Long-term gamma-ray observations of the binary HESS J0632+057 with H.E.S.S., MAGIC and VERITAS

ICRC 2019

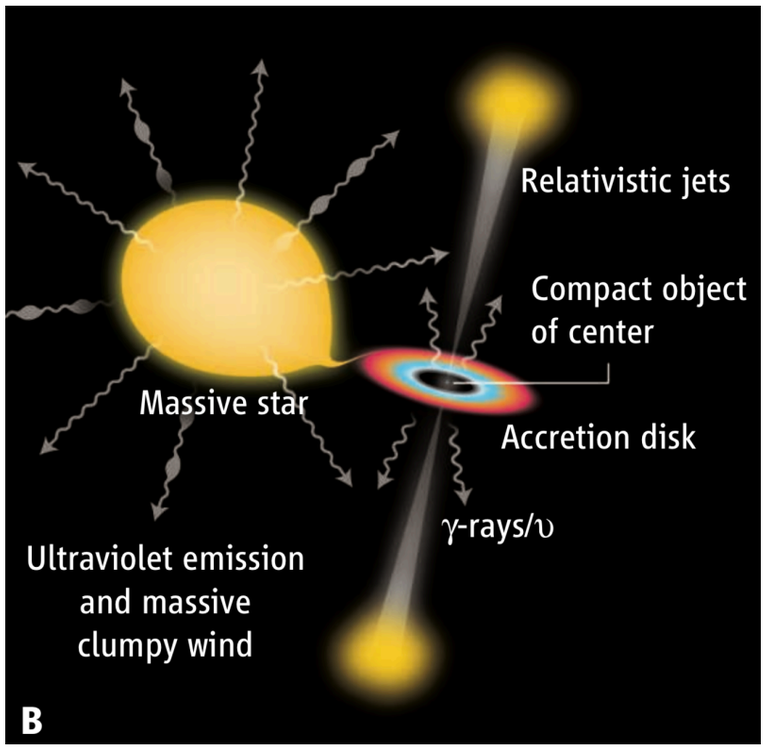
G.Maier, O.Blanch, D.Hadasch, A.López-Oramas, N.Komin, M.Lundy , D.Malyshev, J.Moepi, S.Ohm, G.Pühlhofer, R.Prado, S.Schlenstedt, D.Torres, B.Zitzer
for the H.E.S.S., MAGIC, and VERITAS Collaborations

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

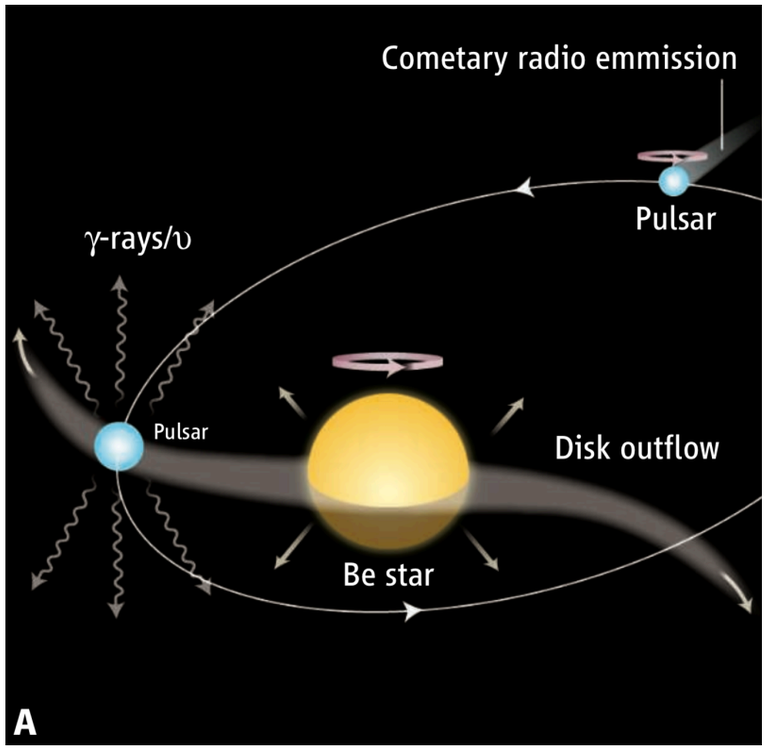
Gamma-ray Binaries

Microquasar



Mirabel 2012

Pulsar wind - stellar disk



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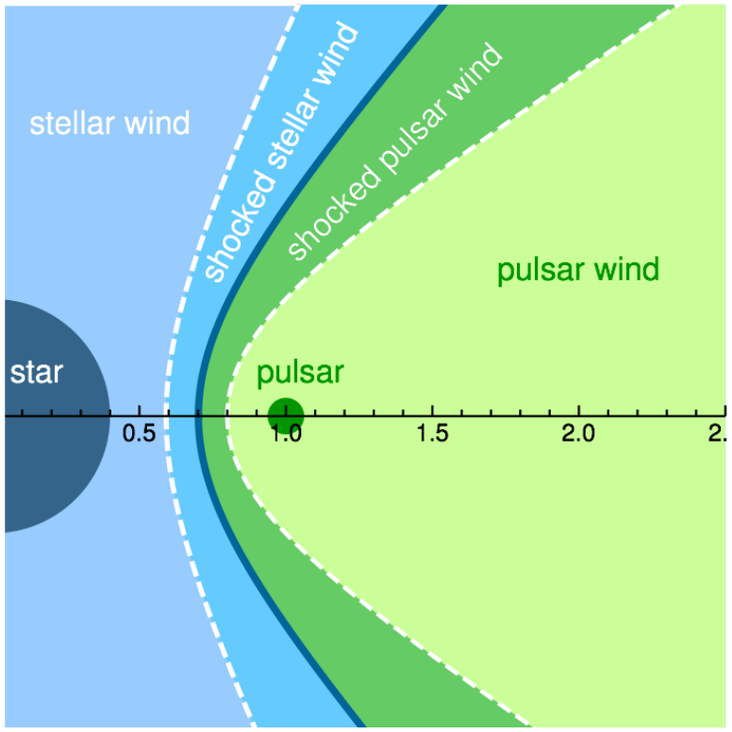
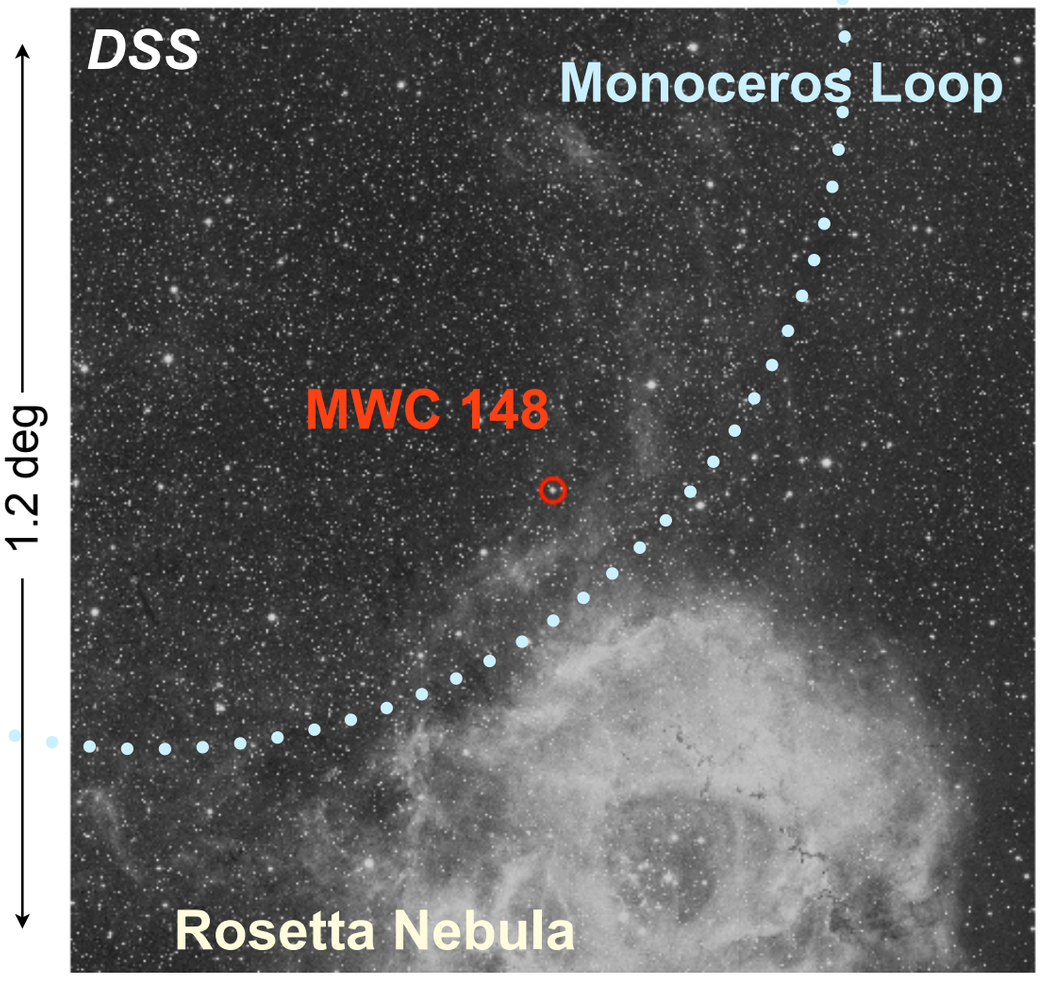
Pulsar wind - stellar wind



Szostec & Dubus (2011)

The gamma-ray binary HESS J0632+057

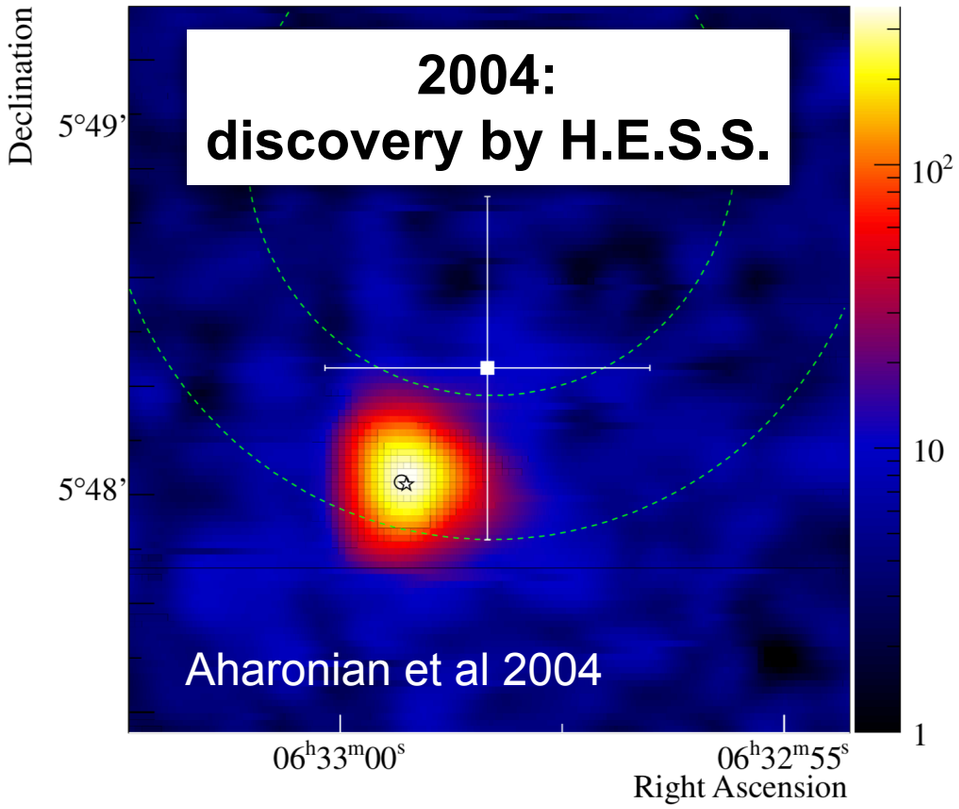


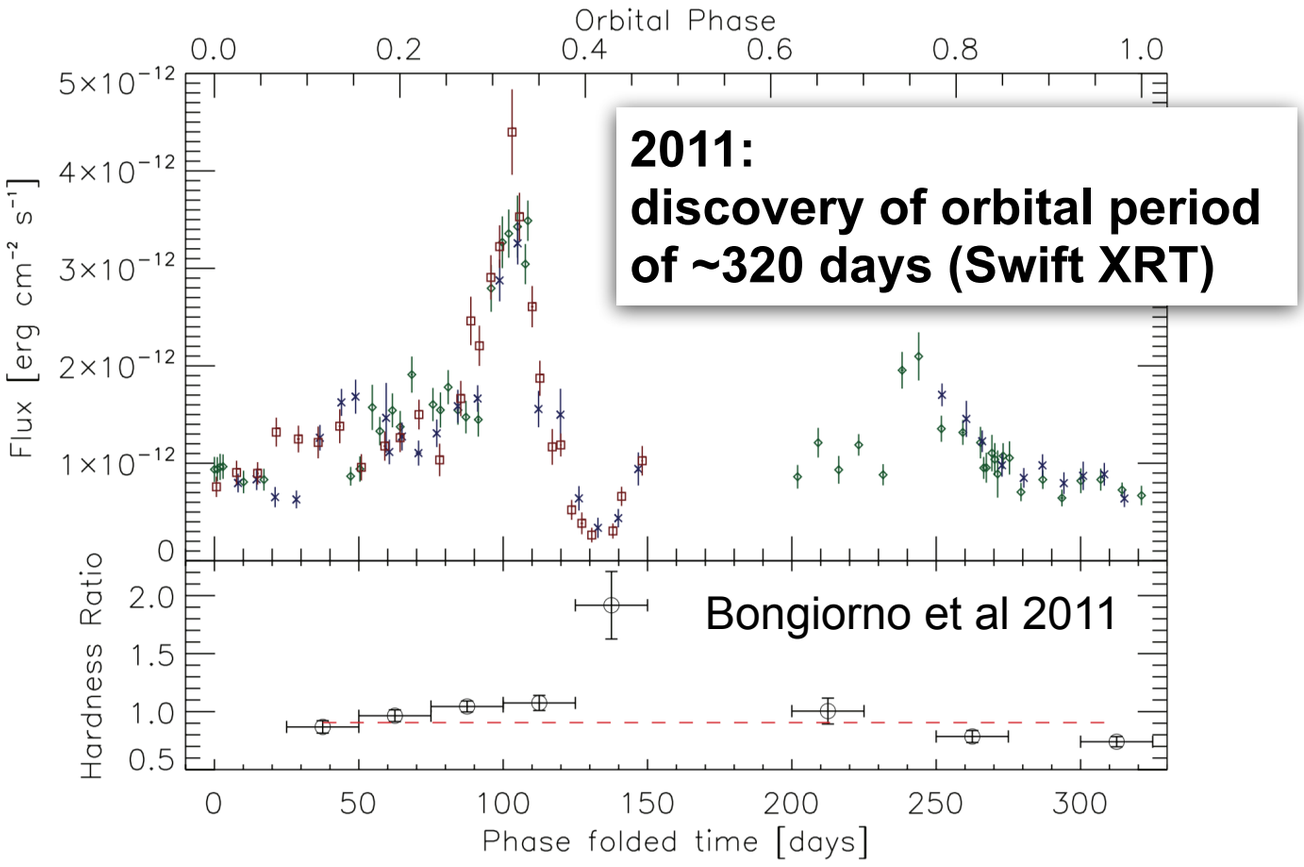
- MWC 148: B0pe star
  (M = 16 M_Θ, R = 6.6 R_Θ, T = 30x10^5 K)
- neutron star or black hole
  (no pulsation found in deep Chandra/ GBT searches)
- peak of SED in gamma rays
- variable in X-rays/gamma rays
- weak MeV-GeV Fermi LAT detection

