Inverse Compton Emission from PSR B1259-63/LS2883 : Pulsar Wind and Accretion Disk photons

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Gamma-ray binaries

★ Binary system contains a massive O/B star and a compact star

★ Orbits are usually highly elliptical and periods range from 3.9 days to 50 years

★ γ-ray luminosity dominates spectrum (GeV/TeV)

★ The high energy emissions (X-rays/TeV) are mainly produced by the interaction between stars, and their fluxes vary with orbital phase

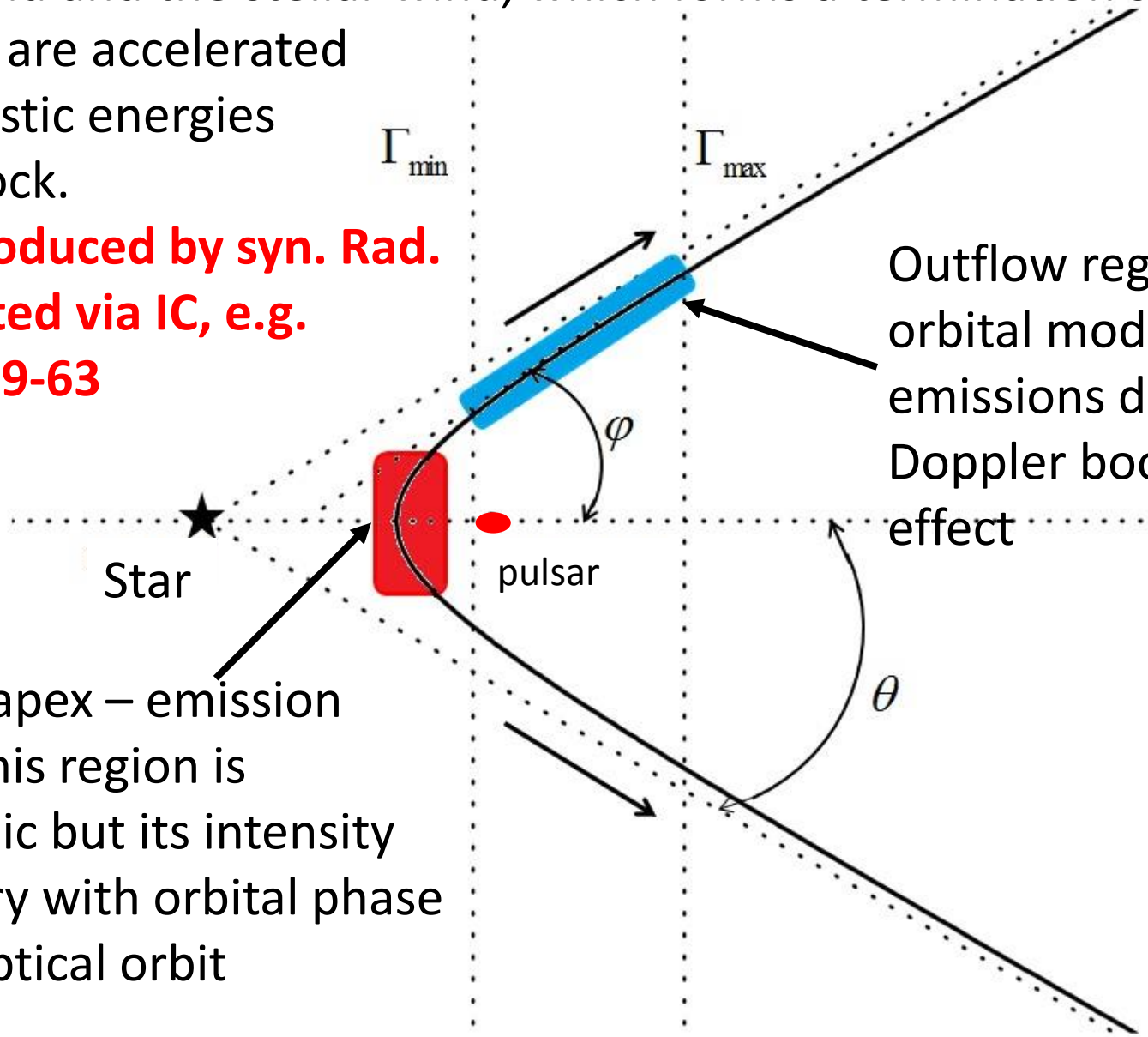
★ Binary population synthesis study predicted the existence of ~ 30 gamma-ray binaries

★ Currently, 7 such systems have been discovered, they are 1FGL J1018.6-5856, HESS J0632+057, LS I +61° 303, LS 5039, PSR B1259-63, LMC P3/CXOU J053600.0-673507 and PSR J2032+4127/MT91 213.

The orbital modulated emission results from the interaction of the pulsar wind and the stellar wind, which forms a termination shock. Electrons are accelerated to relativistic energies in the shock.

X-rays produced by syn. Rad.

