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Letter to the Editor

Discovery of a cataclysmic variable type companion of the M 3 III giant 4 Dra with IUE*

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Summary:

IUE observations show that the bright ($m_v \approx 5$) normal M 3 III giant 4 Dra has a blue companion. Its spectrum increases to shorter wavelengths in the IUE short wavelength region and has strong emission lines of high excitation (CIV, NV, CIII, HeII, ...) superimposed.

The spectrum of the companion of 4 Dra bears similarity to UV spectra of magnetic white dwarfs like AM Her and cataclysmic variables or old novae with some additional low excitation lines (CII, oI, ...) possibly formed in the radiatively excited wind of the M giant. The spectrum of the 4 Dra companion is different from those of all other known WD companions of red giants (e.g. Mira, 56 Peg, SY For).

4 Dra is apparently member of a new subclass of interacting binary systems - a normal M giant plus an AM Her or cataclysmic variable type star.

Key words: Variable stars - AM Her stars - cataclysmic variables - mass loss from red giants - white dwarfs

I. Introduction

Since the launch of the IUE satellite it has become possible to detect and observe faint blue companions of red giant stars because K and M giants have very low or no continuum fluxes below - depending on spectral type - 16oo Å (K 3) and 3ooo Å (M 3).

Böhm-Vitense (198o) detected white dwarf (WD) companions of the Ba stars ζ Cap and ζ Cyg (see also Dominy and Lambert, 1983). Schindler et al. (1982) found a hot, overluminous (Dominy and Lambert, 1983) WD companion of the Ko II p giant 56 Peg with numerous narrow emission lines superimposed upon the blue continuum which Jordan et al. (1982) attribute to the highly active chromosphere of the K giant itself. Finally, a hot WD was detected with IUE to be a companion of the bright K 3 II giant HD 81817 (Reimers, 1984).

In this paper I report the discovery of a blue companion of the M 3 III giant 4 Dra. 4 Dra seems to be the first example of a binary system that consists of a normal M giant and an AM Her or cataclysmic variable type star.

* Based on observations with the International Ultraviolet Explorer collected at the Villafranca Satellite Tracking Station of the European Space Agency

II. Observations

The bright M giant 4 Dra = BS 47o5 = HD 1o89o7 ($m_v \approx 5$, M 3 III a) was on a list of candidates of possible 'hybrid atmosphere' stars (Reimers, 1982) since its circumstellar CaII H+K lines revealed an unusual behaviour known from K giants but never seen in any other M giant: the regular, low velocity (in 4 Dra typically -8 to -15 km/s relative to photosphere) circumstellar CaII K line within the CaII emission core is exceptionally weak for an M giant (see also Boesgaard and Hagen, 1979), and a transient, high-velocity absorption feature was seen at -62 and -92 km/s on plates taken in March 1961 and March 1962 (plates of the Mt. Wilson and Palomar archive, cf. Fig. 3 in Reimers, 1977). According to the Bright Star Catalogue (Hoffleit, 1982) 4 Dra is a spectroscopic binary, and it was obvious that the episodic mass-loss seen in CaII H+K might be related to the binary nature.

The short wavelength low resolution IUE spectrum taken on October 22, 1984 (SWP 24 265 48 min. exposure) was a surprise: instead of the expected faint emission lines near the detection limit the spectrum shows a bright UV continuum with strong emission lines superimposed (Fig. 1). The long wavelength IUE spectrum (LWP 463o, 3o min, October 24, 1984) in addition offers the explanation why the companion was never seen in the optical UV (U-V is normal for an M giant): while the flat UV spectrum of the companion dominates the wavelength range λλ < 29oo Å, the M giant continuum increases steeply for λ > 31oo Å and dominates the spectrum already at 32oo Å.

a) Continuous energy distribution

In the 12oo Å to 19oo Å range the observed flux F_λ increases to shorter wavelengths while in the IUE long wavelength region the spectrum is either flat or the slope of the energy distribution even reverses into a slow decrease of F_λ to shorter wavelengths. It cannot be excluded with the present data that the slow increase of F_λ with wavelength λ in the LWP range between 22oo and 29oo Å is caused by a slowly increasing contribution from the M giant itself to an otherwise flat or even decreasing energy distribution of the companion. A weak interstellar 22oo Å absorption band indicates that dereddening would increase the steepness of the energy distribution in the SWP range somewhat.

