ACB Project NGWTHO016

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Introduction

A cataclysmic variable (CV) is a closed binary system with where a white dwarf is accreting matter to a main sequence star. The white dwarf is referred to as the compact object and the main sequence star is referred to as a companion star. The material that is accreted to the companion star, when it has filled its Roche lobe, is generally transferred through the accretion disc. There are different types of CVs. The first category is that of Dwarf novae. These CVs exhibit periodic outbursts which occur when instabilities in the accretion disc causes the disc to become hot, brighter and thicker [1]. Another category is those of Nova-like variables which have a steady high-mass transfer rate, which means there is constant accretion and therefore no outbursts. The next category of CVs is one which this project will focus on which is on magnetic cataclysmic variables (mCVs).

In the previously mentioned categories, we have assumed that the magnetic field from the white dwarf is negligible and therefore material is accreted through the accretion disc. With mCVs, this is when we consider the magnetic field of the white dwarf. There are two types of mCVs, namely: Polars which have strongly magnetic white dwarfs that disrupt the disk formation. The spin period which is due to the white dwarf's spin equals the period due to the binary orbit which is the orbital period. The second category is that of intermediate Polars (IPs). These systems contains white dwarfs with moderate magnetic fields that may allow a partial disk. The spin period in this system is less than the orbital period.

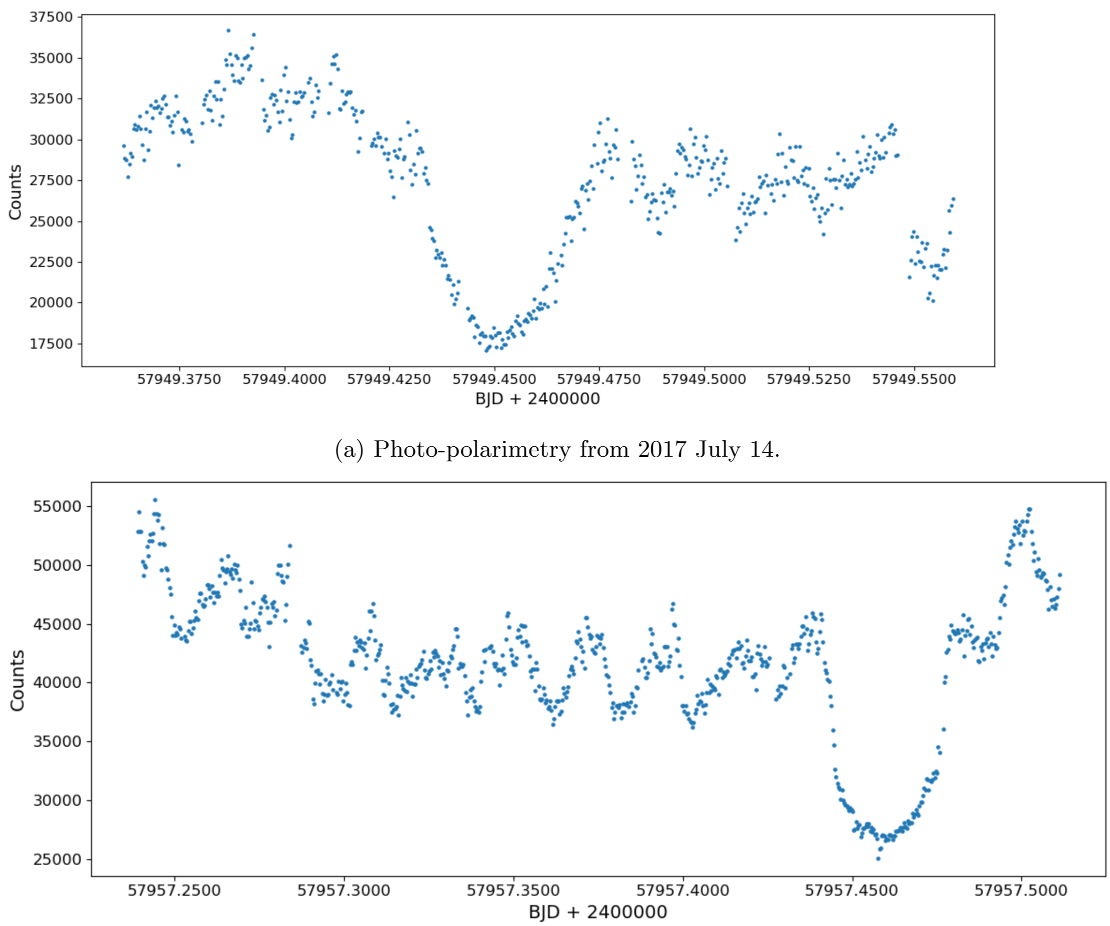
The object of interest for this project is a Nova Scorpius 1437 A.D. also known as IGR J17014-4306. It is the CV remnant of a nova of 1437 March 11 AD. It is a deep eclipsing system. Its RA and Dec coordinates are as follows:

RA (J2000): 17:01:28.15
Dec (J2000): -43:06:12.3

Observations

IGR J17014-4306 was observed for two nights, the 14th of July 2017 and the 22nd of July 2017. From [1], it reveals that the observations for this target were made with the High-Speed Photo-Polarimeter (HIPPO) which is on the 1.9 m telescope from the South African Astronomical Observatory. The filter used for the night of the 25th June was a clear filter, and for the 14th of July it was the OG570 filter.

Figure 1a shows the photo-polarimetry from the 14th of July 2017. From the figure, there are periodic variations as well as an eclipse. Figure 1b also shows an eclipse and periodic variations. This is an indication of a spin-frequency.



(a) Photo-polarimetry from 2017 July 14.

(b) Photo-polarimetry from 2017 July 22.

Figure 1: Images of the light curves from two nights observed.

Fourier Analysis

Figure 2 presents the amplitude spectra of the combined frequencies, done by Period04. The identified spin frequency for this mCV from this spectra is $P_{spin} = 45.97$ cycles/day ≈ 1839.47 seconds. I chose the maximum frequencies for which Period04 should iterate over to be 120 c/d because that it was up to that frequency that there were prominent peaks. Figure 3 shows the Fourier transform of the observation taken on the 14th July 2017. There is a spin frequency in this data too which is about $P_{spin} = 45.63$ c/d ≈ 1893.49 seconds. The Fourier transform of the observation taken on the 22nd July 2017 is shown in Figure 4. The spin frequency is $P_{spin} = 46.29$ c/d ≈ 1866.49 seconds.

Frequencies	Value (c/d)
F1	0.1198
F2	8.0157
F3	11.8388
F4 (f_{spin})	45.9733

Table 1: Extracted frequencies from the Fourier analysis in Figure 2

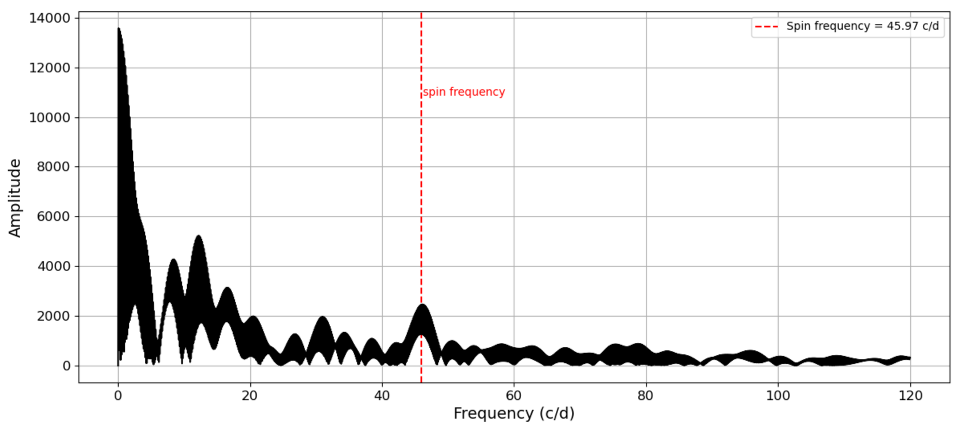


Figure 2: Plot showing the combined Fourier analysis from observation done on the 14th July 2017 and 22 July 2017.

