affects 24% of respondents who say they feel vulnerable if: their knowledge in the content is weak, if they are presenting content that is new to them, if they do not know the answers to questions, and/or if they are unprepared. One respondent summarizes, “I feel like I can’t ever know enough.”

Equipment affects 19% of respondents either in equipment failures or difficulty running their equipment live: “Modern planetariums have multiple points of failure, from a computer crash to a bad pointer. Tap dancing while you solve a problem tops the list.”

Content affects 13% of respondents. This includes respondents who say they do not have certain content to display, showing outdated content, and/or showing content that contains bias: “I feel vulnerable (and at times enraged) when I have to present content that is outdated or in some few cases wrong (facts are wrong). Or if somehow they present biases, whether gender bias (every

single character in the kids show is a boy!), race or any form of superiority indications that demean any person.”

Controversial Topics make 8% of respondents feel vulnerable. This source could be included under “audience” as the responses are more about how the audience responds to these topics: “People in the audience who believe in religion and not science and are waiting to pounce if you mention big bang, age of universe, distance to objects.”

Nothing (or left field blank) includes 6% of respondents who said “nothing” made them feel vulnerable or left the field blank. One respondent modified the question: “Vulnerable is a strong word, so I don’t know about that, but what makes me uncomfortable as a presenter is...” Again, even in an anonymous survey vulnerability is difficult to talk about. All respondents who listed “nothing” for sources that make them feel vulnerable went on to list sources that make them feel powerful when presenting (Question 2 of survey).

Limited support includes 5% of respondents who mention their bosses: “...I always feel more vulnerable if my supervisor(s) have knocked me down mentally instead of lifting me up after achieving a goal. Makes me question my worth and if I’m doing right by my audience.” And also includes respondents who feel unsupported by visiting teachers with their school groups: “Teachers who insist on talking to the children before I start, especially if they tell the kids to be quiet and listen to me. That impacts my authority by implying that I’m not in full control of the space, and immediately frames my relationship with them in a way that works against how I would normally manage things. And above all it is more important to back up the teacher than to save the show, so I just smile and nod and thank them, which makes it worse.”

Other includes 5% of respondents, some of whom feel insignificant under the stars: “I look up at the night sky and I feel so small. Shows like ‘Journey to the Center of the Milky Way’ and its 84 million stars makes me feel small and vulnerable.” Other respondents said the time of day and/or fear that they will make a mistake may have an effect on them.

Power and responsibility



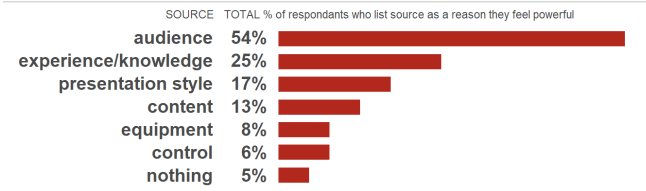
The words “power” and “powerful” come up a lot in discussions and publications. For instance, on Dome-L I found these words in 250 emails when searching back to December 2013.

“Vulnerability” on the other hand was found in eight emails, and five of those were regarding this survey. We see “power” when we learn about powerful technologies, whether it is regarding a new piece of equipment on the market or about the planetarium as a whole. Maciej Ligowski said that they “found the power of the immersive environment under the dome simply astounding” (2018). Torvald Hessel commented on the word Planetarium itself as “a powerful name that everyone understands” (personal communication via Dome-L, Jan. 27, 2015). Additionally, we frequently say that images or visuals are powerful and can elicit a range of emotional feelings. We talk about how astronomical phenomena such as supernovae, black holes, or dark energy are powerful.

Planetarians choose to use powerful technologies, say powerful words, create and use powerful visuals, etc. With every choice we affect someone; we are constantly influencing those around us. And yet, we sometimes pretend as if what we say and do has no effect on people. However, we do not live in a bubble. What we say and how we say it matters. The things we do, as well as the content we present, all have the power to influence and change people. We all have power. Each and every one of us—and with that comes amazing responsibility.

The second question on the survey asks, “What makes you feel powerful when presenting to planetarium guests?” Out of 63 respondents, three stated that “nothing” makes them feel powerful. The other 60 respondents gave a range of reasons as summarized in **Table 3** and described in detail below.

Sources that make planetarians feel **powerful**, according to survey



N = 63. Based on responses to the question, What makes you feel powerful when presenting to planetarium guests? Sources are based on submissions from an open-ended response survey conducted June 2018.

TABLE 3

Audience was mentioned most often (54% of respondents) as a source that makes them feel powerful when presenting. There were three main factors regarding “audience” that make the respondents feel powerful: verbal/non-verbal feedback (79%), influence (18%), and connection (3%). One response that falls under verbal/non-verbal feedback is: “An interactive audience that laughs at my joke and responds to the information I give.” Another respondent summarized how their influence makes them feel powerful: “When a guest reveals I have shifted a part of their worldview.” One respondent said their connection with the audience was empowering: “When presenting Taurus in live sky tours, I overlay the Lascaux bull to demonstrate how that we interpret those stars the same way as people did 17,000 - 30,000 years ago, arguably one of the oldest cultural traditions we share. It is empowering to show people a connection with such ancient ancestors.”

Experience/knowledge was mentioned by 25% of respondents who say they feel powerful if their knowledge of the content is strong, if they have experience presenting on the content, if they

are able to answer questions, and/or if they are familiar with their planetarium system: “Knowing that I have enough background information on the topic to answer more in-depth questions and a list of resources for them to do their own research on the VERY in-depth questions.”

Presentation Style is credited by 17% of the respondents: “Presenting the night sky in a way that evokes awe, wonder, and curiosity.”

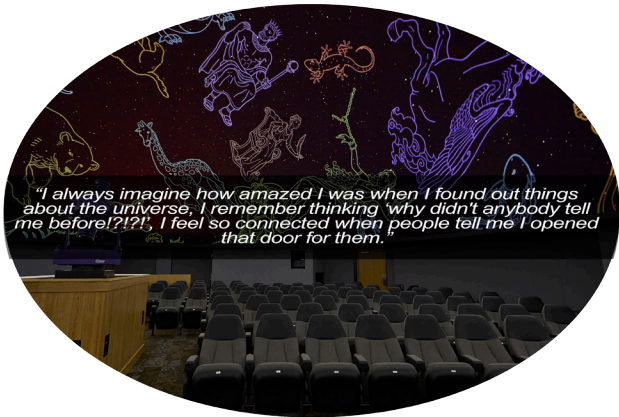
Content that amazes makes 13% of respondents feel powerful when presenting. For example, one respondent said they “feel powerful operating a highly flexible, accurate, and responsive full dome operating system where real data and images are programmed into its 3D database, permitting [them] to take audiences on a journey through space and time.”

Equipment that is reliable, responsive, flexible, etc. makes 8% of respondents feel powerful; even if it is just one respondent’s “laser pointer.”

Control was listed by 6% of respondents who said that being able to control the content, lights, etc. and/or having everyone listening to them is powerful: “The power of light and dark. Not only do you control the universe, you can instantly stop the show and bring the lights up if you need to address issues of behavior. It isn’t a movie that just runs. Back to controlling the universe—what more can you ask than that?”

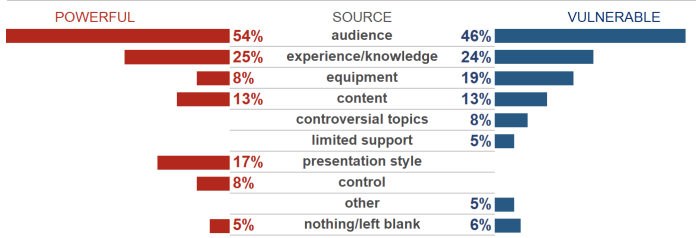
Nothing was listed by 5% of respondents: “I have no wish to feel powerful.”

Connection and courage



I feel that it is important to pause here before addressing survey question 3, “In what ways do you feel connected with your audience?” Let’s first compare the responses to questions 1 and 2, set side-by-side in **Table 4**. “Audience” was the top source listed for both questions. Additionally, experience/knowledge, equipment, and content are also shared popular responses.

Sources that make planetarians feel **powerful** compared to sources that make them feel **vulnerable**, according to survey



N = 63. Based on responses to the question, *What makes you feel powerful when presenting to planetarium guests?* Sources are based on submissions from an open-ended response survey.

N = 63. Based on responses to the question, *What makes you feel vulnerable when presenting to planetarium guests?* Sources are based on submissions from an open-ended response survey.

TABLE 4

The audience has the ability to make us feel vulnerable, but also powerful. Which of these feelings comes first, vulnerability or power? Consider one respondent's summary of presenting: "I think the presentation process is innately vulnerable, one is exposing oneself and one's passions to a potentially critical audience." Yet, we present anyway. Vulnerability precedes feelings that are brought out in the presentation process. We may think of our vulnerabilities as weaknesses, but does the outside world see them the same way? According to research professor and author Dr. Brené Brown, the audience is not seeing your weaknesses when presenting. They instead see your courage. She states that "vulnerability is our most accurate measurement of courage" (2012b). Dr. Brown goes on to say that "vulnerability is the birthplace of innovation, creativity, and change" (2012a, p. 71). We are courageous for presenting and opening ourselves up to our audiences, and when we do this, we open ourselves up to many feelings (including power) but more importantly we open ourselves up to connection.

Let us now review the responses to question #3: "In what ways do you feel connected with your audience?" I divided the responses into two categories: verbal/non-verbal feedback (83%) and shared experiences (41%).

Under the category *verbal/non-verbal feedback*, respondents list getting questions (33%), hearing friendly laughter (13%), making eye contact, "wows," smiles, etc. as ways they feel connected: "When my sense of humor is well received and creates a sense of comfort and enjoyment by the audience. When people feel comfortable enough to ask questions during or after the program." Also, "It's always the interaction—during a live talk if possible and certainly the questions after the talk. Back 20 years ago I had experiences where I've stayed around talking with people after the show often for times longer than the talk itself. I've given astronomy texts away to interested members of the audience, I've used telescopes with people and I even once taught a troop of girl scouts how to use star charts—not just simple star-finders."

For the category *shared experiences*, 23% of respondents gave answers that I labeled as "togetherness in space": "We are all traveling this road together. One planet," "We are all humans in a gigantic universe," "We are earthlings exploring together, full of wonder about our universe," "[W]e are joint participants on our journey through the universe." Respondents also said that sharing similar interests and backgrounds makes them feel connected to their audience: "Humanity has always used the night sky to ask big

questions. Not to mention the sky is the same over large parts of the Earth. It transcends national boundaries, ethnic backgrounds and petty differences. Running the planetarium we have the opportunity to show our visitors 'the big picture.'" This also includes more personal shared experiences: "I became interested in astronomy because of the planetarium, I see a reflection of myself whenever I see an excited guest in the audience."

Conclusion and permissions

I created the survey on vulnerability, power, and connection because I am interested in how people *feel* when presenting planetarium programs. Discussing and bringing these feelings out of the dark planetarium seems important. We talk a lot about developing live, interactive, and/or lasting presentations by using certain presentation techniques, visuals, or activities; however, we do not often discuss how our personality and feelings play a large role in the creation process. Let's look back on vulnerability. We saw above how vulnerability can be seen as courage; when we are vulnerable, we open ourselves up to be seen by our audience. This elicits feelings of power. In turn, feelings of power can help people connect with others (Anderson & Berdahl, 2002). The willingness to be vulnerable, to reveal ourselves to our audiences, shows our authentic selves and opens up avenues for connection.

"Staying vulnerable is a risk we have to take if we want to experience connection."

— Brené Brown, *The Gifts of Imperfection: Let Go of Who You Think You're Supposed to Be and Embrace Who You Are*

Connection begins with vulnerability. One respondent notes this: "I feel the most connected with my audience at the end of the presentation when answering questions even though it is one of the most nerve wracking portions of a show for me. This is because I have the opportunity to discuss with the audience any additional information they may want to know about what was seen in the show or astronomy in general." Recognizing our vulnerabilities is valuable, but be careful of the spotlight effect—the feeling that people are paying more attention to you than they actually are (Gilovich, Medvec, & Savitsky, 2000). Embrace and be aware of your vulnerabilities but do not dwell on what your audiences may, or more likely may *not*, think of you.

It is clear we value connections with our audiences, especially when we put ourselves through "nerve wracking portions" of programs to make lasting impressions. Furthermore, every survey respondent answered the question on connection. It seems that people are comfortable connecting with others and sharing those feelings or experiences. However, with 5-6% of respondents not answering the first two questions on feelings of vulnerability and power, do people feel truly comfortable with themselves? In order to connect, we need to be authentic. Remind yourself that the audience does not want to see perfection, they want to see confidence, which can stem from this authenticity (Gudykunst & Nishida, 2001; Young & Kacmar, 1998). When presenting or just going through life, be yourself and turn any anxious energy into excitement. Repeating a mantra ("I am excited to share my space knowledge today") is a great way to help with this.

There is much more that can be said to help people to look inward to create better planetarium experiences, for the presenter and the guests, than what is included in this article. I hope that sharing these experiences of vulnerability, power, and connection helps in this endeavor, and that it gives you the permission to feel vulnerable, the permission to feel powerful, and the permission to make connections in your world.

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Acknowledgments

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JUPITER-SATURN 12-21-2020: T MINUS TWO YEARS AND COUNTING...START WATCHING NOW!

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Abstract: Using Digistar 6, we will follow Jupiter and Saturn at dawn and dusk in 2019-2020, and preview the beautiful planetary conjunctions leading up to December 21, 2020, the closest pairing of these two giant planets between 1623 and 2080. Among the most impressive groupings with Jupiter-Saturn will include Venus at dawn in Jan.-Feb. 2019, Venus at dusk in Nov.-Dec. 2019, and Mars at dawn in March 2020.

In 2019 and 2020, the impressive showpiece planets Jupiter and Saturn will be separated by no more than 31° in July 2019, and as little as 0.1 degree during their spectacular close pairing on the evening of December 21, 2020. The tight pair will appear 30 degrees east of the Sun, and set more than two hours after sunset.

In this program, we display sequences of daily all-sky views following Jupiter and Saturn in the planetarium dome, with brief stops to observe conjunctions with Moon and with other planets, from first morning appearance to last evening appearance of Jupiter's 2019 and 2020 apparitions. In each day's scene, we represent the sky at dawn or dusk "mid-twilight", defined as the moment the Sun is 9 degrees below the horizon. From latitude 40 degrees north, a solar depression of 9 degrees occurs 43 to 53 minutes before sunrise or after sunset, the time interval depending on time of year. For planet-watchers, mid-twilight is a convenient time to wrap up the morning sessions, or to begin evening observing sessions.

The program is divided into four chapters, each covering just over 6 months of sky events. Chapter One follows Jupiter from the date of its first appearance above the eastern horizon at dawn in December 2018, until the planet hovers just above the western horizon at dawn nearly two weeks after Jupiter's June 10, 2019 opposition. Chapter Two switches to the evening sky and begins nearly two weeks before the same opposition, with Jupiter just risen above the eastern horizon at dusk. The second chapter then follows the planet's progress at dusk until just before its disappearance into the western twilight glow before the solar conjunction of December 27, 2019.

The third and fourth chapters follow Jupiter's next apparition in 2020 in a similar way.

This 10-minute program zips through the sky events at a pretty fast rate. If you adapt it for public use, slow it down! (Digistar users can download this demo from the Digistar Cloud. A YouTube version will be available by late 2018; email John French frenchj@msu.edu for the link information.)

Ready? Here we go!

Chapter One: Morning sky, December 2018 through June 2019

We begin with the morning sky on December 10, 2018, with a spectacular display of planets in the southeast: Venus near greatest brilliancy, brightening Mercury lingering 13° to its lower left for five mornings, and Jupiter just rising 9° lower left of Mercury. Mercury at inferior conjunction overtook Earth just 13 days ago on Nov. 27, and Venus did so a month earlier, on Oct. 26. Both planets are still on the near side of their orbits until greatest elongation—Mercury for five more days until Dec. 15, and Venus for 27 more days until Jan. 6, 2019. Spaceship Earth is heading toward western Virgo as we follow our orbit around the Sun (point to the place on the ecliptic 90° west of Sun, 8° W of Beta Vir if the motion hasn't started yet). As we look daily at the same stage of twilight, with Sun 9° below the horizon—you can see the twilight glow in this direction to the left of the planets—Mercury and Venus, inner planets, are moving faster and so are pulling ahead of us, and will eventually go around to the far side of the Sun. Jupiter is already on the far side of the Sun and so we are catching up with it until we'll pass between Jupiter and Sun six months from now, on June 10, 2019. Jupiter will then appear in opposition, 180° from the Sun.

Here in December 2018, we see Mercury passing less than a degree north of Jupiter on the 21st. Note the star Antares emerging 5° - 6° to the south (lower right) of the planet pair. On Dec. 22, the Full Moon shows up in WNW at opposition near the Tau-Gem border. Follow the Moon daily, watching it pass the bright zodiacal stars Pollux, Regulus, Spica. Each time the Moon passes Last Quarter phase (half full in the morning sky) it cuts across the path of Spaceship Earth about $3\frac{1}{2}$ hours before we'll get there. New Year's morning of 2019 greets us with a beautiful conjunction of Venus and the crescent Moon. On the next three mornings through Jan. 4, watch the waning Moon slide downward—sunward—past Antares, Jupiter, and Mercury. On its way toward superior conjunction, Mercury drops out of view a day or two after the old Moon passes by. Venus passes 8° N of Antares on Jan. 17, and appears within 4.5° from Jupiter—one Pollux-Castor separation—

on Jan. 18-26. On Jan. 20, we'll see the nearly Full Moon below those Twin stars in WNW, and on Jan. 21 we'll catch the bright Full Moon a few hours after a total lunar eclipse. On Jan. 22 we'll see Venus passing 2.4° N of Jupiter, with Saturn 28° to their lower left (Saturn having emerged just a few days earlier). The waning Moon leapfrogs Regulus Jan. 22-23, passes N of Spica Jan. 26, Antares-Jupiter on Jan. 30, and Venus in a close conjunction on Jan. 31. The thinning Moon is about midway between Venus and Saturn on Feb. 1, and closely lower left of Saturn on Feb. 2.

Venus is nearly halfway from Jupiter toward Saturn on Feb. 5, 13° - 14° from each. On Feb. 18, Venus passes 1.1° N of Saturn, with Jupiter 26° to their west. Here comes the Moon around again. Note you can tell we're viewing the morning sky, from the twilight glow in the east, or by the waning Moon, illuminated from the Sun below the horizon in the east. On Feb. 26-March 2, watch Moon pass Antares, Jupiter, Saturn, Venus. Old Moon is still easy to see, lower left of Venus on March 3, but hard to see on March 4. Jupiter-Saturn reach [a temporary] minimum distance apart of just under 26° on March 21.

Moon comes around again, passing Jupiter and Saturn March 26-29, and Venus on April 2. Mercury reappears, and stays less than 5° lower left of Venus Apr. 11-23, and gets as close as 4.3° on Apr. 16. Neither planet passes the other, so this is a *quasi-conjunction*, as defined by mathematical astronomy author Jean Meeus. But it's within a poor, low apparition of Mercury from mid-northern latitudes, because the ecliptic makes a shallow angle with the horizon at dawn this time of year.

The Moon returns, passing very close to Jupiter on Apr. 23, Saturn on Apr. 25. Notice each time the Moon sweeps by the outer planets, it's at an earlier phase. On May 1, Venus is 13° lower left of the crescent Moon. Their conjunction occurs on May 2, but the Moon won't rise until after mid-twilight.

Moon comes around again, sweeping through the Jupiter-Saturn region May 20-23, and landing 6° right of Venus on June 1.

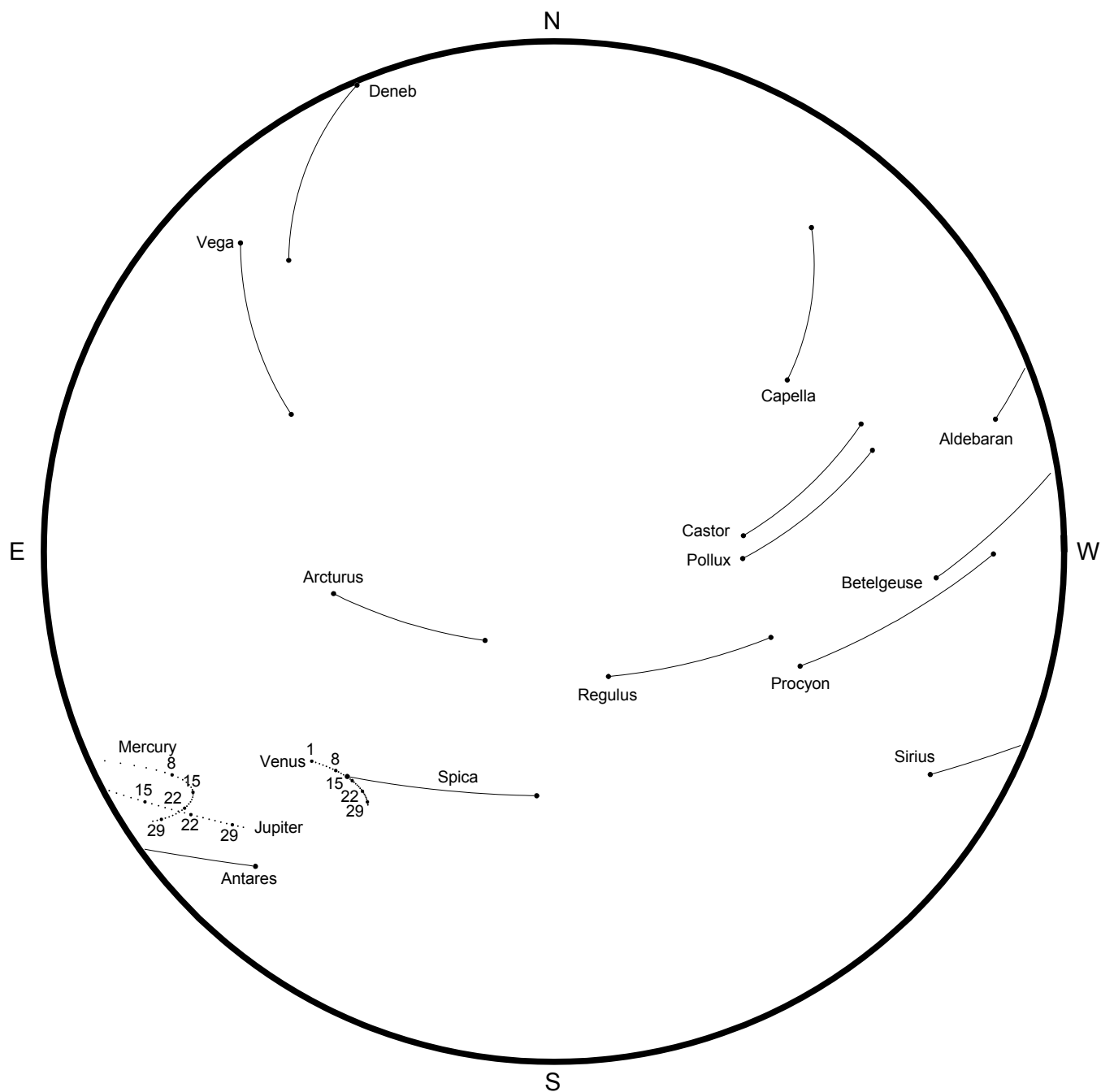
Jupiter is at opposition to the Sun on June 10, as Earth passes between that planet and the Sun.

Moon reappears lower right of Jupiter on June 16, and Full, upper left of Jupiter, on June 17. On June 18, Moon is 10° right of Saturn, and on the 19th, 3° left of Saturn.

On June 23, 13 days after its opposition, we see Jupiter just above the WSW horizon with Saturn nearly 31° to its upper left, and Venus just above the opposite horizon.

Planets and Bright Stars in Morning Mid-Twilight For December, 2018

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

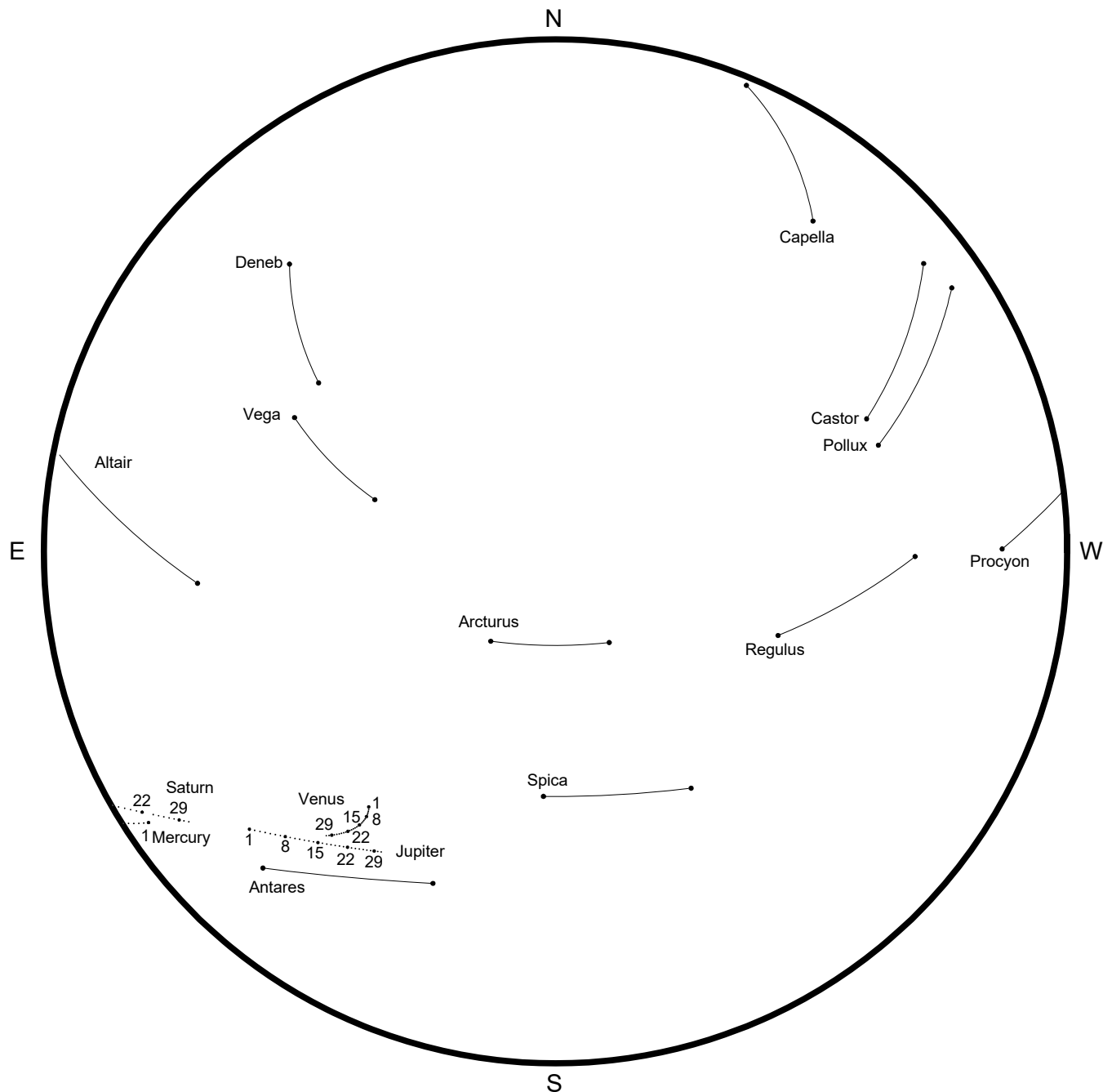


Morning mid-twilight occurs
when Sun is 9° below horizon.
Dec. 1: 47 minutes before sunrise.
15: 47 " " "
31: 47 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For January, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

