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I. Introduction

The AM Her systems are widely believed to be cataclysmic variable systems in which the white dwarf has a magnetic field strong enough to lock the white dwarf to the companion star. The magnetic field channels the accretion flow to the magnetic polar caps of the white dwarf where the gas passes through a strong shock and the accretion energy is released. The continuous spectra of the AM Her systems have three major components: the IR/optical component, the EUV/soft X-ray component, and the hard X-ray component. Models of the AM Her systems generally agree that the hard X-rays are free-free radiation emitted by the hot postshock gas and that the optical component is electron cyclotron emission from the postshock gas. The soft X-ray component is less well understood, primarily because it is very soft (temperature less than 100 eV) and thus is very difficult to measure accurately with current instruments. Models agree that some soft X-ray emission will arise from hard X-rays and cyclotron radiation that is absorbed at the stellar surface and re-radiated, but other sources of soft X-rays have also been suggested. Thus it is important to develop models for the soft X-ray spectrum. This paper presents some preliminary results on the emission in all spectral bands based on numerical models of the accretion flow.

II. The Model

The first requirement in calculating the spectra of the system is to know the run of temperature and density in the accretion flow. This is obtained by solving the steady state flow equations using a numerical hydrodynamics code. The code includes all the usual hydrodynamic terms and also an approximate treatment of the absorption and emission of radiation. This allows the flow to come into radiative equilibrium as it settles onto the surface of the white dwarf and thus naturally includes the reprocessed soft X-rays. The cyclotron emission is treated by assuming that the spectrum is Rayleigh-Jeans up to some cutoff frequency and zero above that. The code then keeps track of the cutoff frequency and uses changes in it to estimate the cyclotron losses. The cooling by free-free radiation in the upward direction is estimated using an escape probability and in the downward direction the radiative transfer equation is solved on a single ray using an estimate of the mean energy of the radiation to compute an opacity. The radiative heating by absorbing the soft X-rays emitted at the surface is also included. All three of these radiation terms use single frequency and direction approximations so they are not terribly accurate. However, adjustable constants (such as an

Eddington factor) are included so that an iterative improvement based on a more accurate radiative transfer solution can be obtained.

The model described so far is capable, at best, of only a crude estimation of the properties of the spectrum and directivity of the radiation. Thus a separate radiation transfer solution is obtained using the temperature and density structure calculated by the hydro code. The radiation is evaluated using an exact solution of the transfer equation at a set of discrete frequencies and angles. The result is a frequency and angle dependent intensity as well as the net radiative losses at all depths in the problem. Another version of this transfer code includes the polarization dependence of the cyclotron radiation, but no results with polarization will be presented here.

III. Results

Figure 1 shows the energy flux as a function of frequency for several angles relative to the magnetic field. The calculation is made using a white dwarf with a mass of $0.5 M_{\odot}$, a radius of 10^9 cm, a polar cap temperature of 5×10^5 K, and a magnetic field of 1.5×10^7 Gauss. The accretion rate is 2×10^{16} gm/s over a polar cap area of 10^{16} cm². The shock height is 5×10^7 cm and the shock temperature is 1.5×10^8 K. In this calculation the geometry is planar, although the code can also handle dipolar geometry. The three spectral components are all obvious. The cyclotron spectrum, as expected, shows a ν^2 shape with a sharp cutoff at high frequency. The soft X-rays are basically a blackbody and the hard X-rays have the spectrum of optically thin bremsstrahlung. The soft X-rays and the cyclotron spectrum below the cutoff show the $\cos^2(\theta)$ projected area effect characteristic of optically thick surfaces.

Figure 2 shows the cyclotron spectrum in more detail. At different viewing angles the spectrum peaks at different frequencies. For most angles the peak is in the optical, but when viewed directly along the magnetic field it cuts off in the IR. The surfaces of the white dwarf and the red dwarf companion will also emit optical radiation, but that is not included here. Figure 3 shows the angular dependence at several frequencies. The projected area factor of $\cos^2(\theta)$ has been divided out so that the angular effects of the cyclotron opacity can be seen directly. Clearly these effects are strong enough that any prediction of eclipse light curves must take them into account.

