



MAGIC view on binary systems

Alicia López Oramas
(Instituto de Astrofísica de Canarias)
for the **MAGIC Collaboration**



Antonio González



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E INNOVACIÓN



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NextGenerationEU



Plan de Recuperación,
Transformación
y Resiliencia



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“NextGenerationEU”/PRTR

VHE binary emitters

the role of **MAGIC**

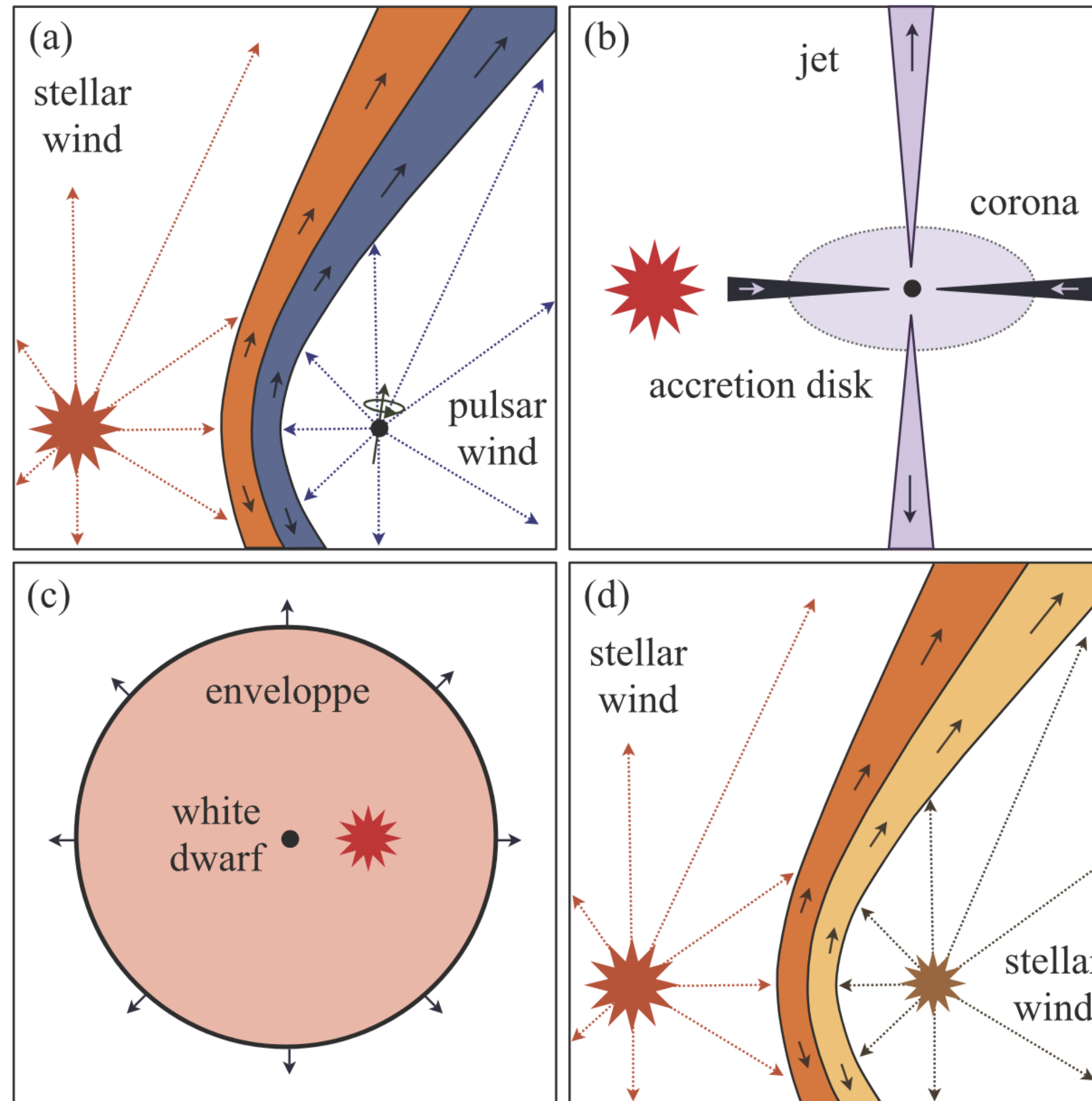
Non-accreting
pulsars



Microquasars



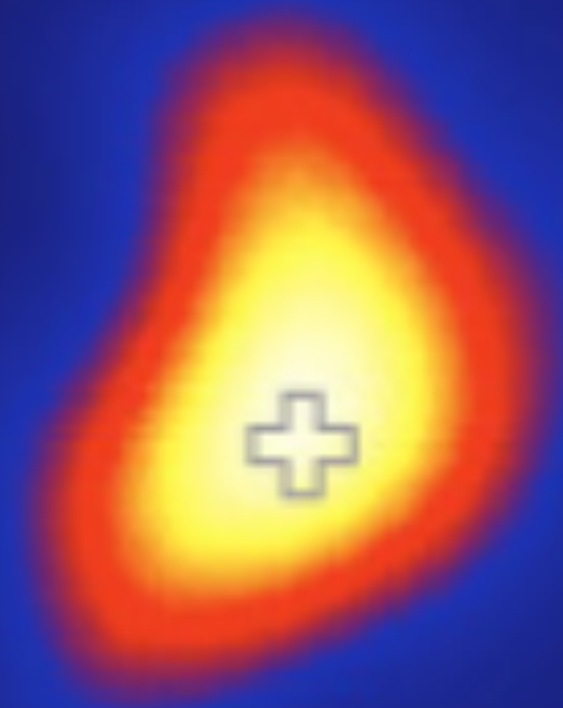
Novae



Dubus 2015

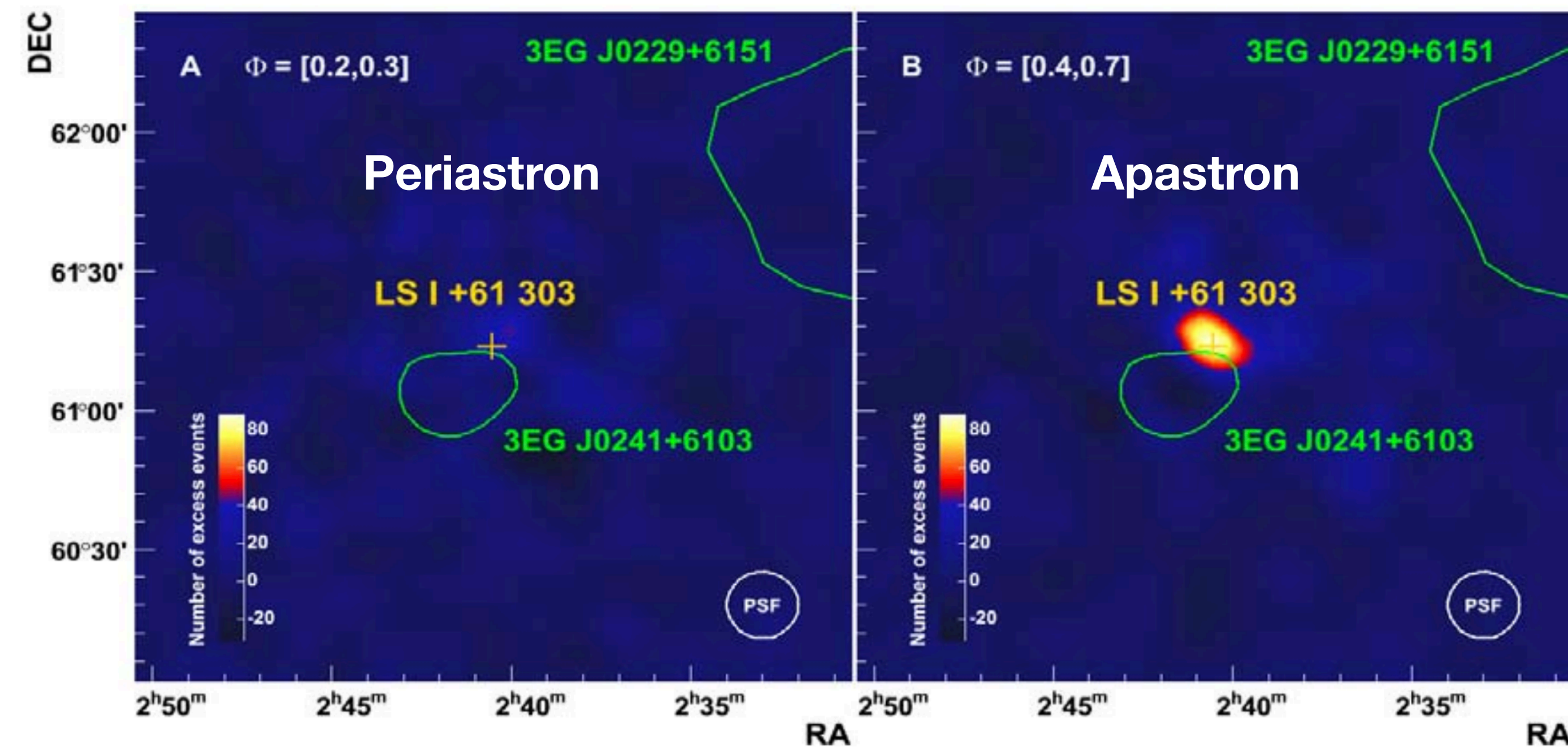
Colliding wind binary





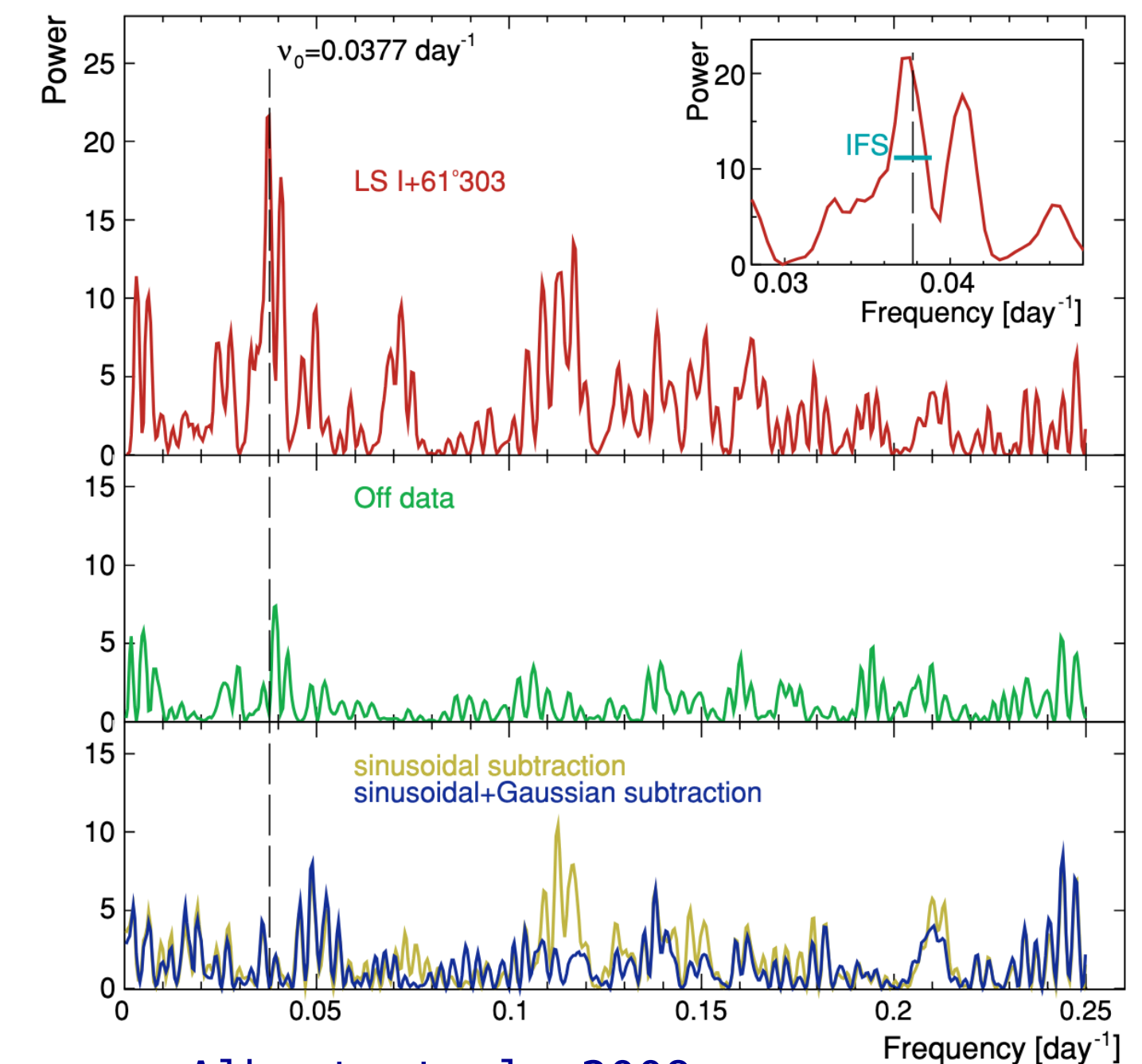
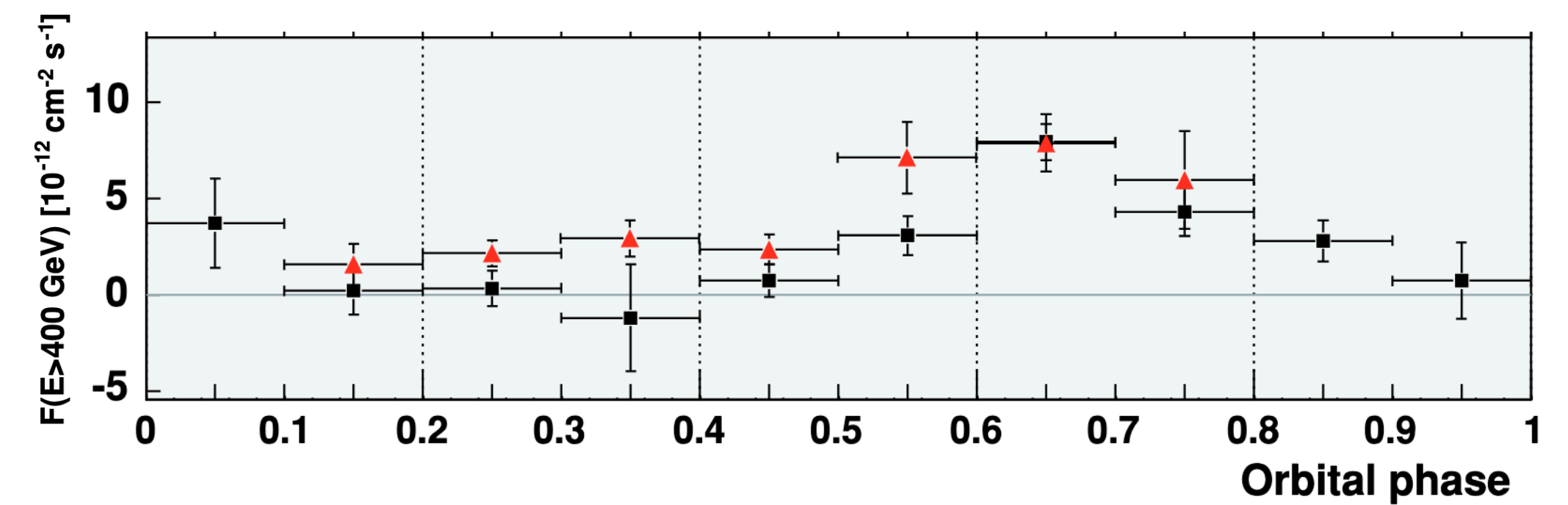
Gamma-ray binaries legacy

