

Long-term VERITAS observations of LS I +61° 303



A multi-waveband perspective

**Patel, S. R. for the VERITAS Collaboration
DESY, Zeuthen, Germany
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**TeV Particle Astrophysics 2021 (TeVPA 2021), Chengdu, China
(Hybrid)**





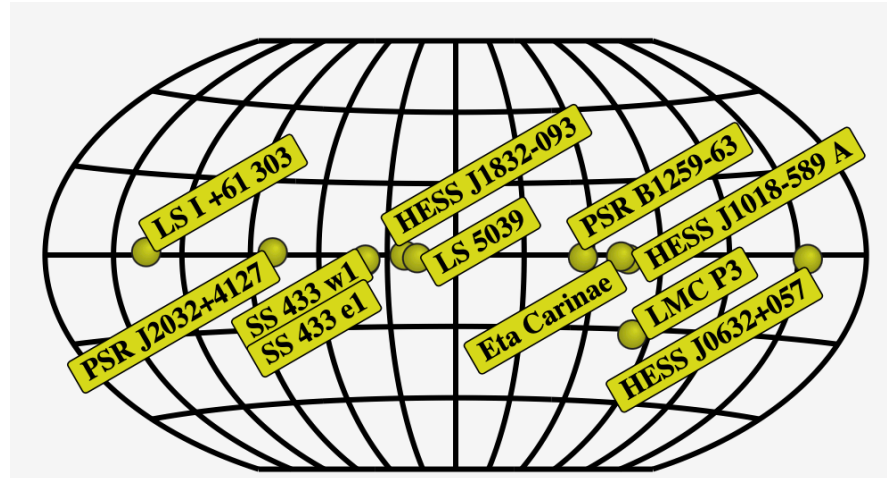
Introduction

Gamma-ray binaries

- A system consists of a compact object orbiting a star and having periodic release of large amount of non-thermal emission at energies >1 MeV

What **modulates** the gamma-ray emission?

What is the nature of **particle population**?



What **powers** the source?

Where and how **particle acceleration** takes place?

Gamma-ray binaries ([TeVCat](#))

- gamma-ray binaries with known compact companion: PSR B1259-63 and PSR J2032+4127

Introduction

LS I +61° 303

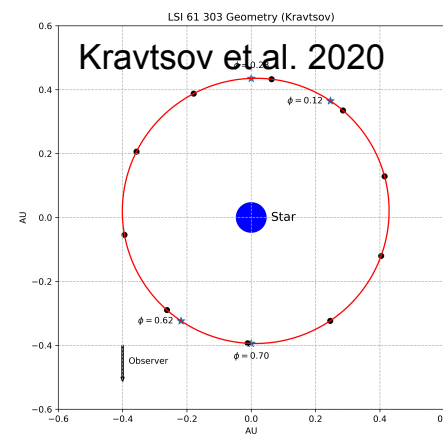
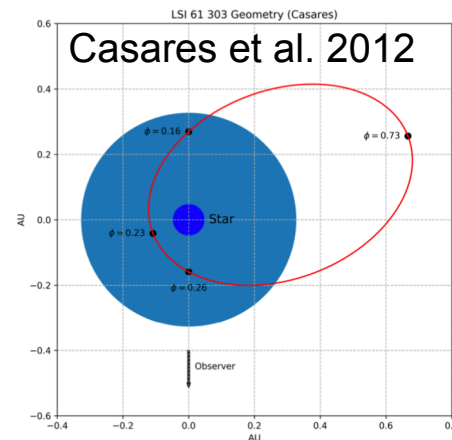


- Be star with **unknown compact companion**
- Orbital period: 26.5 days
- Super-orbital period: 4.6 years (radio, X-ray, GeV, TeV(?))
- Located at ~2 kpc distance

Neutron star

- Non-thermal emission powered by interaction between stellar and pulsar wind
- Detection of pulsation (270 ms period) by FAST (ATel #14297)

Orbital solutions:

