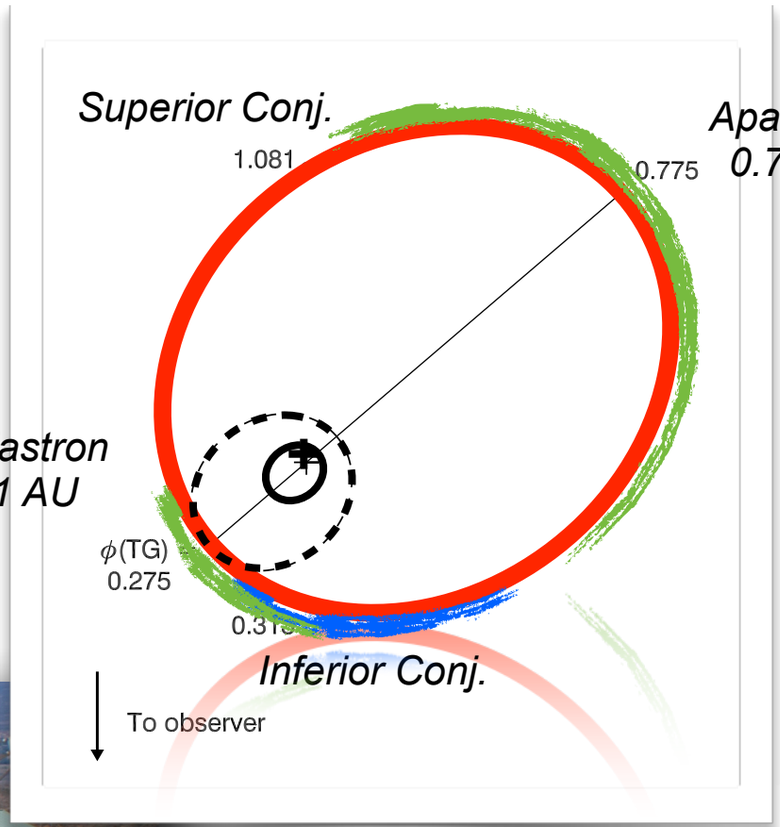
Observation of binary systems at very-high energies with VERITAS

Gernot Maier for the VERITAS Collaboration

New results on LS I +61 303 and HESS J0632+057



VERITAS

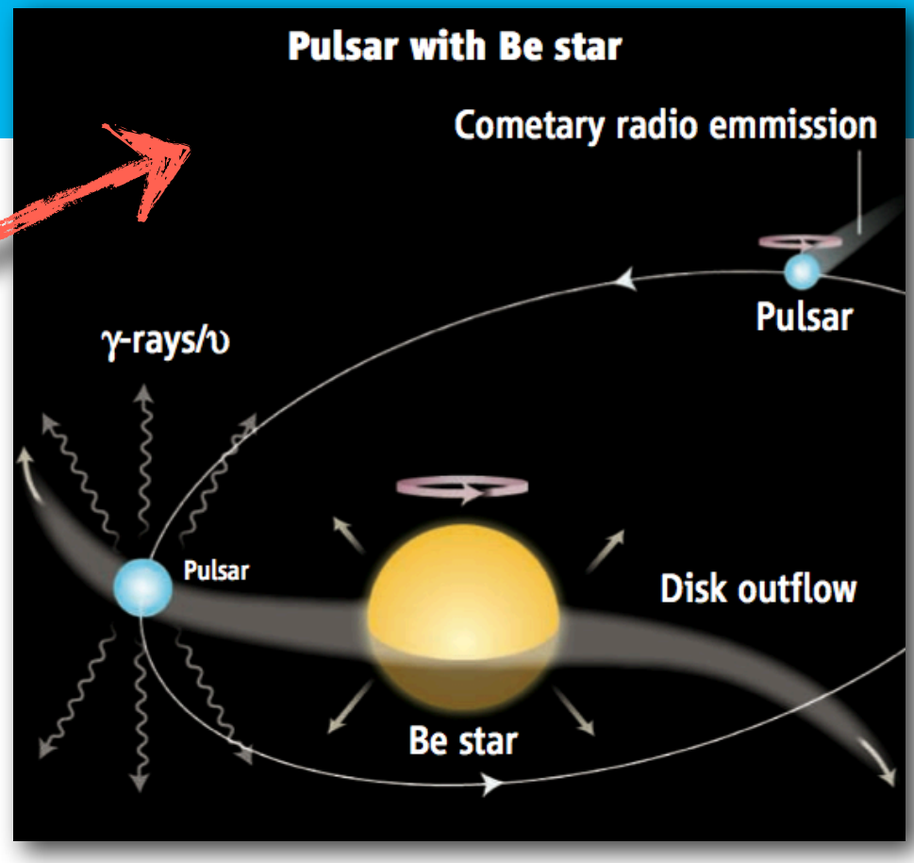
DESY

HELMHOLTZ ASSOCIATION

HUMBOLDT-UNIVERSITÄT ZU BERLIN

Gamma-ray binaries

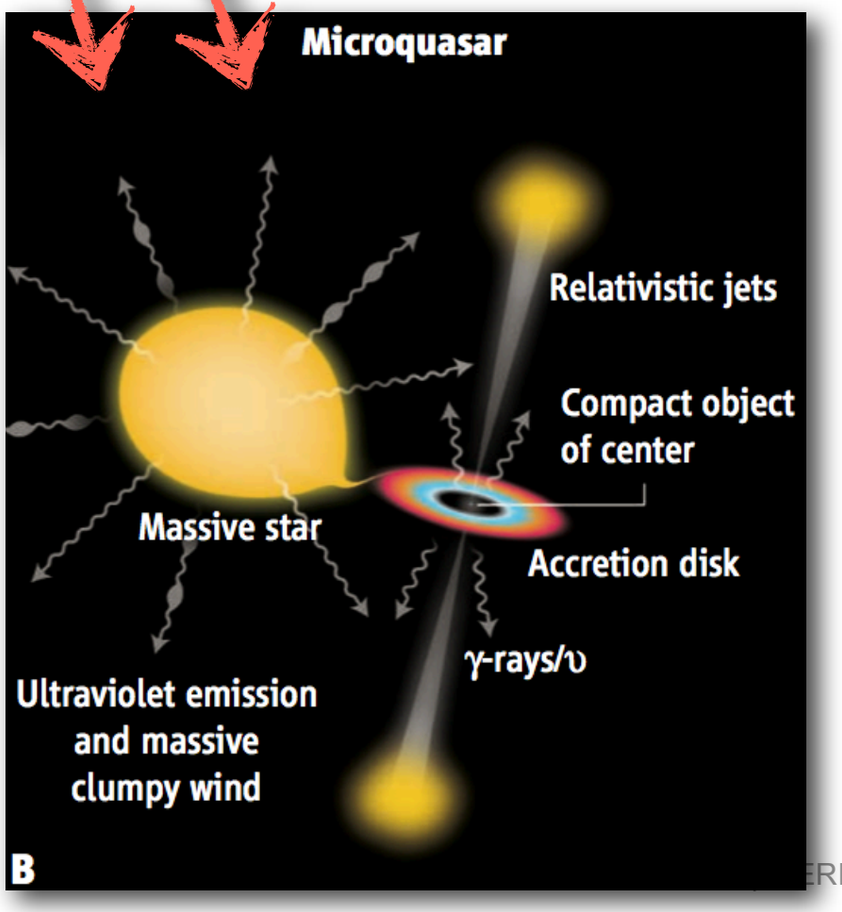
Name	GeV	TeV
PSR B1259-63	✔	✔
LS 5039	✔	✔
LS I +61 303	✔	✔
LS VI +05 11(HESS J062+057)	✘	✔
Cygnus X-1	✔	(✔?)
Cygnus X-3	✔	✘
1FGL J1018.8-5856	✔	✘