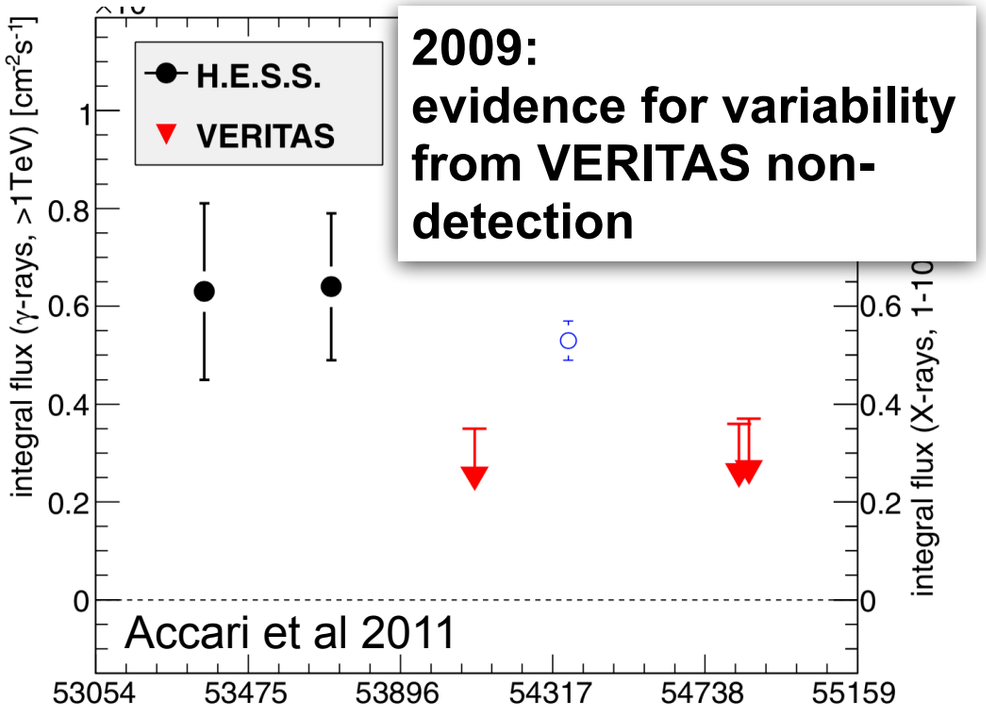
Hinton et al 2009, Falcone et al 2010, Skilton et al 2009, Rea & Torres 2011, Aragona et al 2011, Bongiorno et al 2011, Moldon et al 2011, Skilton et al 2011, Casares et al 2012, Calioandro et al 2013, Ali et al 2014, Moritani et al 2015, Zamanov et al 2016 Bosch-Ramon et al 2017, Malyshev et al 2017, Li et al 2017, Zamanov et al 2017, Moritani et al 2018

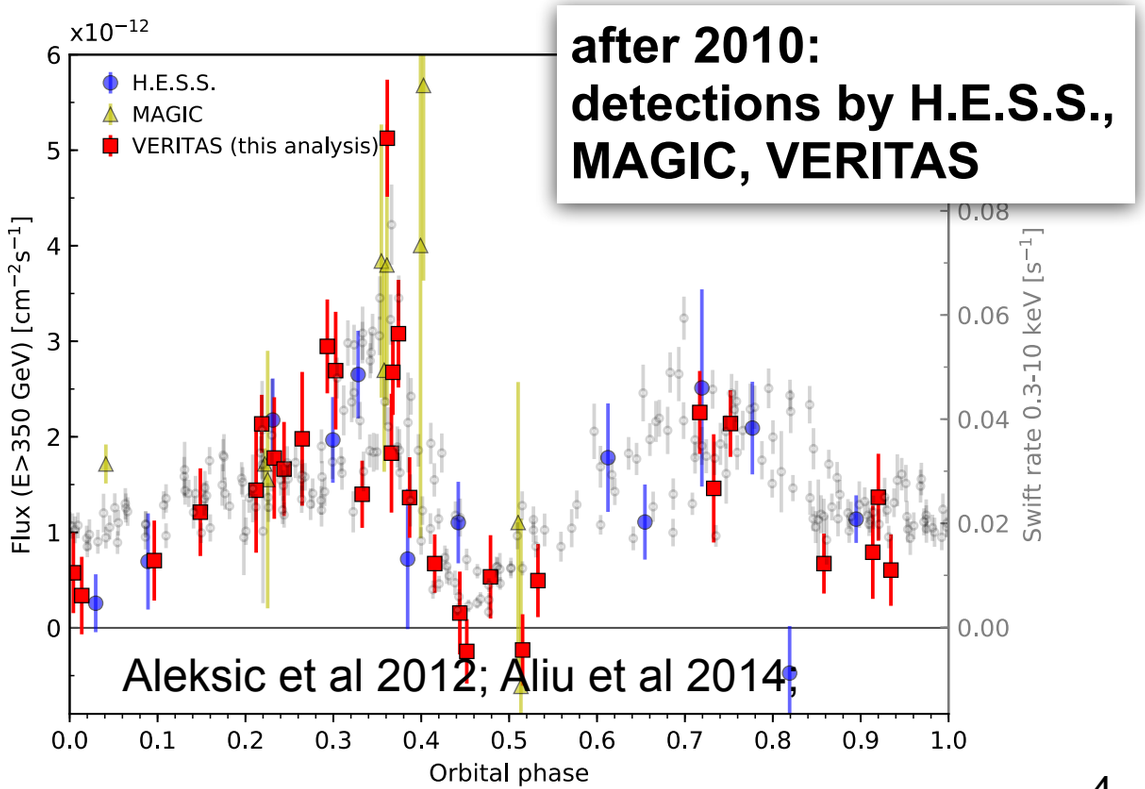
- orbital period from Swift XRT data ~315-320 days
- distance 1.1-1.7 kpc

High-energy history



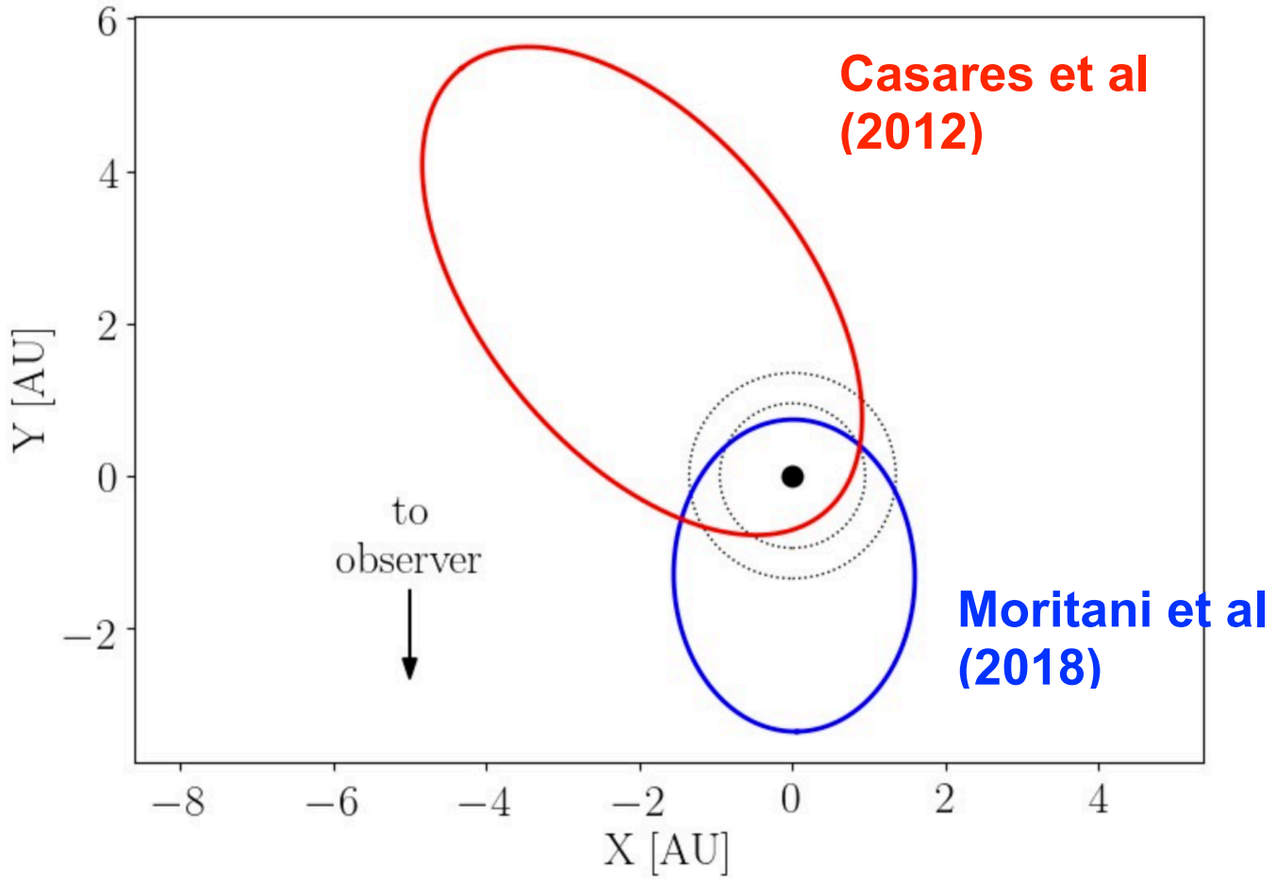






Orbital parameters

- new orbital solution from Moritani et al (2018)
  - based on radial velocity of Hα emission line measurements
  - eccentric (e~0.6)
  - Be disk size of 0.84-1.4 AU
- major uncertainties for system modelling due to uncertainties in orbital parameters
  (orientation, inclination, mass of stars)



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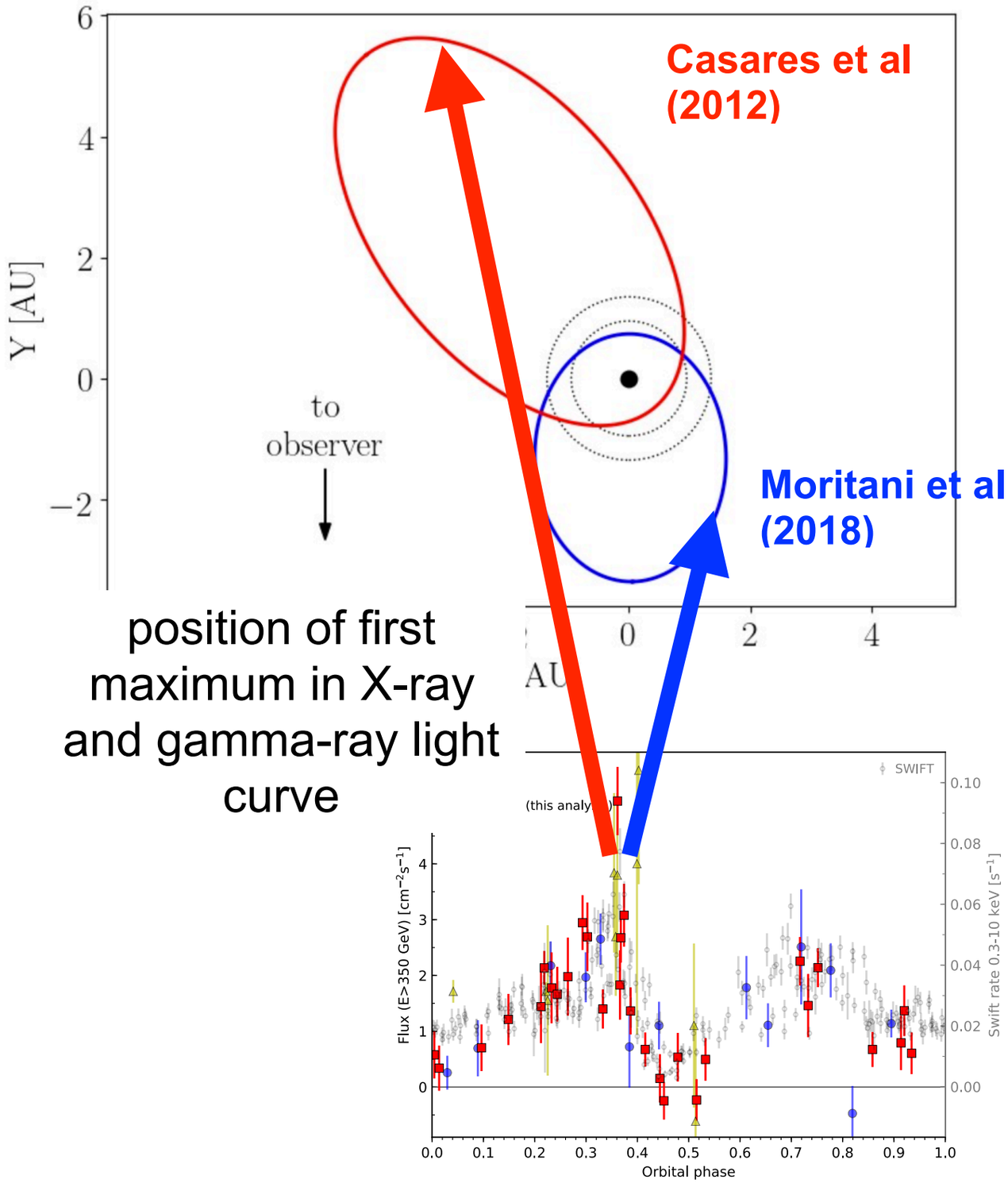
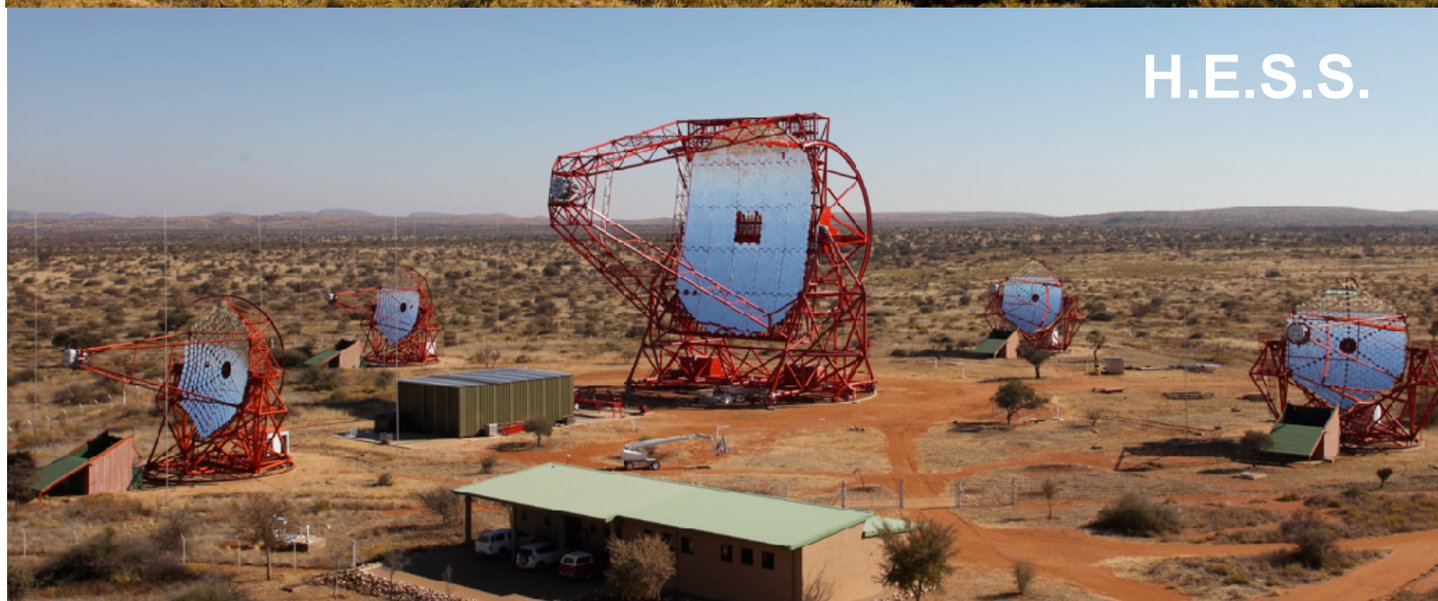
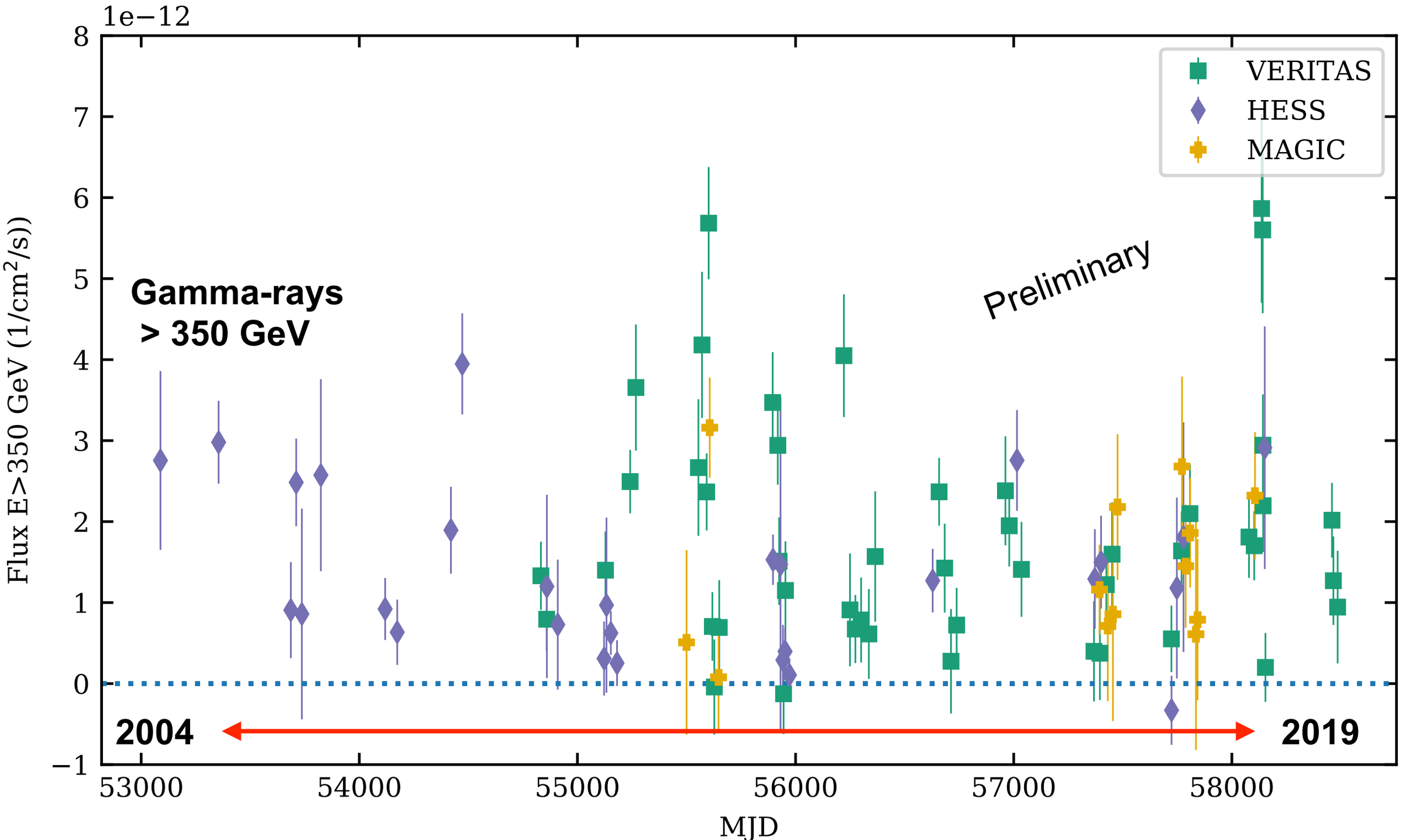


