X-ray Observations of PSR J2032+4127/ MT91 213

Ray Li (Michigan State University) and the FAN collaboration

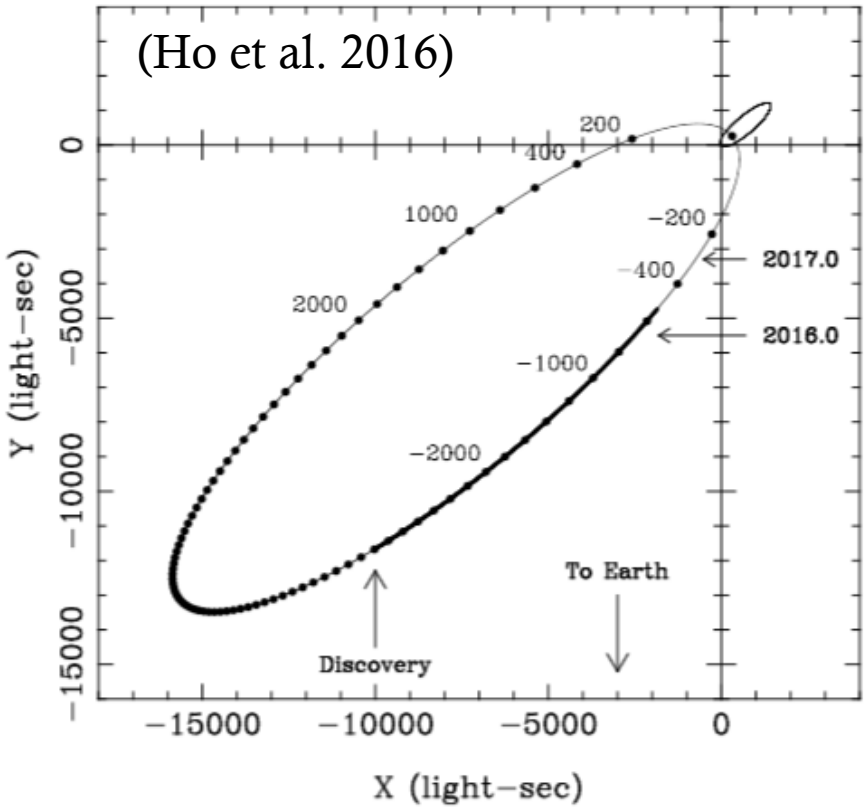
PSR J2032+4127/MT91 213

- A bright gamma-ray source discovered by Fermi-LAT
  - "UFO" in the Fermi catalog; Abdo et al. 2009.
  - Position was poorly known
- Radio/Gamma-ray Pulsations found => a young pulsar (Camilo et al. 2009; Ray et al. 2011).
  - P_{spin} = 0.14 sec
- A V=11.95 mag Be star found at the timing position. (Binary?)

Binary Nature

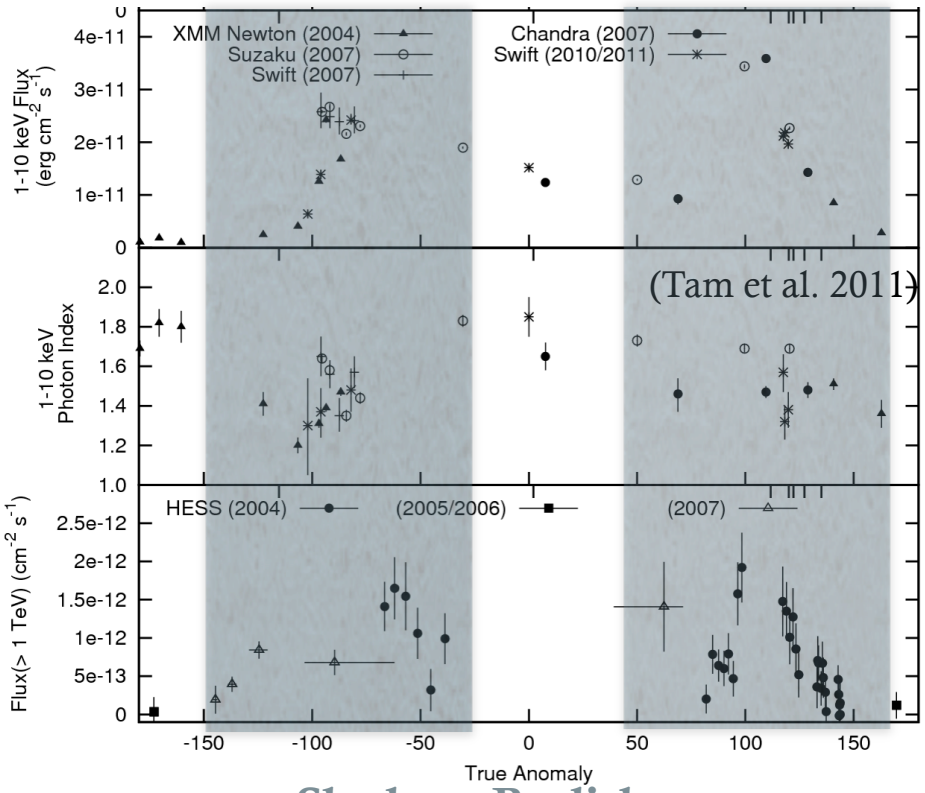
- 7 years of Fermi data + some radio monitoring
  - Doppler Shift in the Time of Arrivals of the pulses (Albert Kong's Keynote Lecture)
  - A binary with a period of 20-30 years and a high eccentricity e > 0.9 ! (Lyne et al. 2015)
- The binary model was improved as more data comes in
  - The true period should be 50 years! (Ho et al. 2016)

