

Multiwavelength observations of gamma-ray binaries

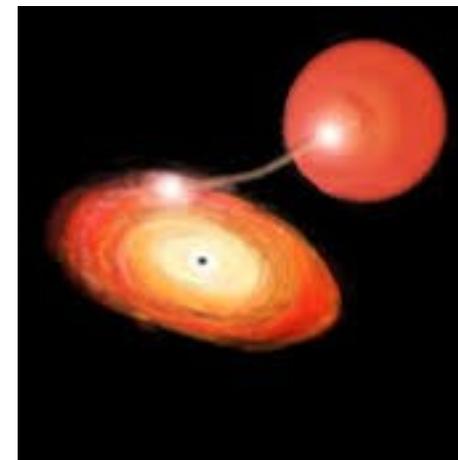
M.Chernyakova (DCU, DIAS), Iu. Babik (DCU, DIAS),
D. Malyshev (ISDC), A. Neronov (ISDC),
Ie. Vovk (MPP), S. Tsygankov (Tuorla observatory)
B. van Soelen (UFS), P. Callanan (UCC), L.O'Shaughnessy (UCC)

X-ray Binaries

Galactic X-ray sky is dominated by the emission from bright 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.

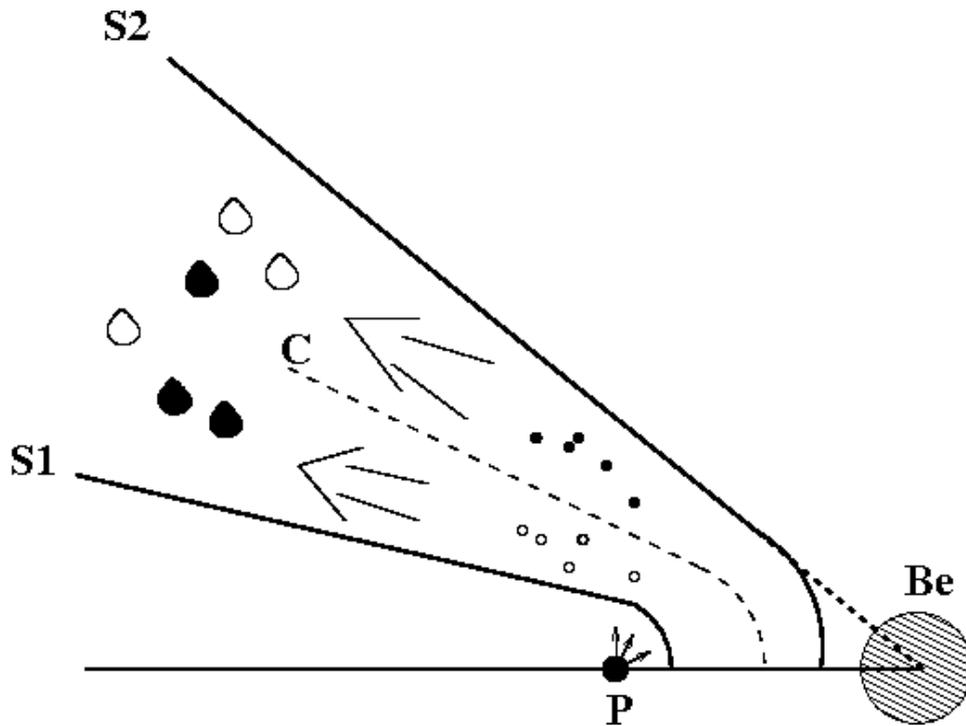


γ -ray Binaries

- 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 (O6V(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=43 years (?))
 - Binary systems with millisecond pulsars



