Multi-wavelength studies of gamma-ray binaries

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–----------- Variable Galactic Gamma-Ray Sources (IV) –-----------

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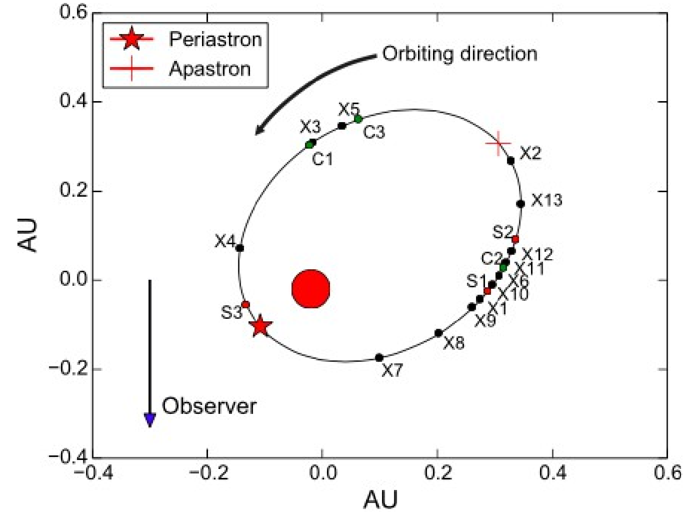
LS I 61º 303

Emission from LSI +61° 303 is modulated on timescales of ~ 26.5 d and ~ 1667 d in the radio (Gregory 2002), optical (Paredes-Fortuny et al. 2015), X-ray (Chernyakova et al. 2012, Li, Torres & Zhang 2014) and VHE (Jaron & Massi 2014) domains. The superorbital variability could be either due to the cyclic change of the Be star disk size (e.g. Chernyakova et al. 2012, Paredes-Fortuny et al. 2015), or precession of a jet associated with the compact object (Massi & Torricelli-Ciamponi 2014).



+ 164 SWIFT observations between 2010 and 2014.

If the superorbital variability in the system is linked with the disk build-up process one can expect the gradual increase of the absorption, as the compact object moves on its orbit. We have systematically reviewed all publicly available data from Suzaku, XMM-Newton, Chandra and Swift observatories in order to

- measure the absorption profile of the circumstellar Be disk as a function of orbital and superorbital phases
- study short-term variability of the system as a function of orbital and superorbital phases
- test the stability of the superorbital period.

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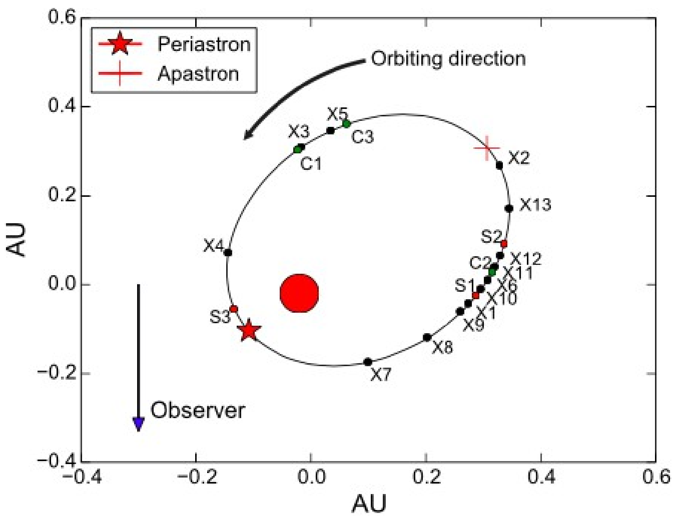
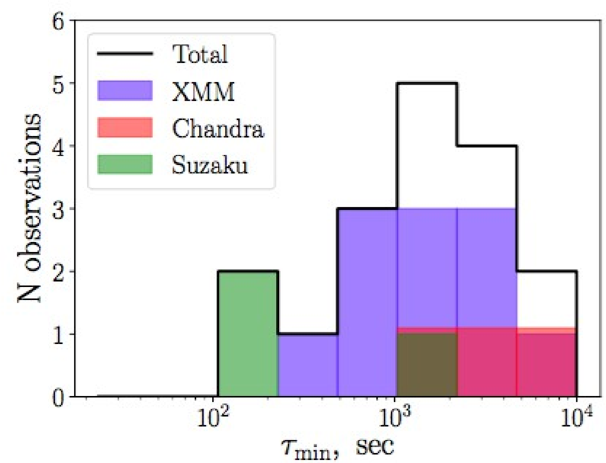
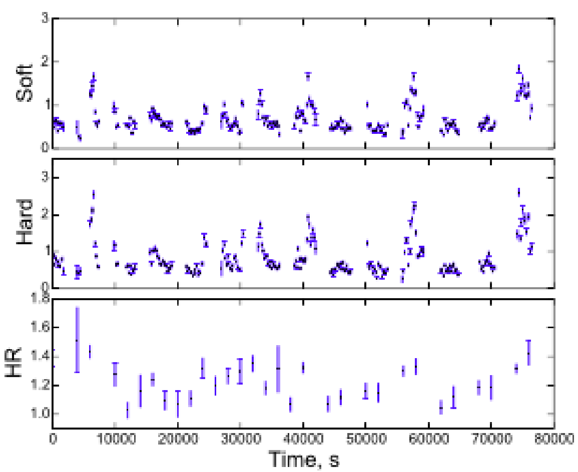
The typical value of τ_{min} lies in the range ~ 100 − 1000 s. Short time scale variability is more evident at the edge of the disk rather than in the center (see also talk of D. Hadasch 2015 at 3^{rd} VGGRS workshop).



