Timing and Spectral studies of the transient X-ray binary pulsar KS 1947+300

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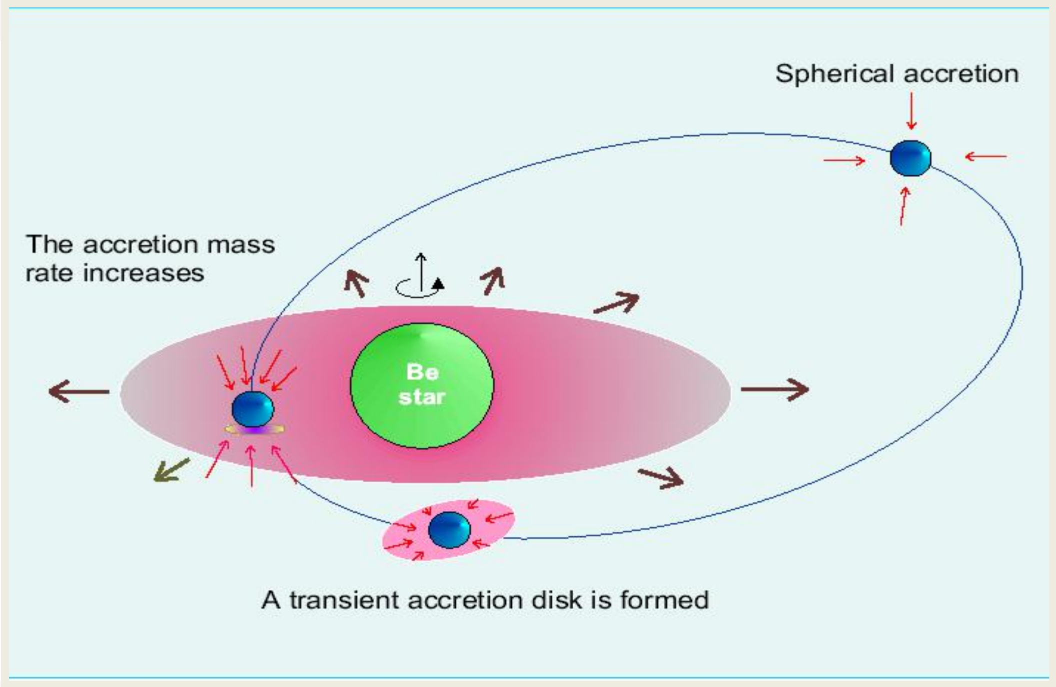
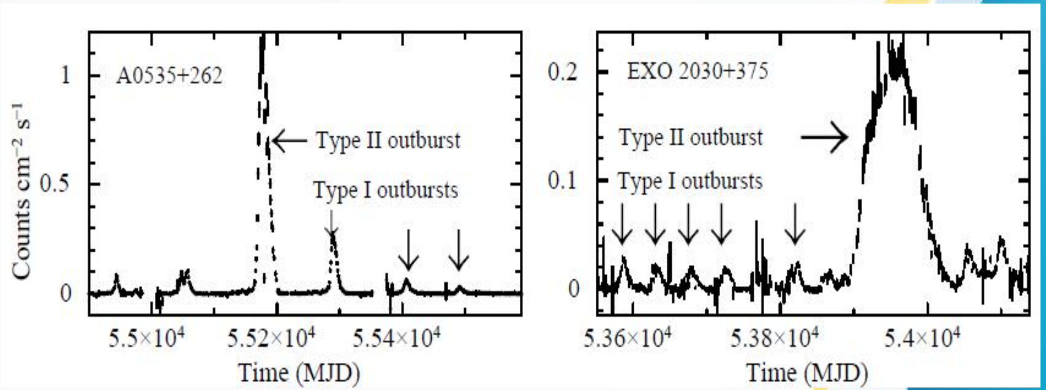
Be/X-ray Binary Pulsars

- Be star + X-ray Pulsar
- Neutron Star is in a wide and eccentric ($0.1 \le e < 0.3$) orbit in these systems.
- X-ray outbursts : due to interaction of NS with the circumstellar disk of Be star.
- Outbursts : Type-I and II



