PERIODIC VARIABILITIES IN THE IUE SPECTRA OF SS CYGNI

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ABSTRACT. The analysis of the IUE low resolution spectra of SS Cyg in quiescence clearly shows modulations with the orbital phase of the continuum and the emission lines total area. The shape of such modulations is depending on the type of the optical outburst preceding the quiescent phase in which the UV spectra were collected. This behaviour, together with those in other wavelength regions, could be explained within the framework of the intermediate polar models.

1. INTRODUCTION

SS Cyg is the brightest dwarf nova. The most recent review of this system has been done by Giovannelli et al. (1985). In this work, starting from the comparative analysis of the multifrequency behaviour and from several evaluations of the magnetic field intensity (~10**6 gauss), they have placed SS Cyg into the class of the intermediate polars, following the criteria of Warner (1983).

2. DATA ANALYSIS AND RESULTS

From the analysis of 37 IUE low resolution spectra (the whole available sample) of SS Cyg in quiescence we have derived the following information:

i) the continuum is fitted by two different power law distributions: shortward ~1450 Å, $F_\lambda \propto \lambda^{-4.0}$, in agreement with Fabbiano et al. (1981), longward ~1450 Å, $F_\lambda \propto \lambda^{-1.2}$ (Giovannelli et al., 1984). It is interesting to note that the UV continuum spectrum of SS Cyg has some resemblance to that of the polar AM Her, which shows a two-component continuum, one with a slope -1 and another one with -4 that dominates in the far-UV and is modulated with the binary

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period (Raymond et al., 1979);
ii) the reddening of SS Cyg is E(B-V) = 0.12 ± 0.02 mag. It has been derived by using the interstellar 2200 Å band and Seaton's (1979) extinction law. This value is in agreement with a first evaluation of Zuckermann (1961) and Kiplinger (1979);
iii) the orbital period phase has been computed using the ephemeris of Feldt and Chincarini (1980) (P = 0.2762213 ± 1.7*10**(-6) days). We decided that two spectra belong to the same orbital phase when the absolute difference between the relative phases is $\Delta\varphi \leqslant 0.04$, corresponding to ~ 14 minutes, which is the exposure time roughly necessary to get a good IUE SW low resolution spectrum of SS Cyg in quiescence. Overmore, we decided to divide in two classes the outbursts of SS Cyg: long and short (including in the short type class also the outbursts named anomalous by Howarth, 1978, due to the short duration of the maxima), in order to investigate the eventual dependence of the behaviour of the system in quiescence on the type of the preceding outburst.

The fluxes were rebinned to 50 Å and the values obtained around 1700 Å and 2700 Å, where spectral lines are

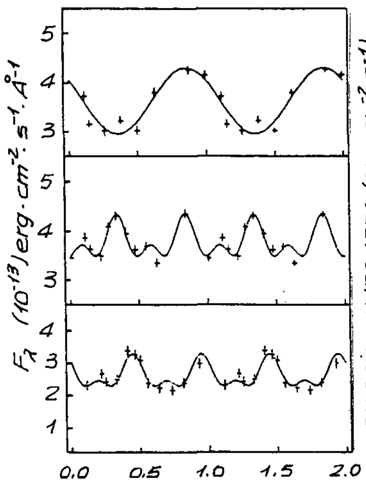

Fig. 1 – ORBITAL MODULATION OF THE CONTINUUM:
a) at 1700 Å AFTER LONG OUTBURSTS.
b) at 1700 Å AFTER SHORT OUTBURSTS.
c) at 2700 Å AFTER SHORT OUTBURSTS.

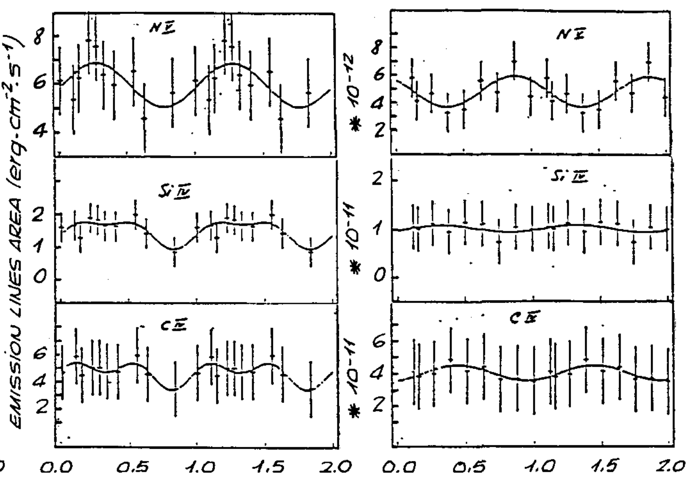

Fig. 2 – ORBITAL MODULATIONS OF N V, Si IV AND C IV EMISSION LINES TOTAL AREA:
LEFT) AFTER SHORT OUTBURSTS.
RIGHT) AFTER LONG OUTBURSTS.

