New Results from a Long-term Photometric Study of the Pre-main Sequence Star V1180 Cas

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Abstract. New results from long-term optical photometric observations of the pre-main sequence star V1180 Cas are reported. During an ongoing photometric monitoring of the V1180 Cas a large amplitude variability is observed, which is interpreted as a combination of accretion-induced and extinction-driven effects. The new observations show increases in the brightness of the star. Recent VRI photometric observations of V1180 Cas have been collected from May 2022 to November 2024.
Key words: stars, stellar evolution, pre-main sequence star, UX Orionis stars

1. Introduction

The pre-main sequence (PMS) star V1180 Cas is associated with the dark cloud Lynds 1340 in the star-forming region in Cassiopeia (Lynds [1962]). Lynds 1340 is a small dark cloud with an area of 0.001 square degrees and class 5 opacity, located at a distance of 600 pc from the Sun.

The first photometric observations performed by Kun et al. [2011] during the period from October 1999 to February 2011 show variability with an amplitude of about 6 mag. (I_c band). Observed characteristic timescales of the faint and bright phases differ from these of the eruptive PMS stars from FU Ori (FUor) and EX Lupi (EXor) type although variability with such a large amplitude is consistent with that of known eruptive young stellar objects.

Kun et al. [2011] determined the spectral type of V1180 Cas as K7-M0 and the luminosity as $L/L_{\odot} \approx 0.07$ with an effective temperature $T_{\rm eff} = 4060$ K of the K7 spectral type. They noted that the color magnitude diagram (I_c versus $R_c - I_c$) shows reddening while a weakening of the brightness of the star occurs. The equivalent widths of H_{α} range from 300 to 900 Å and the mass accretion rate is determined as $> 1.6{\times}10^{-7} M_{\odot}\,{\rm yr}^{-1}$ (Ca II λ 8542).

Our first VRI photometric observations of V1180 Cas for the period September 2011 to April 2018 are presented in Mutafov et al. [2018]. They show dips in stellar brightness with amplitudes up to 3 mag. (I_c). Based on these and on our subsequent observations in the period May 2018 to February 2022 (Mutafov et al., [2022], [2024]) we concluded that 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 from circumstellar clumps of dust, planetesimals or other features of the circumstellar disk. Additionally, we also observed a significant change in the behavior of the variability of the star – in the increase of its brightness, probably caused by increased accretion.

Since autumn 2020, there has been a significant change in the photometric behavior of V1180 Cas. We recorded two increases in brightness (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 increased accretion. In this paper, we present data from the continuation of this multicolor optical monitoring from May 2022 to November 2024 and a preliminary analysis of the observed photometric variability of the star.

2. Observations

The CCD observations of V1180 Cas cover the period from May 2022 to November 2024. They were performed at the Rozhen National Astronomical Observatory (Bulgaria) with its 2-m Ritchey-Chrétien-Coudé (RCC), 1.5-m Ritchey-Chrétien (RC) and 50/70-cm Schmidt telescopes. Three different types of CCD cameras were used during the observations. Their technical characteristics and optical specifications are given in Mutafov et al. [2022], Minev et al. [2024] and Semkov et al. [2025].

We used the observational procedure and data reduction process as described in Ibryamov et al. [2015]. A standard set of Johnson-Cousins' filters were used for all the frames that were taken. Twilight flat fields in each filter were obtained each clear evening. The observations in all filters (VRI) are not simultaneous and have a total duration of 20 – 30 minutes. During this time there is no significant change in the brightness of the star which could lead to significant changes in the color index. The finding chart of the comparison sequences, its coordinates and the VRI photometric data is presented in Mutafov et al. [2022]. The values of instrumental errors are in the range $0.^m01$–$0.^m02$ (for I and R) and $0.^m01$–$0.^m03$ (for V).

3. Results

The current paper presents the data from the multicolour photometric observations of V1180 Cas for the period from May 2022 to November 2024. They are a continuation of the observations that were begun by us in September 2011. Previous data is published in the work of Mutafov et al. [2018] for the period September 2011 to April 2018 and in the work of Mutafov et al. [2022] for the period May 2018 to February 2022.

The new data in the period from May 2022 to November 2024 is shown in Table 1. The columns provide the Julian date (JD) of observation, VRI magnitudes, and the telescope used. In the "Telescope" column, the abbreviation 2-m denotes the 2-m Ritchey-Chrétien-Coudé, Schmidt – the 50/70-cm Schmidt and the new 1.5-m Ritchey-Crétien telescope ASA AZ1500. The typical instrumental errors from VRI photometry are reported in our previous study Mutafov et al. [2022].

