# Time Series Photometry of the Symbiotic Binary V1835 Aql


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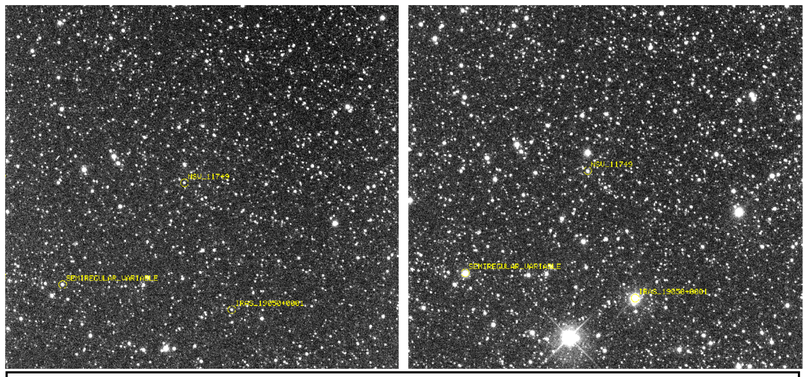
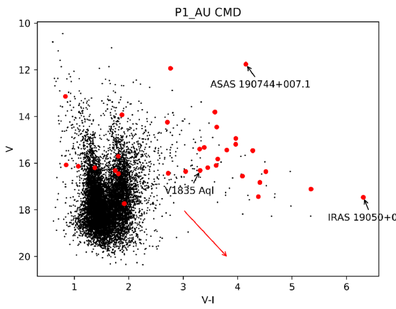
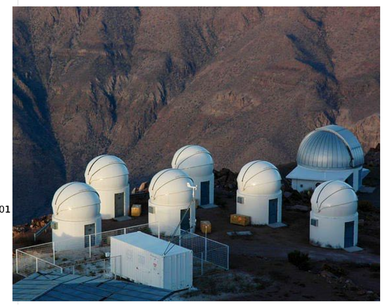


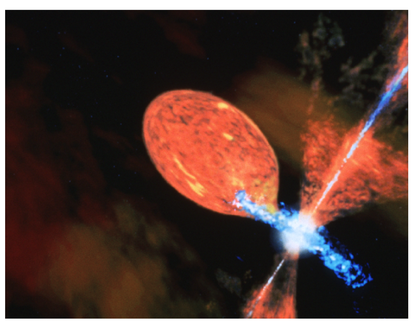
**(Above)** Circled in both images is the location of V1835 Aql (NSV 11749) and two other variable stars, one Mira type and one semi-regular variable. **(Left)** The star field in the *V* band. **(Right)** The star field in the *I* band




**(Above)** Pictured here is the color magnitude diagram of every star in our field, approximately 11,600, with the variables highlighted. The red arrow represents the reddening vector. This plot looks different than a typical color magnitude (Hertzprung-Russel) diagram because the stars in it are all at different distances, ages, and metallicities.



**(Above)** The PROMPT telescopes at the Cerro Tololo Inter-American Observatory in Chile that were used to take our observations. We primarily used PROMPT C5 and a subset of our observations were done with PROMPT C1



**(Left)** An artists conception of R Aquarii, a symbiotic binary system, during an active phase. Symbiotic binaries consist of a large red star in a wide orbit with a smaller compact object, typically a white dwarf star or a neutron star, that has an orbital period greater than a few days. The smaller object accretes material from the stellar wind of the larger star and occasionally experiences nova events similar to what we believe happened to V1835 Aql around the year 1900.

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## Abstract

Photographic plates in the Harvard collection show the star V1835 Aql (also called NSV 11749) brightening by a factor of 100 in flux over four years starting in 1899, remaining at maximum for four years, then declining below the depth of the plates (Williams 2005). This behavior is very atypical for most variable stars and as a result there has been much debate over the exact nature of V1835 Aql. This debate was ended by the discovery of a Raman scattered emission line at 6824 Å which is unique to symbiotic binaries (Bond & Kasliwal 2012), positively identifying V1835 Aql as a symbiotic star. Our research expands our knowledge of V1835 Aql through analysis of five years worth of multi-band, optical, time-series photometry. From this we found the orbital period of this binary and plan to determine if the primary star is tidally distorted and provide a reasonable estimate of the temperature of the white dwarf. This confirms that V1835 Aql is a symbiotic binary, not its closer orbiting cousin, a cataclysmic variable. We are determining the properties of about 30 other variable stars near V1835 Aql.