Binary Nature: The Orbits



- Only less than a half orbit has been observed
  - Why the timing analysis is difficult.
- The pulsar is approaching!
  - Periastron: they will be closest in 2017 November
  - Distance: ~1AU (~10^{13}cm)

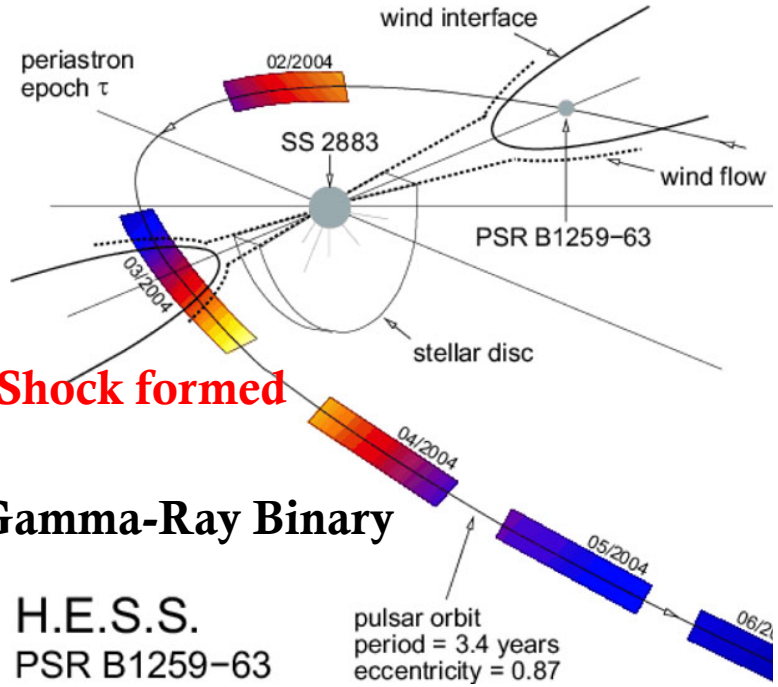
Why interesting in HE? (Close Cousin of PSR B1259-63)



(Tam et al. 2011)

Shadow: Be disk passage

(Aharonian et al. 2005)