TeV emitted via IC, e.g. PSR B1259-63



Outflow region - orbital modulated emissions due to the Doppler boosting effect

Shock apex – emission from this region is isotropic but its intensity can vary with orbital phase for elliptical orbit

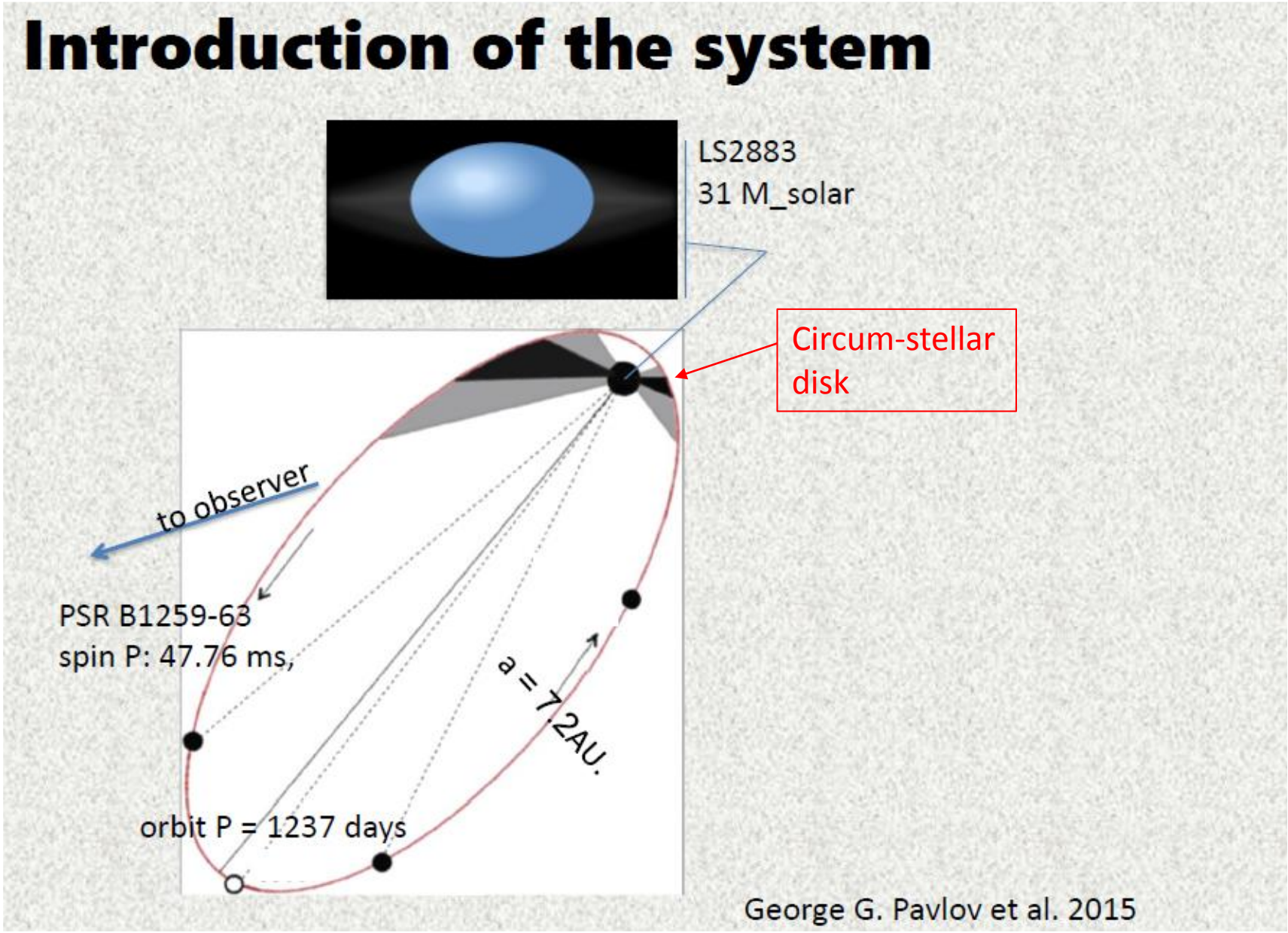
Emissions produced by IC between disk photons and PW – non-orbital/orbital modulation

- The (transient) accretion disk can be formed in some gamma-ray binaries which can also provide soft photons. IC between these soft photons and PW can also produce GeV gamma-rays. In principle this process cannot produce orbitally modulated gamma-rays, e.g. in MSP binary PSR J1023.4+0038. However if the life time of the disk is shorter than the orbital period, the gamma-ray signal exhibits orbital variation, e.g. in PSR B1259-63/LS2883. The characteristic spectrum is given by

$$F_\gamma \propto \int dT_d(t) \exp\left(-\left(\frac{E_\gamma - {\Gamma_w}^2 kT_d}{\sigma_w^2}\right)^2\right)$$