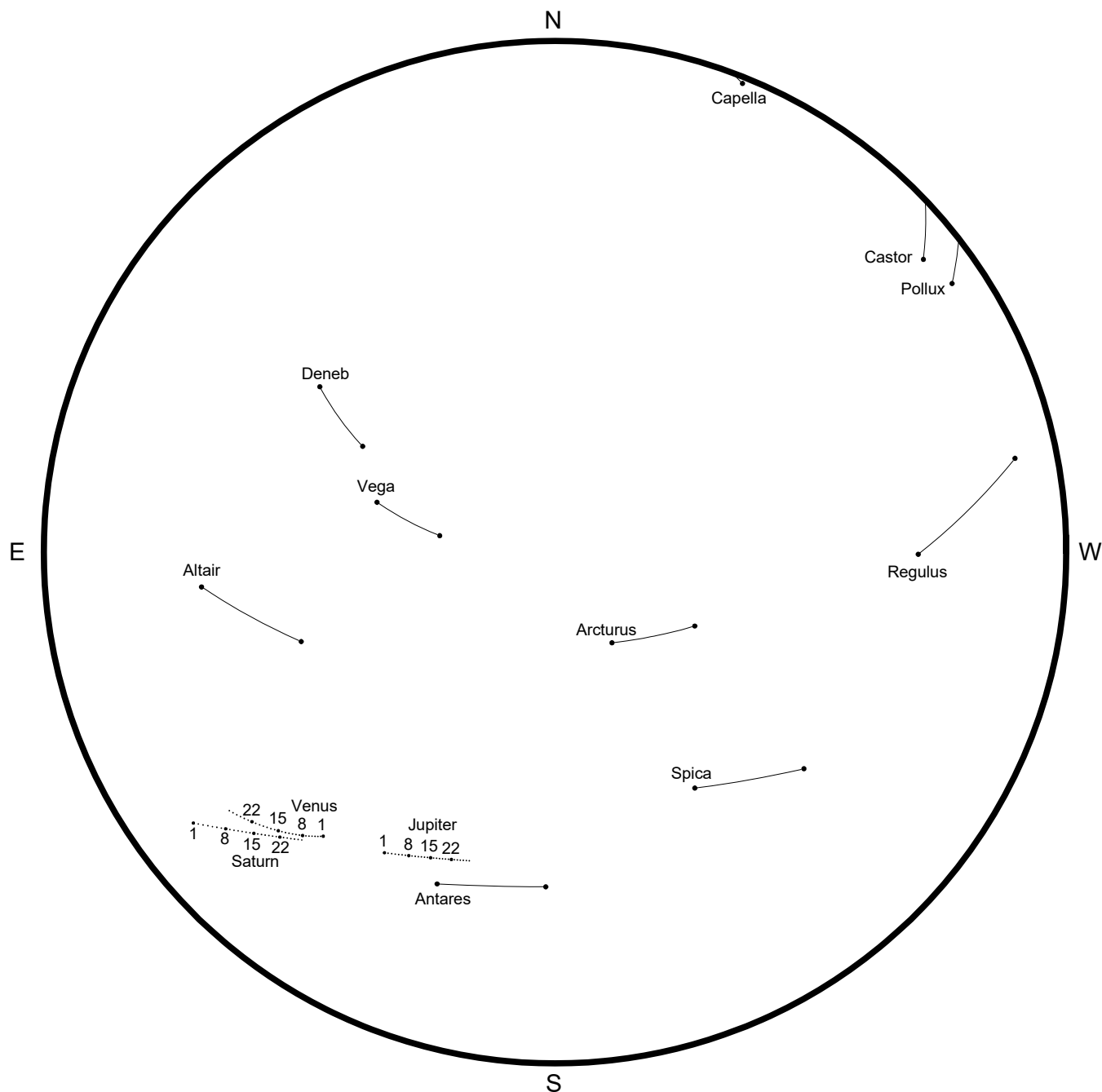


Morning mid-twilight occurs
when Sun is 9° below horizon.
Jan. 1: 48 minutes before sunrise.
15: 47 " " "
31: 45 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For February, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

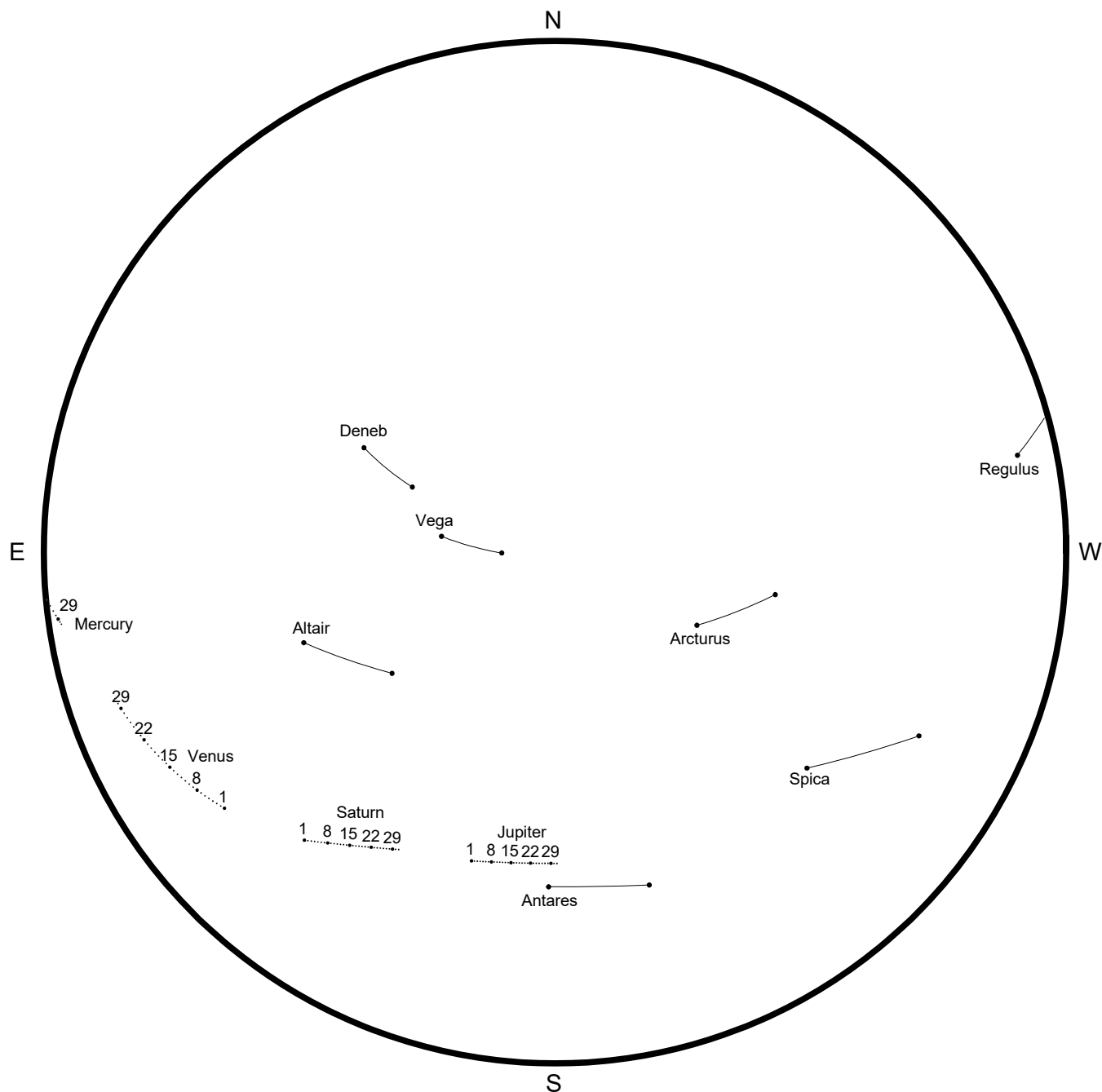


Morning mid-twilight occurs
when Sun is 9° below horizon.
Feb. 1: 45 minutes before sunrise.
15: 44 " " "
28: 43 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For March, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

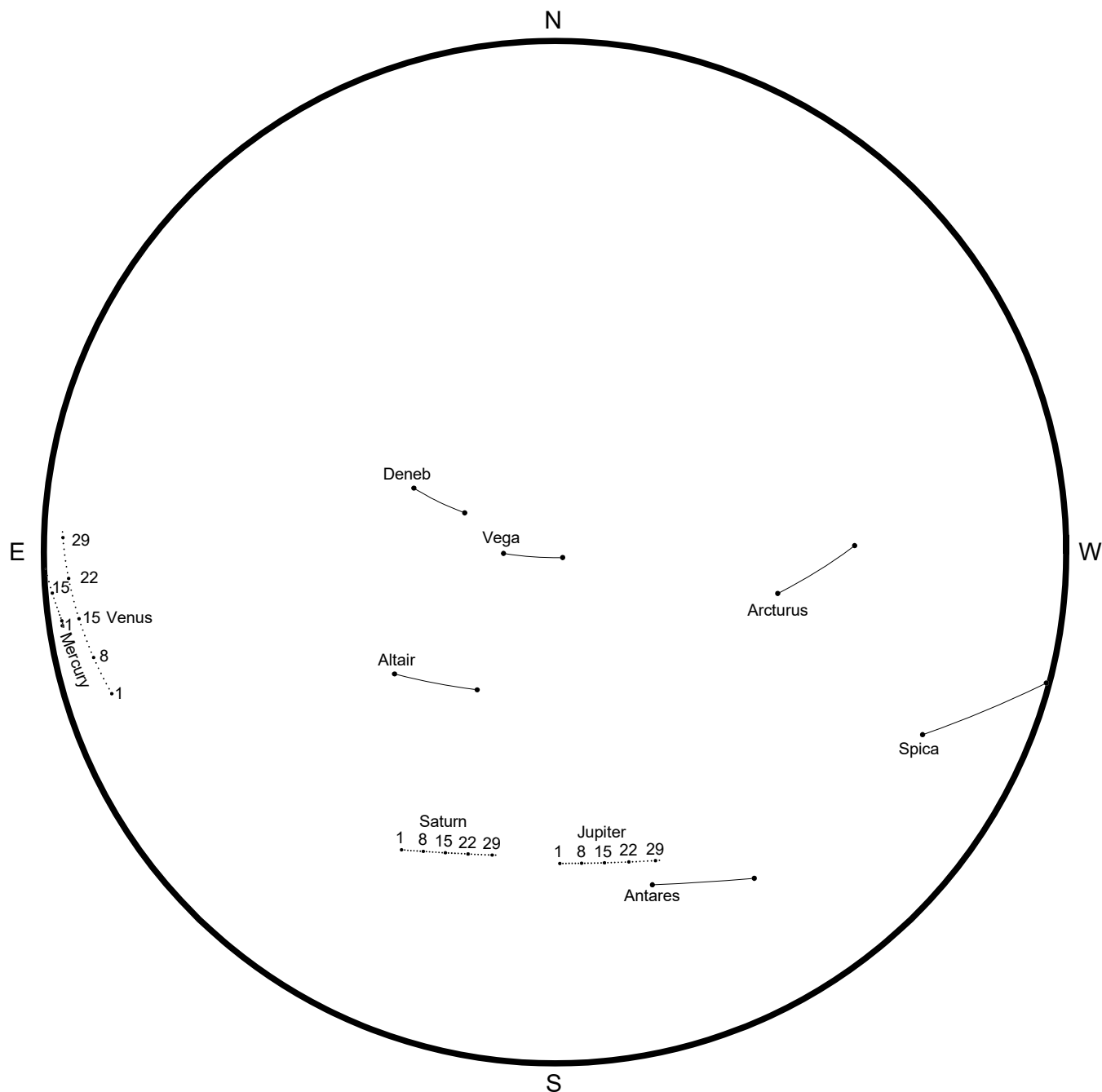


Morning mid-twilight occurs
when Sun is 9° below horizon.
Mar. 1: 43 minutes before sunrise.
15: 42 " " "
31: 43 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For April, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

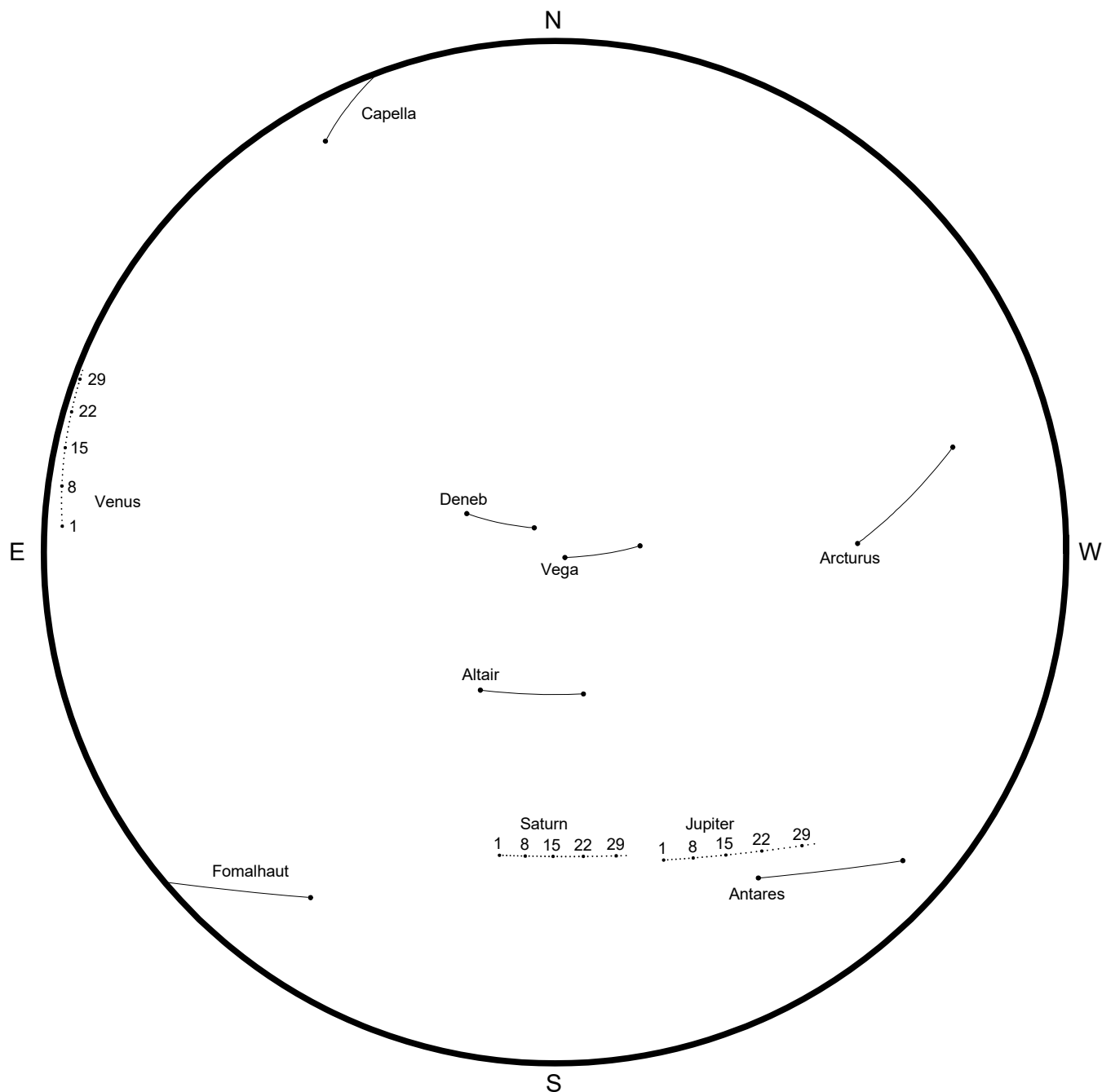


Morning mid-twilight occurs
when Sun is 9° below horizon.
Apr. 1: 44 minutes before sunrise.
15: 45 " " "
30: 47 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For May, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

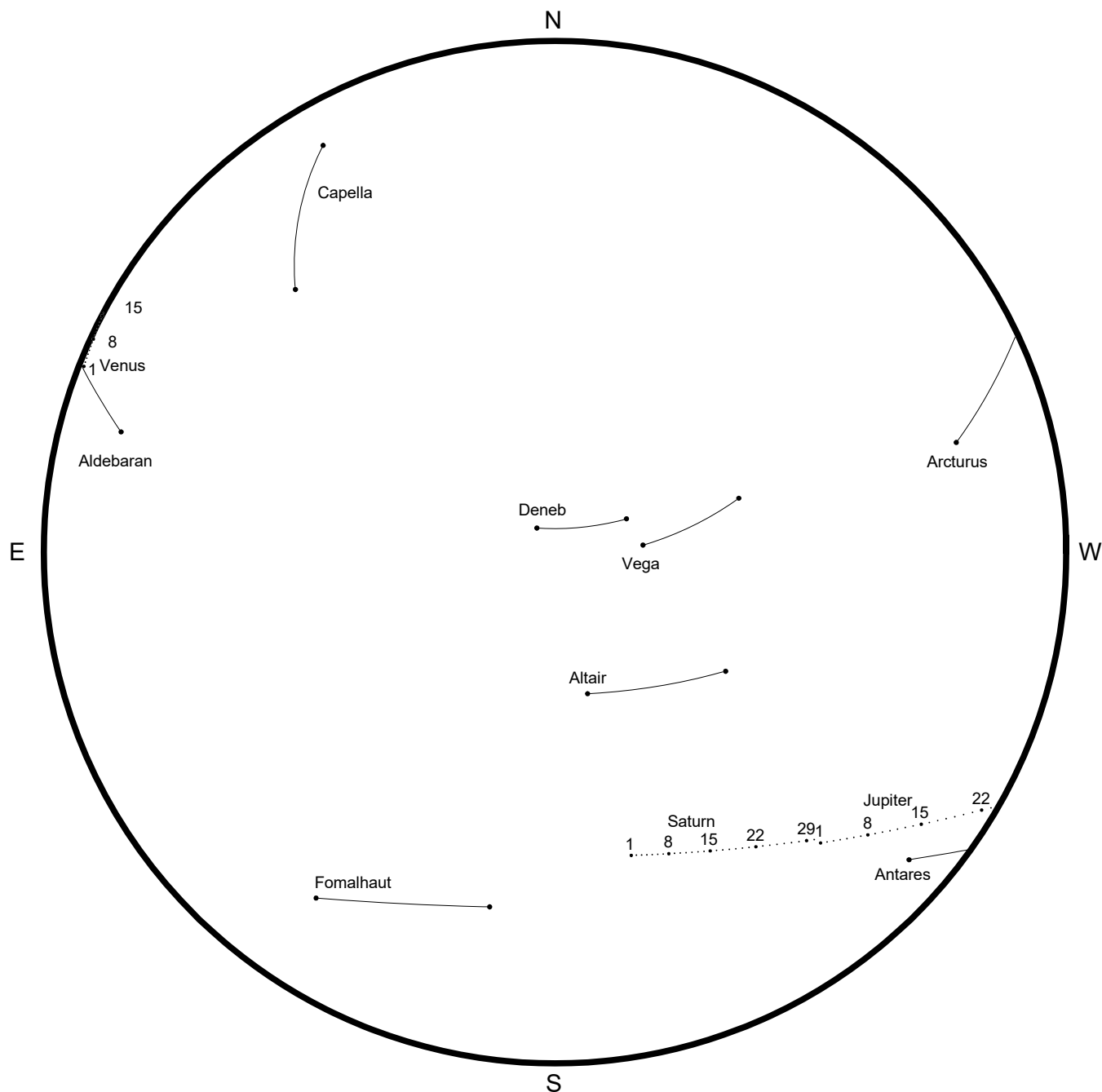


Morning mid-twilight occurs
when Sun is 9° below horizon.
May 1: 47 minutes before sunrise.
15: 49 " " "
31: 52 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For June, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.



Morning mid-twilight occurs
when Sun is 9° below horizon.
June 1: 52 minutes before sunrise.
15: 53 " " "
30: 53 " " "

Stereographic Projection
Map by Robert D. Miller

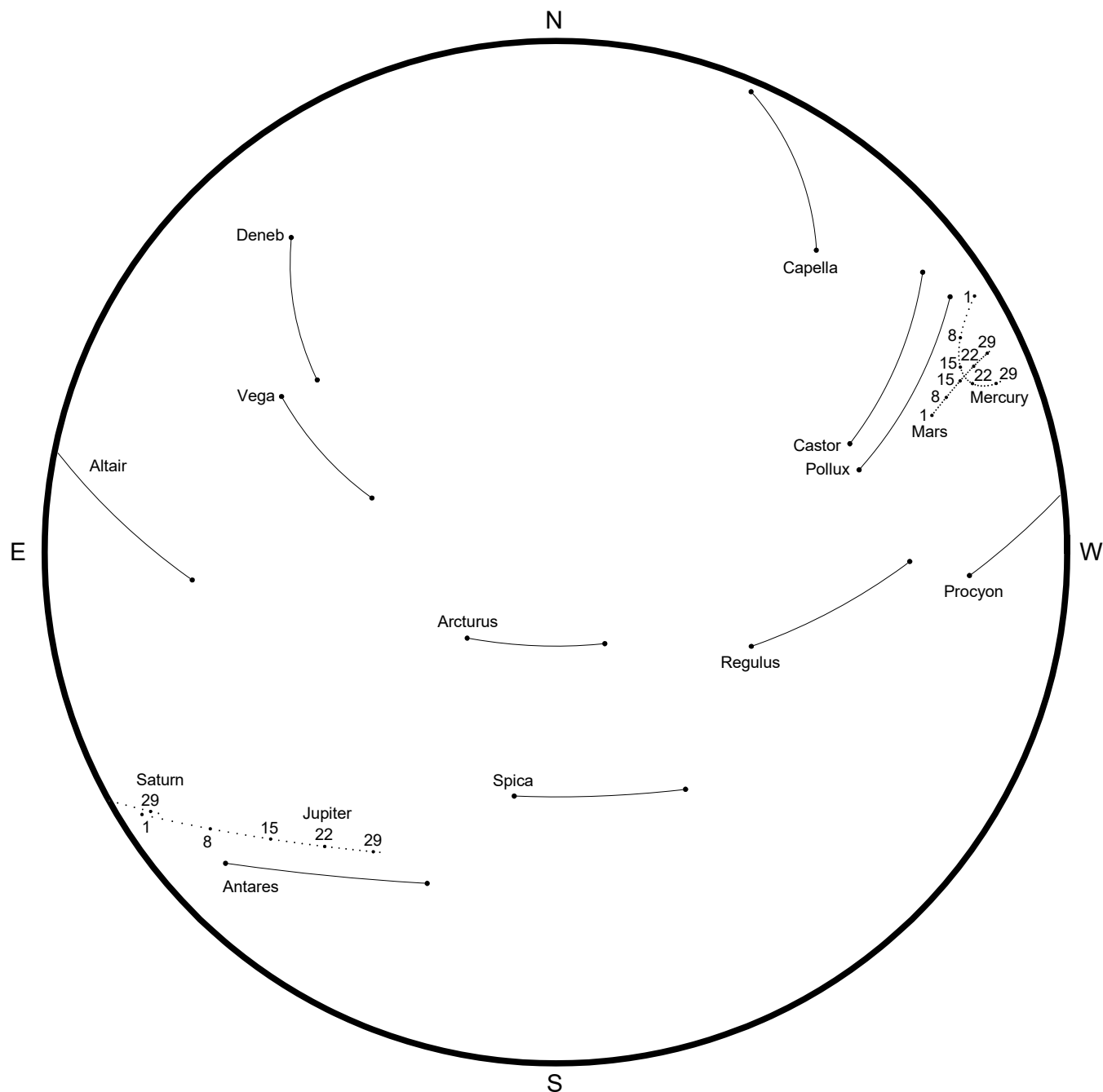
Chapter Two: Evening sky, June through December 2019

We begin our sequence of views at dusk not in June, but on May 30, 2019, 11 days before Jupiter's opposition, with Jupiter just risen in ESE, and Mercury just above horizon in opposite direction, WNW. Faint Mars, near the end of its apparition centered on the brilliant perihelic opposition and close approach of July 2018, is 19° upper left of Mercury. The innermost planet is emerging from the far side of the Sun and climbs higher each evening, while Mars sinks lower. Jupiter reaches opposition on June 10, the Moon sweeps by it on the 16th. A quick glance toward the west catches Mercury passing just 0.3° from Mars on June 18. Saturn appears 1° up, 31° lower left of Jupiter on June 25, two weeks before Saturn's opposition on July 9. Moon appears near Jupiter on July 13 and near Saturn on the 15th. Next times around, Moon passes the two giant planets at intervals of about 27 days, on August 9-11, September 5-8, and Oct. 3-5, each pass with Moon at an earlier phase. During October, Mercury appears in

WSW, but stays very low. Venus soon appears and slowly climbs past Mercury as the innermost planet falls back below the horizon. During Oct. 29-Nov. 1, a thin crescent Moon climbs past Venus, Jupiter, and Saturn. In late November, for the second time in 2019, Venus forms an attractive pairing with Jupiter. They're within 5° for ten evenings, Nov. 19-28, with closest approach on Nov. 23-24, as Venus passes 1.5° S of Jupiter. Saturn is 19° east (upper left) of the Venus-Jupiter pair on Nov. 24. Moon passes Jupiter, Venus, Saturn Nov. 27-29, and next, Venus is about midway between the giants Dec. 2-3. We conclude this evening series on Dec. 10, as Venus passes 1.9° S of Saturn, with Jupiter about to set 17° west (lower right) of the pair, before Jupiter's solar conjunction 17 days later. Recall we saw Venus overtake Jupiter and Saturn twice in 2019, at dawn on Jan. 22 and Feb. 18, and now ten months later at dusk on Nov. 24 and Dec. 10.

Planets and Bright Stars in Evening Mid-Twilight For June, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

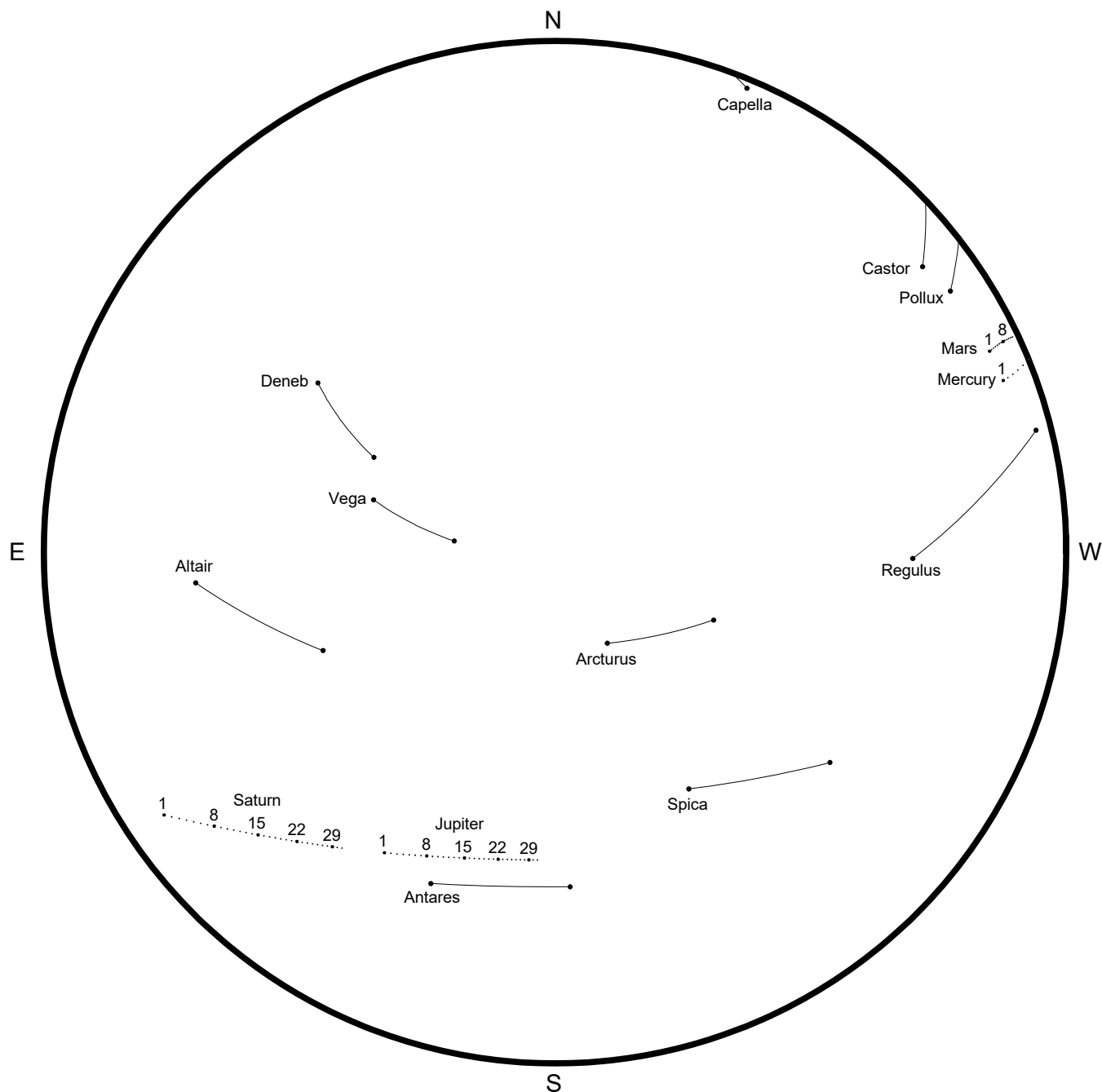


Evening mid-twilight occurs
when Sun is 9° below horizon.
June 1: 52 minutes after sunset.
15: 53 " " "
30: 53 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For July, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

