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Old and New Observational Data of P Cygni

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Abstract

Luminous Blue Variables (LBV) are extremely rare and enigmatic stars on the short-lived evolutionary phase with different variation scales of brightness and spectrum. Some of them are confirmed binary systems and even secondary components have found by direct imaging. The blue supergiant P Cygni is one of the prototypes of LBVs, showing photometric and spectroscopic variability on various timescales. We are going to present results of the old and new photometric observations of P Cygni. Old 1951-1983 years photometric observations were made by E. Kharadze and N. Magalashvili in the Abastumani Astrophysical Observatory, Georgia, during which they found, recalculated and made conclusion that the star should undergone the next great eruption in some 100 years. New observations were obtained in 2014, using the 48 cm Cassegrain telescope of the Abastumani Observatory. Some interesting behaviors of the light curves were revealed.

Keywords: *UBVRI photometry - Luminous Blue Variable Stars - P Cygni.*

1. Introduction

P Cygni is one of the most luminous stars of the Galaxy. It has been classified as an Luminous Blue Variable (LBV) after two major outbursts in 1600 and 1655. The term Luminous Blue Variable was imported by P. Conti in 1984 and combined the P Cygni type stars, S Dor variable and Hubble-Sandage variable (Conti 1984). LBVs are descendants of massive O stars, which are nearly to the end of the core hydrogen burning. They undergo episodic mass-loss and probably represent a transition between the most massive O star and the red supergiant and/or W-R stage (Massey 2006). They are characterized by large variability of amplitudes and violent mass ejections. They have unusually high mass loss rates ranging from 10^{-6} up to 10^{-3}M$_{sun}$/yr.

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LBVs are extraordinary, because they can show different type of photometric and spectroscopic variations. Three types of variability of Luminous Blue Variables are known:
1. Micro-variations with 0.1 mag. amplitude and comparatively small time-scale variations from days to weeks or months;
2. S Dor type variations or outbursts with amplitudes of 0.5 mag.;
3. Large sporadic outbursts with amplitude > 2 mag. on a time-scale of 100 years.

In 1600 Dutch chart-maker, mathematician and geographer W. J. Blaeu recorded P Cygni (34 Cyg) as a nova. Giant eruption occurred in 1600, followed by four, compared with the first one, less capacity eruptions, which began in 1655 and ended in 1684. Analysis of historical observations of P Cygni has shown that between 1700 and 1988 its overall brightness slowly increased by 0.15 ± 0.02 mag/century and reached its current value of V=4.82 (Israelian & de Groot, 1999).

P Cygni is an early B(B1Ia) spectral type hypergiant star. The first spectra of P Cygni, obtained as early as 1897, already shown the famous P Cygni-type spectral lines - an undisplaced emission accompanied by a short-ward displaced absorption core. Initially this was interpreted as a blend of two different lines. McCrea (1929) and Beals (1930) were the first to interpret P Cygni-type profiles in novae, Wolf-Rayet stars and P Cygni itself as due to a radially expanding stellar envelope.

Early serious, detailed analysis of P Cygni spectrum has been carried out by Beals (1950), Hutchings (1969), and de Groot (1969). Later, Stahl et al. (1993) have published spectral atlases with identifications of many weak lines in the visual spectral range. Skinner et al (1996) presented radio observation of the P Cyg, which revealed the nature and speed of its variability at radio wavelengths and the size and structure of the radio nebula. P Cyg's nebula is harder to observe than the Homunculus of η Car because contrast with the central star is very faint at all wavelengths. Study the near IR spectrum of P Cygni Smith Hartigan (2006) show that the total mass of P Cygni nebula is about 0.1 M_{sun}.

P Cygni is located on the upper part of the Hertzprung-Russell (HR) diagram populated by different types of emission-line stars, including Of supergiants, B[e], LBVs, and Wolf-Rayet stars (Israelian & de Groot 1999). It was found that P Cyg has three different type variations: 1. Short, 17 days variation; 2. 100 days variation, which is also observed in LBVs; and 3. Long-period variation of several years period.

