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The Effect of Non-thermal Protons on the High Energy Spectra of Black Hole Binaries

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Abstract. We investigate here the effect on the emitted spectrum of a black hole binary due to the presence of accelerated protons in the inner region of the accretion disk. Our study shows that e^-e^+ pairs and high energy γ-rays created in inelastic $p-p$ collisions contribute mainly in the $1-10$ MeV range and produce a broad feature in the spectrum in this energy range which can be verified by INTEGRAL and GLAST observations.

1. Introduction

Black hole binaries are generally found either in Hard state or Soft state (Gierlinski et al 1999). In the hard state, the $X\gamma$ spectrum has a photon spectral index $\Gamma \sim 1.7$ with a high energy cut-off above $\sim$ 100keV and is, generally, modelled as the Comptonization of the soft blackbody photons from an optically thick accretion disk in a hot thermal, optically thin coronal plasma. The spectrum in the soft state has a soft, blackbody-like component peaking at $\sim$ 1keV and a power law tail with $\Gamma \sim 2.5$ (Zdziarski et al 1998). While the soft component of the spectrum is modelled as the blackbody component from the optically-thick accretion disk, the origin of the power-law component is not clearly understood. The steepness of the spectra and the absence of a spectral break implies that the power-law component arises possibly due to the Comptonization of the soft photons by a non-thermal electrons whose origin and mechanism of acceleration are largely unkown (Zdziarski 2000). It is generally believed that a fraction of thermal electrons in the corona are accelerated possibly in magnetic reconnection processes. If this acceleration process is independent of the particle mass then the acceleration of protons to very high energies is equally possible.

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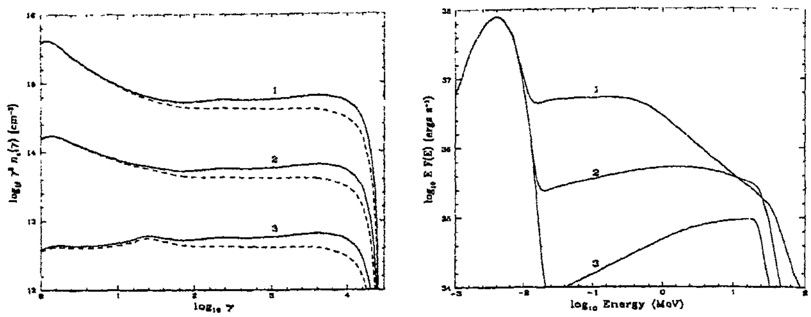

Figure 1. The particle (*left panel*) and photon (*right panel*) spectra for different values of non-thermal proton fraction, $f = 0.1, 0.05, 0.01$ labeled as 1, 2 and 3 respectively. The other parameters are size of the emission region, $R = 10^7$ cm, luminosity of thermal photons, $L_s = 10^{3}7$ erg s^{-1}, temperature of thermal photon distribution, $kT_s = 1$ keV, optical depth $\tau = 2$ and spectral index of non-thermal protons, $\alpha = 2.5$

2. Models and Discussion of the Results

Relativistic protons undergo inelastic collisions with thermal protons via $p - p$ collision and produce π^o and $\pi^{\pm}$ which in turn decay into γ-photons and $e^{\pm}$ respectively. Considering the inverse Compton boosting of soft thermal photons by the relativistic $e^{\pm}$, $e^+ - e^-$ annihilation and $\gamma - \gamma$ pair production as basic processes, we calculate the resultant high energy spectrum. In this calculation the $e^{\pm}$ pairs produced in the $\gamma - \gamma$ annihilation process are fed back into the system and the final electron and position spectra are calculated by solving the steady-state kinetic equation in an iterative manner. Detailed calculations are described elswhere (Bhattacharyya et al 2003).

The left and the right panel in Fig. 1 show particle and photon spectra respectively. The photon spectra are due to inverse Compotonization of soft photons, modified by $\gamma - \gamma$ absorption. Fig. 1 further shows that the presence of non-thermal protons in the inner regions of an accretion disk may have a detectable high enegy signature in the photon spectrum. The spectrum has a broad feature in the $1 - 50$ MeV region which can be detected by future observations by INTEGRAL and GLAST. Its non-detection is likely to constrain the fraction of non-thermal protons present in the system and hence acceleration process itself in the disk as well.

References

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