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Radio to GeV view of PSR B1259-63 periastron passage in 2021.

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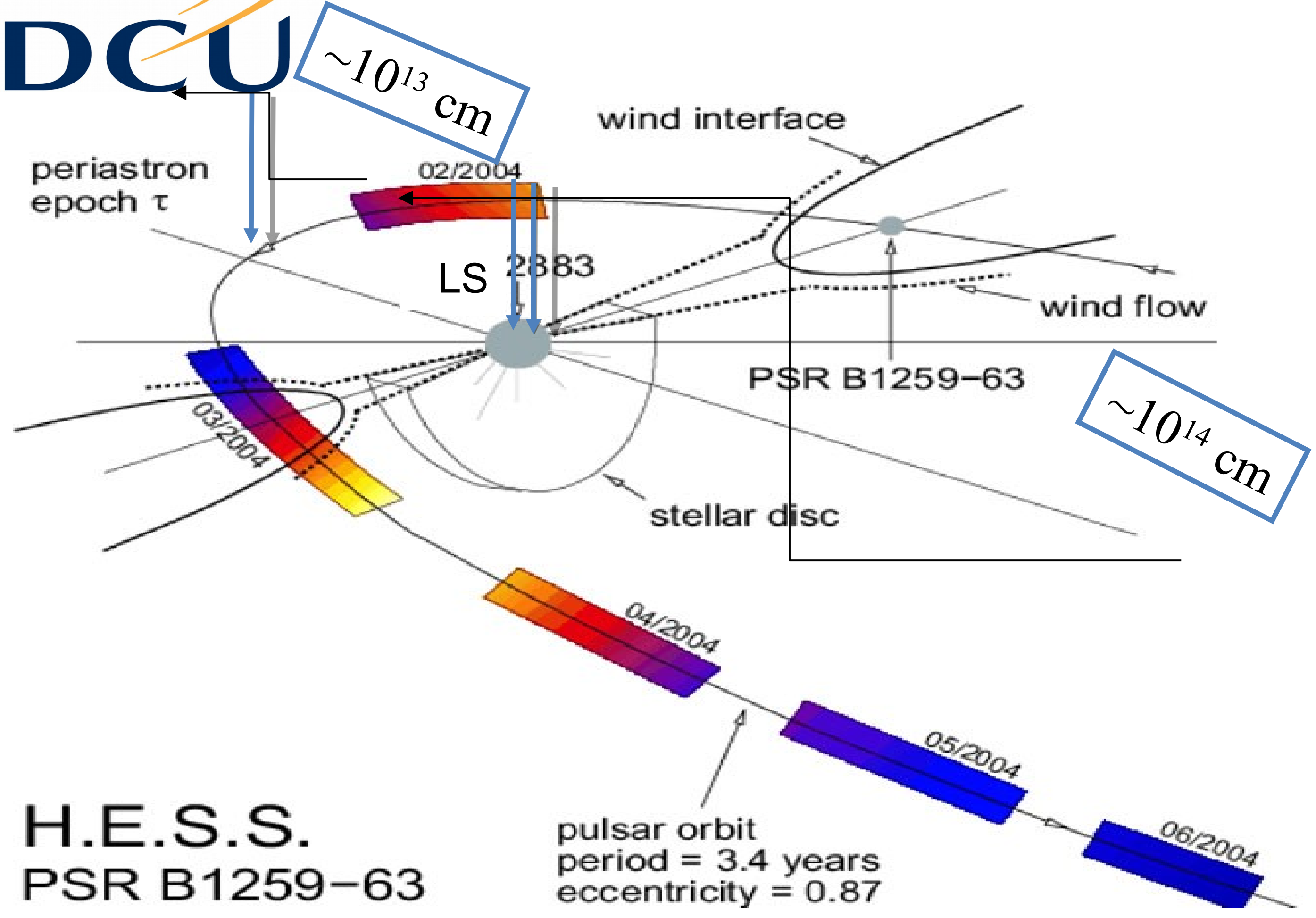
PSR B1259-63: overview



Aharonian et al. 2005.

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

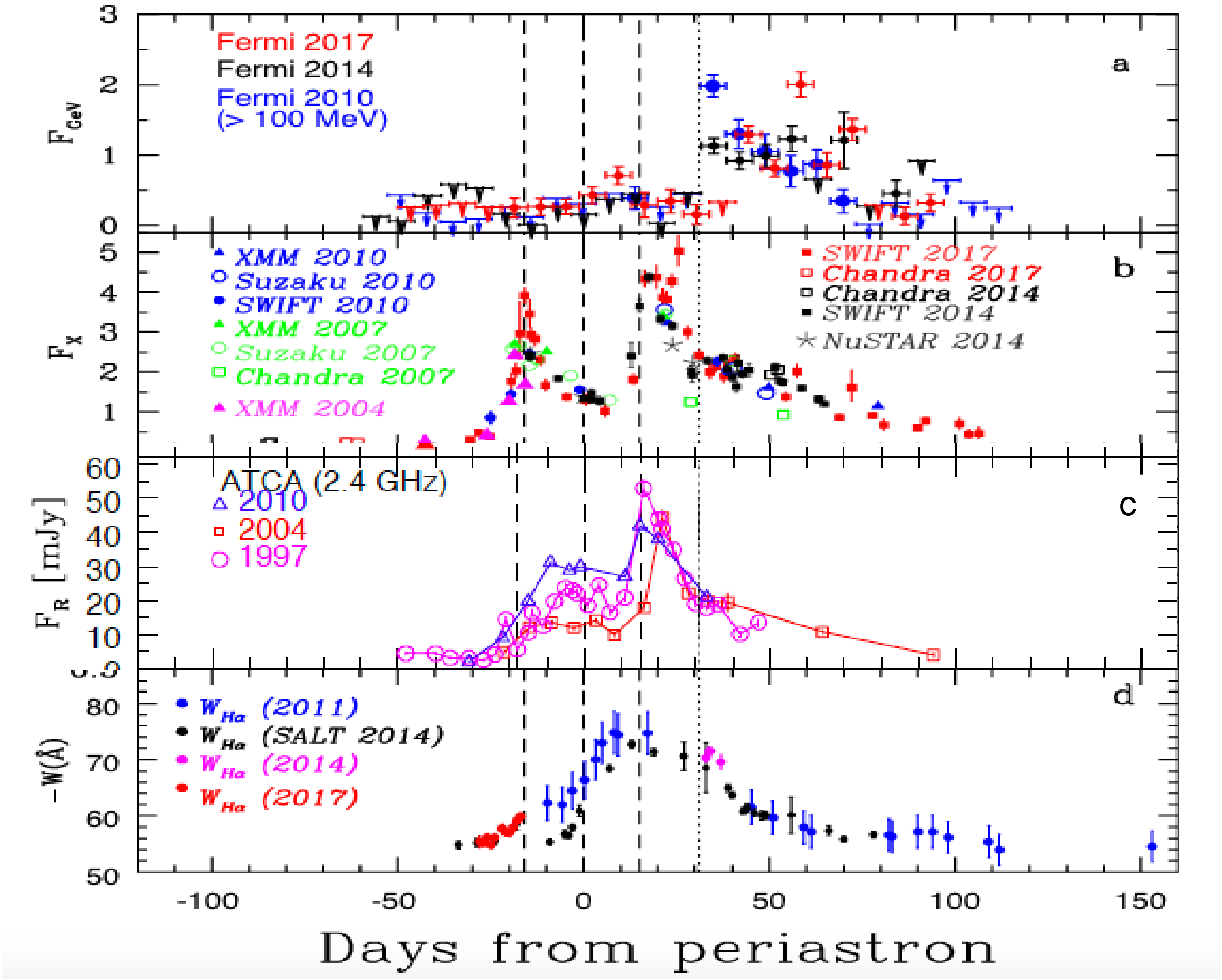
Orbit
Period ≈ 3.4 yr
Eccentricity e≈ 0.87

