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Asymmetric ejection of jets from the symbiotic prototype Z Andromedae

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Z And is considered as a prototype symbiotic star. The binary composes of a late-type, M4.5 III, giant and a white dwarf accreting from the giant's wind on the 758-day orbit. From 2000 September, Z And started a series of outbursts with the main optical maxima in 2000 December, 2006 July and 2009 December. During the 2006 optical maximum, highly-collimated bipolar jets were detected for the first time. They were launched asymmetrically with respect to the reference wavelength of the spectral line. Their presence was transient, they disappeared by the end of 2006. During the following re-brightening, from the beginning of 2008 to its end, faint emission satellite components to the Hα and Hβ were observed again. The red component was enhanced relatively to its blue counterpart. During the recent 2009 major outburst, the mass ejection in the form of jet was indicated almost exclusively on the red side of the Hα line with velocities from +1000 (2009/10/01) to +1800 km s^{-1} (2010/01/05). During the light maxima, our high-time-resolution photometry revealed irregular waves in the star's brightness throughout a night (δm 0.06 mag), while in between the outbursts, they nearly disappeared. Evolution in the rapid photometric variability and asymmetric ejection of jets could be explained by a disruption of the inner parts of the disk ignited by radiation-induced warping of the disk.

Asymmetric ejection of jets from the symbiotic prototype Z Andromedae

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Abstract. In this contribution we present our results of multicolour photometric and spectroscopic monitoring of the symbiotic prototype Z And during its latest active phases from 2006 to 2010. They were characterized by 2-3 mag re-brightening in the U passband and emergence of faint emission satellite components to the H-alpha and H-beta spectral lines. At the beginnings of these outbursts, the red satellite component was always enhanced relatively to its blue counterpart. During the recent 2009 major outburst, the mass ejection in the form of jet was indicated almost exclusively on the red side of the H-alpha line. During the light maxima, when the jets were ejected, our high-time-resolution photometry revealed irregular variations in *B, V* and *R* filters on the time-scale of hours and with a maximum brightness difference around of 0.065 mag, while in between the outbursts, they nearly disappeared. Evolution in the rapid photometric variability and asymmetric ejection of jets could be explained by a disruption of the inner parts of the disk ignited by radiation-induced warping of the disk.

Introduction

Z And is considered as a prototype symbiotic star. The binary composes of a late-type, M4.5 III, giant and a white dwarf accreting from the giant's wind on the 758-day orbit. From 2000 September, Z And started a series of outbursts with the main optical maxima in 2000 December, 2006 July and 2009 December (Fig. 1, top). During the 2006 optical maximum, highly collimated bipolar jets were detected for the first time (Skopal & Pribulla, 2006). They were launched asymmetrically with respect to the reference wavelength of spectral lines. Their presence was transient, they disappeared by the end of 2006 (Skopal et al. 2009). The recent two major outbursts of Z And (2000-03 and 2006-07) were intensively studied by Sokoloski et al. (2006), Skopal et al. (2006), Bisikalo et al. (2006), Burmeister & Leedjärv (2007), and Tomov et al. (2008). In this contribution we present new results of our long-term and high-time resolution photometry as well as the high- and low-resolution spectroscopy, carried out during the following, 2008 and 2009-10, outbursts of Z And.

Observations

Classical photoelectric UBV measurements were carried out at the Skalnaté Pleso observatory by a single-channel photometer mounted in the Cassegrain focus of a 0.6-m reflector. Results are shown in the top panel of Fig. 1. Fast CCD photometry was performed at (i) the Stará Lesná observatory (pavilion G1) during nights 2007/06/24, 2007/09/21 and 2008/07/11. The SBIG ST10 MXE CCD camera (2184x1472 pixels) mounted at the Newtonian focus of the 0.5-m telescope was used. (ii) At the Astronomical Observatory on the Kolonica Saddle the high-time-resolution photometry was made on 2009/11/02 with FLI PL1001E CCD camera (1024x1024 pixels) attached to the Ritchey-Chretien telescope 300/2400 mm (see the bottom panels of the figure). New optical spectroscopy was carried out at the David Dunlap observatory (DDO) and the Crimean Astrophysical observatory. We complemented our new observations with those obtained during the 2006 outburst (see Skopal et al. 2009).