Observations

- **Large data set of 440 h obtained from 2004-2019**
- **VERITAS**
  - pre-T1 move: 20 h
  - post-T1 move: 117 h
  - post-camera upgrade: 112 h
  - bright moon (red. HV): 11 h
- **MAGIC:**
  - stereo: 48 h
- **H.E.S.S.:**
  - CT 1-4: 99 h
  - CT 1-5: 15 h
  - CT 5: 18 h
- large Swift XRT data set (+some XMM, Chandra, Suzaku, NuStar observations)



Long-term light curve: 15 years!



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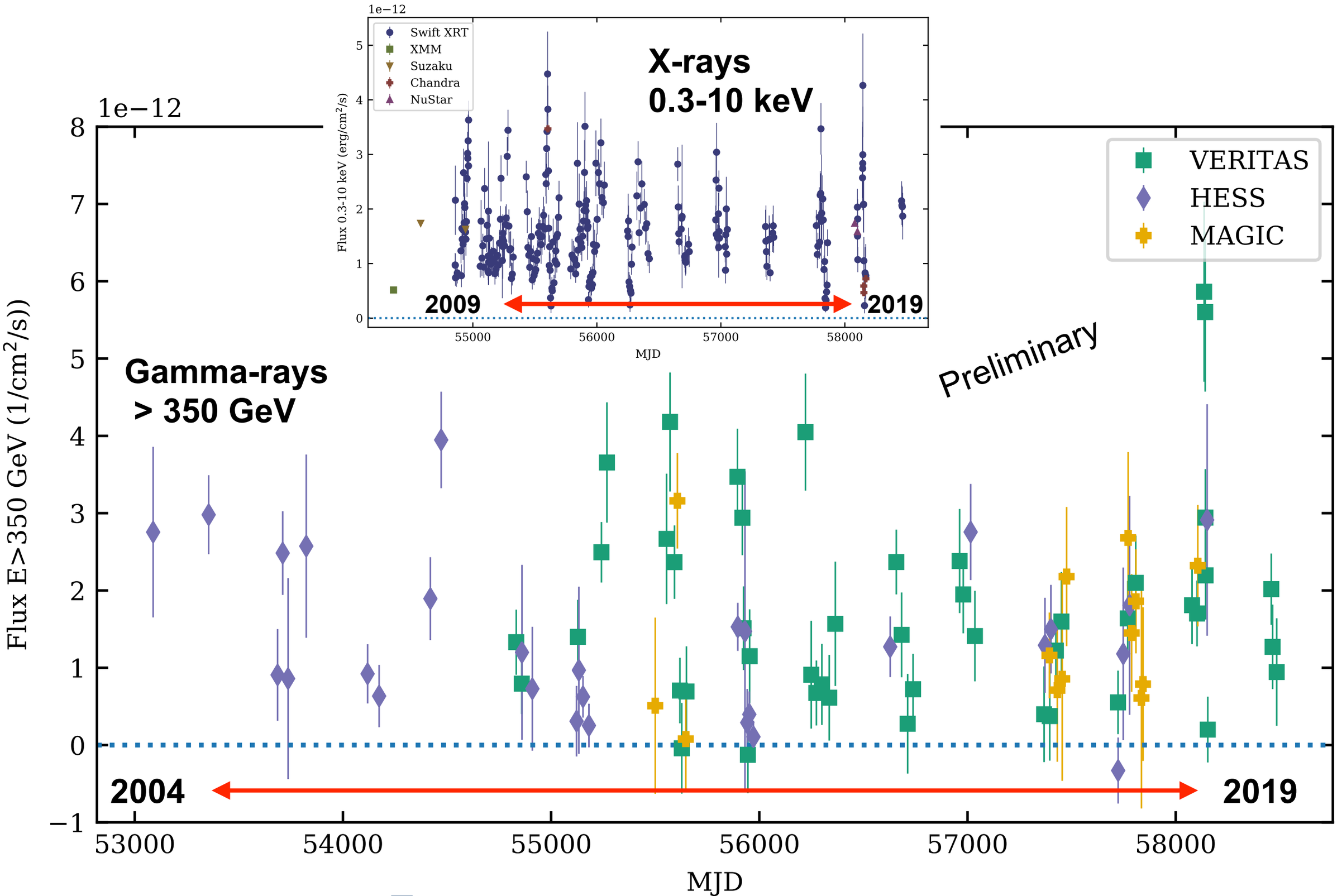
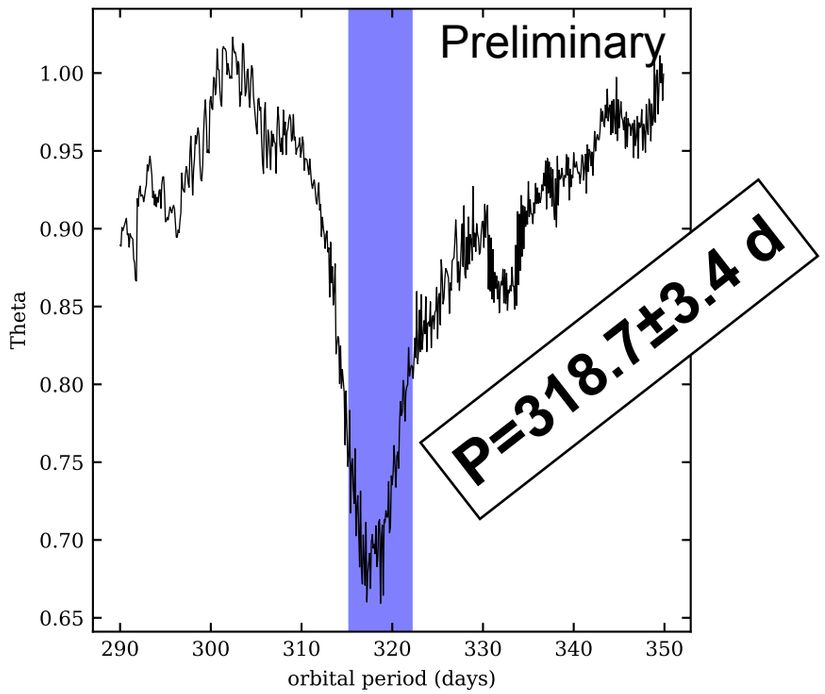
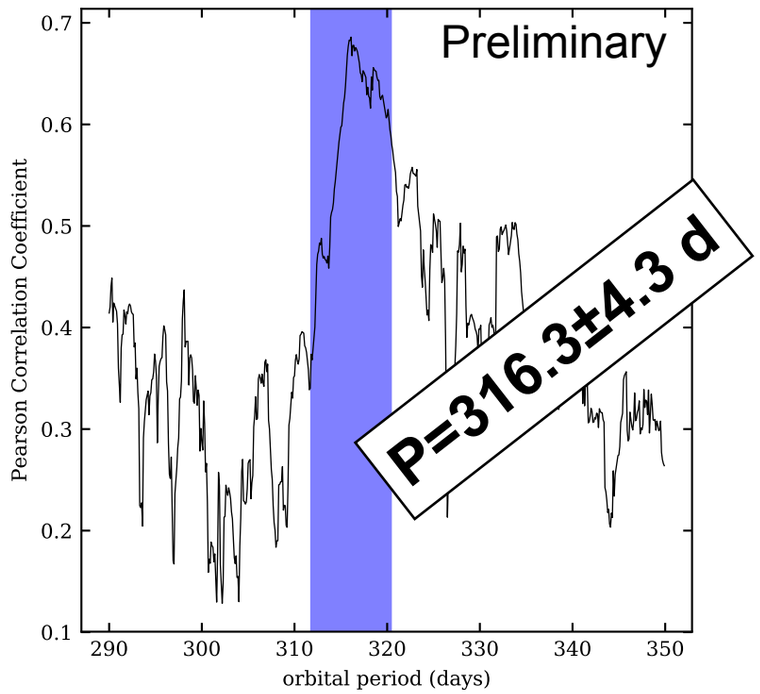


Orbital period determination from gamma rays

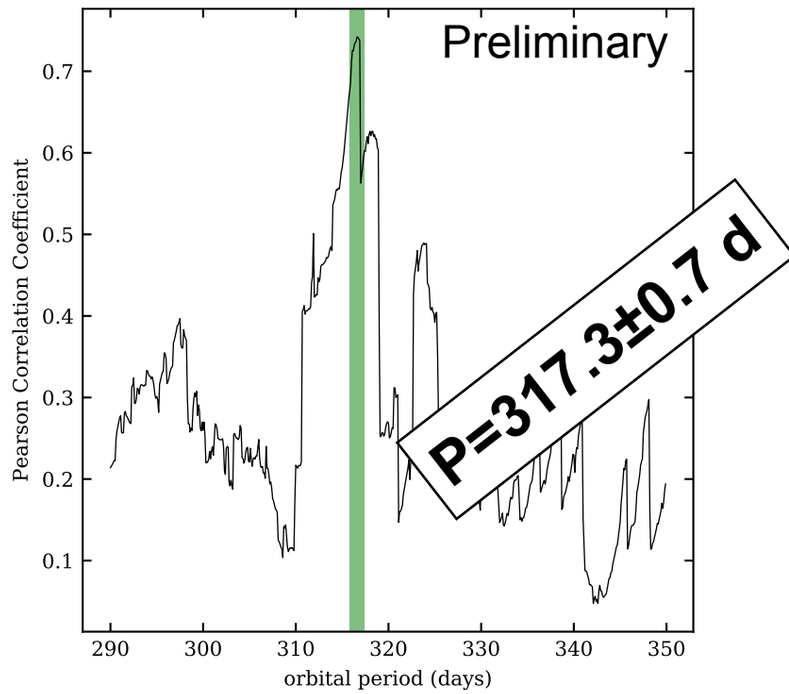
Phase Dispersion Minimisation Gamma-rays > 350 GeV



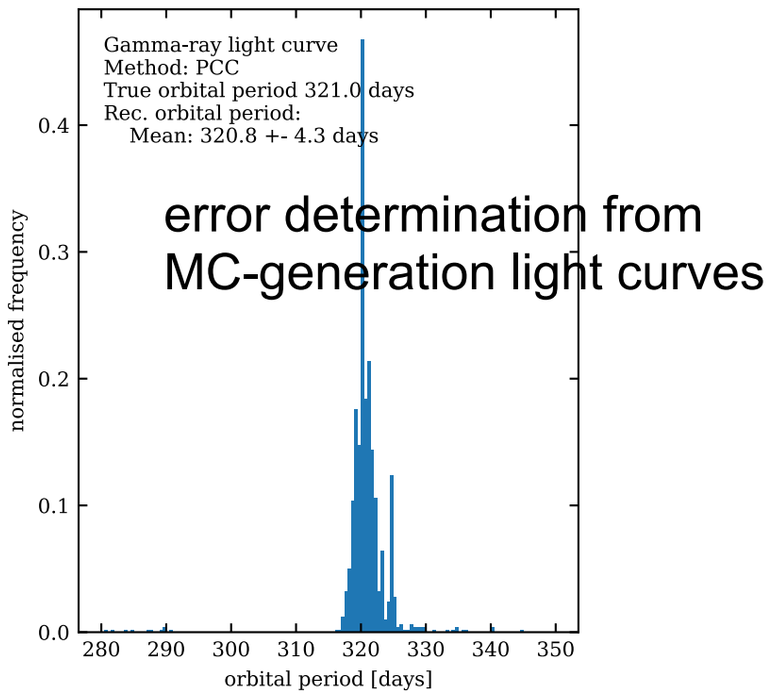
Pearson's Correlation Coefficient Gamma-rays > 350 GeV



