MAGNETIC CATACLYSMIC VARIABLES

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ABSTRACT

Pure cyclotron spectrum of UZ Fornax is deduced assuming that the cyclotron emission is produced by electrons spiraling down the dipole magnetic field lines and forming an accretion plasma column on top of the magnetic pole of a primary star. The velocity distribution function of particles emitting cyclotron radiation is assumed to be a bi--Maxwellian. Assuming that the cyclotron radiation is emitted more or less perpendicular to the local magnetic field then, the contribution of the ordinary and the extraordinary wave modes to the luminosity are investigated. Besides, the optical photometry of AM Her was obtained using Russian-Turkish 1.5m telescope (RTT150) at TÜBİTAK National Observatory (TUG) in R filter.

1. INTRODUCTION

Cataclysmic variable stars (CVs) are binary stars, include systems such as novae, dwarf novae, polars, and intermediate polars. Polars and intermediate polars, which are often referred to as AM Her and DQ Her systems respectively, form the subclass of magnetic Cataclysmic Variables (mCVs). Polars are binary systems in which a secondary star, usually a red dwarf, donates mass to the primary white dwarf star. The magnetic field intensity of WDs is in the range of 10 - 230 MG. Accreting matter is captured by the magnetosphere of the primary and guided by it to the magnetic poles of the primary (Schwope, 1995). Hence, due to the high magnetic field intensity an accretion disk do not form around the WDs in polars. An accretion column forms close to the magnetic poles of WDs. This is the region where the cyclotron emission is most intensely released. Broadened humps in the optical and/or infrared part of the spectra of polars are identified as the harmonics of the cyclotron radiation. The magnetic field intensity of polars was inferred from the cyclotron lines which are identified first in the spectra of VV Pup (Visvanathan & Wickramasinghe, 1979; Wickramasinghe & Meggitt, 1982).
In 1975, Berg and Duthie made the first photoelectric observations of AM Herculis; the prototype of this class. They found that the light from AM Her "flickered incessantly".
The variations in AM Her may be thought to belong to two groups, the long-term changes and the short-term changes. The long-term changes are characterized by the existence of two different states, one the high, in which the luminosity fluctuates around visual magnitude 13.0, and the other low state, where the brightness remains at about 15.0 magnitude (Hoffmeister et al 1985). These two states are thought to be the result of mass-transfer rates from the secondary to the primary star (Hessman et al 2000). The orbital motion of a binary system AM Her with an orbital period of 3.1 hours can be explained as short-term phenomena in the light curve. The other short term light variation is the incessant flickering which is supposed to occur due to the turbulent nature of the transfer of mass from the secondary to the WD star (Hellier 2001).

2. CYCLOTRON EMISSION MODEL

If we transfer the single particle approximation to the one for a dispersive medium with n_e radiating particles, the Green function becomes,

$$G(r,t;r',t')=\frac{N_e}{4\pi^3}\int d^3k\int d\omega\frac{\exp[ik\cdot(r-r')-i\omega(t-t')]}{k^2(\omega)-\frac{\omega^2(k)}{c^2}} \qquad (1)$$

Electron cyclotron emission implies a strong wave - particle interaction. Therefore, the term k^2/w^2 should be determined by the dispersion relation for a specific wave mode. The dispersion relations for the extraordinary and for the ordinary mode (Wu, 1985),

$$1-\frac{c^2k_\perp^2}{\omega^2}+\frac{\omega_{pe}^2}{\omega^2}\int d^3v\left(\Omega_e\frac{\partial F_e}{\partial v_\perp}+k_{//}v_\perp\frac{\partial F_e}{\partial v_{//}}\right)\times\frac{v_\perp J_1'^2(b)}{\left(\omega-\frac{\Omega_e}{\gamma}-k_{//}v_{//}\right)}=0\;, \qquad 1-\frac{c^2k^2}{\omega^2}+\frac{\omega_{pe}^2}{\omega^2}\int d^3v\left(\Omega_e\frac{\partial F_e}{\partial v_\perp}+k_{//}v_\perp\frac{\partial F_e}{\partial v_{//}}\right)\times\frac{v_{//}^2J_1^2(b)}{v_\perp\left(\omega-\frac{\Omega_e}{\gamma}-k_{//}v_{//}\right)}=0 \qquad (2)$$

where the unperturbed electron distribution function F_e is a bi--Maxwellian (Schmidt, 1979). We shall drop the arguments of Green function for the sake of brevity and finally get the Green function for the extraordinary mode:

$$G=-\frac{8\Omega_e\alpha_\perp^2c^2}{3R\omega_{pe}^2\tau}\left[\left(-\omega+\frac{\Omega_{ce}}{\gamma}\right)i\cos(\omega\tau)-\frac{\sin(\omega\tau)}{i\tau}\right][\cos(0.5x)-\cos(0.175Rx)] \qquad (3)$$

