MODELS FOR OPTICAL AND INFRARED POLARIZATION FROM CW1103+254

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Abstract

Multiband observations of the AM Herculis-type binary CW1103+254 show significant circular polarization (~ 13%) in the J band. Recently, a model with high temperature (kT ~ 20 keV) and small dimensionless plasma parameter ($\Lambda \sim 10^4$) was suggested for the emitting region. However, it gives negligible polarization in the J band. In this paper, a method, in which the J band polarization and the peak frequency $\nu_\star$ of the spectrum are taken into account, is used to determine T and Λ. For the viewing angle $\theta = 80°$ and the magnetic field B = 30MG, we find that kT = 5.0 keV and $\Lambda = 10^6$. The temperature of the emitting region is close to the value (kT = 8.7 keV) derived for the region emitting cyclotron lines in VV Puppis. If these radiations arise from the post-shock regions, then these temperatures are significantly lower than those predicted by standard accretion models or the shock structure is inhomogenous and more complex than previously assumed.

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1. Introduction

The AM Herculis binaries form a subclass of cataclysmic variables in which a magnetic white dwarf rotates synchronously with the orbital period. The magnetic field B is so strong (~ 20 - 30 MG) that the formation of an accretion disk is prevented. Instead, material from the secondary star is accreted onto the white dwarf through an accretion column and forms a strong shock near the surface of the degenerate star (see e.g. the reviews by Lamb 1985, Liebert and Stockman 1985).

The AM Herculis-type binary CW1103+254 has been studied using multiband optical and near infrared photometry and polarimetry and optical spectroscopy and spectrophotometry (Bailey et. al. 1985). The orbital inclination i is 69° and the lattitude of the accreting magnetic pole Δ is -56° (Schmidt, Stockman and Grandi 1983). With this geometry, the viewing angle to the magnetic field is 77°-90° in the bright phase (Wickramasinghe and Meggitt, 1985). The Zeeman effect shows that the surface magnetic field ~ 18MG, which corresponds to a 30MG polar field (Schmidt, Stockman and Grandi, 1983). The excess flux during the bright phase (i.e. bright phase flux minus faint phase flux) is a typical cyclotron flux which peaks near 7100Å. The optical emission is strongly polarized (~ 20%). In the infrared region, the J band is about 13% circular polarized, however there is no observed polarization in the H and K bands (Bailey et. al. 1985).

2. Method and Discussion

Recently, fits to the spectrum of CW1103+254 have been made by Wickramasinghe and Meggitt (1985), but their model gives negligible polarization in the J band. Here, we deduce a model which fits the polarized spectrum and gives significant circular polarization (> 10%) in the J band.

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In the calculation, the cyclotron emitting region is assumed to be a hot homogenous plasma slab with temperature T, electron number density N, magnetic field B and thickness L. The magnetic field is assumed to be perpendicular to the slab. The cyclotron radiation from this region is optically thick and follows a Rayleigh-Jeans curve up to a frequency $\nu_\star$ and is optically thin for $\nu > \nu_\star$. The peak frequency $\nu_\star$ is a function of T and the dimensionless plasma parameter $\Lambda \equiv \omega_p^2 L/\omega_c c$ where $\omega_p = (4\pi Ne^2/m)^{1/2}$ and $\omega_c = e\,B/mc$ (see e.g. Chanmugam and Dulk 1981). A set of T and Λ can then be generated by fixing the magnetic field B, the viewing angle θ and the peak frequency $\nu_\star$.

We choose B=30MG and θ = 80° in our calculation. The observed $\nu_\star$ lies in the range (4.0-4.8) x 10^{14} Hz, which corresponds to harmonic numbers 4.75-

