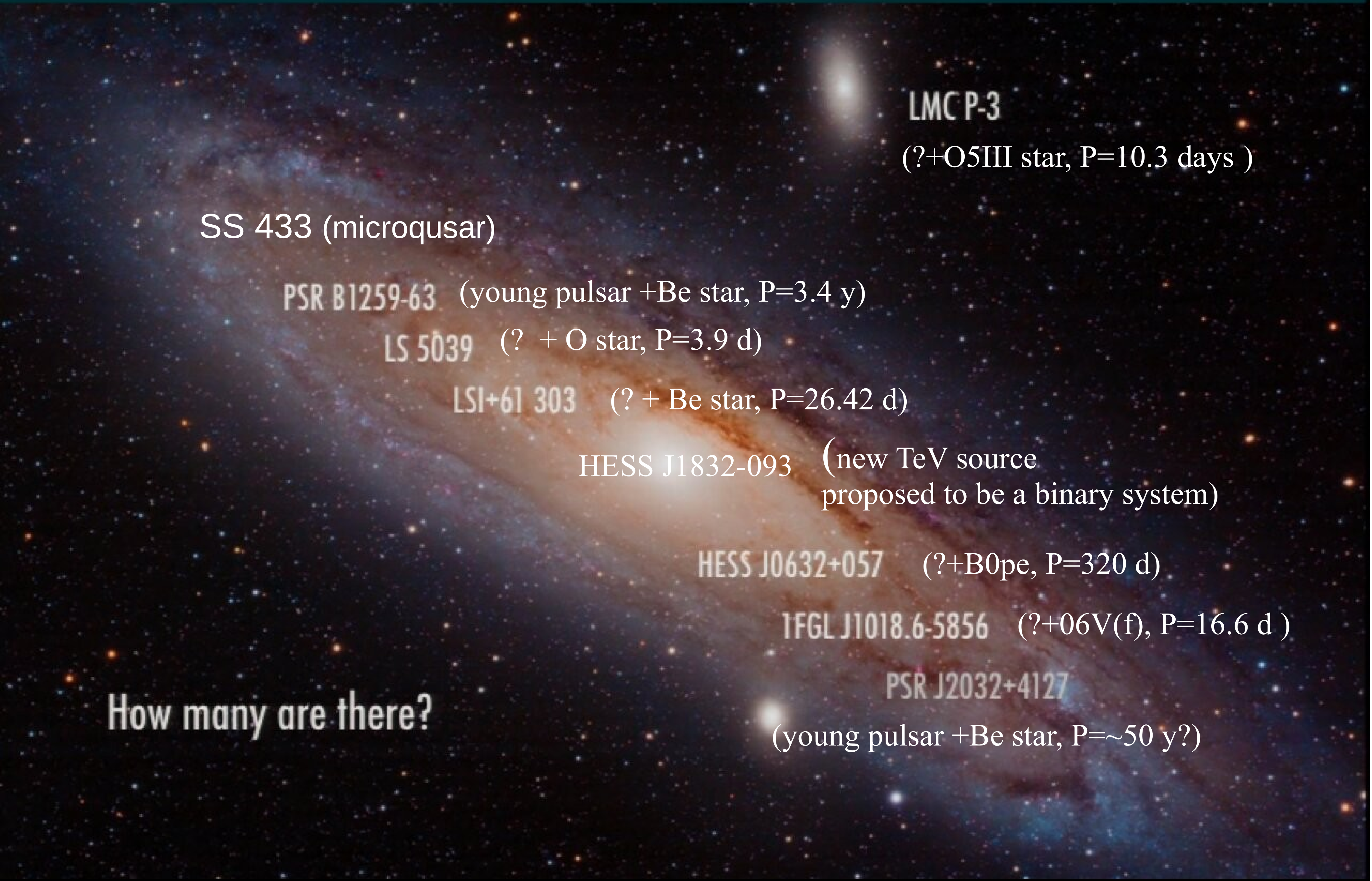
Broad band emission from gamma-ray binaries with a radio pulsar

Maria Chernyakova (DCU, DIAS)
Sam Mc Keague (DCU)
Denys Malyshev (Uni. Tuebingen)
Brian van Soelen (Uni. Free State)
Shane O'Sullivan (DCU)
Charlotte Sobey (CSIRO)

