Infrared SOAR Observation of Pre-Cataclysmic Binaries

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Observations

All observations were taken care with the 4.1m SOAR telescope at Cerro Pachon, Chile, with OSIRIS (Pogge et al., 1999) in imaging mode and were performed in queue mode. The NIR photometry was permorfed simultaneously in J, H and K_s, except in cases where the system was too faint to guarantee the required orbital resolution. The simultaneous photometry is basically to perform one dithering sequence in one filter, change to the next filter, perform another dithering sequence and so on. Data reduction were performed with IRAF. The sky contribution is obtained by taking the median af $ndith$ (the number of images in a dithering sequence) images and subtracted from each image of the set. Differential light curves (target star flux divided by comparison star flux) were computed, in order to avoid fluctuations in sky transparency during the night, and flux calibrated using **2MASS** zero point constants Skrutskie et al. (2006) and absolute magnitudes for comparison stars.

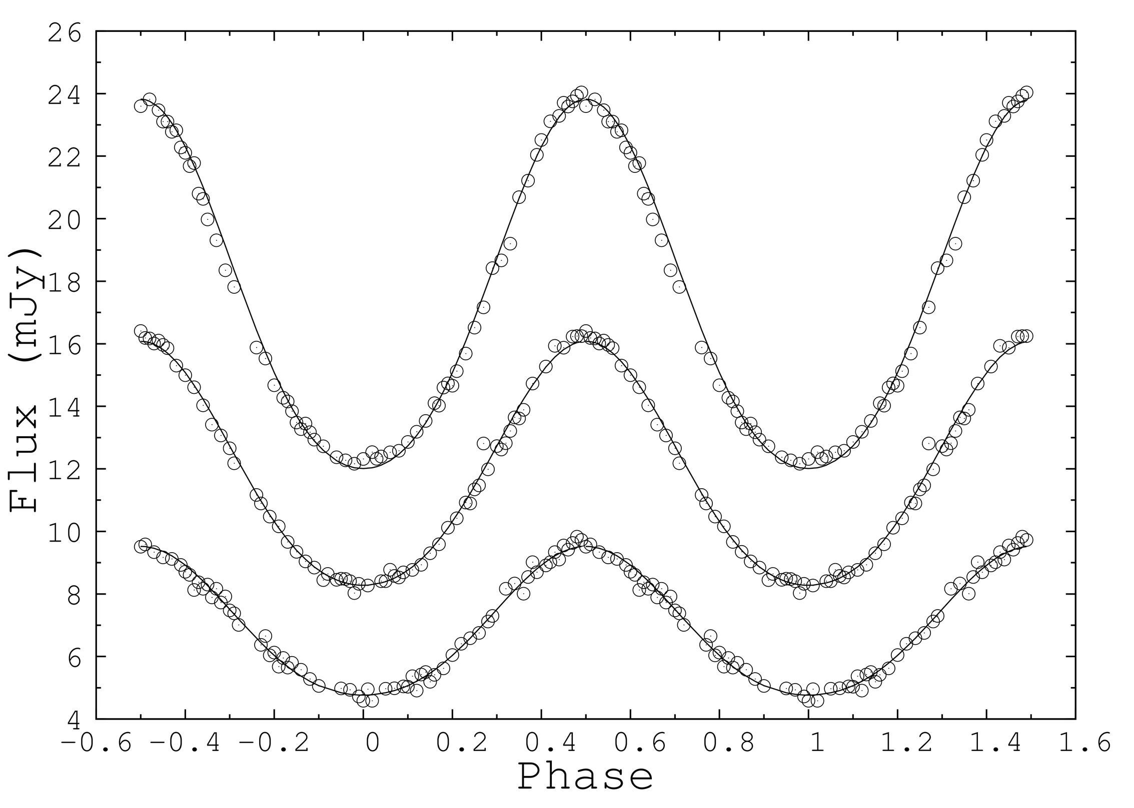

Figure 1: Light curves of KV Vel with modeled light curve fit to the data (solid lines). From top to botton light curves in J, H and K_s respectively.

Data Analysis.