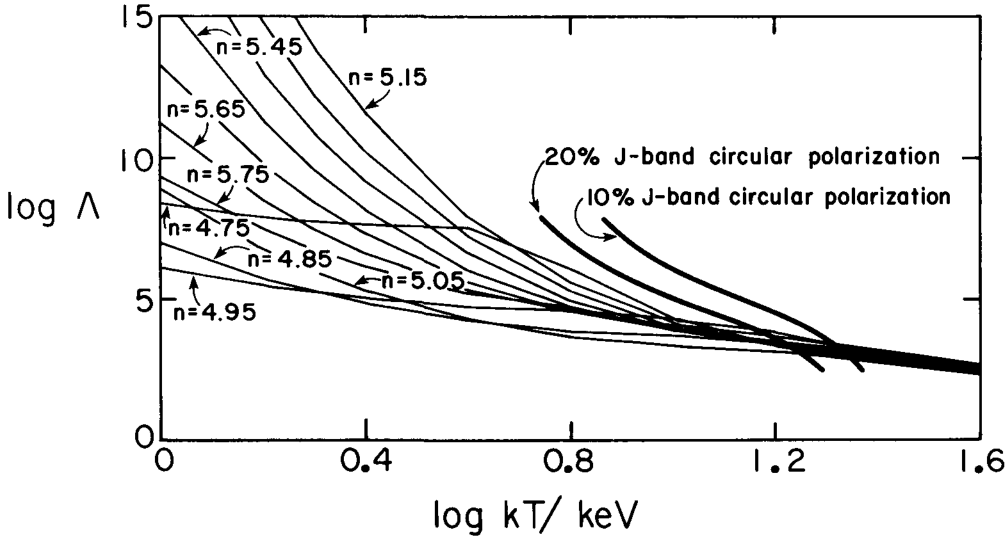

Fig. 1. The T-Λ diagram of CW1103+254, assuming the polar magnetic field B=30MG and the viewing angle to the field θ = 80°. The thin lines are determined by the peak of the observed spectrum. Each of them corresponds to a harmonic number ranging from 4.75 to 5.75. The thick lines indicates the J-band circular polarization.

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5.75. For each harmonic number, there is a corresponding T, Λ curve and such curves compose a parameter set (see the lines in Fig. 1).

Like ν_*, the circular polarizaton is a function of T, Λ, θ and B. Thus, by choosing values for θ, B and the circular polarizaton in the J band, we can generate another T, Λ set which is independent of the previous one. Since the observed circular polarization is a mean value over the observed band width, we have averaged it over the whole band which is taken to be $\lambda = 1.25 \pm 0.19$ μm (Greenstein et. al. 1970).

For a fixed pair of T and Λ, one requires the circular polarization to be greater than the observed value (13 ± 3%) because dilution by the background radiation reduces the polarization. However, due to the uncertainties in the observation, we take the lower limit (10%). Furthermore, we restrict the value of Λ to the range 10^4 to 10^8, characteristic of the AM Herculis binaries. The possible T, Λ are presented in Fig. 1.

The intersection of these sets satisfies both conditions: (1) the peak frequency ν_* is at (4.0-4.8) x 10^{14}Hz and (2) the circular polarization in the J band is greater than 10%. Therefore, it is the most probable T, Λ set for the cyclotron emission region with B = 30MG and $\theta = 80°$. We have picked a particular pair (kT = 5.0 keV, $\Lambda = 10^6$) in the midst of the intersecting region in Fig. 1 to fit the polarized spectrum (Fig. 2) and the circular polarization (Fig. 3). Within the limits of uncertainties in the observations, it is a good fit to the data, and hence shows the consistency of our method.

In our calculation, we have taken $\theta = 80°$. However, θ varies from 77° to 90° during the orbital cycle. Further calculations will be done by choosing different θ within this range. Also, B is not exactly 30 MG. Because no cyclotron lines are observed in CW1103+254, there is no direct measurement of the polar magnetic field. The deduced value for the field, which is assumed to be dipolar from the Zeeman effect, has a ±5 MG uncertainty. Hence, values of B ranging from 25 MG to 35 MG should be tried, hoping that a better T, Λ, θ, B parameter set may be obtained.

