Time Resolved Spectroscopy of High Mass X-ray Binaries

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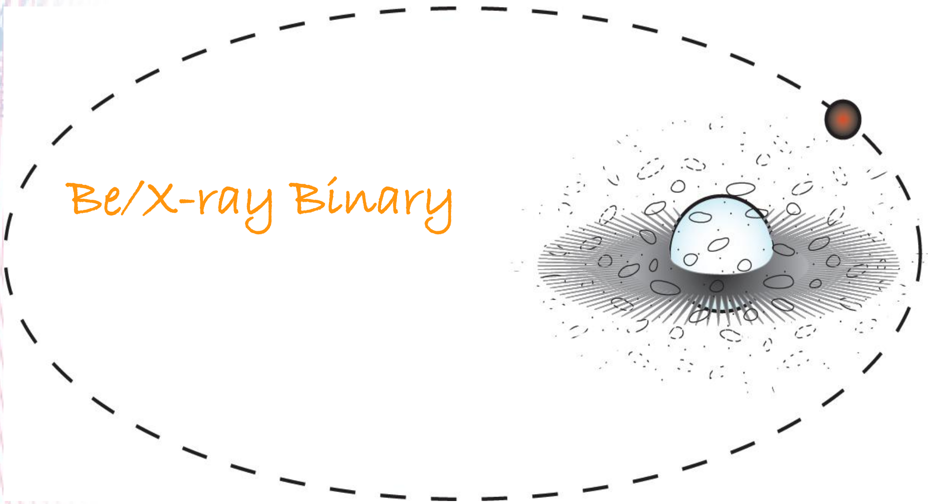
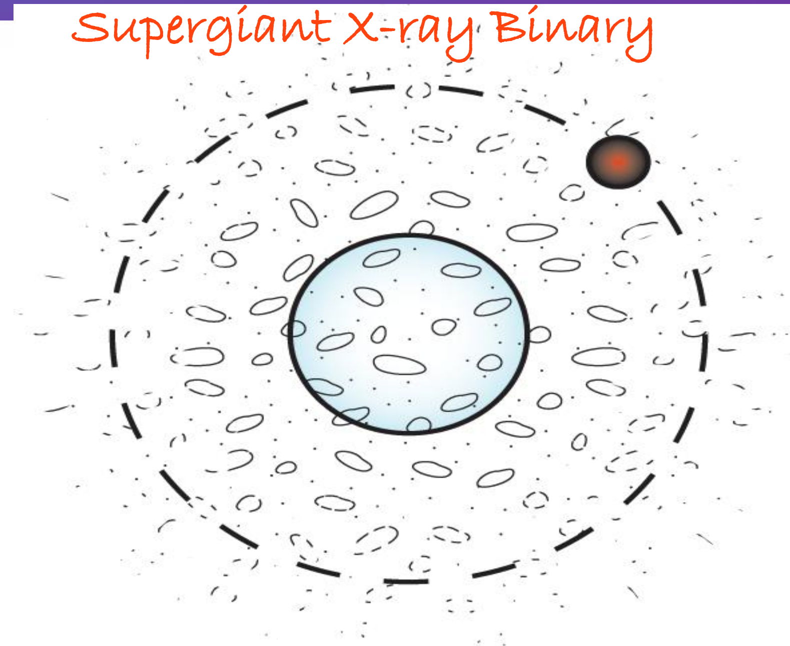
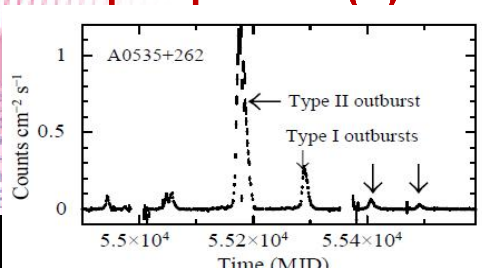
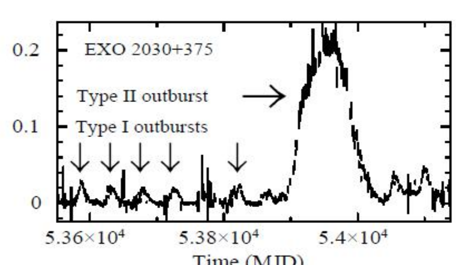
Neutron star HMXB

