COMPTONIZATION-SOFTENING AND THE HARD X-RAY SPECTRUM OF CYG X-1

YE ZHONG GUO and YOU JUNHAN*

Center for Astrophysics, University of Science and Technology of China, Hefei, Anhui, China

(Received 20 August, 1984)

Abstract. The Comptonization-softening of very hard X-ray photons with \( E < m_0 c^2 \) in the 'cold' electron gas is discussed. The frequency diffusion equation for Comptonization of hard X-rays has been derived to the zero-temperature approximation. By use of this equation, and under the assumption of pair-annihilation origin of hard X-rays, we calculated the energy spectrum with \( E > 80 \) keV, for Cyg X-1, which is in good fit with the observation. The high-energy edge \( \sim 400 \) keV of the observed spectrum and the small bump in the range 100–200 keV also can be explained by this way.

1. Introduction

1.1. THE X-RAY SPECTRUM OF CYG X-1 AND CONVENTIONAL EXPLANATION

Cyg X-1 is one of the brightest X-ray point sources, \( L_x \sim 3 \times 10^{37} \) erg s\(^{-1}\). The main features of the observed X-ray radiation of Cyg X-1 are as follows (e.g., Graham Bingham and Clark, 1969; Haymes and Harnden, 1970; Schreier et al., 1971; Tananbaum et al., 1972; Agrawal et al., 1972; Li and Clark, 1974; Frontera and Fuligni, 1975; Jain et al., 1976; Mandrou et al., 1978; Dolan, 1979).

(1) Except for the strong soft X-ray flux, there is also a slightly harder X-ray flux. The high-energy edge of the spectrum is located at \( \sim 400 \) keV. There is still a very weak \( \gamma \)-ray flux above 400 keV, up to a few MeV.

(2) There is an irregular variation with time-scale \( \sim 50 \) ms. In addition, non-periodic variation of intensity with time-scale \( \sim \) days were also observed – i.e., the 'high state' and 'low state'.

(3) There is an obvious knee in the spectrum near 10 keV. When \( E < 10 \) keV, the observed spectrum is in good agreement with a bremsstrahlung spectrum with \( T \sim 10^7 \) K; for \( E > 10 \) keV, spectrum is more like a power-law shape (Figure 1); and there is an obvious 'bump' which is located between 100 – 200 keV. When it is in the high state, the bump is located near \( \sim 100 \) keV; when in low state, it is near \( \sim 200 \) keV (Figure 2). On the high-frequency side of the bump, the slope of spectrum is very steep.

(4) When the soft X-ray intensity is varied, the spectrum of hard X-ray usually keep unchanged.

The general characteristics of the luminosity and the soft X-ray spectrum of Cyg X-1 could be explained by the disk models around a black hole. But according to the standard cooling disk model, the high-energy part of the spectrum is cut-off near 5 keV.

* Visiting scholar at Kapteyn Laboratory, Groningen, The Netherlands.

The flux density of X-ray photons of Cyg X-1 (Agrawal et al., 1972). Dashed line is the theoretical spectrum in the cooling disk model (from Sunyaev and Trümper, 1979).

The observed small bump 100 keV (Agrawal et al., 1969, 1971; Matteson, 1975; Mandrou, 1976).