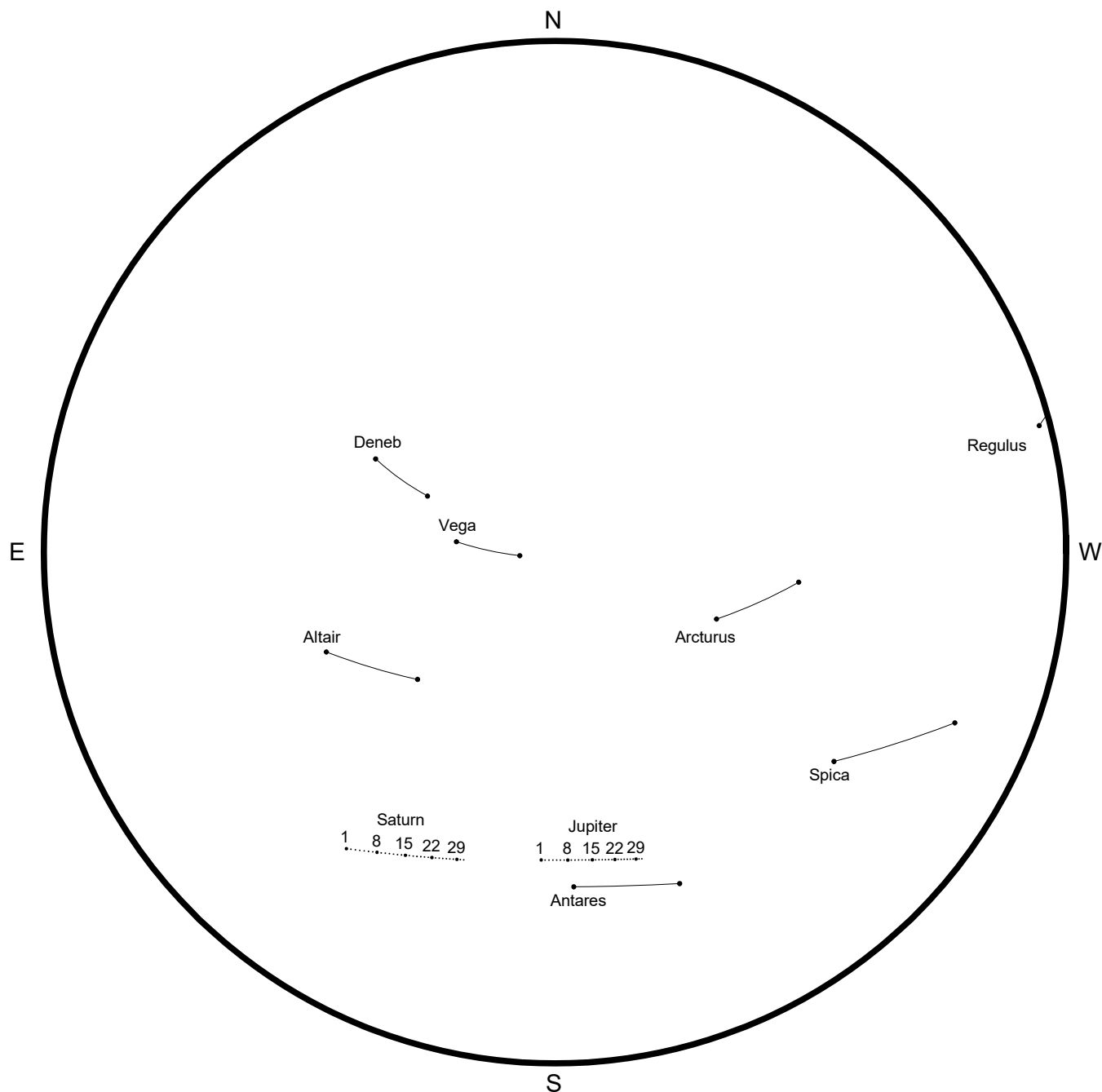


Evening mid-twilight occurs
when Sun is 9° below horizon.
July 1: 52 minutes after sunset.
15: 51 " " "
31: 48 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For August, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

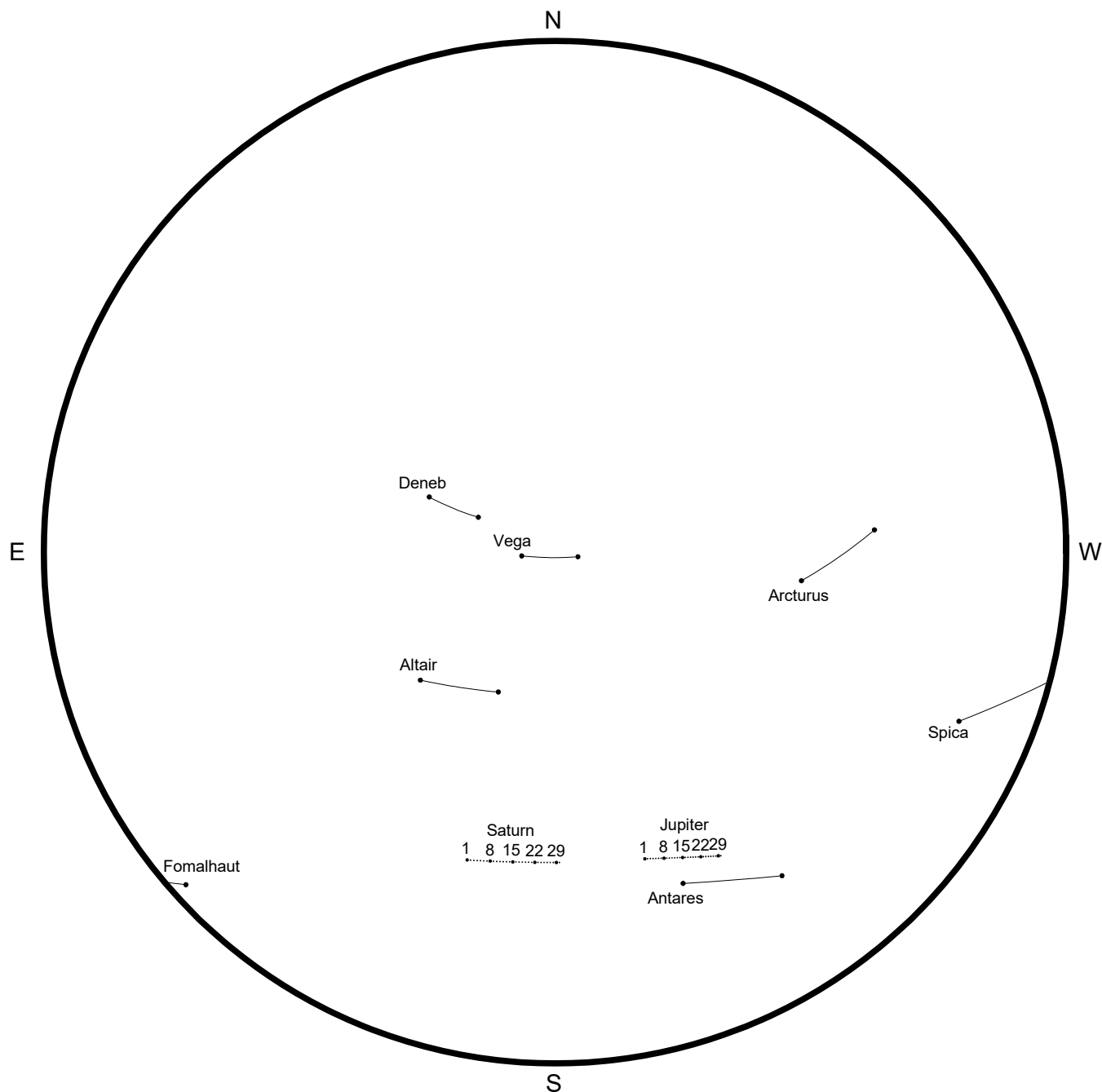


Evening mid-twilight occurs
when Sun is 9° below horizon.
Aug. 1: 48 minutes after sunset.
15: 46 " " "
31: 44 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For September, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.



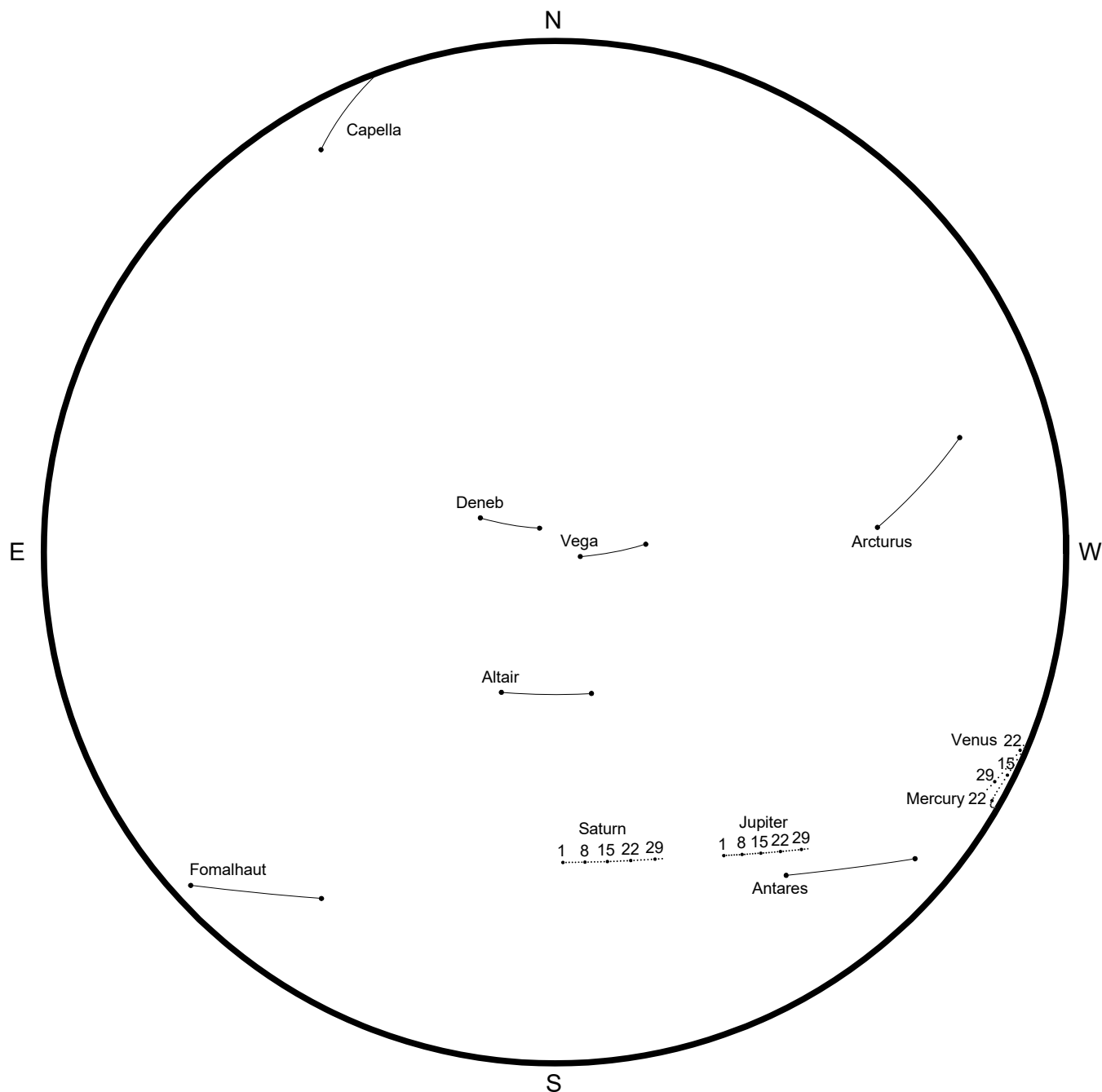
Evening mid-twilight occurs
when Sun is 9° below horizon.
Sept. 1: 45 minutes after sunset.

15: 43 " " "
30: 42 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For October, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

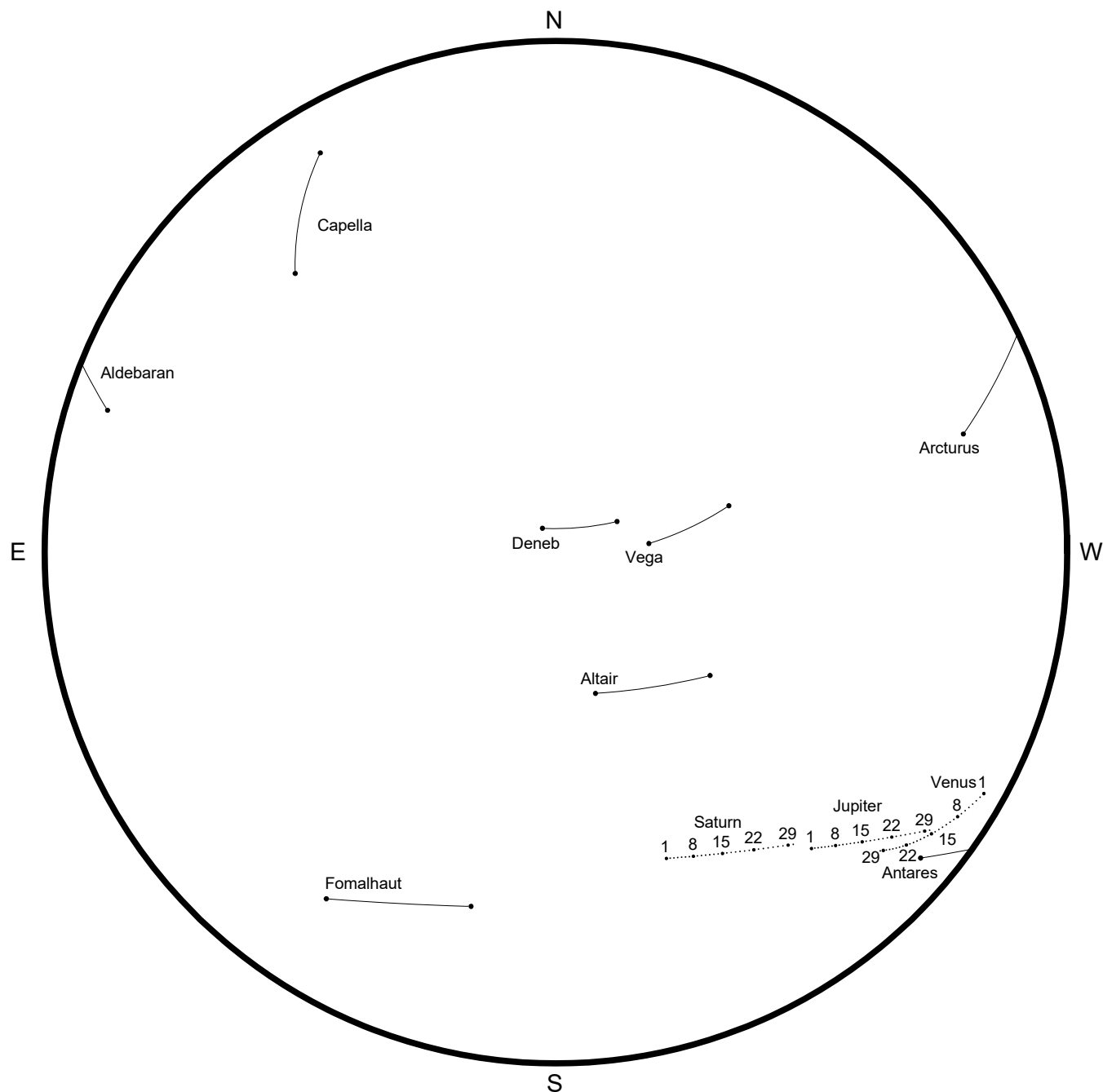


Evening mid-twilight occurs
when Sun is 9° below horizon.
Oct. 1: 43 minutes after sunset.
15: 43 " " "
31: 44 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For November, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

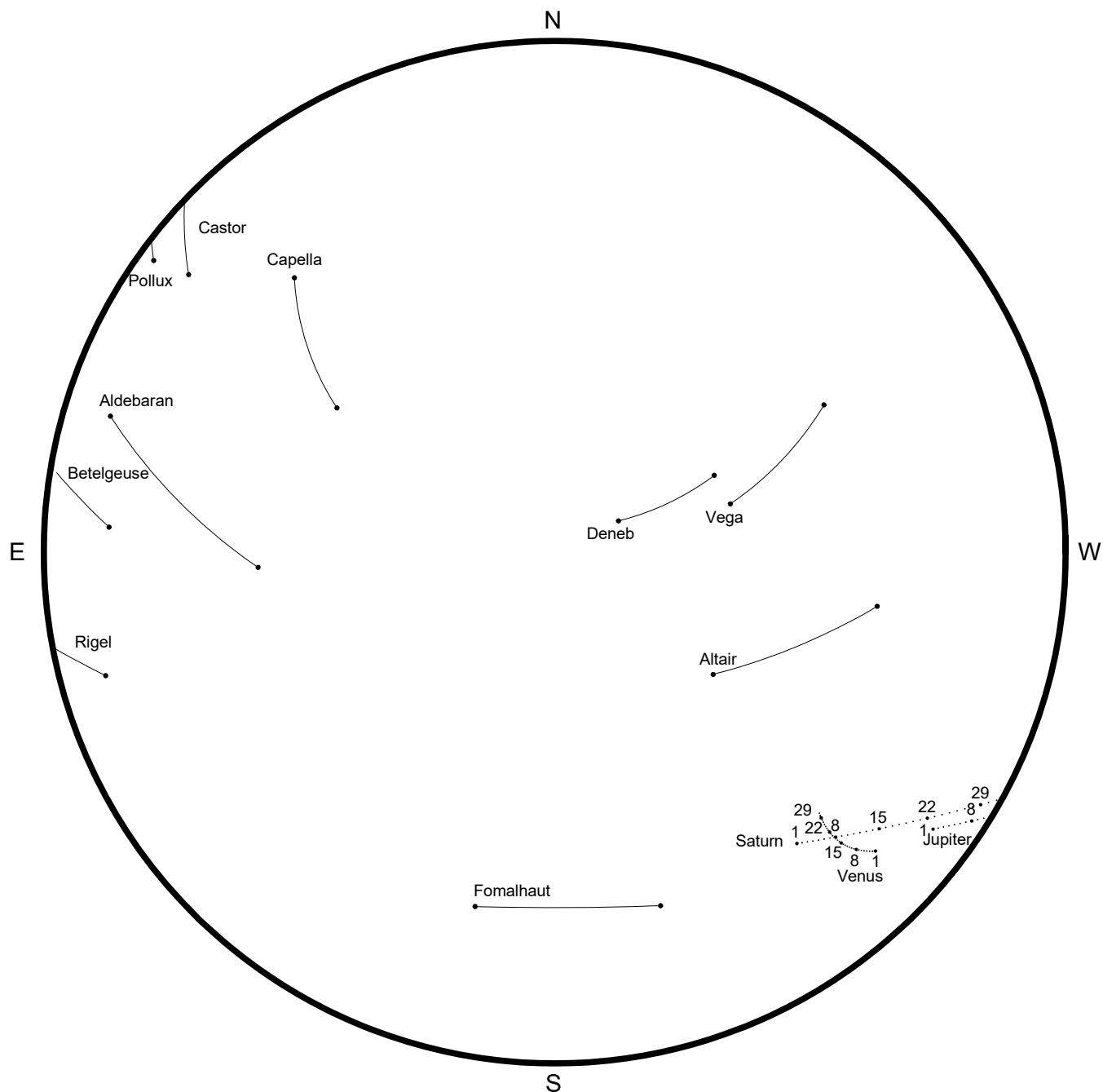


Evening mid-twilight occurs
when Sun is 9° below horizon.
Nov. 1: 44 minutes after sunset.
15: 46 " " "
30: 47 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For December, 2019

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.



Evening mid-twilight occurs
when Sun is 9° below horizon.
Dec. 1: 47 minutes after sunset.
15: 48 " " "
31: 47 " " "

Stereographic Projection
Map by Robert D. Miller

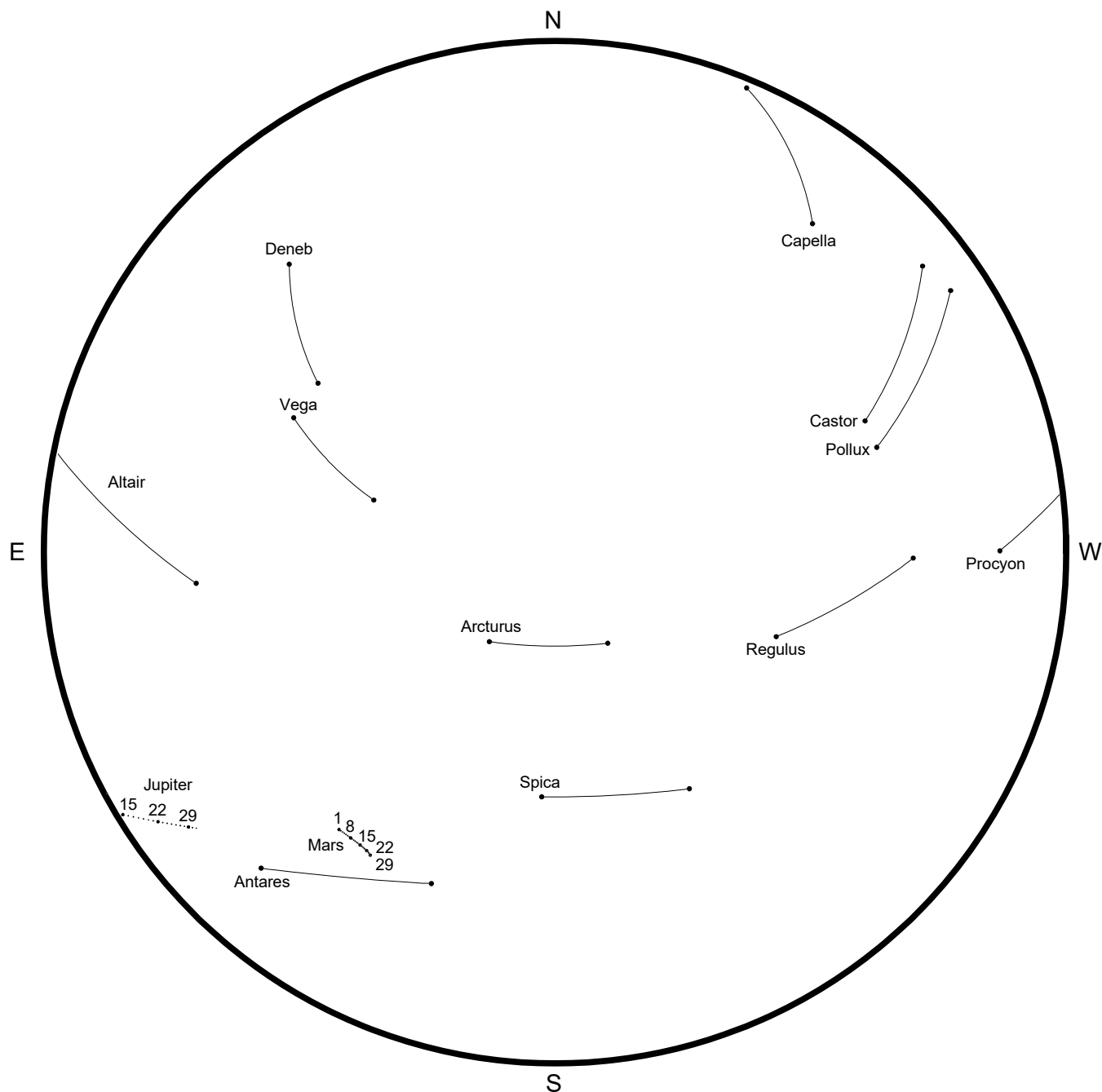
Chapter Three: Morning sky, January through July 2020

We skip about 5 weeks ahead, past Jupiter's solar conjunction, to catch Jupiter just risen at dawn mid-twilight on January 15, some 32° lower left of faint Mars. Daily views show Mars passing within 5° N of Antares, closest on the 18th. Waning crescent Moon skips past Mars on Jan. 20-21, and Jupiter Jan. 22-23. By Feb. 1, Saturn has emerged 11° lower left of Jupiter. Now all three bright outer planets are visible, spanning 35° . The Moon passes through Feb. 18-20. The occultation of Mars on the 18th is real, in progress at mid-twilight from 90W 40N, just as portrayed here. It's visible from most of North America, though observers in the East will have to put up with bright twilight or daylight. In mid-March Mercury climbs highest, only 3° up in a very poor morning apparition. Moon comes around again to pass the three bright outer planets March 17-19, with the middle date very impressive. On March 20, Mars passes 0.7° S of Jupiter, with Saturn just 7° east of the pair. Eleven days later, on March 31, Mars passes 0.9° S of Saturn, with Jupiter just 6.2° - 6.3° west of the pair. This is the most compact gathering of the three bright superior planets between the years 2000 and 2040.

The Moon sweeps through those three planets again on April 14-16, the four bodies spanning just 15° on the 15th. Jupiter-Saturn are within 5° of each other during April 28-June 6. Moon sweeps through the three superiors next on May 12-15. On May 18, Jupiter-Saturn reach a temporary minimum distance apart of 4.7° , another *quasi-conjunction*, before Jupiter pulls away to the west. In the Moon's next pass, it appears close to Jupiter-Saturn June 8-9 and near Mars on June 12-13. A few days later, Venus emerges from inferior conjunction, in plenty of time for the old Moon to meet it in a close conjunction on June 19. Both Moon and Venus are in crescent phase. Venus ends retrograde about 5° upper right of Aldebaran on June 23-24. Watch the Moon jump through Jupiter-Saturn July 5-6, and skip over Mars July 11 and 12. Venus at greatest brilliancy at mag. minus 4.7 passes 1.0° N of Aldebaran on July 12. Jupiter stands at opposition to the Sun on July 14 and appears 180° from the Sun. The Moon appears in a spectacular gathering with Venus and Aldebaran on July 17. Mercury has emerged from inferior conjunction and has brightened enough to be visible as the old crescent Moon passes near on July 19. We have *all five naked-eye planets simultaneously*, from west to east, Jupiter, Saturn, Mars, Venus, Mercury. On July 20, Saturn reaches opposition, with Jupiter about to set 7° to its lower right. Chapter Three ends here, and we return to the evening sky to follow the rest of the Jupiter-Saturn action.

Planets and Bright Stars in Morning Mid-Twilight For January, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

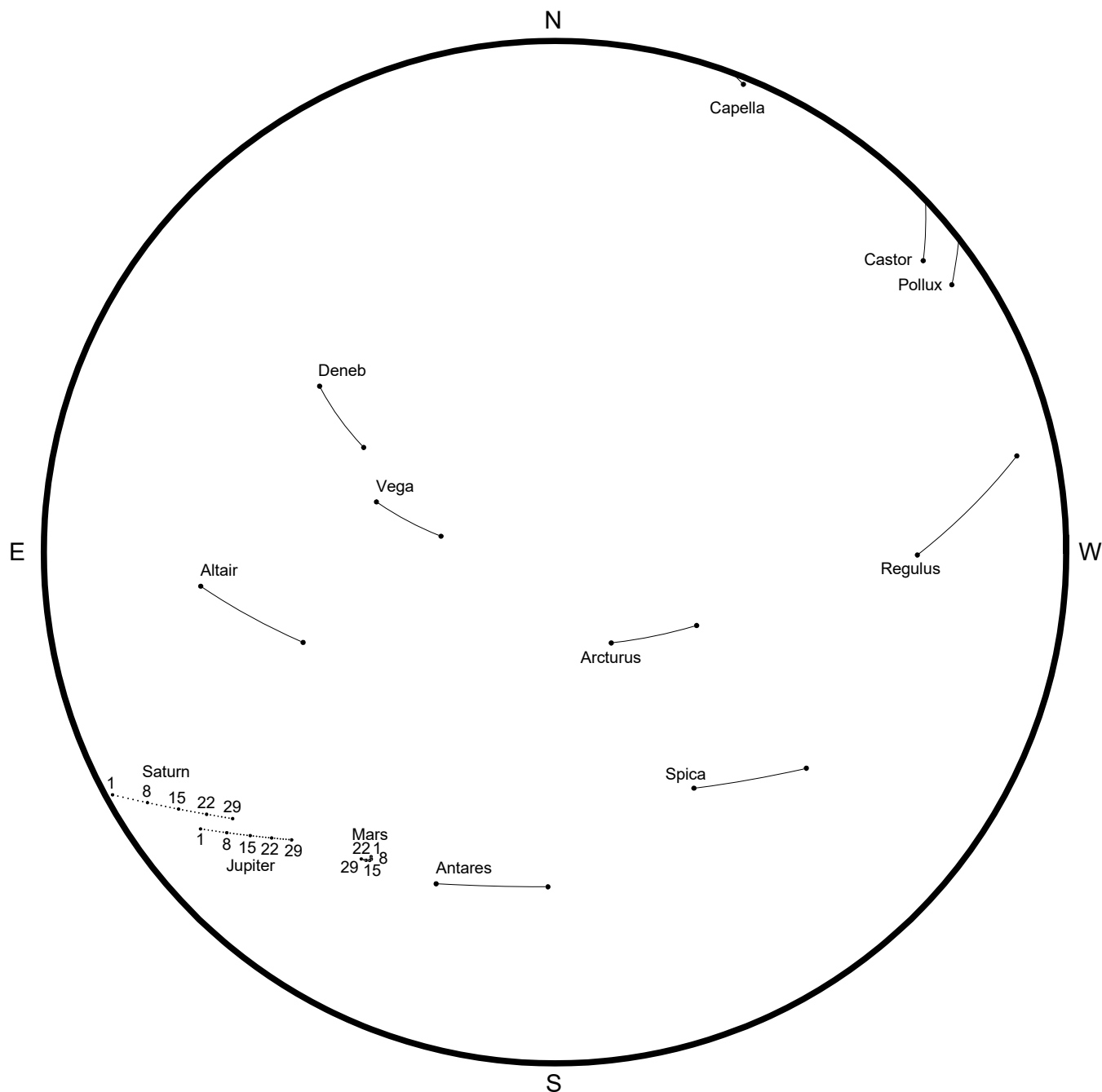


Morning mid-twilight occurs
when Sun is 9° below horizon.
Jan. 1: 48 minutes before sunrise.
15: 47 " " "
31: 45 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For February, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

