Institute of Space Sciences

EXCELENCIA MARÍA DE MAEZTU

LS I +61 303 – 16 years at GeV

Daniela Hadasch

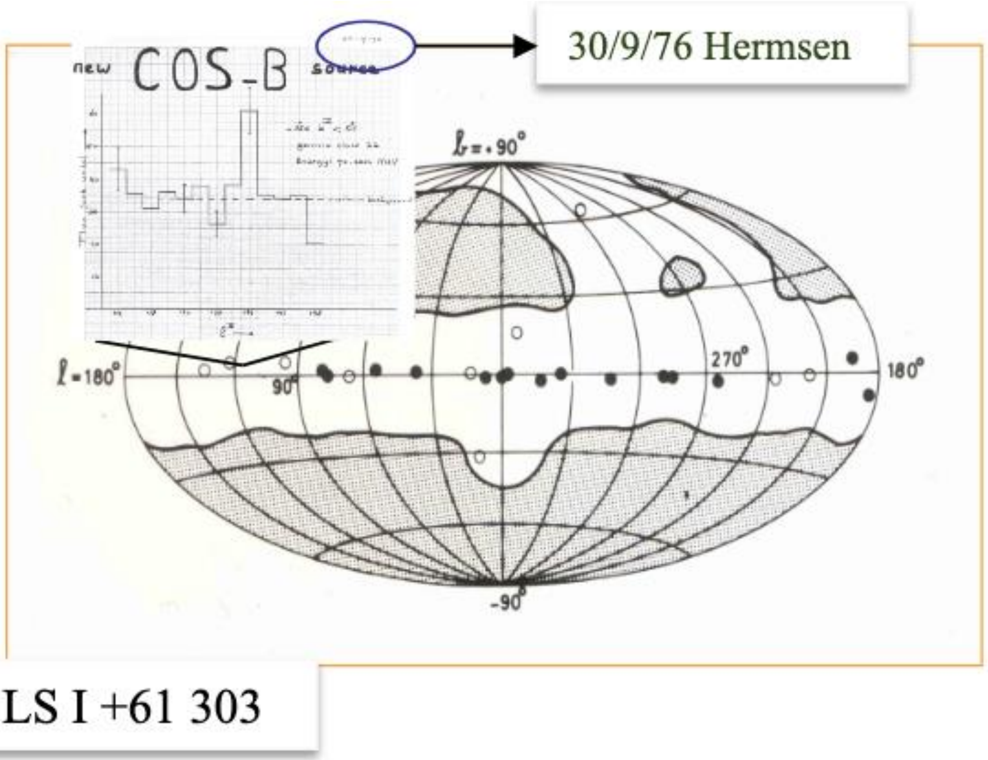
Overview

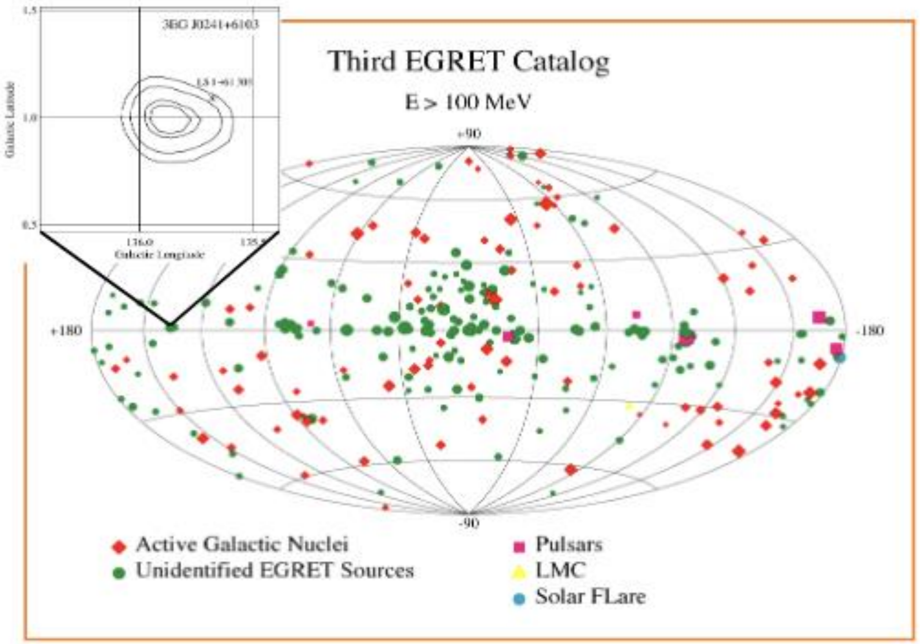
MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

- Addressed issues during the last decades.
- Open issues.
- For discussion: Prospects how to proceed.

First observations of LS I +61 303…

- …started ~50 years ago.
- No orbital variability detected.
- Source position not clear & source confusion → Binary could not be identified.

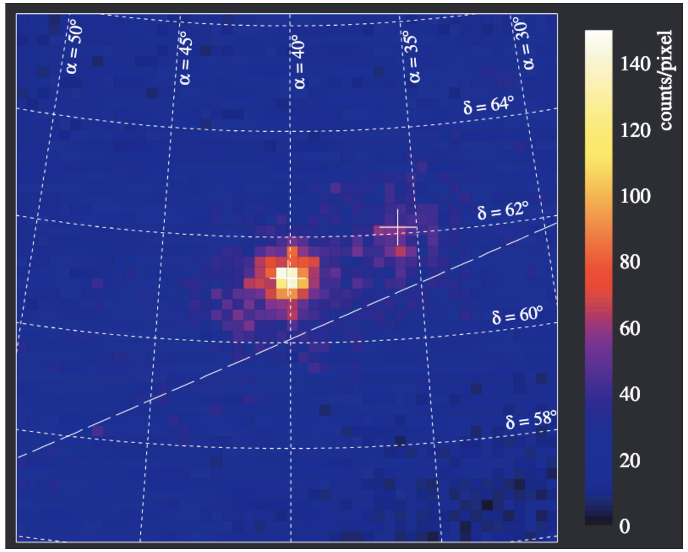




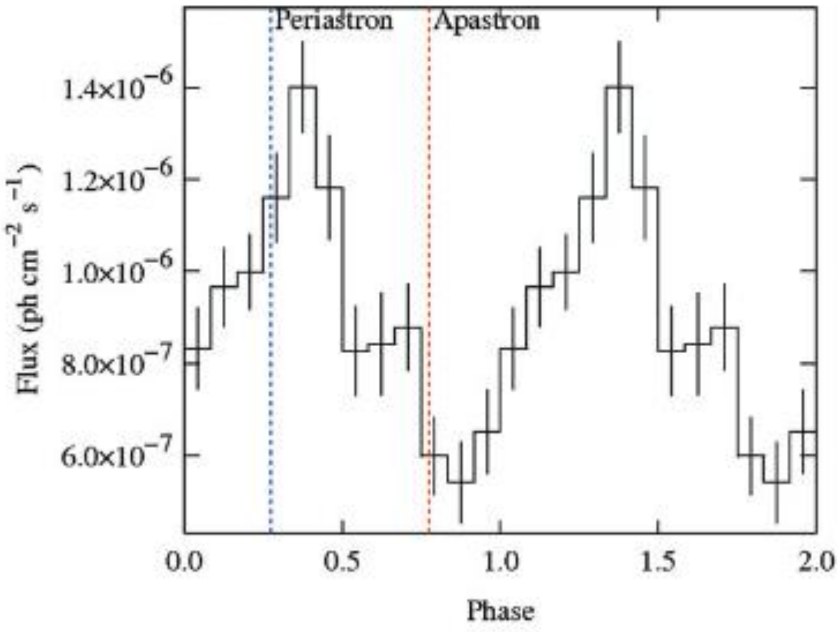
Fermi-LAT view on LS I +61 303

- Source position coincident with position known from the optical.
- Orbital variability clearly visible.
- Periodicity detected: 26.6 +/- 0.5 days.

