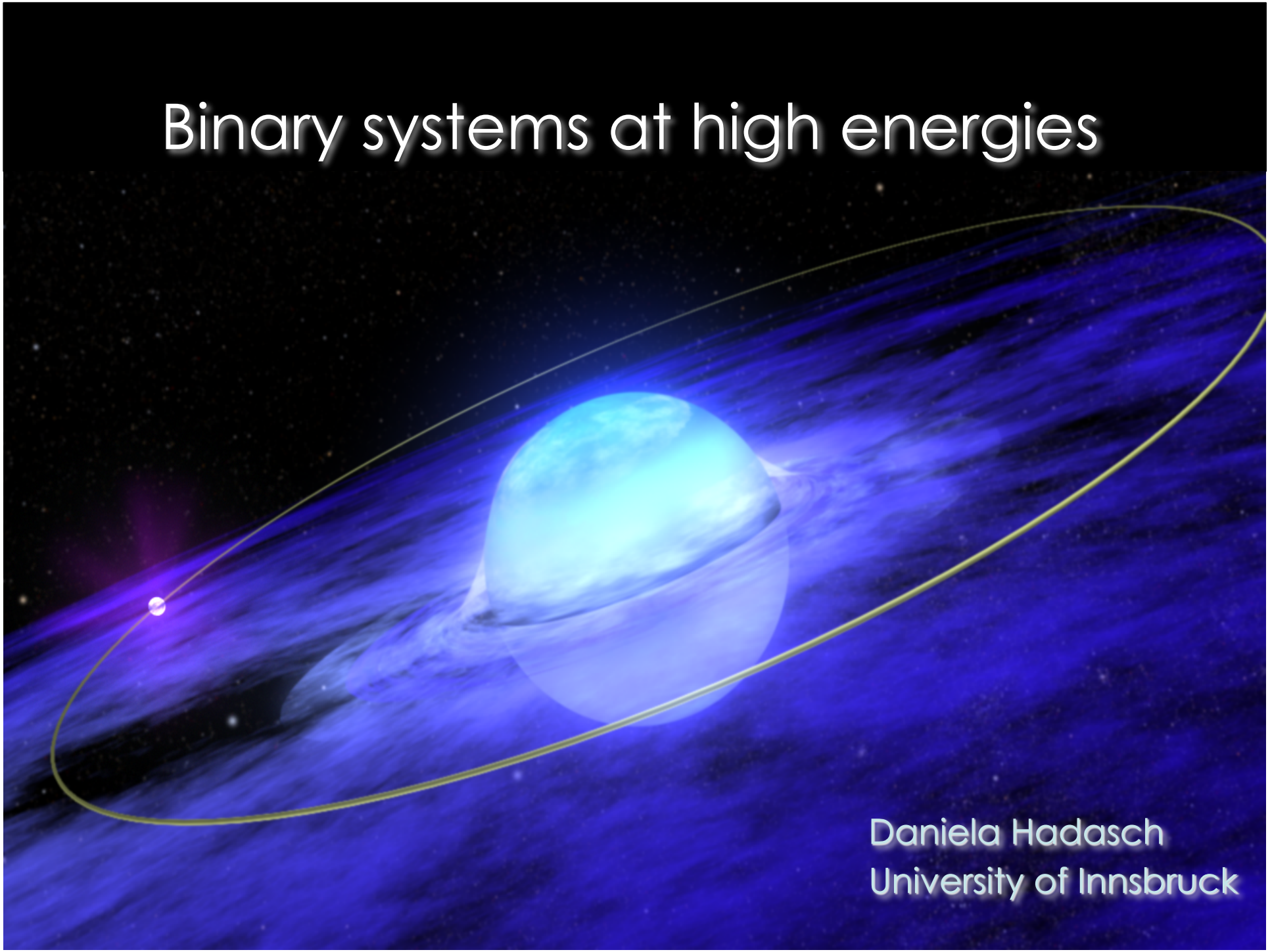
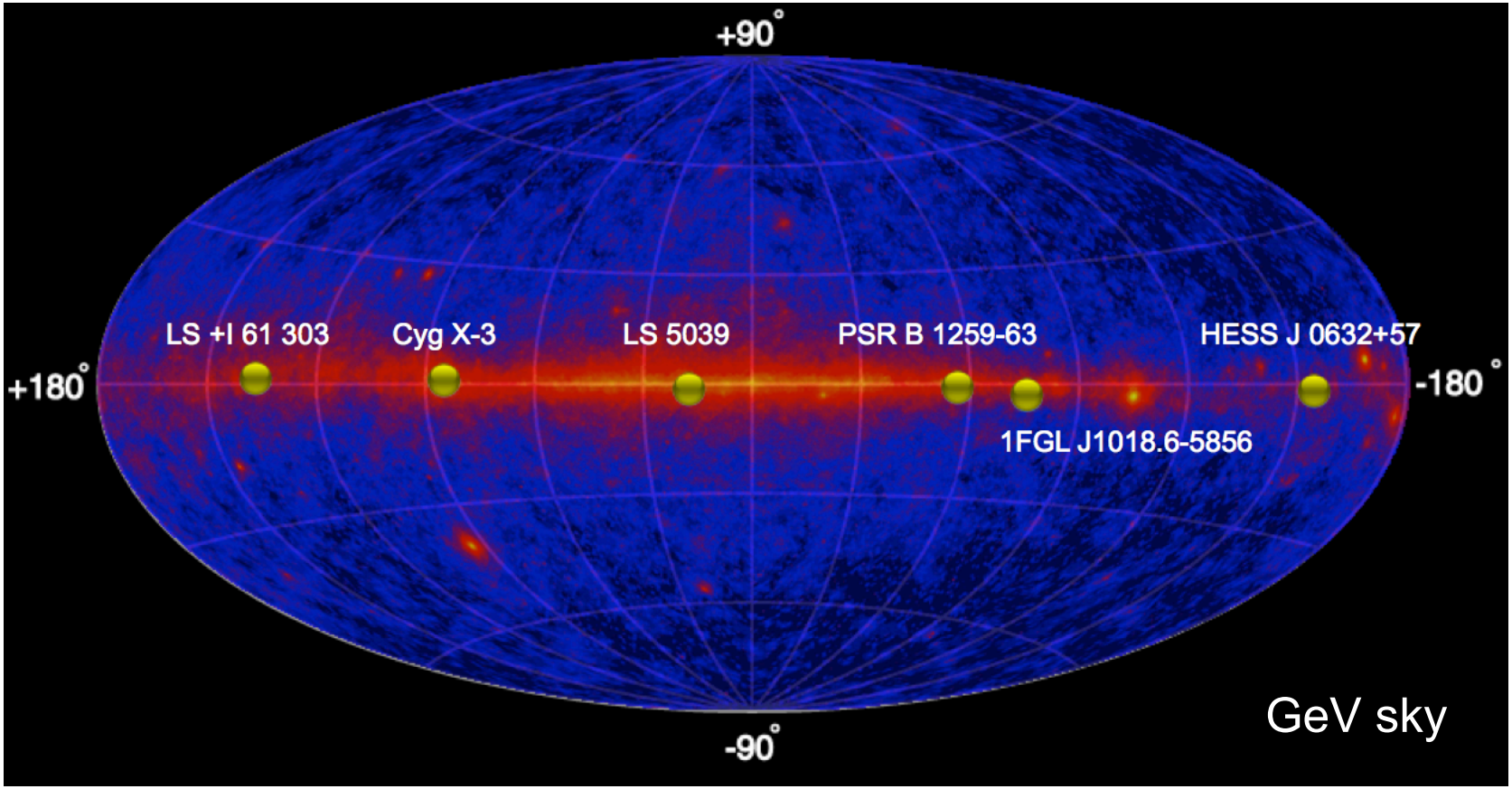
Binary systems at high energies