The VRI light curves of V1180 Cas during the period of our observations are plotted in Figure 1. In most cases, the size of the error bars is smaller than the size of the symbols used.

During the whole period from 2011 to 2024, our data shows very strong photometric variability with large amplitude variations (ΔI $\sim$ 5 mag.). In the first part of the period (September 2011 – September 2020) the I-band brightness of the star is within the range of 15–16 mag., which is considered to be the maximum light magnitude in the previous studies (Kun et al. [2011], Antoniucci et al. [2013], [2014] and Lorenzetti et al. [2015]). But from September 2020

Table 1. New VRI photometric observations of V1180 Cas

JD (24...)	V	R	I	Tel	JD (24...)	V	R	I	Tel
59707.52	-	15.73	14.52	2-m	60184.48	16.88	15.81	14.77	Sch
59762.47	16.26	15.46	14.25	2-m	60120.43	16.57	15.55	14.31	Sch
59766.47	17.18	16.15	14.87	2-m	60211.44	16.67	15.61	14.38	Sch
59796.54	19.96	19.05	18.14	2-m	60238.46	17.73	16.52	15.21	Sch
59811.49	19.08	18.24	17.01	2-m	60258.34	16.82	15.71	14.51	Sch
59820.45	-	17.23	15.85	Sch	60288.31	17.29	16.04	14.76	Sch
59822.47	-	16.75	15.38	Sch	60341.31	16.63	15.56	14.35	Sch
59842.40	17.29	16.29	14.97	2-m	60347.26	16.91	15.88	14.54	Sch
59842.43	17.34	16.24	14.91	Sch	60349.26	17.02	15.80	14.57	Sch
59869.43	17.30	16.13	14.83	Sch	60398.31	16.74	15.68	14.48	1.5-m
59871.36	17.08	16.03	14.71	2-m	60400.33	17.45	16.18	14.85	1.5-m
59871.45	16.68	15.73	14.57	Sch	60402.26	16.74	15.65	14.38	Sch
59872.38	17.12	15.98	14.80	Sch	60415.29	16.82	15.74	14.56	1.5-m
59872.44	17.13	16.13	14.89	2-m	60436.41	18.74	17.26	15.79	1.5-m
59940.30	18.88	17.33	15.69	Sch	60469.52	-	16.84	15.41	Sch
59997.27	-	18.07	16.50	Sch	60504.51	18.41	17.15	15.62	2-m
60120.54	18.39	17.10	15.58	2-m	60505.49	18.31	17.01	15.50	2-m
60144.52	17.53	16.29	14.89	Sch	60506.50	18.05	16.83	15.40	2-m
60145.53	17.76	16.43	15.01	Sch	60559.47	16.43	15.92	14.66	2-m
60148.52	16.78	15.93	14.61	2-m	60562.56	-	16.06	14.78	Sch
60149.54	16.61	15.78	14.47	2-m	60612.40	18.83	17.35	15.82	Sch
60150.51	16.92	16.02	14.66	2-m	60621.41	19.26	17.60	16.05	2-m
60182.60	17.40	16.13	14.77	Sch	60622.40	19.04	17.63	16.11	2-m

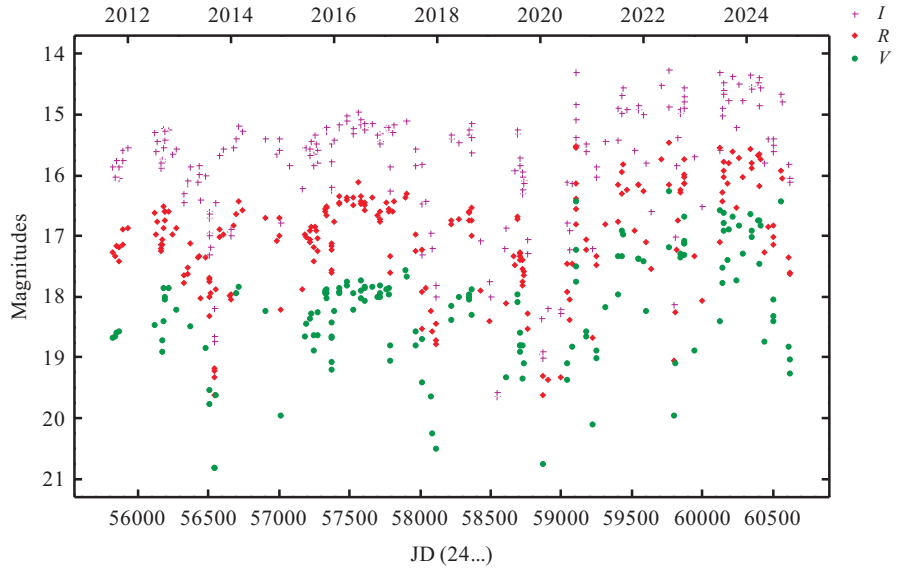

Fig. 1. VRI light curves of V1180 Cas for the whole period of our photometric monitoring (September 2011 - November 2024).