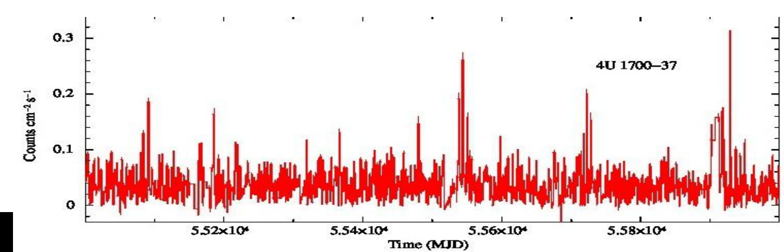




X-ray luminosity (erg/s)	10^{36} — 10^{37}	10^{35} — 10^{37}
on-timescale	weeks/months	quasi-continuously
off-timescale	months/years	minutes
Orbital period (d)	16—330	1.4—10
Spin period (s)	4—1000	100—5000

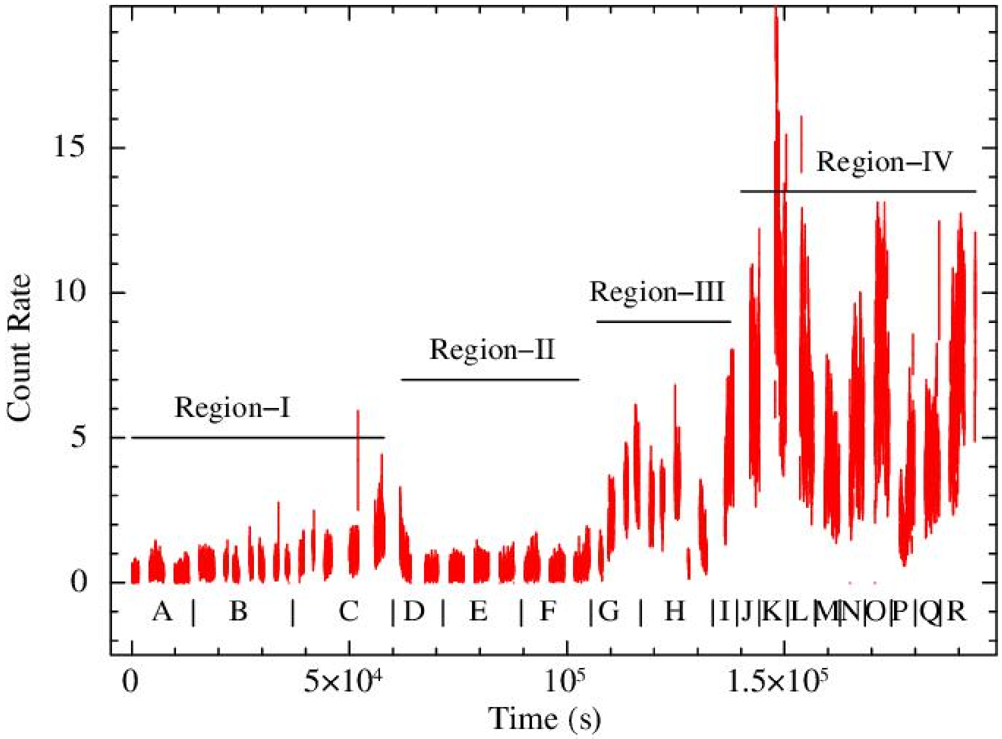