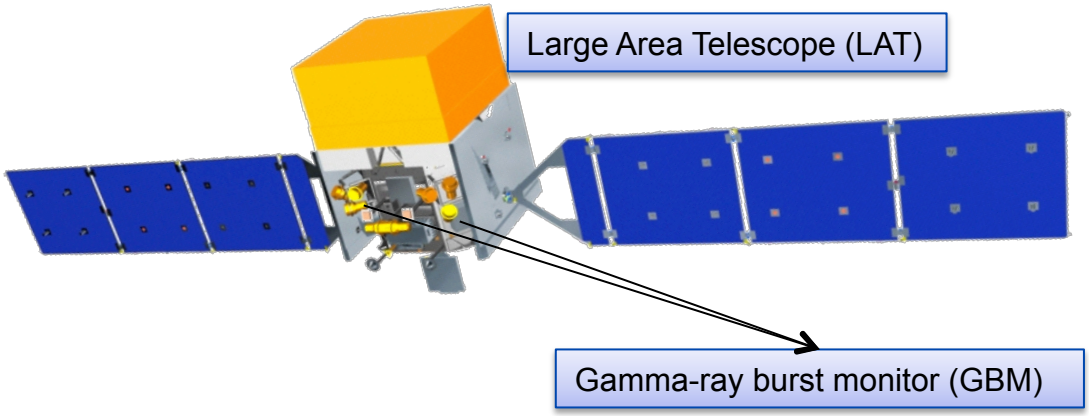
Daniela Hadasch
University of Innsbruck

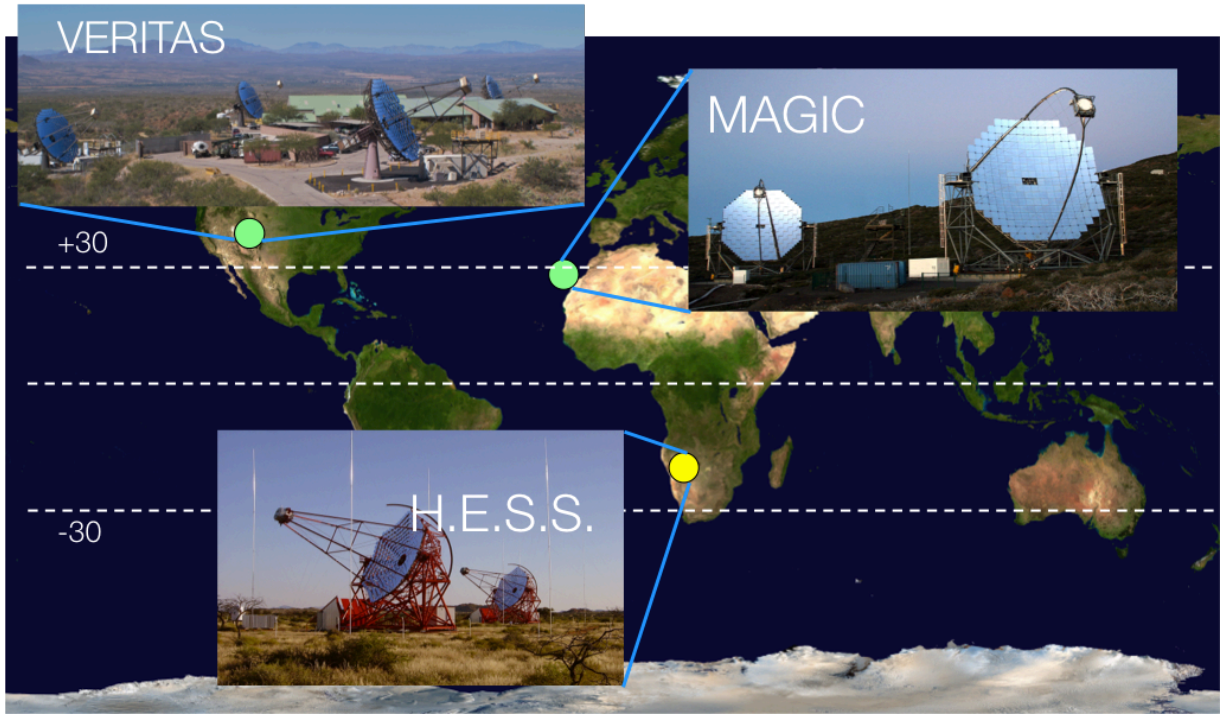
Overview

- Presentation of γ-ray binaries detected at GeV and/or TeV energies
  - Compact object + O or Be massive star companion
  - Peak emission beyond 1 MeV
- Microquasar Cygnus X-3



Instruments

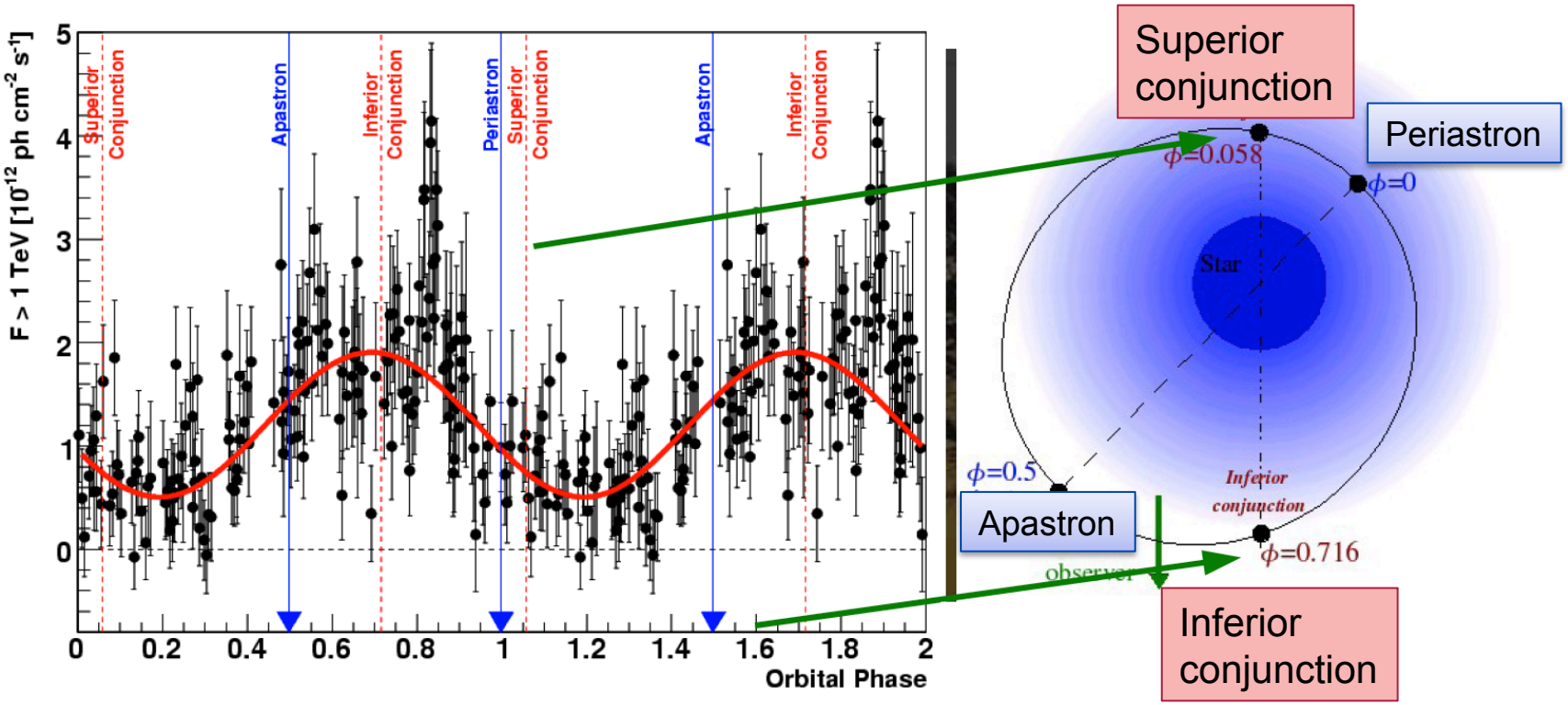




LS 5039

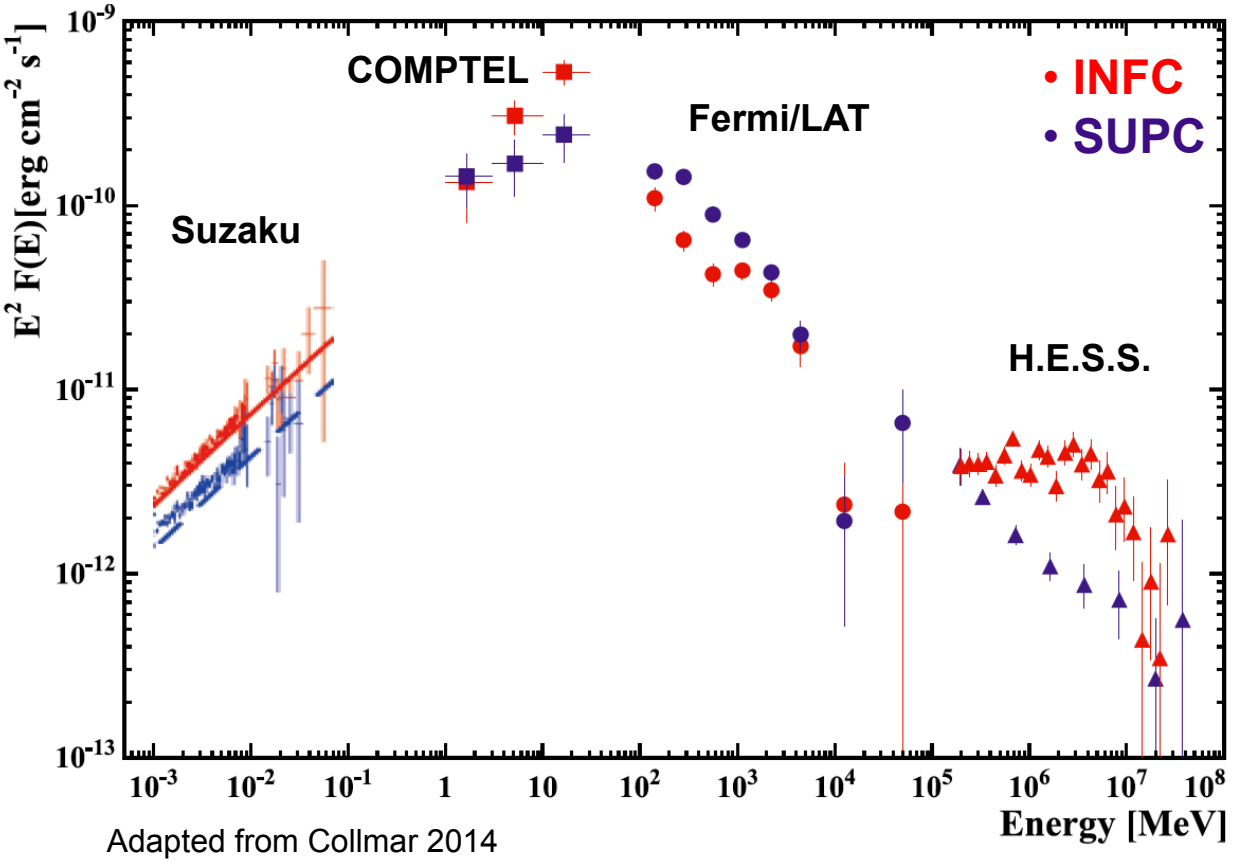
LS 5039 – time variability

- Periodicity detected in GeV (Fermi) and TeV (H.E.S.S.) at **3.9 days**
- Peak of emission at **GeV** around **periastron**, **anti-correlated** with **VHE**
  - Explanation: Modulation from inverse Compton on stellar light