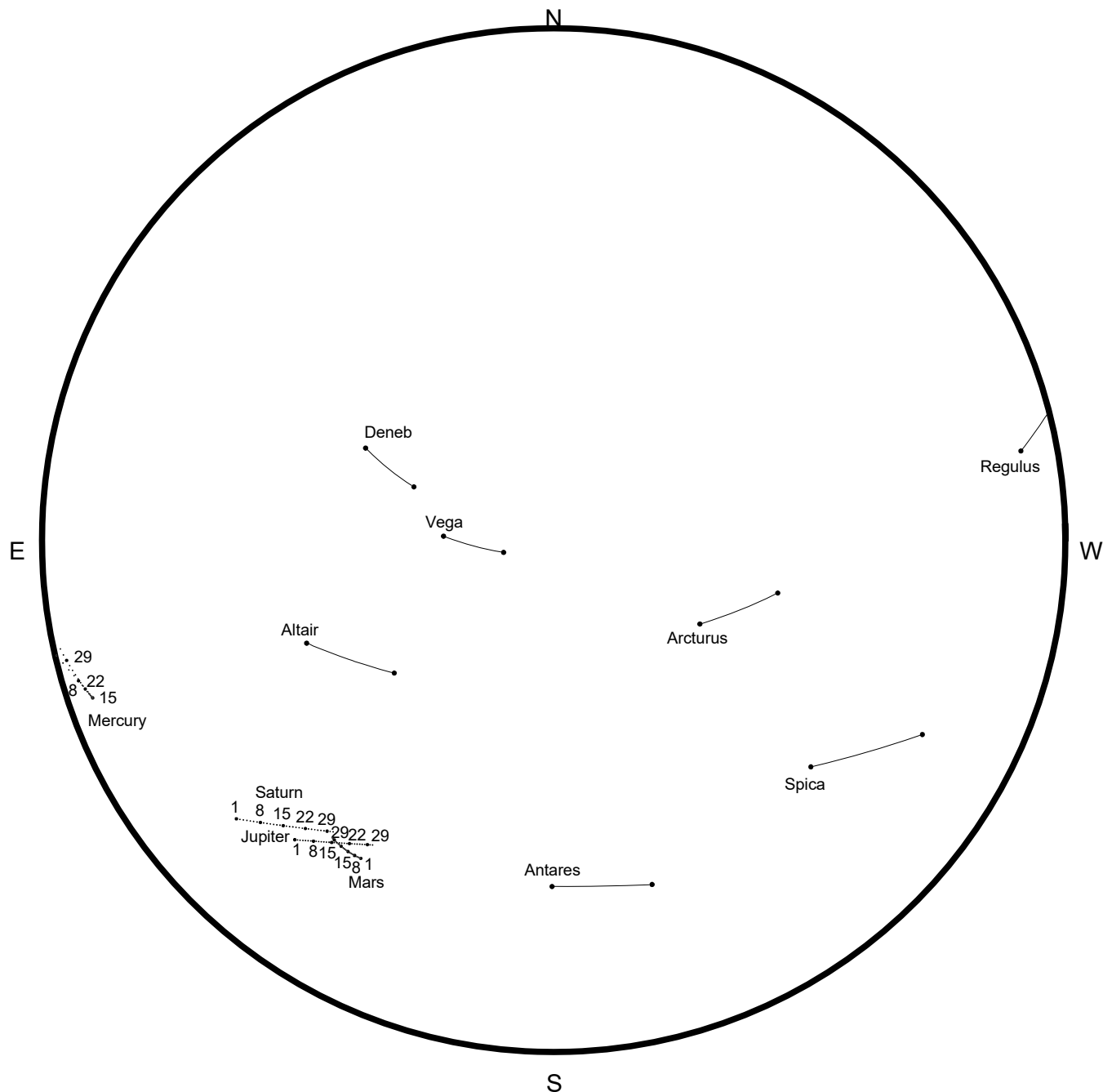


Morning mid-twilight occurs
when Sun is 9° below horizon.
Feb. 1: 46 minutes before sunrise.
15: 44 " " "
29: 43 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For March, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

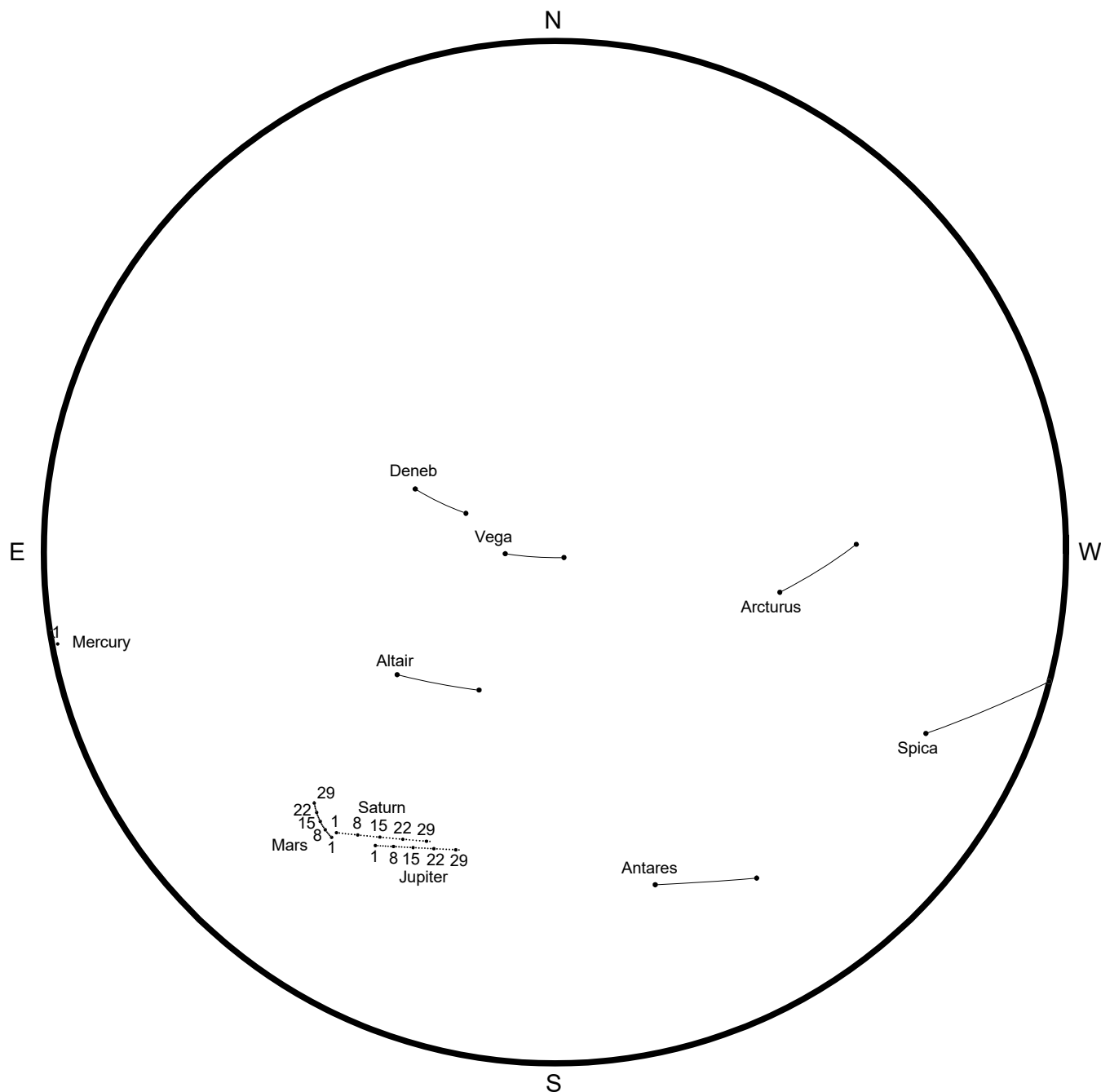


Morning mid-twilight occurs
when Sun is 9° below horizon.
Mar. 1: 43 minutes before sunrise.
15: 43 " " "
31: 43 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For April, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

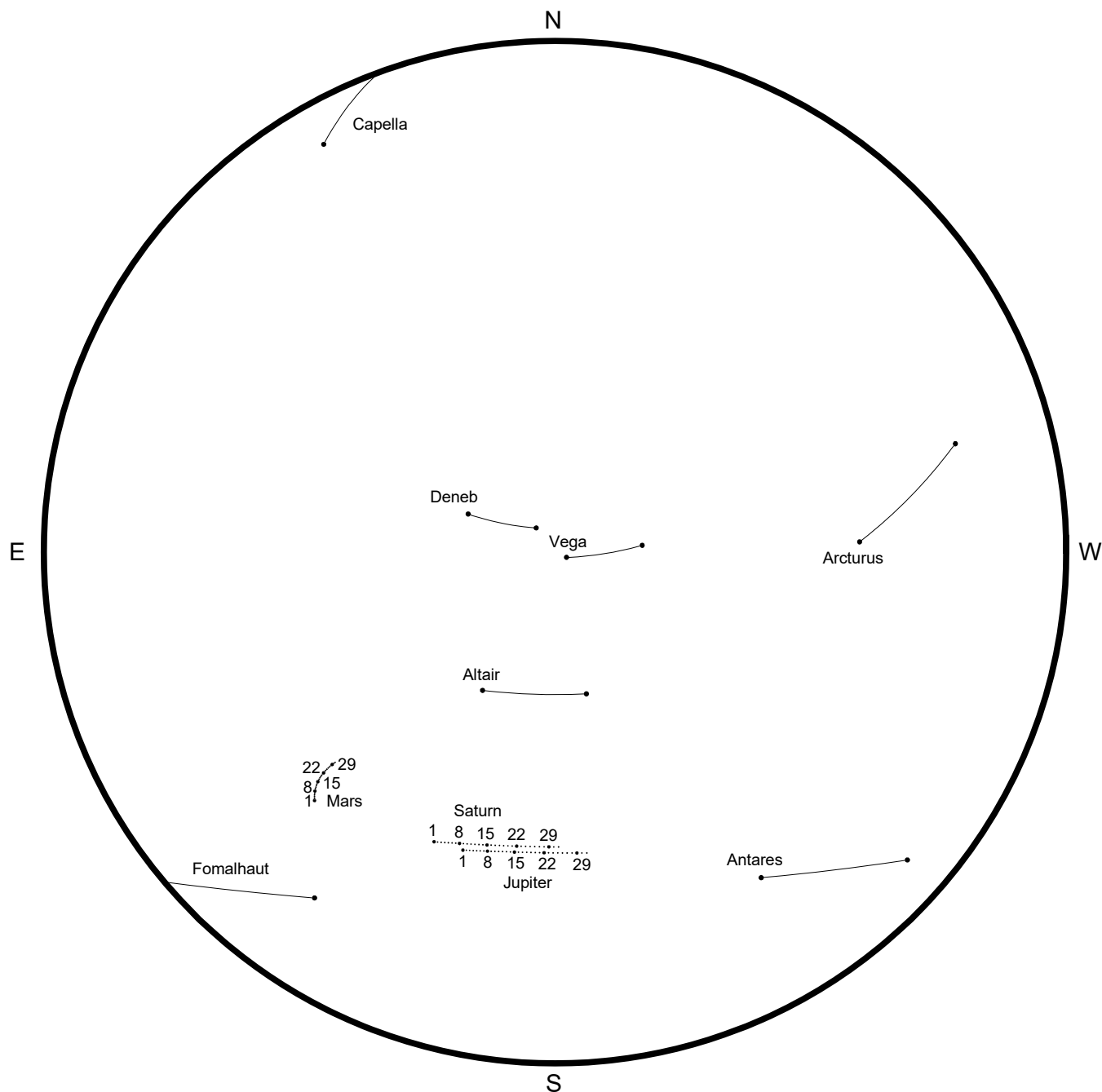


Morning mid-twilight occurs
when Sun is 9° below horizon.
Apr. 1: 43 minutes before sunrise.
15: 45 " " "
30: 47 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For May, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

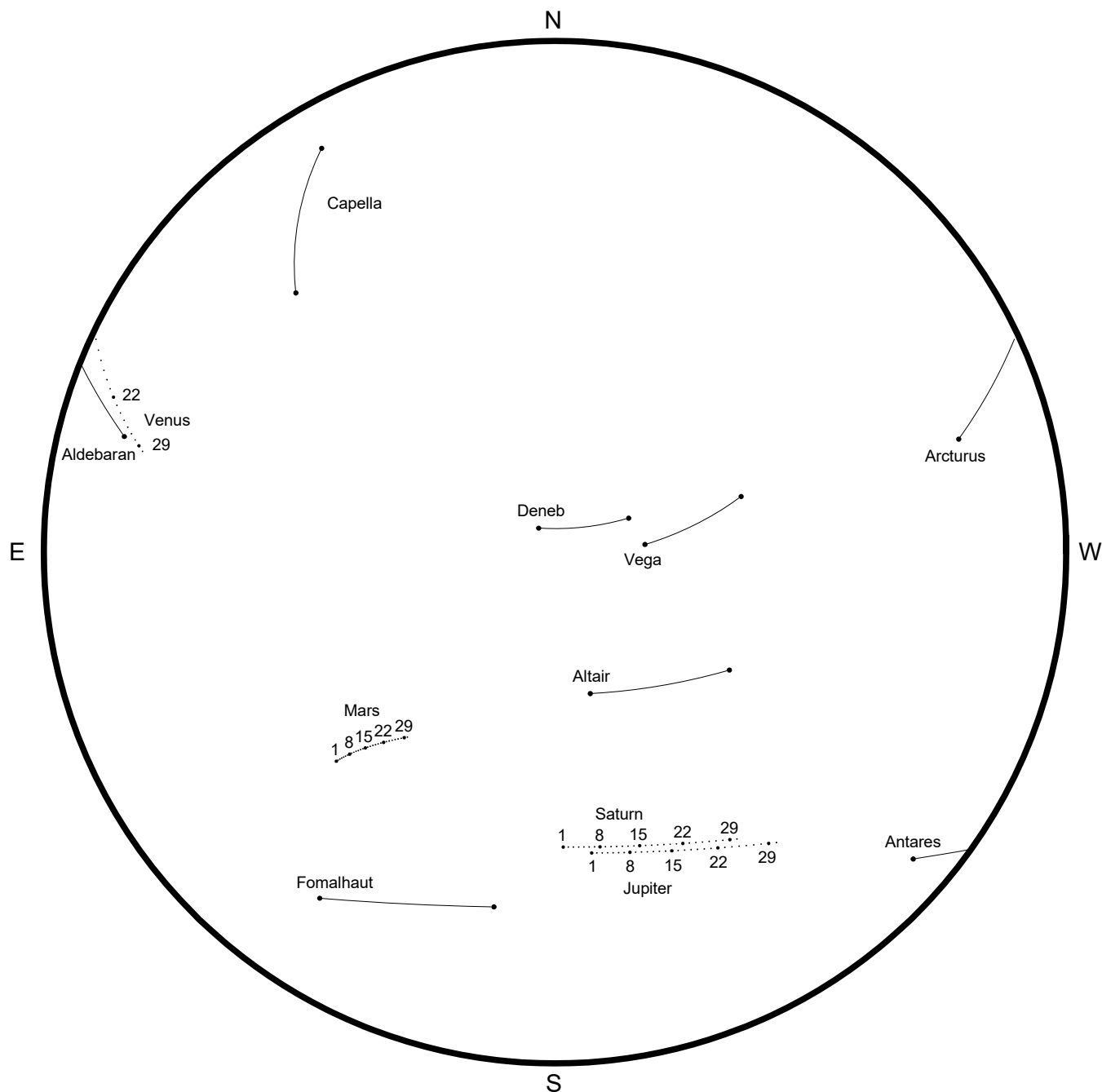


Morning mid-twilight occurs
when Sun is 9° below horizon.
May 1: 47 minutes before sunrise.
15: 50 " " "
31: 52 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For June, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

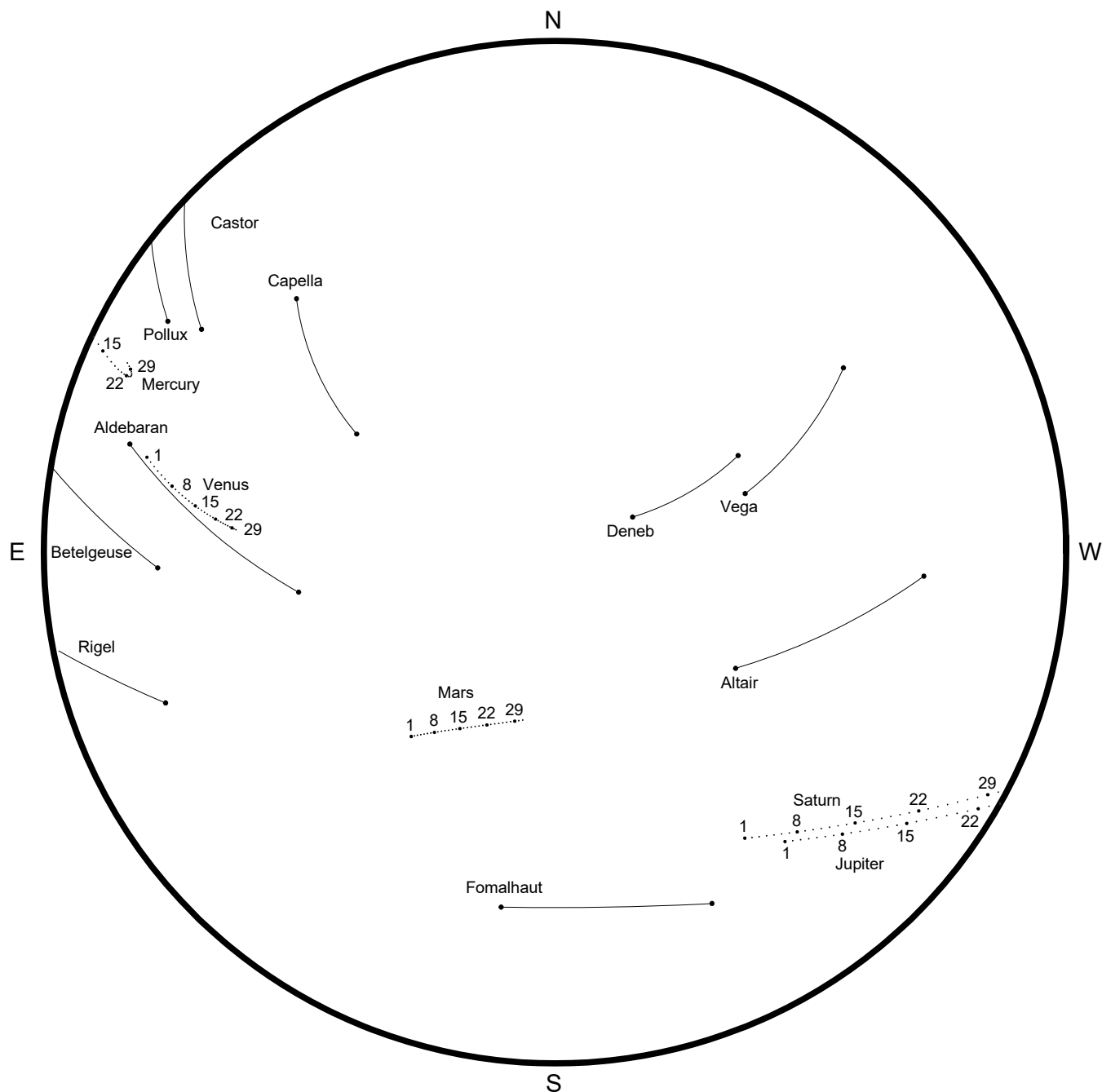


Morning mid-twilight occurs
when Sun is 9° below horizon.
June 1: 52 minutes before sunrise.
15: 53 " " "
30: 53 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Morning Mid-Twilight For July, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.



Morning mid-twilight occurs
when Sun is 9° below horizon.
July 1: 52 minutes before sunrise.
15: 52 " " "
31: 49 " " "

Stereographic Projection
Map by Robert D. Miller

Chapter Four: Evening sky, July 2020 through early January 2021

We jump back in time nearly three weeks to June 30, two weeks before Jupiter's opposition. It is evening mid-twilight, and Jupiter has just risen about 30° south of east. The Full Moon is 11° upper right of Jupiter on July 4, and just rising to lower left of Jupiter and right of Saturn on July 5. That evening, Jupiter-Saturn are 6.3° apart, spreading to 7° on July 17, 8° on August 8. Both planets are retrograding, Jupiter reaching opposition on the night of July 13, Saturn a week later, on July 20. The Moon next passes through the pair on July 31-Aug. 2, before reaching Full on Aug. 3. Watch the Moon pass through again on Aug. 27-29. On Aug. 28, Jupiter-Saturn reach a temporary maximum distance apart of 8.3°, before their final approach. Moon passes through again on Sept. 24 and 25, when their spread has shrunk to 7.7°. By October 6, Mars on the date of its closest approach to Earth, has popped up north of east. Opposition of Mars occurs on Oct. 13. Now all three bright outer planets are visible at dusk until early in January 2021. Watch the waxing Moon visit Jupiter-Saturn less than 6° apart on Oct. 22, and Mars a week later, on Oct. 29.

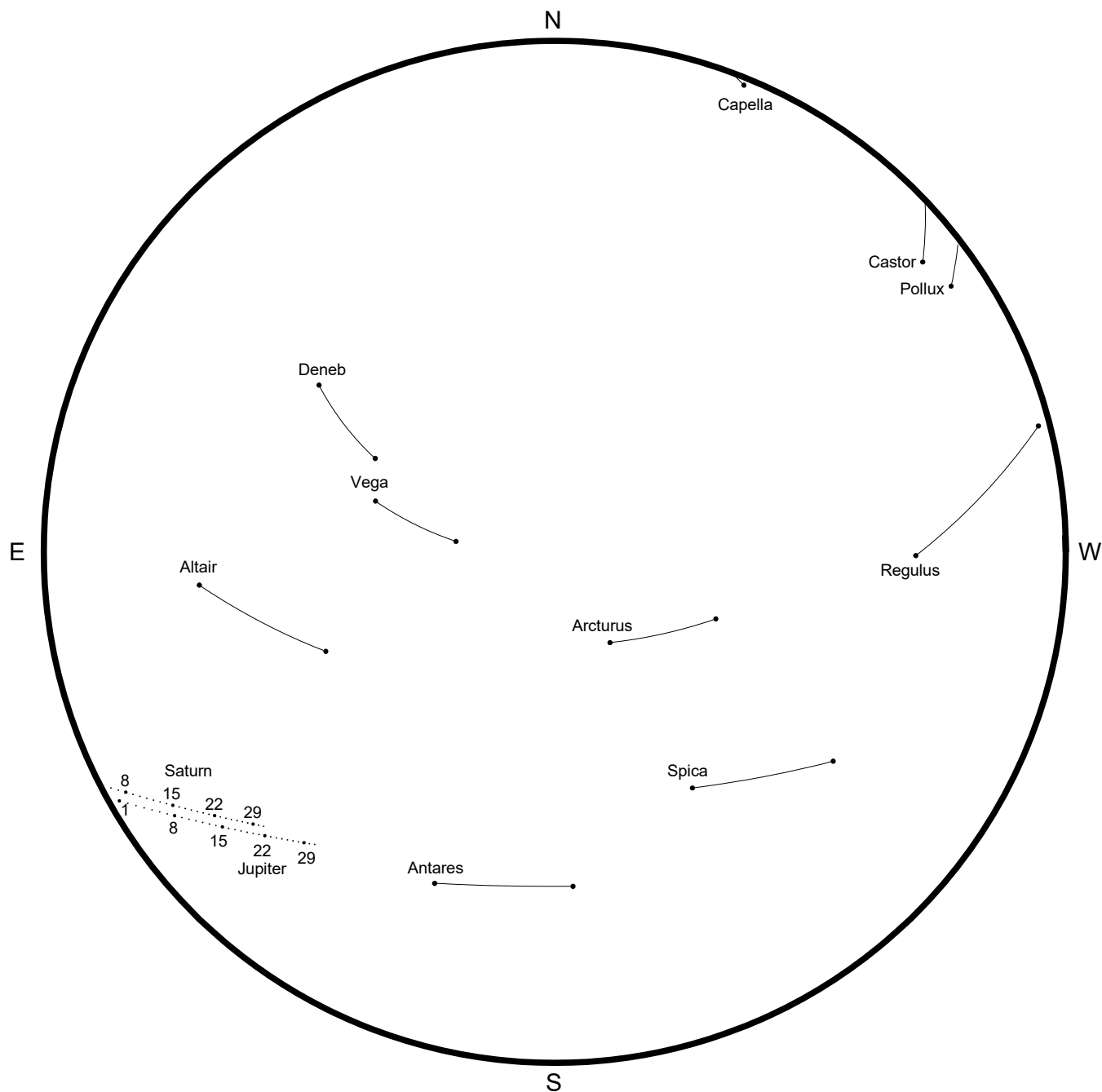
Watch the Jupiter-Saturn gap close to 5° on Nov. 2, to 4° on Nov. 13, to 3° on Nov. 23. Each evening, the giants appear about 0.1° closer than on the previous evening. Watch the Moon skip over Jupiter-Saturn Nov. 18-19, and pass Mars on Nov. 25.

Jupiter-Saturn are 2° apart on Dec. 2-3, 1.5° apart on Dec. 7, and 1° apart on Dec. 12. On Wed. Dec. 16, a crescent Moon, of age 30-33 hours across mainland U.S., hangs about 5° below the planet pair, then separated by just over half a degree, or a moon's width. On Mon. Dec. 21, the planets are separated by 6 arcminutes, or one-tenth of a degree, their closest pairing since 1623, in Galileo's time, and their closest until 2080. The pair appears 30° east of the Sun, and from lat. 40° N sets in a dark sky 2.3 hours after sundown. Also on Dec. 21, the Moon stands at First Quarter phase, just south of the Vernal Equinox, and Mars shines 24° east of the Moon. In two more nights, on Dec. 23, the Moon passes within 6° south of Mars.

Watch Jupiter-Saturn separate as they set earlier each evening: They're just over 1° apart on Dec. 30, 1.5° apart on Jan. 3, nearly 2° apart on Jan. 7. Emerging from superior conjunction, Mercury comes into view, passing south of the planets. From mid-U.S., Mercury appears 1.6° lower left of Saturn on Jan. 9, and within 1.5° lower left of Jupiter on Jan. 11. Binoculars are highly recommended for catching this trio very low in the twilight glow just before Saturn and Jupiter leave the evening sky.

