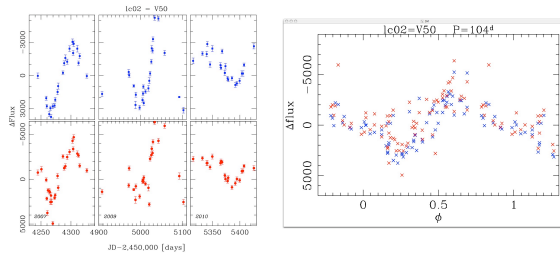


### Abstract

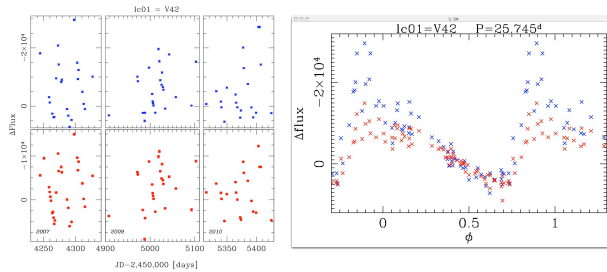
The topic of the study is Long Period Variable Stars (LPV's) which are red giant stars that vary in brightness in a cyclic fashion over months to years. The astronomical field however, is short on information on these stars due to lack of study and/or poor quality of study due to limiting technology. This research will help remedy this problem by studying properties of LPV's in two globular clusters, like the period of these cycles, or oscillations, and the stability of these oscillations in order to determine how well they match current stellar evolution models, and add our data to an ongoing research project directed by Dr. Layden.

Our main objective of this study is to gather data on variable stars in the globular cluster NGC 5904, which has a low metallicity, to detect/identify long period variable stars (LPV's) and characterize them using amplitude, period, and the stability of the oscillations.



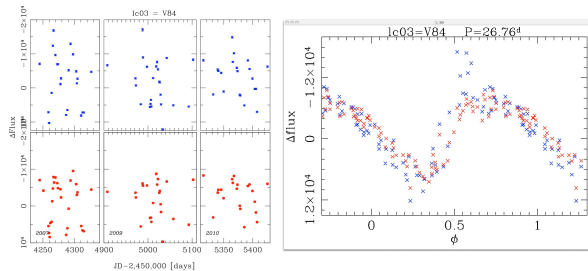
Above Left: a plot of flux vs. time in days for the known LPV 50 with a period of around 100 days

Above Right: a folded light curve to a best period of 104 days. The rep points are the I filter and the blue points are the V filter



Above Left: a plot of flux vs. time in days for the known Cepheid variable V84 with a period of around 26 days

Above Right: a folded light curve to a best period of 25,745 days. The rep points are the I filter and the blue points are the V filter



Above Left: a plot of flux vs. time in days for the known Cepheid variable V84 with a period of around 25 days

Above Right: a folded light curve to a best period of 26.76 days. The rep points are the I filter and the blue points are the V filter

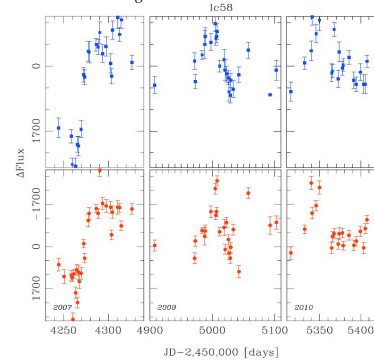
### Methods

By using several processing techniques, we can produce high quality images that can further our understanding of stars. These techniques are:

- Subtracting bias frames to remove 500 counts of electrical activity
- Subtracting dome flats to remove dust particles
- Subtracting sky flats to remove the sky background level and any shadowing caused by dust particles.
- Combining images to remove bad pixels using a rejection algorithm
- Trim the image to prepare it for ISIS