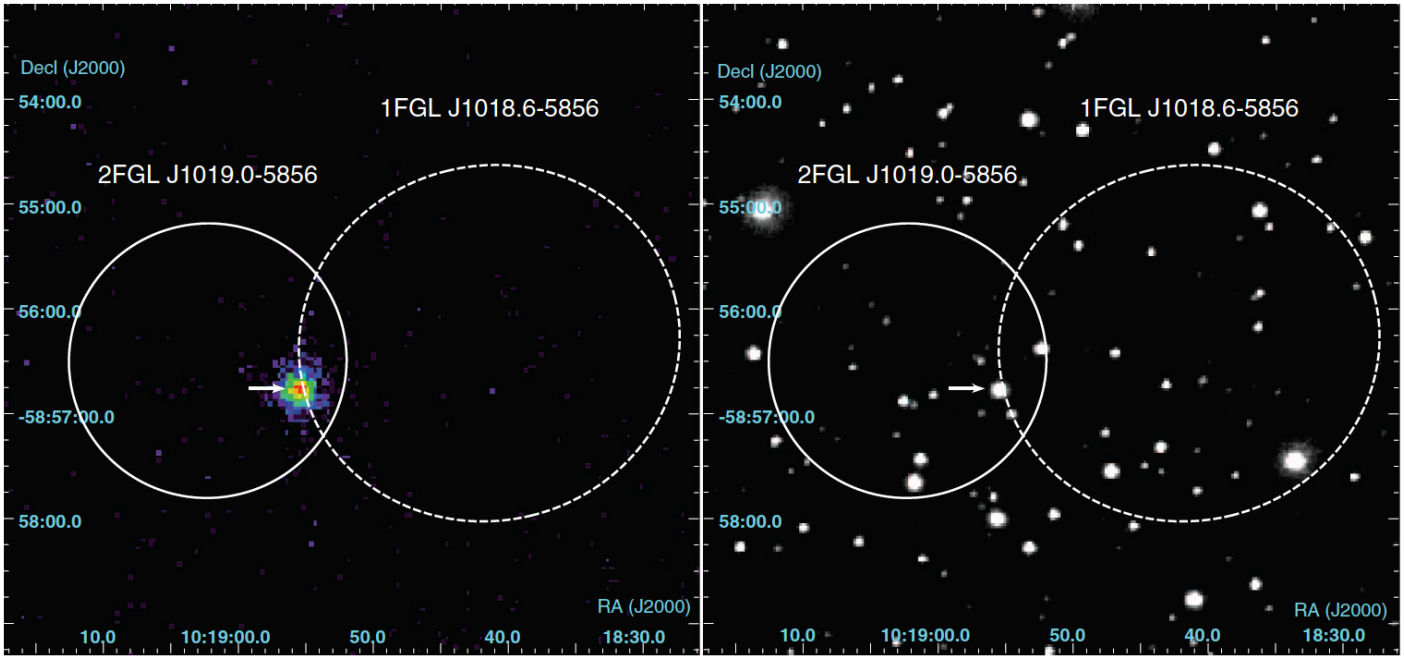


LS 5039 – SED

- No spectral or flux change during Fermi monitoring
  - Indications of **spectral variability** along the orbit from X-ray to TeV



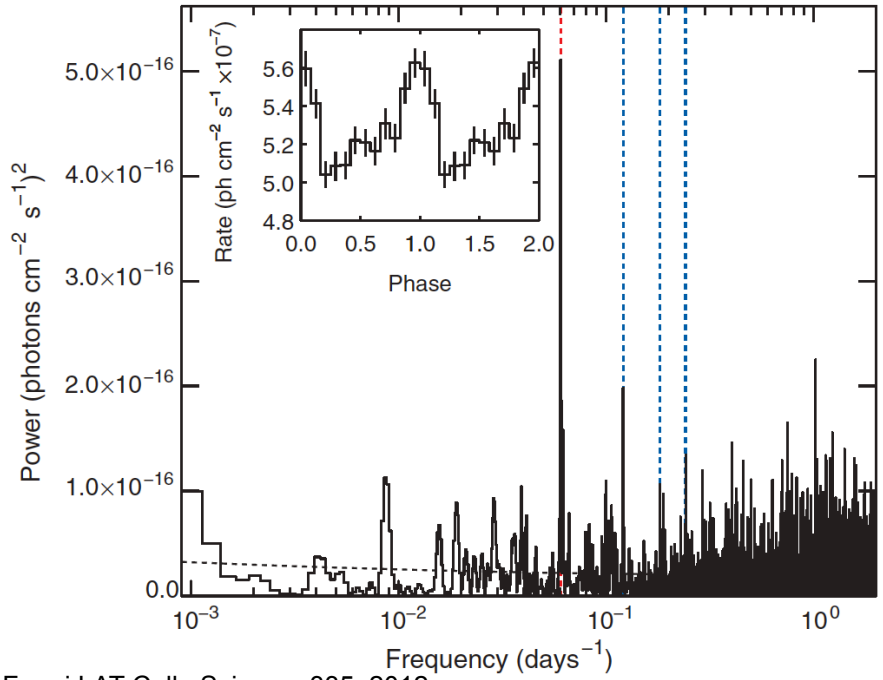
Adapted from Collmar 2014



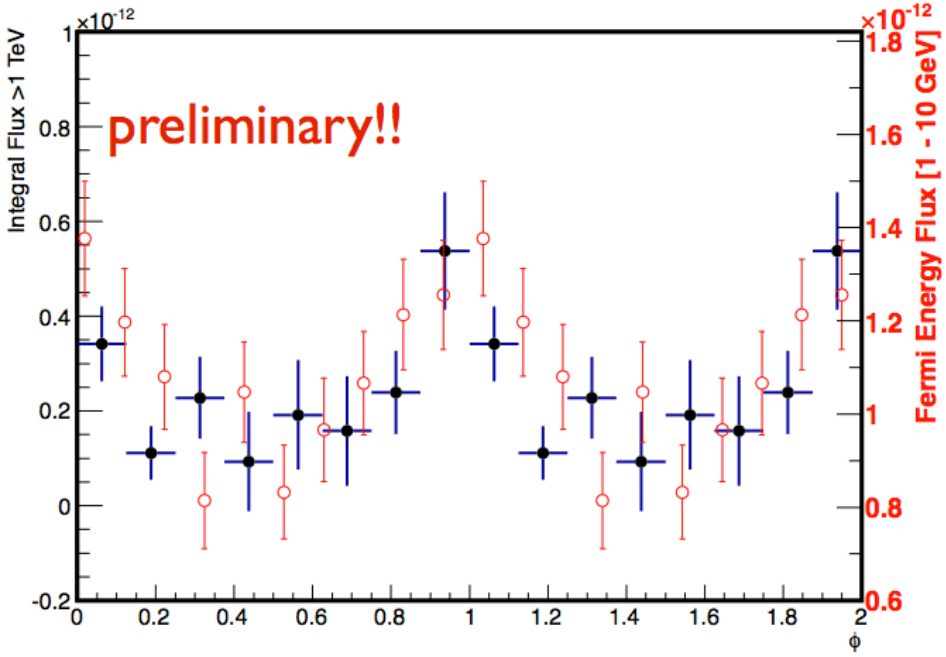
1FGL J1018.6-5856

1FGL J1018.6-5856

- **Search for modulation** in all 1FGL sources
  - **16.6 day periodicity** identified in one of them: 1FGL J1018.6-5856
- Source is qualitatively similar to LS 5039
- Associated with HESS J1018-589
  - **VHE data** folded in known 16.58 d period show modulation **in phase** with 1-10 GeV folded light curve measured with Fermi/LAT