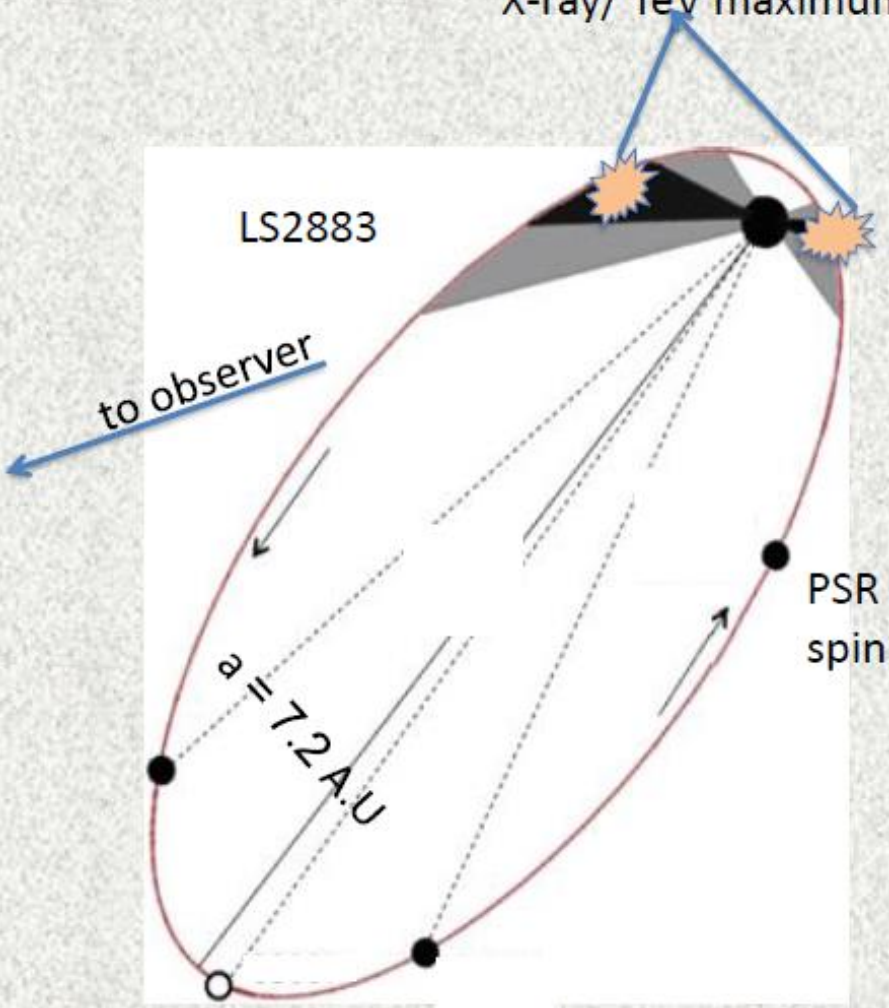
where $T_d(t)$ is the temperature of the transient disk at time t. This will give rise a broader spectrum.

PSR B1259-63/LS2883

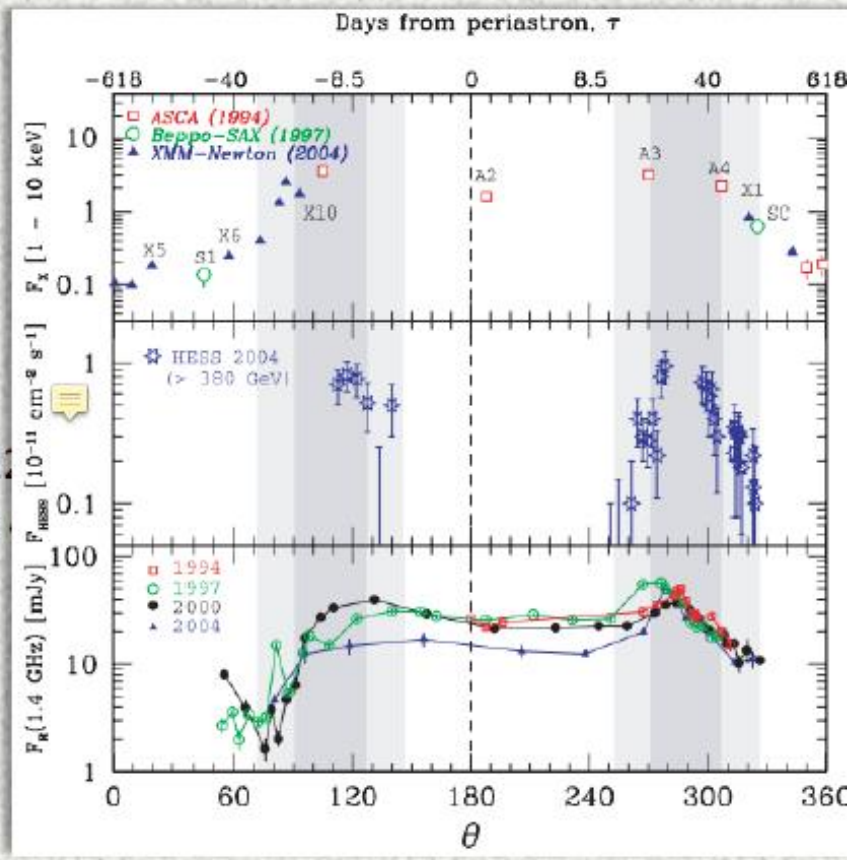


X-ray/TeV emission

X-ray/ TeV maximum emitted by the shocked relativistic electrons via Syn. and IC respectively