P Cygni is the nearest LBV, at a distance of 1.7 kpc. At present estimated that its mass is 30 M_{sun}, however initially it might have been 50 M_{sun}, but portion of the mass was lost during evolution. The effective temperature is T_{eff} = 18200 K, radius - R=75 R_{sun} and Luminosity of L= 5.6 x $10^5 L_{sun}$. A. Kashi (2010) suggested that P Cyg has a companion star with approximately 3-6 solar masses and with orbital period of 7 years. Using

photometric observations taken from AAVSO databases and photometric data from Abastumani Observatory obtained during 1951-1983 Michaelis et al (2018) found that the P Cyg companion orbital period should be 4.7 years.

2. Observations of P Cygni in Abastumani

Observations of P Cygni were held in the Abastumani Astrophysical Observatory from its very establishment. Two articles are published (Nikonov, 1937 and Kharadze, 1937). Photoelectric observations of P Cyg were made using 33 cm reflector. The telescope was equipped with electro-photometer with maximum of spectral sensitivity at 4350 Angstrom of wavelength. The photometric system was similar with Johnson's B band (color).

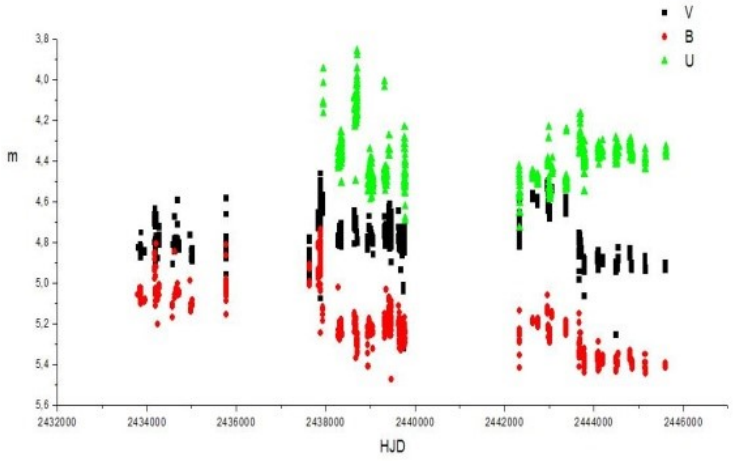

Figure 1: UBV observations of P Cygni made by E. Kharadze and N. Magalashvili during 1951-1983. 36 Cygni = HD 193369 used as a comparison star.

From 1951 N. Magalashvili and E. Kharadze were regularly observing P Cyg, using 33 cm reflector with electro-photometer. B and V filters were used during 1951-1960 and then, after 1961, U, B and V filters instead. On the basis of these above-mentioned observations, Magalashvili and Kharadze made conclusion that the behavior of the star was similar to W UMa variability, with the period of 0.500565 d and 0.10-0.08 mag. (Magalashvili & Kharadze, 1967). The article gained great attention from the investigators of variable stars, but W UMa variability was not confirmed. Kharadze and Magalashvili continued observing the star until 1983. After 1968 they used the same filters and the same photometer with the 48 cm Cassegrain telescope of the Abastumani Observatory. We had the opportunity to re-process

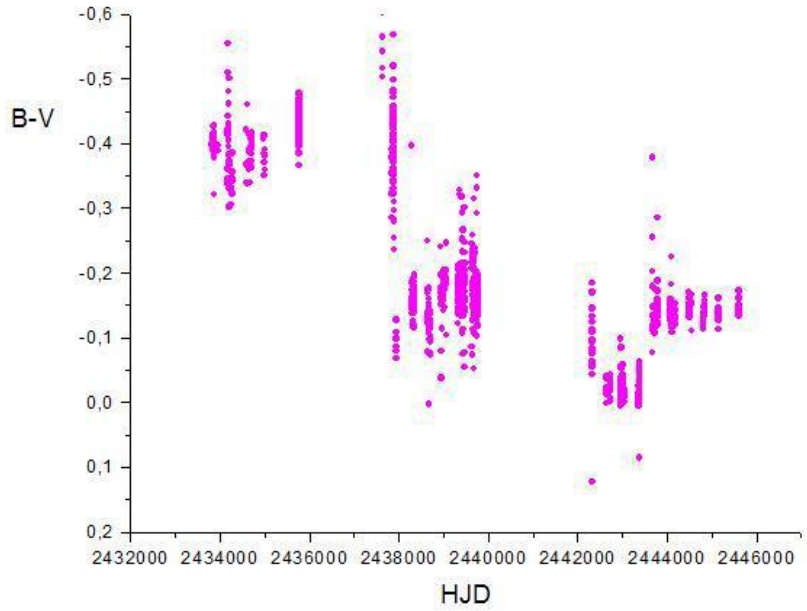

Figure 2: Color behavior of P Cygni during 1951-1983. The star became redder by at least 0.4: B-V changed from -0.5 to -0.1 during 1951-1983.

the observations and calculate difference of brightness between the variable and 36 Cyg, which gave us a real light variation of P Cyg and we are giving these UBV data on Fig. 2.

