POLARIZED RADIATION FROM INHOMOGENEOUS ACCRETION COLUMNS IN AM HERCULIS BINARIES

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Abstract

The polarization of radiation emitted by inhomogeneous accretion columns is found to be significantly different from homogeneous columns. A good fit to the V-band circular polarization light curve of EF Eri is obtained using the two-core model with temperature kT=15keV, magnetic field B=26MG, and dimensionless plasma parameter $\Lambda \approx 10^6$.

I. Introduction

The AM Herculis binaries, a subclass of cataclysmic variables, consist of a magnetic white dwarf rotating synchronously and accreting matter from a lower main-sequence secondary through an accretion column. A distinguishing characteristic of these systems is the strong circular polarization ($\sim$ 10%) observed in the optical and infrared bands (e.g. Liebert and Stockman 1985, Lamb 1985). Such polarized radiation is believed to be due to cyclotron emission arising from the post-shock region in the accretion column, or its vicinity.

In most calculations, the emitting region was considered to be a homogeneous plasma slab (Chanmugam and Dulk 1981, Barrett and Chanmugam 1984) or a hemisphere (Wickramasinghe and Meggitt 1985) with a temperature $kT \approx 10$ keV, a magnetic field $B \approx 30$ MG, and a dimensionless plasma parameter $\Lambda \equiv 4\pi Nel/B \sim 10^6$ (e.g. Chanmugam and Wu 1987), where N is the electron number density and l the characteristic size of the plasma. However, the predicted optical spectra of these homogeneous models have a very steep slope in the optically thin part and a sharp peak in the transition between the optically thick and optically thin regions, which is in contrast to the flat spectra observed. The predicted polarization is also much higher in the optical band but much lower in the infrared band when compared with the observations.

Recently, inhomogeneous accretion columns have been studied (e.g. Schmidt, Stockman and Grandi 1986; Wu and Chanmugam 1988; Wickramasinghe and Ferrario 1988), and these columns have been found to produce flatter spectra; thus providing better fits to the spectra of ST LMi, V834 Cen, and EF Eri (Wu and Chanmugam 1988). In addition, the inhomogeneous models can also explain the different sizes of the optical and X-ray emitting regions observed by Beuermann (1987). The effects of inhomogeneities on the polarization, which have not been discussed previously, are examined in this paper. The V-band polarization curve of the system EF Eri is fitted using one of the inhomogeneous models, the two-core model.

II. Polarization

Consider an infinite plasma cylinder with a uniform temperature and a uniform magnetic field parallel the the symmetry axis, but an electron density varying across the cylinder. Three types of electron density profiles, homogeneous, Gaussian, and two-core, are studied here. The Robinson and Melrose (1984) analytic formulae for the cyclotron absorption coefficients are used in solving the radiative transfer equations.

In figure 1 the polarization is plotted against the viewing angle θ, with the magnetic field, for the harmonic number $s = 7$. In all cases the electron density profiles are normalised to have an accretion luminosity equivalent to that due to a homogeneous cylinder with $N = 10^{16} cm^{-3}$. The temperature is kT=10keV, the magnetic field 25MG, and the radius of the cylinder $10^7 cm$. Negligible circular polarization is produced by the homogeneous cylinder for $90° \geq \theta \geq 60°$, compared to a few % for the the two inhomogeneous cylinders (Figure 1a). When θ decreases, the circular polarization due to both the homogeneous cylinder and the cylinder with the Gaussian density profile increases rapidly. The former reaches 80%, the latter 70%, while for the two-core profile it increases slowly up to about 30%. All cylinders produce about 1% linear polarization at $\theta \sim 30° - 60°$, but at $\theta \approx 90°$ only the inhomogeneous cylinders produce significant linear polarization ($\approx$ 15%) (Figure 1b). In Figure 2 the circular polarization is plotted against $\log(1/\lambda)$, where λ is the wavelength of the radiation in μm, for the same parameters as in figure 1. Compared to the homogeneous models, the inhomogeneous models generally produce larger circular polarization in the infrared band but smaller circular polarization in the optical band.

