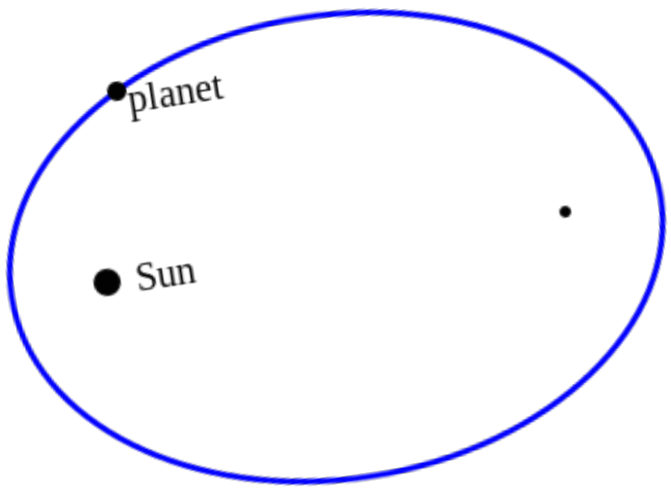
Einstein and Relativity

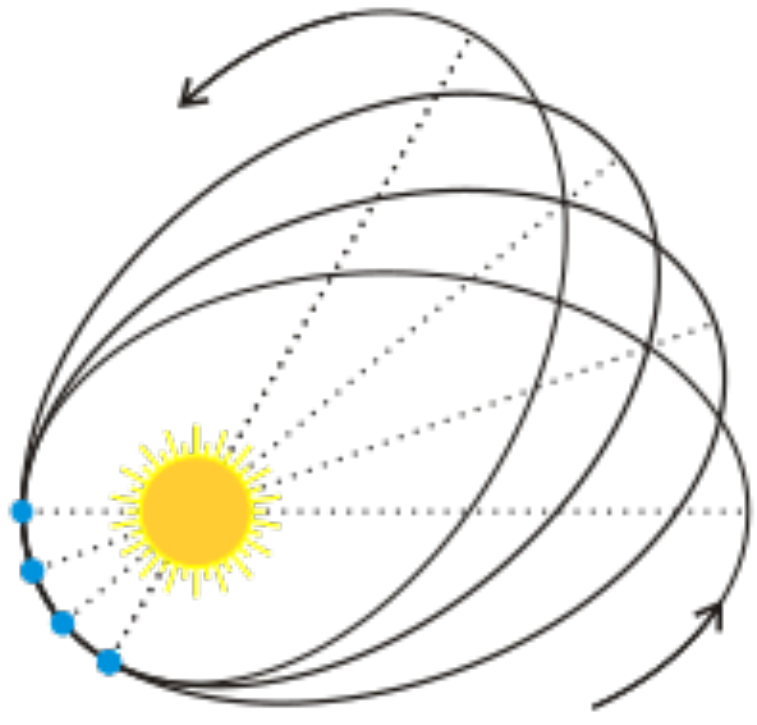
Most people don't associate the majestic beauty of a total solar eclipse with Albert Einstein's breakthrough idea of General Relativity, which proposes that space is curved and time slows near heavy masses. But it took the dimming of a total solar eclipse to provide evidence supporting of Einstein's startling hypothesis. Here's how:

• In 1604, Johannes Kepler realized that planets orbit the Sun in an elliptical shape, with the Sun off-center at one focus of the ellipse (see below-left).

• In the 1820's, irregularities in the elliptical orbit of Uranus led astronomers to realize that the gravitational pull of nearby planets may "perturb" a planet's path, causing it to deviate slightly from its perfect elliptical form. This led to the discovery of Neptune in 1846.

• Similar irregularities were noticed in the orbit of Mercury. Instead of staying fixed in space, the centerline of the ellipse rotated gradually, causing Mercury's orbit to take on a "Spiro-Graph®" appearance. Astronomers hypothesized that gravity from an unseen planet was affecting Mercury's orbit. Some grew so confident of its existence that they named it **Vulcan**, for the Greek god of Volcanoes, due to its proximity to the Sun.