The parameters of the modeling procedure are: mass ratio ($q = M_2/M_1$), inclination (i), flux of the secondary (F_2), and of the primary (F_1), irradiated intensity (I_{irr}) and filling factor (f_{fac}). Since we have no information on the distance between the two components and/or primary temperature with light curve modeling, we have used I_{irr} to account for irradiation effects, assumed $\alpha = 1.0$ and using distances in units of orbital separation, letting the discussion for post-modeling i.e., once we know the amount of the irradiation effect we can discuss its origins. Modeling is also performed simultaneously with any number of light curves we have. For a set of n light curves q, i and f_{fac} are general and F_2, F_1 and I_{irr} are particular of each data set. We proceed by minimizing the χ^2 of the O-C light curve. On next sections we present and discuss the results of the modeling procedure for each target data set.

Table 1: O-C residuals for KV Vel (table 1 of Kilkenny et al. (1988) added with our measured times and analysis). Our cicle timings is the mean measured value on JHK_s bands.

cycle	T(mid) (2400000+)	(O-C) lin. ephem.	(O-C) quad. ephem.	(O-C) ephem. K88
-106	45796.671	-0.00247	-0.0019	-0.0019
0	45834.52803	+0.00062	+0.0011	+0.0011
3	45835.59908	+0.00033	+0.0008	+0.0009
829	46130.5735	-0.00020	-7.2e-05	+0.0000
2834	46846.5850	+0.00065	-1.6e-05	+0.0000
2845	46850.5130	+0.00041	-0.0003	-0.0003
3018	46912.2940	+0.00094	+0.0002	+0.0002
23382	54184.53287	+0.00005	+9.0e-06	-0.0092

KV Vel.

Our NIR light curves of KV Vel (fig. 1) are remarkedly dominated by reflection effects clearly resembling its optical light curves Hilditch et al. (1996). The amplitude of the reflection effect at NIR is $0.7H$ against its $0.55V$ mag.

We have measured the time of maximum light of our light curves and used previous measurements published by Kilkenny et al. (1988) and found a more precise ephemeris of the system. Altogether, we have also fitted a quadradic ephemeris to the data and found a statistical significance of 96% for this result applying the F-test as proposed by Pringle (1975). The results are presented in table 1 and 2.

After analysis of the system's ephemeris we proceeded with the modeling procedure. The parameters that best describes our data are shown in tab. 3 and the corresponding light curves are shown as solid lines on fig. 1. We obtain values for inclination and mass ratio consistents with the obtained by Hilditch et al. (1996).

Table 2: Ephemeris of KV Vel.

$HJD = T_0 + p_0 E$	$T_0 = 2\,445\,834.5274(\pm4)$d
	$p_0 = 0.35711254(\pm3)$d
$HJD = T_0 + p_0 E + cE^2$	$T_0 = 2\,445\,834.5269(\pm5)$d
$c = (-2 \pm 1) \times 10^{-11}$d	$p_0 = 0.3571130(\pm3)$d

NIR flux ratio diagram ($F(J)/F(K_s) \times F(H)/F(K_s)$) for the binary components and for different types of radiator are shown on fig. 2for diagnostic. The color of the non-iluminated face of the secondary star match the color of a black body radiator with temperature $T \sim 4000K$ (filled circle on fig. 2). In the other hand, the color of the irradiation effect (excluding the contribution of the secondary) are consistent with a black body radiator at $T \sim 5500K$.

Table 3: Results of data analysis of KV Vel.

Light curve fitting:	J	H	K_s
$F_2(mJy)$	3.58 ± 0.09	3.32 ± 0.08	2.67 ± 0.09
$F_d(mJy)$	8.7 ± 0.15	5.0 ± 0.1	2.1 ± 0.2
I_{irr}	2.5 ± 0.2	1.8 ± 0.2	1.39 ± 0.09
Simultaneouly fitted parameters:	$i = (61 \pm 3)^\circ$	$q = (0.41 \pm 0.04)$	$f_{fac} = (1.07 \pm 0.05)$

