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Abstract -

The preliminary results of a joint study of this symbiotic star with 6 Italian astronomers are reported. The relative intensities of the intercombination emission lines indicate electron densities of 10^{10} and an upper limit to the dilution factor between 10^{-4} and 10^{-6} . The resonance emission lines give a maximum thickness in the line of sight. A hot (T between 19000° and 26000°) continuum is interpreted as coming from a hot subdwarf, but the high excitation emission lines appear to be formed near the cool giant component of what is probably a close binary.

I- Introduction.

The study here described is a joint collaboration with A. Altamore, G.B. Baratta, A. Cassatella, A. Giangrande, O. Ricciardi and R. Viotti. The calculations are not yet complete and the results are preliminary.

Z Andromedae is often considered to be the prototype of symbiotic stars. Such stars have periods of intense nova like activity followed by quiescent phases. In the latter the visual spectrum shows both the presence of high excitation emission lines and of the spectrum of a cool giant. Cyclic variations of visual luminosity, emission line intensity and radial velocity are often observed.

Different kinds of physical process have been invoked to explain the properties of symbiotic stars. They are most commonly thought to be interacting binaries (Boyarchuk, 1969), but active chromospheres and coronae around single stars, and also in some cases processes associated with the origin of planetary nebulae have also been invoked. In any case the physics of different symbiotic stars is probably not the same. In my conclusions I shall not contradict the binary hypothesis (otherwise I might be kicked out of this binary meeting), but the situation seems to be more complex than indicated by simple forms of the hypothesis.

The IUE short wavelength region was observed at low resolution on May 5, 1978 and at high resolution on February 17, 1979, while the long wavelength region was observed at low resolution on June 13, 1978

and February 17, 1979. The data were converted to absolute fluxes using the sensitivity curves of Bohlin et al (1978). The UV spectrum is seen to be dominated by a large number of narrow emission lines often of high ionization on a weak continuum, clearly visible in the short wavelength region.

II - Analysis of the emission line flux ratios.

The line intensity ratios for the $2^{\text{P}} - 4^{\text{P}}$ NIII] (intercombination) multiplet as a function of electron density N_e have been calculated by my colleagues using the level populations kindly provided by H. Nussbaumer. The result which is fairly insensitive to electron temperature T_e for values of the latter between 3×10^4 and 10^5 °K give a weighted mean over the line ratios of $N_e = 2.0 \pm 0.5 \times 10^{10}$.

Calculations for CIII] were also performed by O. Ricciardi and A. Viotti. A comparison of the CIII] 1908.7 Å and NIII] 1749.7 Å line fluxes assuming cosmic abundances and no outside radiation gives $N_e = 2 - 3 \times 10^{10}$ for $T_e = 6 - 8 \times 10^4$ °K.

The line fluxes for these ions also give a condition concerning the dilution of radiation where the lines are formed. Preliminary calculations by my colleagues of the effect of radiation on the sublevel populations suggest a maximum dilution factor of between 10^{-4} and 10^{-6} .

In the case of the OIV] lines the already published line flux ratio calculations of Flower and Nussbaumer (1975) and of Vernazza and Mason (1978) were compared with observation. The former calculations give at $T_e = 1.5 \times 10^5$ °K a $\log N_e$ between 9.8 and 10.5 from two line ratios. The latter calculations made assuming not quite the same physical data only give definite limits to $\log N_e$ between 10.0 and 11.5 for one line ratio, for T_e between 1.8 and 2.0×10^5 °K. The closeness of the N_e values found for this ion to those found for the two others suggest line formation in similar regions.

