Gamma-gamma absorption in gamma-ray binaries

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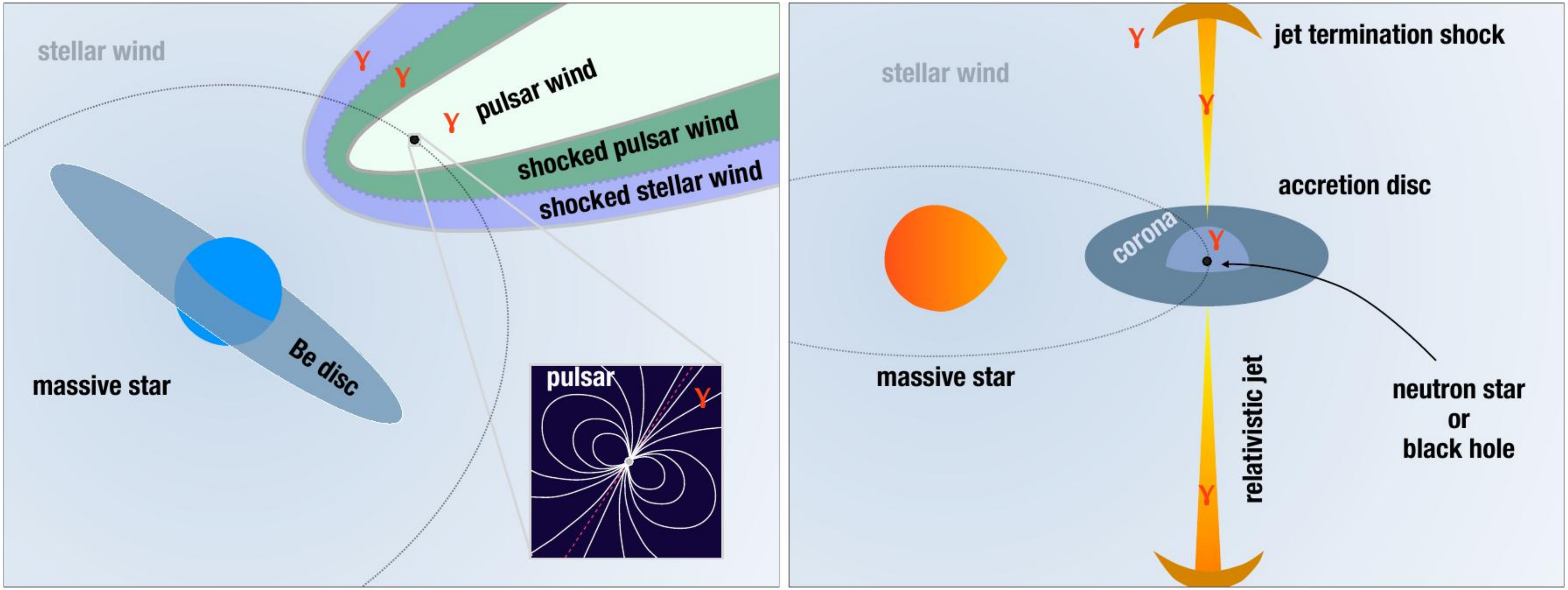
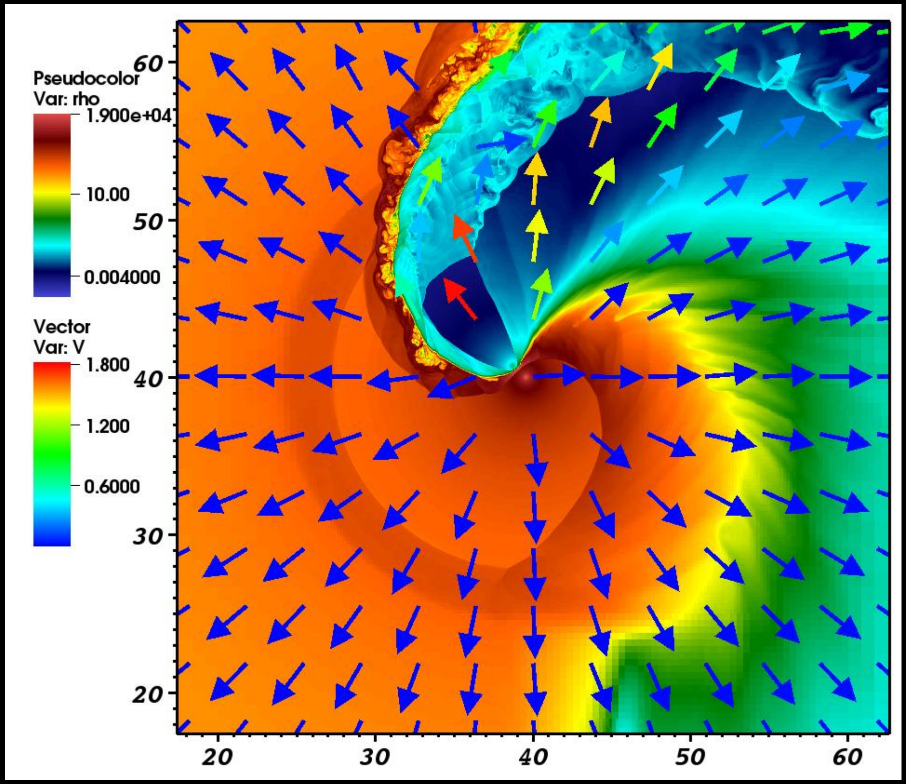
UFS

