Z ANDROMEDAE: THE PROTOTYPE?

R. Viotti, A. Giangrande, O. Ricciardi
Istituto Astrofisica Spaziale (CNR), Frascati, Italy

A. Cassatella
Astronomy Division ESTEC, Villafranca Satellite Tracking
Station of ESA, Madrid, Spain

Z And is considered as the "prototype" of the symbiotic stars. Besides its symbiotic spectrum, the star is also known for its characteristic light curve (and for the related spectral variations). Since many theoretical speculations on Z And and similar objects have been based on the luminosity and spectral variations of this star, it is important to make a critical analysis of the observational data concerning it.

1. The light curve (see Mattei 1978) can be synthetically described as characterized by two (or more) phases = the active phase which starts with a $\sim$ rapid increase of the visual luminosity by about two magnitudes, followed by a kind of oscillation with decreasing amplitude (= transition phase), until a quiescent phase ($V \sim 11^m$) is reached.

The minima (or maxima) are separated on the average by about 632 days. However, the interval between two successive maxima is not constant but varies from 310 to 790 days (Mattei 1978), indicating that the luminosity variations are not periodic. At present Z And is in quiescent since many years, and a new outburst could well occur very soon.

2. The optical spectrum is extensively described in many review papers on symbiotic stars (see e.g. Merrill 1958, Sahade 1960, Swings 1970). At minimum luminosity and quiescence it has a typical symbiotic spectrum with a blue region rich in strong emission lines, having a wide range of ionization energy from FeII to [FeVII]. A weak blue continuum, with a large Balmer excess, is present under the emission lines, but longwards of about 5000 Å a red continuum emerges with several strong TiO absorption bands typical of an $\sim$ M6.5 stellar spectrum (Altamore et al. 1979). At the light maxima the highest ionization energy lines are much weaker with respect to the lower ionization emission lines, and to the blue continuum, which then largely washes out the M-type spectral features.

Figure 1. The low resolution ultraviolet spectrum of Z And in August 1980. Ordinates are log fluxes in $\text{erg cm}^{-2} \text{s}^{-1} \text{\AA}^{-1}$.

Hydrogen and FeII lines show a P Cygni profile, and give evidence for outflowing matter at velocities of about 180 km s^{-1} (Swings and Struve 1941).

3. The ultraviolet spectrum. Like in the other symbiotic stars a large number of emission lines can be identified in the IUE spectra belonging to many different ionization energies, from OI, MgII, FeII to HeII, NV, OV and MgV. At high resolution the emission lines appear narrow. The relative intensity of intercombination lines of CIII, NIII and OIV suggests an electron density of about $2 \times 10^{10} \text{ cm}^{-3}$ (Altamore et al. 1981). At low resolution (Figure 1) a weak continuum is detectable with a depression near 2200 Å suggesting an interstellar extinction of $E(B-V) = 0.35$. According to results we have just obtained, the continuum of the dereddened spectrum (Figure 2) can be fitted by the sum of two components: (a) a hot black body with $T \sim 10^5 \text{ K}$, and (b) a nebular type continuum with $T_e \approx 1.5 \times 10^4 \text{ K}$, for which free-free, bound-free and two photon (negligible) emission have been considered. This result is quite in agreement to that of Boyarchuk (1968) who suggested for Z And a three component model - M giant, hot source, nebular source - based on the optical observations. The black body temperature of 10^5 K is rather uncertain because the slope of the continuum near 1300 Å is close to the Rayleigh-Jeans distribution. This temperature is also critically dependent on the derived value of the interstellar extinction.

Figure 2. The low resolution ultraviolet spectrum of Z And corrected for an interstellar extinction of $E(B-V)=0.35$. The continuum (dashed line) is fitted by the sum of bb and nebular emission.

4. The infrared spectrum. Infrared photometry of Z And was recently obtained in September 1980 at the Wyoming Infrared Telescope by M. Ferrari-Toniolo and P. Persi (paper in preparation), and in July 1981 at Almeria by Eiroa et al. (this volume). The energy distribution between 1 and 10μ agrees well with a black body spectrum with a 3200°K temperature, without any clear evidence for a dust emission. We have also found that the "nebular" component of Figure 2, when extrapolated to the infrared, does not seem to contribute significantly to the 10μ flux.

Observation of low weight near 20μ made by Woolf (1973) suggests a rapid rise of the continuum beyond 10μ . It would be important to confirm or disprove this result because of its strong model implications.

No significant differences have been found among the different IR observations so far reported in the literature, which could support that the cool spectral component of Z And is not variable.

The total power emitted by the cool component is about $2.6 \times 10^{-8} \text{ erg cm}^{-2} \text{ s}^{-1}$, to be compared to about 2×10^{-9} emitted in the UV continuum, and 1×10^{-9} in the UV emission lines. The 10^5 K hot continuum would contribute with about $2 \times 10^{-8} \text{ erg cm}^{-2} \text{ s}^{-1}$ to the total energy output per sec from Z And. This value is of the same order of magnitude of the total radiation power of the cool component, and this could be an argument in favour of the binarity of Z And.

5. The problem of Z Andromedae. In order to know the nature of this star and in particular to understand the origin of the large light variations,

it is important to study the star when it is in a quiescent phase. In fact, during the outbursts the star(s) is (are) certainly surrounded by a massive gaseous envelope which should mask the inner regions, while during quiescence we can look deeper into the object, and it should be easier to derive the basic parameters of the star(s).