Pearson's Correlation Coefficient Swift XRT 0.3-10 keV

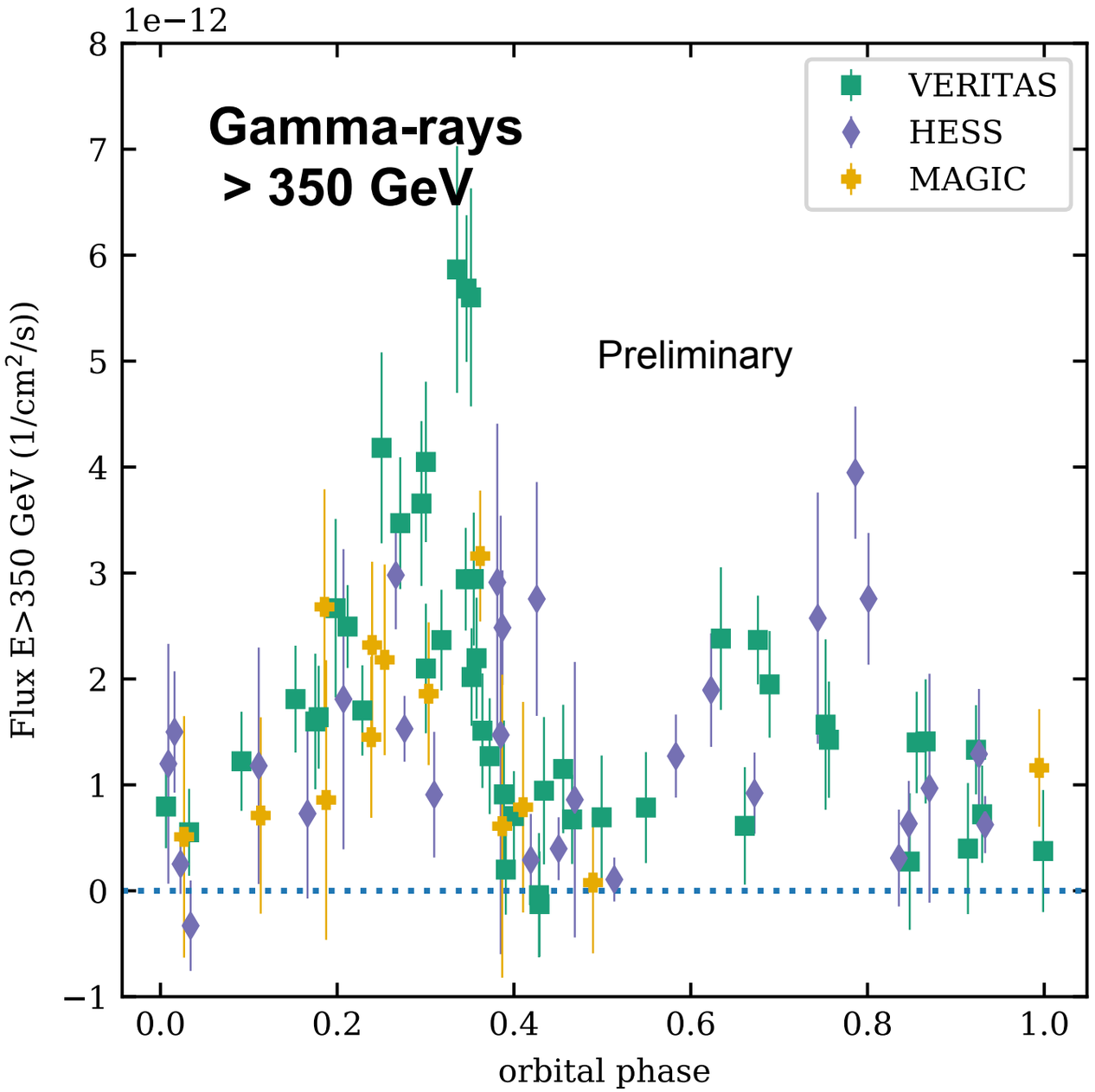


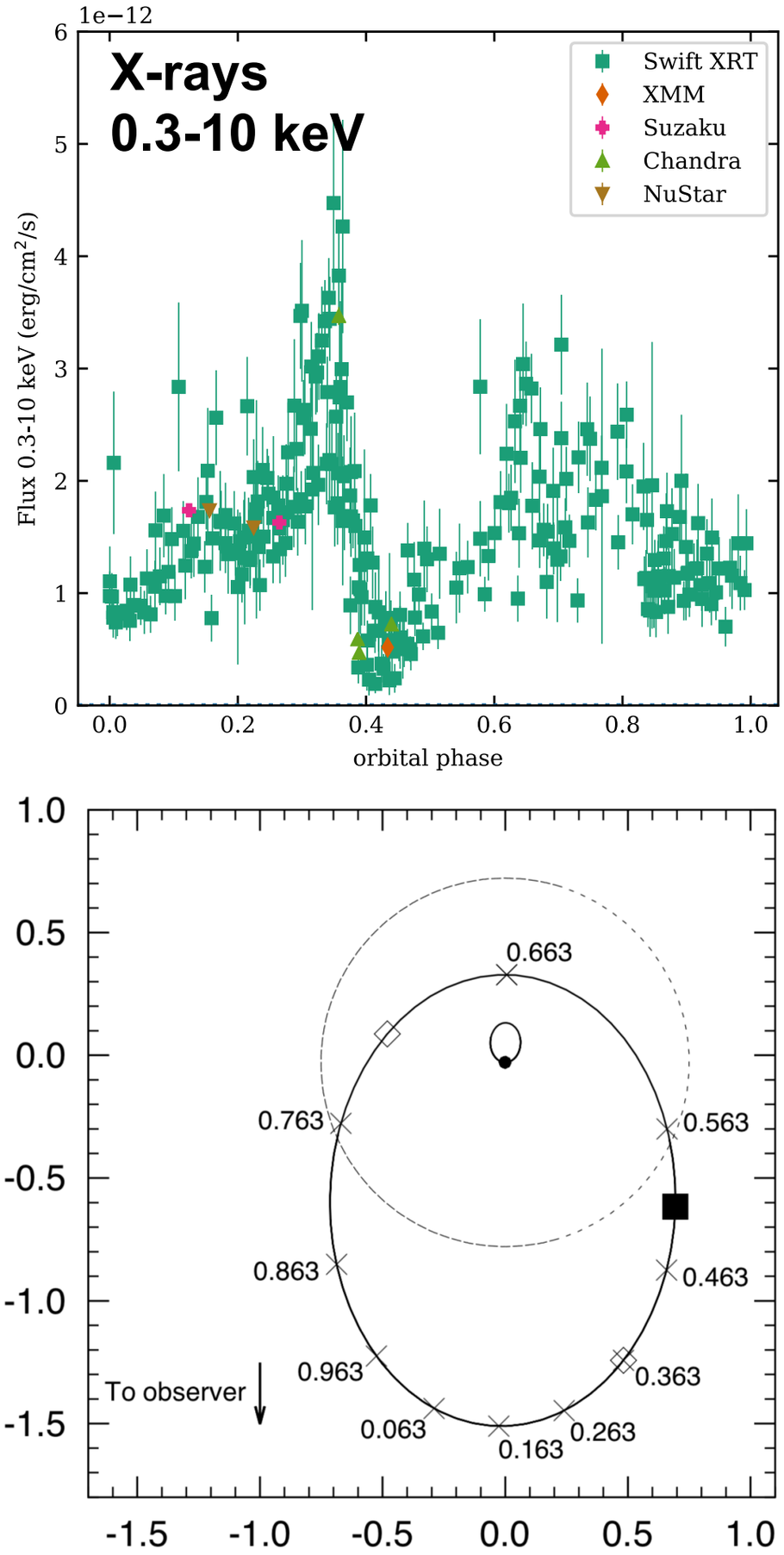
- orbital period determined for the first time from gamma-ray data
- updated X-ray analysis using all available XRT data (MJD 54857–58168)



Phase-folded light curves

assuming an orbital period of 317.3 days





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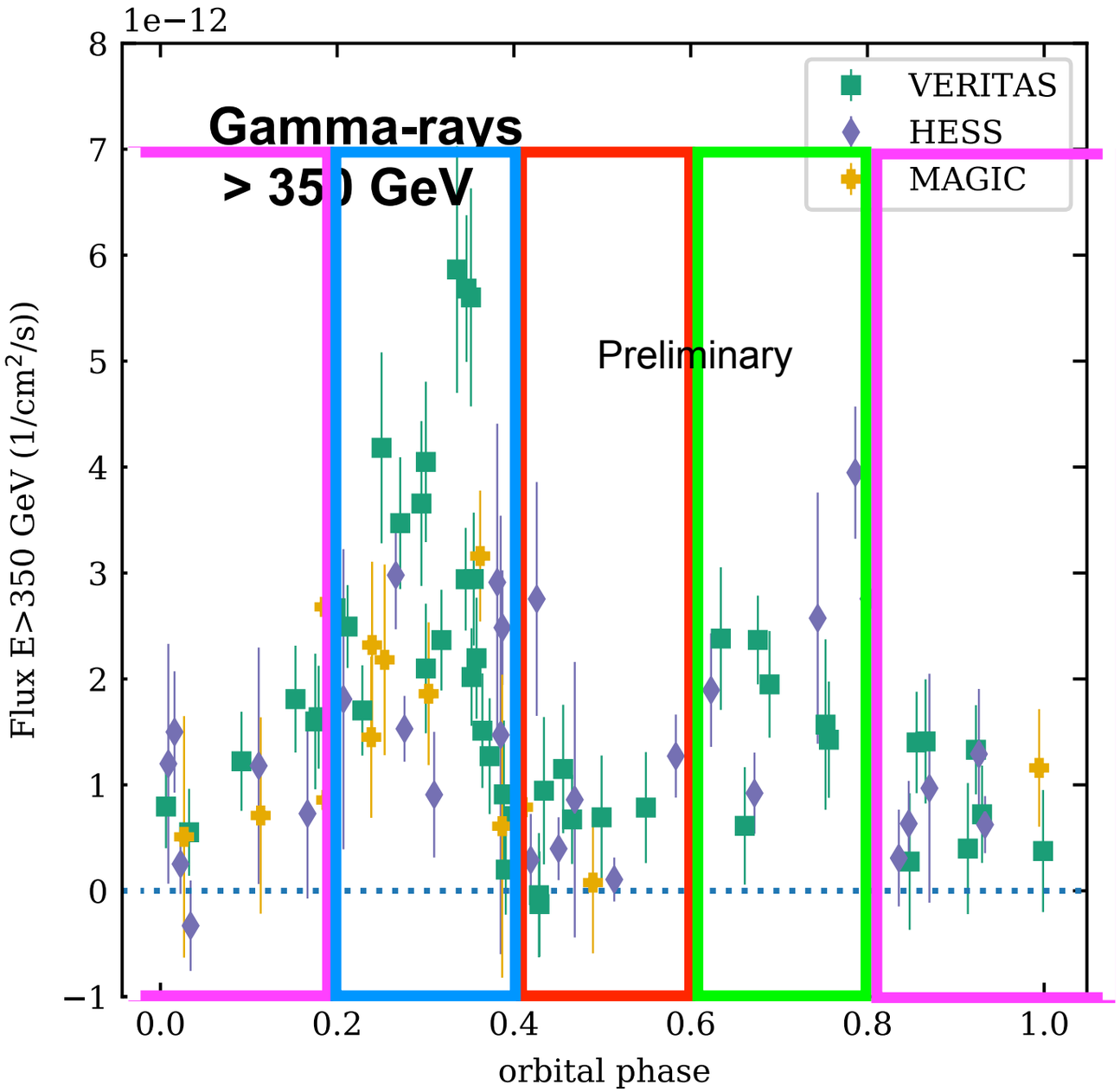
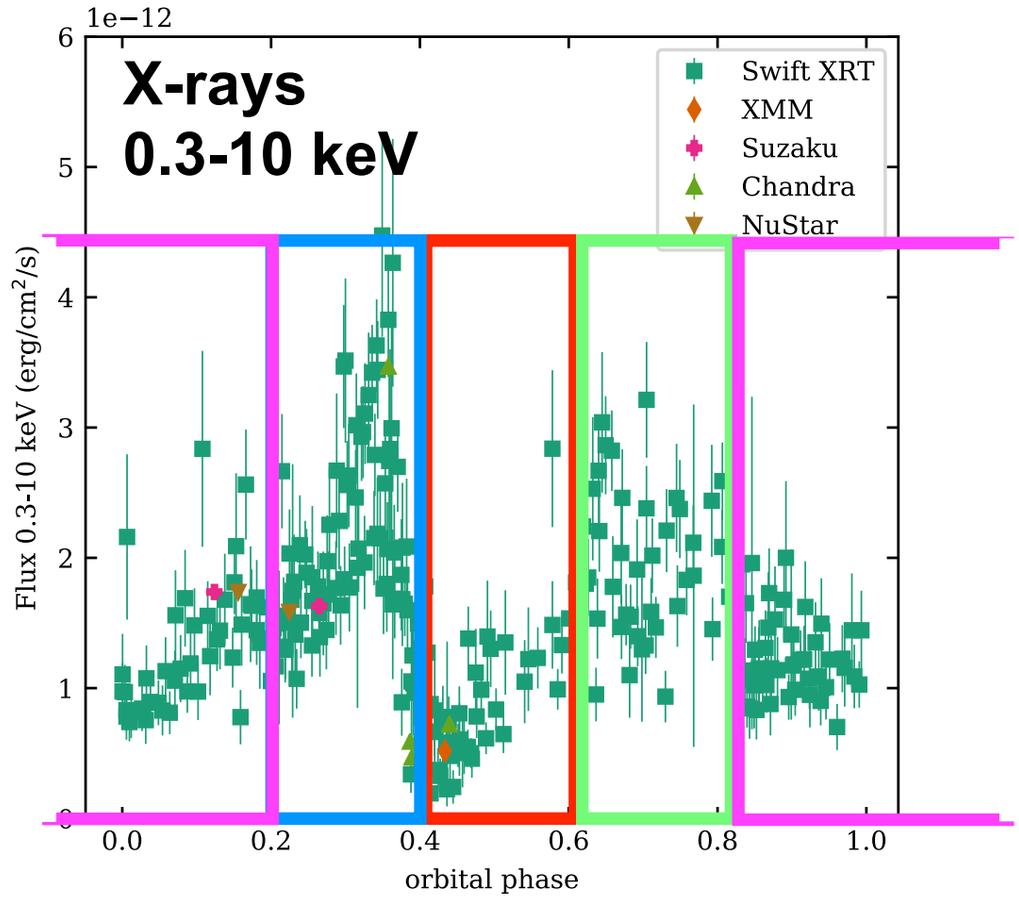
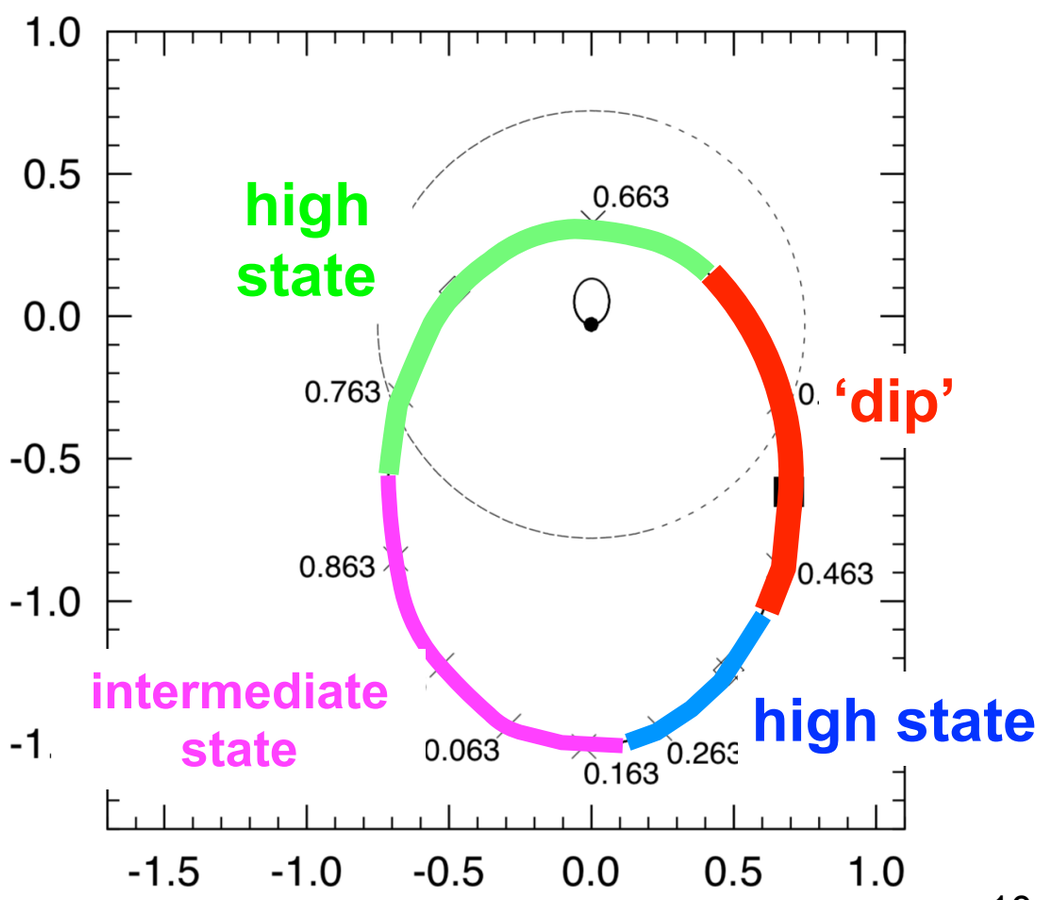
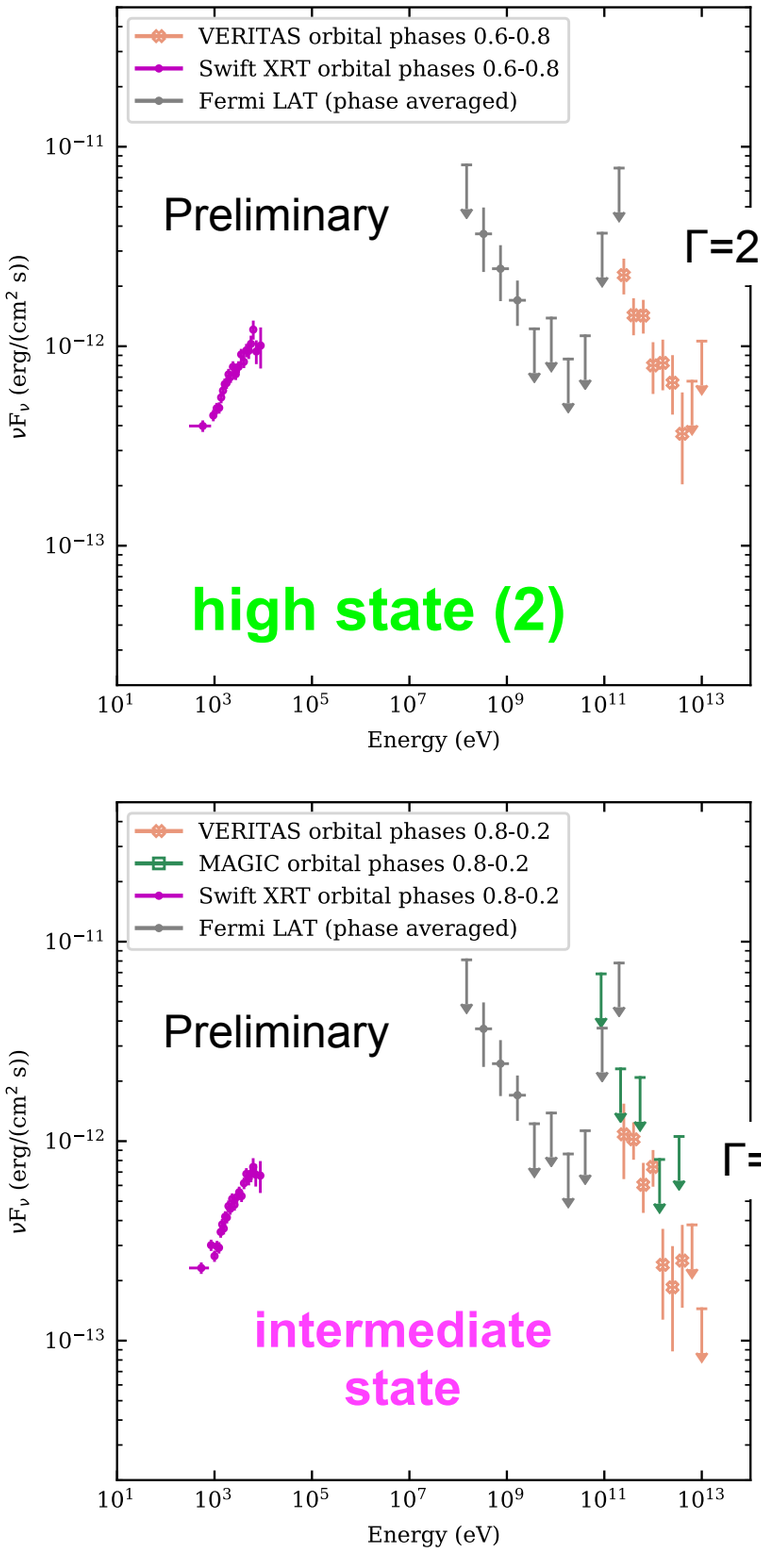
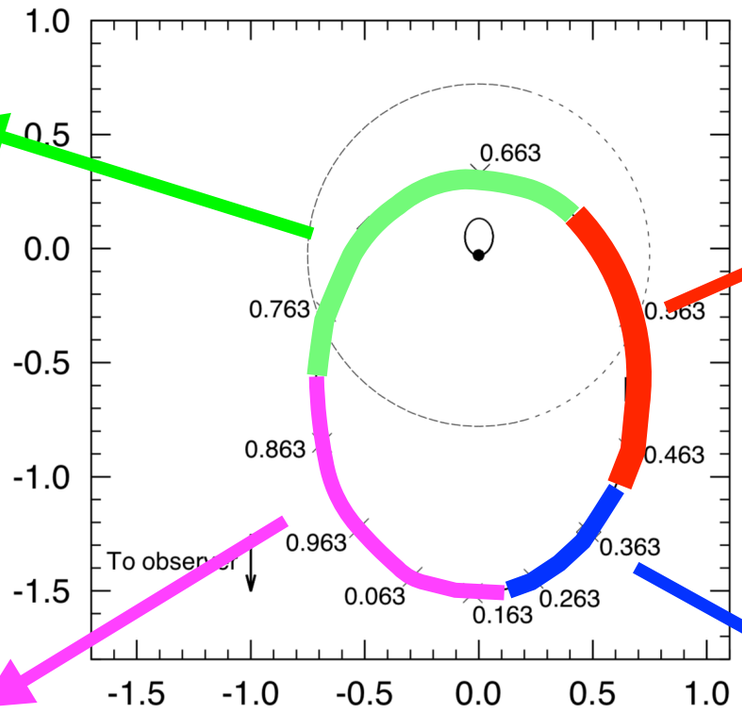