Gamma-ray binaries

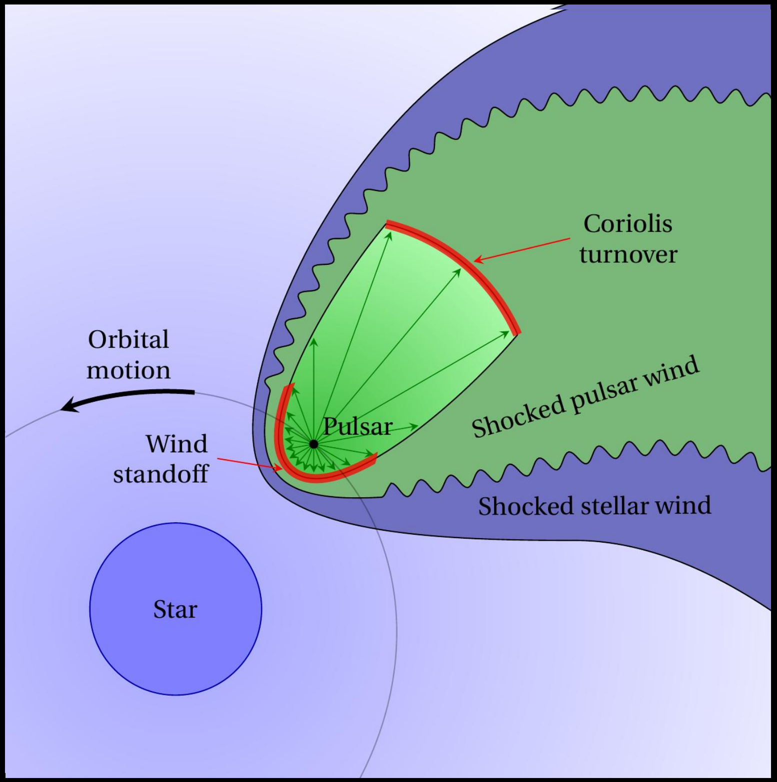


Dubus 2013

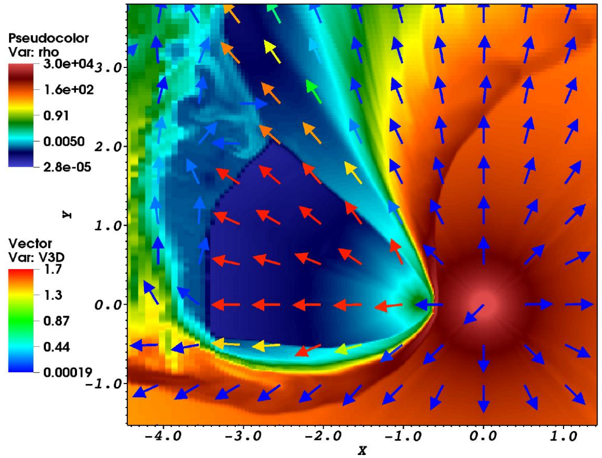
Possible emission locations



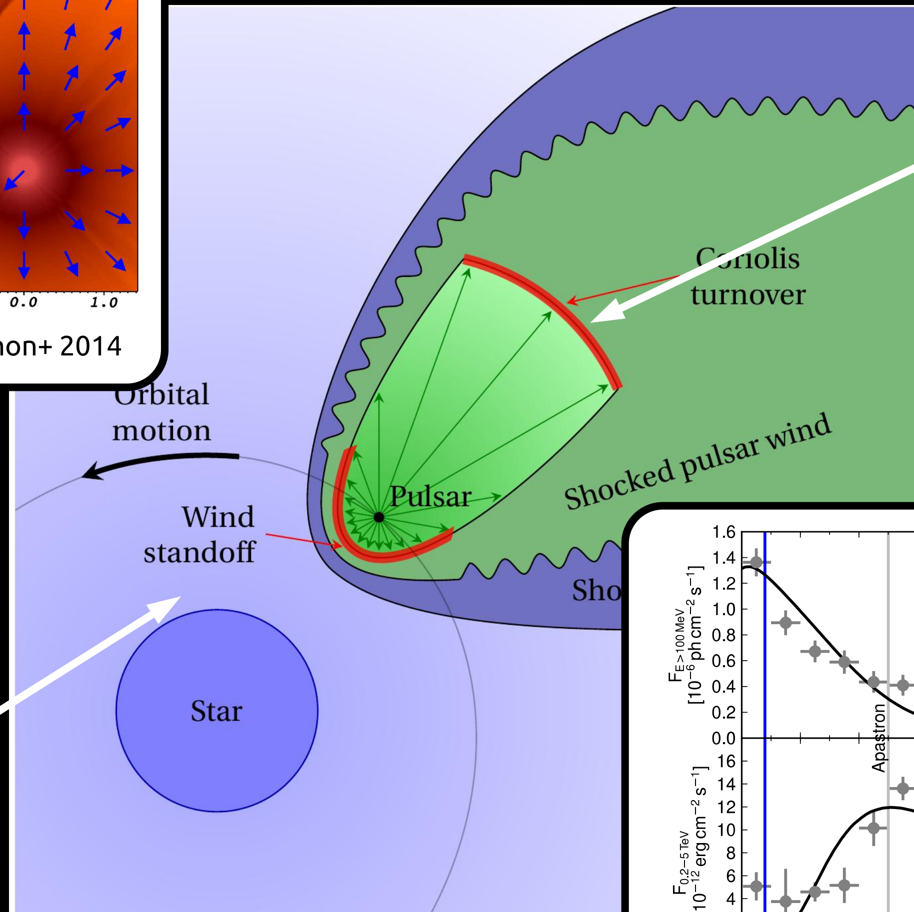
Bosch-Ramon et al 2012



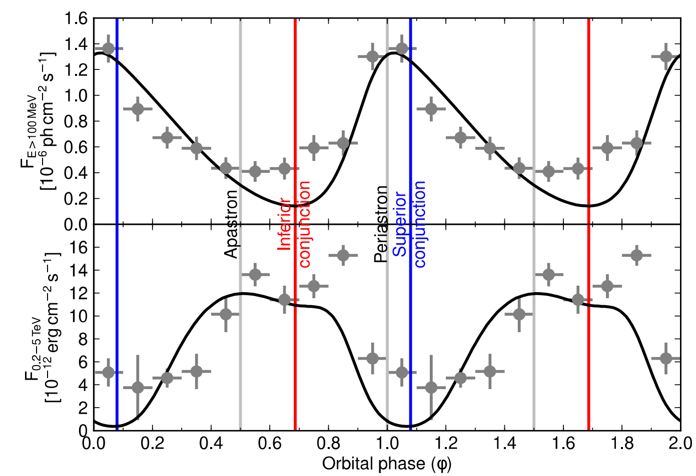
Zabala et al. 2013



Bosch-Ramon+ 2014



Secondary emission region



Applied to LS 5039 (Zabala+ 2013)

Gamma-ray photons will undergo gamma-gamma absorption

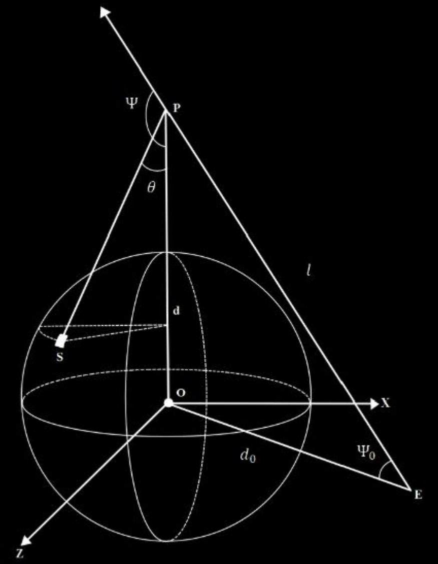
Gamma-gamma absorption and IC emission

Performed the full calculation of the absorption around the gamma-ray binaries

$$\tau_{\gamma\gamma} = \int_0^\infty d\ell \int_0^{4\pi} d\Omega \int_{\frac{2}{\epsilon_\gamma(1-\mu)}}^\infty d\epsilon \, n_\epsilon \sigma_{\gamma\gamma}(\epsilon, \epsilon_\gamma, \mu)(1-\mu)$$