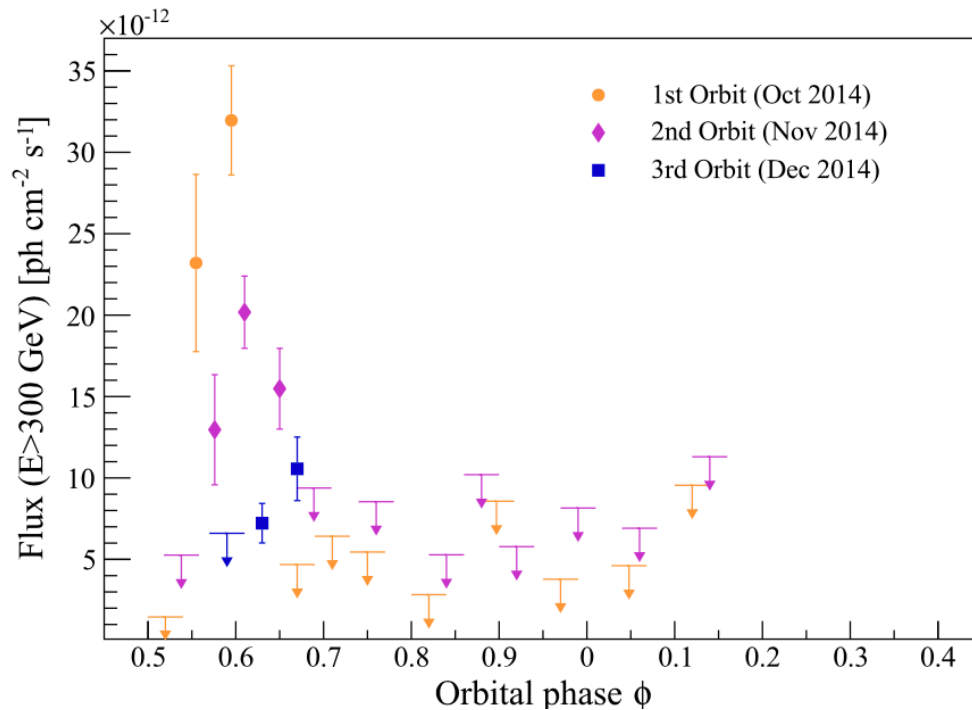


Black hole

- Non-thermal emission powered by accretion and jet-ejection
- Massi, M. et. al 2020, Sharma, R. et al. 2021

Introduction

Motivation



- TeV and X-ray correlation using:
 - Simultaneous data within 0.5 hr of VERITAS good weather observations
 - Simultaneous data within 24 hr

Nightly variability observed by VERITAS
([Archambault, S. et al. 2016](#))

Long-term (rich) dataset

VERITAS and Swift-XRT



Swift-XRT1:

Energy range: 0.3-10 keV

Energy resolution: ~190 eV at 10 keV to
~50 eV at 0.1 keV

Sensitivity: 8×10^{-14} erg cm⁻² s⁻¹ in 10⁴ seconds

Angular resolution: 18 arcsec @ 1.5 keV

VERITAS:

Energy range: 100 GeV to >30 TeV

Energy resolution: 15-25%

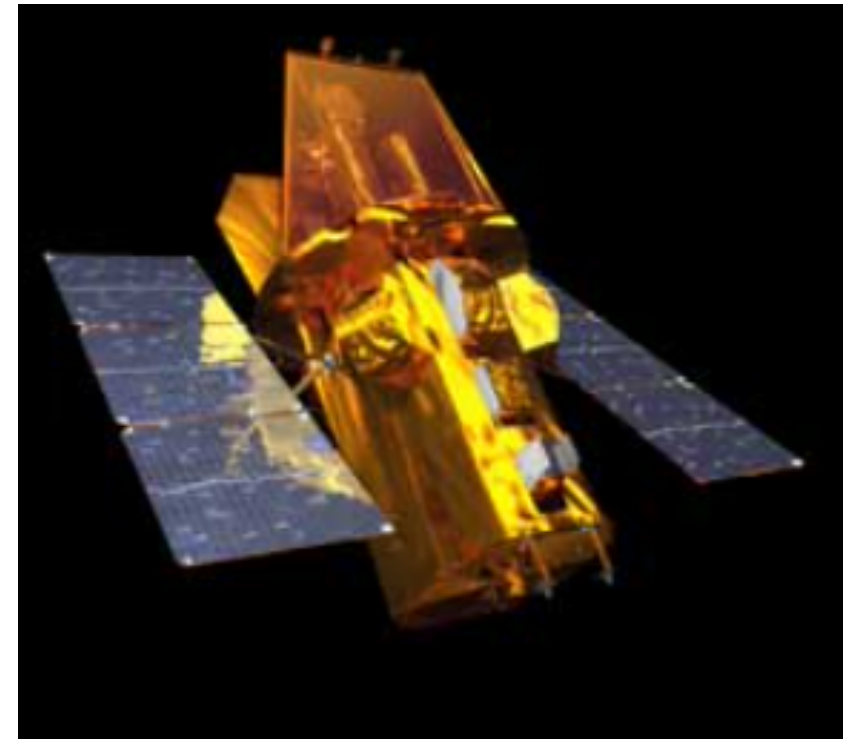
Sensitivity: 1% Crab in ~25h

Angular resolution: $R_{68\%} < 0.1^\circ$ @ 1 TeV

Pointing accuracy: Error < 50 arcsec

Each Telescope has 345 facets

Highlights talk by
Stephan O'BRIEN
(26.10.2021)