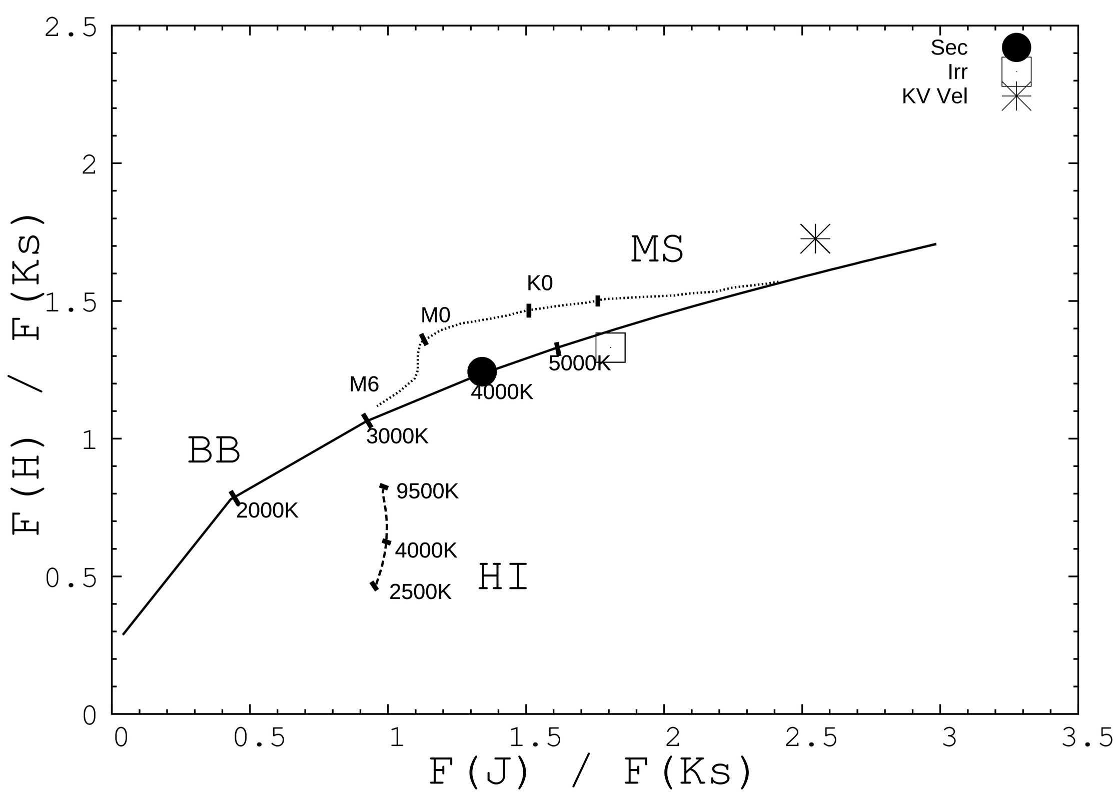

Figure 2: Flux ratio diagram of KV Vel.

TW Crv.

The light curves of TW Crv are also dominated by reflection effect, similar to those of KV Vel. Therefore, the analysis of its NIR light curves is simmilar to the analysis of KV Vel presented last section.

As in the case of KV Vel we have also measured the time of maximum light and recalculated the ephemeris of the system using previous time measured by Chen et al (1995). The resulting ephemeris is showed on eq. 1.

$$T_{mid}(E) = 2448661.6049(\pm3) + 0.3276074(\pm2) \cdot E \tag{1}$$

The resulting ephemeris is in agreement with the value obtained by Chen et al. (1995), only more precise. We have than proceeded with the light curve fitting analysis and the results are presented in table 4and plotted in fig. 3. The filling factor maps a radius of $r2 = 0.264^{+0.009}_{-0.008}$ for the secondary star which, using equation (5) of Chen et al. (1995) gives a mass ratio of $q = 0.288$, consistent with our light curve fitting value.