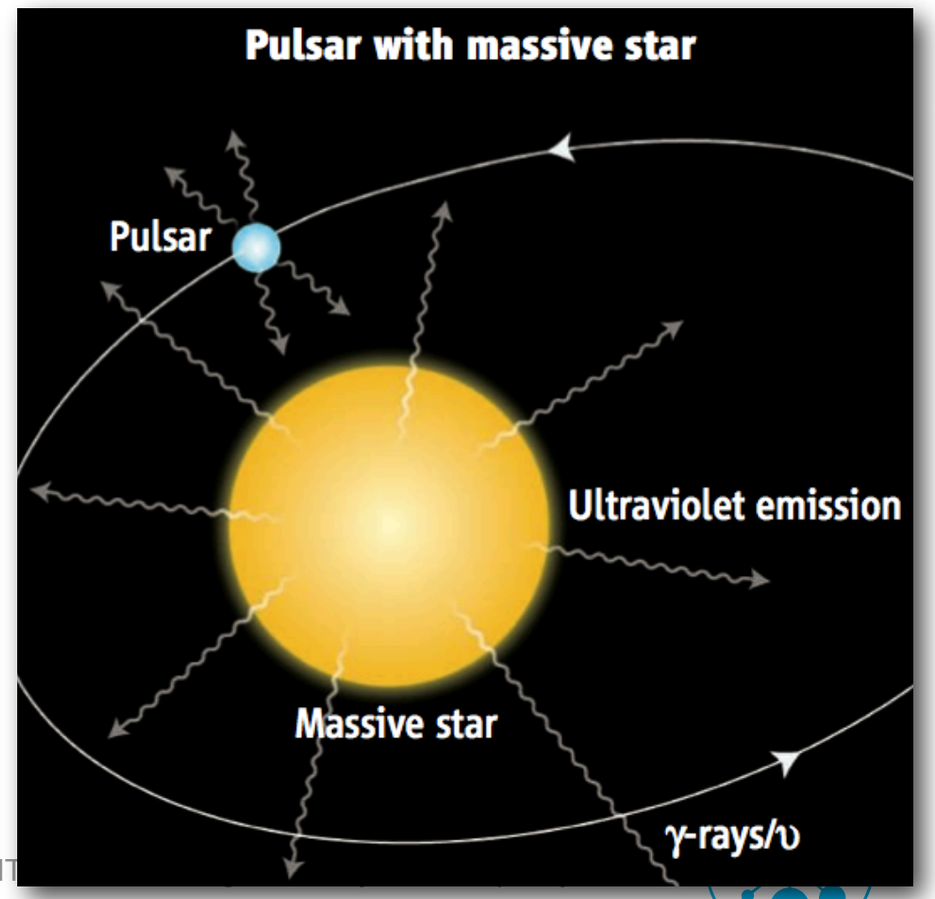


Mirabel (Science 2012)

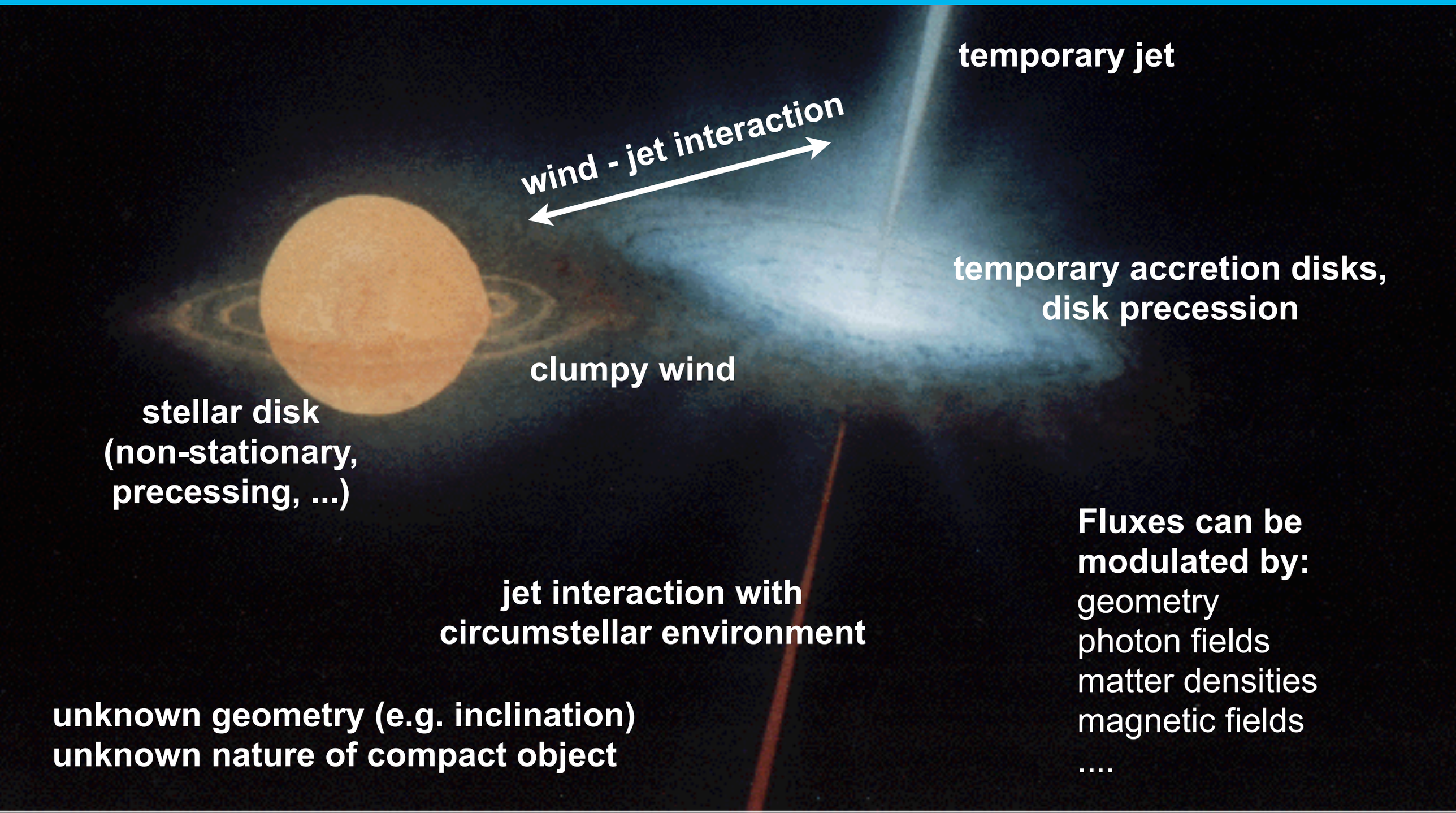
Binaries in the Galaxy

- 200 high-mass X-ray binaries
- 130 low-mass X-ray binaries
- ~20 microquasars identified by radio jet



