Superorbital variability of LSI +61° 303 at different wave bands

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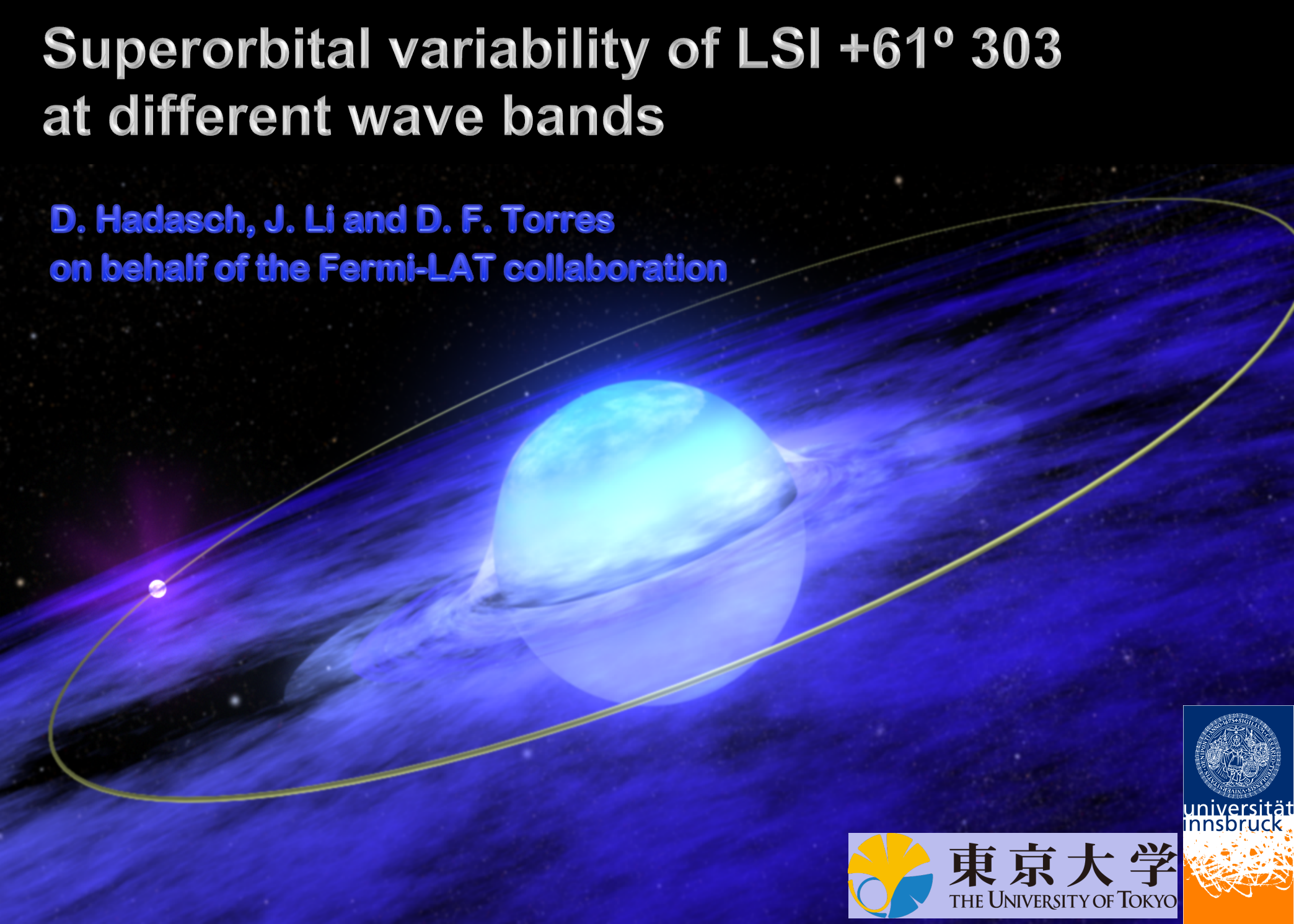
on behalf of the Fermi-LAT collaboration



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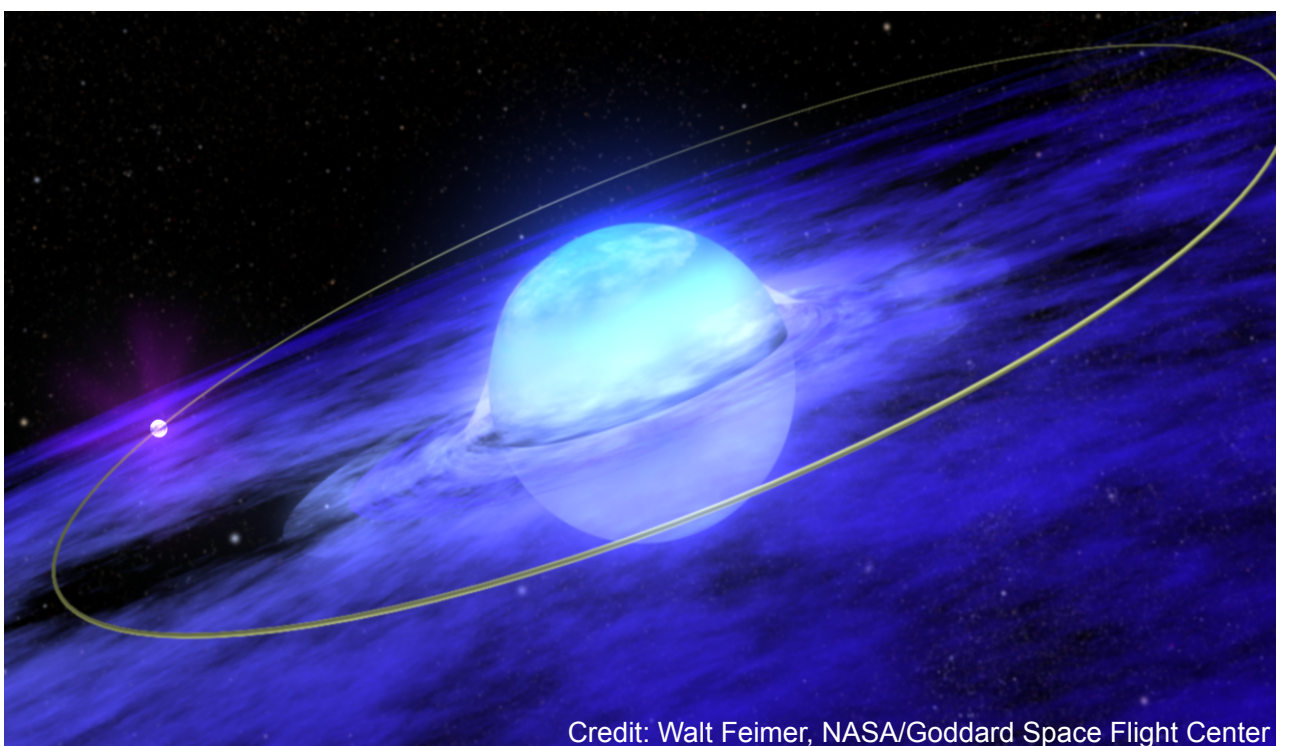
Overview

- Introduction of LSI +61° 303
- Present findings in the GeV energy regime
  - Using Fermi-LAT data
- Putting results into multiwavelength context
  - Comparing GeV data with radio, X-ray and optical data
- Present possible interpretation of source behavior



Introduction: LSI +61° 303

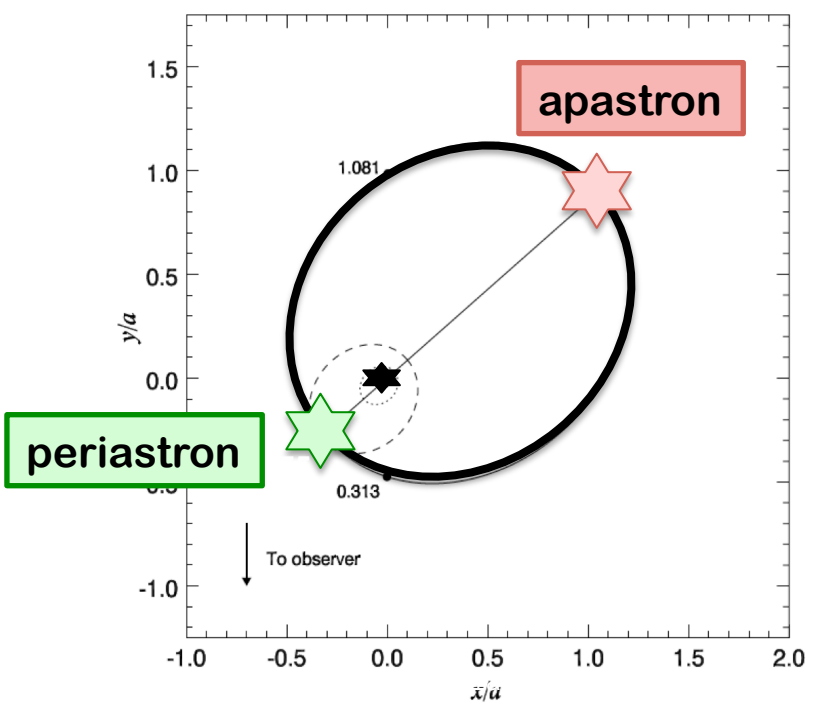
- GeV source discovered in 1977 by Cos B
  - at TeV energies by MAGIC (2006); follow-ups by MAGIC and VERITAS
  - at GeV energies by Fermi (2009)
  - Periodicity found in TeV (MAGIC) and GeV (Fermi/LAT)

- Compact object + Be star
  - Be star: ~10-12 M_{sun}
  - B-type stars lose mass in equatorial, circumstellar disk
  - Compact object: 1.4M_{sun} (neutron star) to 4 M_{sun} (black hole)