Gamma-rays: Inverse Compton

Radio/X-ray: Synchrotron

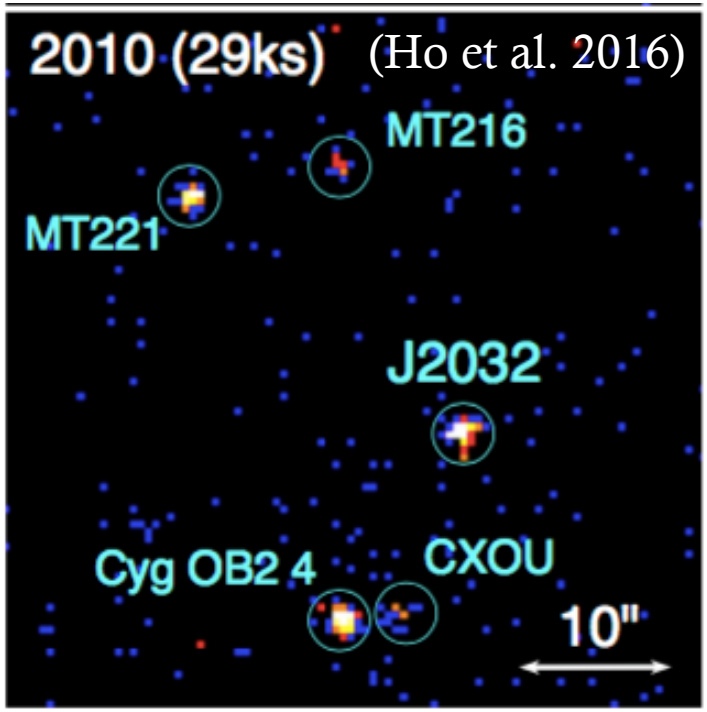
(Later Talk by K. S. Cheng)

=>

The radio/X-ray/Gamma-ray flare(s) are expected from PSR J2032+4127 in late-2017!