$$\sigma_{\gamma\gamma}(\beta) = \frac{3}{16}\sigma_{\mathrm{T}} \left(1-\beta^2\right) \left[(3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right) - 2\beta(2-\beta^2)\right]$$

$$\beta = \sqrt{1 - \frac{2}{\epsilon\epsilon_\gamma(1-\mu)}}$$

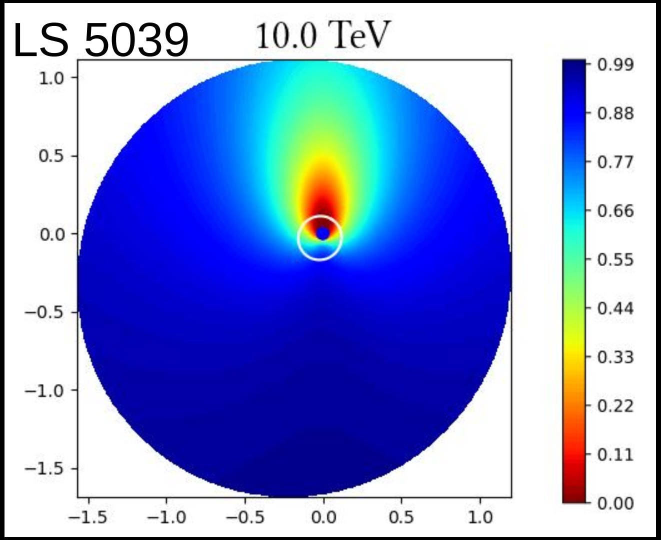


Results have been calculate for different inclination angles and a large range of binary separations.

Emission modelling done using the naima package, calculating the anisotropic inverse Compton emission – approximation from Khangulyan+ 2014.

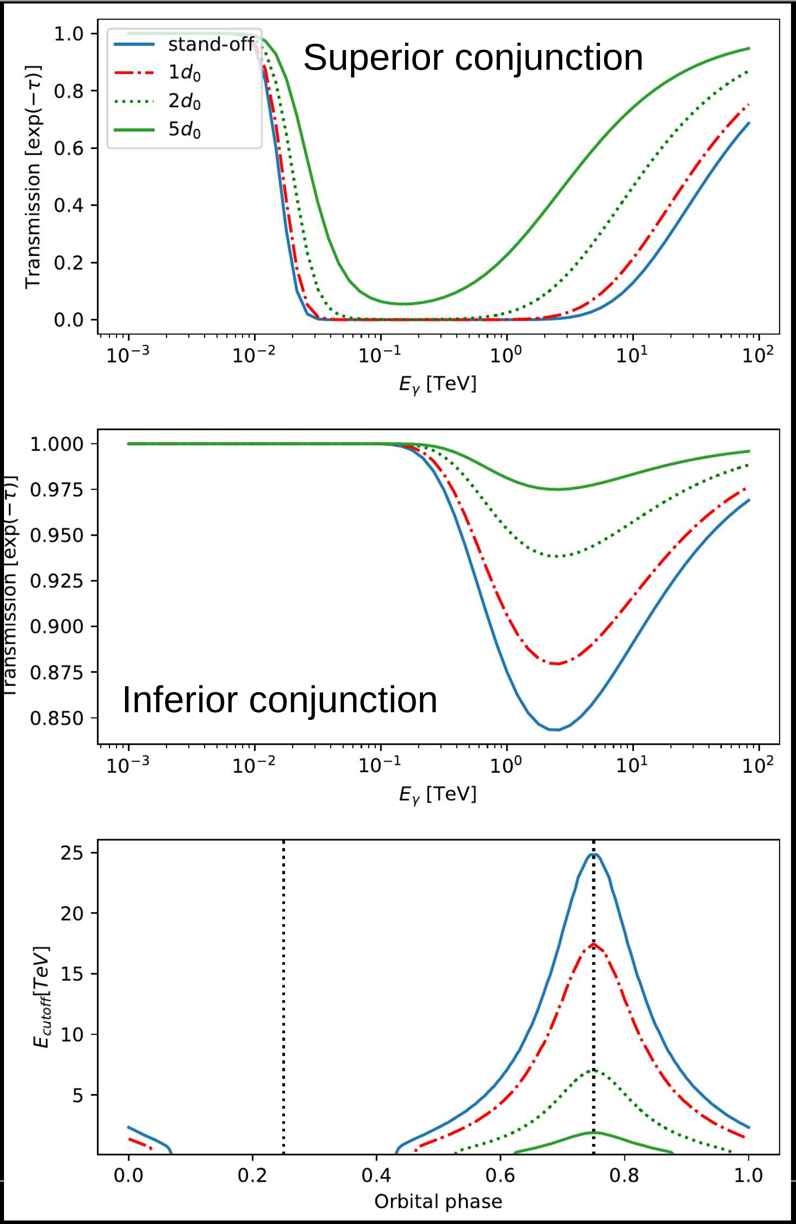
Caveats

- The absorption/emission is only calculated in the orbital plane
- Assume pulsar-wind scenario.
- Emission modelling assumes a point-source approximation for the star.
- The electron spectrum is assumed to be constant; no change, no particle cooling.
- The electron spectrum is matched to observed emission around inferior conjunction, where possible, no detailed modelling
- The instrument response hasn't been considered.

