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UX Ori type stars among WTTS type stars

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UX Ori-type stars are known as irregular variables demonstrating Algol-like minima. This type of variability is usually observed in Herbig AeBe stars, but sometimes T Tauri stars demonstrate it, too. Today, it is commonly accepted that the main reason of variability of UX Ori-type stars is the small inclination of their circumstellar disks relative to the line of sight. Due to the motion of matter in the disk the column density of dust continuously varies along the line of sight, which causes the variations of circumstellar extinction and, hence, stellar brightness. Among all T Tauri stars primarily classical T-Tauri stars have circumstellar disks. Thus, until recently the UX Ori-type photometric activity had been usually observed in these stars. However, within the last ten years we have discovered a number of weak-lined T Tauri stars (WTTS) that one could attribute to the UX Ori type by considering the entire set of their photometric characteristics. This is, in a sense, an unexpected result since the UX Ori-type variability is associated with actively accreting young stellar objects surrounded by young circumstellar disks, while WTTS' disks – if they do exist – are very rarefied and accretion in these objects has almost terminated. We present the results of photometric studies of these objects and discuss a possible nature of their variability.

Keywords: Stars: UX Ori variable stars: cluster IC 348: WTTS

1 Introduction

UX Ori-type stars are known as irregular variable stars with Algol-like minima (Kholopov et al., 1985). This type of variability is usually observed in Ae Herbig stars

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though there is a number of classical T Tauri stars (CTTS) that demonstrate it, too. At present, it is widely understood that the main reason for their variability is a small inclination angle of circumstellar gas-dust disks to the line of sight, in combination with their inhomogeneous structure (Grinin (2000) and references therein). Because of the motion of matter in the disk, the column density of the dust along the line of sight varies continuously, thereby causing the variations of the circumstellar extinction and stellar brightness. Among T Tauri stars circumstellar disks are mostly observed around so-called classical T Tauri stars (Osterloh & Beckwith, 1995), and until recently only CTTS demonstrated the photometric activity of UX Ori-type. However, over the last 10 years we have discovered a number of weak-lined T Tauri stars (WTTS) that can be classified as UX Ori type stars by all their photometric characteristics. This result is quite unexpected, since the UX Ori-type variability is associated mainly with young circumstellar disks and active accretion processes, but WTTS-type stars have weak circumstellar disks where accretion processes almost terminated. We present the results of our photometric studies of three WTTS in the young stellar cluster IC 348 during 13 years and discuss the possible reasons of their variability.

2 Observations

We have analyzed the photometric activity of V695 Per, V715 Per and V719 Per using our optical and infrared observations in the VRI and JHK bands, respectively. The optical observations were obtained from 2003 to 2016 at the AZT-8 (0.7 m) telescope of the Crimean Astrophysical Observatory. All optical data were reduced to the Johnson–Cousins V, R, I photometric system. The average photometric accuracy in the I band is better than $0^m.03$ in all cases. The average accuracy for V695 Per in the V and R bands is better than $0^m.07$ and $0^m.06$, respectively, and for V719 Per – $0^m.06$. Photometric observations were obtained in the near IR (JHK bands) from 2007 to 2016 with the Pulkovo AZT-24 (1.1 m) telescope installed at the Campo Imperatore (Italy) observatory. The measurement accuracy for V715 Per in all three bands is $0^m.03$ on average.

3 Results

As one can clearly see in Fig. 1 V695 Per, V715 Per and V719 Per demonstrate the photometric behavior of UX Ori-type stars: most of the time the stars are observed near the bright state.

The objects' light curves have a complicated shape: large-scale variability combines with Algol-like minima (Fig. 2). There is an interesting feature in the photometric behavior of V715 Per; during the observations of this object the depth of its Algol-like minima gradually increased, but suddenly the dips totally disappeared. The photometric behavior V695 Per and Per V719 was analyzed earlier in Barsunova et al. (2013) and Barsunova et al. (2015). One can see in Fig. 2 that the photometric behavior of V695 Per does not demonstrate large variations during the last time, at