Distance 2.3 ± 0.4 kpc

LS 2883 parameters
- L_*=2.2E+38 erg/s
- M~10M_{sun}
- T~27000 K

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

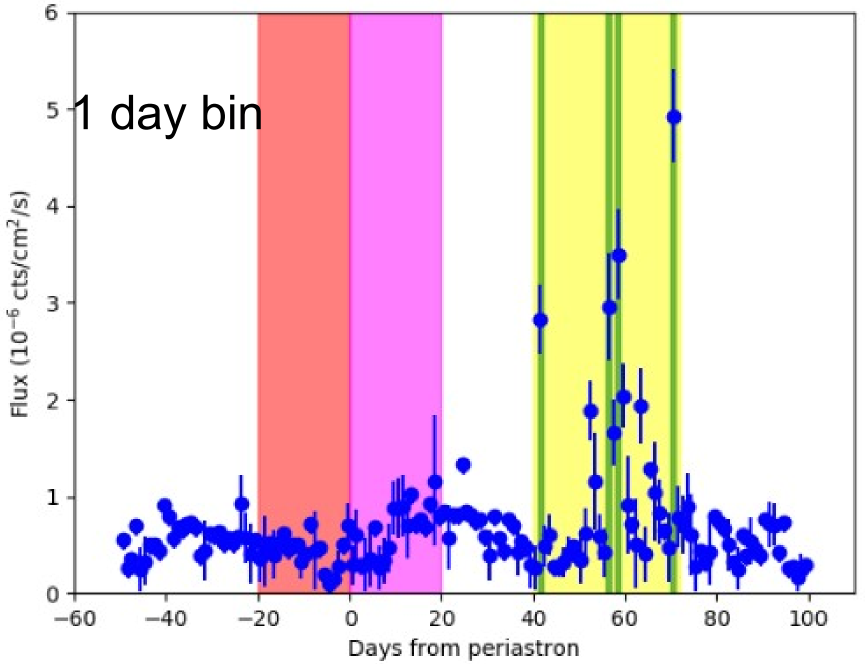
PSR B1259-63: light curves

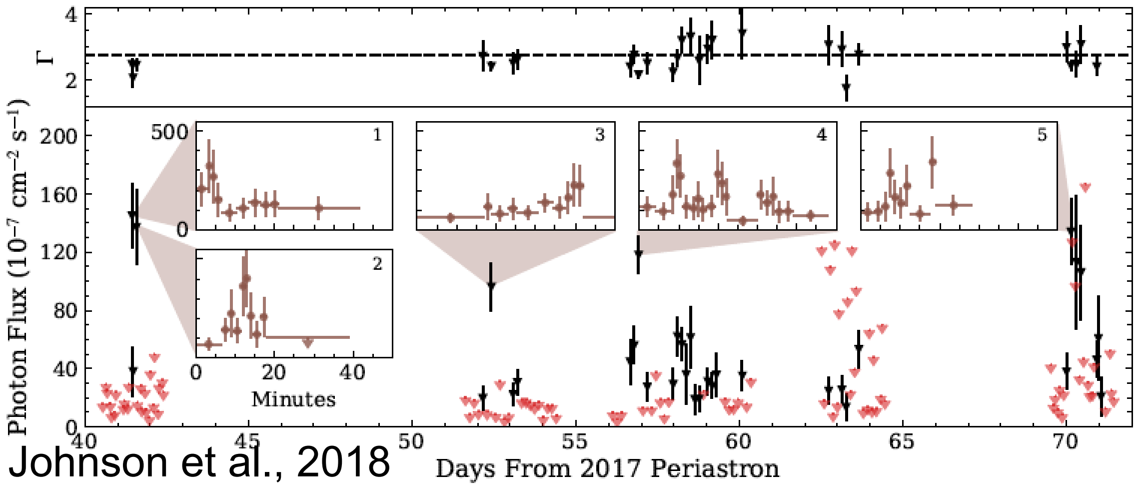


Chernyakova et al. 2020

- Two peaks at X-ray and radio ~20 days around the periastron.
- Corresponds to the passage through the Be star disk.
- Huge GeV flare with energy release close to spin-down luminosity on a weekly scale ~30/40/50 days after the periastron.
- No obvious counterpart at other energies.
- Various models to explain GeV, e.g. Khangulyan et al. 2012, Dubus & Cerutti 2013, Yi & Cheng 2017, Chernyakova et al. 2020

