

PHOTOMETRIC STUDY OF UX ORI TYPE STARS GM CEP AND V1180 CAS

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Abstract. Results from BVRI long-term photometric observations of the pre-main sequence stars GM Cep and V1180 Cas are reported. The two stars were originally classified as eruptive variables from EX Lupi type. But the precise analysis of photometric data accumulated over the year's shows that they are certainly UX Orionis-type variables. Both types of pre-main sequence stars show variability with large amplitudes, but as in the case of EX Lupi stars variability is dominated of non-periodic outbursts, in the case of UX Orion stars long eclipses from circumstellar matter are observed. The analysis of the collected multicolor photometric data indicates the typical of UX Ori variables a color reversal during the minimums in brightness. This, along with the observed deep decreases in brightness, shows that stars are obscured by dust clumps or filaments passing through the line of sight to the stars. Photometric data presented in this study show the usefulness of systematically monitoring of pre-main sequence stars with large amplitude variability. With the accumulation of enough photometric data, we can more accurately determine the causes of photometric variability of young stellar objects.

INTRODUCTION

Photometric variability is a fundamental characteristic of the pre-main sequence (PMS) stars, which manifests as transient increases in brightness (outbursts), temporary drops in brightness (eclipses), irregular or regular variations for a short or long time scales. Both types of PMS stars the widespread low-mass ($M \leq 2 M_{\odot}$) T Tauri Stars (TTs) and the more massive Herbig Ae/Be (HAEBE) stars indicate photometric variability with various amplitudes and periods (Herbst

et al. 1994; Herbst et al. 2007). A significant part of HAEBE stars and early type CTT stars show strong photometric variability with sudden quasi-Algol drops in brightness and amplitudes up to 2.5 mag. (V) (Natta et al. 1997; van den Ancker et al. 1998). During the deep minimums of brightness, an increase in polarization and specific color variability (called “blueing effect”) are observed. The prototype of this group of PMS objects with intermediate mass named UXors is UX Orionis. The widely accepted explanation of its variability is a variable extinction from dust clumps or filaments passing through the line of sight to the star (Dullemond et al. 2003; Grinin et al. 1991).