Gamma-ray binary legacy: LSI +61 303



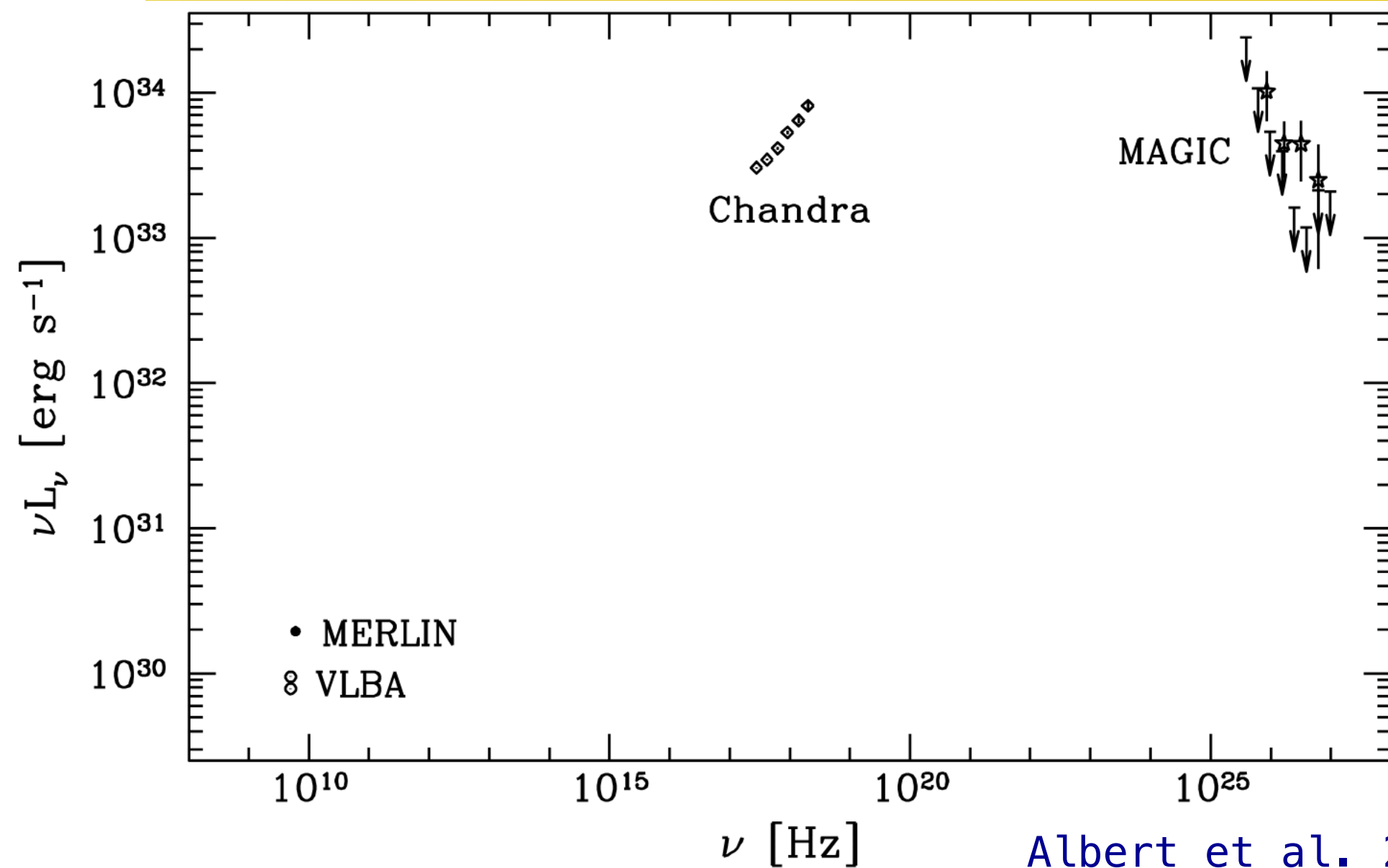
Albert et al. 2006

- **VHE discovery** by MAGIC (Albert et al. 2006)
- Discovery of **periodicity at VHE: 26.8 ± 0.2 days** (Albert et al. 2009)
- **First time LC covering all orbital phases** (Albert et al. 2009)