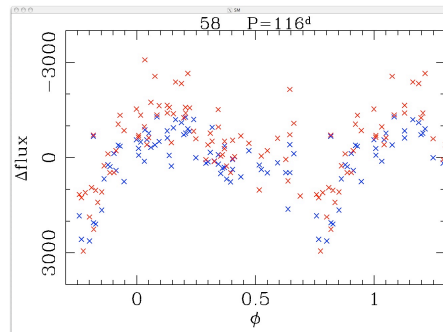
Then we run our images through ISIS which:

- Aligns the center of each image and accounts for rotations
- Creates a master reference image called ref.fits
- Subtracts the master from each image
- Detects any variable stars from the subtracted images, creating a var.fits
- Creates data to be used in light curves



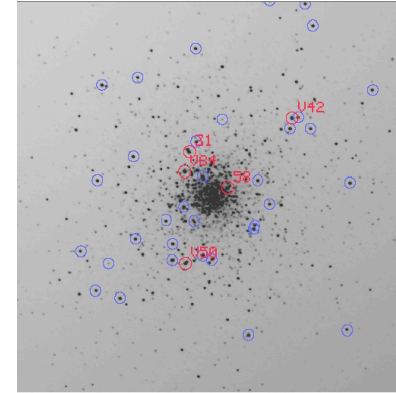
Above: a plot of flux vs. time in days for a newly discovered LPV 58 with a period of around 100 days

Below: a folded light curve to a best period of 116 days. The rep points are the I filter and the blue points are the V filter



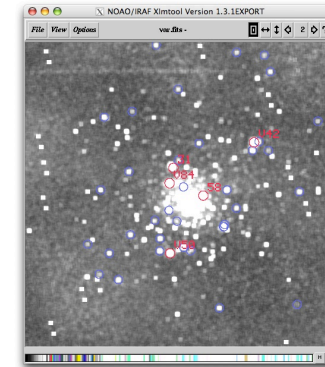
### Observations

The data on NGC 5904 that was processed had been gathered by students Dan Roth and Ryan Rothrock in years past using the BGSU .5 meter telescope until a sufficient amount was acquired. The operation of the telescope requires the observer to be present the night of observing to take Bias frames, Dome flats, Sky flats, and cluster images. The Bias flats taken is a measure of 500 counts of electrical activity on the CCD. The sky and dome flat are taken to remove any impurities like dust particles, shadows, bad pixels and sky brightness from the picture.



Above: a reference image of cluster NGC5904 taken in the Visual (V) filter with the known variables V50, V42, and V84, and the suspected LPVs 31 and 58 circled in red, and possible variable stars circled in blue.

Below: a Var.fits image of cluster NGC5904 taken in the Visual (V) filter with the known variables V50, V42, and V84, and the suspected LPVs 31 and 58 circled in red, and possible variable stars circled in blue.



### Summary and Future objectives

Compared to past studies, we have discovered two to three Long Period Variable stars, and enhanced the precision of measurements of the brightest variable stars: V50, V84, V42. Along with possible Long Period Variable stars, we have also identified about 60 suspected variable stars for future study. We developed light curves and determined periods of these stars

Data is in the process of being taken using a PROMPT remote controlled telescope located in Cerro Tololo, Chile to be later processed by another student. The advantage of the PROMPT telescope is that it allows for more data to be taken for a longer period of time due to better weather conditions. This data will supplement our past data taken at BGSU to further our understanding of LPV's in NGC5904

### References

Clement, C., A. Muzzin, Q. Dufton, T. Ponnampalam, J. Wang, J. Barford, A. Richardson, T. Rosebery, J. Rowe and H. Sawyer Hogg, 2001, *Astronomical Journal*, 122, 2587, "Variable Stars in Galactic Globular Clusters"

Layden, A. et al. 2010, *Publ. Astron. Soc. Pacific*, 122, 1000, "Searching for Long-Period Variables in Globular Clusters: A Demonstration on NGC 1851 Using PROMPT"

### Acknowledgements

BGSU Center of Undergraduate Research and Scholarship