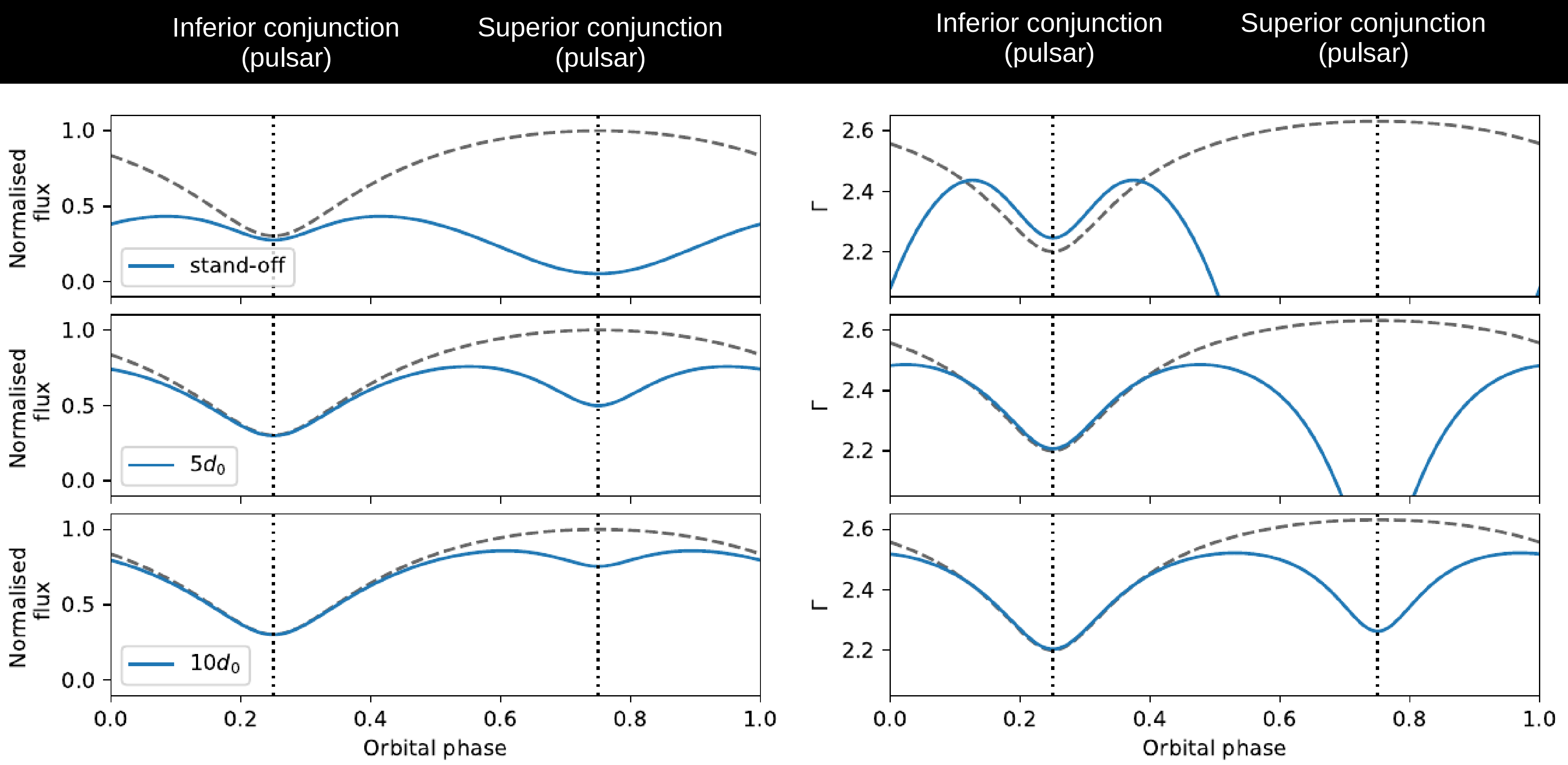


Test model - circular orbit

- Consider a perfectly circular binary
  - Period = 20.0 days
  - M_star = 25.0 Msun
  - R_star = 10.0 Rsun
  - T_star = 40 000 K
  - M_co = 1.4 Msun
  - Inclination = 65.00 degrees
  - Eta=0.1
- All else being equal, the change observed at TeV energies should only be determined by the change in angle between the star, emitting region and the observer.
- There is change in the level of absorption and the energies at which the absorption becomes significant
- The energy of the“low energy cut-off” changes with orbital phase