The Search is On – 1878

• In 1878, a total solar eclipse was forecast to cross the western United States, from Wyoming territory through Texas. Several teams of U.S. and British astronomers journeyed on the new transcontinental railroad into the path of totality. Their expeditions lasted over a month!


The Chicago Times.

MONDAY MORNING, JULY 22, 1878.

THE PATH OF THE ECLIPSE.

• **Maria Mitchell**, a professor at Vassar College led a team of her female students to the young city of Denver where they observed the eclipse from the home of the reknown suffragette Dr. Alida C. Avery. They provided a strong public counter-example to the stereotype of the day that said doing scientific and medical work was not only inappropriate for women, it was actually unhealthy. Their eclipse research and subsequent work towards women's rights was widely followed in the newspapers.

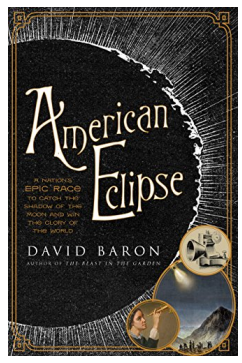
• **Thomas Edison** traveled from his workshop in New Jersey with his new invention, the tasimeter, designed to measure the heat output from the Sun's corona. His observations, made from inside a chicken coop in windy Wyoming, were inconclusive.

• Edison traveled with a group of astronomers from the U.S. and England, among whom was **James Craig Watson**, a professor from the Univ. of Michigan. Famous for spotting new asteroids, his goal was to find the "intra-Mercurial" planet Vulcan that was hypothesized to perturb the orbit of Mercury. While scanning the

sky around the eclipsed Sun, he reported the discovery of not one but two dots of light that were not on his star chart. The story spread quickly in the newspapers and he was hailed as the greatest American astronomer of all time for his discovery.

The lens of Edison's telescope peeks out of the chicken coop. Edison is second from the right; J. C. Watson is the next man to the left.

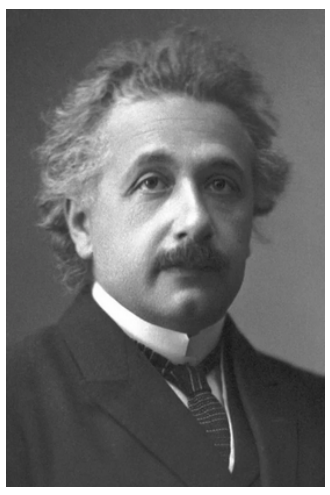
• The details of these expeditions, including others to the 1878 eclipse, and how they bolstered the fledgling American scientific community of the Gilded Age, are shared in David Baron's book ***American Eclipse*** (Liveright, 2024)



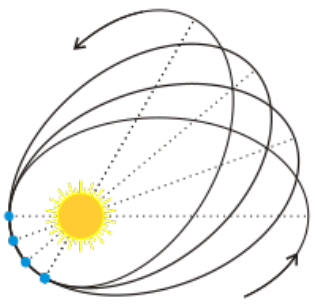
Astronomers in Fort Worth prepare for an eclipse on July 29, 1878.