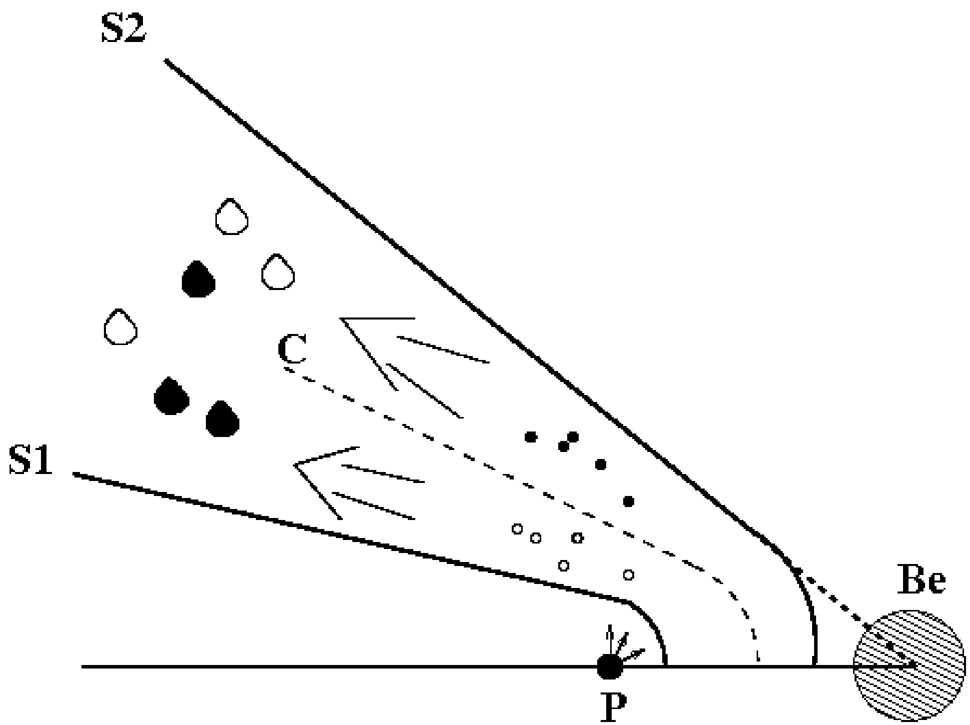
Known gamma-ray binaries

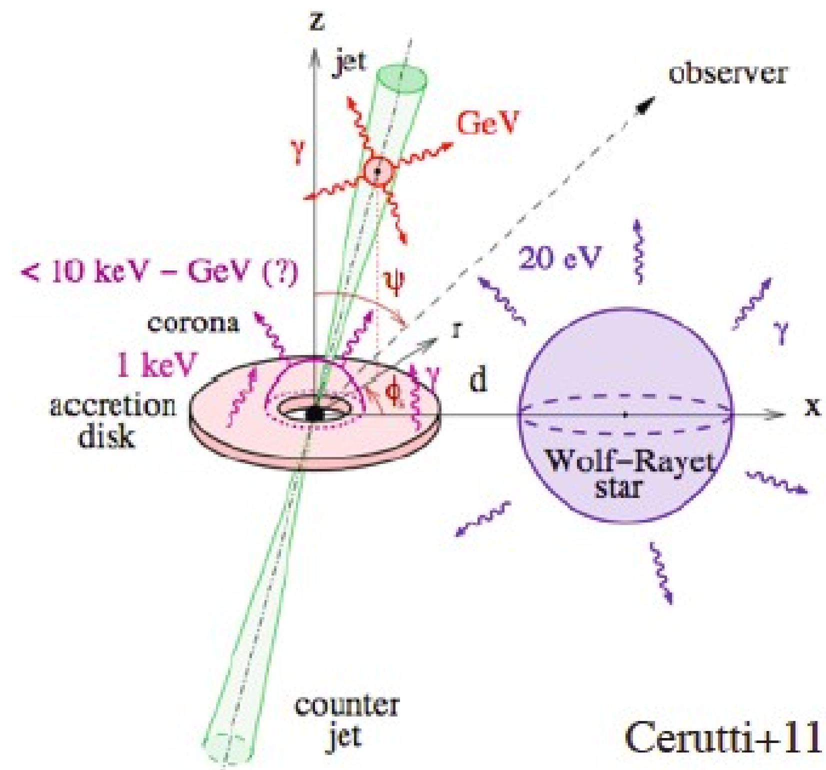


Two Theories for γ-ray Production

Colliding Winds

Microquasar



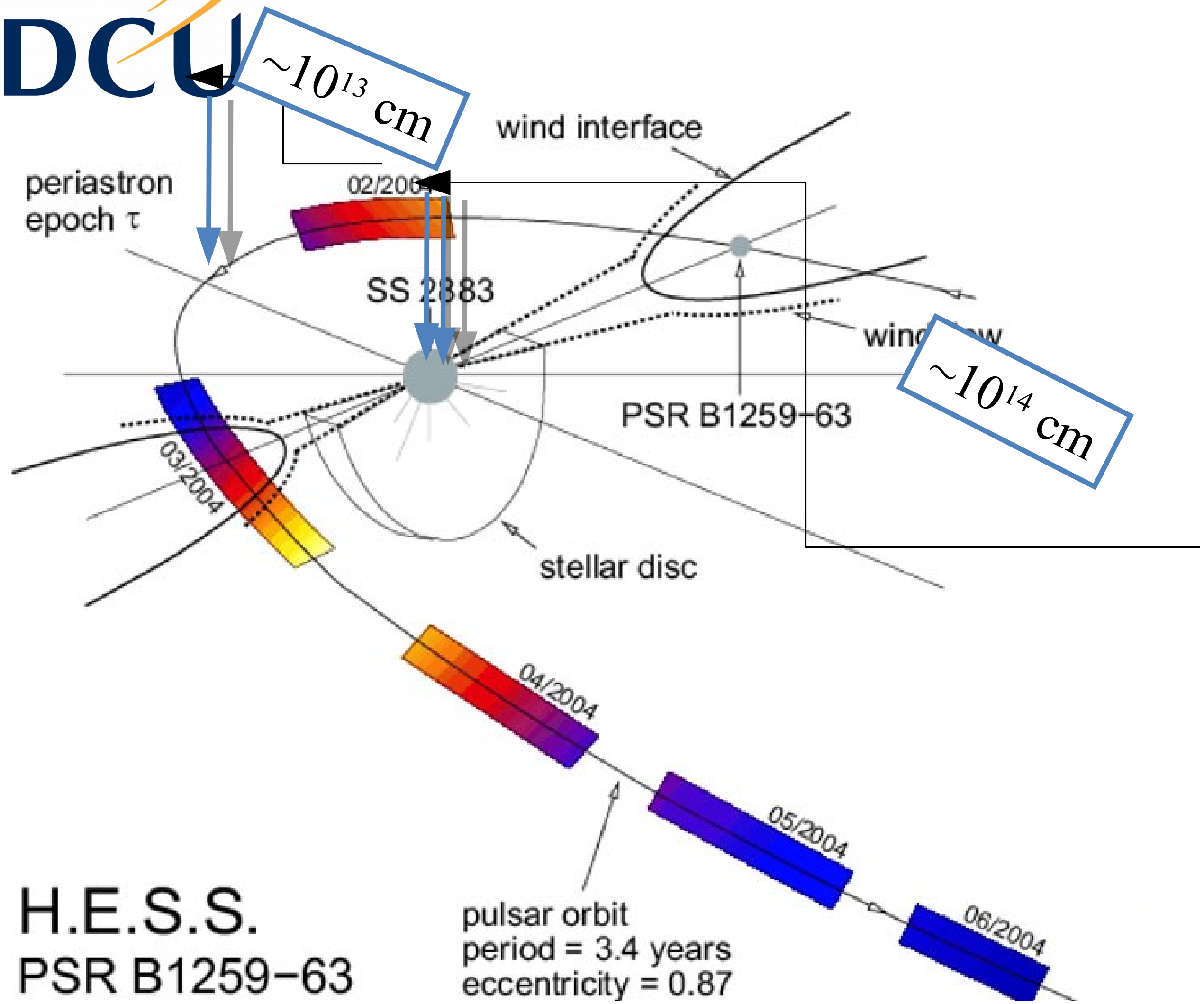


PSR B1259-63
PSR J2032+4127

LS 5039
LS I +61°303
HESS J0632+057
HESS J1832-093
1FGL 1018.6-5856
4FGL 1405.1-6119

Cygnus X-3
Cygnus X-1
SS 433

