Recent outbursts of the symbiotic prototype Z And:
Evidences for a disk, bipolar wind and transient jets

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1. Introduction

Z And is a prototype of the class of symbiotic stars. The binary consists of a white dwarf accreting from the wind of the M4III giant (e.g. Nussbaumer & Vogel 1989). Orbital period is 759 d (Fekel et al. 2000).

From 2000 September, Z And started a series of outbursts with the main optical maxima in 2000 December and 2006 July. During the outbursts the hot active object was characterized by a two-temperature spectrum (a warm stellar radiation and a strong nebular emission) with signatures of a mass-outflow at moderate (~100-200 km/s) and very high (~1000-2000 km/s) velocities. This suggests the presence of an optically thick, slowly-expanding disk encompassing the accretor at the orbital plane and a fast optically thin bipolar wind at higher latitudes (Skopal et al. 2006). .

In 2006 July, during the optical maximum of the outburst, highly collimated bipolar jets from Z And were detected for the first time (Skopal & Pribulla 2006). Their presence was transient, they disappeared by the end of 2006. Evolution in the rapid photometric variability and asymmetric ejection of jets could be explained by a disruption of the inner parts of the disk caused by radiation-induced warping of the disk (Skopal et al. 2009).

2. Observations

Photometric measurements were carried out at observatories of Astronomical Institute of the Slovak Academy of Sciences (Fig. 1). Optical spectroscopy during recent 2000 and 2006 outbursts was carried out within an international campaign and ultraviolet spectroscopy was taken from the IUE and FUSE archives. The recent two major outbursts (2000-03 and 2006-07, see Fig. 1) were intensively studied by Sokoloski et al. (2006), Skopal et al. (2006), Bisikalo et al. (2006), Burmeister & Leedjarv (2007), Tomov et al. (2008) and Skopal et al. (2009).

