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THE ACCRETION COLUMN OF DQ HERCULIS BINARIES

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RESUMEN. Un modelo de la columna de acreción de las binarias en DQ Herculis ha sido desarrollado usando valores bajo en el campo magnético ($\leq$ 25 MG). Obtuvimos una polarización circular < 3% y una polarización lineal < 1.5%. Se pueden comparar estos resultados con aquellos de Chanmugam and Frank (1987), quienes obtuvieron solamente baja polarización para campos magnéticos intensos ($\geq$ 75 MG).

ABSTRACT. A model of the accretion column of DQ Herculis binaries was developed, using low values of the magnetic field ($\leq$ 25 MG). We obtain circular polarization < 3% and linear polarization < 1.5%. These results can be compared with those of Chanmugam and Frank (1987), who only obtained small polarization for high magnetic fields ($\geq$ 75 MG).

Key words: POLARIZATION — STARS-ACCRETION — STARS-BINARY

. INTRODUCTION

A subgroup of cataclysmic variables is the DQ Herculis binaries (DQ Her). They re close binary systems in which a white dwarf accretes matter from a red dwarf (Robinson, 976). The optical and X-ray variations occur at periods shorter than the orbital period hich implies that the white dwarf rotates asynchronously (Chanmugam and Frank, 1987). The ystem shows evidence of an accretion disk (Warner, 1983, 1985) and the degenerate dwarf is elieved to have been spun up to a short rotation period by the accretion torque (Lamb and elia, 1987). The optical light from these systems show little or no optical polarization < 1%). The magnetic field of DQ Her may be weak (<< 10^7 G) (Chanmugam and Ray, 1984) or as trong as a few x 10^7 G (Chanmugam and Frank, 1987). In no case has the magnetic field of Q Her binaries systems been measured spectroscopically.

I. THE MODEL

We constructed a model of the accretion column of DQ Herculis binaries where the radients of temperature, magnetic field, and density are taken into account in both the arallel and perpendicular directions with respect to the axis of the accretion column. We implify the geometry assuming that the column is formed by a pile of thin coaxial cylinders Fig. 1).

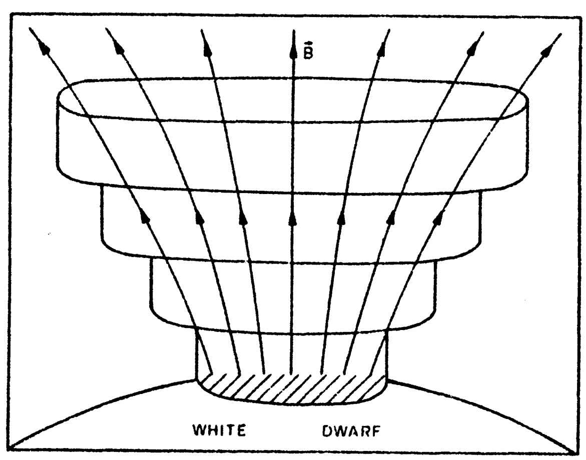

Fig. 1. A sketch of the accretion column represented by a pile of cylinders.

III. THE GRADIENTS

We assume that the white dwarf has a dipole magnetic field with origin at its center ($z = 0$). In Fig. 2 we sketch the dipole magnetic field, the white dwarf, and the accretion column. The axis (z) of the dipole and the axis of the column are coincident, b_z is the radius of the column at height z, b_o is the radius of the column at the base of the column ($z = R_{wd}$), r and α determine a point on the line of the magnetic field (where α is the angle between z and r). The value of b_o is defined by $f = \pi b_o^2/4\pi R_{wd}^2$, where R_{wd} is the radius of the white dwarf. Below we give the relation between z and b_z for a given value of f:

$$b_z^{4/3} - k^{2/3}(b_z^2 + z^2) = 0 \quad , \quad k^{2/3} = (4f/R_{wd})^{2/3}/(1 + 4f) \qquad (1)$$