PSR B1259-63: overview



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

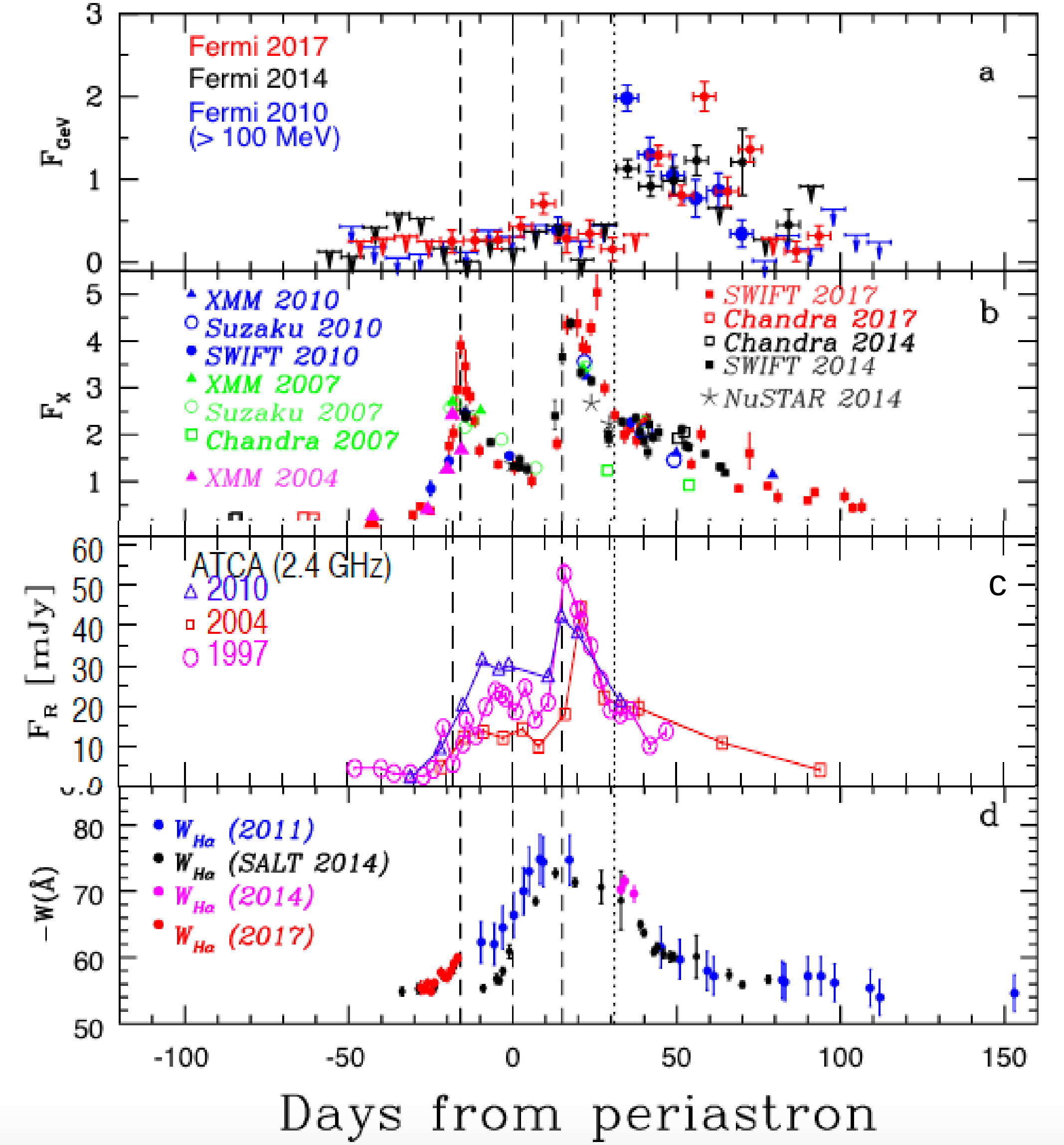
Distance 2.3 ± 0.4 kpc

LS 2883 parameters

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

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

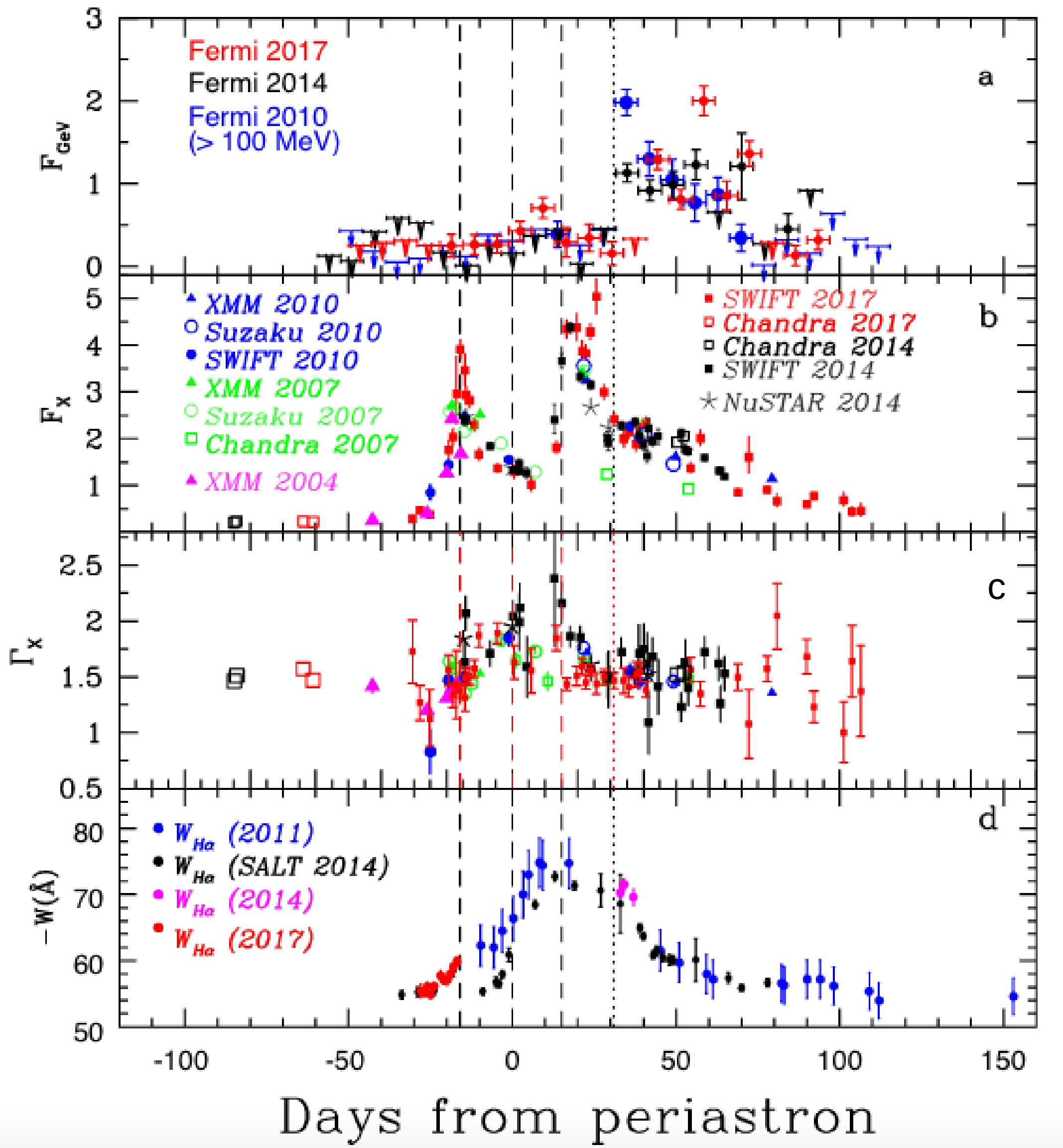
PSR B1259-63: light curves



- Two peaks at X-ray and radio ~20 days around the periastron.
