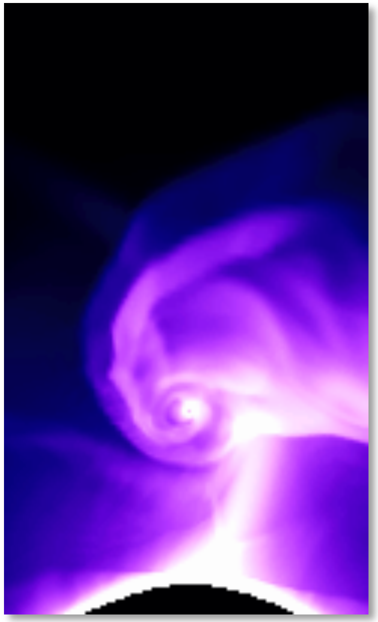
Monitoring Supergiant Fast X-ray Transient with Swift/XRT and XMM-Newton

E. Bozzo
(ISDC, University of Geneva)
on behalf of a large collaboration

Classical SgXBs and SFXTs



Classical Systems

"Persistent" sources:

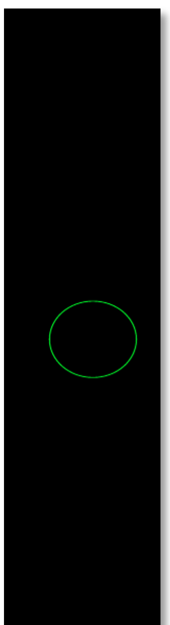
- expected *averaged* X-ray luminosity:

  $V_\infty \sim$ 500-3000 km/s

  $\dot{M}_W \sim 10^{-6}$-10^{-5} $M_\odot$ /yr ~ 10^{19} - 10^{20} g/s

  $L_{acc} \sim G M_{NS} \dot{M}_{capt} / R_{NS} \sim 4\text{x}10^{36}$ erg/s

- Display a limited X-ray luminosity *variability* of ~10-100 on time scales of 100-1000 s
- Many observed and monitored also by MAXI



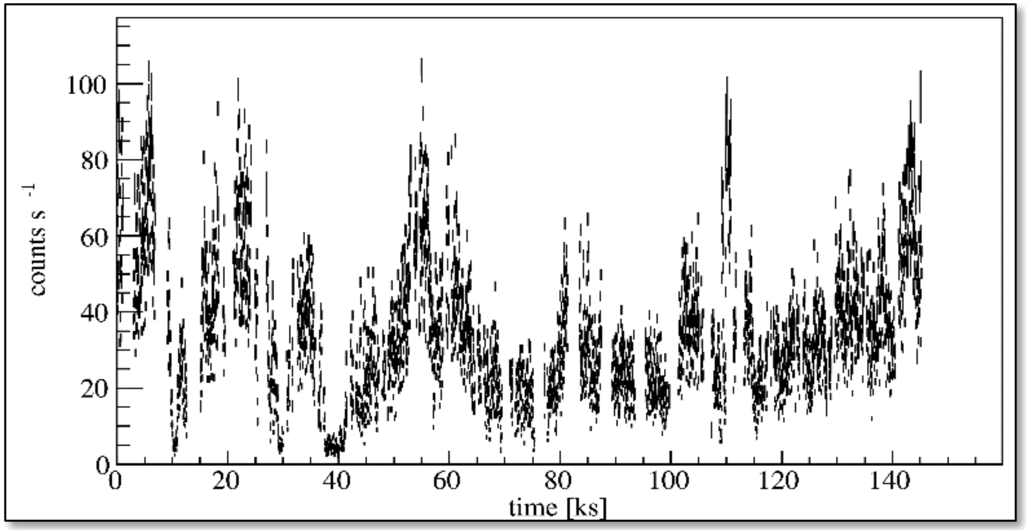
(Sguera+ 2005)

Supergiant Fast X-ray Transients

"Transient" sources:

- Short sporadic flares lasting few ks (sometimes clustered at periastron)
- Average X-ray luminosity much lower than that of classical systems
- Few to hundred days orbital periods
- Very little known about spin periods
- X-ray spectra strongly reminiscent of accreting NSs

- Low luminosity for most of the time, preferred location in crowded regions in Galactic Center/Plane → so far best discovered by INTEGRAL and best monitored with sensitive X-ray focusing telescopes



(Suzaku/XIS; 0.5-12 keV; Odaka 2013)

Vela X-1 (classical SgXB prototype)

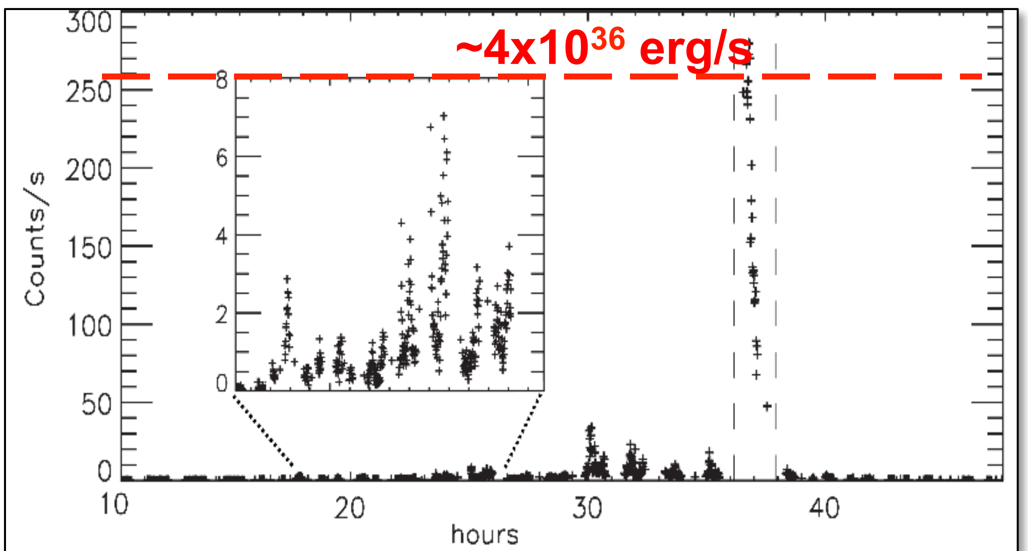
Orbital period 8.9 days

Spin period 283 s

Average luminosity 4×10^{36} erg/s

Luminosity variations ~20-50

Cyclotron line 25 keV → 2.2×10^{12} G (Fuerst+ 2013)



(Suzaku/XIS; 0.5-12 keV; Rampy 2009)

IGRJ17544-2619 (SFXT prototype)

