Broad-band spectroscopy of the eclipsing high-mass X-ray binary 4U 1700−37 with Suzaku

Gaurava K. Jaisawal* and Sachindra Naik

Astronomy and Astrophysics Division, Physical Research Laboratory, Navrangpura, Ahmedabad 380009, Gujarat, India

Accepted 2015 January 6. Received 2015 January 6; in original form 2014 September 9

ABSTRACT

We present the results obtained from broad-band spectroscopy of the high-mass X-ray binary 4U 1700−37 using data from a Suzaku observation in 2006 September 13–14 covering 0.29–0.72 orbital phase range. The light curves showed significant and rapid variation in source flux during the entire observation. We did not find any signature of pulsations in the light curves. However, a quasi-periodic oscillation at ~20 mHz was detected in the power density spectrum of the source. The 1–70 keV spectrum was fitted with various continuum models. However, we found that the partially absorbed high-energy cut-off power law and Negative and Positive power law with Exponential cut-off (NPEX) models described the source spectrum well. Iron emission lines at 6.4 and 7.1 keV were detected in the source spectrum. An absorption-like feature at ~39 keV was detected in the residuals while fitting the data with NPEX model. Considering the feature as cyclotron absorption line, the surface magnetic field of the neutron star was estimated to be ~3.4 × 10^{12} G. To understand the cause of rapid variation in the source flux, time-resolved spectroscopy was carried out by dividing the observation into 20 narrow segments. The results obtained from the time-resolved spectroscopy are interpreted as the accretion of inhomogeneously distributed matter in the stellar wind of the supergiant companion star as the cause of observed flux variation in 4U 1700−37. A sharp increase in column density after ~0.63 orbital phase indicates the presence of an accretion wake that blocks the continuum and produces the eclipse like low-flux segment.

Key words: binaries: eclipsing – stars: individual: 4U 1700−37 – stars: individual: HD 153919 – stars: neutron.

1 INTRODUCTION

4U 1700−37 was discovered by Uhuru satellite in December 1970 (Jones et al. 1973). Extensive follow-up observations with Uhuru revealed the system as an eclipsing binary with an orbital period of 3.412 d. One of the most luminous and hottest optical star among the known high-mass X-ray binaries, a supergiant star (HD 153919) of O6.5 Iaf spectral type, was identified as the optical companion (Hutchings et al. 1973). Using BATSE data, the orbital parameters of the binary system such as inclination i = 66°, eccentricity e < 0.01, 48 < a sin i < 82 lt-sec and semi-eclipse angle θ_e = 28.6° were derived (Rubin et al. 1996). Using Monte Carlo simulation, the mass of compact object and mass and radius of the optical companion star were constrained at M_x ~ 2.6 M☉, M_x ~ 30 M☉ and R_x ~ 18 R☉, respectively (Rubin et al. 1996). Using ultraviolet and optical spectroscopic observations, Clark et al. (2002) evaluated physical parameters of the optical companion and used in Monte Carlo simulation to estimate the mass of the X-ray source and optical companion to be M_x ~ 2.44 ± 0.27 M☉ and M_x ~ 58 ± 11 M☉. The distance of the binary system was estimated to be 1.9 kpc (Ankay et al. 2001).

A tentative detection of pulsation at ~67 s was reported from Tenma observations of 4U 1700−37 (Murakami et al. 1984). However, later observations did not confirm the detection of spin period in the source. Although detection of X-ray pulsations is not yet confirmed, the spectrum of 4U 1700−37 has been well described by the standard continuum models of the accretion-powered X-ray pulsars. Broad-band X-ray spectrum of 4U 1700−37 obtained from various observatories such as HEAO1, EXOSAT, Ginga, BeppoSAX had been described with a high-energy cut-off power-law model (White, Swank & Holt 1983; Haberl, White & Kallman 1989; Haberl & Day 1992; Reynolds et al. 1999). A soft excess component was also detected in the spectrum during the eclipse and eclipse ingress observations of 4U 1700−37 (Haberl et al. 1998; Haberl & Day 1992). 1991 April Ginga observation of the source showed a clear difference in the temperature corresponding to the soft excess component before and after the eclipse (0.47 and 0.74 keV). The

* E-mail: gaurava@prl.res.in