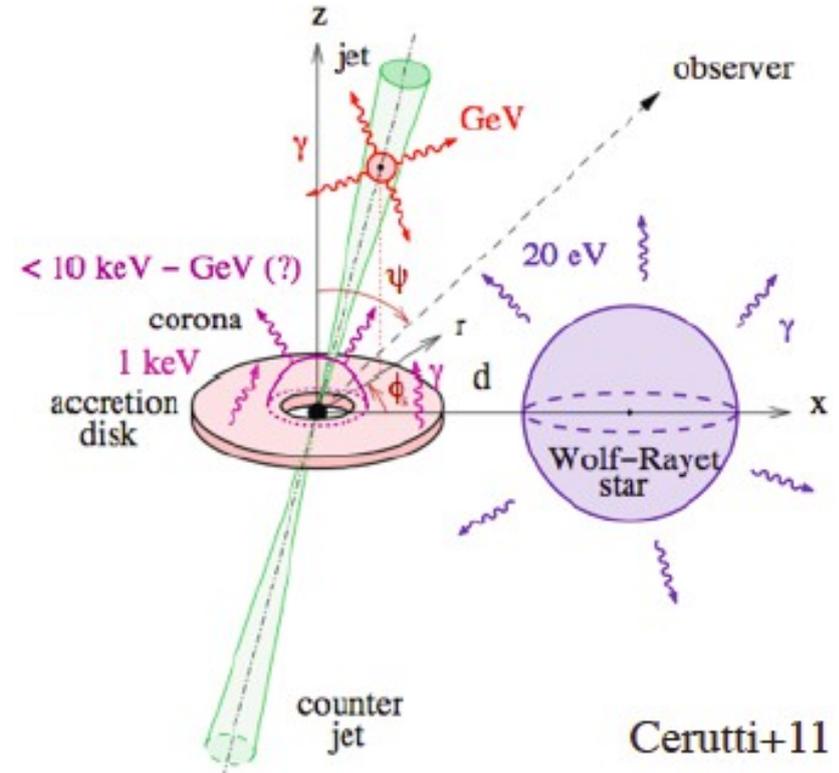
Colliding Winds



PSR B1259-63

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

Microquasar



Cygnus X-3

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

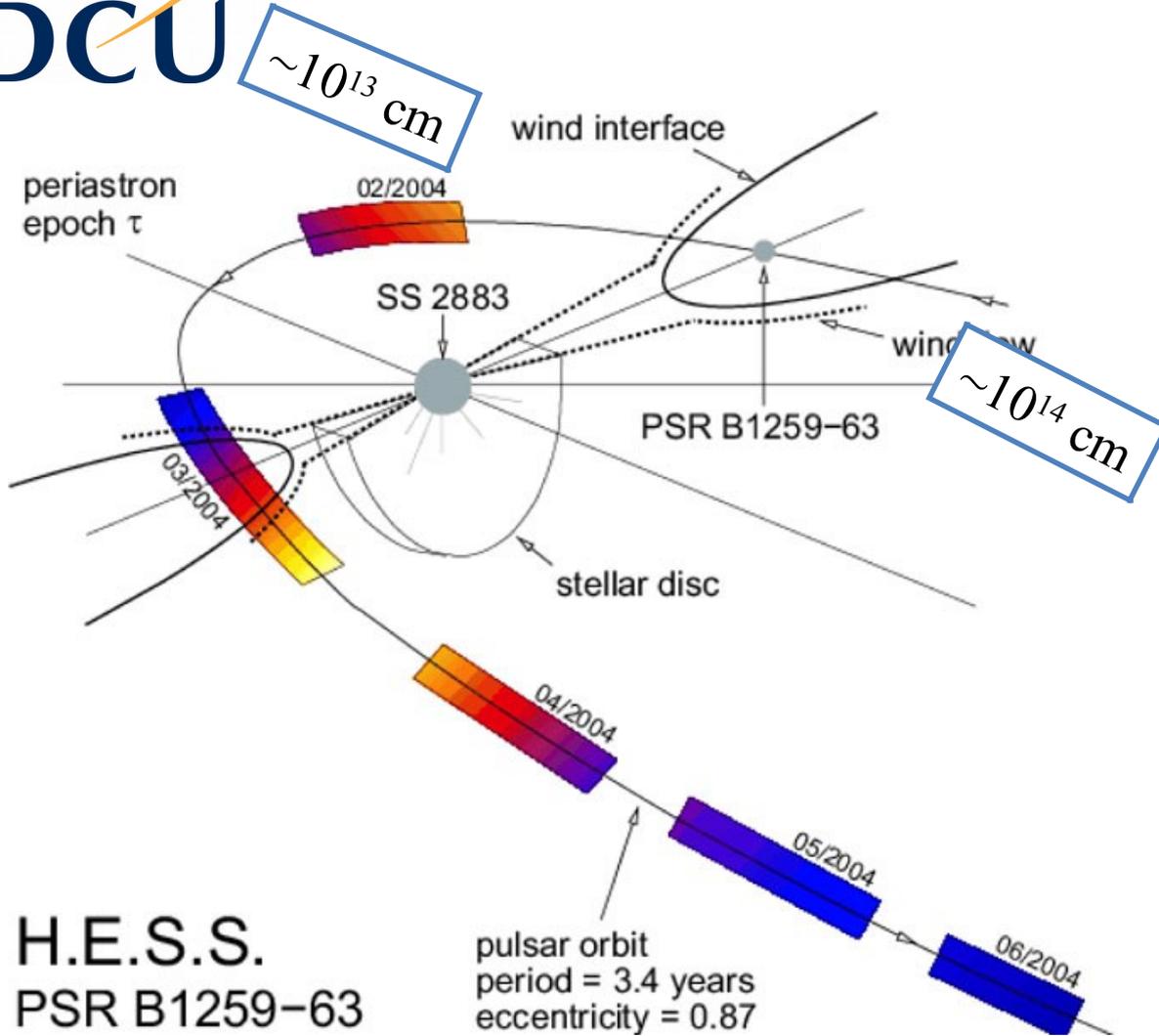
LS 5039

LS I +61°303

HESS J0632+057

1FGL 1018.6-5856

PSR B1259-63 system



H.E.S.S.
PSR B1259-63

Aharonian et al. 2005.

Pulsar:

$$P=47.76 \text{ ms}$$

$$L_{SD}=8.3 \times 10^{35} \text{ erg s}^{-1}$$

Orbit

Period $\approx 3.4 \text{ yr}$

Eccentricity $e \approx 0.87$

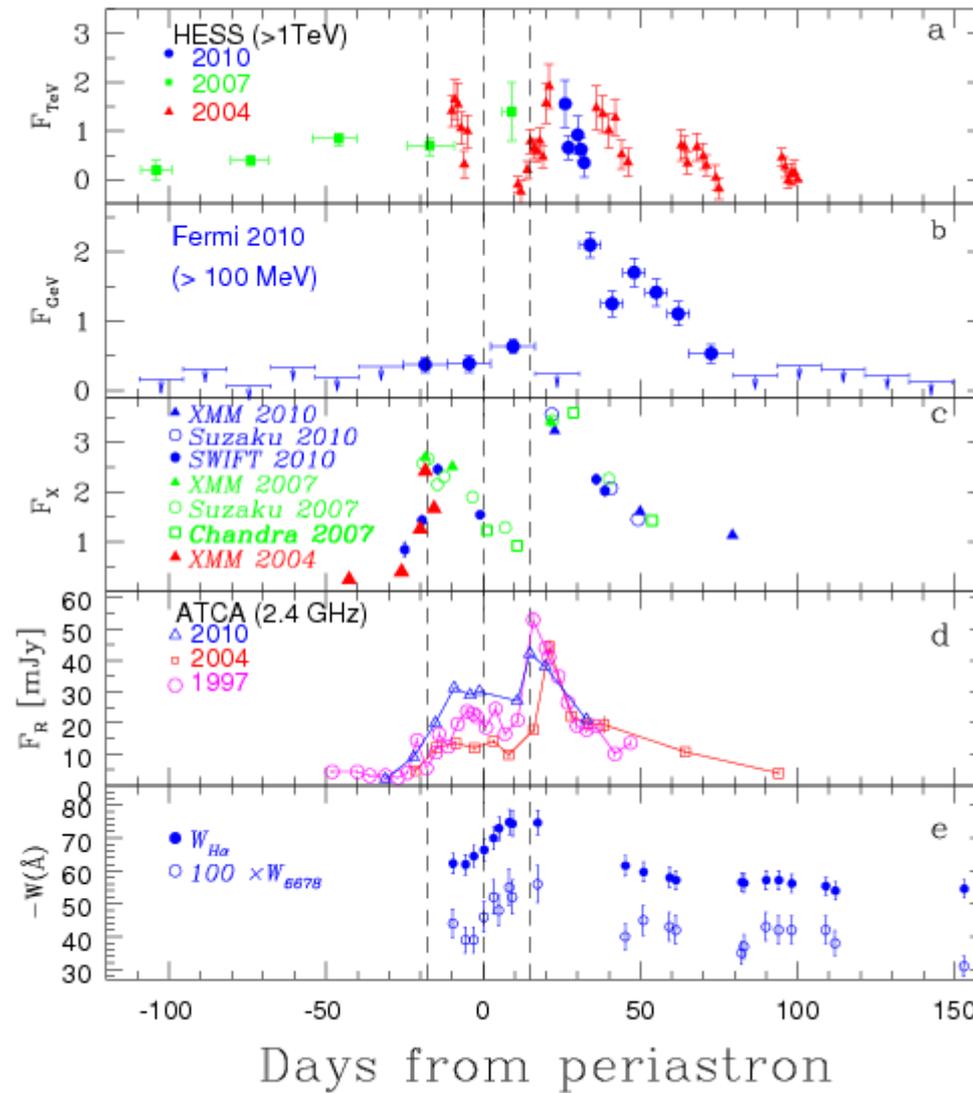
Distance $2.3 \pm 0.4 \text{ kpc}$

SS 2883 parameters

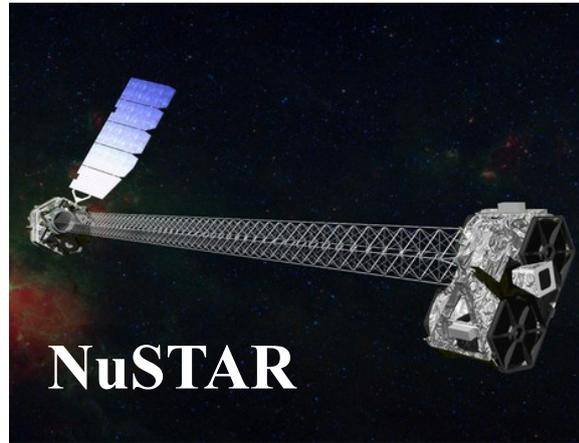
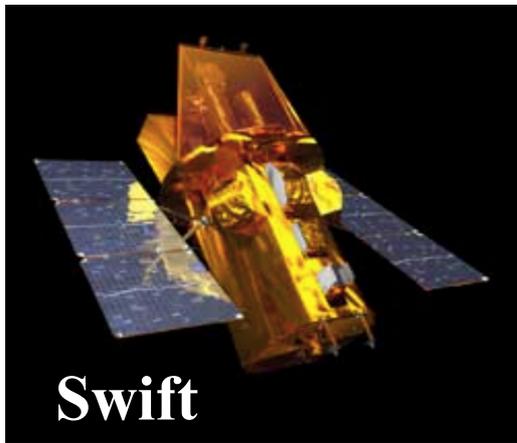
- $L_*=2.2E+38 \text{ erg/s}$
- $M \sim 10M_{\text{sun}}$
- $T \sim 27000 \text{ K}$