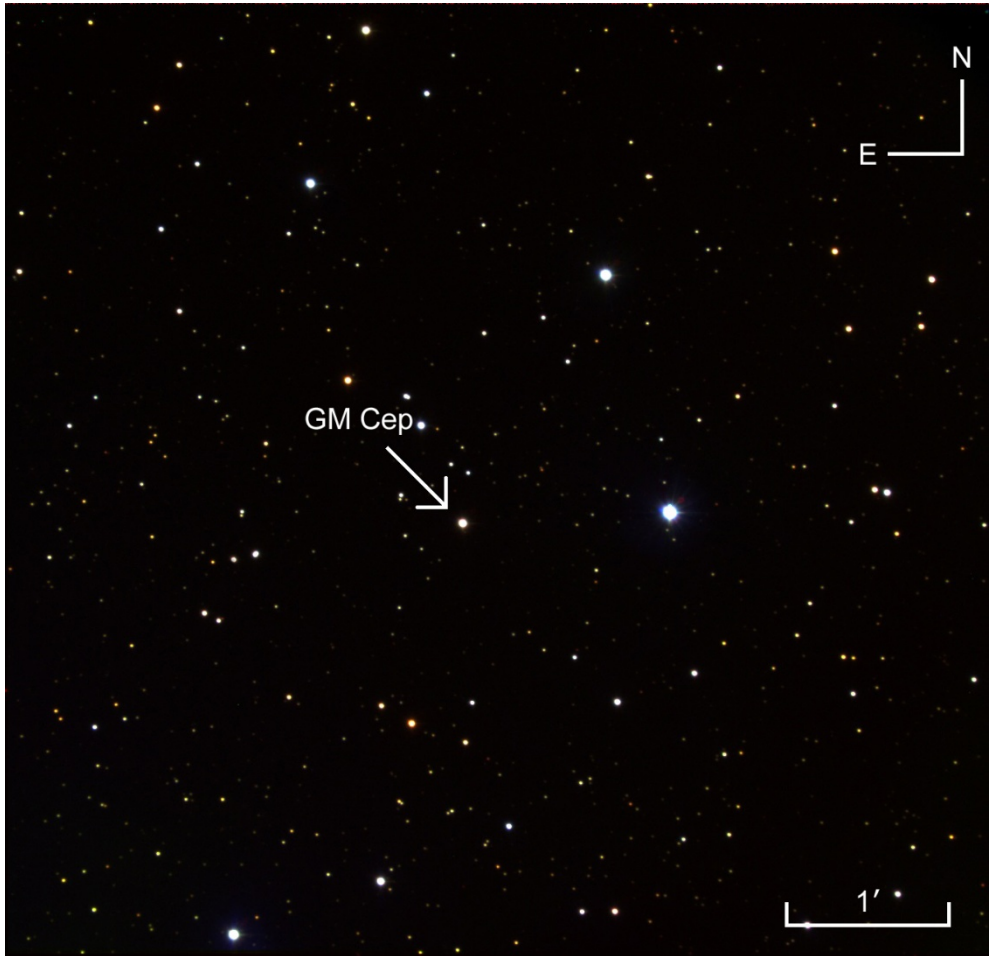


Figure 1: Color image of GM Cep obtained on November 23, 2016 with the 2-m RCC telescope in NAO Rozhen, Bulgaria.

