Multiwavelength observations of gamma-ray binaries

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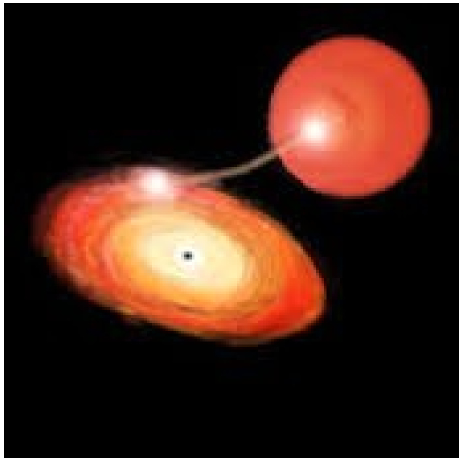
X-ray Binaries

- ~180 known low-mass X-ray binaries (LMXB)
  - Contain an evolved star transferring mass onto a white dwarf, neutron star, or black hole
- ~ 114 high mass X-ray binaries (HMXB)
  - Mass donor star is an O- or B-type star
  - 60% of HMXBs contain Be stars
- 20 black hole systems known

Material is accreted from the normal star onto the compact object.This releases large amounts of gravitational energy and result in the production of X-rays.

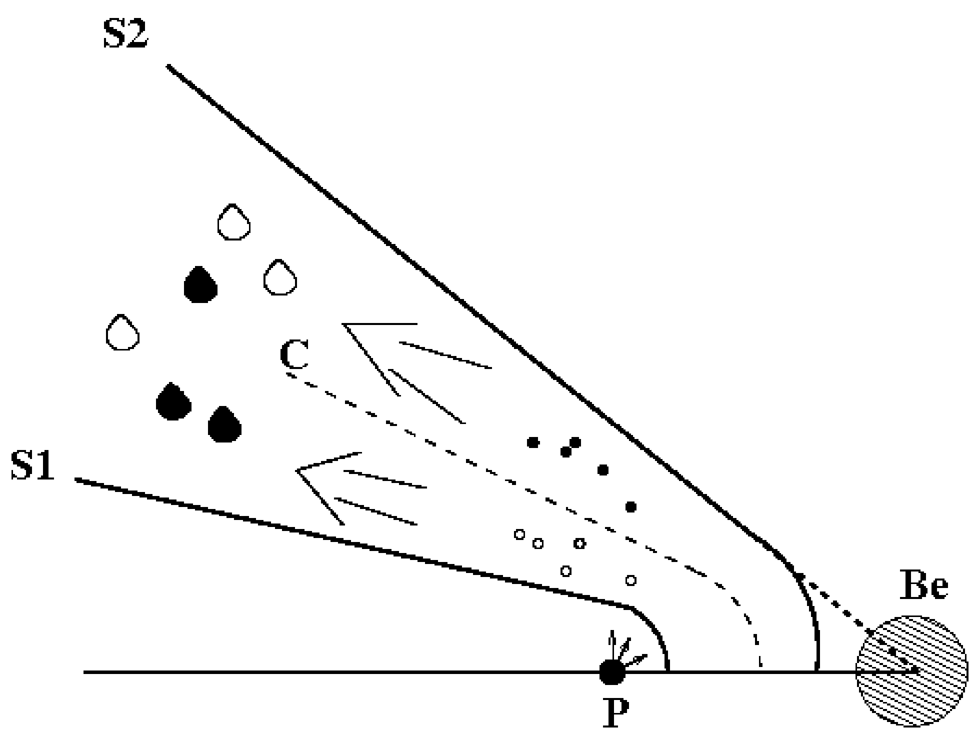


γ-ray Binaries

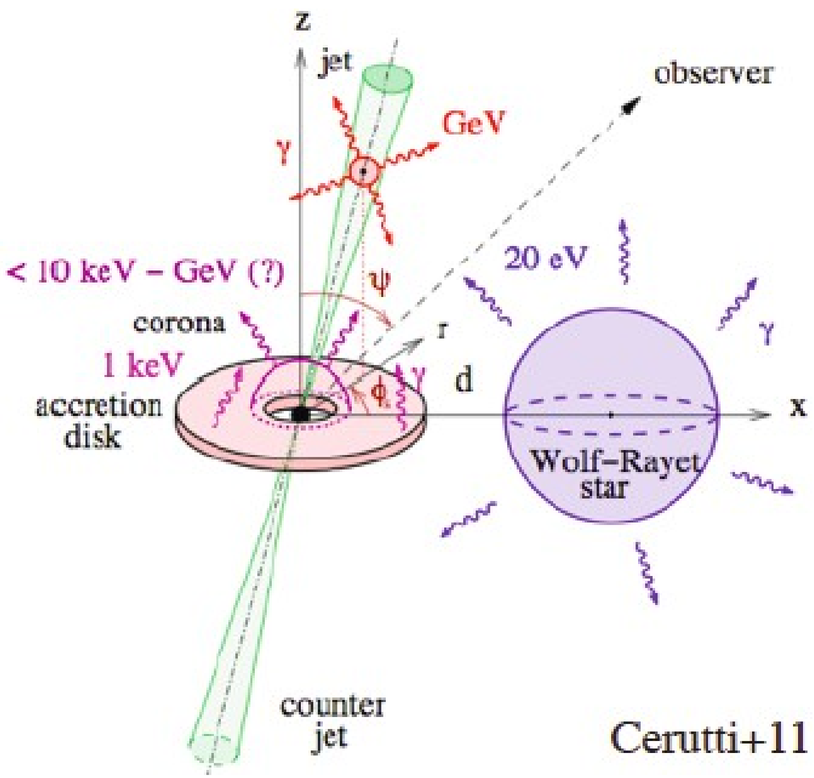
- HMXBs that also exhibit very high energy emission (MeV-TeV) are called "γ-ray binaries"
- Only 5 are regularly observed at TeV:
  - PSR J1259-63 (B2e + pulsar)
  - LS I +61 303 (B0 Ve + ?)
  - LS 5039 (ON6.5 V + ?)
  - HESS J0632+57 (B0pe + ?)
  - 1 FGL J1018.6-5856 (06V(f) + ?).
- More in GeV, but still few...
  - Cygnus X-1 (O9.7 Iab + black hole)
  - Cygnus X-3 (WR + ?)
  - η Car (luminous blue variable star +O star, P=5.53 year)
  - V407 Cyg(symbiotic star, P=43years (?))
  - Binary systems with millisecond pulsars

