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Amplitude of flickering and magnetic field of white dwarf in symbiotic stars

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Abstract. The flickering amplitude in the Johnson U-band increases with the increase of the hot component flux for symbiotic stars T CrB and CH Cyg. We suggest that the flickering amplitude can be used to distinguish between magnetic and non-magnetic white dwarf (WD), when the WD is embedded in a dense accretion disk. We suppose that the flickering amplitude depends on the density at the inner edge of the accretion disk and the mass accretion rate ($\dot{M}$). We expect the flickering amplitude, ΔF, to be a power function of the mass accretion rate, $\Delta F \propto \dot{M}^k$, where $k = 1$ for non-magnetic WD, and $k = \frac{10}{7}$ for magnetic WD. On the basis of observations it has been obtained $k = 1.42$ for CH Cyg (Mikolajewski et al. 1990), and $k \simeq 1$ for T CrB (our observations). This indicates that the white dwarf in CH Cyg is magnetic, but in T CrB it is non-magnetic.

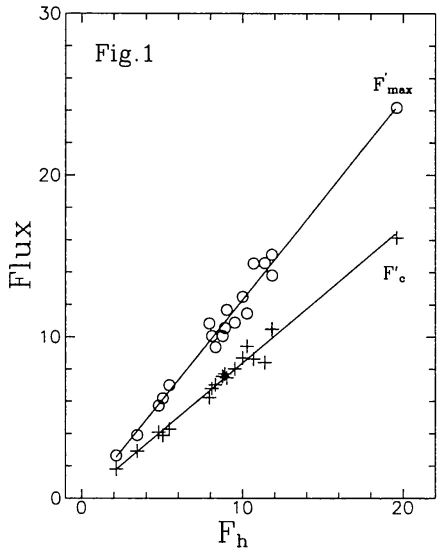
1. Introduction

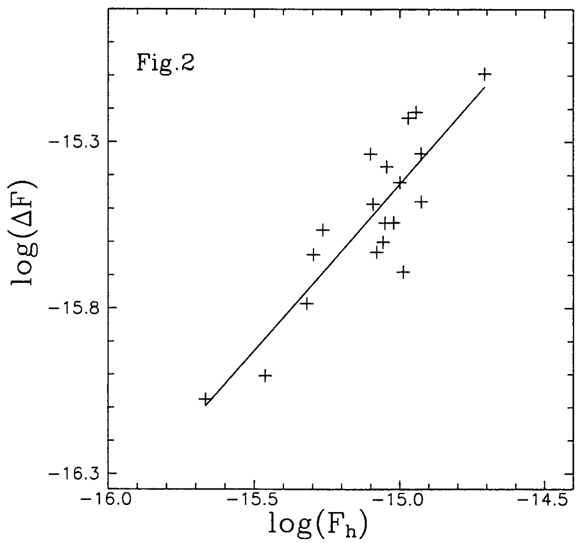
The flickering is a phenomenon connected with the accretion. It is observed in the light curves of classical and recurrent novae in quiescence, of dwarf novae in quiescence and outbursts, and in nova like variables. Bruch (1992) and Bruch & Duschl (1993) identified the boundary layer between the white dwarf and the accretion disk as the most probable source of the flickering.

A part of the cataclysmic variables contain magnetic white dwarfs - polars and intermediate polars. Recently, Mikolajewski et al. (1996) suggested that some symbiotic stars (CH Cyg, MWC 560, RS Oph, T CrB) also contain magnetic WDs. On the other hand the behavior of T CrB during the 1866 and 1946 outbursts as well as the UV observations indicate that the white dwarf accretes material at a rate of about $\sim 10^{-8}\ M_{\odot}\ yr^{-1}$ (Selvelli et al. 1993) in this system, and consequently even if the white dwarf is magnetic it will be in the accreator stage.

2. Flickering Quantities

Fig.1 presents the behavior of the flickering quantities in the Johnson U band for the recurrent novae T CrB. F'_{max}, F'_c and F_h are the maximum flux emitted





Left (Fig. 1): The flickering quantities F'_{max} and F'_c versus the flux of the hot component for T CrB in the Johnson U band. The axes are in units 10^{-16} $Watt\ m^{-2}\ nm^{-1}$. The lines represent the best linear fits.
Right (Fig. 2): The flickering amplitude versus the flux of the hot component in T CrB in logarithmic axes. The best fit is also plotted. The quantities are in units $Watt\ m^{-2}\ nm^{-1}$.

from the hot component, the flux of the quiet source, and the average flux from the hot component respectively, in the Johnson U band for every night of observation. All quantities are corrected for the contribution of the red giant (see also Bruch 1992; Zamanov & Bruch 1998). The best linear fits in Fig.1 are as follows:

$$F'_{max} = (1.231 \pm 0.016)F_h, \qquad F'_c = (0.838 \pm 0.010)F_h. \qquad (1)$$

The fits give better results when we use approximation $y = ax$ instead of $y = ax + b$.

Fig. 2 shows the flickering amplitude versus the flux of the hot component for T CrB in logarithmic scale.

