Long-Term Variability of HBC 379

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Introduction

Binary stars systems are some of the most common types of star systems in the universe, so much so that about half of the "stars" in the night sky are actually binary star systems. Studying young binary stars can provide insight to how stars form and evolve. Because binary stars are formed close to each other at about the same time, looking at how the two stars differ can help understand why stars evolve the way they do. Similarly, looking at the properties and effects of circumstellar disks can also help better understand planetary formation and evolution.

Monitoring the long-term light curve and periods of young stars can give an idea of how the star is changing over time. Active accretion of disk material causes the star's rotation period to spin up, while formation of planets might preserve the star's slower rotation rate. By analyzing photometric variation caused by the dissipation of the disk, contraction of the star, and star spot variation, a timeline of the star's evolution can be determined.

During MIT field camp, my project was to build a long-term light curve of past photometric data for the young binary system HBC 379. The goals were to determine the period and calculate the angle of inclination.

HBC 379

The star my research group was interested in was the unresolved spectroscopic binary HBC 379, pictured in FIgure 1. This star system is located in the nearby Taurus star forming region (~140pc). The assumption was made that the primary star's flux dominated that of its secondary, so all determined stellar properties are assumed to be that of the primary star. Past spectroscopic data has classified the star as an M0.5 type star. Using

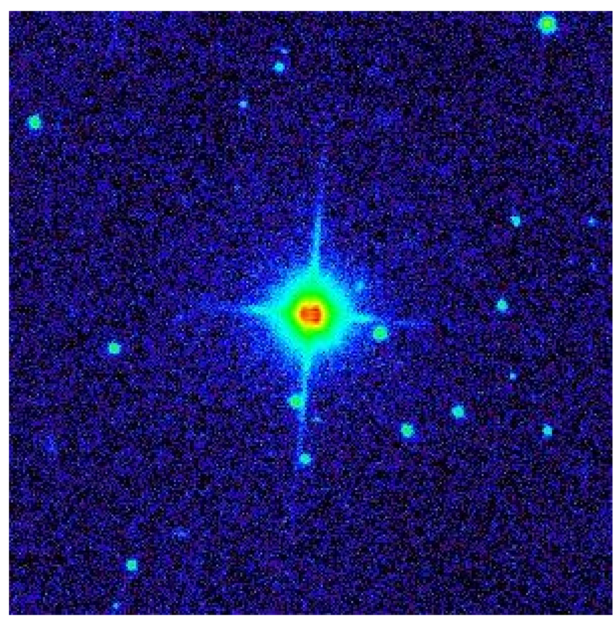

Figure 1: Unresolved Spectroscopic Binary HBC 379
Retrieved from the Sloan Digital Sky Survey

the spectral type and techniques described in Torres, G., et al. 2013, the effective temperature of the primary was calculated to be 3870 K. Finally, using an age of 1Myr, and assuming stellar metallicity, the radius was estimated to be approximately 1.9 R_{sun}.

Data Collecting

My project started by gathering historic photometric data in the visible bands from a variety of sources. Tools such as VisieR and SIMBAD were used to sort through 151 published papers and several catalogs. I encountered several challenges while doing this search.

Most authors do not publish full datasets. In more than half of the cases, I had to extract data using a tool called WebPlotDigitizer. WebPlotDigitizer is a Google Chrome app that allows for data points to be extracted from published figures. While this was better than no data, the tool introduced uncertainties in both JD and Vmag that made determining a period difficult.

While WebPlotDigitizer allowed me to collect more data than I would have originally been able to, many plots were published as a function of phase rather than Julian Date, making them useless. This star wasn't classified until the late 80's, so there were no photometric data published before 1886. Similarly, many later photometric analyses of HBC 379 used previously collected data, and didn't provide any new data.

All in all, I was able to find five good sets of data from three different authors: K. N Grankin, J. Bouvier, and F. J. Vrba.

Light Curve

I first plotted all of the data over time so I could look for long-term variations in magnitude, seen in Figure 2.

