Orbital resolved spectroscopy of GX 301–2 with MAXI: wind diagnostics

Nazma Islam and Biswajit Paul

Indian Institute of Science, India
Raman Research Institute, India

14 December 2015

28^{th} Texas Symposium for Relativistic Astrophysics, Geneva, Switzerland

GX 301–2

- Highly absorbed ($N_H \sim 10^{23}$ cm^{-2}) High Mass X-ray binary with a B hypergiant star WRAY 977 as companion.
- Orbital period of the binary system $\sim$ 41.5 days and the neutron star has a spin period $\sim$ 685 s. Eccentric orbit with no X-ray eclipses.

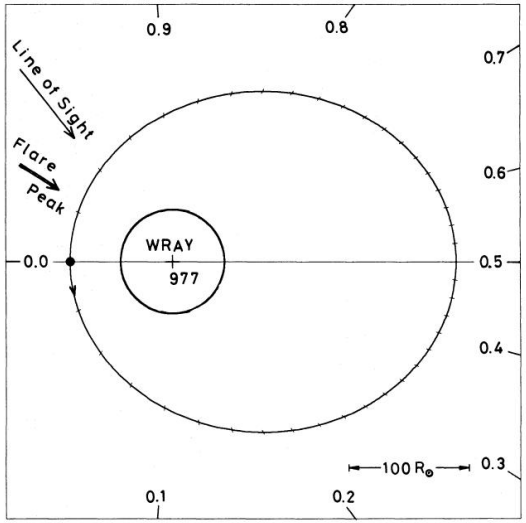


Figure : Schematic view of orbit of GX 301–2. Reference: Sato et.al 1986

Light-curve of GX 301–2

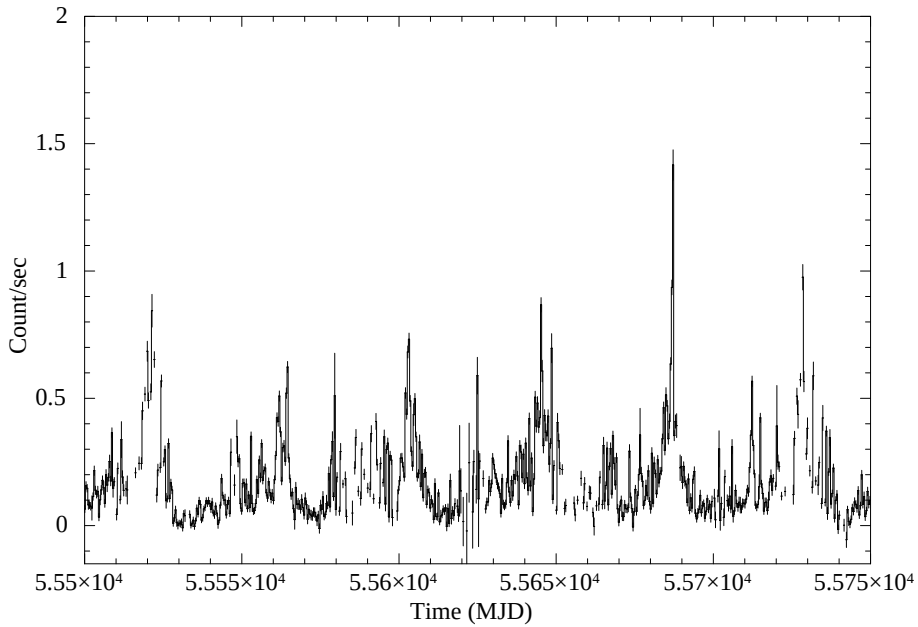


Figure : Light curve of GX 301–2 for 6 orbital cycles in MAXI.