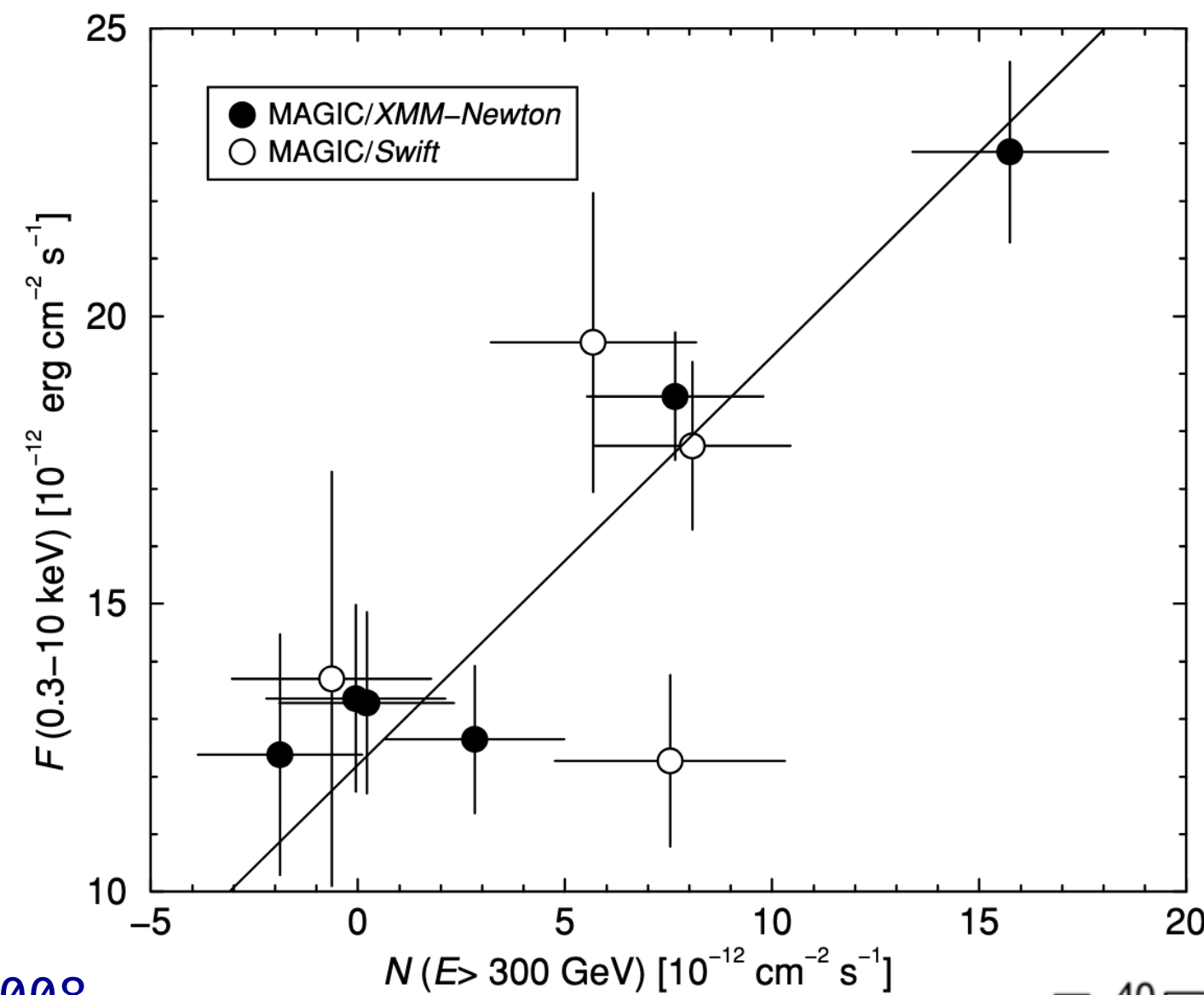


Albert et al. 2009

Gamma-ray binary legacy: LSI +61 303

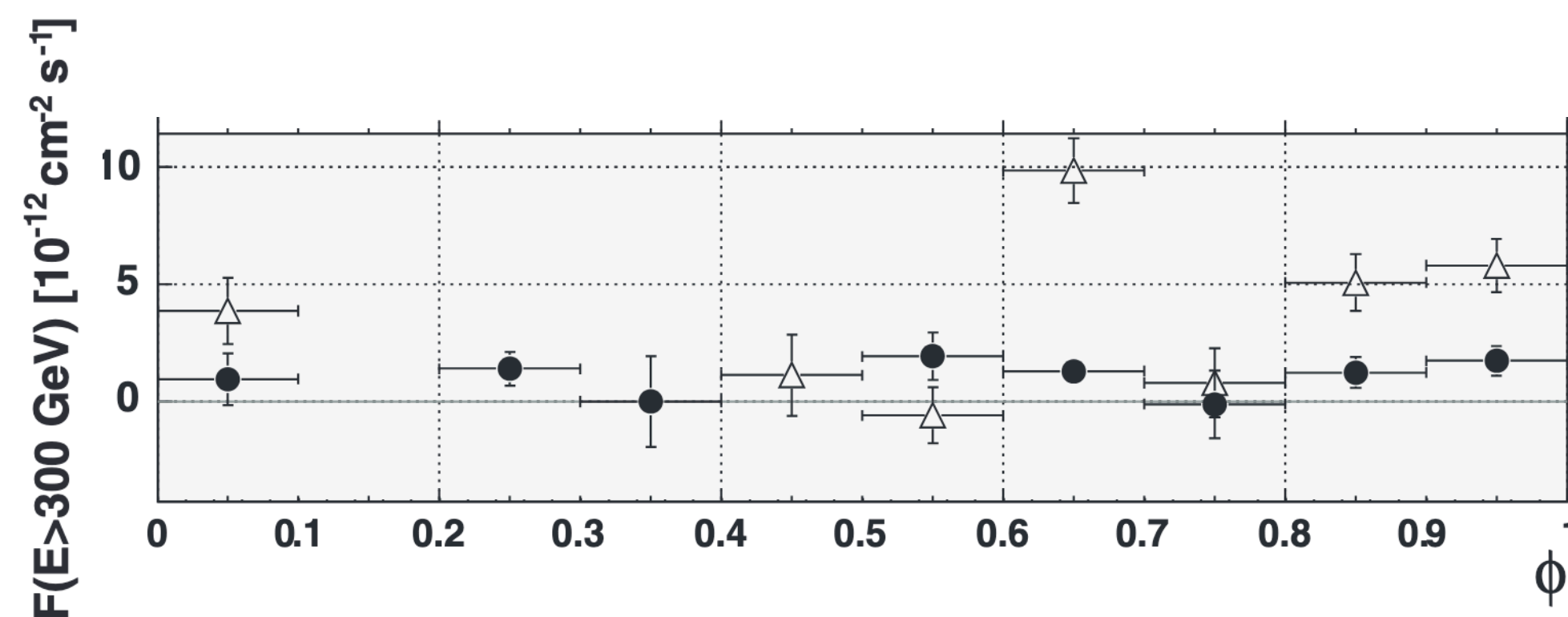


Albert et al. 2008

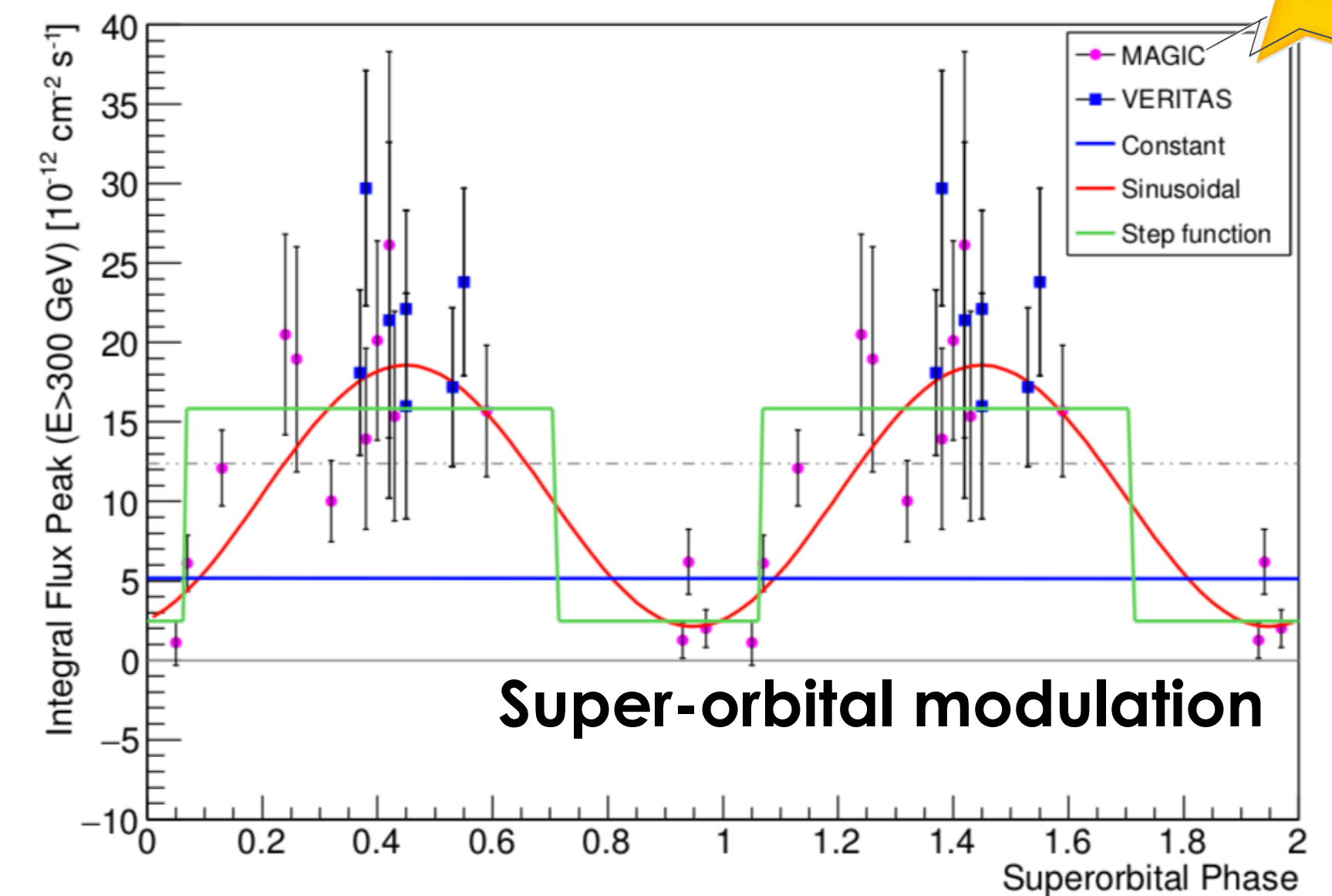


- First **MWL campaigns**

- No radio-TeV correlation in phases 0.4-0.5 (Albert et al. 2008)
- **X-ray - VHE correlation** (Anderhub et al. 2009)



