High-Cadence Measurements of the Symbiotic Star V648 Car using a CMOS Camera

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Introduction

V648 Car (CPD -57 2768; TYC 8607-22-1) is one of only a handful of hard-X-ray-emitting symbiotic stars (SySt). Angeloni *et al*. [1] reported large-scale variability in its *U*-band light curve over timescales of minutes noting that there appeared to be no significant periodicity to this 'flickering'. During a 4½-hour observing session they measured variations of 0.5 magnitude or more; the timescales being less than 15 minutes. The cadence for the CCD camera they used was approximately 2 minutes.

CMOS cameras designed specifically for astrophotography are inexpensive and readily available. They have some clear advantages over CCD cameras including high quantum efficiencies and low noise but, importantly, dramatically faster image processing and download speeds. By using a CMOS astrocamera, flickering in stars like V648 Car can now be studied on timescales of seconds rather than minutes. Through studying such flickering we hope to gain a better understanding of the physical processes present in these complex stellar laboratories; in particular processes in the accretion disc surrounding the white dwarf component.

On the night of 14 February 2018 we observed V648 Car continuously for about 7 hours using a ZWO ASI1600MM cooled CMOS camera attached at the f/4 Newtonian focus of the Mount Burnett Observatory (MBO) 18-inch telescope (URL: http://mtburnettobservatory.org/). The field-of-view for this configuration of telescope and camera was 33x25 arc-minutes, well suited to finding then continuously measuring this 10^{th} magnitude symbiotic star. Measurements were made relative to comparison and check stars that were close by and of similar magnitude. Such differential photometry not only suited our program of continuous monitoring but enabled us to gather useful data even when the seeing was less than ideal.

We settled on an exposure time of 4 seconds as it provided sufficient signal-to-noise while delivering a sampling rate almost 30x faster than that of Angeloni et al. [1]. More than 5,000 images were collected over the 7-hour observing session. A median dark frame was subtracted from each 4-second image then an average flat field image applied. SharpCap 3.0 was used for image capture with subsequent batch photometry of the 5000+ images undertaken using Astroart 6.0.

Photometric Band for Measuring Flickering

The measured amplitude of flickering in SySt is greater in the U band than the B or V bands. For example, Cieslinski *et al.* [2] measured short-duration brightness variations for RT Cru on timescales of 10-30 minutes. They found that the amplitude measured in the V band (~ 0.04 magnitude) increased to ~ 0.09 magnitude for measurements in B band. Angeloni *et al*. [3] also note that the amplitude increased for the shorter wavelength bands and chose to measure V648 Car in U band only.

Unfortunately, the sensitivity of CMOS and CCD sensors is substantially less in U band than B or V. To maximise the amplitude of the flickering, we decided to develop a broadband bespoke filter by cementing a planetary #47 (violet) to a Schott BG39 filter. Taking the published response of the Sony IMX174 as representative of CMOS detectors, we customised an 'F band' with a central wavelength of 399 nm. This has a significantly shorter central wavelength than B band and is in a spectral region where the flickering amplitude is expected to be higher while the CMOS detector remains relatively sensitive. (See Figure 1 for comparison of standard U and B bands with the bespoke F band. The responses shown have been normalised.)