At the first glance we can see that during 1974-1983 years the star was dimmed in U band while brightened in B and V bands (the last third part of the Fig. 1). The middle part of the figure represents time interval of 1961-1967 and here the color behavior of the star is different: during brightening in V band the star is fainter in B and U.

3. Quasi-periods of P Cygni

According to the above mentioned photometric data by Magalashvili and Kharadze, it seems that the star has different longer and shorter quasi-periodic flux variability:
1. (1480 $\pm$ 31) days; (736 $|pm$ 27) days (29 Cyg (HD 192640) used as a comparison star).
2. (1123 $\pm$ 36) days; $\sim$ 579 days and $\approx$ 128.7 days 36 Cyg (HD 193369) used as a comparison star). Short quasi-period was also revealed $\sim$ 15-18 days. Long-period variability maybe due to the binarity of the star.

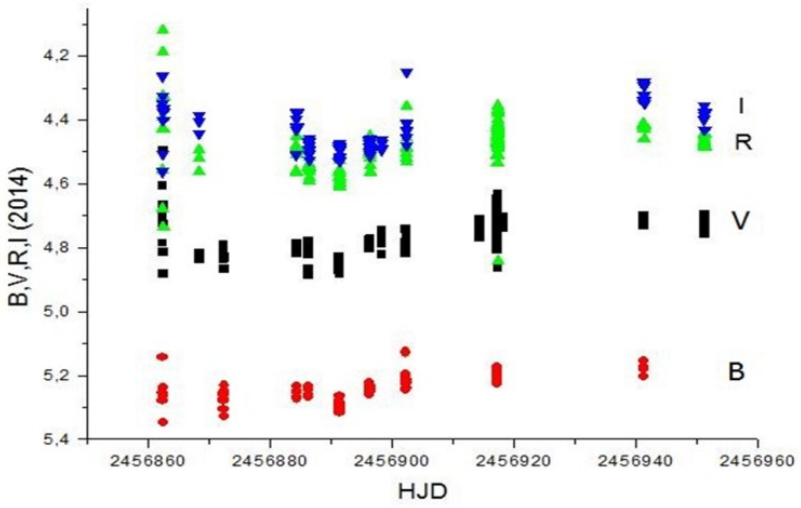

Figure 3: BVRI photometric Observations of P Cygni during 2014.

4. Colour behavior of P Cygni

Long-term photometric observations of P Cygni gives us possibility to trace B-V color variability of the star. Accepted, that P Cygni gradually reddens. This reddening is very impressive in the observations by Kharadze and Magalashvili, because (after correcting for the reddening by 0.5 B-V value) it varies from -0.5 to -0.1 from 1951 up to 1983 (left part of Fig.2). The star's color corresponds to the early B-spectral type.

5. Photometric observations of P Cygni in 2014

We observed P Cygni during July 23 - October 20, 2014 using the 48 cm Cassegrain telescope and standard B,V,R,I filters. HD 228793 (V = 9.9, B = 10.16) has been used as a comparison star (see Fig. 3). We revealed that during our observations the star underwent light variations with the mean amplitude of approximately 0.1 magnitudes in all pass-bands and the period of this change was approximately 68 days.

6. Conclusion

So, we revised observational data of P Cyg obtained during 1951 - 1983 and in 2014 in the Abastumani Astrophysical Observatory. Observations of P Cygni obtained by Kharadze and Magalashvili at the Abastumani Obser-

vatory are very significant due to the following reasons:
1. they represent homogenous data of more than 30 years;
2. There are UBV observations and we can trace colour behavior of the star;
3. The observations by Kharadze and Magalashvili are unique because they are the only existing data of P Cygni observed with UBV filters between 1951 and 1983.

We need more observational data and detailed analysis because we still have some unanswered questions like, for example, the binarity of P Cyg. The mechanism of great eruptions is still not established. Also the connection between stellar rotation, pulsation and magnetic fields of P Cyg are not very clear so far.

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