Mt. Stony Brook Observing Proposal **Panel:** *For office use.*
Date: October 12, 2022 **Category:** Variable Stars

Determining the Distance of DY Pegasi

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Abstract of Scientific Justification *(will be made publicly available for accepted proposals)***:**

SX Phoenicis variable stars are a special type of variable star named after their prototype, SX Phoenicis. They are known to have short periods ($\approx$ 2 hours) and large amplitudes ($\approx$ 0.5 mag). DY Pegasi is a magnitude 9.95 – 10.70 blue-white star; it is one of the brightest SX Phoenicis variable stars in the northern hemisphere and has a period of 1.75 hours. We propose to take a single night to record 3 periods of DY Pegasi using the 14-inch telescope and STL-1001E CCD Camera. We will determine a period and use the known period-luminosity relation to determine its distance from Earth.

Summary of observing runs requested for this project

Run	Telescope	Instrument	Time Request	Moon	Optimal months	Accept. months
1	14-inch	imaging	1 $\times$ 6 hours	dark	Oct	Oct - Nov
2						
3						
4						
5						
6						

Scheduling constraints and non-usable dates *(up to six lines).*

Since the periods are so short (1.75 hours), we have a lot of flexibility. Completing the observations in one night is preferred (less time spent calibrating), but should a problem arise (e.g weather, malfunction), we could complete the periods on different days. An earlier time (October) is strongly preferred due to later culmination—it may be more difficult to squeeze 6 hours of good observations into one night in November. Finally, avoid Nov. 2 due to a midterm the following day.

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

We propose to determine the distance to DY Pegasi using the known period-luminosity relation of SX Phoenicis variable stars. We request 6 hours of observations on one night, which will be sufficient to observe 3 full periods of DY Pegasi, with some additional buffer. We intend to generate a light curve from the plotted data, determine the minima, and determine the period. Three periods will provide additional accuracy in determining the periods. Next, we calculate DY Pegasi's absolute magnitude using the SX Phoenicis variable period-luminosity relation (Cohen & Sarajedini, 2011), calculate DY Pegasi's distance from the difference in apparent and absolute magnitude, and compare to known distance of 407 ± 7 pc (Hintz et al., 2004).

Variable stars as a whole are a critical element of the cosmic distance ladder, as they let astronomers bridge the gap between traditional direct measurements (e.g. parallax) and extragalactic measurements (e.g. Type 1a supernovae). SX Phoenicis variable stars are not as popular as Cepheid or RR Lyrae variables, but they can still be used to determine distances using a period-luminosity relation. The relation has been applied to SX Phoenicis variables within the Milky Way and Local Group. SX Phoenicis variables almost always have blue-white color (between bright F and dim B class stars), have low metallicity (Pop II), and often exist as part of a globular cluster. They tend to be blue stragglers, or stars in a globular cluster that are brighter and bluer than the turnoff point of the cluster likely due to a stellar collision or binary mass exchange. Due to their membership of globular clusters, determining the period-luminosity relationship of SX Phoenicis variables can help measure the distance to a globular cluster.

DY Pegasi in particular is unusual among SX Phoenicis variables in that it is located in the general star field (Xue & Niu, 2020). However, the methodology we use to calculate the distance of DY Pegasi can still be applied to other SX Phoenicis stars within globular clusters.

It is worth noting the stark differences in period and amplitude of SX Phoenicis variables compared to other variable star types. Variable stars with extremely short periods of minutes tend to have minute amplitudes of only a few thousandths of a magnitude, making it difficult to observe any fluctuations from Mt. Stony Brook Observatory. On the other end of the spectrum, large amplitude changes typically require several hours, if not days, months, or even years—RR Lyrae, for example, takes 13 hours to change about 1 magnitude. This would take a few nights to construct a complete light curve of just one period. SX Phoenicis variables stand alone in the middle, with periods of only a few hours (or less) and amplitudes upwards of 0.5 magnitudes. Our target, DY Pegasi, is one of the brightest SX Phoenicis variables and also has one of the shortest periods and largest amplitudes. This provides an exciting opportunity to collect quality data on more than one period a night (without needing to combine separate nights' data) while also providing a large amplitude itself.

References

Bertin, E., & Arnouts, S. 1996, A&AS, 117, 393, doi: http://doi.org/10.1051/aas:199616410.1051/aas:1996164

Cohen, R. E., & Sarajedini, A. 2011, Monthly Notices of the Royal Astronomical Society, 419, 342, doi: http://doi.org/10.1111/j.1365-2966.2011.19697.x10.1111/j.1365-2966.2011.19697.x

Hintz, E. G., Joner, M. D., Ivanushkina, M., & Pilachowski, C. A. 2004, Publications of the Astronomical Society of the Pacific, 116, 543, doi: http://doi.org/10.1086/42085810.1086/420858

Jayasinghe, T., Stanek, K. Z., Kochanek, C. S., et al. 2019, Monthly Notices of the Royal Astronomical Society, doi: http://doi.org/10.1093/mnras/stz84410.1093/mnras/stz844

PopePompus. 2022, A light curve for DY Pegasi. `https://en.wikipedia.org/wiki/DY_Pegasi#/media/File:DYPegLightCurve.png`

Xue, H.-F., & Niu, J.-S. 2020, The Astrophysical Journal, 904, 5, doi: http://doi.org/10.3847/1538-4357/abbc1210.3847/1538-4357/abbc12

