Новая модель широкополосного излучения от системы PSR B1259-63

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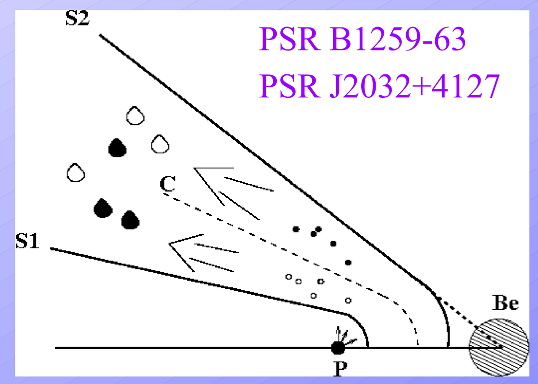
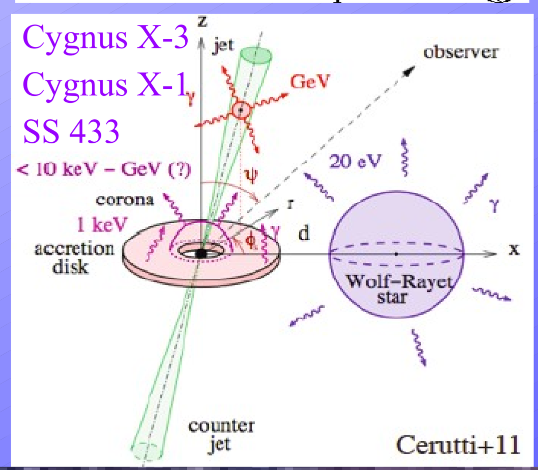
Introduction

- Less than 10 binary systems are visible up to TeV energies
- In these systems a compact object is orbiting around a young massive star.
- Nature of the compact object is known only in two systems hosting a radio pulsar and a Be star.
- In this case the observed broad band emission is due the emission at the collision shock.
- Other systems can either host a radio pulsar as well (pulsations are absorbed due to large optical depth near the optical star), or be microquasars.
- Detailed studies of systems with known companions can help to better understand other systems as well.