to November 2024 the maximum observed light in the I-band brightness has risen up to 14.25 mag. The same increase is observed in V- and R-bands. In this case, the increase in brightness seems to be caused by increased accretion rate.

Throughout the entire period, in addition to the observed changes in brightness with small amplitudes, which is typical of T Tau-type stars, our photometric data also show another type of variability – deep drops in brightness for which no periodicity is observed. In our new observations, we recorded three new deep brightness minima in the light curve of V1180 Cas: in January 2021, in August 2022 and in November 2024.

The color-magnitude diagrams of V1180 Cas V versus $(V-I)$ and R versus $(R-I)$ for the period of 2011 to 2024 are shown in Fig. 2. The collected multicolor photometric data show the typical "blueing" effect of UX Ori stars, a color reversal during brightness minima. The star's color becomes bluer at its brightness minima, consistent with the model of dust-clump obscuration (Semkov et al. [2013], Semkov et al. [2015], Mutafov et al. [2019], Mutafov et al. [2022]).

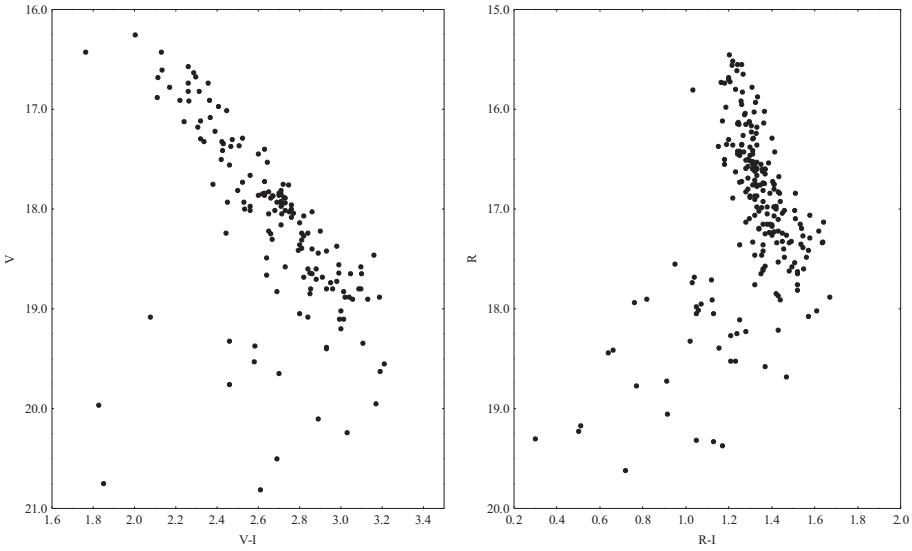

Fig. 2. The color-magnitude diagrams of V1180 Cas in the period of observations September 2011 – November 2024. Left: V vs. $V-I$. Right: R vs. $R-I$.

Figure 2 shows that, for each of the color diagrams, a point of color reversal is observed at different values of the brightness of the star: in the V vs. $(V-I)$ diagram at V about 19.2 mag. and in the R vs. $(R-I)$ diagram at R about 17.5 mag.

Figures 3 and 4 show color diagrams in which a point of color reversal is observed at different periods – before and after September 2020. The observed

increase in the brightness of V1180 Cas after September 2022 did not affect the color reversal point.