III. EF Eri

The optical spectrum of EF Eri, unlike that of ST LMi, is very flat and hence cannot be explained by homogeneous models. However, Wu and Chanmugam (1988) obtained a good fit to the optical spectra using the two-core model with the parameters: kT=15keV, $R = 10^7 cm$, $N_{core} = 10^{17} cm^{-3}$, $N_{shell} = 10^{14} cm^{-3}$, and $(R_{core}/R_{shell})^2 = 0.05$. These values are adopted here to fit the observed V-band polarization light curve obtained by Piirola, Reiz, and Coyne (1987). Polarization light curves for homogenous models with

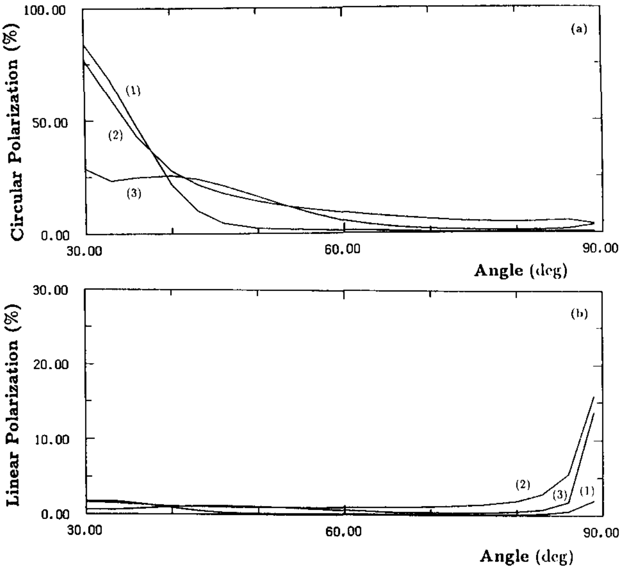

Figure 1: (a) The circular polarization is plotted against θ for $s = 7$ for cylinders with $R = 10^7 cm$, kT=10keV, B=25MG and $\bar{N} = 10^{16} cm^{-3}$. Curve 1 corresponds to a homogeneous cylinder, curve 2 a Gaussian cylinder, and curve 3 a two-core cylinder. (b) The linear polarization is plotted against θ for cylinders with the same parameters as (a).

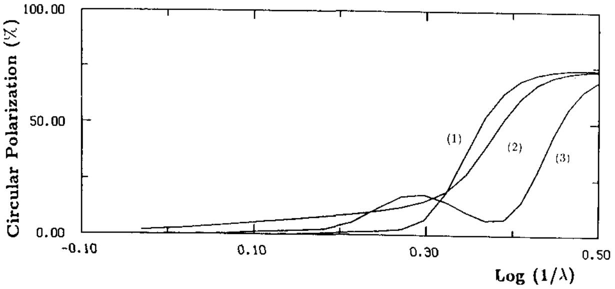

Figure 2: The circular polarization is plotted against $\log(1/\lambda)$ for $\theta = 60°$, where λ is given in μm. Curve 1 corresponds to a homogeneous cylinder, curve 2 a Gaussian cylinder, and curve 3 a two-core cylinder. The parameters are the same as those in figure 1.

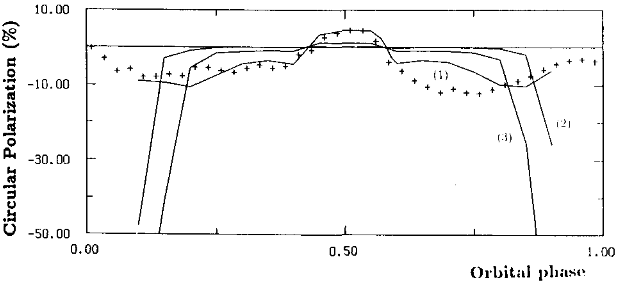

Figure 3: Fit to the V-band circular polarization curve of the system EF Eri: curve 1 corresponds to a two-core cylinder with kT=15keV, $N_{core} = 10^{17} cm^{-3}$, $N_{shell} = 10^{14} cm^{-3}$, $(R_{core}/R_{shell})^2 = 0.05$ and $R = 10^7 cm$, curve 2 a homogeneous cylinder with $N = 10^{16} cm^{-3}$ and $R = 10^7 cm$, and curve 3 a homogeneous cylinder with $N = 10^{16} cm^{-3}$ and $R = 10^6 cm$.

$N = 10^{16} cm^{-3}$ and $R = 10^6 cm, 10^7 cm$ are also generated for comparison (Figure 3). The two-core model clearly provides better fits to both the optical spectrum and the circular polarization.

IV. Conclusions

Our calculations shows that inhomogeneous cylinders generally produce larger circular and linear polarization at angles close to 90° compared with homogeneous cylinders, but smaller polarization at $\theta \approx 30°$ for a given harmonic number. The inhomogeneous cylinders also produce larger circular polarization in the infrared band. A good fit to the V-band circular polarization curve of EF Eri is obtained, showing that the parameters of the emitting region are $kT=$ 15keV, B=26MG, and $\Lambda \approx 10^6$. Such values are identical to those used to fit the optical continuum in Wu and Chanmugam (1988), thus implying the self-consistency of our model and the significance of inhomogeneities on the spectrum and polarization.

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