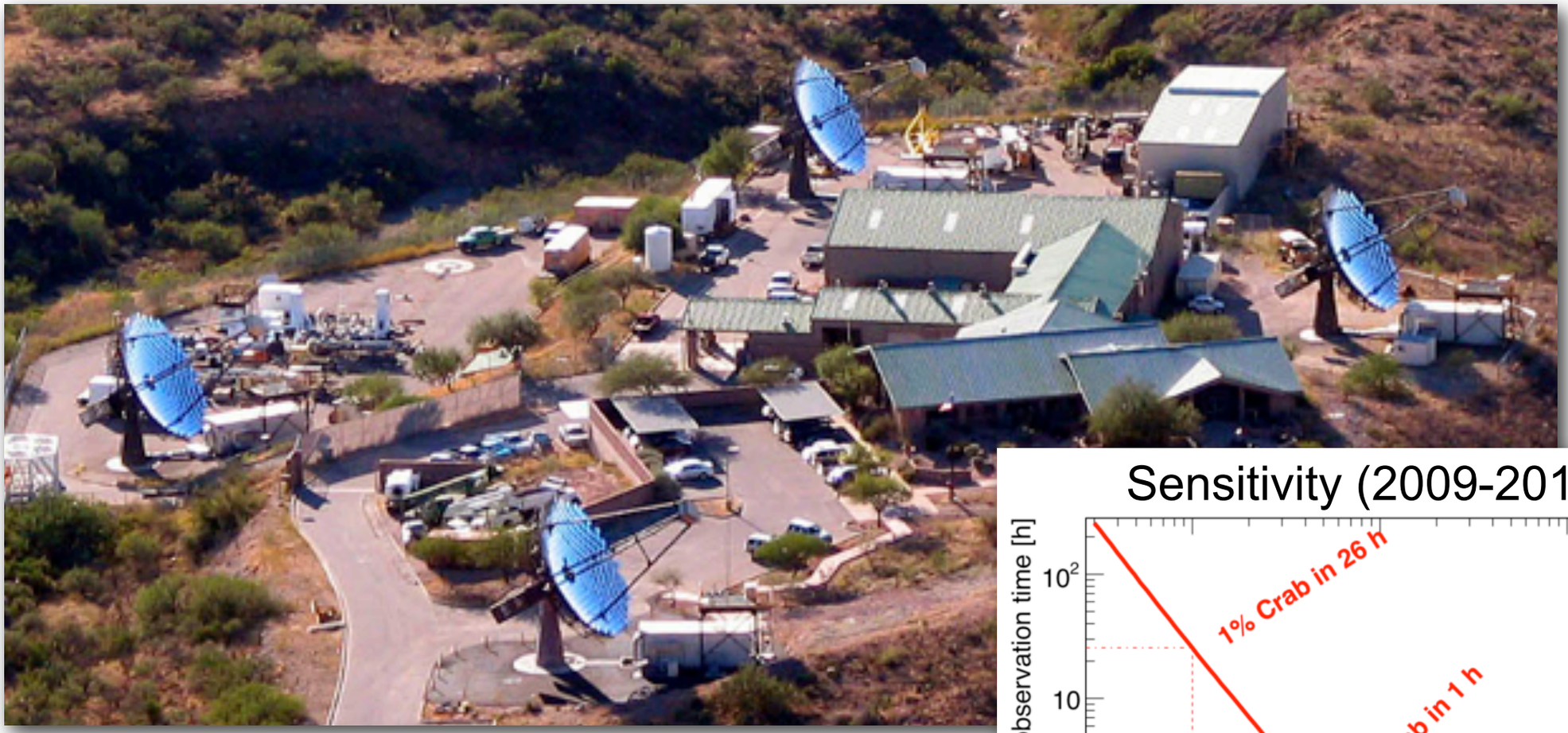


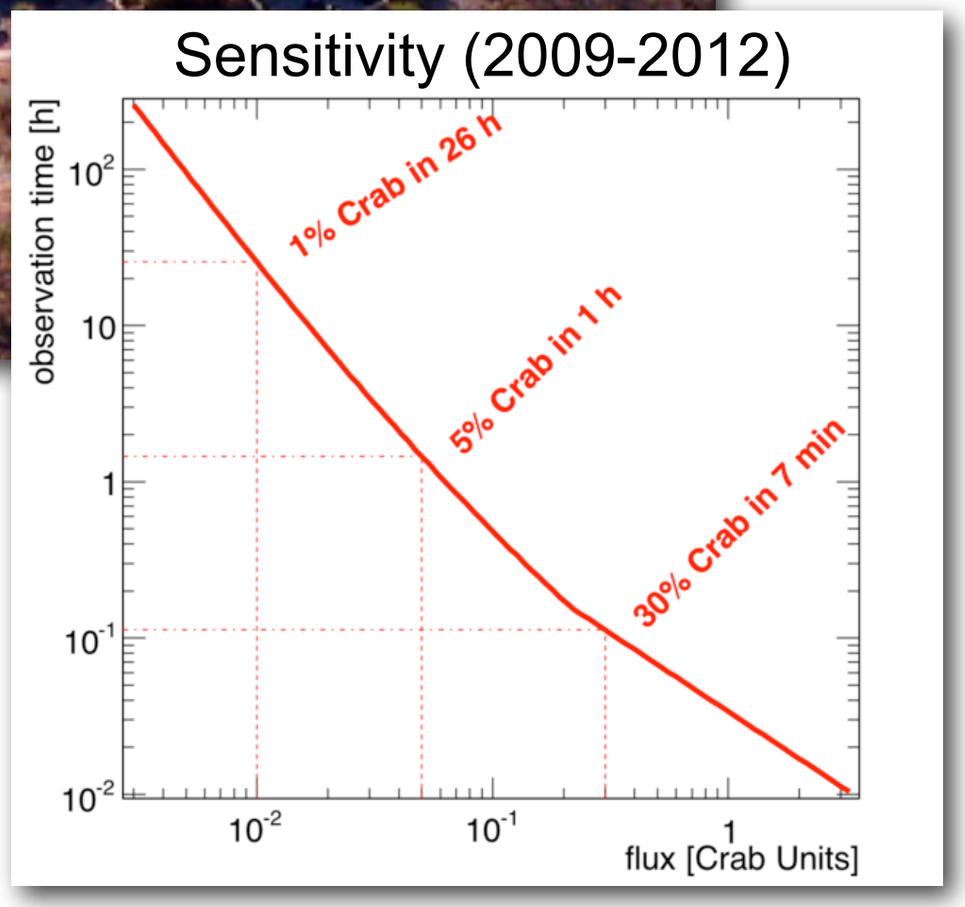
Binaries can be complicated...



VERITAS

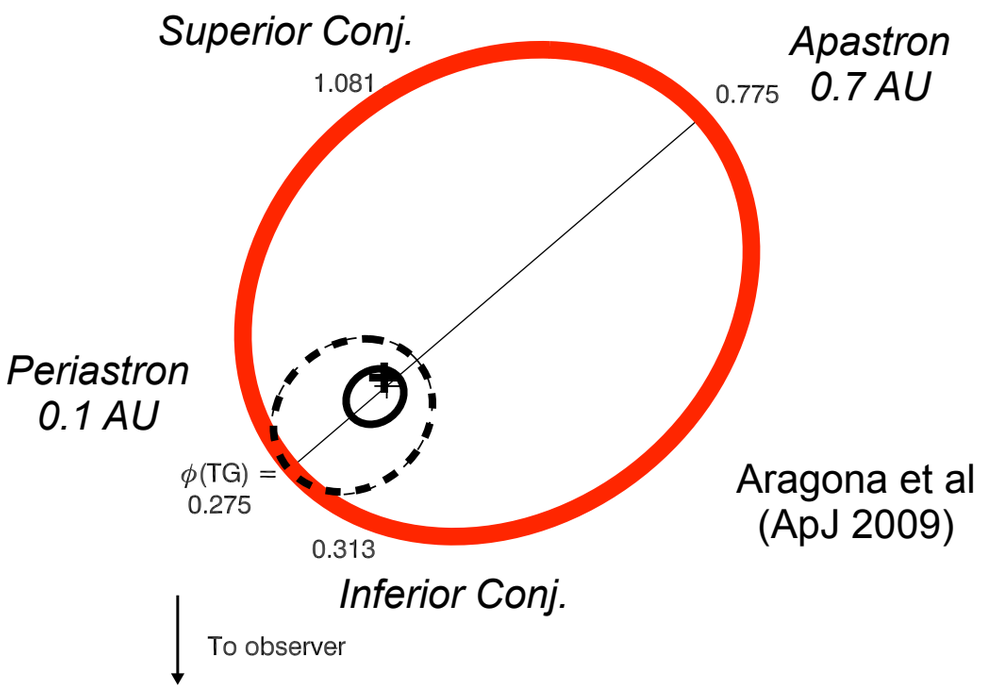
Supported by:
DOE, NSF, SAO, STFC, NSERC, SFI





- located at the Fred Lawrence Whipple Observatory in Arizona, US
- fully operational since 2007, upgrades 2009 and 2011, and 2012
- energy range: 0.1-30 TeV ($\Delta E/E<20\%$)
- 1100 hours of observations/year

LS I +61 303: 150 h of VERITAS observations



- Be star + compact object at 2 kpc
- 26.5 day orbit; unknown inclination
- pulsar wind binary or microquasar (radio inconclusive?)
  - Massi et al 2012: microblazar

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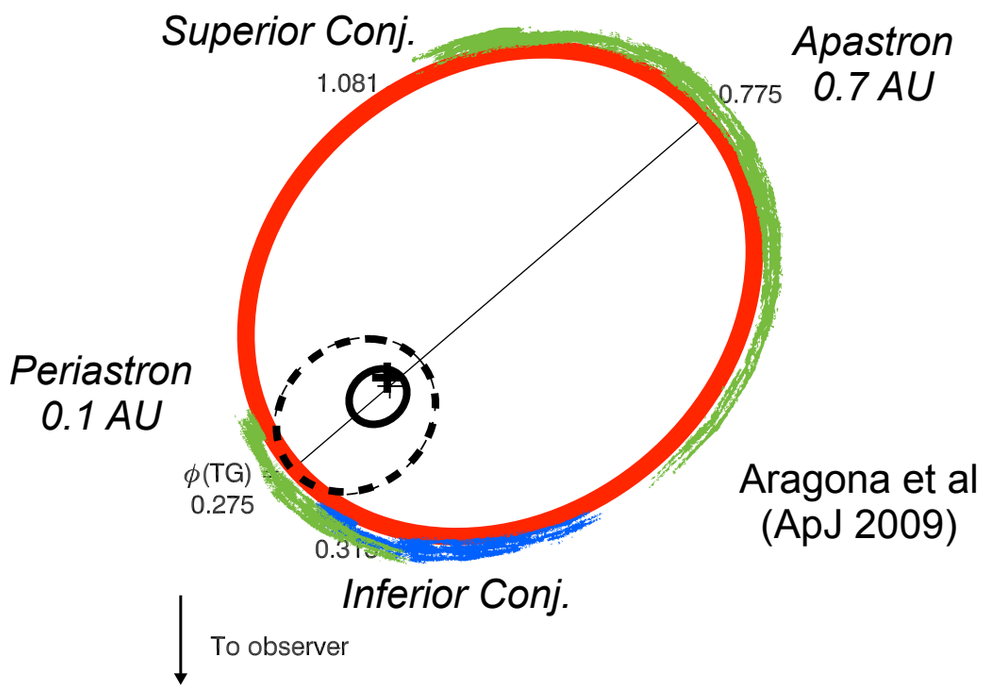