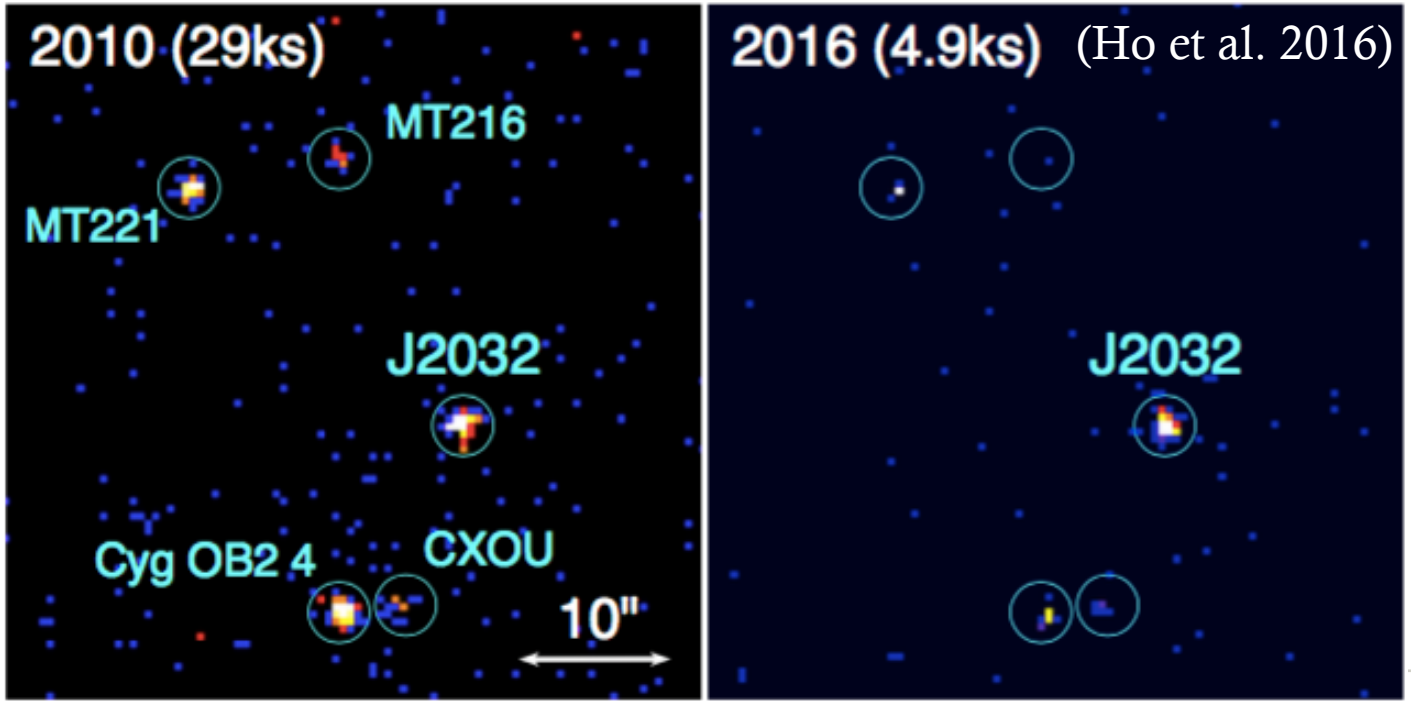
X-ray Properties of J2032 in quiescence

- Chandra in (2002, 2004, and 2010; Ho et al. 2016)
  - F(0.5-7 keV)~10^{-13} erg/cm^2/s
  - Stable over all three epochs
  - Photon Index~1-3
  - Hydrogen column density (N_H) is poorly constrained.

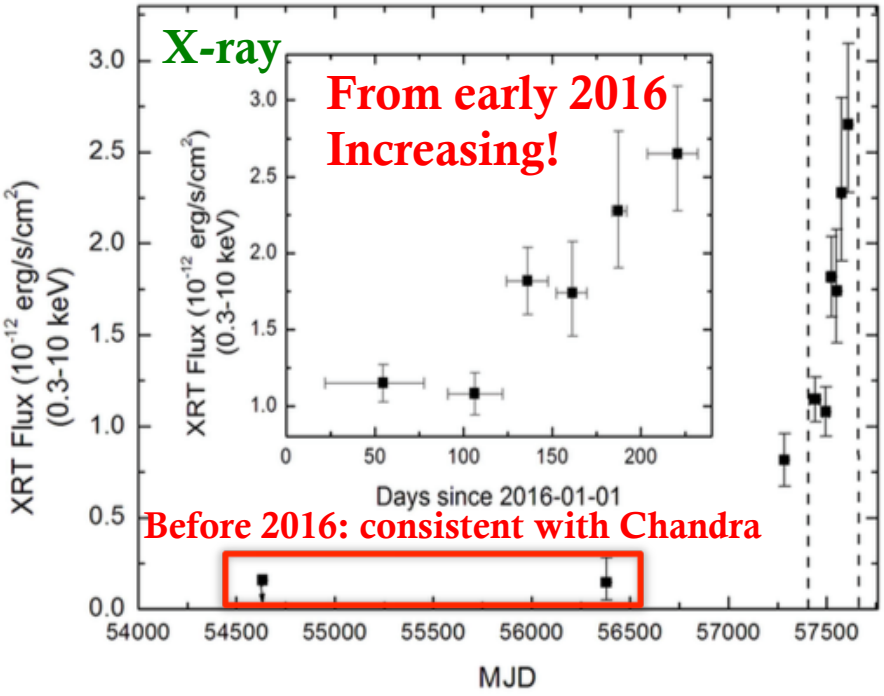


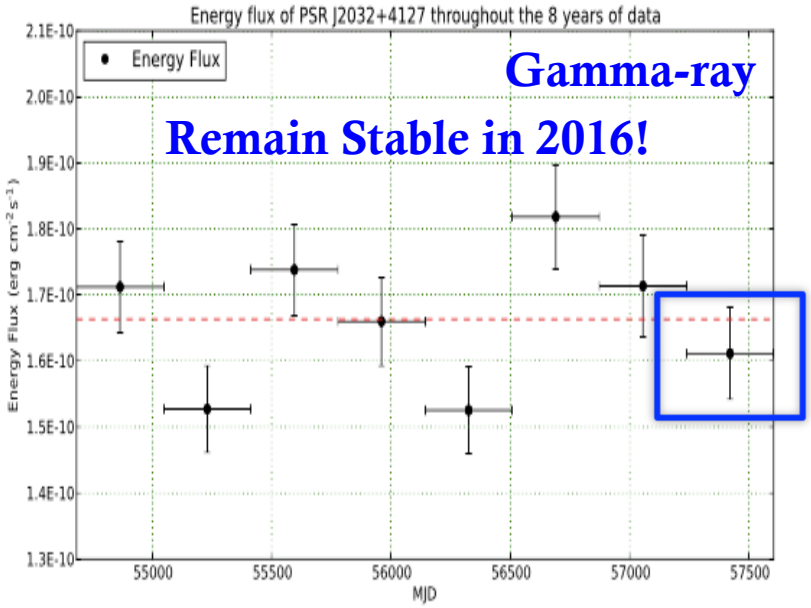
After 2016

- Chandra 4.9 ks in Feb 2016 (Ho et al. 2016)
  - $F_X \sim 10^{-12}$ erg/cm^2/s (10 times brighter)
  - Photon Index~2.7±1.0