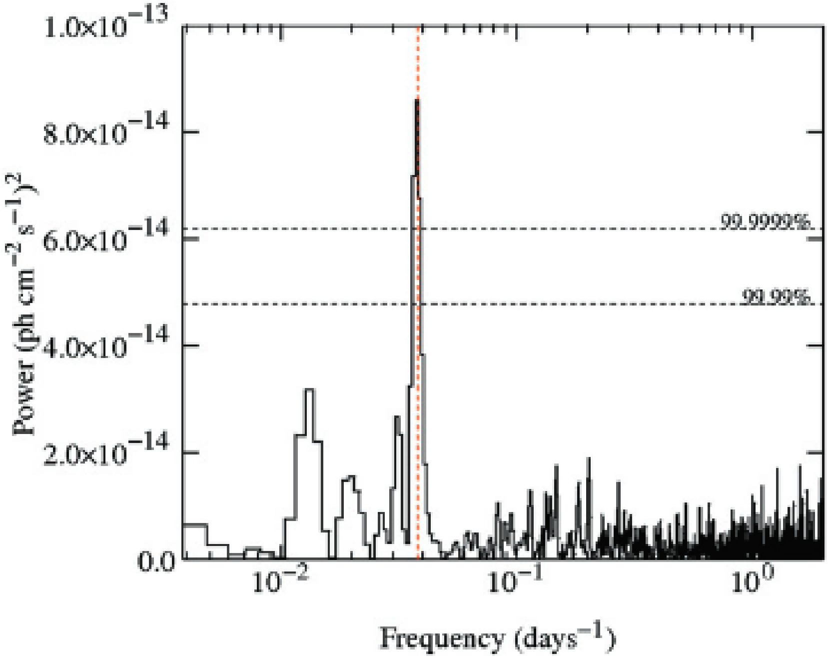
Counts map



Folded lightcurve



Power Spectrum

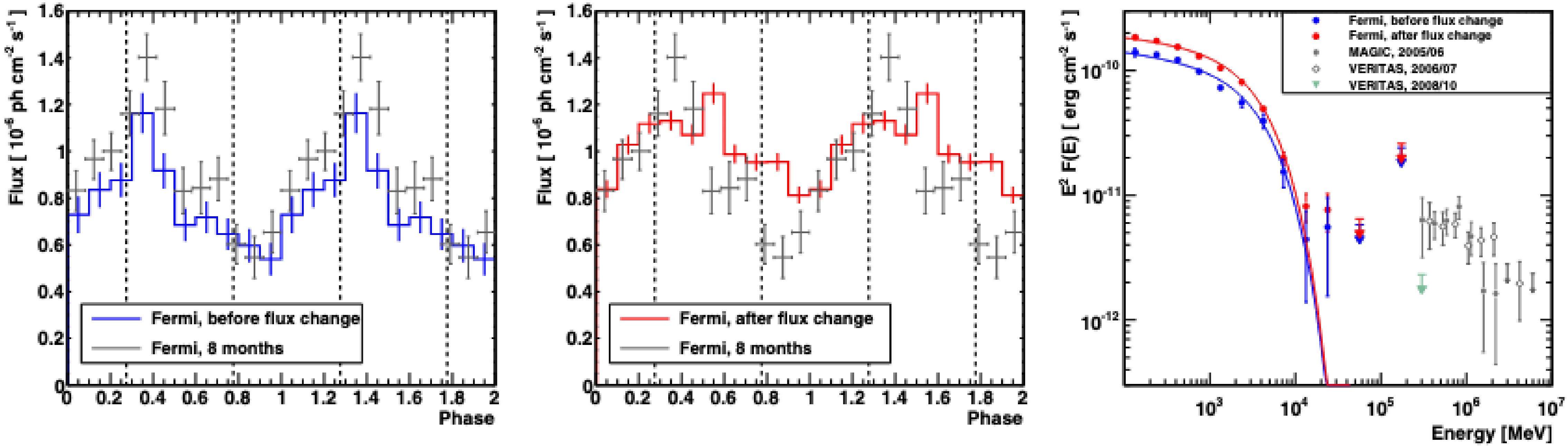


Abdo et al., ApJ 701, L123 (2009)

Flux change seen with Fermi-LAT

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

- 2.5 years of GeV data: Detected flux increased by 33%.
- Orbital modulation got fainter.
- Spectral shape remained the same (power law with exponential cutoff).
- Flux change due to super-orbital periodicity known from radio?

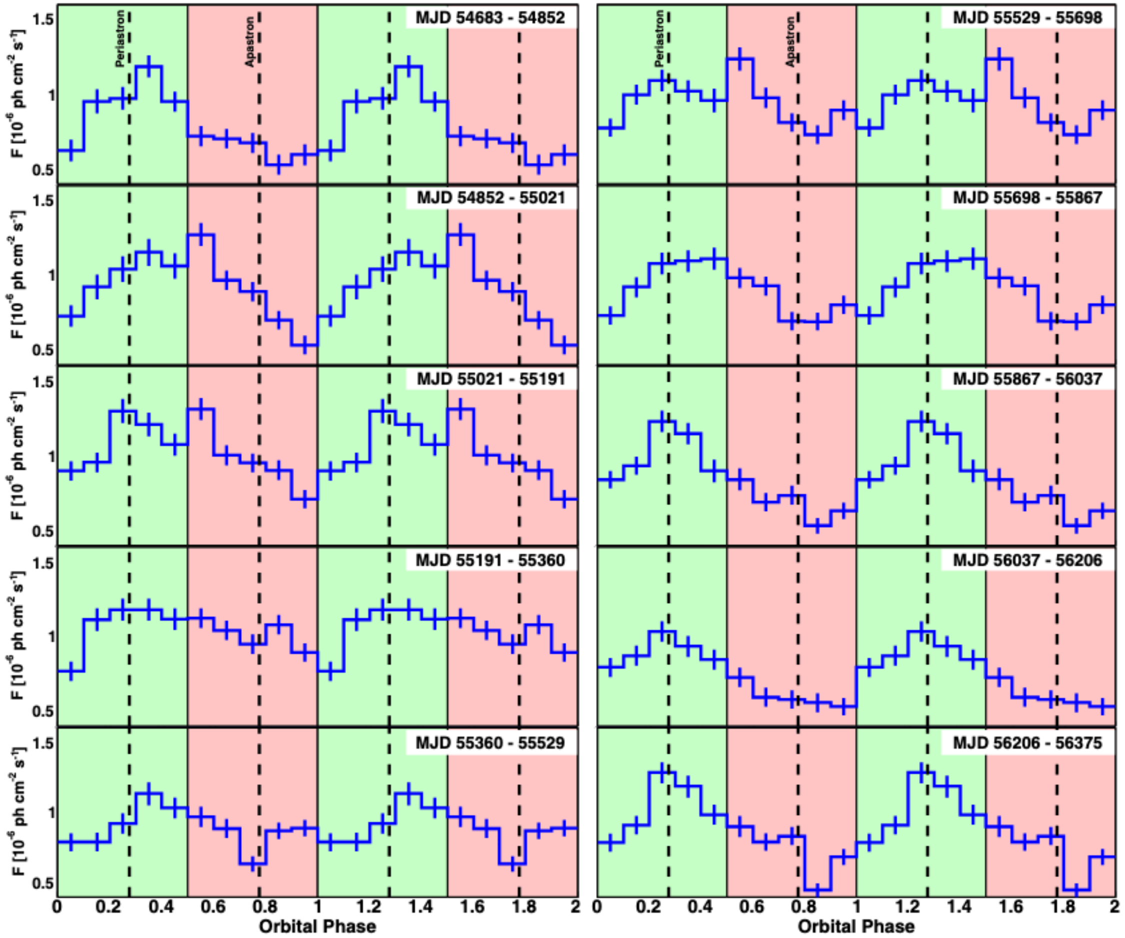


Hadasch et al., ApJ 749, 54 (2012)

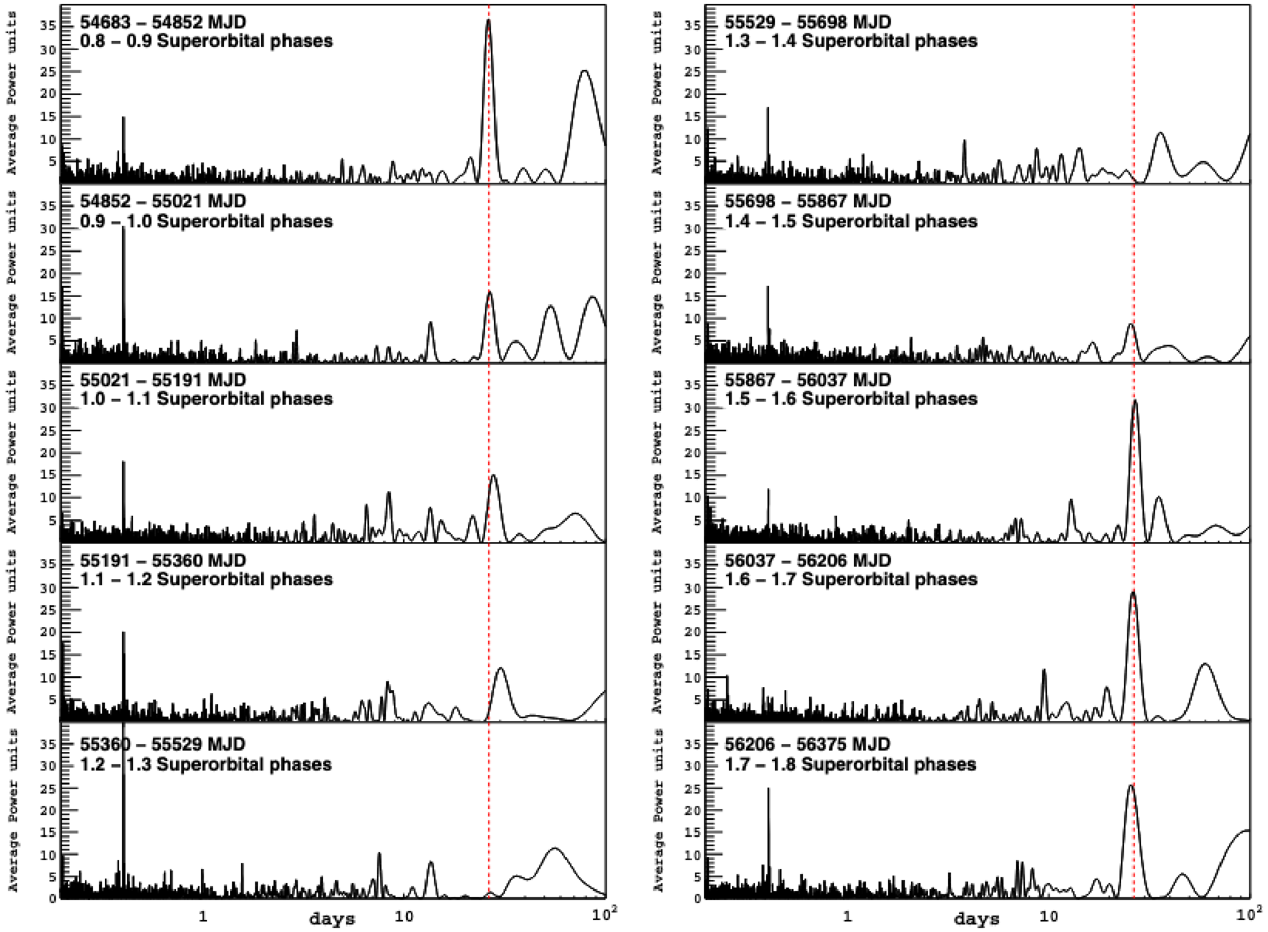
Long term variability detected after 4.5 years of Fermi-LAT

