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V407 Cygni – nova like outburst in symbiotic system

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We presented spectroscopic and photometric observations of V407 Cygni obtained during 2006-2011. Our data shows the different activity stages connected with the two components of this symbiotic binary system. Cool giant exhibits pulsation character typical for Mira-type stars. Simultaneously, classical nova outburst connected with hot white dwarf was observed in 2010. Multicolour photometry and spectra obtained in a wide wave range are necessary to understand behaviour of such extreme binary. Our long-term observations together with gamma-ray, X-ray and radio monitoring reported by other authors covered the whole spectral domain and provide a lot of useful information about the nature of V407 Cyg.

Key words: stars, binaries, observations

INTRODUCTION

V407 Cygni was discovered by Hoffmeister [1] in 1936 as a possible classical nova. However, the extensive observations obtained shortly after the detection exhibited symbiotic star attribution rather than classical nova (a dense nebula and presence of a red giant). Some features indicate propeller symbiotic of D-type (dust) system, similar to the CH Cyg star [10]. With such peculiar objects it is very difficult to understood their true nature. The same problem occurred with PU Vul, which was firstly recognised as a nova-like star by Kuwano [8], but now it is rather known as a symbiotic nova [2]. Identification of the variability type strongly depends on which activity stage our observations are taken. In V407 Cyg system we can find the red giant which pulsate like Mira variable with a period of about 745^d and an amplitude $\Delta m_{pg} > 3^m$ [13]. Second component is the white dwarf which is a source of long lasting active phases observed during last decades by several authors [6, 7, 9]. Active stages of V407 Cygni are connected with occasional increase of the mass transfer rate from the red giant to the hot component via stellar wind [15]. Simultaneously, in 2010 V407 Cygni demonstrated the classical nova outburst and unexpectedly became a good candidate for the recurrent symbiotic nova. Astronomers have never witnessed nova-like outburst in this particular system and it is rarely observed in this kind of binaries.

SYMBIOTIC STARS SURVEY

Since the last three decades many symbiotic stars and related objects were observed at Piwnice Observatory near Toruń in Poland. We monitored practically all symbiotic stars brighter than 15^m, located in northern hemisphere. Simultaneously the Targets of Opportunity project allowed us to collect many useful data on classical novae. Our observations are collected using Schmidt Cassegrain 60/90 cm telescope to obtain spectra in low and high resolution and Cassegrain 60cm telescope to obtain UBVRI photometry. Our experience with erupting events facilitated in observations and analysis of symbiotic novae. For example, we observed outburst of RS Oph and AG Dra in 2006 and CI Cyg in 2008. One of the recent nova-like outbursts in symbiotic star was observed in Piwnice in 2010 and affected V407 Cygni system.

PHOTOMETRIC OBSERVATIONS

The outburst of V407 Cygni in 2010 was first reported in [11]. Several features suggest that it was classical nova outburst, unlike the symbiotic outburst most often observed in symbiotic stars: (i) strong wind was observed shortly after maximum outburst, what in our colour light curves is seen as fast changes in V-R and R-I indices (Fig. 1); (ii) in short time before strong wind appeared, ejecta from the white dwarf surface formed thick envelope observed in B-V index as a "red dip" at time very close to the outburst maximum (JD 2455266). The mean measurement errors are 0.07^m in U band, 0.04 in B, 0.03 in V, 0.03 in R and 0.02 in I band.

It is interesting how a classical nova outburst and a strong wind from a white dwarf have influenced on Mira structure and pulsations. Swift satellite detected strong X-ray radiation after outburst maximum [14]. It was a sign that strong shocks were formed in the very hot environment between components as an effect of interactions between the winds from Mira and from the white dwarf. On the other hand, we plotted ephemeris for giant pulsations from [5, 12] and our Infrared data together and presented

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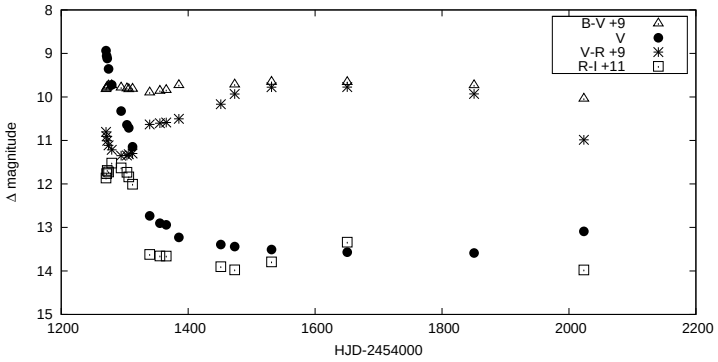

Fig. 1: The light and color evolution after outburst maximum

the results in Fig. 2. Fig. 2 shows that before maximum outburst (JD 2455266) pulsations are in a good agreement with those predicted for Mira but after outburst maximum the variability character changed clearly.