PSR B1259-63: light curves 2017





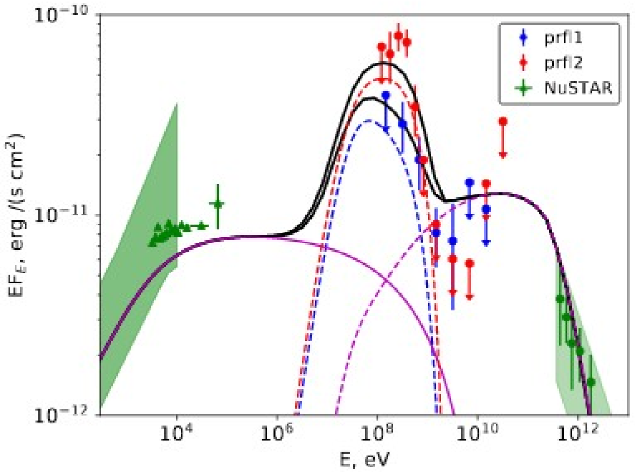
Johnson et al., 2018

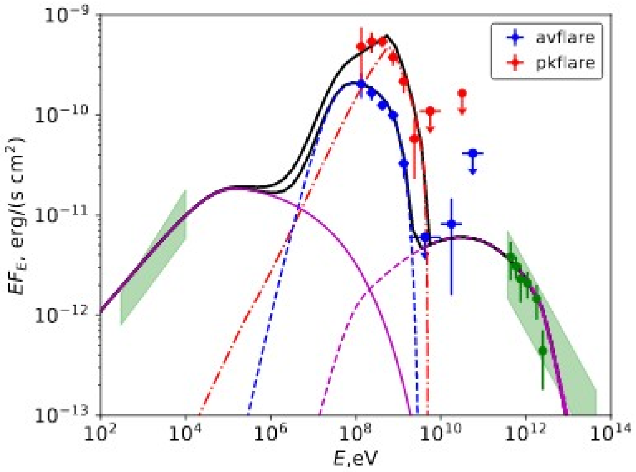
- Evidence of very fast (~15 min) gamma flares
- The isotropic gamma-ray luminosity corresponding to the short flares greatly exceeds the pulsar spin-down luminosity!

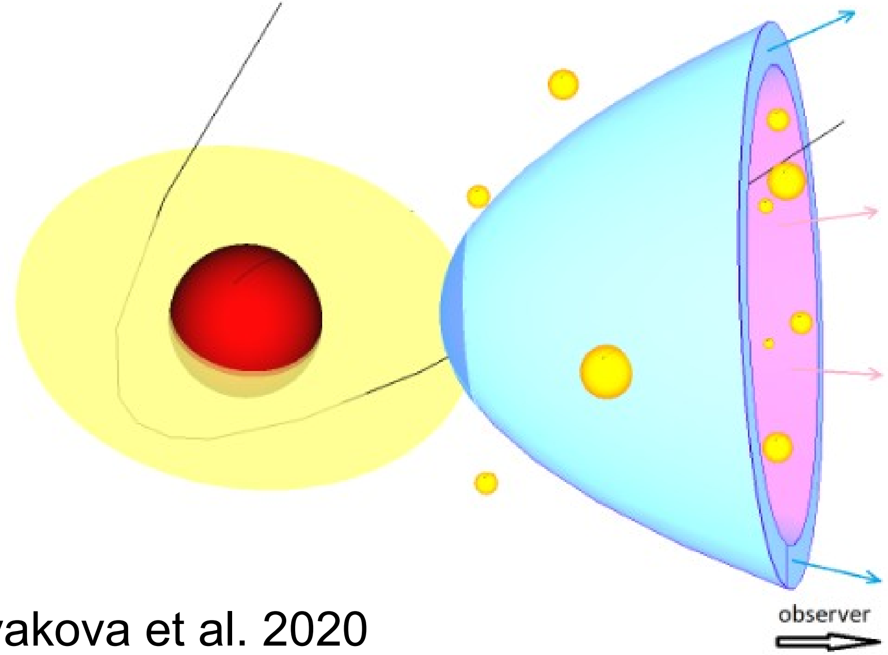
Time Scale	G $(10^{-10}$ erg cm^{-2} s$^{-1})$	L_γ $(10^{35}$ erg s$^{-1})$	$L_\gamma/\dot{E}$
One-week	7.3±0.6	$6.4^{+2.0}_{-1.6}$	0.8±0.2
One-day	14±2	12^{+4}_{-3}	$1.5^{+0.5}_{-0.4}$
One-orbit	70±16	61^{+18}_{-14}	$7.4^{+2.2}_{-1.7}$
Intra-orbit	280±100	244^{+74}_{-56}	$29.8^{+9.0}_{-6.8}$

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







Chernyakova et al. 2020

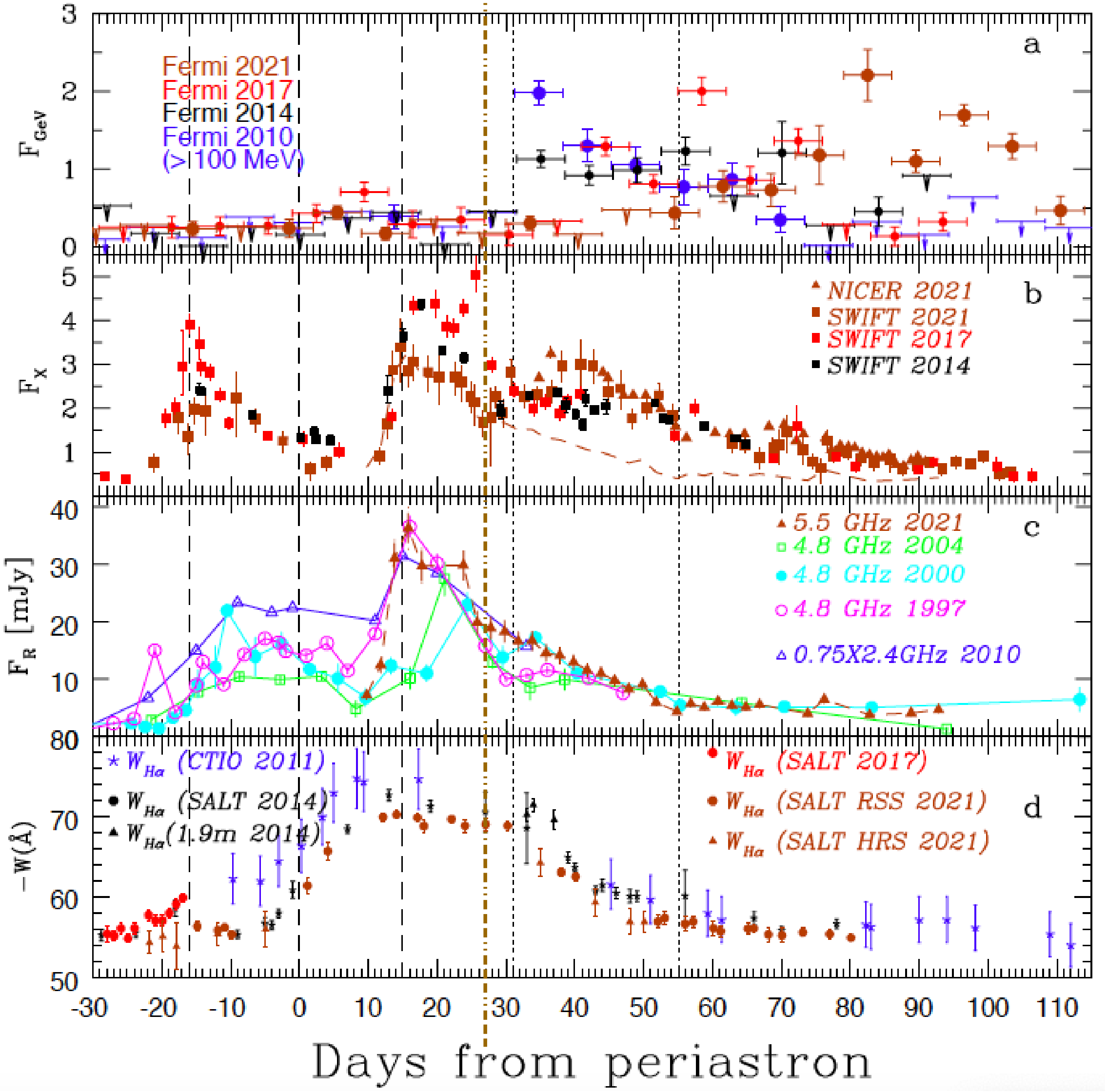
- Observed X-ray and TeV emission can be explained as a synchrotron and IC emission of the strongly shocked electrons of the pulsar wind.