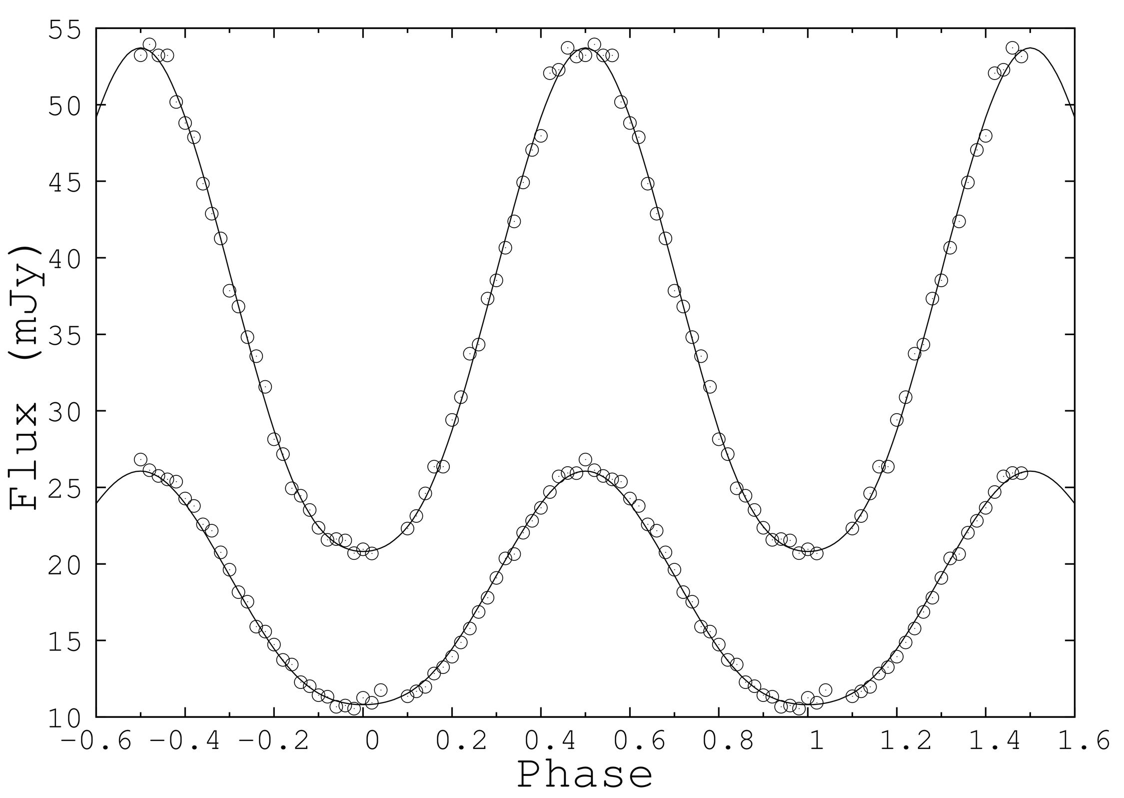

Figure 1: Light curves of TW Crv with modeled light curve fit to the data (solid lines).

Ephemeris refinement:			
T_{mid}	P(days)	cicle	source
$245\,4215.53\overline{7}\,395$	$0.327607\overline{6}503$	16953	J band
$245\,4215.53\overline{1}\,646$	$0.327607\overline{3}112$	16953	H band
$245\,4215.53\overline{4}\,521$	$0.327607\overline{4}807$	16953	average

Light curve fitting:	J	H
$F_2(mJy)$	9.6 ± 0.6	3.3 ± 0.4
$F_d(mJy)$	11.0 ± 0.6	7.4 ± 0.3
I_{irr}	2.6 ± 0.2	3.5 ± 0.4
Simultaneouly fitted parameters:	$i = (48 \pm 9)^\circ$ $q = (0.29 \pm 0.04)$	$f_{fac} = (1.063 \pm 0.007)$

LTT 560.

Unfortunaltely, our NIR light curves of LTT 560 do not have the S/N ratio required to clearly detect the modulation produced by the distorted secondary star of this binary. Therefore, we were unable to apply the modeling procedure to determine the system parameters. But rather, we have used previous determined parameters to produce model light curves and compare them with our data (fig. 4). In this case, it is possible to note some variation in the J and H band light curve. The model light curve seems to corroborate with our interpretation that lack of photometric precision is the cause for the failure in detecting the modulation produced by the secondary star.