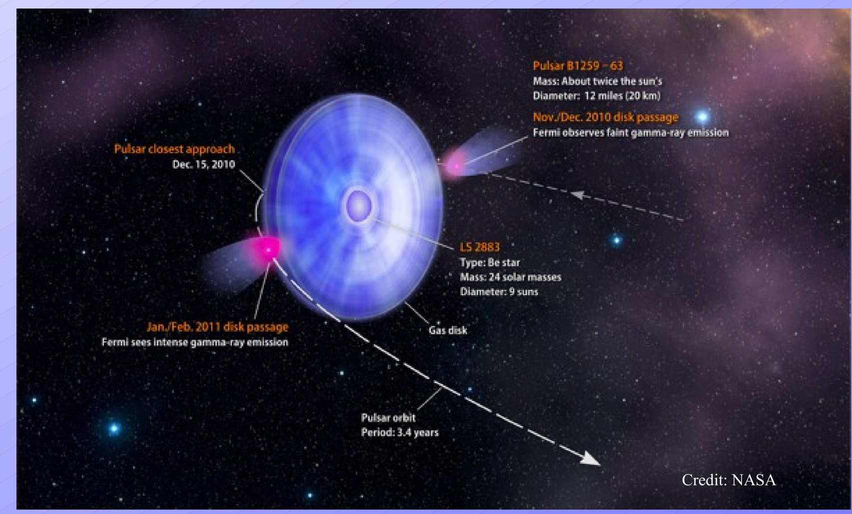




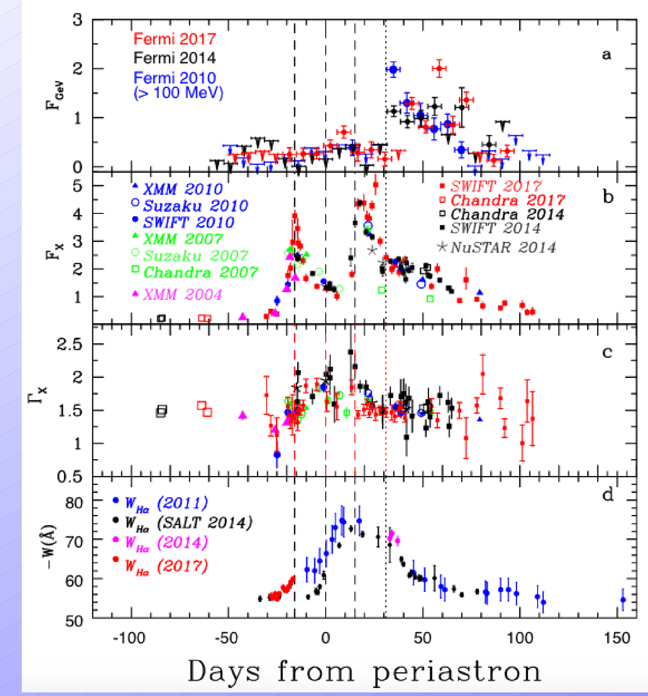
Cerutti+11

PSR B1259-63 / LS2883: overview

- Pulsar:
  - P=47.76 ms
  - L_{SD}=8.3x10^{35} erg s^{-1}
- Orbit:
  - Period ~3.4 yr
  - Eccentricity e~0.87
- Be Star:
  - M~10M_{SUN}
  - T~27000 K
  - Inclined disk
- Distance: ~2.4 kpc
- Pulsar crosses the disk before and after periastron.

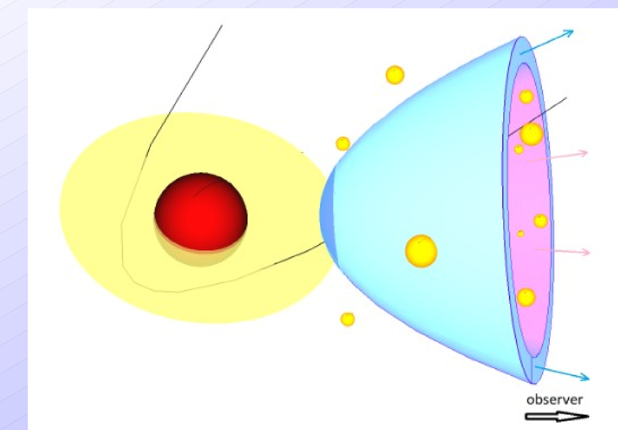


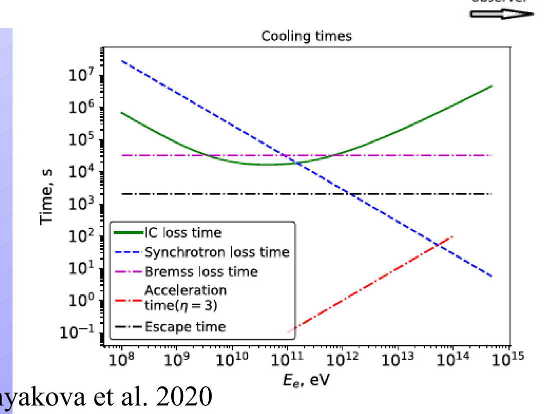
PSR B1259-63: previous light curves



- 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. Evidence of very fast (~15 min) sub flares.
- Isotropic gamma-ray luminosity of short flares greatly exceeds the pulsar spin-down luminosity
- Optics shows disruption of the disk at the time of GeV flare.