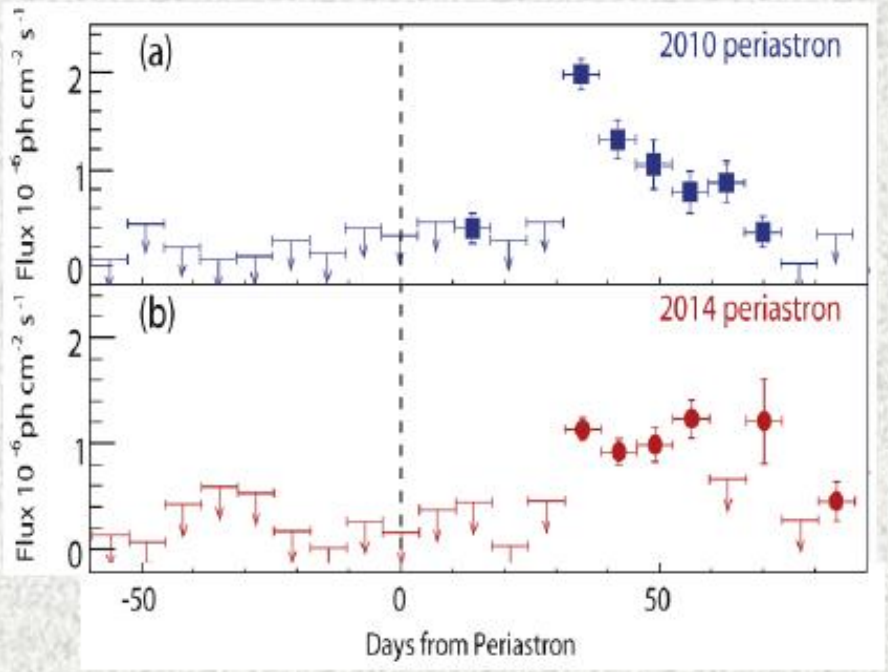


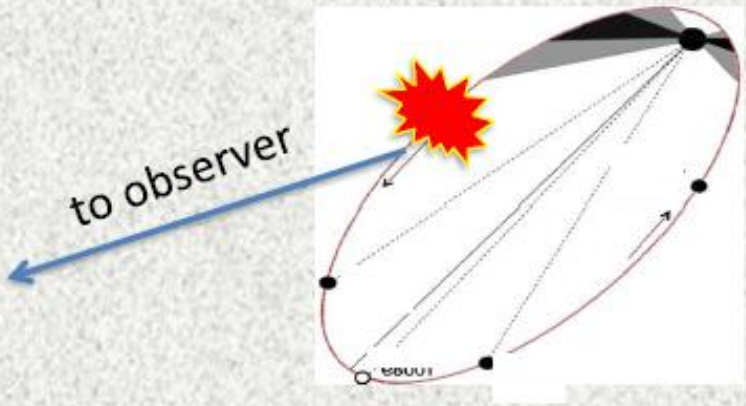
PSR B1
spin P:



orbit P = 1237 days

Emission in 100 MeV-100 GeV





GeV flare at un-expected orbital phase

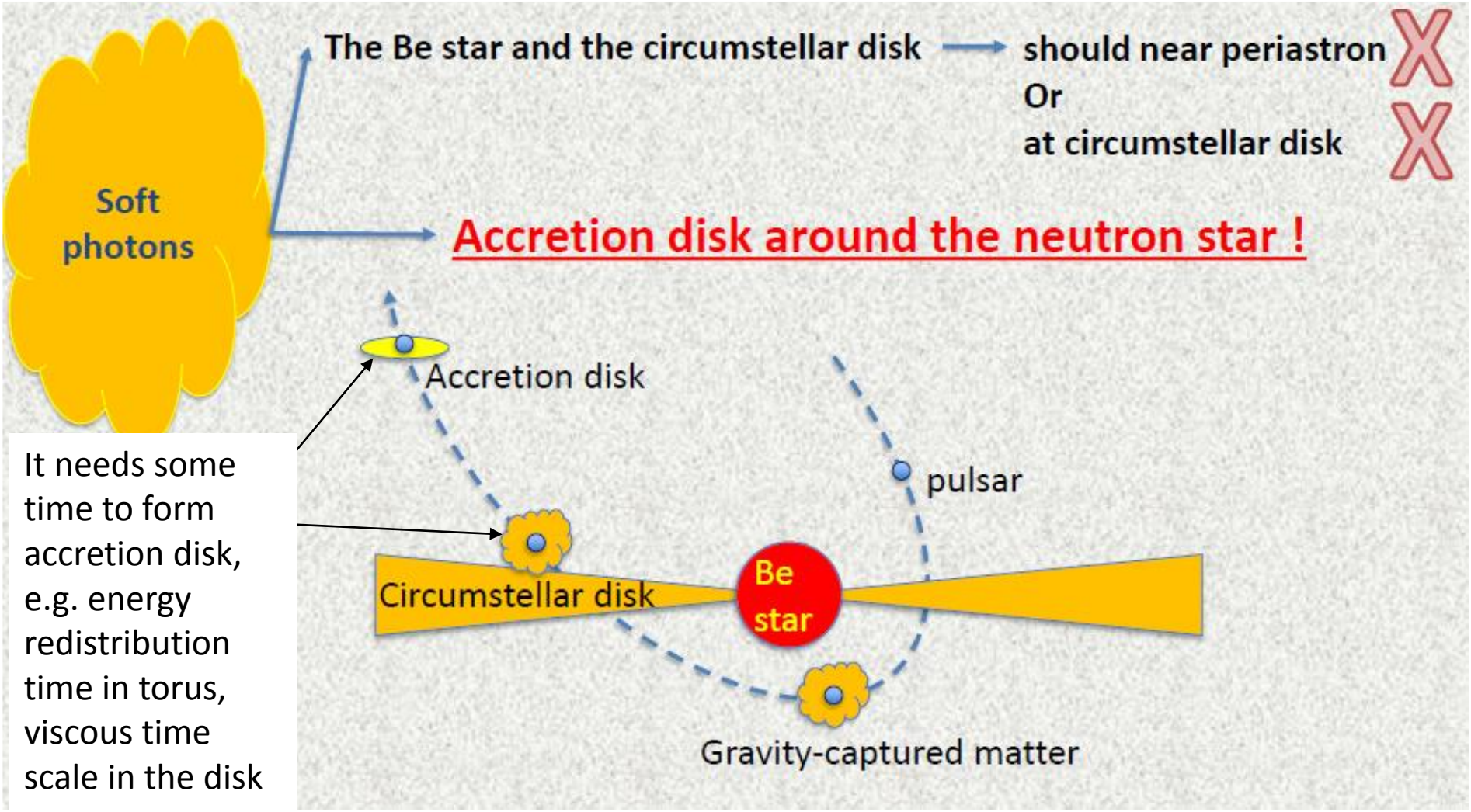
Tam 2011, Abdo 2011, Caliandro 2015

The next periastron passage occurs around September this year, we expect another GeV-flare should happen.

What are the emission mechanism for GeV-photons?

- Synchrotron emission with Doppler boosting effect from shock or IC between lower energy shocked electrons and circumstellar disk photons
- These two possibilities should make GeV peak at the same orbital phase as X-rays/TeV
- If IC is still the emission mechanism of GeV photons, new lower energy relativistic electrons other than the shocked relativistic electrons and new soft photons are necessary.

Model for GeV-flare from PSR B1259-63/LS2883 (Yi & Cheng 2017)



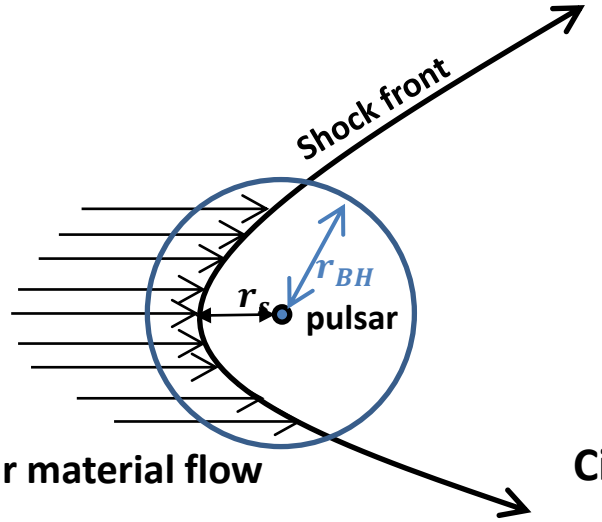
It needs some time to form accretion disk, e.g. energy redistribution time in torus, viscous time scale in the disk

Condition of mass transfer from optical companion

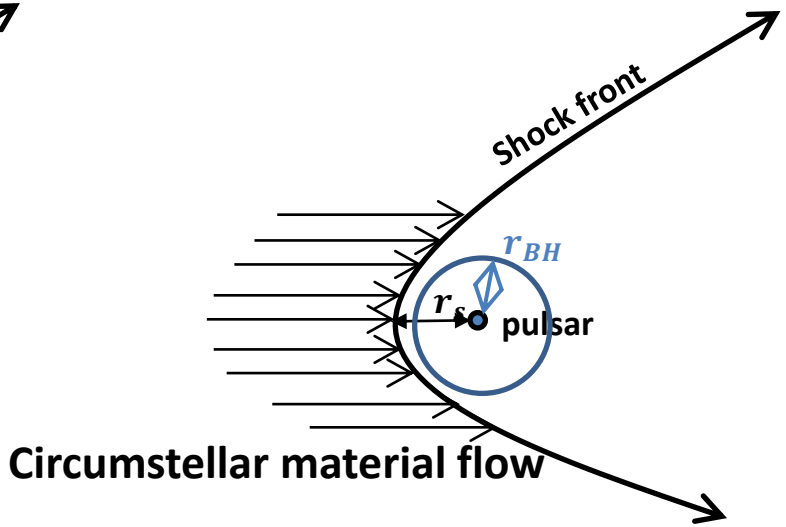
Shock from should inside the Bondi-Hoyle sphere