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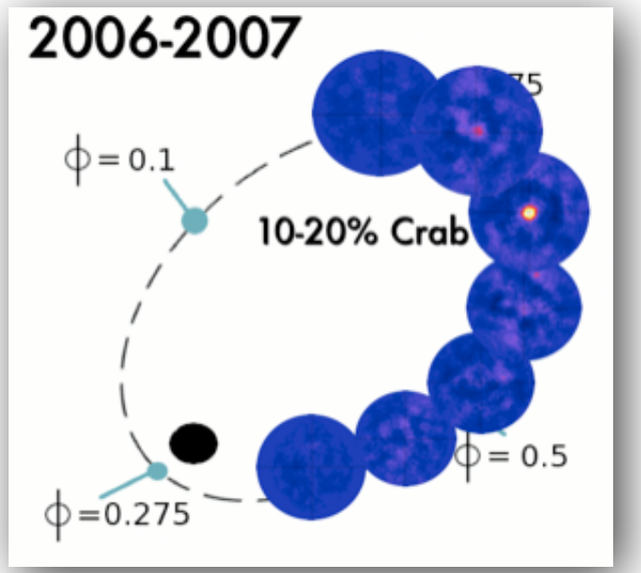
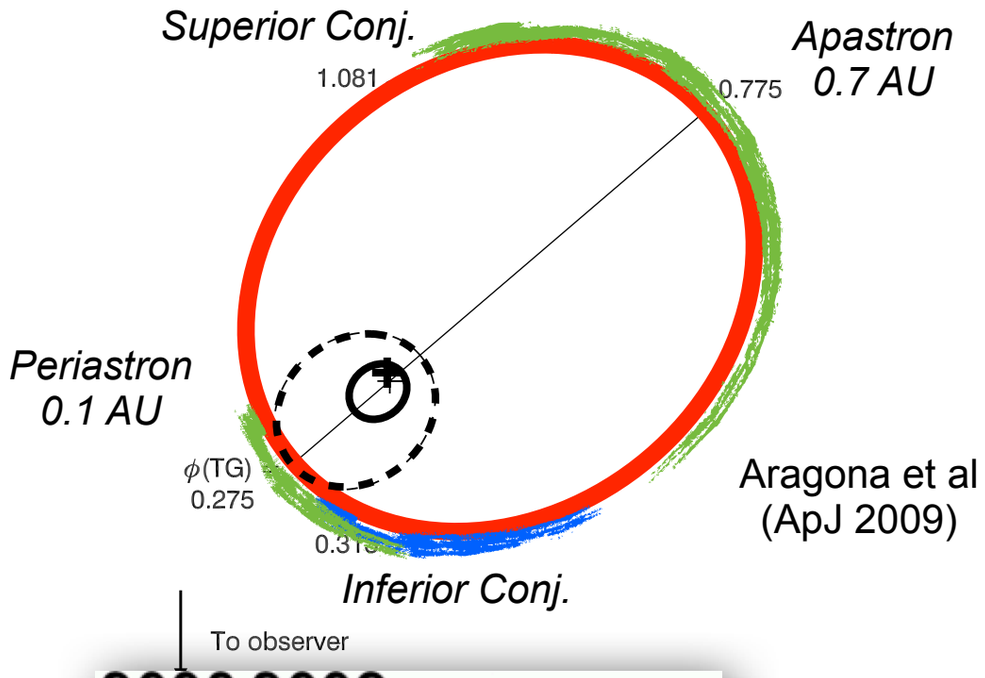


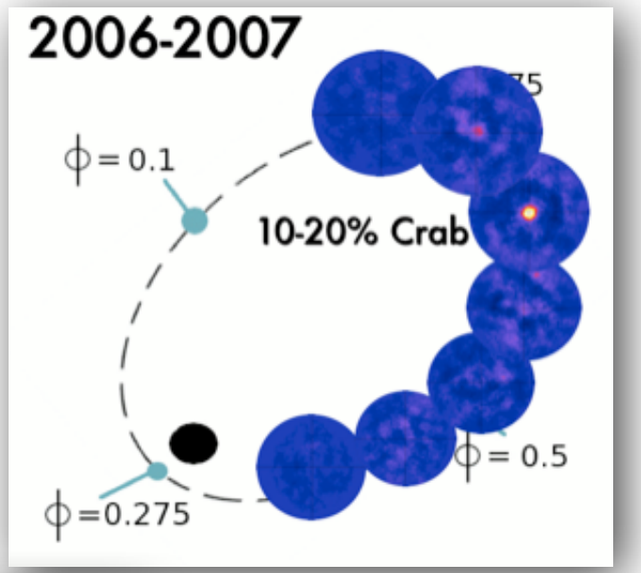
high X-ray activity throughout orbit
(large variations, strongest at apastron/periastron)
extended radio emission peaks at periastron and apastron
Fermi LAT: MeV-GeV emission throughout orbit
(2008-2009: peak after periastron)

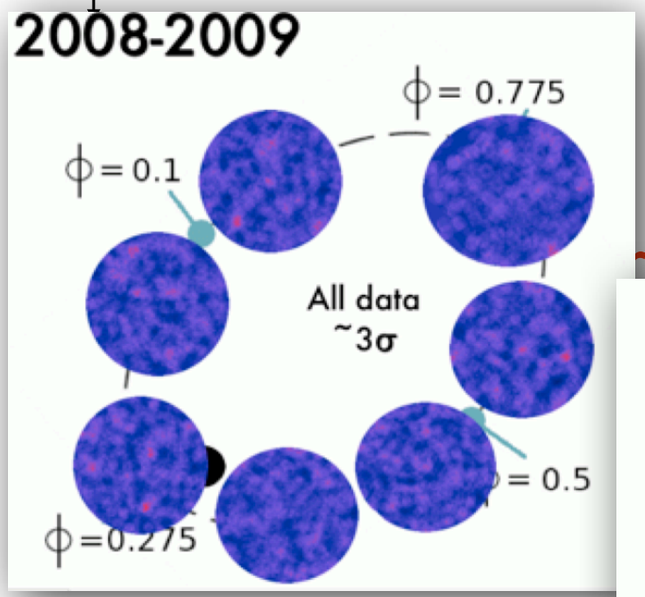
LS I +61 303: 150 h of VERITAS observations



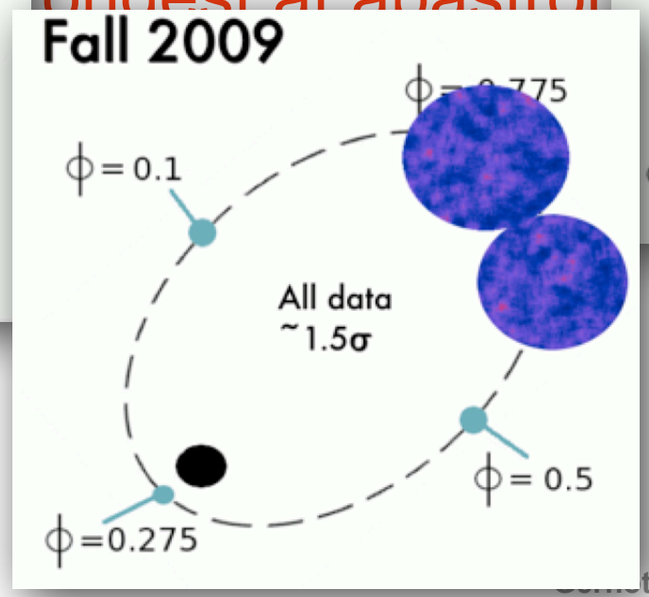
Aragona et al
(ApJ 2009)

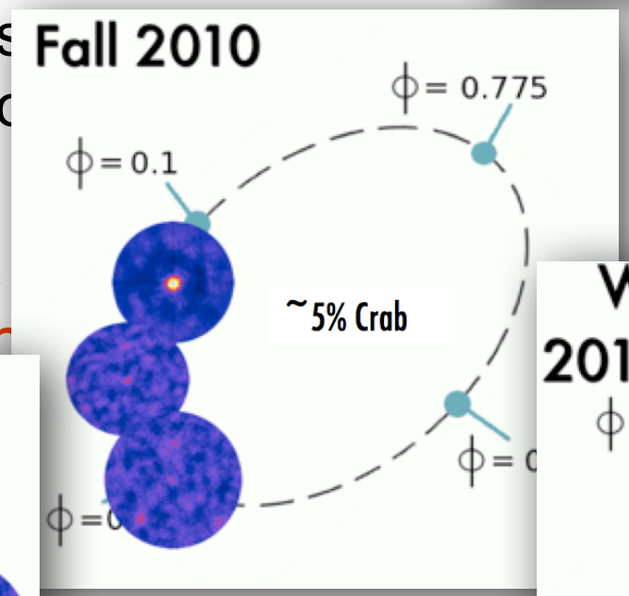
- Be star + compact object at 2 kpc
- 26.5 day orbit; unknown inclination
- pulsar wind binary or microquasar (radio inconclusive?)
  - Mass
  - micro