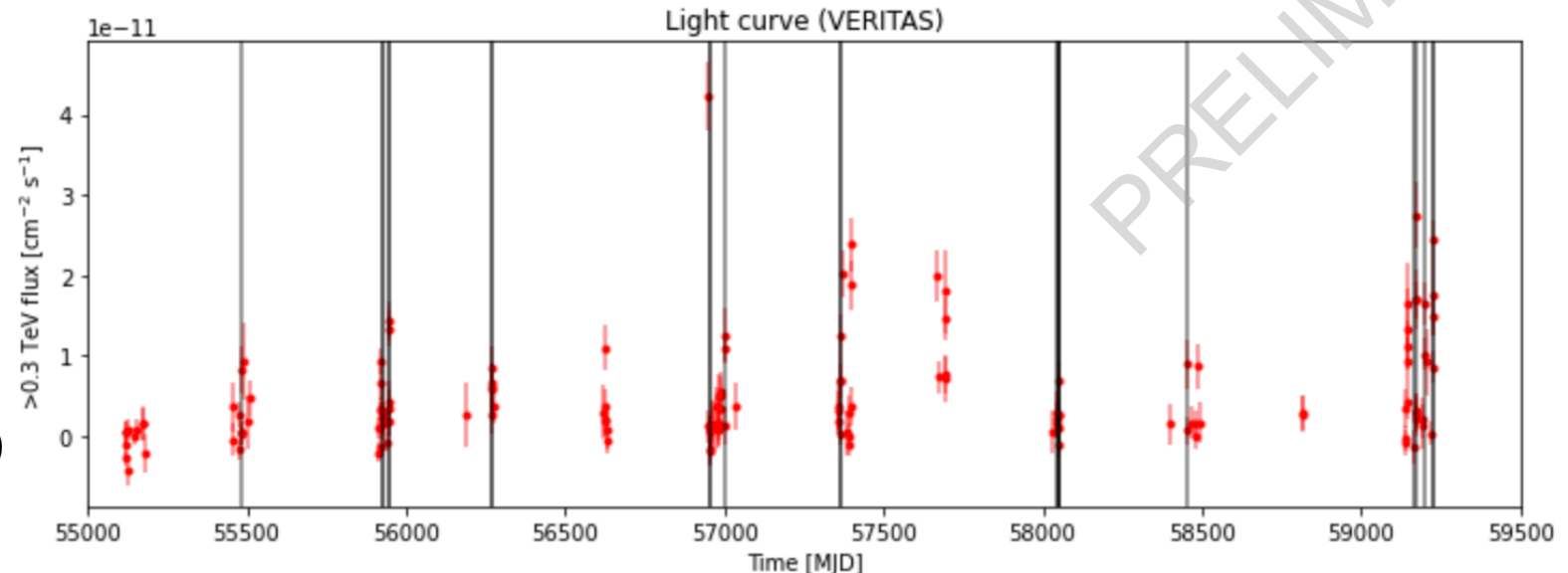
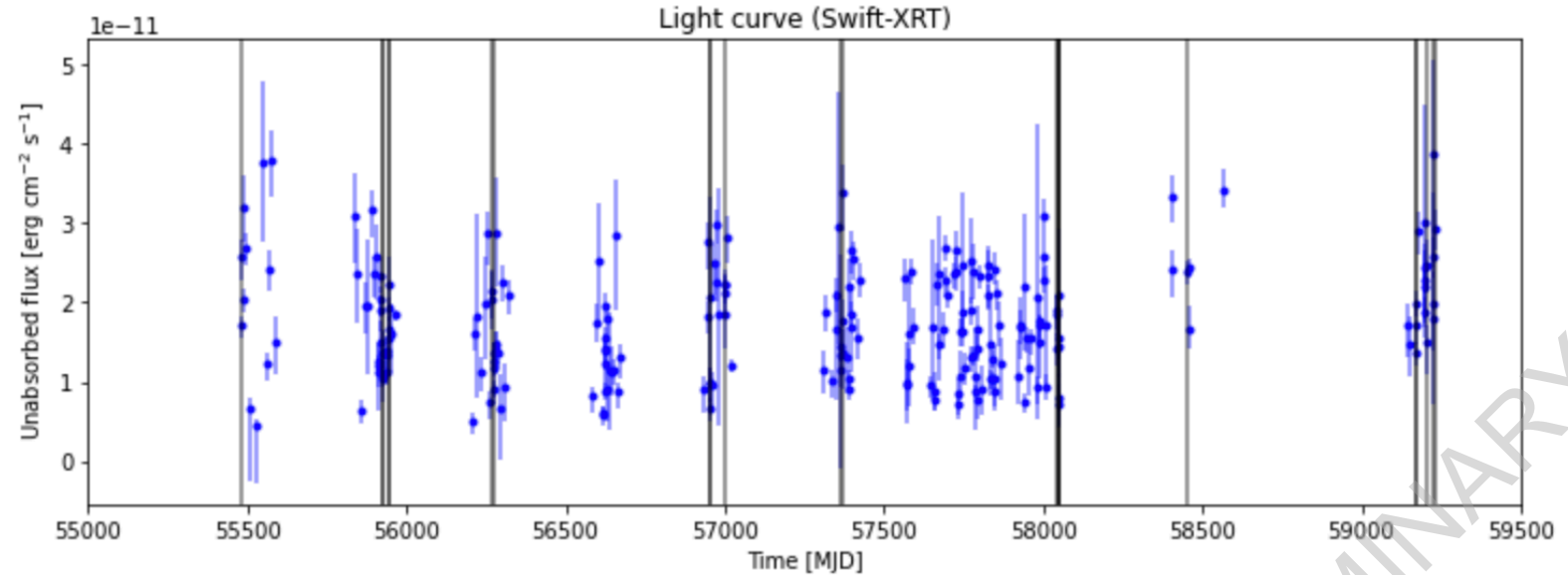