Bi-weekly Swift/XRT Monitoring

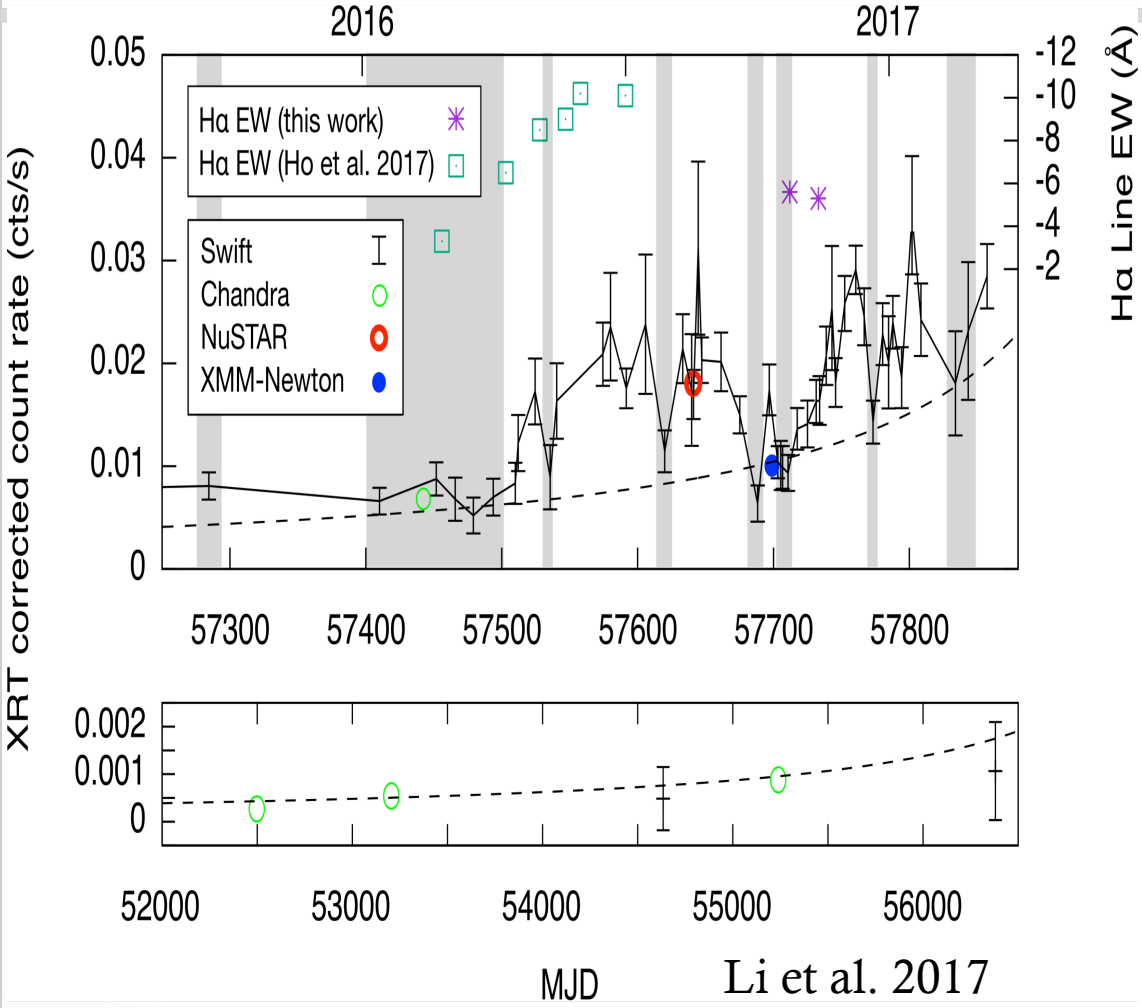




(Takata et al. 2017)

Major Flare already started?