SPECTROSCOPIC OBSERVATIONS

Spectroscopic data of V407 Cyg were taken by Schmidt-Cassegrain Telescope with an objective prism during the outburst in 2010. Fig. 3 shows some of the most representative of them. Two well separated maxima which can be misinterpreted as two sources of black body radiation actually are only a case of blending with an irrelevant object in the field of stars. However, flux around H_α profile is undisturbed by any observational effect, so we were able to measure fluxes of this emission line over those 40 days – its decline from almost $50 \cdot 10^{-11}$ erg/cm^2/s to level of $2.74 \cdot 10^{-11}$ erg/cm^2/s. Even in so low resolution spectra as presented here (12 Å in H_α), one can see changes in some emission lines. Especially well seen in the end of April H_γ profile disappears in the early June. What is noteworthy, 85 days after the outburst flux in H_β profile is lower than flux in forbidden [OIII] λ5007Å profile ([OIII]/H$_\beta$ = 1.83) which can be an indicator of the beginning of the nebular stage [3] and shows that the envelope started to become transparent. Spectra also show a dual nature of the system. At the same time features of nova star and symbiotic star can be seen. E. g. the number of lines of Fe is characteristic for Fe nova (e. g. [16]) but in the red part TiO bands can be found, that points to a late spectral type object, which is a sign of a symbiotic system. Also, the first spectra is similar to spectra of recurrent nova, RS Oph [4], which is an another good example, how pour is our knowledge about complex binary systems.

CONCLUSIONS

V407 Cygni exhibits several features which make it one of the most interesting stars observed at Piwnice Observatory. Long term monitoring started in the past can successfully support the newest observations of nova-like outburst collected by X-ray and gamma observatories. Both data are unique and showed that outburst have strong influence on this system. Additionally our data pointed that about two years after the outburst Mira pulsations are still disturbed so further intensive observations are strongly encouraged.

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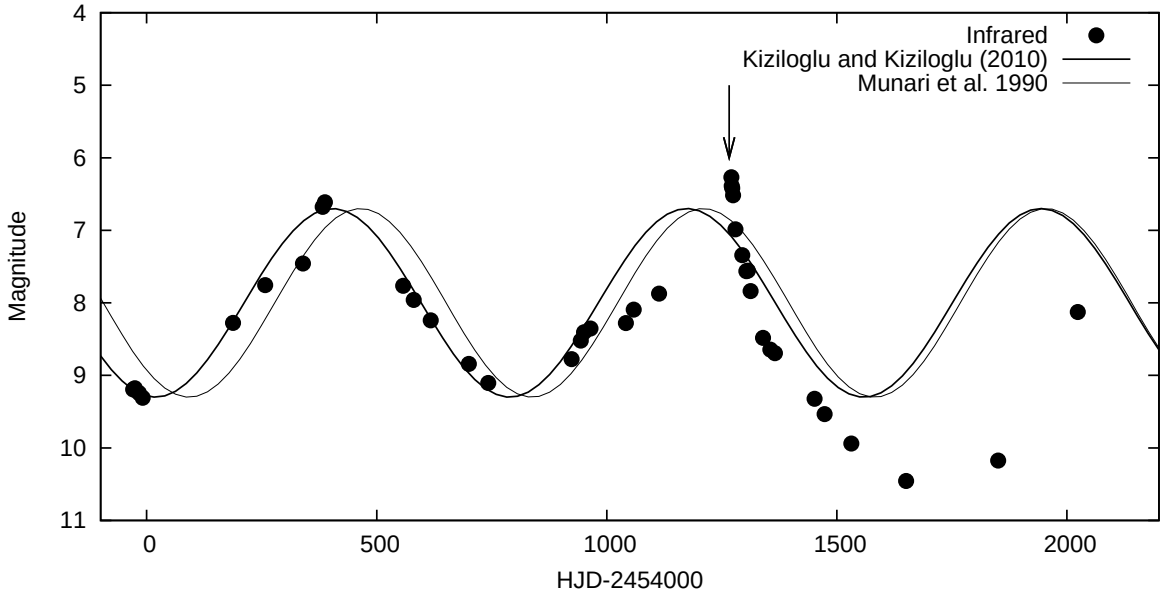

Fig. 2: Brightness changes connected with pulsations of Mira component in V407 Cyg binary observed after and before the outburst maximum. The moment of the outburst maximum is pointed by an arrow.