- GeV component is a combination of the IC emission of unshocked / weakly shocked 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.

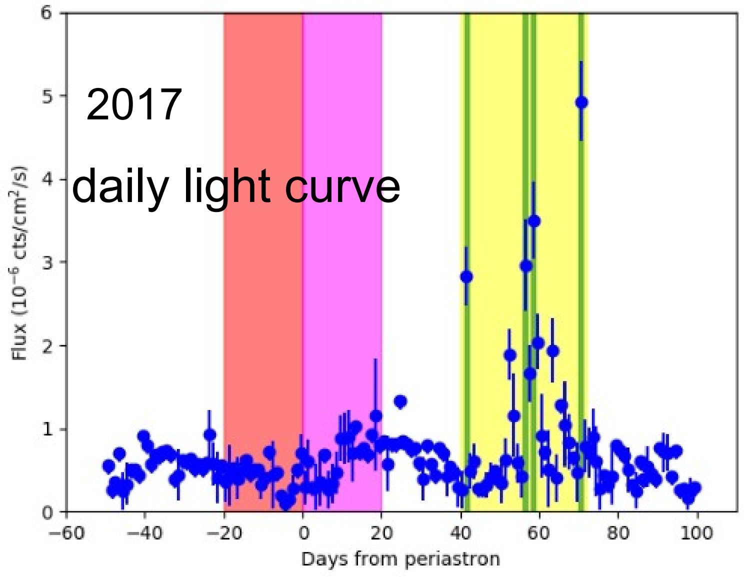
PSR B1259-63: periastron 2021

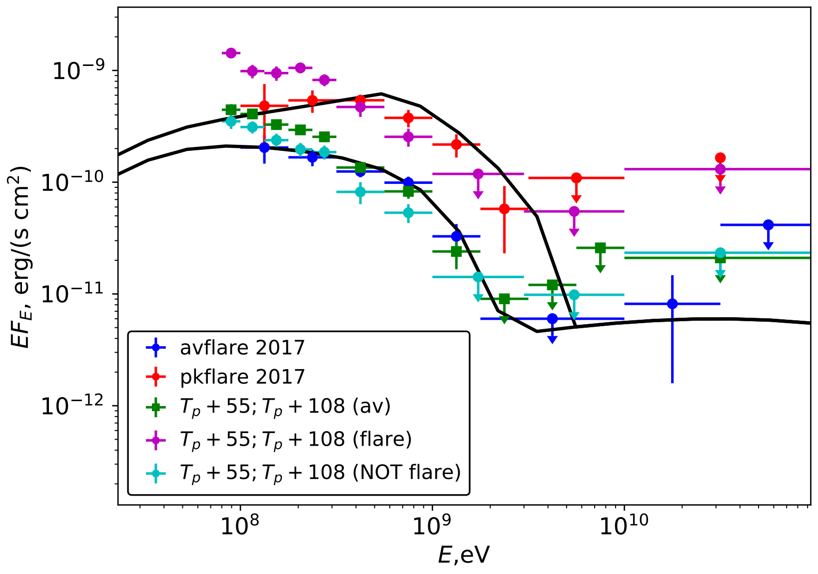
Chernyakova et al. 2021



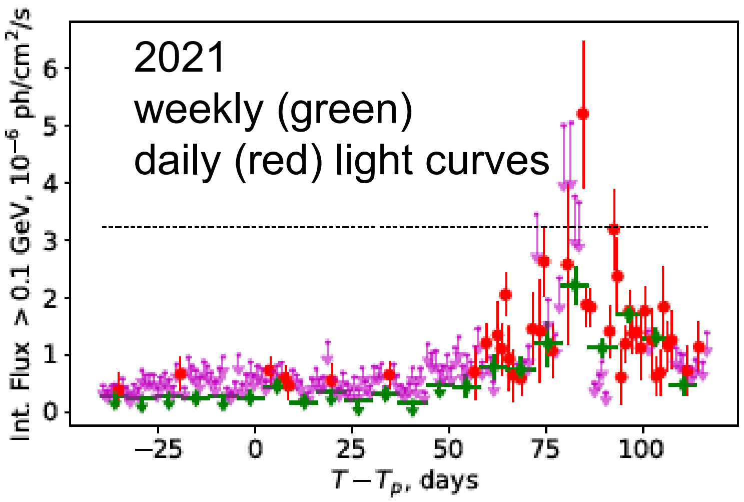
- - GeV flare is delayed
  - similar on daily/weekly time scales
  - weaker on short time scales