Planets and Bright Stars in Evening Mid-Twilight For July, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

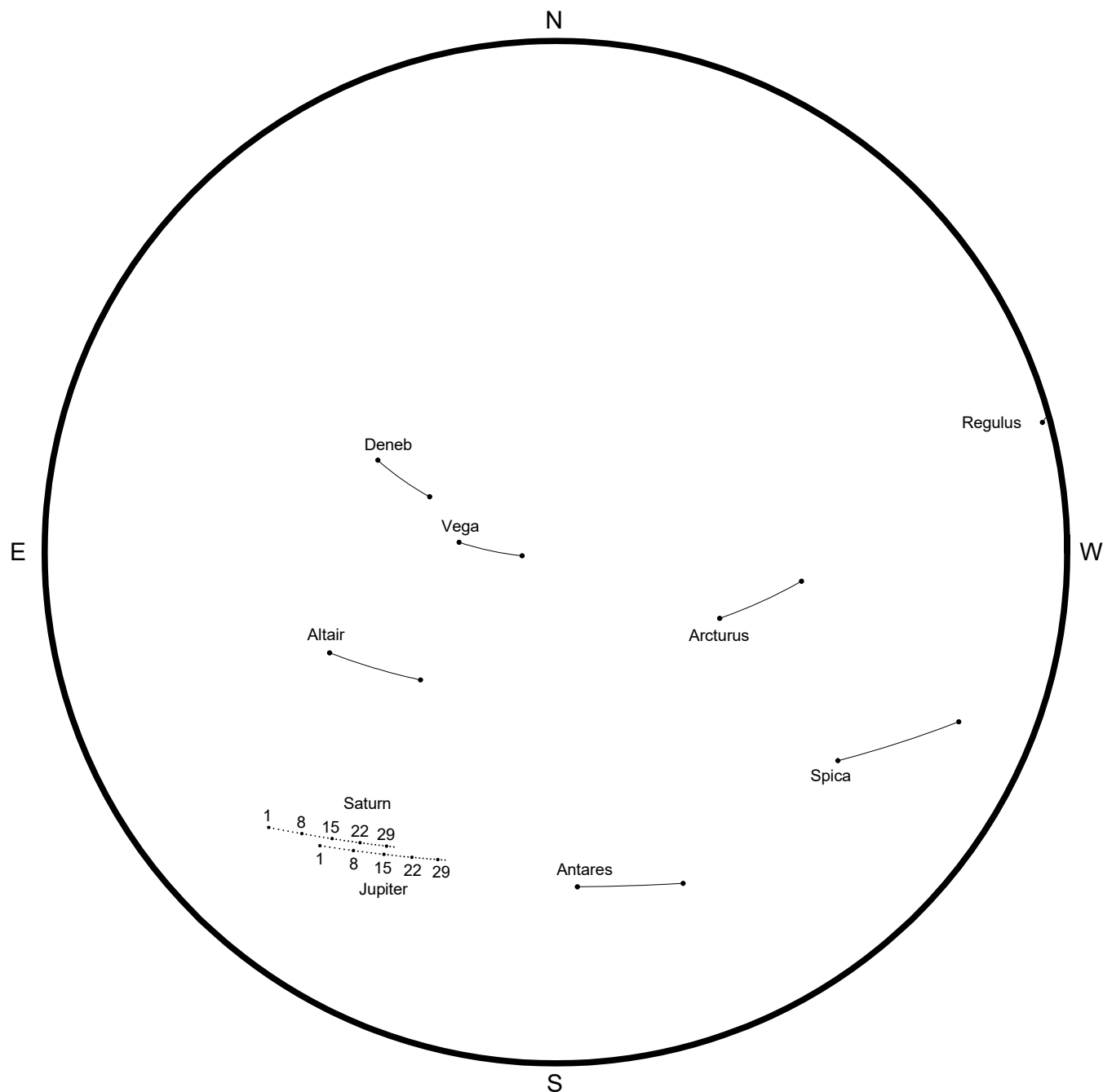


Evening mid-twilight occurs
when Sun is 9° below horizon.
July 1: 53 minutes after sunset.
15: 51 " " "
31: 49 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For August, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

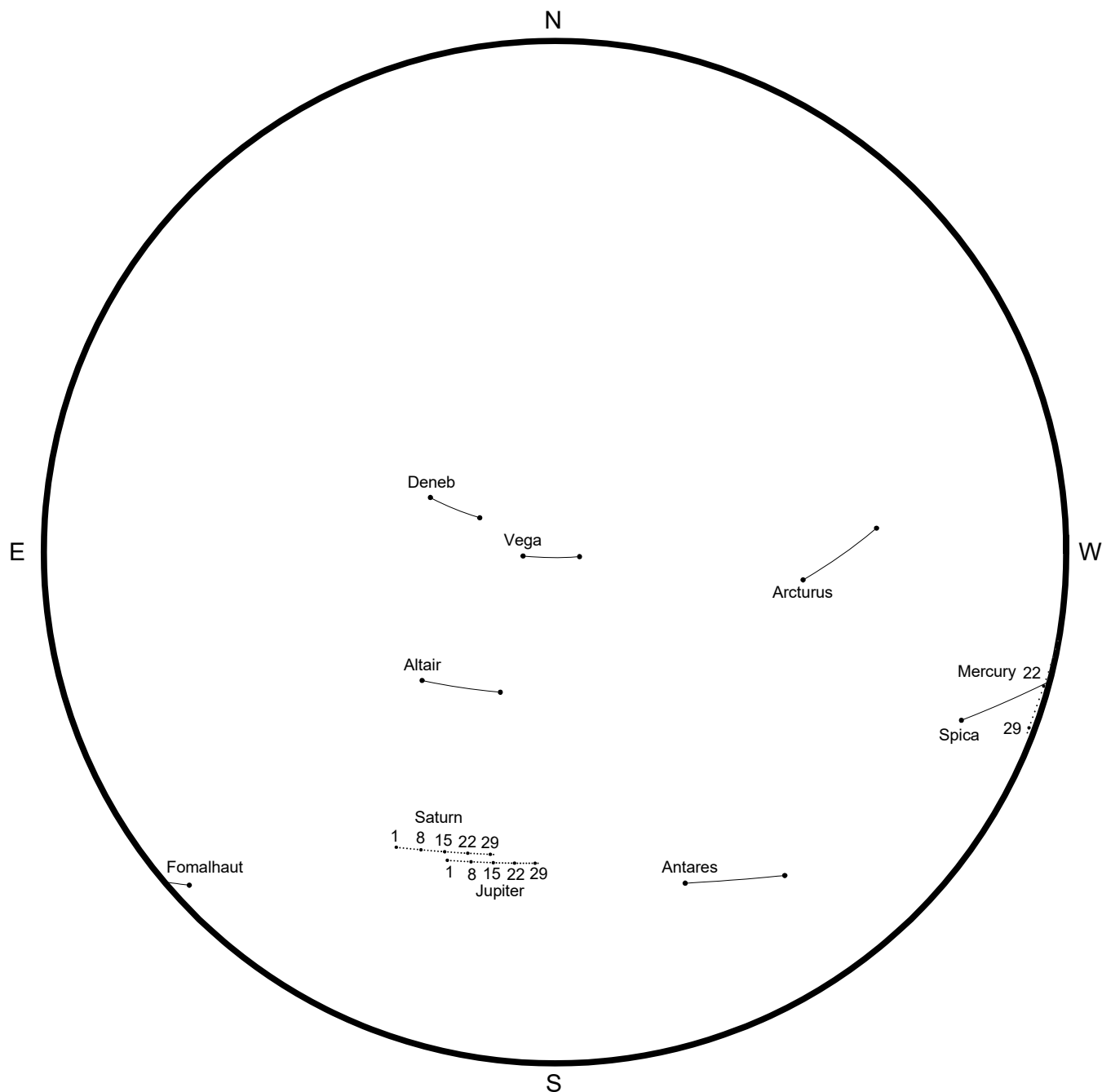


Evening mid-twilight occurs
when Sun is 9° below horizon.
Aug. 1: 48 minutes after sunset.
15: 46 " " "
31: 44 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For September, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

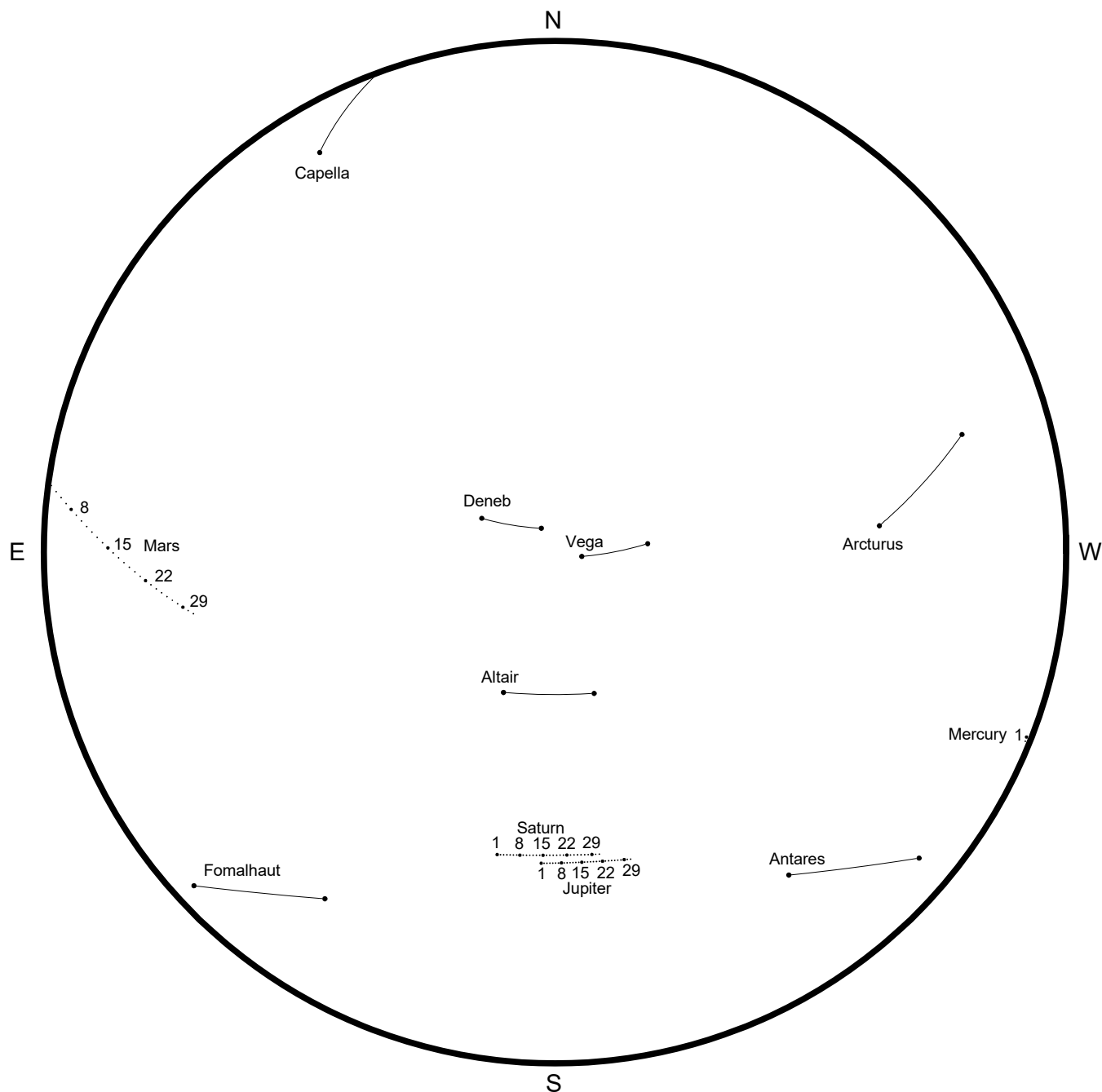


Evening mid-twilight occurs
when Sun is 9° below horizon.
Sept. 1: 44 minutes after sunset.
15: 43 " " "
30: 43 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For October, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

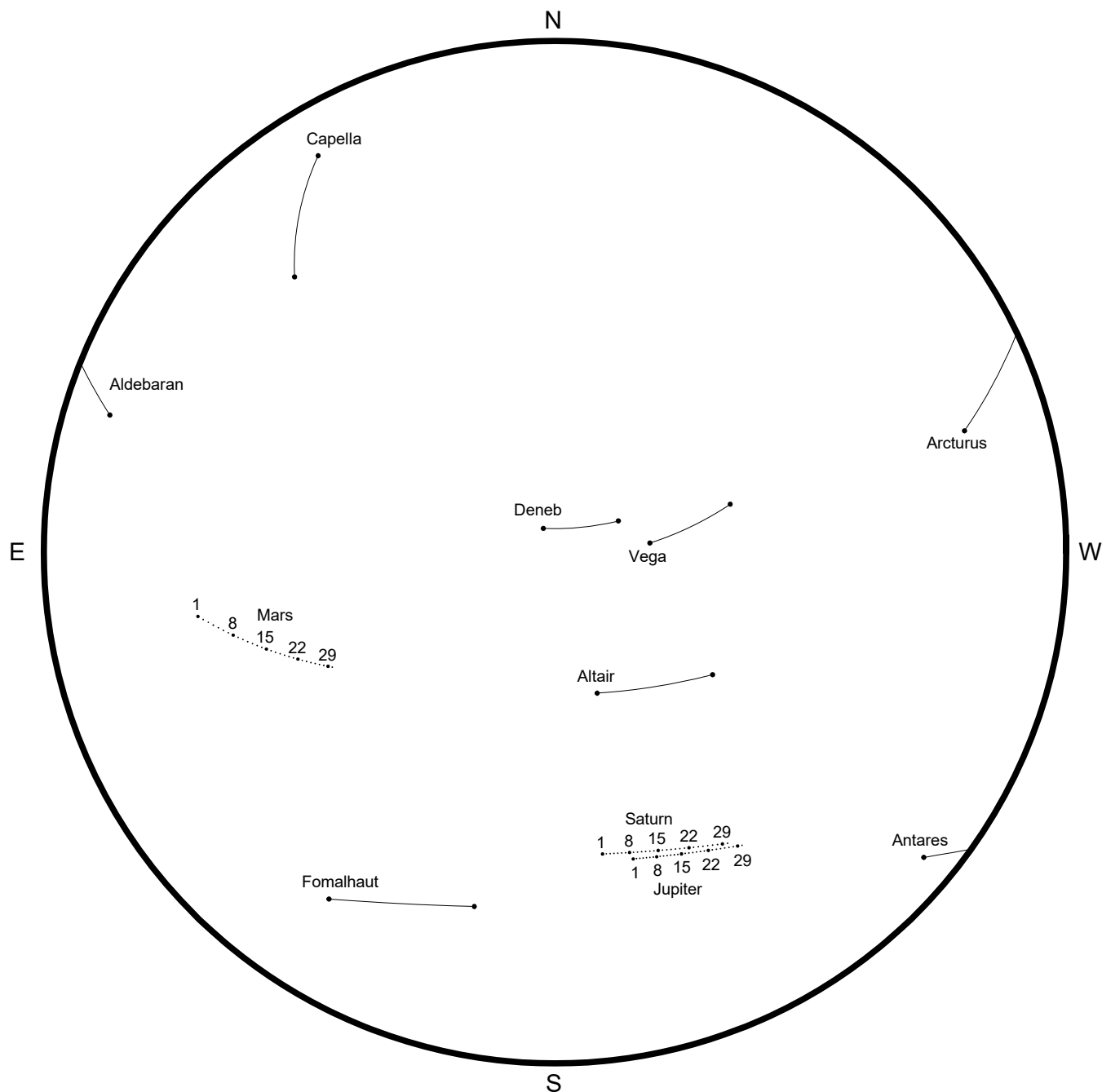


Evening mid-twilight occurs
when Sun is 9° below horizon.
Oct. 1: 43 minutes after sunset.
15: 43 " " "
31: 45 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For November, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.

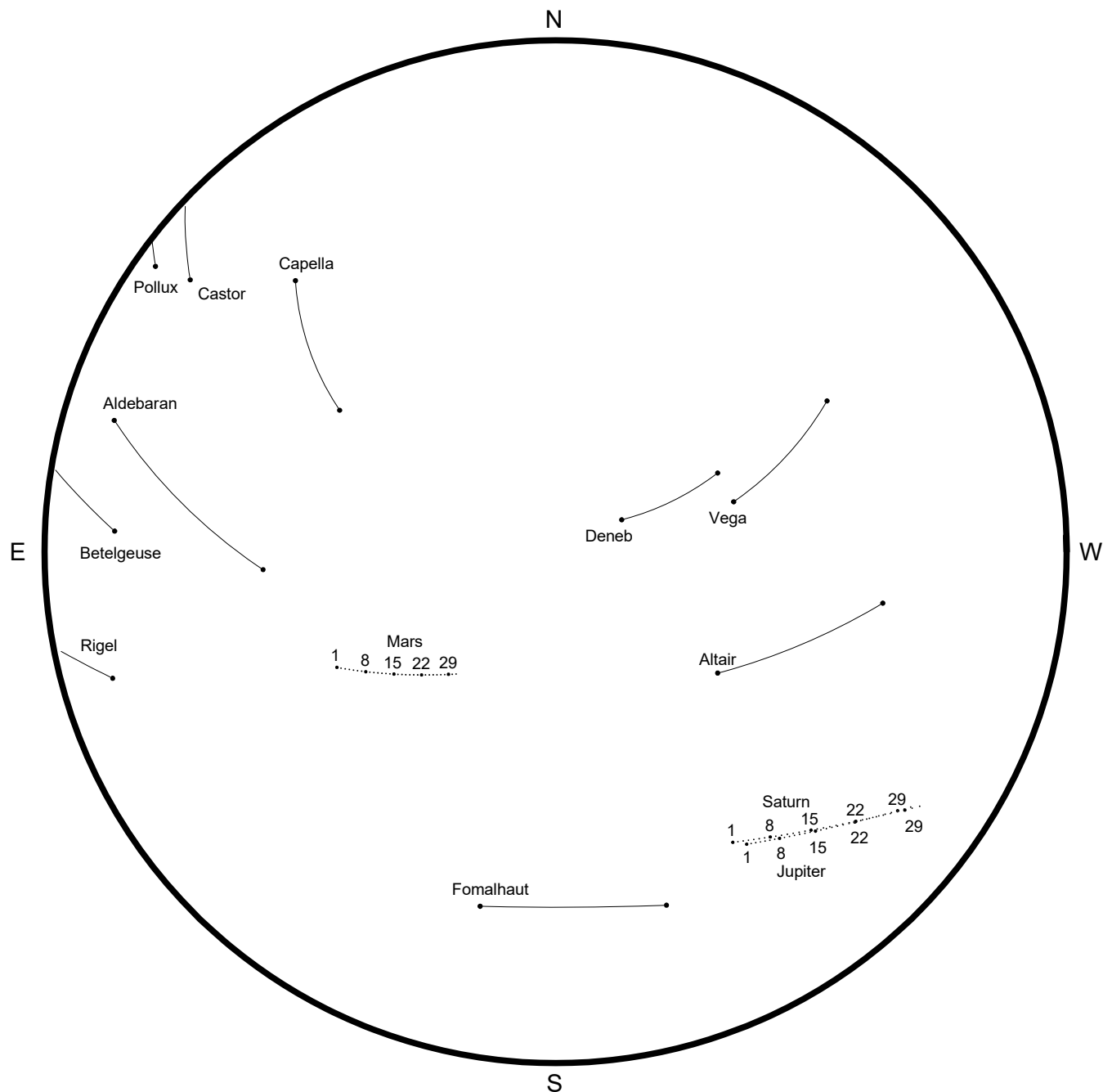


Evening mid-twilight occurs
when Sun is 9° below horizon.
Nov. 1: 45 minutes after sunset.
15: 46 " " "
30: 47 " " "

Stereographic Projection
Map by Robert D. Miller

Planets and Bright Stars in Evening Mid-Twilight For December, 2020

This sky chart is drawn for latitude 40 degrees north,
but may be used in continental U.S. and southern Canada.



Evening mid-twilight occurs
when Sun is 9° below horizon.
Dec. 1: 48 minutes after sunset.
15: 48 " " "
31: 48 " " "

Stereographic Projection
Map by Robert D. Miller

Explanation of Monthly Twilight Sky Chart

Special thanks to Robert D. Miller for providing these charts and for creating the computer program to do the calculations and plotting. Mr. Miller did graduate work in Planetarium Science and later astronomy and computer science at Michigan State University and remains active in research and public outreach in astronomy.

The monthly twilight all-sky charts provided with this paper depict positions of the naked-eye planets and all stars of first magnitude or brighter, which are above the horizon at evening or morning mid-twilight. We define mid-twilight as the times when the Sun is 9° below the horizon. The exact number of minutes after sunset or before sunrise when mid-twilight occurs depends on the latitude of the observer and the time of year. Longest twilights occur in June, on the date of the summer solstice, with a secondary maximum in December, on the date of the winter solstice. Shortest twilights occur a few weeks before the spring (March) equinox and a similar interval after the autumnal (September) equinox. These charts have been plotted for latitude 40° north, and the length of the time interval from sunset until evening mid-twilight (or from morning mid-twilight until sunrise) is mentioned on each map.

Each monthly chart plots the positions of all stars of first magnitude or brighter (plus Castor of mag. 1.6), and the naked-eye planets. For each planet, daily positions are represented by individual dots, with a labeled larger dot every seventh day, thus for the 1st, 8th, 15th, 22nd, and 29th day of the month. For each bright star, the changing position during a month is represented by a continuous curve as the star appears to move from east to west, a consequence of the Earth's revolution around the Sun. If the star is above the horizon at mid-twilight all month, then its positions for the first and last day are represented by bold dots at the beginning and end of the trail. If the star's first or last appearance occurs within the month on a date other than the first or last day, then that end of the trail terminates at the horizon.

Note that an inner planet, Mercury or Venus, when it's visible, will be either in the western sky at dusk or in the eastern sky at dawn. The sequence of events for inner planets is: (1) Superior conjunction, on the far side of the Sun and not visible; (2) Visibility as an "evening star", including arrival at greatest elongation, when the planet reaches its greatest angular separation from the Sun; (3) Inferior conjunction, on the near side of the Sun, and generally invisible, except when Venus makes a wide pass north or south of the Sun and can be viewed with optical aid as a very thin crescent, if proper precautions are taken to avoid accidentally viewing the Sun; (4) Visibility as a "morning star", including arrival at greatest elongation; and (5) Superior conjunction again. The correct order of this sequence can be remembered by visualizing that as seen from north of or "above" the solar system, the revolutions of all the planets is counterclockwise around the Sun, and that the inner planets Mercury and Venus revolve faster than Earth.

The outer planets Mars, Jupiter, and Saturn, like the familiar bright zodiacal stars Aldebaran, Pollux, Regulus, Spica, and Antares, emerge after solar conjunction to begin their apparitions on the eastern horizon at dawn. Then, over several months, they make their way over to the western sky at dawn and opposition to the Sun. Several days before an outer planet reaches opposition

and subsequently disappears below the western horizon on the morning chart, it will appear on the eastern horizon on the evening chart. There are several days of overlap, when the outer planet is visible at both dusk and dawn and so is plotted on both charts. Several days after the planet's first appearance above the eastern horizon at dusk, it arrives at [the previously mentioned] opposition in the eastern sky. Next, over several months, the outer planet makes its way over toward the western sky on the evening chart, eventually disappearing below the western horizon before its next conjunction with the Sun.

Note that Mars near conjunction with the Sun, and Mercury near inferior conjunction, may often be fainter than the nominal +1.5-magnitude limit of the charts. They are plotted anyway.

Planet Rising and Setting Charts

Here are graphs summarizing visibility of planets in evening and morning skies during School Year 2018-2019, for Chicago, Illinois:

SchoolYear2018-19-setting-rising-chicago.pdf

These graphs were kindly provided by Dr. Jeffrey L. Hunt, a retired planetarium director now living in the Chicago area. He has taught astronomy and sky watching to all ages, and studied astronomy education at Abrams Planetarium at Michigan State University. Jeff writes an astronomy blog at jeffreylhunt.wordpress.com and can be followed on Twitter at [@jeff_hunt](https://twitter.com/jeff_hunt).

The curves plotted on the "Evening Skies" (upper graph in the city's pair) plot how long after sunset the setting time occurs (object's setting time minus sunset time) for the five naked-eye planets and five first-magnitude stars (Aldebaran, Pollux, Regulus, Spica, and Antares). The reader can immediately pick out on what dates the best apparitions of Mercury occur—when the curves for Mercury are highest above the baseline time-of-sunset line. Also plotted are times of moonset in relation to sunset time, indicated by the small white open circles. With those, you can tell on what date the thin waxing crescent Moon is likely to be first seen. One application: Determine the dates of the first crescent Moons marking the start of the Islamic month of Ramadan, and the next month, Shawwal. From Chicago, Illinois, on what evening after the New Moon in May 2019 will the crescent Moon first be seen, assuming clear skies? Answer: On May 5, when the Moon sets just after mid-twilight. Ramadan fasting begins the next day. In June 2019, the first crescent Moon won't be seen until June 4. It sets after nautical twilight, and will be very easy to spot. The Moon on June 3 sets much too soon after sunset to be seen, so the Ramadan fast must continue through the day on June 4.

Curves plotted on the "Morning Skies" portion of the chart (lower graph in each city's pair) plot how long before sunrise the rising time occurs (sunrise time minus object's rising time) for the same five planets and five stars. The baseline of the second graph is the sunrise time. Small white open circles indicate time of moonrise in relation to sunrise. In 2018, Venus and the crescent Moon will rise at nearly the same time on Nov. 6. The Moon will rise not long before Venus on Dec. 3 and not long after Venus on Mon. Tues. Dec. 4. In early 2019, Moon rises before Venus on

Jan. 1 and after Venus on Jan. 2; and just before Venus on Jan. 31 and on March 2. In late Nov.-early Dec. 2018, Venus rises more than three hours ahead of the Sun and will be near greatest brilliancy, providing excellent chances to see Venus in the daytime after sunrise, a rewarding schoolyard activity for the start of the school day.

There are a few curves on each chart that look very different from the rest: Rising times on the evening chart, and setting times on the morning chart. These are clearly labeled and look like a row of beads, and are done for the outer planets when near opposition to the Sun (rising in the evening after sunset before the planet's opposition, or setting in the morning before sunrise after the planet's opposition). Bright Jupiter is an example, around its opposition of June 10, 2019. Before its opposition, you can observe Jupiter rising in the southeastern sky during the evening. After opposition, if you get up early enough in the morning, you can still catch Jupiter before it sets in the southwest.

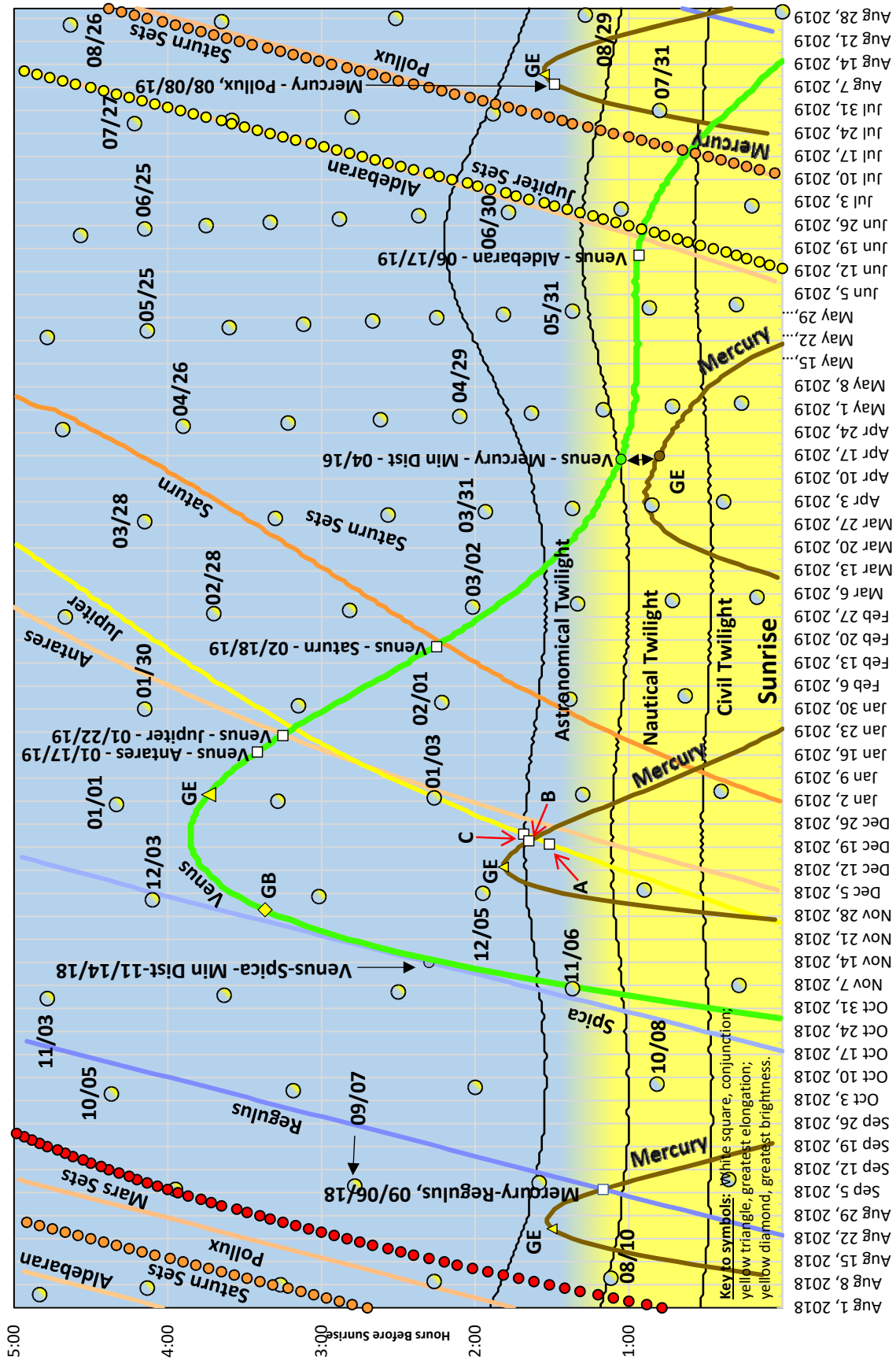
Acknowledgements

Thanks to John S. French at Abrams Planetarium for programming the Digistar 6, to Robert D. Miller for providing monthly all-sky charts depicting daily positions of planets and bright stars in mid-twilight, and to Dr. Jeffrey L. Hunt for providing convenient graphical representations of set/rise times of Moon, planets, and bright zodiacal stars.

Morning Sky, August 2018 - August 2019 Chicago, Illinois

Opposition
Jupiter: 06/10/19
Saturn: 07/09/19

Conjunctions: A, Jupiter-Mercury, 12/21/18;
B, Mercury-Antares, 12/22/18; C, Jupiter -
Antares, 12/23/18



All moon dots, and the curves for planets and stars, indicate rising times in relation to sunrise, except for the three planet curves labeled to indicate times of setting, also in relation to sunrise.

SOLAR MOTION DEMONSTRATOR

Susan Reynolds Button

Quarks to Clusters

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sbuttonq2c@gmail.com

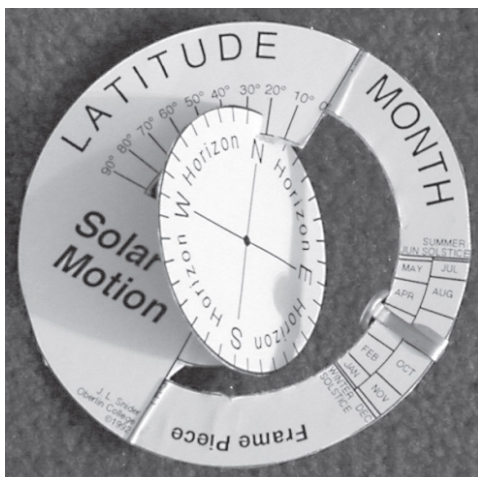
Abstract: Learn to build and use a simple device called a “Solar Motion Demonstrator.” This device accurately models the apparent motion of the Sun (rising and setting points as well as the altitude of the Sun at noon) at any time of the year and any latitude in the northern hemisphere of Earth.

This *solar motion demonstrator* is a supplemental activity provided in the Lawrence Hall of Science planetarium PASS program, “Stonehenge.” During that program visitors predict where sunrises and sunsets will occur along the eastern and western horizons during different seasons. The observations are conducted in the context of judging if the English stone circle of Stonehenge could have been used by its builders as an observatory and calendar.

This *solar motion demonstrator* is just one of several supplemental activities that are provided in the Stonehenge program and that can be used to enhance this show. The titles of the six activities are:

1. Azimuth and Horizons
2. Where’s East and West?
3. Creating a Horizon Sun Calendar
4. Many Moonrises
5. Solar Motion Demonstrator
6. Sunrises at Stonehenge

We will focus on just one of those activities, how to build and use a simple device called a “Solar Motion Demonstrator.” This device accurately models the apparent motion of the Sun (rising and setting points as well as the altitude of the Sun at noon) at any time of the year and any latitude in the northern hemisphere of Earth.