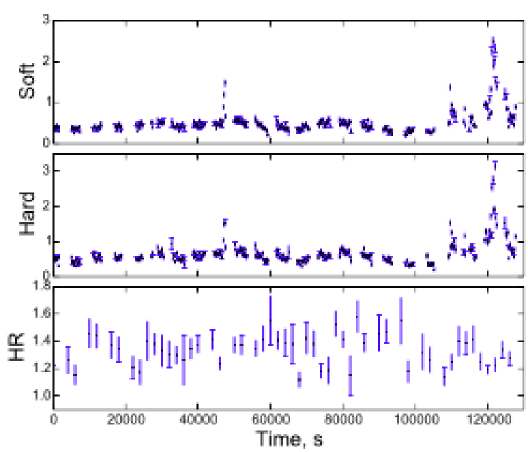


Chernyakova et al. 2017

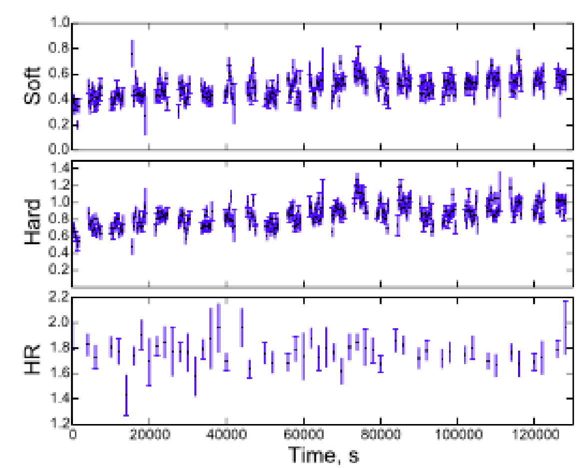
S1



S2



S3



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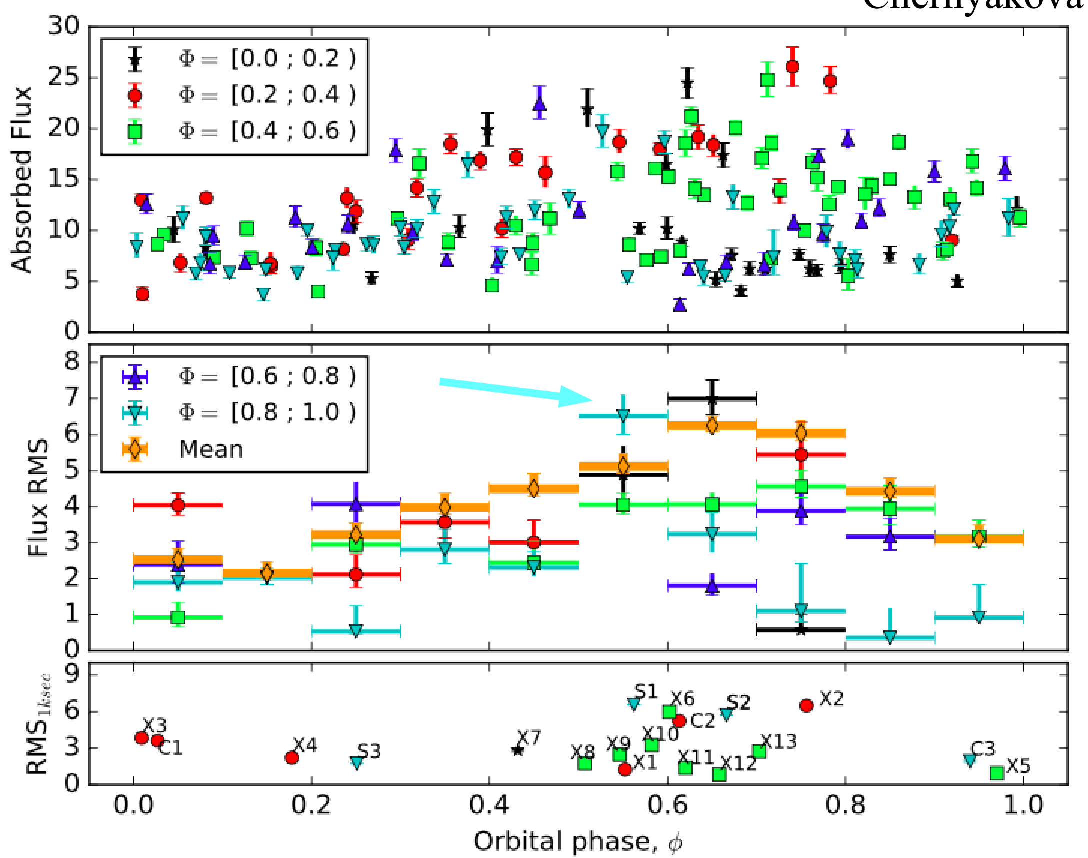

Shift of the max RMS $\varphi = 0.55$ [$\Phi = 0.8-1$] → $\varphi = 0.65$ [$\Phi = 0.0-0.2$] → $\varphi = 0.75$ [$\Phi = 0.2-0.4$] due to a gradual increase of the disk size at superorbital time scales. No shift if the compact object spend the whole orbit inside the dense regions of the near-to-maximum size disk [Φ=0.4 – 0.8] .