Discussion

Period04 folded the light curves produced in Figure 5 where a sine function was fitted. They all represent the spin-frequencies identified in Figure 1. The light curve produced in Figure 5b does not show an obvious sinusoidal modulation but does have a hint of a sinusoidal wave. The same goes for Figure 5c, though the sinusoidal modulation is more visible for this observation. Combining the two light curves gives us the light curve produced in Figure 5. What we know about the spin frequency is that it is the frequency at which the white dwarf rotates. It typically produces strong, stable modulation due to accretion onto magnetic poles. The spin-frequency obtained from this observation is reported to be $P_{spin} = 45.97$ c/d ≈ 1839.47 seconds. According to [1], the white dwarf's spin modulation was reported to be 1859 seconds which is ± 20 seconds more than the one obtained for this observation. The orbital frequency $f_{orbital}$ is reported to be 1.89 c/d which is equivalent to 45720 seconds [1]. The beat frequency (spin frequency - orbital frequency) was then

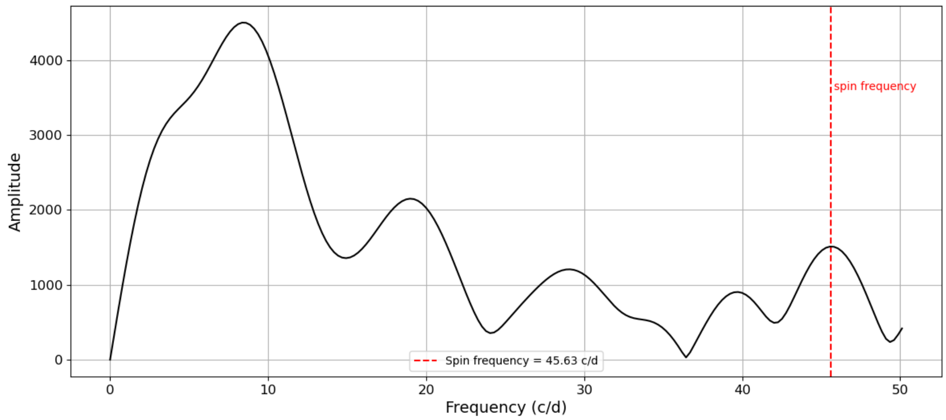


Figure 3: Plot showing the Fourier analysis from the observation on the 14th of July 2017.