From the study of the ultraviolet spectrum of Z And Altamore et al; (1981) argued that the thickness in the line of sight, derived from the ratios of the NV and SiIV resonance lines, when combined with the measured emitting volume, suggest that the geometry of the line formation region is not compatible with formation in an extended nebula. Also the stellar radiation density in the NIII] region should be very low, otherwise the multiplet lines relative intensities would be that characteristic of Boltzman equilibrium contrary to the observations. Finally the emission lines are too narrow to be formed in a wind coming from a hot star, or in a rotating disk (unless the inclination to the line of sight is very small). Altamore et al. concluded that all the arguments are consistent with the formation of the lines around the cool star, in a solar-type transition region. The hot continuum component, confirmed by the present observations, may come from an optically thick region, that is either a hot subdwarf, or a hot active region on the surface of the cool giant, while the nebular continuum should originate in an extended region surrounding Z And.

During the present quiescent phase the star is still variable, with small luminosity variations. Sahade et al. (1981) reported variations of the intensity of the ultraviolet emission lines. In addition we have also noted that the relative intensity of the SiIII] and CIII] lines changed during 1979-81. The long time-scale variation of the intensity of H α found by Altamore et al. (1979) is confirmed, but without any evidence for a periodicity. Large changes in the H α profile were reported by Oliverson and Anderson (this volume).

Clearly it would be important to know more about this activity of the star during quiescence, since it could be of help in understanding the physical processes which are responsible for the outbursts of the star.

Further studies are required mainly with respect to:

- (a) Systematic near-infrared photometry to look for any variation of the M star, and accurate observations near 10-20 μ to search for a possible dust emission.
- (b) Detailed study of the optical and ultraviolet spectrum using well exposed spectra in order to derive the emission line profiles and radial velocities with better accuracy, and to measure the continuum level and, possibly the (interstellar or atmospheric) absorption lines

at high resolution (in this context it would be important to observe a number of representative symbiotic stars with the Space Telescope).

- (c) X-ray observation with the EXOSAT satellite, since Z And may well be a (probably soft) X-ray source detectable with the experiment.

REFERENCES

- Altamore, A., Baratta, G.B., Viotti, R.: 1979, *Inf. Bull. Var. Stars*, 1636
 Altamore, A., Baratta, G.B., Cassatella, A., Friedjung, M., Giangrande, A., Ricciardi, O., Viotti, R.: 1981, *Astrophys. J.* **245**, 630.
 Boyarchuk, A.A.: 1968, *Soviet Astr. -A.J.* **11**, 818.
 Mattei, J.A.: 1978, *J. Roy. astr. Soc. Canada* **72**, 61.
 Merrill, P.W.: 1958, in "Etoiles à Rayes d'Emission", *Mem. Soc. Liège*, p. 436.
 Sahade, J.: in *Stars and Stellar Systems, Vol.6, Stellar Atmospheres*, T. L. Greenstein (ed.), University of Chicago Press, p. 498.
 Swings, P.: 1970, in *Spectroscopic Astrophysics*, G.H. Herbig (ed.), University of California Press, Berkeley, p. 498.
 Swings, P., Struve, O.: 1941, *Astrophys. J.* **93**, 356.
 Woolf, N.J.: 1973, *Astrophys. J.* **185**, 229.
 Sahade, J., Brandi, E., Fontenla, J.M.: 1981, *Rev. Mex. Astr. Astrophys.* in press.

DISCUSSION ON Z ANDROMEDAE

Plavec: On your diagram matching the continua, you use hydrogen continuum at $T_e=15000K$. However, on your NIII] diagram determining the electron density, you use $T_e=80000K$. Why? Is there any observational evidence for such a high electron temperature? Do you observe a continuous hydrogen contribution with this electron temperature? If not, and if N_e is not sensitive to T_e , why assume such a high temperature.

Viotti: In the Altamore et al. paper we found relative consistency between the emission measures for the intercombination and resonance lines in agreement with our model. The corresponding ff+bf contribution of the high temperature region to the UV continuum is lower than that observed suggesting a different source for that continuum. In other words the NIII] lines and the UV continuum are formed in different regions of Z And.

Kafatos: I would like to point out that when we used the OIV] or NIII] multiplet ratios in some stars we found consistent single-valued densities, but in some other stars one gets different values from different ratios of the same multiplet. I believe that this is a real effect, pointing to different density regions rather than an uncertainty in atomic parameters.

Keyes: The ratios of the NIII] 1754/1749 and 1748/1749 should be locked in the ratio of the A-values, as both 1754 and 1748 lines share a common upper level. This provides a useful check on the accuracies of the line intensity measurement. Are the discrepancies you find in densities derived from other line ratios significant compared to the measurement uncertainty implied by your 1754/1749 and 1748/1749 density values?

Viotti: Our results for Z And, RR Tel and AG Dra show that at least the collision strengths of the OIV] and NIII] lines are not well known, and this may partly explain the dispersion of the density values. In addition the intensity of the 1749 line seems weaker than expected, but it is difficult to decide whether this is a real effect or an instrumental one (reseau mark).

Nussbaumer: When employing the OIV] 1401 or the NIII] 1749 multiplets to determine electron densities, you have to allow for uncertainties in atomic data and observations. In practice this means that if the observed intensity ratios lie close to the high or low density limits, then you can no longer expect to obtain very accurate N_e . Thus Viotti just showed us that for RR Tel he obtains $N_e = 10^9 \text{ cm}^{-3}$; well it might be more prudent to conclude $N_e \leq 10^9 \text{ cm}^{-3}$.