Aleksic et al. 2012

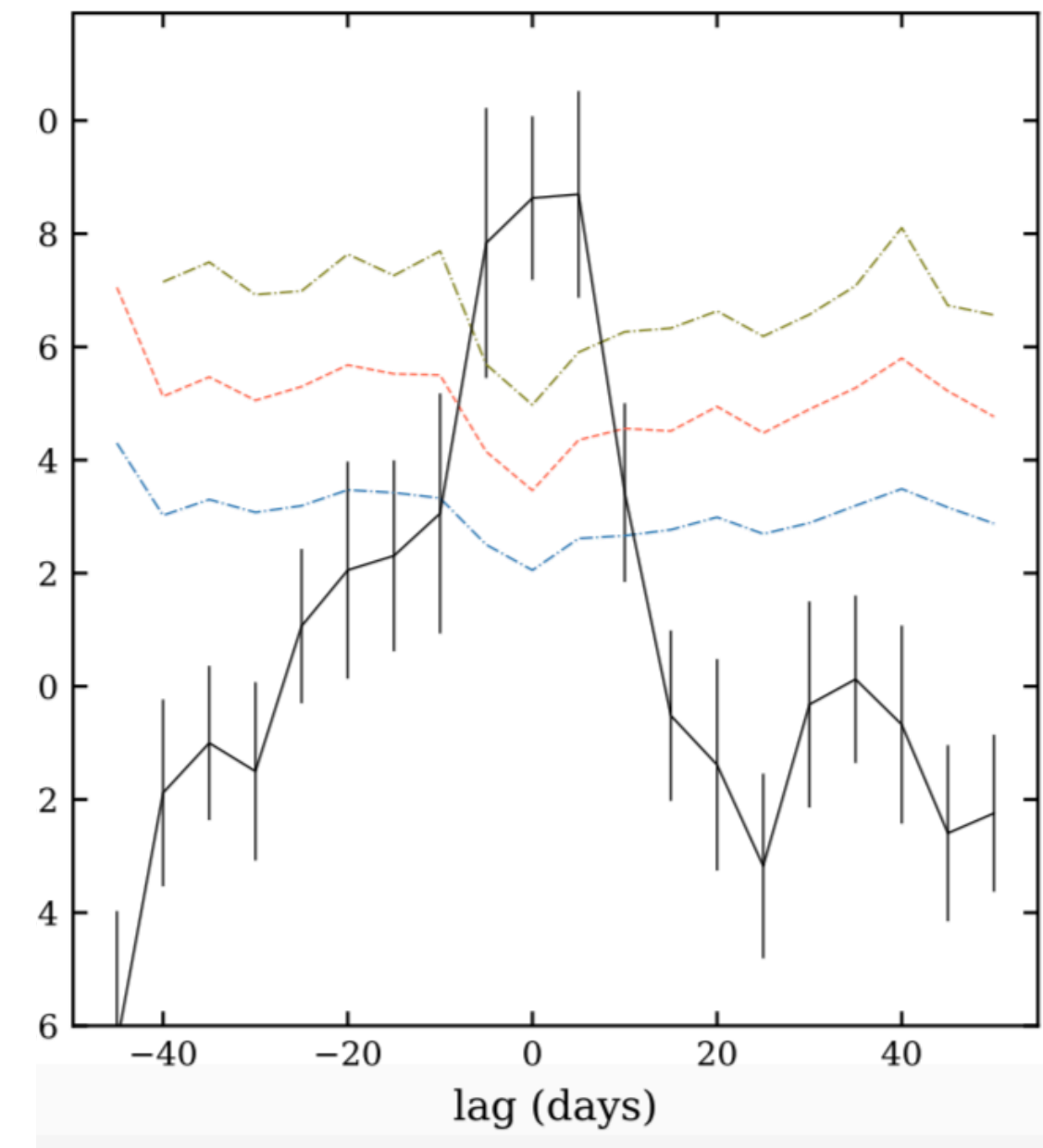
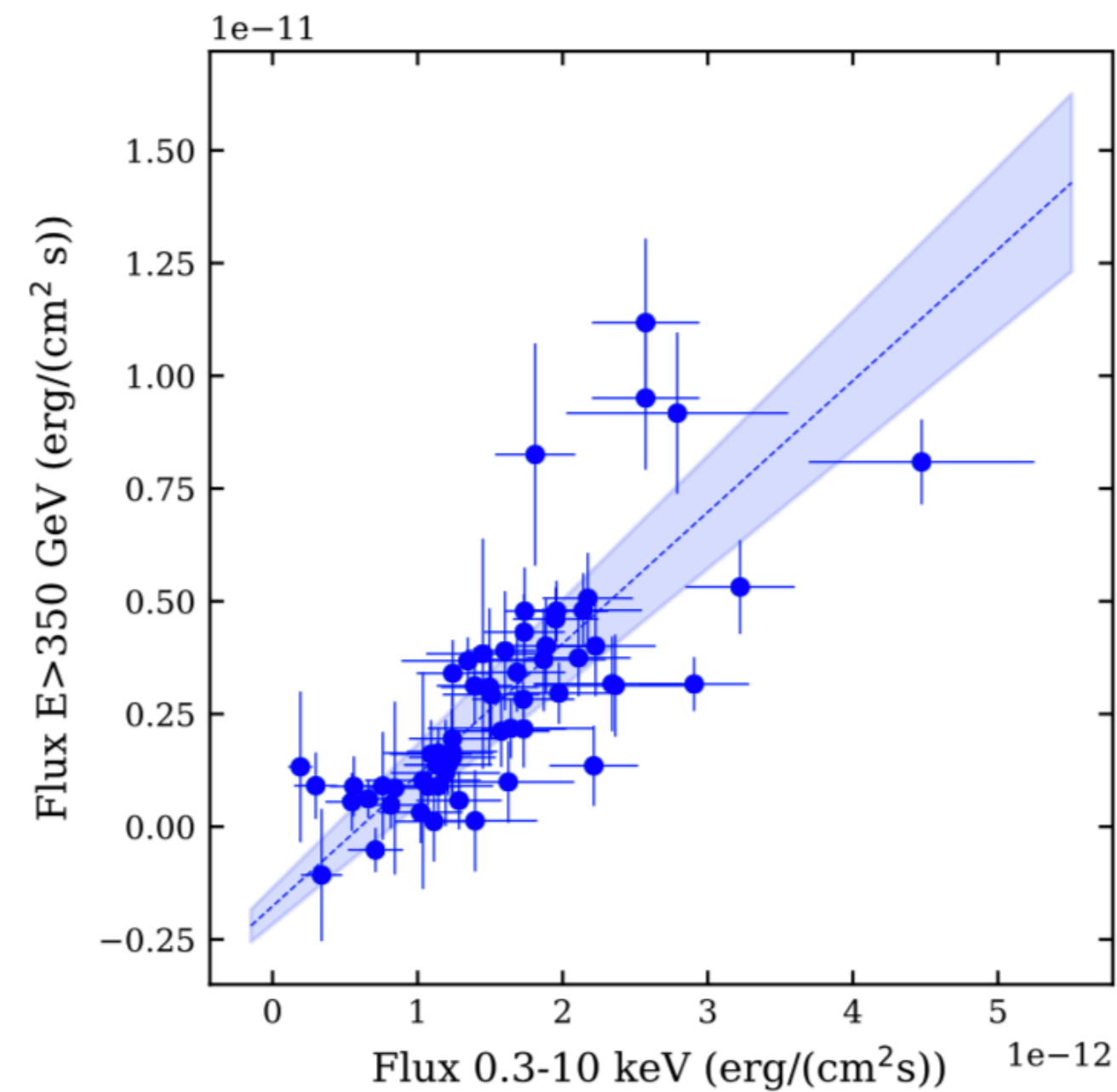
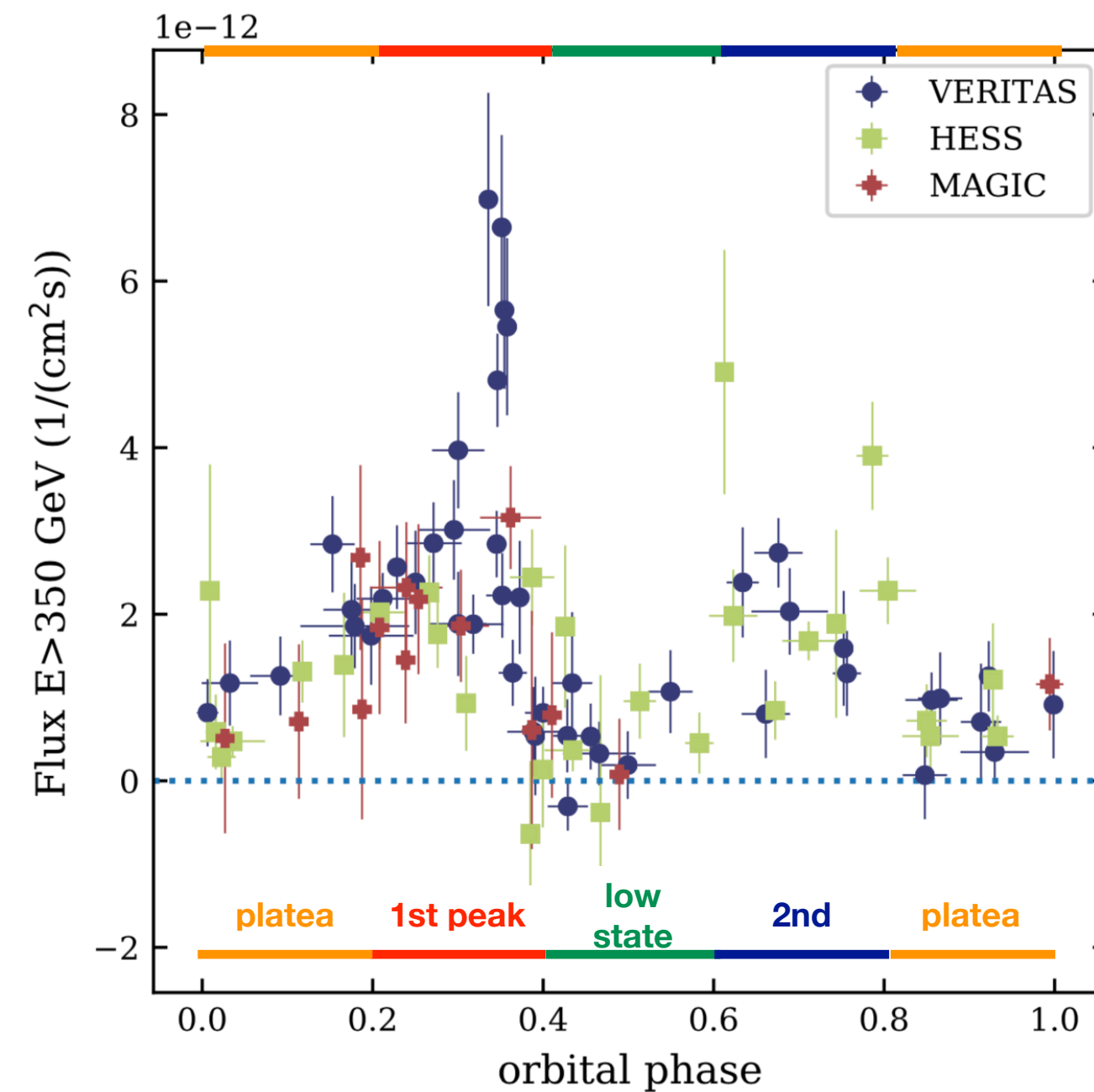