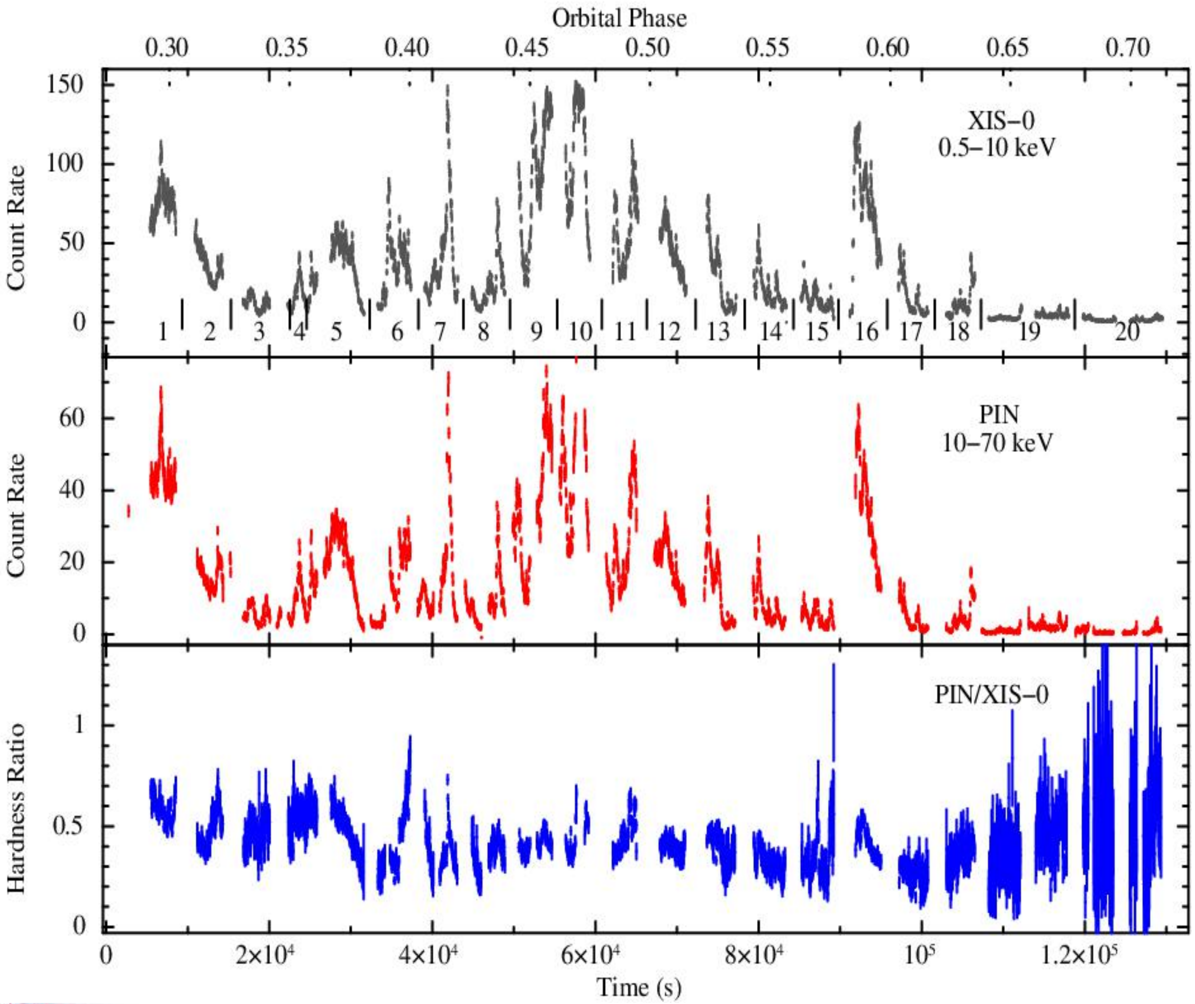
High mass X-ray binaries: OAO 1657-415 and 4U 1700-37

- OAO 1657-415 was discovered by Copernicus satellite.
- Pulsation period : 38.22 s
- Orbital period Porb = 10.4 d
- Eclipsing binary; duration of the eclipse = 1.7d,
- Cyclotron absorption feature at 36 keV.
- Companion is O type star.