Long-term Light curve

VERITAS and Swift-XRT

This work (black vertical lines):
Observations having time
difference of **0.5 hr**

- Includes flux states up to ~15%
Crab

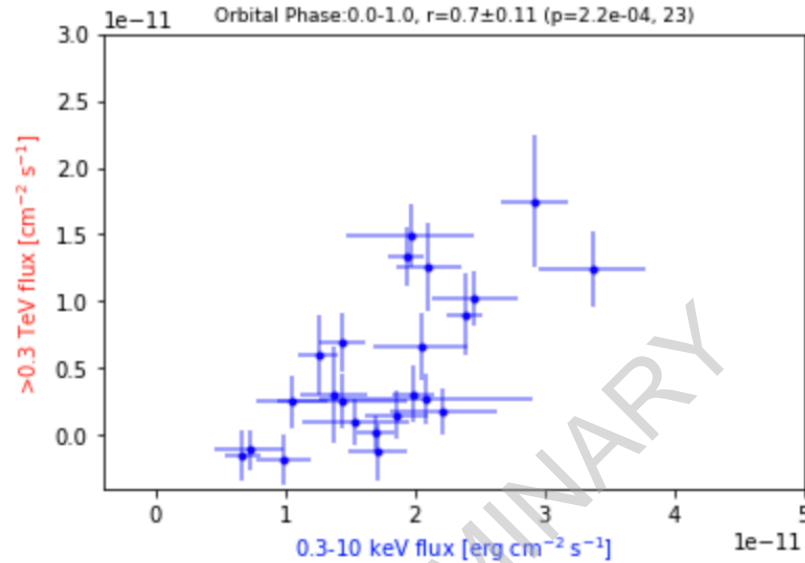
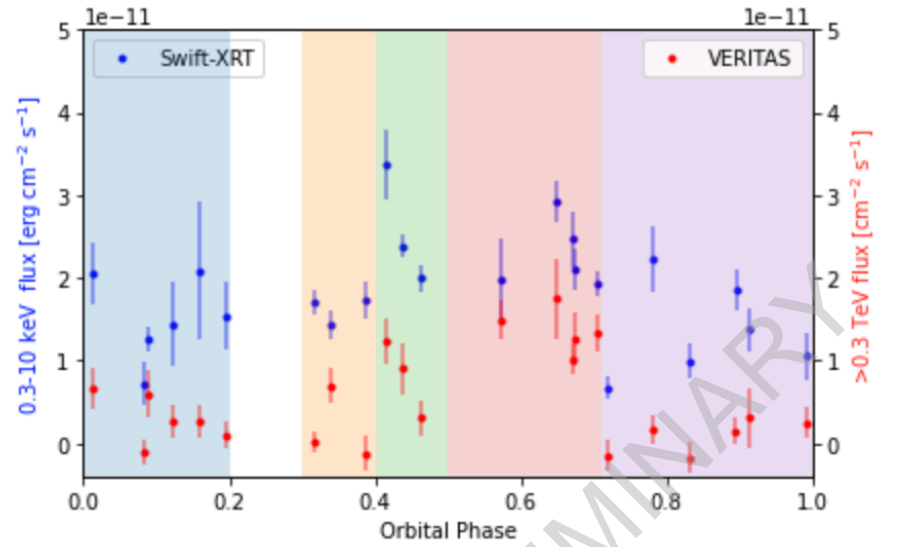


[arXiv:2108.09235](https://arxiv.org/abs/2108.09235) (ICRC 2021)