The data points in Fig.1 and Fig.2. show that the flickering amplitude depends on the average hot component flux. A similar correlation has been reported for CH Cyg by Mikolajewski et al. (1990). Their results show that the flickering amplitude in CH Cyg is a power function of the luminosity of the hot component, i.e. $\Delta F \propto (F_h)^k$, where $k = 1.40 - 1.45$. But the flickering data for T CrB (Fig.1) point to $k = 1.0$. The best fit in Fig.2 is $k = 0.99 \pm 0.12$.

In the next section we will propose an explanation of these results, supposing that the different behavior of T CrB and CH Cyg can be due to the magnetic field.

3. Amplitude of flickering and magnetic field

In our opinion the different behavior of the flickering amplitude can be due to the magnetic field. Hereafter we will adopt that the net flux of the hot component in U, F_h, depends on the mass accretion rate as $F_h \propto \dot{M}$. It is true if the energy distribution does not change. For T CrB the variability of F_h is up to 20 times (Fig.1). Variations up to 20 times has also been observed in the integrated UV flux (Selvelli et al. 1992) which point to the mass accretion rate varies over the same range.

For a long time the hot spot has been considered as the flickering source. Bruch (1992) and Bruch & Duschl (1993) identified the boundary layer between the white dwarf and the accretion disk as the most probable source of the flickering. In our opinion the unsteady mass accretion onto the white dwarf is the most likely cause for the flickering. Elsworth & James (1982) considers blobs of matter formed to the inner edge of the accretion disk. Bruch (1992) supports the idea of unsteady accretion and speculates on the impact of the blobs on the white dwarf surface.

If the white dwarf is magnetic the inner parts of the accretion disk will be destroyed by the magnetic field. Different instabilities can operate at the inner edge of the disk. These instabilities permit the disk material to be absorbed by the magnetosphere as blobs (Gosh and Lamb 1979; Lipunov 1992 and reference therein).

The blob formation in accretion disks is possible because of the turbulence. Several mechanisms of angular momentum transfer and energy dissipation have been supposed (Papaloizou & Lin 1995; Lin & Papaloizou 1996) and the most effective of them operate via turbulence. The turbulent eddies at the inner edge of the disk could make the material fall on the central star as blobs.

In both cases (magnetic and non-magnetic WDs) blobs are expected to be formed at the innermost edge of the accretion disk. The energy released will be unsteady and it is plausible to accept that the amplitude of the flickering is proportional to the typical blob mass, and the mass of the blobs is proportional to the density at the inner edge of the disk, i.e. the more dense inner disk edge will produce more massive blobs and larger flickering amplitude. In other words the flickering amplitude would depend on the density at the innermost edge of the accretion disk. The density in the disk can be estimated as (Lipunov 1992):

$$\rho \approx \alpha^{-1} \left(\frac{R}{H}\right) \frac{\dot{M}}{4\pi R^{3/2}\sqrt{2GM}}, \tag{2}$$

where (R/H) is the ratio between the radius and the vertical size of the disk, (R/H) is usually adopted to be constant of about 0.01–0.1. M is the WD mass, $\dot{M}$ is the mass accretion rate .

If the white dwarf is non-magnetic the inner radius of the disk will be approximately equal to the white dwarf radius (for thin boundary layer) and consequently the density at the inner edge $\rho_{in} \propto \dot{M}$. The same will be fulfilled if the boundary layer is not thin and its size do not change.

If the white dwarf is magnetic the radius R_0 of the inner disk edge may be expressed as (Lamb, Pethick & Pines 1973):

$$R_0 = N(GM)^{-1/7}\mu^{4/7}\dot{M}^{-2/7}, \tag{3}$$

where N is a constant of order 1, μ is the WD magnetic dipole moment. In this case (from Eqn. 2 and 3)

$$\rho_{in} \propto \dot{M}^k, \qquad k = \frac{10}{7} = 1.43 \tag{4}$$

The above considerations give us the result that the innermost accretion disk density will expose different behavior:

$\rho_{in} = const \times \dot{M}^{1.0}$ for non-magnetic WD,
$\rho_{in} = const \times \dot{M}^{1.43}$ for magnetic WD.

The observations of CH Cyg ($\Delta F \propto F^k$, where $k = 1.40 \div 1.45$, Mikolajewski et al., 1990), are in excellent agreement with magnetic WD, if our supposition $\Delta F \propto \rho_{in}$ is correct.

The flickering data for T CrB (Fig.1, Fig.2) point to $k = 1.0$. This implies the white dwarf in T CrB is non-magnetic or its magnetic field is weak and does not affect the accretion.

4. Conclusions

There is not a self consistent picture of the flickering till now. We have supposed that the behavior of the amplitude of the flickering can be used to distinguish between magnetic and non-magnetic white dwarfs in symbiotic stars. Our results point to the white dwarf in CH Cyg is magnetic (as it is supposed from the recent models of this system, e.g. Tomov et al. 1996) and in T CrB it is non-magnetic.

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