- Corresponds to the passage through the Be star disk.

Chernyakova et al. 2020

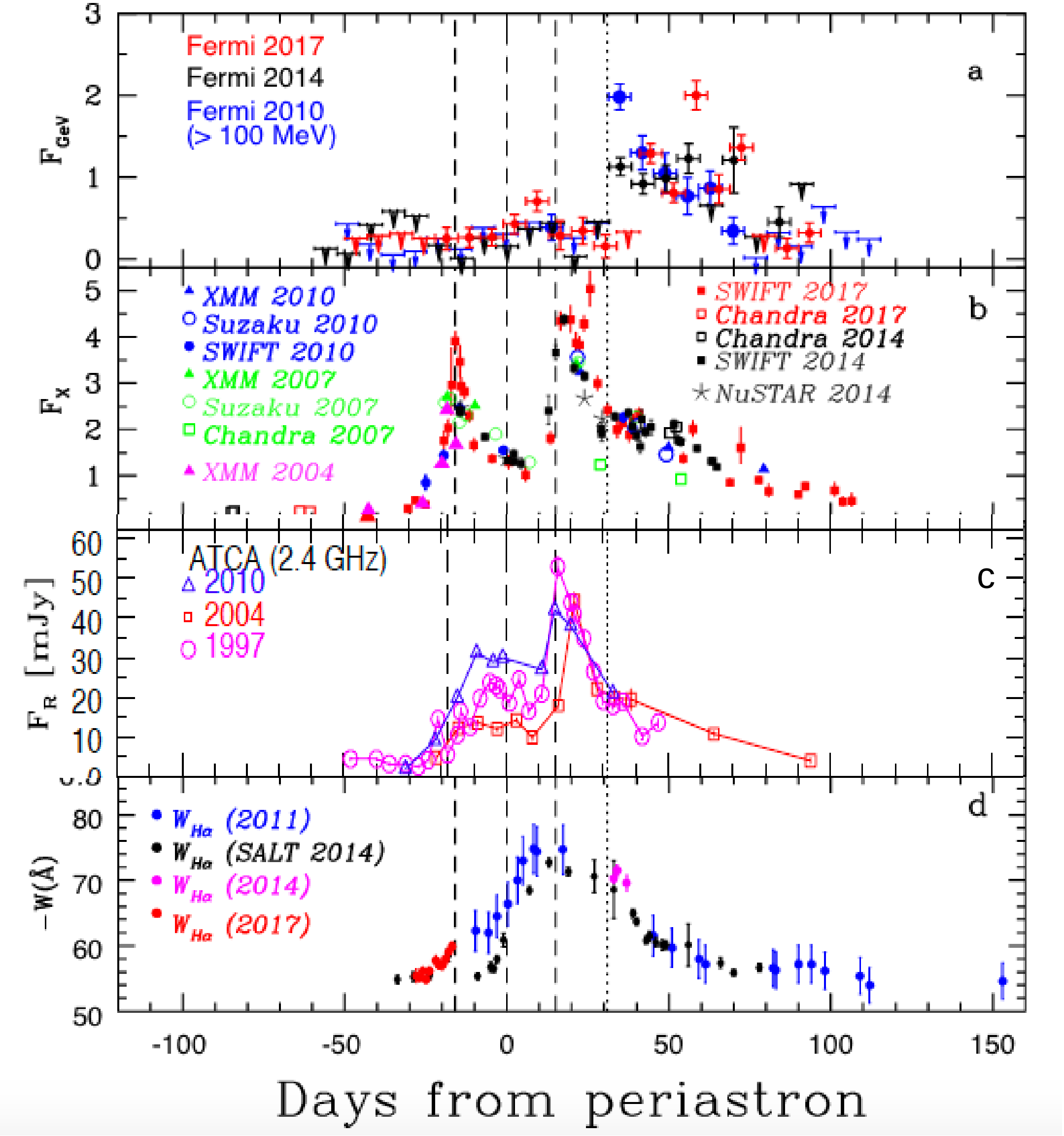
PSR B1259-63: light curves



Chernyakova et al. 2020

- Two peaks at X-ray and radio ~20 days around the periastron.
- Corresponds to the passage through the Be star disk.
- Softening of the X-ray spectra during the disk crossing.

