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An R Coronæ Borealis Variable in Sagittarius

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The details for a serendipitously discovered R Coronæ Borealis (RCB) variable are given.

During an investigation of colour–colour diagrams using the Carlsberg Meridian Catalogue 14 (CMC14; Wyn Evans, 2007), wherein the CMC14 r' magnitude was used in tandem with the 2MASS J and Ks magnitudes (Skrutskie et al., 2006) to generate plots of $r' - J$ versus $J - K_s$ for objects also having OGLE II Galactic Bulge epoch photometry (Szymanski, 2005) north of Declination –25 degrees, as shown in Fig. 1, the outliers had their light curves checked in order both to remove aberrant points and to search for interesting objects. The cross-matching between CMC14 and OGLE II was done with a two arcseconds radius, with the accuracy of CMC14 being to better than one arcsecond, whilst the OGLE II Bulge fields are somewhat variable in astrometric accuracy, ranging from one to several arcseconds depending on how much crowding the field has. Only objects with r' of brighter than magnitude 15.0 were used as these magnitudes are predominantly accurate to 0.1 of a magnitude or better, however if filtering had been done on the quoted error then variable stars would have perforce been removed from the dataset, as the CMC14 photometry is often a mean over several epochs. No filtering was done with the 2MASS magnitudes as the nature of colour – colour diagrams soon reveal discrepant points as outliers.

Approximately half a dozen aberrant points existed away from the main trend of the plot in Fig. 1, all being of the usual variety, such that some were in fact pairs of stars too close for one of the surveys to have cleanly resolved, and thus the colours were an amalgamation of those from two stars and therefore spurious. These were examined using the OGLE II Photometric Database and found to be mostly constant, within the error ranges involved, and examination of their fields showed them to be particularly crowded, often with two to three OGLE II Bulge objects appearing within several arcseconds of each other, and likely all being the same object with multiple identifications, as the CMC14 only found one star at these positions.

The remaining objects outlying the main trend would then be real, and the reason they lay away from the main trend, if below and to the right of said, would be because they had near infra-red (NIR) excess, which is usually caused by circumstellar material. The $J - K_s$ colour is less prone to interstellar extinction than near optical passbands, such as the r' passband, and thus such effects as interstellar extinction would be more likely to spread the data in the $r' - J$ direction, and indeed this spread can be seen in Fig. 1 and is mostly responsible for the thickness of the main diagonal trend. It is a happy consequence that quite a few types of objects with NIR excess are not only stars slightly more exotic than the norm, but often also optically variable.