Suzaku light curve of OAO 1657-415

High mass X-ray binaries: OAO 1657-415 and 4U 1700-37

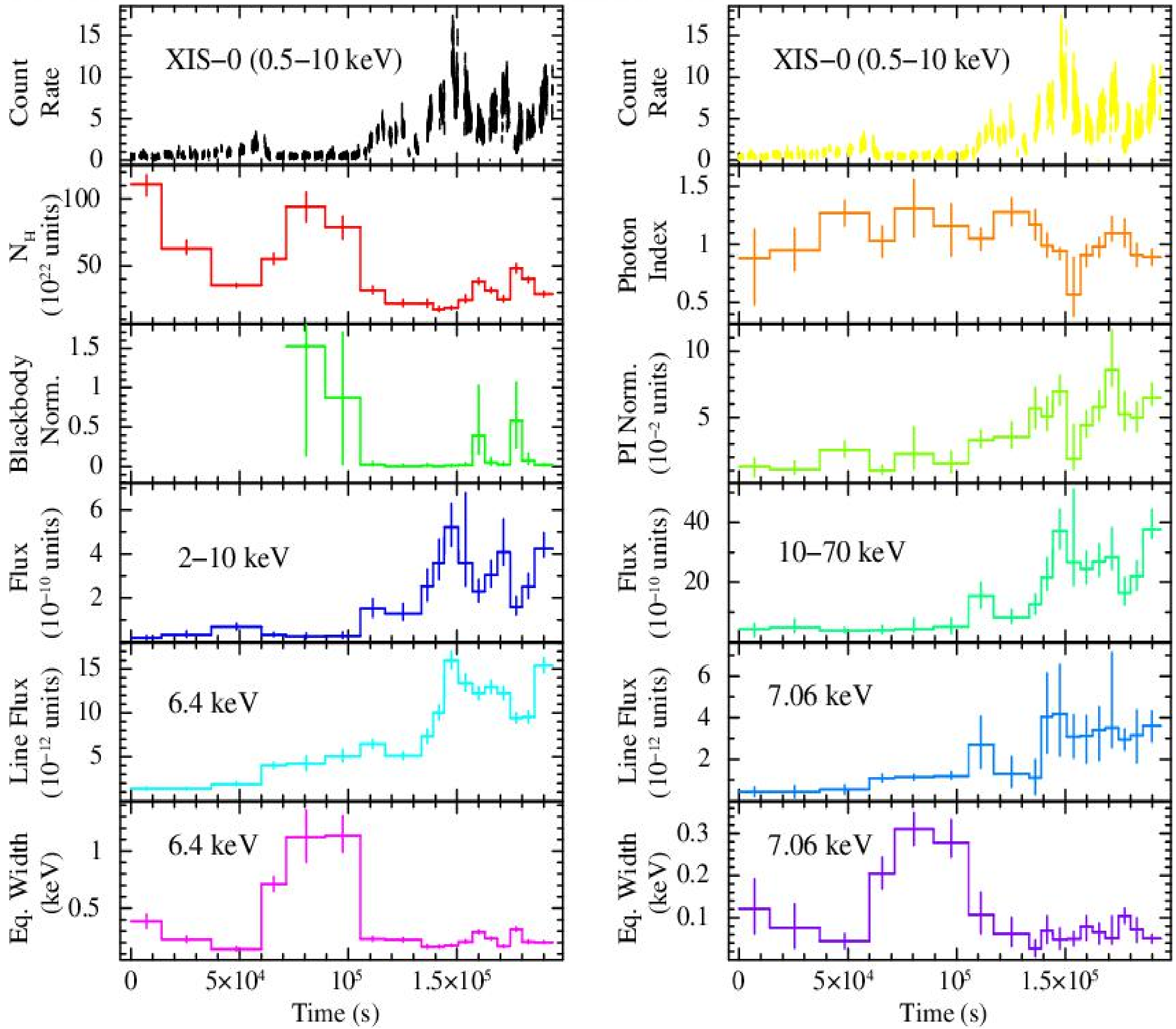


Suzaku light curve of 4U 1700-37

- Discovered with Uhuru satellite in 1970
- No Pulsation; QPOs
- Orbital period 3.412 d
- Eclipsing binary
- Nature of compact object is UNKNOWN
- Possible Cyclotron line at 36 keV
- O type supergiant companion.

Spectral parameters from time resolved spectroscopy of OAO 1657-415

- **Column density is high along in Region-II.**
- **Line flux is low and following source flux trend.**
- **Unusual high value of equivalent widths in Region-II compared to Region-I, though both were at similar flux level, suggested the presence of significant amount of additional matter emitting iron emission lines at that orbital phase of the binary pulsar.**



What can be estimated from the time resolved spectroscopy?