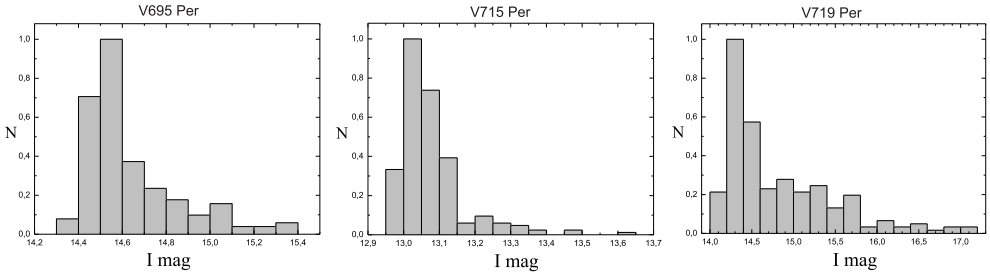


Figure 1 V695 Per, V715 Per and V719 Per histograms in I band.

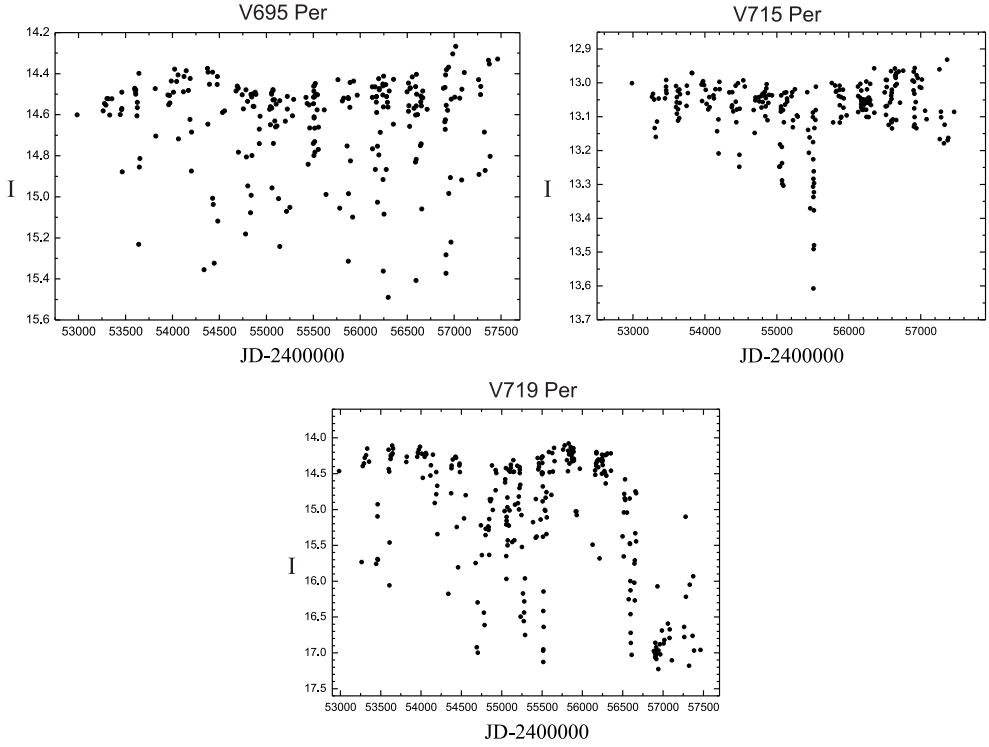


Figure 2 V695 Per, V715 Per and V719 Per light curves in I band.

the same time the abrupt variations occurred in the V719 Per photometric activity (Fig. 2) similar to what was observed in V1184 Tau (Barsunova et al., 2006). The observations of V715 Per in the near IR have also revealed Algol-like minima. In Fig. 3 one can clearly see an IR minimum that matches the deepest optical minimum.

All the three objects demonstrate reddening when the star's brightness begins to decrease (Fig. 4). However, near the minimum only the color track of V719 Per turns blue, as it is typical for UX Ori stars (Grinin, 2000).

