Joint Modeling of GeV and PeV Orbital Modulation of Cygnus X-3

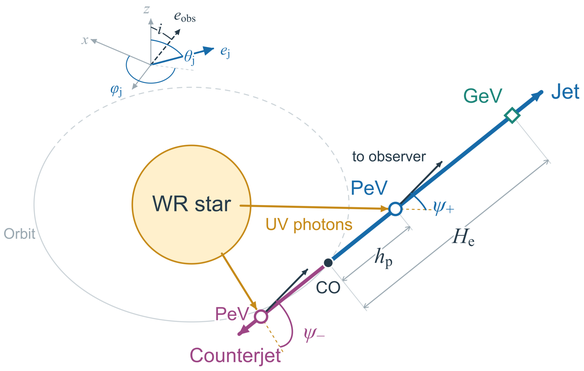
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Abstract

LHAASO has reported evidence for orbital modulation of PeV gamma rays from Cygnus X-3. We jointly model the Fermi-LAT and LHAASO light curves and spectral energy distributions using a shared jet geometry with separate electron and proton emission heights. Anisotropic stellar inverse-Compton and photomeson emission connect the two energy bands. We examine *pp* emission as a weakly modulated PeV baseline and consider photomeson interactions with central X-ray photons as a possible alternative.

Geometry and radiation model

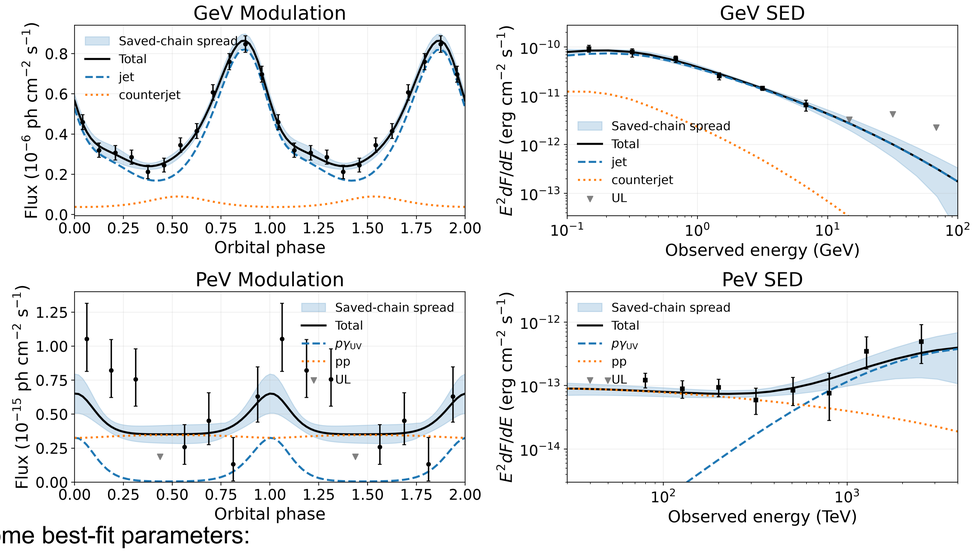


Electrons produce **external inverse-Compton (EC) emission** from stellar UV photons [1,2]. Protons radiate through ***pγ*$_{UV}$ plus *pp* or *pγ*$_X$** [3]. We assume a straight jet with a fixed direction. The GeV and PeV emission **share this geometry but arise at different heights**.

We adopt a broken power-law electron spectrum shaped by IC and adiabatic losses. Protons follow a power law with an exponential cutoff, fixing the index at 2.3 and cutoff energy at 50 PeV.

Phase-varying collision angles modulate EC and *pγ*$_{UV}$ emission. UV absorption modulates *pp* and *pγ*$_X$ emission roughly in antiphase. Phase-independent, energy-dependent CMB+ISRF attenuation reshapes the observed PeV SED and the light curve [3].

Joint-fit: EC + *pγ*$_{UV}$ + *pp*

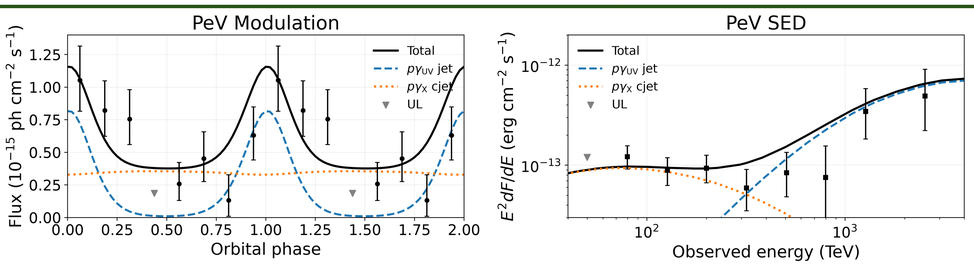


Some best-fit parameters:

Polar angle θ_j: 33.38°; Azimuth ϕ_j: 189.02°; Speed β_j: 0.642; Electron spectral index p: 4.16

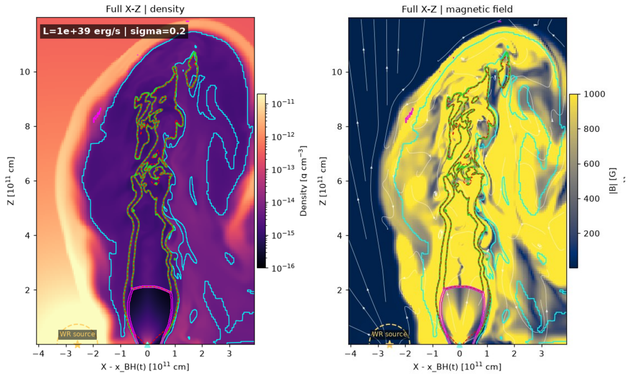
GeV emission height H_e: 6.04×10^{11} cm; PeV emission height h_p: 2.21×10^{11} cm

An alternative PeV radiation model: *pγ*$_{UV}$ + *pγ*$_X$



Model calculations with geometry close to that of the *pp* model suggest that *pγ*$_{UV}$ and *pγ*$_X$ may also describe the PeV radiation. **The *pγ*$_X$ emission is counter-jet dominated, in contrast to jet dominated *pp* emission.** For radial X-ray photons, the counter-jet has larger collision angles throughout the orbit.

Future Work



Our simulations suggest jet expansion and wind-driven bending, and also indicate strong magnetic fields. Future work will incorporate extended emission regions and magnetic-field effects, including synchrotron emission, cooling, and SSC.

References

[1] A. A. Zdziarski et al., MNRAS 421, 2956–2968 (2012).
[2] A. Dmytriiev et al., ApJ 972, 85 (2024).
[3] Z. Cao et al. (LHAASO Collaboration), Natl. Sci. Rev., nwag435 (2026).