Orbital period 4.9 days

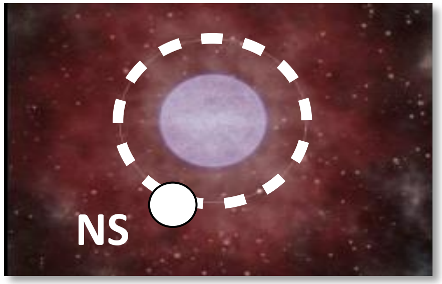
Average luminosity: 4×10^{34} erg/s

Luminosity dynamic range ~10^6

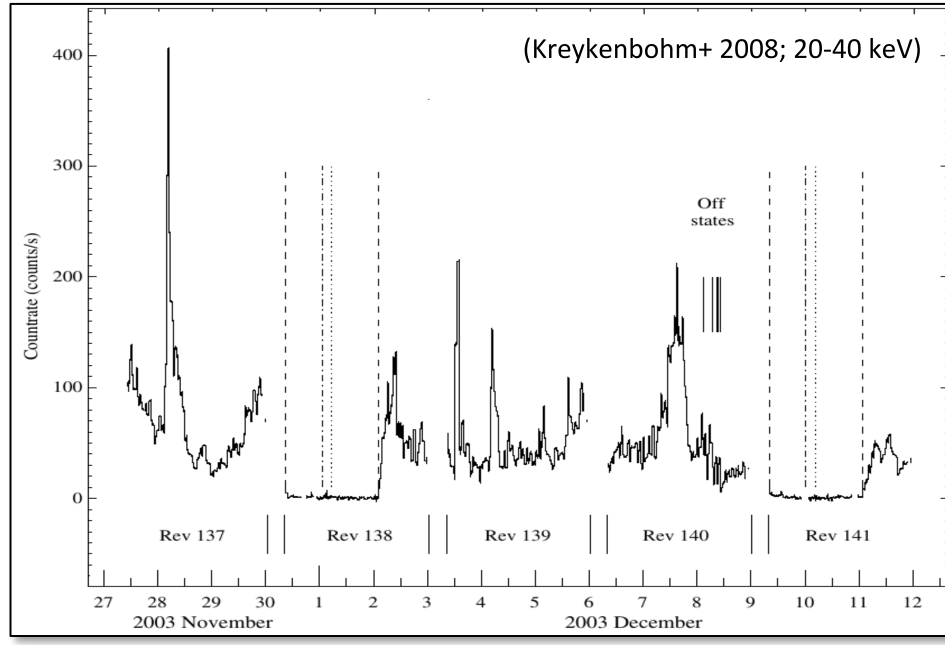
Spin period unknown (71 s? 12 s?)

Cyclotron line at 17 keV → 1.5×10^{12} G (Bhalerao+ 2015)

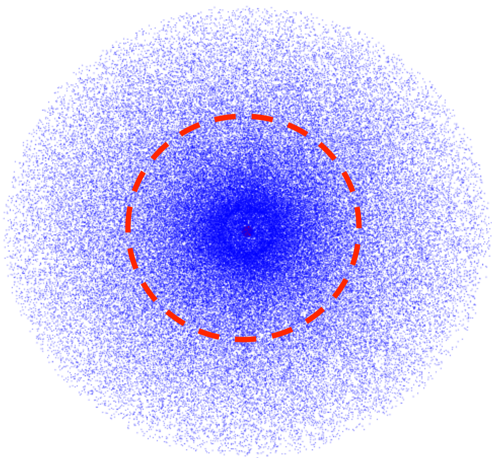
Clumpy wind accretion in classical SgXBs



P_{orb} ~ 8.9 d
P_{spin} ~ 283 s
e = 0.09
B0.5Ib

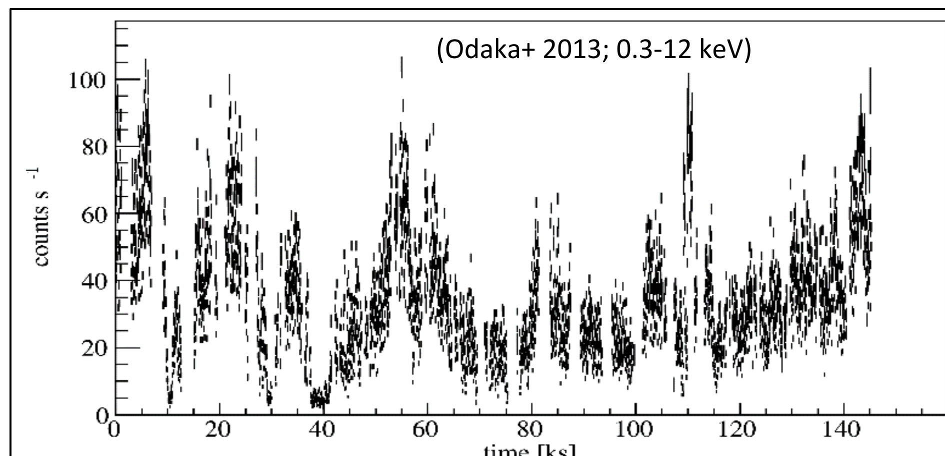


Clumpy Wind Accretion (Sako+ 2003)



M ↓capt ∝M ↓w ~4 r2VW
L↓acc ~
GM↓NS M
↓capt /R↓NS

Δρ ~ 10
ΔV_W ~ 2-3 ⇨ ΔL_X~ 10-100



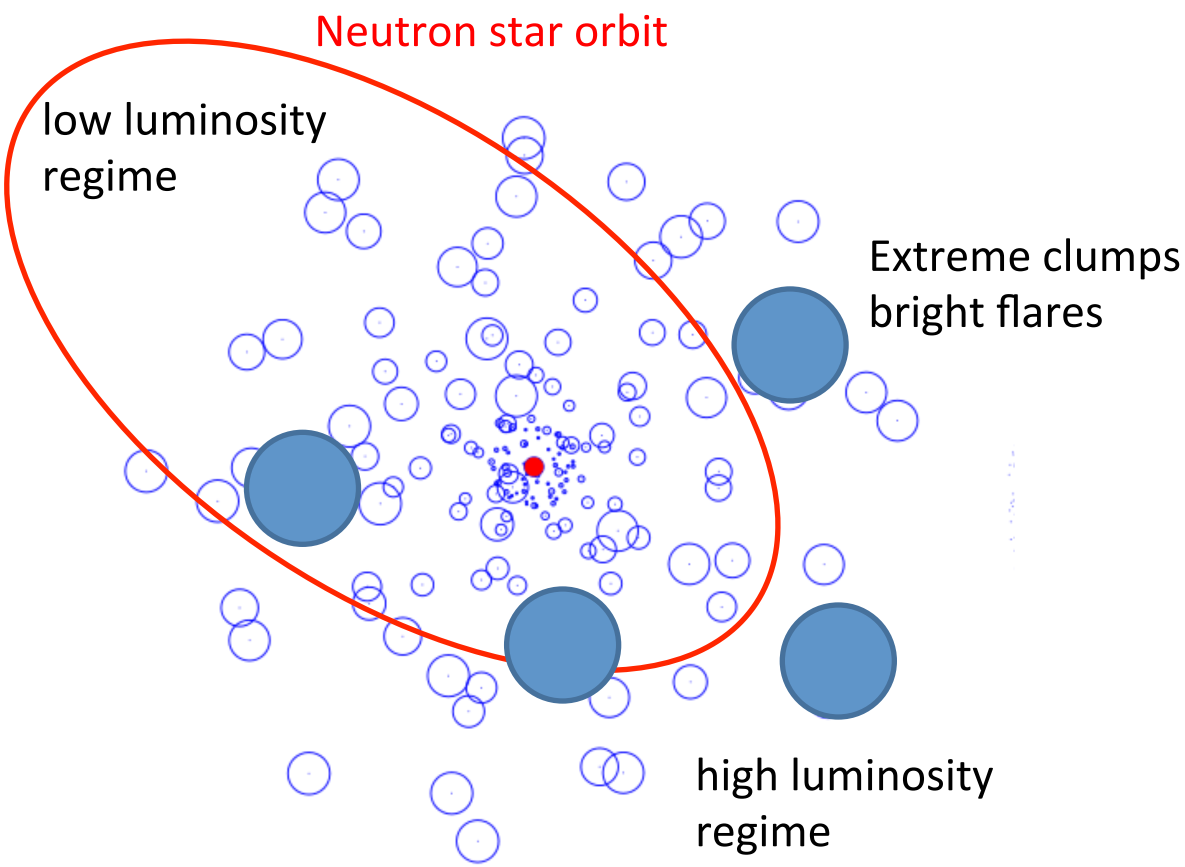
Averaged L_X ~ 4 x 10^{36} erg/s
Flux variations ~20-50 on time scales of 100-1000 s
(see also Martinez-Nunez+ 2014)