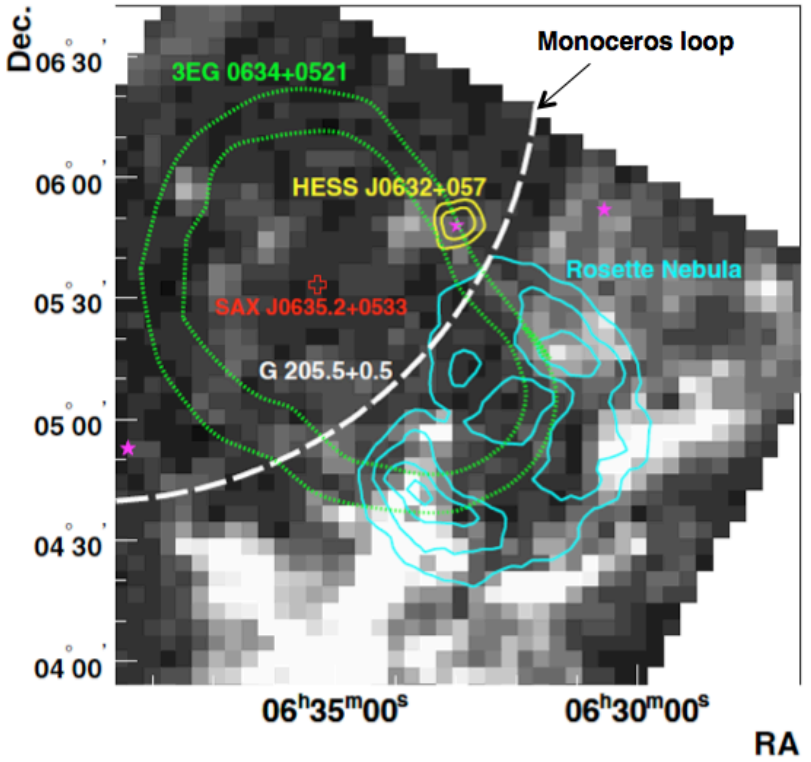


Fermi LAT Coll., Science, 335, 2012



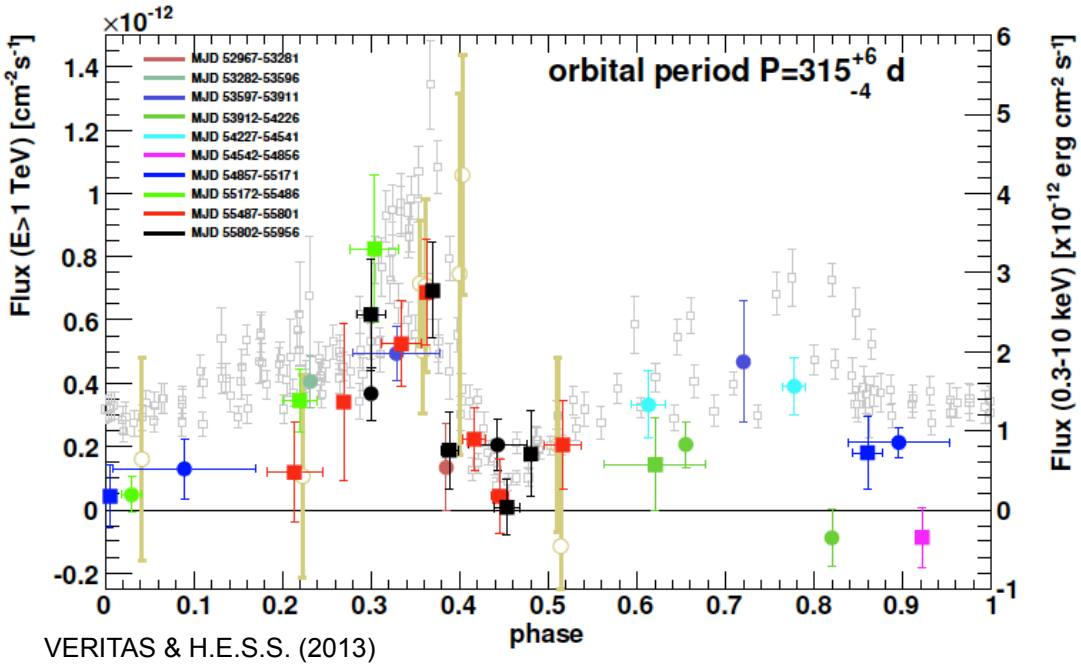
de Oña Wilhelmi 2013, 2013

HESS J0632+057

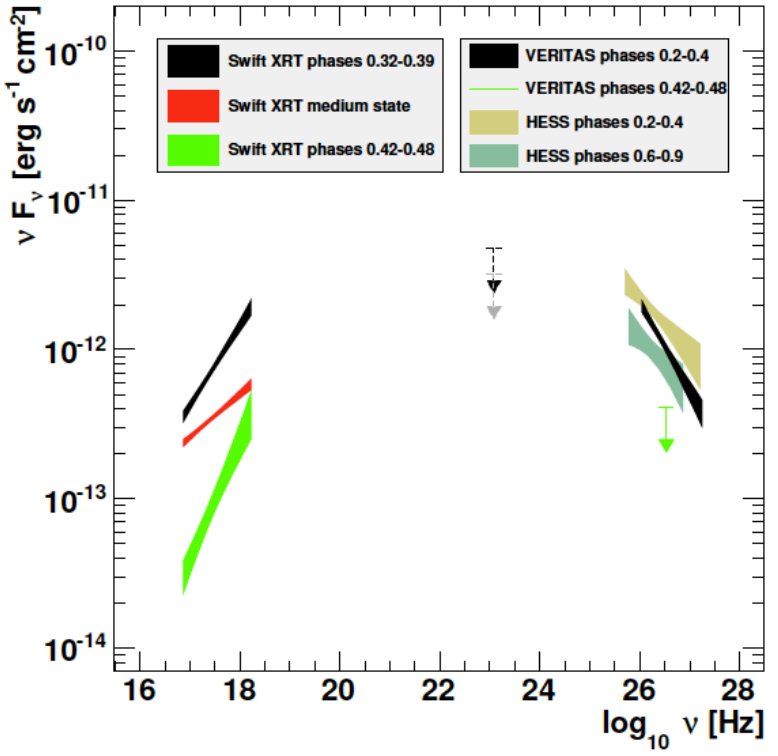


HESS J0632+057

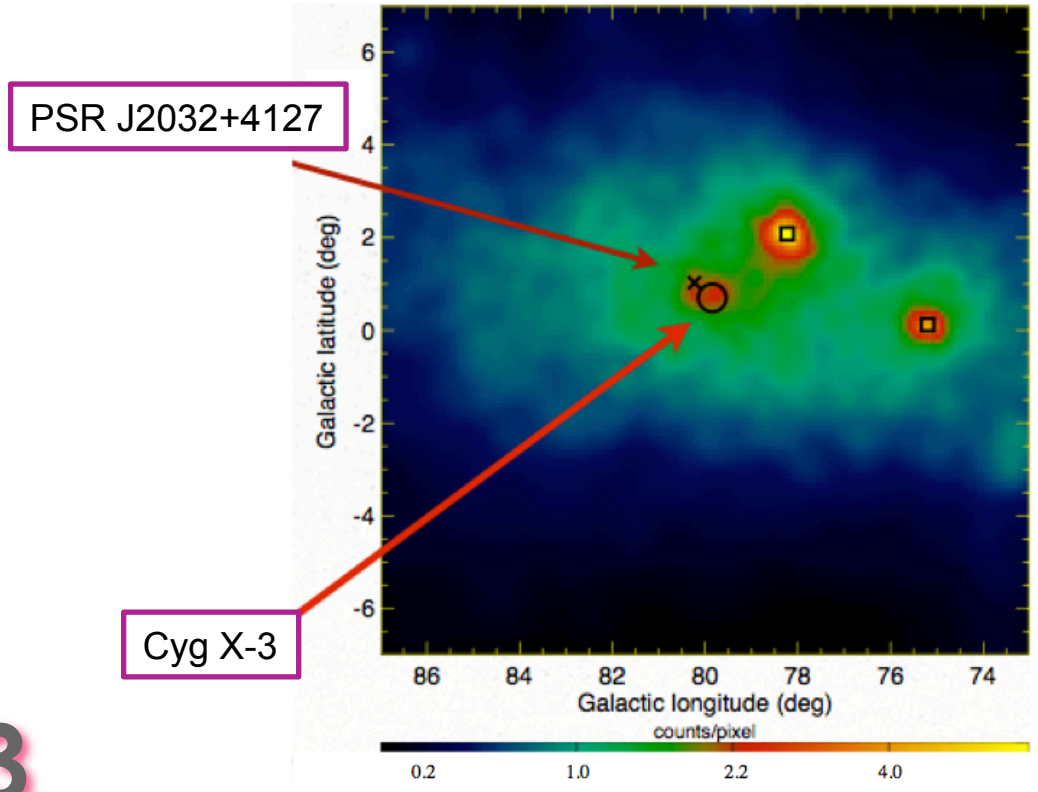
- Discovered serendipitously as point-like VHE γ-ray source (H.E.S.S.)
  - Only binary visible from Northern and Southern hemisphere
- Orbital period of **321 days** detected in X-rays
- **Correlation X-ray/VHE** → link between emission at both energies
- Swift-XRT + VHE during X-ray peak, dip and 2nd maximum
  - One zone leptonic model (sync. & IC)
  - Upper limit at GeV energies (Fermi/LAT)



VERITAS & H.E.S.S. (2013)

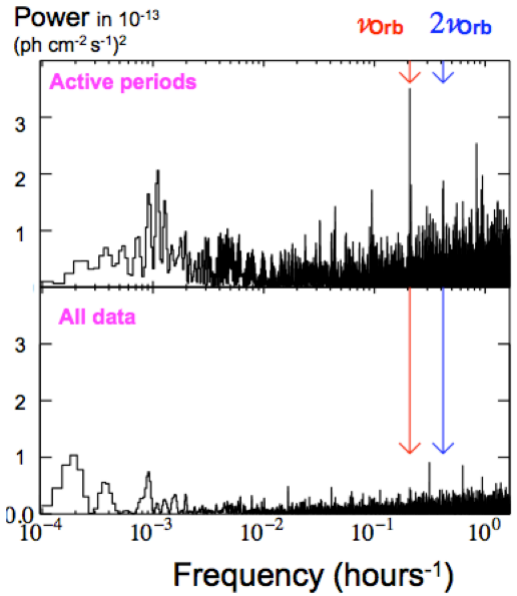


CYGNUS X-3


PSR J2032+4127
Cyg X-3
Galactic latitude (deg)
6
4
2
0
-2
-4
-6
86
84
82
80
78
76
74
Galactic longitude (deg)
counts/pixel
0.2
1.0
2.2
4.0

Cygnus X-3

- Long history
  - X-ray binary discovered 1966, 4.8 hour orbit, large radio flares discovered 70s
  - Confusing history in γ-rays (SAS-2, COS-B, EGRET)
  - Fermi and AGILE report γ-ray emission concurrent with **radio flares**
- Orbital period detected in GeV: **4.8 hours** (red arrows) → definitive ID
  - No significant orbital modulation in the entire dataset
  - Only confirmed γ-ray **microquasar** (Wolf-Rayet star + black hole (?))
- No detection at **VHE** although deep observations during active phase

