Two-phase spectrum of the black hole candidate 1E1740.7-2942

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Abstract

Combined ASCA and SIGMA data of 1E1740.7-2942 during its standard state (September 1993 and 1994) were successfully fitted with two-phase model ISM [1]. The classical cold accretion disk does not extend up to the innermost stable orbit, but is truncated at $\sim 30GM/c^2$. A hot inner disk has electron temperature $T_e \approx 60$ keV and radial Thomson optical depth $\tau \approx 2.4$. The cold disk radiates ≈ 40 % of the total luminosity with $\dot{M} \approx 0.04\dot{M}_{Edd}$ of $10M_\odot$.

1 Introduction

1E1740.7-2942 (1E) is the famous jet-source (micro-quasar, Great Annihilator) close to the Galactic Center, observable in the cm/mm and X/Gamma-ray wavelengths [2-9]. During the last few years, new tools for modelling of X-ray data of black hole binaries have been developed. In this paper we model 1E data using two-phase pair plasma sombrero model, ISM, (iterative scattering method) [1] (see Figure 1). ISM computes the Comptonization spectrum in a given geometry. Electrons (pairs) can be thermal or non-thermal. Here we consider thermal plasma.

2 The data

We use ASCA GIS and SIS archival data (Sept 1993 and 1994) and SIGMA hard X-ray observations (1990 - 1995) to explore 1E1740.7-2942 with the help of ISM model. We noticed, that statistics of SIGMA data accumulated during a few days around the dates of ASCA 93 and 94 observations don't allow us to restrict the ISM parameters, therefore we had to accumulate SIGMA data for a longer period. We are aware of the problems introduced with the use of non-simultaneous data. During 90 - 95 1E goes through different spectral states and its hard flux varies by a factor of 10 [10]. However, we noticed that in 30 - 300 keV range the SIGMA 90-95 data is consistent (within the errors) with the SIGMA data accumulated during a few days around the dates of ASCA 93 and 94 observations.

The ASCA GIS data have been analyzed earlier [6-7], and the 93 SIS data have been analyzed in [7], using a simple power-law model for the continuum, while our modelling is more physically meaningful. We also analyzed earlier the ASCA data used in this paper [9], but we use here an updated version of ISM, and different set of SIGMA data.

3 Results and conclusions

We fitted 93 ASCA GIS, 94 ASCA GIS, 94 ASCA SIS and SIGMA 90-95 data simultaneously, allowing normalizations vary between the data sets. The essential parameters in ISM model are T_e (electron temperature of the hot cloud), τ (Thomson optical depth of the cloud), T_{bb} (inner temperature of the cold disk), and a ratio of the inner radius of the disk to the radius of the corona R_{in}/R_c. Since the ISM model is quite complex and contains correlations between parameters, we decided to fix parameters R_{in}/R_c and inclination, i, keeping the reflection amplitude fixed to a standard value of 1 (corresponding to the amount of reflection expected from an infinite cold plane disk with a hole of size R_{in} in the center and a source of hard photons from a spherical homogeneous cloud of size R_c in the center). We noticed that $R_{in}/R_c = 1$ gives better fit than smaller R_{in}/R_c and that decrease of the inclination improves χ^2 without much effect on the best fit values of T_e, τ and T_{bb}. However, the inclination must be non-zero, because radio jets have been observed from 1E [5]. Therefore we give best fit values of other parameters fixing $R_{in}/R_c = 1$ and $i = 18°$ as follows: $T_e = 60$ keV, $\tau = 2.4$, $kT_{bb} = 0.27$ keV, $N_H = 13.1 \times 10^{22}$ cm^{-2} (see Table 1). $\chi^2 = 835.7$ with 760 d.o.f., so the data can be fitted very well with the ISM model, see Figure 2.

The 93 and 94 data of 1E are both well fitted with a similar set of parameter values, but the total flux in 93 is 40 % higher than in 94, whereas Sheth et al. [6] found a difference of 20 % using power law model. We are currently working on studying the time variability of ISM parameters that cause the flux variation. Here we use the average 94 and 93 ASCA flux, together with the above parameters to derive results. Since the electron scattering modifies the spectrum in the upper layers of the accretion disk we take the effective inner temperature of the disk to be $T_{eff} = 0.6T_{bb}$ [11]. This gives an inner radius of disk as ≈ 450 km or ≈ 15 Schwarzschild radii of $10M_\odot$ black hole radiating with $L_{disk} \approx 1.8 \times 10^{37}$ erg/s, corresponding to the mass transfer rate of $\approx 1 \times 10^{18}$ g/s, ($\dot{M} = L_{disk}/c^2$/efficiency, using efficiency = 0.016 at R_{in} [12]). This mass transfer rate ≈ 0.04 $\dot{M}_{Edd}$ ($\dot{M}_{Edd} = L_{Edd}/c^2$/efficiency, where the efficiency, calculated at $r = 3R_{Sch}$, is 0.057 [14]). Inside R_{in}, the spherical hot corona ($T_e \approx 60$ keV) emits Comptonized radiation with $L_h = 2.6 \times 10^{37}$ erg/s.