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

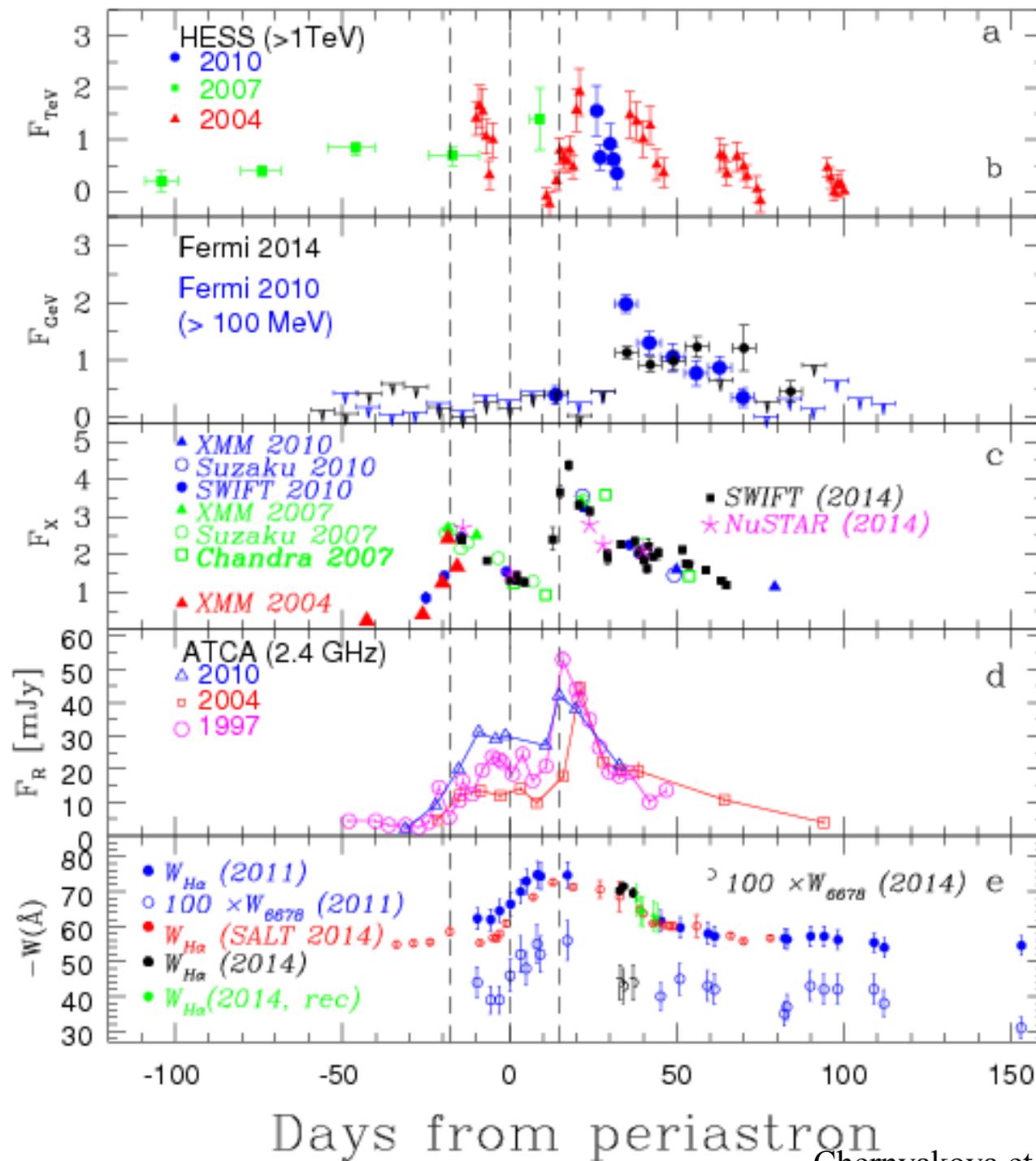
2010 periastron passage

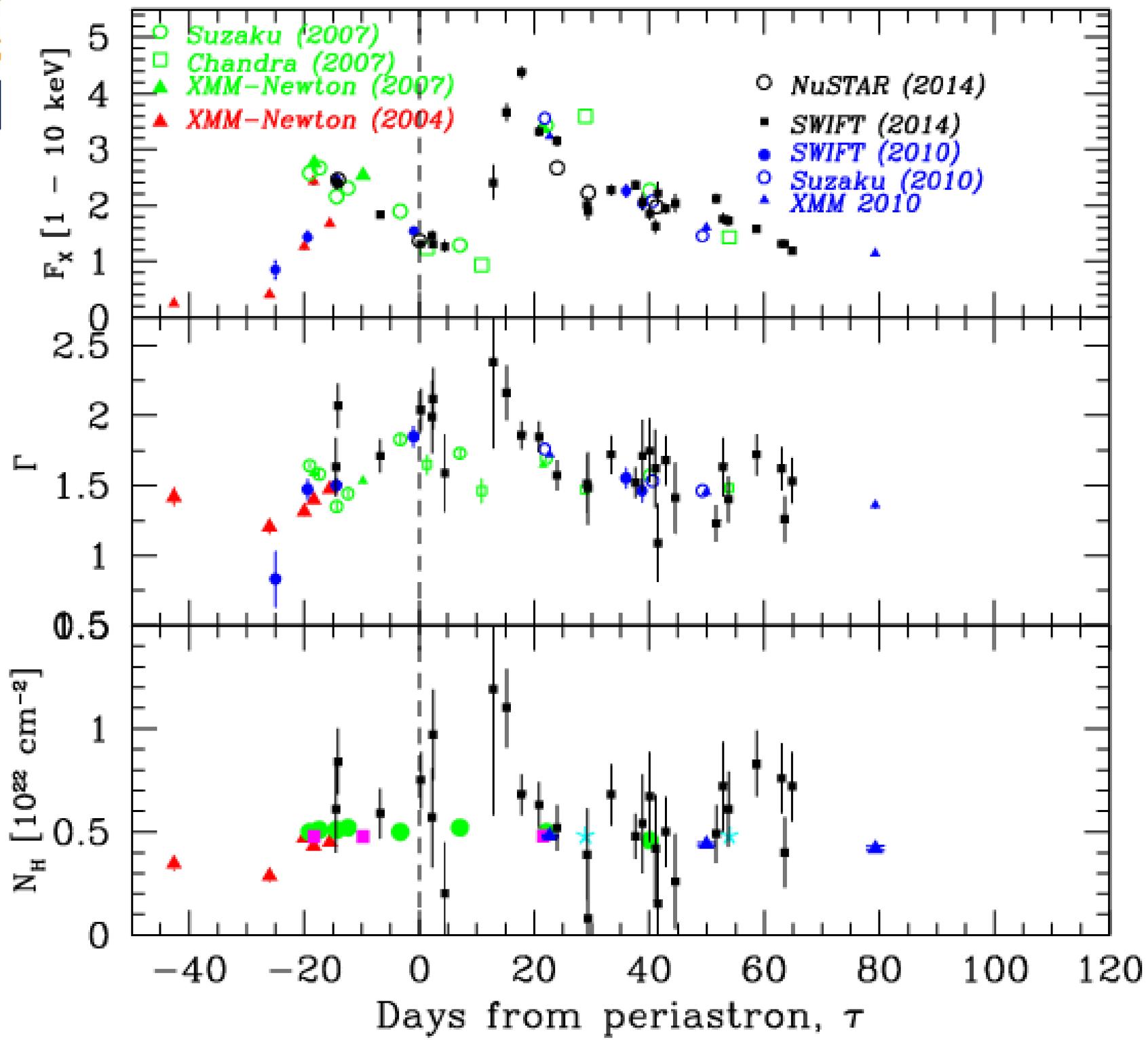


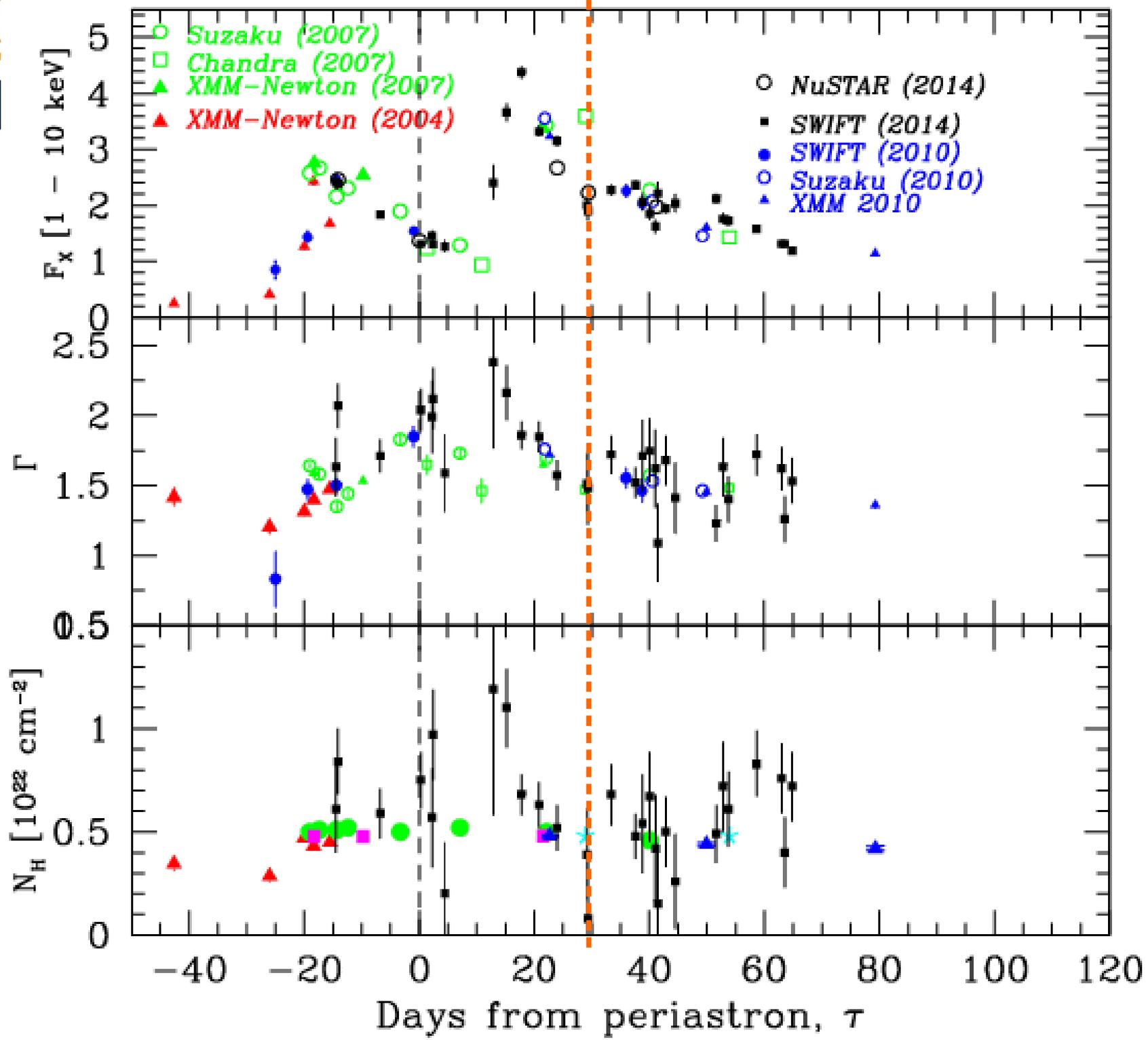
DCU2014 Multi-wavelength Campaign



- 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 $2 \times 10^{-8} M_{\odot}$ to $3.9 \times 10^{-9} M_{\odot}$.



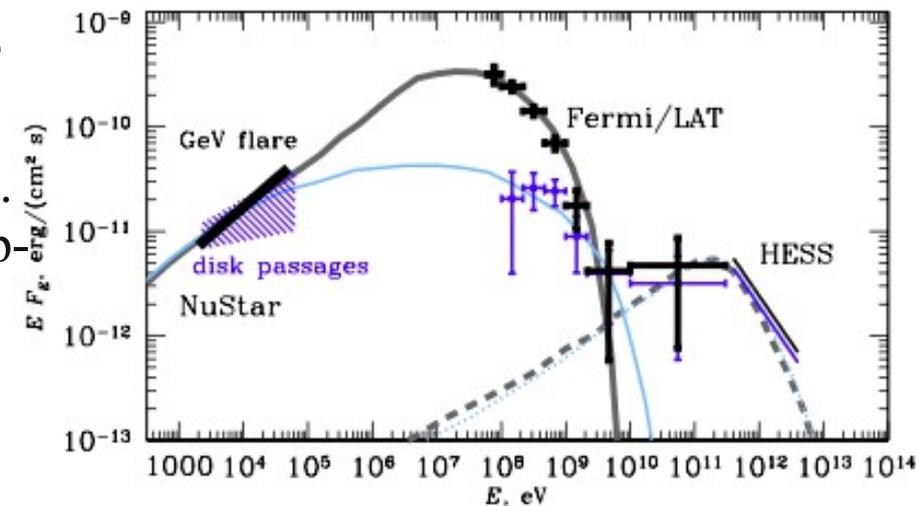




→ GeV flaring is recurrent $t \sim t_p + 30$

→ Optical spectroscopy data show that the onset of the flare coincides with a rapid decrease of the $W_{H\alpha}$

→ X-ray observations show that the flare is not orphan. The rate of decay of the X-ray flux changes in a step-like manner at the moment of the flare, i.e. an additional flux component appearing at the moment of the GeV flare. This disfavors Bremsstrahlung mechanism of the flare.