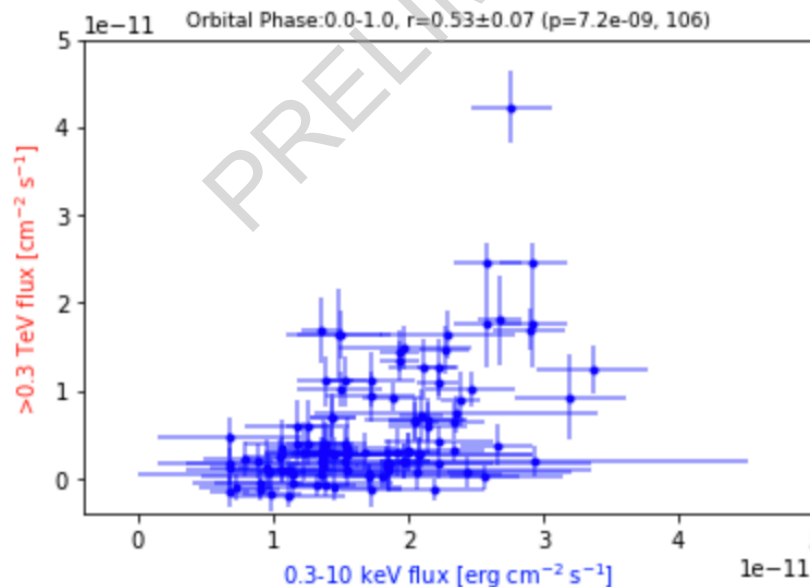
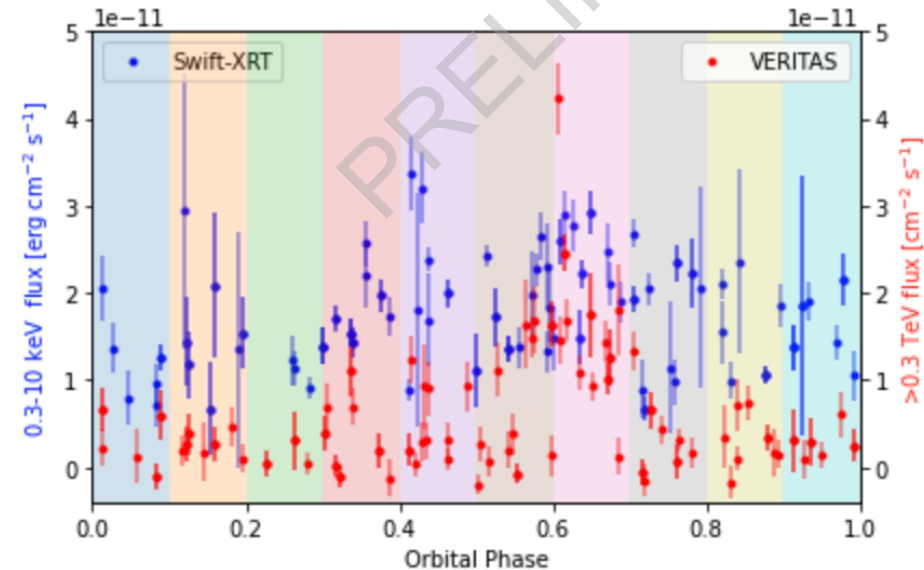


Phase-folded light curve and correlations

Simultaneous data



Simultaneous within 0.5 hr



Simultaneous within 24 hr

Correlation

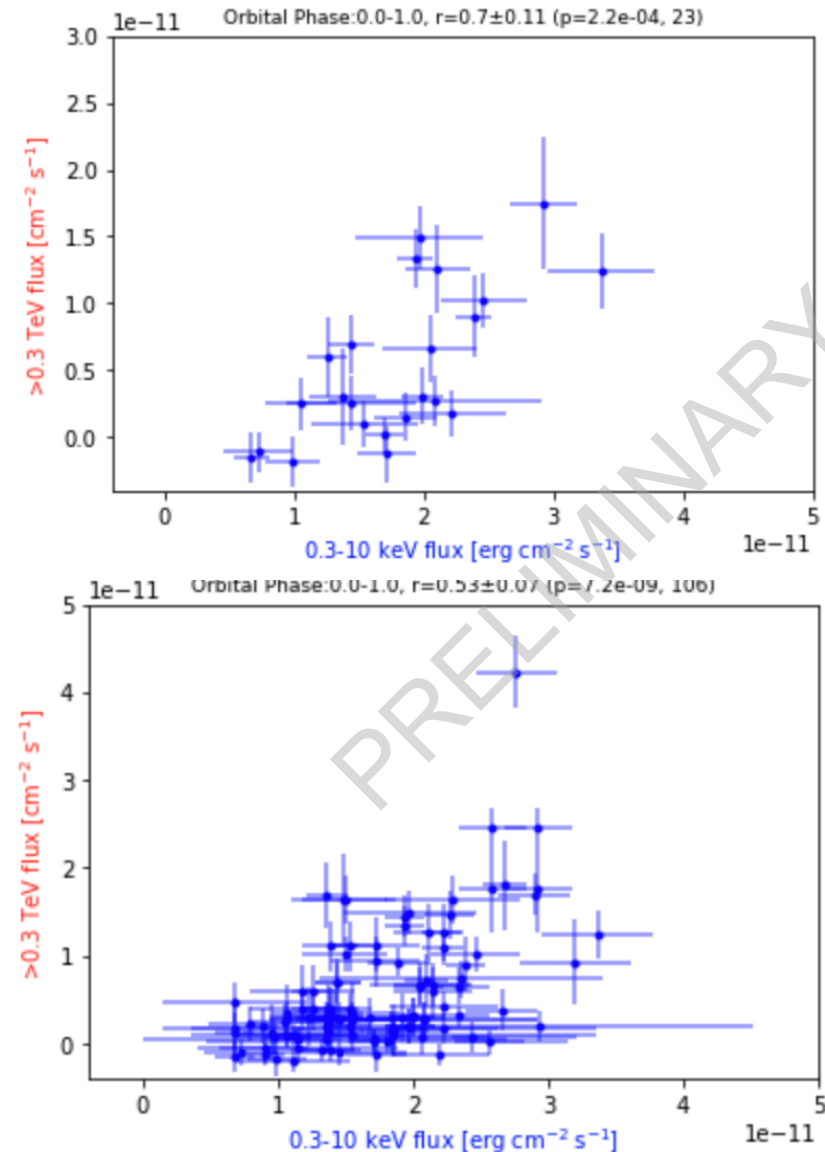
TeV and X-ray

On timescale of 0.5 hr:

- Correlation coefficient = 0.69 ± 0.11
- Could be originating from same population of particles!
- **Pulsar scenario:** X-ray to TeV emission powered by IC scattering off stellar UV photons (Zdziarski et al. (2008))
- **Microquasar scenario:** Synchrotron dominates X-ray, while IC (SSC+EC) dominates above 1 MeV (Gupta & Böettcher (2006))

On timescale of 24 hr:

- Correlation coefficient = 0.53 ± 0.07
- Weaker
- Short correlation timescale?
- Intrinsic to the source or poor data sampling?
- Higher than linear order correlation?

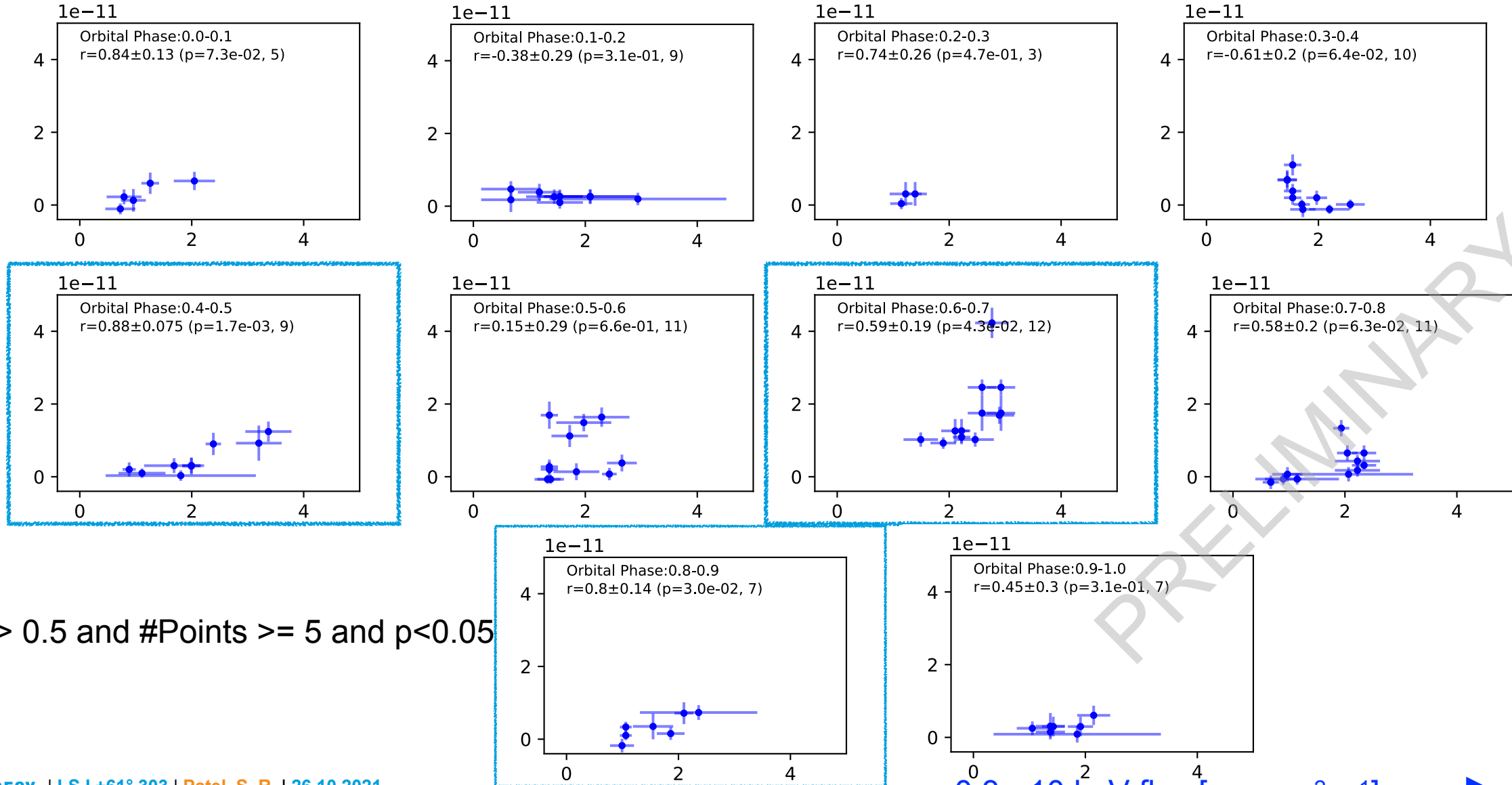


Correlation: Orbital phase-wise

TeV and X-ray (simultaneous within 24 hr)



>0.3 TeV flux [$\text{cm}^{-2} \text{s}^{-1}$]