Two Theories for γ-ray Production

Colliding Winds



Microquasar



PSR B1259-63

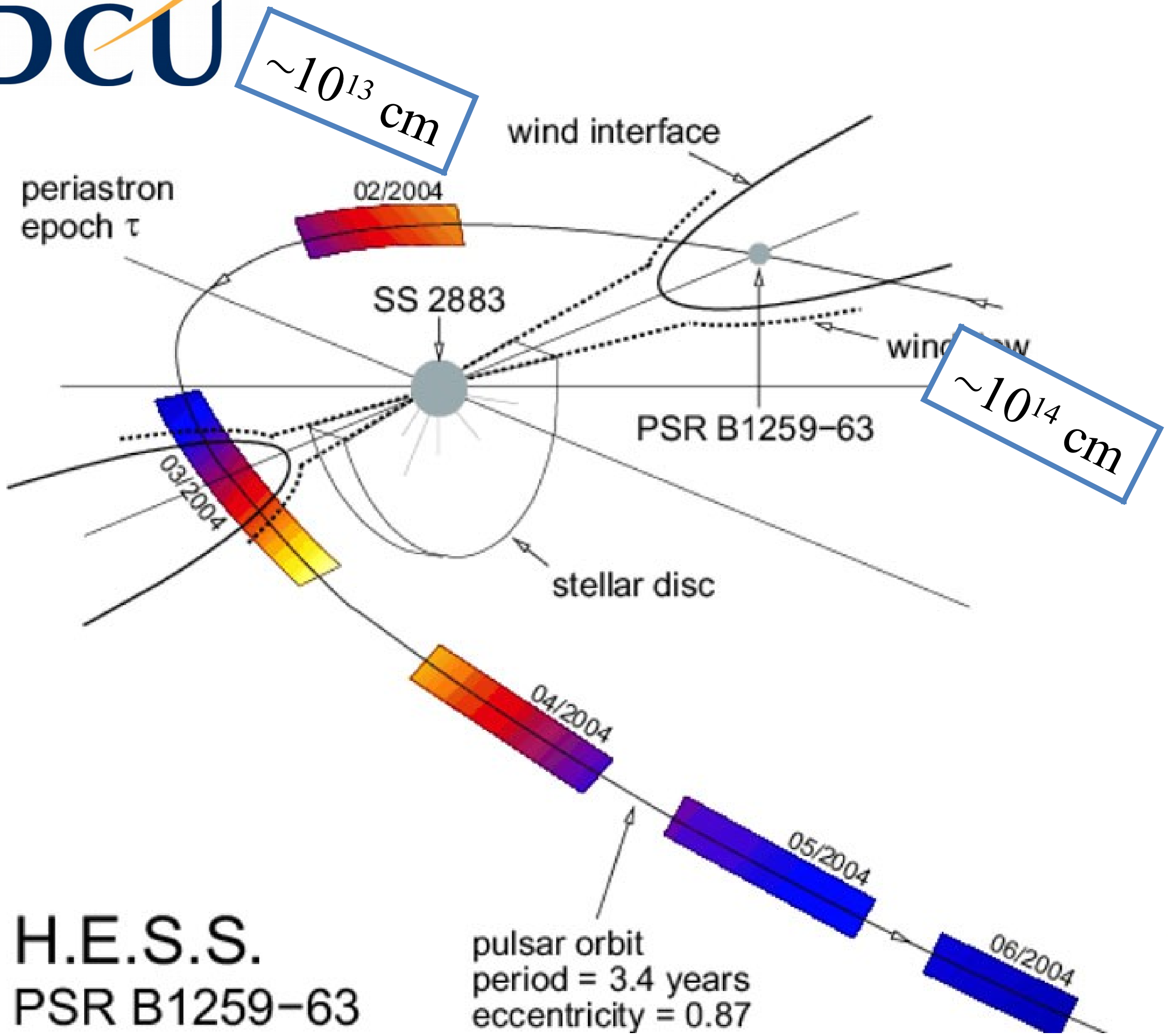
- Powered by pulsar spin down luminosity.
- Involves interaction with companion

LS 5039
LS I +61°303
HESS J0632+057
1FGL 1018.6-5856

Cygnus X-3

- Accretion onto black hole (or neutron star).
- Broad band emission from jet and accretion disk.

PSR B1259-63 system



Aharonian et al. 2005.