→ Destruction of the equatorial disk leads to a system of clumps, closing the escape path for the unshocked pulsar wind, note also Chandra observations (Pavlov et al. 2015). Increase of the luminosity up to $\sim 68\%$ of the spin-down luminosity in 2010 (Abdo et al. 2011).

→ Spectrum of flare emission is consistent with the synchrotron emission from monoenergetic electrons cooled by the synchrotron energy loss. The synchrotron cooling leads to the formation of a $dN_e/dE \propto E^{-2}$ low energy tail, leading to the observed $dN_\gamma/dE \propto E^{-1.5}$ X-ray spectrum.

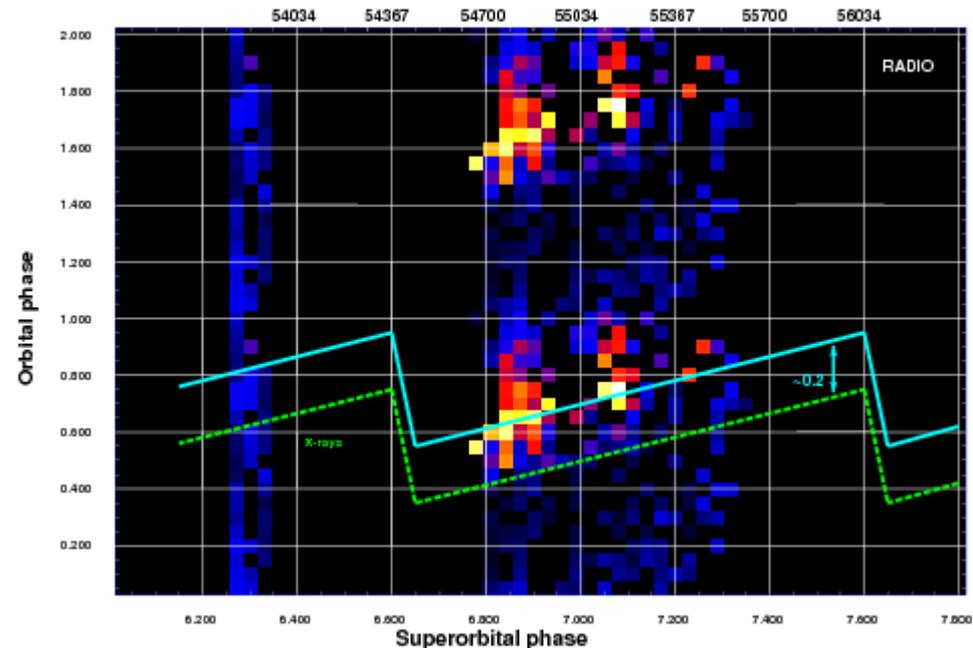
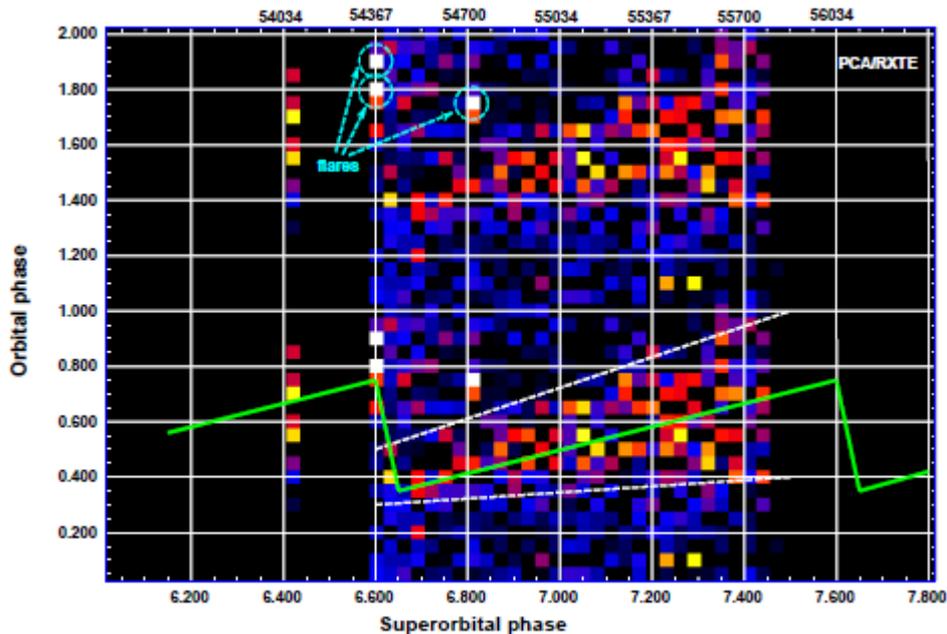
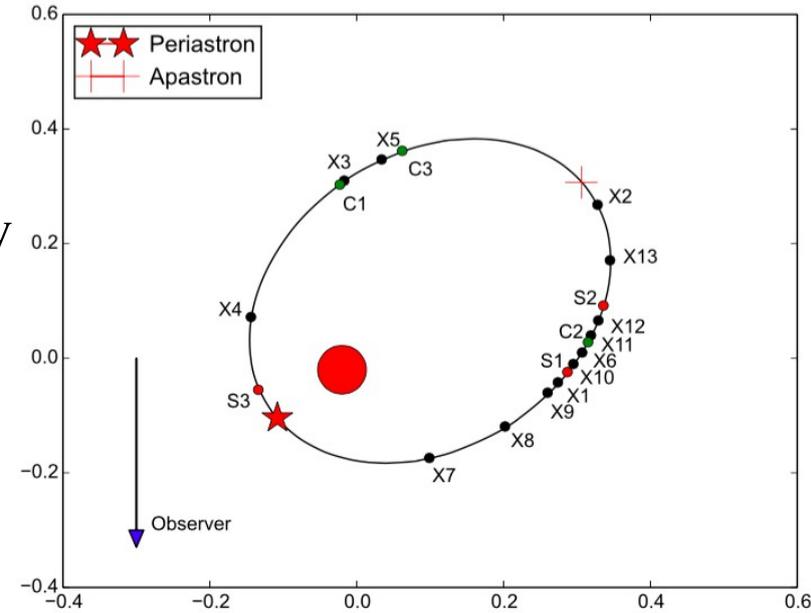
→ The persistent spectral component is consistent with $dN_e/dE \propto E^{-2}$, with an observed spectral softening in X-rays to GeV spectrum by $\Delta\Gamma \cong 1$ due to synchrotron cooling.