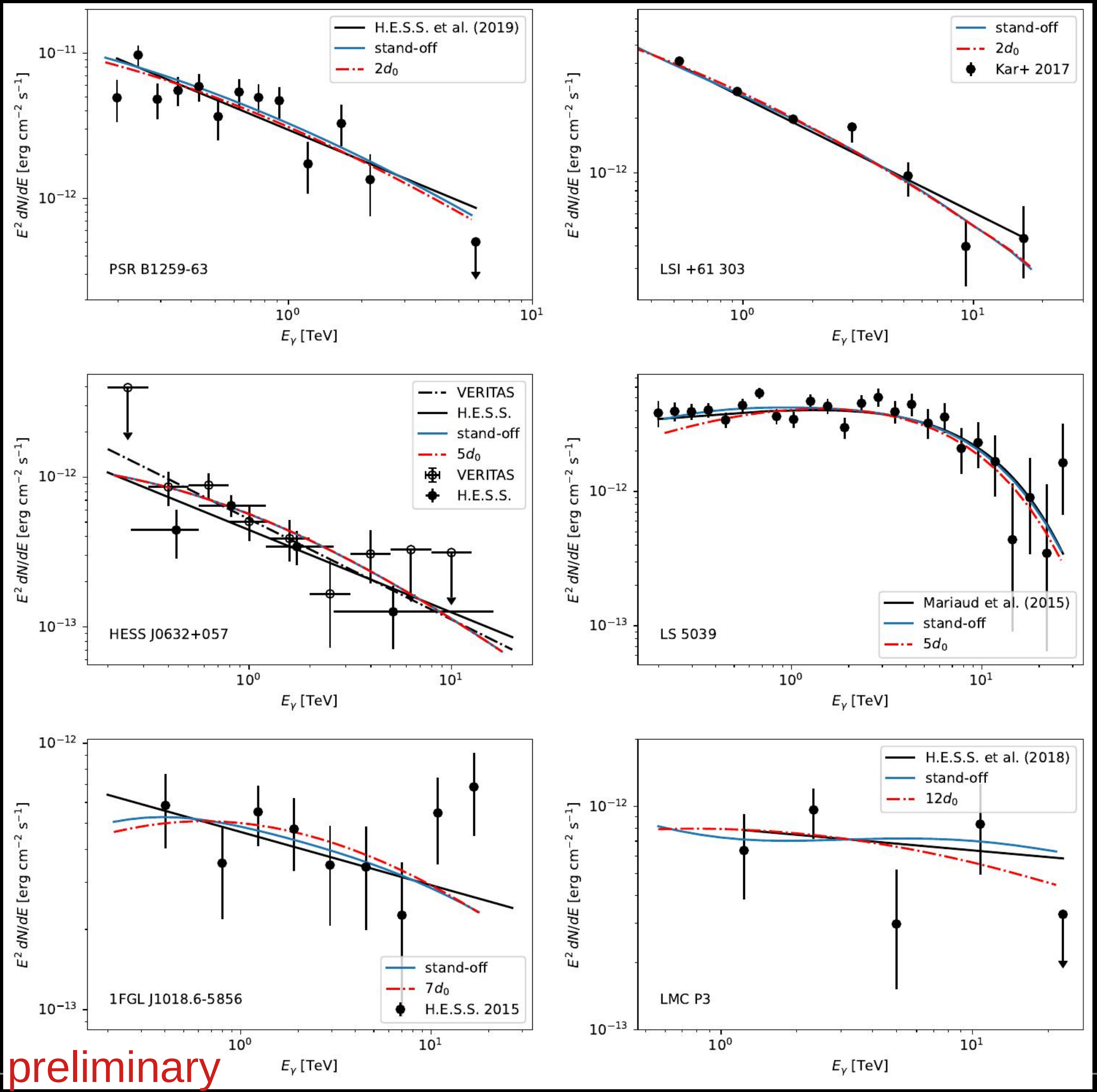


Test model - Expected emission from inverse Compton scattering

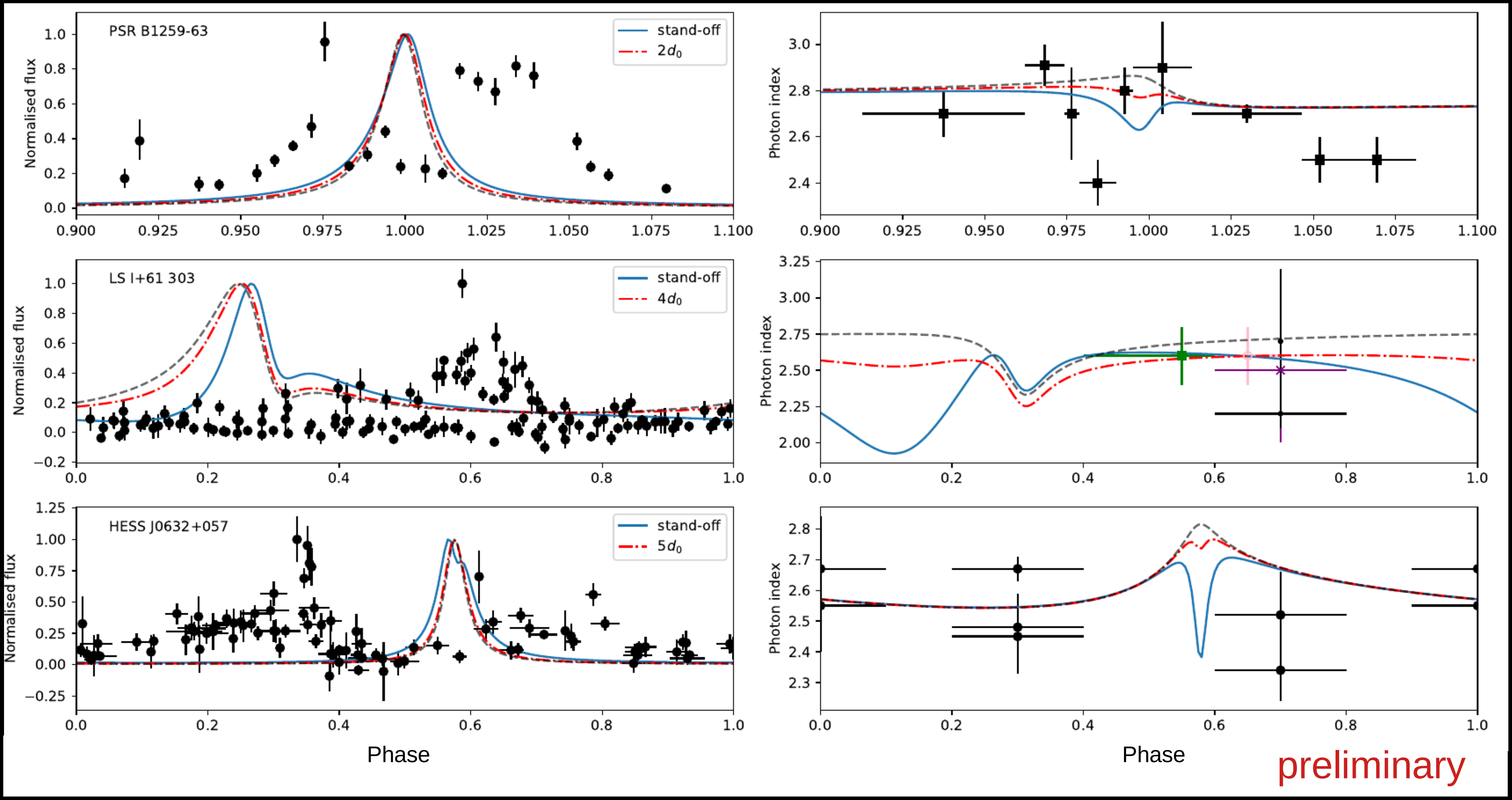


Application to known gamma-ray binaries

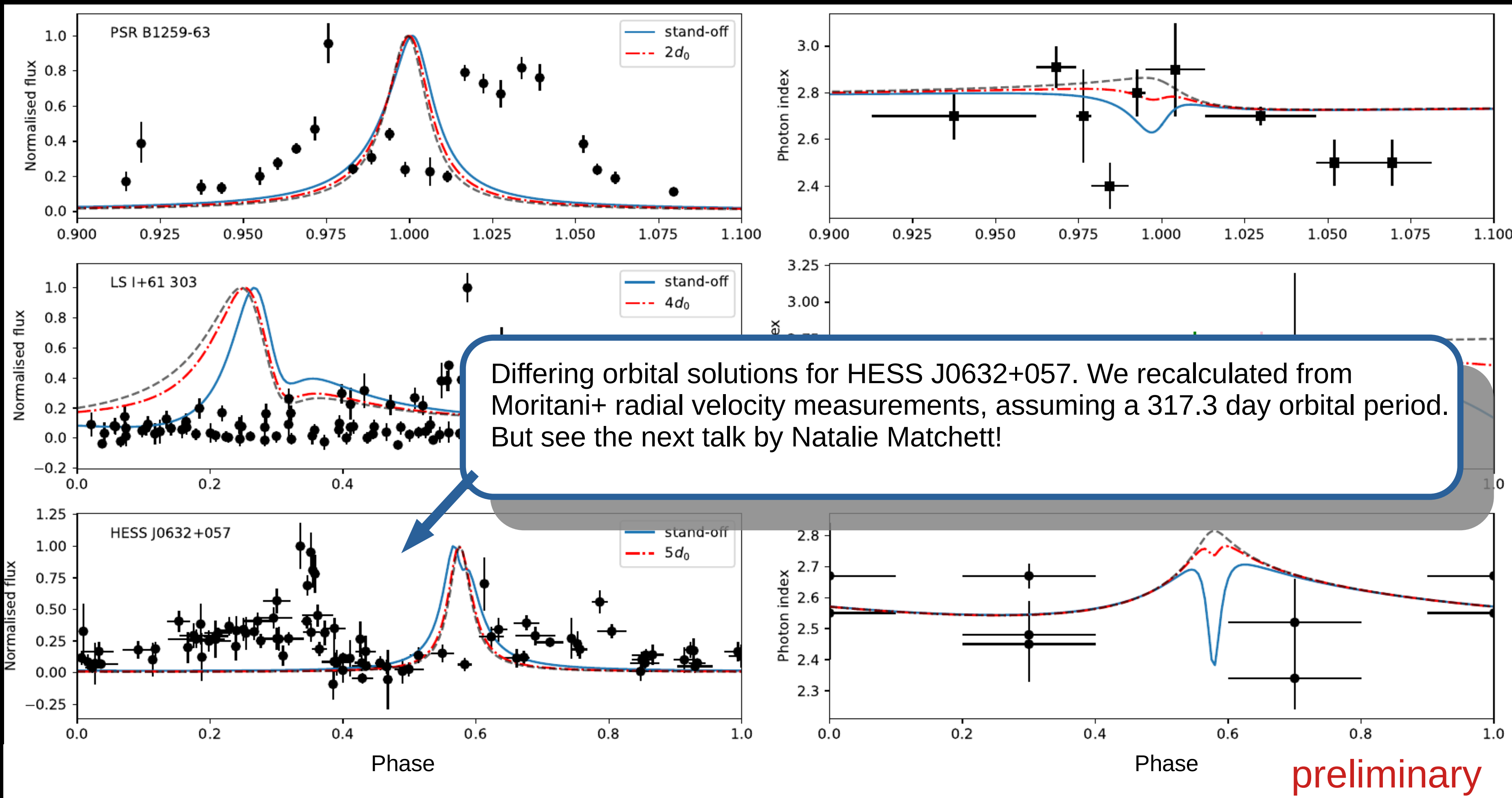
- Adapted to the six sources with known orbital solutions (excluding PSR J2032+4127)
- Electron spectrum is modified to approximate the observed spectrum, taking into account gamma-gamma absorption
- Assume power-law electron spectrum for all sources, except LS 5039.