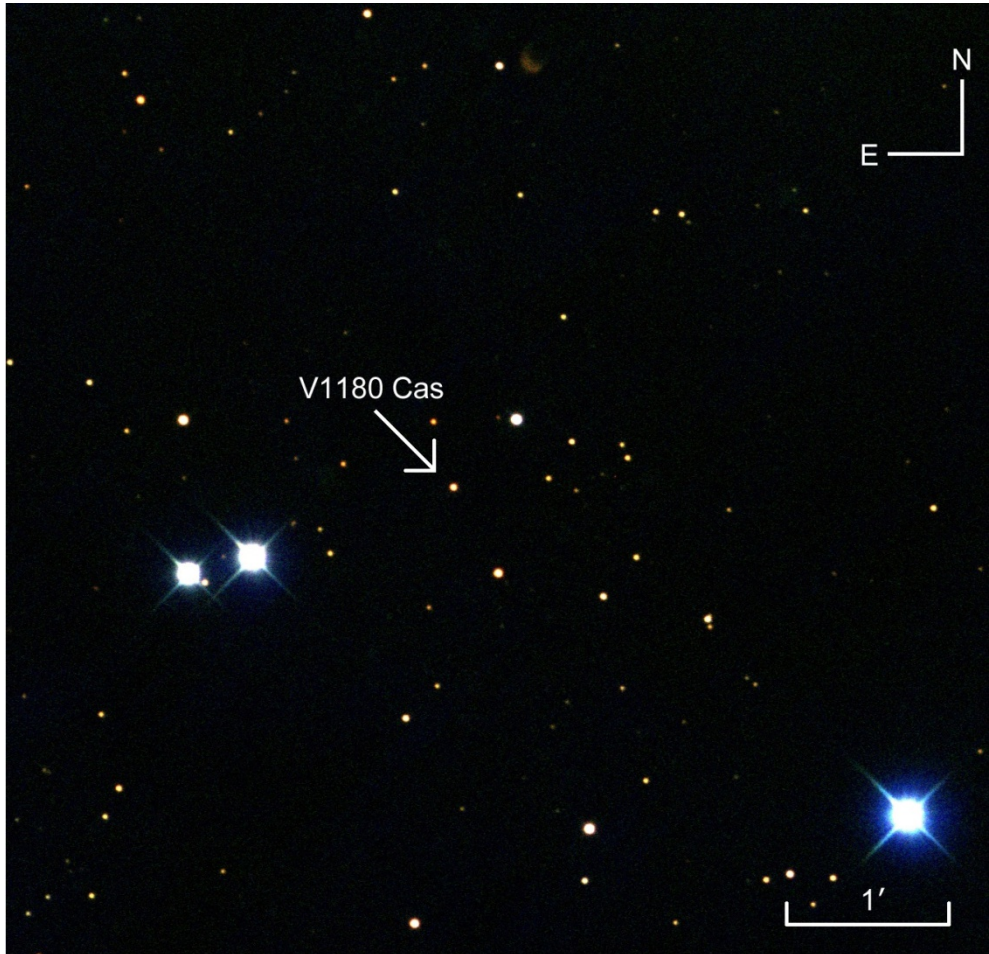


Figure 2: Color image of V1180 Cas obtained on August 12, 2015 with the 1,3-m RC telescope in Skinakas Observatory, Greece.

The PMS star GM Cep lie in the field of the young open cluster Trumpler 37 (~ 4 Myr old) at a distance of 870 pc (Contreras et al. 2002) and most likely is a member of the cluster (Marschall & van Altena 1987; Sicilia-Aguilar et al. 2005). According to Sicilia-Aguilar et al. (2008) GM Cep is a PMS star with solar mass ($M \sim 2.1 M_{\odot}$) from G7V-K0V spectral type and with radius between 3 and 6 R_{\odot} . The results from *BVRI* optical photometric observations of the star collected in the period June 2008 – August 2014 are reported in our two previous papers (Semkov & Peneva 2012; Semkov et al. 2015). During our new photometric monitoring three deep minimums in brightness are observed. The collected multicolor photometric data shows the typical of UXor variables a color reversal during the minimums in brightness. Recent *BVRI* CCD photometric observations of GM Cep collected from November, 2014 to April, 2018 are reported here.

V 1180 Cas is a young variable associated with the dark cloud Lynds 1340 – a star forming region in Cassiopeia, located at a distance of 600 pc from the Sun. The star was first recognised to be a H α emitter by Kun *et al.* (1994). According to Kun *et al.* (2011) the object exhibited large amplitude (5–6 mag in the I_C band) brightness variations on 2–3 years timescales. Data from our *BVRI* photometric monitoring in the period October 2011 – April 2018 show drops in stellar brightness with amplitude up to 3 mag (I_C).

OBSERVATIONS

The CCD observation of GM Cep and V1180 Cas were performed in two observatories with four telescopes: 2-m Ritchey-Chretien-Coude, the 50/70-cm Schmidt and the 60-cm Cassagrain telescopes of the Rozhen National Astronomical Observatory (Bulgaria) and the 1.3-m Ritchey-Chretien telescope of the Skinakas Observatory of the University of Crete (Greece). The observations were performed with eight different types of CCD cameras. All frames were taken through a standart Johnson-Cousins set of filters. All data were analyzed using the same aperture, for GM Cep which was chosen to be with 6'' radius (while the background annulus was taken from 11'' to 17'') and for V1180 Cas which was chosen to be with 4'' radius (while the background annulus was taken from 13'' to 17''). As a reference, the *BVRI* comparison for GM Cep sequence reported in Semkov & Peneva (2012) was used.