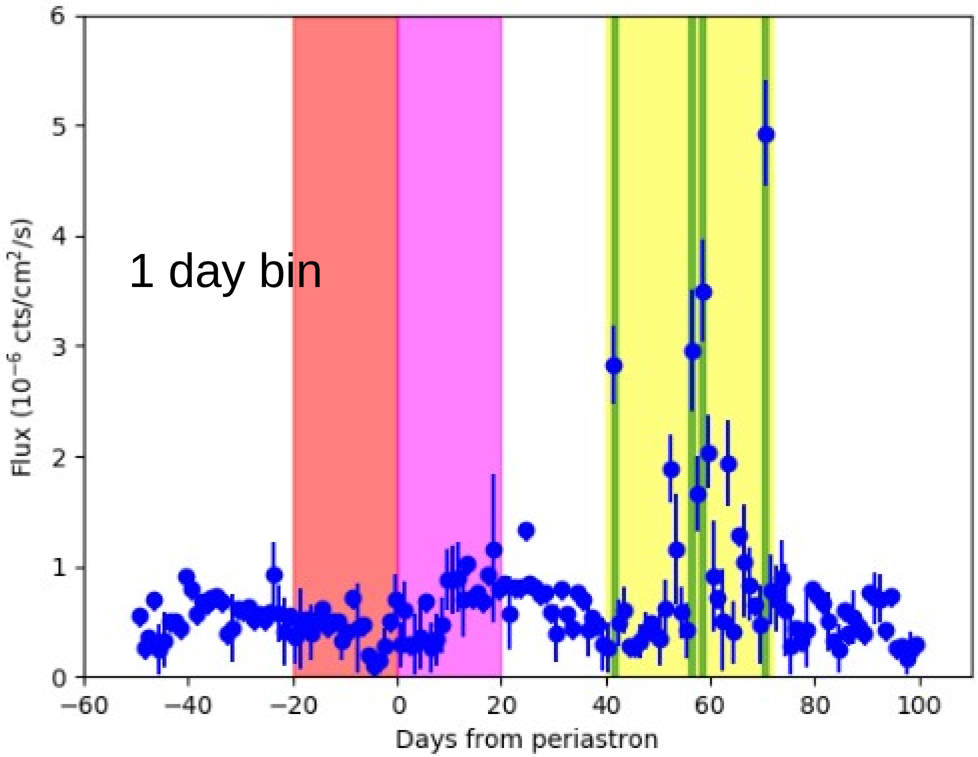
PSR B1259-63: light curves

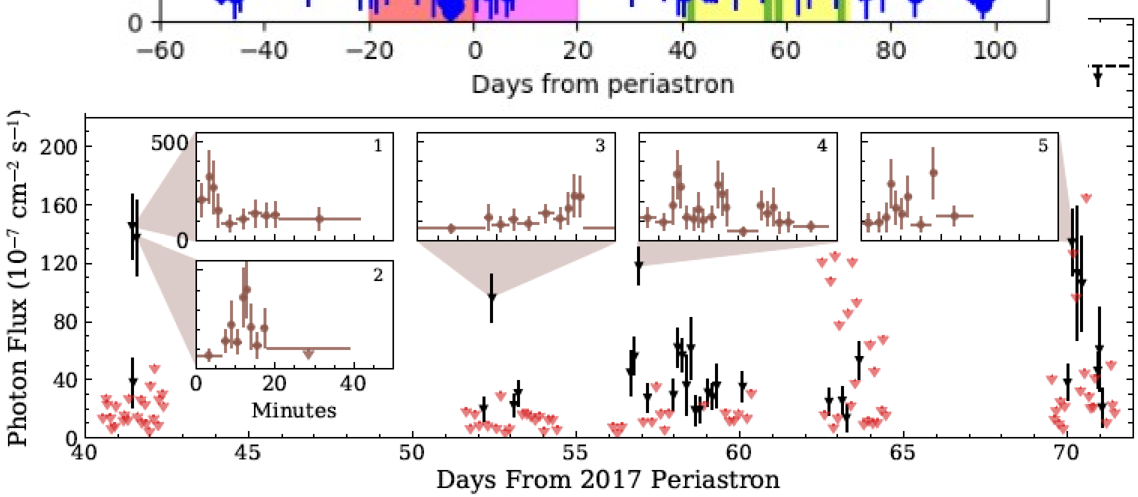


Chernyakova et al. 2020

- Two peaks at X-ray and radio ~20 days around the periastron.
- Corresponds to the passage through the Be star disk.
- Softening of the X-ray spectra during the disk crossing.
- Huge GeV flare ~30 day after the periastron.
- No obvious counterpart at other energies but optics, which shows disruption of the disk at the time of GeV flare.