The soft X-ray spectrum and the angular dependence of this model is not particularly interesting. When the opacity model is improved to include atomic opacity the soft X-rays will start to show some interesting spectral structure.

The hard X-ray spectrum is shown in more detail in Figure 4. The emitting region is optically thin to hard

X-rays, but the spectrum is not a simple exponential because there is a range of temperatures in the emitting region. The hard X-ray flux is independent of angle because the emitting region is optically thin.

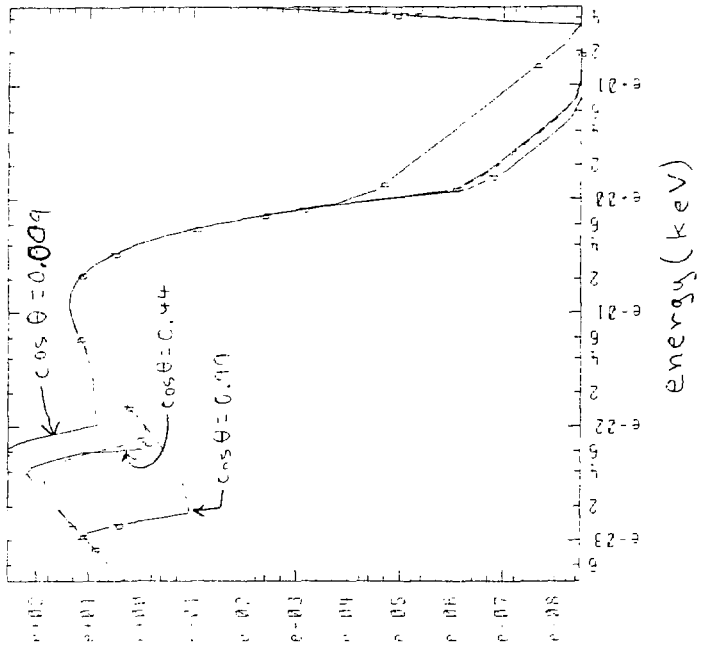
IV. Conclusions

This paper has presented a combined hydrodynamics and radiative transfer model for the spectral and angular dependence of the AM Her stars. The model treats the region near the photosphere more accurately than earlier work. The spectrum and the angular dependence is exact given the density and temperature structure calculated by the hydro code. The results are in good agreement with earlier calculations that made different approximations and extend those results. The model can be improved by including additional effects such as atomic opacity and a more accurate calculation of the radiative losses in the hydro code. Any attempt to depart from the 1D geometry used in this model will introduce many new problems and greatly increase the computational requirements, which fortunately are almost negligible for the current model.

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~~Flux~~ vs energy for $B = 10^7$ Gauss



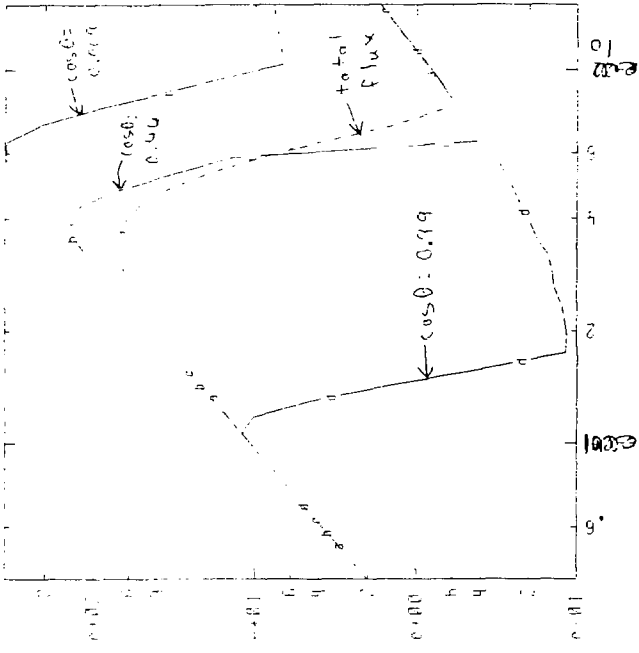
$$\frac{\text{erg}}{\text{cm}^2 \text{ Hz} \cdot \text{s}}$$