PSR B1259-63: model

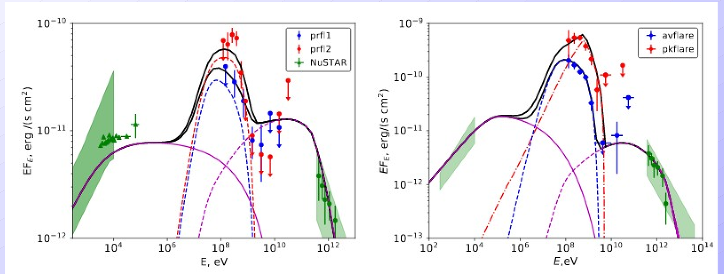


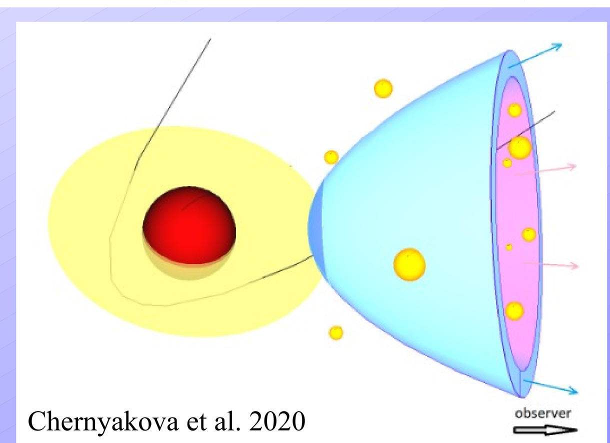


Chernyakova et al. 2020

- Data suggests the presence of two populations of relativistic electrons: (i) electrons of the unshocked and weakly shocked pulsar wind and (ii) strongly shocked electrons.
- The spectrum of unshocked electrons was selected to be a power law with the slope Γ=2 in 0.6–1 GeV.
- On the weak shock electrons could be additionally mildly accelerated leading to a power-law tail with Γ ~ −3 up to ~5 GeV.
- A small fraction of electrons are additionally accelerated at the strong shock near the apex up to 500 TeV with slope Γ=2
- Spectra of both populations are modified by radiative and non-radiative losses.

PSR B1259-63: model

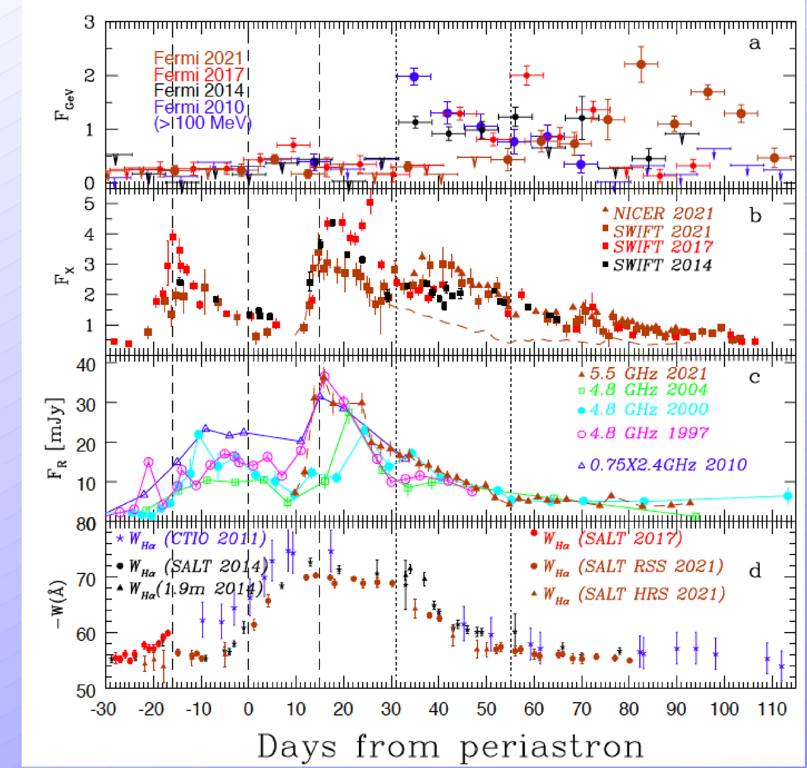




Chernyakova et al. 2020

- 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.

