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Extracting flow parameters of H 1743-322 during early phase of its 2010 outburst using two component advective flow model

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Abstract. We study the spectral properties of Galactic transient black hole candidate H 1743-322 during its early phase of 2010 outburst with Two Component Advective Flow (TCAF) model, after its inclusion in spectral analysis software package XSPEC as a local model. For the analysis, spectral data from RXTE/PCA instrument in 2.5 – 25 keV energy band are used. From the spectral fit, accretion flow parameters such as Keplerian (disk) rate, sub-Keplerian (halo) rate, location of the shock and strength of the shock are directly extracted. QPO frequencies are predicted from the TCAF model spectral fitted shock parameters, 'closely' matches with the observed frequencies.

Keywords : stars: individual: H 1743-322 – black holes physics – shock waves

1. Introduction

The Galactic transient black hole candidates (BHCs) are interesting objects to study in X-rays because these sources generally show evolutions in their timing and spectral properties during their outbursts, which are strongly correlated to each other. In last few decades, more precisely after the launch of RXTE satellite, our understanding on BHCs have progressed a lot, although still we believe that there is a large space to improve our knowledge on the accretion flow dynamics around the BHCs. Here, we try to understand this important physical property of H 1743-322 during the early phase of its recent 2010 outburst by the spectral study using Two Component Advective Flow (TCAF) model (Chakrabarti & Titarchuk 1995, hereafter CT95).

It is a well known fact that the standard Keplerian disk (Shakura & Sunyaev 1973)

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cannot explain everything about the X-ray spectrum from BHCs, one necessarily require another flow component, namely the 'Compton' cloud (Sunyaev &Titarchuk 1980), which produces the non-thermal power-law part of the spectrum. In TCAF model, this Compton cloud is replaced by a low angular momentum (*sub-Keplerain*) flow. Matter in this accretion flow becomes hot close to the black hole, where the centrifugal pressure starts dominating and an accretion shock may or may not form depending on whether or not the shock condition is satisfied (CT95; Chakrabarti 1997, hereafter C97).

The recurrent low-mass X-ray binary candidate H 1743-322 has shown several epochs of X-ray flaring activity in the last decade. Recently in 2010, it showed X-ray outburst (Yamaoka et al. 2010) which continued for around two and half months and was monitored with RXTE on a daily basis. Detailed timing and spectral properties and their evolutions during the 2010 & 2011 outbursts of H 1743-322 are presented in Debnath et al. (2013a). Evolutions of QPO frequencies as of other transient BHCs (Chakrabarti et al. 2008, 2009; Debnath et al. 2010; Nandi et al. 2012) are also observed during the both rising and declining phases of the outbursts, fitted with propagating oscillatory shock (POS) solution. In Debnath et al. (2013a), spectral properties are studied with the combination of disk black body and power-law models. Here, spectral properties of the source during the early phase of its 2010 outburst are studied with TCAF model (CT95), after its inclusion in XSPEC. Also from the spectral fitted shock parameters, frequency of the observed QPOs are predicted, which approximately matches. The *paper*, is organized in the following way. In next Section, we present observation results based on the TCAF model spectral fit. Finally, in §3, we present the brief discussion and make some concluding remarks.

2. Observation and data analysis

We present spectral analysis results of publicly available archival data from the RXTE PCA instrument for the early phase of the 2010 outburst of H 1743-322. We have extracted and analyzed the RXTE archival spectral *standard2* mode data starting from 2010 August 09 (Modified Julian date, MJD=55417) to 2010 August 16 (MJD=55424) from the PCA instrument. For the spectral study using TCAF model, we first generated model *fits* file by feeding $\sim 4 \times 10^5$ numbers of theoretical model spectra in a program written in FORTRAN (for detailed properties of the model and its implementation in XSPEC see, Debnath et al. 2013b). The model spectra are generated by varying five input parameters in modified CT95 code.

2.5 – 25 keV PCA background subtracted spectra are fitted with TCAF model *fits* file. To achieve best fit a Gaussian line of peak energy around 6.5keV is used. For the entire outburst, the hydrogen column density (N_H) is kept fixed at 1.6×10^{22} (Debnath et al. 2013a) and also 1.5% systematic error is assumed. For the spectral fittings with TCAF model, one needs to supply five model input parameters: *i*) Keplerian rate ($\dot{m}_d$ in Eddington rate), *ii*) sub-Keplerian rate ($\dot{m}_h$ in Eddington rate), *iii*) black hole mass (M_{BH}) in solar mass ($M_\odot$) unit, *iv*) location of the shock (r_s in Schwarzschild radius r_g=$2GM/c^2$), and *v*) compression ration (R) (ratio between post- and pre- shock