Super-orbital modulation

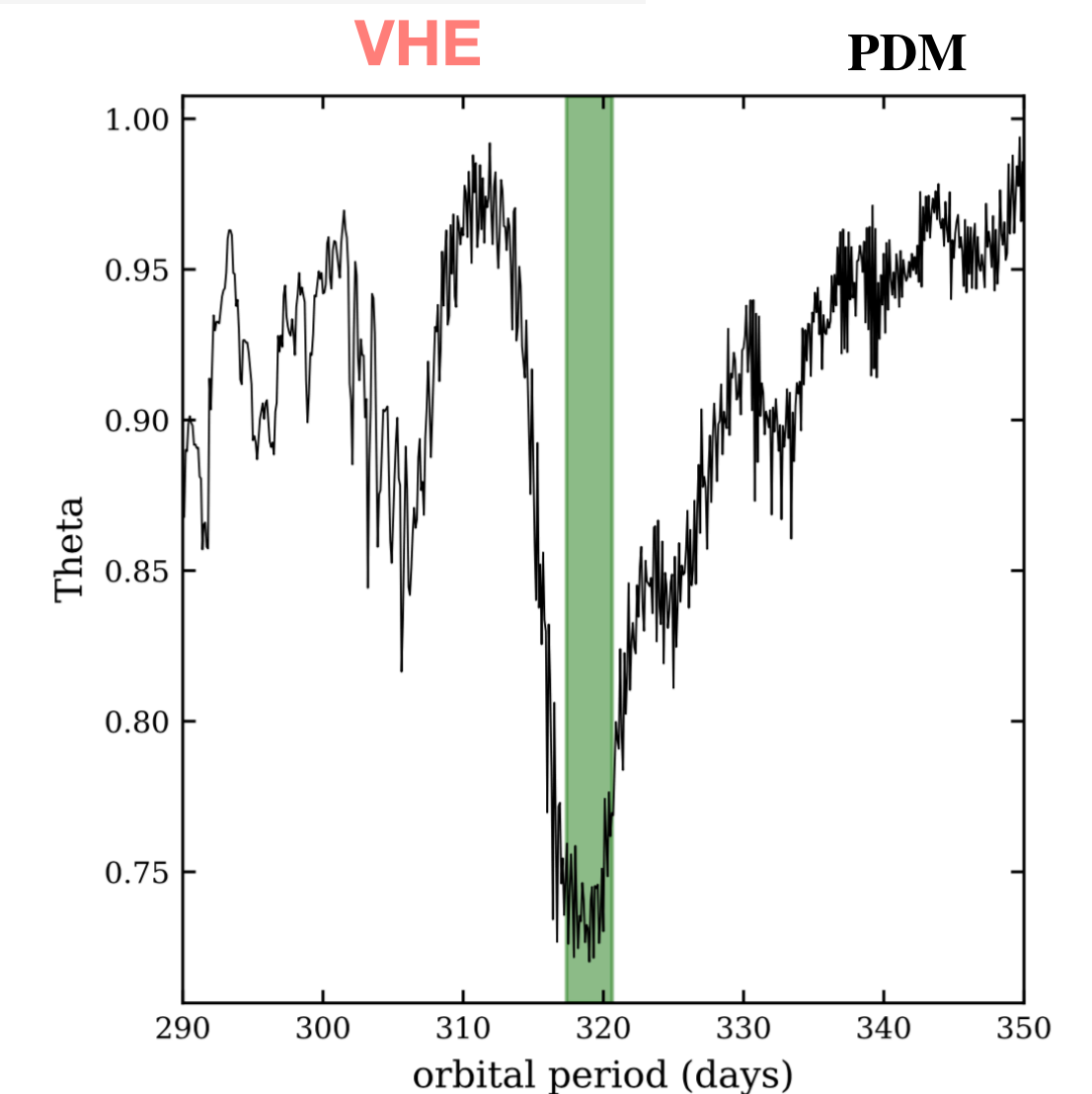
- Low flux state identified (Aleksic et al. 2012)
- Discovery of **TeV super-orbital modulation: 1610 ± 58 days.** (Ahnen et al. 2016)

