AG DRA A SYMBIOTIC STAR WITH AN UNCOMMON COOL COMPONENT

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SUMMARY. AG Dra is probably a metal poor symbiotic binary of the galactic halo. The luminosity of the cool component is uncertain, which contributes to doubts about the correct model. Behaviour in activity is non classical with high ionization emission lines still having been seen then in the spectrum. This may perhaps most easily be explained by a weak thermonuclear event.

1. INTRODUCTION

In order to find out whether one "symbiotic phenomenon" exists, we need to examine symbiotic stars of very different types. I shall talk about a star whose cool stellar component appears to be less cool than that of most other symbiotic stars. It also seems to be metal deficient and the radial velocity of AG Dra indicates that it is not of population I. Such differences compared with more "classical" symbiotic stars can pose problems if they are not taken into account in interpretation and in the comparison of the "symbiotic phenomenon" with that of other stars.

In this short review I shall not describe all the work done on AG Dra (for detailed summaries of previous work see Kenyon 1983,1986), but I shall try to emphasize what is distinctive and what can teach us about symbiotic stars in general. The properties in quiescence will first be considered and then those of active phases. Finally possible interpretations and problems will be discussed.

2. PROPERTIES IN QUIESCENCE

What are presumably orbital radial velocity variations of the cool component were measured by Garcia (1986). They were consistent with the photometric period of 554 days (Meinunger 1979). According to Garcia the radial velocity curve is sinusoïdal indicating an orbital eccentricity near 0.0. The semi amplitude K equals 7.5 km s^{-1} assuming a mass of 1.5 $M_\odot$ for the cool component and 1 $M_\odot$ for its companion, Garcia found an orbital separation of 400 $R_\odot$. The periodic photometric variations (Meinunger 1979, Oliverson and Anderson 1982) had when observed by the last authors an amplitude of ≃ 0.8 mag in U, with weaker variations in B and V. The variations are continuous, and do not indicate classical

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"eclipses". Recently Kaler (1987) measured the variations in 11 intermediate and narrow wavelength bands from the near ultraviolet to the far red. He found periodic variations largest at 3470 Å, decreasing towards the red but also present to some extent for emission lines while indications of "secondary eclipse" at some wavelengths were also noted.

The systemic radial velocity is according to Garcia (1986) - 146 km s^{-1}.Such a high radial velocity already given by measurements of Roman (1953) and Eggen (1964) suggests that AG Dra is a halo star. Stars with such velocities may be expected to be metal deficient, and this according to Iijima et al.(1987) can explain the contradictions in spectral classifications of the cool component. These include G7 III (Smith and Bopp 1981), K1 (Allen 1982), K3 III (Boyarchuk 1966) and K5 III (Belyakina 1969) among others. Iijima et al. point out that the absorption spectrum is that of a late G dwarf, while the in particular infrared colours correspond to those of a K3-S III star (Taranova and Yudin 1982, Viotti et al 1983). The colour but not the absorption spectrum then gives the effective temperature.

It is naturally perhaps even more difficult to avoid uncertainty in the determination of the luminosity class. Huang (1982) gives a class of K0 Ib, i.e. the cool component would then be a supergiant. This high luminosity was suggested by the strength of Ti II, Sr II and Ba II absorption lines. Other classifications mentioned above suggest a giant III luminosity class. The recent accurate classification of Kenyon and Fernandez-Castra is one of < K4 III, the luminosity classification unlike that of temperature being however not quantitative. Nevertheless the luminosity classification is probably also affected by a metal underabundance. The last authors used features due to CN between 8000 and 8100 Å and blends of Ti O and Fe at 8308 and 8330 Å. The sensitivity of CN to what appeared to be differences in metal abundance was shown by O'Connel (1973), so one cannot be sure of the lumiosity class of AG Dra before a detailed high dispersion abundance study is undertaken. Other anomalies may be present; Lutz et al. (1987) suggest that the cool component of AG Dra might be a barium star.

Knowing the luminosity class is necessary, in order to know whether the cool component fills its Roche lobe, Garcia (1986).Taking a radius for it of 20-40 R_0 (the former value is that of a K3 III star according to the Landölt-Borstein tables), Garcia found the Roche lobe to be underfilled by factors of more than 3.5 for different assumptions about the mass ratio and the mass of the compact companion star. In principle one can also obtain information about the radius of the cool star if one can give limits to its distance. A K3 III star having a V of 9.8 (the magnitude in quiescence when the hot continuum can be expected to be least important) would for an E (B-V) of 0.06 (Viotti et al., 1983) be at a distance of 0.73 kpc and have a distance of 0.5 kpc from the galactic plane. If the cool component fills its Roche lobe its distance would be of the order of 3 kpc. The weakness of the interstellar C IV lines in the ultraviolet spectrum (Viotti et al. 1983) may be an argument against such a distance.