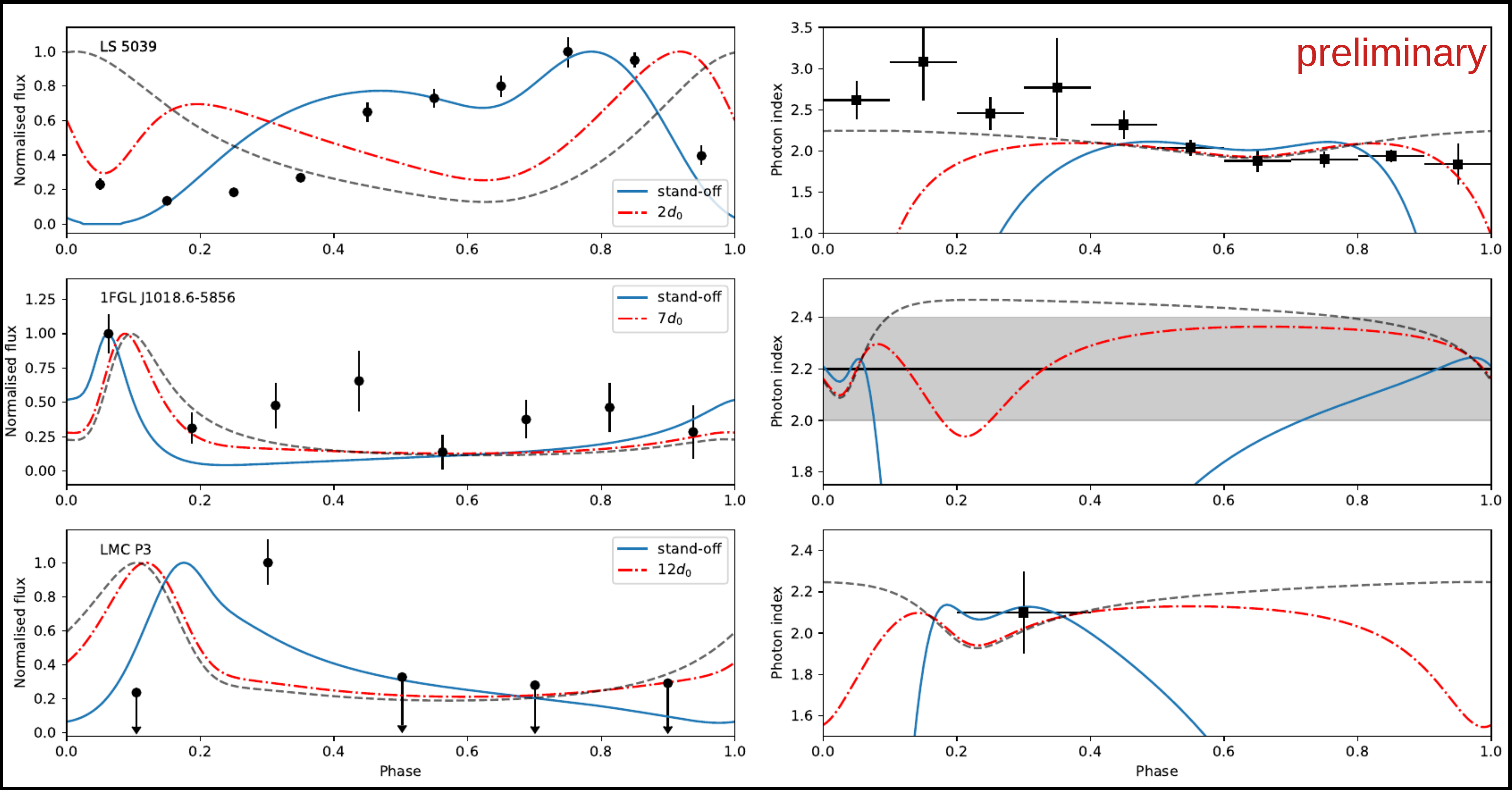
Oe/Be systems



Oe/Be systems



O star systems



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