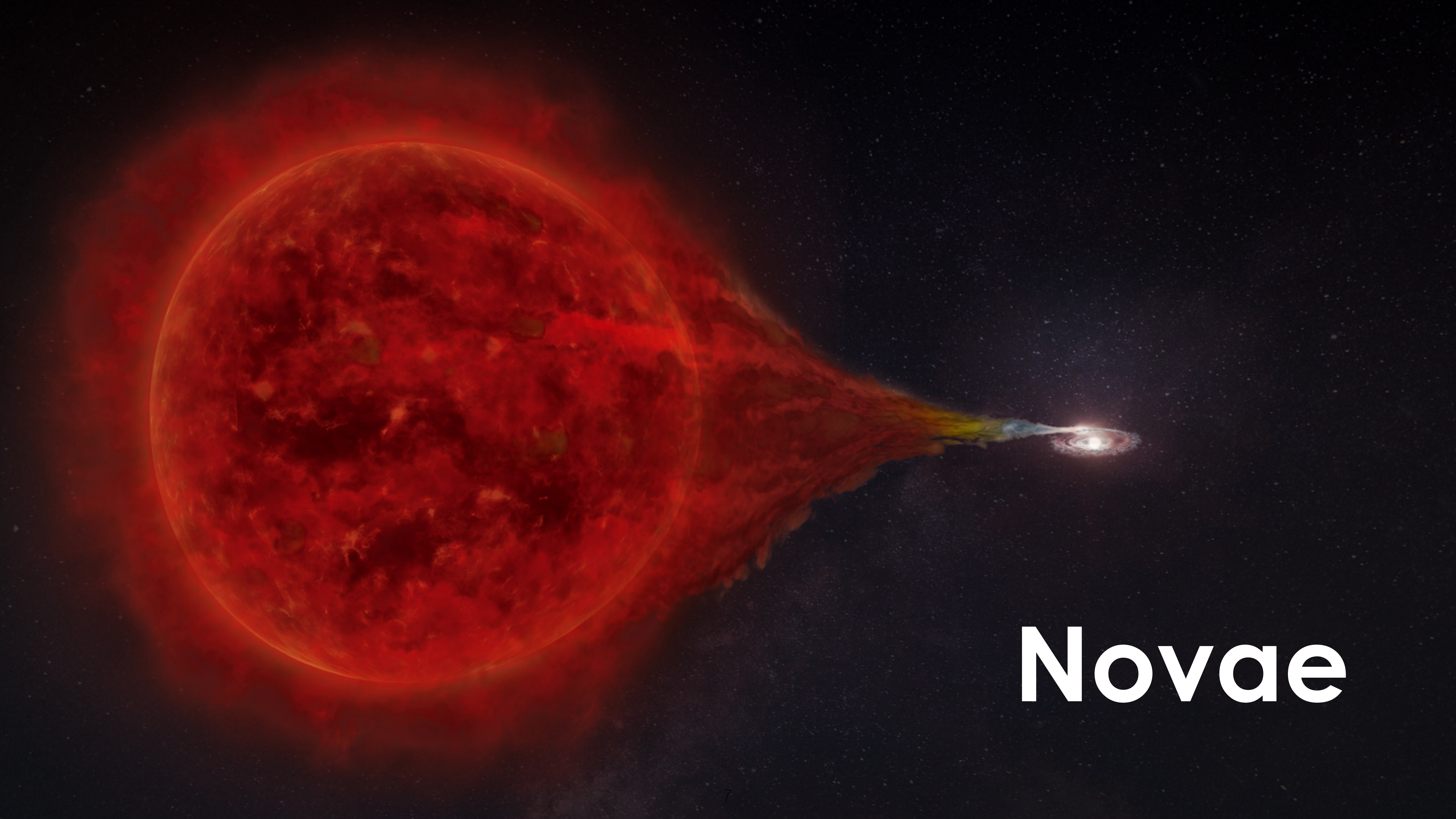


Gamma-ray binary legacy: HESS J0632+051



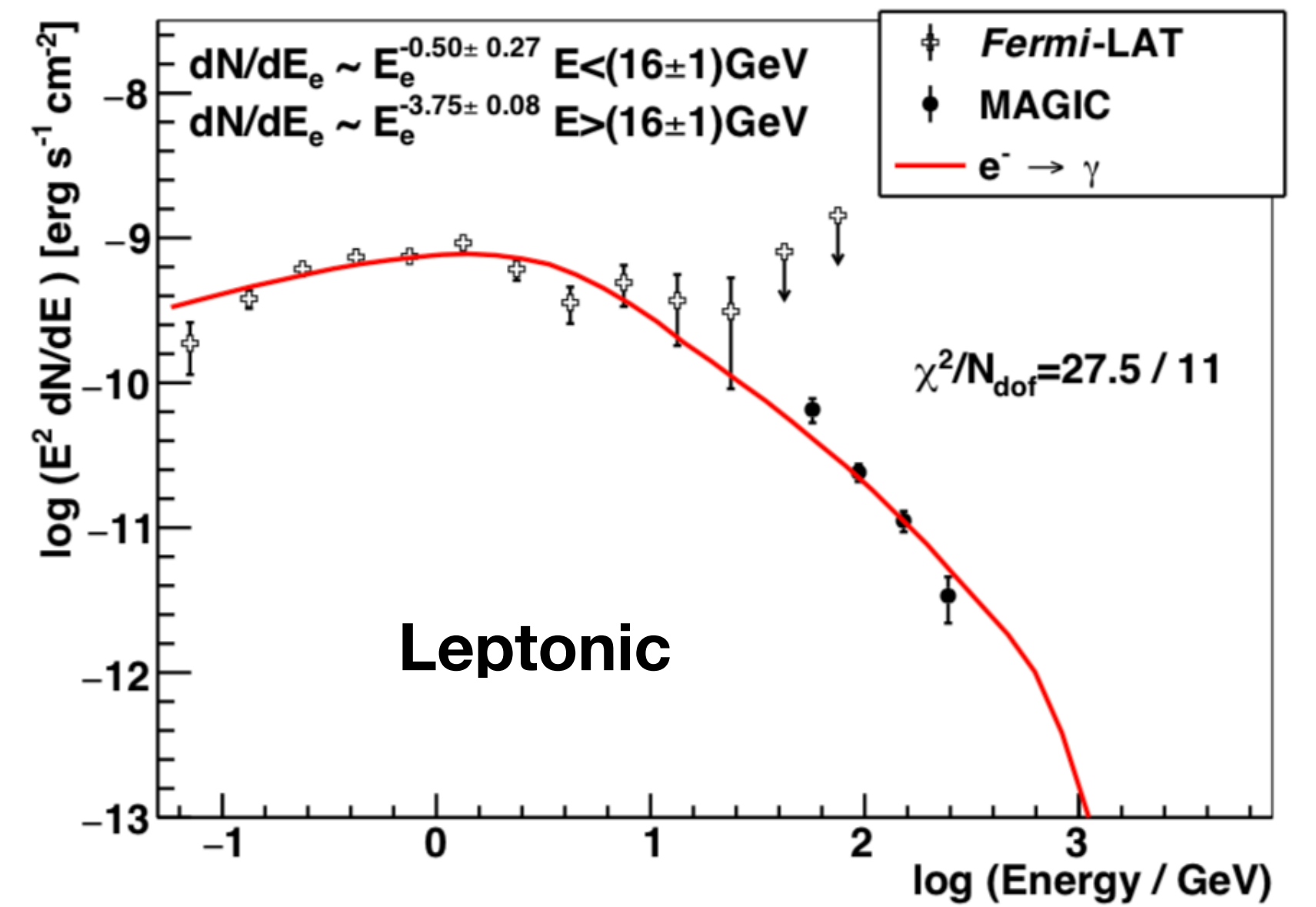
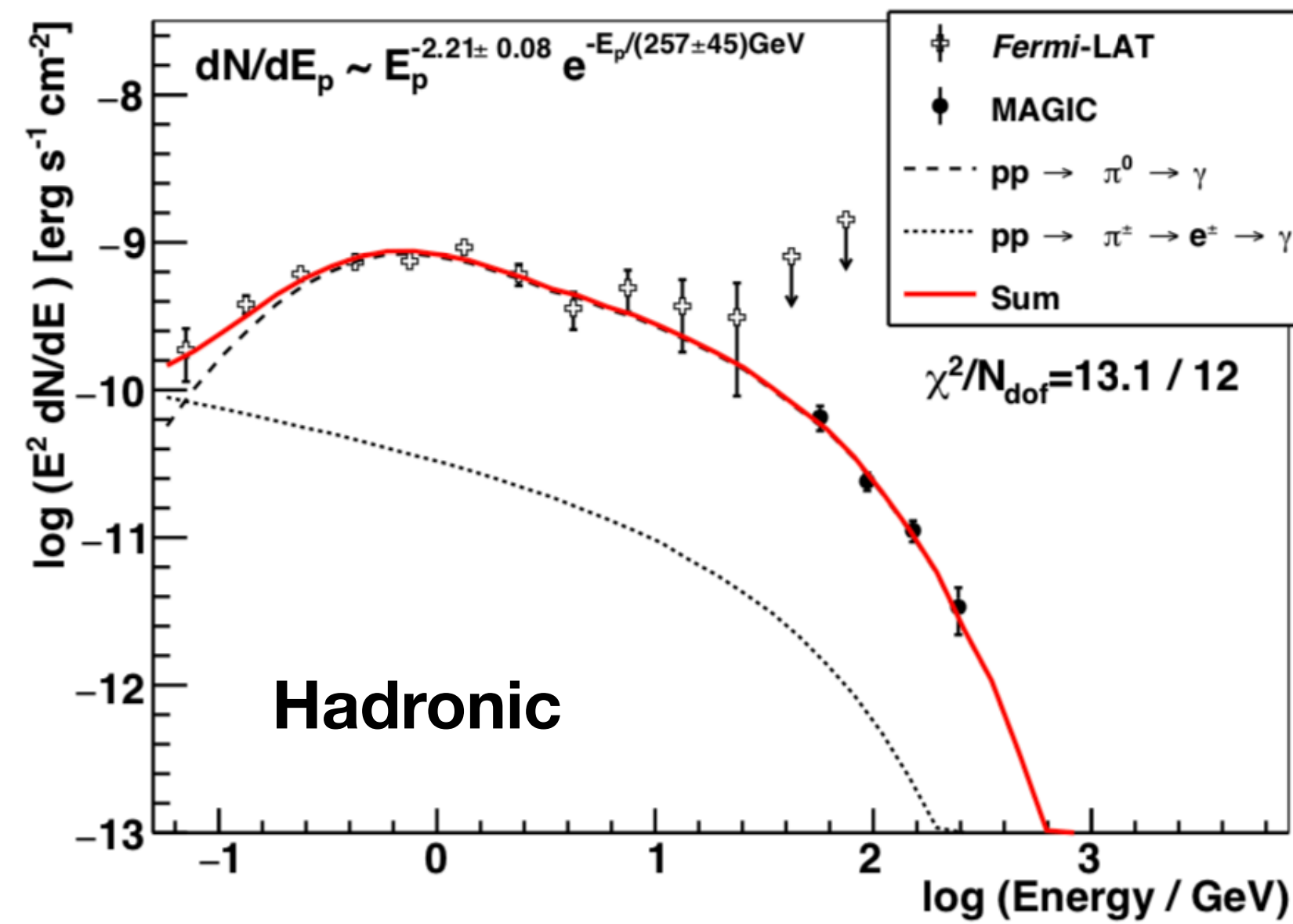
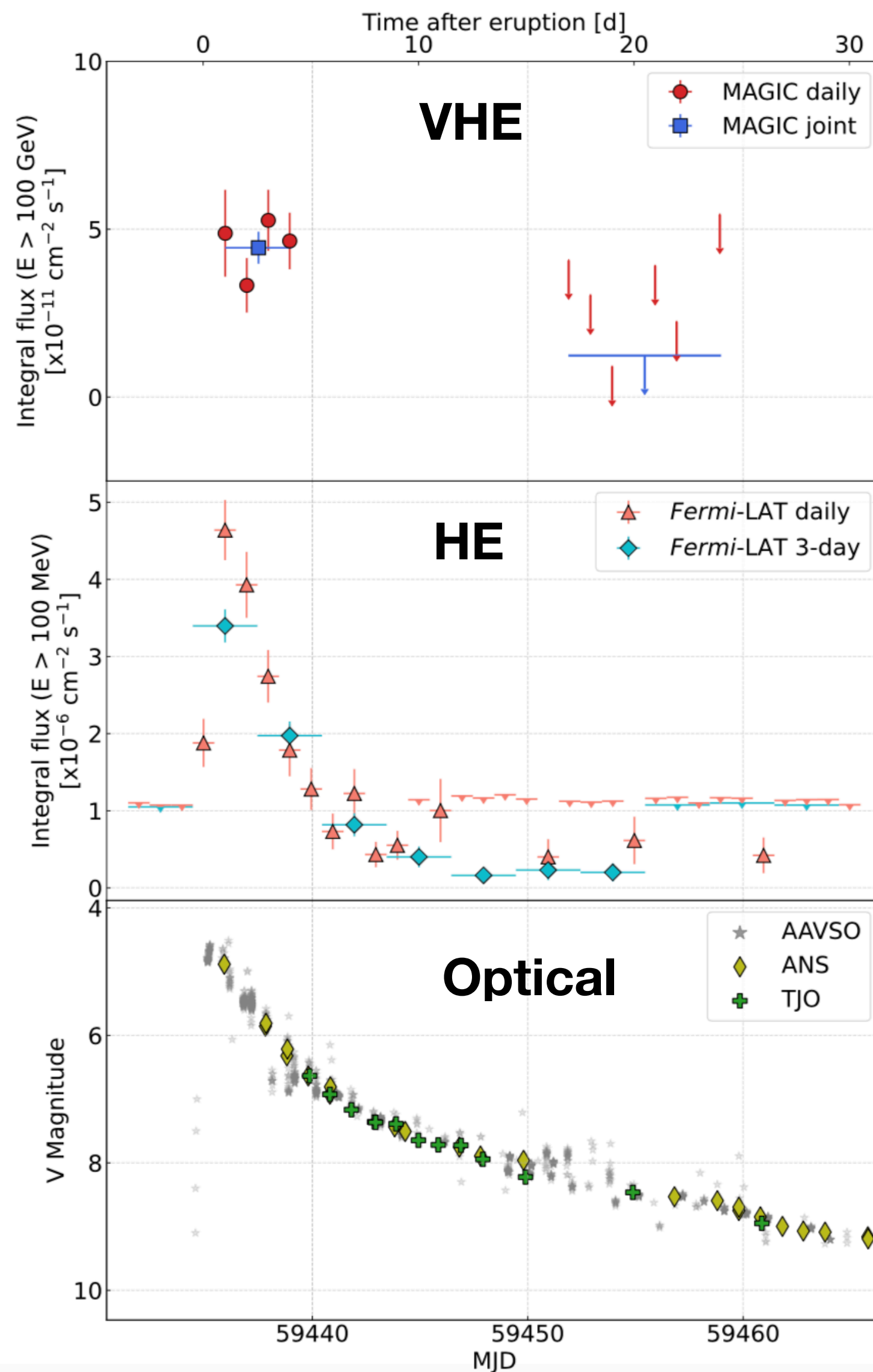
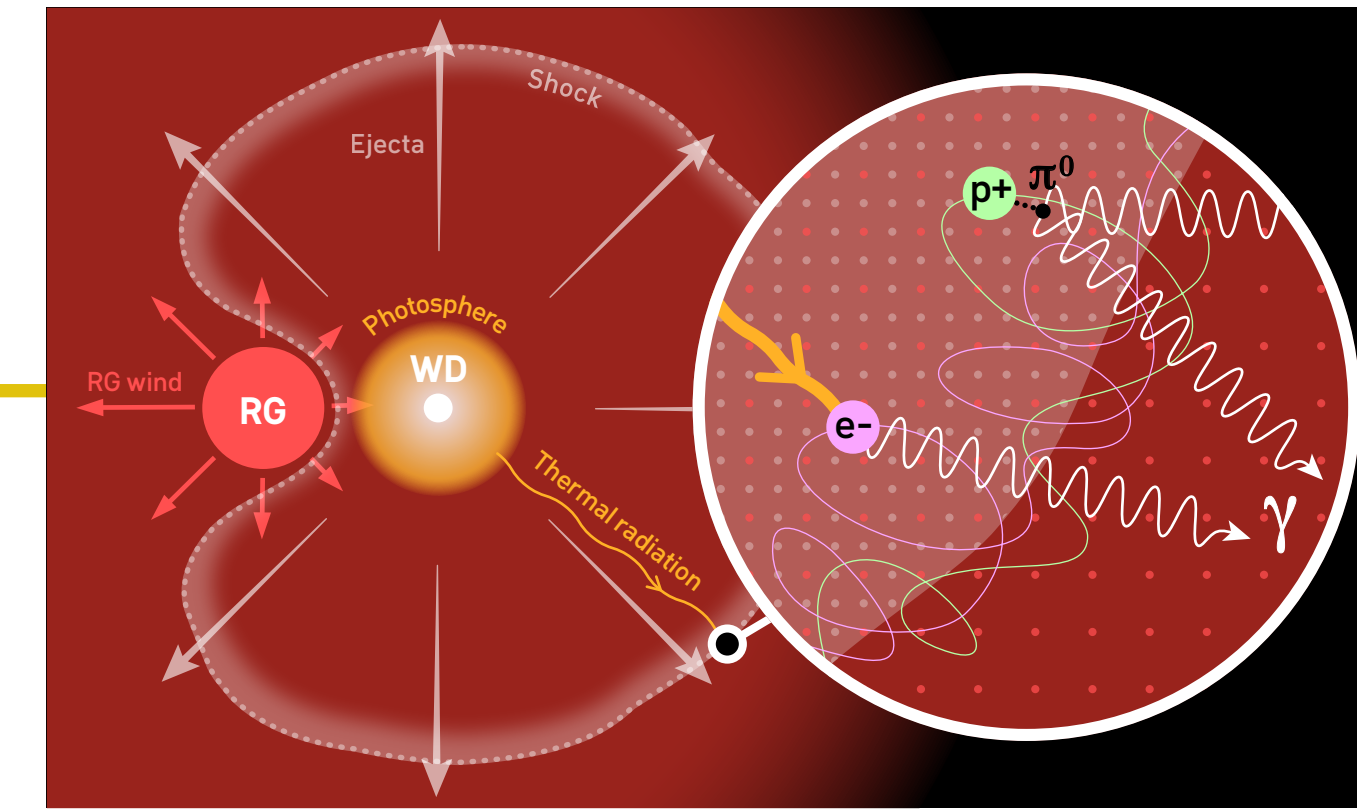
- TeV emission during X-ray outburst (Aleksic et al. 2012)
- **Multi-IACT campaign** (HESS, MAGIC, VERITAS coll. 2021)
- Existence of **orbit-to-orbit variability**
 - **No evidence for a super-orbital period**, as observed e.g., in LS I +61°303 (Ahnen et al. 2016)
- **Strong variability of the VHE flux on time scales of <20 days**
- We determine **for the first time**, the **orbital period at TeV: $316.7 \pm 4.4(\text{stat}) \pm 2.5(\text{sys})$ days**
- **Strong correlation between X-ray and gamma rays**
 - Emission in both bands is **produced by the same population of particles**
 - **No time lag** is observed (although not probing time lags $\tau \leq 10$ days)