→ 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 +61° 303



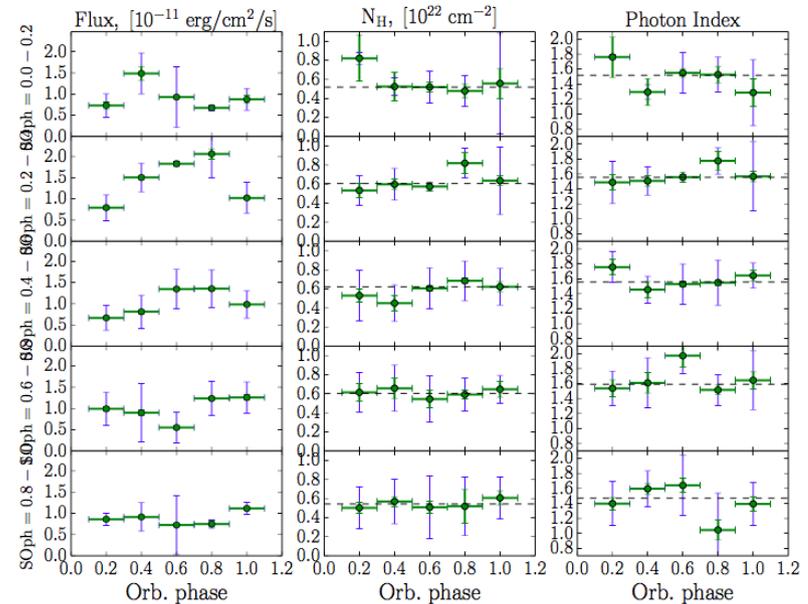
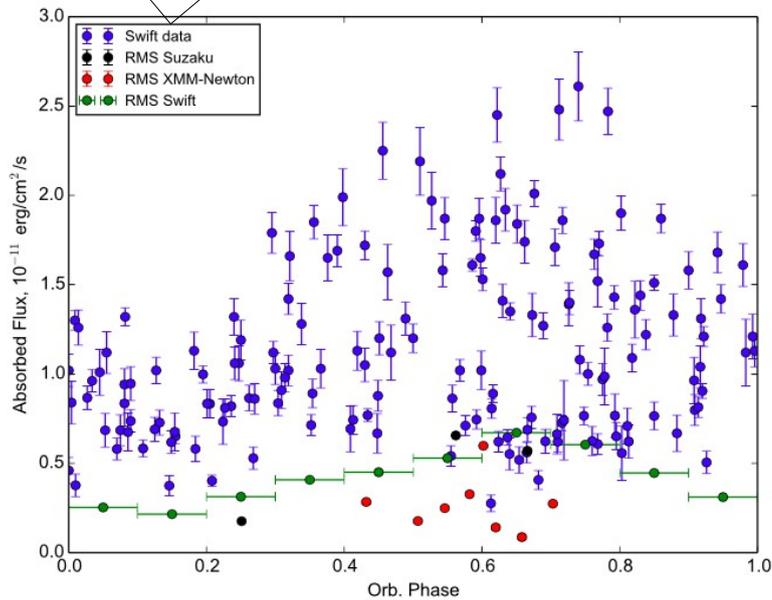
- 26.5-day orbital period
- In radio, X-ray and GeV -- one flare per orbit
- The orbital phase of the periodic flares drifts with a superorbital period $P=4.6$ year (Gregory 2002).
- Similar SO period in X-rays, phase of the X-ray activity period always precedes the phase of the radio outburst by ~ 5.3 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).
- Alternatively SO can be due to the jet precession. (Massi et al. 2014).



DCU Spectral variability on orb and SO scales



Preliminary!

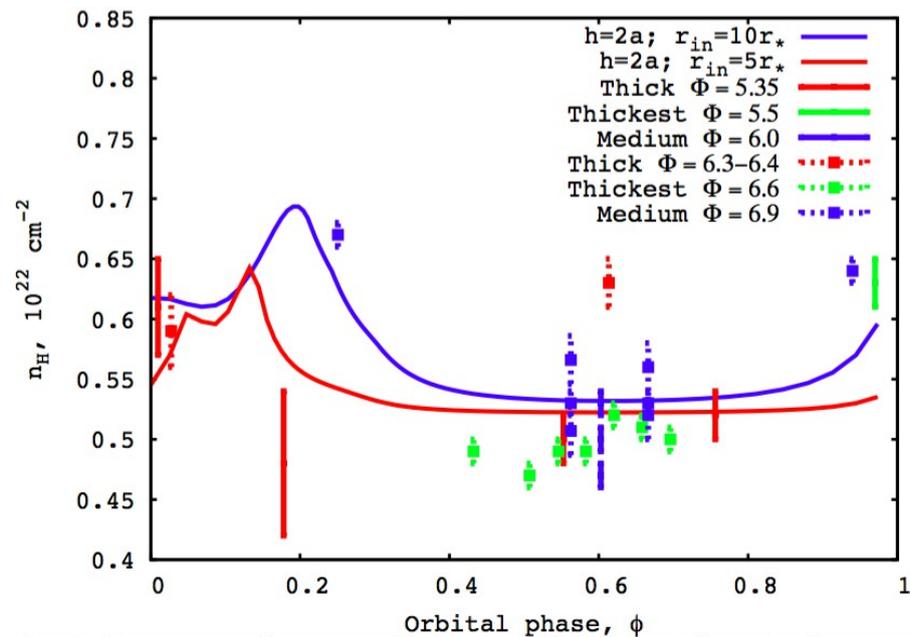
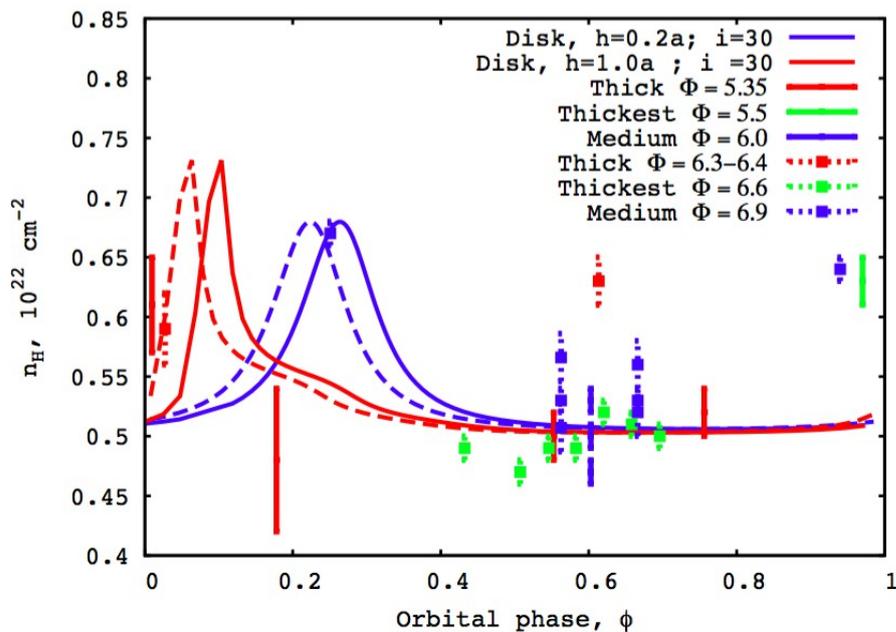
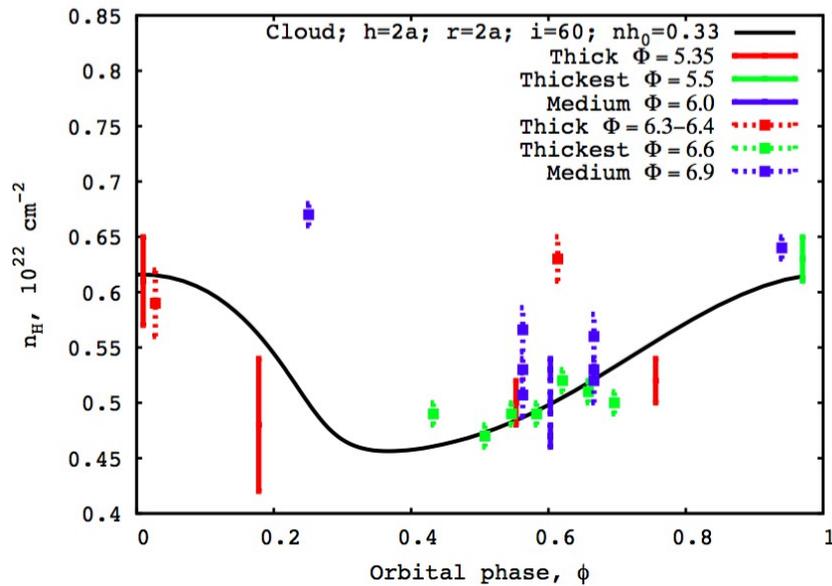