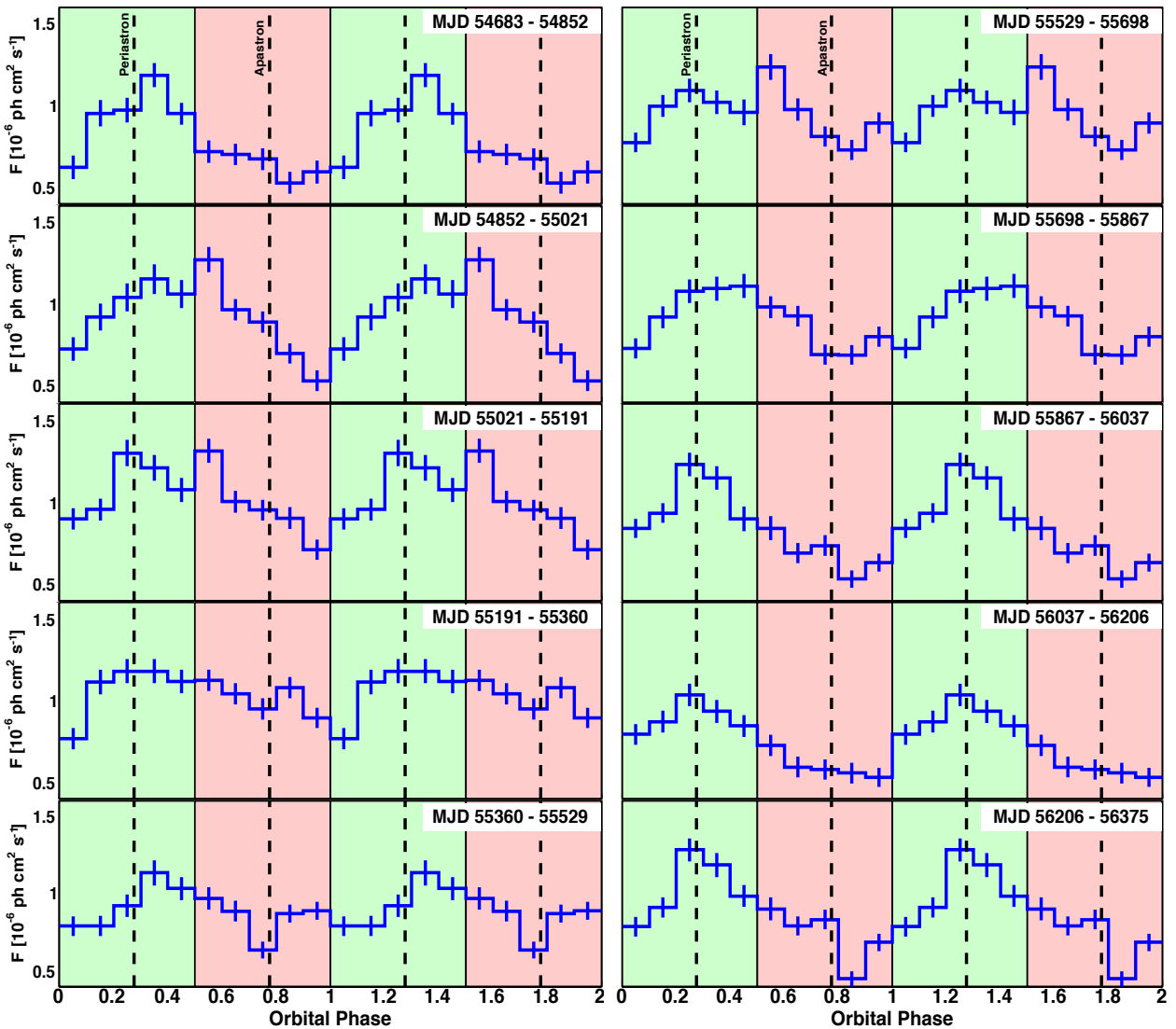
- Orbital period
  - (26.496 +/- 0.0028) days (Gregory et al. 2002)

- Periodic radio outbursts (Gregory et al. 2002)
  - Superorbital period: (1667 +/- 8) days

- What is happening at GeV energies?



Light folded in the orbital phase



Each panel is ~6 months integration of Fermi data.

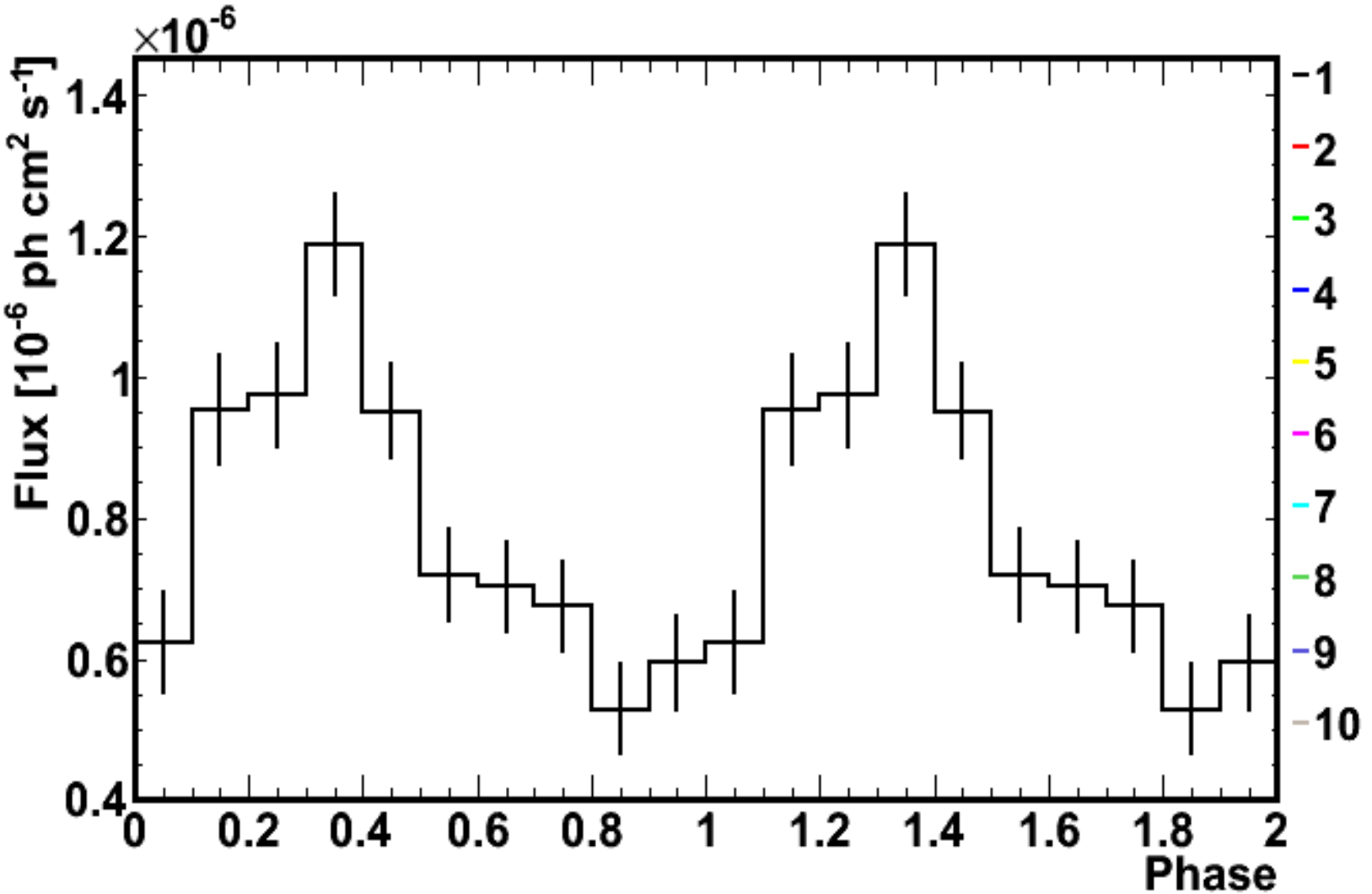
Green and red background represents regions of periastron and apastron, respectively

Trends for location of max and min

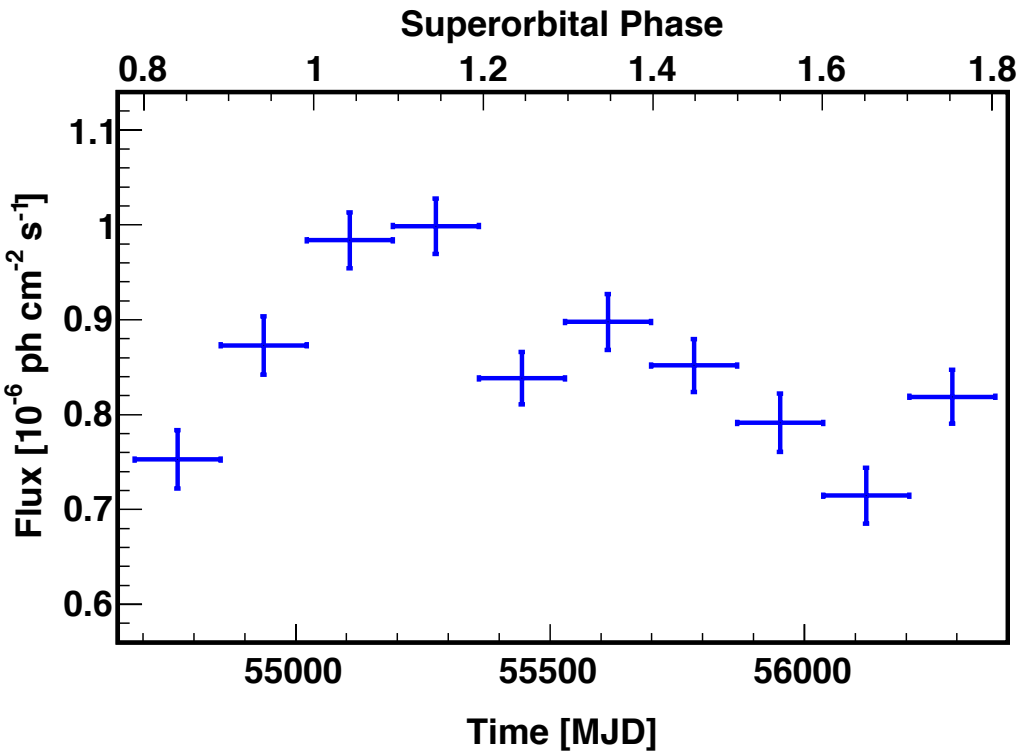
Maximum near periastron, but with significant variability

Ackermann et al. 2013

10 half years shown for GeV data



Is there variability in the super orbit?