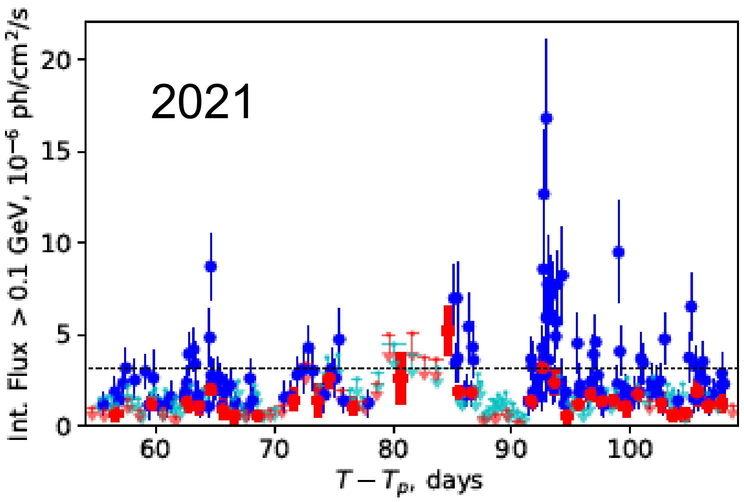
PSR B1259-63: GeV 2017 vs 2021





2021: Similar spectral shape of low and high states during the flare. Noticeably different spectral shape from 2017.

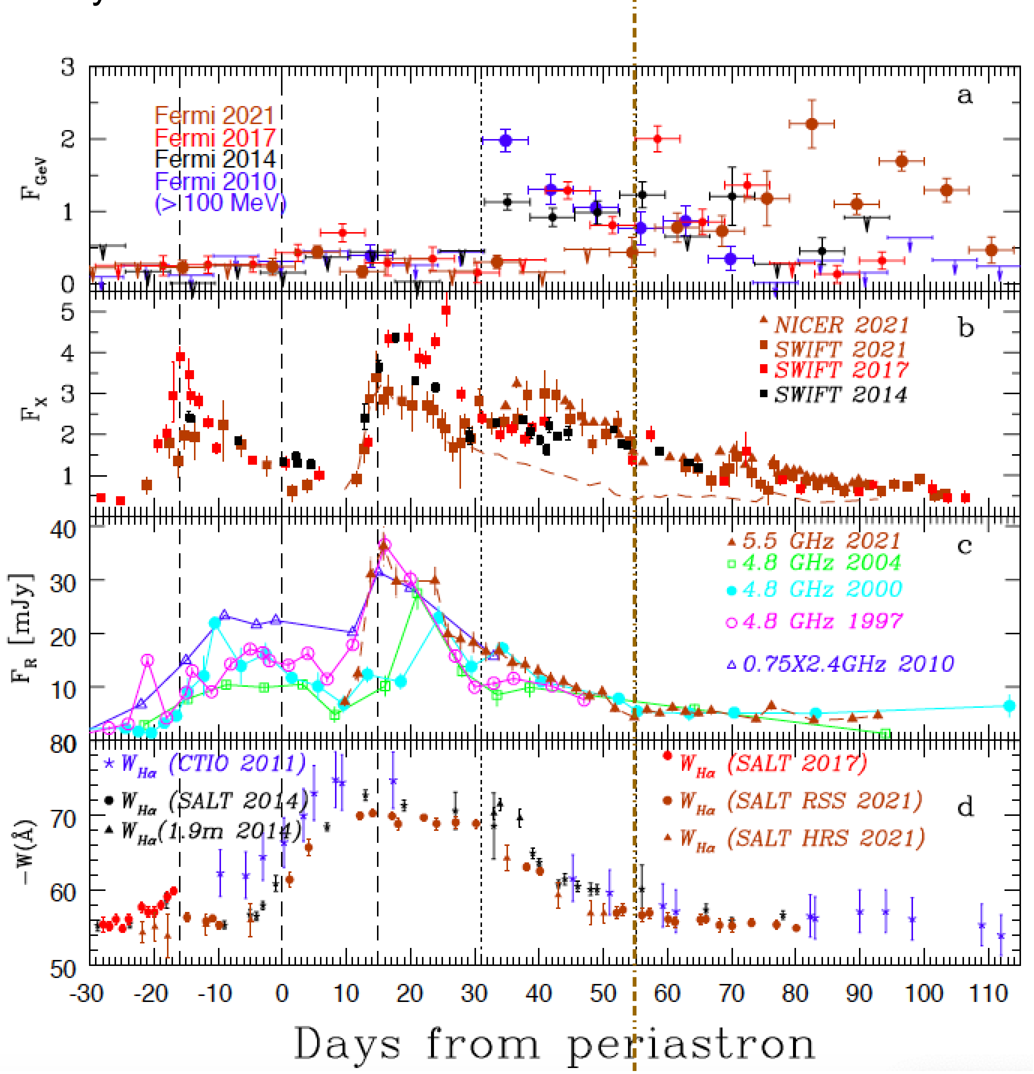




Variable-length time bins (blue), each time bin accommodates 9 GeV photons in a 1 degree circle around PSR B1259-63. Time bins have durations from 5 min to 2.8 days with an average duration of ~6 h.

PSR B1259-63: periastron 2021

Chernyakova et al. 2021



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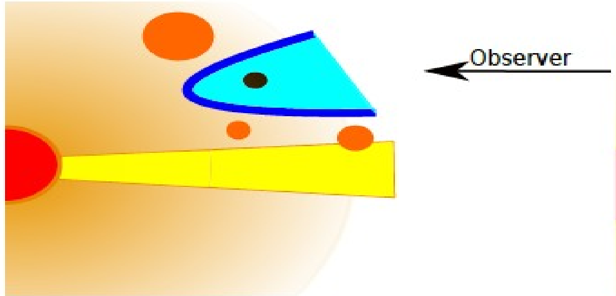
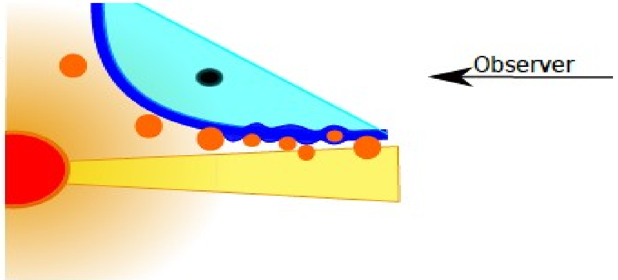
- Very different X-ray LC:
  - dim 1st and 2nd flares
  - presence of 3rd peak!