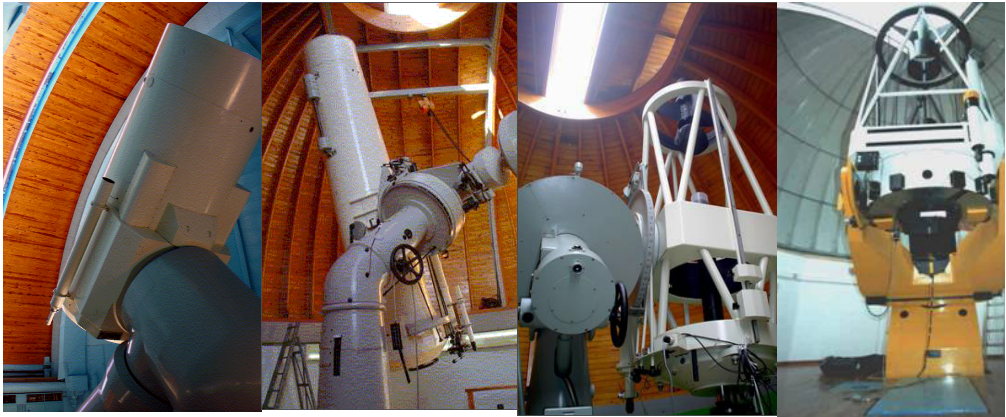


Figure 3: The used telescopes. Left to right: the 2-m RCC, the 50/70-cm Schmidt and the 60-cm Cassagrain telescopes of Rozhen NAO (Bulgaria) and the 1.3-m telescope of the Skinakas Observatory (Greece).

RESULTS

Long-term light curves of GM Cep from all our observations and data from the literature are shown in Fig. 4. In Fig. 5 we plot the B , V , R and I light curves for the whole period of our CCD photometric monitoring (2008 - 2018). The typical values of instrumental errors for all of our observations are in the range 0.01^m - 0.02^m (for I and R), 0.01^m - 0.03^m (for V) and 0.01^m - 0.05^m (for B). The new photometric data showed continued strong brightness variability of GM Cep as the registered in the previous studies (Sicilia-Aguilar et al. 2008; Xiao et al. 2010; Semkov & Peneva 2012; Chen et al. 2012, Semkov et al. 2015). Out of deep minimums GM Cep shows significant brightness variations in the time scale of days and months. The summarized results of over ten years period of observations show very strong photometric variability. We have registered eight deep minimum in brightness in the light curve of GM Cep.

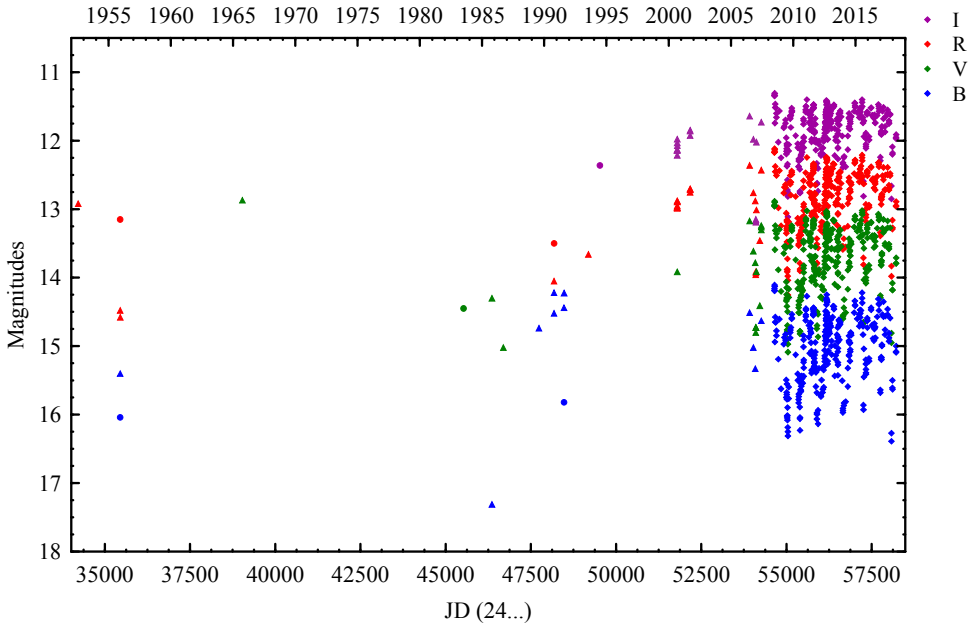


Figure 4: Long-term light curves of GM Cep. The diamonds denote our CCD photometric data; triangles – data from Sicilia-Aguilar (2008); circles – photographic data from POSS I and POSS II plates.