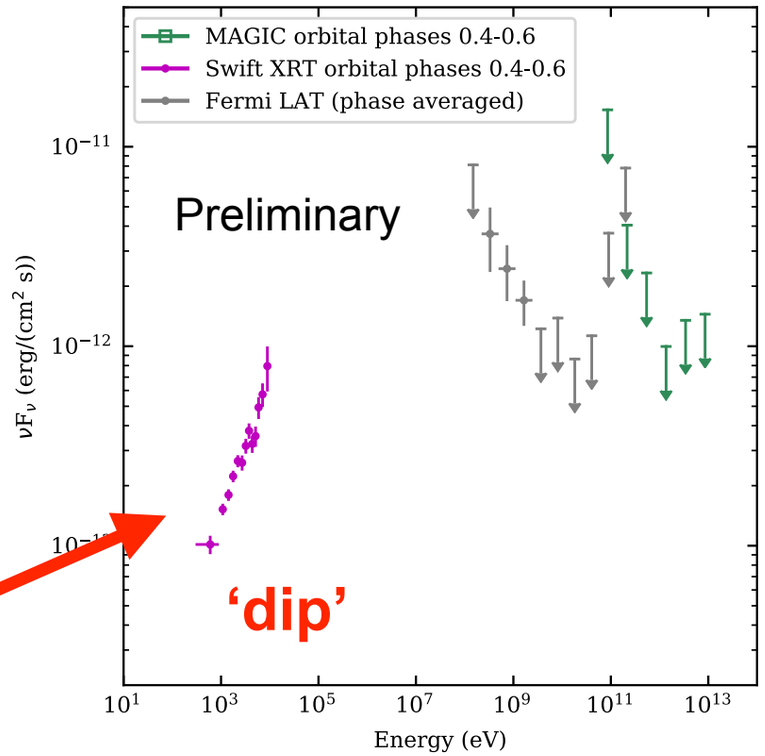


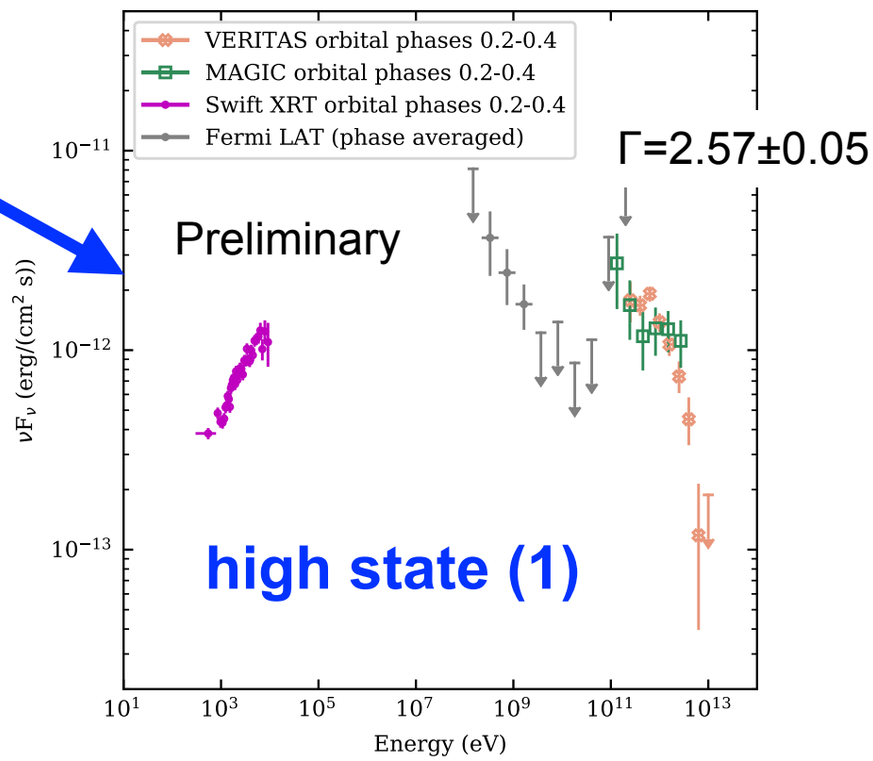


Phase-averaged spectra



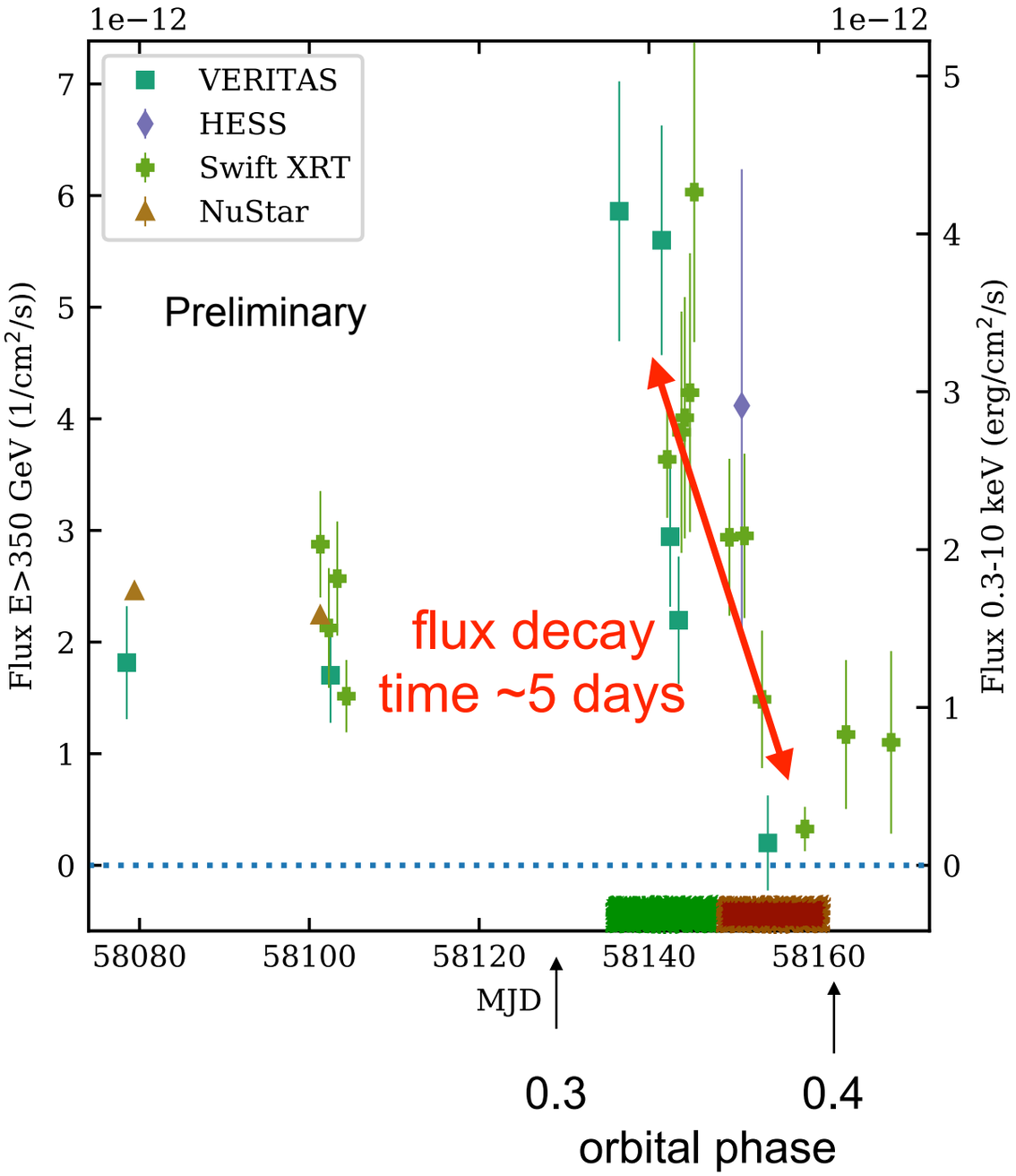


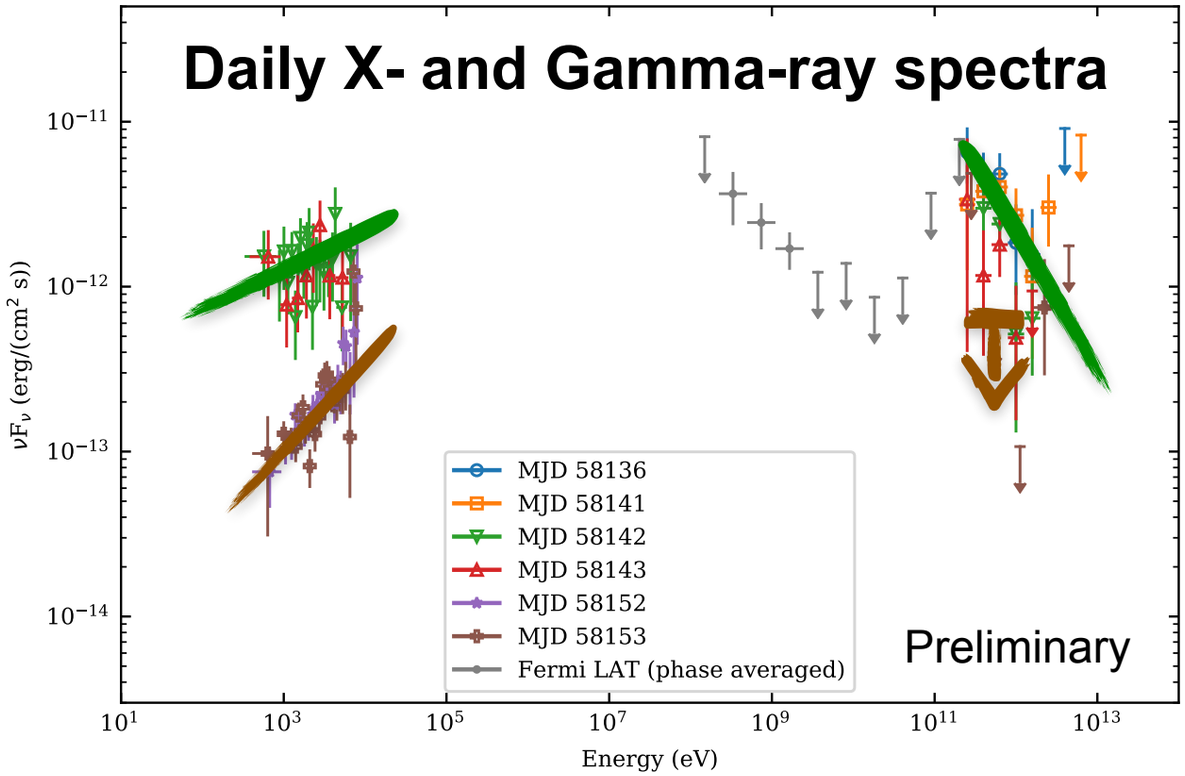


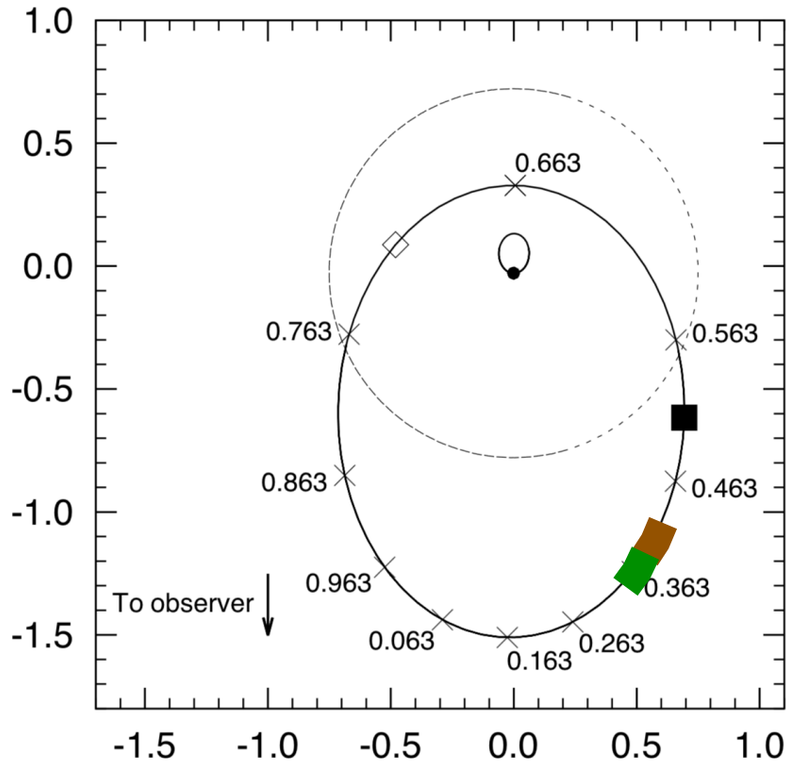


see also Poster by R.Prado et al on NuSTAR+VERITAS observations of HESS J0632+057