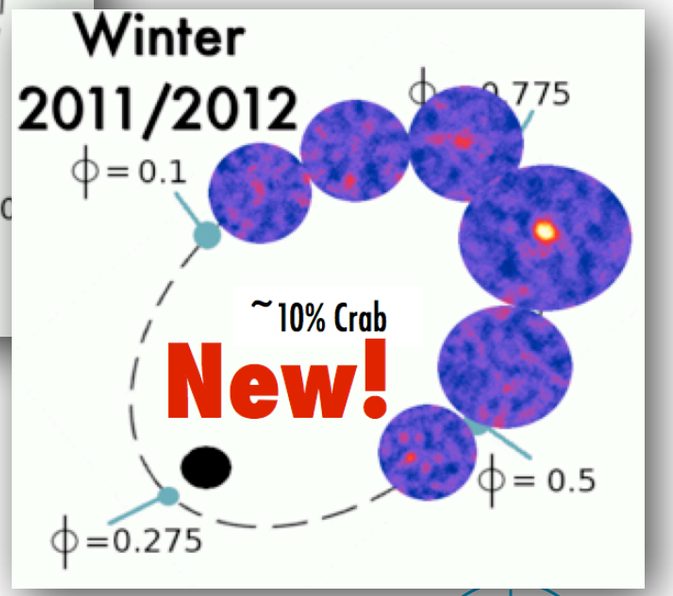




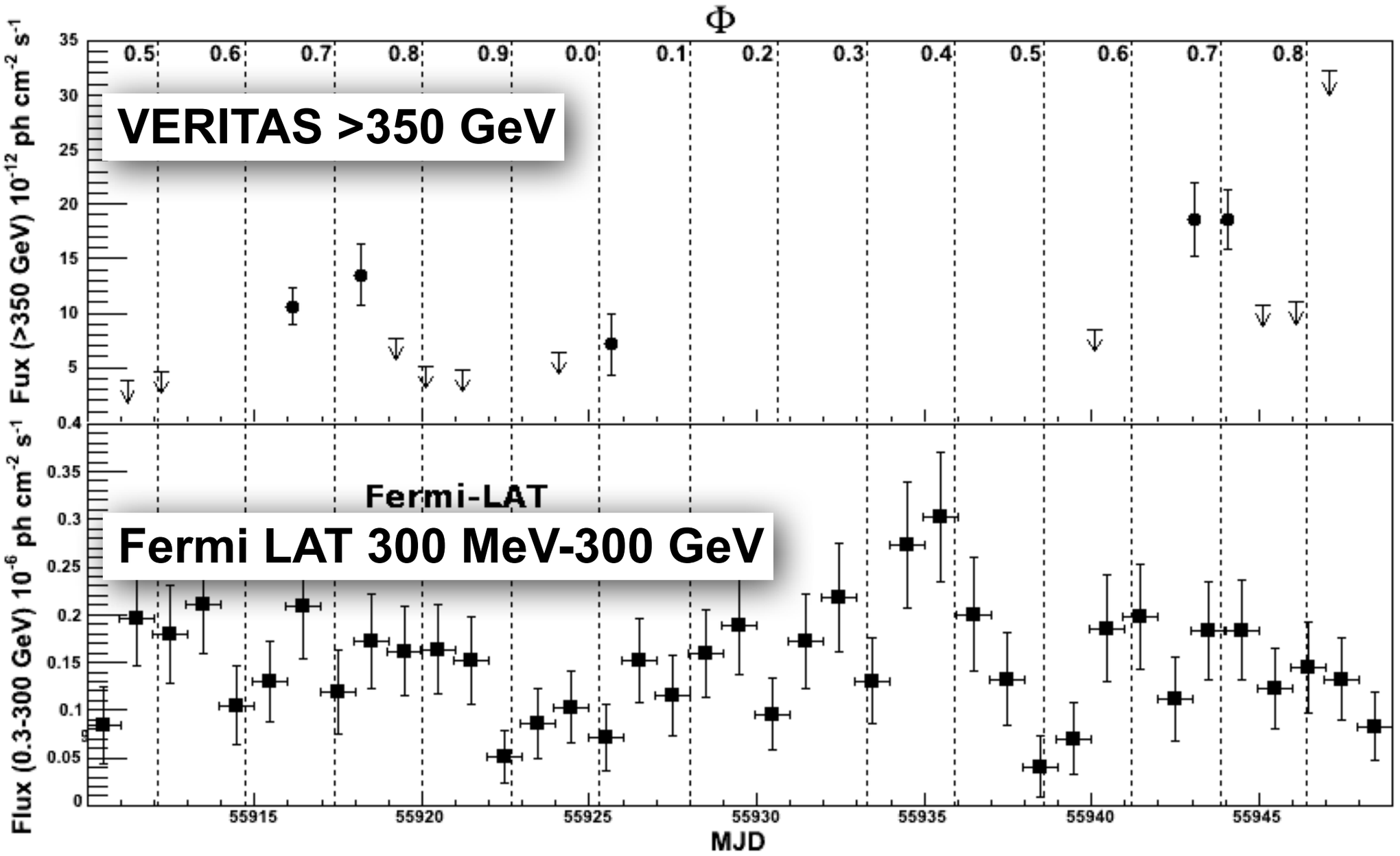
throughout orbit
ongest at apastron



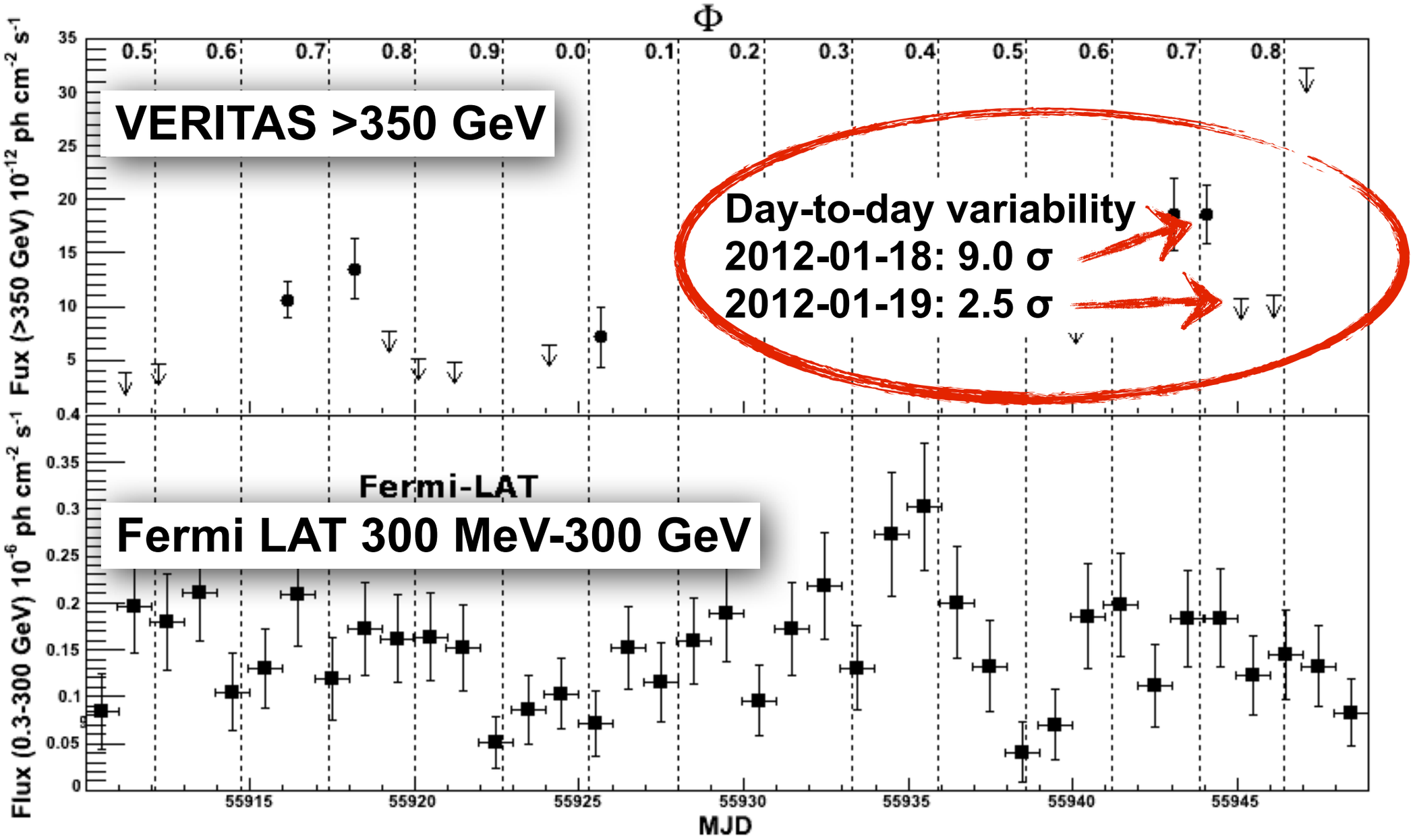




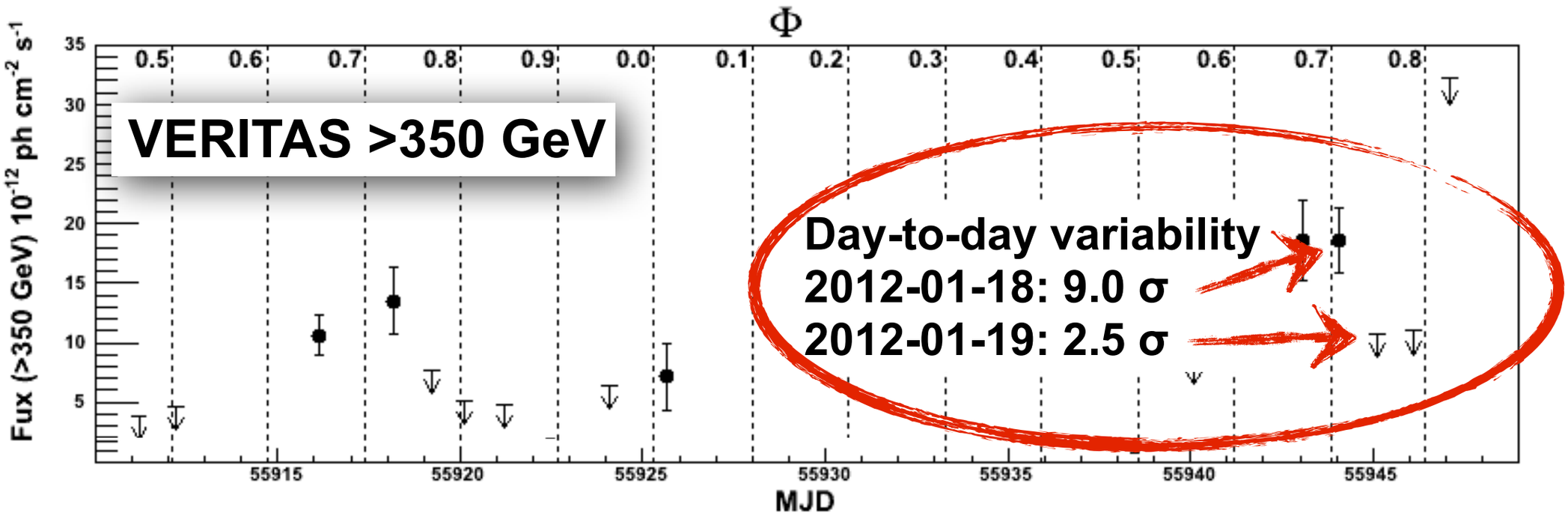
LS I +61 303: VERITAS observations 2012



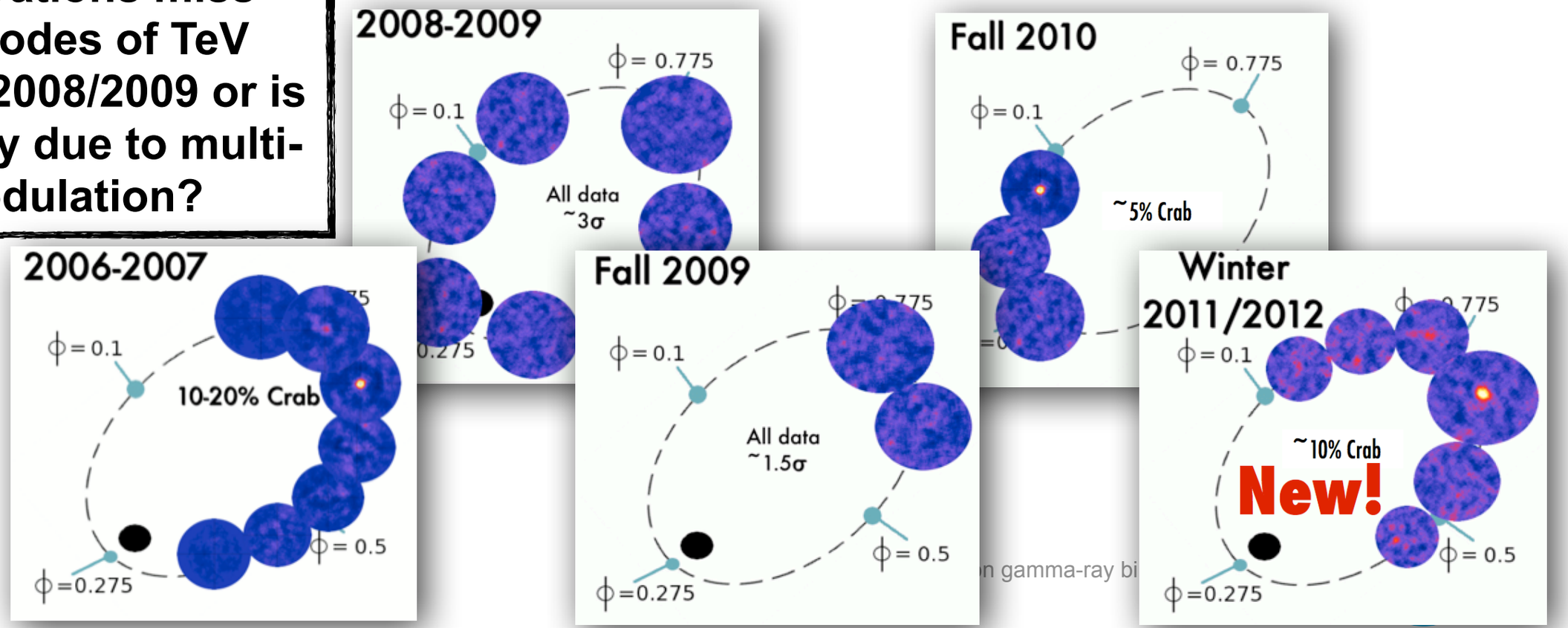
LS I +61 303: VERITAS observations 2012



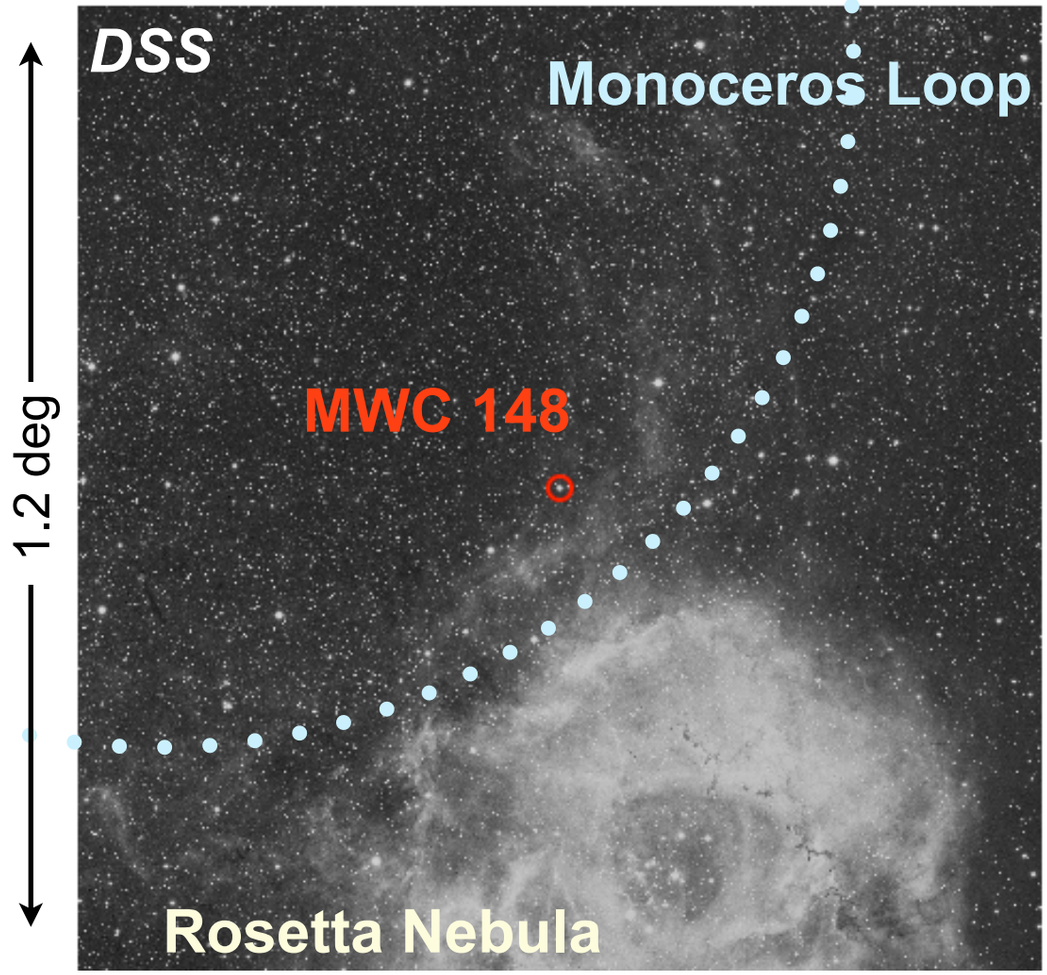