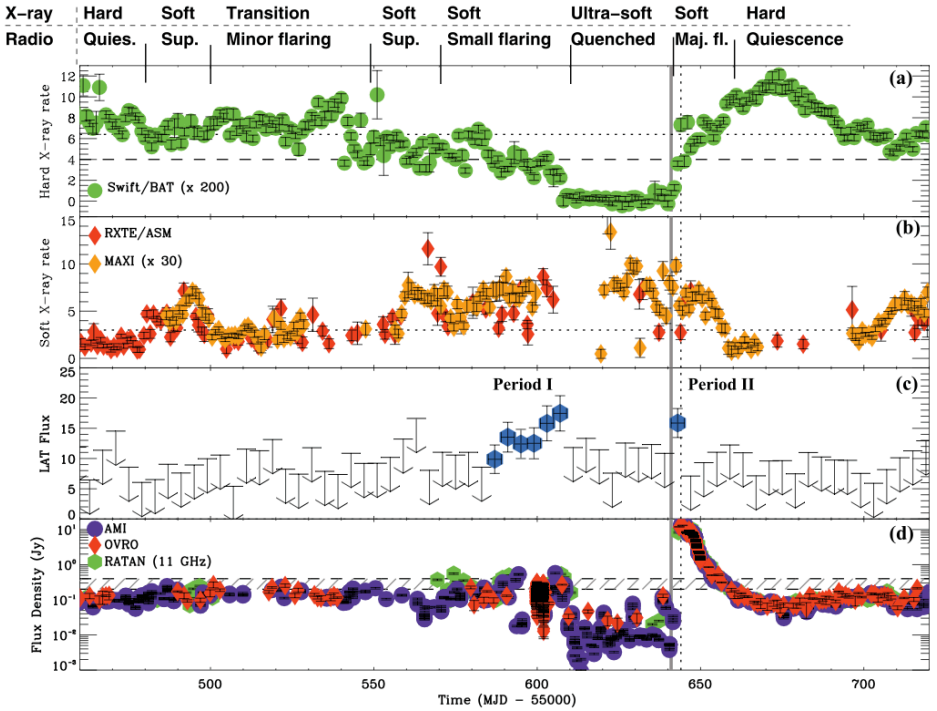


Fermi-LAT coll. et al., 2009, Science, 326, 1512
Tavani et al., 2009, Nature, 462, 620

Cyg X-3: giant radio flare

- 2011: **giant radio flare** observed, following a quenched radio state
- 3 conditions to detect high-energy γ-rays:
  1. **High level** of **soft X-ray** emission
  2. **Low level** of **hard X-ray** emission
  3. **Presence of significant emission** with **rapid variation** from active **relativistic jets** (radio flux > 0.2-0.4Jy)

- **Connection** between **γ-ray** and **radio** implies the emission is associated with the **relativistic jet**



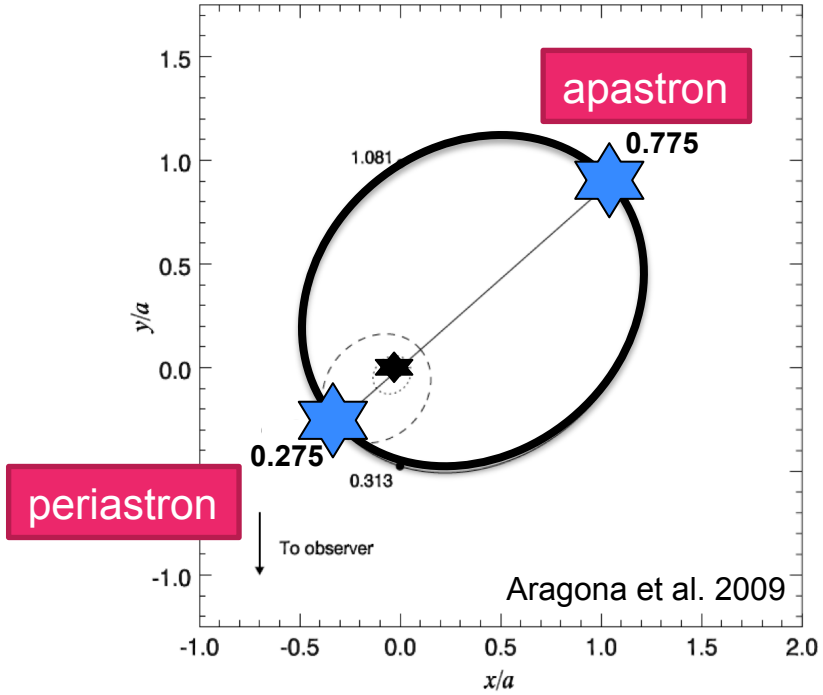
Accretion (disc/corona)

Non-thermal

Ejection (Jet)

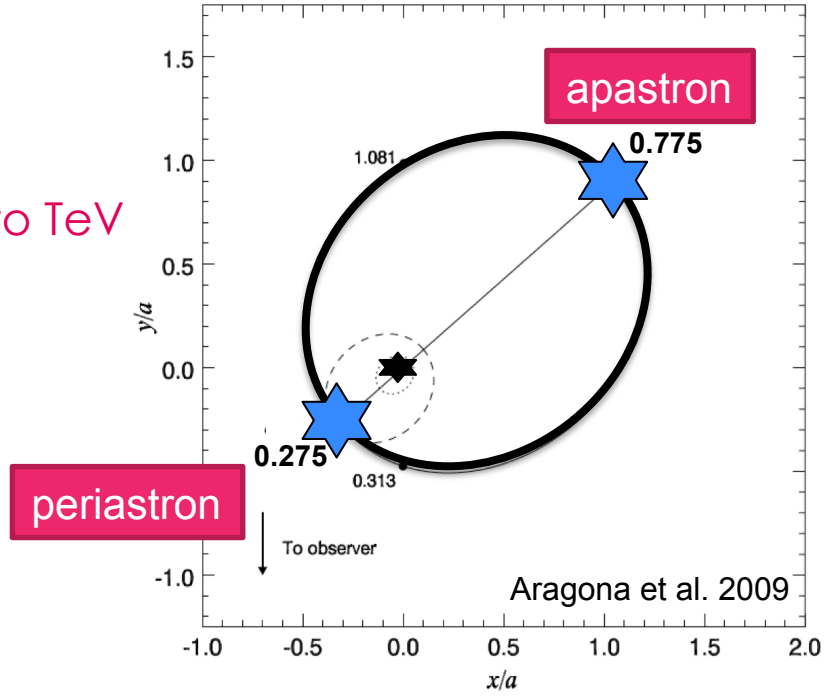
Corbel et al. (2012)

LS I +61° 303

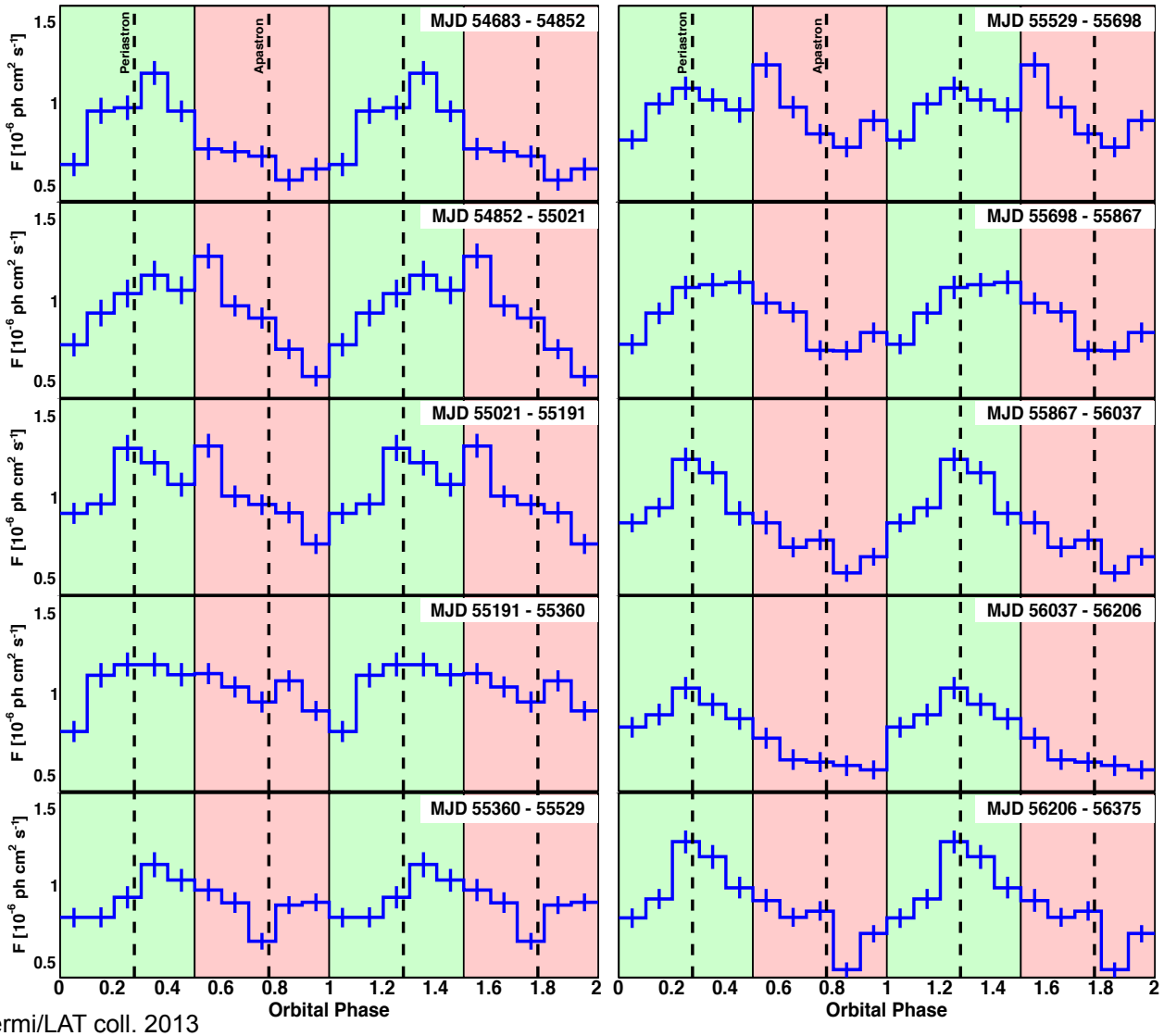

apastron
periastron
0.775
1.081
0.275
0.313
To observer
Aragona et al. 2009
y/a
x/a
1.5
1.0
0.5
0.0
-1.0
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0