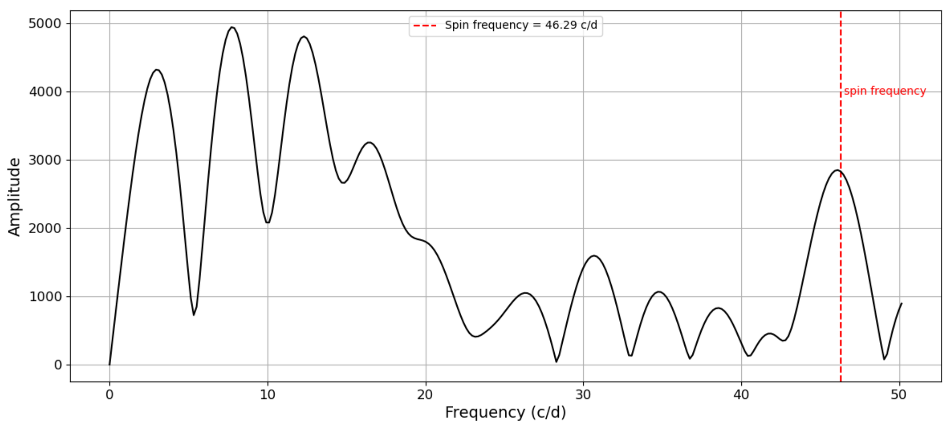
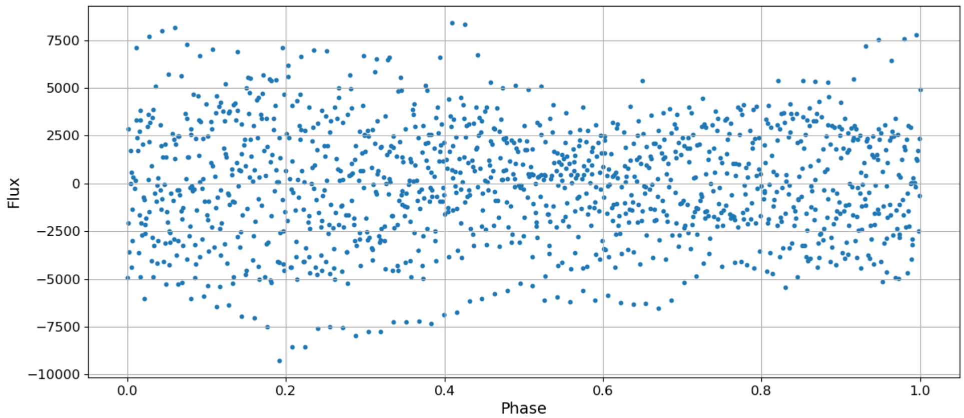


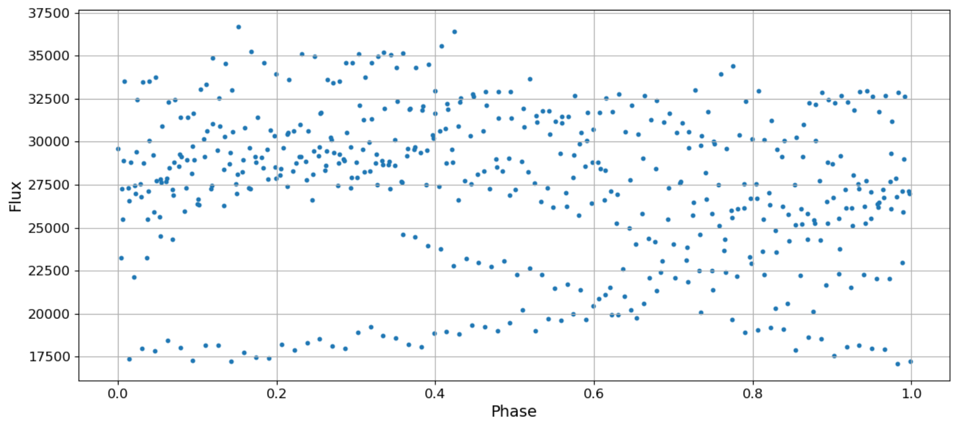
Figure 4: Plot showing the Fourier analysis from the observation on the 22nd of July 2017.

expected to be 44.08 c/d which is 1960.07 seconds, but there was no frequency reported to equal to the one of the beat frequency from the Fourier analysis in Figure 2.