Pulsar:
P=47.76 ms
L_{SD}=8.3 × 10^{35} erg s^{-1}

Orbit
Period ≈ 3.4 yr
Eccentricity e≈ 0.87

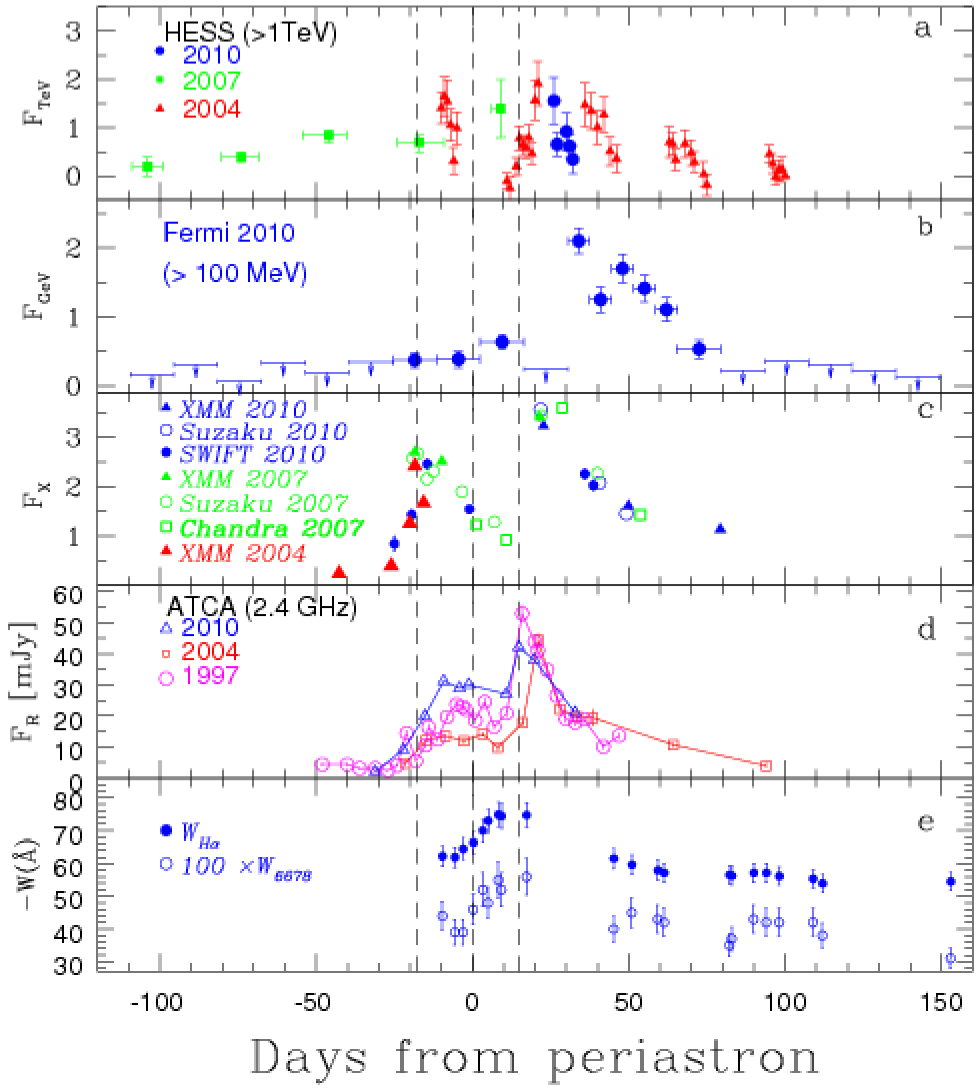
Distance 2.3 ± 0.4 kpc

SS 2883 parameters

- L_*=2.2E+38 erg/s
- M~10M_{sun}
- T~27000 K

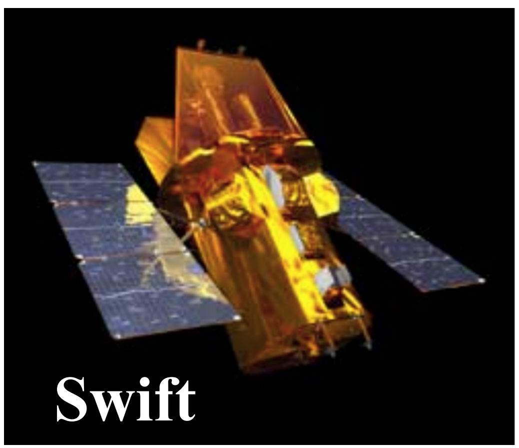
"Laboratory" for the study of the properties of pulsar winds

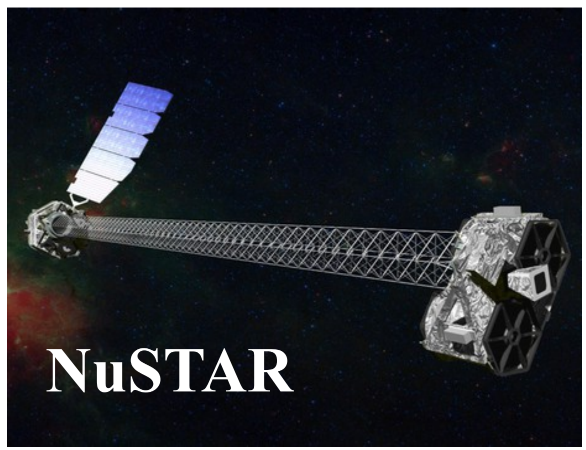
2010 periastron passage

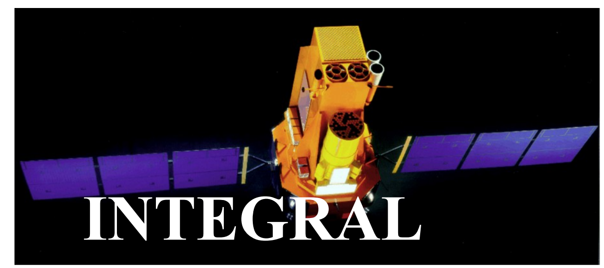


Chernyakova et al. (2014)

