The first simultaneous X-ray/γ-ray observations of Cyg X-1 by Ginga and OSSE

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Abstract. We present the results of 4 simultaneous observations of Cygnus X-1 by Ginga and OSSE. The X-ray/γ-ray spectra can be described by an intrinsic continuum and a component due to Compton reflection including an iron Kα line. The intrinsic spectrum at X-ray energies is a power-law with a photon spectral index of $\Gamma = 1.6$. The intrinsic γ-ray spectrum can be phenomenologically described by either a power-law without cutoff up to 150 keV, and an exponential cutoff above that energy, or by an exponentially cutoff power law and a second hard component.

1. Introduction

Cygns X-1 is a binary system that consists of an O9.7 supergiant and a compact object which is believed to be a black hole. Its X-ray and γ-ray spectrum shows enormous variability: the total flux can change by a factor three within a few hours. On June 6, 1991 Cyg X-1 was observed by Ginga and GRO/OSSE simultaneously. This gives us a unique opportunity to see instantaneous, wideband spectra of Cyg X-1, covering the energy range from 2 to 1000 keV (Gierliński et al. 1996).

2. The spectra

Fig. 1 shows four spectra of Cyg X-1, taken at different hours of June 6, 1991. The solid curves represent the two-component model described below. The strongest and the weakest spectra differ in time by $\sim 15$ hours; the flux in the range 2–1000 keV had changed during this time by a factor $\sim 3$. The observed spectra fall into the high-state of Cyg X-1 as observed in the OSSE energy range (Phlips et al. 1995).

3. Ginga and OSSE separately

The Ginga data can be described well by a power-law intrinsic spectrum accompanied by Compton reflection, which component includes a fluorescence Fe Kα at 6.4 keV. The photon spectral index is $\sim 1.6$ and the covering factor of the reflecting medium (with an Fe overabundance of $\sim 1.5$) is $\sim 0.4$. We used angle-dependent reflection Green’s functions (Magdziarz and Zdziarski 1995) and assumed the disk inclination angle of 30°.

The OSSE data are well described by either an exponentially cut-off power-law or a thermal Comptonization model. The photon spectral index is $\sim 1.0$, the e-folding energy, $E_f \approx 140$ keV, and the plasma temperature, $kT \approx 90$ keV.
4. How to fit the joint Ginga and OSSE data?

Although we find excellent fits for the Ginga and the OSSE data separately, those fits do not match. We have found that good fits to the joint Ginga and OSSE data require a modification of the form of the γ-ray cutoff as well as an increase of the relative normalization of the Ginga data by ∼ 15%. Two models providing good fits to the joint data are described below.

4.1. Model one: exponential cutoff above 150 keV

This model consists of a power-law with an exponential cutoff that acts only above some cut-off energy $E_c$:

$$F_E = AE^{-\Gamma} \begin{cases} \exp\left(-\frac{(E - E_c)}{E_f}\right), & \text{for } E > E_c, \\ 1, & \text{for } E \leq E_c. \end{cases}$$

The model includes Compton reflection continuum and an Fe line at 6.4 keV. Fig. 2 shows how this model fits the data. We have found the photon index of $\Gamma \approx 1.6$, the cut-off energy, $E_c \approx 150$ keV, and the e-folding energy, $E_f$, between 200 and 240 keV for the four data sets.

4.2. Model two: two power-law components

The base for this model is a simple, exponentially cut-off power-law with Compton reflection and a Gaussian line at 6.4 keV. However, this model requires an addition of another component peaking around 200 keV, represented by an exponentially cut-off ($E_f \sim 70$ keV), hard power-law ($\Gamma < 0$). Fig. 3 shows the resulting fit.

5. Discussion

Our results demonstrate unambiguously the presence of Compton reflection in Cyg X-1. The reflection continuum is accompanied by a Fe Kα fluorescent line with an equivalent width of about 100 eV, as expected theoretically (George & Fabian 1991). The observed spectra are cut off above $\sim 150$ keV; however the form of the cutoffs is described neither by an exponentially cut off power law nor by thermal Comptonization (treated relativistically). This effect can be due to a distribution of the plasma temperature and optical depth. Alternatively, the cutoff can be reproduced by adding a hard component peaking at 200 keV. Note that the spectral index of the X-ray power law, $\Gamma \sim 1.6$, is significantly harder than the average spectral index in Seyfert 1's ($\Gamma \sim 1.9$, Nandra & Pounds 1994).

References

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