Light curve of GX 301–2

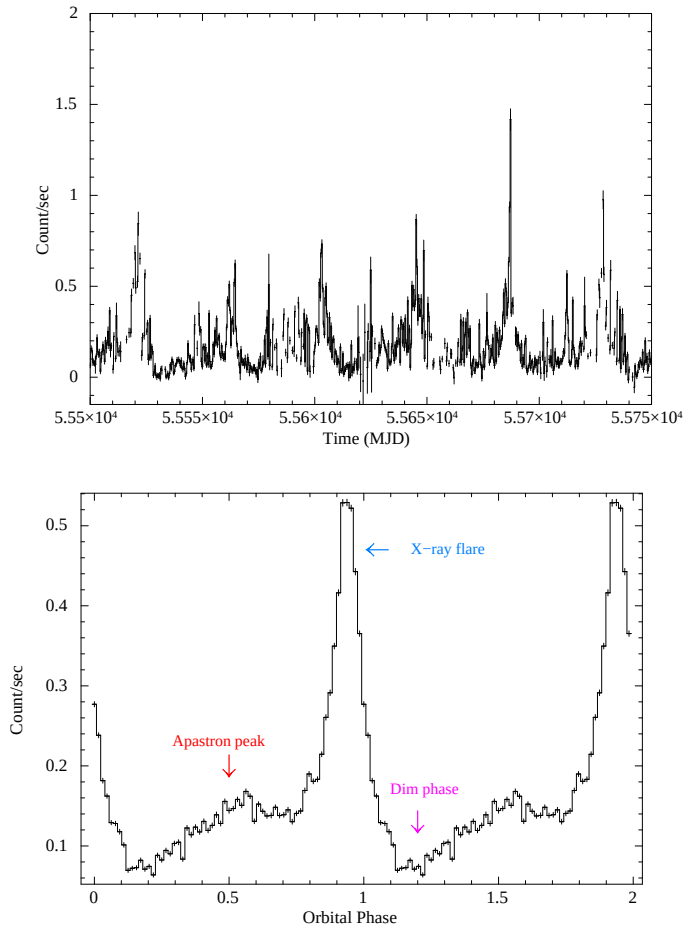
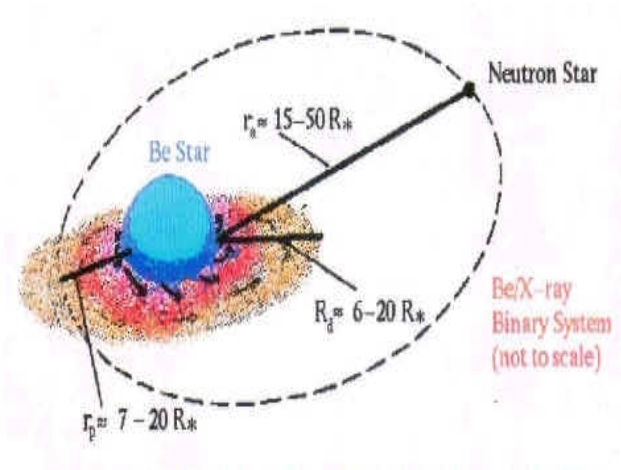
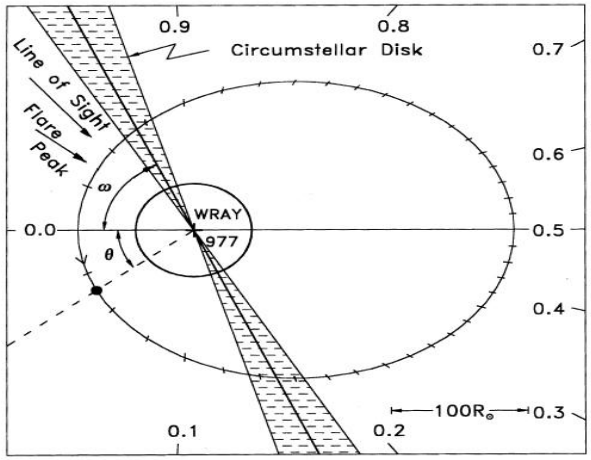


Figure : Orbital intensity profile of GX 301–2 showing strong periodically variable X-ray intensity modulations with a pre-periastron X-ray flare.