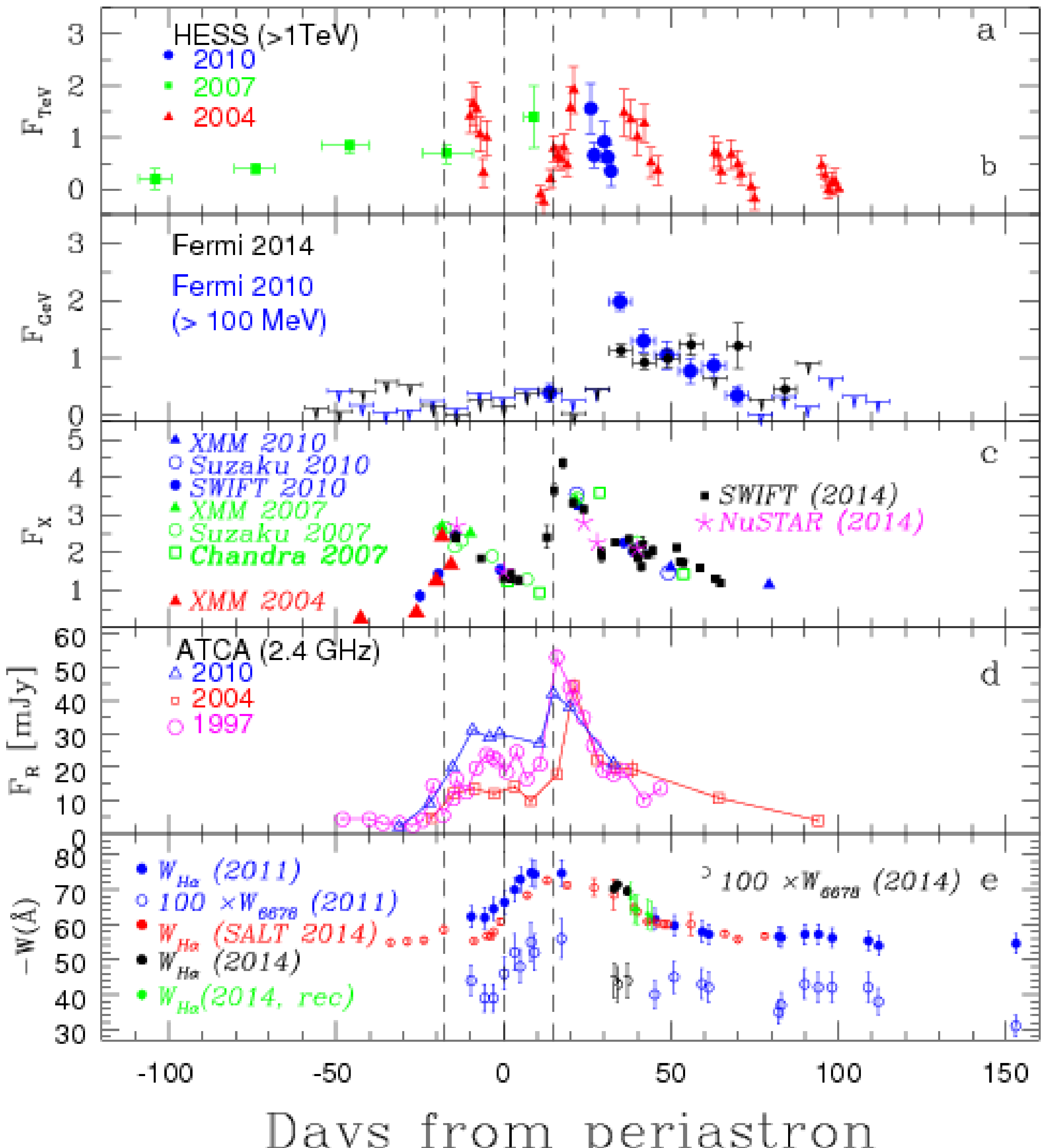
2014 Multi-wavelength Campaign



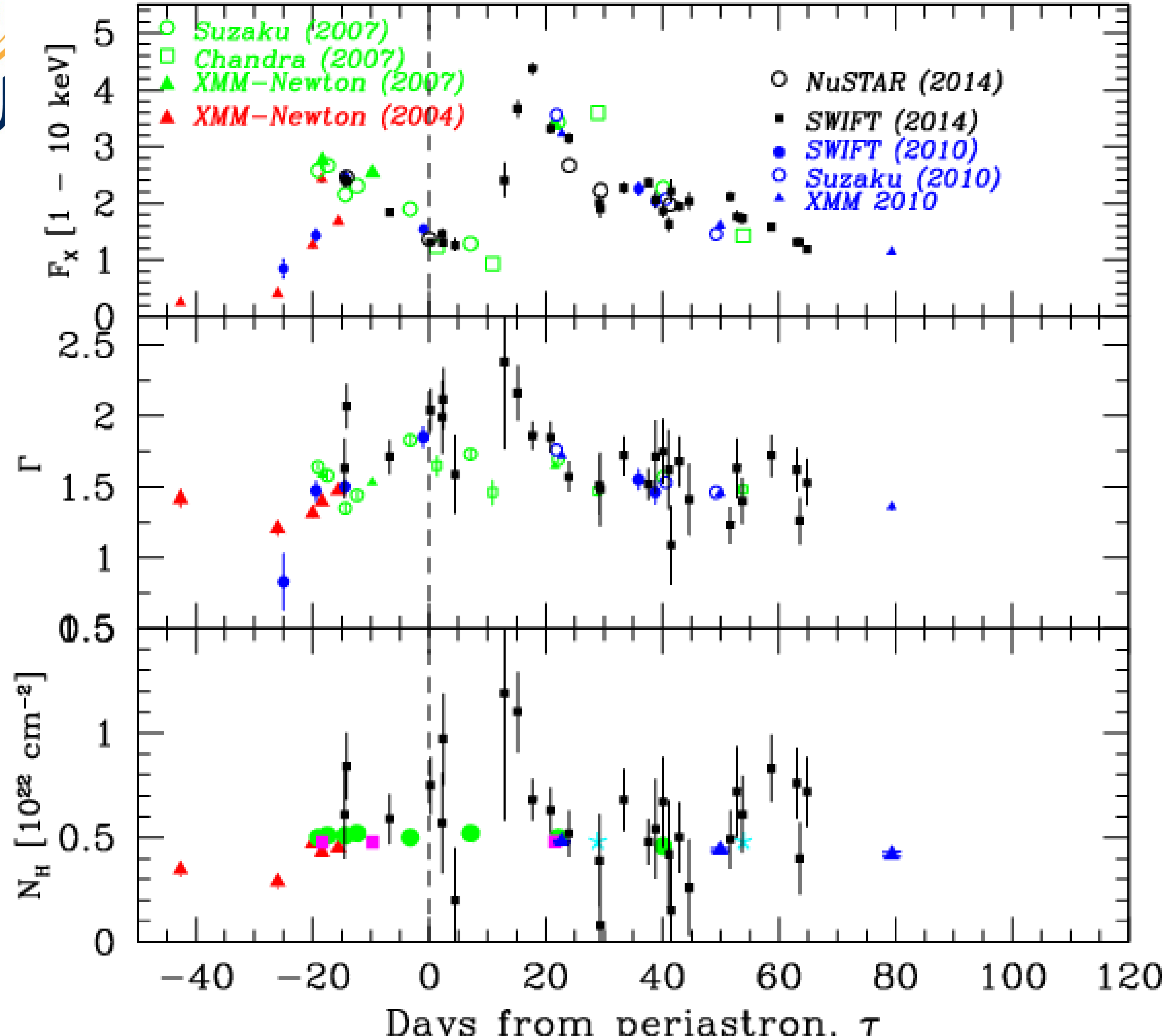




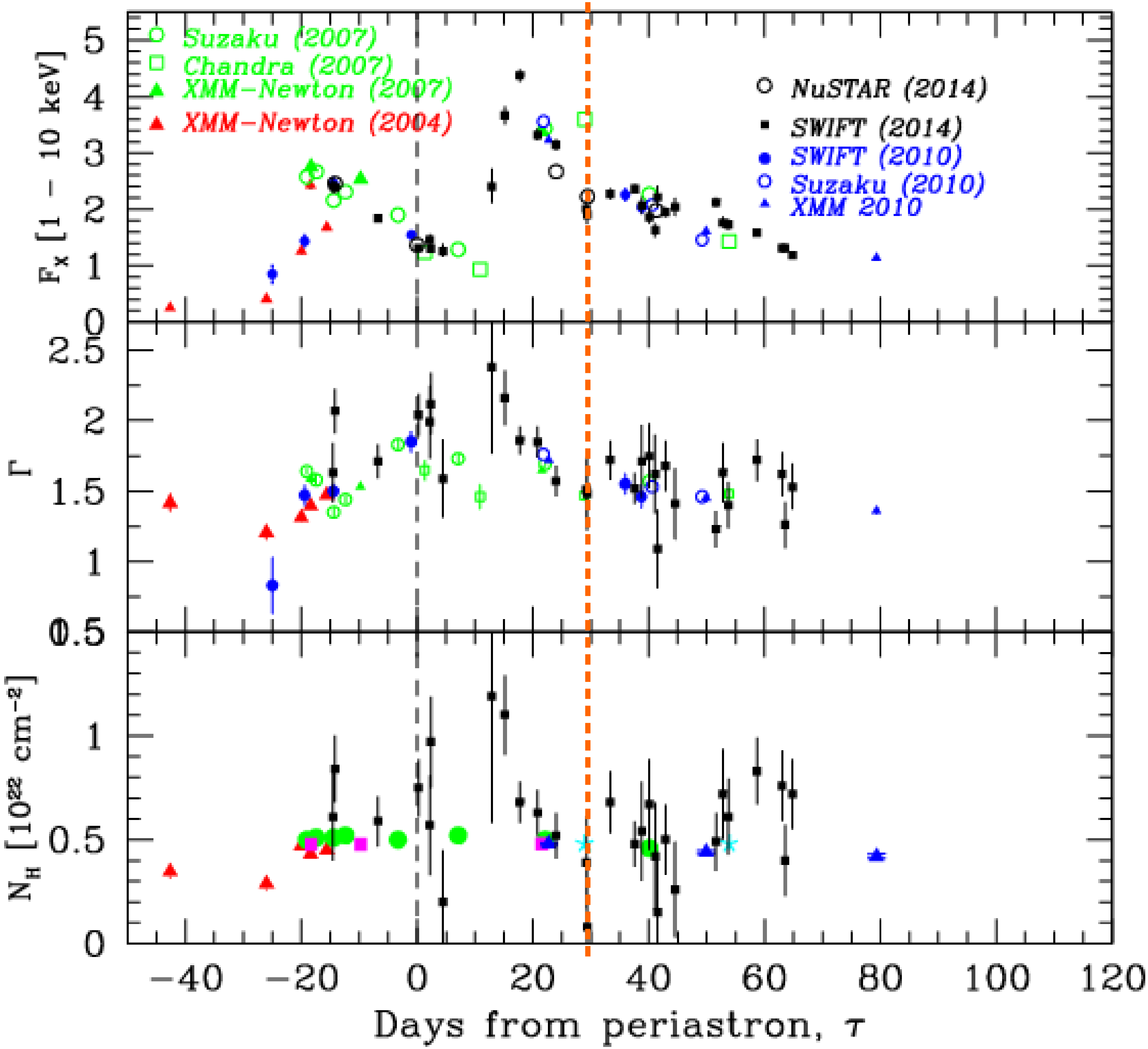
- GeV flaring is recurrent $t \sim t_p+30$
- Optical spectroscopy data demonstrate that the onset of the flare coincides with a rapid decrease of the $W_{H\alpha}$
- From the disk model of Grundstrom & Gies (2006),one finds that in 5 days the mass of the disk reduced by a factor of 5, from $2\times10^{-8}M_{\odot}$ to $3.9\times10^{-9}M_{\odot}$.