Eq. (3) is the general solution for the Green function. Once the Green function is known, the electric component of the radiation field can be evaluated from the formula given by Boyd & Sanderson, (1969). After some calculations we find the electric component of the radiation field. Energy flux is given by the Poynting vector, $S=(c/4\pi)|E|^2\hat{n}$. The energy emitted to the unit solid angle is $dP(t)/d\Omega=(c/4\pi)|RE|^2=|a(t)|^2$ where Ω is the solid angle. It is also our concern to determine as to how the radiated energy is distributed in frequency. For this, one introduces the Fourier transform of $|a(t)|^2$ and then using Parseval's theorem, the energy radiated per unit solid angle per unit frequency interval is obtained after some calculations in its final form for extraordinary mode :

$$\frac{d^2W}{d\omega d\Omega}=\frac{4B_e em^2c^3T}{9\pi k_B^2N_e\Lambda T_\perp^2L}\left|\sum_{l=1}^{10}J_l\left(\frac{\omega}{\Omega_{ce}}\beta\sin\theta\right)\times\left[\left(-\omega+\frac{\Omega_{ce}}{\gamma}\right)\cos(\omega\tau)-\frac{\sin(\omega\tau)}{\tau}\right][\cos(0.5x)-\cos(0.175Rx)]\dot{\beta}\right|^2\delta(l\Omega_{ce}-\omega[1-\beta_{//}\cos\theta]) \qquad (4)$$

and for ordinary mode we find;

$$\frac{d^2W(\omega)}{d\Omega d\omega}=\frac{16B_e em^2c^3T}{\pi k_B^2N_e\Lambda T_{//}^2L}\left|\sum_{l=1}^{10}J_l\left(\frac{\omega}{\Omega}\beta_\perp\sin\theta\right)\left[\left(-\omega+\frac{\Omega}{\gamma}\right)\cos(\omega\tau)-\frac{\sin(\omega\tau)}{\tau}\right][\cos(0.5x)-\cos(0.175Rx)]\dot{\beta}\right|^2\delta(l\Omega-\omega[1-\beta_{//}\cos\theta]) \qquad (5)$$

In this study, we model the observed pure cyclotron spectra of UZ For (Fig.1).

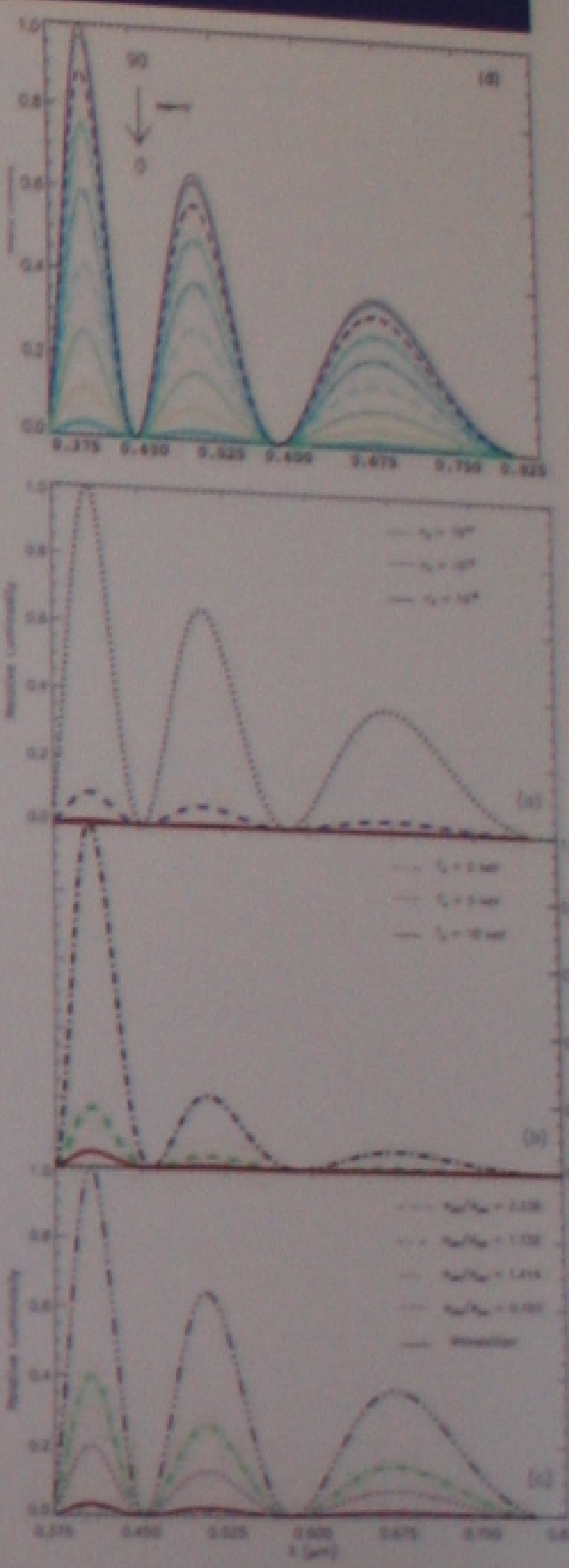

Fig.1 The model cyclotron spectra of UZ For. The variation of luminosity with respect to a) the angular dependence of cyclotron radiation b) particle number density, c) electron temperature, and d) $\alpha_{par}/\alpha_{per}$ ratio