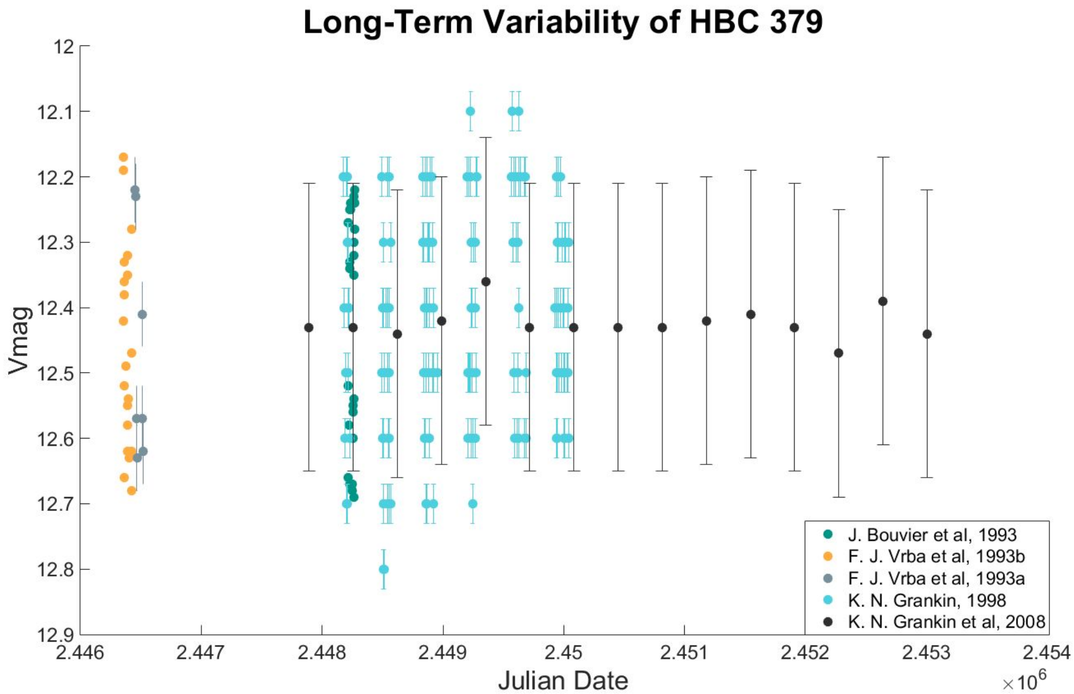

Figure 2: Full light curve of HBC 379 Photometric Data From the years 1984 to 2006

The first thing of note about Figure 2 is that the mean Vmag doesn't change much over the course of 22 years. This can be seen most clearly with the Grankin et al, 2008 dataset (black). This data was taken over the course of 15 years, and for each year the data was averaged and plotted as a single point. The second is that this dataset also shows that the change in magnitude did not vary appreciably over the course of 15 years. From this it can be inferred that there is no disk around the star or accretion occurring.

Looking at the other datasets, they resemble the Grankin 2008 dataset in that the change in magnitude and mean Vmag do not seem to vary. The Grankin, 1998 dataset (light blue) illustrates this most clearly, as it is the most complete long-term dataset I was able to collect. It spans 5 years (from 1990 to 1995) and has 177 individual data points.

Unfortunately, these data were extracted from a published plot, and the uncertainty in Julian Date made them not usable for period verification. Similarly, the Grankin, 2008 dataset (black) were averaged over the course of a year and did not have associated Julian Dates, and so were also discarded before verifying the period.

Period Verification

The previously published period for HBC 379 is around 5.66 days. I used the data I was able to collect to try and verify this period.

I analyzed the data (neglecting the two Grankin sources) using a Lomb-Scargle Periodogram, seen in Figure 3.