Chernyakova et al. (2015)



Suzaku (2007)
Chandra (2007)
XMM-Newton (2007)
XMM-Newton (2004)
NuSTAR (2014)
SWIFT (2014)
SWIFT (2010)
Suzaku (2010)
XMM 2010
F_x [1 – 10 keV]
Γ
N_H [10^{22} cm^{-2}]
Days from periastron, τ



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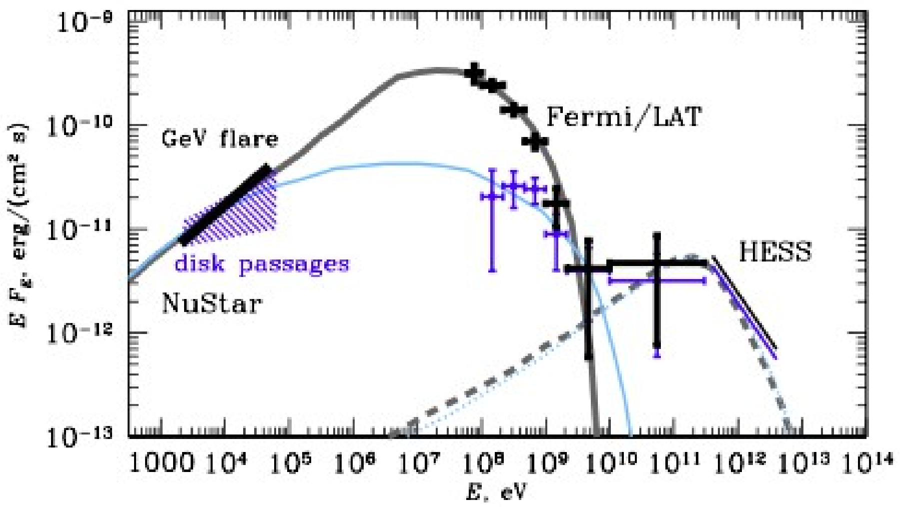
Discussion

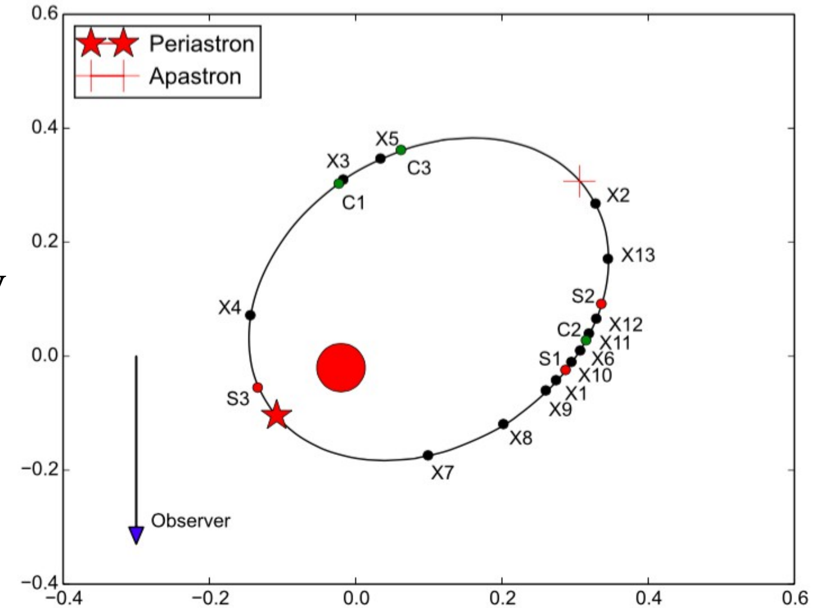
- GeV flaring is recurrent $t \sim t_p + 30$
- Optical spectroscopy data demonstrate that the onset of the flare coincides with a rapid decrease of the $W_{H\alpha}$
- Rapid change of X-ray behaviour.
- Destruction of the equatorial disk leads to a chaotic system of clumps, closing the escape path for the unshocked pulsar wind.