Accretion models of GX 301–2

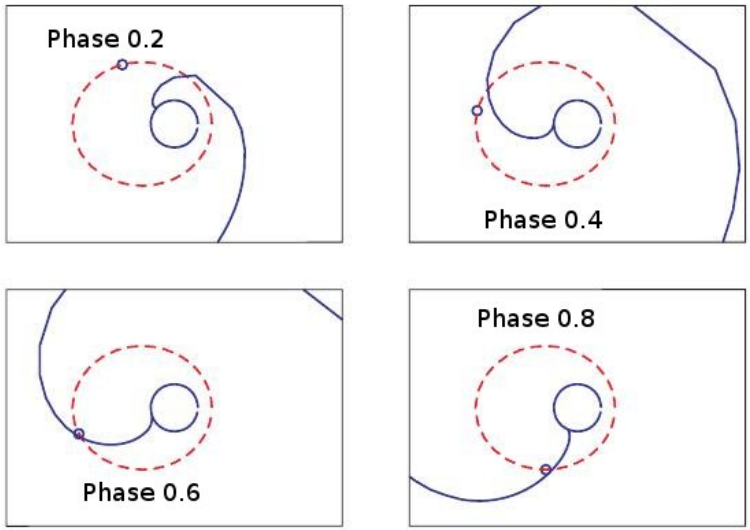
- Pravdo & Ghosh 2001 (PG model): enhanced circumstellar disk around the star.





Accretion models of GX 301–2

- Leahy and Kostka 2008 (LK08 model): stellar wind plus high density accretion stream.



Using Iron line as tracer

- In X-ray binaries, Fe Kα fluorescence line is produced by reprocessing of radiation from the surrounding circumstellar matter.
- Equivalent width of Fe Kα line is the ratio of line intensity to the continuum intensity. Measure of strength of emission line.
- Equivalent width of the Fe Kα line depends on the geometry and density of the surrounding matter.

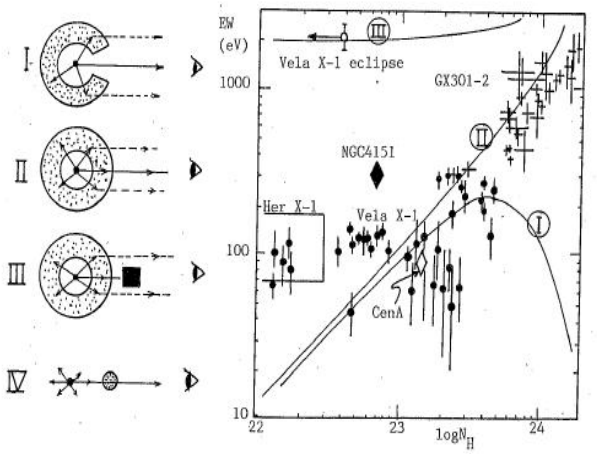


Figure : Dependence of Eqw on N_H for different geometry of surrounding matter. Reference: Makishima 1986

Observational Signatures of GX 301-2

- Orbital dependence of column density.
- Relation between the line equivalent width and column density as a function of orbital phase.
- Main criteria for such analysis is uniform orbital coverage which is required for orbital phase resolved spectroscopy.

Monitor of All Sky X-ray Image (MAXI)

- MAXI is the first astronomical mission operated on the ISS since Aug 2009.
- Best sensitivity and highest energy resolution among the all sky X-ray monitors.
- Uniform orbital coverage for GX 301-2 for multiple orbital cycles. Smearing out of short time scale variations and long-term accretion characteristics are brought out.
- Gas Slit Camera: Xe gas proportional counters and slit-slat energy band: 2-20 keV.