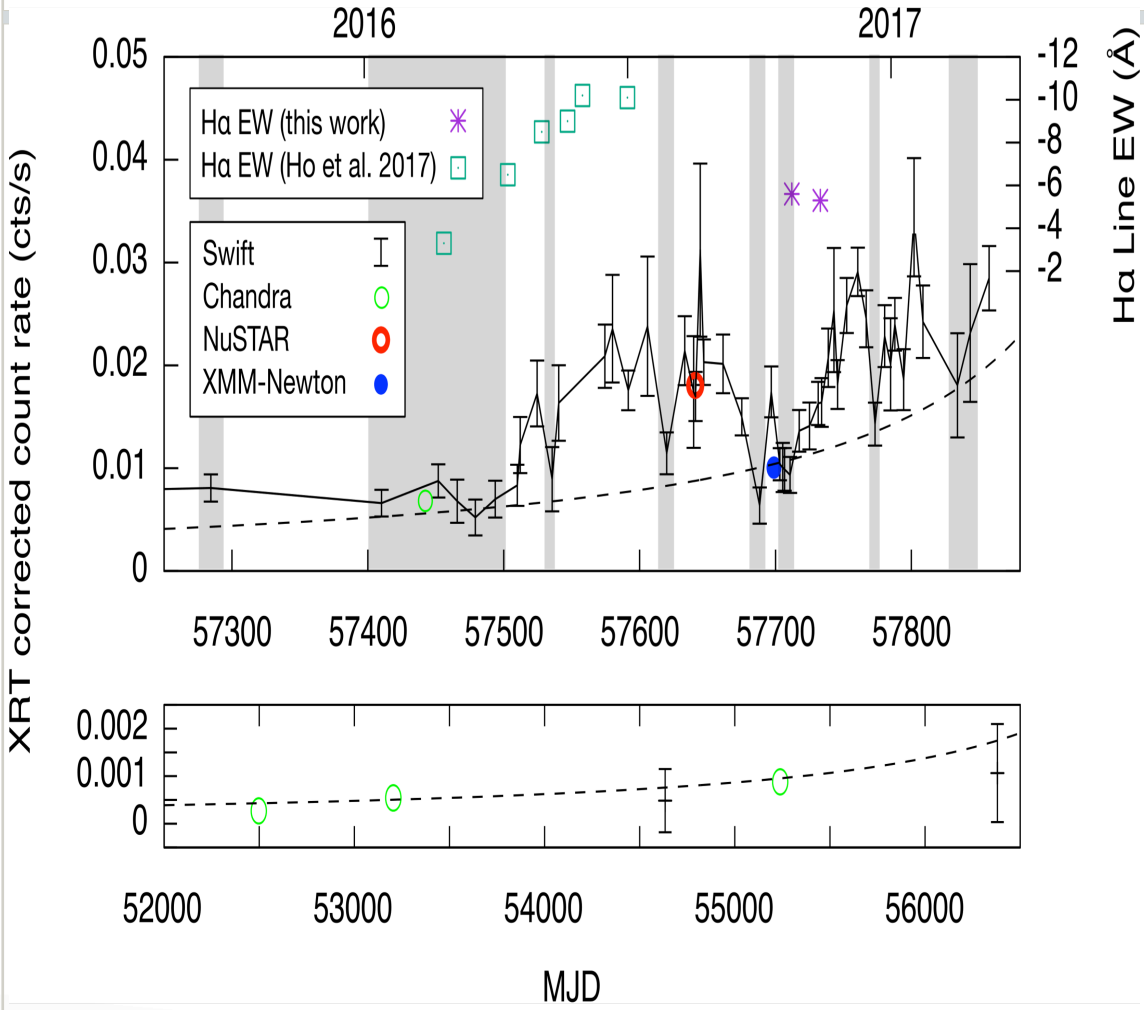
Recent Swift Observations



Li et al. 2017

- The Brightening stopped!
  - Just individual flares on a $t_p^{-1.2}$ baseline (dashed line, where t_p is the days from the periastron)?
  - An "anonymous high state"
- H_α line is evolving
  - The Be disk size is changing?
  - How does the change correlate with the X-ray flux?