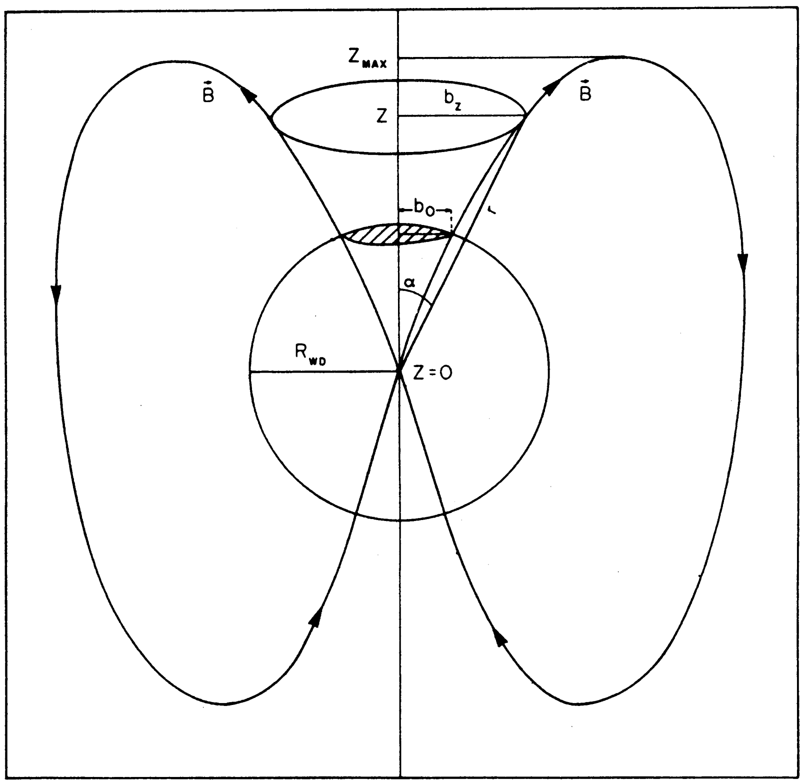

Fig. 2. Sketch of the relation between the lines of the dipole magnetic field, the white dwarf and the accretion column.

The gradient of magnetic field:

$$\vec{B} = \frac{B_o R_{wd}^3}{2 z^3} \frac{(4 + (y/z)^2)^{1/2}}{(1 + (y/z)^2)^2} \quad , \quad 0 \le y \le b_z \qquad (2)$$

The gradient of density:

$$N(y,z) = N(0,z) \exp(-(y/b_z)^2 k_n) \quad , \quad 0 \le y \le b_z \qquad (3)$$

where

$$N(0,z) = N(0,R_{wd})\ (b_o/b_z)^2\ (z/R_{wd})^{1/2} \tag{4}$$

where $N(0,R_{wd})$ is the value of the density at the center of the base of the accretion column ($z = R_{wd}$).

The gradient of temperature:

$$T(y,z) = (T(0,z_{max}) - (T(0,z_{max})-T(0,R_{wd}))\ (1 - (\frac{z - R_{wd}}{z_{max} - R_{wd}})^P)\exp(-(\frac{y}{b_z})^2 k_T) \tag{5}$$

where $T(0,z_{max})$ is the high temperature (upper end) of the accretion column and $T(0,z=R_{wd})$ is the temperature at the base of the column, and $R_{wd} < z < z_{max}$. P and k_T are positive parameters to be adjusted (Canalle and Opher, 1988, 1989a). The equations of radiative transfer and polarizations were taken from Canalle and Opher (1989b).

IV. RESULTS AND CONCLUSIONS

The circular polarization is small in Fig. 3. For a magnetic field 5 10^6 G (letter b), the circular polarization is approximately 0.5%; for 1.5 10^7G (letter c) it is approximately 2% and for 2.5 10^7 G (letter d) it is approximately 3.5%. For a magnetic field 1 10^6 G (curve a) the circular polarization is 4.5% for λ = 4000 Å and decreases to 1.5% for λ = 7000 Å. For 1 10^6 G and 5 10^6 G the linear polarization is almost zero, for 1.5 10^7 G the linear polarization is approximately constant and equal to 0.3%, and for 2.5 10^7 G the linear polarization is in the range of 0.6 - 1.5%. The results of Fig. 3 indicate that the magnetic field in DQ Her binaries is, probably, less than 10^7 G.