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

Orbital phase folded lightcurves



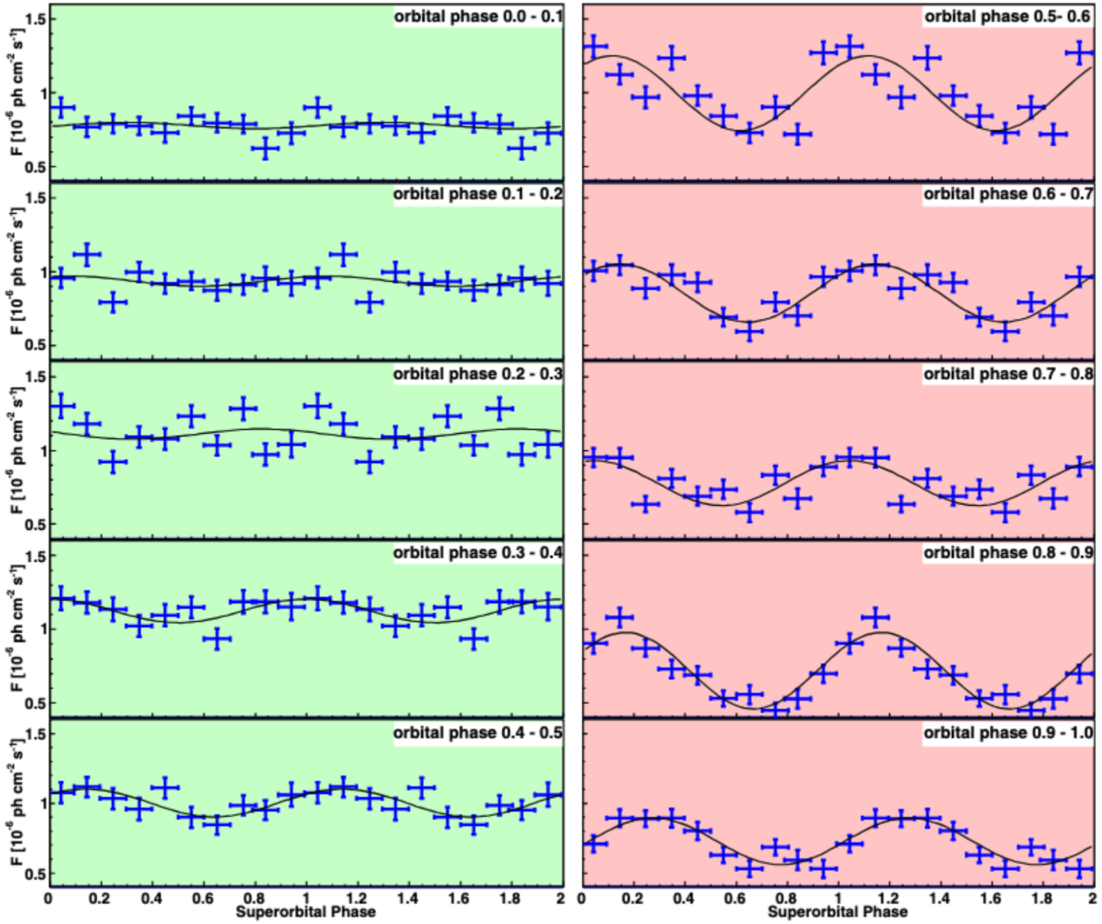
Power spectra



Ackermann et al., ApJ 773, 35A (2013)

Long term variability associated with super-orbital periodicity

Super-orbital phase folded lightcurves



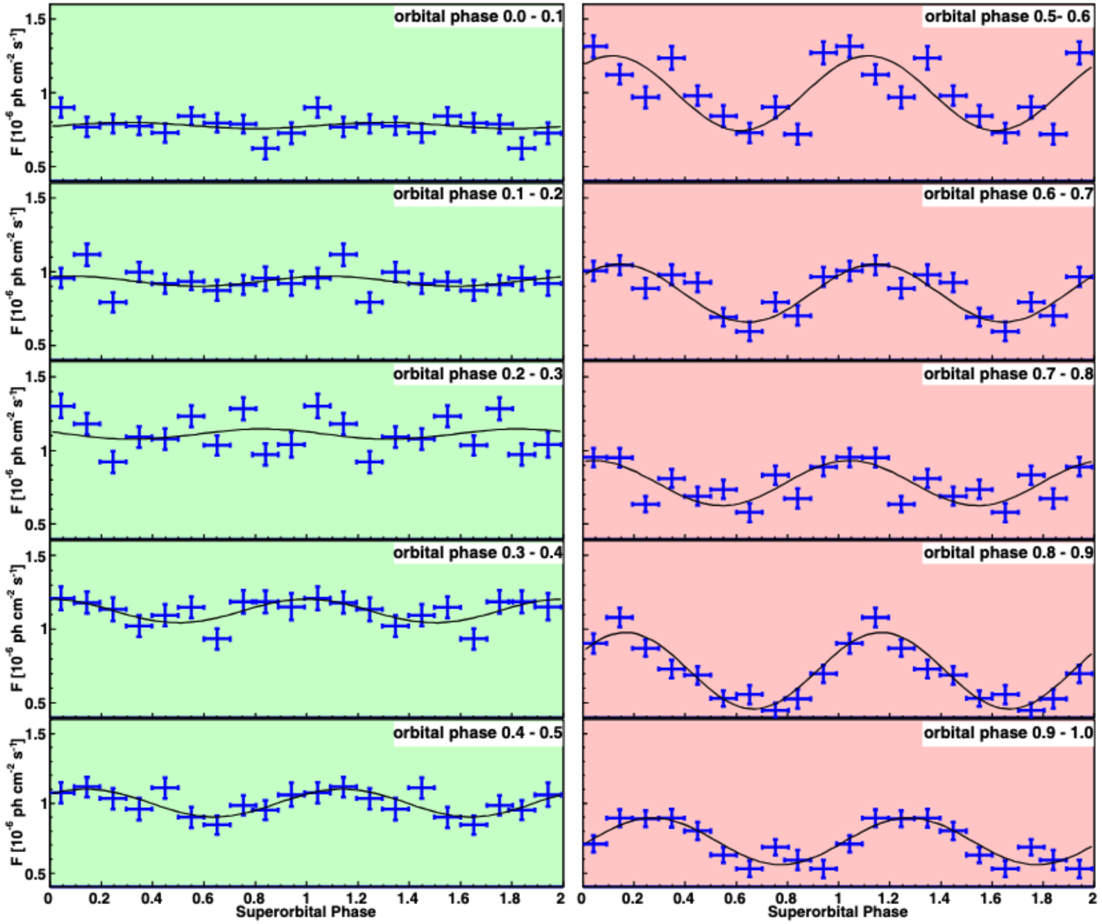
- Each panel shows the GeV flux at a fixed orbital position folded into the super-orbit (~4.6 years).
- Green background: periastron
  → no significant flux change
- Red background: apastron
  → super-orbit induces clear variation
- Black line: sinusoidal fit with fixed super-orbital period

Ackermann et al., ApJ 773, 35A (2013)

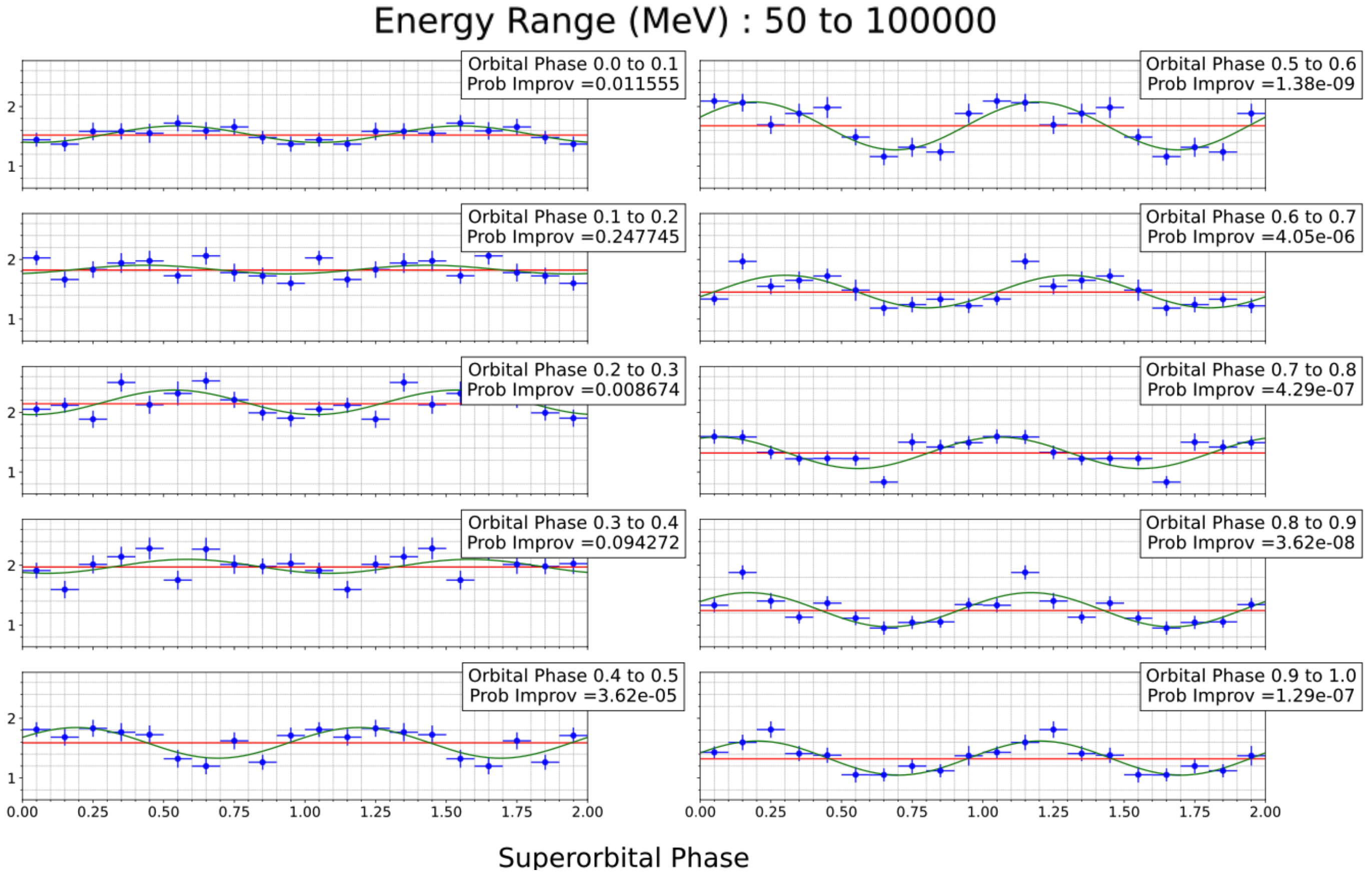
Fermi-LAT view after 16 years of GeV data → same trend