- Luminosity is the function of density and velocity (Bondi & Hoyle 1944). Fluctuations in density and velocity profile changes the luminosity. $L_x \propto \rho v^{-3}$

- Assuming the clumps of matter producing variations in luminosity, the mass of the clump can be estimated by comparing the gravitational potential energy of clump to the energy released due to its accretion onto the neutron star

$$M_c = \frac{L_x t_f R_{ns}}{\eta G M_{ns}} = 5 \times 10^{21} \left(\frac{L_x}{10^{37}\ \mathrm{erg\ s^{-1}}} \right) \left(\frac{t_f}{10\ \mathrm{ks}} \right) \mathrm{g}$$

Therefore, for a given set of physical parameters of the spherical clump, its mean density (nc) and radial column density (Nc) can be estimated as

$$n_c = \frac{3M_c}{4\pi m_p R_c^3} = 4 \times 10^{11} \left(\frac{L_x}{10^{37}\ \mathrm{erg\ s^{-1}}} \right) \times \left(\frac{t_f}{10\ \mathrm{ks}} \right)^{-2} \left(\frac{v_{rel}}{250\ \mathrm{km\ s^{-1}}} \right)^{-3} \mathrm{cm^{-3}}$$

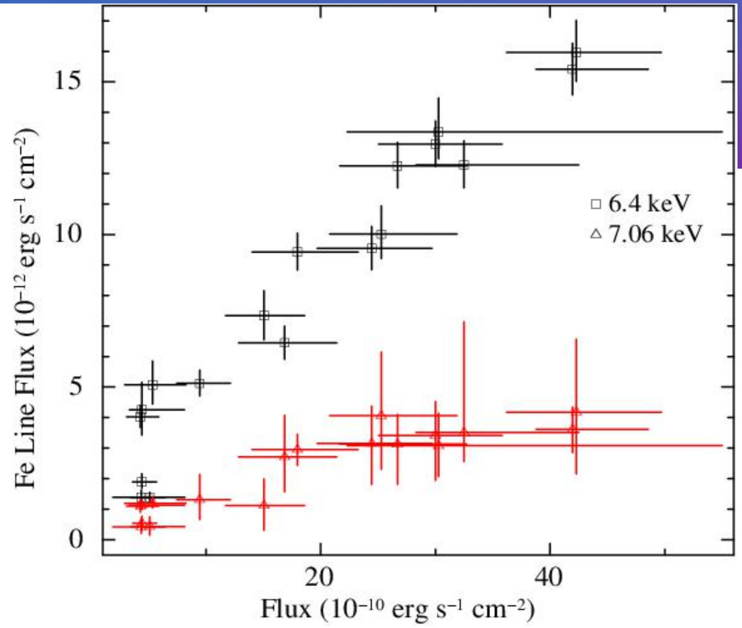
$$N_c = n_c R_c = 5 \times 10^{22} \left(\frac{L_x}{10^{37}\ \mathrm{erg\ s^{-1}}} \right) \times \left(\frac{t_f}{10\ \mathrm{ks}} \right)^{-1} \left(\frac{v_{rel}}{250\ \mathrm{km\ s^{-1}}} \right)^{-2} \mathrm{cm^{-2}}$$

- From time resolved spectroscopy, we have column density (Nc), luminosity and duration (from LC).

- We have calculated the mass of clumps.

- Estimated the column density for some segments which matches with the observed values.

Iron emission regions



Reprocessing or emission region closer to neutron star.

HOW CLOSER???

Distance can calculated from the iron line parameters…

For all segments, the energy of iron lines is found variable.

The value of line flux ratio (Fe beta/ Fe alpha) was found to be higher than the theoretically predicted value (~0.13) for neutral iron atom in optical thin medium (Kaastra & Mewe 1993). This suggests that the line emitting region can be a mixture of neutral and ionized iron atoms. The observed line energy and flux ratio indicate the possible existence of ionized iron atoms in ionization state between Fe VIII to Fe XVIII .

Ionization of the iron atoms is characterized by the ionization parameter L/nr^2 and its value should be $10^{2.5}$ erg/cm/s (Ebisawa et al. 1996) for ionization below FeXVIII.