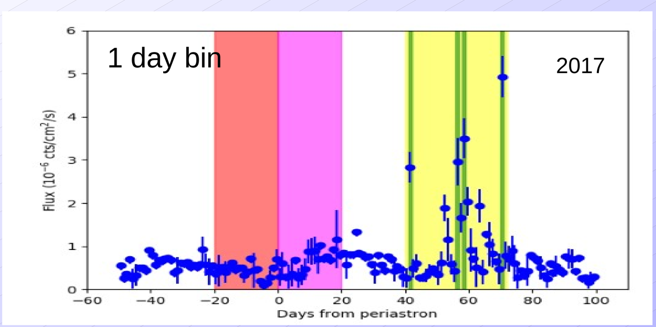
PSR B1259-63: 2021 observations



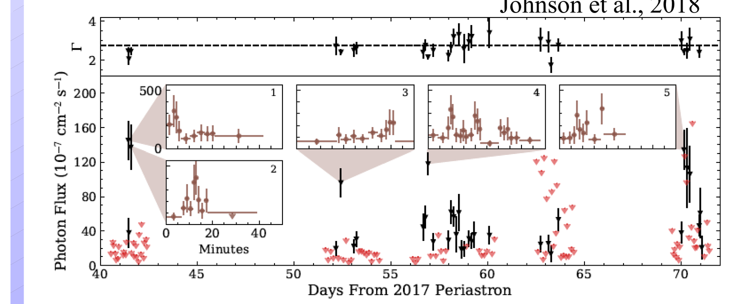
Chernyakova et al. 2021

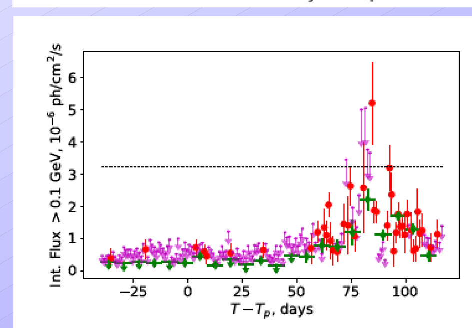
- GeV flare is delayed and weaker on short time scales
- Very different X-ray LC: dim 1st and 2nd flares presence of 3rd peak!
- Radio - X-ray correlation during the 2nd peak
- Correlation breaks at the beginning of the 3rd peak.
- No major change in optical behaviour around GeV peak.
- IR studies are crucial to study the disk closer to the edge.

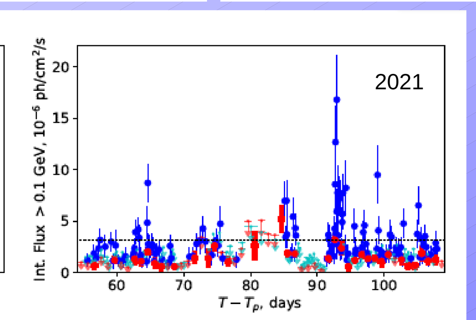
PSR B 1259-63: GeV 2017 vs 2021



Johnson et al., 2018





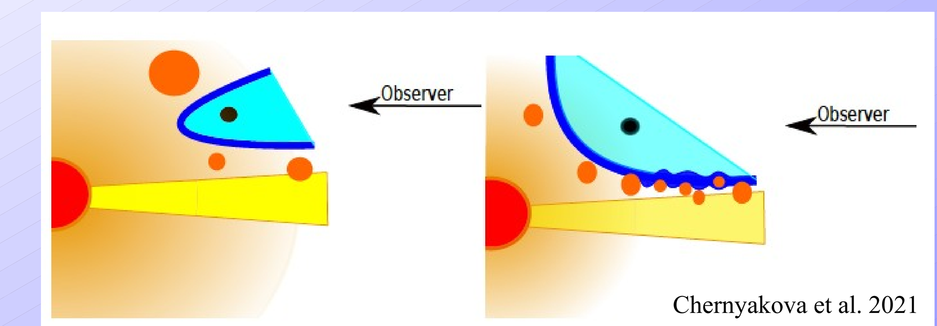


Weekly (green) and daily (red) light curves in 0.1 – 10 GeV energy range.