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

Super-orbital phase folded lightcurves
4.5 years of data



Super-orbital phase folded lightcurves
16 years of data

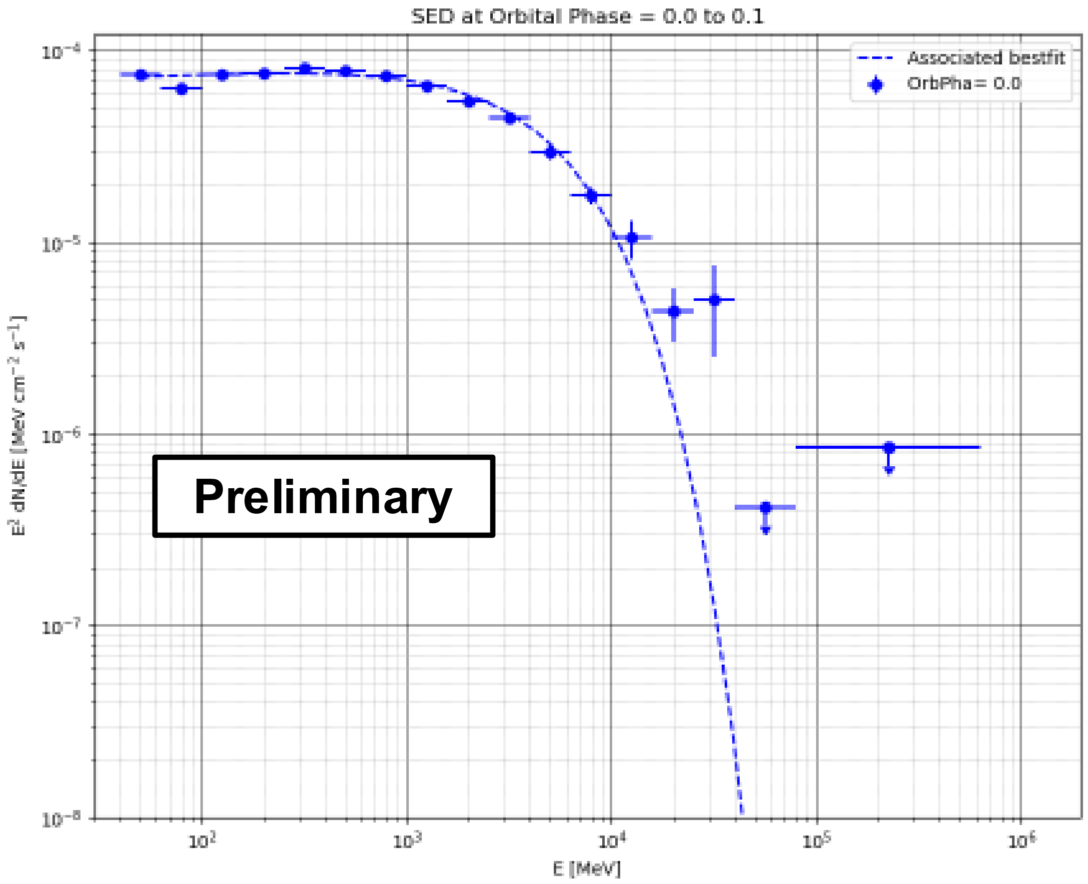


Energy ranges differ!

Monnier 2024, Summer project

Spectral studies

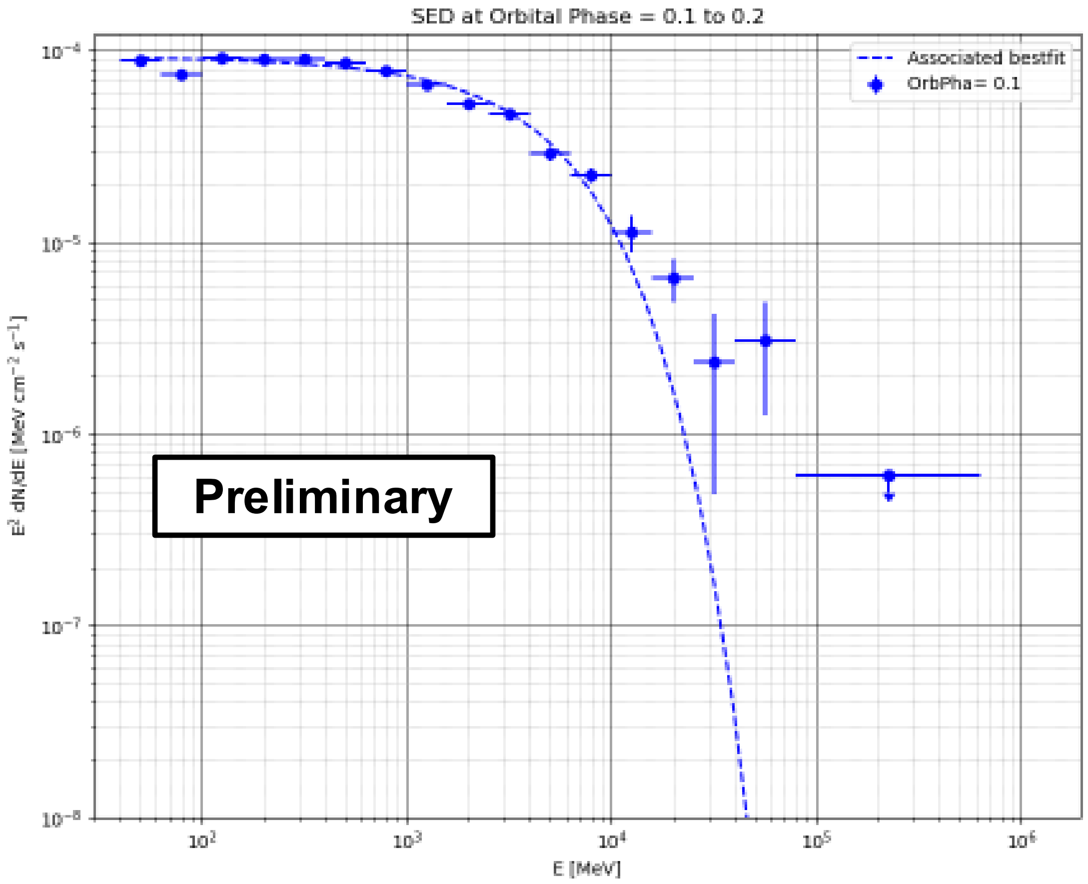
Spectra for each orbital phase bin of 0.1.



Monnier 2024, Summer project

Spectral studies

Spectra for each orbital phase bin of 0.1.

