

**SU Aur:  
A DEEP FADING EVENT IN VISIBLE AND NEAR-INFRARED BANDS**

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SU Aur is one of the brightest classical T Tauri stars (cTTS). It is located in the Taurus-Aurigae star-forming region at the distance of about 140 pc. The star is of spectral type G2 III-IV. Its mass  $M = 1.9 \pm 0.1 M_{\odot}$  and luminosity  $L = 9.2 \pm 2.8 L_{\odot}$  (Grankin 2016) place it among the intermediate-mass TTS. More massive young stars belong to the class of HAeBe stars. As a cTTS, SU Aur possesses an active accretion disk. The rate of mass accretion is estimated as  $0.5 - 0.6 \times 10^{-8} M_{\odot} \text{ yr}^{-1}$  (Calvet et al. 2004), which is near the mean value for cTTS. The inner radius of accretion disk, determined from long-baseline interferometry, is about 0.18 AU (Akeson et al. 2005). The images of the circumstellar environment of SU Aur directly show that the disk extends out to 500 AU (Jeffers et al. 2014).

SU Aur is a rapid rotator with  $v \sin i \approx 66 \text{ km s}^{-1}$  (Petrov et al. 1996), which implies a high inclination of rotational axis to the line of sight. SU Aur has been a subject of several spectroscopic monitoring programs (Giampapa et al. 1993; Johns and Basri 1995; Petrov et al. 1996; Unruh et al. 2004). The emission line profiles indicated both accretion and outflows. Periodic modulations of the blue- and red-shifted absorption components in the Balmer line profiles showed a period of 2.7–3.0 days. It was interpreted as a rotational modulation due to inclination of the magnetic dipole axis with respect to rotation axis of the star (Johns and Basri 1995). Multi-site spectroscopy campaign of SU Aur found a period of 2.7 days in variation of the HeI 5876Å emission line and revealed that the wind and infall signatures are out of phase in this star (Unruh et al. 2004), which supports the model of oblique rotator. SU Aur is an X-ray emitter with luminosity of  $\sim 8 \times 10^{30} \text{ erg s}^{-1}$  in the 0.5 – 10 keV band (Skinner and Walter 1998). This indicates a high level of magnetic activity of the star.

SU Aur is an irregular variable. It has a long photometric history (Timoshenko 1981; Herbst and Shevchenko 1999; DeWarf et al. 2003). Analysis of long-term observations of several tens of cTTS, performed during 1983 – 2003, showed that SU Aur belongs to a small group of four stars that exhibits the largest seasonal variations in their photometric amplitude (Grankin et al. 2007). The long term light curve of these objects is characterized by a nearly constant maximum brightness level with a usually small amplitude of variability, but interrupted at times by deep fading episodes. In particular, during these 20 years, the average level of brightness of SU Aur varied smoothly from 9<sup>m</sup>08 to 9<sup>m</sup>51 with

a characteristic time of 5–6 years (Grankin et al. 2007, Fig. 2). At the same time, several deep fadings were recorded with the amplitude up to  $0^m8$ – $0^m9$ , and the minimal values of brightness were close to  $10^m0$  in the  $V$  band. More intensive photometric monitoring, lasting several months, allowed to detect three such deep fading episodes within 190 days (DeWarf et al. 2003). Several similar deep dimmings can be found in the ASAS-SN and AAVSO databases. Typically, the duration of such events is from a few days to weeks.

Two sources of irregular light variability are usually considered in cTTS: 1) hot spots at the base of accretion channels, whose continuous radiation veils the photospheric spectrum of the star, and 2) circumstellar dust. In the case of SU Aur the veiling in visible spectrum is small or absent. This may be due to a small contrast of a hot accretion spot in front of the hot photosphere of the G2 star. It means that accretion has a minor effect on the visible brightness of the star, and the observed light variability is solely due to the variable circumstellar extinction.

The high inclination of SU Aur implies that the line of sight to the star intersects the disk wind, and the dust in the disk wind may be the main cause of the circumstellar extinction (Babina et al. 2016). Therefore, SU Aur is a suitable object for studying the distribution of dust in the disk wind.

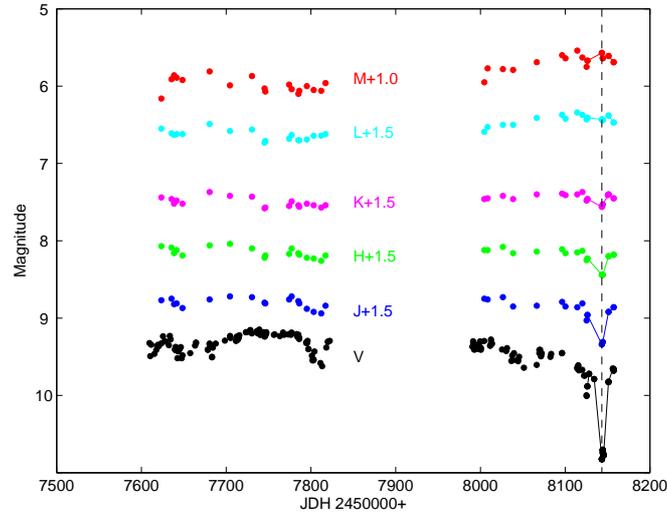
In three seasons of 2015–2018 we carried out a series of optical and near infrared (NIR) photometry of SU Aur. In course of this photometric monitoring we detected an event of a deep fading of the star in spring of 2018. In this paper we present preliminary analysis of our photometry.