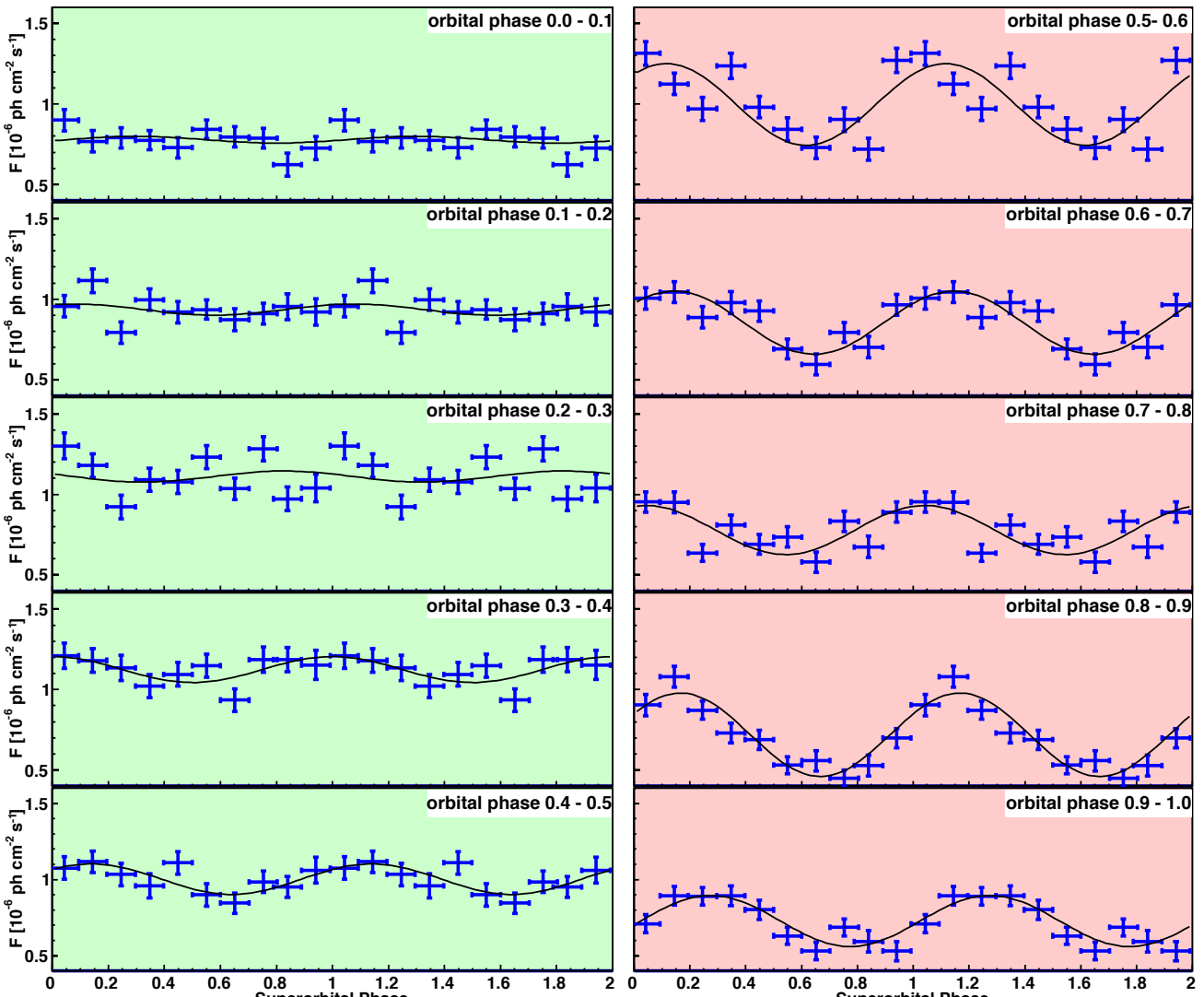
Ackermann et al. 2013

- Best determined superorbital period from radio campaign: (lasting 23 years): 1667±8 days

→Probability that γ-ray flux evolution is a random result: $< 1.1 \times 10^{-12}$

→ Source is variable along the superorbit in the GeV regime

Orbital phase bins in superorbit



Each panel shows the GeV flux at a fixed orbital position, along a period of 4.5 years

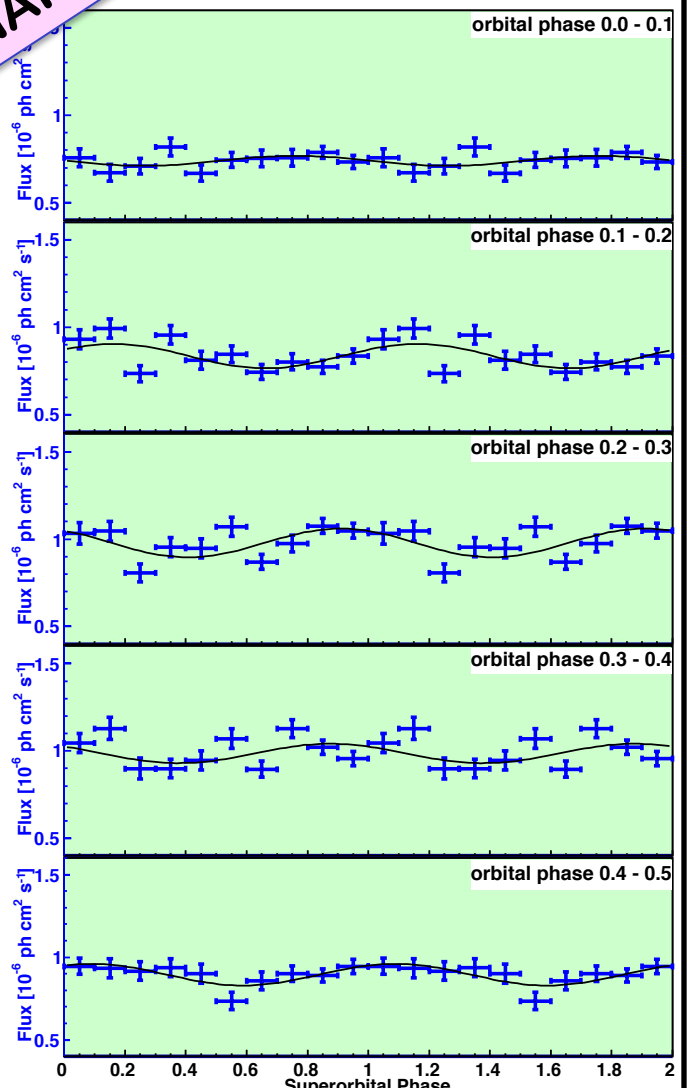
Green and red background represent the region of periastron and apastron, respectively