2017 vs 2021





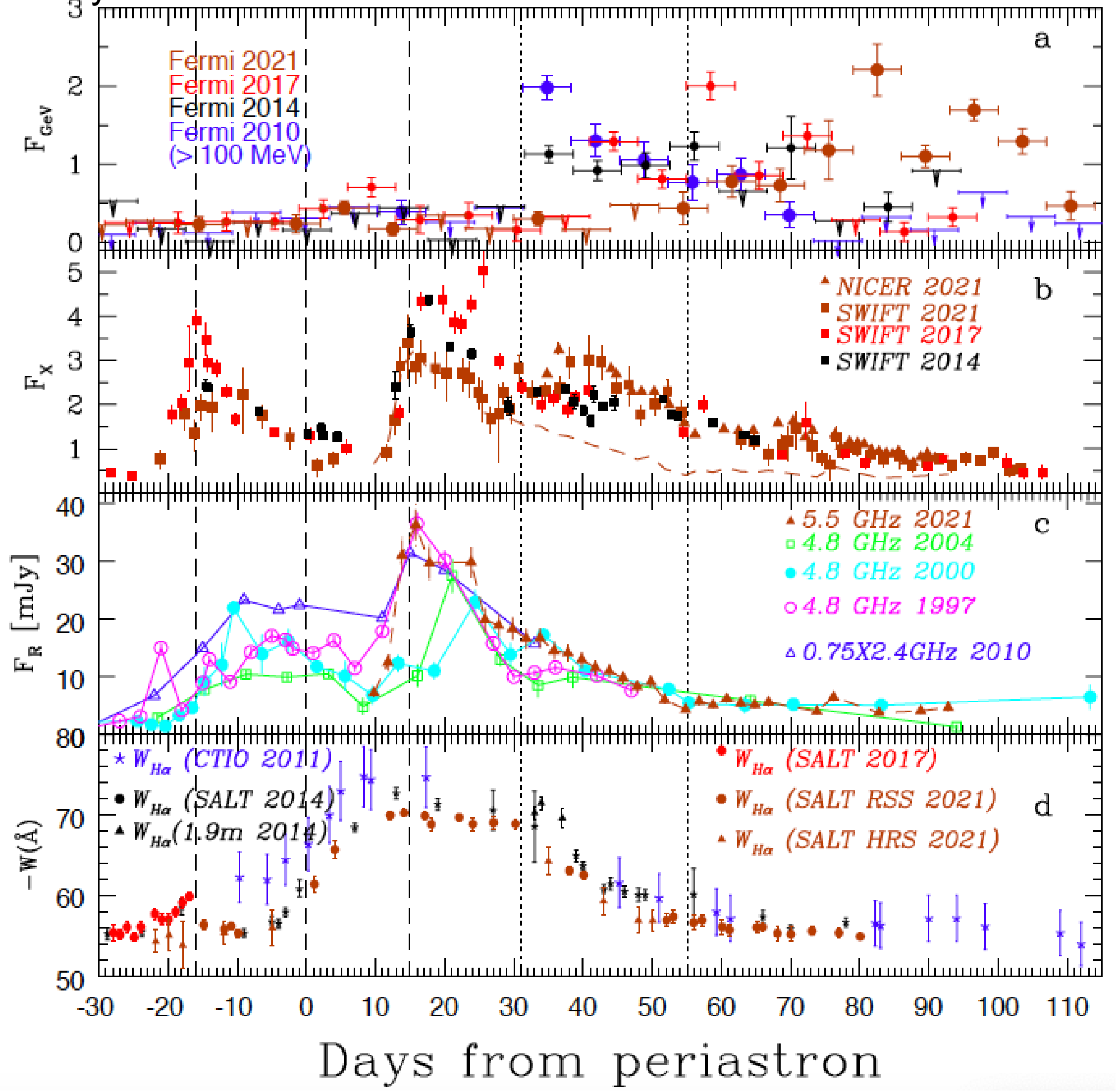
- Sparser state of the Be star outflow in 2021 lead to a much larger opening angle of the emission cone and a weaker magnetic field (hence weaker X-ray flux)

- The peak level of the GeV emission is inversely proportional to the shock 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 in 2021 versus factor of 30 in 2017.

- Large number of clumps at the edge of the disk will modify the shock front, increasing the escape time of the relativistic electrons, leading to the third X-ray peak.

PSR B1259-63: periastron 2021

Chernyakova et al. 2021



- GeV flare is delayed
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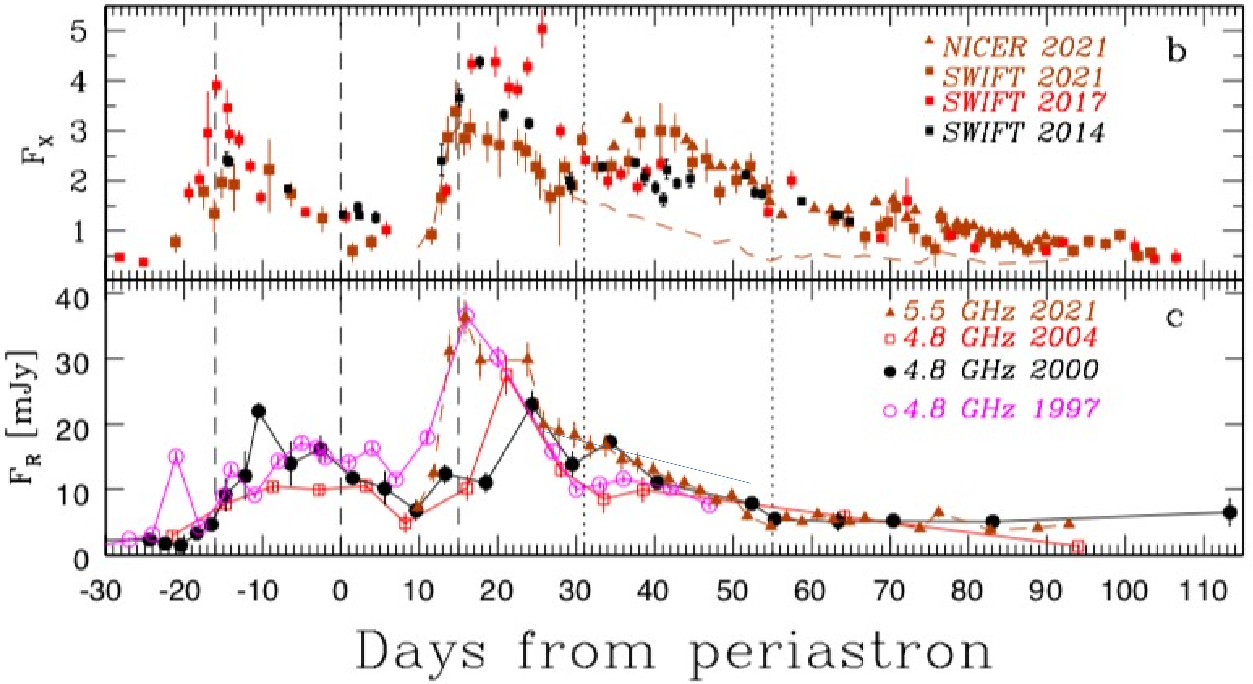
  - presence of 3rd peak!
- Radio - X-ray correlation during the 2nd peak
- Correlation breaks at the star of the 3rd peak.