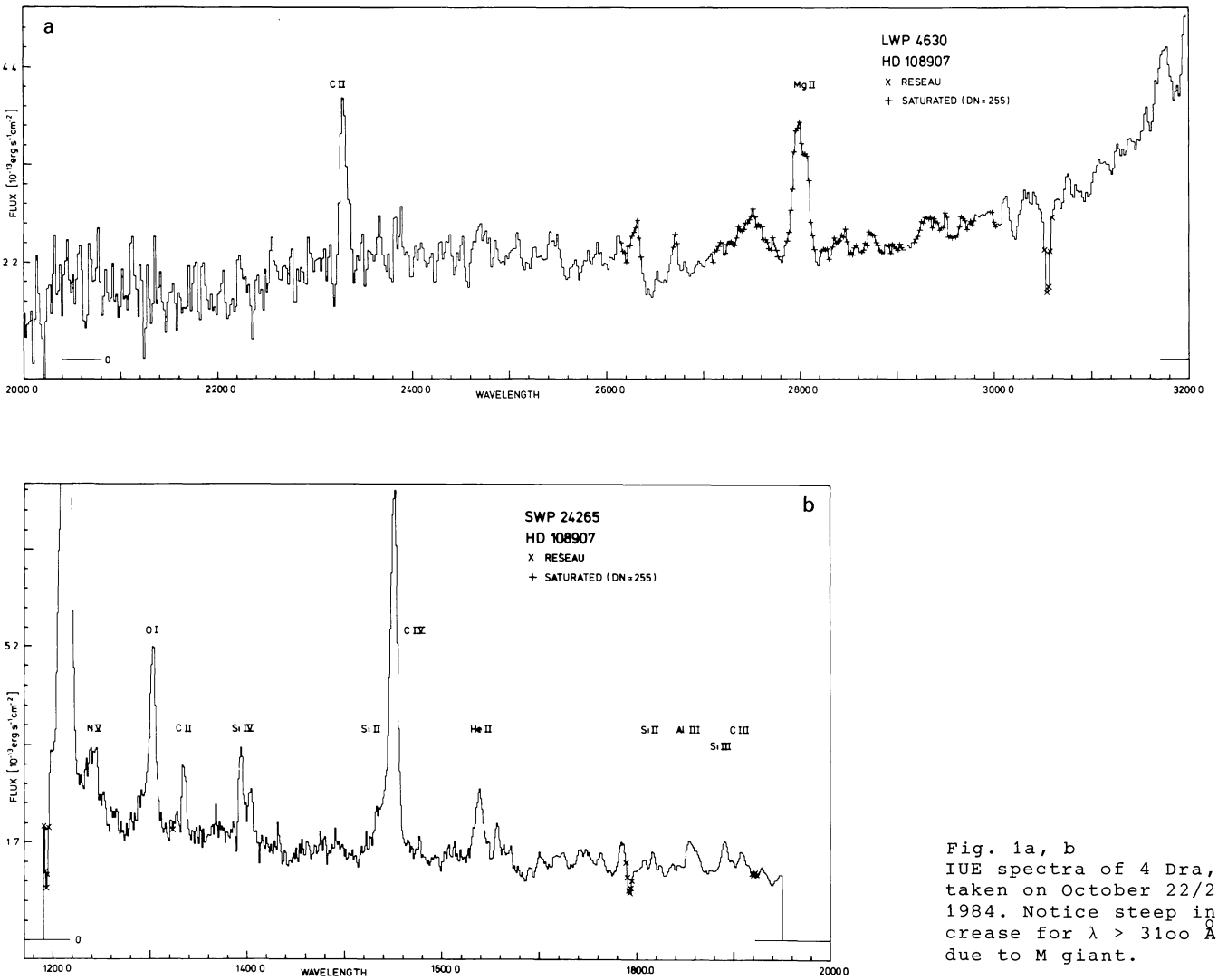

Fig. 1a, b
IUE spectra of 4 Dra, taken on October 22/24, 1984. Notice steep increase for $\lambda > 3100$ Å due to M giant.