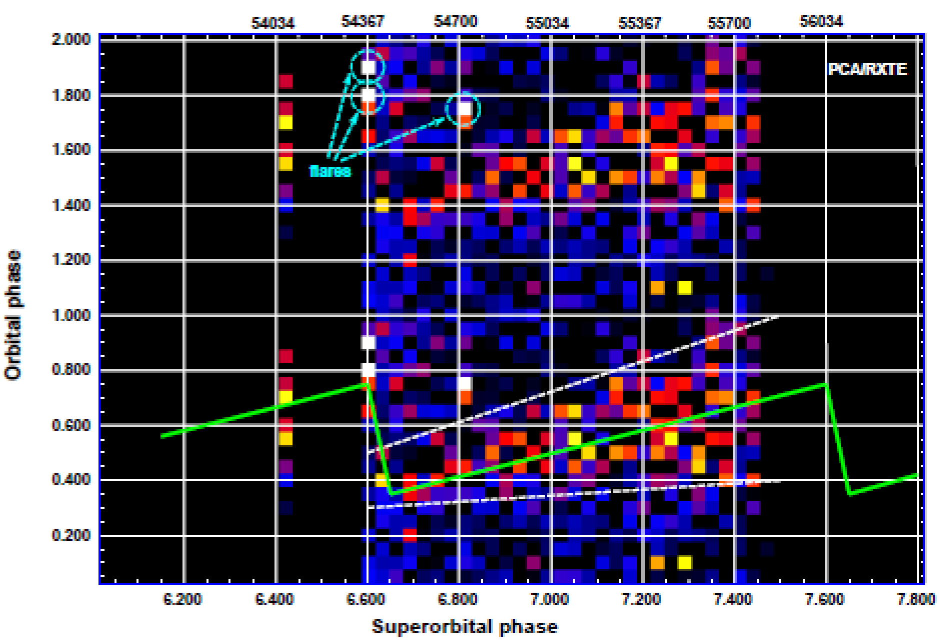


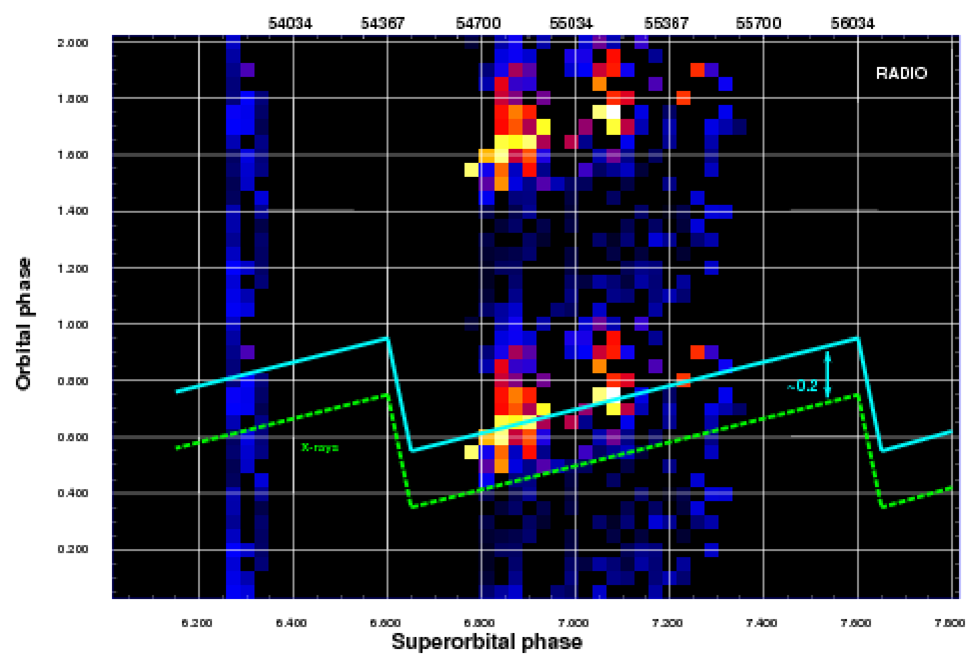
- Spectrum of flare emission is consistent with the synchrotron emission from electrons injected with a close to monoenergetic spectrum and cooled by the synchrotron energy loss. The synchrotron cooling leads to the formation of a $dNe/dE \propto E^{-2}$ low energy tail, leading to the observed $dN\gamma/dE \propto E^{-1.5}$ X-ray spectrum.
- The persistent component of the broad band spectrum is flat for the X-ray-to-GeV spectrum $dN/dE \propto E^{-2}$, i.e. $dNe/dE \propto E^{-3}$.
- Different injection spectra of electrons responsible for the persistent and flaring emission suggests two populations of high-energy electrons, i.e. electrons originating from the pulsar wind and electrons from the stellar wind.

LSI +61º 303

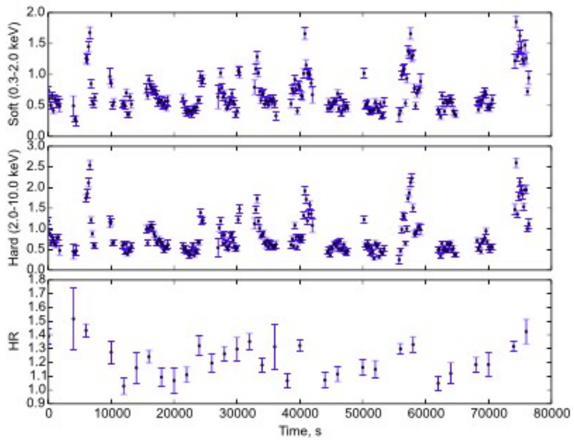
- 26.5-day orbital period
- In radio, X-ray and GeV -- one flare per orbit
- The orbital phase of the periodic flares drifts with a superorbital period P=4.6 year (Gregory 2002).
- Similar SO period in X-rays, phase of the X-ray activity period always precedes the phase of the radio outburst by ~ 5.3 days (Chernyakova et al. 2012).
- One of the explanation of the 4.6 yr time scale is the build up and decay of the equatorial disk around the massive Be star in the system (Zamanov et al. 1999).