LS I +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 stars: B-type stars that lose mass in an **equatorial, circumstellar disk**
- Orbital period
  - 26.496 +/- 0.0028 days (Gregory et al. 2002)
  - Intra-orbital variability known from X-rays to TeV
- Periodic radio outbursts (Gregory et al. 2002)
  - **Superorbital period** of 1667 days



Light curve folded in the orbital phase



Fermi/LAT coll. 2013

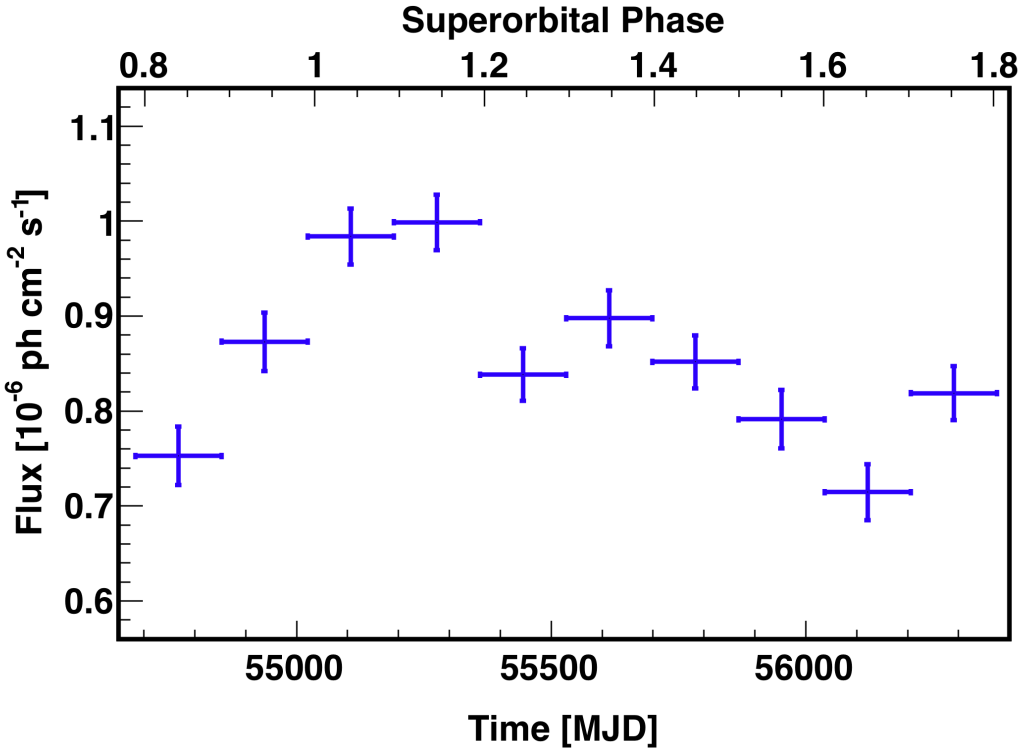
Each panel is ~6 months integration of Fermi data.

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

Is there variability in the superorbit?



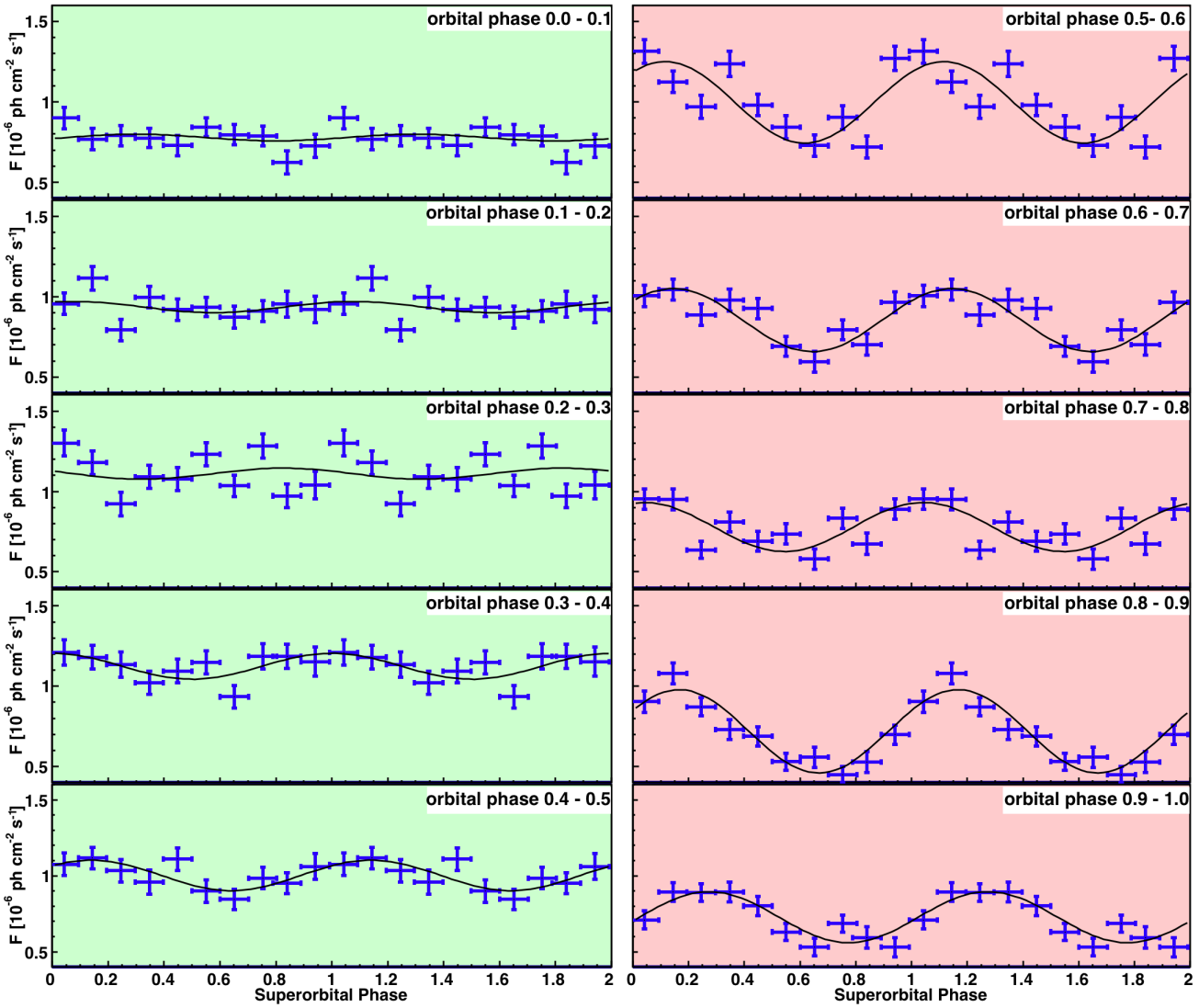
Fermi/LAT coll. 2013

- 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

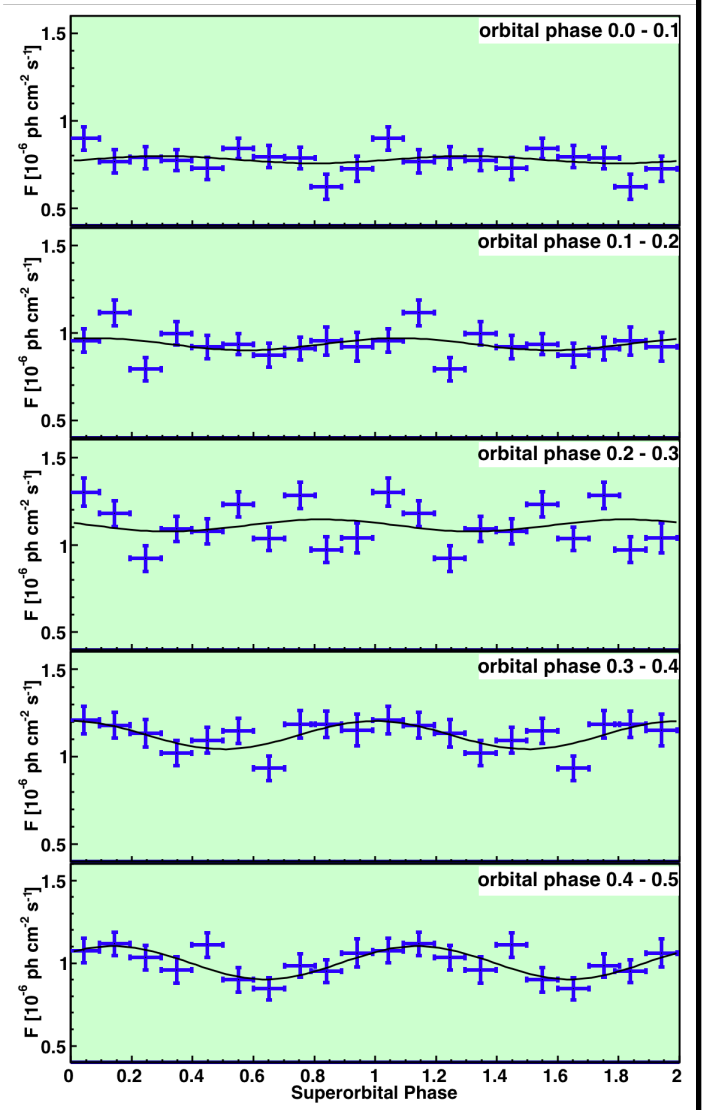


Each panel shows the GeV flux at a fixed orbital position, along a period of 4.5 years