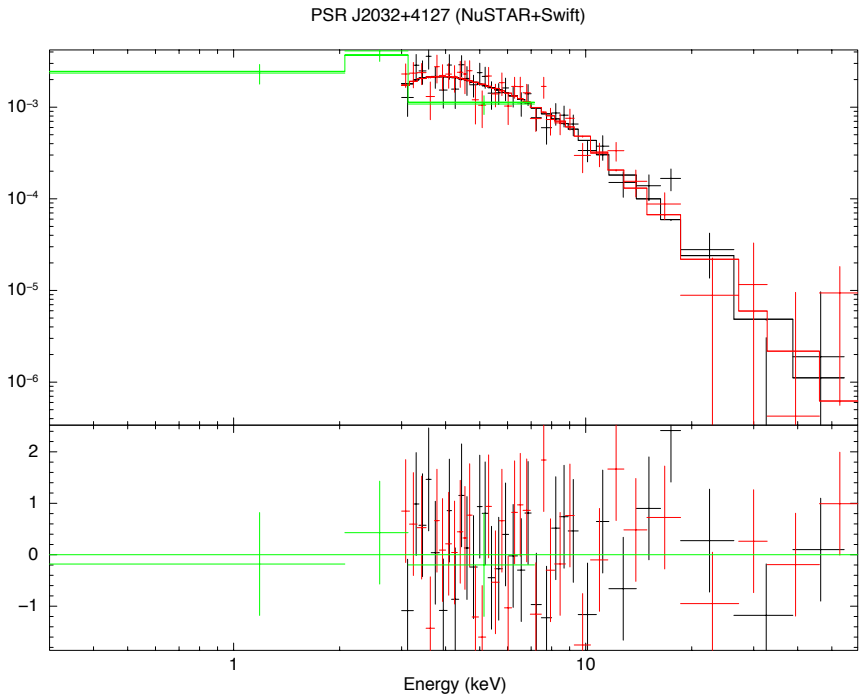
Recent Swift Observations



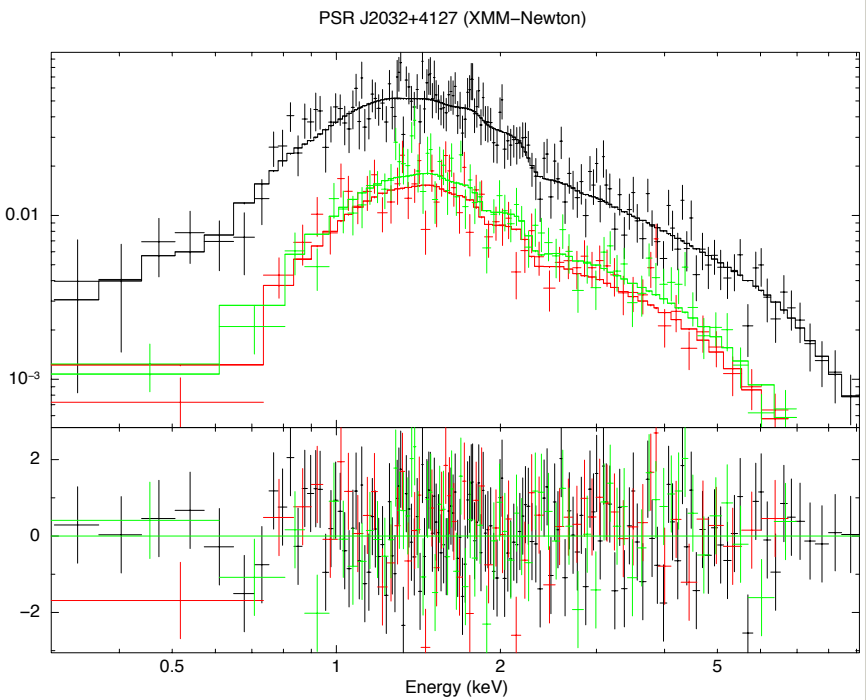
- **NuSTAR: 2016 September (46 ks)**
  - For the flare
- **XMM-Newton: 2016 November (43 ks)**
  - For the baseline ("anonymous high state")