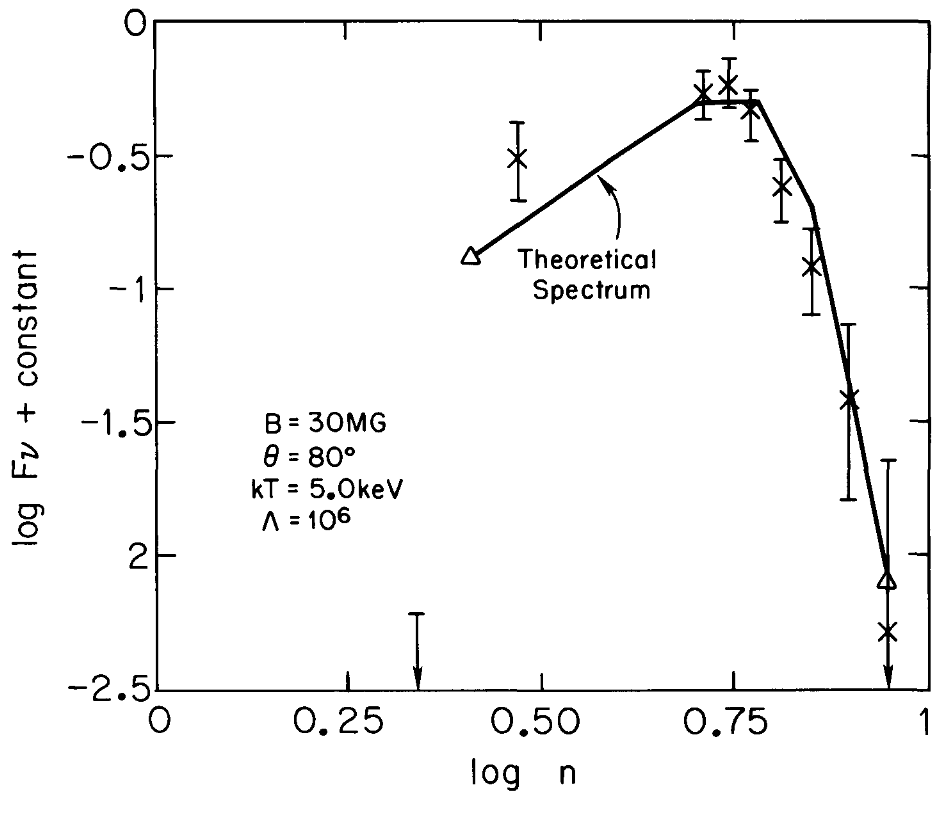

Fig. 2. The polarized spectrum of CW1103+254. The crosses, with error bars, are observed data of Bailey et. al. (1985). The solid curve is the theoretical spectrum with parameters: B = 30MG, θ = 80°, kT=5.0 keV and $\Lambda = 10^6$.

3. Conclusion

The method discussed here provides information about the important parameters T and Λ of the cyclotron emitting region. It is not only applicable to CW1103+254 but also to other AM Herculis-type binaries if infrared polarization is observed. The temperature deduced here (kT=5.0 keV) is lower than the typical shock temperature (~ 20-30 keV) predicted by standard theories. However, it is consistent with values derived from cyclotron lines observed in VV Puppis (≈ 8.7 keV) by Barrett and Chanmugam (1985) and (~ 10 keV) by Wickramasinghe and Meggitt (1982). This implies that the shock temperature of these two systems may be different from that of the standard model or that inhomogeneous effects are important. Alternatively, the cyclotron emission may arise in a region which is separated from the shock-heated region.

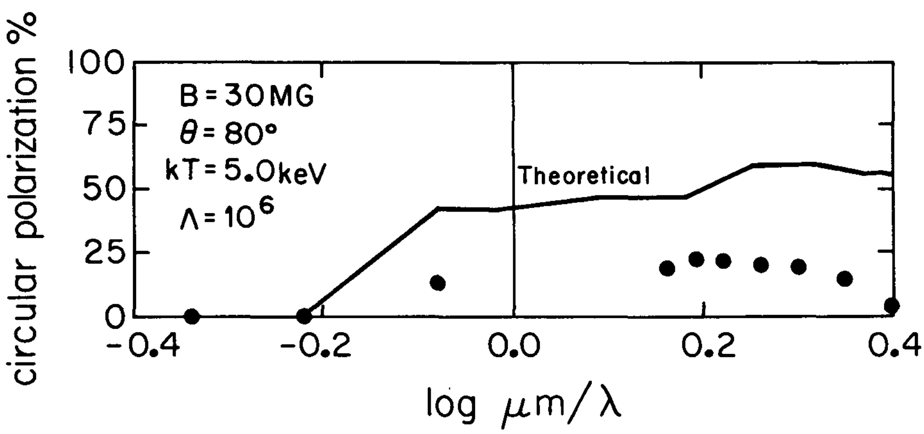

Fig. 3. Fit to the J-band circular polarization. Observed data are taken from Bailey et. al. (1985). The parameters for the theoretical polarization (solid curve) are B = 30 MG, θ = 80°, kT = 5.0 keV and $\Lambda = 10^6$.

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