Black line: Fit sinusoidal with fixed superorbital period

Ackermann et al. 2013

Orbital phase bins in superorbit

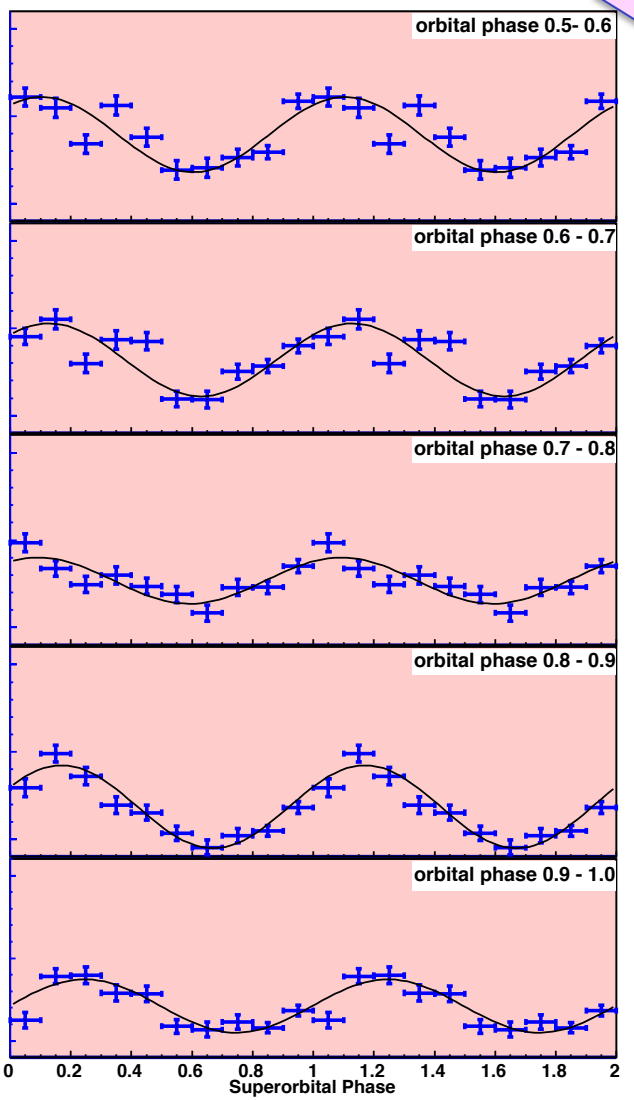
PRELIMINARY



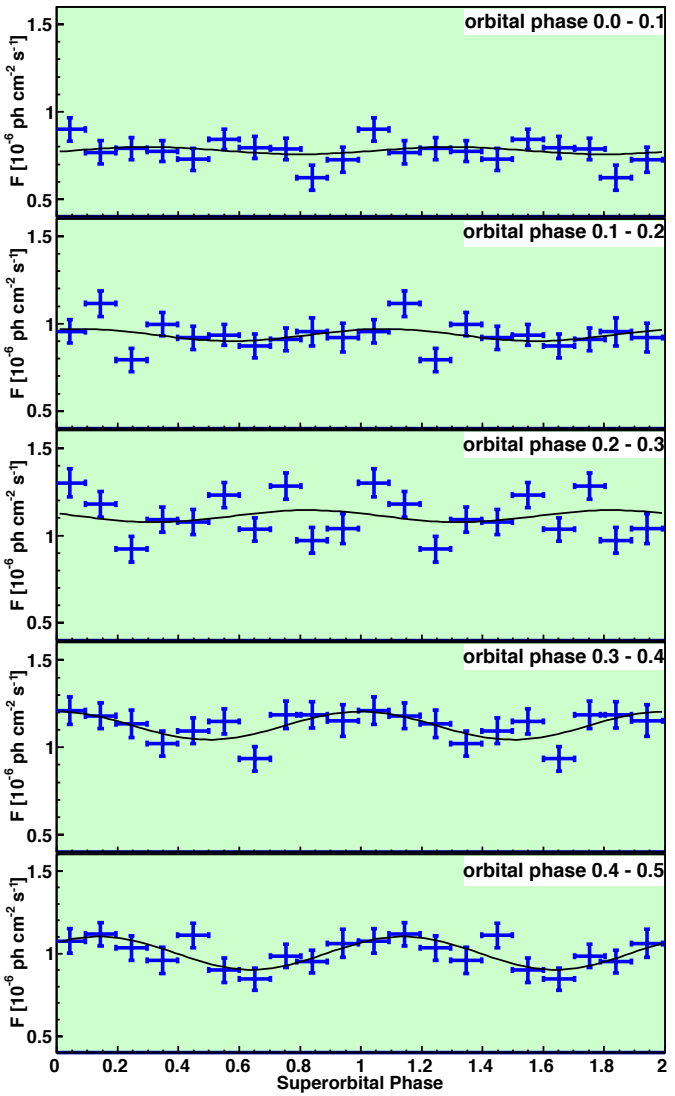
- From orbital phase 0.1 to 0.5, including the periastron region, there is no significant flux variation along the superorbit.
- As soon as we depart from periastron we start to see superorbital variability (see phase 0.5)
- Conditions for GeV generation must not significantly change

Orbital phase bins in superorbit

- From orbital phase 0.6 to 1.0, including the apastron region, there is significant flux variation in the superorbit.
- The variation is maximal before and after apastron
- Concurrently, a sine with a fixed period of 1667 days is at all orbital bins a better fit to the data than a constant
- Close to apastron, the superorbit induces clear variations. GeV emission conditions change.



Orbital phase bins in superorbit



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Ackermann et al. 2013

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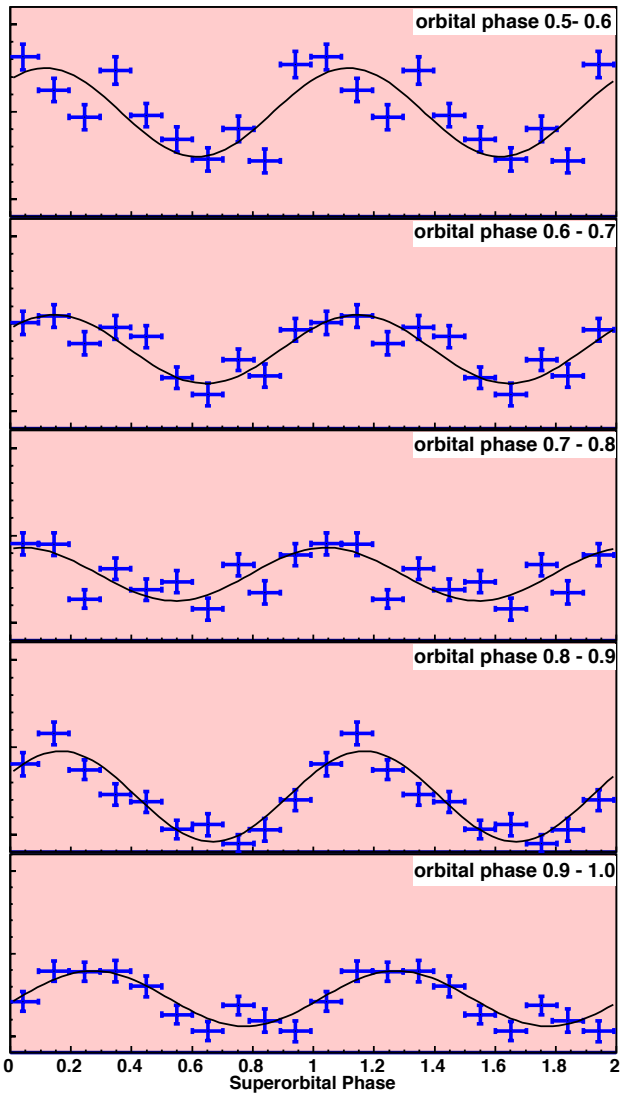
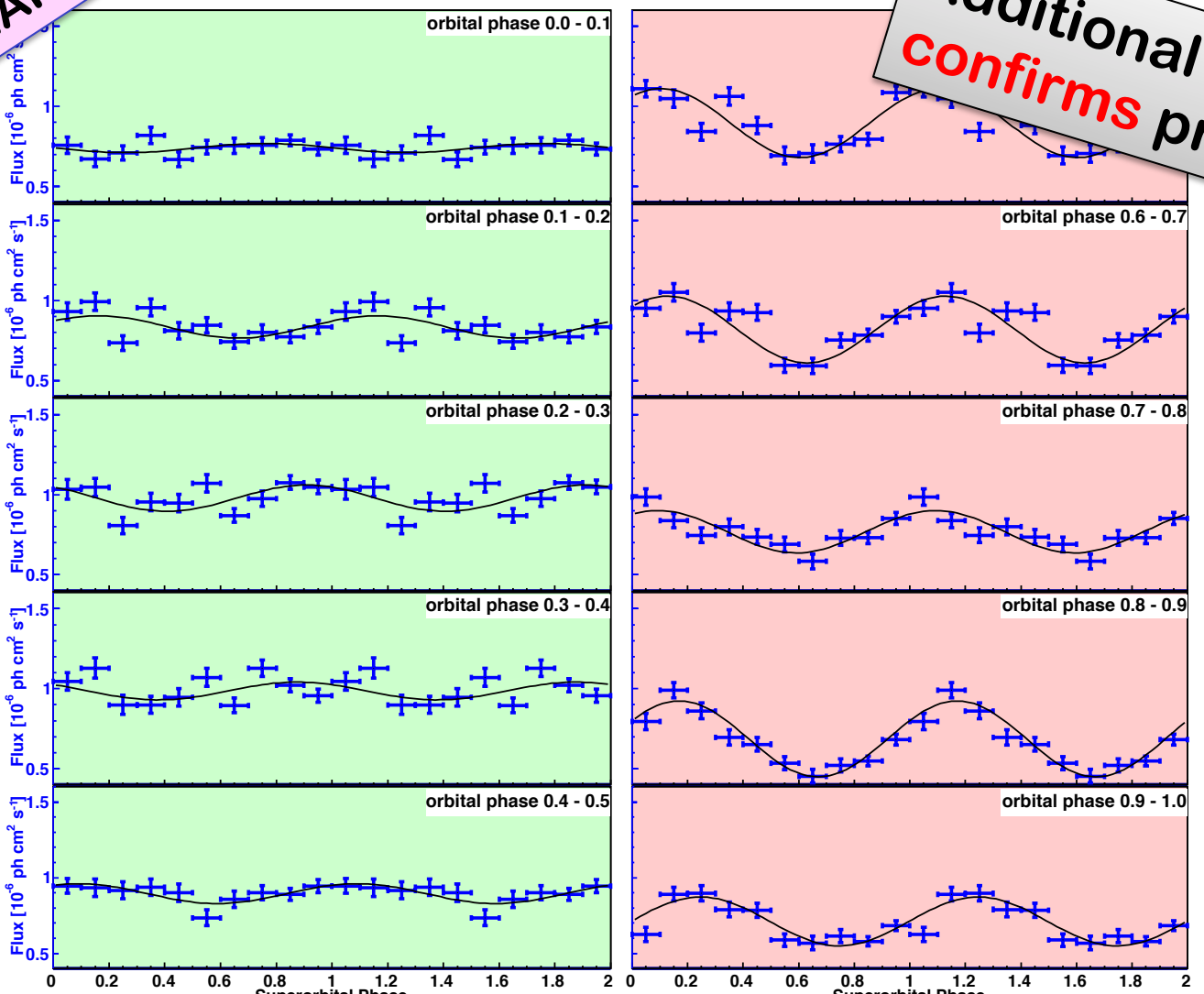