*Solar Motion Demonstrator from PASS Stonehenge program.
Designed by Joseph L. Snider.*

You can explore the following questions with this device:

1. Where Will the Sun Rise and Set for different latitudes?
2. Is Daytime as Long as Nighttime?
3. When are Day and Night Equally Long?
4. When Will the Noon Sun be the Highest or Lowest in the Sky?
5. Why Does the Earth Have Seasons?
6. Can You Always See a Sunset?
7. When and Where Will the Sun Pass Directly Overhead?
8. What Path Does the Sun Take at the Equator?
9. What is the Motion of the Sun for an Observer at the North Pole?
10. Using the device as a compass.

Acknowledgements

The Solar Motion Demonstrator was designed by Professor Joseph L. Snider of Oberlin College. The design and directions for use are copyrighted by Professor Snider. You may reproduce them as needed for your own classroom or planetarium but not for commercial purposes.

References

Planetarium Activities for Successful Shows (PASS) Stonehenge: <http://www.planetarium-activities.org/shows/sh> and for other PASS programs go to: https://www.lawrencehallofscience.org/programs_for_schools/curriculum

CREATE 360 CONTENT USING GOOGLE STREET VIEW

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Abstract: This poster describes the process I found for extracting 360 Google Street View images and getting them onto the planetarium dome. Tips on how to take the best 360 photographs with your smartphone using the Google Street View app will also be shared.

Introduction

As soon as I got my hands on a fulldome system this year I was curious about being able to “travel anywhere” with it. I thought there was no simpler way to get content of locations than through Google Street View Images. Not only would figuring out how to do it be fun and educational for me, but it could also be used for educational purposes in schools we service. To achieve this, I had to find a way to download a Street View panorama and then make it suitable for viewing on my dome. Here I have outlined my process for achieving this.

You can also contribute to the Google Street View panoramas you see online using the app on your smartphone. This app helps you to take many photographs of your surroundings that get stitched together into one panoramic image. Getting a good resultant image can be tough since you have to take many images from a certain perspective while also moving around. This basically requires you to become a human tripod, which can be tricky business so I give you a couple of my best tips to help you get the best panorama possible.

Downloading an Image

The simplest way I discovered to download a Google Street View panorama is with an app made by Thomas Orlita, <https://svd360.istreetview.com/>. Still there are a few steps needed before obtaining that image.

1. Locate your Image

- In a browser find the Google Street View panorama you would like to download.
- Copy its URL.

2. Get the Panorama ID

- In a browser, go to the sister app, iStreetView.com.
- Go to “Load a panorama” on the left side of the window.
- Paste your URL.
- Hit Load and your image should appear.

- Copy the Panorama ID (Figure 1), located to the right of the heart and paper clip in the middle, top of the window.

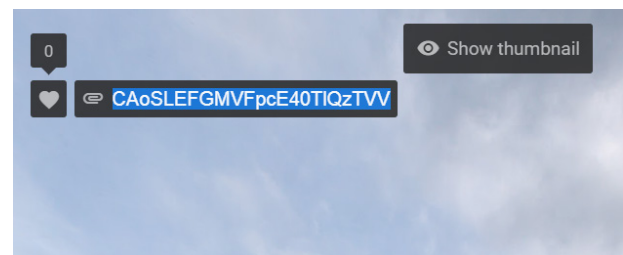


Figure 1. Location of the Panorama ID

3. Download your Image

- Open the “Street View Download 360” app.
- Identify where you would like the image to save to.
- Paste the panorama ID.
- Hit download panorama.

The image that is downloaded (figure 2) is the Street View panorama in an equirectangular format with a 2:1 aspect ratio.



Figure 2. The downloaded Street View image

Convert the Image

GIMP is a useful and powerful open source package that I have used to convert the image from rectangular to polar coordinates. This gives it the perspective needed for viewing on my dome.

1. Open the image in GIMP.
2. Crop your image (figure 3)
3. These images capture everything around it, including the ground, which is not a natural perspective to have. To get the perspective right you must crop out from the bottom of the image what you do not want to be shown.
 - a. Using the Rectangle Select tool choose the area of the image that you would like to keep.
 - b. In the menu click Image > Crop to Selection

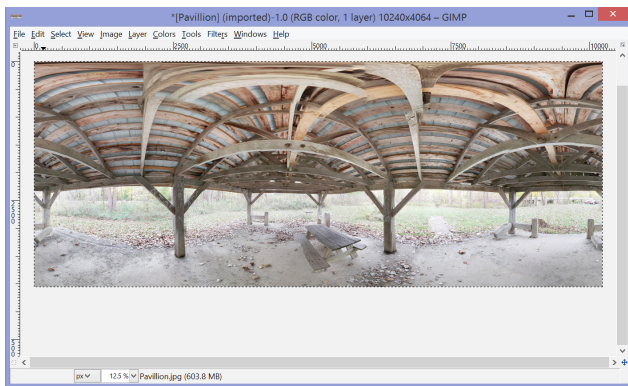


Figure 3. Image cropped in GIMP

4. Rectangular to Polar
 - a. From the menu select Filters > Distorts > Polar Coordinates...
 - b. You can use the offset angle (figure 4) to rotate the initial perspective of the exported image.

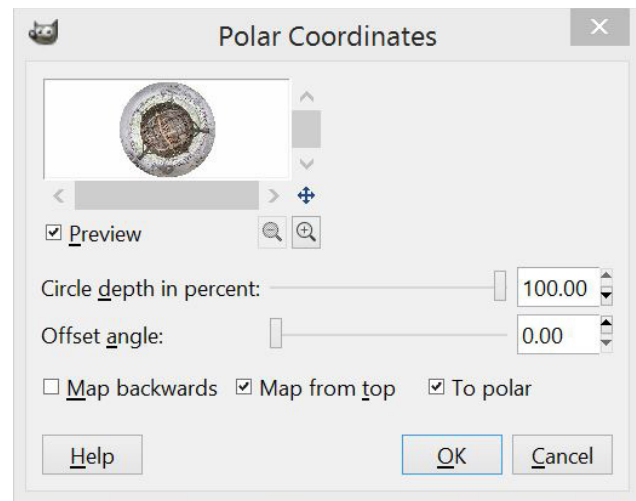


Figure 4. Example of the Polar Coordinates window. Note that the preview shows blank space on either side.

5. Re-crop and Export (figure 5)
 - a. To get rid of the blank space from the menu select Image > Autocrop Image
 - b. To save your converted image got to File > Export As...



Figure 5. The final image.

Smartphone Tips

Before I was able to get an actual 360 camera, I was just taking these images with my smartphone using the Google Street View app. The output from this can be very good but requires a bit of technique. These are a few tips and tricks that I have picked up for getting good results.

1. Make a marker
2. Identify a central location on the ground for your image.
It is best if you can make this marker part of the natural environment like using a leaf or design in the floor. This will be the spot that you will be revolving around to take the several images required to stitch together a panorama.
3. Prepare yourself
4. You want to try and keep your phone lens in the same location in space while you take your images. Doing this will reduce the stitching error and the best way to achieve this is to prepare yourself to be a revolving tripod.
 - a. Try to put where the lens of your phone is at eye level and your screen close to your face.
 - b. Tuck your elbows to your side and keep them there the whole time.
 - c. Straddle your feet around your marker so that you can comfortably try and target your phone's position to be maintained above the marker while you go around it.
5. Know how to Move
 - a. Go layer at a time. Start with your horizon and continue up. Save the bottom for last.
 - b. For vertical adjustments rotate your wrists.
 - c. For horizontal adjustments shuffle around your ground marker. (Basically, recreate a slow, synchronous orbit around your marker.)
 - d. Stay rotating in one direction. Once you start in one direction, keep in that direction.

SKYLORE - ORION IN FULLDOME, FREE!

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Abstract: The Williamsville Space Lab Planetarium has made dome adaptations for Dayle Brown's first book, *Skylore from Planet Earth: Orion*. The multicultural nature of the stories fits perfectly with our elementary school curriculum. We turned her book into a planetarium show and we're happy to share it with you. Dayle Brown generously offered us the use of her illustrations. A kindergarten teacher named Paul McGirr provided our narration. The Williamsville North High School students did all the rest: audio design and mixing, image editing and scripting in Sky-Skan's Digital Sky software. We hope you find it useful and enjoyable.

When I learned about Dayle Brown's *Skylore from Planet Earth* books, I thought about how wonderfully they would fit with what we do at the Williamsville Space Lab Planetarium. Our school district is very multi-cultural, with kids from all around the world. I thought it would be great for them to hear stories from around the world about things in the sky. I asked Dayle if she would be open to the making of dome adaptations from her books, and she graciously gave us full permission to use her texts and illustrations.

We decided to start with her original book about Orion. The first task was to create sound tracks for each story. One of the kindergarten teachers in our school district volunteered to do the narration. Ms. Paula McGirr had formal training in theater and lots of experience reading aloud to children. I set up a small recording studio in one of the music practice rooms. Paula, being the professional that she is, studied the Teachers' Guide for pronunciations and came very well prepared. Almost every story came out great on the first take. I asked a former student to narrate each story as well so that we would have some variety among the stories, but he struggled with pronunciation and timing. In the end, I decided that I would only use Paula's narration.

One of my student assistants was given the task of finding music for each story. Aaron Borok found that Kevin MacLeod's Incompetech website had great selections. We would like to thank Kevin for this royalty-free resource. Aaron used Audacity to mix the music with the narration for each story.

Several other student assistants worked on this project over the next few years. We set up a spreadsheet so that we could keep track of who was working on what. They took the artwork that Dayle had sent us and used Adobe Photoshop to cut out images from each page layout. This gave us the visual assets to use with each story. After preparing the art, they wrote script code for Sky-Skan's Digital Sky 2 software. We would discuss a "vision" for each story and then the kids would figure out how to make it work

on the dome. Each story in the book was its own mini-show of about three to five minutes, so this was a great training exercise for the students.

With 17 stories, an introduction and a closing credits section, it turned out to be a lot of work for the kids. After five years, the nine students that had worked for me finally completed the dome adaptations. I didn't anticipate how much fine tuning and correction would be necessary. Two more students worked on each story to clean up the code and fix errors during the next school year. At last, by the spring of 2018 they were finally done! But they weren't ready for the most important step—sharing! All along, I had intended to make these adaptations available for others in the planetarium community.

We rendered dome master frames for each story at both 1K and 2K resolution. I considered rendering them at 4K as well, but it would have taken a lot more time and I didn't feel like the product was much better looking because of the resolution of the artwork in the book. I may still do that if there are requests. We also encoded each story as a fisheye movie at 1K resolution for users of single projector and simpler systems.

Dayna Thompson and Tom Dobes from GLPA have set up a website to make these materials available to others. The website is <https://glpa.org/shows/skylore>. Users can download them in a few different ways. There are script and asset files for Digital Sky users. There is a compressed archive with all of the 1K fisheye movie files, and there are compressed archives for each story with 2K dome master frames. Each archive is password protected. Contact me at mpercy@willamsvillek12.org for the password. I just want to keep track of who is using them. Feel free to contact me with any other questions or requests.

We may take on Dayle's next Skylore book, but I want to see how things go with this first project for a while. Let me know what you think. I hope you can enjoy Dayle Brown's great book in your planetarium!

IPS 2022 BIDS

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Abstract: Two global cities have submitted bids to host the 2022 International Planetarium Society (IPS) conference: Houston, USA, and Saint Petersburg, Russia. GLPA's IPS Representative, Mike Smail, will cast a single vote for one of these locations on behalf of GLPA at the IPS Council meeting in June, 2019. Learn more about content, costs, planned activities, and community concerns for each conference site, and submit your vote for which location you think GLPA should support.

The Houston Museum of Natural Science invites you to Space City to explore 'Space Time' from July 4-8, 2022. The conference will focus on new astronomical fields of study/discoveries, and the past, present, and future of space exploration. All conference activities will take place at the Houston Museum of Natural Science, which contains a 400-seat giant screen theater, 190-seat planetarium, and a Dome Village with space for five portable domes. All attendees would also participate in a one-day mid-conference tour to Johnson Space Center/Space Center Houston. Conference registration will be \$400, which includes the day at Johnson Space Center. The conference banquet will be an additional \$80. Hotels range from \$70-279/night and are connected to the museum via Houston's light rail network. Budget dorms at Rice University will also be available for \$50/night. Houston has two international airports, and offers non-stop service to over 100 domestic cities, including over a dozen in the GLPA region.

Planetarium 1 invites you to focus on 'Astronomy for Everyone!' in St. Petersburg, Russia on August 7-11, 2022. As the world's largest planetarium (37m dome), most conference events can be hosted on-site at Planetarium 1. Additional meeting and lab spaces in the Planetarium 1 complex will also be used for delegate talks and sponsor demonstrations. Registration will be \$250-370, and the banquet will be an additional \$65. A wide variety of hotels are available in walking distance of Planetarium 1, ranging from \$40-\$280/night. Pulkovo Airport serves St. Petersburg with non-stop flights from many European capital cities, but no non-stop service from North America. High-speed trains also serve St. Petersburg from both Moscow and Helsinki, Finland. US residents are required to acquire a Passport and a tourist visa to visit Russia.

IPS OFFICER ELECTIONS

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Abstract: This fall, International Planetarium Society (IPS) members will vote on a full slate of organization officers: President-Elect, Secretary, and Treasurer/Membership Chair. Read position statements from prospective candidates, and maybe even talk to some of them first-hand at this poster session.

Candidate for Treasurer

Ann Bragg

I am honored to have the opportunity to continue in the office of IPS Treasurer for a third term. Despite the additional work that holding an International Planetarium Society office entails, I have enjoyed participating in IPS in a deeper way and I am happy to serve in this role, and also as membership chair, for another two years.

Why do I want to serve the planetarium field as an IPS officer? While I began my post-secondary education intending to become an astronomy researcher, I ultimately concluded that I was primarily interested in teaching and outreach, which eventually lead to my current position as both the planetarium director and an associate professor of Physics at Marietta College in Marietta, Ohio. In this role, I teach physics and astronomy courses at all levels, interacting with both general education students and physics majors.

I also regularly present outreach planetarium programs to groups of all ages. Participation in both IPS conferences and regional affiliate conferences has aided me greatly due to the professional development opportunities and the networking opportunities I have found there. Serving as an officer has allowed me to give something back to this wonderful community.

The most exciting aspect of my time as treasurer has been Vision 2020. During my nearly four years as treasurer, I have participated in some lively days with IPS Council dedicated to the eventual transformation of the society. While many of the changes are not yet fully implemented, the seeds have been planted for a bright future, promising increased resources and opportunities for IPS members to enhance their skills as planetarians in collaboration with others. I look forward to continued participation in this process to improve the society for the good of all of its present and future members, and in seeing the process through its “2020” target date.

That said, some of the most essential duties of a treasurer are far less exciting. I have worked to maintain the financial integrity of the International Planetarium Society through timely and accurate record keeping, bill payment, and tax filing, through ensuring that IPS funds are spent appropriately and in accordance

with our by-laws, as well as through working with accountants on a review of our finances each year. In a third term, I would continue to be a good steward of IPS resources while working to grow IPS membership through Vision 2020.

Candidate for Secretary

Patty Seaton

It is quite an honor to be asked again to run for the office of Executive Secretary. I appreciate the opportunity to serve this organization, being able to use the experience I have gained by serving my regional planetarium society.

I have 12 years of experience serving consecutive terms as president-elect, president, and past-president of the Middle Atlantic Planetarium Society (MAPS), from 2003-2015. I was recently re-elected to the Board of Directors in early June 2018.

I am the chair of the MAPS Elections Committee and recently filled the role as Awards Chair. I served as part of the ad-hoc Strategic Planning committee, where I took the minutes and maintained all the documents we developed for the organization.

While President of MAPS, because I believed that we should work more collaboratively with other regional organizations I attended several Western Alliance Planetarium Conferences to meet my colleagues from the West Coast and Central regions. I helped orchestrate the 2007 “Triple Conjunction” conference sponsored by three US regions and attended by delegates from all seven US regions.

As president of MAPS, I was also the representative for IPS Council, so I attended my first council meeting at IPS 2012 in Baton Rouge. I enjoyed meeting representatives from all over the world and learned the process of how Council works. I was part of the initial discussions for Vision 2020, and look forward to being part of the team that helps continue to implement the initiatives proposed by this project. I have been an active participant at these meetings, as well as a regular presenter at every IPS since Baton Rouge.

I cannot stress enough the importance of participation in an international organization:

- To be exposed to projects that are running all over the world, from small planetariums in Ghana to large planetariums in Beijing, China.
- To share educational ideas and out-of-the-box ideas for our theaters.
- To see how technology is being used all over the world to inspire a love of science in all we come in contact with.
- What an unbelievable opportunity we have through IPS! I am ready to use my talents and abilities to serve this organization, because I truly love it with all my heart.

Candidates for President-Elect

Levent Gurdemir

I am truly delighted and honored to receive another nomination for IPS president elect. It is such a prestigious and challenging six-year-long commitment to the organization with tremendous amount of work. However, I feel ready for the challenge.

I am the planetarium director of the University of Texas-Austin Planetarium located in the Dallas/Fort Worth Metroplex of Texas, USA. I have served as Southwestern Association of Planetariums (SWAP) president twice, and have gained significant experience in organization running that I would like to extend to IPS.

I am currently involved in the IPS Vision 2020 team as the head of Goal #5: Provide support and leadership in transitioning to next-generation planetarium design, technologies, and content development. I am also a current board member of the NASA Texas Space Grant Consortium (TSGC) that disseminates space grants in the Texas region.

I see a great potential in IPS to grow in membership. Currently, about one of every five planetariums in the world are IPS members (according to the Worldwide Planetarium Database there are 3000+ planetariums around the world; the number of IPS members is around 600). This means that we need to implement new initiatives to recruit more members.

As IPS being a worldwide organization, increasing membership will require understanding the culture and economics in each region where the membership is running behind. Therefore, IPS needs strong communication and involvement with regional organizations that will be instrumental to accomplish this goal.

To be able to offer attractive initiatives, the organization will also need better financial resources as relying on membership income alone won't be sufficient. In my opinion, the next president should be working on tying to increase the amount of sponsorship and government grants to the organization. This will require increased presence of the organization around the world and partnership with major observatories as well. Astronomy organizations may play a key role.

As part of the Vision 2020 team, I am currently working on defining our industry standards and developing an online library

that will host rich resource documentation. I will continue working on this task until it is accomplished and I will be happy to serve you as the next president of IPS.

Kaoru Kimura

Thank you for considering me as a candidate for the position of president-elect of the International Planetarium Society. I am honored to receive this nomination and am pleased to have the opportunity to share my international relationship, astronomy education, and planetarium experience with IPS members around the world.

I am an astronomy educator at the Science Museum, Tokyo, and education/public outreach staff of Venus Climate Orbiter Akatsuki (Planet-C) operated by JAXA, the Japan Space Agency. I am engaged in ongoing work to relate formal/non-formal education to research organization goals.

I have been involved with planetariums since 1987 and joined IPS in 1996 in Osaka. After our astronomical museum GOTOH Planetarium was closed, I studied program coordination at Yerkes Observatory in Wisconsin and worked at the Riken Institute for E/PO staff in Japan. After that, I became more involved with IPS. I acted as the representative of the Japan Planetarium Association for over ten years and now sit on the Education Committee and the professional development team of Vision 2020.

IPS is a unique organization. All members have the same purpose and passion under the sheltering sky of air or dome, even if we have different languages and cultures. My vision as president-elect is that I would like to use my experience and be even more involved in IPS' work including international exchange through astronomy education, culture and the planetarium, museum-school relations, and relations with research organizations.

We share communication methods of all astronomical information, including the latest astronomy data visualization. My efforts would be to intensify collaborations with relevant organizations that align with IPS, and promoting the latest scientific materials and see that they are used more effectively.

Also, IPS will be starting a new management system. I would advocate for collecting more information using websites and social communication so that IPS becomes the hub of localized information. I really look forward to working with committees and officers together to assure each region's interests and support of their projects.

If I become the president-elect, I suggest four priorities:

1. Make a good strategy for communication with different languages and cultures.
2. Focus on STEM and STEAM education at our planetariums and more professional development training.
3. Carry out Vision 2020 and make communication more comfortable between each region.

4. Celebrate the 100th anniversary of the invention of the planetarium in 2023.

I am committed to serving IPS to the best of my ability and humbly request your support.

Maciej Ligowski

I'm honored to receive this nomination from my colleagues who have served IPS for so many years. Ever since I joined the planetarium community I've been astonished by how friendly and collaborative it is. We are a global community that connects people from around the world. We're coming from different countries, and different cultures, but it is our mission that brings us together: to make the world better, to educate, to inspire, to bring awareness, to shape the future. And this why I believe being IPS president elect is not only an honor, but also a great responsibility. The world around us is evolving at a great pace. There are new immersive technologies appearing every day. Every year we see important scientific discoveries that shape our understanding of the universe.

There are also some global challenges we face. Today, it is perhaps more important than ever to share this knowledge and awareness with the public. Planetariums are unique in this sense. We use high-end technologies to achieve important goals. But the expectations of the audiences that are accustomed to visual quality of games and giant screen animations are high. It is therefore important to constantly improve the quality of planetarium content. I believe that with forward thinking and well-planned actions we can stay competitive and increase the number of people we reach every day.

I have always believed that each of us can make a difference if only we want it. This motivated me to organize IPS2016 in Warsaw, which was a great experience. Being a host, I've learned a lot, not only about myself but also about the organization. I've joined several council meetings, I'm an ad-hoc member of Vision 2020 planning team, and I've been a member of the Conference Committee. Being involved with IPS for several years I recognize its great number of strengths but also some weaknesses. If elected I will focus on:

- Introducing new governance structure as the result of Vision 2020 planning process to achieve more equitable representation of membership worldwide, make the governing board more accountable, and increase the IPS membership.
- Introducing standards and developing new strategies to ease bringing fresh and attractive content to domes worldwide.
- Expanding professional development opportunities by offering chances for in-depth discussions and workshops
- Finding ways to encourage young people to join IPS structures.

Coming from Poland and being a witness to its political and economic transformation, I also have an experience that may help IPS to become more international and expand to emerging countries.

In my career I worked both in a big public planetarium and as an independent producer. These two perspectives give me better understanding of needs and expectations of various members of our community. I humbly ask you for your support as IPS president elect and I can assure you that, as with anything else that I do in my life, I will put all my heart and energy into serving IPS to make it better.

BIG HORN MEDICINE WHEEL: A PHOTOGRAPHIC TOUR OF ASTRONOMICAL ALIGNMENTS

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Abstract: The Big Horn Medicine Wheel in Wyoming is a Native American stone circle with several stone cairns around its perimeter. Lines of sight among these cairns encode probable astronomical alignments. This poster features explanations of these alignments and photographs taken during a July 2017 visit to the site.



- at 9600 feet on ridge top in Wyoming
- at least 250 years old
- sacred site to Native Americans
- one of ~100 such wheels in US & Canada
- snow-free only in July & August



Introduction

The Big Horn Medicine Wheel is a well-known stone circle in Wyoming with probable astronomical alignments among cairns around its perimeter. It is located in the Bighorn Mountains between the cities of Sheridan and Cody. Access is via a spur road off Alt US 14. The spur road ends at a car park with interpretive signs and staffed in the summer as a National Historic Landmark.

Then you walk the last mile and a half to the Wheel itself. When I visited in July 2017, the guide explained to me that the walk is uphill both ways. Indeed it is! The walk is downhill, then uphill both ways. My walk from car park to site, cloudy both ways, helped me appreciate the effort of constructing the Wheel. Though the walk in and out was cloudy, during the hour I spent at the site, the Wheel was bathed in bright sunlight and completely free of other visitors!

I had had the impression from panoramas in planetarium shows that the Wheel was on a high plain, but it is in fact on a ridge-top, as is evident in the figure below. At 9600 feet elevation, the ridge top was at a comfortable 70°F while the cities below sweltered at nearly 100°F. Though snow-free in the summer, the site is buried in snow most of the year and the access road usually does not open until mid-June.

The site's age and origin are unknown, but it is at least 250 years old and was possibly built by Plains Indians 300-800 years ago. Today it is sacred to Native Americans, especially the Crow, and Native American groups visiting the site for ceremonies have priority over other non-Native visitors. There are dozens to hundreds of other such stone circles in the plains of the northern US and southern Canada.

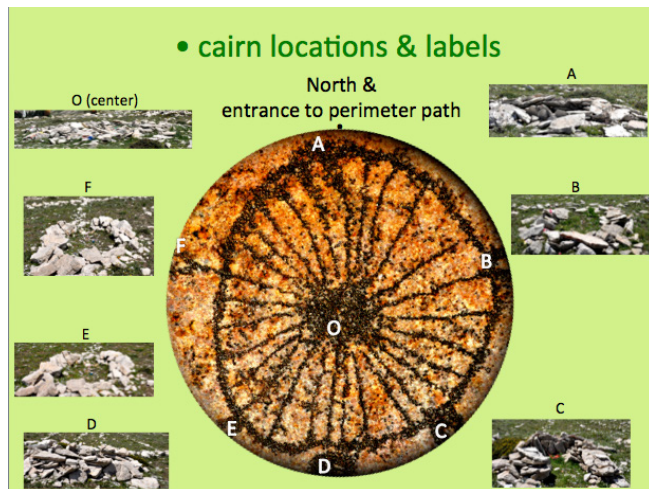
The Medicine Wheel

The Medicine Wheel, so called because of its sacred meaning to Native Americans, is a rough 25-meter-diameter stone circle. The ridge it rests on slopes gently to the east, so one has a view of the ridges and mountains to the east, but not to the west. This slope is evident in the lower south-facing photo in the figure below.

The stone circle is enclosed by a modern fence that protects it from visitors. Only Native Americans are allowed inside the enclosure. Access to the path around the enclosure is from the north and you are asked to walk clockwise around the path.



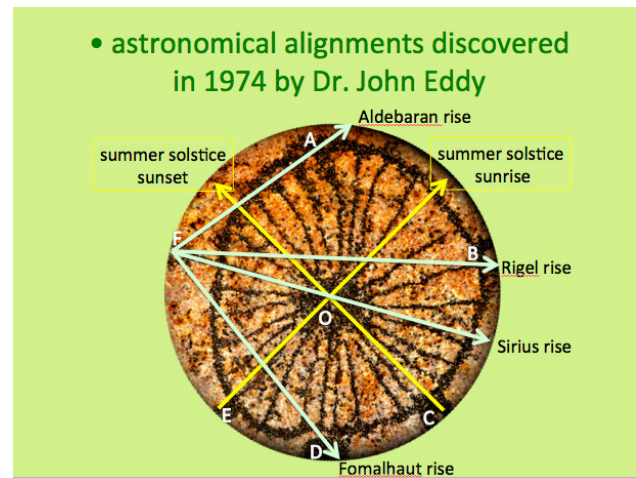
Seven smaller stone circles (cairns) are arranged on the Wheel, one in the center and six at apparently irregular spaces around the perimeter. As is evident in my photos below, the cairns are rough rather than refined in shape. The central cairn is labeled O and the perimeter cairns are labeled A through F going clockwise from north.



Stone spokes—28 of them—radiate out from central cairn O to the perimeter. Like the cairns, the spokes are rough rather than refined. The number 28 approximates the length of the synodic month or the cycle of the Moon's phases.

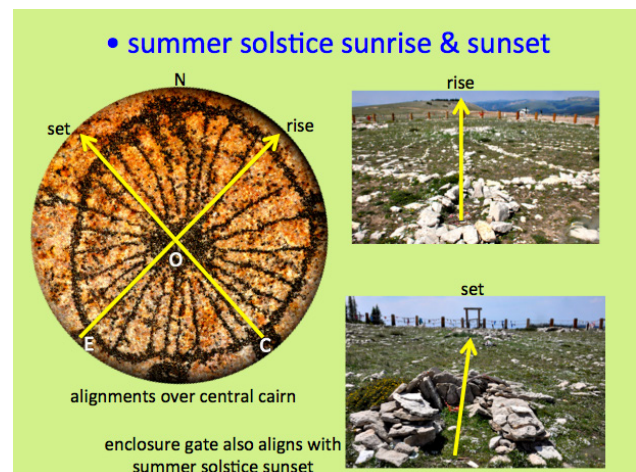
Astronomical alignments revealed

In 1974 astronomer-ethnographer Dr. Jack Eddy surveyed the site and uncovered probable astronomical alignments among the cairns. Though some of his astronomical colleagues were dismissive of his work, Eddy was careful not to over-interpret and that caution won him the respect of practitioners in the emerging field of archaeoastronomy.



Eddy's work showed that all seven cairns were involved in probable alignments that in turn explained the cairns' irregular spacing. When I visited the site, I carried a photocopy of his alignment map so I could recognize the cairns and their possible alignments.

Two of the alignments involved summer solstice sunrise and sunset. A sightline from cairn E to central cairn O aligns with summer solstice sunrise and extends on to the point on the distant ridge where that sunrise occurs. A sightline from cairn C to central cairn O aligns with summer solstice sunset, though the slope of the ground obscures the distant ridge on which that sunset occurs. Interestingly, the one gate in the modern enclosing fence lies along this solstice sunset line. I suspect that this placement was deliberate and is a modern affirmation and extension of the probable historic intentions. As expected, there are no winter solstice alignments because the site is inaccessible in winter.