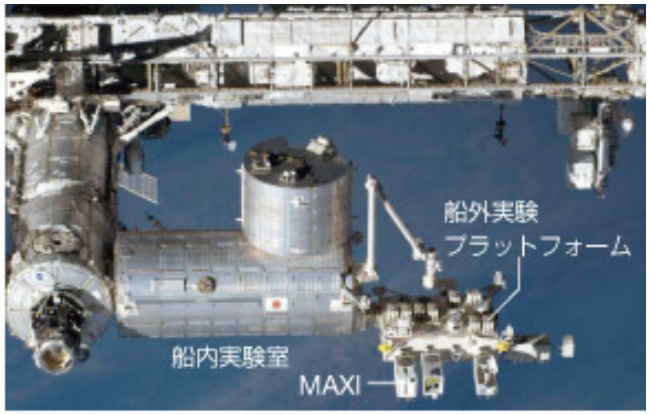
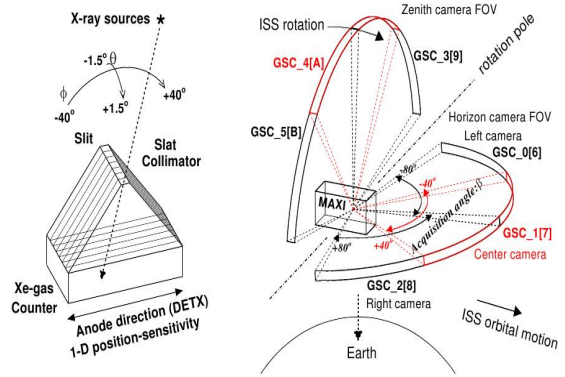
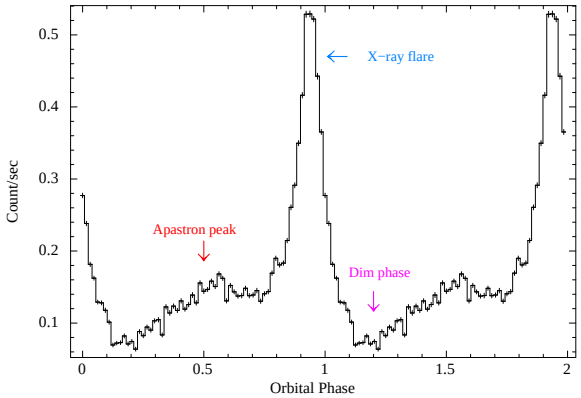


図1 全天X線監視装置（MAXI）写真提供：NASA



Orbital resolved spectroscopy of GX 301-2



- 21 independant orbital bins are chosen for orbital resolved spectral study.
- Spectrum fitted with a power-law with a high energy cut-off model and a power-law model modified by photo-electric absorption by column density of absorbing material along our line of sight.
- Fe Kα line found in the spectrum is modelled by a gaussian emission line.