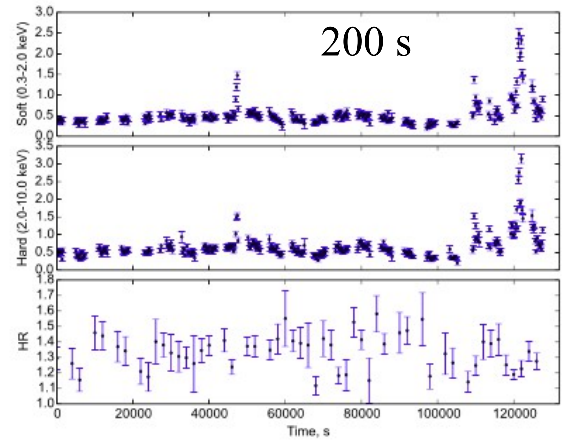


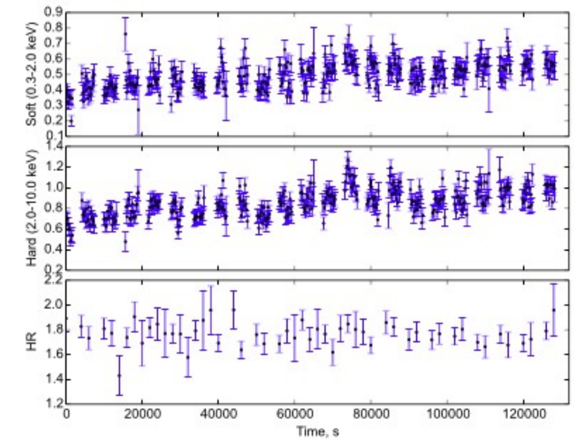


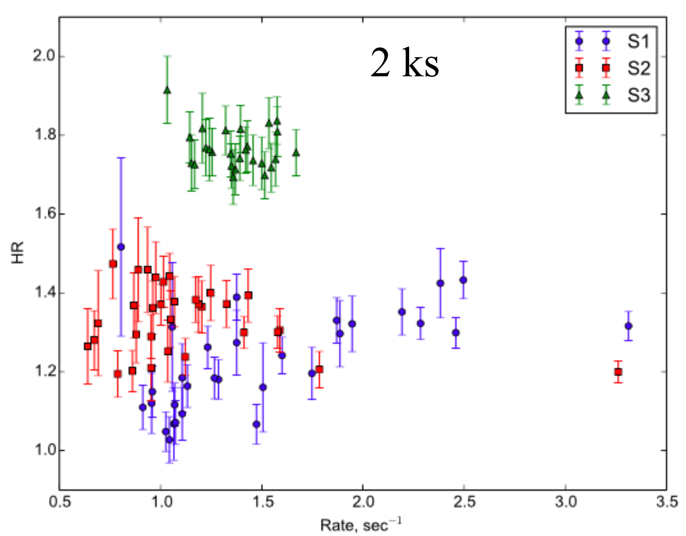


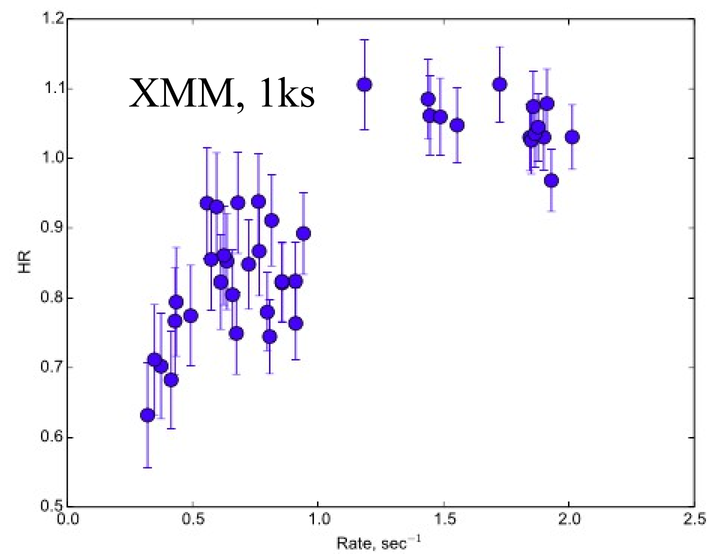
Variability within a single observation







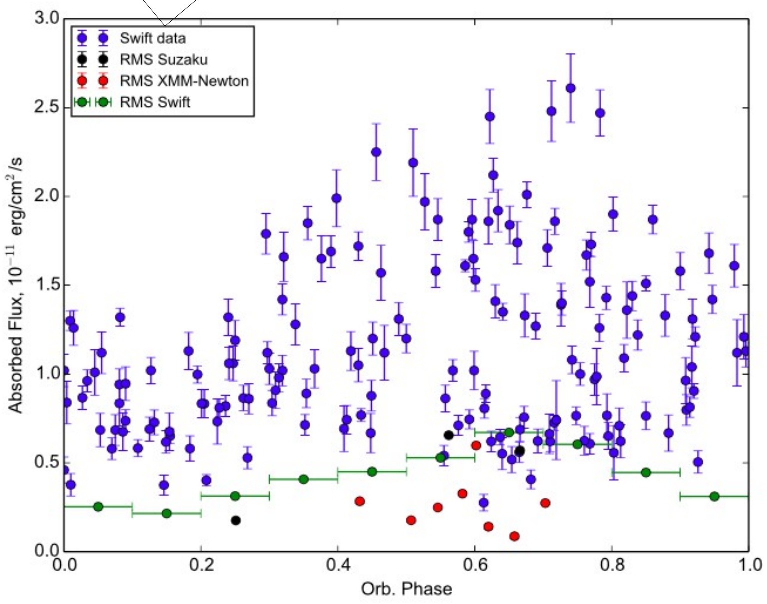


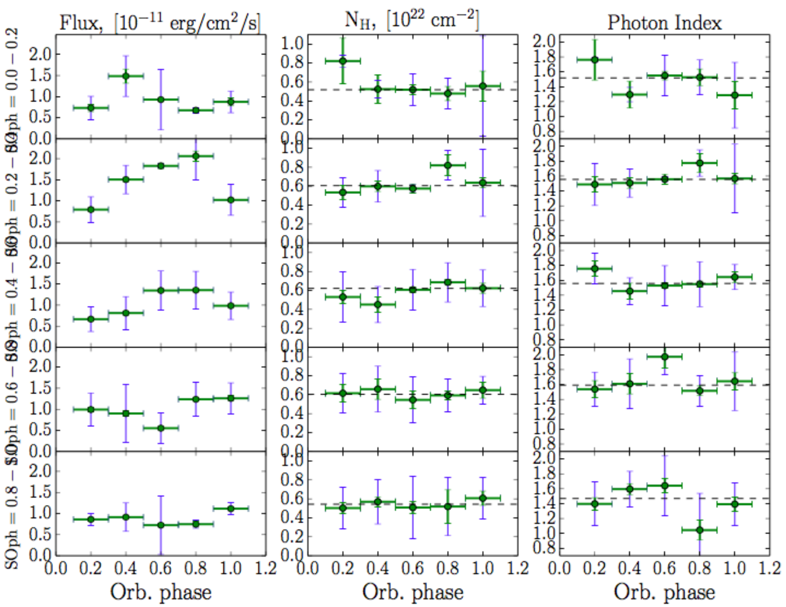


HR=F(2.0-10.0 keV)/F(0.3-2.0 keV). For S1 spectrum hardening with the increase of the flux along with the findings of Sidoli et al. (2006), but not for S2 and S3.

Spectral variability on orb and SO scales

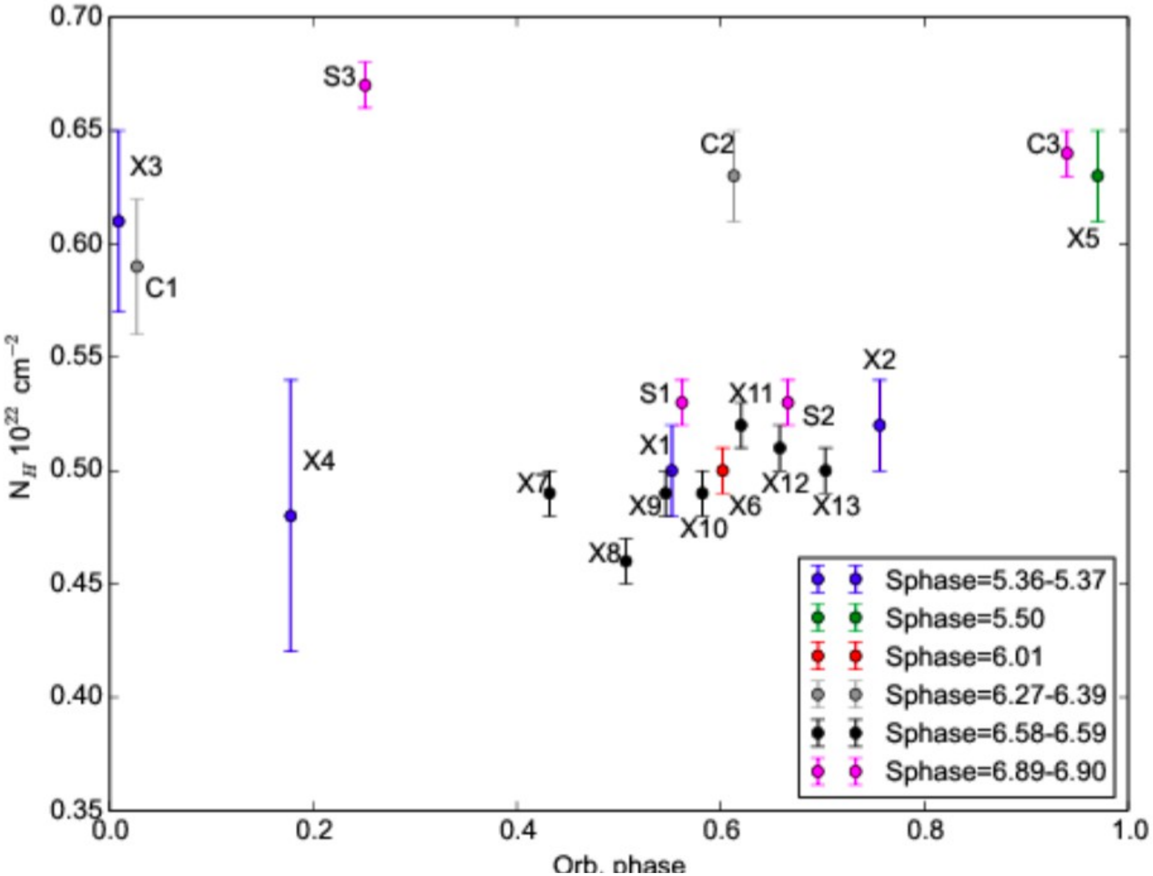
Preliminary!