LS I +61 303: variability

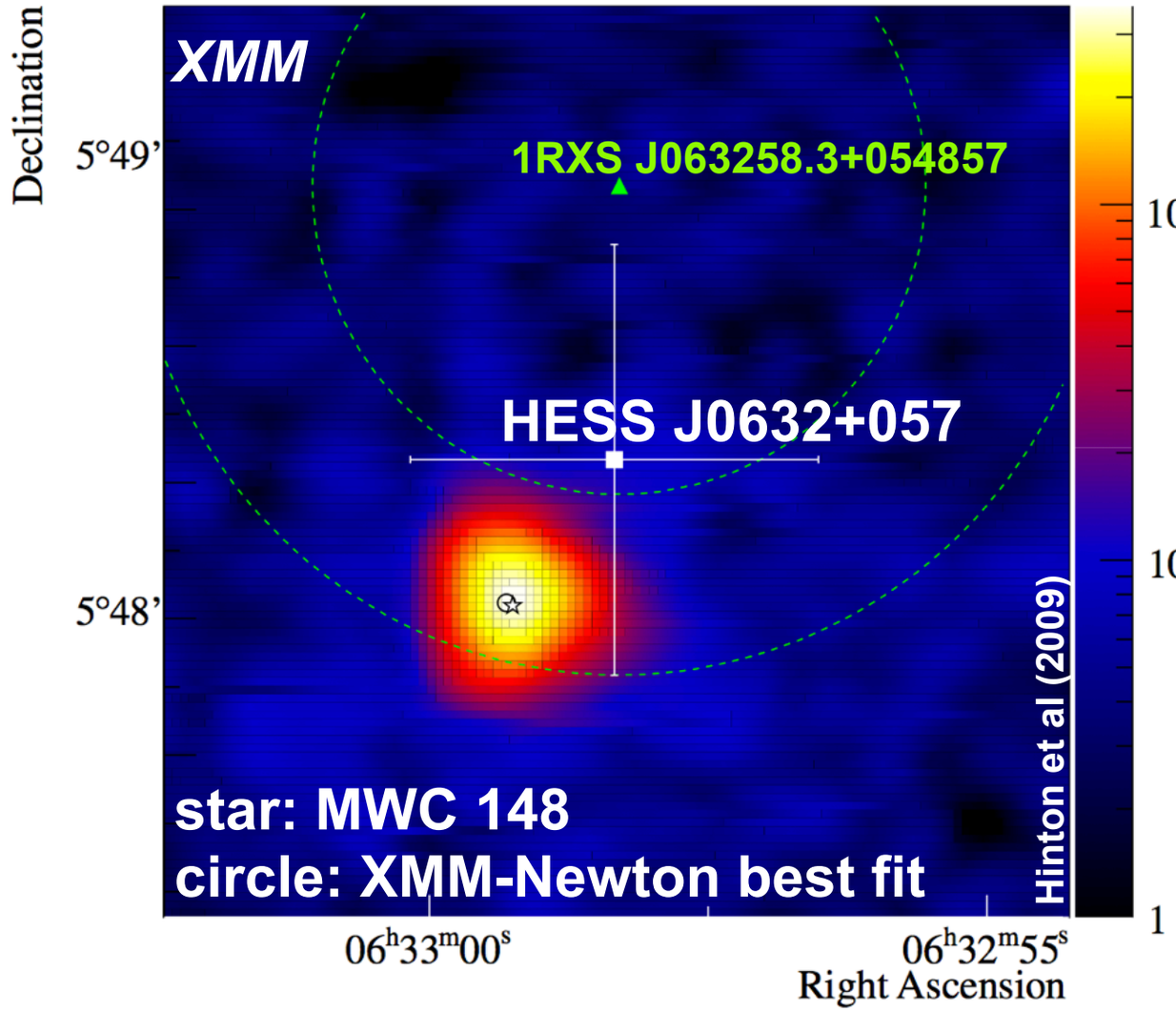


Did observations miss short episodes of TeV emission in 2008/2009 or is the variability due to multi-year modulation?



HESS J0632+057 - A new TeV binary!

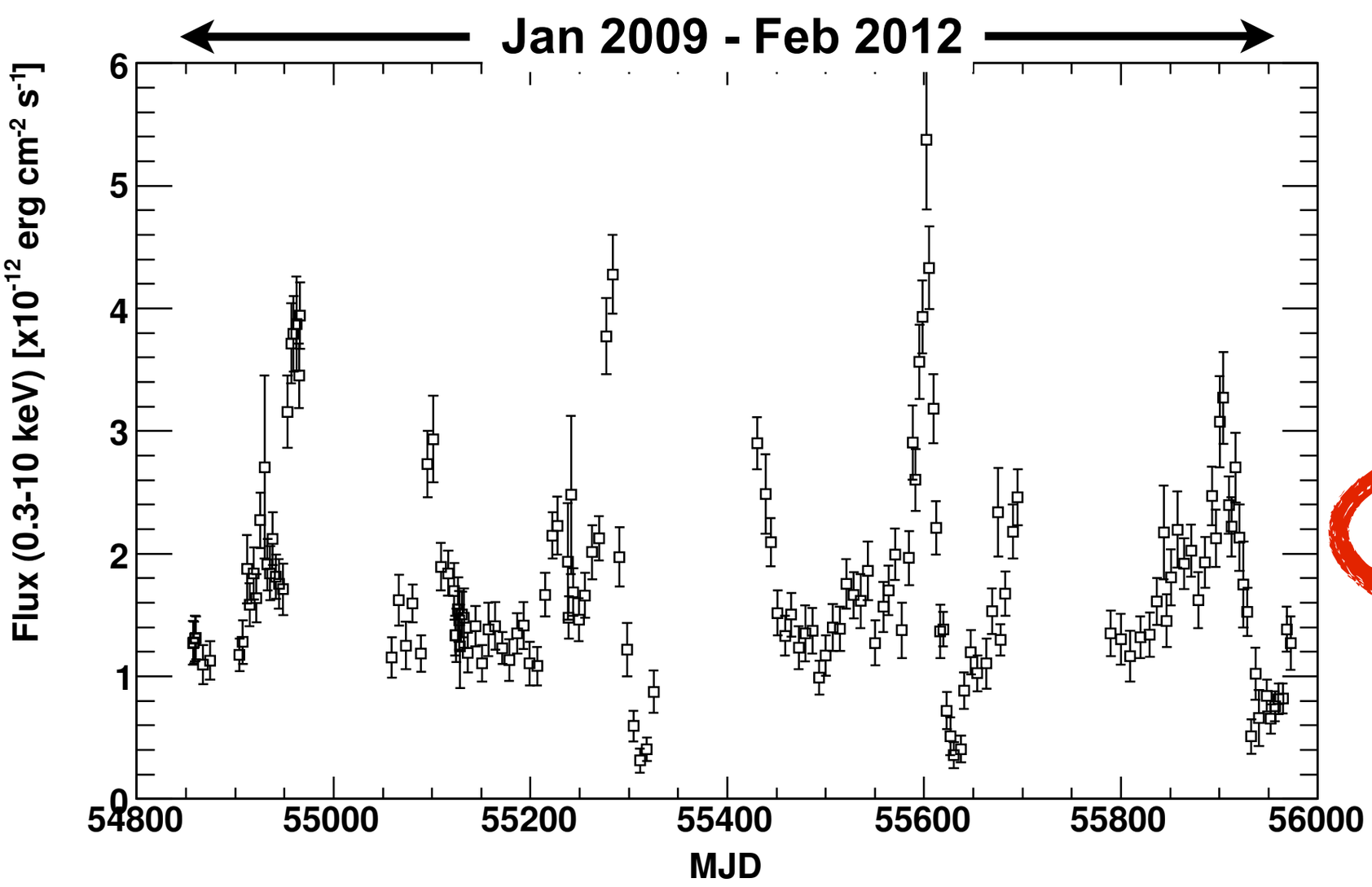


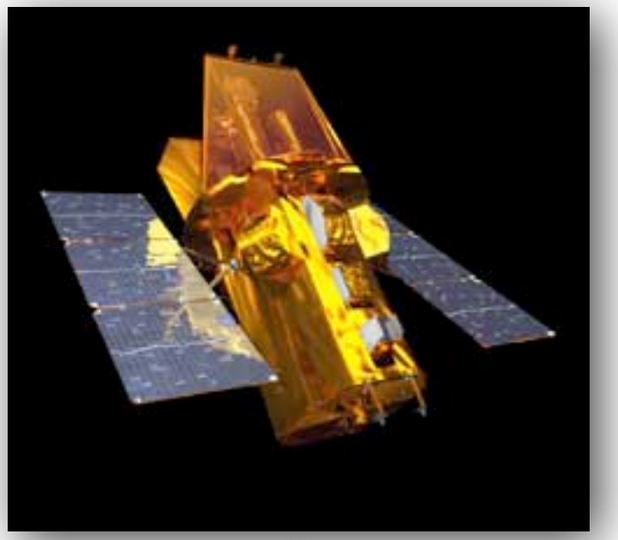


- 2004 discovery (H.E.S.S.)