Averaged over superorbital phase RMS also indicates that close to periastron the compact object is embedded into the smooth dense region of the Be star disk (most stable with respect to superorbital changes), while closer to the apastron the compact object moves in clumpy outskirts of the disk.

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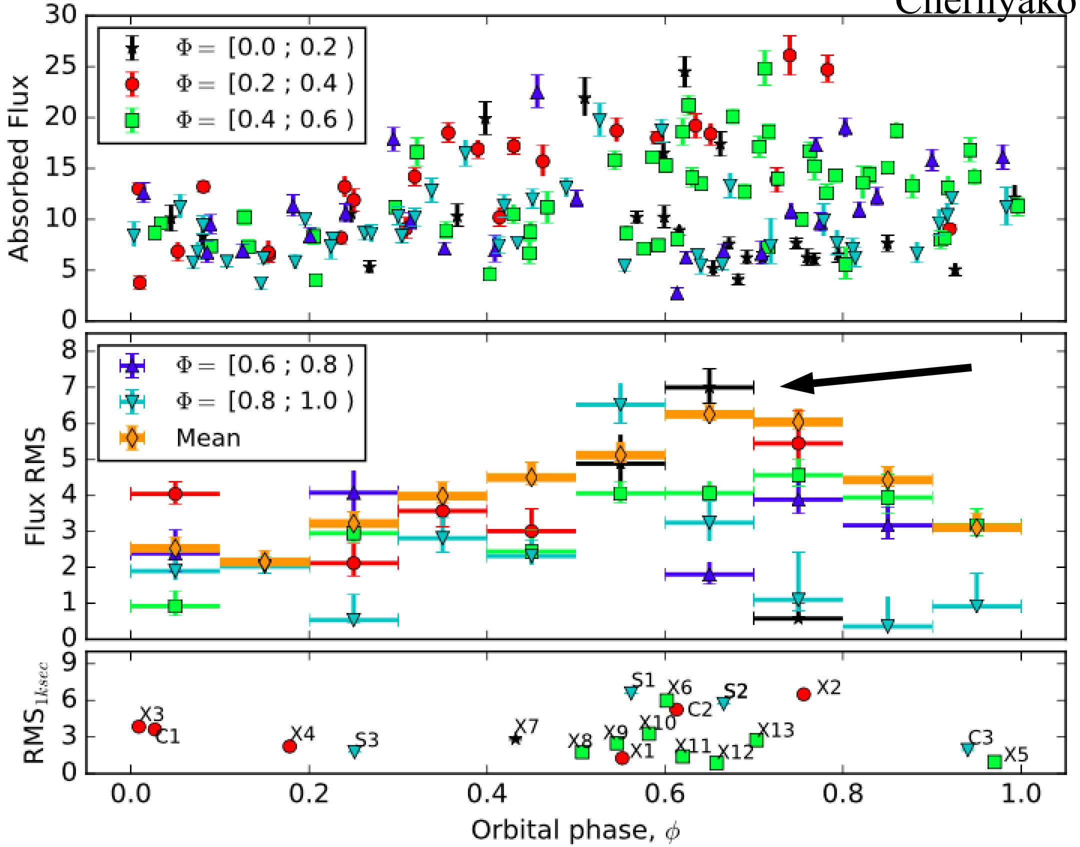

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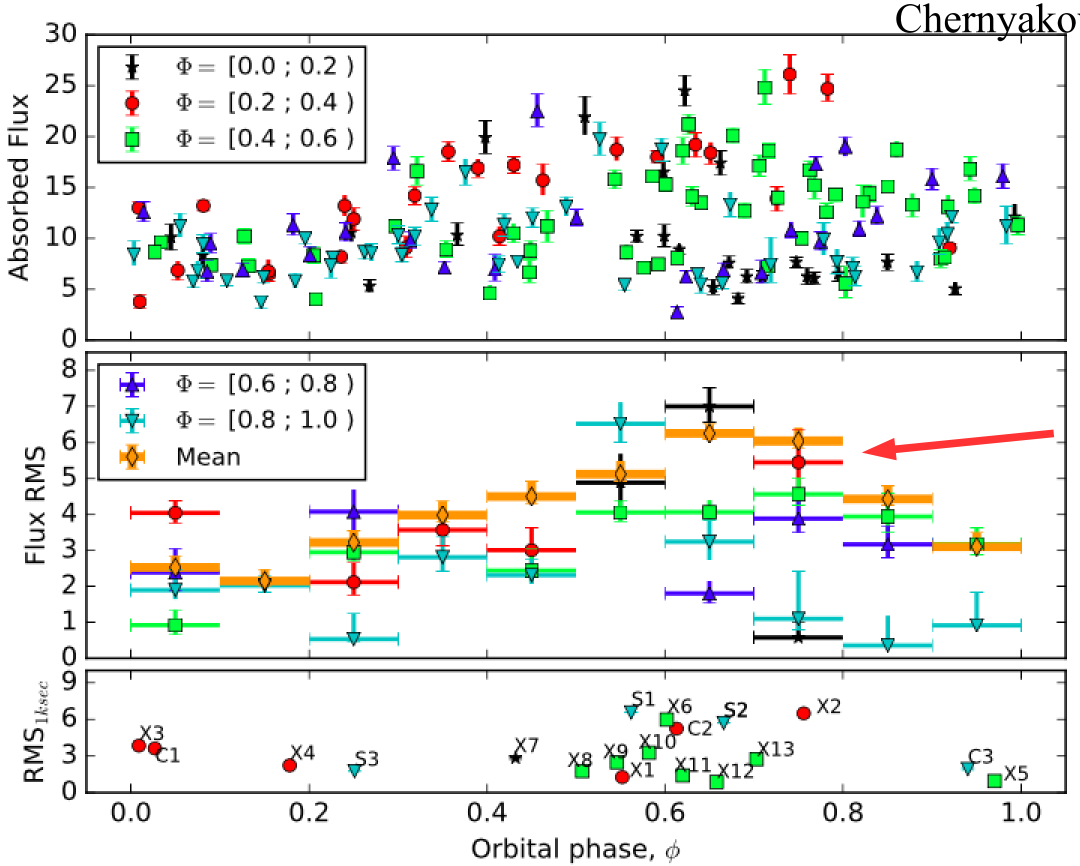