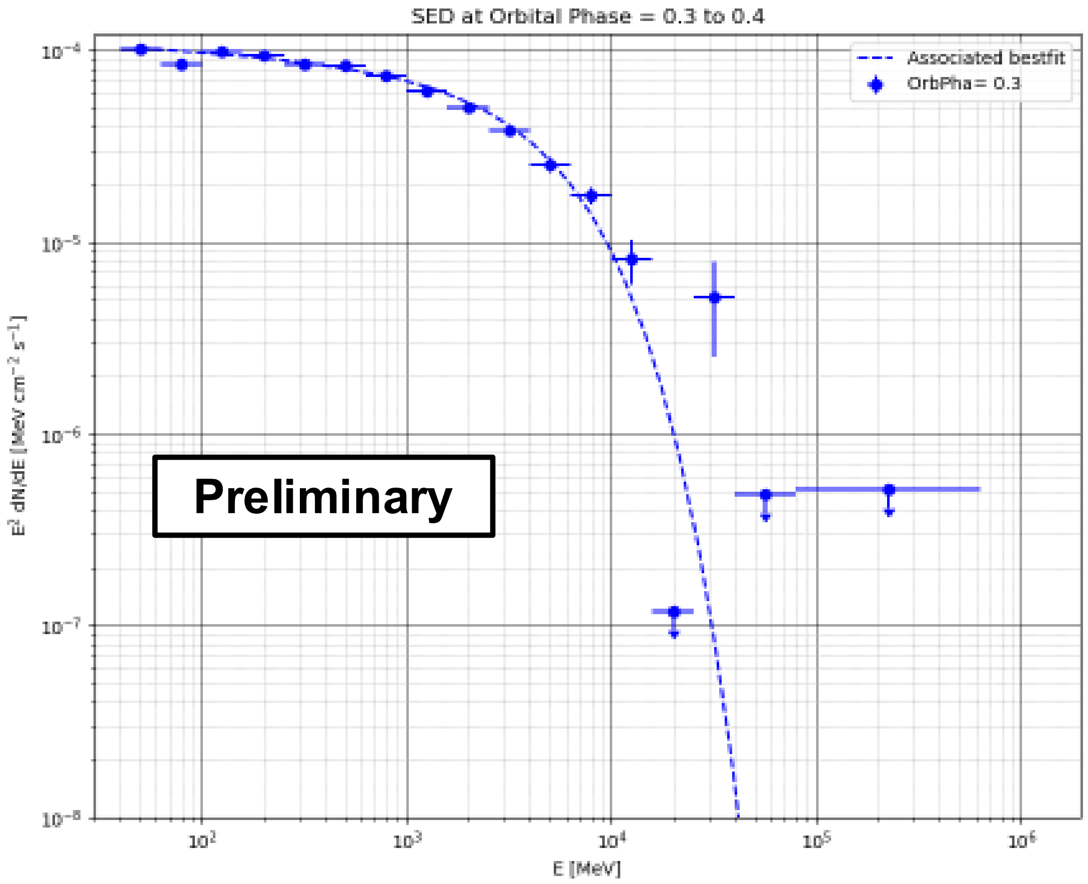


Monnier 2024, Summer project

Spectral studies

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

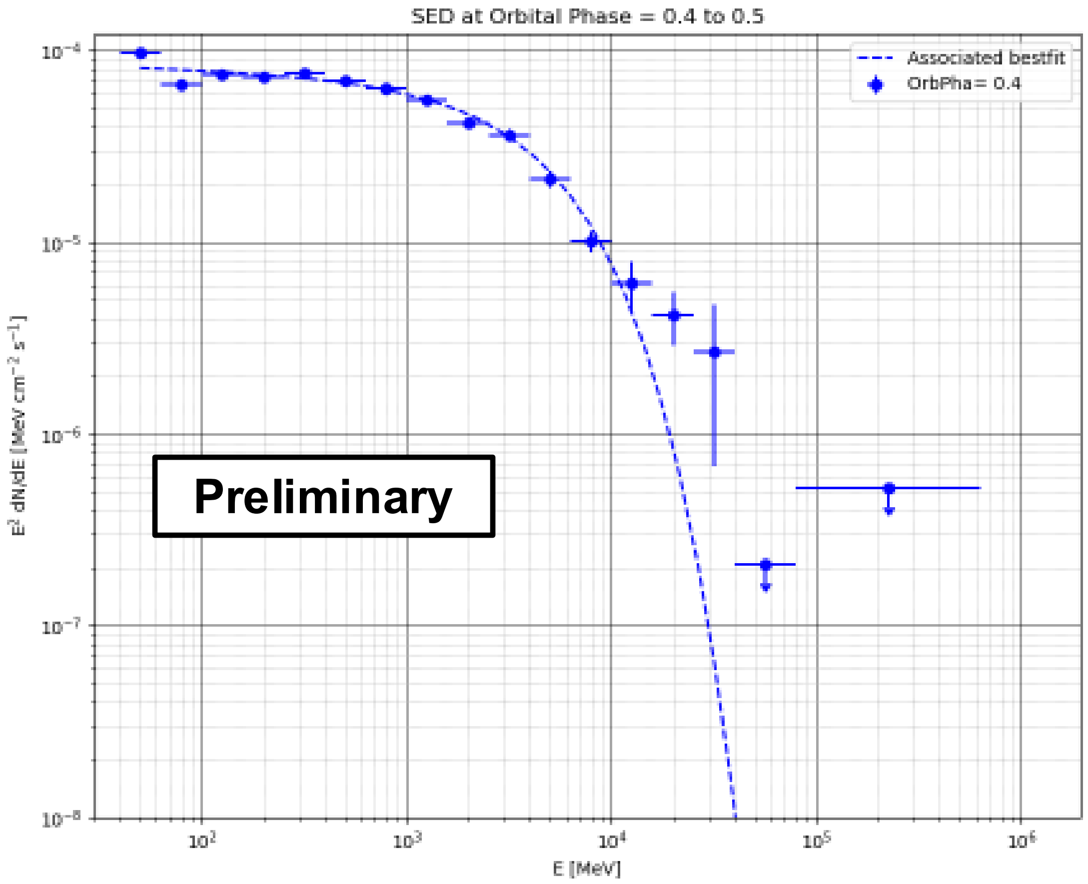
Spectra for each orbital phase bin of 0.1.



Monnier 2024, Summer project

Spectral studies

Spectra for each orbital phase bin of 0.1.

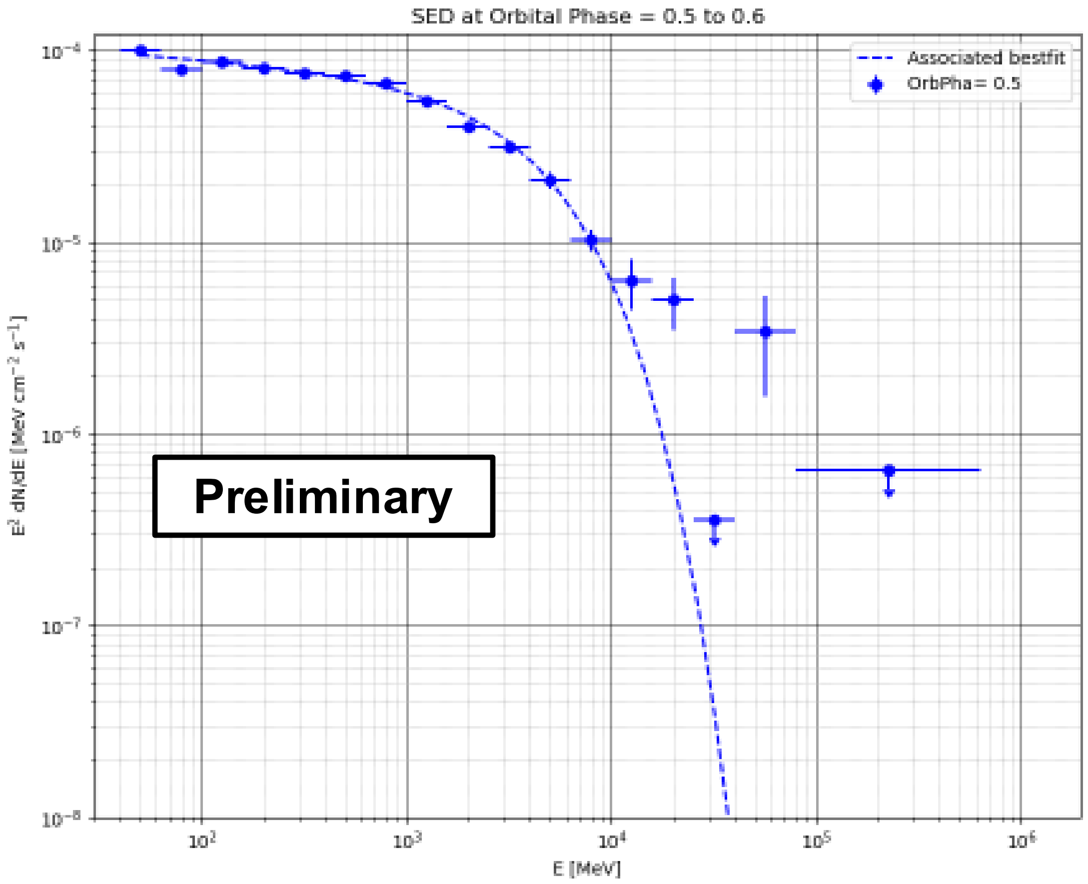


Monnier 2024, Summer project

Spectral studies

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

Spectra for each orbital phase bin of 0.1.