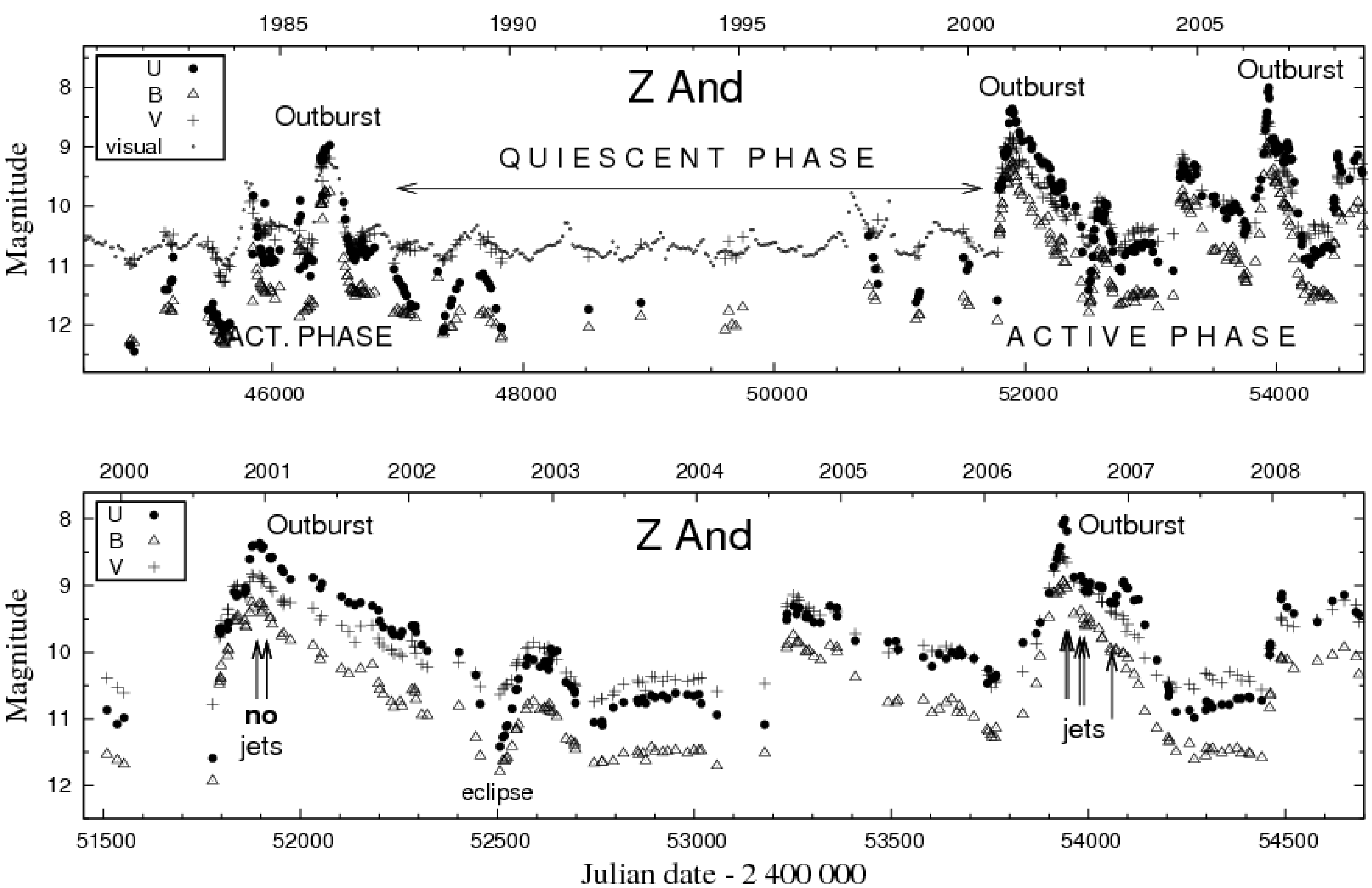

Fig. 1. The UBV light curves of the symbiotic prototype Z And covering the period from 1981. Quiescent phases are often abandoned by numerous 2-3 mag eruptions. During the recent (2000-03) outburst, a two-velocity type of the mass outflow was detected, while during the 2006 outburst, additional collimated outflow in the form of bipolar jets was observed for the first time.

3. Evidences for a Large Disk During Active Phases

They are given by the following observational features.
(i) Two-temperature type of the hot object spectrum (Fig. 2):
The cooler component <=> a warm stellar source, T ~ (1-3) x 10^4 K.
The hotter one <=> strong nebular emission (lines + continuum).
(ii) The blueward shift of the HeII 4686 A emission line: the disk blocks a fraction of the redward-shifted emission in the direction of the observer.
(iii) Disappearance of the Raman scattered OVI 6830 A emission:
The disk blocks the OVI 1032 A photons from the hot star in directions to the densests part of the neutral wind at the orbital plane.
These observations suggest the presence of an optically thick disk around the accretor seen under a high orbital inclination (cf. Skopal et al. 2006 in detail).
During quiescence, disk signatures (i),(ii) and (iii) are not observed.