Accretion of clump → X-ray flare
Accretion from intra-clump → low X-ray state

Extreme clumpy wind accretion in SFXTs

Extremely clumpy winds and eccentric orbits

(in't Zand 2005; Negueruela 2006, 2008; Walter 2006)



M ↓capt ? M ↓w ? ? V_W

$\Delta L_X \sim 10^5$-10^6

$\Delta\rho$ >1000

But theory and observations of massive stars suggest:

$\Delta\rho$ **~ 10**

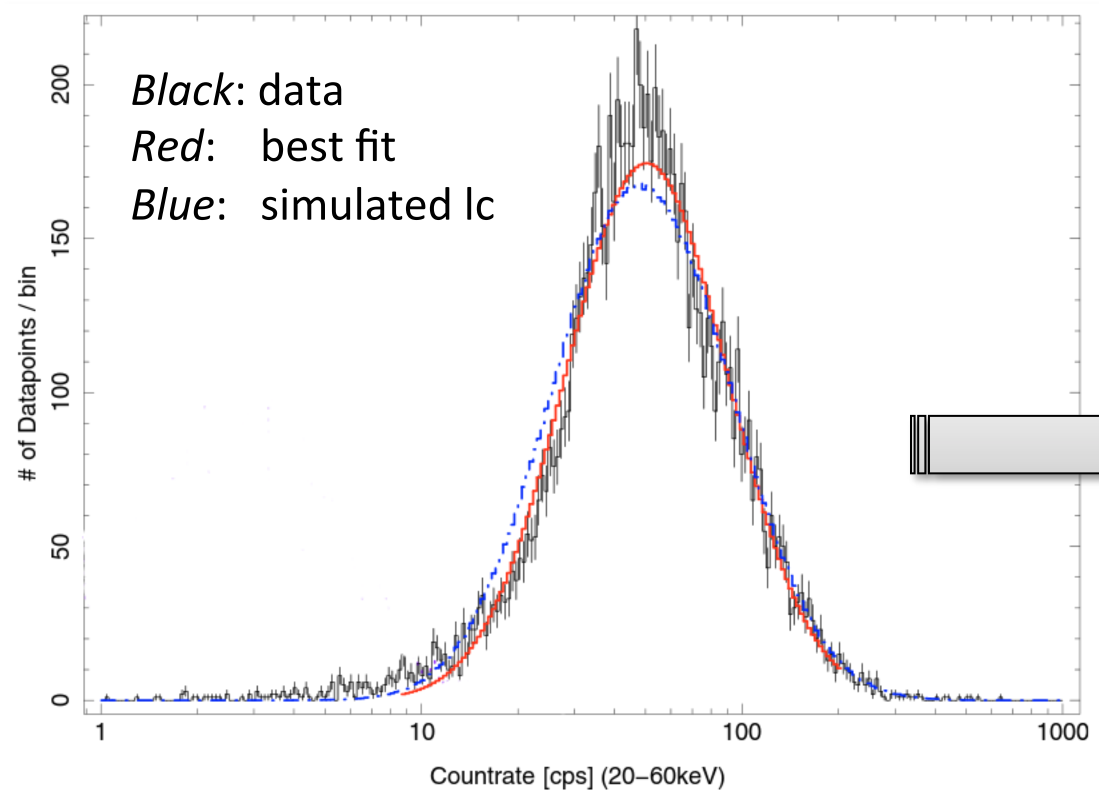
$\Delta L_X \sim$ 10-100

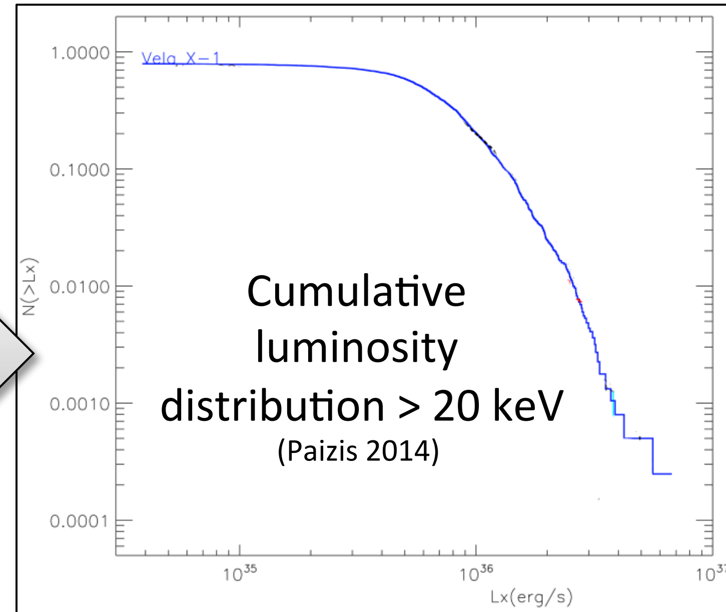
(Surlan 2013)

Challenged by supergaint wind theories + discovery of short orbital period SFXTs

Luminosity distributions in clumpy wind accreting systems

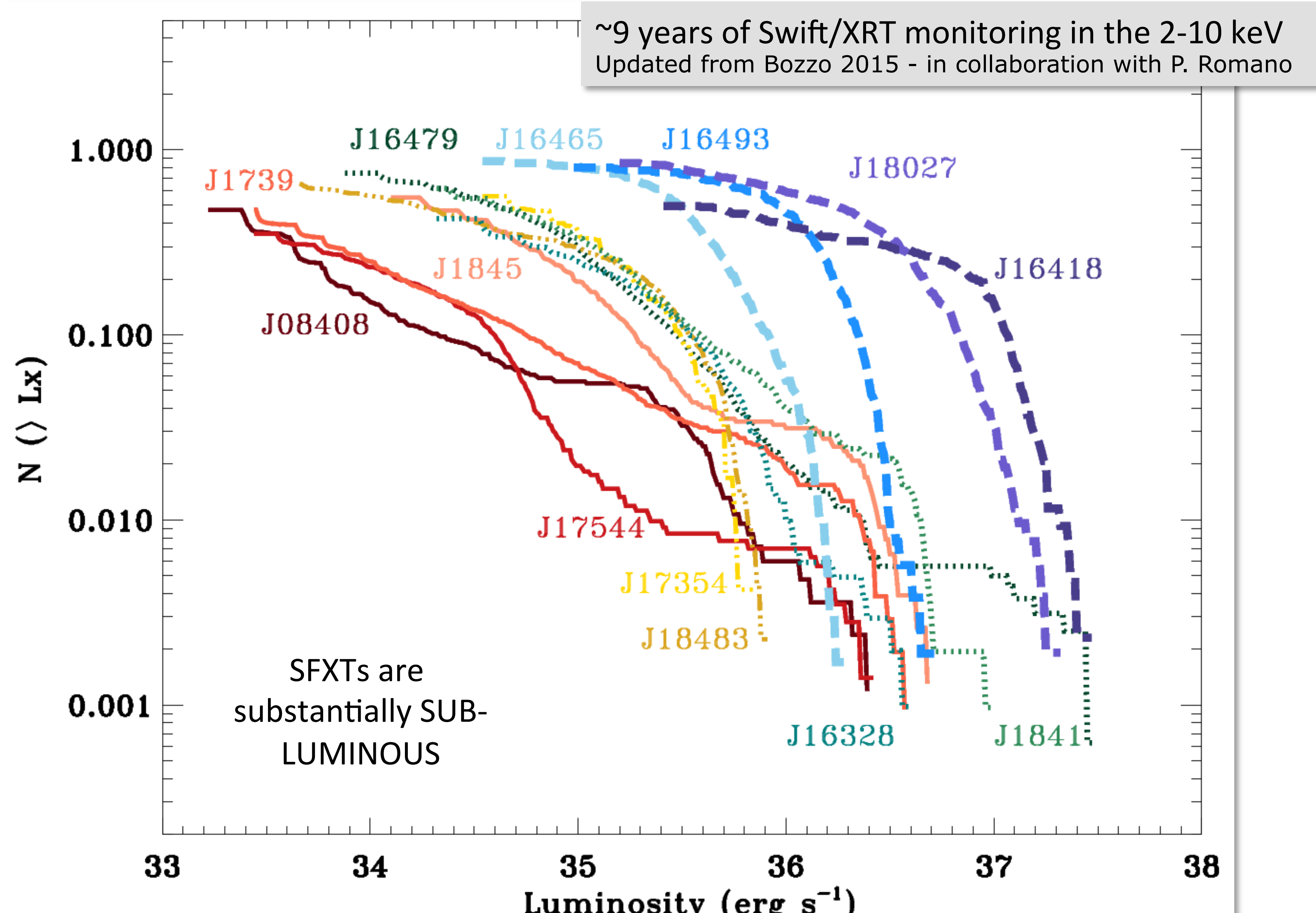
Accretion from a clumpy wind produces log-normal distributions of the source X-ray luminosity (Fuerst 2010)