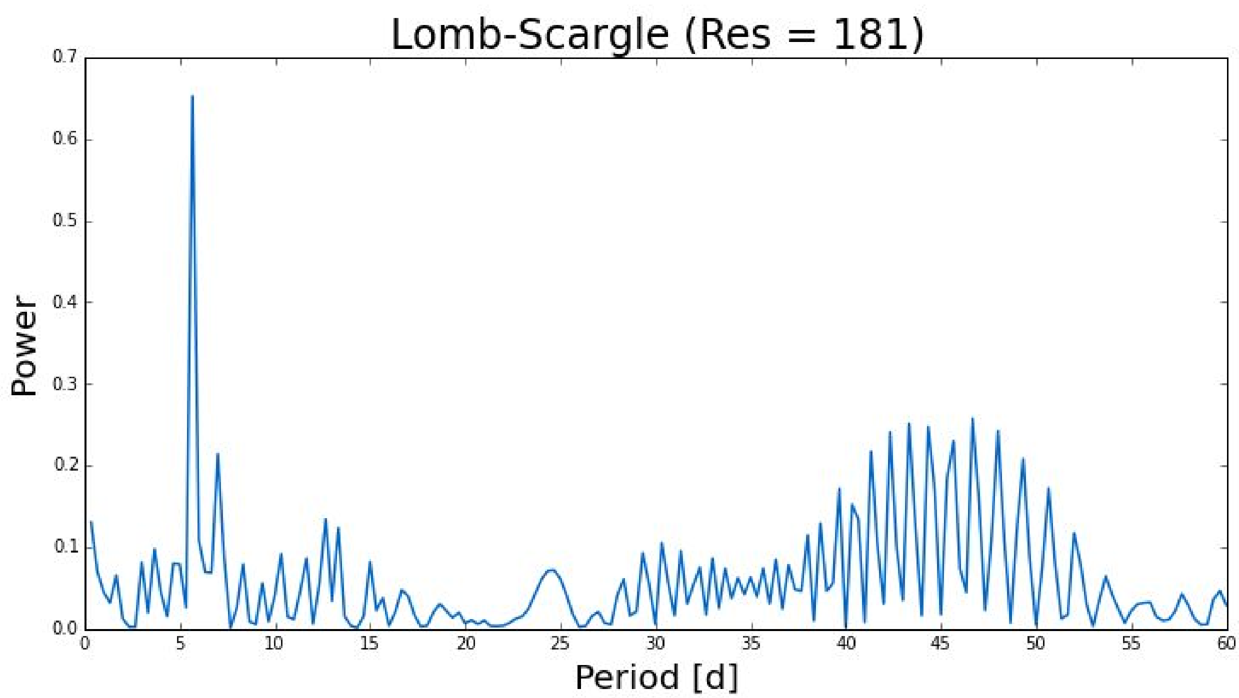

Figure 3: Lomb-Scargle Periodogram for HBC 379

The large point near 5 days corresponds to the most likely period for the given dataset. The exact peak happens at 5.6633, which agrees with the published period of 5.66. To verify this, the data was phased using this period, shown in Figure 4.