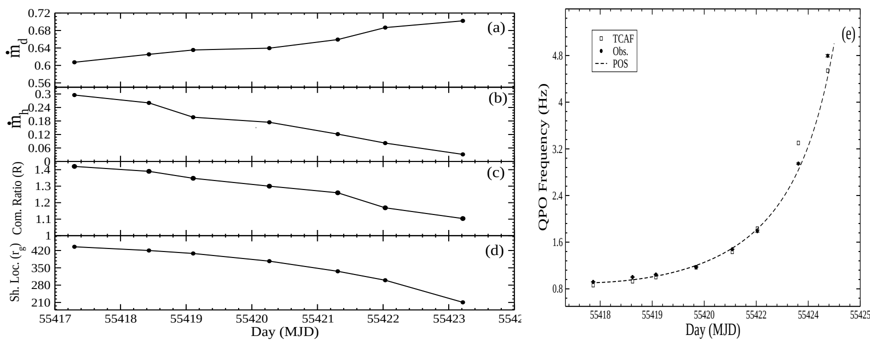

Figure 1. (a-e) Variation of TCAF model fitted spectral parameters (Keplerian rate $\dot{m}_d$, sub-Keplerian rate $\dot{m}_h$, compression ratio R, and shock location r_s) are shown in the plots of left panel and in right panel, recalculated QPO frequencies from the TCAF model fitted shock parameters and from the observations are shown. Also, day-wise QPOs calculated from POS model solution (dotted curve) as presented in Debnath et al. (2013a) are shown in this plot.

densities, i.e., equal to ρ_+/ρ_-) of the shock other than model normalization value (*norm*), which is equivalent to $\frac{1}{4\pi D^2} cos(i)$, where D is the source distance in 10 kpc unit and i is the disk inclination angle.

In Fig. 1(a-d), the variation of TCAF model fitted spectral parameters, such as two types of accretion flow rates ($\dot{m}_d$ and $\dot{m}_h$), and shock parameters (R and r_s) are discussed. From the figure it is clear that as time passed, disk becomes more cooler with the rise in Keplerian component and fall in sub-Keplerian rate.

According to shock oscillation model (SOM), shock wave oscillates either because of a resonance, where the cooling time of the flow is approximately the infall time (Molteni et al. 1996) or because the Rankine-Hugoniot condition is not satisfied (Ryu et al. 1997) to form a steady shock and the QPO frequency is inversely proportional to the infall time (t_{infall}) in post-shock region. According to POS (which is nothing but a time varying version of SOM) solution (Chakrabarti et al. 2008, 2009; Debnath et al. 2010, 2013a; Nandi et al. 2012), one can obtain the QPO frequency (ν_{QPO}) if one knows the instantaneous shock location compression ratio or vice-versa. Here from the TCAF model spectral fit, these two important shock parameters are extracted and from there we have predicted frequency of the observed QPOs as defined in the equation $\nu_{QPO} = C \left[R r_s (r_s - 1)^{1/2} \right]$, where C is a constant, equals to $M_{BH} \times 10^{-5}$, and M_{BH} is the mass of the BHC. In Fig. 1e, these predicted QPO frequencies along with observed and day-wise calculated POS model fitted QPOs (Debnath et al. 2013a) are shown. From Fig. 1(c-d), it is clear that with time shock moved inward with reducing strength; as a result of which, frequencies of the observed QPOs are increased.

3. Discussions and concluding remarks

Here, we present preliminary results based on TCAF model spectral fit of the early rising phase of 2010 outburst of the Galactic transient BHC H 1743-322. We have included TCAF model in HEASARC's spectral analysis software package XSPEC as a local additive model after generation of model *fits* file using a bank of theoretical spectra. From the spectral study with TCAF model, accretion flow properties of the source during the early phase of the outburst are understood in a better manner, where variation of two component accretion flow rates as well as shock parameters are observed directly.

From the spectral fit, it is also clear that initially spectra are dominated with the Comptonized sub-Keplerian halo rate and the source is found to be in hard/low-hard state. As time goes, supply from the Keplerian component increases, as a result of which, the source moved towards the softer states. On the first day of our observation, shock was found to be at $\sim 435\ r_g$, and it moved towards the black hole horizon with time (day) with decreasing shock strength and reaches $\sim 175\ r_g$ on the last day of our present observation. From the shock parameters the frequency of the observed QPOs are also predicted, which roughly matches with the observed as well as POS model fitted values. The evolution of the spectral properties and observed QPO frequencies as predicted from the TCAF model spectral fit for 2010 & 2011 outbursts of H 1743-322 will be presented in our future journal articles (Mondal et al. 2013; Debnath et al. 2013b).

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