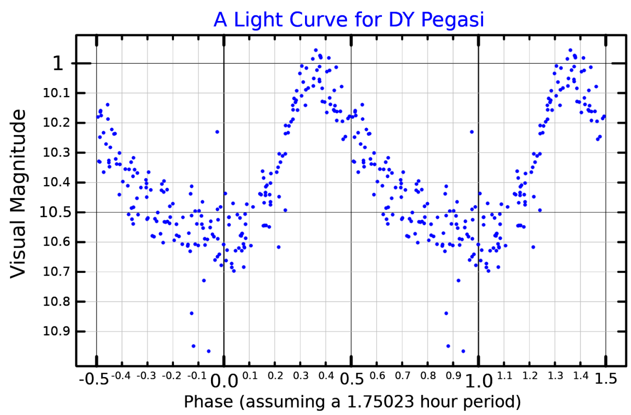

Figure 1: Sample light curve, created by PopePompus (2022), using ASAS data (Jayasinghe et al., 2019).

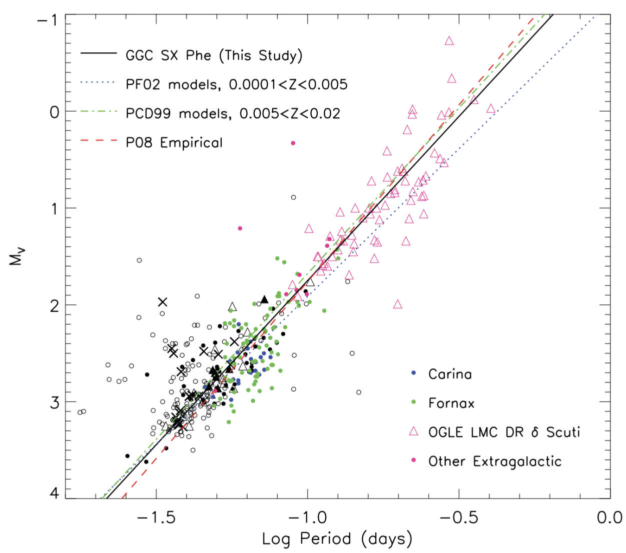

Figure 2: Period-luminosity relation of SX Phoenicis variables from Cohen & Sarajedini (2011). The solid black line is the relation $M_V = -1.640 - 3.389 \log P_f$.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science. (limit text to one page)*

DY Pegasi is our target for this proposal. It was chosen because it is the brightest known SX Phoenicis variable that is visible in autumn from the northern hemisphere. For example, SX Phoenicis, being the prototype, is much brighter than DY Pegasi, but it is located in the southern hemisphere with no chance of being observed from Mt. Stony Brook Observatory.

DY Pegasi will culminate at about 65° altitude in October-November at about 9:00 PM local time. It will be above 30° altitude for the entire night up until about 2:00 AM.

We will more likely than not use the maximum reasonable exposure time for imaging without the AutoGuider of 30 seconds. A rough calculation yields that at peak magnitude of 10, we will obtain about 5400 counts above noise with this exposure, while with minimum magnitude of 10.7 we will obtain about 2880 counts. For perspective, this is a factor of nearly 2 change in luminosity in mere hours.

Given the surface temperature of 7660 K (Hintz et al., 2004), the peak wavelength will be ≈ 380 nm, so we shall use the blue filter.

On the night of observations, we will set up the telescope for imaging using the STL-1001E CCD camera. Then, we plan to take 30 second exposures of DY Pegasi for the next 6 hours while monitoring weather and relative position on the CCD. Then we will take our dark and flat calibration images. After calibrating and astrometrically solving all our images, we will concatenate a light curve of our star using calculated fluxes from Source Extractor (Bertin & Arnouts, 1996). We can perform a low-order polynomial fit on the data around each minimum to determine the minimum. Then we calculate the period from these minima, calculate the luminosity from the period-luminosity relation, and calculate the distance from the comparison of apparent and absolute magnitudes of DY Pegasi. We compare our results to the literature.

Analysis Plan *Describe the steps that you will take to analyze the data. State which tasks will be due for the weekly check-ins (weeks 1, 2, 3). The week 4 task will be to complete the lab report. In case you have less than four weeks between taking the observations and the last day to submit lab reports, how will the analysis plan change?*

+1 week: Calibrate and astrometrically solve science images.
+2 weeks: Concatenate a light curve using fluxes from SExtractor.
+3 weeks: Find the distance of DY Pegasi.
+4 weeks: Submit the lab report.

Observing Run Details for Run 1: 14-inch/STL-1001E

Technical Description *Describe the observations to be made during this observing run. Justify specific instrument choices such as the required filter, or the grating choice, as well as the requested lunar phase. List targets, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below.*

We will use the B filter since our star is blue (peak wavelength is 380 nm). Other fields are irrelevant.

Instrument Configuration

Filters: B
Grating/grism: -
Order: -
Cross disperser: -

Slit: -
Multislit: -
λ_{start}: -
λ_{end}: -

Fiber cable: -
Corrector: -
Collimator: -
Atmos. disp. corr.: -

R.A. range of principal targets (hours): 23.1475

Dec. range of principal targets (degrees): 17.2156

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Target Table for Run 1: DECam

Obj ID	Object	α	δ	Epoch	Mag.	Filter	Exp. time	# of exp.	Lunar days	Sky	Seeing	Comment
1	**DY Pegasi**	**23:08:51**	**17:12:56**	**2000.0**	9.95 – 10.70	**B**	**30 s**	$\approx$ 720	**Flexible**			

Mt. Stony Brook observing proposal LaTeX macros v0.9.