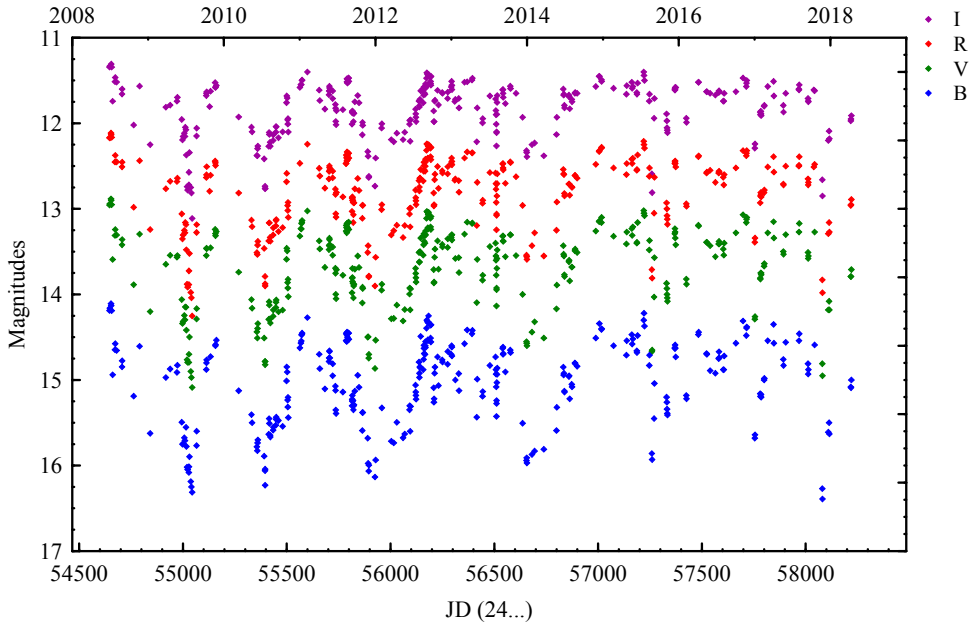


Figure 5: UBVR light curves of GM Cep for the whole period of our photometric monitoring (2008 - 2018).

The collected multicolor photometric data shows the typical of UXor variables a color reversal during the minimums in brightness. Using data from our *BVRI* photometry the three color-magnitude diagrams ($B - V/V$, $V - R/V$ and $V - I/V$) of the star are constructed and displayed on Fig. 6. The existence of a turning point of each of the diagrams is seen on the figure. After analysis of data collected our conclusion is that the photometric properties of GM Cep can be explained by superposition of both: (1) highly variable accretion from the circumstellar disk onto the stellar surface, and (2) occultation from circumstellar clumps of dust, planetesimals or from features of the circumstellar disk. Our photometric results for the period June 2008 – April 2018 suggest that the variable extinction dominates the variability of GM Cep.

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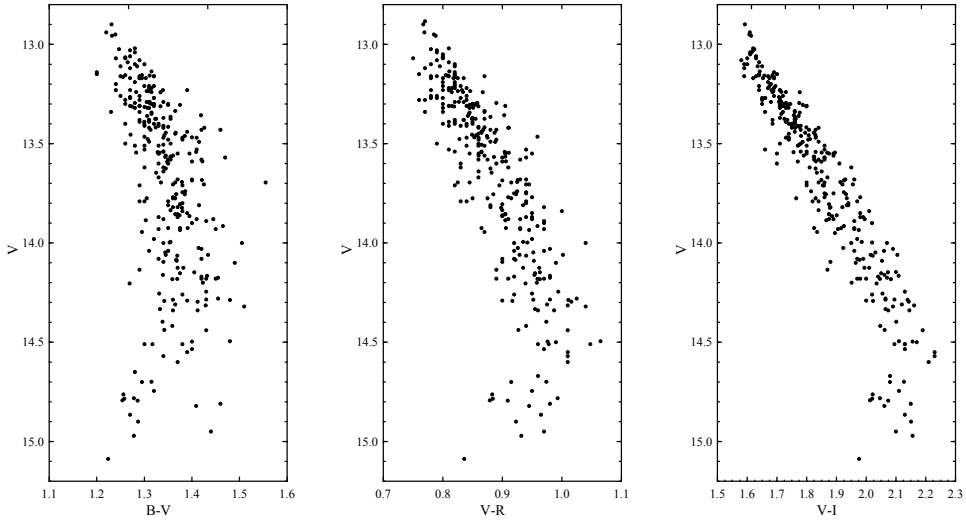


Figure 6: The color-magnitude diagrams of GM Cep in the period of observations June 2008 - April 2018.