Bright state in Jan 2018

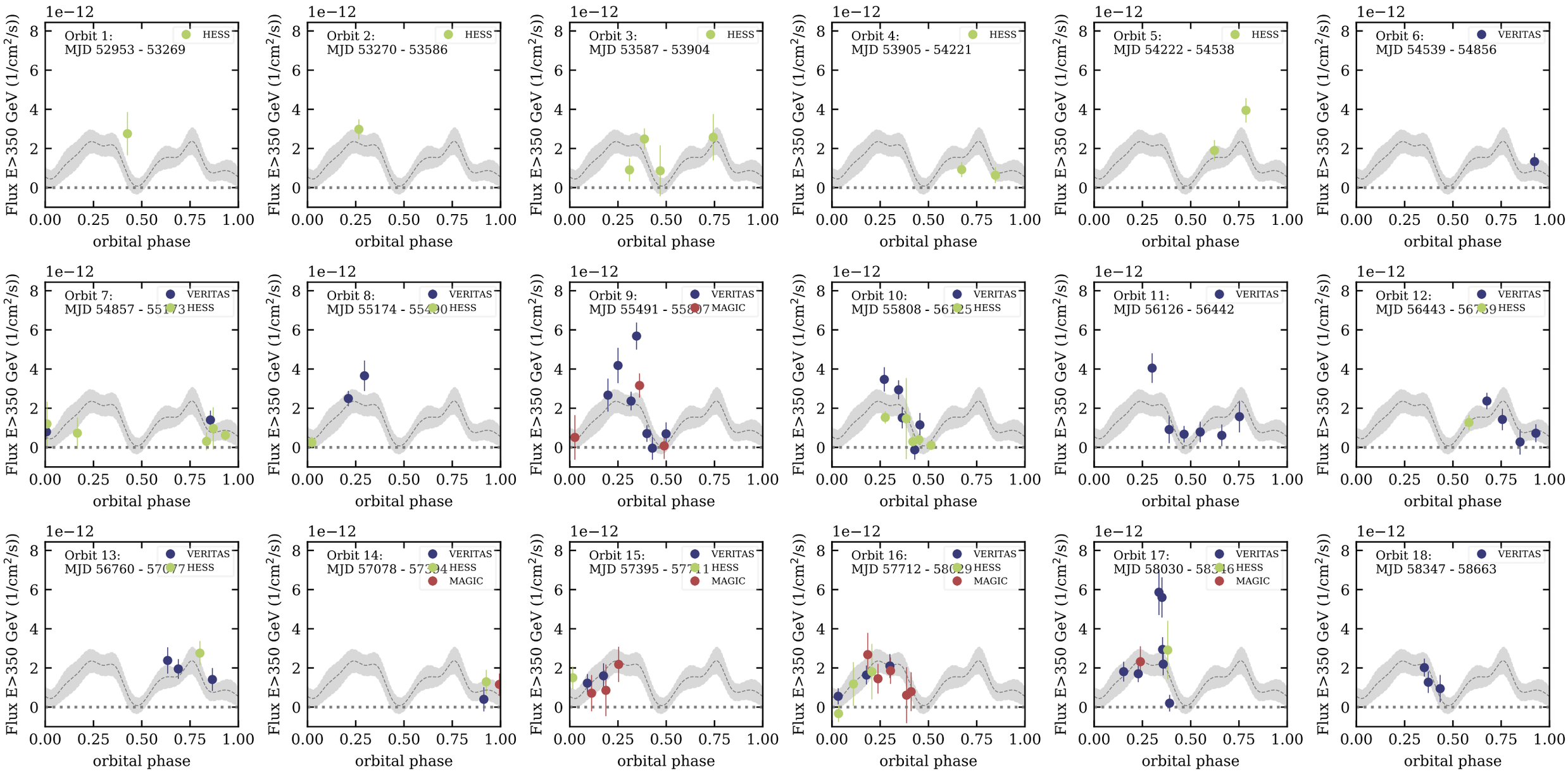






Bright states

Coverage per orbit - still limited despite large data set (18 orbits)



Assuming an orbital period of 317.3 days
Grey band: average Gamma-ray light curve
(68% uncertainty band)

Bright states

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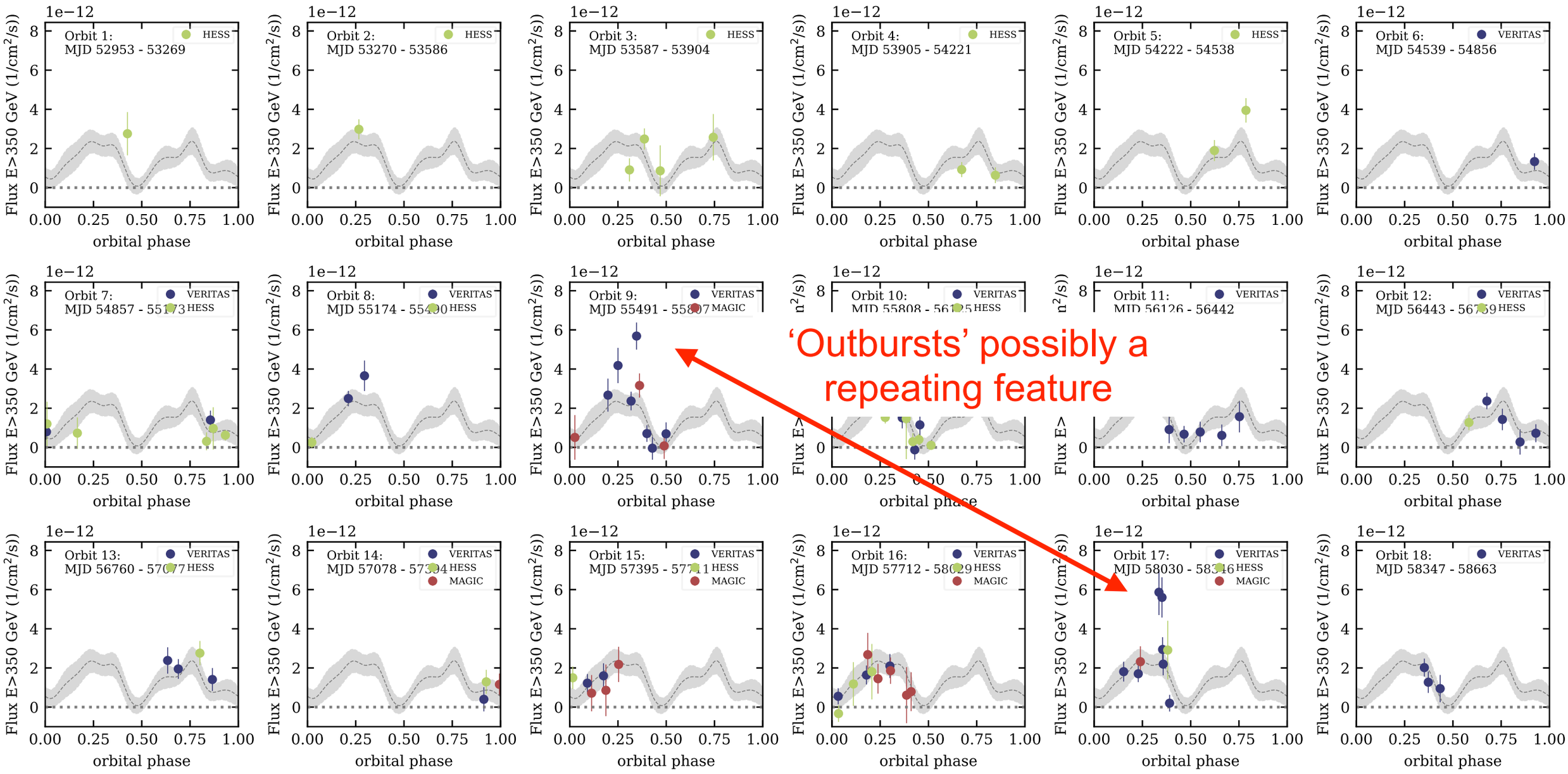

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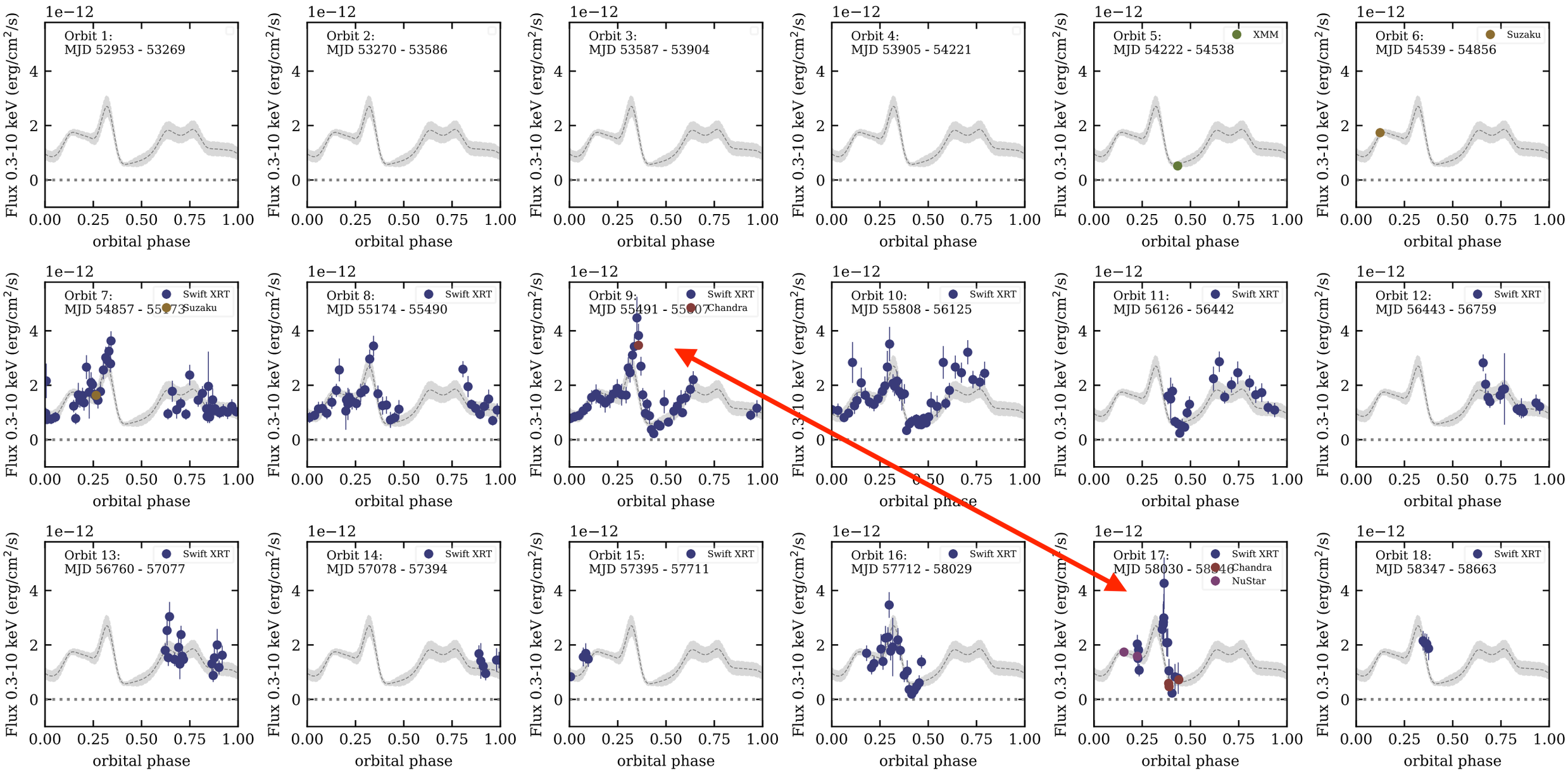
Bright states - X-rays

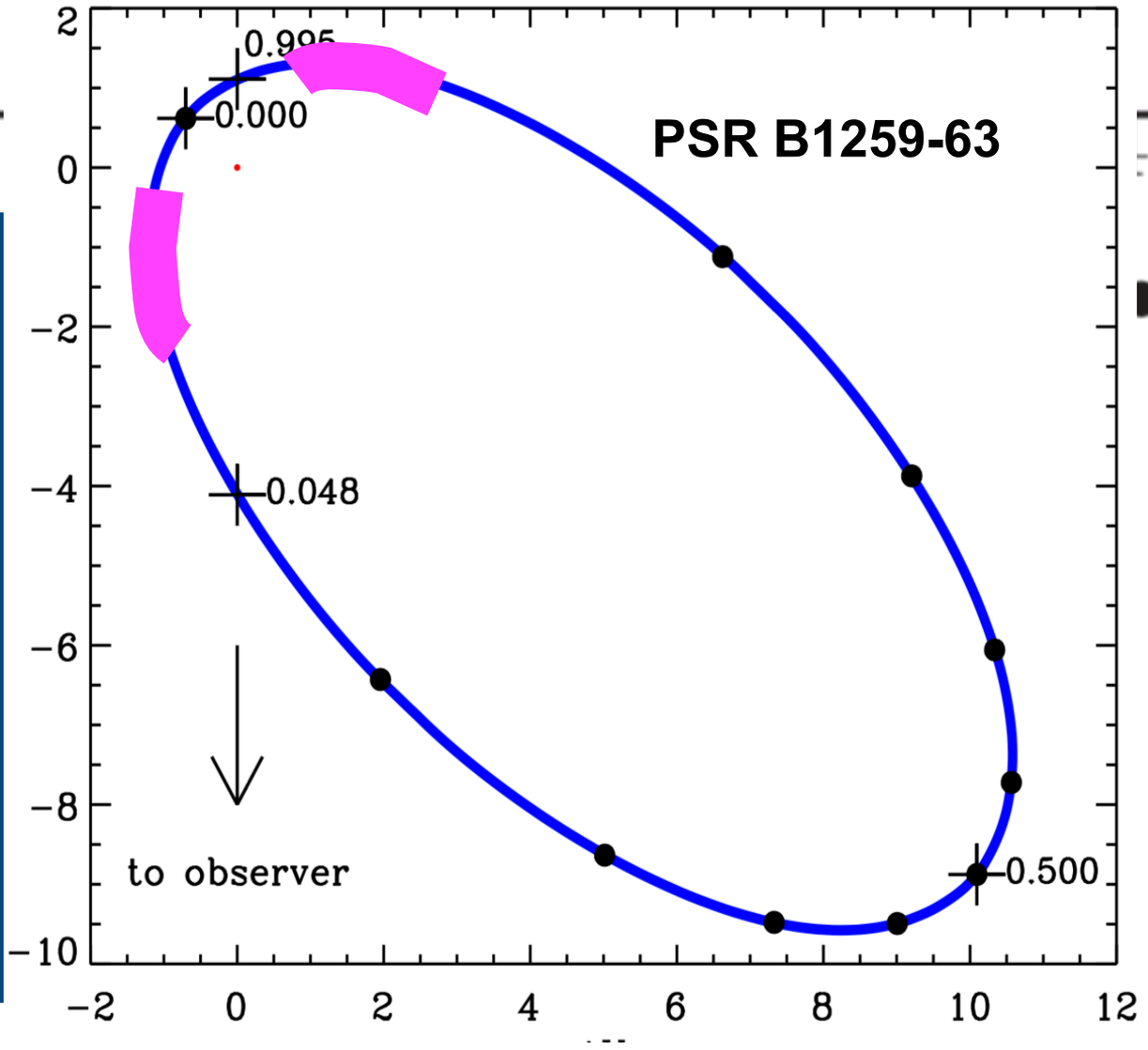
Large data set - but still limited coverage per orbit