Ackermann et al. 2013

Orbital phase bins in superorbit

PRELIMINARY

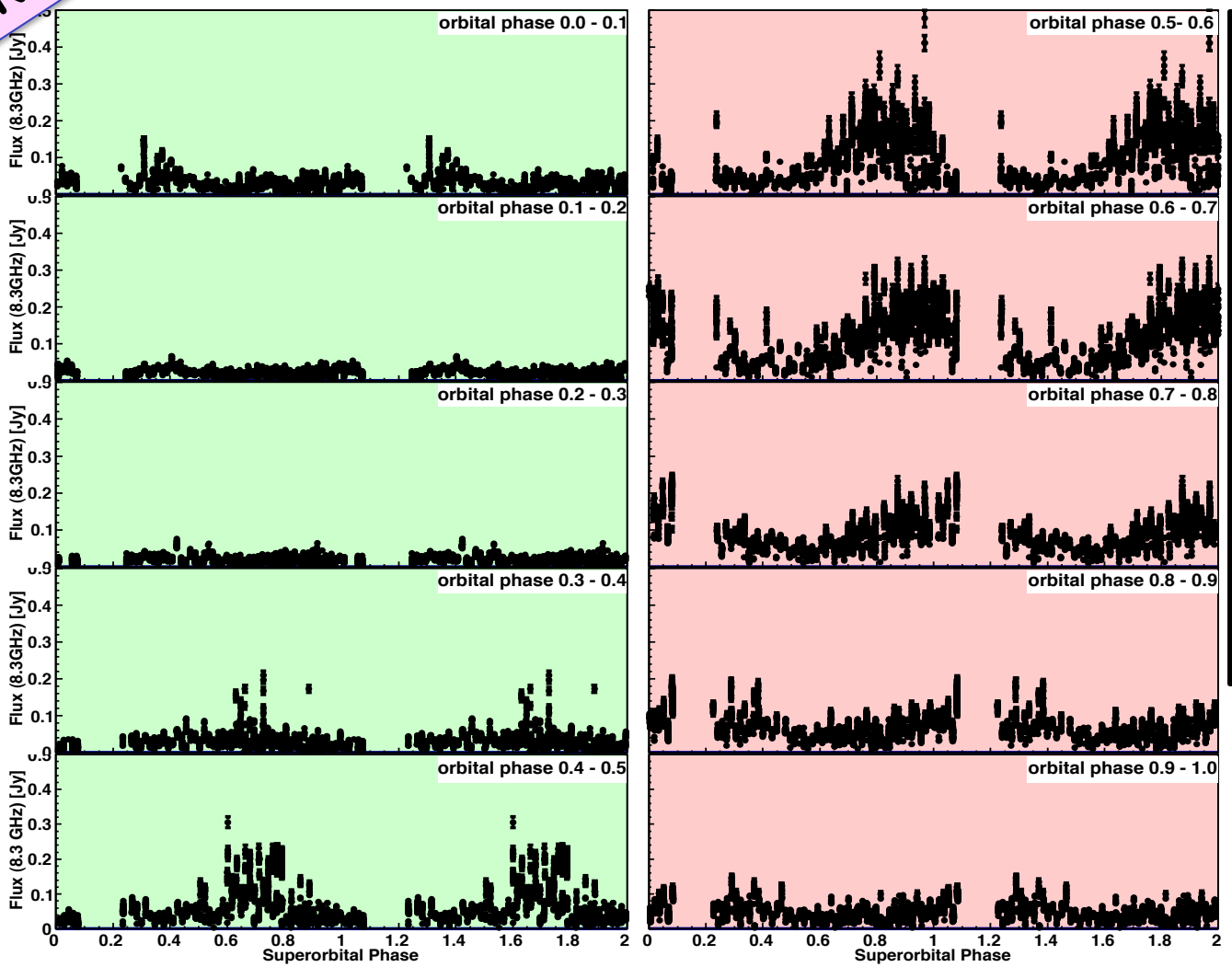
Additional 1 year of data confirms previous trend



RADIO DATA

GBI data, 8.3GHz, 1994-2000

PRELIMINARY



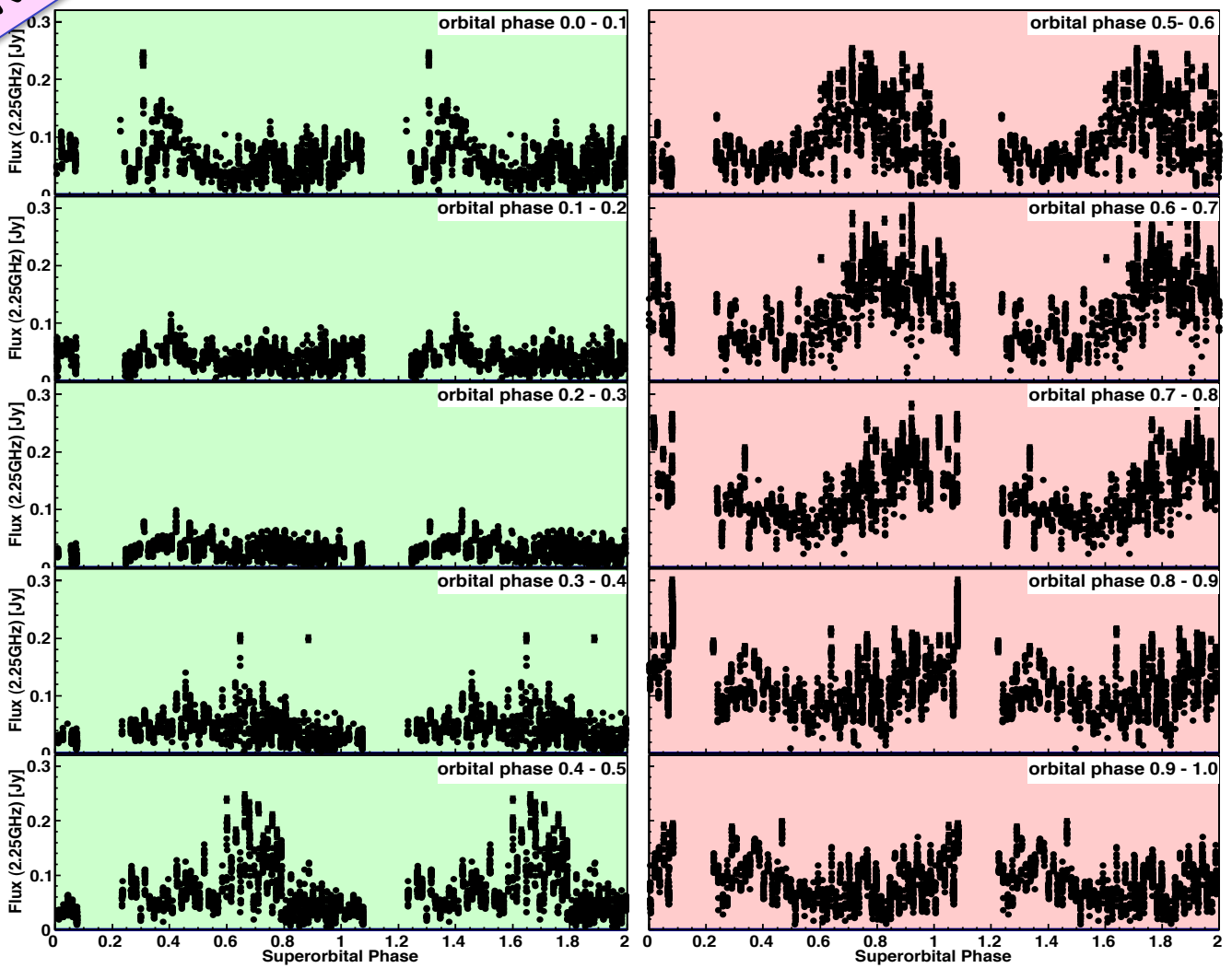
Same folding like in GeV

→Modulation visible around apastron

→Modulation starting earlier in orbital phase than in GeV?