Break of the X/Radio correlation



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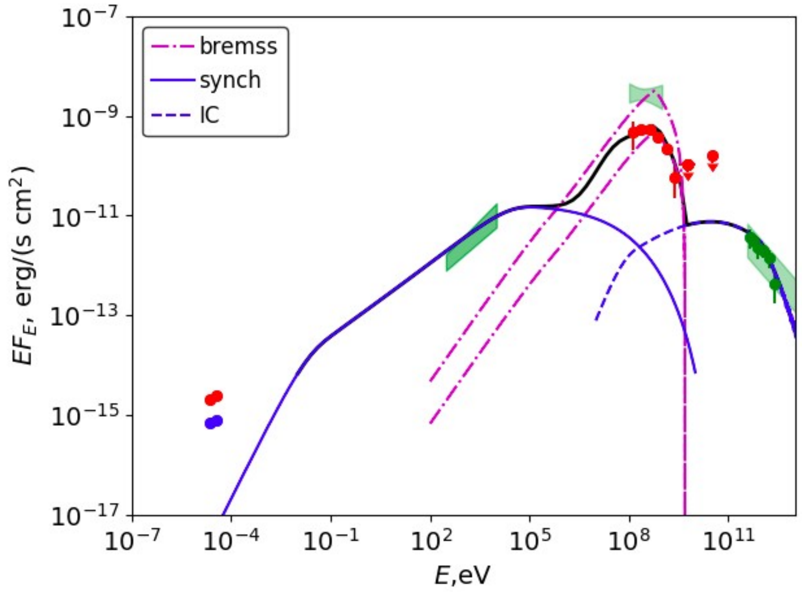
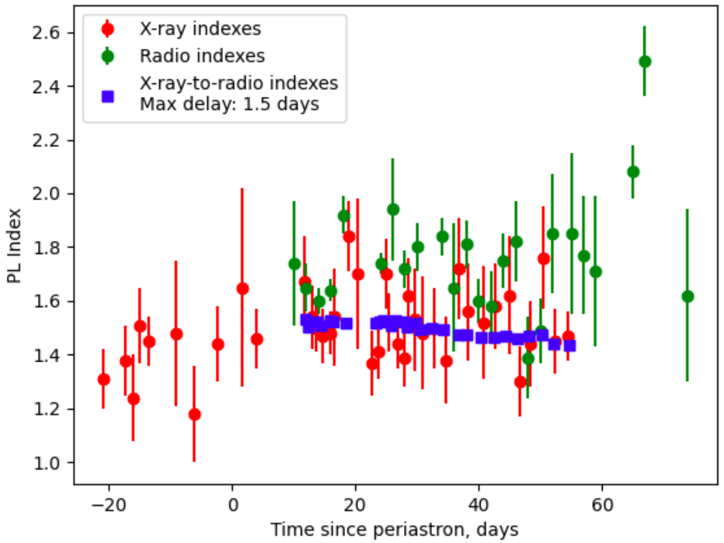
- No rise of radio data due to free-free absorption.

$$\tau_{ff}=7\,x\,10^5\left[\frac{T}{10^5\,K}\right]^{-3/2}\left[\frac{n_i}{10^8\,cm^{-3}}\right]^2\left[\frac{\nu}{5\,GHz}\right]^{-2}\frac{L_{clump}}{10^{10}\,cm}$$

Radio/X-ray data





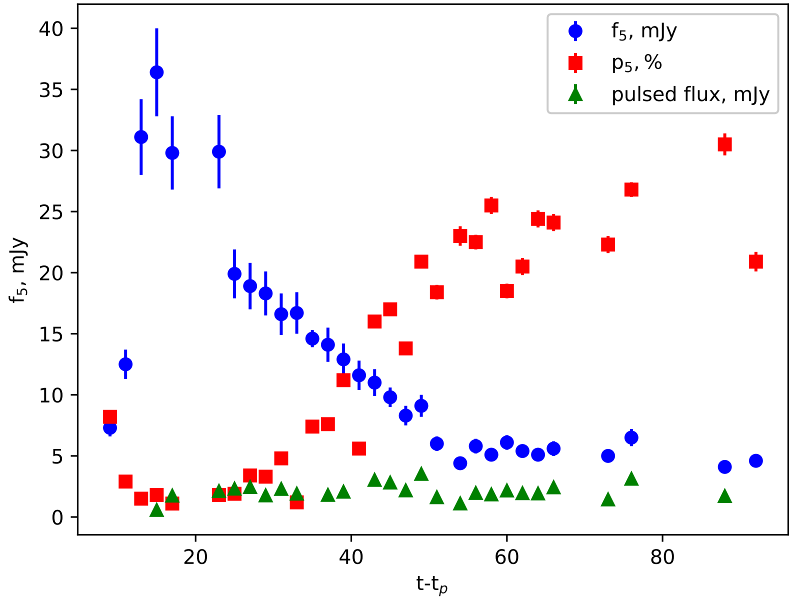
- Radio data has systematically softer spectrum than X-rays.
- Energetics constraints makes it impossible to inject electrons from radio to X-ray with a power law distribution.
- Subsequent cooling of injected electrons leads to a very long cooling time

$$t_s = 4\times10^6 \left[\frac{1G}{B}\right]^2 \left[\frac{100\ MeV}{E_e}\right] s$$

$$t_{IC} = 6\times10^4 \left[\frac{10^{38}\ erg\ s^{-1}}{L_*}\right] \left[\frac{D}{10^{13}\ cm}\right]^2 \left[\frac{100\ MeV}{E_e}\right] s$$