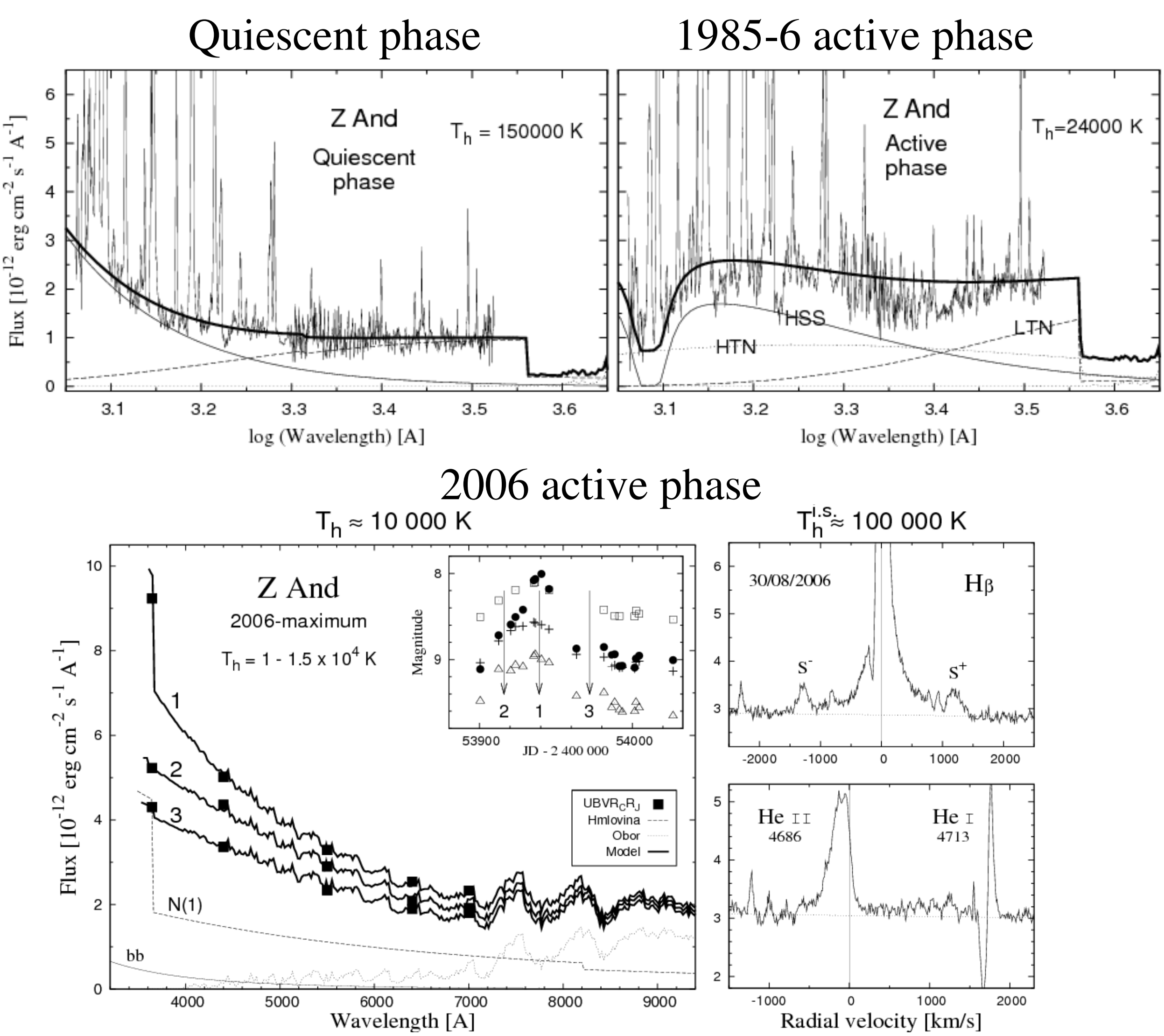

Fig. 2. The UV/optical SED of Z And during its quiescent and active phases. The two-temperature hot object spectrum developes during each outburst.

4. Bipolar wind and Expanding Disk During Active Phases

Line profiles during outbursts suggest two types of a mass outflow:

(i) at moderate velocities (100-200 km/s) as indicated by P-Cygni profiles (see bottom right panels of Fig. 2). And

(ii) at very high velocities (~1000-2000 km/s) as reflected by the broad emission wings of the Hα line profile (Fig. 3).

The two-temperature type of the hot object spectrum (Fig. 2) and the two-velocity type of the mass outflow from the hot object suggest an optically thick disk-like structured material surrounding the central hot star, expanding at moderate velocities in the orbital plane, while at higher star's latitudes a fast optically thin wind escapes the star.