PSR B1259-63: light curves 2017





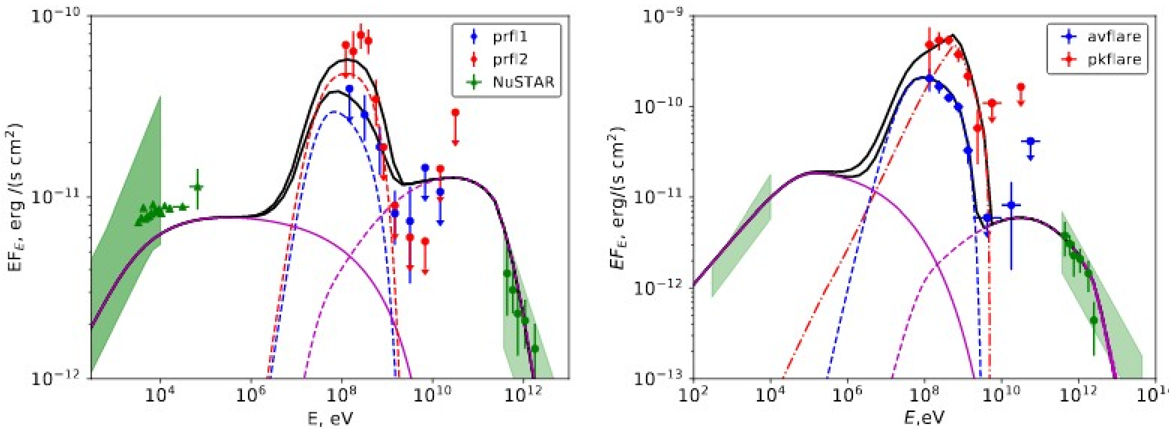
Johnson et al., 2018

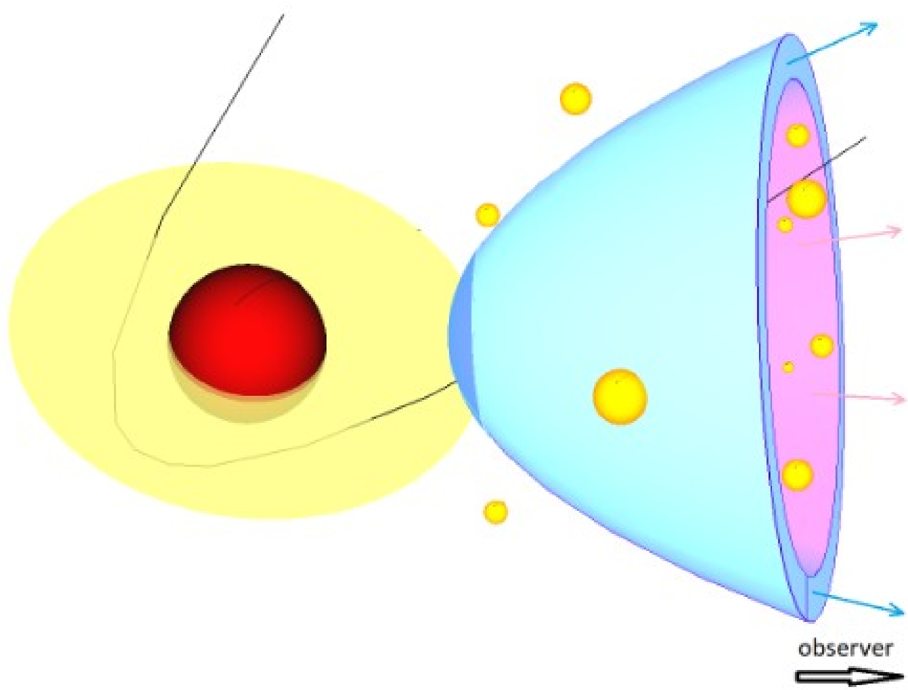
- Evidence of very fast (~15 min) gamma flares
- The isotropic gamma-ray luminosity corresponding to the short flares greatly exceeds the pulsar spin-down luminosity!

Time Scale	G (10^{-10} erg cm^{-2} s^{-1})	L_γ (10^{35} erg s^{-1})	$L_\gamma/\dot{E}$
One-week	7.3±0.6	$6.4^{+2.0}_{-1.6}$	0.8±0.2
One-day	14±2	12^{+4}_{-3}	$1.5^{+0.5}_{-0.4}$
One-orbit	70±16	61^{+18}_{-14}	$7.4^{+2.2}_{-1.7}$
Intra-orbit	280±100	244^{+74}_{-56}	$29.8^{+9.0}_{-6.8}$

NOTE—For the time scales listed during the 2017 periastron passage, this table provides the maximum energy flux (G), gamma-ray luminosity (L_γ), and luminosity as a fraction of the spin-down power $\dot{E} = 8.2 \times 10^{35}$ erg s^{-1} ($L_\gamma/\dot{E}$). For the uncertainty on L_γ, we incorporate both the energy flux and distance uncertainties.

PSR B1259-63: model

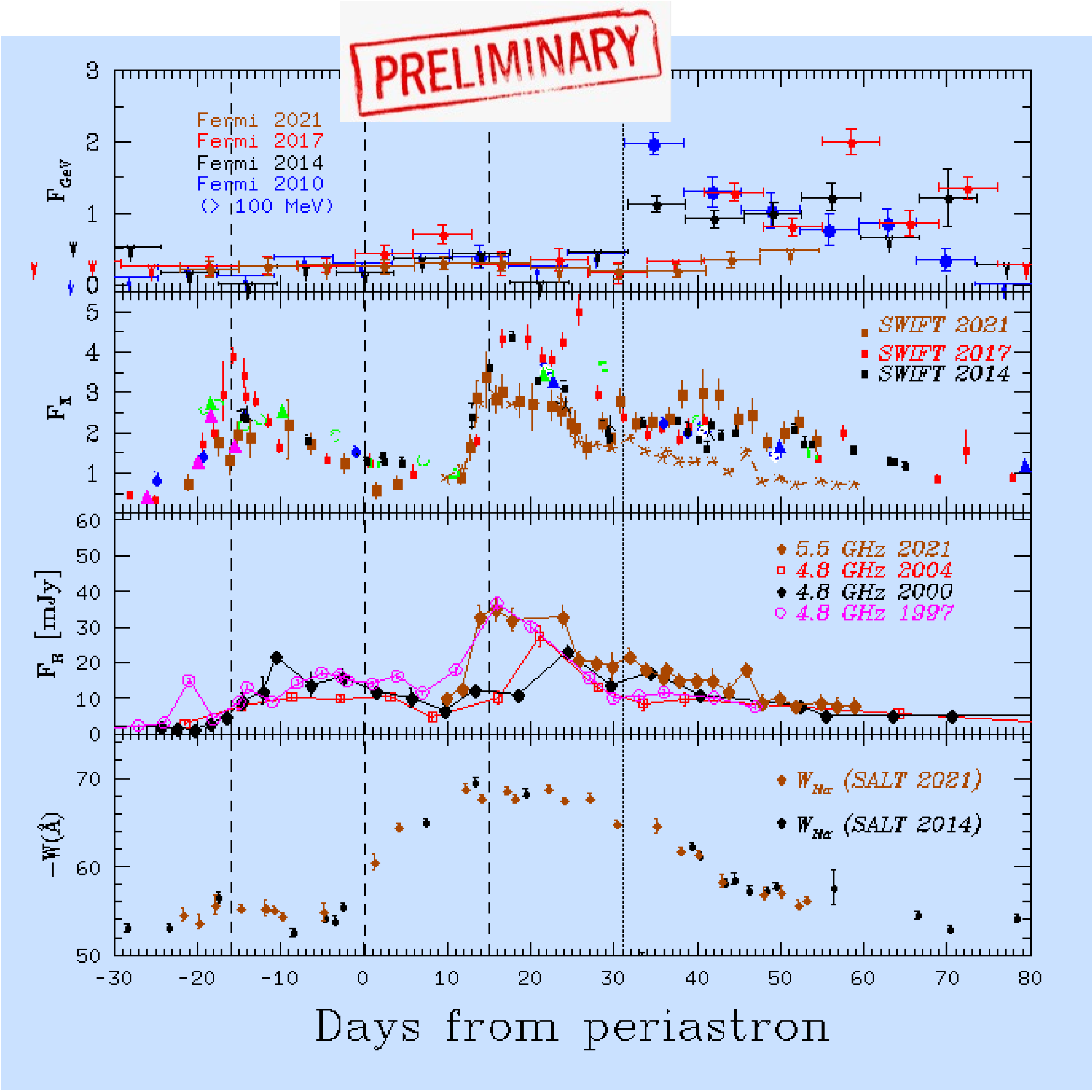




- Observed X-ray and TeV emission can be explained as a synchrotron and IC emission of the strongly shocked electrons of the pulsar wind.
- GeV component is a combination of the IC emission of unshocked electrons and bremsstrahlung emission.
- Luminosity of the GeV flares can be understood if it is assumed that the initially isotropic pulsar wind after the shock is reversed and confined within a cone looking, during the flare, in the direction of the observer.