Turning now our attention to other components of the AG Dra system emission lines of H, He I and He II in particular are observed in the optical spectrum, while excess continuum emission can be explained by emitting gas (Boyarchuk, 1966). Emission lines of other ions including

[O I] O III, Fe I, Fe II, [Fe V] and [Fe VII] were reported by Smith and Bopp (1981). These authors studied profile variations of Hα. A blue asymmetry was found to be strongest near photometric minimum. The main red component is what varied, it being weakest when the asymmetry was strongest. Other Balmer lines also seem to show the blue asymmetry.

Postponing discussion of IUE ultraviolet observations to the next section on active phases of AG Dra, the detection of X ray emission before the peak of the 1980 outburst, still needs to be emphasized. This detection by the Einstein observatory was reported by Anderson et al. (1981, 1982). The source was both very strong and very soft, exceeding the X ray luminosity of normal late type giants by roughly two orders of magnitude.

Taking into account various constraints, the authors explained the X ray emission as either due to hot plasma with a temperature between $2x10^3$ and $1.6\ x10^6$ K, or due to a spherical black body with a temperature of $2.5x10^5$K and a radius of 1000 km (the last best fit assumes an interstellar hydrogen column density in front of the source of $3x10^{20} cm^{-2}$). The black body fit could be stretched to one of radius $1.4x10^4$km at a temperature of $1.5x10^5$K.

3. PROPERTIES IN ACTIVE PHASES

The photographic light curve over many years was given by Robinson (1969) (see Fig.1). This curve appears rather to be one of the Z And type than one of a "symbiotic nova". It is possible as will be seen that this appearance is misleading, when one attemps to understand the nature of the activity of AG Dra. It may also be noted that Iijima (1987a) found a periodicity of about 15 years for times of strong activity since 1930.

The spectrum during the activity following the 1980 outburst has been studied in several papers. It must be emphasized that high ionization emission lines were still present during activity of this star; this behaviour is not that of a classical symbiotic star. He II was still seen in the optical, while the same effect is clearly shown by the ultraviolet spectrum, especially observed after outburst. Viotti et al. (1983) report ultraviolet permitted and intercombination emission lines including N V as well as He II, C III], C IV, N III], N IV], O I, O III, O III], O IV], O V, Mg II, Al III, Si II, Si III], Si IV, Si IV] and S V. The relative intensities of the O IV] lines suggested formation in a region with an electron density of $1x10^{10} cm^{-3}$, where radiation was very dilute (at a radius of perhaps at least 10^2 of the hot ionizing source). The density, combined with the He II 1640 Å emission measure, suggested a radius for the formation zone of $3x10^{12}$cm, if the He II and O IV] were formed in the same region. The 1981 ultraviolet continuum had two components, a steep hot one shortwards of 1600-1700 Å and a flatter one at longer wavelengths. Lutz et al. (1987) also studied the ultraviolet spectrum, finding similar electron density values from the OIV] lines, with a possible increase from $2.5x10^9 cm^{-3}$ before outburst to one near $10^{11} cm^{-3}$. Analysis of Si III] lines however gave much lower values near $10^5 cm^{-3}$, suggesting stratification effects or something wrong in the interpretation of the line fluxes.

The time variation of the ultraviolet spectrum following the 1980

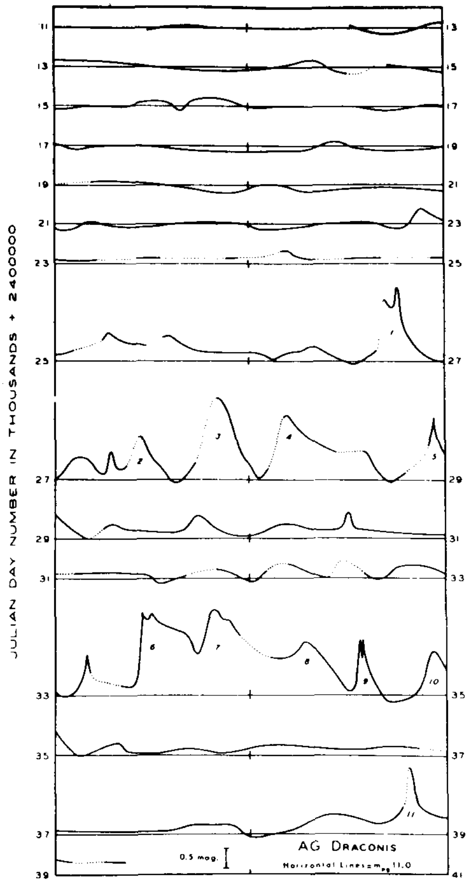

Figure 1. Photographic light curve of AG Dra from Robinson (1969).