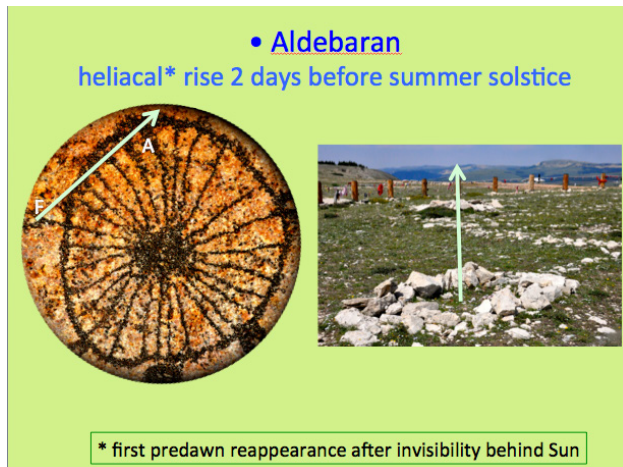


The other four alignments are to stars whose heliacal rising dates are connected with the date of summer solstice. These alignments are all from cairn F and go to cairns A, B, O, and D.

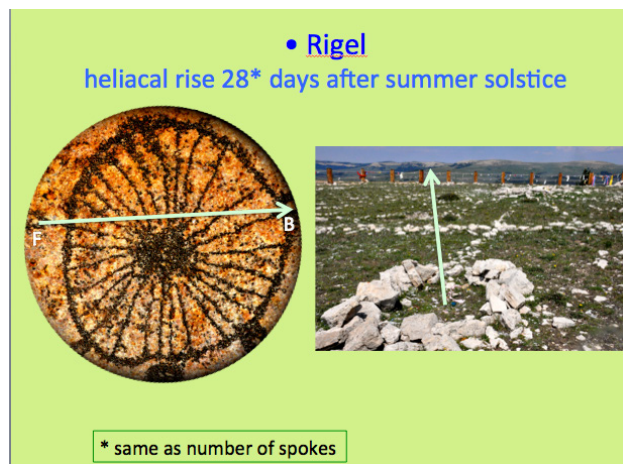
Heliacal rise is when a star first reappears in the morning sky after a period of invisibility due to lining up with the Sun. As the Sun moves eastward along the ecliptic, a given star will rise four minutes earlier each day. If the star is too close to the Sun, morning twilight will be too bright for the star to be visible. Eventually, however, the star will rise long enough before the Sun that

the morning twilight will be deep enough that the star can briefly be seen twinkling in the twilight before the twilight brightens and washes out the star. The day on which the star is first visible in this way is the date of heliacal rising.

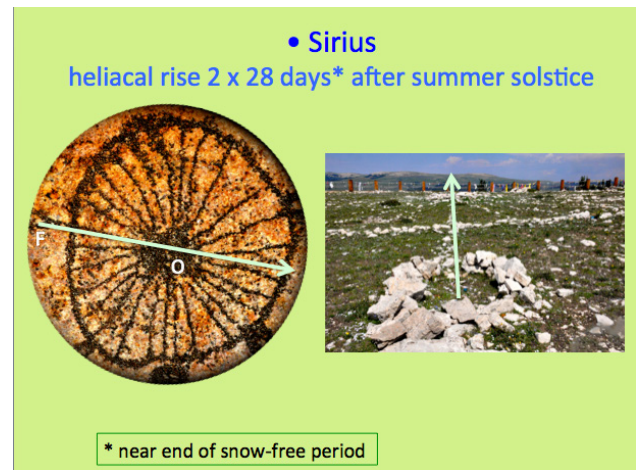
A line from cairn F to cairn A points to the rising direction of Aldebaran, whose heliacal rise occurs about two days before the summer solstice and thus announces the solstice.



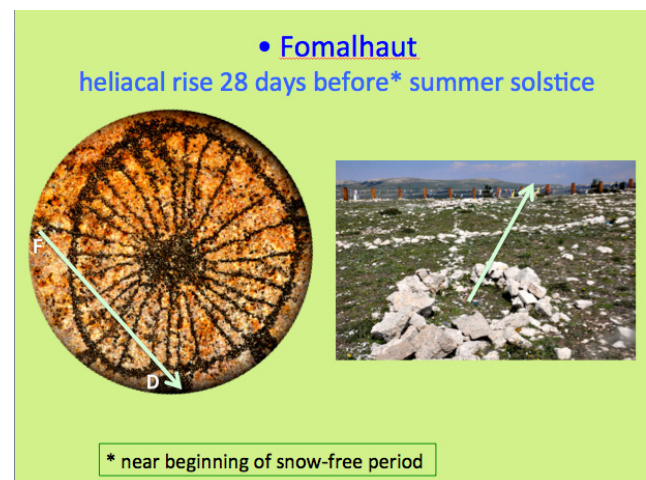
Moving clockwise, a line from cairn F to cairn B points to the rising direction of Rigel, whose heliacal rise takes place 28 days after the summer solstice.



Continuing clockwise, a line from cairn F to central cairn O points to the rising direction of Sirius, whose heliacal rise falls 2x28 days after the summer solstice.



Finally, a line from cairn F to cairn D points to the rising direction of the star Fomalhaut, which rises heliacally 28 days before the summer solstice, near the beginning of the snow-free period when the site becomes accessible.



So all seven cairns, despite their apparently irregular spacing, are involved in alignments. This argues that the alignments are intentional rather than coincidental, though of course it does not prove it because we have no written record from the builders describing their intention. But in a sense, the stones may well be their script that speaks out to us across the centuries telling us how they encoded the sacred sky in their construction. "Read us!" they may well be saying, and perhaps, thanks to Jack Eddy, we have done just that.

Reference

Eddy, John A. (1974). *Astronomical Alignment of the Big Horn Medicine Wheel*. *Science*, vol. 184, no. 4141, pp. 1035-1043.

NATIONAL CHEMISTRY WEEK: CHEMISTRY IS OUT OF THIS WORLD!

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Abstract: Every year the American Chemical Society (ACS) sponsors National Chemistry Week, with a different theme each time. This year's theme is "Chemistry is Out of this World." It's the perfect opportunity to partner with colleagues or make new contacts, and offer astronomy activities for your public audiences. Fernbank Science Center is celebrating on Saturday, November 3.

We've probably all partnered with groups—a library, a local theater, an astronomy club. One suggestion for 2018 is partnering with the American Chemical Society for their "Chemistry is Out of this World" theme.

ACS hosts a web site with information about the current year's events. <https://www.acs.org/content/acs/en/education/outreach/new.html>. Graphics, activities, an editable banner, a "branding" kit, press release templates, all there for anyone's use. For example:



The only concern I have about these graphics is the orientation of several characters. While allegedly in a space station orbiting Earth, plants are watered as though in a one-g environment.

Partnering with other groups is a great way to extend your dome's presence. Advertising and marketing can be shared, other audiences contacted, new members are a possibility, different feedback can help with your own programming.

Fernbank Science Center is utilizing the NISE Net (National Informal STEM Education Network) kits for our celebration on Saturday, November 3: Let's Do Chemistry: It's Out of this World. Their web presence can be located at <http://www.nisenet.org/earthspacekit>.

Student science clubs from area universities set up tables in the exhibit halls and offer hands-on crafts and demonstrations. Fernbank staff give "Chemical Magic" programs. Local ACS chapters provide supplies and give-aways.

Ultraviolet-sensitive beads are always fun. A short segment of chenille stem (what we used to call "pipe cleaners") and four or five white UV-sensitive pony beads make an ultraviolet detector. The chemistry of the dye in the beads, and wavelengths of light provide a connection between astronomy and chemistry.

Steve Spangler Science has good prices for the beads — <https://www.stevespanglerscience.com> and for experiments with sunscreen, the Stanford Solar Center has a .pdf of the procedure at <http://solar-center.stanford.edu/activities/UVBeads/UV-Bead-Instructions.pdf>.

There are plenty of other online resources for astronomy activities, suitable for a science celebration.

The Astronomical Society of the Pacific has excellent resources at <https://www.astrosociety.org/education/hands-on-astronomy-activities/>.

NASA's Space Place page has lists of web sites and crafts. Check out their "sun paper" at <https://spaceplace.nasa.gov/sun-paper/en/>.

If you're looking for a fun and educational science connection, National Chemistry Week can be engaging and educational for your visitors. And provide new contacts and partners for your dome.

STREAMING SCIENCE

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Abstract: Most weeks I stream on Twitch for Science Sunday. I focus on colorizing telescope data for my live audience. During the process, I talk about to my audience about the processes that turn data into pretty pictures.

What I do

1. Decide what astronomical object I'm going to work on. I generally give viewers a few options or ask for suggestions.
2. Download data from either Hubble Legacy Archive or MAST Portal. MAST covers all space telescopes while Hubble Legacy Archive only has Hubble data. I always download files before I stream. I will show my audience the process of getting the data for themselves.
3. Load data into FITS Liberator. Here I make a few adjustments to contrast and saturation to better see fainter features in the image. Once I'm done, I save the image as a TIF which is a file format that Photoshop can work with.
4. Load the converted images into Photoshop. Each image will become its own layer in the final composite. Now is a good time to give the layers a name that you'll understand and recognize later.
5. Make the magic happen. This is where I spend most of my time on an object. Colorizing is a multi-step process and making the final image can easily take hours -- especially if you're not completely familiar with Photoshop. I've found that setting small goals at the beginning of the stream works well. (For a breakdown of this process, see Thomas Kaffka's step-by-step guide at https://www.spacetelescope.org/projects/fits_liberator/stepbystep/)
6. Entertain my audience. My webcam is pointed at my dogs and I bribe them into staying in frame with low-calorie treats. When a viewer donates I will toss handfuls of treats at the dogs. It's a bit gimmicky, but both the dogs and the viewers like it. (As one of my viewers said: "come for the science, stay for the doggos!") I also chat with my audience while I work. Topics are not necessarily astronomy related but I will go over what I'm doing and why. New viewers typically drop in while I'm colorizing an object so giving them a brief overview of what I'm doing is helpful for them.

What I've learned

- Sunday afternoons—especially while the weather is nice—is frequently a time when friends and family make plans. You will often have no control of this.
- The general public does not realize that the pretty pictures they know from Hubble are false color.
- Photoshop is worth spending money on. GIMP works but Photoshop is the industry standard for colorizing data.
- Viewers will donate for seemingly silly things: throwing copious amounts of treats at dogs or overloading your computer and causing the stream to crash.
- Twitch's minimum computer requirements are literally the bare minimum you need to stream. If you can afford it, upgrade your computer.
- People really enjoy seeing pets.

Tips

- Make a schedule and stick to it. Try to stream at the same time, every time.
- If you need to cancel or reschedule, let your audience know as soon as possible through whatever channels you use to communicate with them.
- Inform those around you (loved ones, roommates, colleagues) of your streaming schedule. This helps prevent interruptions and conflicting plans.
- Always download files before you start streaming.
- Decide ahead of time what boundaries you want to maintain with your audience. (Do I want my audience to know if I'm in a relationship? Am I okay with my loved one showing up on the stream?)

How to set up your very own stream

Equipment

Essential:

- Computer meeting following minimum requirements
 - * CPU: Intel Core i5-4670 or AMD equivalent
 - * Memory: 8GB DDR3 SDRAM
 - * OS: Windows 7 Home Premium
 - * Graphics card that can support DirectX 10 and up
- Microphone
- Open Broadcasting Software (OBS) Studio (<https://obsproject.com/>)
- Twitch, YouTube or other streaming service account
- Web browser

Extra:

- Webcam
- Two light sources with matching temperature bulbs
- Softbox
- Green screen
- Nightbot (<https://beta.nightbot.tv/>)
- More RAM
- Better processor

Getting started

One-time setup for OBS:

- Download and install
- Get your stream key from channel settings and copy/paste into OBS's stream settings
- Adjust video settings. Output at 1280x720 -- not 1920x1080. (This reduces lag for your viewers.)
- Create a basic scene with various sources such as input audio, images, window capture, text and webcam

One-time setup for Twitch:

- Set category on Dashboard to "Science & Technology"
- Upload profile picture
- Upload profile banner
- Upload a video player banner
- Set moderation settings

One, two, three, stream!

Prepping to stream:

- Take a "bio" break: use the bathroom, smoke, eat a snack, whatever you need to do to make yourself physically comfortable for the next hour or so
- Do an audio and webcam check
- Announce when you'll be streaming to both on- and off-line social networks
- Gather materials/prep software
- Adjust lighting, if you have it

While you're streaming:

- Chat and interact with your audience
- Welcome new viewers
- Acknowledge donations and new subscriptions
- Avoid the use of filler words
- Don't respond to obvious trolling or baiting
- Be authentic and genuine

Resources

<https://hla.stsci.edu/>
<https://mast.stsci.edu/>
https://spacetelescope.org/projects/fits_liberator/
https://www.spacetelescope.org/projects/fits_liberator/stepbystep/
<https://obsproject.com/>
<https://beta.nightbot.tv/>

Sources

<https://help.twitch.tv/customer/en/portal/articles/792761-how-to-broadcast-pc-games>
<https://help.twitch.tv/customer/en/portal/articles/1253460-broadcast-requirements>

GLIPSA PRE-CONFERENCE WORKSHOP

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Dayna Thompson

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Abstract: This all day workshop was intended to give GLPA attendees a sense of what happens at the annual Live Interactive Planetarium Symposium (LIPS). LIPS is a multi-day gathering that focuses on all facets of live programming: Presentation skills; sample activities; etc. GLIPSA was open to anyone registered to attend GLPA. As with LIPS, ideas and content presented at GLIPSA applied to everyone who does live shows, no matter whether those shows are in a portable dome or fixed, with a digital system or starball. 2018 was the sixth GLIPSA, and there were 24 attendees.

Presentations included (listed in chronological order):

1-hour presentation by Michael McConville: Fundamentals of Visual Storytelling

This session provided a primer for understanding how our audiences experience and interpret information. Choices of color, position, relationships, and context can make good shows great and great shows extraordinary. We walked through numerous examples of how proper visual storytelling can make even the most complicated concepts and data sets easier to understand, and we shared some best practices and visualization decisions as a group.

2.25-hour workshop by Keith Davis Planetarium Presentation Planning and Process: How do we build shows and what methods can we share?

When you create a new planetarium program, there are many decisions to make. For example: What topic should you choose? How long should you make the show? How much (or how little) information should you include? We discussed these questions, and worked in groups to create an outline of a new program.

60-minute workshop by Dayna Thompson Fostering Future Scientists

During this workshop, participants worked in teams and actively explored the characteristics of a scientist. As a group, we came up with creative activities and methods that teach planetarium learners how to be a scientist.

40-minute workshop by Karrie Berglund Willkommen, Bienvenue, Welcome!

Planetariums come in all shapes and sizes, with varying seating configurations, springline heights, diameters, and more. All of these elements can contribute to the type and quality of audience interaction in your planetarium programs. In this session we explored some barriers to audience participation, brainstormed ideas for removing or reducing barriers associated with your dome configuration, and discussed ideas for how to best encourage audience interaction in your dome.

CONSTRUCTION OF A DRAMATIC CLASSROOM SPECTRUM PROJECTOR

Gary Tomlinson

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Abstract: This workshop details construction and use of an inexpensive classroom lab station where students can actually investigate how to add and subtract colors from a spectrum, the effect of filters, and an absorption spectrum. In addition it shows the construction of a device to show dramatically that there are an infinite number of colors in a rainbow.

N.B. This workshop will NOT result in a finished project (too big to easily transport) but will provide all hard to find items and detailed construction and use of the Spectrum Projector will be demonstrated.

i.e. it will cost approximately between \$8 & \$61 additional to complete this project

Participants will be furnished over \$30.00 of materials

The finished Spectrum Projector is commercially available for \$225.17 (plus shipping) from Science First

- A Continuous spectrum
- The effect of filters on light
- Adding and subtracting colors of light
- Absorption spectra
- The fact that a rainbow has many more colors than just 7 (very dramatic)

The construction of both the spectrum projector and the colorimeter will be demonstrated and this document describes detailed construction.

Participants will be furnished with over \$30.00 worth of materials. The grating used in this project is *100 times more efficient* than acetate gratings.

Overview

Participants will receive the hard to find materials necessary to construct a spectrum projector and colorimeter that was demonstrated in the author's talk at the 2011 GLPA conference in Champaign (see "Color Activities That Can be Used in Conjunction With Cosmic Colors," GLPA 2011 Proceedings pp 97 + Supplemental Material). The spectrum projector and colorimeter can be used to investigate and demonstrate:

Materials NOT furnished:

Items NOT furnished	Estimated Cost	Source
A large cardboard box	Free	Home or Grocery store
White poster board 5 by 6" (or larger)	\$2.00 or Free	Art store or art teacher
Colored cardboard 5 by 6" (or larger) Red, Blue, Green or could use a file folder	\$4.00 or Free	Art store or art teacher
Felt blackboard eraser	\$3.00 or Free	Teacher store or classroom
Blocks of wood	\$15.00 or Free	Toy Store or shop teacher
4 by 4 inch corrugated cardboard	Free	Home or Grocery store

Aluminum foil (2 ½ by 5 inches)	Minimal	Home or Grocery store
Didymium lens	\$30.00 or Free	Glass blowing shop or eBay
200 watt clear light bulb, <u>vertical</u> filament	2.84	Home Improvement Store, e.g. Home Depot or Amazon
Light bulb socket	1.19	Home Improvement Store, e.g. Home Depot
Octagon knock out box	0.99	Home Improvement Store, e.g. Home Depot
NM clamp 3/8"	0.33	Home Improvement Store, e.g. Home Depot
Extension cord (8 or 12 feet)	2.97	Home Improvement Store, e.g. Home Depot
2 paper towel tubes	Free	Home
Total cost of non-furnished material	\$8.32 to \$61.00	

Prices are April 2018 prices

Materials furnished:

Materials furnished	Cost	Source
Socket base, 5 x 5" ½" plywood	Furnished by author	Shop teacher
2 Double convex lens 38 mm diameter 100 mm fl.	1.50/each. One included in workshop fee	Science First # 614-0310 800-875-3214
Two 2 ½" x 2 ½" Holographic grating	\$17.33 One included in workshop fee	Science First # 614-0075 800-875-3214
Five ½" Mirror squares	\$18.00 per hundred or \$0.90 for 5 Included in workshop fee	Art supply or Amazon
1 box of paraffin	\$9.00 Included in workshop fee	Grocery store or Amazon
Colored Jells 20 by 24 inch* Need 3 by 5 inches Roscolux #27, 83 & 91	\$8.00 each = \$24.00 or \$0.60 per set. Included in workshop fee	Theater supply
Total cost of furnished materials	\$29.33+	

*1 sheet of jel makes 32 three by five inch rectangles.

Tools needed

Scotch/masking Tape
Scissors
Wire cutters/strippers

X-acto knife
Knife
Glue
Flat blade screw driver

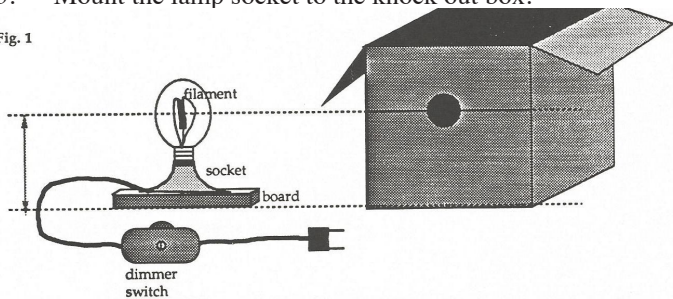
Spectrum Projector Construction

(from "Handling Color: Preconception-Based, Hands-On Spectrum Activities," a workshop presented at AAPT, 1990 by Anne G. Young & Andrew MacFadyen for Project STAR)

Procedure for making a spectrum projector:

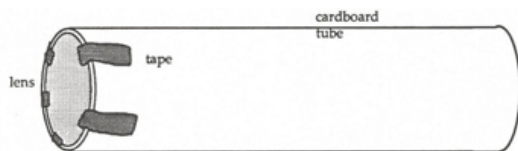
1. Cut end off extension cord.
2. Knock out one opening on the octagon knock out box. Install the MN clamp and run the wires through the clamp.
3. Strip the wires and connect the wires to the base. The ribbed wire (with the wider prong) is neutral and should be mounted to the side of the socket while the other wire should be mounted to the center of the socket.
4. Tighten down the screws on the cord (NM) clamp.
5. Mount the lamp socket to the knock out box.

Fig. 1



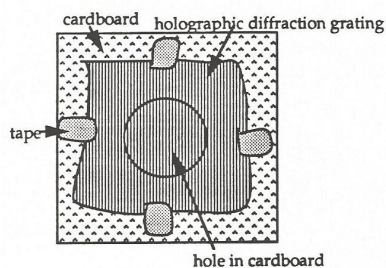
6. Install lamp.

Fig. 2

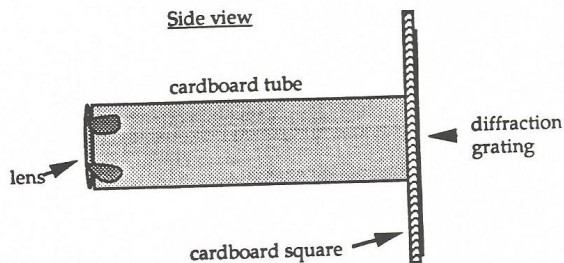


7. Place lamp assembly into box.
8. Using an X-acto knife, cut a round hole in each end of the cardboard box the same size as the paper towel tube and at the same height as the center of the lamp filament.

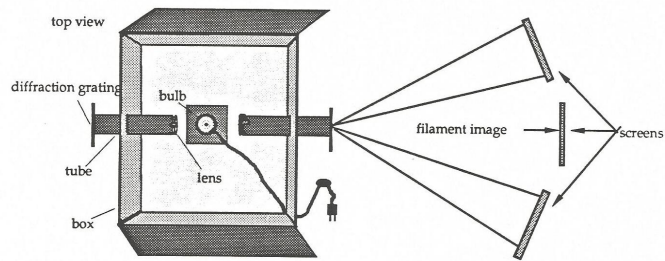
Fig. 3



Side view



9. Tape a lens on the end of the paper towel tube



10. Cut a hole in the center of the 4" cardboard squares the same size as the paper towel tube and attach a diffraction grating. Do NOT touch or scratch the grating. Then press fit the 4" square onto the paper towel tube (opposite end from the lens).
11. Place the lamp and socket inside the box and insert (lens end first) the paper towel tube into the holes in the side of the box
12. Take three 5 by 6 inch pieces of cardboard (file folder, etc.) and make a windows 2½ by 4½ inches cutting out the center and tape the colored jels (1 of each color) to the cardboard.
13. Affix (glue) a mirror square onto one side of each of the toy blocks.

Using the Spectrum Projector

(Note, each spectrum projector can be used to set up 4 lab stations, 2 per side)

Procedure:

Plug in the lamp and focus the projector onto white cardboard held in the felt eraser (you may need to place the eraser on top of books to adjust to the proper height).

Now locate the spectra of the projector (see diagram 1). You may have to rotate the paper towel tube.

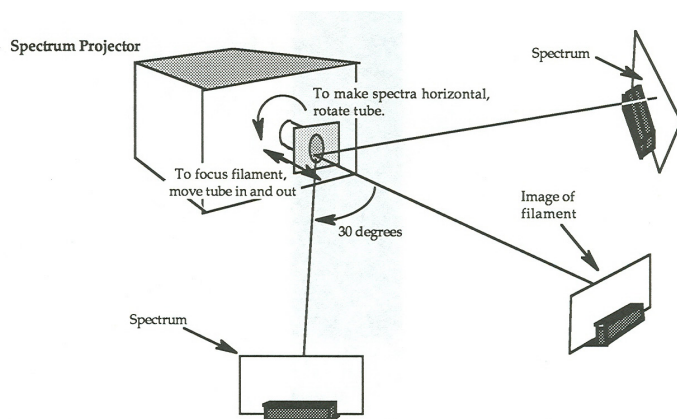


Diagram 1

Using the spectrum projector to re-combine colors of light

Now place two mirrors into the colored (spectra) light. Aim the reflected colors onto the side of the projector. Tape a piece of white paper onto the side where the two colored reflected lights converge (see diagram). "Mix" several pairs of colors.

If the intensity of the two colors is not the same, take another mirror and reflect the dimmer color twice. If more adjustment is needed use a neutral density filter(s) on the brighter color.

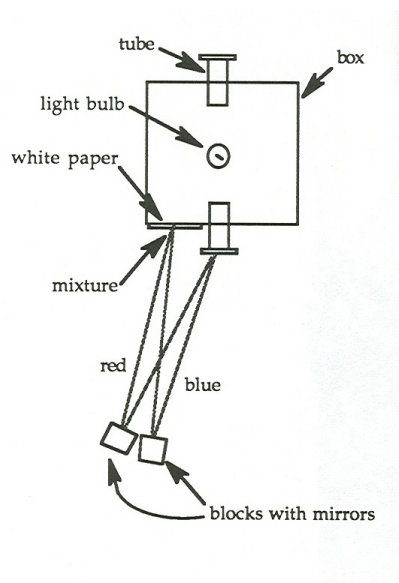


Diagram 2

Using the spectrum projector to see the effect of colored filters

- Remove the grating assembly (tube) from the spectrum projector so that you just have white light showing on white cardboard and follow the visual instructions below.

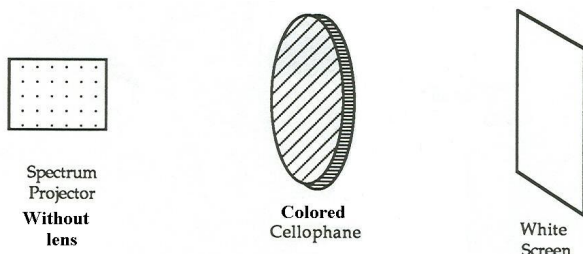


Diagram 3

- Now use 2 different filters.

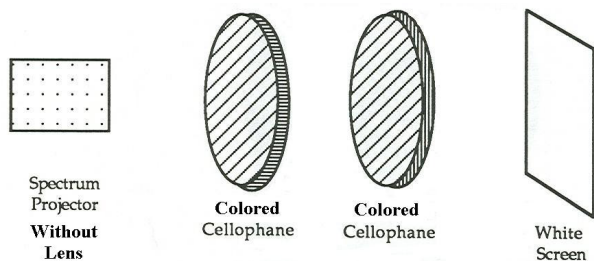


Diagram 4

- Reinsert the lens/grating assembly (tube) from the spectrum projector so that you have a spectrum showing on the white cardboard and follow the visual instructions below. Note the white cardboard is not straight in from of the lens assembly but offset about 30 degrees—see diagram # 1.

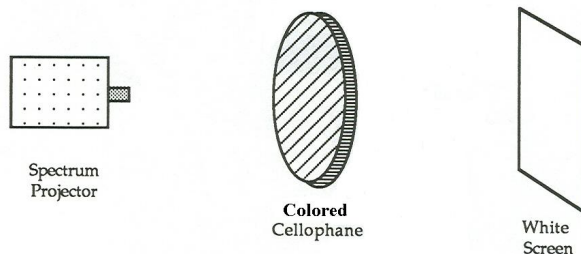


Diagram 5

- Now use 2 different filters.

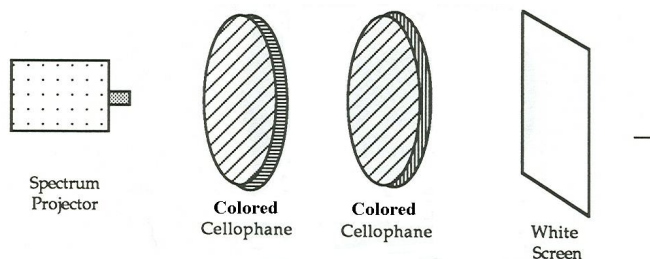


Diagram 6

Sample questions:

What color would a red car look under blue light?

What color would a blue car look under red light?

Good filters can cost hundreds of dollars each and would be better suited to the above experiment. Since we use cheap filters, some “incorrect” observations were made. A good filter will only let through a very specific color. Likewise, cardboard of a true color will only reflect only one color of light. The cheap cardboard we used reflects mainly the color it appears under white light. Unfortunately it also reflects many other colors, just not as well. Using good filters and cardboard then you would have observed the following:

- A red filter lets through only red light; red cardboard only reflects red light
- A green filter lets through only green light; green cardboard only reflects green light
- A blue filter lets through only blue light; blue cardboard only reflects blue light

Therefore, using a red filter (which only lets through red light) & shining this light upon a perfectly blue car (which only reflects blue light) would show a black (absence of light) car as there is no blue light to reflect. Similarly, a green car under any color of light other than green would also look black. In real life, just like the cheap cardboard, cars are not pure color. You may have noticed that some parking lot lights are yellowish in color and cars look vastly different under that light, so much so that people

have not been able to find their cars even when they were standing right next to them. So your answers to the previous two questions would have been “black” if you were using quality equipment.

Absorption spectra

Absorption spectra or dark line spectra are seldom demonstrated or observed in the classroom. By placing a Didymium lens (glass blowers often use this type of lens and may give you one if you ask) in front of the Spectrum Projector’s spectra, you can show a broad absorption spectrum.

Building a Colorometer

Materials needed:

One 1 lb box of paraffin

Aluminum foil

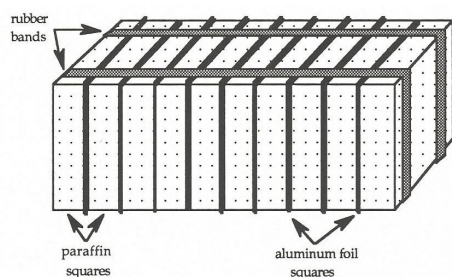
Two large rubber bands

One piece of cardboard (the same size as the paraffin blocks) cut in half.