Results

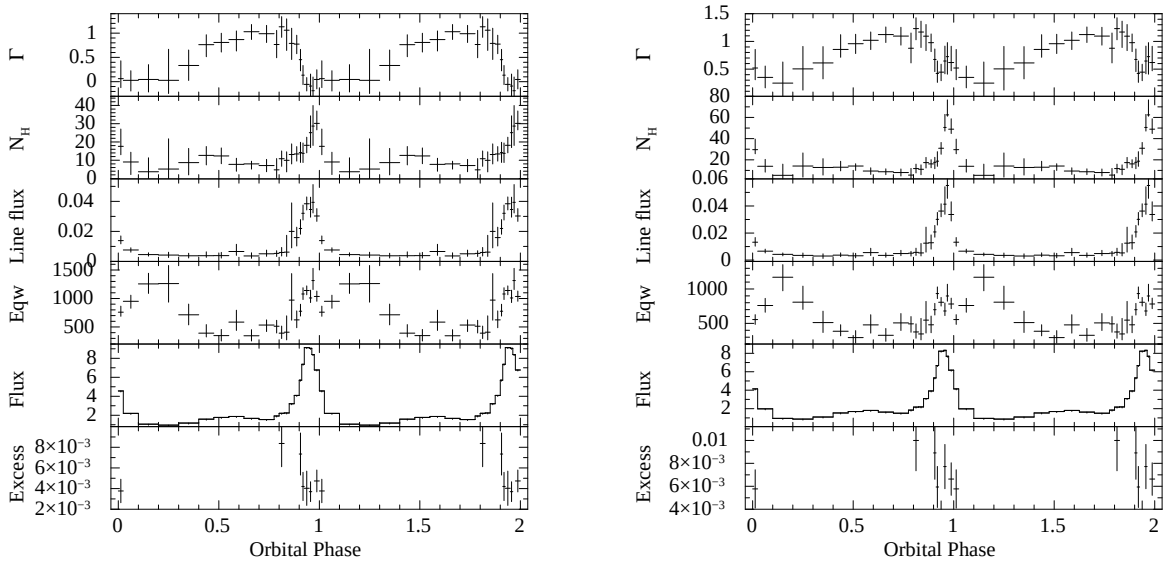


Figure : Orbital variation of Photon index (Γ), column density (N_H in units of 10^{22} cm^{-2}), Line flux of Fe Kα (in units of photons cm^{-2} s^{-1}), Equivalent width of Fe Kα line (Eqw in units of eV) and Flux of source (F in the units of 10^{-9} ergs s^{-1} cm^{-2}). There is a presence of a soft excess at some orbital phases which we model by a blackbody component to estimate the flux of the soft excess.

Examination of different accretion models in light of results

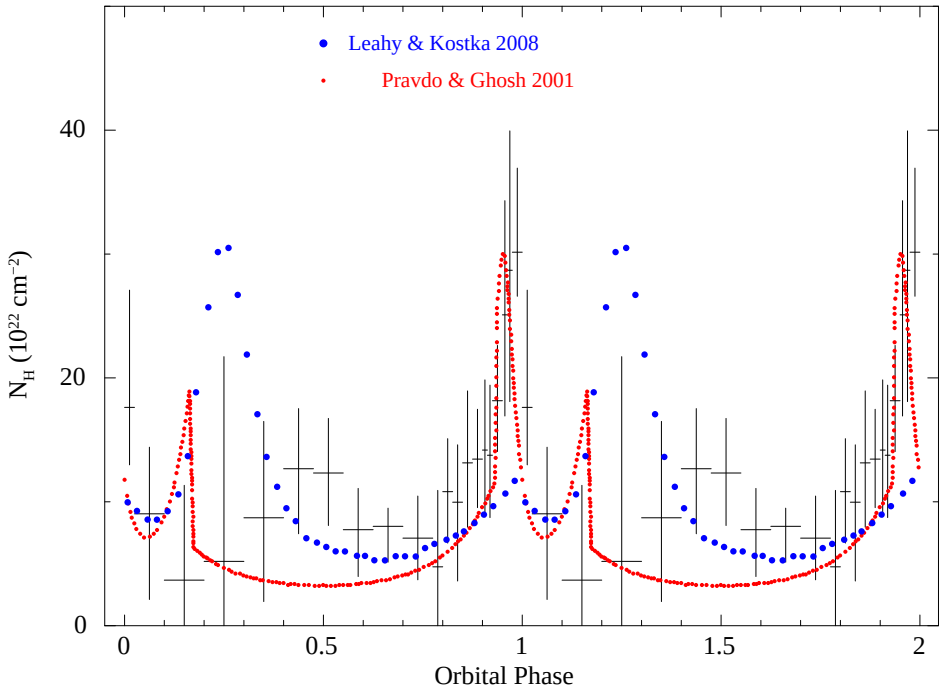
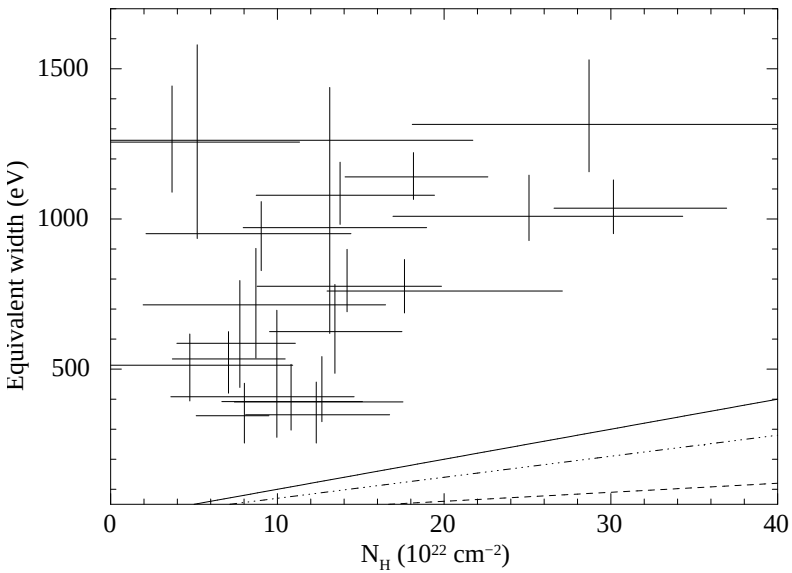