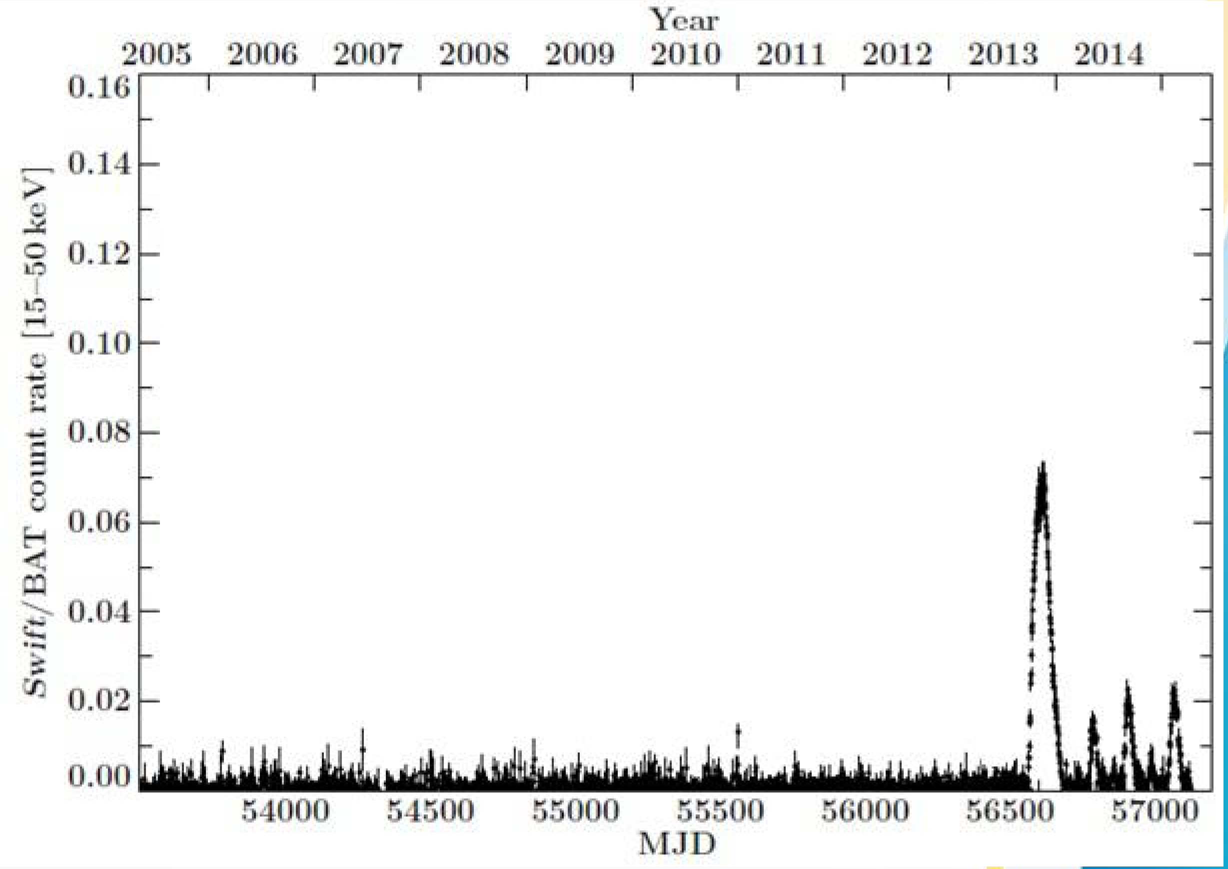


KS 1947+300

A Neutron Star Be/X-ray Binary

Swift/BAT light curve (Krimm et. al. 2013) of KS 1947+300

Giant outburst in 2013.