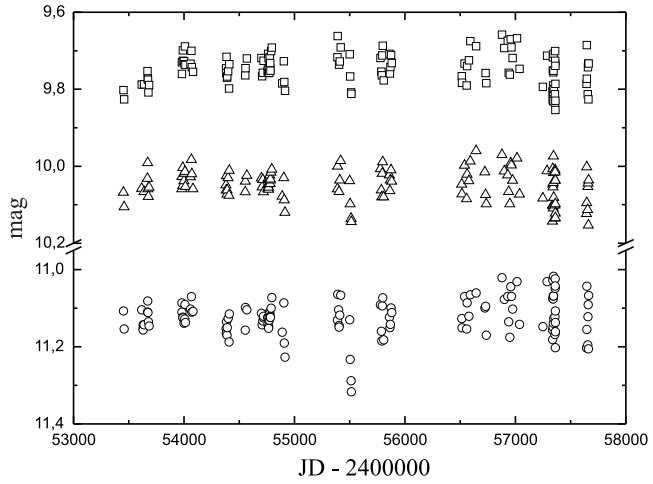


Figure 3 V715 Per light curves in JHK bands. Circle, J band; triangle, H band; square, K band.

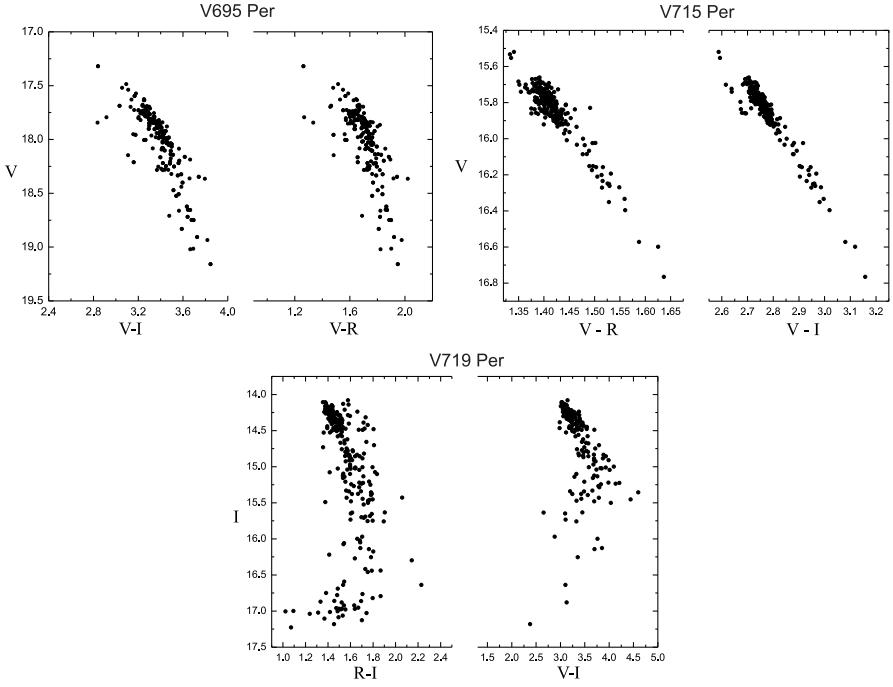


Figure 4 V695 Per, V715 Per and V719 Per color tracks in optical VRI bands.

In the IR the color tracks of V715 Per differ from those in the optical wavelengths (Fig. 5): in the J and K bands their directions are opposite for the same part of the light curve.