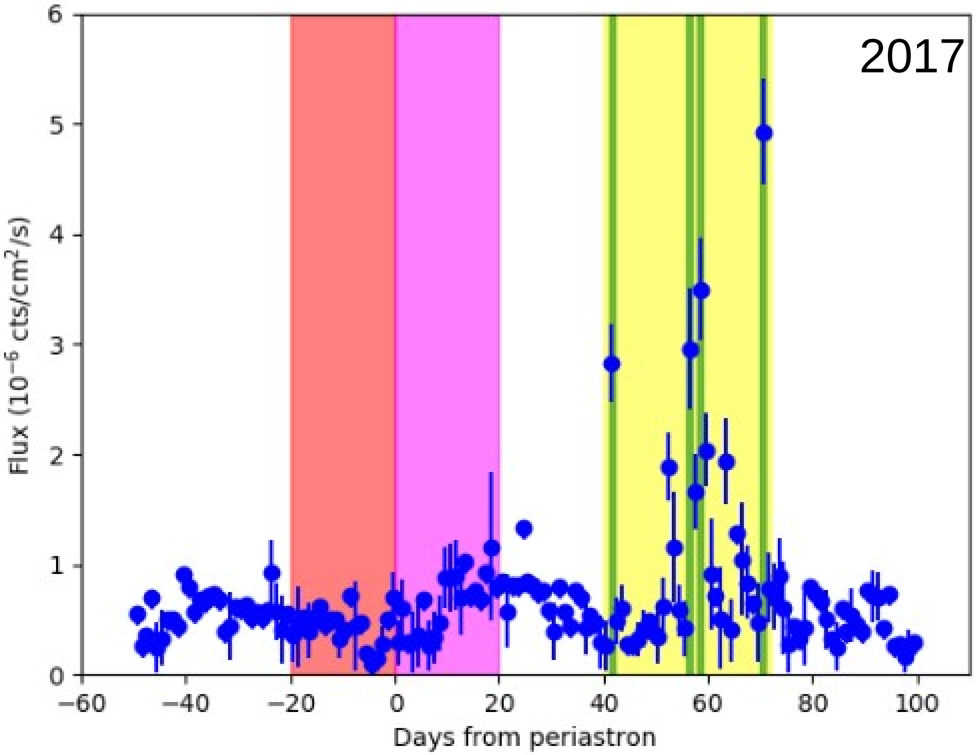
Chernyakova et al. 2020

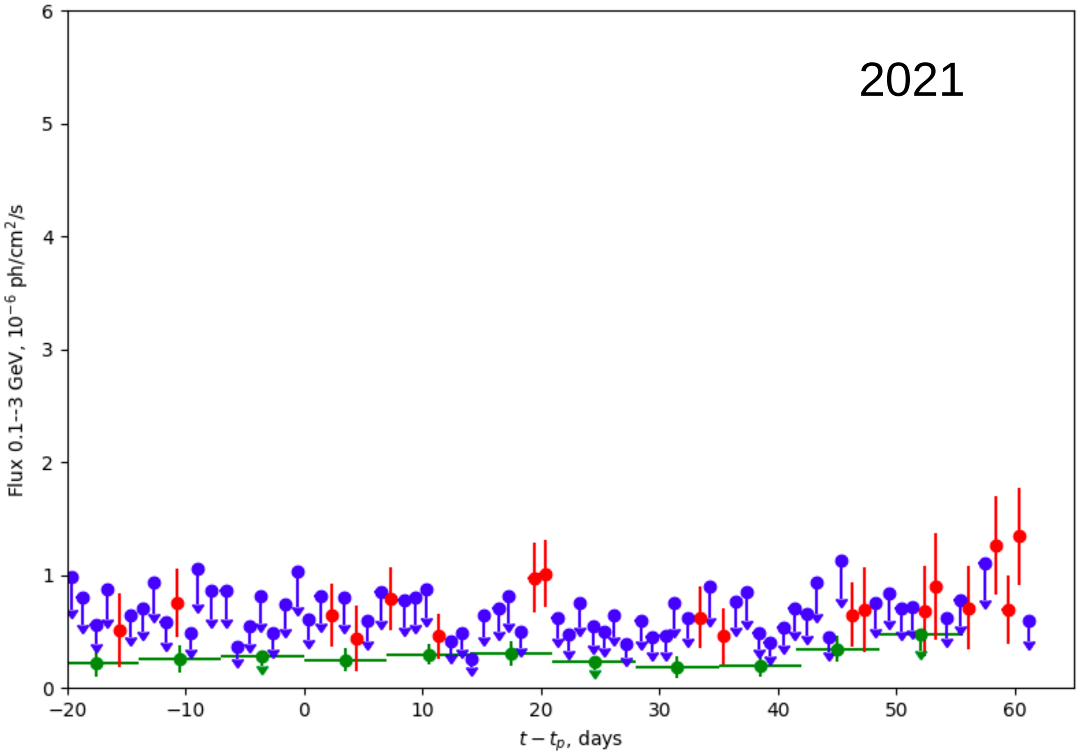
PSR B1259-63: periastron 2021



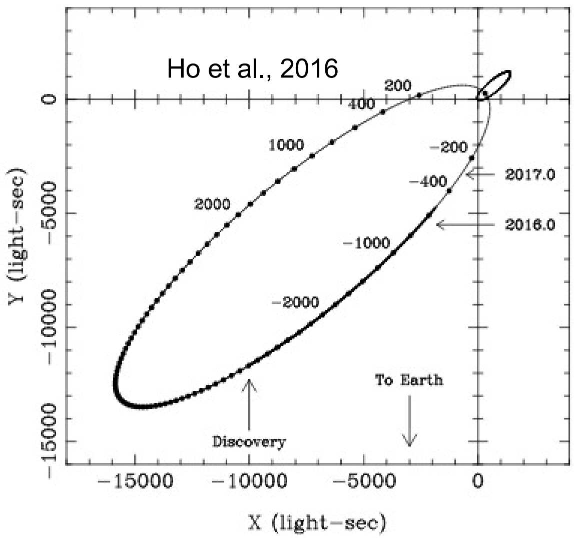
- Very different X-ray LC:
  - dim 1st and 2nd flares
  - presence of 3rd peak!
- Weak (delayed?) GeV flare
- No change in optical behaviour.
- Radio - X-ray correlation during the 2nd peak
- Correlation breaks at the beginning of the 3rd peak.
- IR studies are crucial to study the disk closer to the edge.
- Model is under development, stay tuned.