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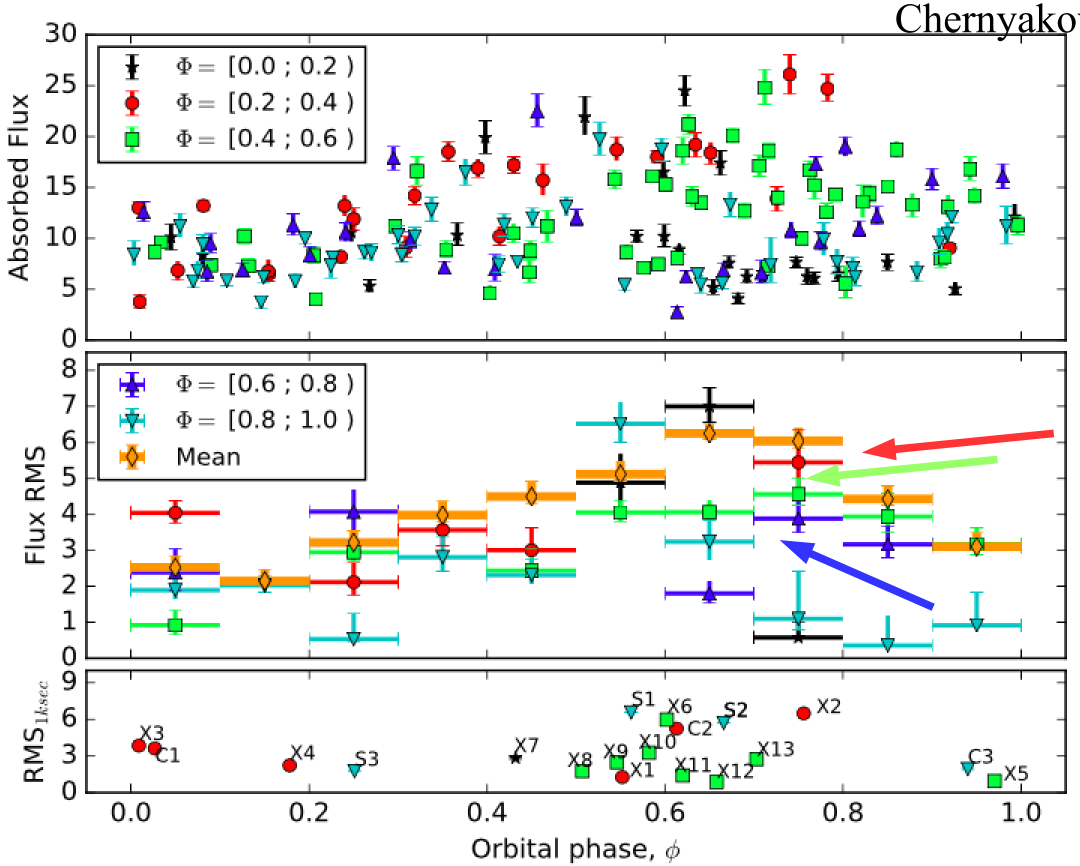

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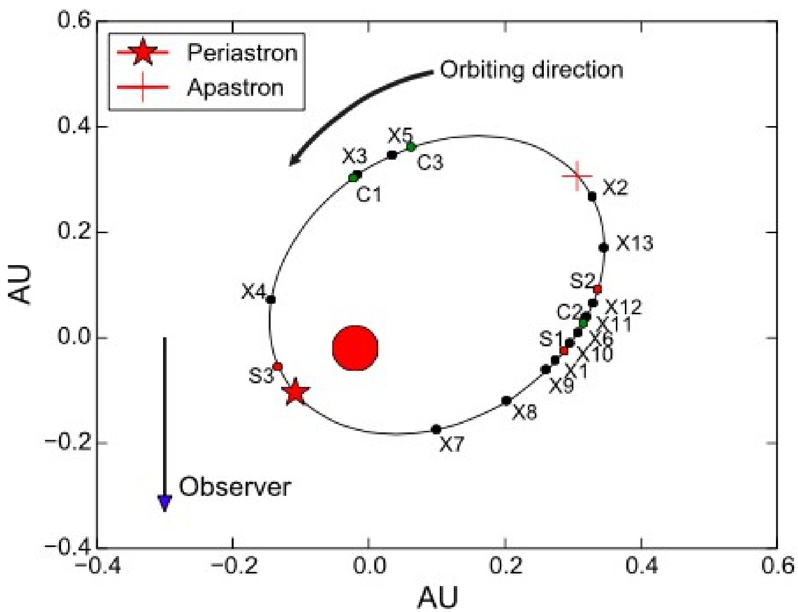