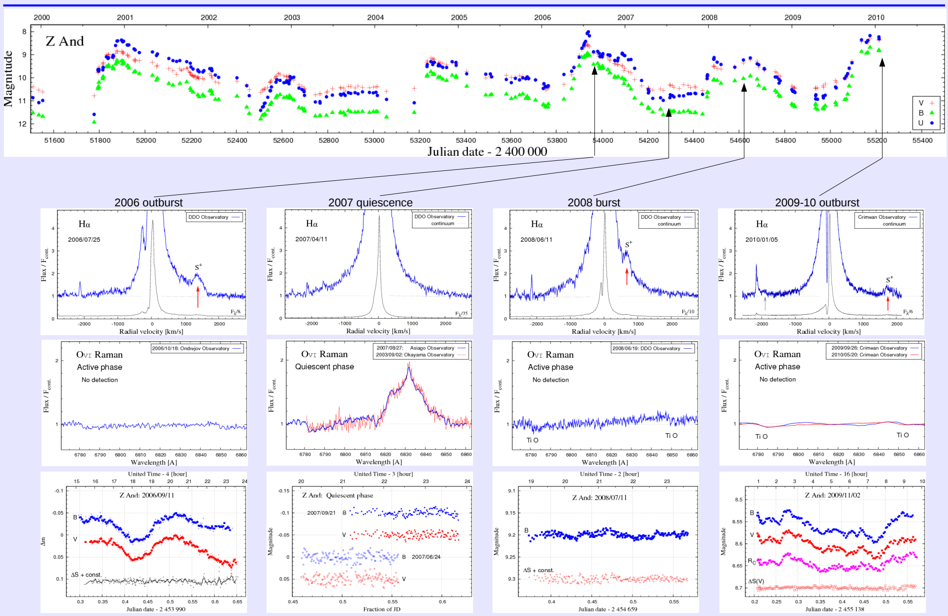

Figure 1. Top: UBV light curves of Z And covering the period of multiple outbursts during the last 10 years. Bottom rows of panels show evolution in the H-alpha line profile (note the sateliite components on the red side of the profile), in the Raman scattered OVI 6830 Å line, and in the fast photometric variations observed during outbursts and quiescence.

Evidence of a disk-jet connection

An important condition of producing a high-velocity bipolarly collimated mass outflow is a large accretion rate. Mass loss rate via jets and the accretion rate are proportional. Their typical ratio is $\dot{M}_{\rm jet}/\dot{M}_{\rm acc} \approx 0.1$. Skopal et al. (2009) estimated average outflow rate via jets in Z And to $\dot{M}_{\rm jet} \sim 2\times10^{-6}\,M_{\odot}\,{\rm yr}^{-1}$. Accretion rate from the wind of the giant is of a few times $10^{-8}\,M_{\odot}\,{\rm yr}^{-1}$. Therefore, a very high $\dot{M}_{\rm acc}$, required by the high value of $\dot{M}_{\rm jet}$, can only result from a disk instability. Critical observations supporting this suggestion can be summarized as follows:

(i) The hot *active* object has a disk structure. Photometric measurements indicate an A5 type spectrum during the maximum (i.e. $T_{\rm h} \sim 10^4$ K), while the emission line spectrum suggests $T_{\rm h} \sim 10^5$ K. Such the two-temperature type of the hot star spectrum can be explained by a disk-like structure of the hot object viewed under a high inclination angle (see Skopal et al. 2006, for detail). Creation of a large disk around the active star is also suggested by disappearance of the Raman scattered O VI 6830 Å emission band (see the mid row of panels in the figure), in spite that its original counterpart (O VI 1032 Å) can still be produced by the central ionizing source. In this case, the disk blocks the O VI 1032 Å photons from the hot star in directions to the densest part of the neutral wind at the orbital plane.