Clumpy wind seems to effectively be driving accretion in SgXBs….

X-ray cumulative luminosity distributions



Inhibition of accretion in SFXTs

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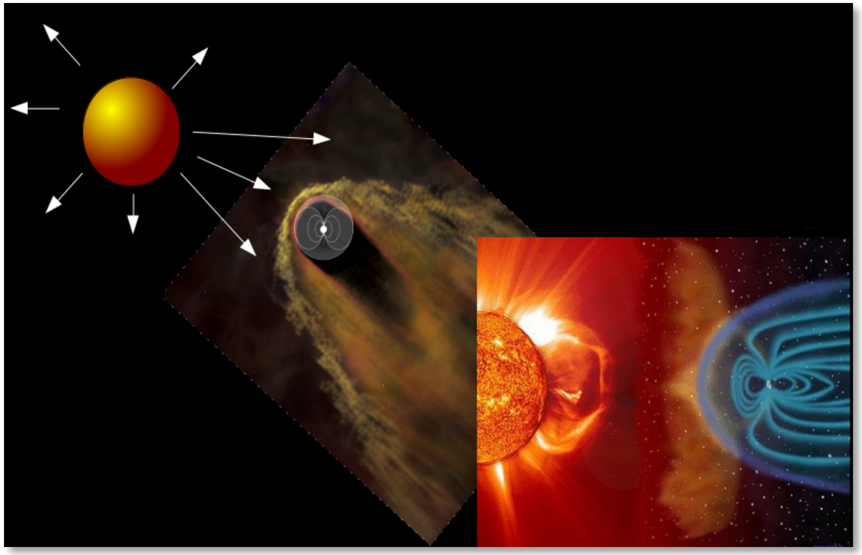
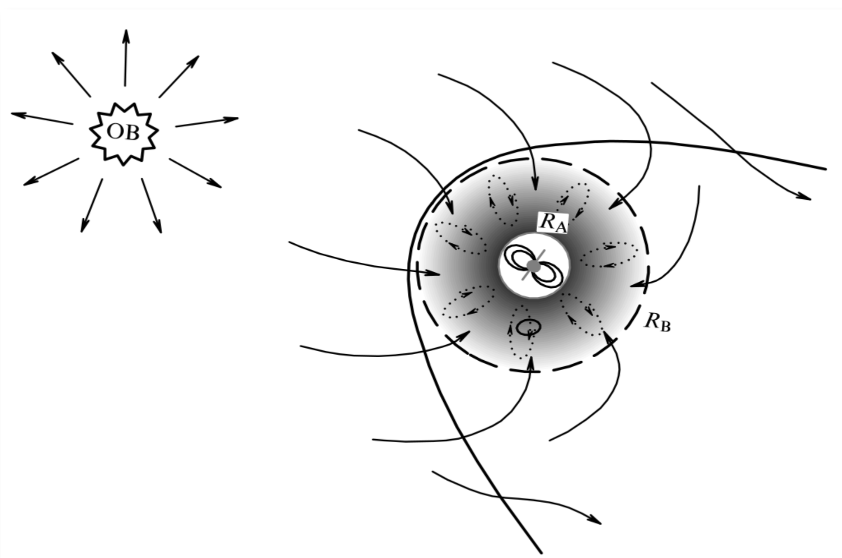


The centrifugal/magnetic gating model
(Bozzo 2008; Grebenev 2007)

Centrifugal gating → “propeller effect”
Magnetic gating → no gravitational focusing of wind material

Requires NS with long spin periods (>1000 s) and strong magnetic fields (~10^{14} G) → IGRJ17544-2619 (Bhalerao 2014)



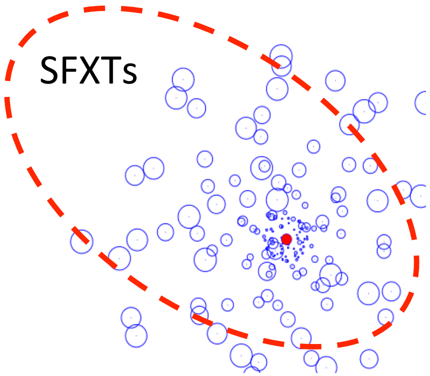
The quasi-spherical settling accretion model
(Shakura 2011,2013,2014)

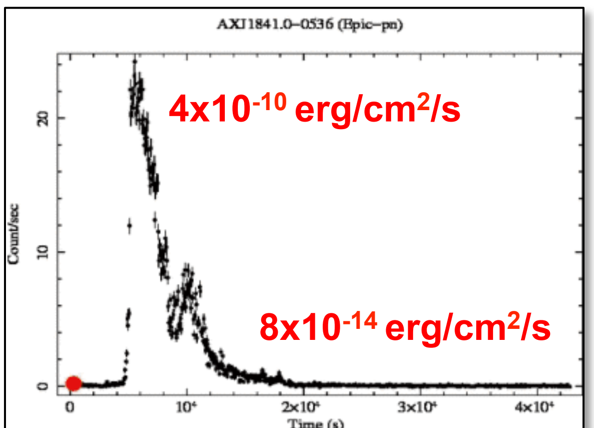
Assuming low $\dot{M}_w$ ($L_X<4\times10^{36}$ erg/s) and slowly rotating NS

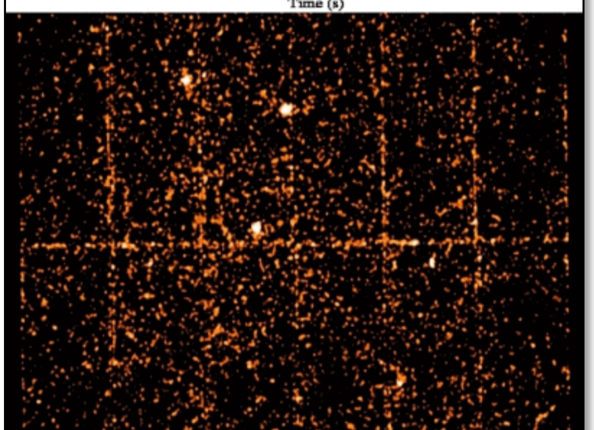
Hot shell inhibits accretion:

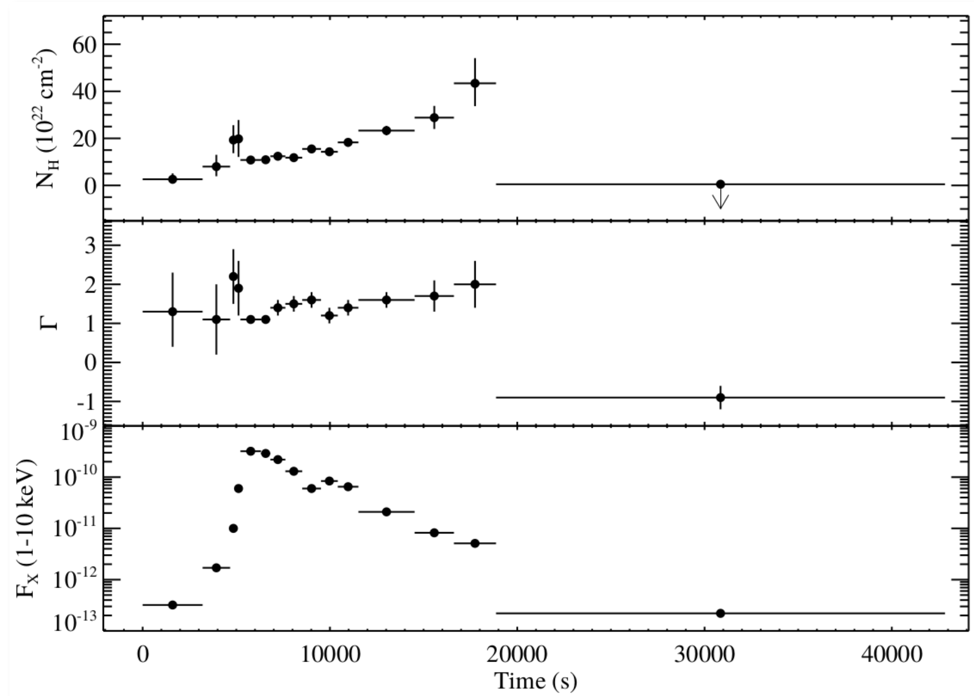
- *1/30 x Bondi* (radiative inefficient regime)
- *1/3 x Bondi* (Compton cooling regime)
- *= Bondi* (sporadic magnetic reconnections)

Extremely Clumpy Stellar Winds

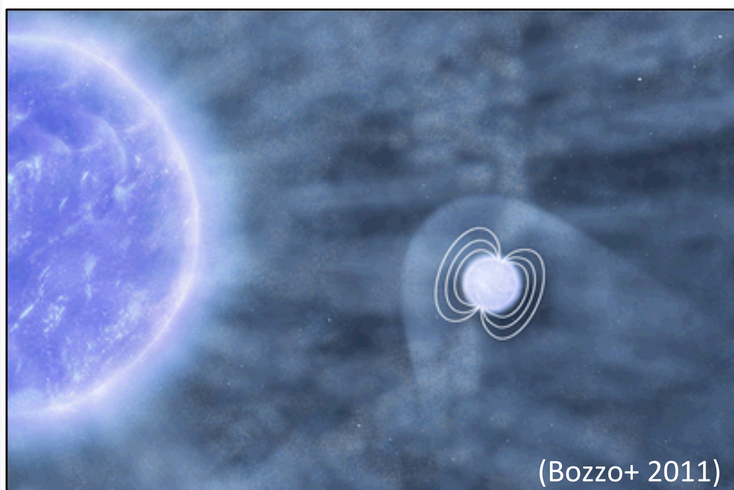








15 h observation of IGRJ18410-0535



Estimated clump size:

$$R_{cl} \simeq 8 \times 10^{11} \text{ cm}$$

$$M_{cl} \simeq 1.4 \times 10^{22} \text{ g}$$

60% Supergiant star radius

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Multi-wavelength observations of IGR J17544-2619 from quiescence to outburst