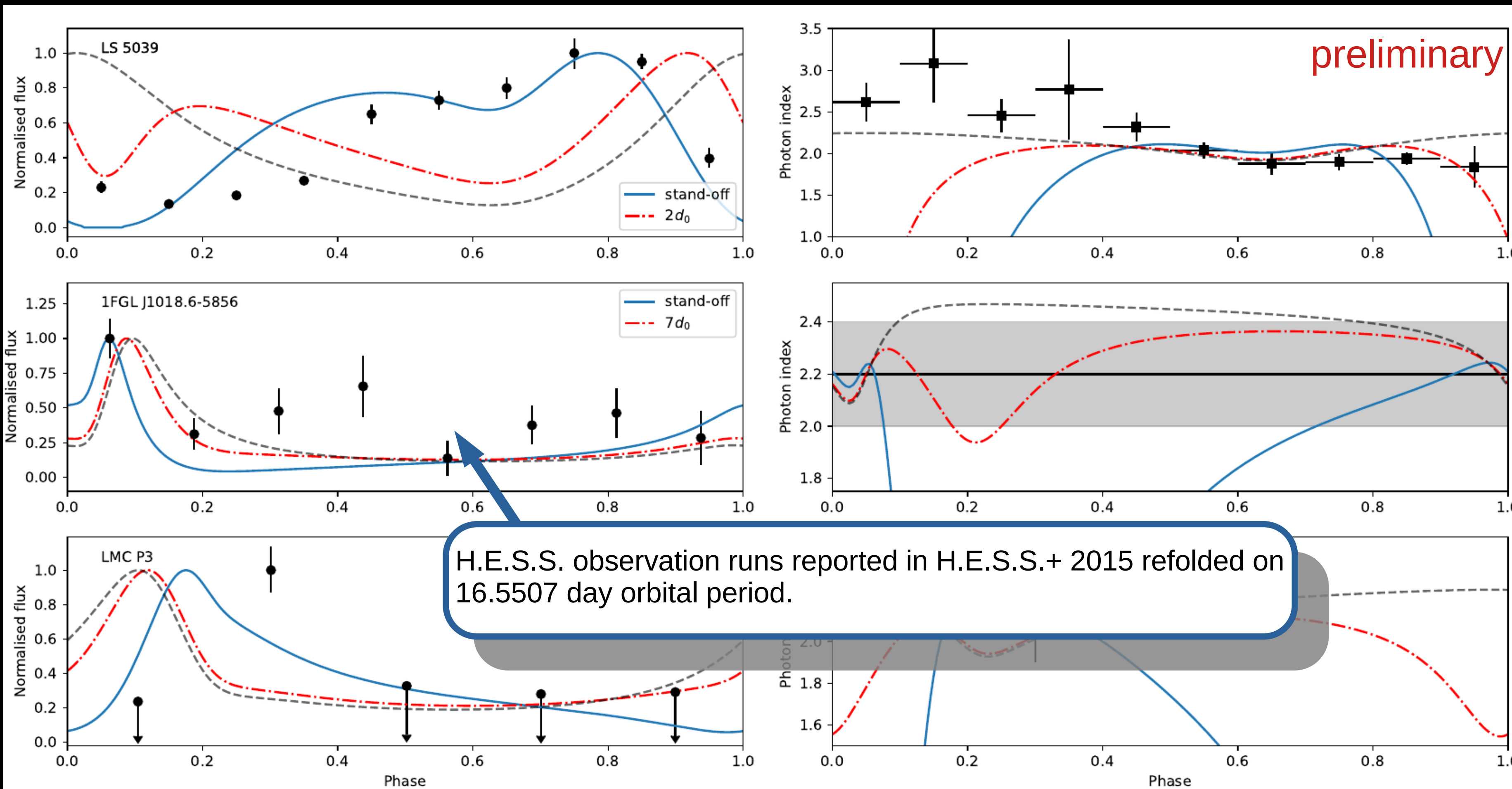
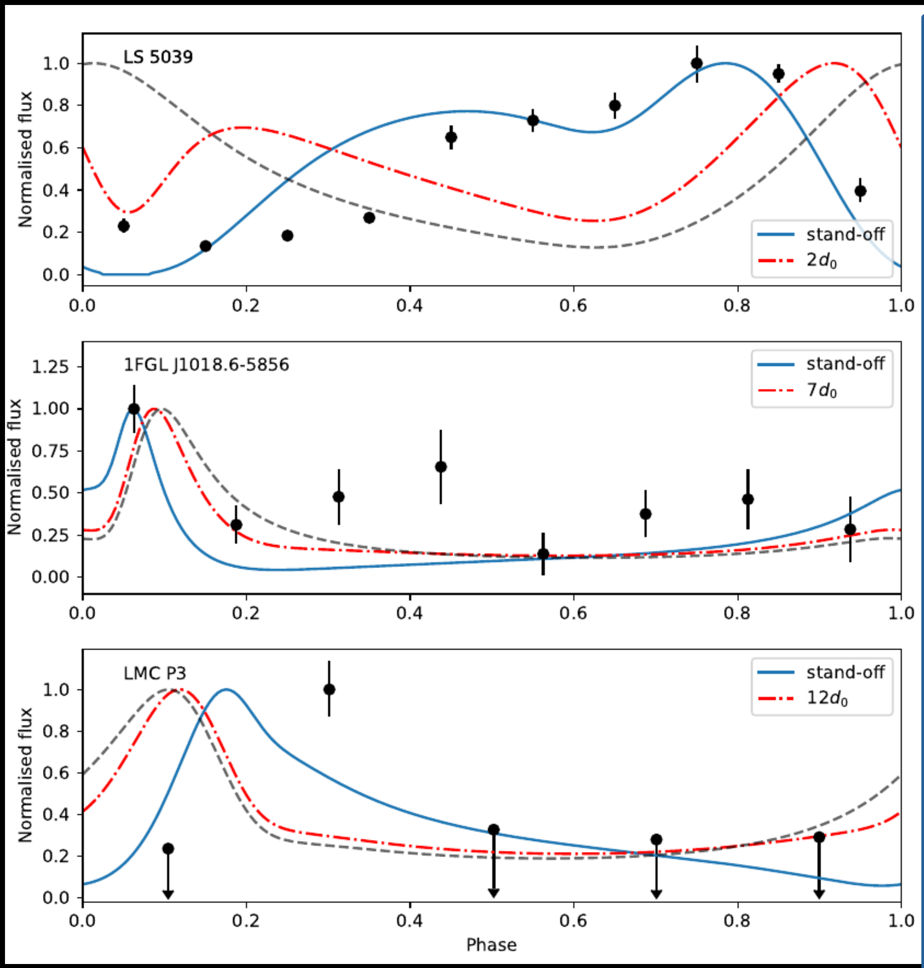
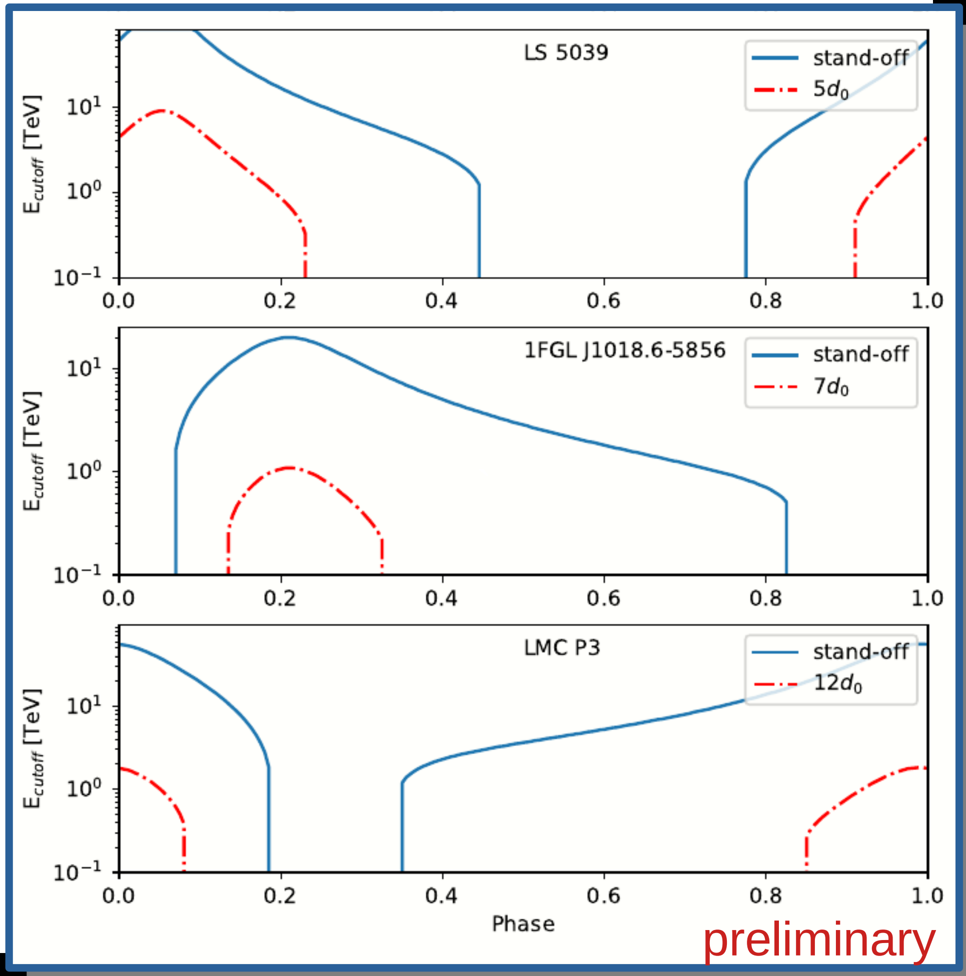