Variable-length time bins (blue), each time bin accommodates 9 GeV photons in a 1° circle around PSR B1259-63. Time bins have durations from 5 min to 2.8 days with an average duration of ~6 h

- Evidence of very fast (~15 min) gamma flares both in 2017 and 2021
- The dotted line in the 2021 plot represents the flux corresponding to spin-down luminosity of PSR B1259-63.
- In 2021 the short outbursts are 5 times less luminous than in 2017.

PSR B1259-63: 2017 vs 2021



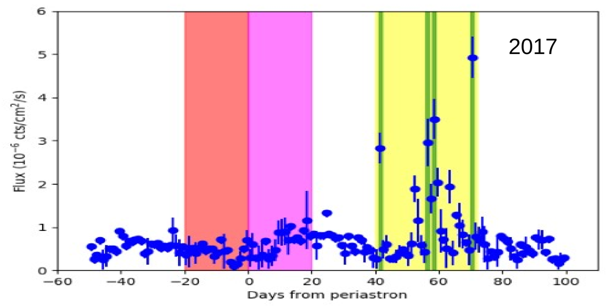
Chernyakova et al. 2021

- Sparser state of the Be star outflow in 2021 lead to a much larger opening angle of the emission cone and a weaker magnetic field (hence weaker X-ray flux)
- Large number of clumps at the edge of the disk will modify the shock front, which would increase the escape time of the relativistic electrons, leading to the third X-ray peak.
- The peak level of the GeV emission is inversely proportional to the cone opening angle, which naturally explains the relatively low average flux level seen by Fermi/LAT in 2021. Brightest outbursts require luminosities exceeding the spin-down one by a factor of 6, which is consistent with a large (~π) opening angle of the emission cone.
- Detailed model is ongoing.

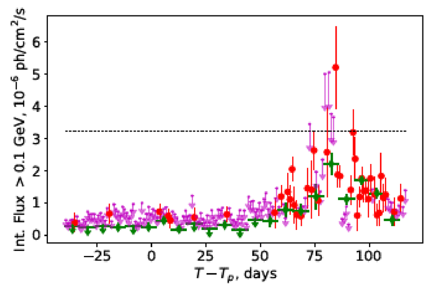
Conclusions

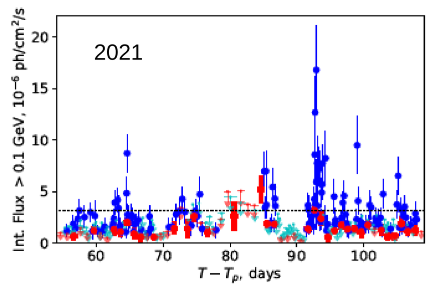
- Very high energy emission from gamma-ray binaries is a result of interaction of relativistic wind from the compact star with the non-relativistic wind of the massive optical companion.
- Unique features of 2021 periastron passage of PSR B1259-63:
- Lower X-ray flux during the periods of disk crossings.
- Presence of a third X-ray flux peak starting ~30 days after the periastron.
- Correlation between the X-ray and radio fluxes during the 2nd X-ray peak, and an absence of such a correlation with the 3rd rise of the X-ray flux.
- Rise of the GeV emission started only 55 days after the periastron.
- Surprising similarity in the variability of the Hα equivalent width compared to previous periastra passages indicates the need to use observations at longer wavelengths (infrared to millimeter) to trace the disk's behavior at later orbital phases.
- Observed features are inline with the model of Chernyakova et al. 2020 under the assumption that the outer parts of the Be star's disk are characterized by lower densities.
- More details on the described models and full set of references is given in
  - Chernyakova et al., 2020, MNRAS 497, 648
  - Chernyakova et al., 2021, Universe 7, 242

PSR B1259-63: GeV 2017 vs 2021



daily light curve





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