The Search Shifts – 1919

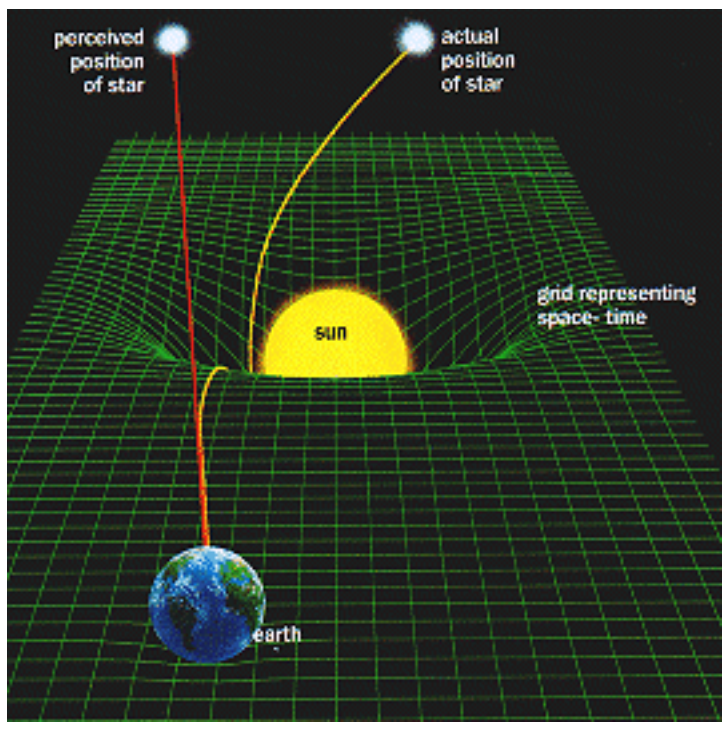
• Other astronomers were eager to observe Watson's intra-Mercurial planets during the total solar eclipses of 1883, 1887, 1889, 1900, 1901, 1905, but to no avail. No one could rediscover Vulcan, let alone the second reported intra-Mercurial planet, and belief in their existence waned.



• Meanwhile, the German physicist **Albert Einstein** was developing deep new ideas called Relativity. They began in 1905 with thought experiments about how observers would view each other if they were traveling relative to each other near the speed of light. They grew deeper to include a new understanding of gravity and its relation to space and time, a mathematically complex formulation published in 1915. An exciting effect of relativity's view of gravity is to shift Mercury's orbit when it is near the Sun, and cause the "Spiro-Graph®" shape that had long been observed.