Figure : Comparison of orbital variation of column density of GX 301-2 with the prediction of circumstellar disk model and accretion stream model.

Results and Discussions



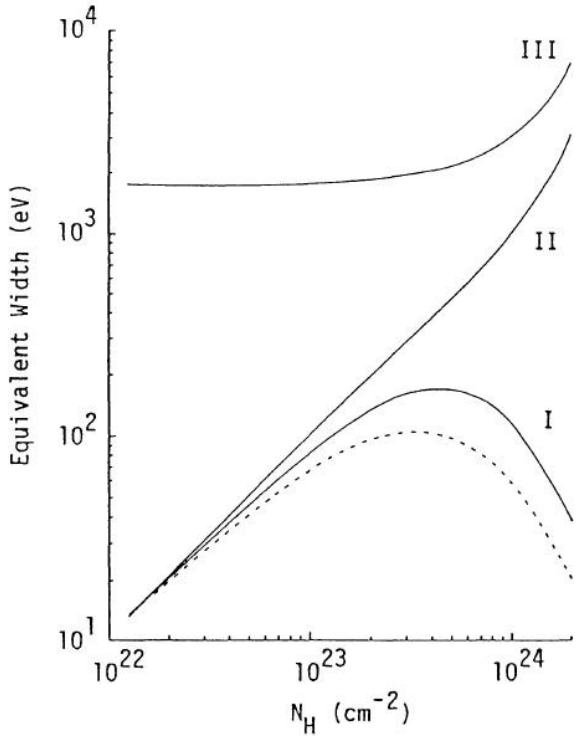
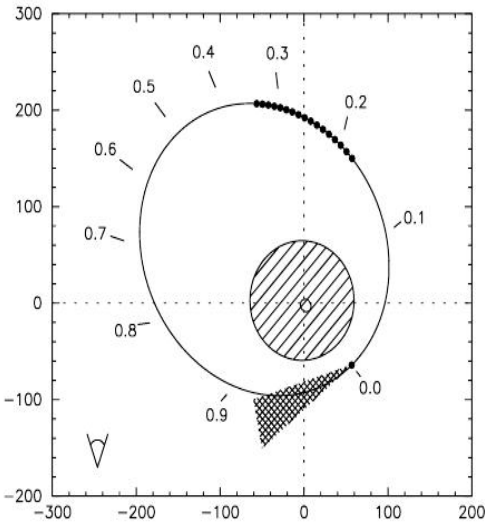


Figure : Plot of equivalent width versus N_H compared to the linear relation expected for a isotropically distributed circumstellar matter taken from Inoue 1985.