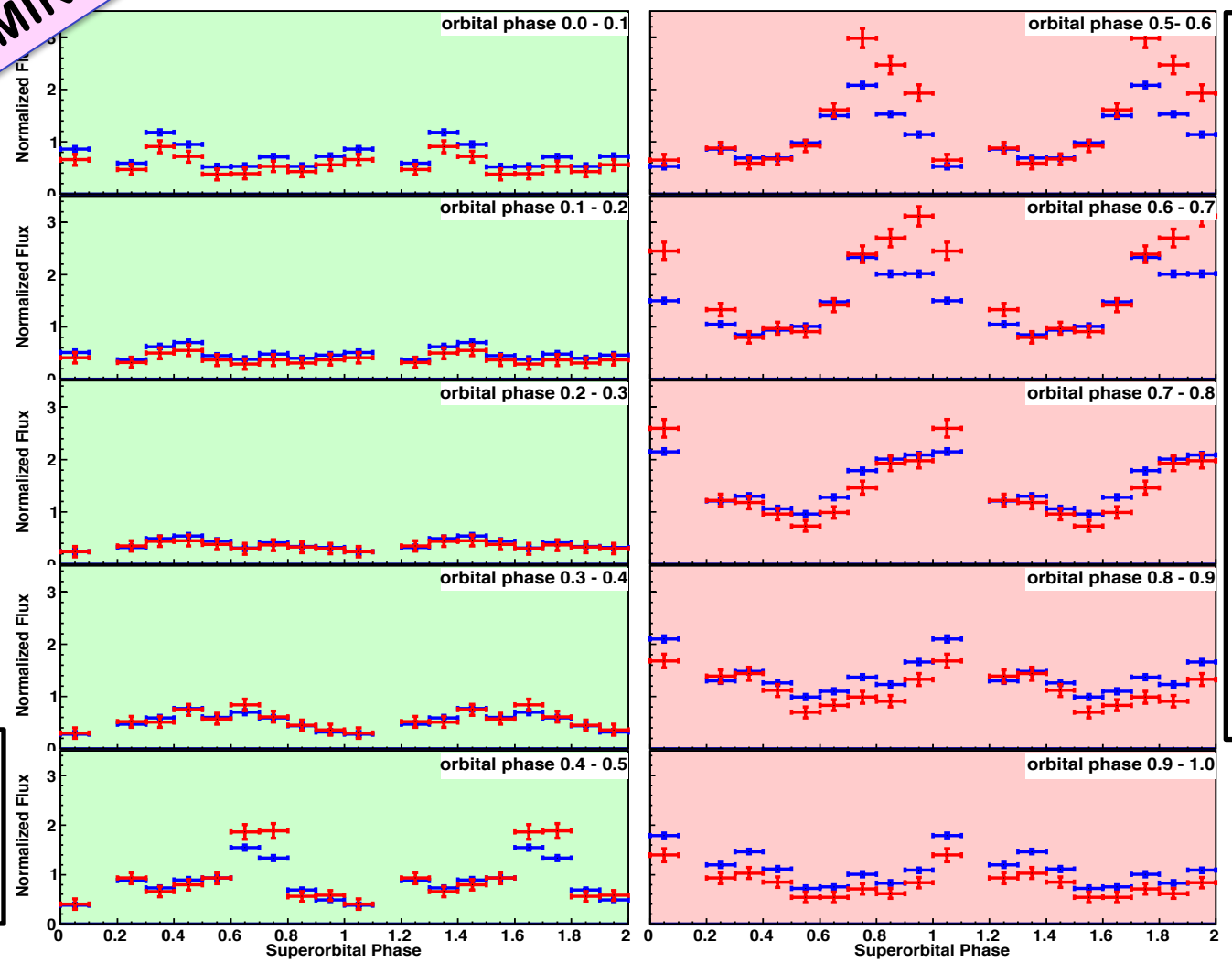
GBI data, 2.25GHz, 1994-2000

PRELIMINARY



GBI Data set: 2.25 GHz & 8.3 GHz

PRELIMINARY



Blue: 2.25GHz
Red: 8.3GHz

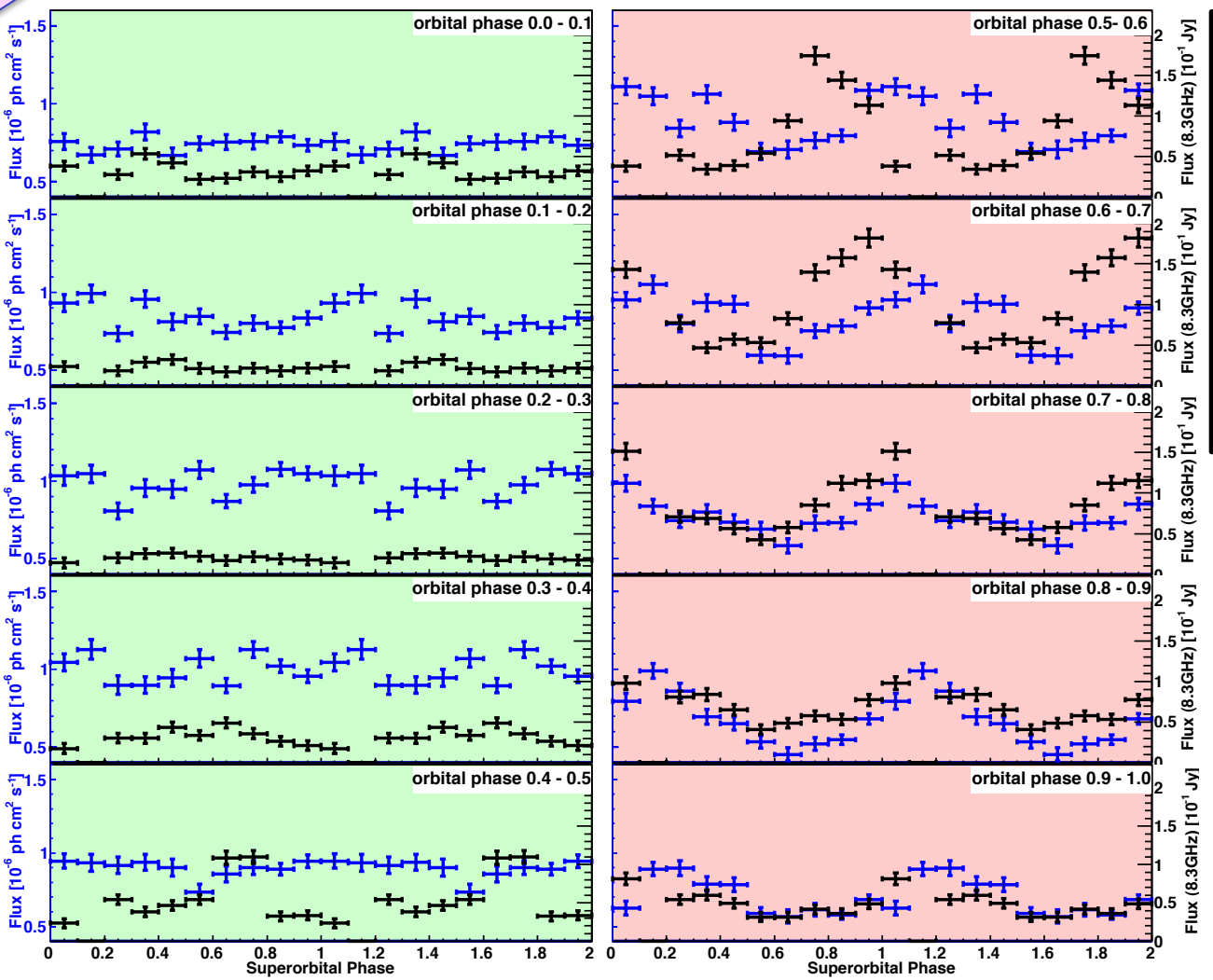
Average radio data in superorbital bins of 0.1

Both frequencies show almost same behavior

Modulation visible around apastron, like in GeV

Radio (8.3GHz) - GeV

PRELIMINARY



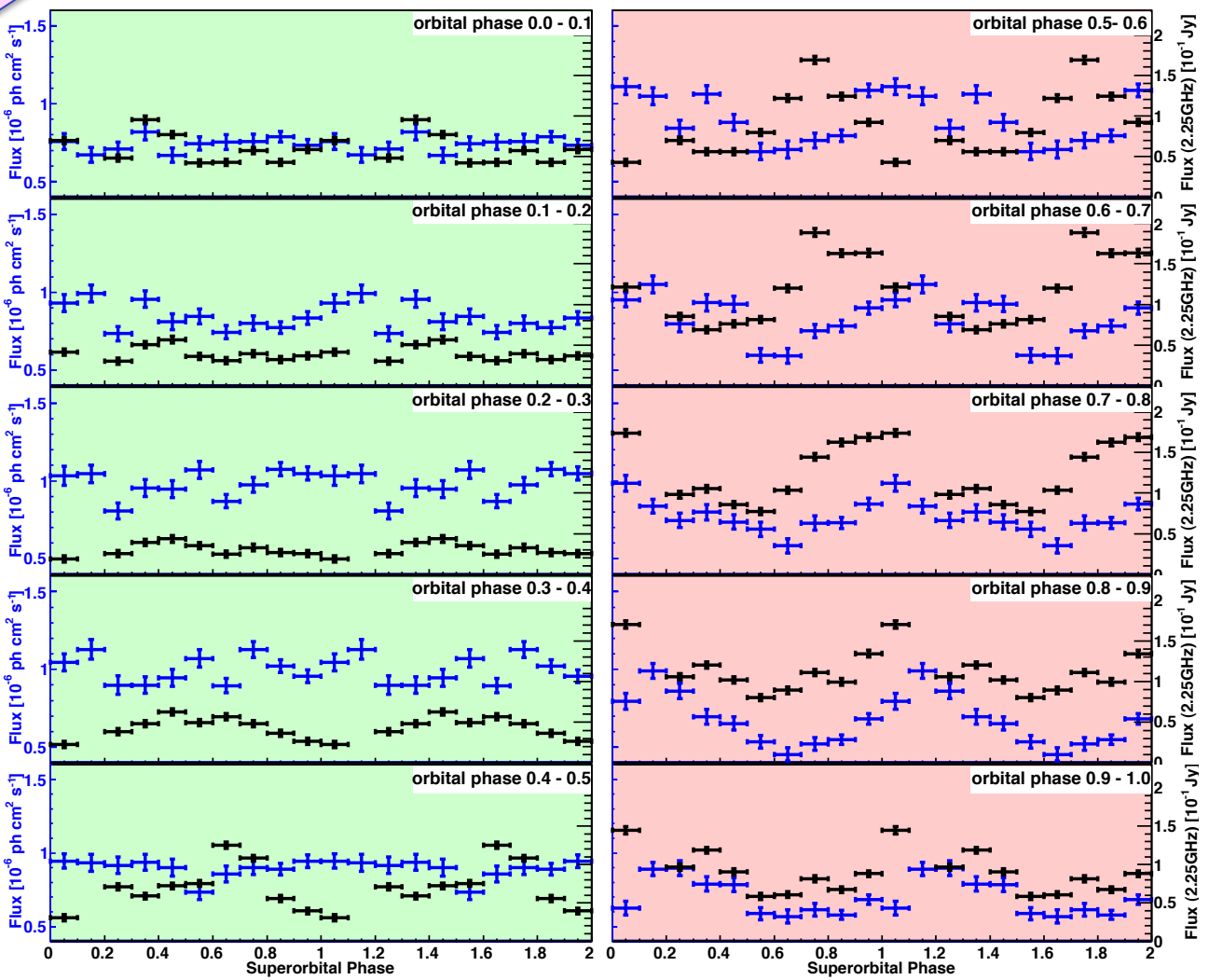
Pearson Corr. Coefficient:

Correlation GeV – Radio on 3σ level around apastron

Blue: GeV
Black: 8.3GHz

Radio (2.25GHz) - GeV

PRELIMINARY

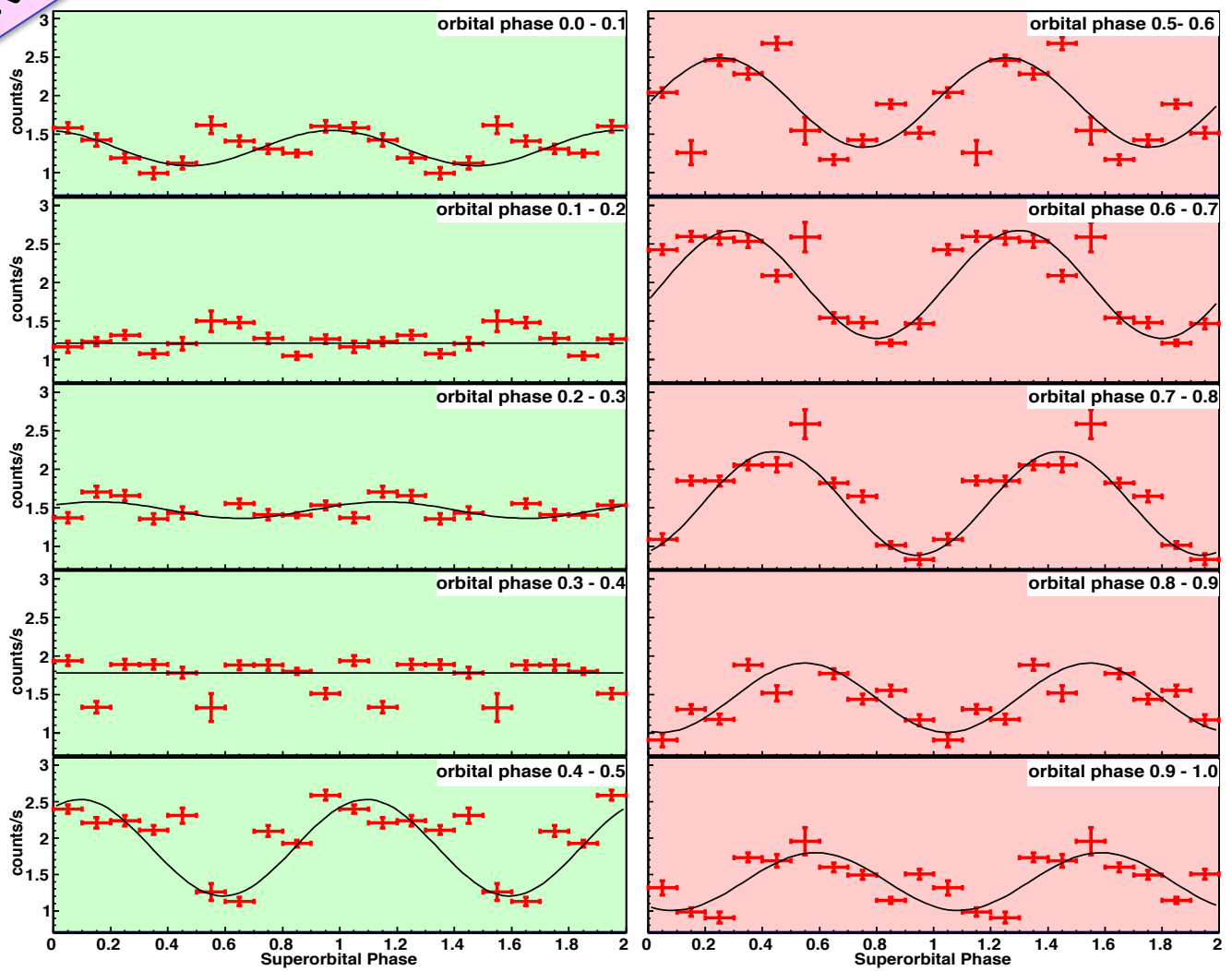


Blue: GeV
Black:
2.25GHz

X-RAY

X-ray (RXTE): Orbital phase bins in superorbit

PRELIMINARY

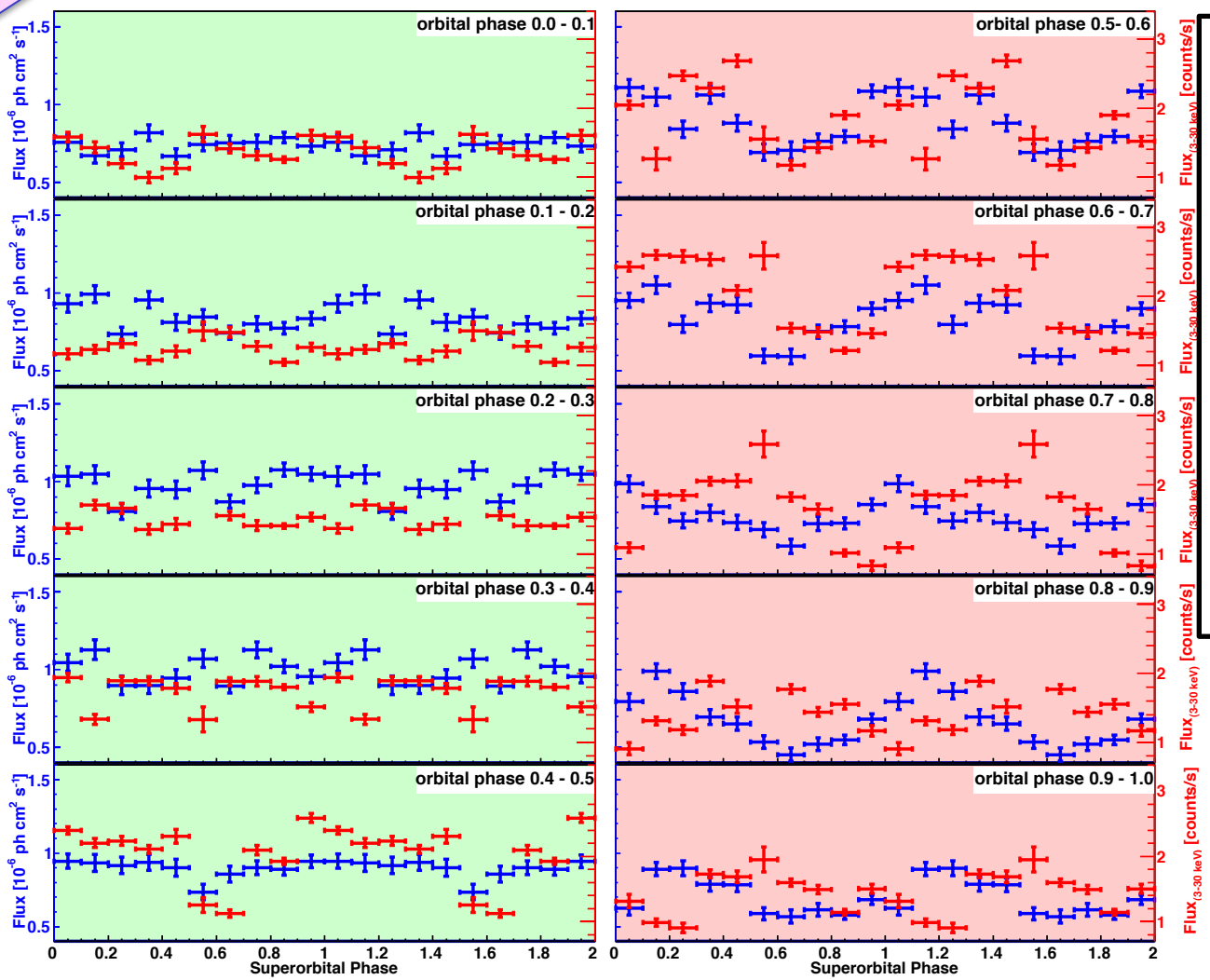


Modulation visible around apastron, like in GeV

Black line: Sinusoidal fit with fixed superorbital period

Comparison X-ray - GeV

PRELIMINARY



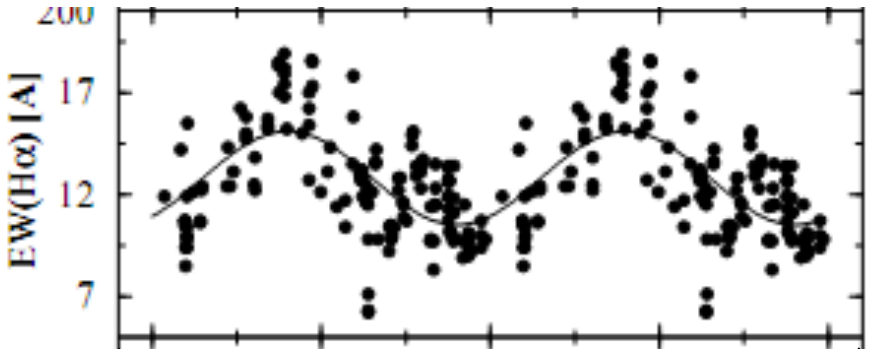
Blue: GeV
Red: X-ray

Pearson Corr. Coefficient: No significant correlation nor anticorrelation visible

X-ray emission shifted wrt GeV?