In agreement with RXTE data (Hadasch et al., 2015) flux modulation as observed with SWIFT is much stronger around apastron.

Reconstruction of the disk parameters

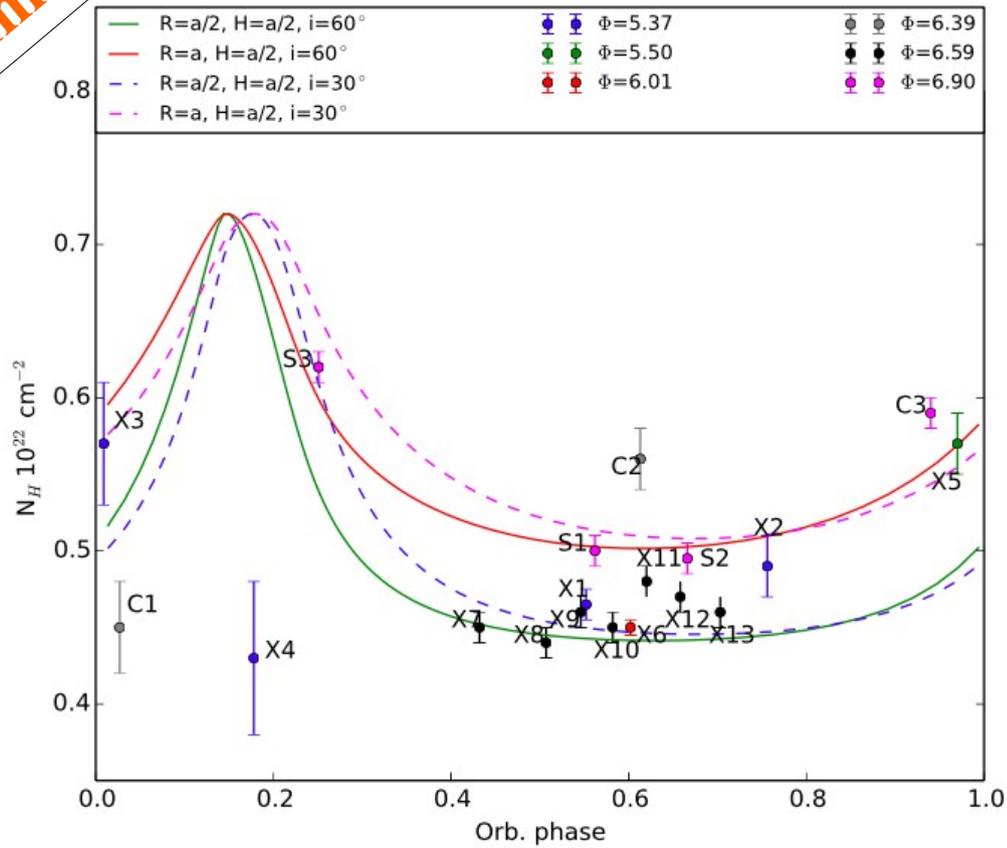


Preliminary!