KS 1947+300

A Neutron Star Be/X-ray Binary

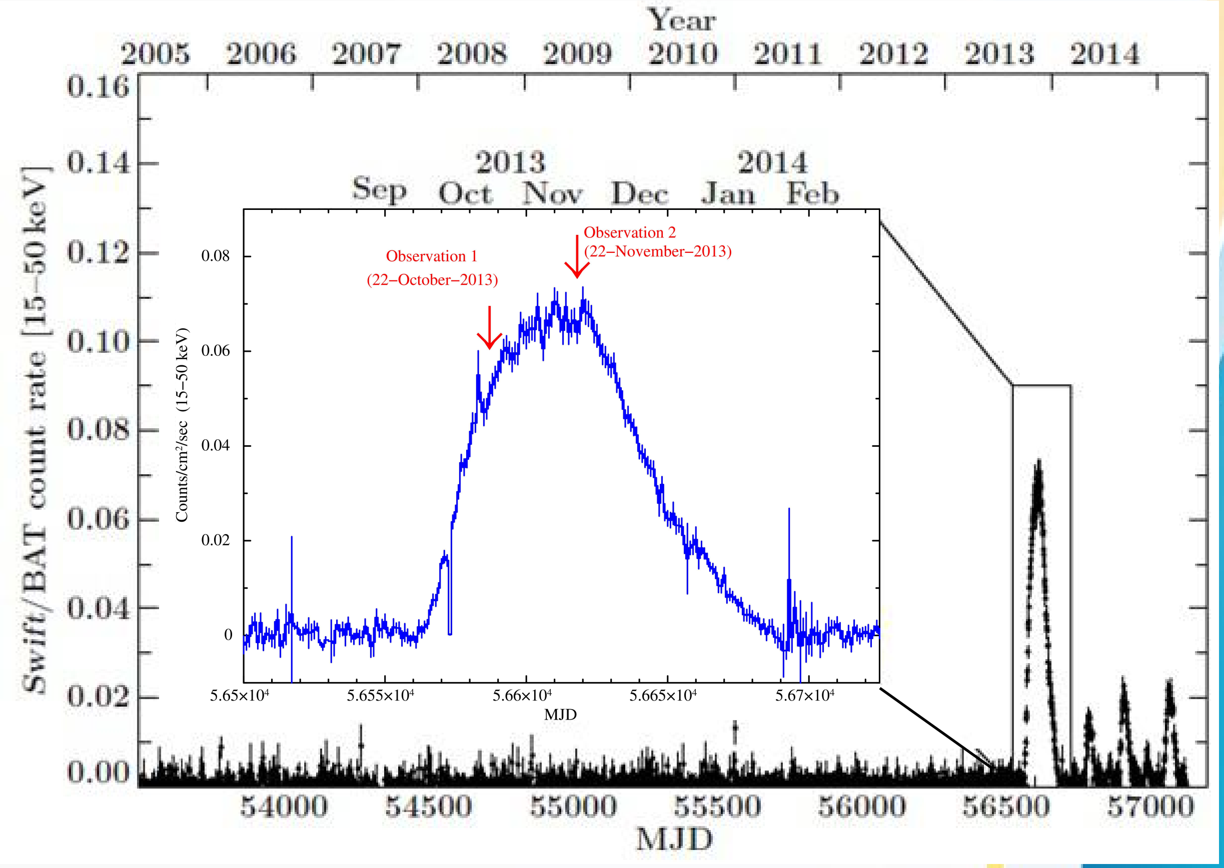
Swift/BAT light curve (Krimm et. al. 2013) of KS 1947+300 with a zoomed view of 2013 outburst , marked with the ***Suzaku*** **observations**.

Giant outburst in 2013.