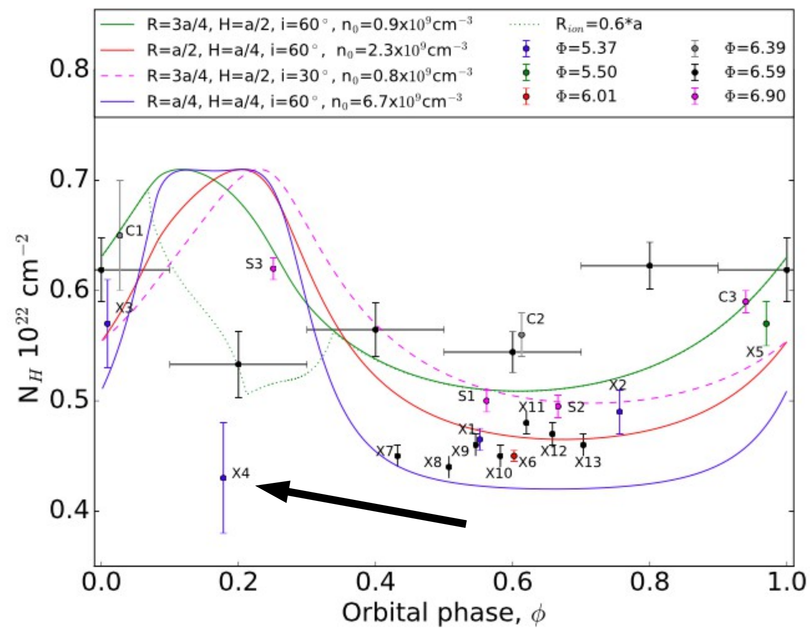

- Variability of N_H is another tool to study the geometry and structure of the disk.
- The value of N_H is clearly non-constant along the orbit at a 19.6 σ level.
- Disagreement of the simple model with observations can be due to the ionization of the central region of the disk.

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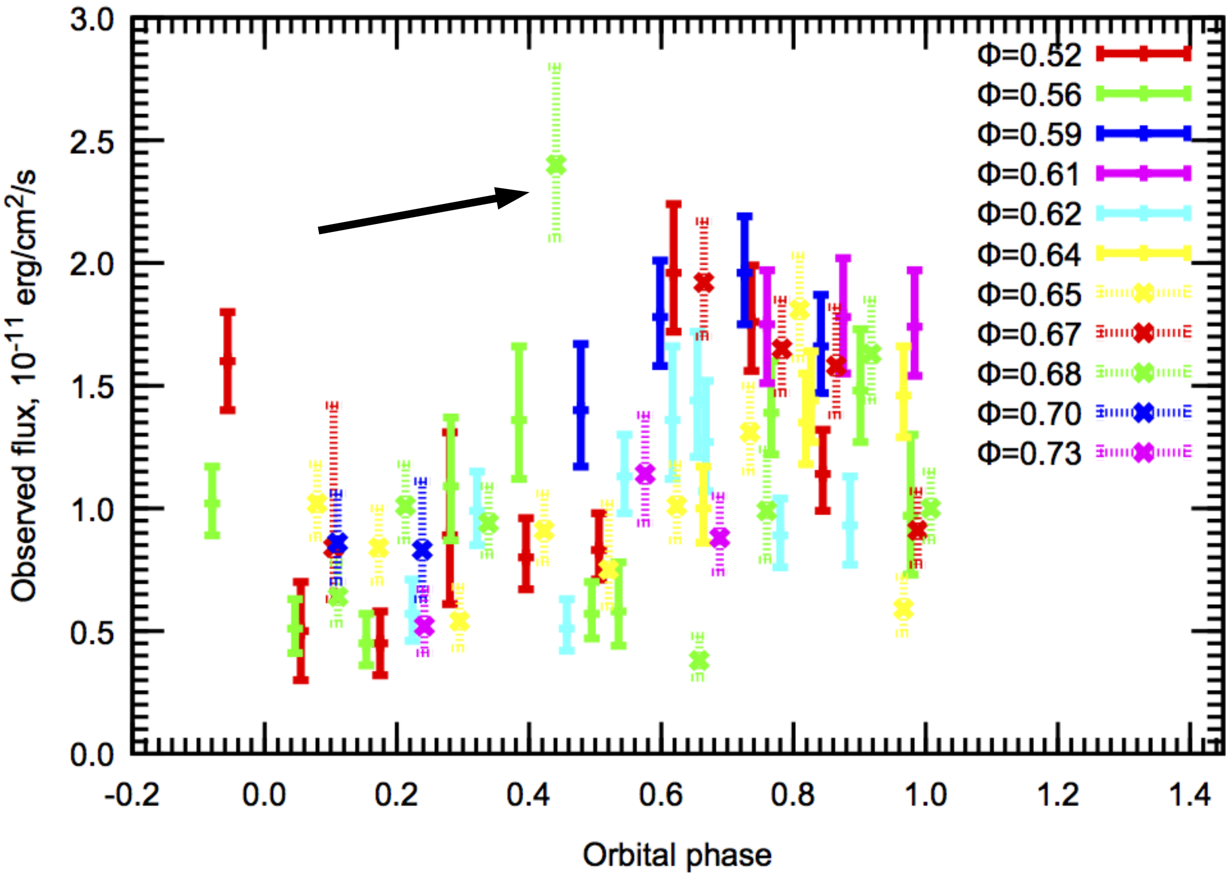
Φ=0.52
Φ=0.56
Φ=0.59
Φ=0.61
Φ=0.62
Φ=0.64
Φ=0.65
Φ=0.67
Φ=0.68
Φ=0.70
Φ=0.73
Observed flux, 10^-11 erg/cm^2/s
Orbital phase
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