H.E.S.S. observation runs reported in H.E.S.S.+ 2015 refolded on 16.5507 day orbital period.

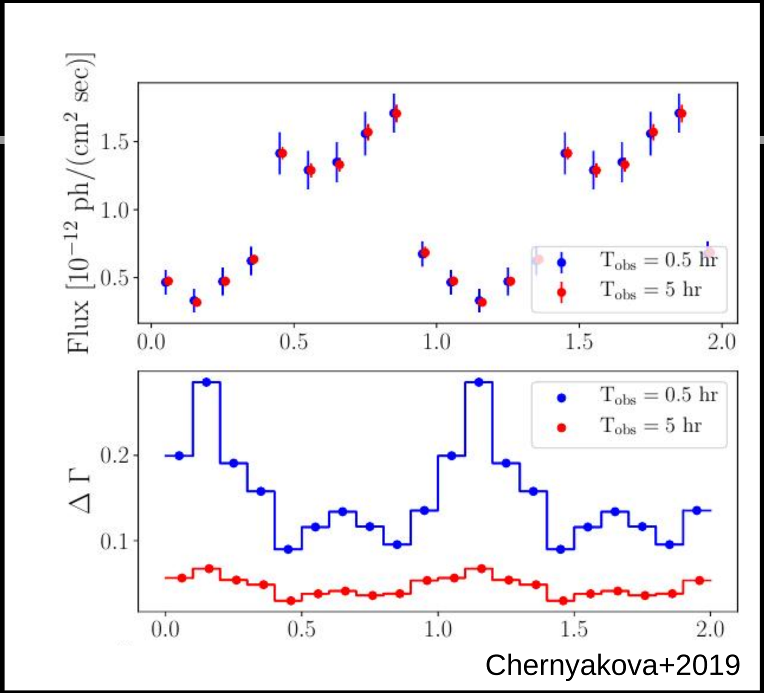
O star systems

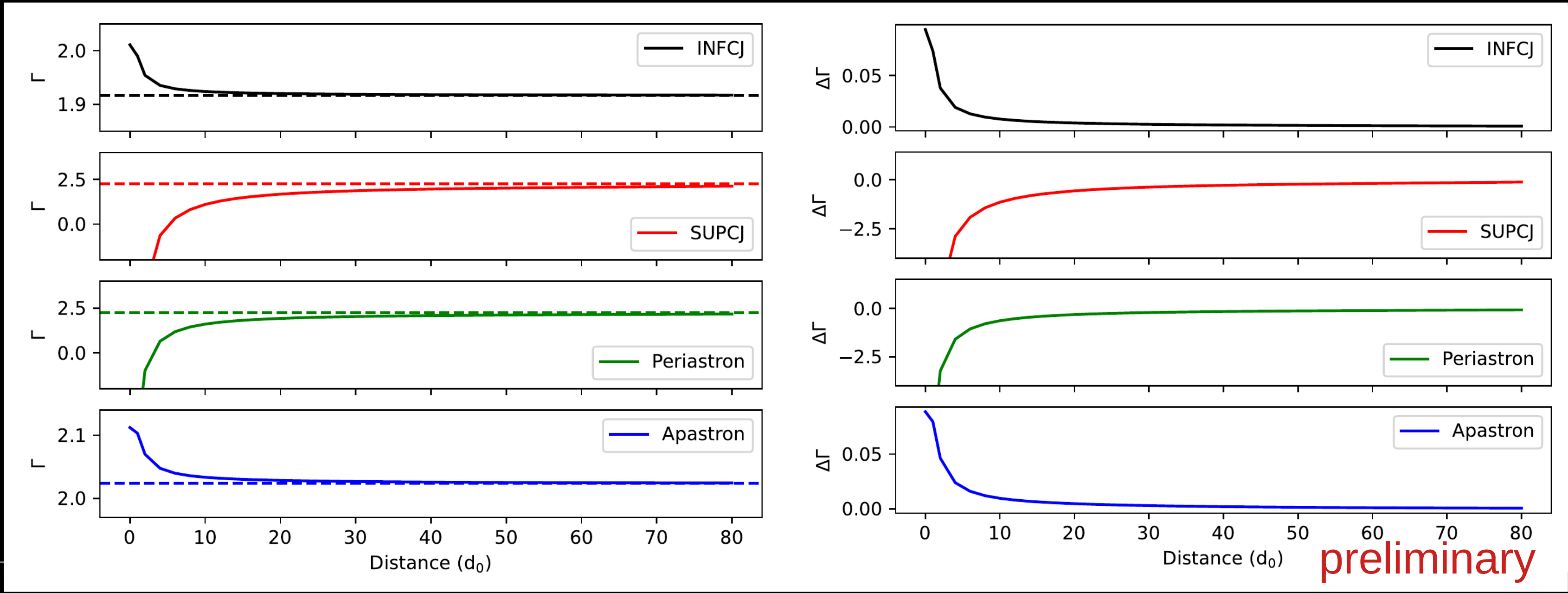




CTA

- The predictions for CTA show a much better constraint on the photon index
- For LS 5039, errors < 0.1 for 5 hour observations
- At certain phases, the gamma-gamma absorption induced change of the photon index will be of the order of ~0.1 depending on distance from the star





Conclusions

- Full calculation of the gamma-gamma absorption in the plane of the binary has been performed
- Overall the alignment with the maximum in TeV flux agrees fairly well with the minimum in the gamma-gamma absorption for systems with shorter periods/O-type stars.
- Since the gamma-gamma absorption is a maximum around 0.1-1 TeV, this could make the spectrum appear harder when fainter at VHE.
- A cut-off should be introduced at lower energies independent of the emission process/electron distributiont.
- The higher sensitivity of CTA could allow us to directly constrain where the emission occurs from in the system.

Thank you

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