- 2009: evidence for variability (VERITAS)
- 2010 detection (VERITAS)
- 2011/2012: detection (H.E.S.S./ MAGIC/VERITAS)

- MWC 148: B0pe star; d=1.5 kpc
- no binary companion resolved in optical observations
- until 2011: unidentified point source without obvious counterpart

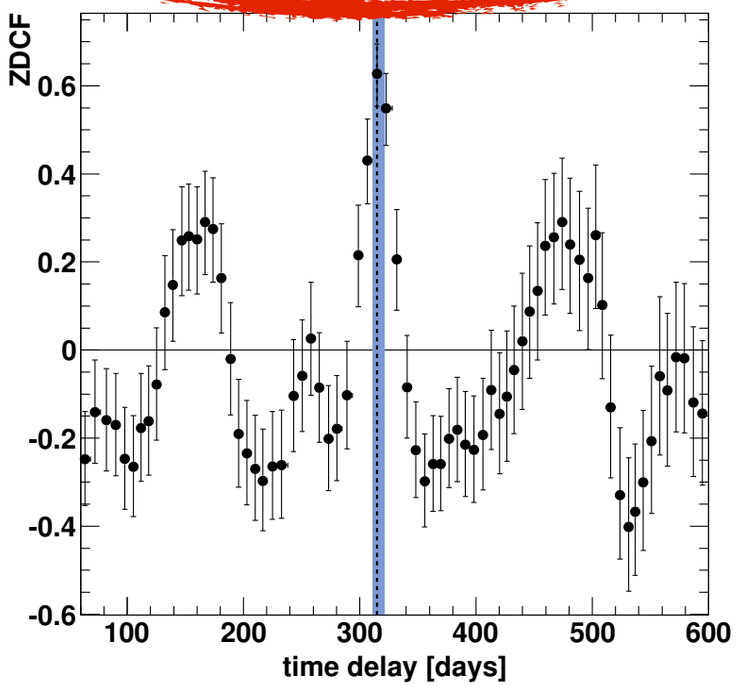
HESS J0632+057 - long-term X-ray observations