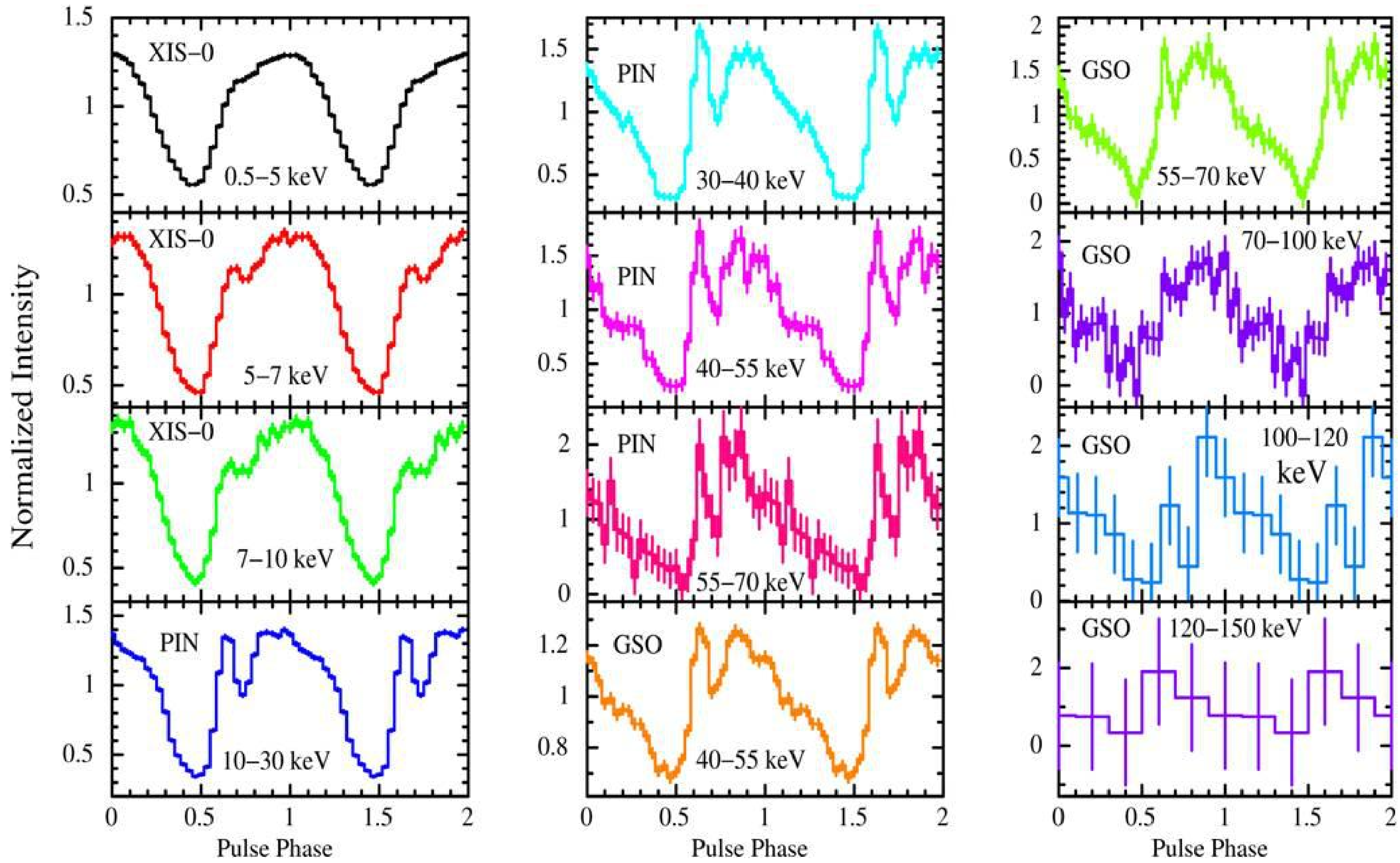
Pulsations Detected with Pulse periods of :

18.8088 s (Observation-1)
18.7878 s (Observation-2)

Pulsar is Spinning Up !!
$(d\omega/dt) = 1.27 \times 10^{-5}$ [Hz/day]



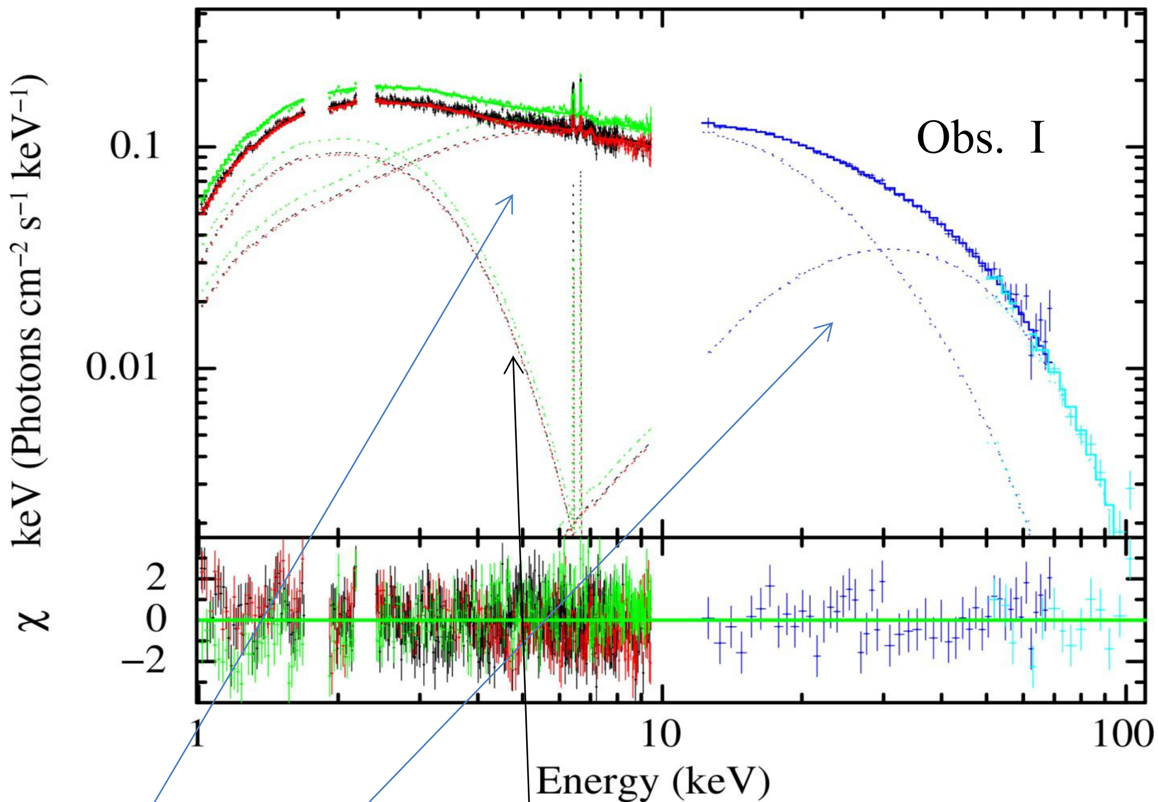
Timing Properties (Pulse Profiles)