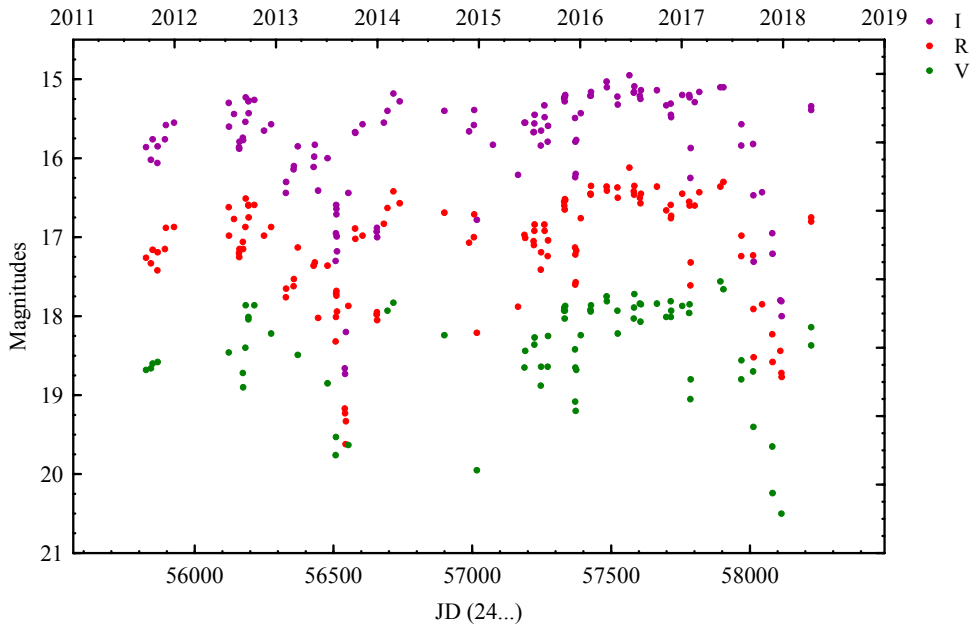


Figure 7: VRI light curves of V1180 Cas in the period October 2011 – April 2018.

Data from our *BVRI* photometric monitoring of V1180 Cas in the period October 2011 – April 2018 are presented in Fig.7. The photometric data show a large amplitude variations ($\Delta R \sim 3.3^m$) during the 6.5 years period of observations. The first deep minimum is registered at September 2013 and the second at December 2017. Out of deep minimums V 1180 Cas shows significant brightness variations in the time scale of days and months, similar to another UX Ori type variable star GM Cep (Semkov & Peneva 2012; Semkov et al. 2015).

V 1180 Cas show color reversal at minimum of brightness a similar to GM Cep (Fig. 8).

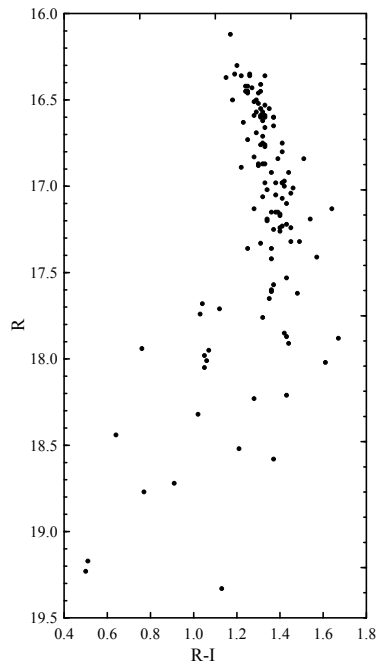


Figure 8: The color-magnitude diagrams of V1180 Cas in the period of observations October 2011 - April 2018.

Acknowledgements

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