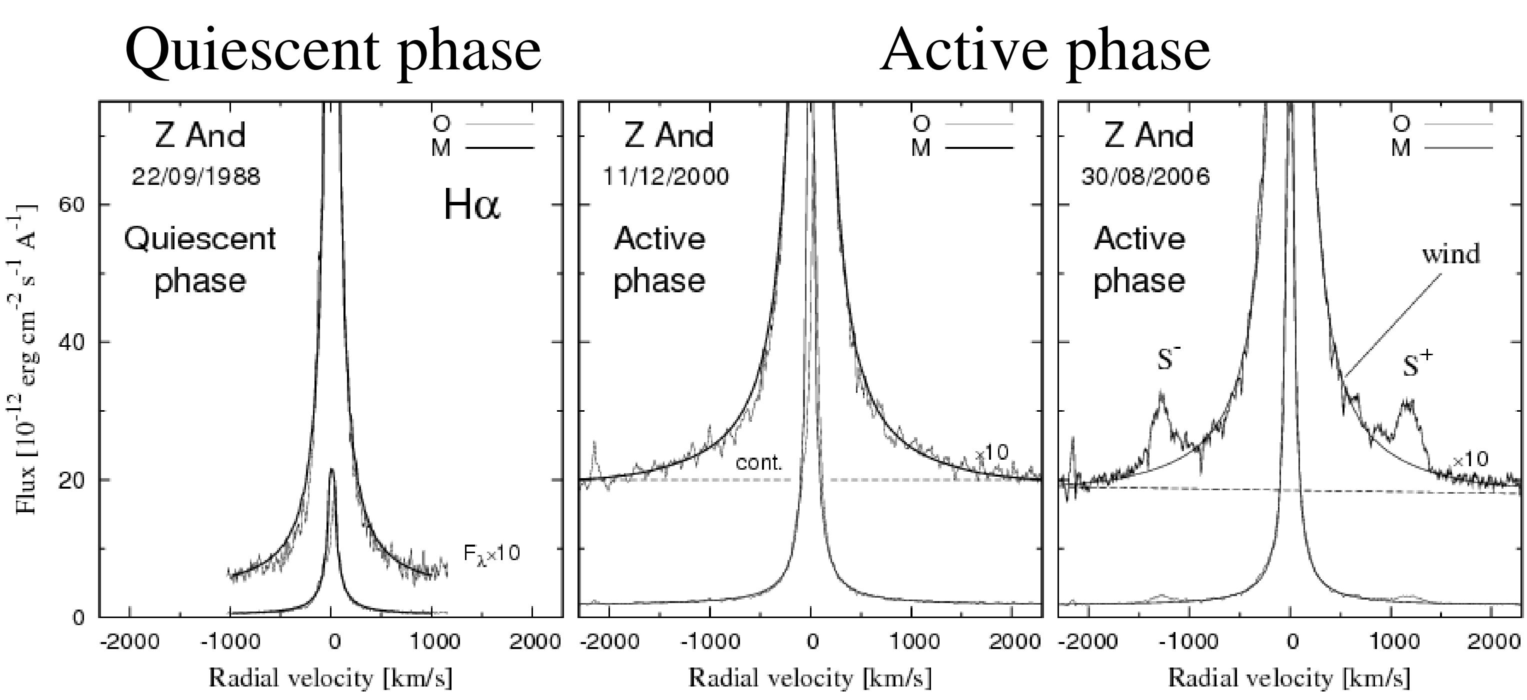

Fig. 3. Comparison of the modeled (M) and observed (O) Hα profiles during quiescent phase (left panel) and active phases (right panels) of Z And. The model reflects the optically thin stellar wind from the central hot star (Skopal, 2006). During the optical maximum of the 2006 outburst, high-velocity satellite components appeared on both sides of the Hα and Hβ emission line profiles.

5. Transient Jets from Warping Disk

1. Collimated bipolar jets from Z And were transient (Fig. 5).
2. The hot object has a disk structure (Sect. 3, Fig. 2).
3. The rapid photometric variability originates in the disk, because its contribution dominates the optical (from the SED, see Fig. 2).
4. The change of a low-amplitude irregular variation prior to the outburst to a slower, but higher-magnitude variation (see Fig. 4), can be interpreted as a result of a disruption of the innermost parts of the disk during the period when the jets were launched (see also Sokoloski & Kenyon 2003 for the case of CH Cyg).
5. 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 the disk – the so-called radiation-induced warping of the disk.