## Observations

- Observations were taken in *V* and *I* bandpass filters from July 2012 to May 2017 using the using the PROMPT cluster of robotic telescopes at the Cerro Tololo Inter-American Observatory in Chile
- Observations in *B* and *R* bandpass filters were taken from August 2012 to September 2014

## Data Analysis

- Image reduction and data analysis was done primarily with DAOPHOT[1]. DAOPHOT scans each image to locate stars, uses the brightest stars to make a point spread function (PSF), and determines the instrumental magnitudes of each star using that PSF.
- After all the stars on each image are found we then used DAOMASTER to create a mapping to match up the same star across multiple images
- Next we used ALLFRAME with a particular good image as a “master image” to find stars that the first run of DAOPHOT might have missed and used differential photometry to account for differences in sky value, cloud cover, exposure length, etc between different images
- Finally we used the instrumental magnitudes from ALLFRAMRE and the known standard magnitudes of several stars to determine the correction from instrumental magnitude to standard magnitude and applied that correction to all the objects found using a python program written by Robert Caddy
- The extreme regularity of the light curve of V1835 Aql (right) is very indicative of an ellipsoidal variable, a star that varies in brightness due to tidal distortion caused by a close companion star so that we see a cyclically varying amount of surface area throughout the orbit. If it were a pulsating variable instead of an ellipsoidal variable we would expect a light curve with more irregularity from cycle to cycle, similar to the Mira and semi-regular variable candidate light curves pictured on the right.
- The variability of the color of V1835 Aql (*V-I* graph on right) shows that the brightness variability cannot be totally explained by ellipsoidal variation. The change in color during the cycle is probably caused by the cooler component of the binary absorbing and reemitting light from the hotter, smaller component.

## Ongoing Work

- Finalize a computational model of the system using PHOEBE 2.0 to constrain the temperature of the compact star via its illumination of the red giant
- Determine periods of other variable stars in the field

## References


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2. Bond, H. E., & Kasliwal, M. M. (2012). *NSV 11749: Symbiotic Nova, Not a Born-Again Red Giant.* Publications of the Astronomical Society of the Pacific, 124(922), 1262-1265
3. Bertolami, M. M., Rohrmann, R. D., Granada, A., & Althaus, L. G. (2011). NSV 11749, An Elder Sibling of the Born-Again Stars V605 All and V4334 Sgr?? The Astrophysical Journal, 743(2)
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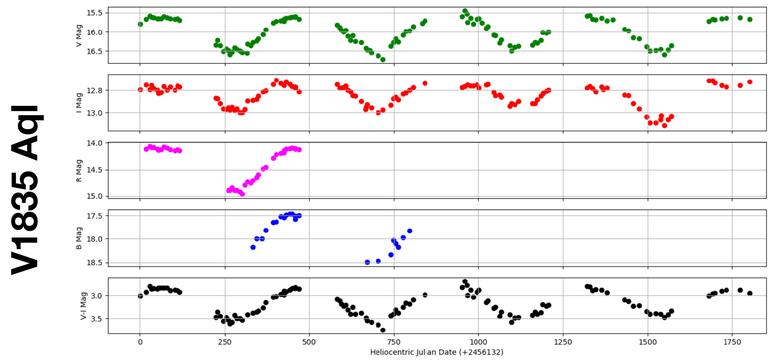
5. Williams, D. B., 2005, Journal of the American Assoc. of Variable Star Observers, 34, 43
6. Wehrung, M. & Layden, A. 2013, *Time-Series Photometry of the Symbiotic Nova NSV 11749 and New Variable Stars in Aquila*, Information Bulletin on Variable stars Number 6071
7. Artists conception of symbiotic star taken from http://hubblesite.org/image/17/news_release/1990-15 on August 3rd, 2017
8. Image of PROMPT telescopes taken from https://users.physics.unc.edu/~lacluyze/prompt/poster.html on on August 3rd, 2017
9. A. Prša et al 2016, *Physics of Eclipsing Binaries. II. Towards the Increased Model Fidelity,* The Astrophysical Journal Supplement Series, 227:29


**(Above)** The light curve for the symbiotic star V1835 Aql. The period of this light curve corresponds to the orbital period of the binary as the hotter star heats a section of the larger star. As the star rotates the hotter and brighter side comes into view causing the change in brightness. Using Fourier-fitting code VSTAR we found that V1835 Aql has an orbital period of 419 days.

**(Below)** Light curves for two of the other variable stars in our star field. **(Top)** The light curve for the star IRAS 19050+0001. It has two periods, one at 425 days an a secondary at 319 days. The large changes in brightness and regular cycling are both consistent with a Mira variable. **(Bottom)** The light curve for new variable star #26. It has three periods at 70.3, 67.4, and 74 days. The small changes in magnitude and less regular cycling are typical of a semi-regular variable star. Our light curve of V1835 Aql (above) is regular and clearly unlike the light curves of the common, red pulsating variables shown below, This indicates that we are indeed seeing the rotational variation from which we can determine the system’s orbital period.