The study of the high ionization resonance lines gives more information. At the high electron densities found, electron scattering becomes important at quite small geometrical thicknesses. If the line optical thickness of the line emitting region is τ_e and the electron scattering optical thickness τ_c , the effective continuum optical thickness encountered by a photon in its random walk is $\sqrt{\tau_e \tau_c}$. The line flux ratios in a resonance multiplet excited by collisions unaffected near $\tau_e = 1$ when no sublevel mixing occurs, are changed near $\sqrt{\tau_e \tau_c} = 1$ (for the physical conditions here calculated, collisional de-excitation is negligible). The measured line flux ratios are significantly smaller than in the optically thin case; this could however be due to blending with interstellar absorption as well as to the effect here considered. In any case the lines would disappear for $\sqrt{\tau_e \tau_c} > 1$, as photons would then be scattered out of them because of the Doppler effect. Taking $\log N_e = 10.4$ the whole half widths of lines supposed broadened by the Doppler effect equal to 60 km/s, and assuming cosmic abundances (justified by Boyarchuk, 1970), a line of sight maximum log thickness of 10.7 is obtained when the fluxes of the NV and SiIV resonance doublets are considered.

The emissivities of the regions giving the different lines can in principle also be used to calculate volumes, if certain assumptions

are made concerning their physical conditions. Such calculations are not yet complete. However if the solar model calculations of Yang et al (1975) are used for the SiIV 1393.8 and the NV 1242.7 Å lines assumed formed where excitation and ionization are collisional at $\log T_e = 4.40$ and 5.30 respectively, the volumes found are the same as those of spheres with log radii of 11.5 and 11.7 respectively.

III - The Continuum.

The faint continuum seen cannot be due to free-free and free-bound emission from where the high ionization line emission is produced. It is best interpreted as coming from an optically thick region. If $E(B-V)$ is taken as zero, my colleagues found that the continuum is fitted by black body radiation at 19000° from a sphere of radius 2×10^{10} cm while if $E(B-V)$ is taken as 0.5, one has a temperature of 26000° and radius of 4×10^{10} cm. The 2200 Å feature is hard to measure because of the presence of many emission lines, but leads to a conservative $E(B-V)$ of 0.25.

IV - The model.

The hot continuum is most easily interpreted as coming from a subdwarf companion, as suggested by Boyarchuk (1967).

The high ionization line emission however probably comes from a region around a cool component. The reasons are :

a) The low maximum dilution factor indicates formation far from any hot star.

b) The narrow lines if formed in a wind expanding at at least the local escape velocity would have to come from at least 7×10^{12} cm from a $1M_\odot$ star. This is hard to reconcile with the thickness and preliminary emitting volume calculations. If the lines were formed in a rotating disk, one could only avoid high ionization line formation in a low velocity region of the order of the size of a cool giant, if the inclination was small. Boyarchuk (1967) suggested an inclination of $< 10^\circ$ to explain the lack of observed orbital radial velocity variations of lines supposed due to the hot star; the probability of such a geometry is only 1/66 .

c) The thickness and preliminary volume calculations are hard to reconcile with formation in an extended nebula.

Formation near the atmosphere of a cool giant of the high ionization lines during the present quiescent phase is most compatible with the data. This conclusion may contradict the results of Linsky and Haisch (1979) concerning the lack of regions of high ionization for cool stars to the right of the Hertsprung-Russel diagram. However in the present state of knowledge it is not certain whether this is a difficulty.

References -

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DISCUSSION FOLLOWING FRIEDJUNG

Hack: Is it possible that the difference in intensity between the two resonance lines of NV, of CIV, and of SiIV is due to partial blends of the two components of the doublet? How broad are these lines?

We have observed CI Cyg last June with IUE and the spectrum looks very similar to that of Z And you have shown.

Friedjung: We have observations at high resolutions, where the resonance lines are well resolved. They are narrow with a width (before correction for instrumental resolution) of the order of 0.3 Å.

Stencel: Do not completely dismiss the Linsky-Haisch thermal locus (*Astrophys. J. Letters*, 1979). It will be discussed with new observations at IAU Colloquium 51: Turbulence in Stellar Atmospheres.

Also, how does the hot component cause the hot M star atmosphere? Will there be phase dependent emission line variations?

Friedjung: I would not like to speculate at the present stage on the modulation of the hot region lines.