$r > 0.5$ and #Points ≥ 5 and $p < 0.05$

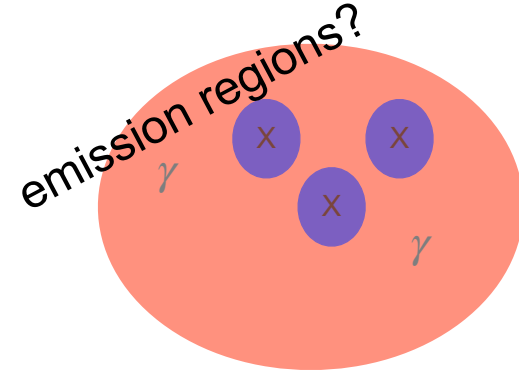


Summary

Results and future outlook

Results:

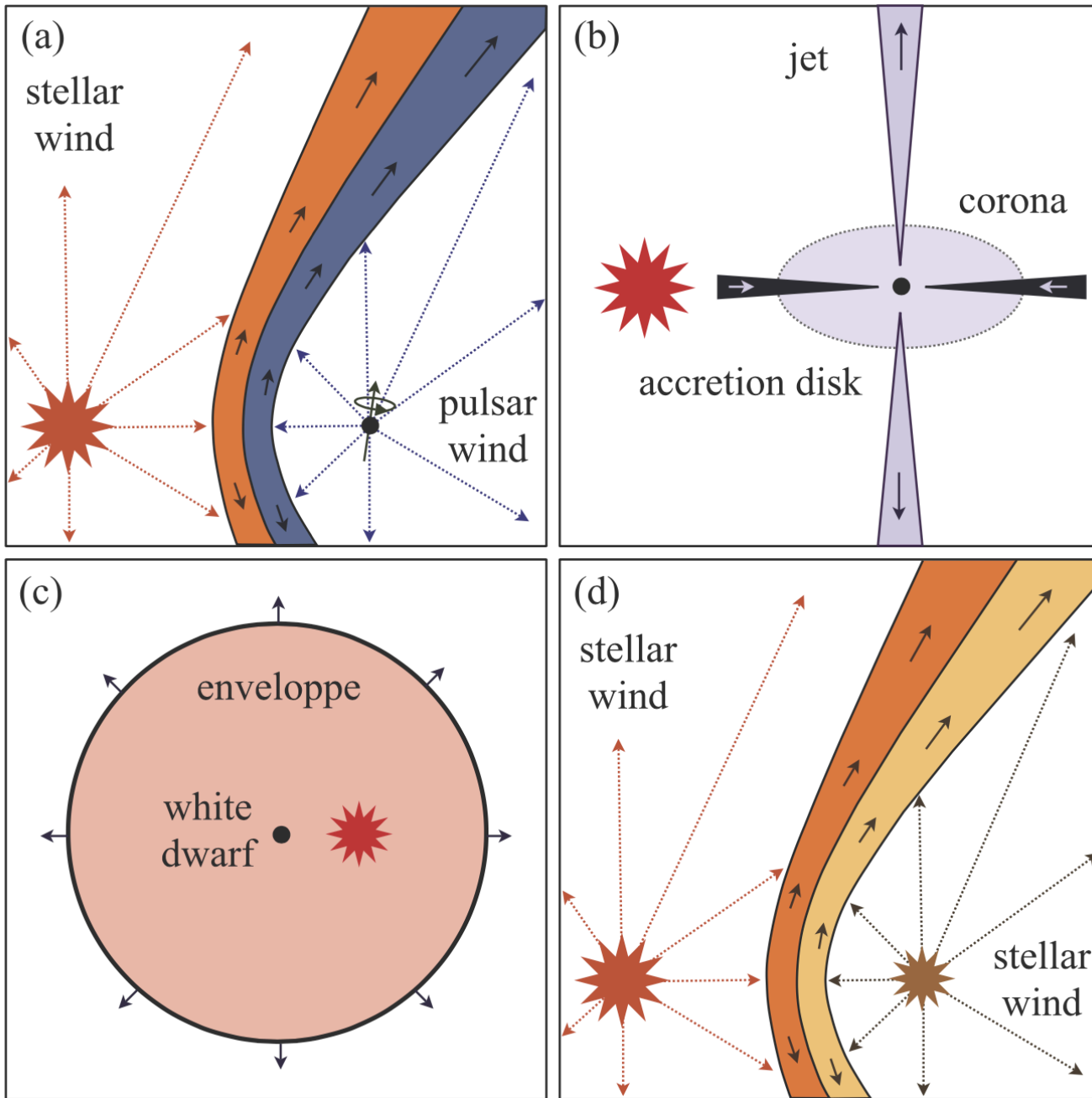
- X-ray and TeV emissions appear to be correlated for data simultaneous within 0.5 hr
 - X-ray variability: timescale of ~ 1000 sec (Chernyakova et al. (2017), Nösel et al. (2018))
 - TeV variability: Order of one day or less



Outlook:

- MWL SEDs
 - To shed more light on single/different/overlapping emission regions scenario
 - Pulsar or micro-quasar

Thank you!