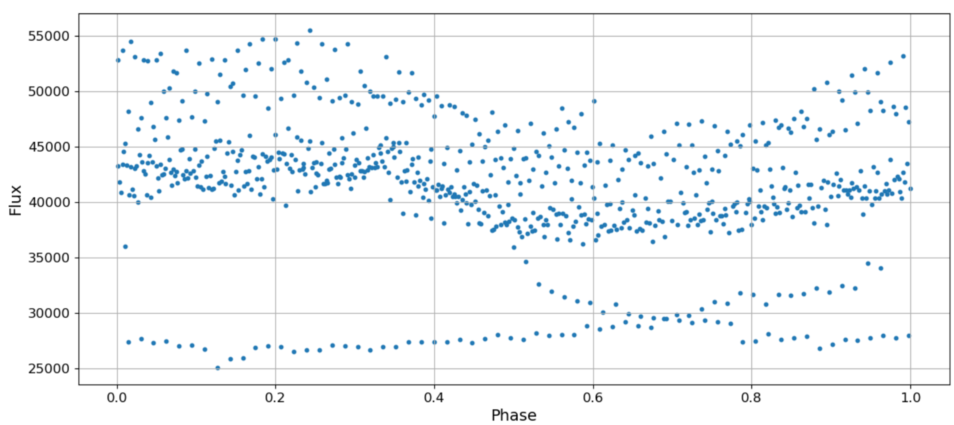
The reason for the difference in spin-frequencies is the number of nights this source was observed for. In [1], the source was observed for 9 nights, with a maximum gap between nights of 5 days. From [2], the dip regions shown in Figure 1 are eclipses which makes IGR J17014-4306/Nova Sco 1437 one of the known intermediate polars that are eclipsing. The reported orbital period is $P_{orbital} = 12.7$ hours for this IP from [1]. This value is clearly more than the spin-frequency which supports why this target is an intermediate polar. The magnetic field of the white dwarf is strong enough to channel accreting material along field lines but not strong enough to lock the white dwarf's spin.



(a) Folded light curve for the combined observations produced by period04.



(b) Folded light curve for the observation on the 14th July 2017, produced by period04.



(c) Folded light curve for the observation on the 22nd July 2017, produced by period04.

Figure 5: Folded light curves for the observations taken on the 14th and 22nd of July 2017, with the combined folded curve for the two nights.

Conclusion

This project has investigates the photometric variability of the cataclysmic variable system, the Nova Scorpius 1437 A.D. also known as IGR J17014-4306, through Fourier analysis of time-series data collected on two nights, the 14th of July 2017 and the 22nd of July 2017, separated by an 8-day gap. By combining and pre-processing the datasets using Period04, a power spectrum was generated. Given that the data was only for two nights, with an 8-day gap, the output light curves from the combined dataset was not clear enough and therefore separate light curves for each night was produced. A dominant frequency was identified at approximately 45.97 cycles/day, which was interpreted as the spin-frequency of the white dwarf.

The detection of the spin frequencies supports the classification of the system as an intermediate polar. Despite the challenges posed by sparse sampling and aliasing due to the long period gap, the spin modulation was strong and coherent when phase folded, further confirming the presence of magnetic accretion processes. No polarimetric data was available, so the presence of circular polarization could not be tested directly. However, the photometric evidence provides an indication of asynchronous rotation and magnetic channeling of accreted material. An expanded multi-epoch observation would help provide a more detailed analysis of the orbital period of the system. Further investigation would also help calculate the strength of the magnetic fields from the white dwarf.

References

[1] Stephen B. Potter and David A. H. Buckley. "Discovery of spin-modulated circular polarization from IGR J170144306, the remnant of Nova Scorpii 1437 AD". In: *Monthly Notices of the Royal Astronomical Society* 473.4 (Nov. 2017), pp. 4692–4697. ISSN: 0035-8711. DOI: 10.1093/mnras/stx2493. eprint: https://academic.oup.com/mnras/article-pdf/473/4/4692/21941722/stx2493.pdf. URL: https://doi.org/10.1093/mnras/stx2493.

[2] M. Shara, K. Iłkiewicz, J. Mikołajewska, et al. "Proper-motion age dating of the progeny of Nova Scorpii AD 1437". In: *Nature* 548 (2017), pp. 558–560. DOI: 10.1038/nature23644. URL: https://doi.org/10.1038/nature23644.