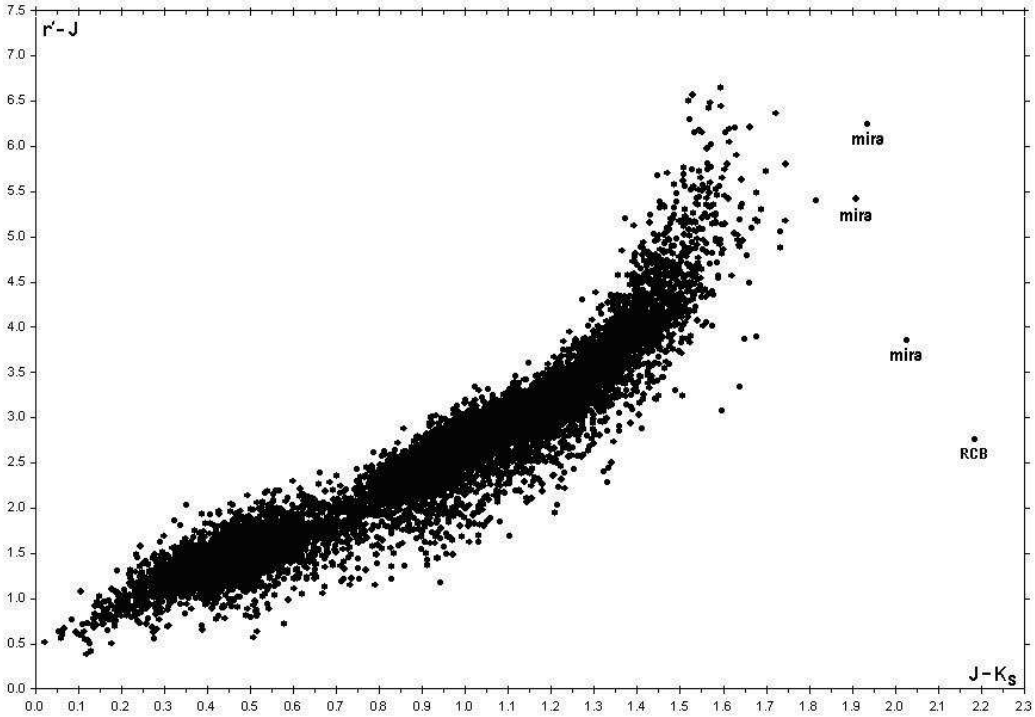

Figure 1. $r' - J$ versus $J - K_s$ for approximately 9900 stars with photometry in all of CMC14, 2MASS and OGLE II.

Bessell and Brett (1988) took stars that were standards in several photometric passbands, especially infra-red ones, and also with known spectral classes, to derive transformation formulæ between said passbands. Another result of this work is that their figures also show the behaviour of such stars in colour – colour diagrams. One thing they note is that oxygen rich red stars dogleg from the main trend, which they assume is likely caused by the Titanium Oxide (TiO) in their atmospheres causing absorption bands in their spectra and therefore making the spectral continuum non-blackbody. Corroboration for this view appears in small "spurs", or smaller doglegs, in their figures, just prior to the main one, which included the known red dwarf stars used in the sample (there are no readily discernible red dwarfs in Fig. 1 of this paper). Unfortunately it appears that no Carbon stars were used in their dataset, as plots using r', J and K_s magnitudes will show that the main diagonal and near linear trend does in fact continue redward, albeit sparsely, and these objects can sometimes be identified with known Carbon stars, which are not affected by TiO absorption bands.

Accordingly, the lowest object marked as a Mira in Fig. 1 is likely a Carbon star. All three objects marked as Mira in that figure have Mira-like light curves in the OGLE II Photometry database. The other two are likely to be spectral class M Miras with some small NIR excess from circumstellar matter moving them just beyond the main dogleg. Many of the dogleg stars will be red long period variables.

Other near infra-red excess objects can also appear on such plots, but in this instance there are very few. Near the left hand side of the plot any object significantly below the line has a chance of being a Be star, however it also has a chance of being an object with aberrant magnitudes. Towards the middle and right of the plot, again at below or well below the main linear trend, is where Herbig/Haro Ae/Be stars usually lie, especially

optically variable ones. Again, none appear in this plot.

Between this general area and where the sparse line Carbon star continuation of the main trend normally lies is a zone of overlap where Carbon Mira stars can have colours adjacent to UX Orionis variable Herbig/Haro Ae/Be stars, due to the combinations of near infra-red excess due to circumstellar material and the interstellar and local circumstellar extinction affects upon the optical r' band. This is also where some rarer objects usually lie, again usually objects having near infra-red excess due to circumstellar material, such that they are "redder" in the near infra-red than in the optical (interstellar extinction works preferentially upon optical wavelengths, such that it causes optical magnitudes to "redden" more than it does near infra-red ones, and therefore cannot be the reason for NIR excesses). Due to the diversity of objects that can occupy this area, and the plethora of circumstances which cause these types to have a wide range of possible parameters, thus creating a great deal of overlap in the colour – colour diagram for these various types, the final arbiter has to be a time series light curve.