Energy resolved pulse profiles of KS 1947+300 from Observation-1

Phase-averaged Spectroscopy

- Deconvoluted Spectra with the best-fitted (NPEX) model



Spectral Model :

$$F_{ph,model}(E) = \mathrm{Const} \times \mathrm{PCFABS} \times \mathrm{PHABS} \times (\mathrm{CUTOFFPL} + \mathrm{CUTOFFPL} + \mathrm{BBODY} + \mathrm{Gauss} + \mathrm{Gauss}) \times \mathrm{CYCLABS}$$

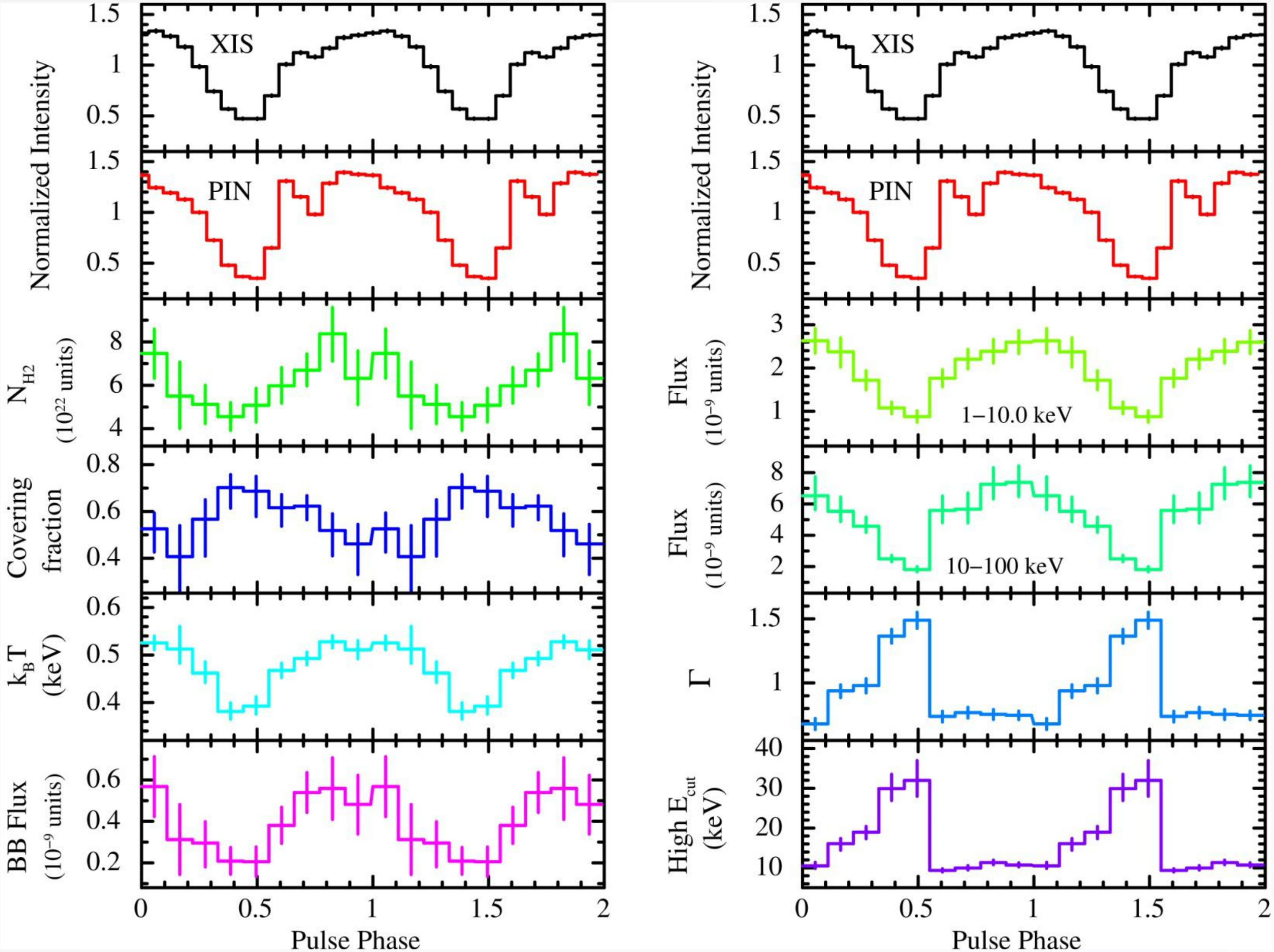
Lines Identified: **$Fe_{6.4\ keV}$ + $Fe_{6.7\ keV}$**