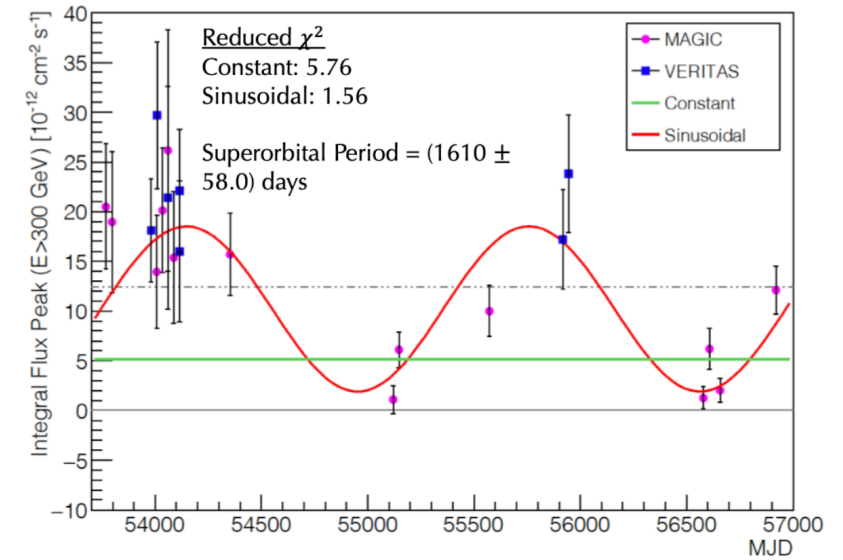
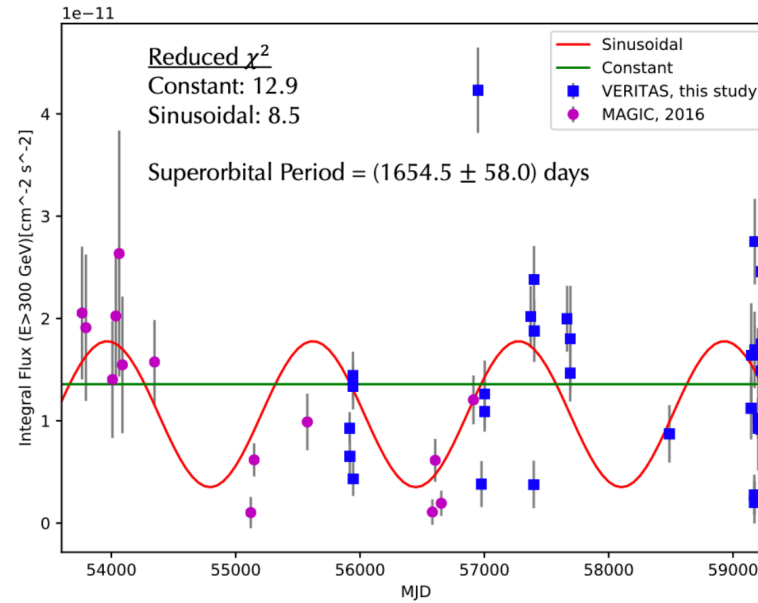
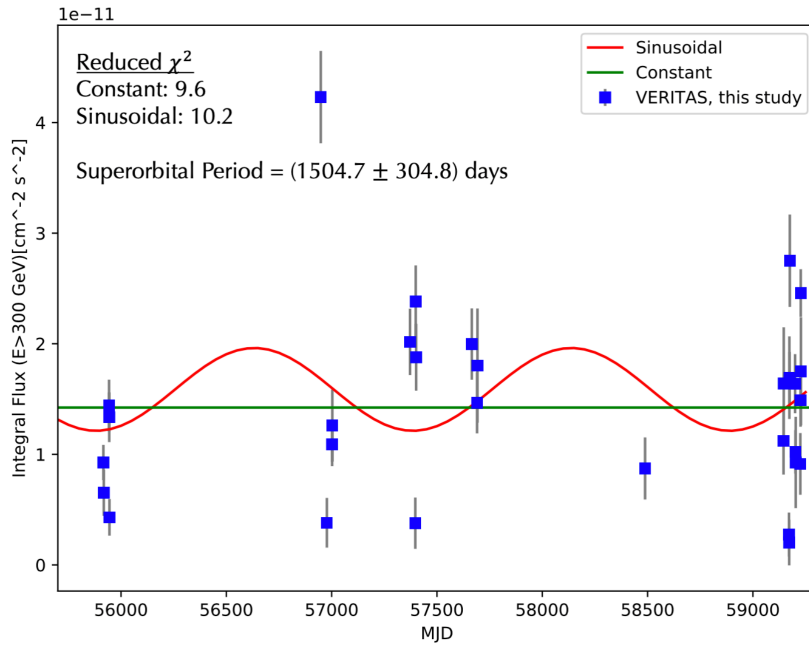
Dubus 2015

Back up

Super-orbital period (TeV)



Orbital period: 0.5-0.75



M. L. Ahnen et al.: Multi-year study of LS I +61° 303