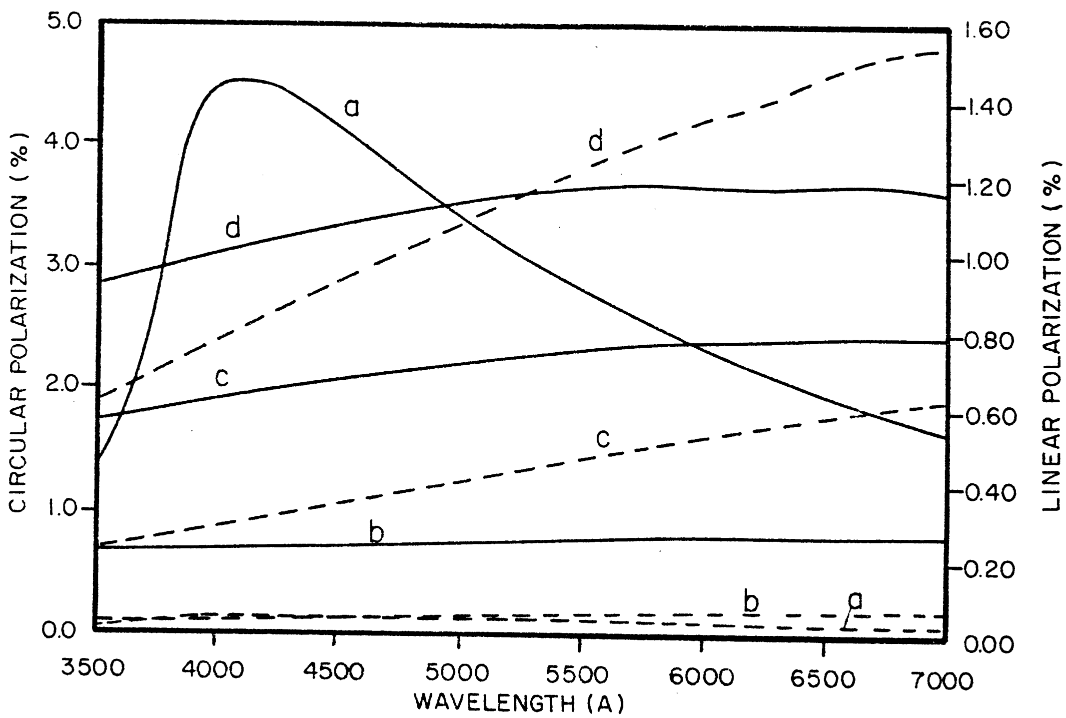

Fig. 3. The circular and linear polarizations as a function of wavelength (in Angstroms) for various values of the magnetic field. The parameters used are: density N_o = 7 10^{16} cm^{-3}, temperature at the center of the base of the accretion column 1 keV/k_B and at the top of the column 5 keV/k_B, height of the column H = 0.04R_{wd}, radius of the white dwarf R_{wd} = 8 10^8 cm, radius of the accretion column at the base b_o = 4.9 10^8 cm and at the top 5.2 10^8 cm, f = 0.092, angle between line of sight and axis of the column

80º, $k_n = 1$, $k_T = 2$, and $p = 10$. The symbols a, b, c, and d are the values of the magnetic field at the center of the base of the column, and are respectively $1\ 10^6$ G, $5\ 10^6$ G, $1.5\ 10^7$ G and $2.5\ 10^7$ G. The solid (dashed) curves are the circular (linear) polarization.

Chanmugam and Frank (1987) investigated the polarization emitted from a large polar cap, assuming constant density and temperature and a small height ($h \sim 10^6$ cm). They obtained little polarization only when using high values of the magnetic field ($\gtrsim$ 75 MG). In our model, using physical parameters similar to that of Canalle and Opher (1988, 1989b), we obtain small polarizations for lower magnetic fields in the range 5 - 25 MG, closer to previous estimated values of DQ Herculis binaries.

In general we found that smaller values of f produce larger polarizations. For example, for the parameters of Fig. 3 and a magnetic field of 25 MG, $f \sim 10^{-2}$, 10^{-3}, and 10^{-4} produce circular polarizations $\sim$ 10% and linear polarizations $\sim$ 4%, while for f = 0.09, for example, we have a circular polarization < 3% and a linear polarization < 1.5%.

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