Figure 2 presents the light curve from the object marked in Fig. 1 as an RCB. It is OGLE II BUL_SC13 17058 = 14CMC J181639.2–241833 = MSX6C G007.4572–03.7315 = IRAS 18135–2419 and lies at J2000 co-ordinates $18^{\rm h}16^{\rm m}39\overset{\rm s}{.}2$ and $-24°18'33''$. The OGLE II Bulge epoch photometry gives a somewhat characteristic RCB variability profile, with a moderately sedate return to maximum at the onset of the run, and a fairly sharp dip in magnitude at the end of the run, both events being separated by an appropriate timescale, and quasi-cyclic low amplitude long term pulsation being hinted at in between (the magnitude range is somewhat suppressed as OGLE II uses the Cousins I near infra-red passband).

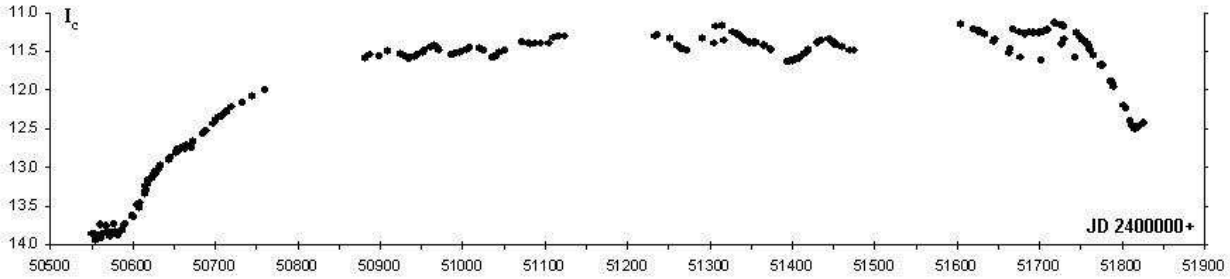

Figure 2. OGLE II Galactic Bulge epoch photometry for the likely RCB variable OGLE II BUL_SC13 17058.

Examination of VizieR catalogue holdings reveals that the OGLE team themselves included this star in a list of over 200 000 candidate variables (Wozniak et al., 2002), however the automated search flagged it as a "transient" object, rather than a continuous and/or continuous plus transient variable. As a good seventy percent of these candidates are flagged as transients, and usually only so because of one or two brighter than usual outliers in the light curve, it is unlikely for the nature of the object to be revealed by this catalogue. Similarly, an optically somewhat brighter star lies 8 arcseconds south east, and the ASAS3 survey appears to have classed that brighter star as a variable (Pojmanski & Maciejewski, 2005). The resolution of the ASAS3 camera system makes it more likely that some interference from the nearby RCB star has caused contamination of this brighter star's light curve leading to a spurious variability signal for it. However, the situation is unclear as there appears to be no independent photometry for the object from the OGLE II Galactic Bulge survey, likely because it is too bright for said latter.

In summary, during the perusal of combined optical and near infra-red colour – colour diagrams for objects common to both the CMC14 and OGLE II Galactic Bulge stars the serendipitous discovery of an R Coronæ Borealis variable in Sagittarius was made as a consequence of its position in the colour parameter space as compared to those of the far vaster majority of the other near 10 000 objects examined. The nature of the OGLE II Galactic Bulge Ic light curve, the proximity to a trend region in the colour – colour diagram normally occupied by Carbon stars, yet the near infra-red excess offset from that line likely due to circumstellar material, all point towards the variability nature of this star. The field is a crowded one and a bright neighbour lies very adjacent, such that more direct pointed observations may be valuable in fully confirming and following this star.

Acknowledgements: This study made use of data products from the CMC14, 2MASS, OGLE II and ASAS3 sky surveys, as well as using the CDS Vizier in order to check for a possible known variability identity. Patrick Wils is also greatly acknowledged for providing a PERL script that greatly facilitated the cross matching of the co-ordinates from the very large raw CMC14 and OGLE II databases.

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