Spectral Properties

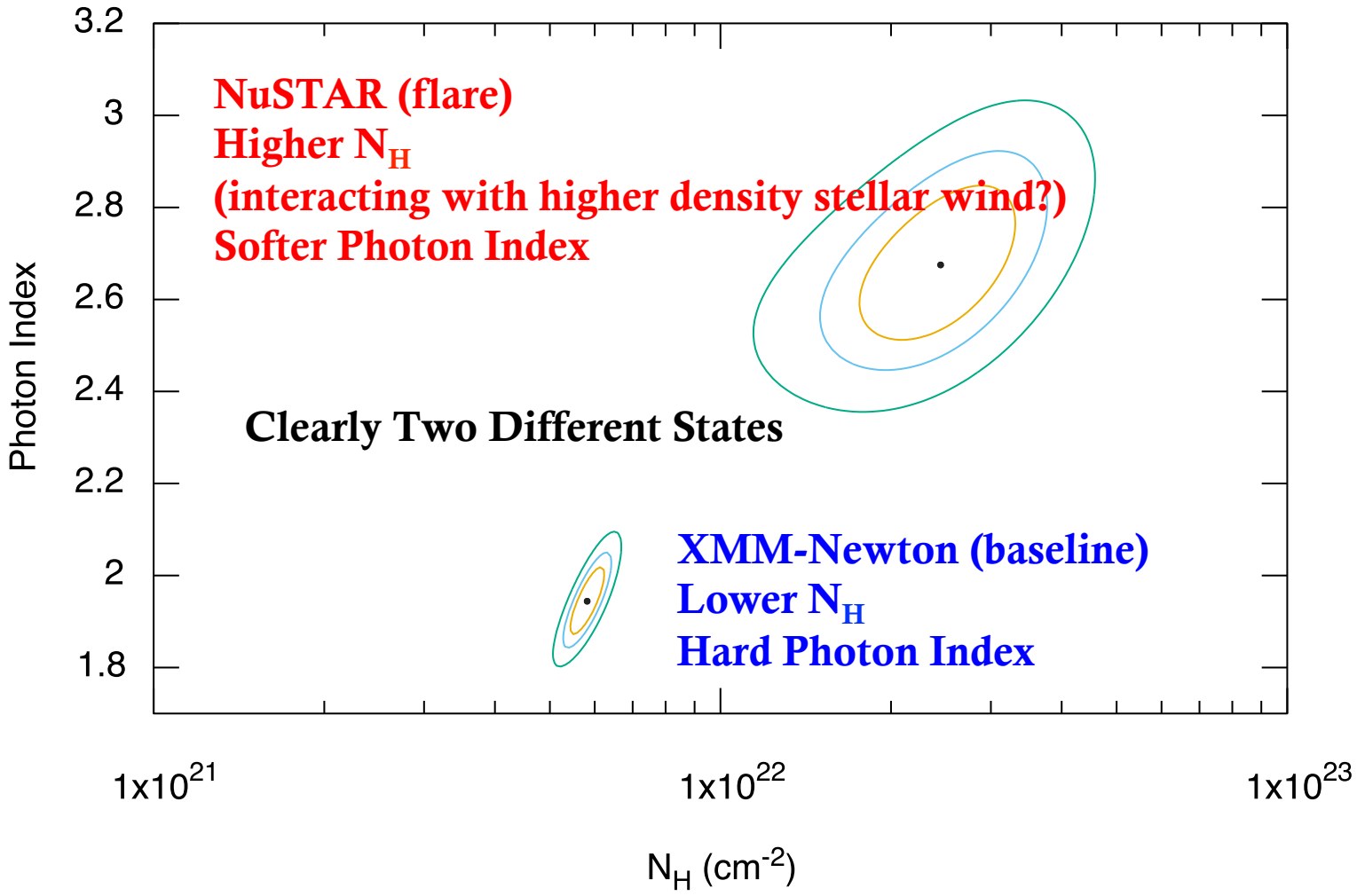
NuSTAR+Swift (0.3-78 keV)
Photon Index: 2.7±0.2
N_H: 2.4×10^{22} cm^{-2}



XMM-Newton (0.3-10 keV)
Photon Index: 1.9±0.1
N_H: 0.6×10^{22} cm^{-2}



Look into the parameters



Remarks

- Questions:
  - How J2032 entered the so-called "anonymous high state"?
    - What is the nature of the flares (high N_H and photon index)?
    - Can the NuSTAR data presents the flare properties?
  - Are the expected periastron flare(s) really coming?
    - Too far away to interact with the Be disk?
    - Unbounded system?
- More Observations are certainly required:
  - We will continue our bi-weekly Swift monitoring.
  - We will be monitoring the system with optical spectra. (variability in H_α)
  - Fermi-LAT monitoring.