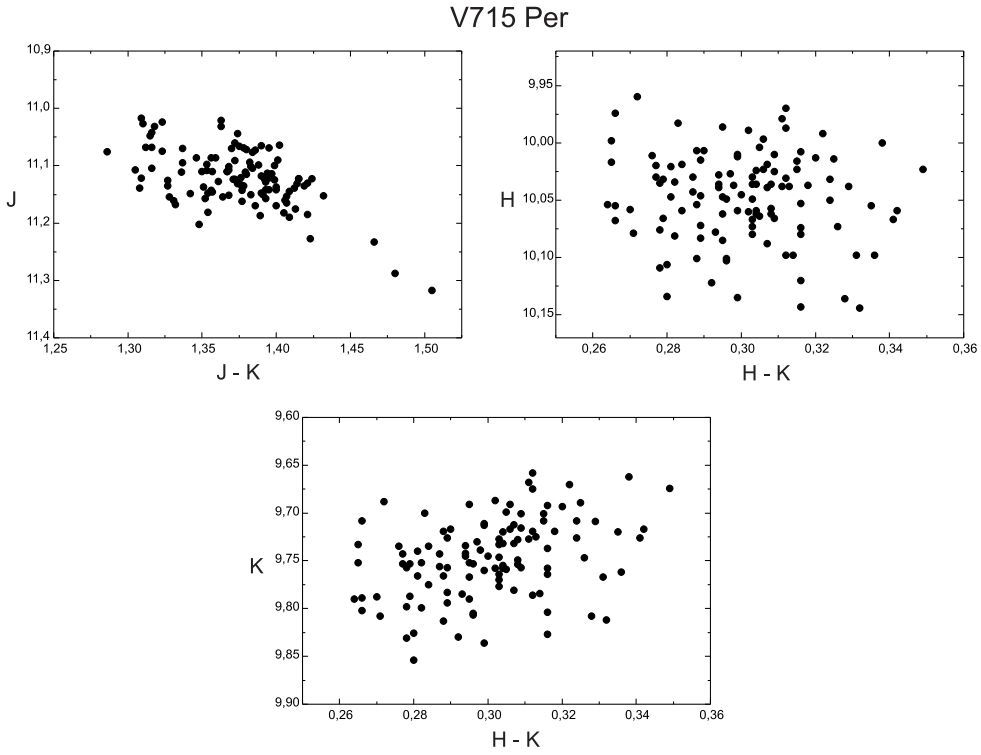


Figure 5 V715 IR color tracks.

When analyzing the Lomb–Scargle periodograms of V695 Per and V715 Per we have found two well pronounced periods of their minima: 7.6 d and 5.23 d, respectively (Fig. 6 and Fig. 7). We should note that algol-like minima of V695 Per are grouped near the main minimum on the phase light curve, while the phase light curve of V715 Per follows the typical behavior of UX Ori type stars.

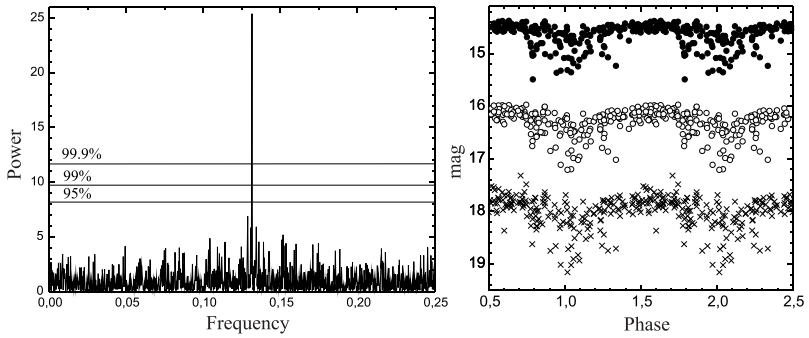


Figure 6 Periodogram and optical phase curves of V695 Per. Filled circles, I band; open circles, R band; crosses, V band.

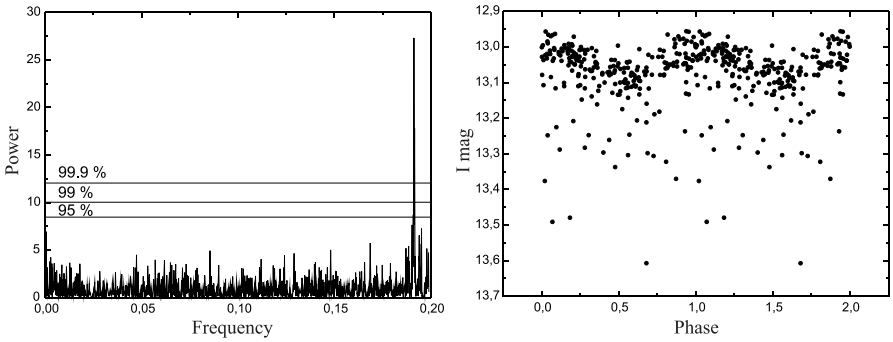


Figure 7 Periodogram and optical phase curve of V715 Per.