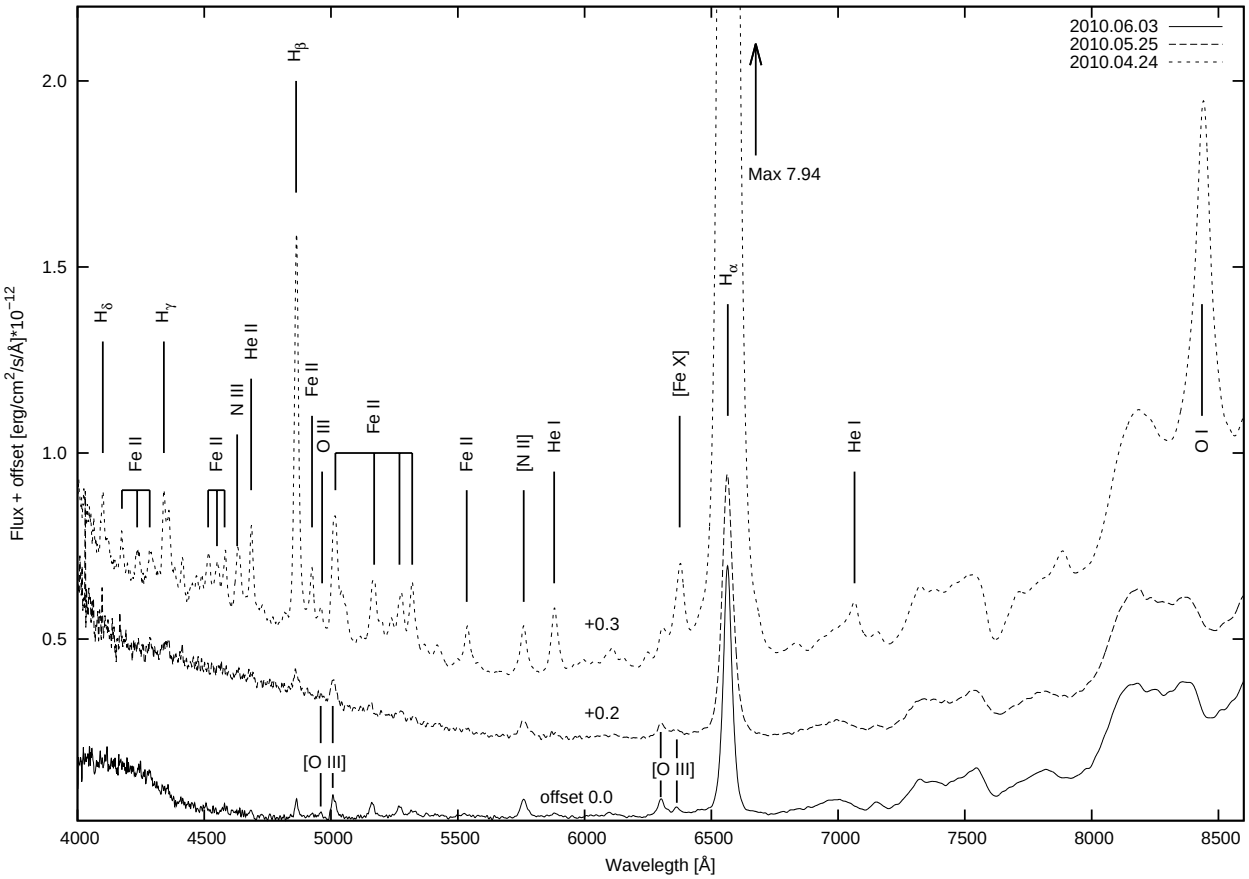

Fig. 3: Evolution of the optical spectrum of the V407 Cyg during the 2010 outburst. Only several emission lines are identified [11]. On the blue part of spectra flux is unnaturally high because of overlapping by another object in the star field.