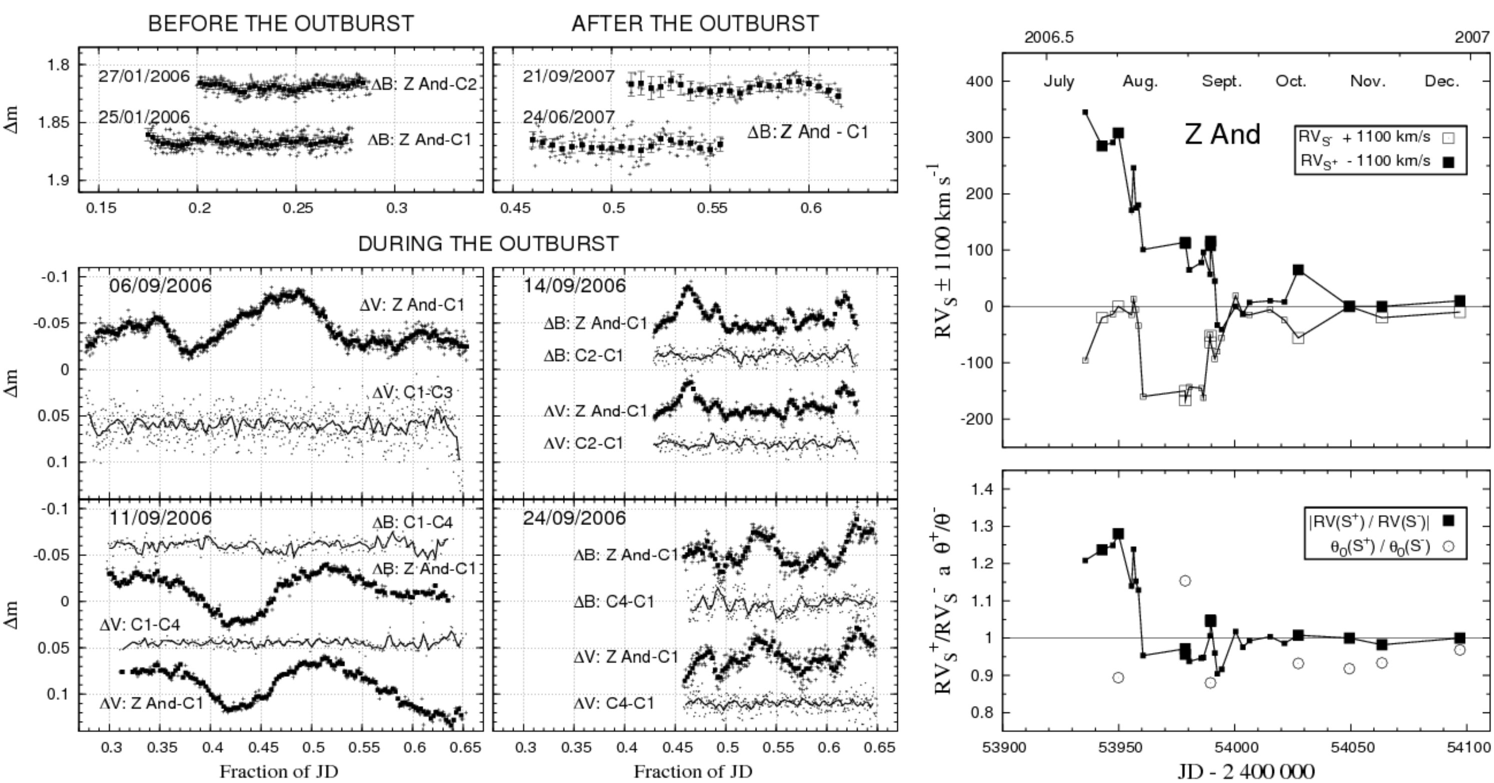

Fig. 4. Left: High-time-resolution photometry prior to and after the 2006-outburst (top panels) and during the period when the jets were launched (lower panels). Right: Evolution in radial velocities of jets during their presence in the spectrum. The short duration of their asymmetric ejection around the optical maximum and the evolution in the rapid photometric variability resulted from a disruption of the innermost disk due to its irradiation from the central star.