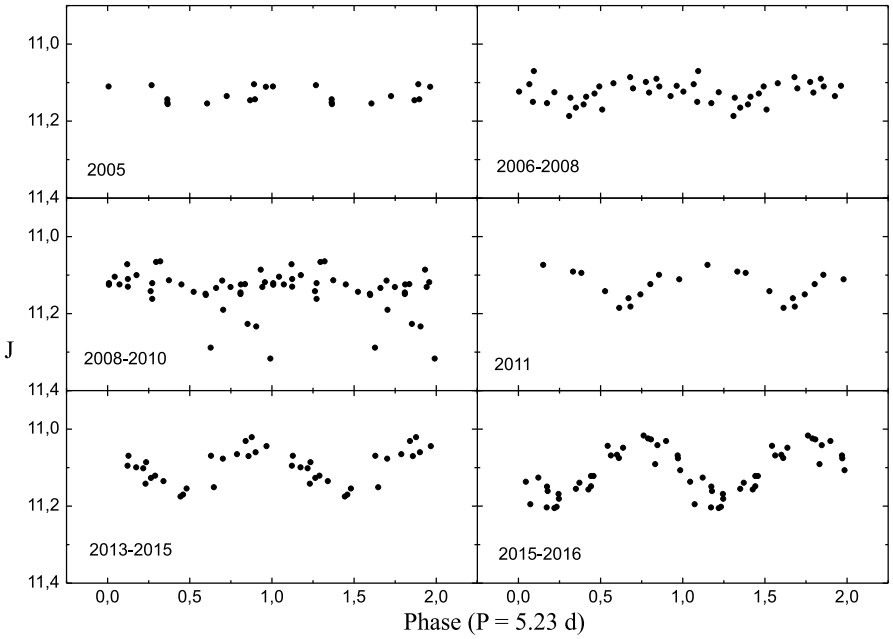


Figure 8 Phase curve of V715 Per in J-band divided into observational seasons.

The period determined for V715 Per in Flaherty et al. (2013) in the mid-IR (3.6 μm and 4.5 μm) is longer than the value obtained by us in optical wavelength ranges. Using the periodogram analysis we could not find any signs of the period in our near-IR observations due to low density. However, the convolution of our IR-data with 5.23 d. period has shown the well-defined periodic brightness variations (Fig. 8).

4 Discussion

In Nordhagen et al. (2006), Herbig (1998) and Luhman et al. (2005) the authors have analyzed the variability of V695 Per and proposed two possible scenarios explaining

the nature of its photometric activity: 1) cold spots or 2) a hot accretion spot on the star's surface. However, the complete set of photometric characteristics rather prompts one to relate this object to AA Tau-type stars (Bouvier et al., 1999). Therefore, we suppose that the main photometric features of this object are caused by the extinction in the very inner regions of the dust disk disturbed by the star's rotating magnetosphere, as in the case of AA Tau. The disturbances occur, since the magnetic axis of the star's dipole field is inclined with respect to its rotation axis (Bouvier et al. (1999), Romanova et al. (2004)). This idea is in a good agreement with the results of simulation of the circumstellar disk of V695 Per based on the spectral energy distribution (Le Blanc et al., 2011). We suppose that the low-amplitude periodic variability of V715 Per has the same origin.

The weak accretion rate of V715 Per and V719 Per may be explained by the existence of large inner annuli in their circumstellar disks, where the material is very rarified (these annuli may develop, for instance, as a result of the formation of a planetary system) (Le Blanc et al., 2011). At the same time the high level of their photometric activity caused by the strong fluctuations of circumstellar extinction may point to the existence of dust clumps in the disk that occasionally intersect the line of sight and increase the circumstellar extinction. These two factors indicate that the circumstellar disks of V715 Per and V719 Per are oriented almost edge-on.

A more detailed analysis of V715 Per and V719 Per photometric activity is being prepared for publication.

References

Barsunova O.Yu. et al., Astron. Let., **32**, 832 (2006)
Barsunova O.Yu. et al., Astrophysics, **56**, 395 (2013)
Barsunova O.Yu. et al., Astrophysics, **58**, 193 (2015)
Bouvier J. et al., A & A, **349**, 619 (1999)
Flaherty R.M. et al. , AJ, **145**, 66 (2013)
Grinin V.P., ASP Conf. Proc., **219**, 216 (2000)
Herbig G.H., ApJ, **497**, 736 (1998)
Kholopov P.N. et al., CGCVS, Nauka (1985)
Le Blanc T.S. et al., AJ, **142**, 55 (2011)
Luhman K.L. et al., ApJ, **623**, 1141 (2005)
Nordhagen S. et al., AJ, **132**, 1555 (2006)
Osterloh M. & Beckwith S.V.W., ApJ, **439**, 288 (1995)
Romanova M.M. et al., ApJ, **610**, 920 (2004)