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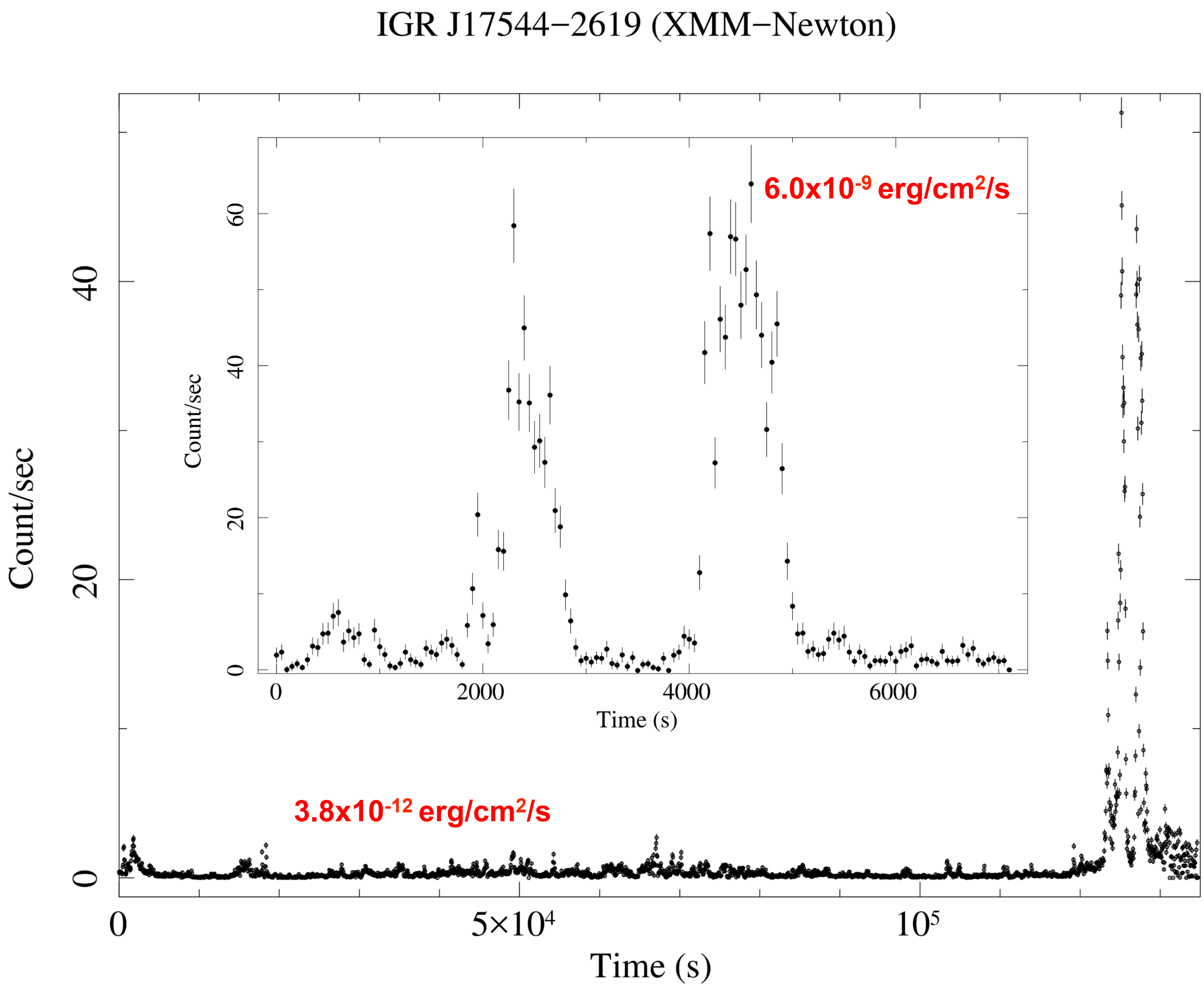
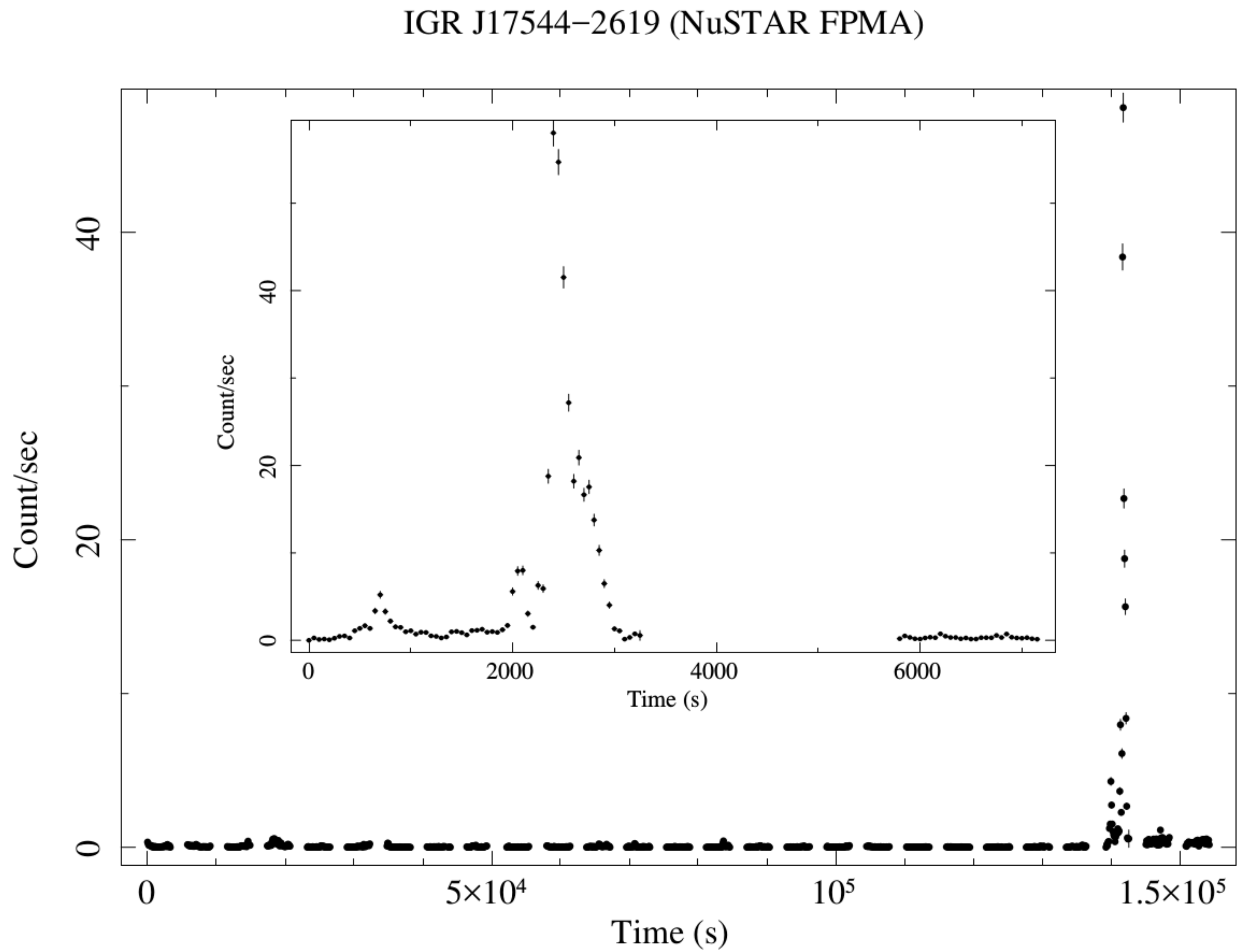
XMM
March
2015



