Orbital resolved spectroscopy of GX 301–2 with MAXI–GSC

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Abstract

The highly absorbed bright high mass X-ray binary GX 301–2, exhibits stable periodic orbital intensity modulations with a strong pre-periastron X-ray flare. Several models have been proposed to explain the accretion at different orbital phases, invoking accretion via stellar wind or equatorial disc, and accretion stream from the companion star. In Islam & Paul (2014), we presented results from exhaustive orbital phase resolved spectroscopic measurements of GX 301–2 using data from the Gas Slit Camera onboard MAXI. We have found a strong orbital dependence of the absorption column density and equivalent width of the iron emission line. A very large equivalent width of the iron line along with a small value of the column density in the orbital phase range 0.1–0.3 after the periastron passage indicates the presence of high density absorbing matter behind the neutron star in this orbital phase range. The orbital dependence of these parameters are then used to examine the various accretion models of GX 301–2 and provide stronger constraints.

Key words: stars: individual: GX 301-2 stars: neutron X-rays: stars

1. Introduction

GX 301-2 is a high-mass X-ray binary (HMXB) system with an X-ray pulsar and a B-emission line hypergiant star WRAY 997. The orbital period of the binary system is ~ 41.5 d and a spin period of ~ 685 s (Koh et al. 1997). It exhibits periodically varying intensity modulations: a bright phase during X-ray flare (pre-periastron passage around orbital phase 0.95), dim or low intensity phase (after periastron passage around orbital phase 0.15–0.3) and intermediate intensity phase (during the apastron passage around orbital phase 0.5). A strong X-ray flare occurs before the periastron passage as well as a medium intensity peak is observed at the apastron passage, indicating accretion on to the neutron star due to both spherical stellar wind along with a possible equatorial disc or accretion stream (Pravdo & Ghosh 2001; Leahy & Kostka 2008).

GX 301–2 has a highly absorbed X-ray spectrum with a partial covering high energy cutoff power-law component and several emission lines. It has a very high line of sight photoelectric absorption, which is attributed to the dense circumstellar environment in which the neutron star moves. The column density varies strongly with orbital phase with certain amount of clumpiness attributed to the stellar wind (Mukherjee & Paul 2004). A prominent Fe Kα line is found to exist in almost all orbital phases. This fluorescence line is produced due to reprocessing of X-ray photons from the pulsar by the circumstellar matter. The equivalent width of the Fe Kα line depends on the distribution (geometry and column density) of the surrounding matter (Inoue 1985; Kallman et al. 2004). Therefore, by comparing the equivalent width of Fe Kα line with N_H, we can study the distribution of circumstellar matter around the neutron star at different orbital phases and can be further used to examine various accretion models.

In Islam & Paul (2014), we carried out orbital phase resolved spectroscopic study of GX 301–2, using MAXI–Gas Slit Camera (Matsuoka et al. 2009). Using spectroscopic analysis of the MAXI data with unprecedented orbital coverage for many orbits continuously, we studied the orbital phase dependence of the column density and the line equivalent width, which are then used to examine the various models about the distribution of circumstellar matter and the mode of accretion in GX 301–2.

1.1. Data and Analysis

Using MAXI on demand data, [1] we extracted orbital resolved spectra in 21 independent orbital bins. These orbital resolved spectra are fitted with two models: an absorbed power-law continuum, with and without a high energy cut-off. A Fe fluorescence line was found in all the orbital phases, which was modelled by a single Gaussian

*1 http://maxi.riken.jp/mxondem/

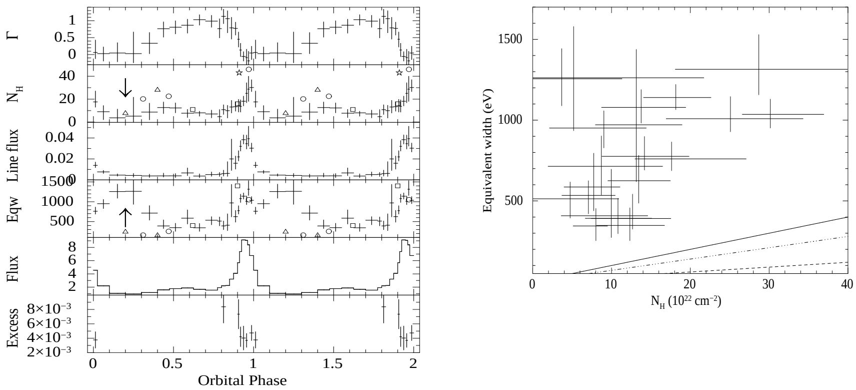

Fig. 1. Left panel (a): Orbital variation of Photon index (Γ), column density (N_H in 10^{22} cm^{-2}), Line flux of Fe Kα (photons cm^{-2} s^{-1}), Equivalent width of Fe Kα line (Eqw in eV) and Flux of source (F in 10^{-9} ergs s^{-1} cm^{-2}) for power-law model with high energy cut-off model. The arrow denotes the orbital phase of high equivalent width of Fe Kα line for low N_H. Circles corresponds to the spectral fit value taken from Endo et al. (2002) (ASCA), squares from La Barbera et al. (2005) (BeppoSAX), triangles from Suchy et al. (2012) (Suzaku) and star from Fürst et al. (2011) (XMM-Newton). Right panel (b): Plot of equivalent width of Fe Kα versus N_H. Solid line and dashed lines represents the relation between equivalent width and column density of absorbing matter for isotropically distributed matter at different Γ (Inoue 1985; Kallman et al. 2004).

line. For some orbital phases near the X-ray peak, a low energy excess is found to be present in the spectra. To only estimate the flux in the soft excess, we have modelled the low energy excess with an unabsorbed blackbody component.

2. Discussions and Conclusions

Figure 1a shows the orbital variation of Γ, N_H, flux and equivalent width of Fe fluoresence line, total flux of the system and ratio of flux included in the low excess to the total flux, for the absorbed power-law with a high energy cutoff model. The N_H and equivalent width measurements of the Fe Kα using single pointed observations at different orbital phases are overlaid on the plot and they show a large scatter in the measurements. The short scale variations are smeared out while studying the long term averaged behaviour of this source with MAXI–GSC data and the long term accretion structures are brought forth.

The column density N_H is found to vary with a pattern similar to the flux of the system, indicating a possible origin of flare due to increased mass accretion. The orbital variation of equivalent width of Fe Kα line shows a different trend as compared to the orbital variation of column density. The highest equivalent width occurs at the dim phase of 0.1–0.3 which also has lowest N_H along the line of sight (denoted by arrows in Figure 1a). Figure 1b is the plot of equivalent width of the iron line and the absorbing column density N_H in different orbital bins. These observations highly deviate from the relation expected for an isotropically distributed gas (Inoue 1985; Kallman et al. 2004). Instead, there seems to exist high anisotropicity in the distribution of circumstellar matter around the X-ray pulsar, especially in some orbital phases. These results strongly favour a high density gas stream plus a stellar wind model for mode of accretion on to the neutron star in GX 301–2 and provide stronger constraints to the model (Leahy & Kostka 2008). The relation between equivalent width of Fe line and column density of absorbing matter can be used for probing the geometry and distribution of circumstellar matter around other wind-fed systems.

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