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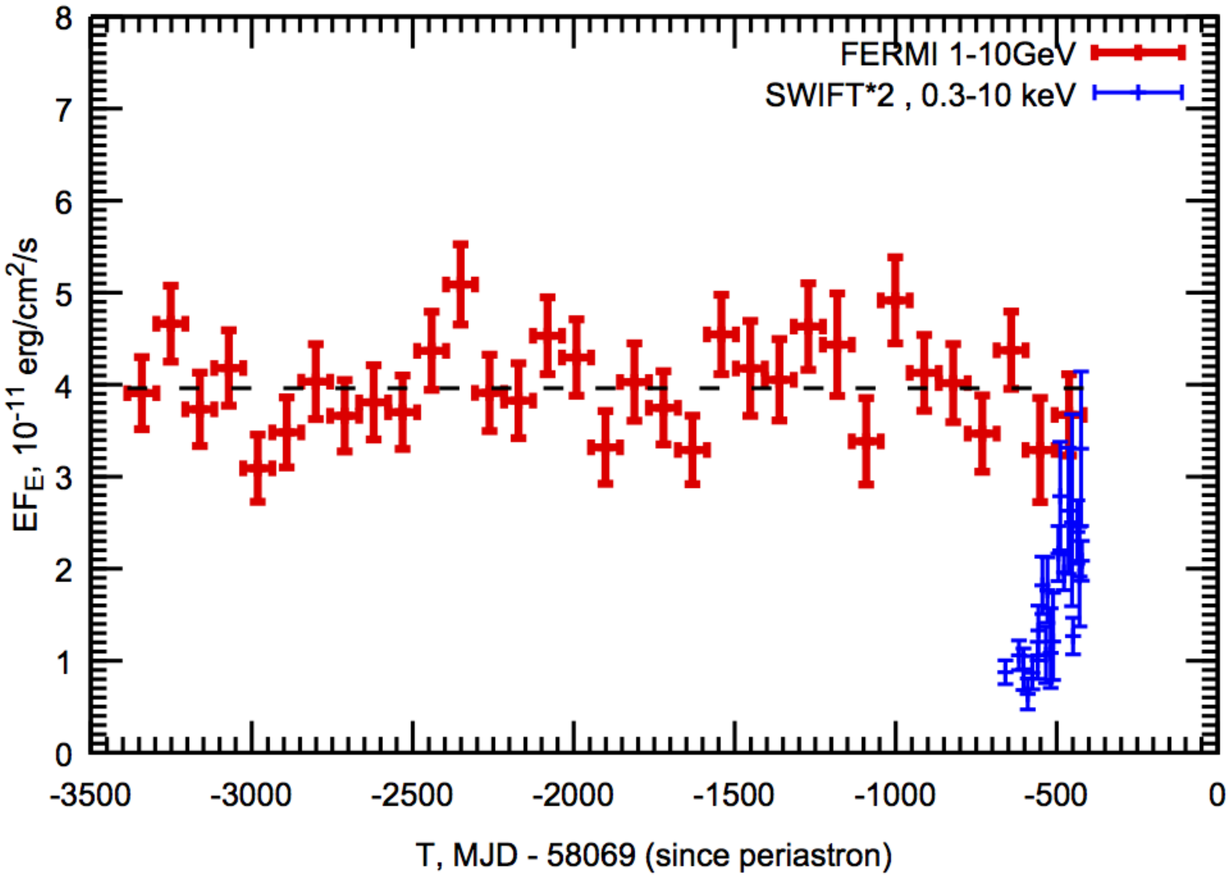
New observations disagree with P_{so} = 1667 ± 8 days orbital period of Gregory 2002.