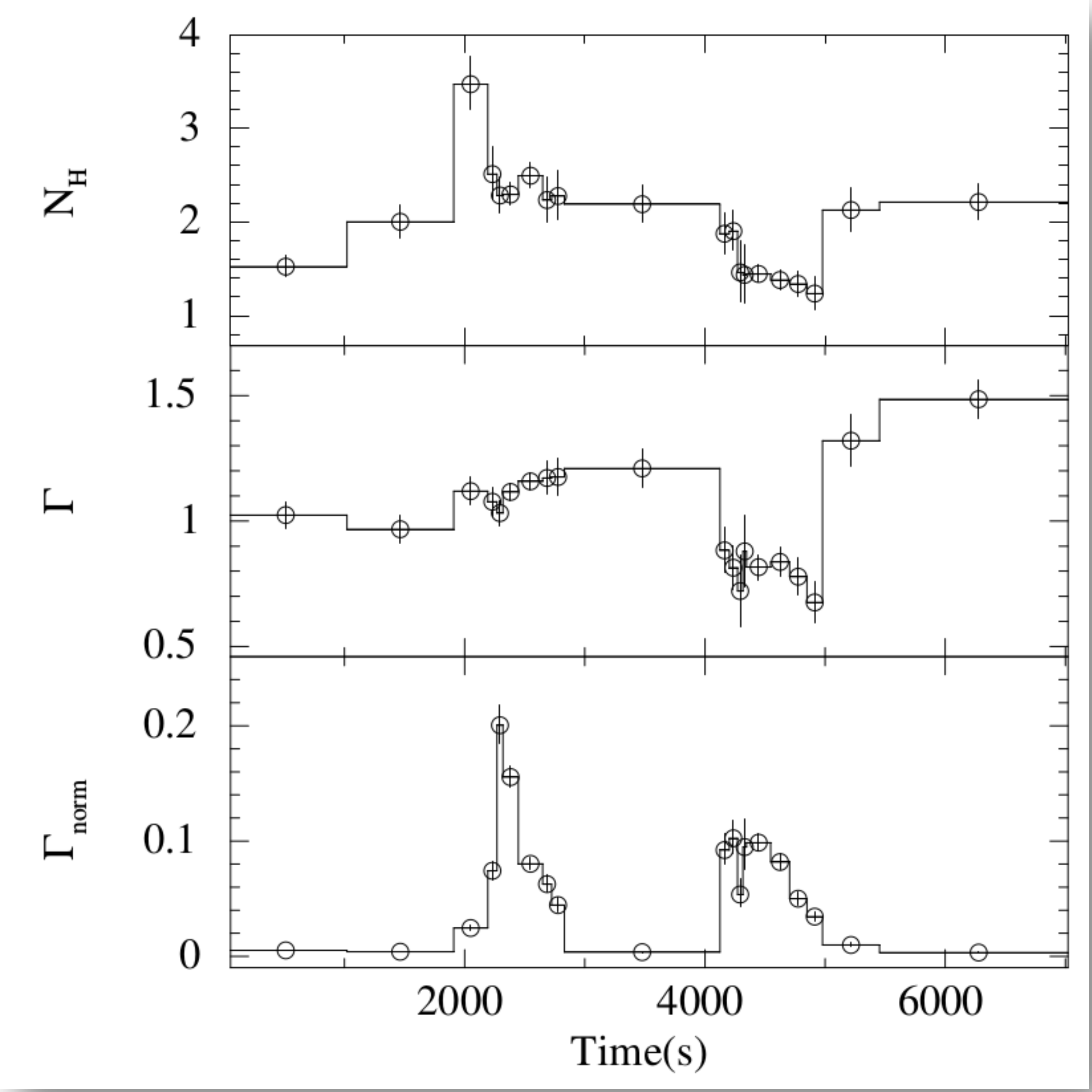
Recent observations of IGR J17544-2619

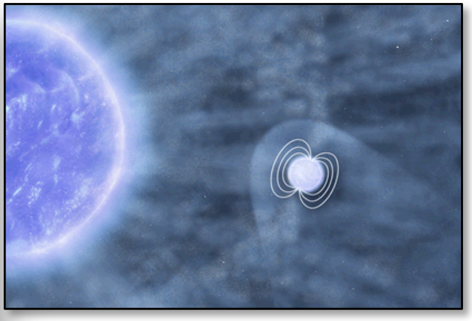
NuSTAR
March
2015



Recent observations of IGR J17544-2619

XMM
March
2015

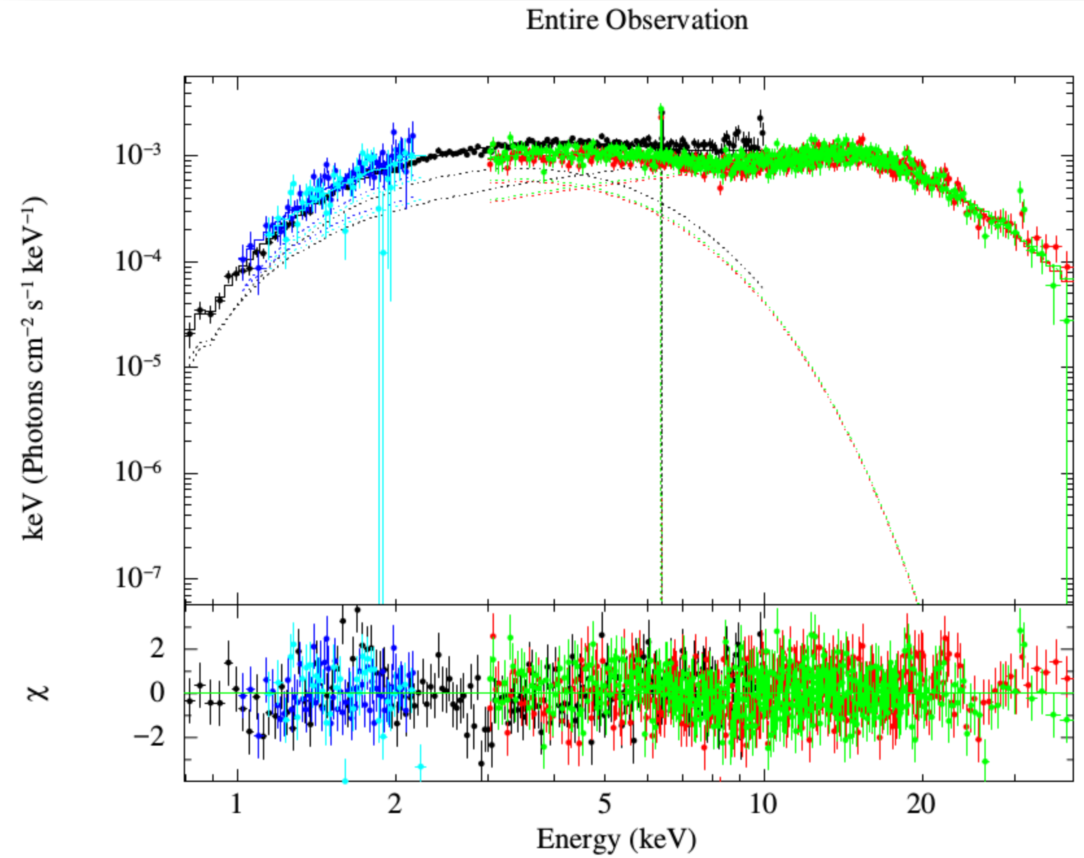




Spectral variability during flares:

- Qualitatively similar to IGRJ18410-0535
- Much reduced N_H increase during rise to the 1st flare
- Drop of N_H before the peak of the 1st flare
- Different spectral variations in the two larger flares
- First fainter flare difficult to study due to low count-rate

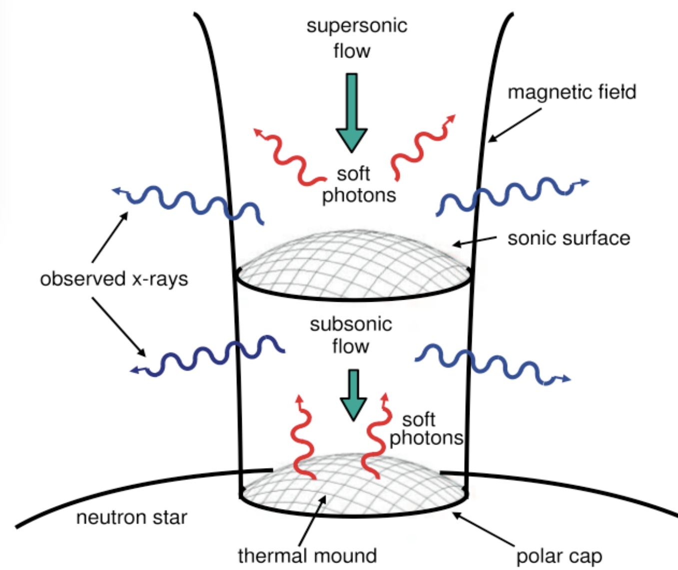
Recent observations of IGR J17544-2619



Broad-band spectral analysis (XMM+NuSTAR):

- Thermal + non-thermal component with evident cut-off around 20-30 keV
- Enhanced emission 10-20 keV
- No sign of previously reported cyclotron line at 17 keV

Broad-band spectral behavior in X-rays reasonably similar to classical systems with young highly magnetized NSs