outburst was discussed by Viotti et al. (1984). A minimum in the ultraviolet continuum was slightly later than the predicted photometric minimum from the pre-outburst light curve; it is not clear whether this variation is or is not related to that in quiescence. If the ionization is measured by the NV/CIV ratio it did not change, if measured by the HeII/continuum ratio some variation occurred.

Another feature of the ultraviolet spectrum must also be pointed out. The lines of the NV doublet have been observed to have P Cygni profiles. This could be caused by a wind with a terminal velocity of 170 km s^{-1}. No other lines were observed to have P Cygni profiles, but HeII 1640 Å was seen to have broad emission wings. The NV and HeII emission lines were observed to be broader when the luminosity was higher.

X ray observations with EXOSAT (Viotti, 1987) show an anticorrelation of observed flux with activity. Indeed no X ray flux was detected in February 1986, following a new increase in luminosity. The question is whether the X ray flux really decreased, or just become softer.

Radio emission was detected by Torbett and Campbell (1986). The image appeared to be extended and asymmetric, which could suggest bipolar flow or a jet.

4. INTERPRETATIONS

Kenyon and Webbink (1984) interpreted the energy distributions of symbiotic stars in terms of a hot stellar companion, or assuming an accretion disk around the companion. In the case of AG Dra they found that they could only fit the energy distribution, by supposing the presence of a hot star. This apparent absence of an optically thick accretion disk might then suggest that the cool component of AG Dra does not fill its Roche lobe, and produces no overflow. The temperature according to Kenyon and Webbink's calculations of the order of 1.1×10^5 K increased slightly during the outburst, the radius 0.014 $R_\odot$ typical of a white dwarf before outburst (assuming a cool component of a normal K3 III type) then increasing by a factor of 2-3. They considered that the 1980 outburst of AG Dra was thermonuclear, but substancially less developed than the large scale events of other stars. The white dwarf would not then develop a very extended envelope, and its effective temperature would remain high. It may be noted that Iijima et al. (1987) did not find any published thermo-nuclear runaway model which fitted AG Dra; more model calculations may be needed. In any case the uncertainty in the luminosity of the cool component will affect the determination of that of the hot component; it is better to be sure of the correct luminosity before attempting a fit !

Garcia (1986) calculated the cool component mass loss rate required, if the X ray luminosity was converted gravitational energy due to capture of part of the wind from this component. He obtained the exceptionally high mass loss rate (for a K giant) of 10^{-7} $M_\odot$ yr^{-1}. This shows that the X rays are most easily explained by another mechanism such as radiation from an intrinsically hot white dwarf. However some uncertainty remains because of doubts concerning the nature of the cool component. The weakening of X ray emission during active phases does not have an obvious explanation, though one might suppose a drop of the effective temperature of the hot component. It remains to be seen whether this might be reconciled with the interpretation of the emission line fluxes.

The causes of the photometric and line profile variations in quiescence are not clear. Iijima (1987b) proposed that the orbit was elliptical, and that the photometric variations were due to a variation in the mass transfer rate during the orbital cycle. The low eccentricity found by Garcia (1986), if correct, seems to contradict this. Viotti et al. (1983) suggested an explanation by a "reflection" effect; in fact one could conceive of variations in the visibility of ionized regions of a "chromosphere" of the cool component (it is unlikely that the wind could give enough emission) present in quiescence. According to Garcia (1986) photometric maximum occurred at a phase of the radial velocity consistent with this interpretation.

The P Cygni profiles only seen for the NV doublet may suggest the presence of a rather low velocity wind of uncertain origin near the hot star.This wind could indeed be that from the cool component, accelerated by the pressure of radiation from the hot one. Such a wind might also play a role in producing the blue component of the Hα profile observed by Smith and Bopp (1981). A model with a "warm wind" from the cool component (temperature > 10^5K) proposed by Viotti et al. (1983) also to explain X ray emission, now seems less likely.

To conclude many interpretations of AG Dra are unsure. In order to test them we must be more certain about "elementary things" such as the luminosity of the cool component, and the elements of the binary orbit.

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