fixed

Fürst et. al. 2014: **E_{CRSF} = 12.2 keV** **σ_{CRSF} = 2.5 keV** **τ_{CRSF} = 0.16**

Pulse Phase-resolved Spectroscopy

spectral parameter variations with pulse phases



Observation-1

Soft X-ray excess emission in KS 1947+300

- Presence of excess emission in soft X-rays - pulsating with phase.

Soft X-ray excess detected in both the *Suzaku* observations.

Observation	Blackbody Flux (10^{-9} ergs cm^{-2} s^{-1})	Blackbody (kT) (keV)	Size of Emission region (km)
Obs. I	0.88±0.13	0.54±0.02	~31 km
Obs. II	1.34±0.19	0.63±0.03	~28 km

Size of soft X-ray excess emission region, indicates regions close to accretion column as most probable origin site of soft X-ray excess in KS 1947+300 .

Magnetic field estimation from the pulsar spin-up

$$\dot{\omega}_{su} \cong 10^{-9}[Hz\, d^{-1}]\, \Pi_{su}\, \mu_{30}{}^{1/11}\, v_8{}^{-4} \left(\frac{P_b}{10\, d}\right)^{-1} \dot{M}_{16}{}^{7/11}$$

(Shakura et. al. 2012, Postnov et. al. 2015)

$\dot{\omega}_{su}$: spin-up (angular frequency rate)

$1.27 \times 10^{-5}\, [Hz/d]$ (present case)

Π_{su} : ~ 4.6 Dimensionless parameter, system independent

$P_b = 40.42\ days$, **(Galloway et. al. 2004)**

$\dot{M}_{16} = M/10^{16} \left[\frac{g}{s}\right] = 100$, for the luminosity of $\sim 10^{38}\ erg\ s^{-1}$

$v_8 = v/10^8\ cm\ s^{-1} \sim 0.2$ (i.e. 200 km/s) stellar wind velocity for typical BeXRB

(Waters et. al. 1988)

$\mu_{30} = \mu/10^{30}\, [G\, cm^3] \approx 0.6$ NS dipole magnetic moment (estimated from spin-up rate)