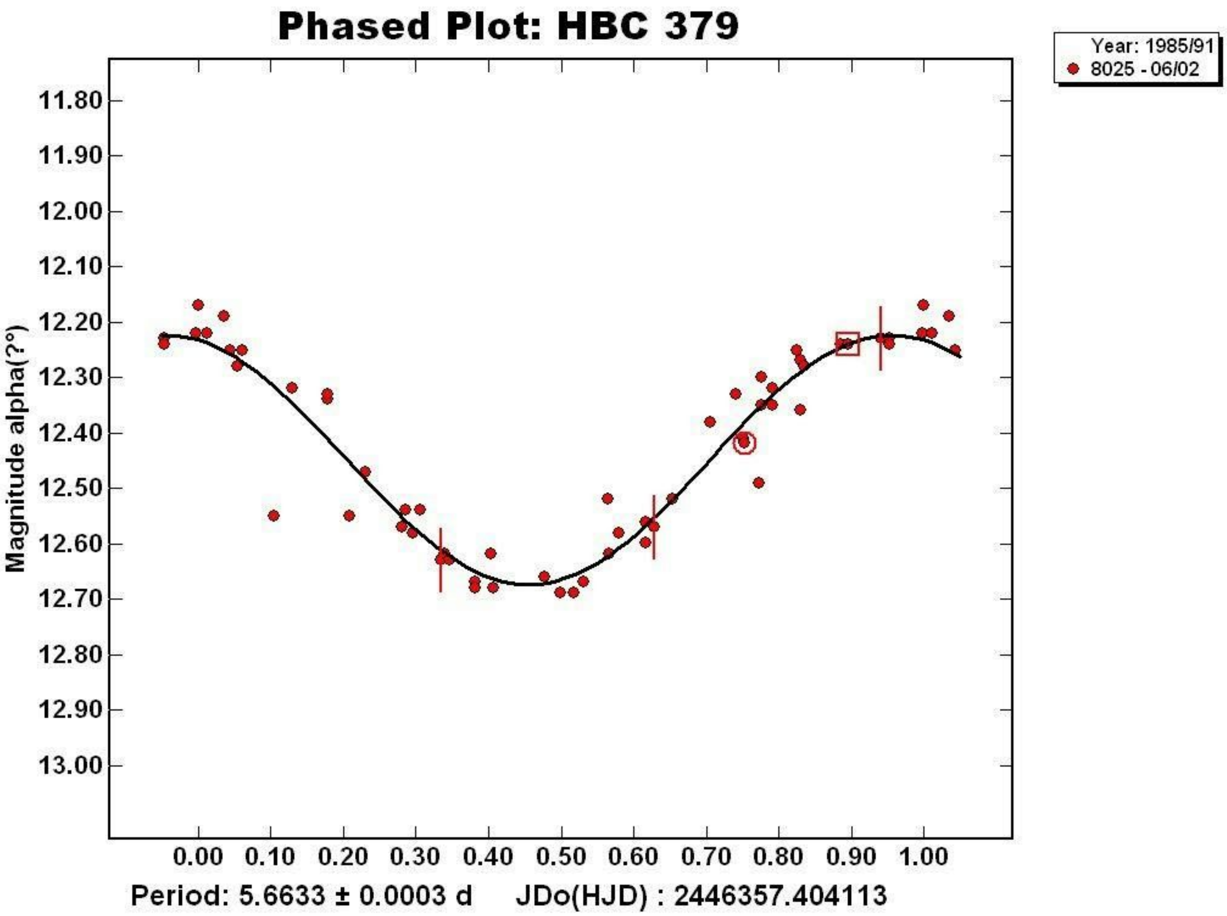

Figure 4: Phased light curve of HBC 379

The data fits the phase well enough that the 5.66 day period published in the literature could be confirmed.

Inclination Calculation

After verifying the period, the inclination could then be calculated using $\frac{2\Pi R_{star}}{P_{rot}} sin(i) = vsin(i)$.

A value for vsin(i) was determined from previous spectroscopic data at 14 $\pm$ 3 km/s. The stellar radius was estimated using spectroscopic data to be 1.9 R_{sun}. After plugging in the confirmed period of 5.66 days, the inclination of the primary star towards Earth was calculated to be 55.0±0.2°

Future Work

While collecting data, many more recent papers used photometry data from past sources instead of taking new data. To ensure the period has not changed over time, it would be valuable to take new data and analyze it in a similar way. More sources of data would be similarly helpful. I was only able to identify 5 reasonable sources, so more good sources could only serve to improve my result.

Because the inclination was only determined for the primary star, the next step is to determine all physical parameters for the secondary star. The primary star can be subtracted out using techniques described in Torres, G., et al. 2013 in order to observe the secondary star. Knowing the physical parameters of the secondary star and how they relate to the primary could lead to a better understanding of how stars and binary systems form in general.

Works Cited

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