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

Fermi/LAT coll. 2013

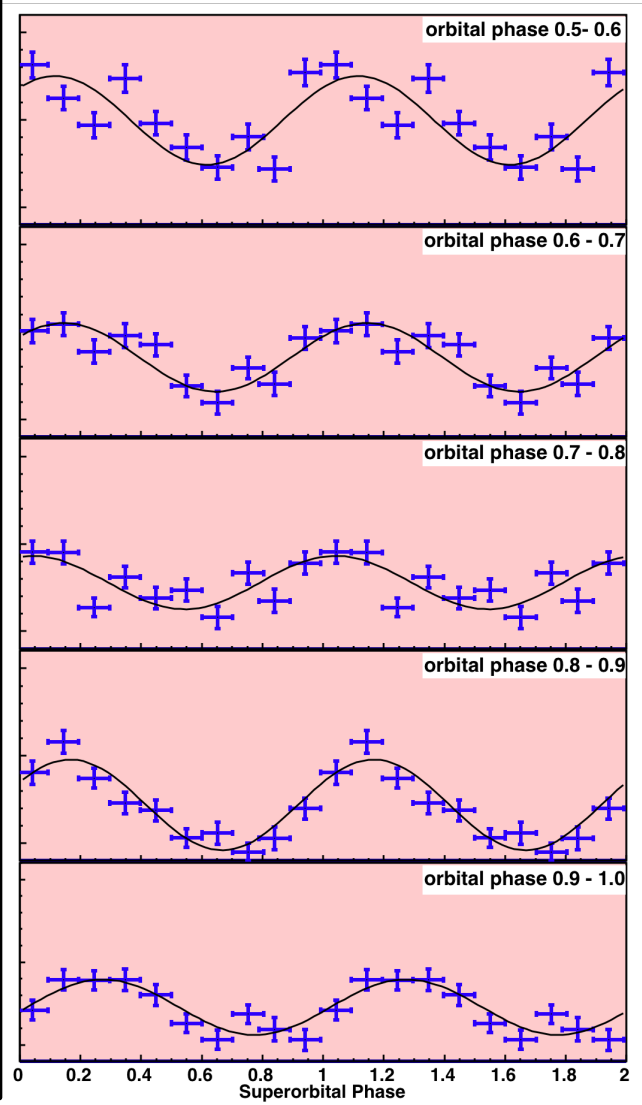
Orbital phase bins in superorbit



- 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.

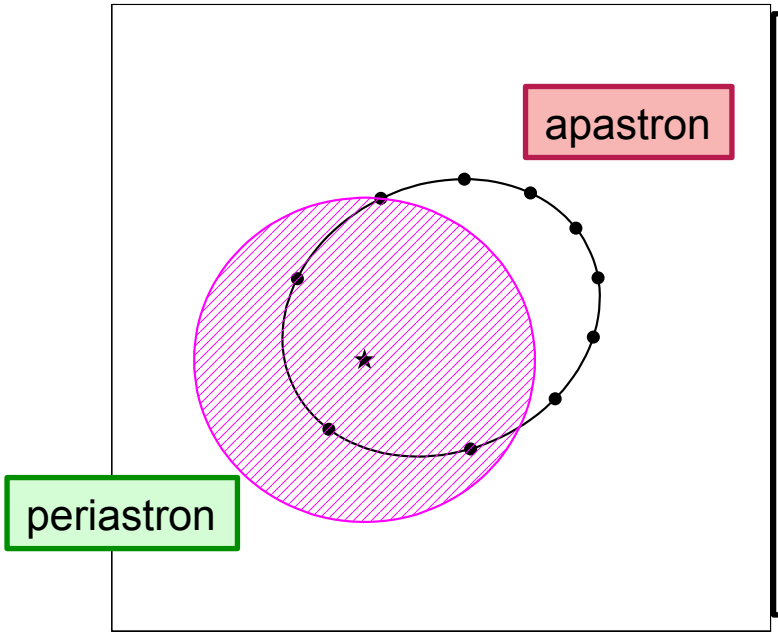


A possible direct interpretation

The superorbital variability in Be binary is a cyclical increase of the circumstellar disc size and mass decretion rate

The stellar disk of Be stars is well known to grow larger as the equivalent width of the Hα emission line increases (e.g., Hanushik et al. 1988; Grundstrom & Gies 2006, etc).

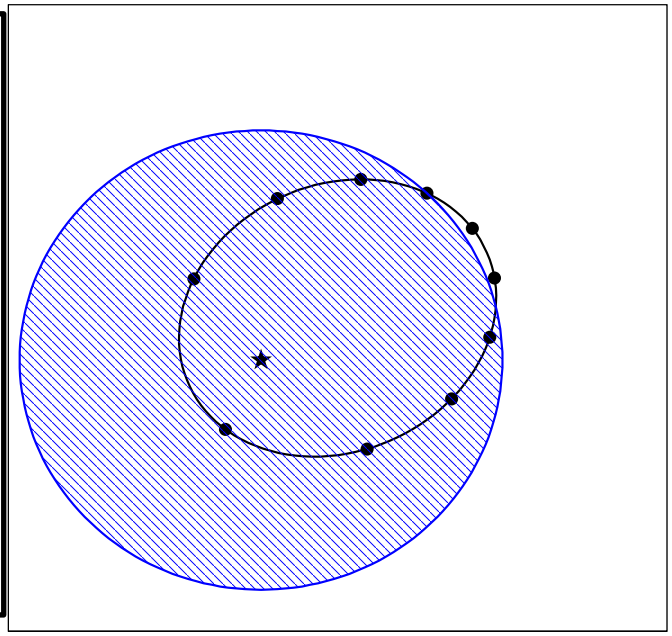
Periods of a relatively smaller disc



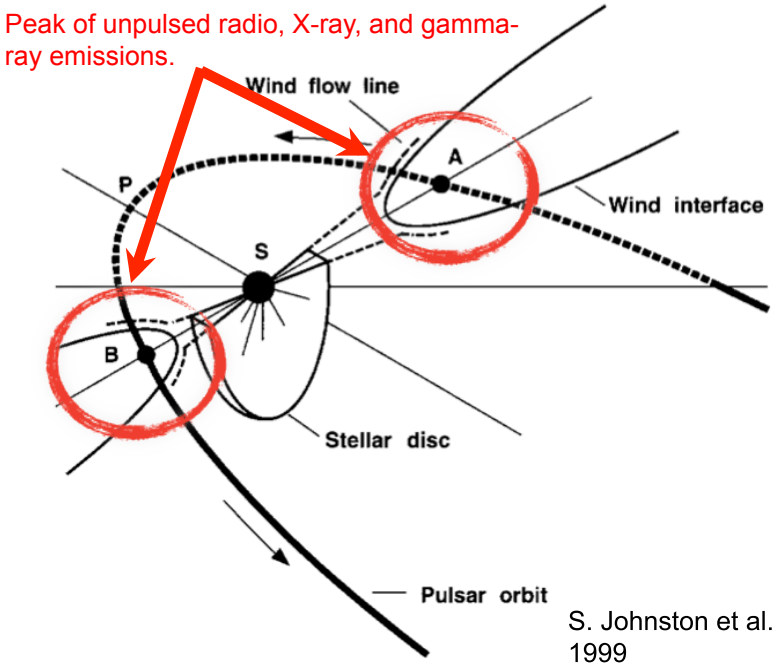
In periastron the influence of the cyclical increase of the disc is minor or nil, since the compact object is always affected by it.

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.

Periods of a relatively larger disc



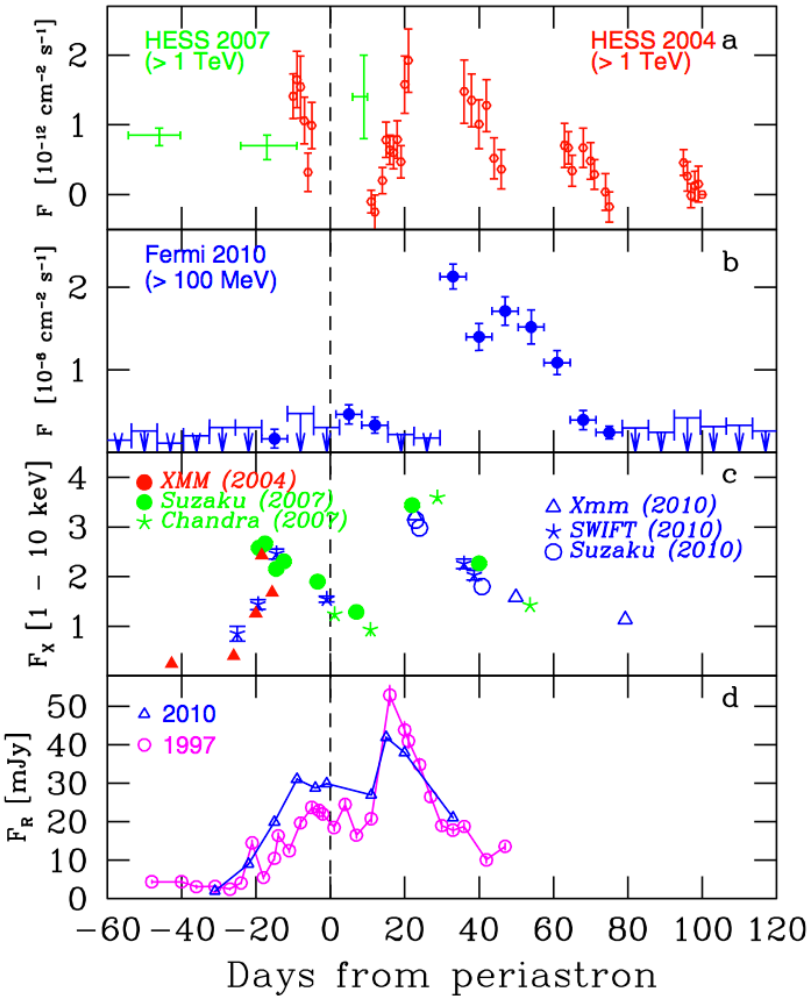
PSR B1259-63



S. Johnston et al. 1999

PSR B1259-63

- Highly elliptical **3.4 year** orbit of Be star
- **Radio pulsar** with period 47.76 ms
- **No pulsed emission** detected at **GeV** energies
- First GeV detection as the pulsar approached **periastron**
- Unexpected dramatic rise in the GeV flux **~30 days after periastron** and after the passage of the dense equatorial wind of the massive star
  - no corresponding changes in the X-ray flux
- Flaring behavior could be due to: emission anisotropies; abrupt changes in physical conditions; a new emission component