New analyses of a longer radio data set by Massi et al. 2016 give different value with larger errors P_{so} = 1628 ± 48 , FERMI data analyses gives P_{so} = 1610 ± 58 (Ahnen et al. 2016)

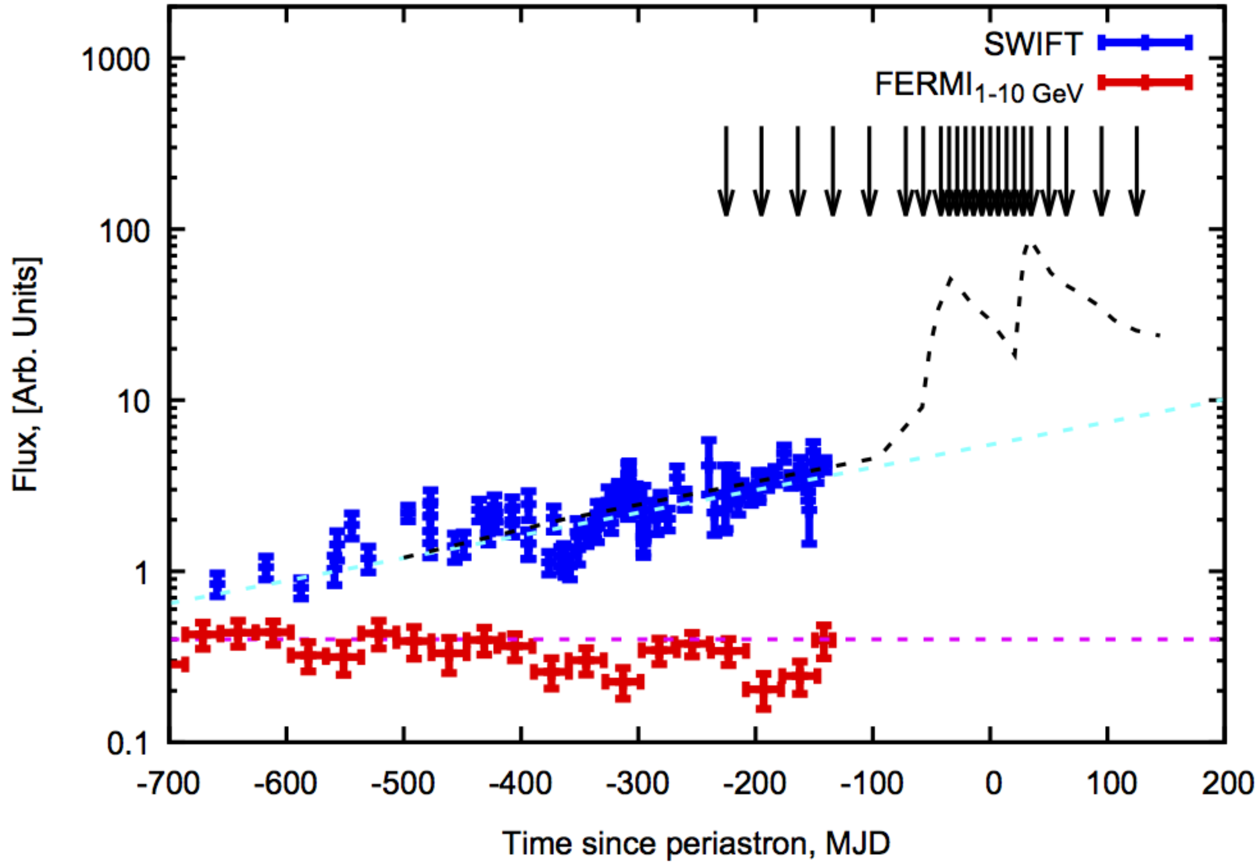
Evidence of variability of this period?

PSR J2032+4127 / MT91 213



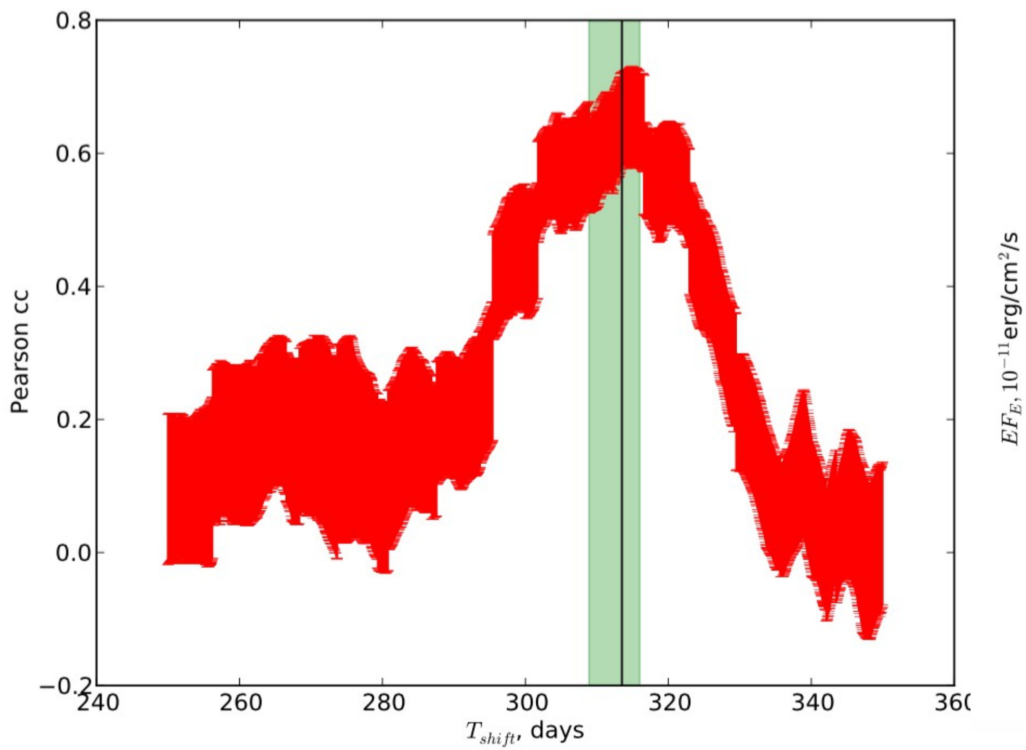
Young 143 ms pulsar, first discovered by the Fermi (Abdo et al. 2009). Radio observations (Lyne et al. 2015) demonstrated an extraordinary two-fold increase in the spin-down rate, indicating that the pulsar is rotating around the 15-solar-mass Be star in a very eccentric orbit. Unpulsed X-ray and TeV emission has been also detected from the system (Camilo et al. 2009). Ho et al. (2016) confirmed the binary nature and an orbital period of 45-50 years with a periastron in November 2017. Swift observations showed order of magnitude changes in the X-ray flux from the source indicating the beginning of the interactions between the pulsar and the Be star winds.