$$r_{\rm BH} = \frac{2GM_{\rm p}}{v_{\rm rel}^2},$$

$$r_{\rm s} = \sqrt{\frac{L_{\rm spin}}{4\pi\rho_{\rm cd}v_{\rm vel}^2 c}},$$

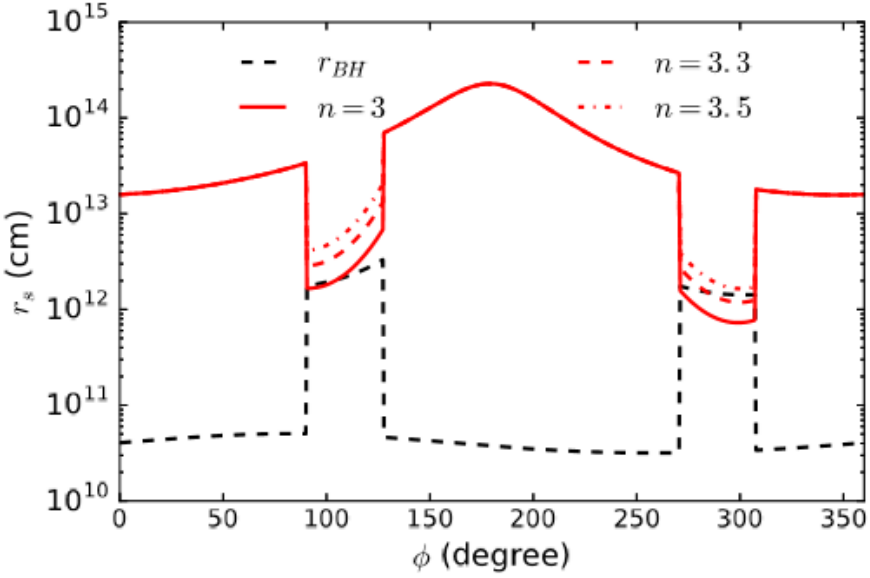


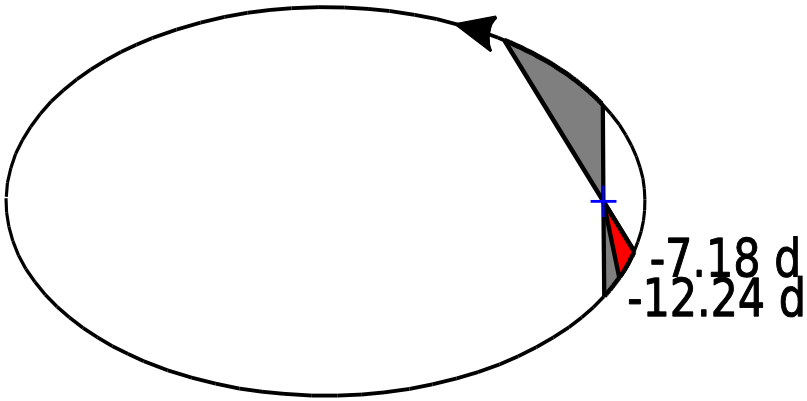
Mass can transfer



Mass can NOT transfer

Location of the circumstellar disk, and phases of mass transfer





n represents the density profile of the circumstellar disk

Condition of the formation of accretion disk

- The transferred material should have enough specific angular momenta: $r_{circ} > r_{lc}$
- $r_{circ} = \frac{l^2}{GM_p}$
- The angular momenta of the transferred material are due to the density and velocity gradient of the circumstellar disk.

$$l(t) = \frac{(GM_{\rm p})^2}{v_{\rm rel}^3}\left(\frac{|\nabla v_{\rm vel}|}{v_{\rm rel}} + \frac{|\nabla \rho_{\rm cd}|}{\rho_{\rm cd}}\right).$$

Formation of transient disk around NS during the passage of stellar disk

Yi and Cheng 2017

- Mass are captured by the gravity of NS during the passage of the CD
- The capture matter spiral in to form an accretion disk surrounding the pulsar, which takes roughly a few tens days (viscous time)
- The optical/UV emission is gradually increasing with time as the disk moves in and decreasing with time after reaching the Alfven radius (cf. Fig.1)
- GeV gamma-ray emission via IC between PW and disk photons (Fig. 2 and 3)