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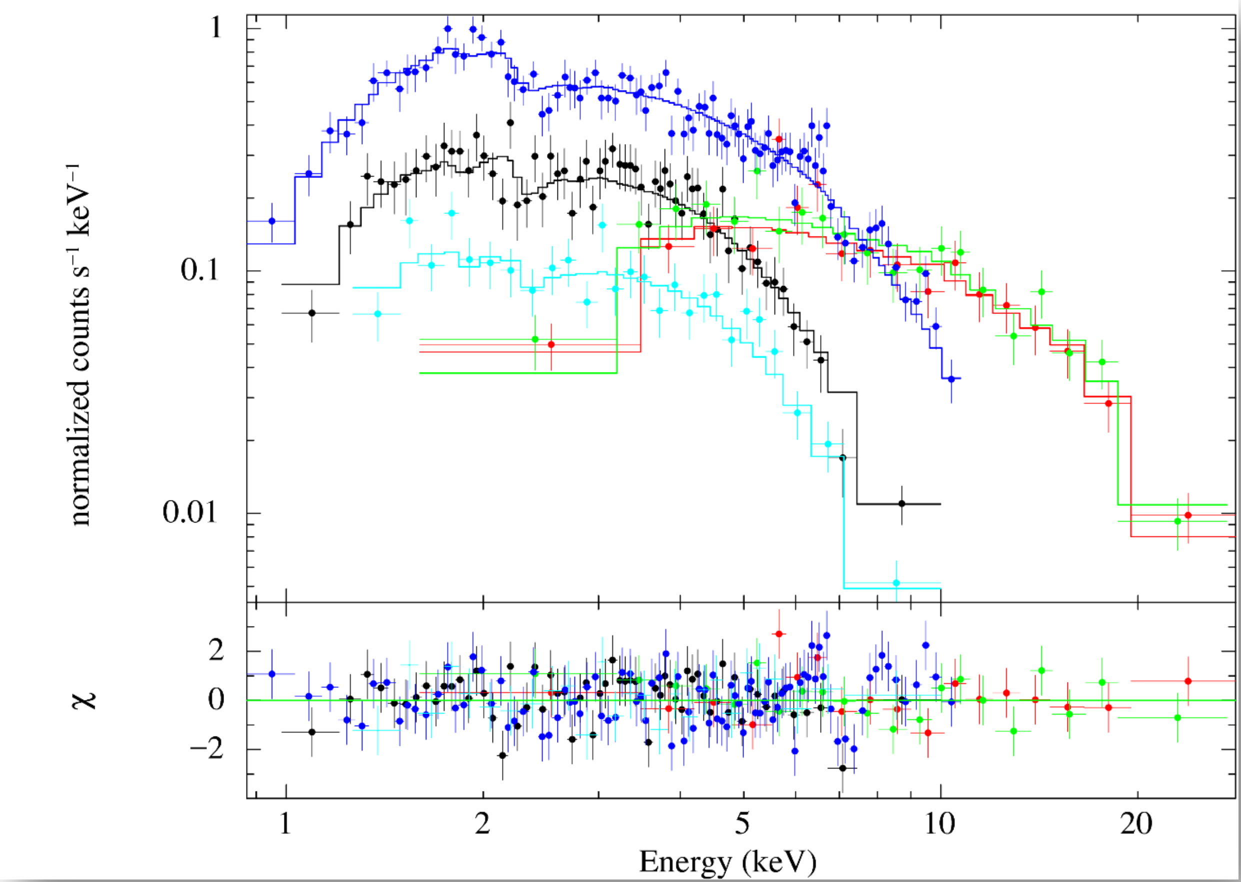
Intriguing absorption feature at 7.2 keV only during the time interval 10

- signature of a temporary accretion disk?
    - Unlikely that IGRJ17544 is seen at high inclination (no eclipses)
- Absorption from a ionized stellar wind?
    - Why never seen before in other similar systems?



Recent observations of IGR J17544-2619

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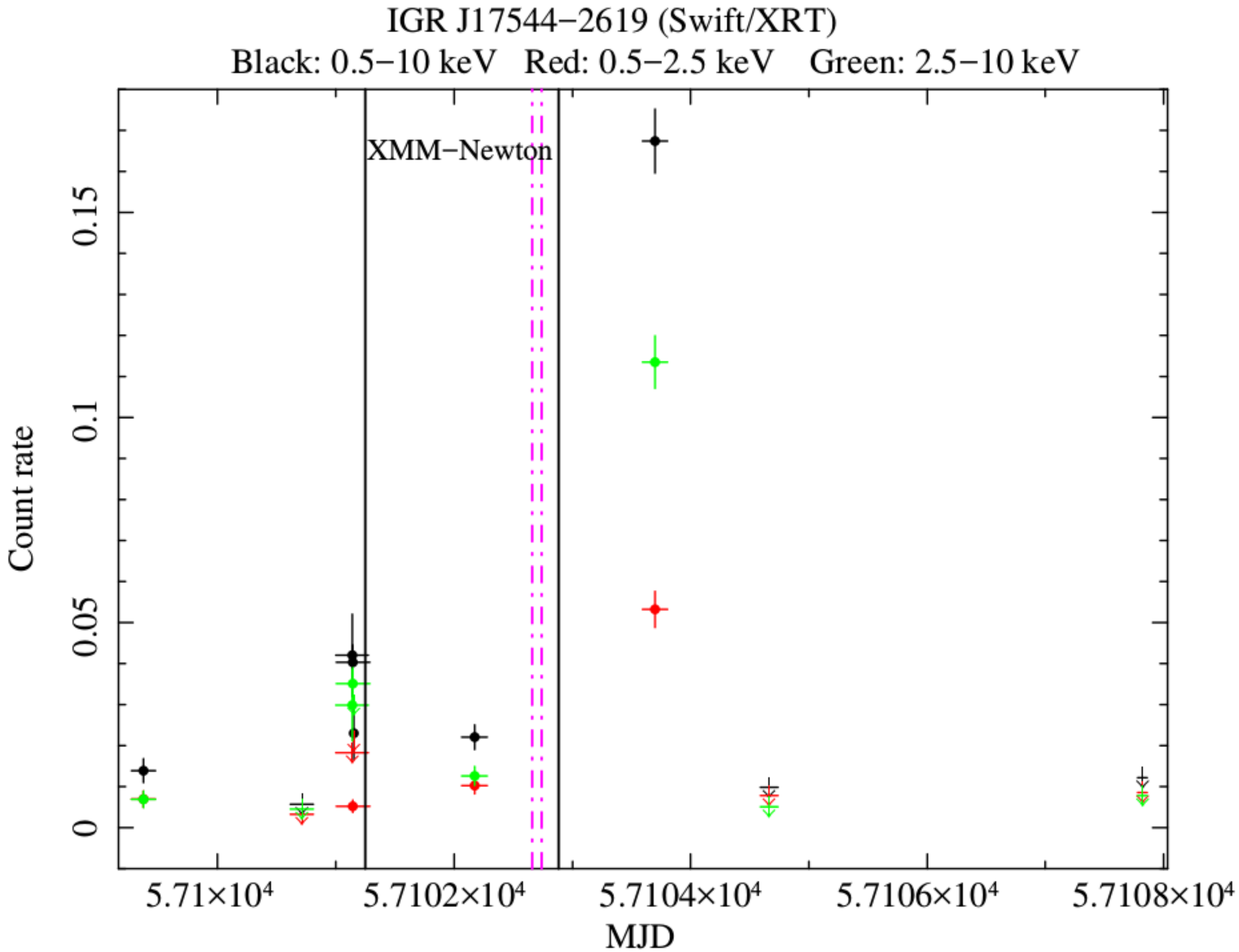
Swift coverage of the whole system orbit (4.9 days)

- Source sub-luminous in X-rays as expected
- 1 small flare about 1 day after the outburst seen by XMM and NuSTAR
- UVOT measurements compatible with previous values
- Optical and IR observations during quiescent interval
  - μ-variability as expected for supergiant stars



Conclusions: what do we understand about SFXTs

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- SFXTs are largely sub-luminous compared to classical systems:
  - Inhibition of accretion required but detailed mechanism(s) still debated

- SFXTs flares/outbursts:
  - Clumps should trigger variability as in classical SgXBs and give rise to flares
  - Extremely massive clumps required to produce the brightest outbursts
    - Cannot be excluded due to evidences in X-rays
    - Not all outbursts accompanied by large NH variations: dichotomy?
    - Other mechanisms could widen the variability achieved with standard clumps

- Alternative mechanisms to produced bright outbursts proposed:
  - Short-lived accretion disks close to periastron
    - Poorly known formation and evaporation mechansisms
    - Evidence in two observations of IGRJ17544-2619
  - Others?

- Urgent need to discover more SFXTs and enlarge the sample:
  - Need a wide field of view instrument:
    - Lobster-eyes technology - very good sensitivity to low luminosities: well suited but poor spectral capabilities (Einstein-Probe,…)
    - Improved sky coverage compared to INTEGRAL but still reduced sensitivity only to outburst (e.g., HMXT, eXTP WFM, …)
    - Combine the two? (ESA/M5 THESEUS,…..)

INCOMING!

http://www.isdc.unige.ch/extp