A young star’s hectic months

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Abstract. We present preliminary results of the optical photometric and spectroscopic monitoring of the young eruptive variable star PV Cephei, performed during its recent conspicuous fading in 2008–2009, and try to find the reasons of the observed variations.

1. Introduction

Young solar-type stars are highly variable across the whole electromagnetic spectrum. The main source of the variability are various types of interaction of the star with the surrounding accretion disk. Accretion disks evolve rapidly, giving rise to conspicuous variations of the central star: disk structures change significantly within 2–4 million years (e.g. Dahm & Carpenter 2009), and most primordial disks disappear by an age of 10 Myr (e.g. Sicilia-Aguilar et al. 2006). Variability studies offer a useful tool for probing the disk structure and evolution (e.g. Juhász et al. 2007). Causes of photometric and spectroscopic variability of young stars in the optical wavelength region include cool spots, induced by magnetic activity, hot spots, produced by infalling gas, and variable circumstellar extinction (Herbst et al. 1994, Scholz et al. 2009). Eruptive young stars (FUors an EXors), characterized by occasional, powerful brightening due to enhanced disk accretion, represent an especially interesting subclass of young variable stars. The target of our studies, PV Cephei, is a well known young eruptive star. It produced a large outburst in 1977–1978 when it brightened from 16th to 11th magnitude in the red (Cohen et al. 1981). This event ranked the star into the class of EXor type young stars, characterized by recurrent outbursts, lasting for several months. After the outburst in 1977–1978, no similar brightening of PV Cep has been recorded in the literature. The remarkable fading of the star between April and June 2008 in the near infrared was reported by Lorenzetti et al. (2009). We performed long-term optical photometric and spectroscopic monitoring observations of PV Cep in 2005–2009. Our goal is to better understand the nature of the observed variations. This paper presents our preliminary results.

2. Observations

Photometric observations were performed using the Schmidt and RCC telescopes of the Konkoly Observatory at Pizskéstető Mountain Station between 2005 and 2009 as part of a long-term observational project involving several other young stars. Spectroscopic observations were obtained at five epochs using the CAFOS instrument installed on the 2.2 m telescope of Calar Alto Observatory. The data reduction was carried out using standard IRAF routines. Detailed description of the data and results will be presented in a forthcoming paper.
3. Results

3.1. Light curve of PV Cep

Figure 1 shows the light curve of PV Cephei in the $I_C$ band between October 2005 and September 2009. The sporadic data, available before April 2008, show that PV Cep was significantly brighter in 2005 than later. A steep decline of the light curve, similar to that reported by Lorenzetti et al. for the near infrared, started in April 2008. The light curve suggests that we probably observed the end of a large outburst of the star between April and June 2008, resulting from the significant drop of the disk accretion rate. The $J H K$ two-color diagram (Fig. 10 of Lorenzetti et al. 2009), however, indicates that the fading might be caused by enhanced extinction along the line of sight. To clarify the nature of the fading and the variations during the present low-brightness state we examined the relations between the flux and color changes as well as the optical spectroscopic behavior of the star in the period covered by the light curve in Fig. 1.

3.2. Possible origin of variations

Cool spots as source of variability are obviously not relevant in the case of PV Cephei, because the light curve is not periodic, and the amplitude of variations is larger than it would be expected (cf. Herbst et al. 1994). Hot spots on the surface of accreting young stars arise where the infalling gas hits the photosphere. Changes in accretion rate or in the geometry of infall can lead irregular photometric changes on broad timescales. The amplitude of photometric variations caused by hot spots decreases toward longer wavelengths. If hot spots are responsible for the photometric variability, the star becomes redder when fades. We estimated the amplitudes of variations in the $R_C I_C J H K$ bands, caused by hot spots for several spot temperatures between 6500 and 12000 K and surface filling factors between 0.01 and 0.4. We assumed an effective temperature of $T_{\text{eff}} = 5500$ K for PV Cep.

The left panel of Fig. 2 shows the measured $R_C$ magnitudes against the $R_C - I_C$ color indices. Star symbols show the measurements before the fading, and dots show the low-brightness phase. The arrow indicates the displacement introduced by an extinction of $A_V = 1$ mag. As an example for the effect of hot spots, the length and direction of the dashed line shows how the star would
Figure 2. left: $R$ vs. $R - I$ diagram of PV Cep between Oct 2005 and Sep 2009. Star symbols show data obtained during the bright phase before June 2008. Right: Variation of the $J - H$ and $H - K$ color indices during the fading in 2008.

It can be seen that the variations during the dim phase can be explained by both extinction and disappearance of hot spots, whereas neither of these mechanisms work for the main fading. During the drop of the brightness the star became bluer, probably due to the higher proportion of the scattered light. The right panel displays the near-infrared two-color diagram, based on published data (2MASS, Lorenzetti et al. 2009). The color variation of the star between April and June 2008 can readily be explained by an extinction of $A_V = 5$ mag. The short arrow shows the effect of hot spot removal, assuming that in the bright phase 40% of the stellar surface was covered by spots of temperature of $T_{\text{spot}} = 12000$ K. Obviously, variable hot spots could produce much lower amplitude variations than observed.

According to the optical and near infrared observational results, the most likely reason of the photometric changes of PV Cep is apparently the variable extinction along the line of sight. The source of the extinction is probably the circumstellar dust, like in UX Orionis type stars, where orbiting dust clumps occasionally obscure the star. The observed light curve, however, markedly differs from the UXor type light curves (Herbst et al. 1994, Ismailov 2005). Both the amplitude and timescale of the fading, as well as the variations of near infrared color indices during the fading are remarkably similar to the behavior of the V1647 Ori at the end its outburst in October–December 2005 (Aspin & Reipurth 2009).

Spectroscopic observations of PV Cep at different epochs confirm that the accumulation of absorbing dust was accompanied by spectral variations indicative of variable accretion and wind. Figure 3 shows the time variation of the [OI], H$\alpha$, and [SII] lines during our observing period. For comparison, a bright-phase spectrum, obtained in 2004, is also shown.

4. Conclusion

The observed behaviour of PV Cep in 2008–2009 allow us to conclude that the star returned from an outburst into quiescence in spring 2008. Curiously, the beginning of the outburst remained undetected. According to Movsessian et al. (2008), PV Cep was bright in 2004. Unfortunately no photometric data are available for 2004. The bright phase continued in 2005, then the star faded between Nov 2005 and Sep 2006, and brightened again by April 2008. Similar large-amplitude variations were observed during the outburst in 1977–1978.
Figure 3. Five optical spectra of PV Cep in the red spectral region, obtained during the recent dim phase, and one obtained during the bright phase in 2004. The variable shape of the Hα line and the changing [SII] 6717/6731 flux ratio are indicative of the variable wind.

Acknowledgments
A significant part of the photometric observations have been performed by Attila Moór and Miklós Rácz. The spectroscopic observations were performed at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated jointly by the Max-Planck-Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC). Our observations were supported by the OPTICON. OPTICON has received research funding from the European Community’s Sixth Framework Programme under contract number RII3-CT-001566.

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