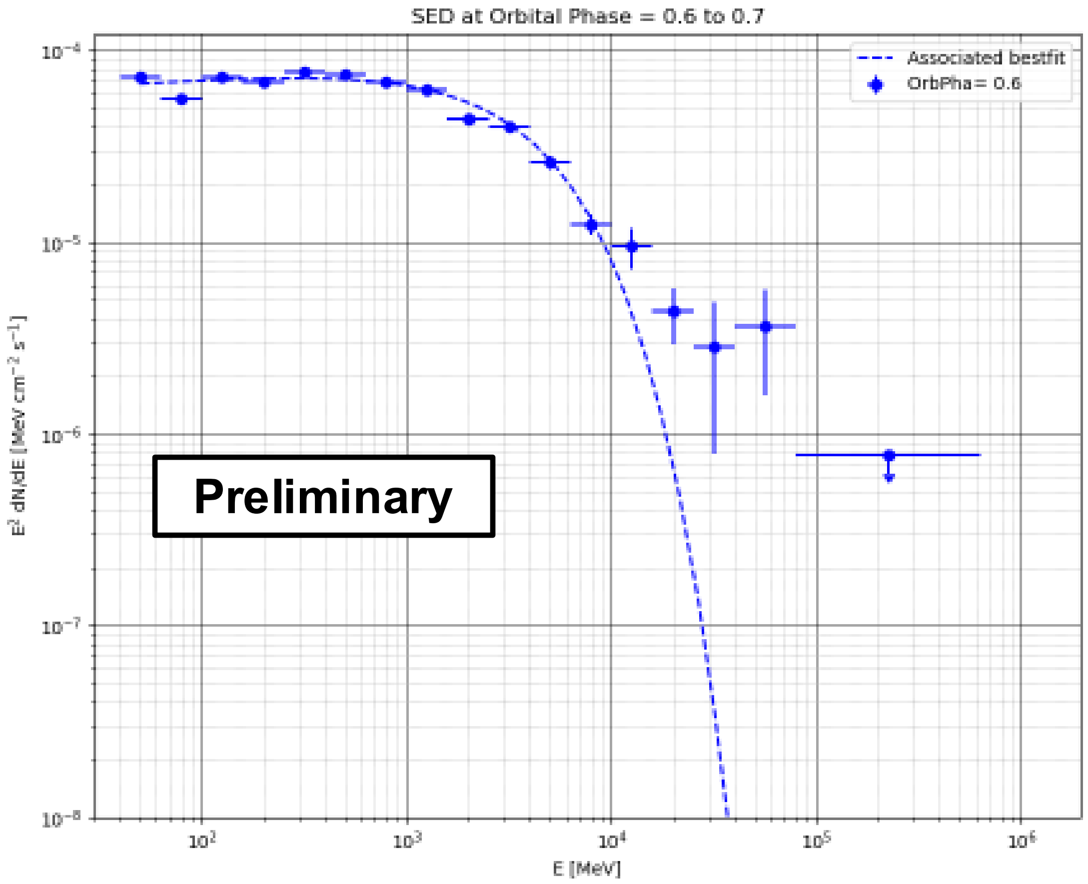


Monnier 2024, Summer project

Spectral studies

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

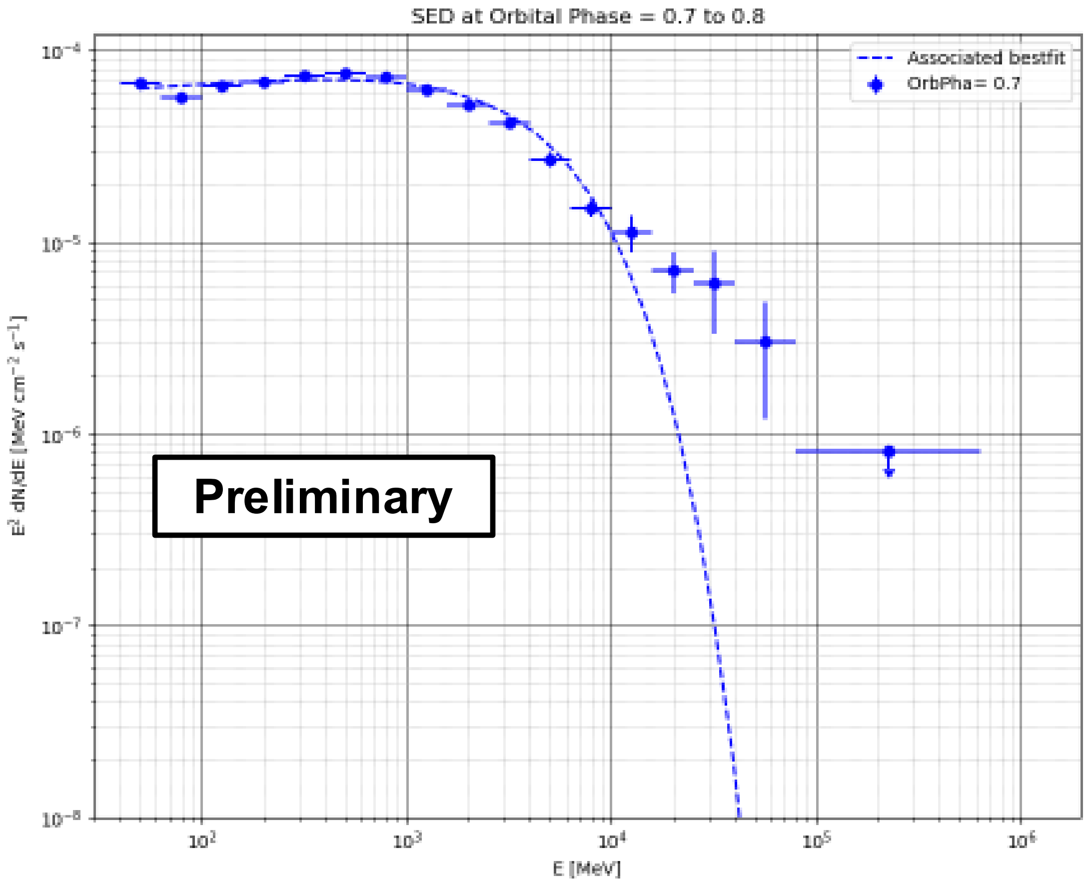
Spectra for each orbital phase bin of 0.1.



Monnier 2024, Summer project

Spectral studies

Spectra for each orbital phase bin of 0.1.

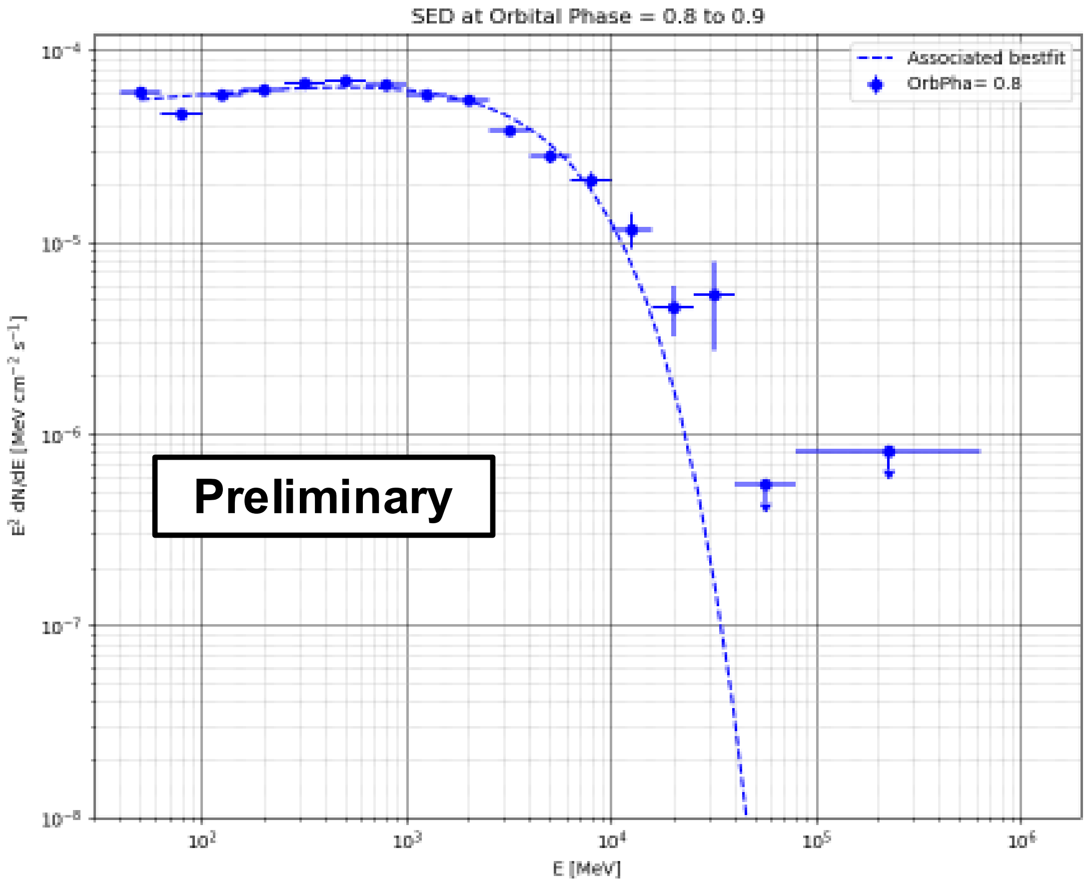


Monnier 2024, Summer project

Spectral studies

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

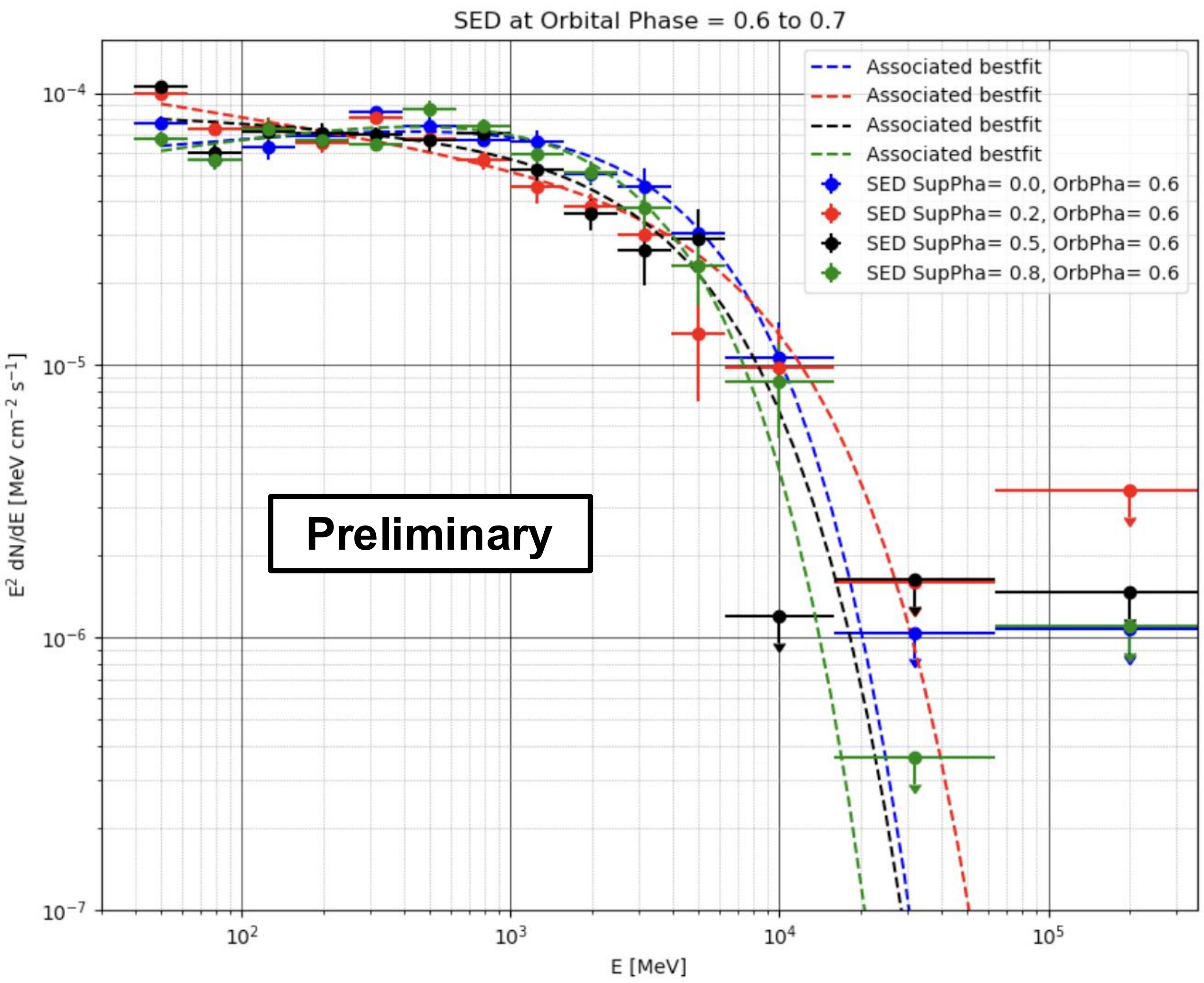
Spectra for each orbital phase bin of 0.1.