PSR B1259-63: GeV 2017 vs 2021

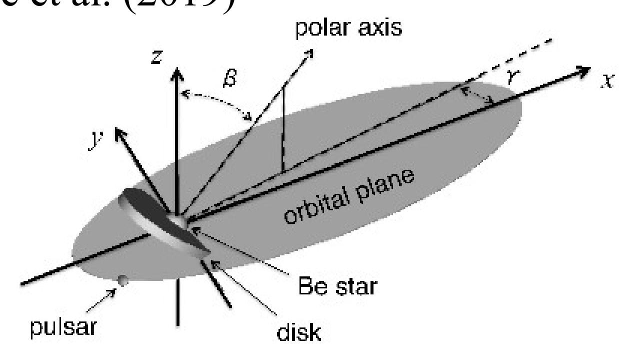




PSR J2032+4127 / MT91 213

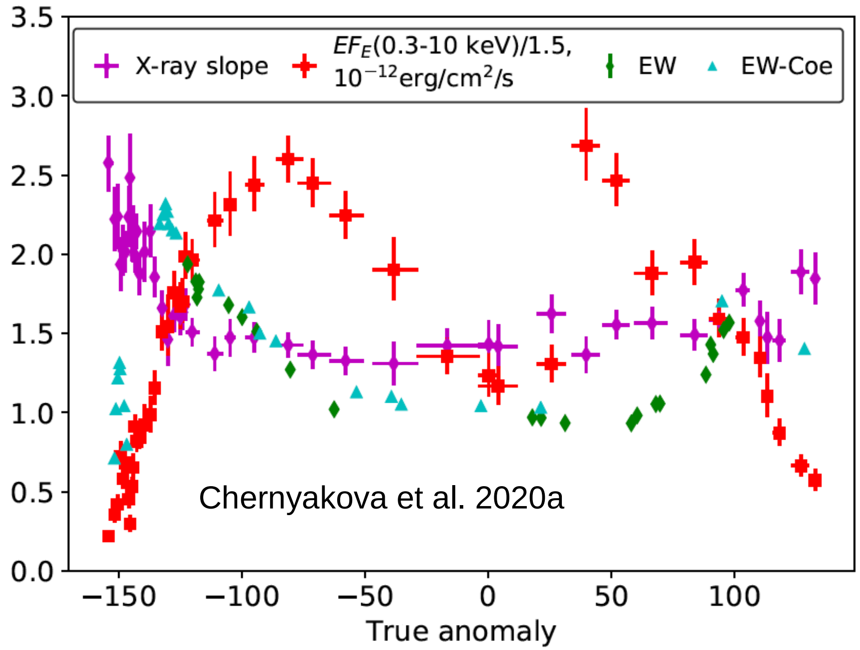


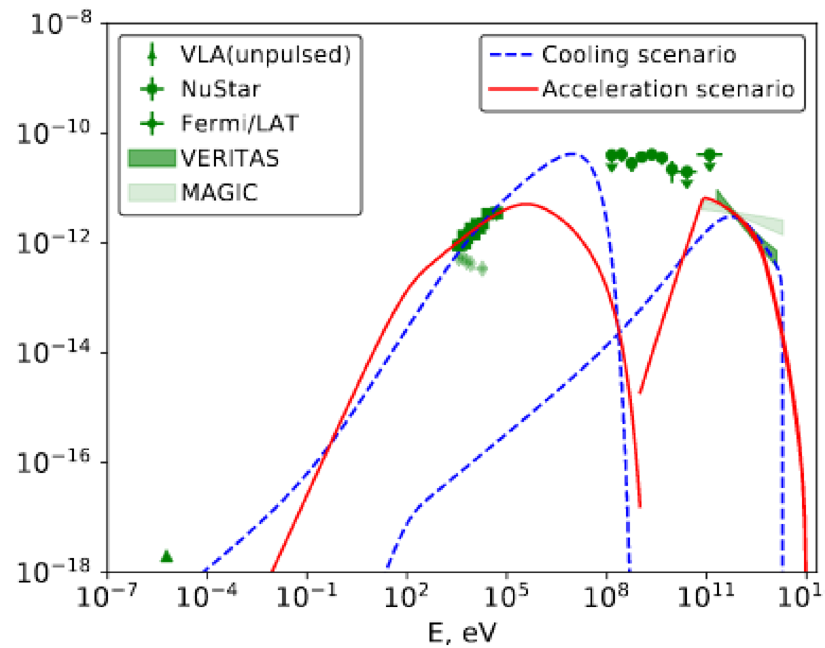
Coe et al. (2019)



- 143 ms radio pulsar, first discovered by the Fermi (Abdo et al. 2009).
- The pulsar is rotating around the 15-solar-mass B0Ve star MT 91-213 in a very eccentric orbit.
- Ho et al. (2016) confirmed the binary nature and an orbital period of 45-50 years.
- Periastron passage occurred on 13/11/ 2017.
- Unpulsed radio, X-ray and TeV emission are detected around the periastron.
- Stable GeV emission, probably from the pulsar's magnetosphere.
- Disk of the Be star is inclined to the orbital plane.
- Extensively studied by Takata et al. (2017), Li et al. (2018), Coe et al. (2019), Ng et al. (2019), Chernyakova et al. (2020) ...

PSR J2032+4127: X-rays





- Similar to PSR B1259-63 two peak X-ray light curve.
- X-ray and TeV emission are of synchrotron and IC origin correspondingly.
- GeV emission is dominated by the magnetospheric emission from the pulsar and thus is stable along the orbit.
- Peak and dips in the X-ray curve can be explained due to the shift of the emission region further from /closer to the star as the pulsar enters / leave the disk.
- Evolution of Hα emission line confirms this picture, tracing the enlargement of the disk due to tidal interactions and destruction of the disk due to the pulsar passage nearby.

Conclusions

- Study of the gamma-ray binaries with a pulsar allow detailed modeling and interpretation of such systems and to build a model that can be applied to other systems to identify the nature of their compact objects.
- Very different behaviour of X-ray and GeV lightcurves during 2021 periastron passage.
- Multi-wavelength observations are critical to study the details of wind interaction, existing observations are not sufficient to explain the details of the physical processes taking place in these systems.
- Future instruments, like CTA, HERD, eXTP, will allow to study broad band spectral evolution of these systems on short time scales which is critical for testing the existing models.