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THEORETICAL LINE PROFILES OF THE MAGNETIC COMPACT STARS

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ABSTRACT

Using a phenomenological model for the accretion onto the magnetic white dwarf, we calculated some optical line profiles from the magnetosphere of such systems. Line profiles of these systems seem to be produced in the magnetosphere of the compact star due to the reemission of X-ray produced near the stellar surface. Some results of our new calculation and the analysis of these results will be presented. Our results show that the model used here can reproduce the observed optical line profiles and open the possiblity to determine the parameters of individual systems.

Key Words : Stellar Astronomy - magnetic compact stars - accretion

I. INTRODUCTION

Magnetic cataclysmic variables contains a mass-accreting magnetic white dwarf and a late type main sequence star. According to the standard model, an accretion disc may form around the magnetic star in this system. The magnetic field of the compact star can disturb the accretion disc. At the so-called Alfven radius where the ram pressure and magnetic pressure are equal, the accretting matter will be funneled to the magnetic field, and flow into the magnetic pole(s) of the compact star. General description of the accretion phenomena in the magnetic white dwarfs can be found in Schmidt & Liebert (1987) and Chanmugam (1992). Standard model assumes the statinary flow of the shock heated accreting material near the stellar surface and the radiation mainly in the form of bremsstrahlung at a temperature of typically $T_s \sim 10^8$ K. These hard X-rays will be partially absorbed in the magnetosphere before escaping. Hence the azimuthal structure of both the emission region and the absobing matter will be imprinted upon the escaping radiation. Similarly, the geometry of the heated accretion stream will determine the phase dependence of the emitted optical radiation (Rosen et al. 1988, Norton & Watson 1989).

There are some calculations for the modulation of either the X-ray or the optical flux (Rosen et al. 1988, Ferrario et al. 1993, Norton 1993), however they can not explain the interplay between the radiative transport in the X-ray and optical regimes consistently. Kim & Beuermann (1995, 1996, henceforth papers I and II) have presented a calculations for the case of accretion from a surrounding disk into the magnetosphere of the white dwarf.

Using this phenomenological model, we calculated some optical H β line profiles from the magnetosphere of such systems. Our calculation is an attempt to provide the tools necessary for direct comparison with observation.

II. CALCULATION

It is assumed that the accreting matter penetrates inward to the Alfven radius. We adopted a dipole geometry and a partial-covering model for the absorption of X-rays in the magnetosphere. From the calculation the X-ray flux absorbed in the accretion flow of the magnetosphere, we estimate the absorbed energy which is responsible for the reemission in the optical wavelength.

The magnetospheric stream is divided in longitude into 36 flux tubes, and each flux tube is subdivided into 20 poloidal segments, yielding a total of 720 mass-carrying segments in the magnetosphere. For each segment, we calculated the re-processed optical spectrum from the estimated absorbed energy with the assumption of LTE. The observed optical flux is then calculated at a given phase by adding up the optical spectrum of all visible segments (Eq. 5 of paper II). We adopted some simplification in the radiative transfer of the optical radiation. More details of such simplification can be found in papers I and II.

III. RESULTS AND DISCUSSION

A specific set of nominal parameters has been defined as our reference model and any individual parameter is varied around this value, keeping the other parameters constant (see Table 1 in paper I). The reference model is close to the set of parameters appropriate for the system EX Hya as determined by Hellier et al. (1987).

Figure 1 shows the Hβ line profiles for i=40, 70 and 85 ° at the phase 0.5. It is clear that the line shape depends on the inclination. Peaks in the line profile originate from the velocity crowding of the accreting matter. If many accreting segment with similar radial velocity are observed, a centeral peak will form in the line profile. The overall profile corresponds therefore to the range of the line of sight components of the free fall velocities in the flux tube. The width of the line profile

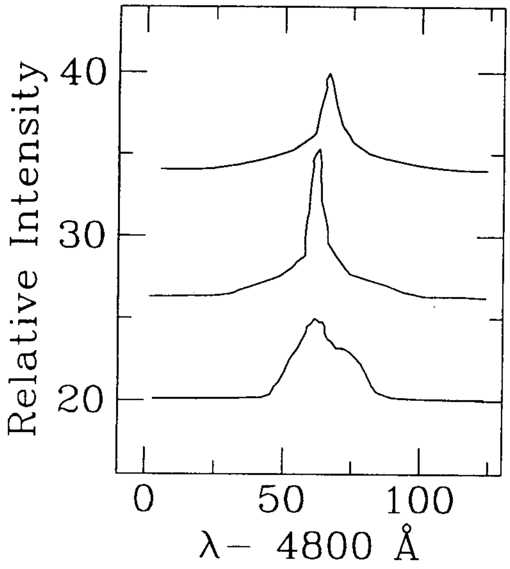

Fig. 1.— Inclination dependent Hβ line profiles for i = 40, 70 and 85 ° (from bottom) at ϕ =0.5. Individual profiles are shifted upwards by a constant amount.

Table 1. The radial velocity of the central peak of the line profile at ϕ = 40, 70 and 85°

$i\backslash\phi$	0.0	0.25	0.5
40°	-5	-3	-3
70°	-3	-2	-2
85°	-1	0	0

is also phase dependent, and seems to be maximum at ϕ = 0.5. This dependency has been observed in EX Hya (Hellier et al. 1987). More careful analysis of the formation of line profile showed that the broadening of line profiles comes from the relative more contributions by the inner segments of the accretion flow than by the outer segments.

Another characteristic feature is the double peak structure which develops at lower inclination. This result suggests that the occurrence of double peaks in the spectra of intermediate polars (e.g. Rosen et al. 1988) may not necessarily represent unique evidence for the presense of an accretion disk. We conclude that a more detailed study of the funnel flow is required to exclude that such peaks may be mistaken for disk lines.

In our new calculation, the radial velocities of all funnel segments has been tabulated at a given phase, in order to identify the region responsible for the line structure. We present the result in Table I. As can be seen in Figure 1 and Table I, the radial velocity of the central peak depends on the inclination. The position of the peak varies not only with the phase, but also with inclination. The numbers in the table corresponds to the wavelength shifts in $\AA$, and the negative sign implies the blue shift. 1 $\AA$ corresponds to the radial velocity of 63 kms^{-1}. This result can be used to the comparison study of theretical and observational line profiles of the magnetic compact stars.

In conclusion we note that model calculation of the present type can be used to determine the accretion geometry of the magnetic compact star. The calculation of the Hγ line profile is on progress.

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