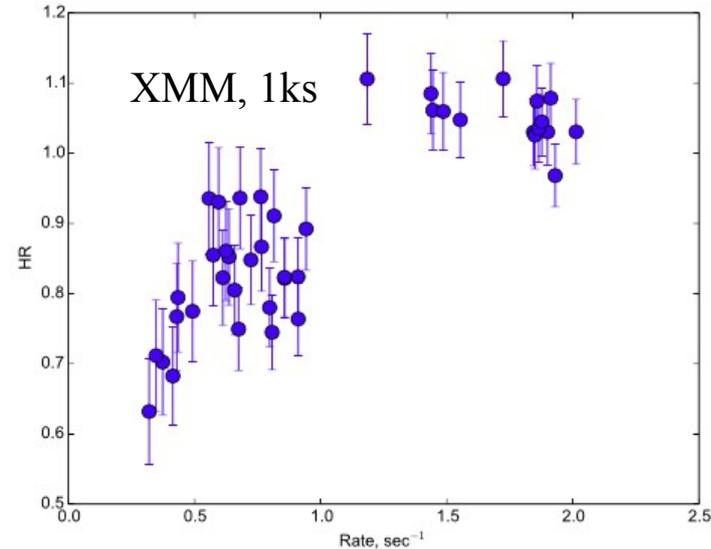
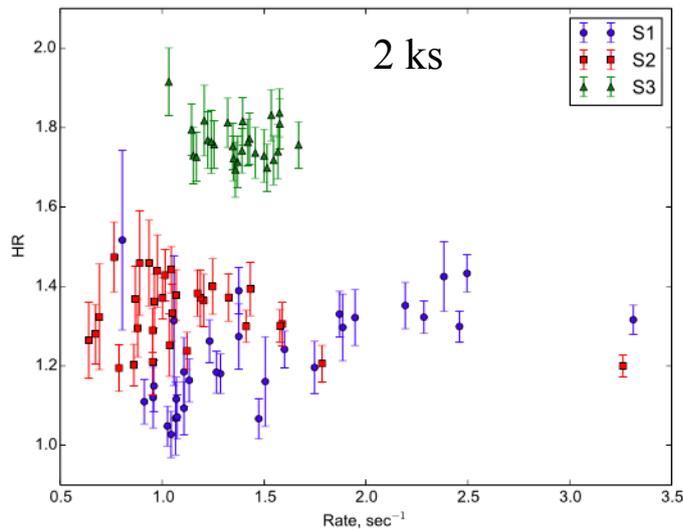
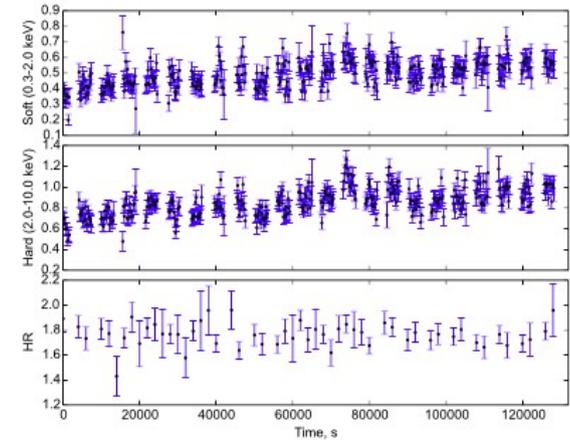
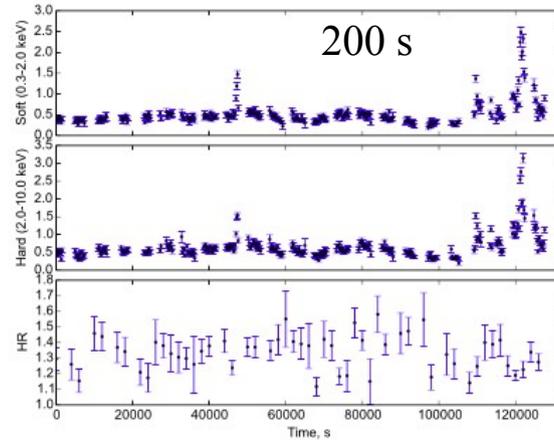
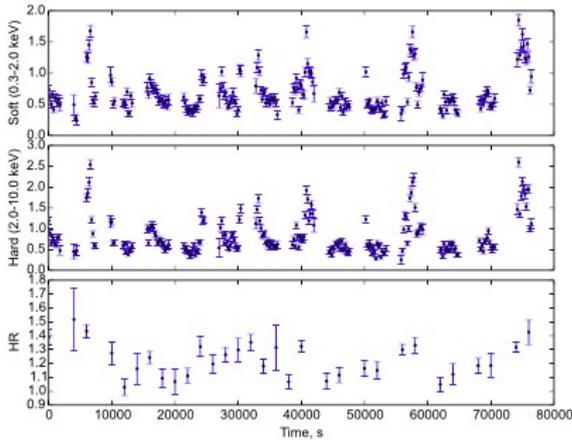


N_H Variability

Preliminary!

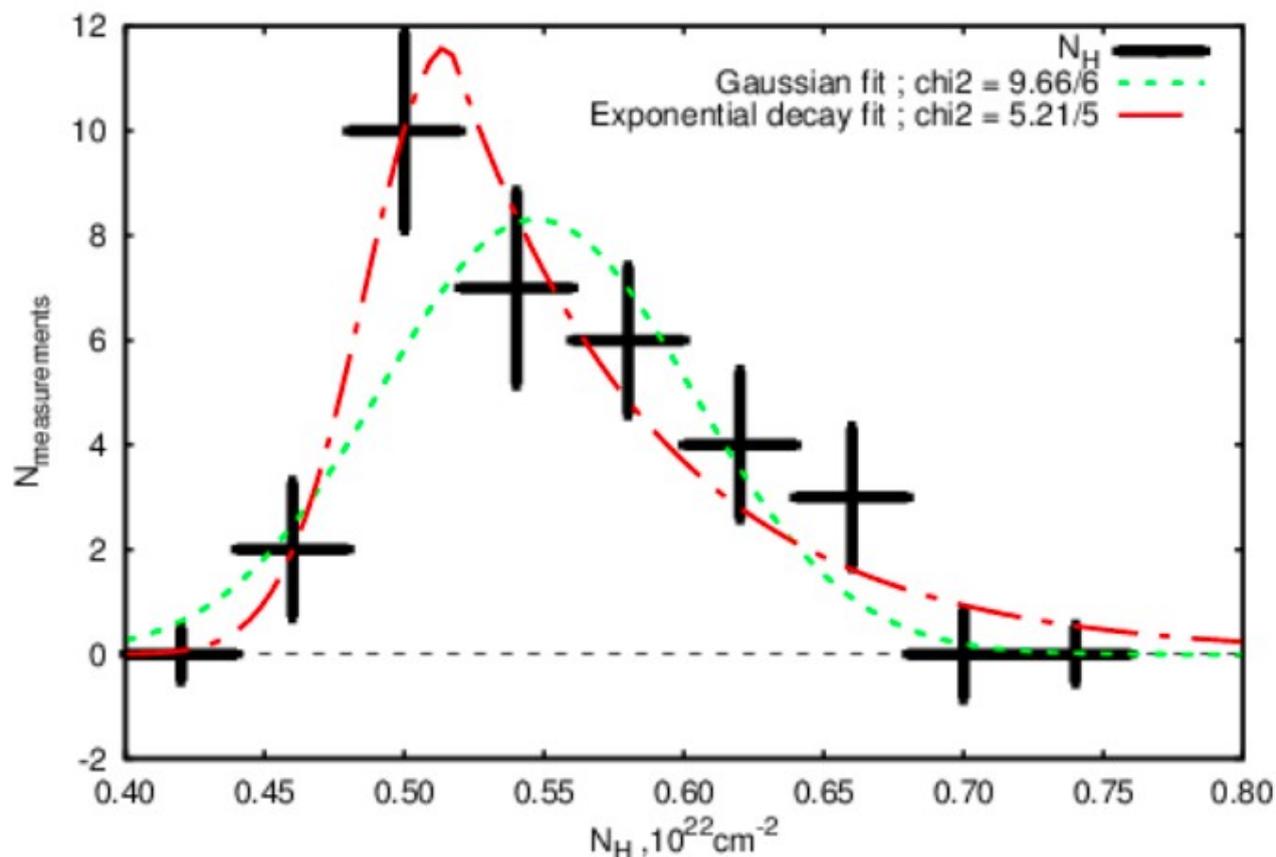


DCU Variability within a single observation



$HR = F(2.0-10.0 \text{ keV}) / F(0.3-2.0 \text{ keV})$. 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.

Presence of the clumps



Alternatively, the observed distribution of N_{H} can originate from the constant N_{H} level modified by the presence of the dense clumps. The observed deviation from the gaussian fit could be either due to the un-accounted systematic errors in N_{H} measurements, due to the time variability of the clumps density, or presence in the disk clumps with a certain distribution of densities. More data are needed to distinguish between these hypothesis.

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 H α 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 stronger around apastron.
- Orbital variability of N_{H} can be used to study properties of the Be star disk.