Transient Jets: 2006 July-December

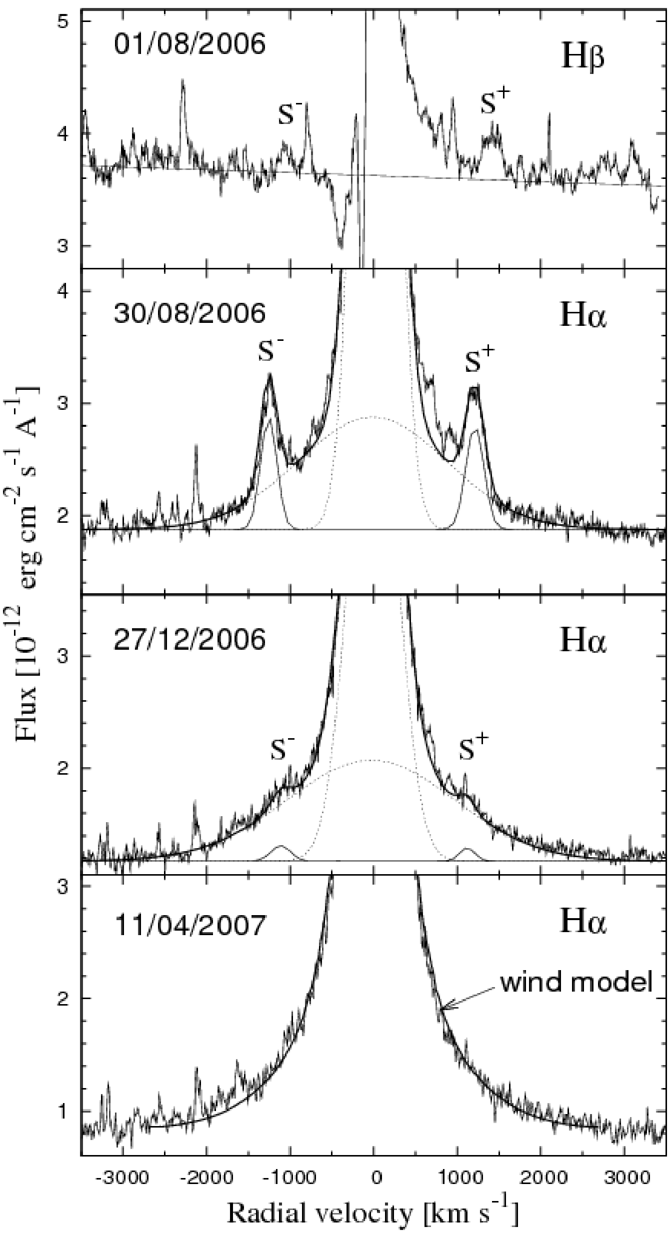

Fig. 5. Evolution of the jet components from their creation during the optical maximum to their disappearance at the end of 2006. From 2007, only broad wings produced by the hot star wind were observed (see Fig. 4 in Skopal et al. 2009).

6. Conclusions

The two-temperature type of the spectrum and the two-velocity type of the mass outflow suggested that the active object consists of an optically thick, slowly expanding disk-like structured material encompassing the white dwarf at the orbital plane and of a fast optically thin wind escaping the star at higher latitudes.

During the maximum of the 2006 outburst, highly collimated bipolar jets from Z And were detected for the first time. Their presence was transient. They could result from a disruption of the inner parts of the disk due to the radiation-induced warping of the disk at the outburst's maximum.

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