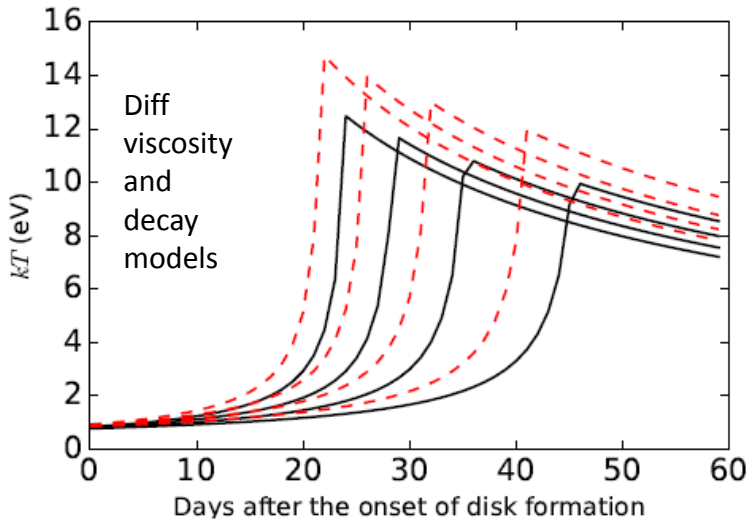


Fig. 1 Time for the peak T depends on α

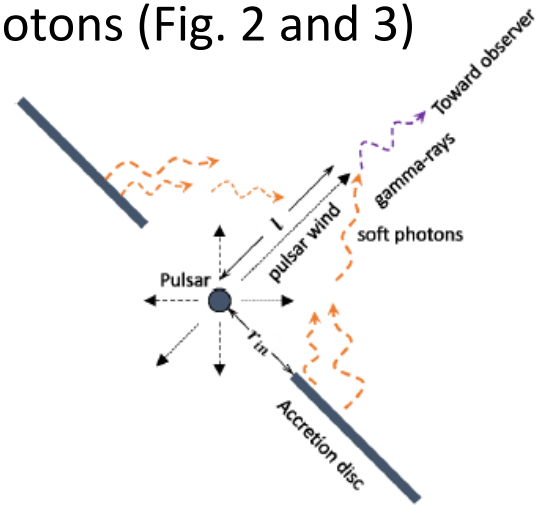


Fig. 2

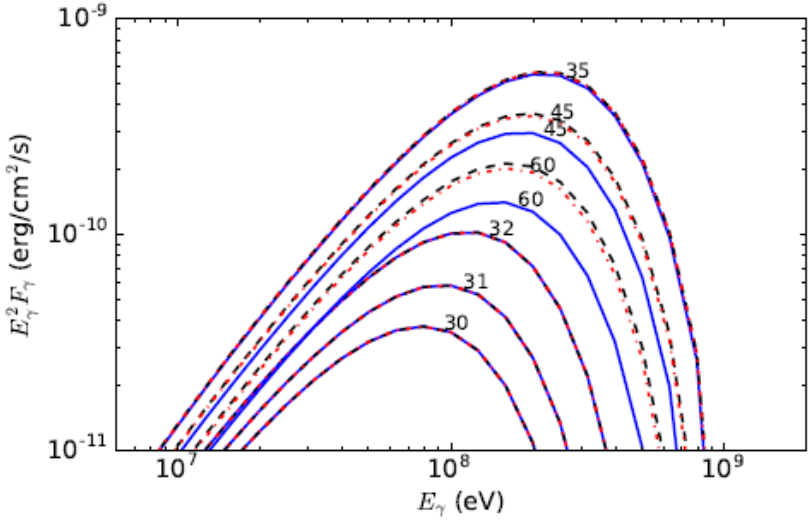
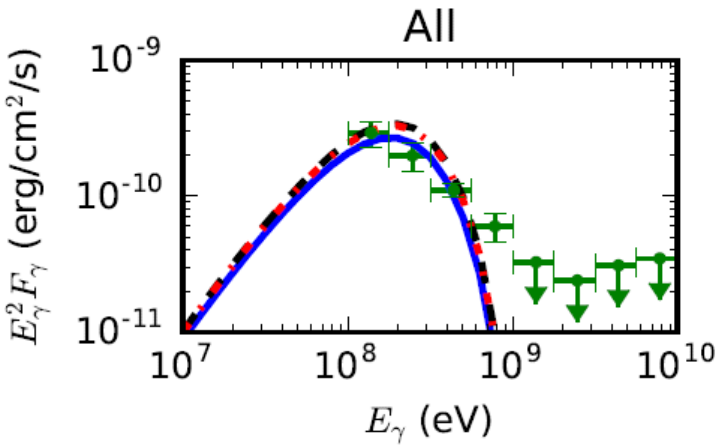
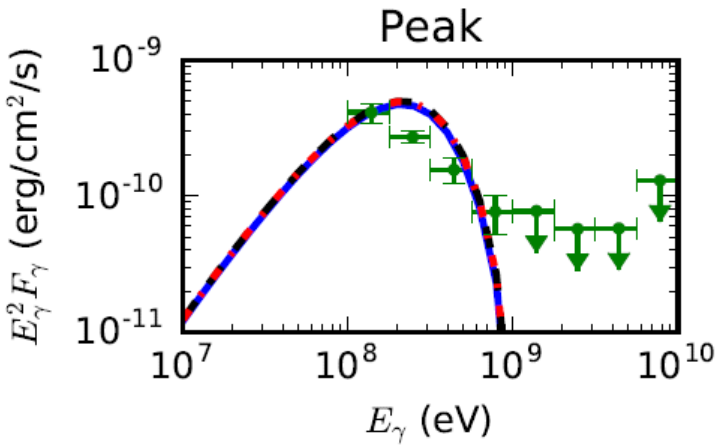