$$B = \frac{2\mu}{R_{NS}{}^3} = 1.2 \times 10^{12}\ G$$

From cyclotron line measurements, $B \sim 1.1 \times 10^{12}\, (1+z) G$

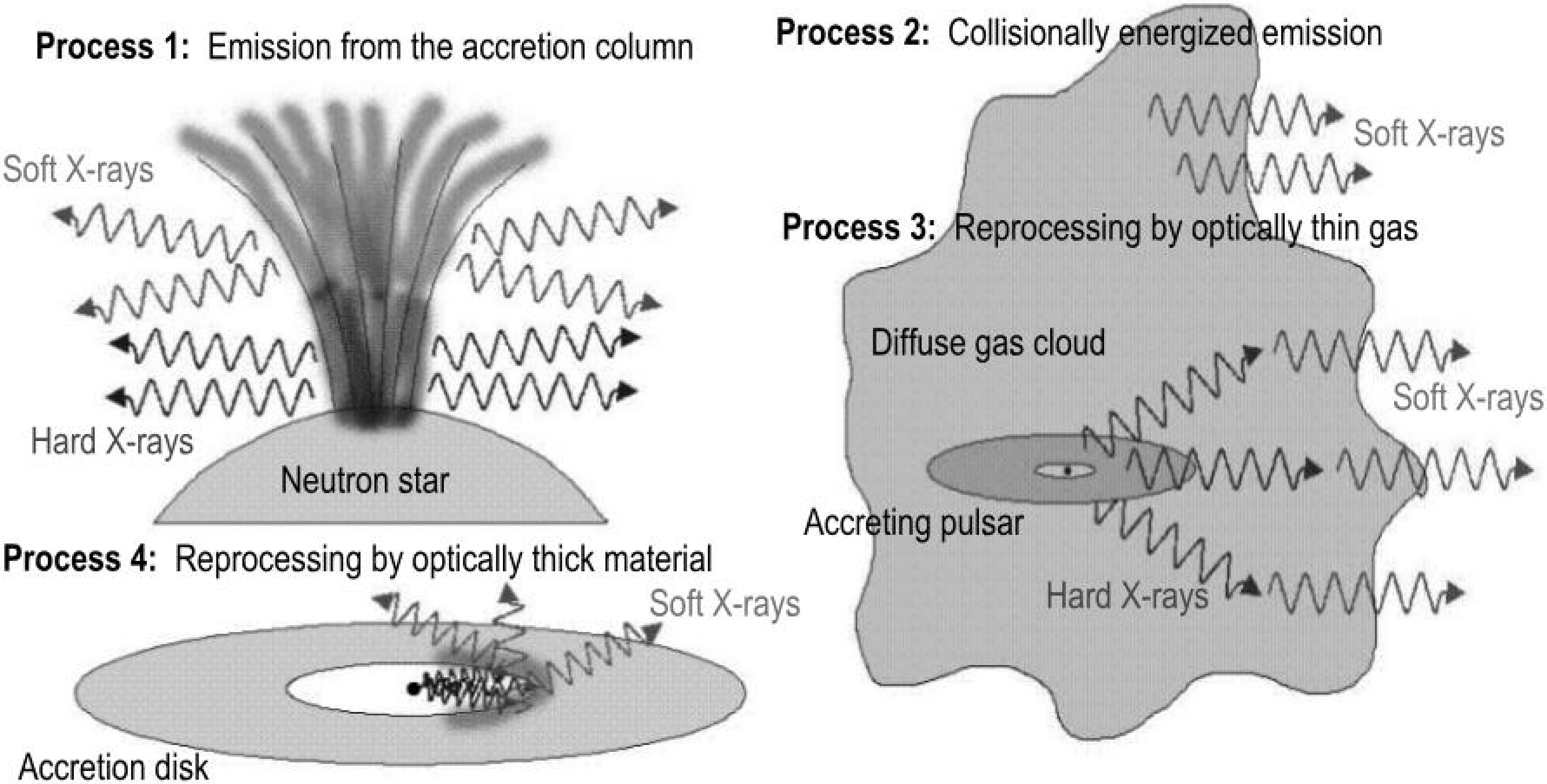
(Fürst et. al. 2014)

Summary

- ✓ Smooth and single peaked soft X-ray pulse profiles. Appearance of dip like structures in hard X-ray pulse profiles.
- ✓ 1-100 keV Broadband spectra well described by a partially absorbed NPEX continuum model along with a blackbody component.
- ✓ Marginal enhancement in additional column density at dip phases discards the origin of dips due to absorption of hard X-rays by additional matter.
- ✓ Geometrical effect : probable cause of dips in hard X-ray pulse profiles.
- ✓ Pulsation in soft X-ray excess flux confirmed the nearby accretion column origin.
- ✓ Presence of soft X-ray excess may be cause of absence of dips in soft X-ray pulse profiles.
- ✓ Estimated magnetic field from the pulsar spin-up rate is comparable to that from cyclotron line energy.

Thanks …

Possible soft excess emission processes in XRBs



Hickox et.al. 2004

X-ray Pulsars

- Highly Magnetized neutron stars in binary systems, accreting matter from a companion star.

- Stellar wind accretion

  In case of high-mass $(\geq 8\ M_{sun})$ companion

- Roche-lobe overflow

  In case of low-mass $(\leq 3\ M_{sun}\ )$ companion