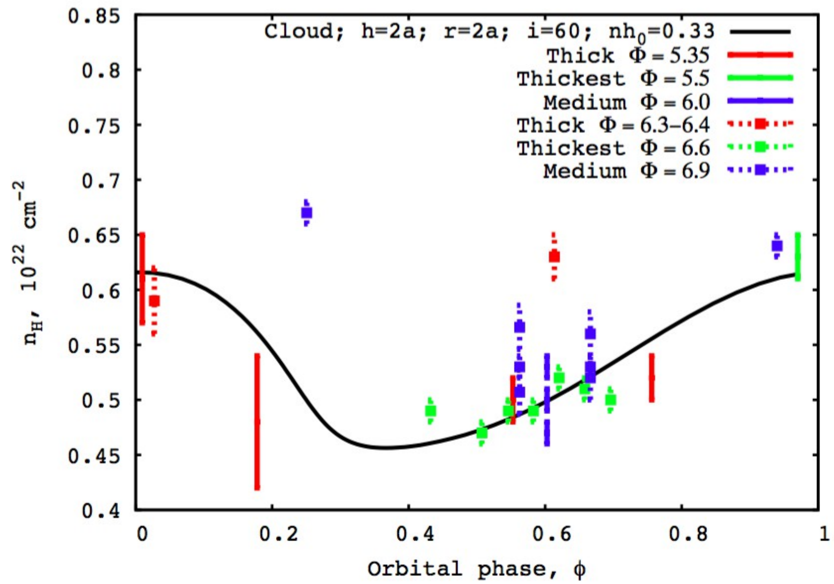
In agreement with RXTE data (Hadasch et al., 2015) flux modulation as observed with SWIFT is much stronger around apastron.

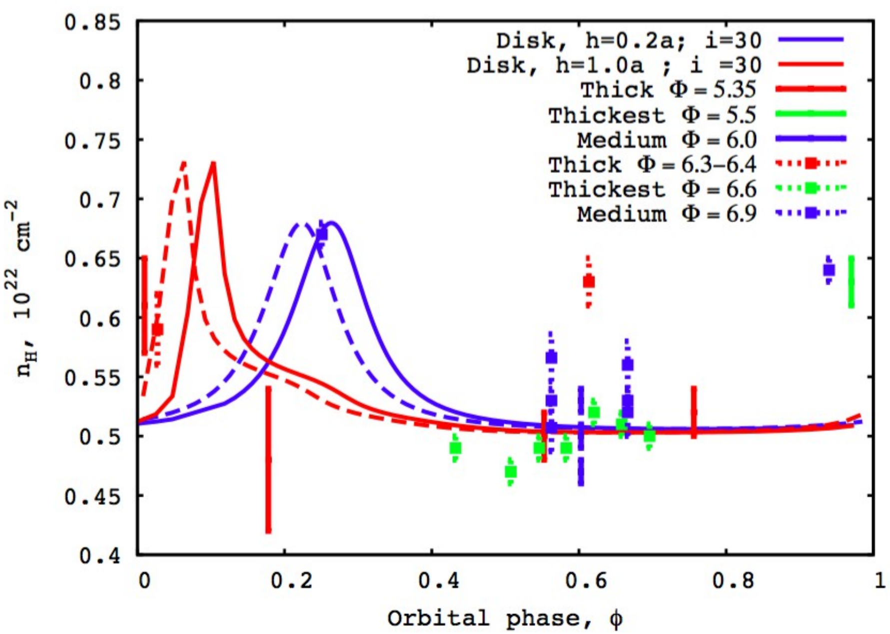
N_H Variability

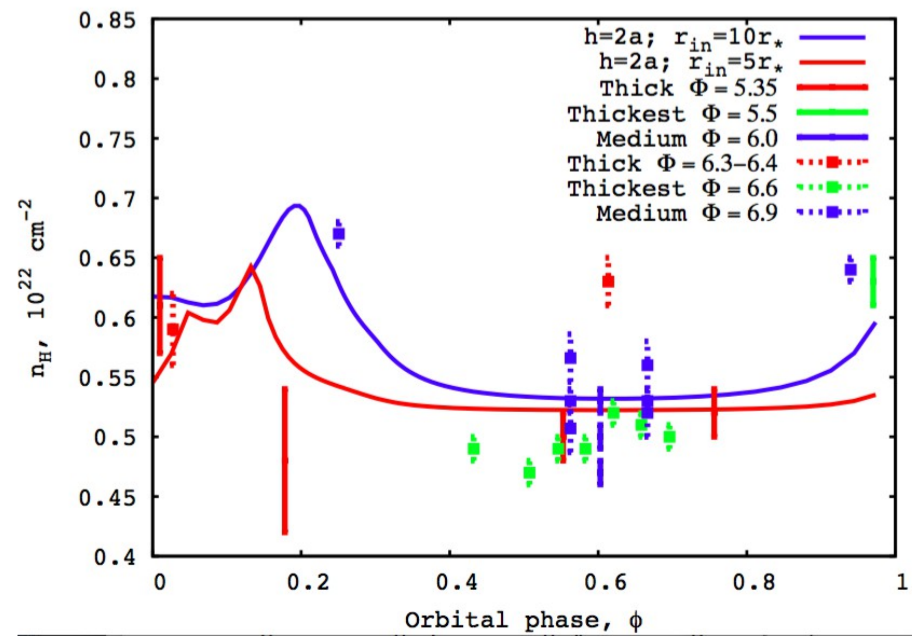


Reconstruction of the disk parameters

Preliminary!







Conclusions

Gamma-ray binaries are excellent laboratories to study interaction between the relativistic outflow from the compact source and companion star under varying conditions.

PSR B1259-63:

- During 2014 periastron passage we have seen repetitive nature of the GeV flare, accompanied by
  - Rapid drop of the Hα equivalent width just after the onset of GeV flare
  - Change of X-ray spectral behaviour.

Such a behaviour could be understood in terms of disruption of the disk, and two different populations of electrons injected during the persistent and flaring states.

LSI +61° 303:

- Complex spectral and timing behaviour different at periastron / apastron
- Flux modulation as observed with SWIFT is much stronger around apastron.
- Orbital variability of N_H can be used to study properties of the Be star disk.