PULSAR MAGNETIC FIELD: SPECTRAL FORMATION IN HER X-1

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The spectrum of Hercules X-1 reveals line features at 58 keV and probably at 110 keV, which have been interpreted as first and second cyclotron harmonics originating in the radiation from the hot polar cap region of a magnetic neutron star. The inferred magnetic field strength is $\sim 5.3 \times 10^{12}$ Gauss (Trümper et al. 1978). Other noteworthy spectral characteristics of this source are the very 'flat' intensity continuum in the frequency range 2 - 20 keV followed by a rather sharp spectral break near 25 keV and an intensity minimum near 40 keV. This spectrum is certainly not reminiscent of typical black-body emission. How can one understand these diverse characteristics?

Let us first note that the source luminosity of $\sim 10^{37}$ erg s^{-1} along with the presence of a strong magnetic field result in rather dense accretion funnels (see e.g. Lamb et al. 1973; Davidson 1973) whose transverse optical depth to Thomson scattering significantly exceeds unity in free fall. The resultant geometry would then favor fan-beam emission originating in the main (radiation shock) deceleration region, which we will assume to lie immediately below the base of an idealized cylindrical column. One can distinguish two separate regions: (1) The deceleration zone, where the infalling matter releases its gravitational energy, probably, onto a cushion of trapped radiation and (2) the optically thick free-fall zone, which should act as a very strong frequency, polarization and direction filter due to the complex dependence of the photon mean free path on these variables. In Figure 1 I have shown the frequency dependence of the Thomson opacity for two directions of propagation. The polarization normal modes are assumed to be those of the magnetic vacuum having their E-vector parallel or perpendicular to the Bk plane (cf. Mészáros and Ventura 1978, 1979; Ventura et al. 1979; Ventura 1979). The resonant structure of these coefficients includes the (anisotropic) thermal broadening effect corresponding to a hot plasma as well as the relativistic Doppler shift due to the 'bulk' velocity $v \sim 0.4$ c assumed for the free-fall zone. The strength of the second harmonic resonance shows the expected $\sin^2\Theta$ dependence on direction.

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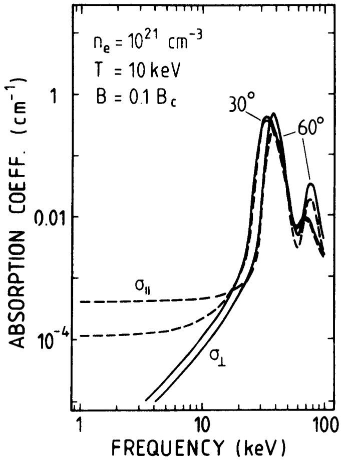

Figure 1: Thomson opacity

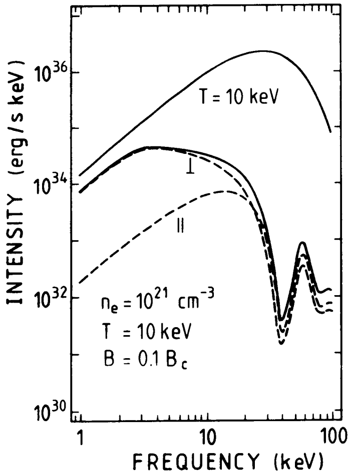

Figure 2: Radiated spectrum

The probability of a photon injected at the base of the column (with a given frequency and direction) to escape through the free-fall zone without scattering is $P = e^{-\tau}$ (τ = optical depth). This leads in turn to an effective cooling area $A_{eff} \sim \pi(c/v)a\sigma^{-1}$ (for $\sigma^{-1} < a$; a is the radius of the cylindrical column and σ is the Thomson opacity). The spectrum of escaping photons shown in Figure 2 is obtained by folding A_{eff} for each mode to a 10 keV Planck profile, which we assume injected at the base of the column and integrating over the photon's direction. It has been recently argued (Ventura 1980) that in the presence of fast accretion flows such as envisioned here, injected photons tend to be reconvected back into the 'hot spot' after about $(c/v)^2$ scatterings. The above discussion should therefore give a simulation of the filtering action of a fast accretion flow.

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