(ii) The rapid photometric variability originated in the disk, because its contribution dominated the optical during the outburst (from the SED: contributions from the nebula and the giant were relatively small at the optical maxima). The bottom row of panels in the figure shows the change from an irregular low-amplitude variations, observed out of outbursts, to a slow and higher-magnitude variation, observed during the period, when the jets were launched. This behaviour could be caused by disruption of the innermost parts of the disk. This view is based on the relationship between the disk radius and variability time scale Sokoloski & Kenyon (2003).

(iii) Simultaneous presence of both the disk and jets and their disappearance, just after the bright stages, suggest that bulk of the accretion energy was released in the form of jets (a relevant discussion in this direction can be found in Livio et al. 2003). As a result the hot stellar source in Z And reduced significantly its radiation just after the jet disappearance, which led to a *sudden* decline in the star's brightness. In contrast, the previous 2000-03 outburst, during which no jets were detected, showed a *gradual* fading in brightness from the maximum (Fig. 1, top).

Asymmetric jets ejection: A self-induced warping of the disk?

Asymmetric ejection of jets and evolution in the rapid photometric variability can be ascribed to disruption of the inner parts of the disk. The origin of the disk disruption could be connected with the luminosity increase at the outburst maximum. According to Pringle (1996), irradiation of the disk by the central star can lead to a twisting and tilting of an originally planar disk. He derived a criterion for the radiation-driven warping, that can occur at all radii R satisfying the condition

$$R/R_{\rm S} \geq 20\eta^2/\epsilon^2, \qquad (1)$$

where $R_{\rm S} = 2GM_{\rm acc}/c^2$, $\epsilon = L/(\dot{M}_{\rm acc}c^2)$ is efficiency of the accretion process and η is the ratio of azimuthal and vertical viscosities in the disk. The net accretion from the wind in Z And, $\dot{M}_{\rm acc} = 7\times10^{-8}\,M_{\odot}\,{\rm yr}^{-1}$, implies $\epsilon \sim 7\times10^{-5}$ and $R > 7\times10^{14}$cm ($M_{\rm acc} = 0.64\ M_{\odot}$ and $\eta = 1$), which is far larger then any reasonable disk size in Z And, which is in order of tens of solar radii. However, an additional energy liberated during the outburst by thermonuclear burning on the white dwarf surface increases formally the efficiency ϵ of the accretion process, which then could lead to radiation-driven warping close to the disk's centre. For Z And luminosity of $\sim 10^4\,L_{\odot}$, the radiation-induced warping occurs at all radii $R > 0.6\,R_{\odot}$.

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References

Bisikalo, D. V., Boyarchuk, A. A., Kilpio, E. Yu., et al. 2006, Astronomy Reports, 80, 722
Burmeister, M., & Leedjärv, L. 2007, A&A, 461, L5
Livio, M., Pringle, J. E., & King, A. R. 2003, ApJ, 593, 184
Pringle, J. E. 1996, MNRAS, 281, 357
Skopal, A., & Pribulla, T. 2006, ATel 882
Skopal, A., Vittone, A. A., Errico, L., et al. 2006, A&A, 453, 279
Skopal, A., Pribulla, T., Budaj, J., et al. 2009, ApJ, 690, 1222
Sokoloski, J. L., & Kenyon, S. J. 2003, ApJ, 584, 1021
Sokoloski, J. L., Kenyon, S. J., Espey, B. R., et al. 2006, ApJ, 636,1002
Tomov, N. A., Tomova, M. T., & Bisikalo, D. V. 2008, MNRAS, 389, 829