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not present, show orbital modulations correlated with the type of the preceding optical outburst. fig. 1 shows these modulations of the continuum: a) at 1700 Å after long outbursts; b) at 1700 Å after short outbursts; c) at 2700 Å after short outbursts. Unfortunately, LW IUE spectra corresponding to quiescent phases after long outbursts are not available.

Also the spectral emission lines total area, during quiescence, show orbital modulations depending on the type of the preceding outburst, and, obviously, on the type of the considered ion. As example, the modulations of N V, Si IV and C IV after short and long outbursts are shown in Fig. 2, to the left and right, respectively. The best fit of the experimental data has been obtained by a least squares method, firstly developed for sinusoidal functions as described by Lomb (1976) and references therein; then, a goodness test has been used in order to verify the single fit. Generally, the fitting function can be described by

$$\psi(\varphi) = c_1 f_1(\varphi) + c_2 f_2(\varphi) + c_3$$

where φ is the orbital phase, f_1 and f_2 are sinusoidal functions of φ (or 2φ). The minima in the quiescent modulation curves of the reported ions are roughly around 0.25 and 0.75 orbital phase, after short outbursts.

3. DISCUSSION AND CONCLUSIONS

Voloshina and Lyutyi (1983) have found orbital modulations in UBV light curves of SS Cyg in quiescence. The two minima are at 0.25 and 0.75 orbital phase, roughly corresponding to the minima detected by us in the UV emission lines total area after short outbursts. So that, the behaviour in optical and UV ranges seem to become from the same process. Voloshina and Lyutyi (1983) have explained this phenomenon as due to eclipse of the disk by the secondary star and have derived an orbital inclination angle equal about to 70 deg. Then, the deduced masses of the white dwarf and the secondary star (M5 V in their evaluation) are 0.3 M⊙ and 0.2 M⊙, respectively.

Against these conclusions, we have some remarks, namely: a) the spectral type of the secondary star cannot be M5 V because features, characteristic of such a spectral type, do not appear in the optical spectrum of SS Cyg (sum of the two spectra: accretion disk and secondary star); b) with the orbital period equal to 6.6 hours, the mass and radius of the secondary star cannot be less than 0.5 M⊙ and 0.66 R⊙, respectively, unless to invalidate all the theories on cataclysmic variables; c) all the evaluations of the orbital inclination angle give $i \approx 40$ deg (e.g. Giovannelli et al., 1983, and the references therein; Hessman et al., 1984), which does not allow the eclipse in the system.

Then, leaving the idea of the eclipse, we believe that all the panorama could become clear considering SS Cyg as an intermediate polar, like suggested by Giovannelli et al. (1985). In fact, in this case, the magnetic field of the white dwarf is sufficient to shift the magnetosphere and therefore the boundary layer between the accretion disk and the white dwarf without the disruption of the disk itself and with the formation of two large polar caps. The magnetic axis, not coincident with the rotational axis, could be responsible of the precessional motion causing the modulations of the continuum and the emission lines total area. Alternatively the energy dissipated in the boundary layer could heat locally the white dwarf up to about few tens thousands °K causing an effect like the presence of a pseudo-white dwarf at such a temperature (Patterson and Raymond, 1985). Therefore, the resulting radiation in EUV/soft-hard X-ray ranges could be orbitally modulated. A composition of the two last described effects could be also possible.

The optical UBV behaviour of SS Cyg, showing orbital modulations in phase with those in UV, could be simply the tail of the same process started close to the white dwarf in higher energies.

Simultaneous X-ray, UV and optical observations could give the final answer to this still open problem. We have planned such sort of simultaneous observations, in particular in UV and X-ray with IUE and ASTRON satellites in December 1986 - January 1987.

REFERENCES

Fabbiano, G., et al.: 1981, Astrophys. J. 213, 145.
Feldt, A.N., Chincarini, G.: 1980, Pub. Astr. Soc. Pacific 92, 528.
Giovannelli, F., et al.: 1983, Acta Astron. 33, 319.
Giovannelli, F., et al.: 1984, ESA SP-218, p. 391.
Giovannelli, F., et al.: 1985, in Multifrequency Behaviour of Galactic Accreting Sources, F. Giovannelli (ed.), Siderea, Roma, p. 37.
Hessman, F.V., et al.: 1984, Astrophys. J. 286, 747.
Howarth, I.D.: 1978, J. Br. Astron. Assoc. 88, 5, p. 458.
Kiplinger, A.L.: 1979, Astron. J. 84, 655.
Lomb, M.R.: 1976, Astrophys. Space Sci. 39, 447.
Patterson, J., Raymond, J.C.: 1985, Astrophys. J. 292,535.
Raymond, J.C. et al.: 1979, Astrophys. J. Letters 230,L95.
Seaton, M.J.: 1979, Mon. Not. R. astron. Soc. 187, 73p.
Voloshina, I.V., Lyutyi, V.M.: 1983, Soviet Astron. Letters 9, 319.
Warner, B.: 1983, IAU Coll. No. 72, p. 155.
Zuckermann, M.C.: 1961, Annales d'Astrophysique 24, 431.