Monnier 2024, Summer project

Spectral studies

- Spectra at fixed orbital phase for different super-orbital phases.



Monnier 2024, Summer project

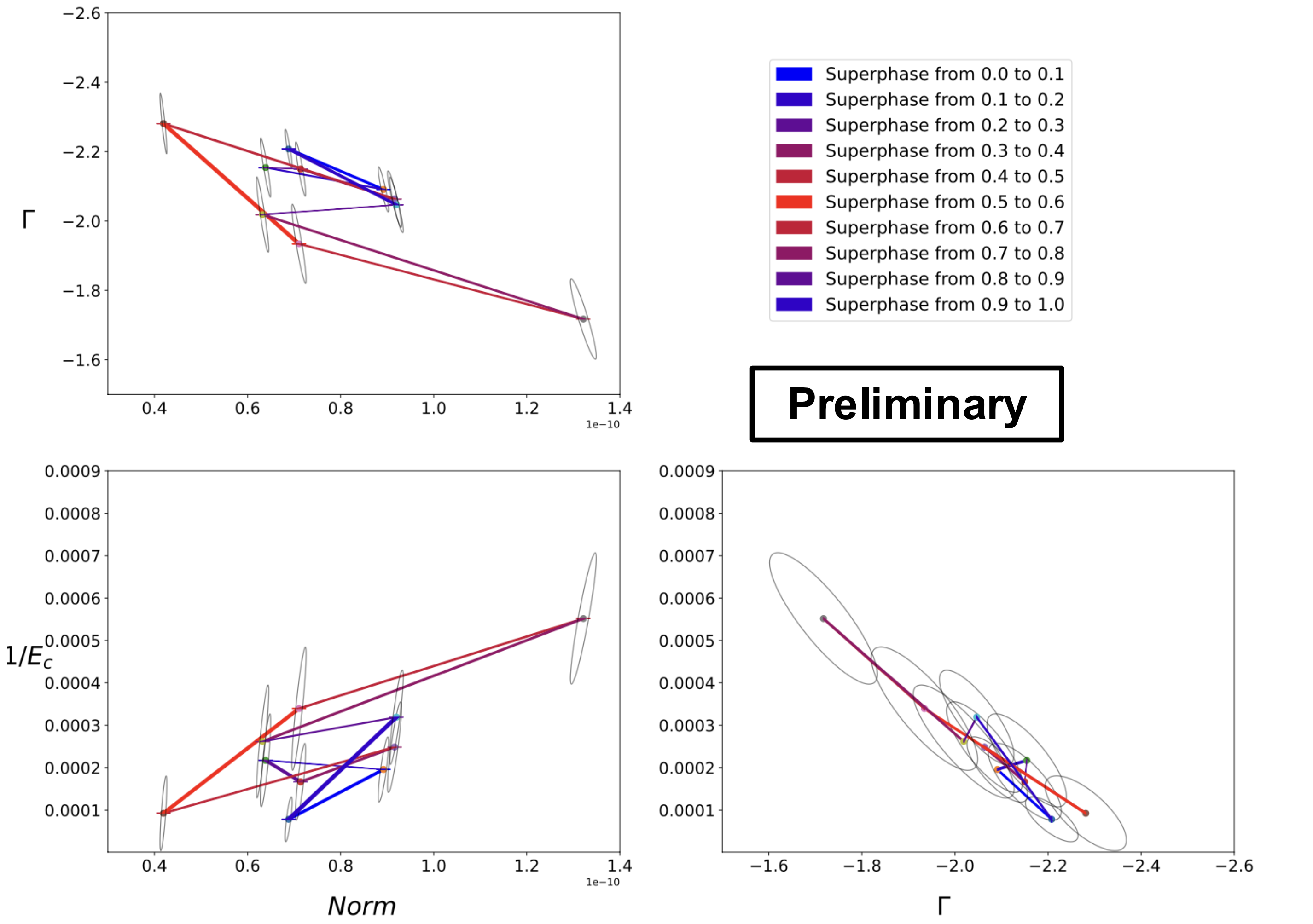
Correlation studies

- Correlation plots along the super-orbit at fixed orbital period.

→ Correlation cutoff energy and spectral slope.

- Work ongoing…

Parameters Ellipses : Orbit = 0.5 to 0.6



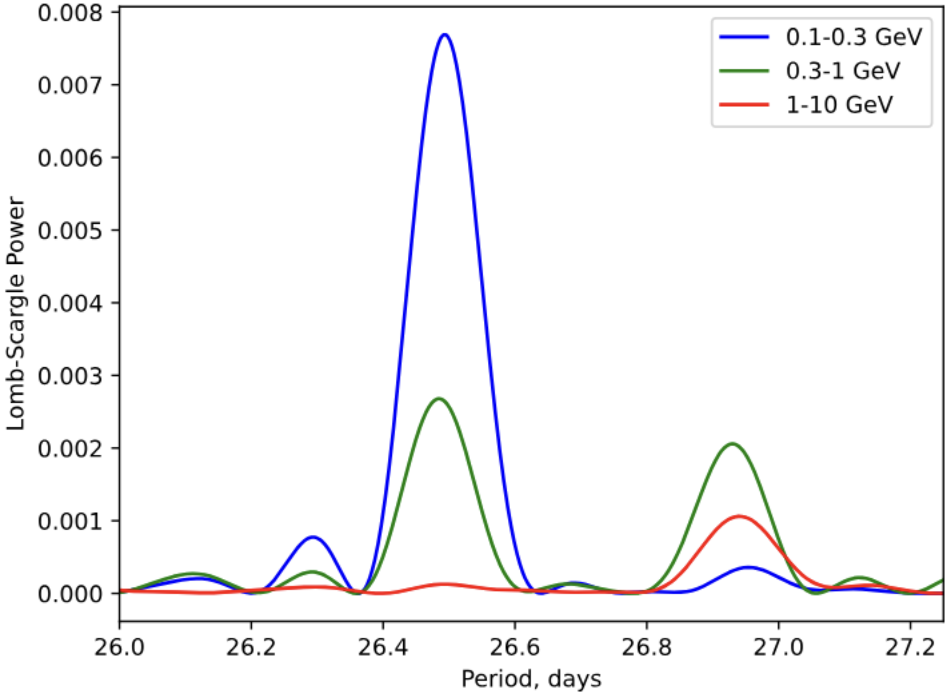
Monnier 2024, Summer project

Periodicity studies

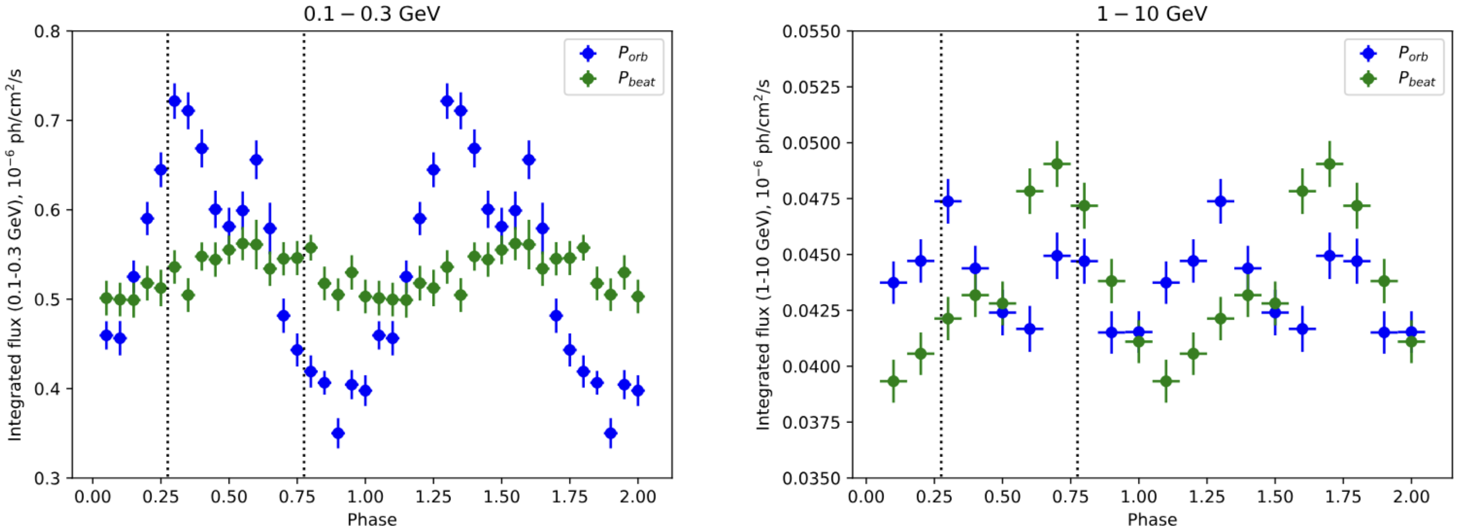
MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