Simultaneous optical ( $BVRI$ ) and infrared ( $JHKLM$ ) photometry was carried out from September 2015 till April 2018. In the NIR region the star was observed at the 125-cm telescope of the Crimean Astronomical Station (CAS) of the Moscow University. InSb-photometer with a standard  $JHKLM$  system was used. Technical characteristics of the photometer, methods of observations and calculations of magnitudes were described in details by Shenavrin et al. (2011). The standard error of the measured magnitudes of SU Aur is about  $0^m02$  in  $JHKL$  bands, and about  $0^m05$  in  $M$  band.

The optical  $BVRI$  photometry of the star was carried out at the Crimean Astrophysical Observatory (CrAO) at 1.25m telescope, using alternatively a five-channel photometer and the PL23042 CCD camera. Some additional  $BVRI$  photometry was obtained with two CCD cameras (PL4022 and Apogee Aspen) at the Zeiss-600 telescope of CAS. The typical rms error in the  $BVRI$  bands were 0.04, 0.02, 0.03,  $0^m03$ , correspondingly.

The light-curves of SU Aur in the two seasons of our observation are shown in Fig. 1, with the minimum of brightness at  $JD = 2458144$ . During this eclipse-like event the star’s brightness dropped to  $10^m8$  in the  $V$  band. In such a weak state ( $10^m70$ – $10^m82$ ), the star stayed for three days. Unfortunately, we have no observations at the moments of the beginning and the endings of the minimum. If we use  $9^m8$  as the bright state, then the maximum duration of this event is 17 days. The minimum was also traced in the  $JHK$  light curves, but not in the  $LM$  bands. The pattern of light variability may be illustrated with the spectral energy distribution (SED). Fig. 2 shows the SEDs of SU Aur, corrected for *interstellar* extinction  $A_V = 0^m9$  (Grankin 2016), in three dates of observations: at high brightness, at minimum and after egress off the minimum. The observed SED at maximal brightness is approximated as a sum of two black bodies at  $T_{\text{eff}} = 5945$  K (the stellar photosphere) and  $T_{\text{eff}} = 1650$  K (a hot dust). At lower brightness the SEDs of stellar photosphere are distorted by the variable circumstellar extinction. One can also note the increased NIR flux at the moments of low visual flux. The relative depth of the eclipse-like minimum in the light-curves in different bands roughly corresponds to the interstellar reddening law with the ratio  $A_V/E(B-V) \sim 4$ . This confirms that the eclipse

was caused by a cloud of small dust particles.



**Figure 1.** Light curves of SU Aur in *VJHKLM* bands in 2016–2018. The moment of the dimming event is marked with a dashed line.

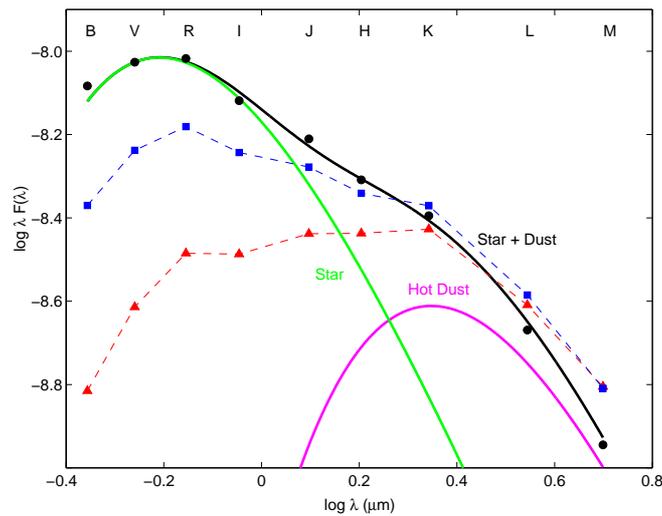
Figure 1 also shows that during the second season (2017-2018), before the eclipse-like event, there was a gradual decrease of brightness in the *V* band with simultaneous increase of brightness in the *L* and *M* bands. This may be interpreted as appearance of a hot dust which radiates the additional IR flux. The hot dust may be lifted up by the disk wind from the inner region of the disk near the star (Safier 1993). The same dust causes the observed decrease of brightness of SU Aur in the *V* band, and probably is responsible for the eclipse-like event. Similar effect was even more clearly seen in another cTTS, namely RW Aur A (Shenavrin et al. 2015). The decrease of visual brightness of RW Aur A in 2014 was accompanied by a considerable increase in the IR flux.

In the case of SU Aur the orbital period at the inner radius of the accretion disk is  $P_{\text{orb}} \approx 20$  days, and the orbital velocity  $V_{\text{orb}} \approx 100 \text{ km s}^{-1}$ , which is comparable to the disk wind velocity (e.g. Kurosawa et al. 2006). During one orbital period a hypothetical dust cloud is lifted up from the disk plane and never returns to the line of sight, therefore there is no periodicity in the light minima. Taking into account the duration of the minimum (about 12 days), the obscuring matter was not a distinct cloud but rather a smoothed non-uniformly distributed dust in the disk wind. A more detailed analysis using spectral data will be published elsewhere.

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**Figure 2.** Spectral energy distributions of SU Aur from our visual/NIR photometry. The flux  $F$  is expressed in units of  $\text{erg cm}^{-2}\text{s}^{-1}$ . Filled circles - bright state (07.09.2017), triangles - deep minimum (25.01.2018), and squares - after egress (01.02.2018). The upper solid envelope curve is a sum of stellar radiation at high brightness and the radiation of a hot dust with  $T = 1650$  K.

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