Procedure for making the Colorometer

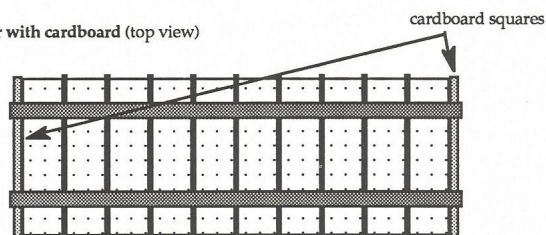
1. Cut 9 pieces of aluminum foil the same size as the paraffin blocks.
2. Cut each paraffin block in half to make 10 paraffin squares
3. Fold each piece of aluminum foil in half (to make it equally shiny on each side)
4. Place the aluminum foil between each square of paraffin and place a piece of cardboard on each end

Fig. 1



5. Wrap with the rubber bands to hold together.

Colorimeter with cardboard (top view)



Using the Colorometer

By moving the Colorimeter in front of the Spectrum Projector’s spectra, you can easily demonstrate there are not just seven ROY G BIV colors.

The human can differentiate at most 10 million different colors but there are, in reality, an infinite number of colors.

Resources

- Project STAR Survey: How Much Do You Know About the Nature of Light?
- Planetarium Activities for Student Success, Volume 8, Colors and Space, Lawrence Hall of Science
- NASA Facts: The Spectrum, NF-54/1-75
- NASA/JPL: Infrared Astronomy: More than Our Eyes Can See, JPL 400-745, Rev 1, 12/98; LG-1998-11-001-JPL
- Spectra Quest! Discovering the Magic and Message of Light by Michael Zeilik and Stephen Jacobs, The Learning Zone
- How Astronomers Use Spectra to Learn About the Sun and Other Stars by Dr. Jeffrey W. Brosius, NASA NP-1998-10-055-GSFC
- The Electromagnetic Spectrum, NASA, STScI P-01-02 # NW-2002-5-03-GSFC
- The Multiwavelength Universe, NASA/JPL
- More Universe at Our Fingertips: Astronomy Activities & Resources, Astronomical Society of the Pacific
- The Universe at Our Fingertips: An Astronomy Activity and Resource Notebook, Astronomical Society of the Pacific.
- Handling Color: Preconception-Based, Hands-On Spectrum Activities, Project STAR

CONSTRUCTION OF A UNIQUE TABLE TOP MODEL OF THE EARTH, SUN, & MOON

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Abstract: This workshop details the construction and use of an inexpensive classroom lab station where students can actually investigate seasons, day & night, moon phases, eclipse and the reasons for each. In addition it allows students to measure the time and direction of sunrise/set at different latitudes as well as the altitude of the mid-day Sun.

N.B. This workshop will NOT result in a finished project (too big to easily transport) but will provide all hard to find & custom made items as well as provide detailed construction details and educational use instructions.

i.e. it will take approximately an additional \$32.00 to complete this project

Participants will be furnished custom made materials.

The finished Table Top Model is not commercially available.

Participants will receive the hard to find (almost impossible even) materials necessary to construct a table top model of the Earth, Sun and Moon that was described in an article appearing in the *Planetarian* Sept 2003, Vol 32. # 3 pp. 11-17.

- This model can be used in the classroom to:
- Explain the two reasons for seasons
- Why the seasons are reversed from Northern to Southern Hemisphere
- Tell time of sunrise/set at different latitudes
- Explain eclipses & eclipse seasons
- Explain day and night
- Illustrate the varying lengths of daylight at different latitudes/seasons

- Measure the altitude of the midday Sun at different seasons
- Illustrate “land of the midnight Sun”
- Explain the reason the North Star doesn’t change with the Earth’s rotation or as the Earth revolves around the Sun
- Explain why different stars are visible during different seasons
- Moon phases
- Address the misconception that the Earth changes its direction of “tilt” as it revolves around the sun

The complete construction of the table top model will be demonstrated as well as complete written instructions will be distributed. Plus other season demonstrations will be illustrated.

Materials NOT furnished:

<i>Item NOT furnished</i>	<i>Estimated Cost</i>	<i>Source</i>
4 three inch Styrofoam spheres	\$5.99/6	Craft store
1 four inch Styrofoam sphere	\$3.99	Craft store
1 3 by 4 foot science fair cardboard	\$5.50	Office or craft store
8 two inch Styrofoam spheres	\$5.99/12	Craft store
File folder	Free	Office supply store
Black latex spray paint (that can be used on Styrofoam without melting it!) such as Design Master Colortool #725	\$8.99	Craft store

Large nail or Tent Stake	\$2.19/8 \$0.99	Home improvement store
Block of wood or children's toy ABC blocks	\$0.00 \$15.00	H. S. shop or Toy store
5 # 4 or #6 3/4 " wood screws	\$0.82/18	Home improvement store
Total cost of non-furnished material	~\$32.00	

Materials furnished:

<i>Material furnished</i>	<i>Cost</i>	<i>Source</i>
4 3/4 "roofing nails	\$2.47/310 or \$0.03/4	Home improvement store
4 custom made Earth axis base	Priceless	Author or make them yourselves
1 custom made Sun axis base	Priceless	Author or make them yourselves
4 plastic Earth latitude indicators + master	Free	Author or make them yourselves
4 paper clocks + master	Free	Author or make them yourselves
Total cost of furnished materials	Priceless	

Tools Needed

- Glue
- String
- Push pin
- Ink pen
- 5/16" hole punch
- 5' straight edge
- Starter nails
- Scotch tape

Construction of the Model

The construction of the Earth, Sun Moon model should only take a few hours to complete. Most of the materials are available at common hardware or craft stores.

Procedure

Using the straight edge draw diagonal lines from corner to corner of the 4' x 3' science fair board to locate its center. Use the string to construct a 17" compass using the push pin and ink pen. Draw a circle with a radius of 17 inches on the cardboard to show the orbit of the Earth. Now attach the four Earth wedges using the wood screws and glue on the circle where the diagonals cross the circle (i.e. every 90 degrees). Make sure the dowels (axis of the Earth) all slant the same way (one should point toward the Sun and the opposite one, away). Use the final screw and glue to mount the Sun base in the center.

Cut a strip of file folder 2" x 11 1/2. Make a cylinder from the

strips of file folder and tape around each 3-inch ball along at its widest part. This will serve as a holder and also act as a mask to keep paint from getting on the "day" side of each Earth ball. Now spray half of each Earth ball black. Be aware that many kinds of paint will "melt" or shrink Styrofoam. Latex spray paint, available from many craft and hobby stores should not damage Styrofoam. There is also a type of Styrofoam that is shrink resistant and does not "melt" as easily, but it is often difficult to find.

After the paint is dry, carefully make holes through the center of the ball for the wooden dowel on the Earth axis base to fit through. For the two balls that represent the Earth at the equinox, the axis entrance and exit hole is right at the terminator. The two balls that represent the Earth at the solstice are also identical (one is just placed upside down from the other on its wedge). Here you must make the axis hole enter and exit 23 1/2° from the terminator. On the 3-inch ball, that is about 5/8-inch. You could also use one of the latitude locators plastic strips to mark where 23 1/2° mark should be.

It is easier to make holes in the Styrofoam balls if you first mark the ball where you want the hole to enter and exit. At the exit point insert a toothpick or other object (nail) to serve as a visual guide. Now push something skinny (e.g. a knitting needle, long nail, section of clothes hanger wire or a pencil) through the Styrofoam ball and increase the size to 5/16-inch.

Now copy the master paper "clock." Cut out four 1-inch square clocks and punch a 5/16" hole in the center of each. Glue the "clocks" onto each Styrofoam ball over the hole you created. On the two balls with the entrance and exit hole on the terminator,

glue the “clock” such that the two “6’s” point along the terminator. These two balls, of course, represent spring and fall. Take one of the remaining balls and glue the “clock” over the hole on the painted (black) side with its two “6’s” parallel to the terminator. This ball represents winter in the Northern Hemisphere. Take the last ball and glue its “clock” over the hole in the white portion again with its two “6’s” pointing parallel to the terminator. This represents summer.

Take the “latitude locator” master and make a transparency. Cut the latitude locators out and use the paper punch (or drill) to make a 5/16-inch hole at each end. *NB: Use the master latitude locator as a template as some of the transparencies I gave you are a little small.* Punch a 5/16” hole 4 7/8” apart at the 90° mark.

Now place the bottom end of the “latitude locator” strip on each Earth dowel and place the correct Earth ball on each dowel, being careful to have the paper “clock” on top. The ball with the “clock” glued on the black part should be placed on the dowel that points away from the center (Sun), and the ball with the “clock” in the white part should be placed on the dowel that points toward the Sun. The two remaining balls may be placed on either remaining dowel.

Pull the latitude locator up over the top dowel exit hole and place the wide top (roofing) nail through the hole into the dowel to hold it in place. Now install the 4-inch Sun ball to its base by pushing the ball onto its dowel. If you make a hole in the Styrofoam first, just make sure the hole does not go all the way through.

Construction of the Moon orbit ring

Take 36-inch long by 1½-inch flexible plastic strip or cardboard (you could glue several strips of file folder together) to make a 10-inch diameter ring. Paint eight of the 2-inch Styrofoam balls the same way you did the 3-inch Earth balls. When dry, carefully slit each ball half way up, being careful to orient the slits appropriately on each ball. All Moon ball terminators must be parallel, with their black sides all facing the same way. You are now ready to use your model.

*The original idea for this model was by:
G. Olof Larson, Professor, Emeritus
Ferris State University*

Using the model

In the film *A Private Universe*, it is clear that reasonably intelligent people have great difficulty understanding the effects the motion of the Earth (and Moon) has on what we observe in our sky, i.e. seasons, Moon phases, length of daylight, etc. Perhaps some of this confusion comes from using only one model of the Earth (i.e. globe) at a time. The Table-Top Earth, Sun Moon Model shows 4 positions of the Earth throughout the year (one at the beginning of each season) so that students can compare how the Earth has and has not changed in 3 months.

This model can be used to illustrate 13 different concepts, but you don’t have to use them all—making this model useful from

kindergarten through college/adult.

To review, here are some of the things you may do with the Earth, Sun & Moon model:

1. Explain day and night.
2. Explain the reasons for the Earth’s seasons (or any planet for that matter).
3. Estimate the time of Sun rise/set at different latitudes/seasons.
4. Illustrate the changing direction of rise/set points of the Sun with the seasons.
5. Illustrate the varying lengths of daylight at different latitudes/seasons.
6. Measure the altitude of the midday Sun at different seasons.
7. Illustrate “land of the midnight Sun.”
8. Address the misconception that the Earth changes its “tilt,” i.e. that the Earth first tilts toward the Sun and then away from the Sun (as opposed to a “constant tilt”).
9. Explain the reason the North Star doesn’t change with the Earth’s rotation or as the Earth revolves in its orbit around the Sun.
10. Explain why different stars are visible during different seasons.

By using a Moon “orbit ring,” the following may also be illustrated:

11. The reason the Moon exhibits phases and its location during these phases
12. Eclipses
13. Eclipse Seasons

Introduction

The teaching of seasons and Moon phases is not difficult, but having students understand those concepts is another matter. The classroom 3-D model described here of our planet, the Sun, and Moon is a very useful device to illustrate basic but often hard to comprehend spatial concepts and others that every teacher needs to discuss at one point or another. Note: References to seasons or observations in this paper are with respect to the Northern Hemisphere.

Advantages of this model

Using pencil and paper, you can teach many of the concepts this model illustrates. And while going to a planetarium to first observe the effects of seasonal changes will assist students in comprehension, it will not allow the students to “see” the *cause* behind the observations. The problem with a traditional planetarium presentation (as well as the real sky) is that both are Earth centered and the reason we experience changing seasons require non-Earth centered spatial visualizations of the Earth and Sun. These visualizations are often difficult, even for adults. Therefore, a student’s understanding can be greatly enhanced by a “god’s eye” view, so that the reasons for these observed changes can be understood.

Using this model as a lab station is not only more interactive; it allows for immediate feedback. It is also handy to be able to

directly compare the four different seasonal positions of the Earth. And this model is fairly inexpensive to construct.

A novel aspect of this model is the movable “latitude locator” mounted on a north-south arc from pole to pole. The “latitude locator” not only shows the observer’s latitude, it allows estimation of both time and direction of sun rise/set at particular latitudes. It can also show how day/night ratios change with the seasons. Again, while all the above *can* be observed in a planetarium, this model illustrates *why* the observations are as they are.

Illustrating Different Concepts Using the Model

Day and Night

Four Styrofoam balls on the assembled model represent the Earth at the beginning of each season, and a larger Styrofoam ball (mounted in the middle) represents the Sun. The four Earth balls are each painted half black (representing night), they can be rotated such that the day-night terminator is not oriented properly with respect to the Sun. Ask your students (or groups of students) to adjust the Earth balls until day vs. night is correct for each location. This helps to set up understanding for explaining Moon phases later.

Seasons

Two of the Earth balls are painted alike, i.e. their day-night terminators pass directly through their North and South poles. These represent spring and fall. The Earth ball with its north pole in the black portion (i.e. in the dark) represents winter in the Northern Hemisphere, and the one where the North Pole is unpainted (i.e. in sunlight) represents summer. Since the Earth revolves counterclockwise in its orbit as seen from above the North Pole, the teacher and/or the students can figure out which ball represents which season. Also from this viewpoint, it is obvious that the Earth’s axis does not change its “tilt” but stays at a constant angle (the word “tilting” implies something that is changing and is not appropriate to use when talking about seasons) and orientation with respect to its orbital plane. (See “Why the North Star is the North Star” and “Altitude of the Midday Sun” sections below.)

Time of Sunrise/set

Each Earth ball on the model has a paper “clock” located at its North Pole. Using the “latitude locator” and this “clock,” you can estimate times of sunrise and sunset for any latitude. The time on the “clock” is “local mean time.” To relate that to “standard time,” requires knowing the local longitude and the longitude of the standard time meridian within your standard time zone. Standard time meridians in the United States are 75° W (Eastern), 90° W (Central), 105° W (Mountain) and 120° W (Pacific). To convert local mean time to standard time, for every degree difference between the local longitude and your standard time meridian, add 4 minutes if you are west of that standard time meridian or subtract 4 minutes for each degree if you are located east of it. The result will be your standard time.

For example, if you are located at 85° W longitude you are west of the 75-degree standard time meridian. Subtract 75 from 85 to get 10 and multiply that by 4 to get 40 minutes. Add this to the local time read from the paper “clock” to obtain the approximate standard time.

To observe the time of sunrise/set first make sure that the Earth’s terminator is correctly positioned with respect to the Sun. Next, place the center of the “latitude locator” on the terminator *at* the latitude in question on either the sunrise or the sunset terminator—once you have figured out which one is which. *Hint:* The Earth rotates counterclockwise as seen from the North Pole. So the terminator on the left side of each Earth ball (as seen observing from next to and facing each Earth ball) is sunset. Right side is sunrise. Now read the time on the paper clock where the center line of the “latitude locator” intersects.

For example, on June 21st at 85°W longitude and 43½° N latitude, the model indicates that sunrise is about 4:30 a.m. Add 40 minutes and you get 5:10 a.m. The actual time of sunrise for that location is 5:04 a.m., so we are within 10 minutes. Not bad for such a simple model. If you change your latitude toward the south, you will notice that the time of sunrise on the paper “clock” is later. Conversely, if you change your latitude toward the north, sunrise gets earlier. In fact, if you go far enough north, there will be no time of sunrise (see “Land of the Midnight Sun” below).

Direction of Sun rise/set

To assist students in estimating the direction of Sun rise/set, it may help to run a string from the “latitude locator” (centered at the latitude in question) to the Sun. Note that East and West directions are identified on the “latitude locator” at the zero degree position. The angle that the string makes with the directions identified on the “latitude locator” is the direction of sunrise/set. Remember that the Earth rotates counterclockwise as seen from above its North Pole. This knowledge is required to determine if you are measuring sunrise or sunset. In our June 21st example above, the Sun rises north of East, just as in the real sky!

If you wanted to run a string from the sunrise point on the Earth to the Sun and use a protractor to measure the angle from East the string makes, you could determine how many degrees north of east the Sun rises.

By using this model, students can better understand why the Sun rises North of East, why there are more daylight hours and why the Sun’s altitude is higher in the summer. By observing the real or a traditional planetarium sky, students can note this effect, but by using this model, they can directly observe the *cause and the effect*. Therefore, the model is a wonderful supplement to an observational planetarium session.

Length of Daylight

By measuring both the rise and set times of the Sun at different seasons, it is easy to show that daylight is longer in the summer. More importantly, students can use the model to more clearly see this effect. Using straight pins to mark the points of sunrise and sunset, as well as several other points at that same latitude (by

moving the “latitude locator”) on each of the four Earths, it is easy to visualize the length of the Sun’s path in our sky during each season illustrating that the Sun’s path in the summer is longer (therefore in the sky longer) than in the other seasons.

Determining the Altitude of the Midday Sun

Find mid-day (Noon local time) at your latitude on each of the four Earth balls and run a string from the center of the Sun ball to the local noon position (i.e. half way between sunrise and sunset). Using a protractor held tangentially where the string intersects the Earth, you can estimate the altitude of the mid-day Sun at each season. A simpler observation would be to just note the angles in comparison to each other, e.g. the Sun is at a greater angle (i.e. higher in the sky) in the summer and lower in the winter.

Land of the Midnight Sun

Just by looking at the summer season Earth ball, students can observe that the North Pole is always in sunlight, i.e. the Sun is up all night long in summer, while it always in darkness in winter. (A more sophisticated model, using a bright light for the sun and unpainted balls in a darkened room would illustrate this effect even better.)

The Tilt of the Earth and Why the North Star is the North Star

One of the most misunderstood concepts in astronomy concerns the “tilt” of the Earth’s axis. Many people believe that, as the Earth moves around the Sun, first one hemisphere leans towards the Sun and then the other, i.e. changing the orientation of its axis in space. They don’t understand that the Earth’s axis *always* points in the *same* direction, and that it does *not* point first one way and then another way at a different season. *To emphasize, the Earth’s axis always points in the same direction*, i.e. toward the North Star. With this model, it is easy to see that the “tilt” *and* orientation of the Earth’s axis is unchanging (ignoring precession). This concept is fundamental to understanding the basis for seasons. If the Earth’s axis “tilt” were not constant, the Earth would not have changing seasons.

Why We See Different Stars at Different Seasons

By hanging drawings of appropriate constellations around the walls of your classroom (and orienting the model correctly), students can observe that the night side of the Earth faces different constellations at different times of the year.

Moon Phases

Using about a 10 inch diameter cardboard or plastic ring to represent the orbit of the Moon around the Earth and by carefully placing 8 small Styrofoam balls on this ring with the “day side” of each ball facing the same direction, students can learn about Moon positioning and phases. They can quickly see that half of the Moon is illuminated at any one time (of course, so is the Earth, as is *every* body in the Solar System—well, except the Sun) and that the shadow (dark) side of the Moon always faces away from the Sun. Don’t let students assume that the dark side of the Moon is always the same as the side of the Moon that faces away from

the Earth, i.e. that there is not day and night on the Moon. Another way of saying this is to explain that the side of the Moon that always faces the Earth is not always in sunlight.

More importantly, you can now talk about Moon phases. But students have to have the mental ability to place themselves within the ring representing the Moon’s orbit. This is not an easy task, even for adults. To aid students, you could also use a larger ring (e.g. a hula-hoop) with larger half black Styrofoam balls all oriented the same way. The unpainted (white) side of the balls must *always* face the Sun. You could also use a bright light source located several feet away and unpainted Styrofoam balls on the hula-hoop. As the students’ heads rotate around within the hula-hoop (their heads representing the Earth), they would observe different phases of the Moon. You could use this activity to supplement the Styrofoam ball on a stick and light bulb activity described in *The Universe at Your Fingertips*, pages 17-19.

Eclipses

It is important to note that this model is *not* to scale. Since the Sun is represented by a 4-inch ball and the Earth by 3-inch balls it is *clearly* not to scale. Distances are also not to scale. That has not been important up to this point, but now we have to exaggerate the tilt of the Moon’s orbit to help explain eclipses. (If any students catch you in this exaggeration, congratulate them!)

If you want to illustrate the true scale of the Earth/Moon system, use a 12-inch classroom globe and a 3-inch ball (about the correct size scale). Place the 3-inch ball 30-feet from the globe and 2 1/2-feet above the plane containing the center of the Earth globe. This scale model represents the 5-degree tilt of the Moon’s orbit at that distance. Students can see that even a 5° tilt at the distance of the Moon means the Moon’s shadow can completely miss the Earth. They can see that the Moon needs to be in the same plane as the Earth and Sun for an eclipse to occur.

Therefore, on our model we need to elevate one side of the Moon orbit ring by about 2-inches above the base of our model. Do this by placing a 2-inch block of wood 5-inches away from each Earth location. Just be sure that you place the block on the same side of the Earth as seen from space at each seasonal Earth location. With the blocks located properly, place the Moon orbit ring around the Earth (make sure the day/night terminators are correct; see below) with one side of the ring on the block. There should be only two positions on the Moon’s orbit that “line up” with the Earth and Sun. These locations are called the “nodes.” All other locations on the Moon orbit ring should be either above or below the Earth/Sun plane (ecliptic). Be sure that whenever you place the Moon orbit ring around the Earth ball, the unpainted (sunlight) sides of the Moons are facing toward the Sun and that the “tilt” of the ring is constant, i.e. always pointed in the same direction in space, just like the Earth’s “tilt”. (However, just like the Earth, the Moon’s orbit does precess. See “Eclipse Seasons” below.)

Nodes occur two times per month. From the model, you can clearly see that for an eclipse to occur, the Moon has to be located near a node. Otherwise the Moon will be above or below the Earth/Sun orbital plane (ecliptic). So the Moon has to be at one of

its nodes *when* the nodes are on line extended between the Earth and the Sun for eclipses to occur, i.e. when the Moon is in front or behind the Earth. If the Moon is passing through its orbital node when the geometry is not correct, no eclipse can occur. Students should also observe that for an eclipse to occur, the Moon either has to be Full or New. Therefore a good evaluation question might be, “What has to be true for an eclipse to occur?” The possible answers should include the Moon has to be either Full or New *and* located near a node.

Eclipse Seasons

This leads into a discussion of “eclipse seasons.” From the model, it is implied that an eclipse can only occur at two times (or “seasons”—not to be confused with Earth seasons) during the year, and that these times are the same year in and year out. You may have some students notice that this is not how it works in real life. While it is true that eclipse seasons occur about six months apart, perturbations of the Moon’s orbit cause the eclipse seasons to shift forward (i.e. earlier) approximately 20 days each year such that in about 18½ years, the nodes are back where they started. The eclipse seasons in 2018 are Jan/Feb and July/Aug and in 2019 they are Dec/Jan and June/July. It may also be of interest that the maximum number of eclipses that can occur in a year is seven, with no less than two solar eclipses occurring each year.

Conclusion

The Earth, Sun, & Moon model affords an excellent activity for investigating seasons, observational astronomy, eclipses, and Moon phases. The use of this model provides a valid way to check comprehension after classroom instruction into some of the concepts it covers. Since the model illustrates many concepts, it can be used with many different age levels, starting with the Earth as a planet in orbit around the Sun, Earth rotation, relative day and night lengths, sunrise/set directions, seasons, Moon phases and eclipses. This model has been successfully used with elementary, secondary, and college students, and with adults.

KINESTHETIC LEARNING UNDER THE DOME

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Abstract: With the stunning visuals produced in planetariums, we are experts in visual teaching. But what about those who learn by doing? In this workshop we will discuss how people learn and how to use kinesthetic practices to engage audiences in a planetarium setting. Examples include introducing planets to 3-year-olds and explaining how we locate black holes to a general audience. Join us if you want to engage your guests in new ways and be ready to get moving with activities of your own creation!

Introduction

As the planetarium reaches its centennial, the now thousands of domes across the world continue to provide a unique and immersive experience for guests. With our roots deeply planted in the night sky, the learning potential of planetariums has only grown over time. Stunning visuals, unique and personal experiences with live programming, and the whole universe at our disposal, planetariums are powerful tools for communicating science and inspiring people of all ages and backgrounds. In order properly utilize that learning potential, programming in a planetarium should be as diverse as our audience.

Planetariums easily cater to specific styles of learning, but those methods are not always ideal for our audience. In 1983, Howard Gardner published a book detailing his theory of multiple intelligences. He claims that people have several different ways of processing information and separate them into eight primary categories: Linguistic, logical-mathematical, musical, spatial, bodily/kinesthetic, interpersonal, intrapersonal, and naturalistic. Today, this theory is criticized for its lack of empirical evidence (The Illusory Theory of Multiple Intelligences). In fact, some studies have shown that the theory of multiple intelligences does not hold up. (*Gardner's Theory of Multiple Intelligences: Myth or Truth?*, 2018). Still, this theory changed the landscape of education as it critiques traditional measures like IQ tests. Gardner's theory shows that there is more than one way to teach and to learn. Other research-supported theories followed Gardner's theory, such as Constructivist teaching, which places the student in the center of learning (Brooks & Brooks, 1993) and multidisciplinary teaching, which suggests students learn best when approaching new material using a variety of methods (Greeno, Collins, & Resnick, 1996).

Science is a Verb

Kinesthetic learning, or learning through bodily movement, can be a challenge in planetariums, which are typically dark with seats bolted to the ground. But science is verb; we learn and understand the world through experiment. Kinesthetic learning is

a great way to engage your audience and put them in the center of the scientific process.

Some planetarium guests benefit from physical movement under the dome more than others. Aside from Kinesthetic learners of all ages who visit a planetarium, young children learn best when they are moving around. David Kolb's experiential learning theory argues that children need to experience things directly in order to learn (Stice, 1987). Pre-K children in particular are natural explorers who find it challenging (and sometimes frustrating) to sit in a seat for an hour-long planetarium show.

This workshop explores different ways to modify planetarium programs in order engage kinesthetic learners of all ages. From simple tactics like pointing, clapping, making animal sounds for constellations (Live From the Planetarium, 2013) to scavenger hunts under the dome, we will show that kinesthetic learning can enrich a planetarium show experience.

Examples Included in the Workshop

Observing Black Holes

During her public lecture "Gasbags and Blowhards: Supermassive Black Holes in the Universe," Dr. Sarah Gallagher of Western University used a couple of glow sticks and a few volunteers to demonstrate how scientists study black holes when they cannot directly observe them. She placed a glow stick necklace around one volunteer labeling them a "star" and the other the black hole. Then, with the all lights down in the planetarium, she asked her volunteers (a married couple she recruited before the show) to hold hands facing each other and spin in a circle. The audience could not see the black hole, but they could see that the "star" was orbiting something.

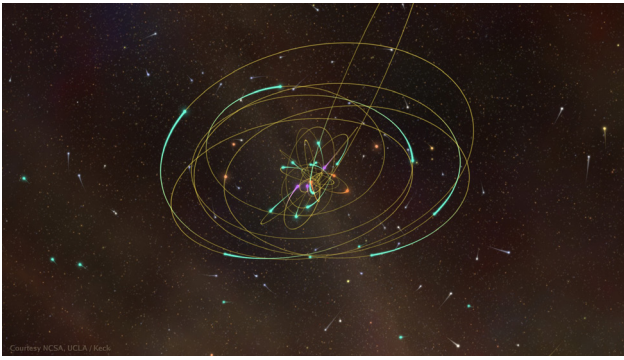


Figure 1. Observing gravitationally bound stars around black holes.

Space Shapes

Space Shapes is an hour-long Pre-K show offered at Ward Beecher Planetarium broken up into four or five segments of 10-15 minutes each. It is built for the youngest guests and meant to have them explore the planetarium as they learn. The first segment of the show is the introduction where we discuss the planetarium, how the lights will sometimes be on, sometimes be off, and can be any color of the rainbow, what we expect to see and do in the planetarium, and introduce the “twinkling star sound,” or a windchime that will signal the end of a segment and a time to refocus on planetarium staff to listen for what comes next. The windchimes are a direct application from the Montessori method and do a wonderful job at refocusing young guests with no dialog or raised voices (Montessori, 2015).



Figure 2. “Twinkling Star Sound” to signal a new activity

The second segment is a shape scavenger hunt where visitors explore the planetarium to find hidden felt shapes. Once we return to our seats, we discuss shapes, colors, and 2D shapes versus 3D shapes.



Figure 3. Guests explore the planetarium finding shapes in a scavenger hunt

The third segment is the nine-minute full-dome show, Space Shapes, produced as an open source show at Ott Planetarium by participants of the 2010 Blender Production Workshop. It is a fantastic, simple introduction to space and the planetarium.



Figure 4. 2010 Blender Production Workshop planetarium show, “Space Shapes”

The fourth segment is an introduction to the planets where guests build the solar system from Mercury to the Kuiper Belt, learning a movement for each planet. All guests pretend to be the planets by going through each of the characteristic movements. Planet rotation causing day and night may or may not be mentioned.



Figure 5. Planetarium guests learning about the planets



Figure 6. Learning Saturn's characteristic movement

If time allows, the optional fifth segment is a brief star talk with introduction to the Big Dipper, North Star, and possibly moon or planets will be shown. The house lights are never completely down and this portion will typically last no longer than 10 minutes.

Other Examples

Spacetime Simulator



Figure 7. Spacetime Simulator demonstrates the fabric of spacetime (See References for YouTube link)

Conclusion

This workshop is meant to spur creativity in engaging audiences with kinesthetic activities under their dome. Planetariums are impressive education tools and their utilization is only limited by our imagination. Adapting to the learning style of our audience can enrich a planetarium show and create lasting memories for our guests.

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