CYCLOTRON EMISSION FROM THE SHOCK-HEATED REGION OF AM HERCULIS

G. Chanmugam

Department of Physics and Astronomy
Louisiana State University
Baton Rouge, LA 70803

and

Department of Physics and Astronomy
University of Rochester
Rochester, NY 14627

There has been considerable interest recently in the AM Herculis binaries, which are believed to contain a strongly magnetic white dwarf accreting matter from a lower-main-sequence companion (Tapia 1977, Chanmugam and Wagner 1977, Stockman et al. 1977). Models for these systems feature an accretion column above a magnetic pole of the white dwarf. A shock-heated region, with a temperature $kT \approx 20$ keV (Raymond et al. 1979) and a height $h \sim 10^6$cm (Masters 1978), believed to be formed in AM Her just above the magnetic pole is likely to be responsible for the emission of the hard X-rays observed (Swank et al. 1977). It has been further suggested that this region should emit optically thick cyclotron emission in the ultraviolet because of the presence of the strong magnetic field $\sim 10^8$ gauss (Masters 1978, Lamb and Masters 1979). Such UV emission has not been observed (Raymond et al. 1979).

Estimates of the cyclotron emission from AM Her have been made by determining the angle-averaged emission from a homogeneous plasma slab with the magnetic field parallel to the surface of the slab (Masters 1978, see also Chanmugam and Wagner 1979). Since the cyclotron opacity at high harmonics is highly anisotropic (Trubnikov 1961) and since the magnetic field is perpendicular to the slab we consider the angular distribution of the cyclotron emission from such a slab.

The cyclotron radiation, for frequencies $\omega >> \omega_p$ (the plasma frequency), may be estimated by using the emission from one electron (Trubnikov, 1961) and the two-dimensional Maxwellian distribution for the electrons used for discussing the angle-integrated emissivity (Masters 1978, Chanmugam and Wagner 1979). The absorption coefficient $\alpha(\theta,\omega)$ may then be determined by using Kirchoff's law (Beard and Baker 1962, Drummond and Rosenbluth 1960). For simplicity we restrict the discussion to a two-dimensional cross-section, through the center of the star. Consider radiation travelling through the plasma at an



https://doi.org/10.1017/S025292110007617X Published online by Cambridge University Press

angle $\theta$ with the magnetic field. The absorption in the plasma is $\alpha(\theta, \omega/\omega_c)h \sec\theta$ and depends only on $\omega/\omega_c$, $\theta$, $\mu \equiv mc^2/kT$ and the dimensionless parameter $\Lambda \equiv \omega_p{}^2 h/\omega_c c$, where $\omega_c = eB/mc$, the cyclotron frequency. The absorption coefficient $\alpha(\theta,\omega)$ is greatest for $\theta = \pi/2$ and drops off drastically with increasing $|\theta-\pi/2|$. For fixed $\mu$, $\Lambda$ and $\omega/\omega_c$, there is a critical angle $\theta = \theta_c$ when

$$\alpha(\theta_c, \omega/\omega_c)\ h \sec\ \theta_c = 1. \tag{1}$$

Hence the radiation is absorbed by the plasma and is black-body-like for $\theta_c \lesssim \theta \lesssim \pi/2$, while the plasma is optically thin for $0 \lesssim \theta \lesssim \theta_c$. Hence the flux from the slab is

$$F(\omega) \approx \cos^2\ \theta_c\quad B_{RJ}(\omega) \tag{2}$$

where $B_{RJ}(\omega)$ is the Rayleigh-Jeans flux ($h\omega << kT$).

If one assumes that the distance to AM Her is 100 pc, the luminosity of AM Her is $\approx 10^{35}$ ergs $s^{-1}$ (Raymond et al. 1979). For a white dwarf of mass = $1M_\odot$, the value of $\Lambda$ may be deduced to be $\approx 10^6$ (Masters 1978). For a plasma with $\Lambda = 10^6$ and $\mu = 25.55$ (kT = 20 keV) the angle-averaged results predict a Rayleigh-Jeans spectrum for frequencies up to $\approx 11\omega_c$ (Masters 1978). If the angular distribution of the radiation is taken into account it is found that the Rayleigh-Jeans spectrum is not filled for $\omega/\omega_c \gtrsim 4$ with $\cos^2\theta_c$ decreasing with increasing $\omega/\omega_c$. The value of $F(\omega)/B_{RJ}(\omega)$ being $\approx 1/5$ at $\omega \approx 11\omega_c$.

In conclusion we point out that when the angular distribution of the cyclotron emission is taken into account (a) the Rayleigh-Jeans spectrum is not filled and (b) for a field strength B $\approx 6.5 \times 10^7$ gauss the UV flux at $\approx$ 1500Å is a factor of 5 less than predicted before. Further details will be discussed elsewhere.

This research was supported by NSF grant AST-76-06807-A01 and completed when the author was a summer visitor at the University of Rochester. The author thanks Professor H.M. Van Horn for his hospitality there.

## References

Beard, D.B. and Baker, J.C. 1962, Physics Fluids, 5, 1113.
Chanmugam, G. and Wagner, R.L. 1977, Ap.J. (Letters), 213, L13.
———, 1979, Ap.J., Sept. 15, in press.
Drummond, W.E., and Rosenbluth, M.N. 1960, Phys. Fluids, 3, 45.
Lamb, D.Q., and Masters, A.R. 1979, Ap.J. (Letters), submitted.
Masters, A.R. 1978, Ph.D. thesis, University of Illinois at Urbana.
Raymond, J.C., Black, J.H., Davis, R.J., Dupree, A.K., Gursky, H., Hartmann, L. and Matilsky, T.A. 1979, Ap.J. (Letters), 230, L95.
Stockman, H.S., Schmidt, G.D., Angel, J.R.P., Liebert, J., Tapia, S., and Beaver, E.A. 1977, Ap.J. 217, 815.
Swank, J., Lampton, M., Boldt, E., Holt, S., and Serlemitsos, P. 1977, Ap.J. (Letters), 216, L71.
Tapia, S. 1977, Ap.J. (Letters), 212, L125.
Trubnikov, B.A. 1961, Phys. Fluids, 4, 195.