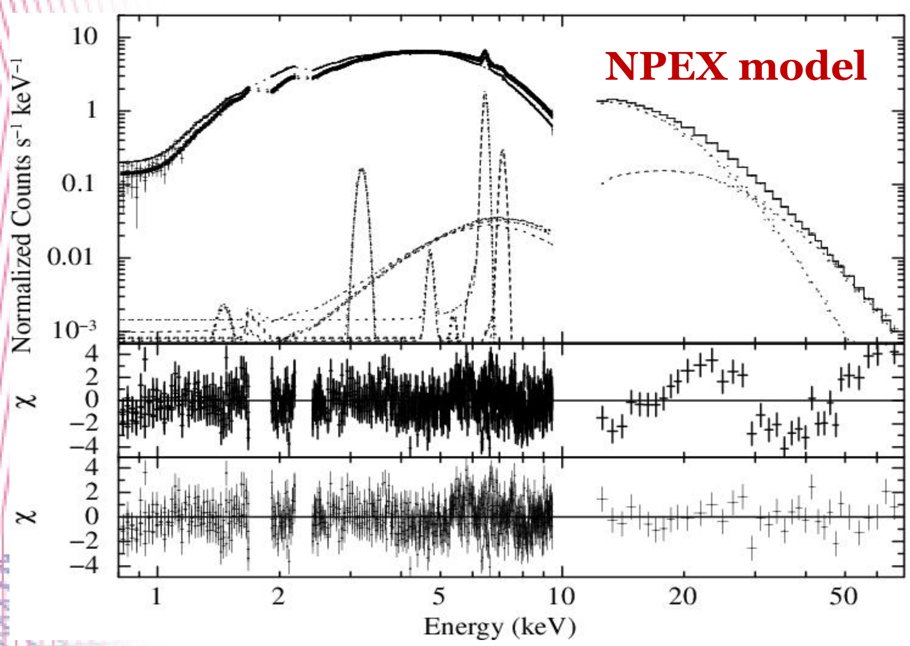
For typical parameters from observations, the distance is calculated to be 5.7×10^{11} cm. It is within the accretion radius.

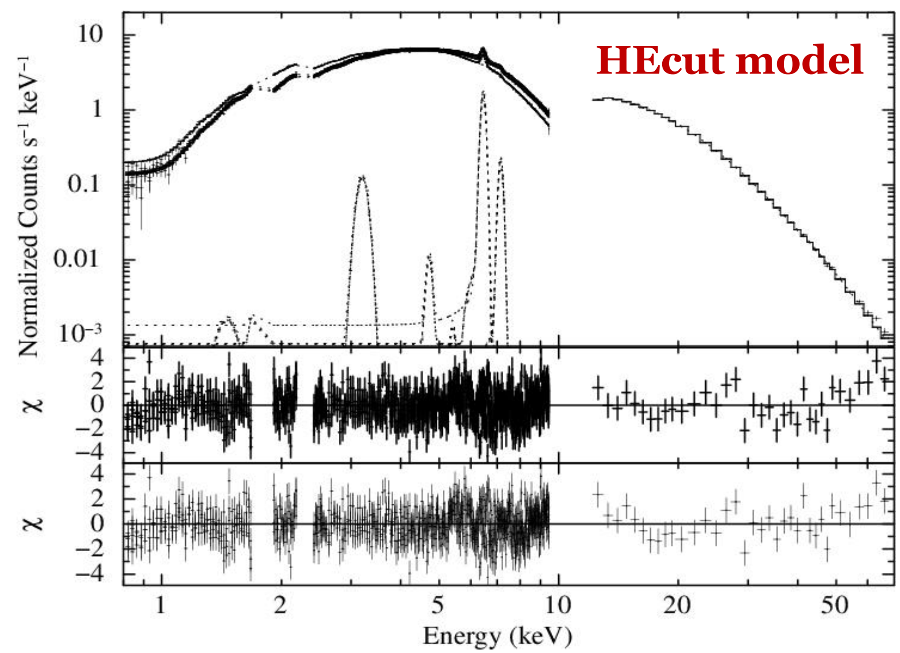
Spectral Properties

- **Well described with NPEX model.**
- **Possible detection of cyclotron line at 37 keV. The magnetic field of neutron star (*if*)**

-- 3.4 × 10^{12} G.