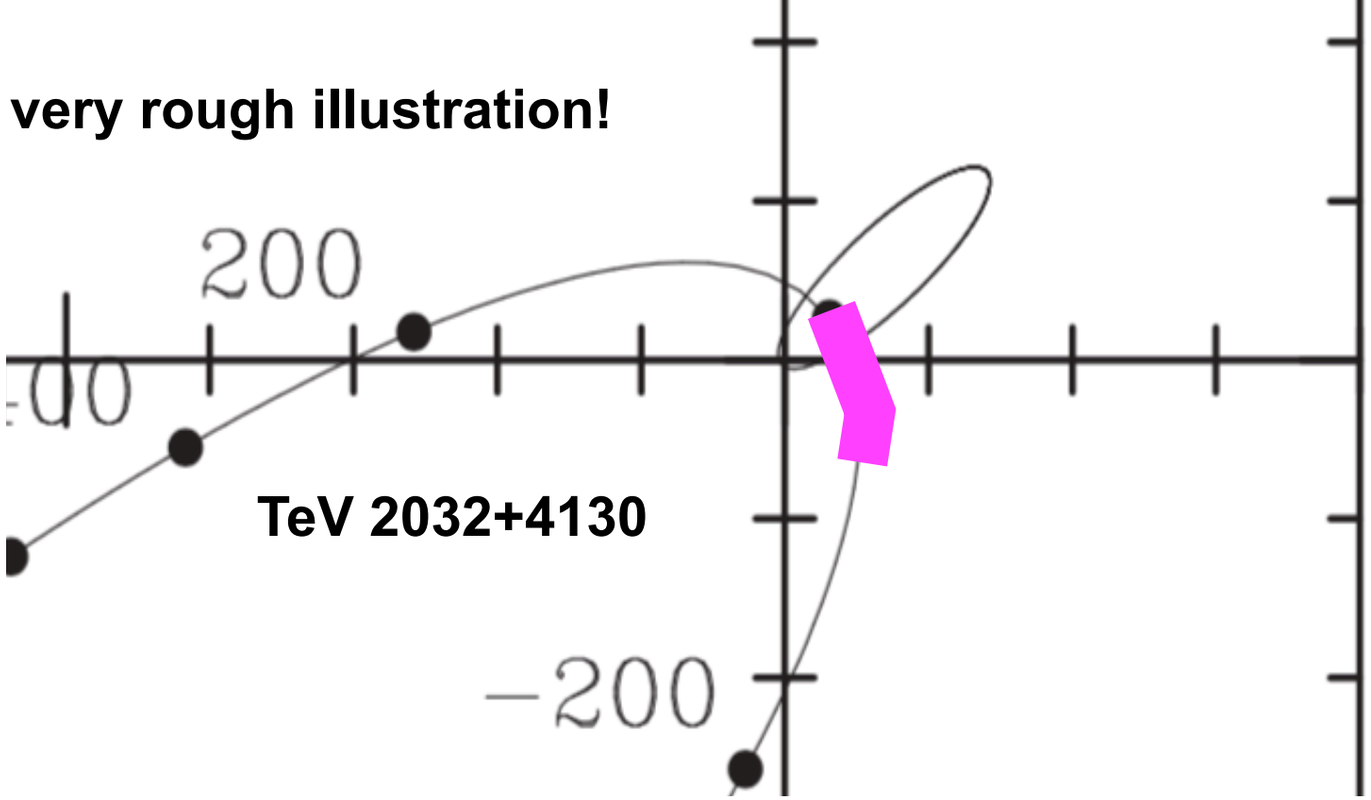


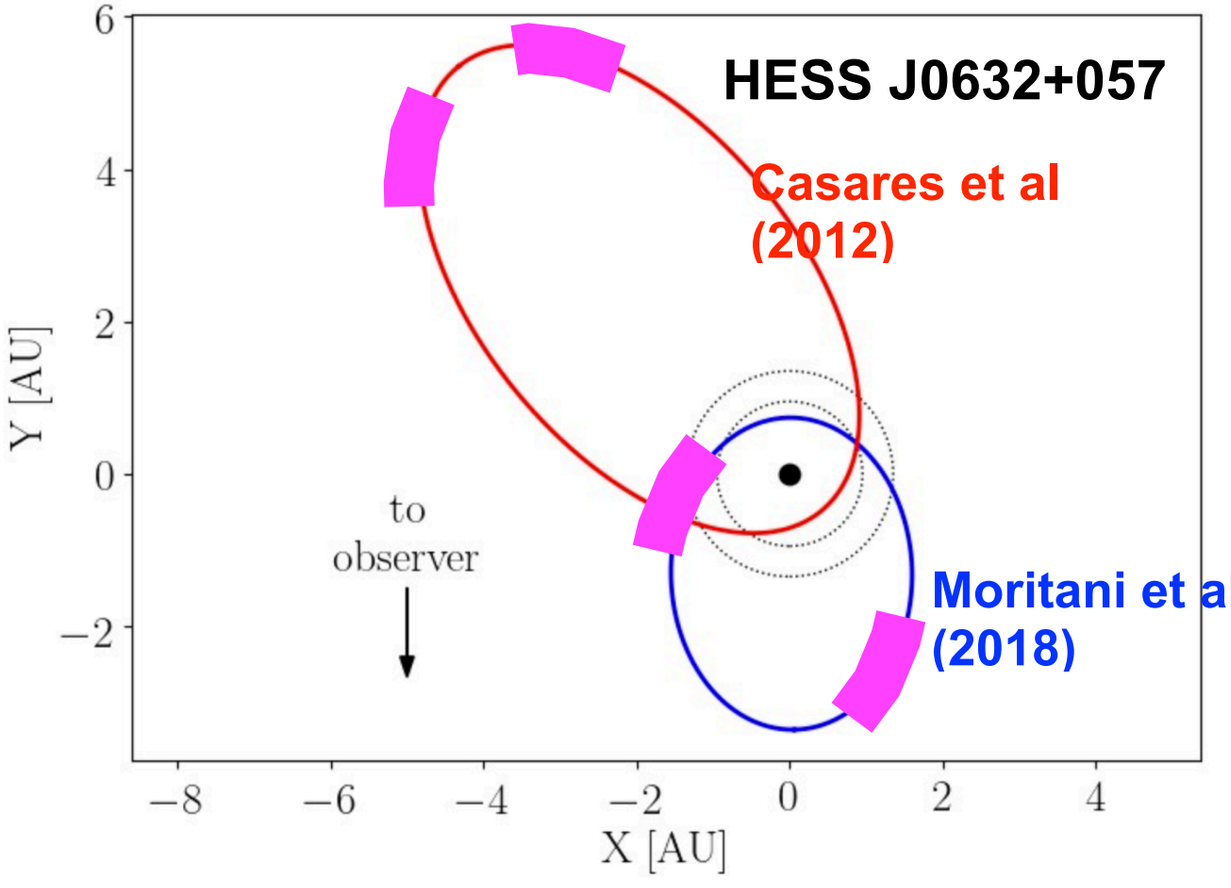
Assuming an orbital period of 317.3 days
Grey band: average Swift XRT light curve
(68% uncertainty band)

Common picture?

very rough illustration!







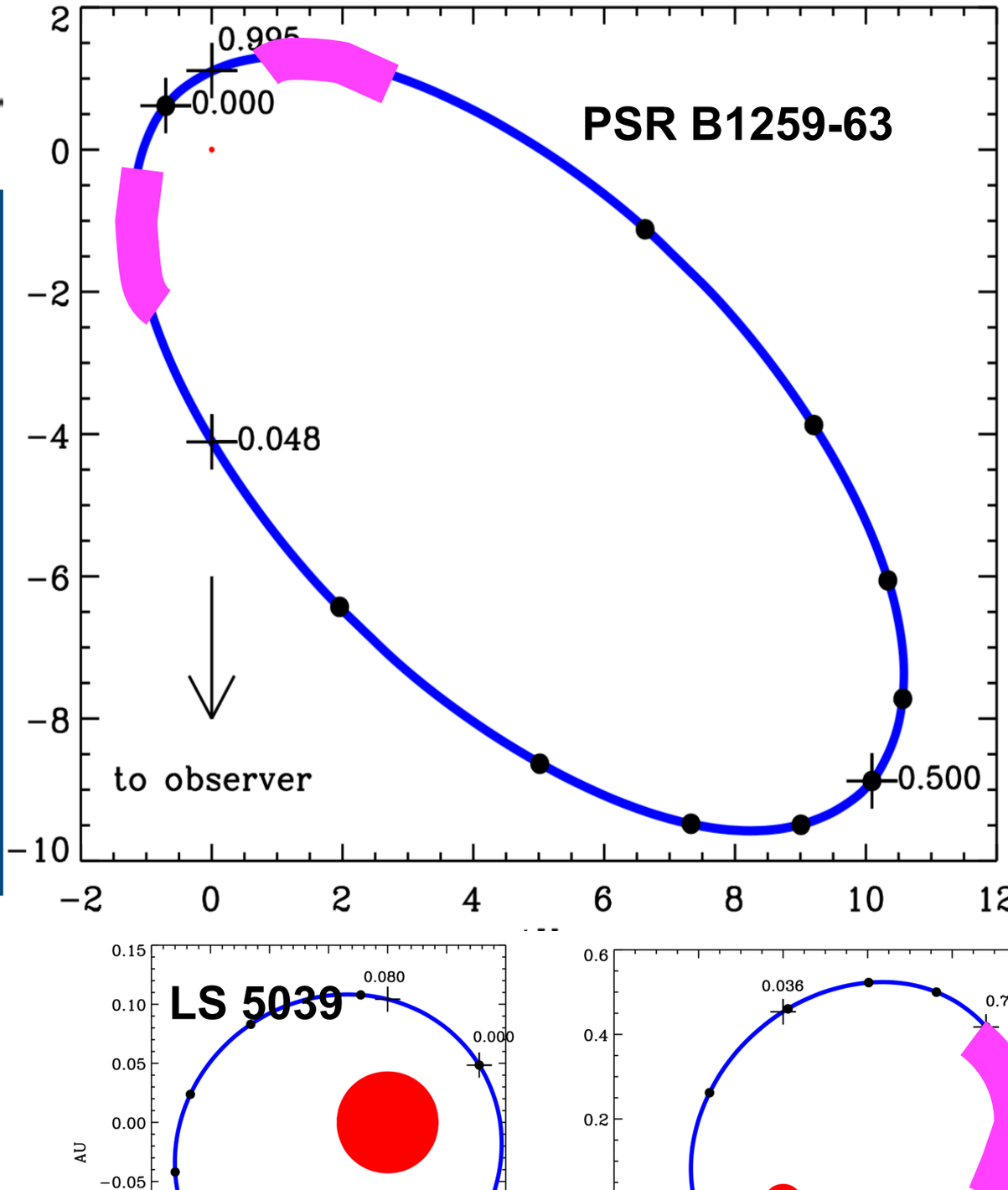
orbital plots from Dubus 2013, Ho et al 2018

LS 5039

LS I +61 303

(ignoring large uncertainties in orbital solutions)

Common picture?



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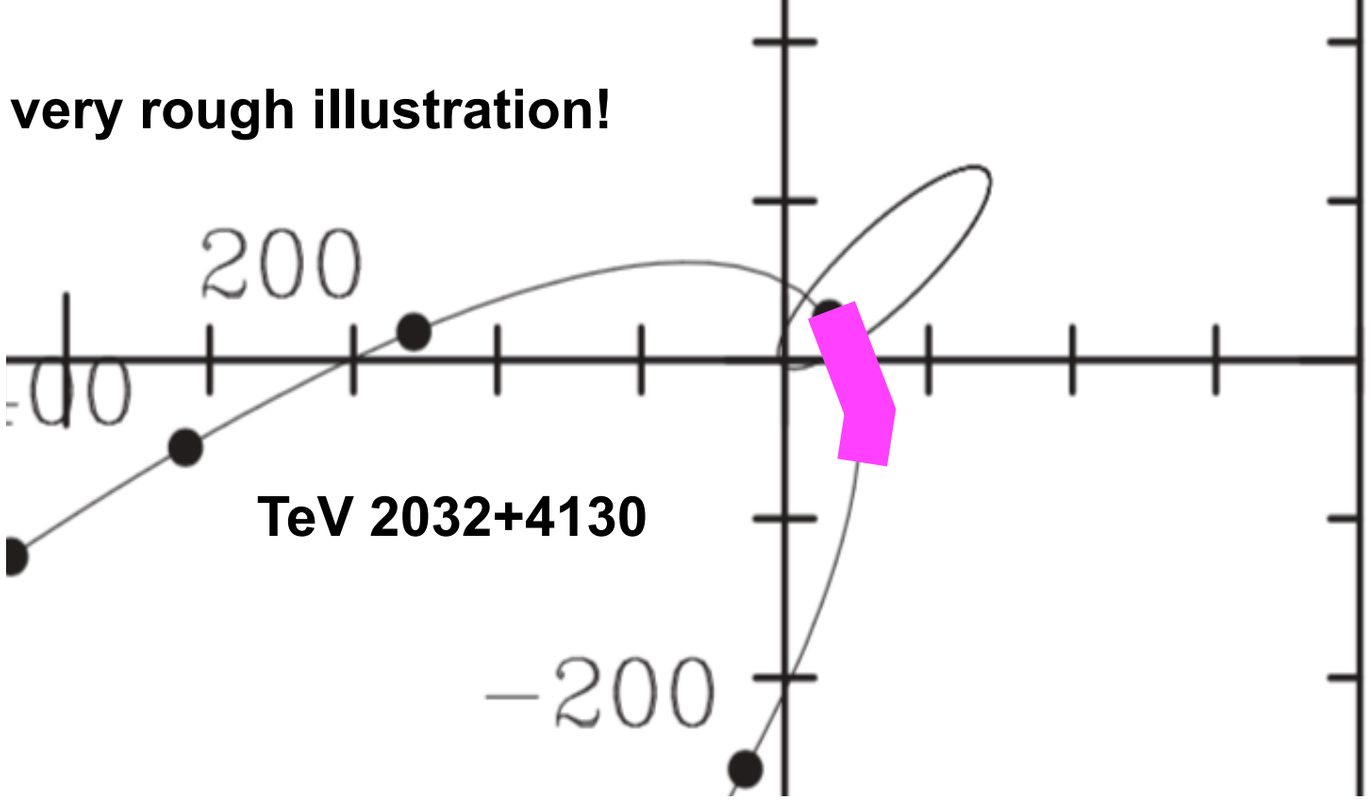
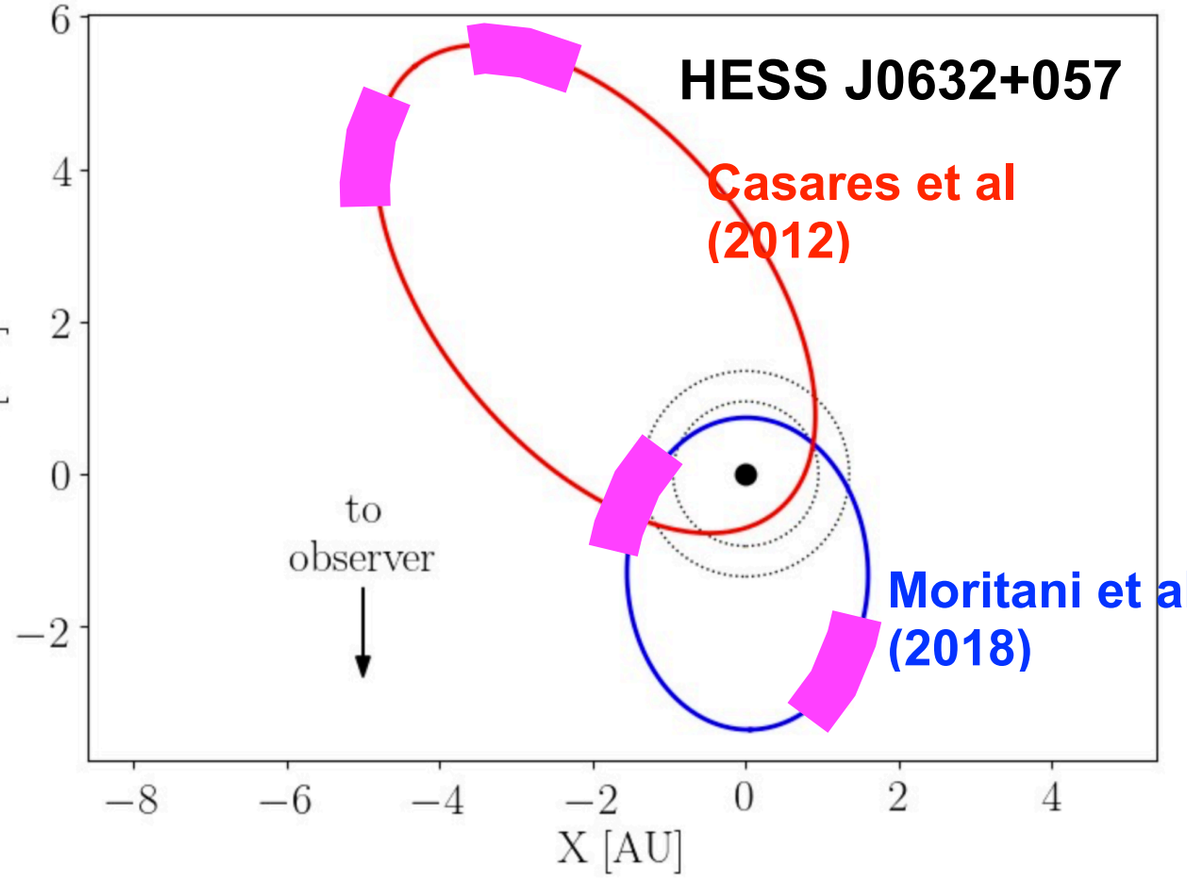
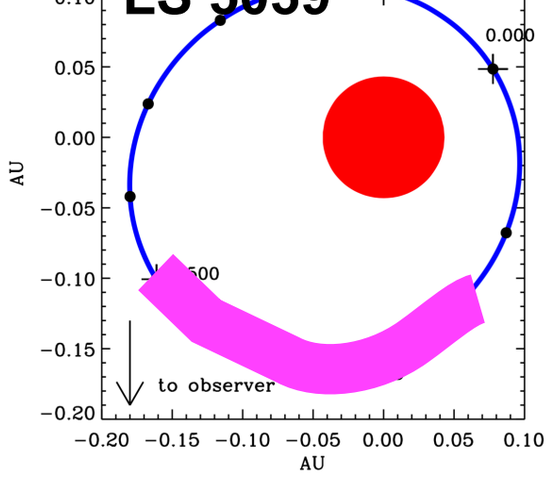
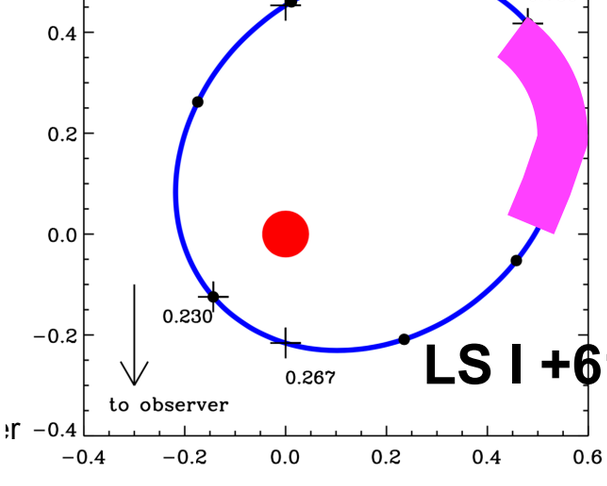