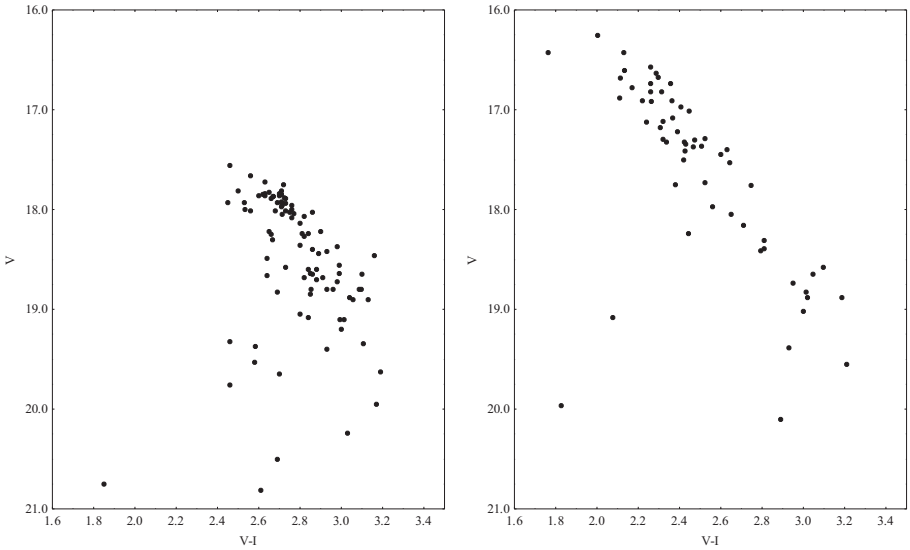

Fig. 3. Comparison of color-magnitude diagrams V vs. $V - I$ of V1180 Cas in the period of observations September 2011 – September 2020 (left) and September 2020 – November 2024 (right).

The assumption that the observed variations in the brightness of V1180 Cas are a combination of variable accretion and variable extinction in the line of sight was made by Kun et al. [2011] and Antoniucci et al. [2015]. Using data from multicolor photometry we can distinguish the two phenomena over different periods of time.

4. Conclusion

The latest collected multicolor photometric data confirm that in the time scale of days and months outside the deep minima V1180 Cas shows significant brightness variations.

The same data confirms again the presence of a "blueing effect" during minimum brightness and is an independent evidence that the variability of V1180 Cas is dominated by variable extinction. The VRI light curves of V1180 Cas are similar to other UX Ori objects (see Semkov and Peneva [2012]; Semkov et al. [2015]; Mutafov et al. [2022]; Mutafov et al. [2019]; Ibryamov et al. [2020b]; Findeisen et al. [2013]; Ibryamov et al. [2020a]).

We can confirm our conclusions, made in our previous papers (Mutafov et al. [2018]; Mutafov et al. [2022], [2024]), that the photometric properties

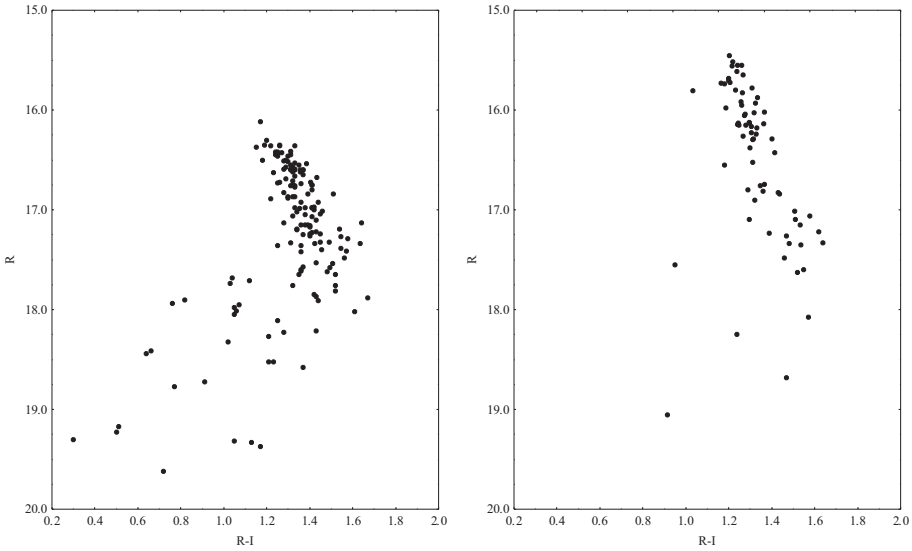

Fig. 4. Comparison of color-magnitude diagrams R vs. $R-I$ of V1180 Cas in the period of observations September 2011 – September 2020 (left) and September 2020 – November 2024 (right).

of V1180 Cas can be explained by a superposition of highly variable accretion from the circumstellar disk onto the stellar surface and occultation from circumstellar clumps of dust, planetesimals or features of the circumstellar disk. We also observed a significant change in the variability behavior of the star – an increase in its brightness, probably caused by increased accretion. A detailed explanation of this effect requires further observations.

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Our dear colleague and friend Prof. Evgeni Semkov passed away in December 2024.

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