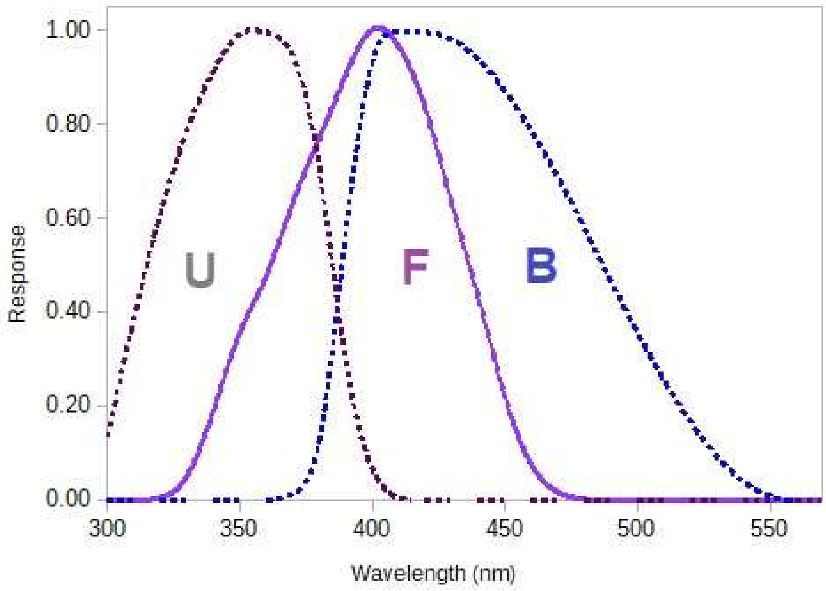

Figure 1. Normalised response of the new F band compared to Johnson U and B bands.

Currently, our F-band measurements are simply the instrumental-magnitude differences between the variable and comparison and check stars selected. To standardise the F band would require establishment of a suitable F-V colour index with a set of standard stars where F-V is set to 0.00 for unreddened A0V stars. The open cluster IC 2602 has a group of bright stars around A0 that are essentially unreddened. A customised colour index, F-V, could then be readily established by setting the average F-V for this selection of A0 stars to 0.00. Further work to establish a 'standard' F-V index for specifically studying flickering with CMOS cameras is being considered as it would enable photometric measurements from different observers or equipment to be combined.

F-Band measurements of V648 Car

Measurements of V648 Car for the 14 February 2018 are shown in Figure 2. The comparison (TYC 8607-276-1) and check stars (TYC 8607-345-1) were of a similar magnitude to V648 Car and close by (separated by 1½ and 5 arc-minutes respectively). The signal-to-noise was thus similar for variable, comparison and check stars. The standard deviation of the differences between the comparison and check stars for the 7-hour observing session was ±0.050 magnitude and, as shown in Figure 1, this magnitude difference remained constant while V648 Car varied by several tenths of a magnitude.

