Eclipse Variables of UX Ori Type

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The present work is devoted to the extended photometric study of the stars V1180 Cas and GM Cep showing brightness variations characteristic of the UXors type. The main goal of the present work is to accurately classify the variability of the studied stars on the basis of the luminosity curves over a long period of time and to draw conclusions about the physical mechanisms initiating the observed changes in their luminosity. The dissertation complements the earlier incomplete overview of the photometry of the studied stars and presents their photometric history.

The dissertation is divided into a short introduction, six chapters and a bibliography. Chapter 1 describes the basic characteristics and variability of pre-main sequence stars. Chapter 2 presents the observations and data processing for the studied stars. Chapter 6 presents a list of publications and citations. The main points and results of the research are presented in the last three chapters: Chapter 3 - results of object observations and analysis of the obtained results; Chapter 4 - conclusion and in Chapter 5 - scientific contributions. The key points and results of the study are summarized below:

The results of our photometric $BVRI$ data from an over 12-year long period (June 2008 - October 2020) of observations of GM Cep show continuous very strong variability in the brightness of GM Cep, previously recorded in other studies (Sicilia-Aguilar et al. [2008], Xiao et al. [2010], Semkov and Peneva [2012], Chen et al. [2012], Semkov et al. [2015], Huang et al. [2019], Mutafov et al. [2022]). During this period, we recorded nine deep brightness minima: the first two minima observed in 2009 and 2010 lasted from one to two months, the third (2011/2012) and fifth (2013/2014) minima lasted about half a year, and the fourth minimum (August 2013) lasted one week. We observed the sixth, seventh, eighth and ninth minima in August 2015, January 2017, November 2017 and August 2020, respectively. The collected multi-color photometric data show the typical UXor color reversal during brightness minima. For each of the color diagrams such a reversal point is observed at a different stellar brightness: in the $V/B-V$ diagram the reversal point is observed at V about 14.0 mag, in the $V/V-R$ diagram at V about 14.5 mag and in the $V/V-I$ diagram at V about 14.6 mag. The analysis of the obtained data allows us to accurately classify GM Cep as a UX Orionis type variable. The glow curves over a long period of time are dominated by dips, and at the minima there is the characteristic color reversal of the color–magnitude diagrams similar to the glow curves of other uxors. On the time scale of days and months outside the deep minima GM Cep also shows significant brightness variations. We can confirm our previous conclusions that the photometric properties of GM Cep can be explained by a superposition of highly variable accretion from the circumstellar disc onto the stellar surface and obscuration by circumstellar dust particles, planetesimals or by other features of the circumstellar disc.

During the period from 2011 to 2020, our observations of the star V1180 Cas in VRI colors show very strong photometric variability with large amplitude variations ($\Delta I \sim 5$ mag) for which no periodicity is observed (Mutafov et al. [2019a]; Mutafov et al. [2022]). The same brightness variability was also recorded in the previous studies of Kun et al. [2011], Antoniucci et al. [2013], [2014] and Lorenzetti et al. [2015]. During this period, we recorded four deep brightness minima in the light curve of V1180 Cas: in September 2013, in December 2017, in February-March 2019, and in January 2020. Most of the time, the brightness of the star in the I-filter is in the range of 15-16 mag., which are considered maximum values in previous studies. During these periods, however, there are changes in brightness with small amplitudes, which is a characteristic feature of T Tau stars. These data confirm that outside of the deep minima, V1180 Cas exhibits significant brightness variations lasting days and even months. They again confirm that the variability of the star is dominated by the variable extinction. Multi-color photometric data collected during the observed period show the typical UXors color reversal during brightness minima. For each of the color diagrams, a color reversal point is observed at different star luminosities: in the $V/V-R$ diagram the reversal point is observed at V around 19.0 mag, in the $V/V-I$ diagram the reversal point is at V about 19.2 mag and in the $R/R-I$ diagram at R about 17.5 mag. In the color-magnitude diagrams of V1180 Cas, as well as in the case of GM Cep and V1184 Tau, the "blueing" effect is observed also in $R-I$ color in addition to $V-R$ color (Semkov et al. [2013], Semkov et al. [2015], Mutafov et al. [2019], Mutafov et al. [2022], Mutafov et al. [2022a]). Since autumn 2020, there has been a significant change in the photometric behavior of V1180 Cas. We recorded two brightness increases (local brightness maxima): the first in September 2020 and the second in July/August 2021. In these cases, the brightness increase appears to be caused by by an increase in accretion. Evidence for this is the decrease in the color indices ($V-R$ and $V-I$) of the star during an increase in brightness. The suggestion that the observed variations in the brightness of V1180 Cas are a combination of variable accretion and variable line-of-sight absorption was made by Kun et al. [2011] and Antoniucci et al. [2015]. On the basis of the multicolor observations of V1180 Cas that we obtained, we can confirm that during different periods the star shows a different type of variability: both the characteristic uxor significant decrease in brightness and reversal of colors during the minima caused by the variable extinction, typical of exors increases in brightness (local maxima of brightness) caused by increased accretion. A significant fraction of the protostellar gas-dust cloud remains in the vicinity of the newly formed stars and causes variable absorption. The photometric properties of V1180 Cas can be explained by a superposition of highly variable accretion from the circumstellar disk onto the stellar surface and occultation by circumstellar dust clumps, planetesimals or other features of the circumstellar disk.

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