(ignoring large uncertainties in orbital solutions)

orbital plots from Dubus 2013, Ho et al 2018

Conclusions

- 15 years of observations of HESS J0632+057 with H.E.S.S., MAGIC, and VERITAS

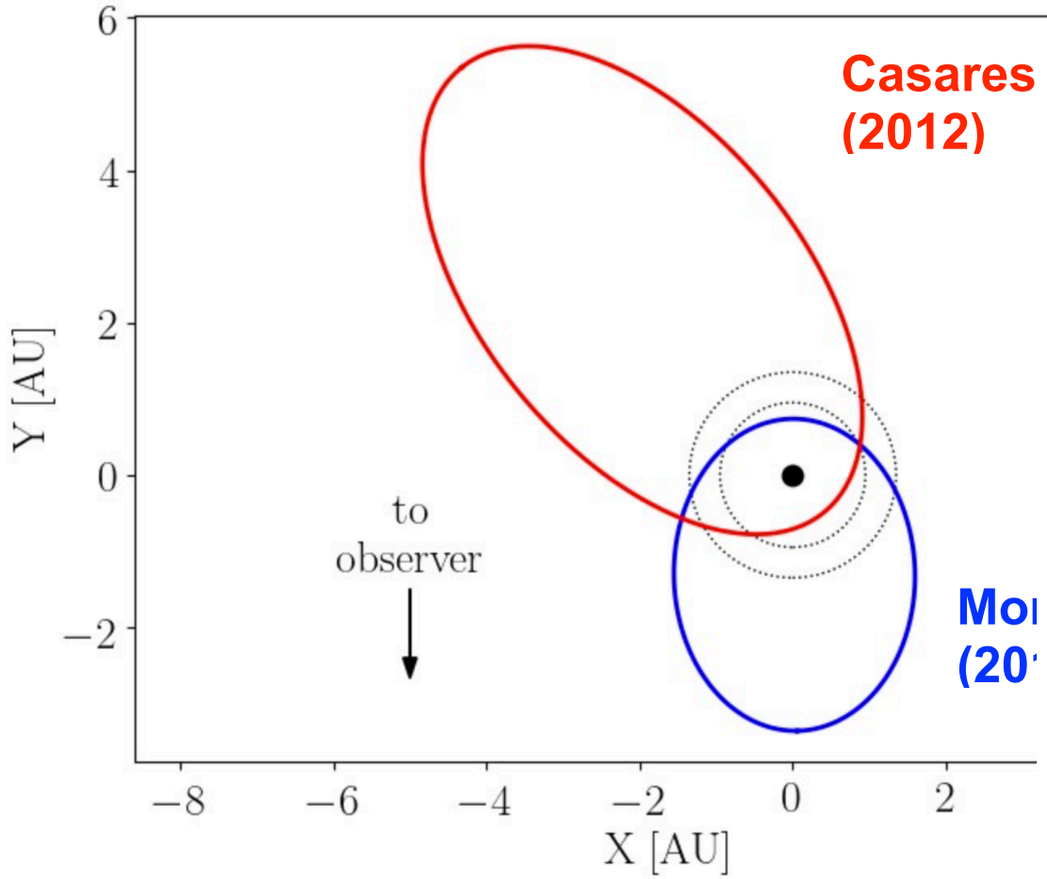
- orbital period and light curve well established at X- and gamma-ray energies

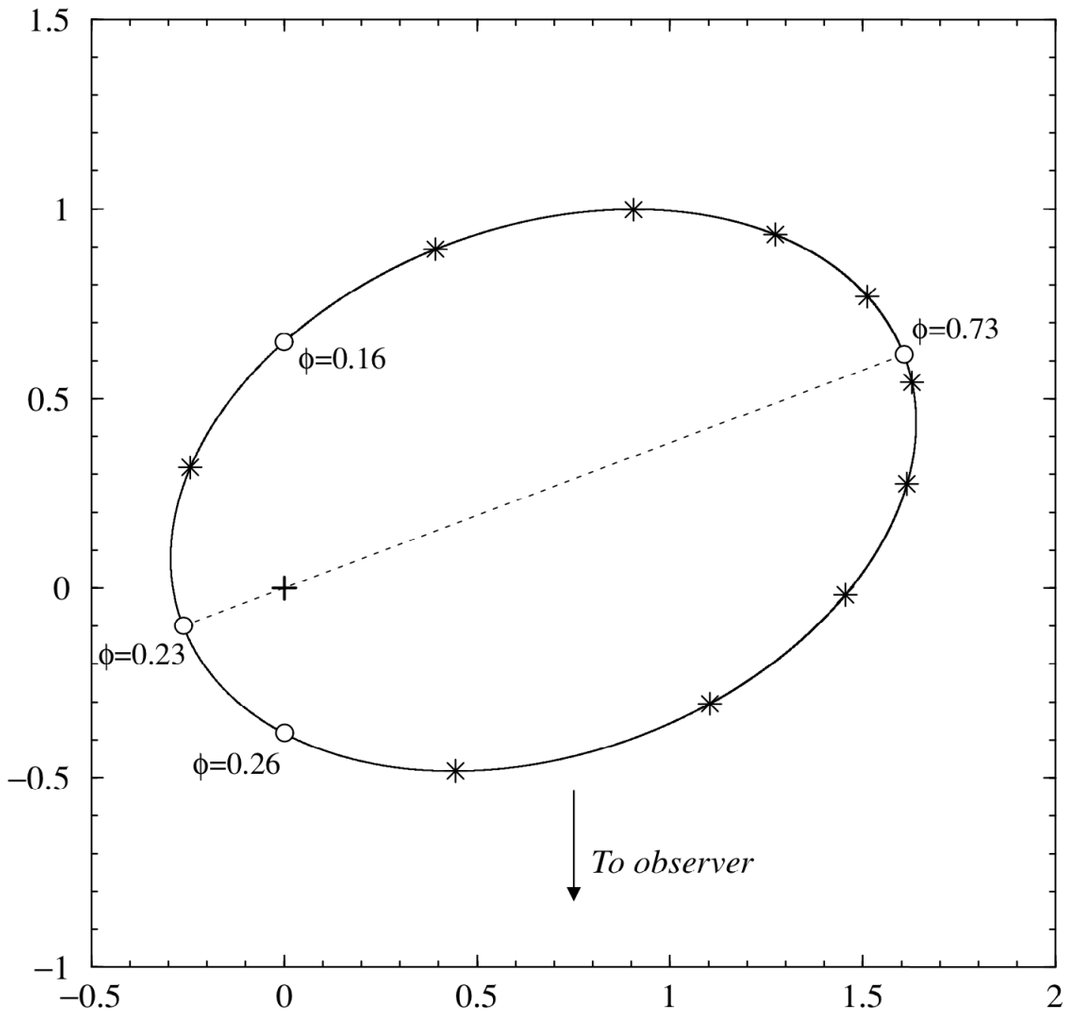
- optical observations required to pin down the orbital geometry and the properties of the massive star

- publication with detailed spectral analysis (phase averaged and in short time bins) in preparation

Additions

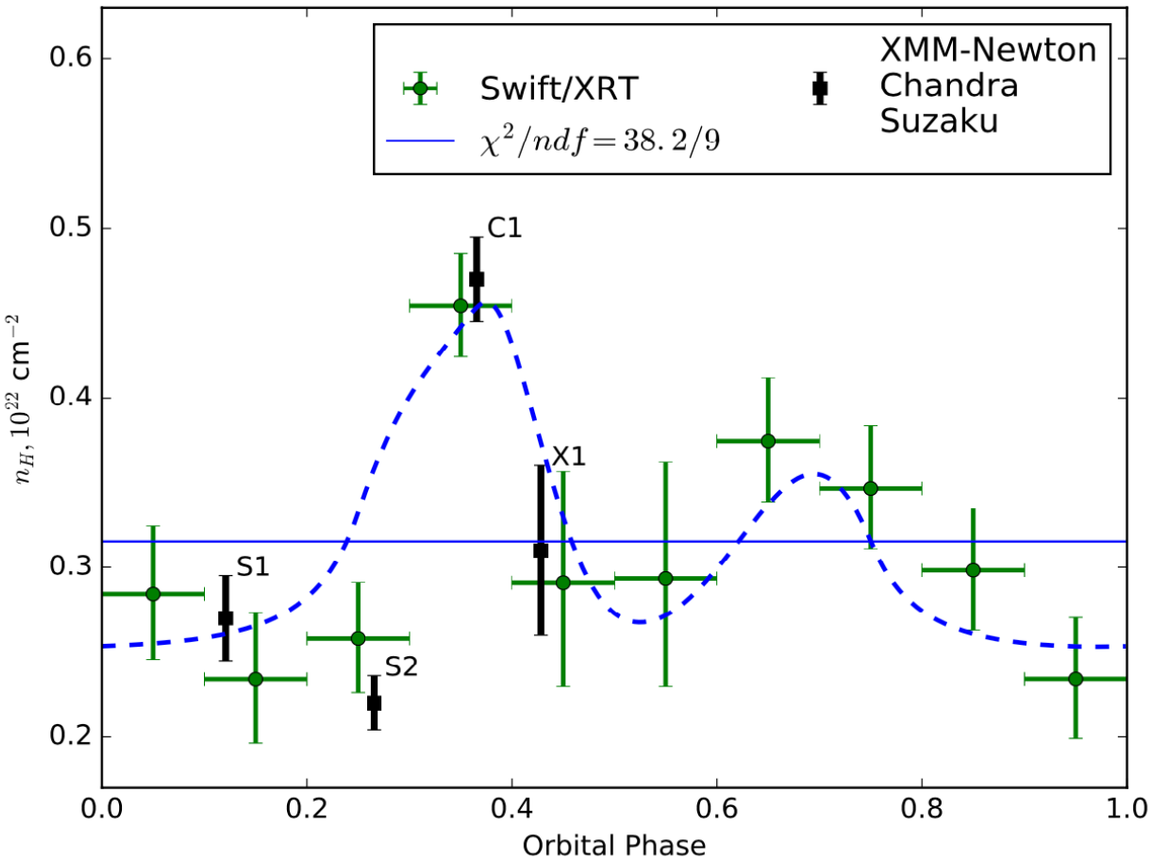
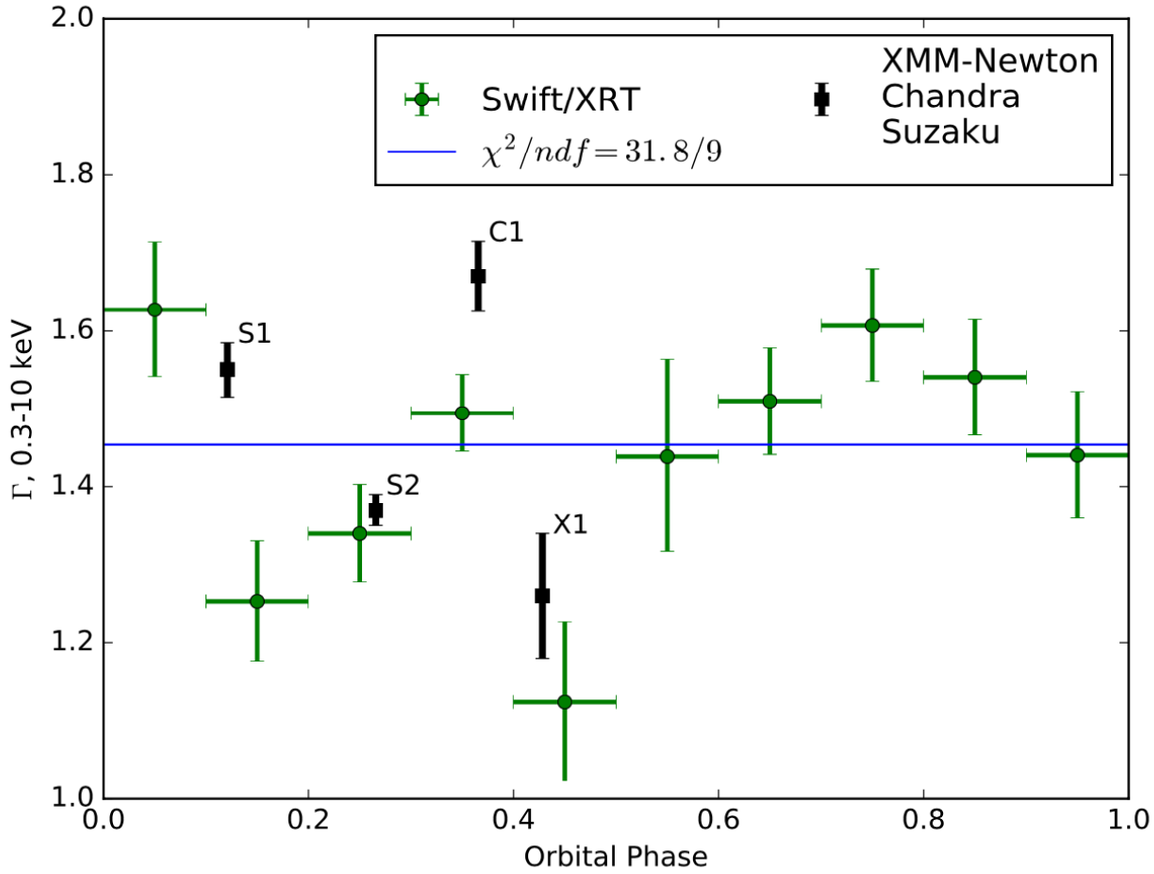
Common picture?





Orbital periods

Publication	Instrument/ Wavelength	MJD Range	Method	Orbital period (days)
This work	*Swift*-XRT	54857–58168	PDM	316.7 ± 1.5
This work	*Swift*-XRT	54857–58168	DCF	318.9 ± 2.2
This work	*Swift*-XRT	54857–58168	PCC	317.3 ± 0.7
This work	Gamma ray	53087–58490	PDM	318.7 ± 3.4
This work	Gamma ray	53087–58490	PCC	316.3 ± 4.3
Bongiorno et al. (2011)	*Swift*-XRT	54857–55647	Peak fitting	321 ± 5
Aliu et al. (2014)	*Swift*-XRT	54857–55972	Z-DCF	315^{+6}_{-4}
Moritani et al. (2018)	*Swift*-XRT	54857–57052	Fourier Analysis	308^{+26}_{-23}
Moritani et al. (2018)	Hα	56566–58118[a]	Z-DCF	313^{+11}_{-8}
Malyshev et al. (2017)	*Swift*-XRT	54857–57860	PCC	$316.2^{+1.8}_{-2.0}$

Outcome of the orbital period derivation from this work and from the literature. The applied methods are: Peak fitting (Bongiorno et al. 2011), Z-transformed discrete correlation functions (Alexander 1997, ZDCF), phase dispersion minimisation method (Stellingwerf 1978, PDM), discrete correlation functions (Edelson & Krolik 1988, DCF), and correlation analysis comparing the light curves with a binned-average light curve (Malyshev et al. 2017, PCC).

Malyshev et al 2017: X-ray orbital profile