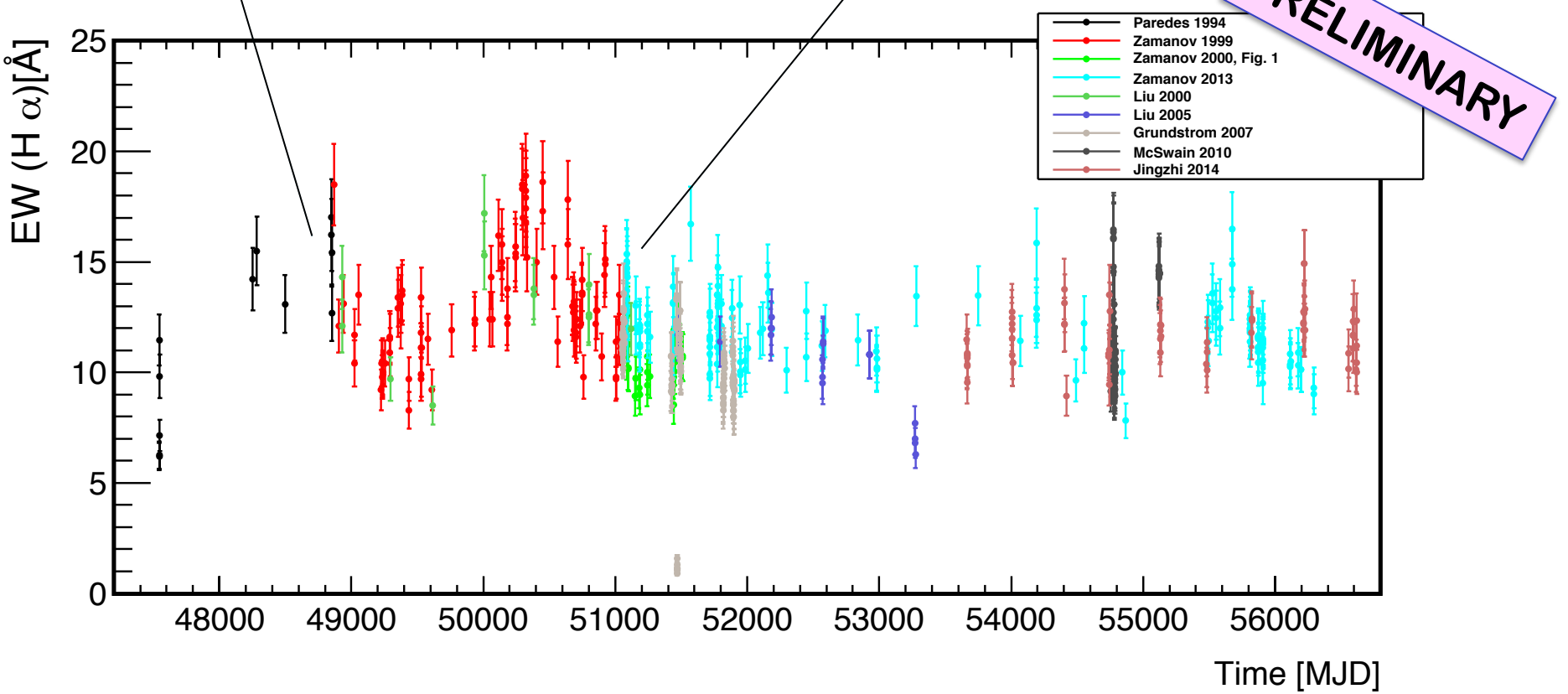
OPTICAL DATA

Hα data over several years



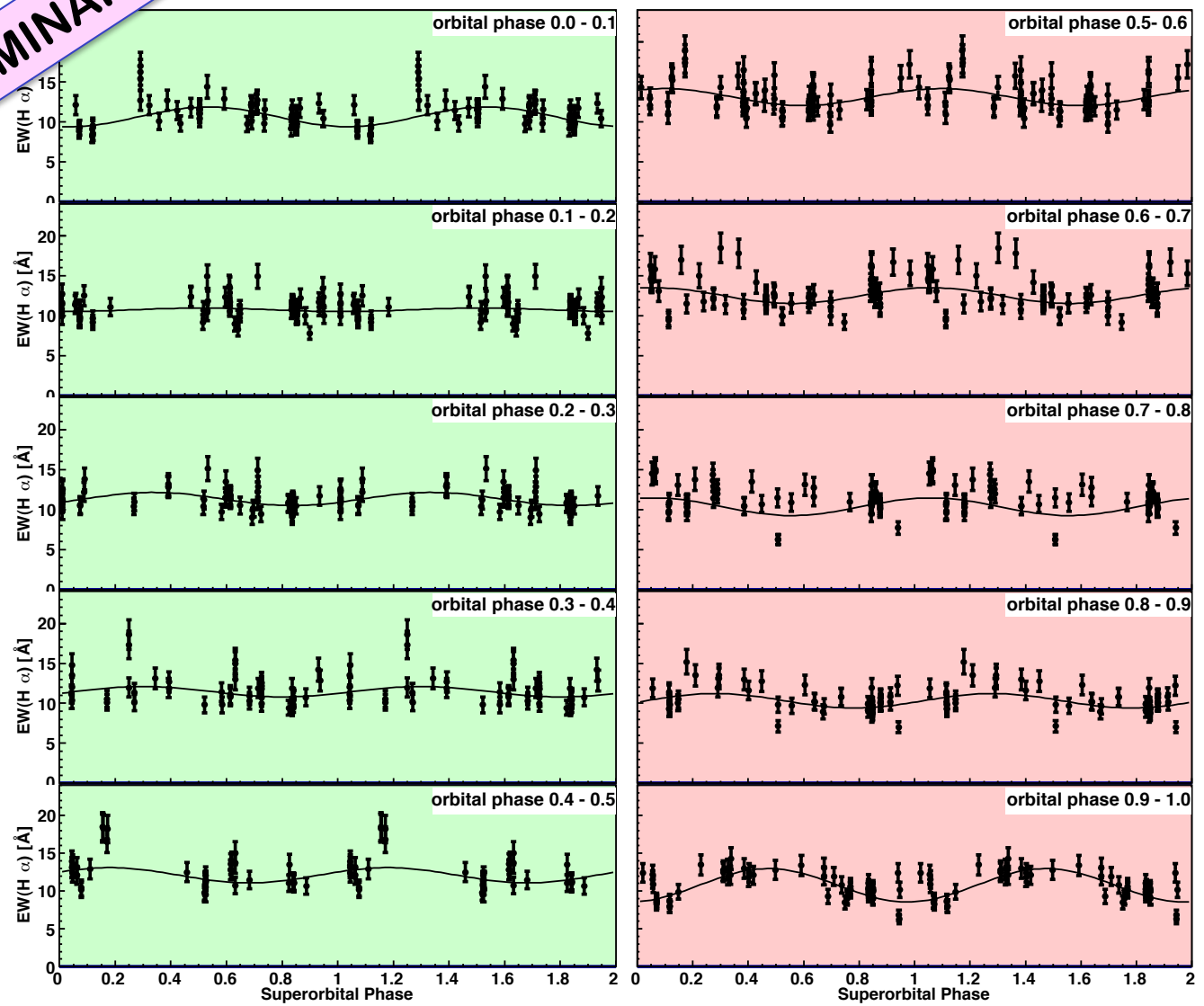
Equivalent width of Hα emission line also shows superorbital variability

PRELIMINARY



Hα: Orbital phase bins in superorbit

PRELIMINARY



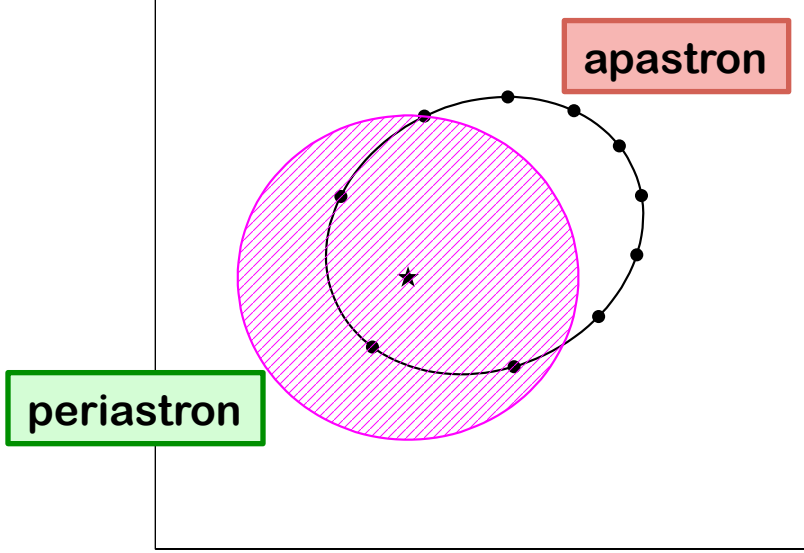
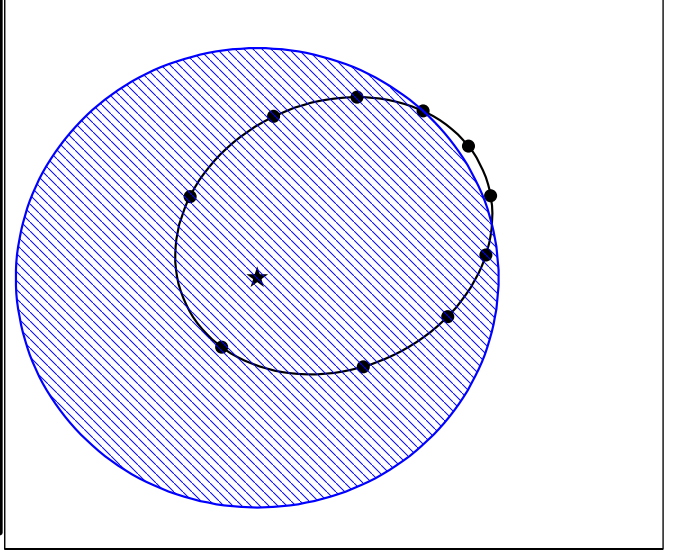
No clear modulation at any part of the orbit visible

Hα not a good tracer for characteristics of the disk?

A possible interpretation for modulation

The superorbital variability in Be binary could be understood as a quasi-cyclical increase of the circumstellar disc size or mass decretion rate

The influence of the matter stripped off from the disk by the compact object's passage can be larger and located farther out in periods of higher mass loss

Periods of a relatively smaller disc		Periods of a relatively larger disc
	In periastron the influence of the cyclical increase of the disc is minor or nil, since the compact object is always affected by it. In apastron the influence of the cyclical increase of the disc is larger, but likely not maximal since the disc may not reach to overtake it.	

Summary - Outlook

- Monitoring ongoing
  - Behavior in GeV stays the same with additional one year of data

- Multiwavelength behavior
  - Radio: Also shows superorbital modulation distinguishing apastron from periastron regions, like in GeV → Correlation at level of 3 sigma (Pearson corr. Coeff.)
  - X-ray: the same, plus no clear (anti)correlation visible. Emission shifted wrt GeV?
  - Hα: no clear superorbital modulation visible when all data is considered together
    →Hα not a good tracer? Too complex region mass-wise.

→Shown for first time that long term modulation visible at almost all frequencies
  →Radio, X-ray and GeV good tracer

- Future plans
  - Complete multi wavelength picture with TeV data
  - Find tracer for disk behavior

THANK YOU

ARIGATŌ GOZAIMASU

有難う 御座います