The energy distribution of the 4 Dra companion bears great similarity to continuous energy distributions of cataclysmic variables of either the magnetic type (AM Her) or non-magnetic type (old Novae etc.), cf. Raymond et al. (1979), Fabbiano et al. (1980), Maraschi et al. (1984) and Giovanelli et al. (1984). In particular, there seem to be two components: A fairly flat component for $\lambda > 1500$ Å and a steeper component for $\lambda < 1400$ Å which is a characteristic of AM Her stars (in high state) or SS Cyg type stars, too. The total continuous UV flux at earth (1150 Å $< \lambda <$ 3200 Å), uncorrected for reddening, is about $3 \cdot 10^{-10}$ erg $cm^{-2} s^{-1}$. This leads to a UV luminosity of $L_{UV} \geq 3.6 \cdot 10^{32} (D/100\ pc)^2$ erg s^{-1}, where D is the distance [pc] of 4 Dra. An M3III giant has a typical absolute magnitude M_V between -0.5 and -1. With $m_V \approx 5$ this leads to a distance of about 150 pc and $L_{UV} \geq 8 \cdot 10^{32}$ erg s^{-1} which is comparable to the UV luminosity of AM Her in a high state, i.e. near X-ray maximum (Raymond et al., 1979). Without knowledge of the X-ray emission of 4 Dra B it is not possible to determine the total luminosity. Again, if it were comparable with AM Her, it would be $\sim 10^{34}$ erg s^{-1}.

b) Emission line spectrum

As can be seen in Fig.1, the SWP range is dominated by strong emission lines of highly ionized metals (CIV, CIII, NV, SiIV, AlIII, HeII). In addition, a few low ionization species (OI 1300, SiII 1808/15, SiII 1526/33, CI 1657 ?) and weak intercombination lines (SiIII] 1892, CIII] 1909) and unidentified lines are seen. The LWP range shows two strong emission lines: the MgII doublet and the CII UV Mult. 0.01 2325 Å multiplet.

Most lines appear unresolved in the IUE low resolution mode (6 Å) although some resonance lines look asymmetric with a steep violet emission edge and possibly absorption on the blue side (cf. CII 1335, SiIV, CIV, OI). At high resolution, these lines might show P Cyg type profiles. Other lines like HeII

164o Å are very broad and appear resolved (HWHM ≈ 9oo km/s).

Both the degree of excitation (ionization) and the line profiles (broad lines : HeII, CIV, NV; narrow lines: CII 1335/2325, SiII, λ 1658 Å) seem to indicate that the emission line spectrum is a mixture of lines formed under quite different physical conditions. While the high ion line spectrum bears similarity to the spectra of AM Her stars or cataclysmic variable type stars like SS Cyg, the additional emission not seen in such stars (CII 2325, SiII, strong OI) might well be formed in the wind of the red giant ionized and excited by the strong UV (and X-ray ?) continuum of the companion. Ionization of CaII in the M giant wind by UV photons with $\lambda \leq$ 1o44 Å from the companion seems indeed to be responsible for the unusual weakness of CS CaII H and K lines in 4 Dra.

The question of where and how the various emission lines of 4 Dra B are formed will be open at least until the line profiles are spectroscopically resolved. At high spectral resolution one might also see the matter ejected by the 4 Dra companion at velocities of about 1oo km/s and detectable at suitable binary phases in the CaII H+K lines of the M giant.

III. Conclusions

The M 3 III giant 4 Dra has been discovered with IUE to have a blue companion which can be seen only at wavelengths $\lambda \leq$ 31oo Å. The blue companion has a continuous and emission line spectrum in the UV similar to AM Her type stars or certain cataclysmic variable type stars. Additional lines are possibly formed in the M giant wind.

The spectrum of the companion is different from that of all other interacting WD companions of red giants observed so far with IUE: Mira B, SY For, 56 Peg, symbiotic stars. Mira B shows essentially a low temperature ($\sim 1o^4$ K) optically thin hydrogen f-b recombination continuum on which broad allowed and semiforbidden emission lines are superimposed which are formed in a rapidly rotating disk (Reimers and Cassatella, 1984). According to Coudé spectra and low resolution IUE spectra taken by myself, the late M giant SY For has a peculiar, blue companion visible already at wavelengths $\lambda \leq$ 42oo Å with an energy distribution that decreases to shorter wavelengths (see also Feast, 1975). 56 Peg has been described earlier in this paper.

4 Dra seems to be the first member of a new subclass of interacting binary stars: a normal M giant plus a cataclysmic variable or AM Her type star.

It will be interesting to observe 4 Dra with high resolution in the UV and in X-rays, as well as to determine the orbital elements of the system with optical radial velocity spectrometers. The X-ray brightness of 4 Dra could be comparable to that of AM Her.

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