- **However, the line width is quite large.**
- **Less prominent in HEcut model.**

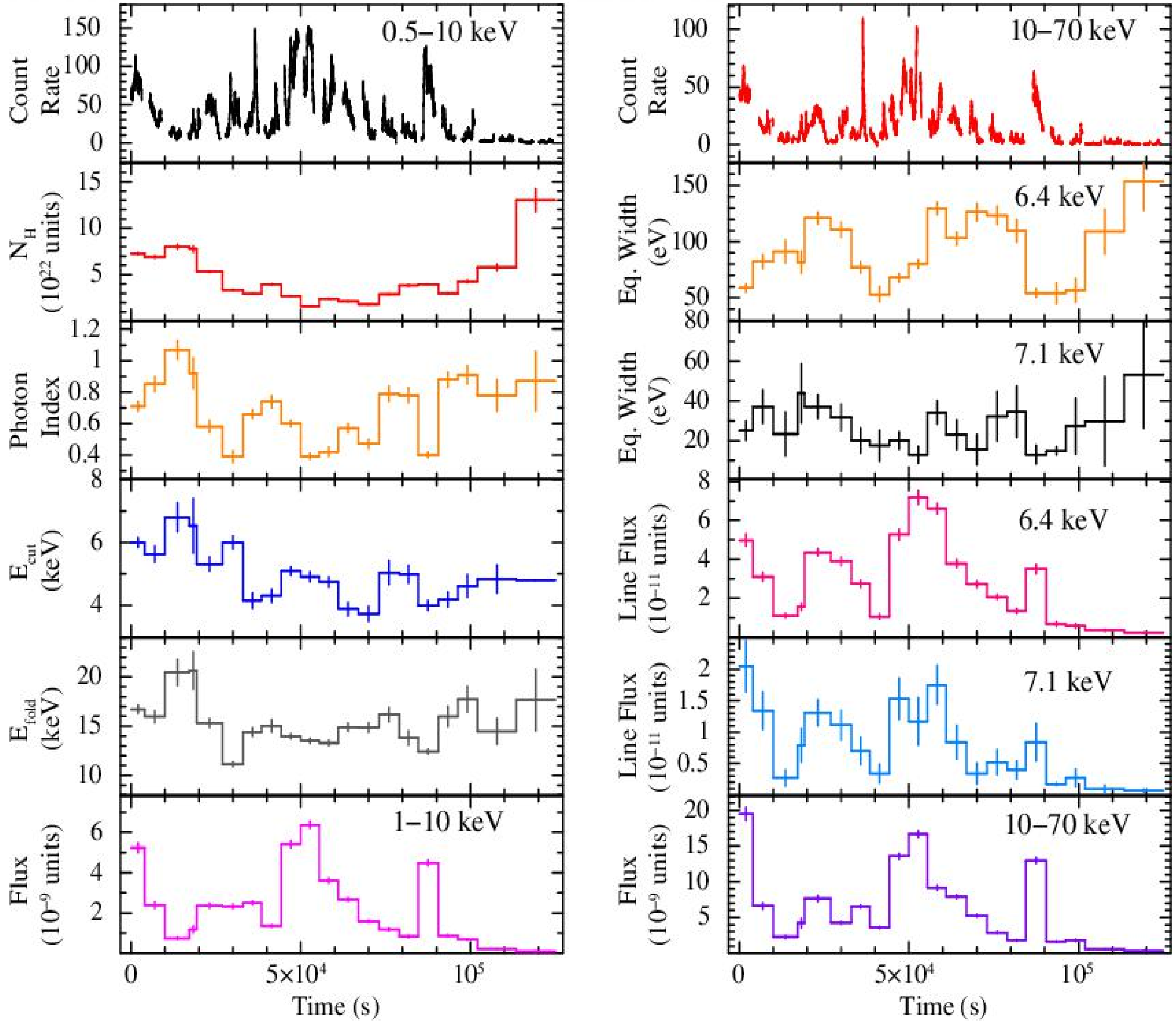




1-70 keV energy spectrum of 4U 1700-37

Spectral parameters from time resolved spectroscopy of 4U 1700-37

- Column density was nearly constant over the observation.
- A sharp rise at late orbital phases (end of observation).
- Indication of accretion wake.
- Earlier detected during Optical observations.
- Similar seen in SGXBs such as Vela X-1.