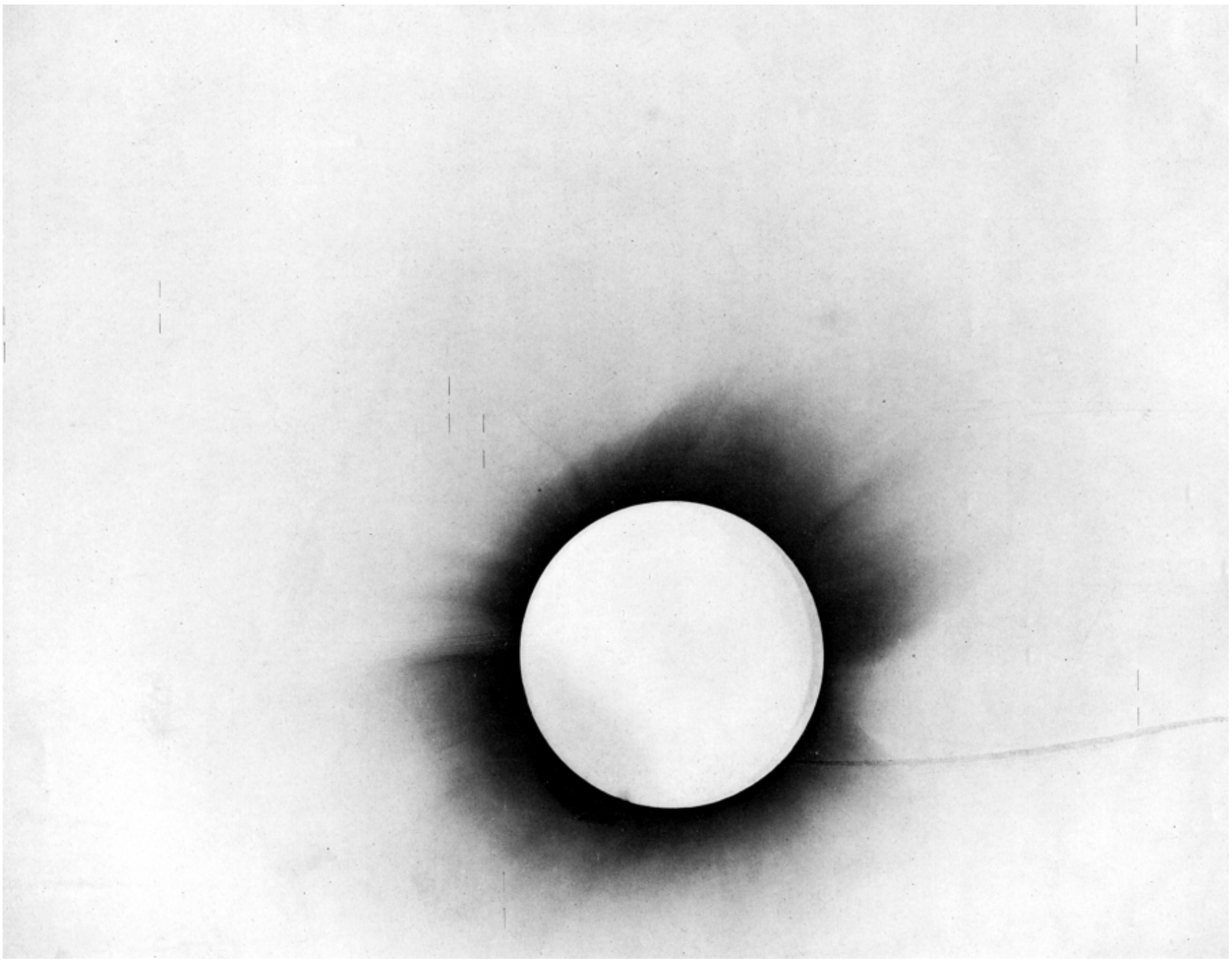


• Like any good scientist, Einstein looked for ways to test his new ideas. One prediction he could make involved the strongest nearby source of gravity, the Sun. His idea said that the mass of the Sun would warp space-time, and cause the light of stars behind it to bend a tiny fraction of a degree, a result not predicted by Newton's notions of gravity, in which light would travel straight.



• After World War I, British astronomers led a pair of expeditions into the path of totality of the 1919 eclipse to photograph the stars around the darkened Sun, and look for the predicted shifts. One team voyaged to the coast of Brazil to set up their telescopes, the other set up camp on an island off the west African coast.

• While both teams struggled with cloudy weather, both acquired photographs during totality that showed stars. After taking comparison photos months later when the Sun was no longer in the field of view, to establish the stars' true positions, both teams found that the stars were deflected by just the amount Einstein had predicted. He quickly became famous.



A negative image of the 1919 total solar eclipse showing the Sun's corona and five stars used to measure the deflection by gravity.

• Thus, Einstein's theory was supported, and could account for Mercury's odd orbit without the need for intra-Mercurial planets. The need Vulcan was gone, and the idea of it receded into history.

• Since 1919, Einstein's theory received further support from star deflections measured at other eclipses, and using other methods including radio light detected by the huge dishes of radio telescopes. The precision of the methods improved with time, further cementing Einstein's theory of relativity.

Prof. James Craig Watson Univ. of Michigan p.12 Ed/WY
Prof. George F. Barker Univ Pennsylvania p.22 Ed/WY
C. H. F. Peters p.30
Prof. Maria Mitchell Vassar College p.36 Denver
Prof. Simon Newcombe p.47
Prof. Joseph Henry p.62
Thos. A. Edison p.64 and tasimeter p.97 Ed/WY
Prof. S. P. Langley - p.68
Prof. Charles A. Young Princeton p.122
Prof. Joseph Norman Lockyer UK p.139 Ed/WY
Cleveland Abbe p.153 PP

Places:

Denver p.119
Vassar camp, Denver p.131
USNO camp p.135
Edison camp Rawlins WY p.144
Pike's Peak pp.160-1

Camera p.191
Totality p.165, 18