Nevertheless, as seen in table 5, our calibrated data agrees well with 2MASS measurements. Furthermore, indicating that the system was in its usuall bright state.

Table 5: Comparison between 2MASS absolute magnitides measurements of LTT 560 and ours.

Filter	2MASS	this work
J	$12.651(\pm24)$	$12.667(\pm??)$
H	$12.130(\pm21)$	$12.134(\pm??)$

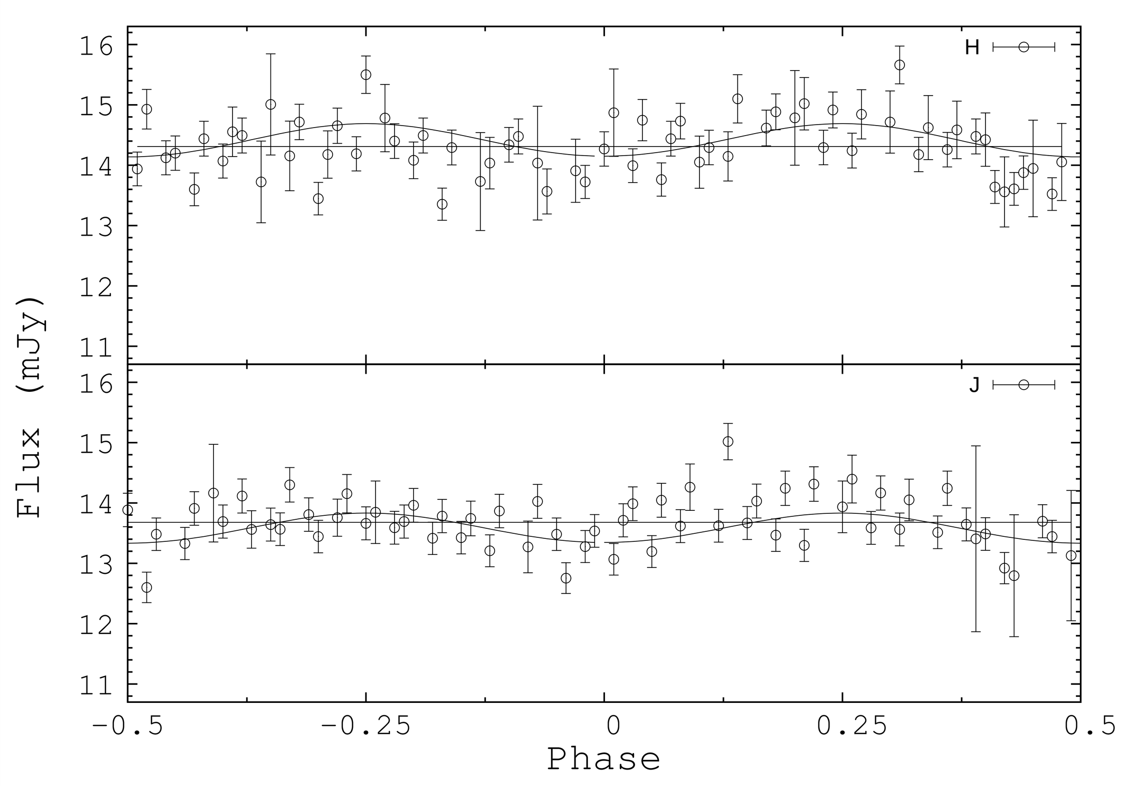

Figure 4: Light curves of LTT 560 with modeled light curve fit to the data (solid lines).

Conclusions.

New NIR photometry of two long period pre-Cataclysmic binaries, KV Vel and TW Crv, and the intermediate period LTT 560 is presented. By measuring times of maximum light of KV Vel and TW Crv we were able to improve the the systems ephemeris (see table 2and eq. 1for KV Vel and TW Crv results, respectively) and, in the previous case, detect a possible period variation. Though this results require further investigations, it is indeed significant, as we have previously shown by applying the F-test proposed by Pringle [1975].

References

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