Wind Diagnostics



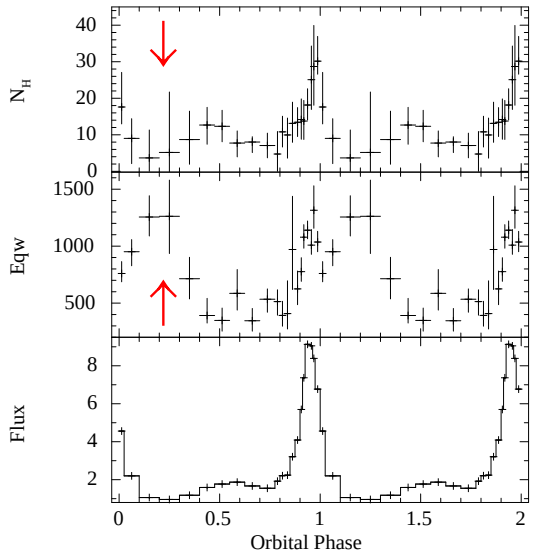


Figure : Optical observations by Kaper et.al 2006, indicate a dense gas stream trailing behind the compact object away from line of sight around phase 0.18-0.34. A very large equivalent width of the iron line along with a very small value of the column density is found around phase 0.1-0.3, strongly indicating the presence of matter behind the neutron star.

Wind Diagnostics

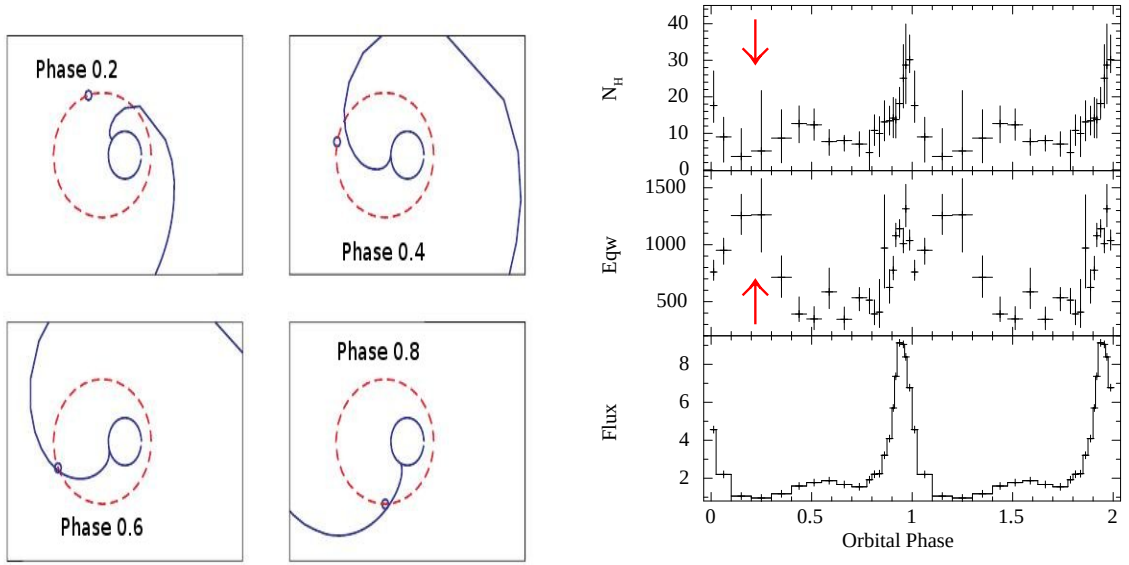


Figure : These observations do not conform to the direction of the accretion stream predicted by Leahy and Kostka 2008.

Summary

- Orbital resolved spectroscopy of GX 301–2 with MAXI, averaging over multiple orbital cycles.
- Using Fe line as additional tracer, we find changes in the accretion geometry. The results favor the model of high density accretion stream around GX 301–2. The orbital dependence of N_H and equivalent width of Fe line provides stronger constraints to the accretion stream model.

Islam N. & Paul B.; 2014, MNRAS, 441, 2539.

Thank You

Summary

- Orbital resolved spectroscopy of GX 301–2 with MAXI, averaging over multiple orbital cycles.
- Using Fe line as additional tracer, we find changes in the accretion geometry. The results favor the model of high density accretion stream around GX 301–2. The orbital dependence of N_H and equivalent width of Fe line provides stronger constraints to the accretion stream model.

Islam N. & Paul B.; 2014, MNRAS, 441, 2539.

Thank You