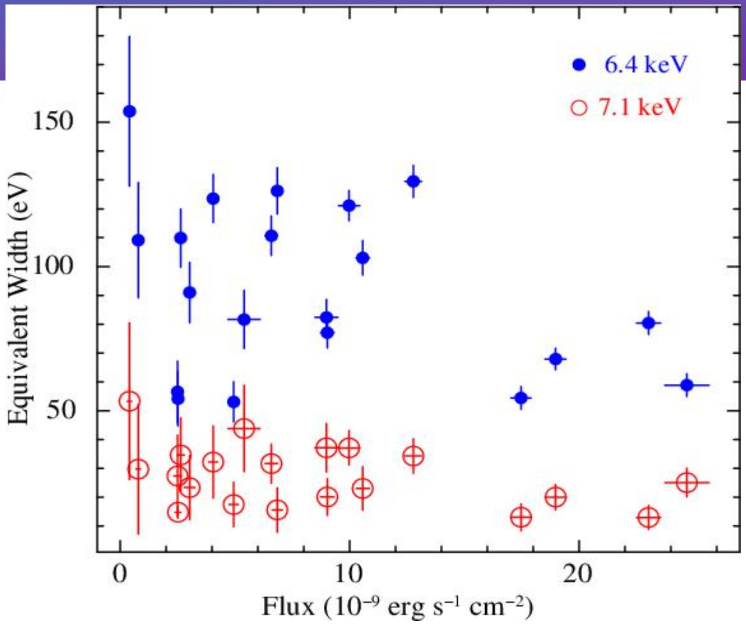


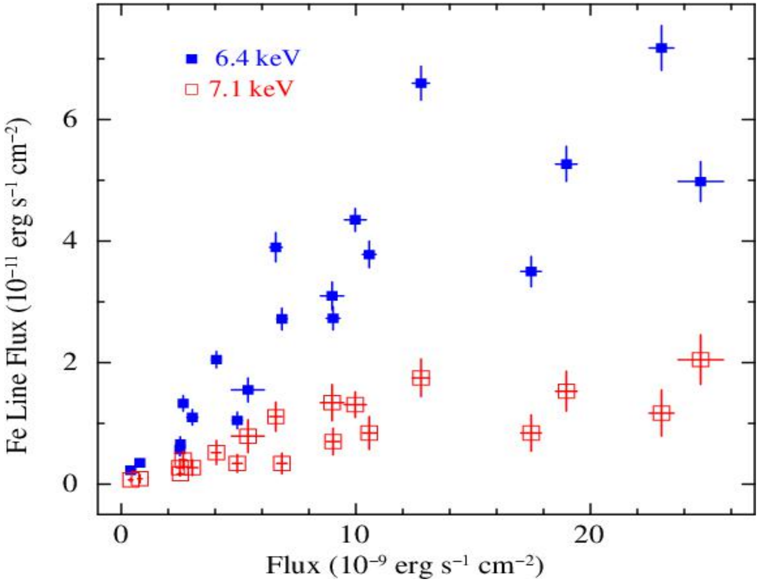
Iron line parameters

❑ The equivalent widths of both the lines are found to be marginally variable with the column density.

❑ For such correlation, the X-ray source is expected to be surrounded by inhomogeneously distributed absorbing material that covers a fraction of radiation along the line of sight.

❑ Reprocessing or emission region is closer to the compact object (neutron star).





Summary and Conclusions

- Light curves are found variable on time scales of hundred to kilo-seconds for both sources OAO 1657-415 and 4U 1700-37.

- kilo-second variability can be explained by considering the clumpiness in stellar wind.

- Short-term variability on order of 1 ks, can be described through the instability in temporary accretion disk for 4U 1700-37.

- Mass and radius of clumps were estimated and well matched with calculated values.

- Location of ionization region was estimated which is found within the accretion radius.

- Astrosat observations would be crucial to understood the distribution of stellar wind at different orbital phases in detailed.

Thanks

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