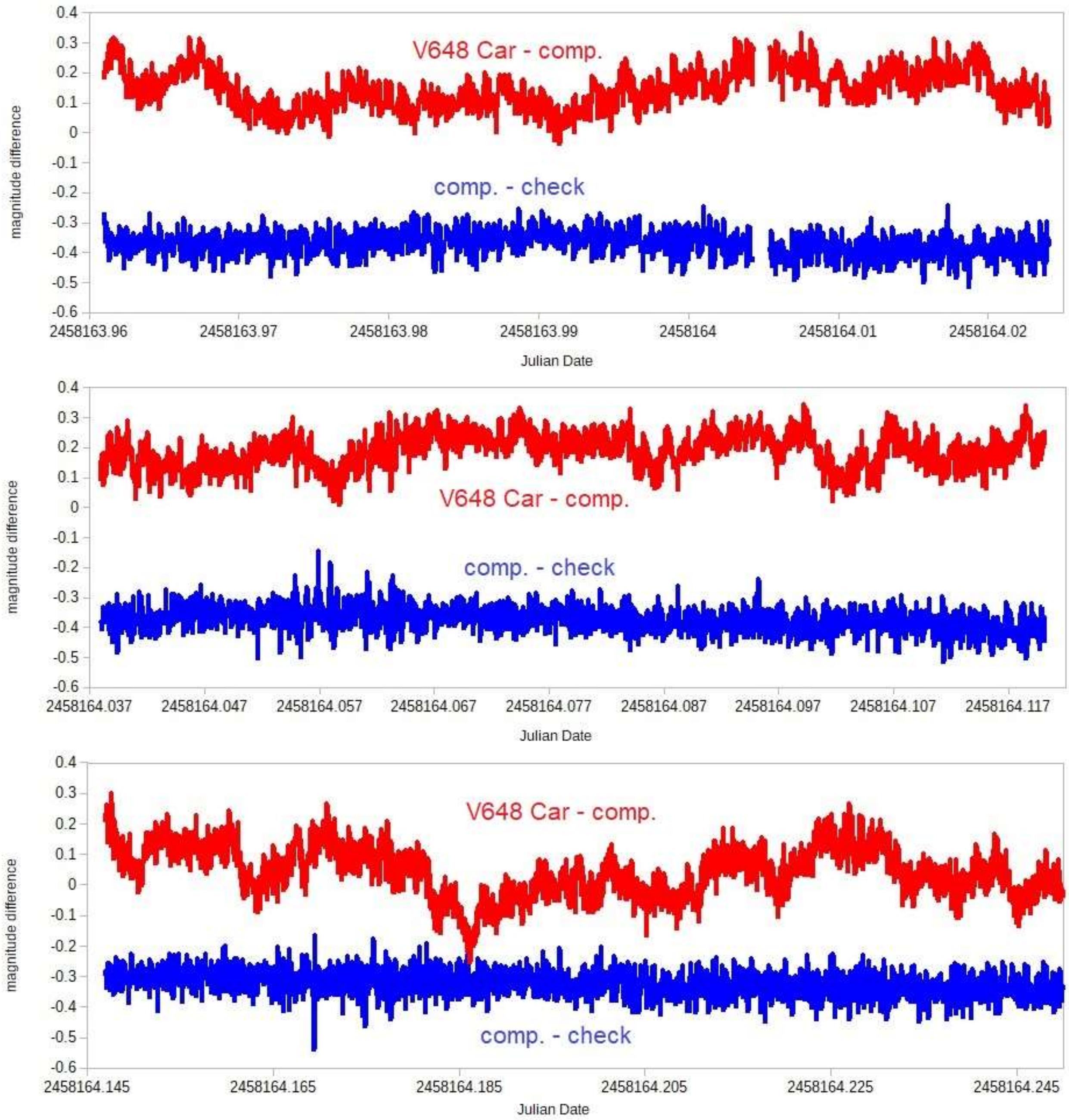

Figure 2. Measurements of V648 car relative to comparison and check stars for 14 February 2018.

Using the software package PerSea [4, 5] a search was undertaken for periodicity in the light curve of V648 Car over a range of frequencies defined, at the upper end, by the cadence of our measurements (4 seconds) and, at the lower end, by the timescale of variations reported in the literature (20 minutes). Subsequently the search range was extended so as to explore the aliasing effects arising from the collection of the data.

In Figure 3 there is an aliasing peak at the frequency related to the length of the observing run (~ 0.29 day) and a smaller peak at a frequency defined by the cadence (4 seconds). Although variations in the order of several tenths of a magnitude were clearly observed during the observing session, there is no evidence from the period analysis that they are periodic.