The inner radius of the disk that we deduce from observation of 1E is very similar to one obtained for other black hole candidates in their hard states. Poutanen et al. [13] and Życki et al. [14-15] deduce $R_{in} \approx 10 - 20 R_{Sch}$ for the disk in Cyg X-1 and X-ray novae GS 2023+338 (V404 Cyg) and Nova Muscae. The central hot cloud in 1E has temperature $T_e \approx 60$ keV and optical depth $\tau \approx 2.4$. These values are surprisingly close to electron temperatures and optical depths obtained from the spectral fits to the broad band data of Cyg X-1 ($T_e = 90$ keV, $\tau \approx 1.8$ [16, 17]) and GX 339-4 ($T_e = 60$ keV, $\tau \approx 2.0$ [18]). It seems that the electron temperature of order 60–100 keV and optical depth of the Comptonizing cloud of 1.5–2 are the signatures of the accreting black holes.

PARAMETERS	
N_H (10^{22} cm^{-2})	13.1
kT_{bb} (keV)	0.27
kT_e (keV)	60
τ_e	2.4
$\cos i$	0.95
reflection (fixed)	1.0
R_{in}/R_c	1.0
χ^2/d.o.f.	1.1
L_{total}(10^{37} erg/s)	4.4
L_{disk}/L_h	0.7
R_{in} (km)	450
R_{in}/R_{Sch}^a	15
$\dot{M}$ (10^{18} g s^{-1})	1
$\dot{M}/\dot{M}_{Edd}$ ^{b}	0.04

^{a} in units of Schwarzschild radius, $2GM/c^2$, for a $10M_\odot$ black hole
^{b} For $M = 10M_\odot$ and efficiency of 0.057

Table 1: ISM fit parameters of the standard state of 1E1740.7-2942

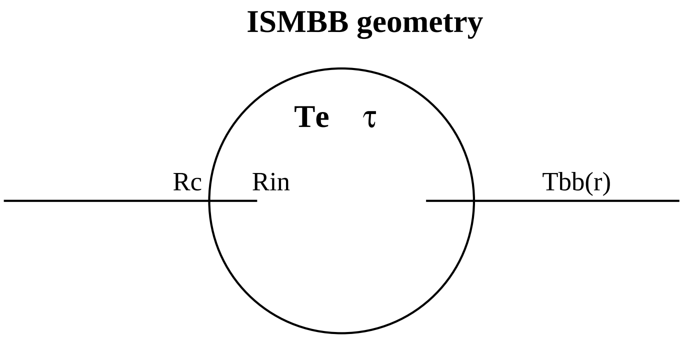

Figure 1: The schematic view of the geometry of the ISM model.

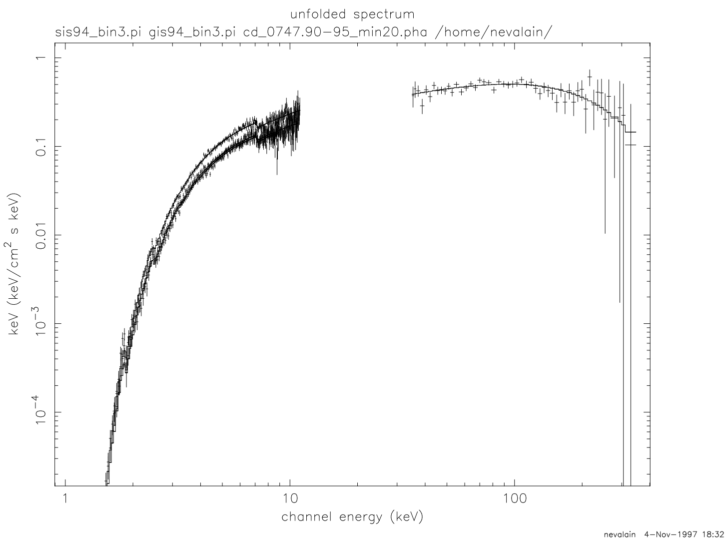

Figure 2: The best fit ISM model to ASCA and SIGMA data as explained in the text.

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