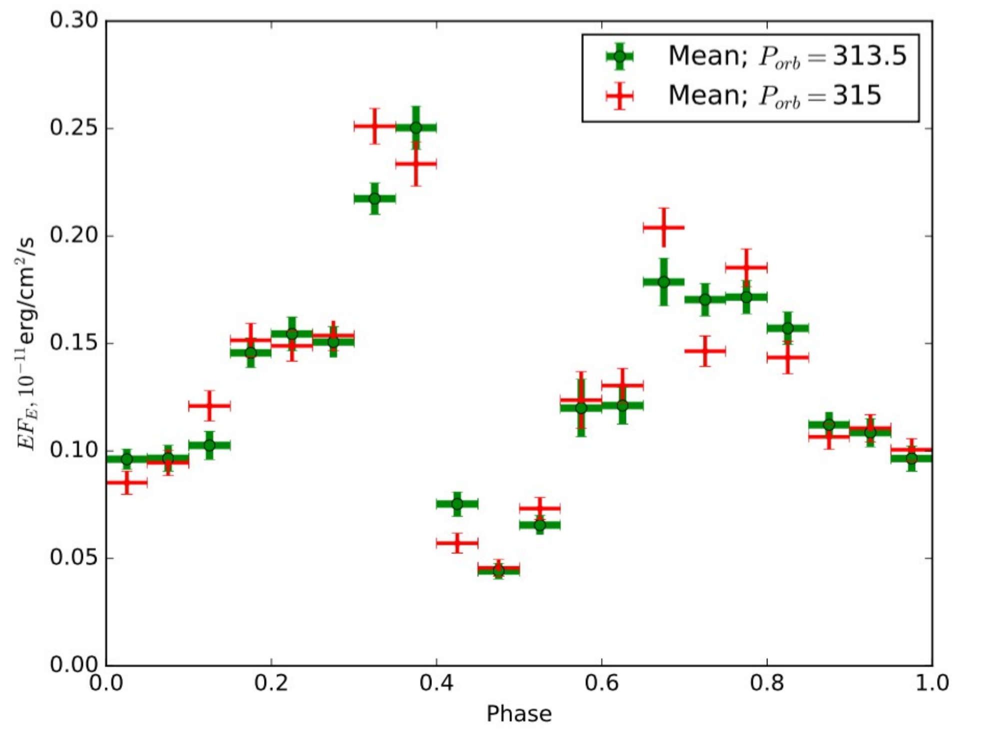
PSR J2032+4127



PSR J2032+4127 / MT91 213 is a 143 ms pulsar in a very eccentric, long orbital period binary system. The pulsar is expected to reach periastron in November 2017 with its high-mass Be star companion. In X-ray, the brightening of this source has been obvious over the last few years, and is thought to be a close analogue of the classical system PSR B1259-63. Approved SWIFT/XRT program (24 observations).

HESS J0632+057





The binary nature of HESS J0632+057 was established with the measurement of flux modulations with an initial period determination of 321 ± 5 (Bongiorno et al. 2011). Aliu et al. (2014) derived new orbital period of 315_{-4}^{+6}. With new SWIFT 2017 data taken around first X-ray peak the period become $P_{new}=313.5_{-4.6}^{+3}$. See also poster of Yuki Moritani.

On-going campaigns

LSI +61° 303 : SWIFT monitoring + Optical measurements (NOT +DIPOL-2, Hα + photometry + polarization)

PSR J2032+4127: SWIFT monitoring + Optical measurements (NOT)

PSR B1259-63: SWIFT monitoring + Optical measurements (SAAO: Hα) + radio (ATCA)

Conclusions

- Interaction of the compact source with a massive star outflow gives a chance to measure various parameters of the stellar wind (e.g. geometry, density, clumpiness).
- Multi-wavelength observations are critical to study the interaction of relativistic wind from the compact object with the stellar wind.
- Existing observations are not enough to explain the details of the physical processes taking place in these systems.
- On-going campaigns should help to answer multiple questions.