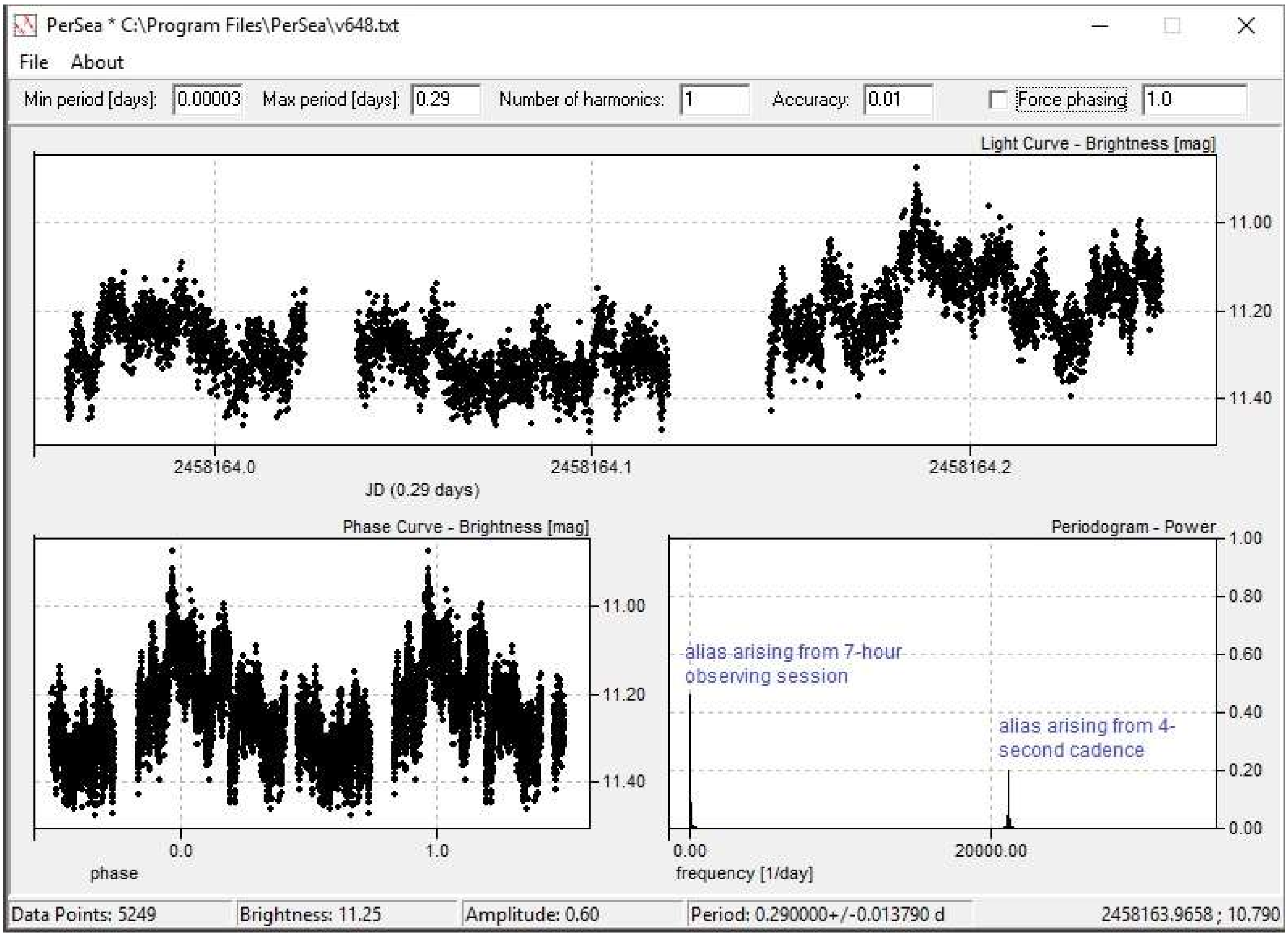

Figure 3. Periodogram for measurements of V648 Car taken on 14 February 2018. There was no evidence of periodicity over the range of 0.00005 to 0.0010 days. When the range is extended to 7 hours (length of observing run) an alias appears at 0.29 day as shown on the LHS of the periodogram. The alias at around 0.00005 day arises from the cadence of 4 seconds.

Conclusion

Flickering in the light curve of the symbiotic star V648 Car (reported by Angeloni *et al*.) was confirmed along with its non-periodic nature.

Continuous measurement of V648 Car over a 7-hour observing session demonstrated that inexpensive CMOS astrocameras enable such flickering to be studied at a higher cadence (seconds rather than minutes) than that attained previously using CCDs. Coupled with their high quantum efficiencies, low noise and fast image download and processing times, CMOS astrocameras appear ideally suited to studies of such short-duration variability in SySt enabling physical processes associated with disc accretion to be further explored. Further studies of the optical variations in selected SySt are planned.

References

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