3. PHOTOMETRIC OBSERVATION

Our observations of 6-7 August 2003 cover the transition period when AM Her passes from high to low state (Fig. 2). Optical photometry of AM Her was obtained using Russian-Turkish 1.5m telescope (RTT150) at TÜBİTAK National Observatory (TUG) in R filter. The exposure times were set as 15 seconds. The comparison and check star were chosen GSC 3533 1026 and GSC 3533 1021, respectively. All the CCD reductions were done with IRAF. Since most observable properties of CVs depend on the instantaneous accretion rate, the photometric, spectroscopic and polarimetric behavior of AM Her may change with respect to the observation time.

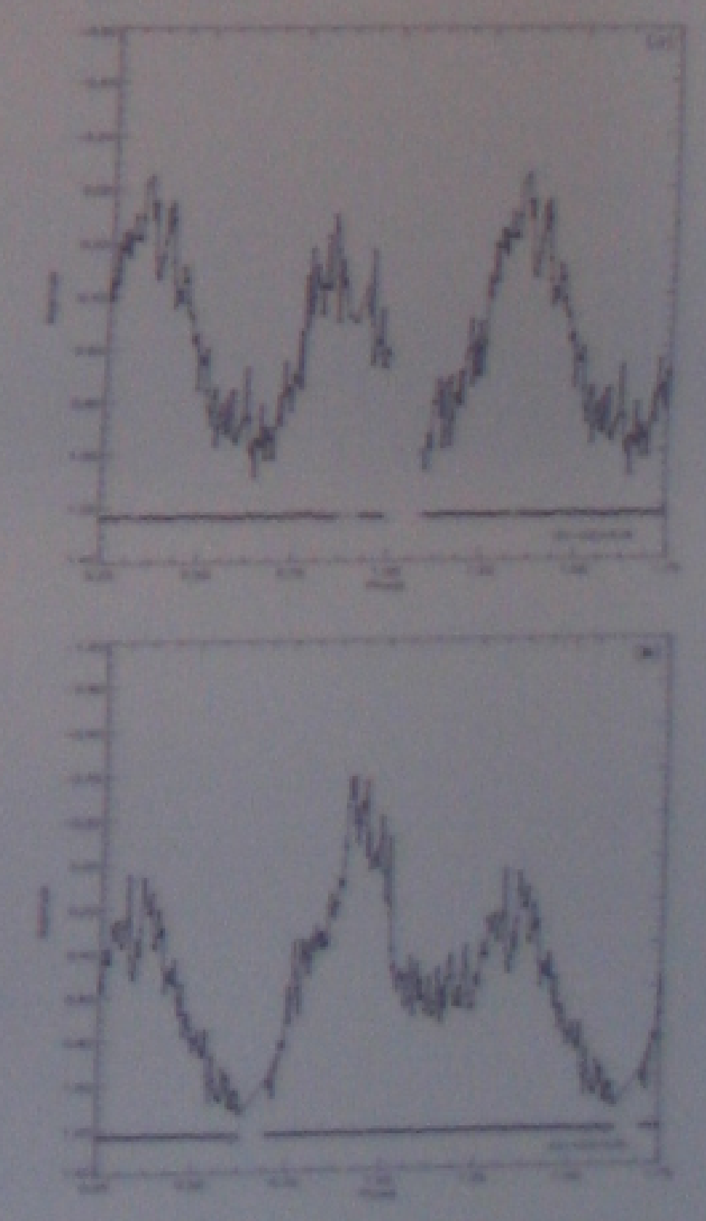

Fig.2 Light curves of AM Her obtained on August 6 and 7. The variation of C1-C2 is shown on the bottom panel.

4. RESULTS

In this study, we model the observed pure cyclotron spectra of UZ For and present the optical photometry of the prototype of polars, AM Her. We extended the Green function construction (Jackson, 1975) to a dispersive medium. The appropriate dispersion relation of the ordinary and extraordinary modes bear all the information about the propagation characteristics. Once the Green function is known one can find the radiation field and the Poynting vector, and then determine the instantaneous flux of energy. We deduce our formulae in low mass accretion state, when cyclotron cooling becomes dominant. The model spectra of UZ For seems to be consistent with the observation. The optical photometry of AM Her is obtained at TÜBİTAK National Observatory when the system passes from high to low state. Non-periodic changes, with 3-10 minutes duration, that is supposed to occur due to the turbulent nature of the transfer of mass from the red dwarf to the WD star are observed.

5. REFERENCES

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