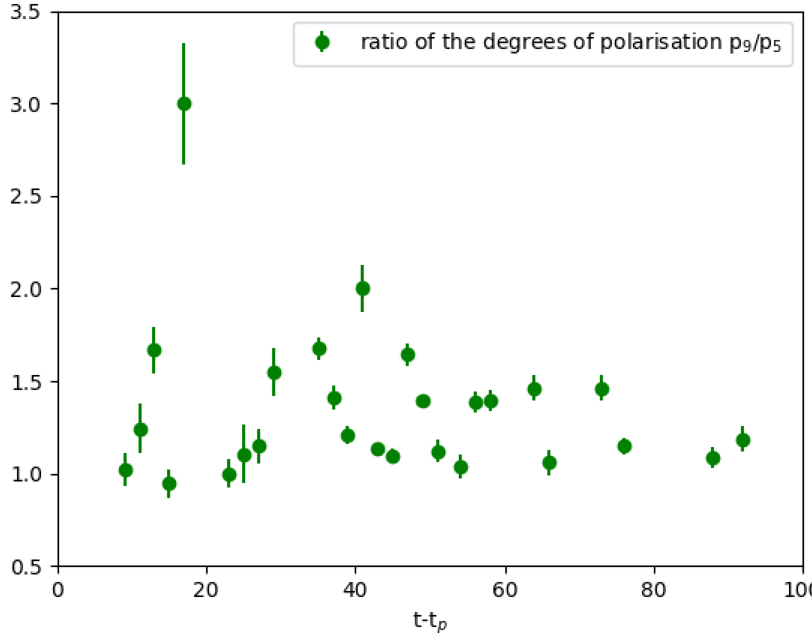
- Indication that radio emission is coming from accelerated stellar wind

Radio Polarization



Observed depolarisation indicates that the radio emission region is located far from the pulsar.

Comparison of polarization properties at different wavelengths allow to measure the parameters of the region where the radio emission is produced.



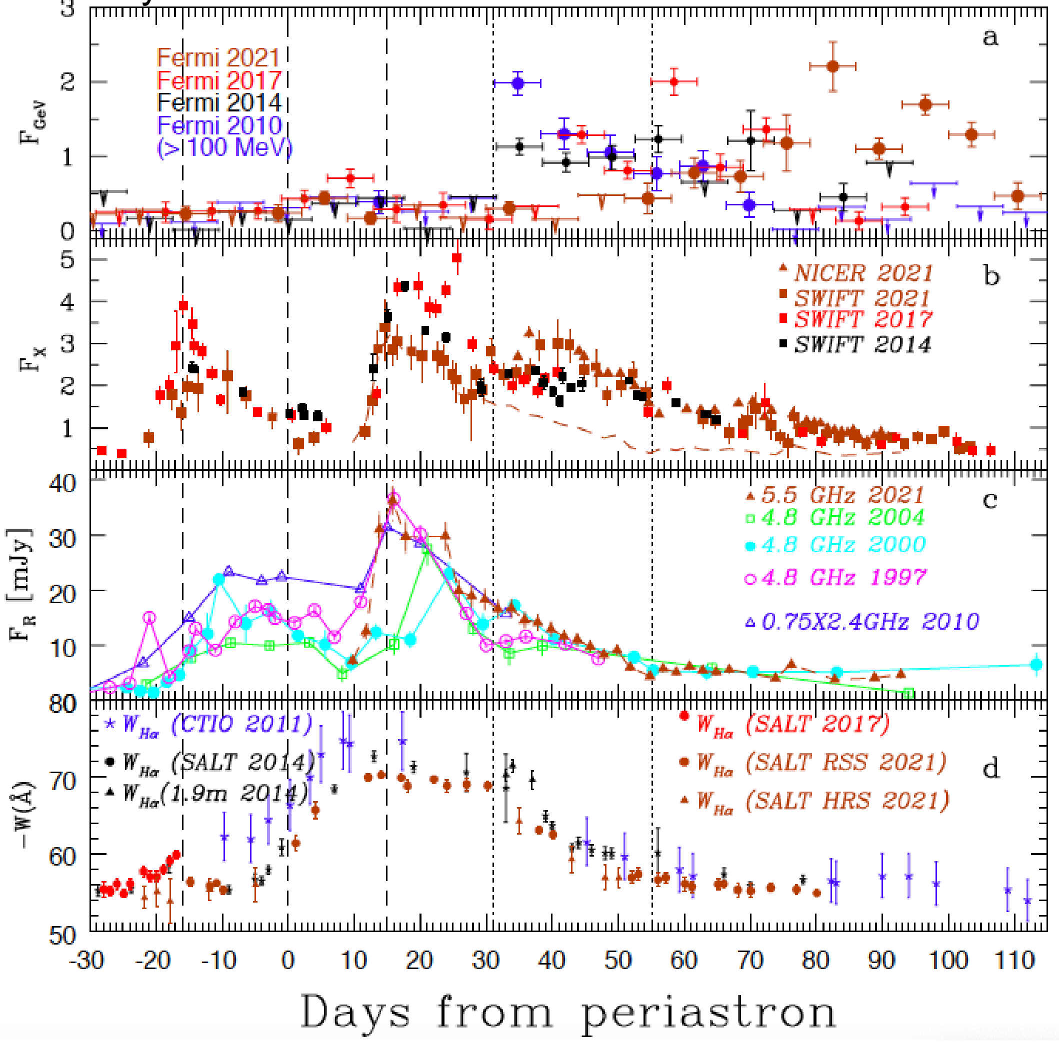
$$\frac{p_9}{p_5} = e^{2\sigma_{RM}^2(\lambda_5^4 - \lambda_9^4)}$$

$$\sigma_{RM} = 0.83 \frac{n_e}{1\,cm^{-3}} \frac{B}{1\,G} \sqrt{\frac{d}{10^{12}} \frac{L}{10^{13}\,cm}} = 256.5 \sqrt{\ln[p_9/p_5]}\, m^{-2}$$

(e.g. Knuettel et al. 2019)

PSR B1259-63: periastron 2021

Chernyakova et al. 2021



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- Radio - X-ray correlation during the 2nd peak
- Correlation breaks at the star 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.

Conclusions

- 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 2^{nd} X-ray peak, and an absence of such a correlation with the 3^{rd} rise of the X-ray flux.
- Indication that radio emission is coming from accelerated stellar wind.
- 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.

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Thank you for your attention!

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