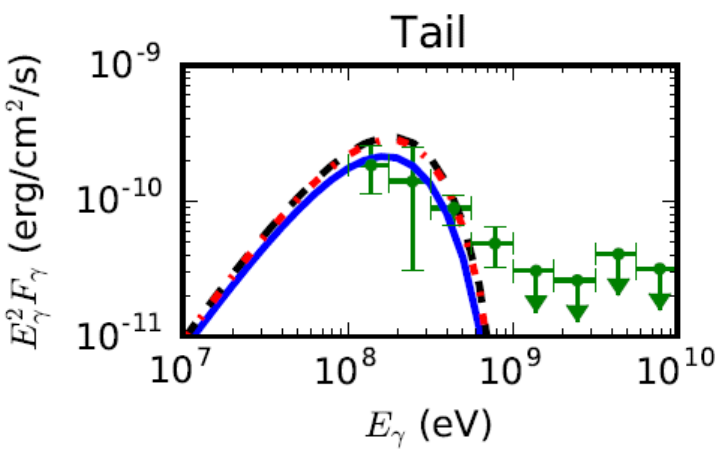
Fig. 3 Time evolving spectrum

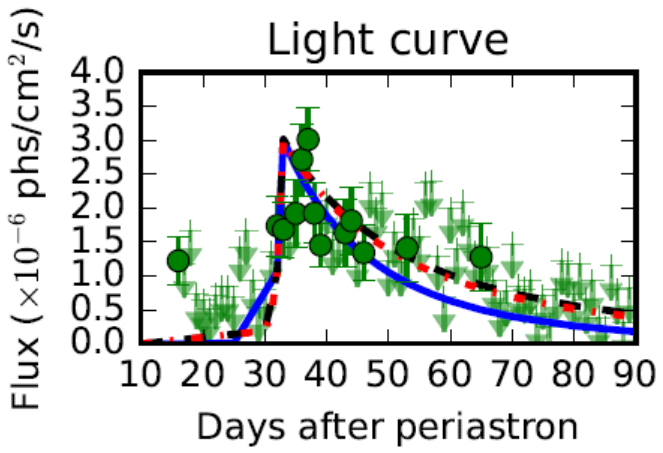
Transient gamma-ray emission via IC between the accretion disk photons and PW

Data : Caliandro et al. (2015)



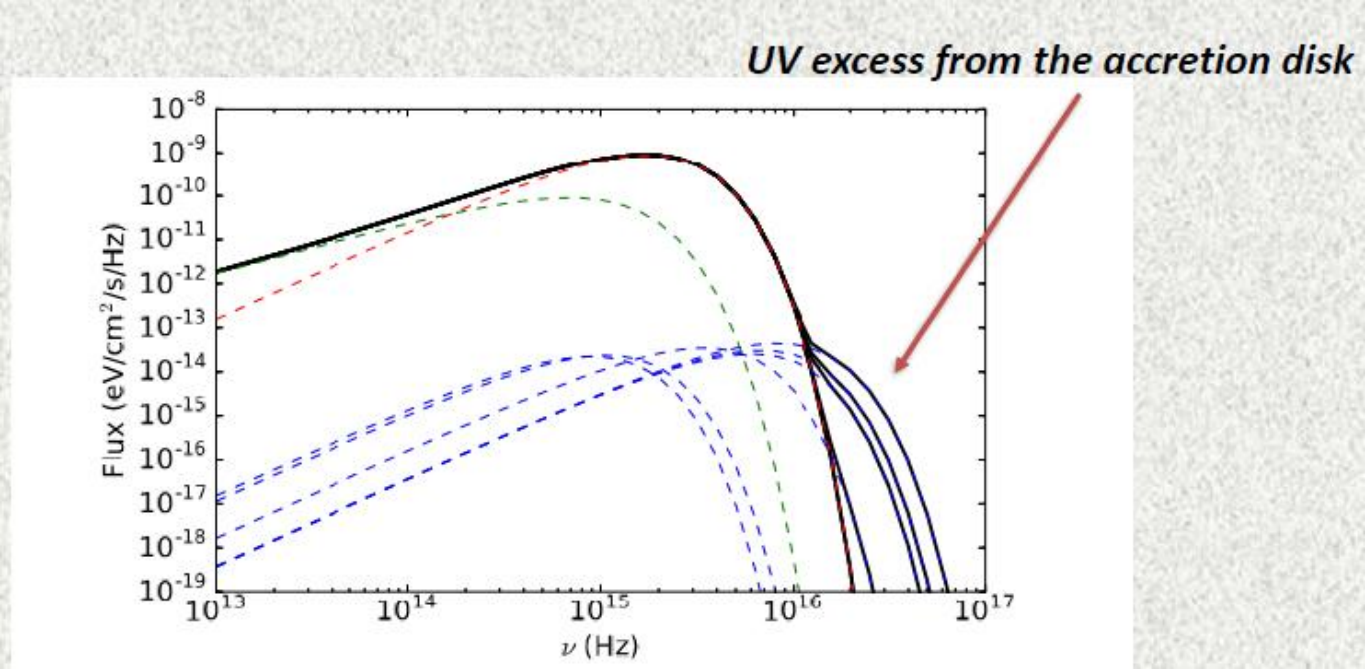






Model predictions

- UV



- The disk also produces addition spin-down torque and hence $\dot{P}$ should be larger during the GeV-flare phase

Summary

- We suggest that once a transient disk is formed around the pulsar a new component in GeV range should be produced via IC between the cold pulsar wind and the disk soft photons. In addition to PSR B1259-63/LS2883, we speculate that two gamma-ray binaries with Be companion but not yet detected in GeV PSR J2032+4127/MT91 213 (Takata et al. 2017) and HESS J0632+057 may also have GeV-flare after passing through the Circumstellar disk.
- The existence of disk can be examined by UV excess and larger $\dot{P}$.