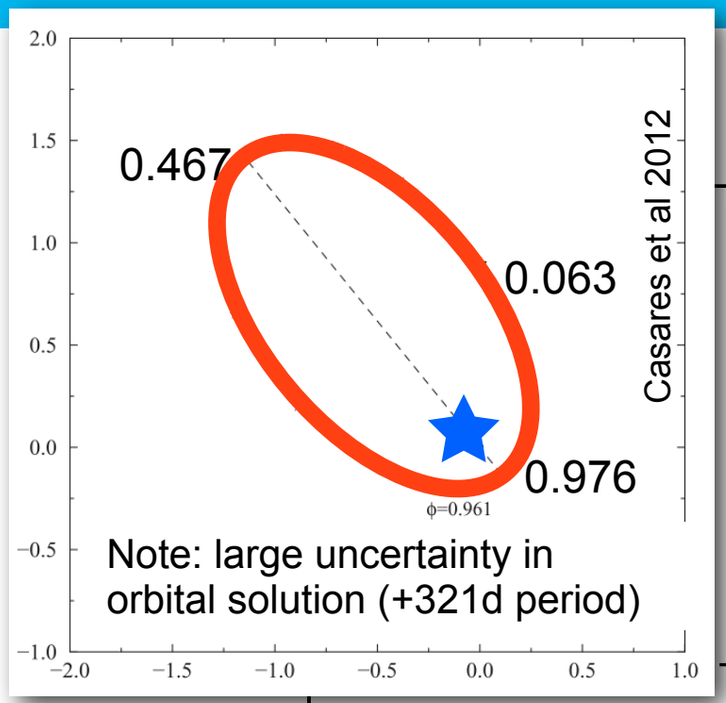
Z-transformed discrete correlation function:

period of 315^{+6}_{-4} days



Swift XRT observations typically 5 ks per week for more than 3 years !

HESS J0632+057 - folded light curve (315 days orbit)



Apastron

Periastron

X-ray

two maxima typical for binaries with eccentric orbits ($\dot{M} \sim \rho_{wind}/v_{rel}^3$)

dip typical for binaries with wind-wind interaction

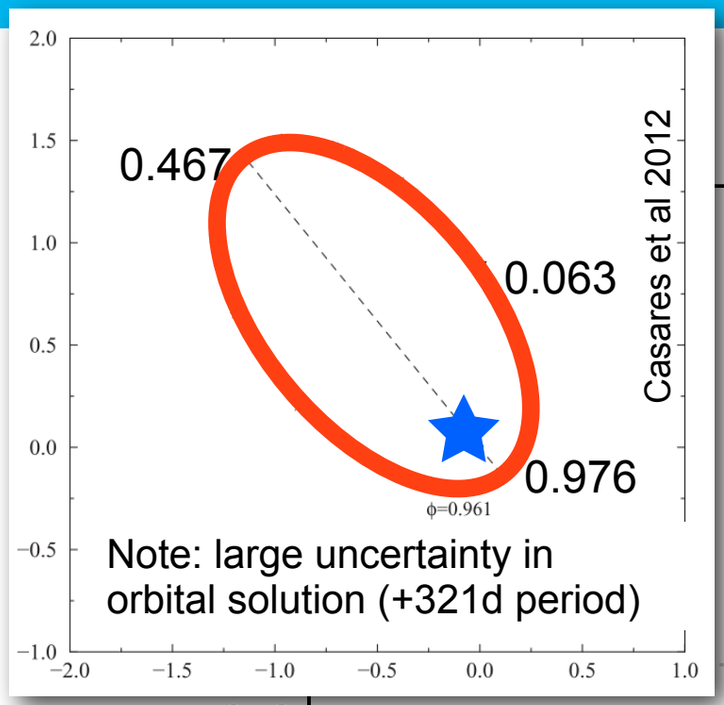
or shadowing?

Flux (0.3-10 keV) [x10^{-12} erg cm^{-2} s^{-1}]

phase

VERITAS observations of HESS J0632+057

VERITAS+ H.E.S.S. results: poster by P.Bordas et al



Apastron

Periastron

X-ray + γ-ray

Total VERITAS data set: 144h
New data 2012: 34 h, 9.8σ

time lag -4^{+7}_{-14} days

Flux (E>1 TeV) [$\times 10^{-12}$ cm^{-2}s^{-1}]

Flux (0.3-10 keV) [$\times 10^{-12}$ erg cm^{-2} s^{-1}]

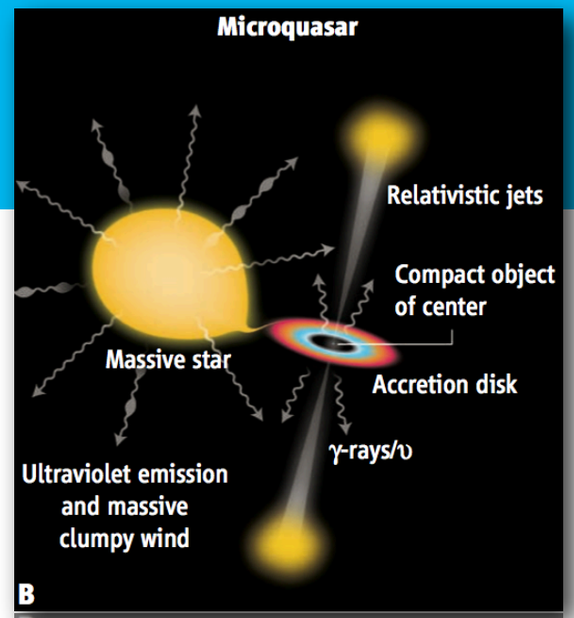
phase

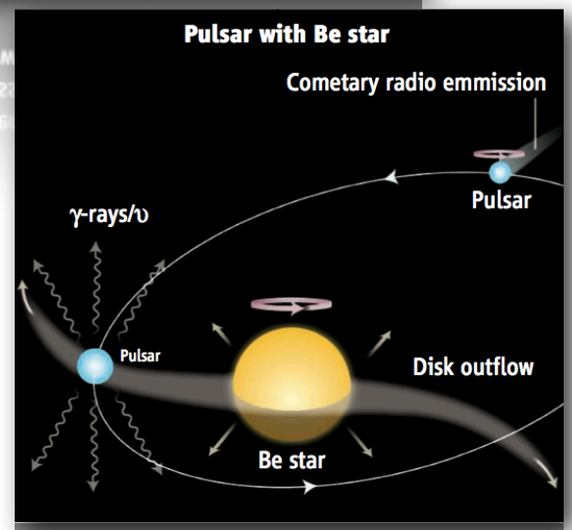
VERITAS observation periods:

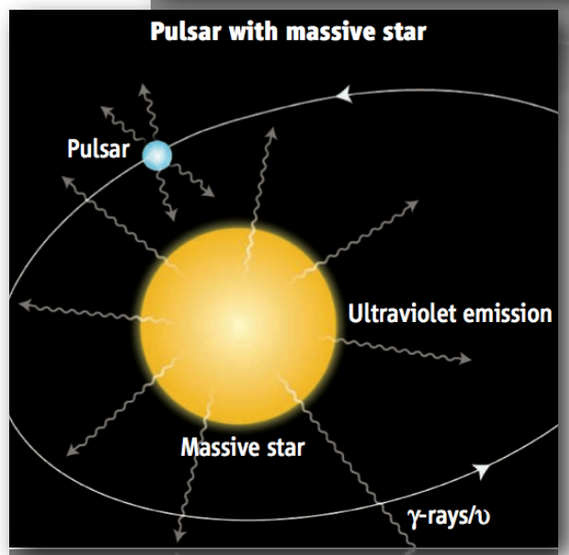
Nov 2011 - Feb 2012
Dec 2010 - April 2011
Feb 2010 - March 2010
Oct 2010
Jan 2009
Dec 2008
Dec 2006 - Jan 2007

Conclusions

- large set (>250 h) of VERITAS binary observations
- LS I +61 303 more puzzling than ever
  - orbit-to-orbit and day-to-day variability
  - unclear GeV-TeV connection
- HESS J0632+057 first binary detected through VHE gamma-ray observations
  - updated orbital period from X-rays: 315^{+6}_{-4} d
  - maximum simultaneously at X- and gamma-rays
- >300 binaries in the galaxies, why these two?
  - Be star, radio emission, geometry, ..?







Mirabel (Science 2012)