1	0.0000000000
2	0.0000000000
3	0.0000000000
4	0.0000000000

Figure 1

Cyclotron Spectrum vs. Energy for $B = 10^7 G$

~~Intensity vs energy for $B = 10^7 G$~~

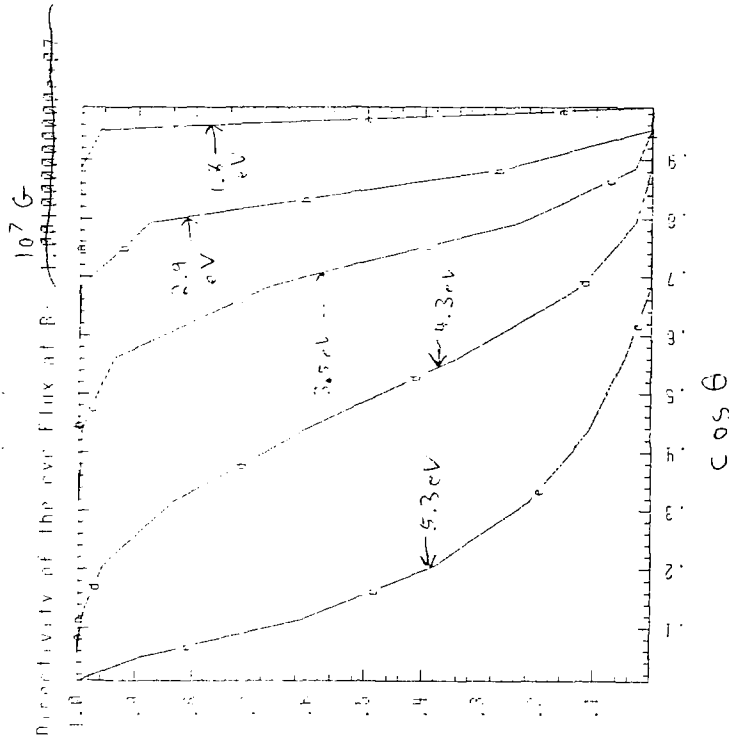


$$\frac{\text{ergs}}{\text{cm}^2 \text{ s Hz}}$$

Energy (eV)

1	0.000
2	0.000
3	0.437
4	0.000

Figure 2



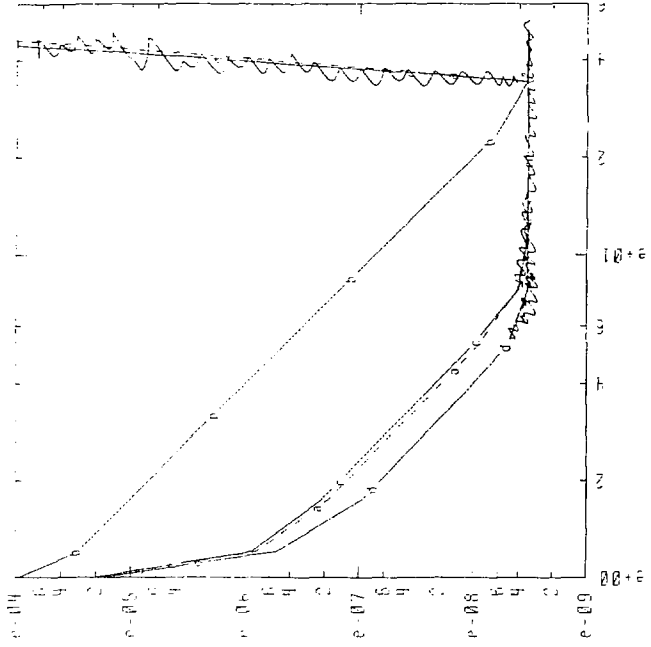
$$\frac{I_y(G)}{I_y(0)}$$

- a) 1.8 eV
- b) 2.9 eV
- c) 3.5 eV
- d) 4.3 eV
- e) 5.3 eV

Figure 3

$$\frac{\text{ergs}}{\text{cm}^2 \text{ s Hz}}$$

Intensity vs energy for β . 10^{-6}



Energy (keV)

- a: 1.0×10^{-6}
- b: 0.5×10^{-6}
- c: 0.3×10^{-6}
- d: 0.2×10^{-6}

Figure 4