- Two different periods in two energy ranges
  - E > 1GeV: P_1 = 26.932 ± 0.004(stat), orbital–superorbital beat-period
  - E < 0.3GeV: P_2 = 26.485 ± 0.004(stat), orbital period

Lomb-Scargle Periodogram



Folded lightcurves

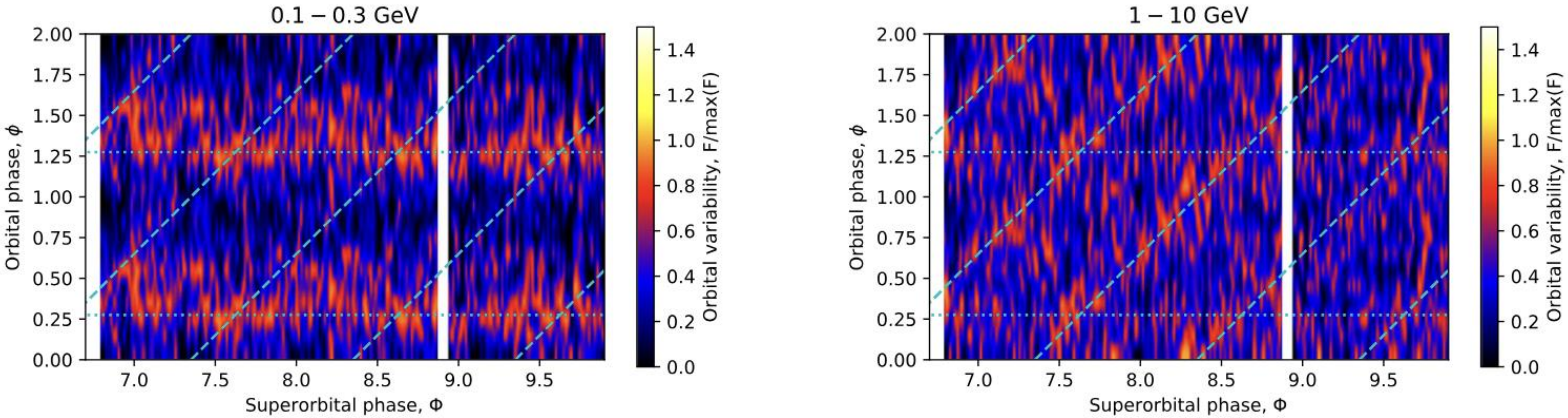


Chernyakova et al., MNRAS 525, 2202 (2023)

Energy-dependent variability

MULTIMESSENGER ASTROPHYSICS
COSMIC RAYS - COMPACT OBJECTS - RELATIVISTIC ENVIRONMENTS
@ THE INSTITUTE OF SPACE SCIENCES (ICE, CSIC) SINCE 2006

- 0.1 – 0.3 GeV: Flux maximum at periastron
  - Synchrotron or Inverse Compton → higher flux due to increased magnetic and/or soft photon field densities
- 1 – 10 GeV: Gradual drift of the phase of the maximum throughout the super-orbital cycle
  - Due to precession of the system components or cyclical change of Be star's disc

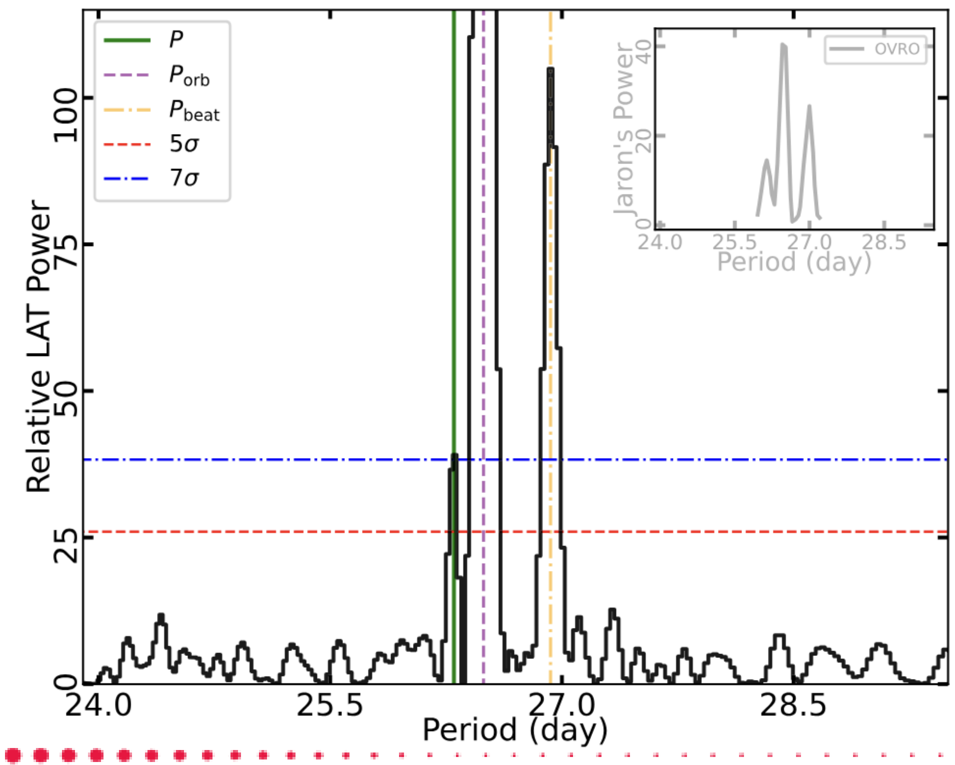


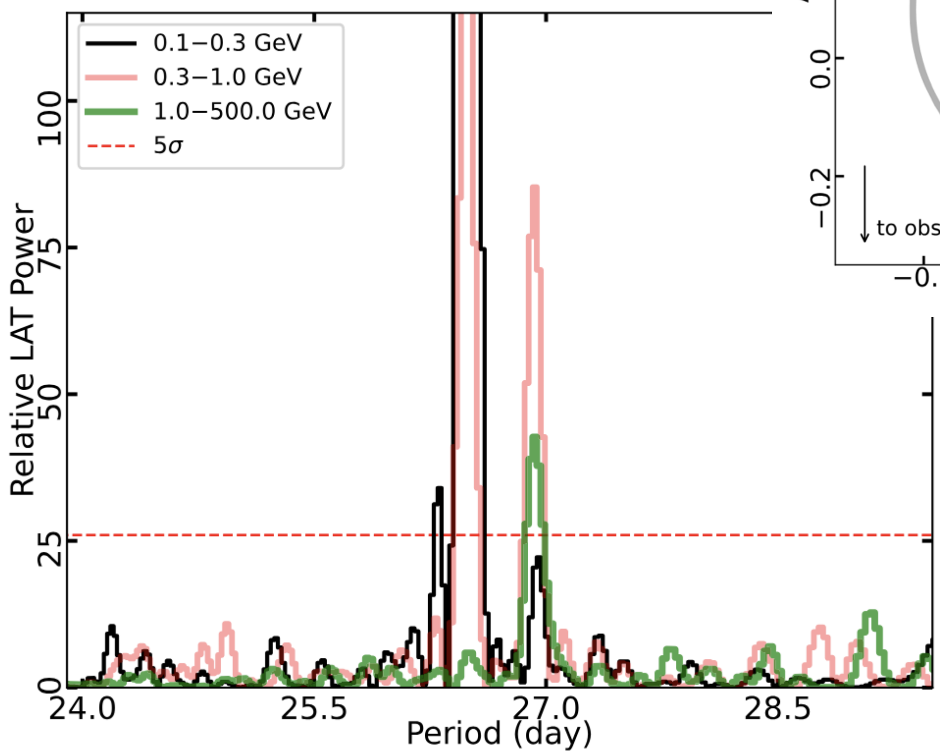
Chernyakova et al., MNRAS 525, 2202 (2023)

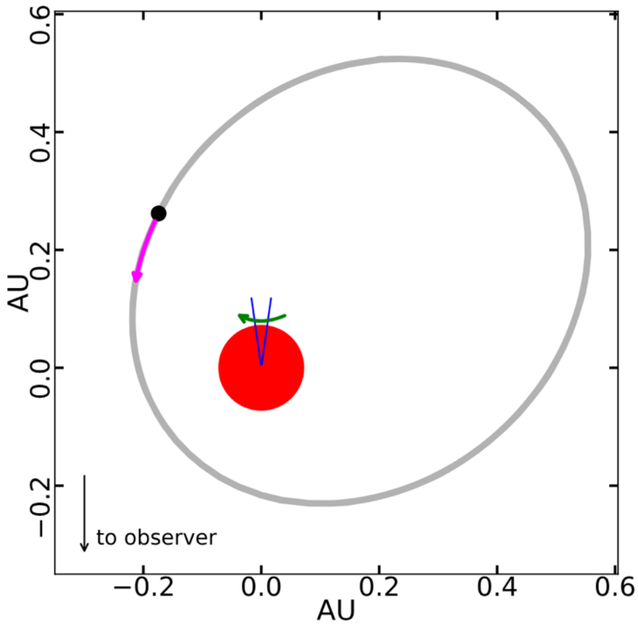
New periodic signal

- New period of 26.301 ± 0.037 days.
  - Not a combination of frequencies from any known period.

→ Coupling effect between the orbital period and the retrograde stellar precession period.







P. Zhang, ApJ 972, 80 (2024)

Open issues@GeV energies

- Is the super-orbital behaviour stable over the years?
- Can we detect pulsations at GeV energies?
- Deeper spectral studies needed?
- What is the origin of the new periodic signal?
- How can multi-wavelength observations help in a deeper understanding of the system?
  - Optical observations to study the Be star disc
  - Correlation studies
  - Connect GeV & TeV spectra to distinguish different components
  - New periodic signal visible at other wavelengths?
- ...

Thank you

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

CSIC

Institute of Space Sciences

EXCELENCIA MARÍA DE MAEZTU

ICREA

Extra slides