Abdo et al. (2011)

PSR B1259-63: NEWS

- Periastron passage: **May 4th, 2014**
  - Several Astronomical telegrams on rise of flux about 30 days after periastron passage
  - Rise is consistent with **repetition of the GeV light curve** observed at the 2010-2011 periastron

Flaring activity from PSR B1259-63

ATel #6204; *D. Malyshev, A. Neronov (ISDC - University of Geneva, CH), M. Chernyak (DCU, Ireland)*
on 6 Jun 2014; 10:06 UT
Credential Certification: Carlo Ferrigno (Carlo.Ferrigno@unige.ch)

Onset and Rapid Increase of Gamma-Ray activity from the Binary System PSR B1259-63 detected by Fermi LAT

ATel #6225; *K. S. Wood (NRL), G. A. Caliandro (CIFS/SLAC), C. C. Cheung (NRL), J. Li (IEEC-CSIC), D. F. Torres (IEEC-CSIC), for the Fermi LAT Collaboration*
on 10 Jun 2014; 23:52 UT
Distributed as an Instant Email Notice Transients
Credential Certification: Teddy Cheung (ccheung@milkyway.gsfc.nasa.gov)

Short-term X-ray/gamma-ray variability from PSR B1259-63

ATel #6248; *P. Bordas (Max-Planck-Institut fur Kernphysik), V. Zabalza (Department of Physics and Astronomy, University of Leicester), C. Romoli (Dublin Institute for Advanced Studies), D. Khangulyan (Institute of Space and Astronautical Science/JAXA) and G. Puehlhofer (Institut fur Astronomie und Astrophysik, Universitat Tuebingen)*
on 19 Jun 2014; 14:06 UT
Credential Certification: Pol Bordas (pol.bordas@mpi-hd.mpg.de)

Fermi LAT detection of a flaring activity from PSR B1259-63/LS 2883

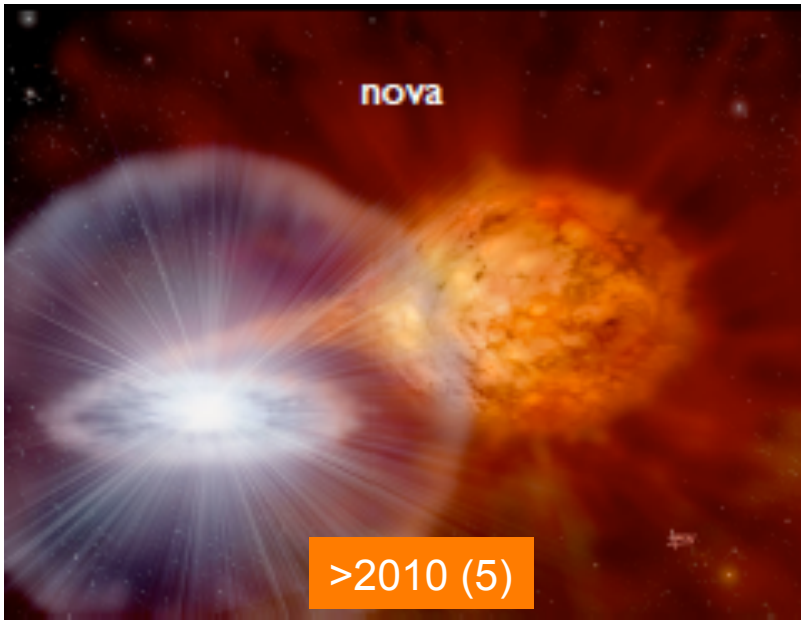
ATel #6216; *P. H. Thomas Tam, Albert K. H. Kong (National Tsing Hua University, Taiwan), and Gene C. K. Leung (The University of Hong Kong)*
on 9 Jun 2014; 15:51 UT
Distributed as an Instant Email Notice Transients
Credential Certification: P.H.Thomas Tam (grbtom@gmail.com)

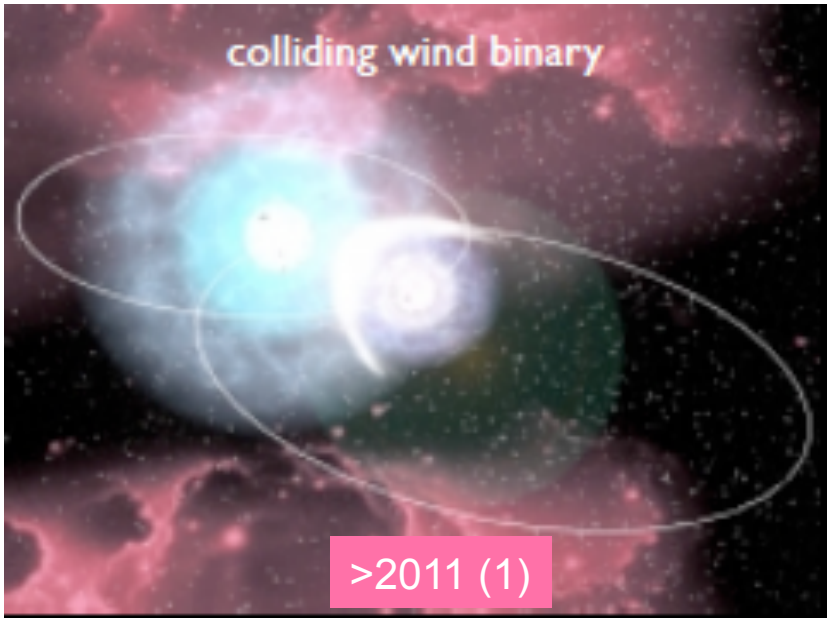
AGILE detection of a gamma-ray flare from the PSR B1259-63 region

ATel #6231; *C. Pittori, F. Verrecchia (ASDC and INAF/OAR), M. Tavani (INAF/IAPS, and Univ. Roma Tor Vergata), V. Fioretti (INAF/IASF-Bo), G. Piano (INAF/IAPS), F. Lucarelli (ASDC and INAF/OAR), E. Striani (CIFS and INAF/IAPS), S. Vercellone (INAF/IASF-Pa), A. Bulgarelli (INAF/IASF-Bo), I. Donnarumma (INAF/IAPS), M. Cardillo (INAF/OA-Arcetri and INAF/IAPS), F. Gianotti, M. Trifoglio (INAF/IASF-Bo), A. Giuliani, S. Mereghetti, P. Caraveo, F. Perotti (INAF/IASF-Mi), A. Chen (Wits University and INAF/IASF-Mi), S. Colafrancesco (INAF/OAR and Wits University), E. Del Monte, Y. Evangelista, M. Feroci, F. Lazzarotto, L. Pacciani, P. Soffitta, E. Costa, I. Lapshov, M. Rapisarda, A. Argan, G. Pucella, S. Sabatini, A. Trois, V. Vittorini (INAF/IAPS), F. Fuschino, M. Galli, C. Labanti, M. Marisaldi, G. Di Cocco (INAF/IASF-Bo), A. Pellizzoni (INAF/OA-Cagliari), M. Pilia (ASTRON, the Netherlands), G. Barbiellini, E. Vallazza (INFN Trieste), F. Longo (Univ. Trieste and INFN Trieste), A. Morselli, P. Picozza (INFN and Univ. Roma Tor Vergata), M. Prest (Univ. dell'Insubria), P. Lipari, D. Zanello (INFN and Univ. Roma Sapienza), P. W. Cattaneo, A. Rappoldi (INFN Pavia), P. Giommi (ASDC), L. Salotti, and G. Valentini (ASI)*
on 13 Jun 2014; 21:59 UT
Credential Certification: Francesco Verrecchia (francesco.verrecchia@asdc.asi.it)

Further binary systems

- γ-ray novae population at GeV
  - White dwarf in orbit around a red giant
  - Recent novae discoveries: 5 systems in ~5 years detected at GeV energies
  - No detection at TeV
- Colliding wind binary: Eta Carinae
  - Detected at GeV: this summer one complete orbit (5.5 years) covered
  - No γ-ray emission from other CWB
  - Upper limits derived by H.E.S.S.





Summary – HE binary population

- Most compact objects still unknown: **neutron star** or **black hole**?

	LS I +61 303	LS 5039	PSR B1259-63	1FGL J1018.6-5856	HESS J0632+057	Cyg X-3
Orbital period	26.5 days	3.9 days	3.4 years	16.6 days	321 days	4.8 hrs
Star type	Be	O	Be	O	Be	Wolf-Rayet
Compact obj.	?	?	Pulsar (48ms)	?	?	Likely BH
Distance (kpc)	2.0	2.5	2.3	5.4	1.5	~7
Eccentricity	0.54	0.35	0.87	-	0.83	-
GeV	✔	✔	✔	✔	✖	✔
TeV	✔	✔	✔	✔	✔	✖

Cyg X-1:
• AGILE detected hint of γ-ray flare, Fermi puts upper limits
• Hint of TeV flare emission reported by MAGIC, deeper observation also with VERITAS → ULs

THANK YOU