Novae

RS Oph



- RS Oph: red giant + white dwarf, recurrence
- **VHE** signal in the **first four days after eruption in 2021**
- **Joint Fermi-LAT +MAGIC** : **single**, smooth **component** spanning from **50 MeV to 250 GeV**
- **Hadronic scenario is favored**

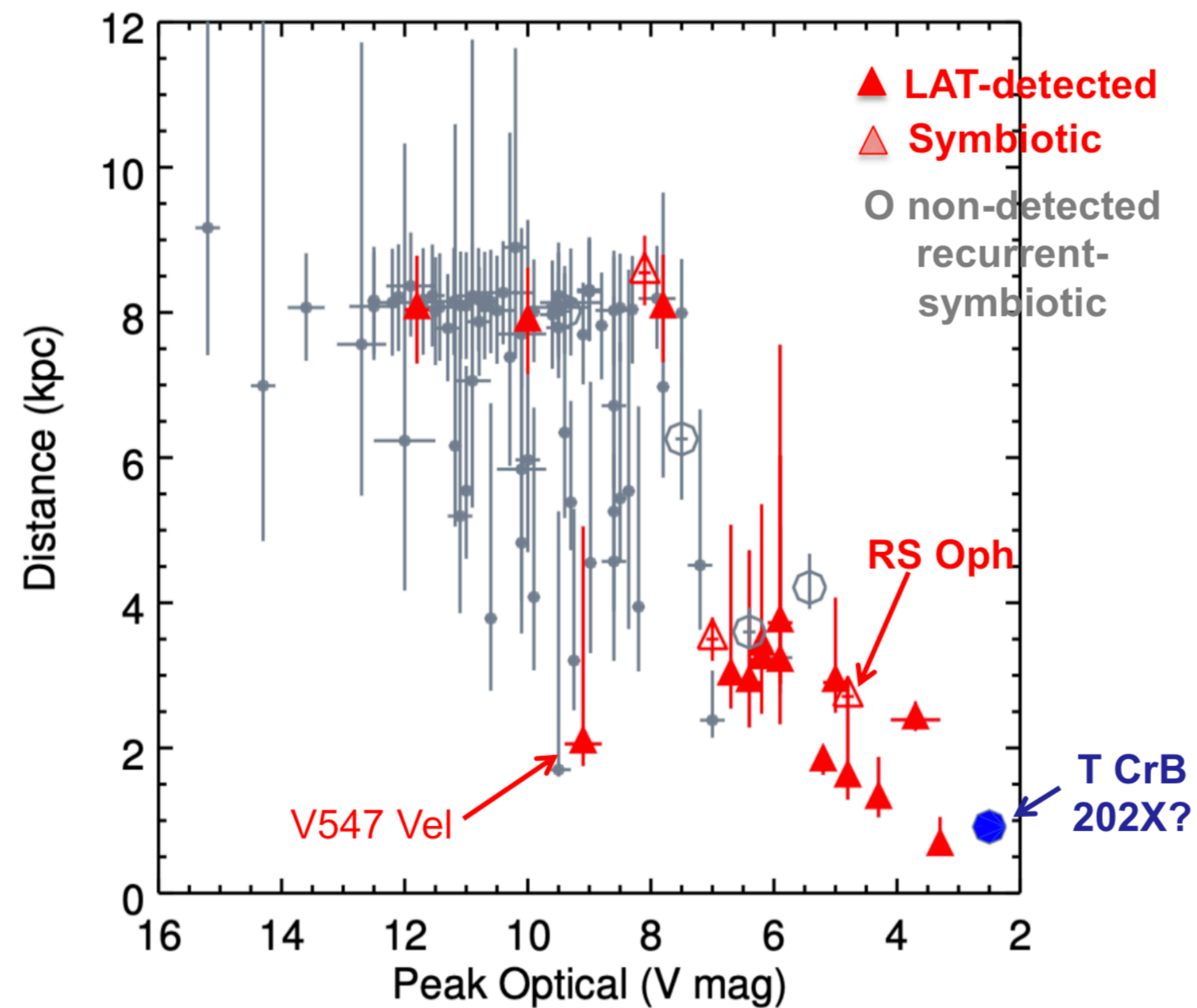
(Recurrent symbiotic) novae established as a new type of source of VHE gamma rays

T CrB: when is it happening?

WD (1.37 ± 0.13) $M_{\odot}$

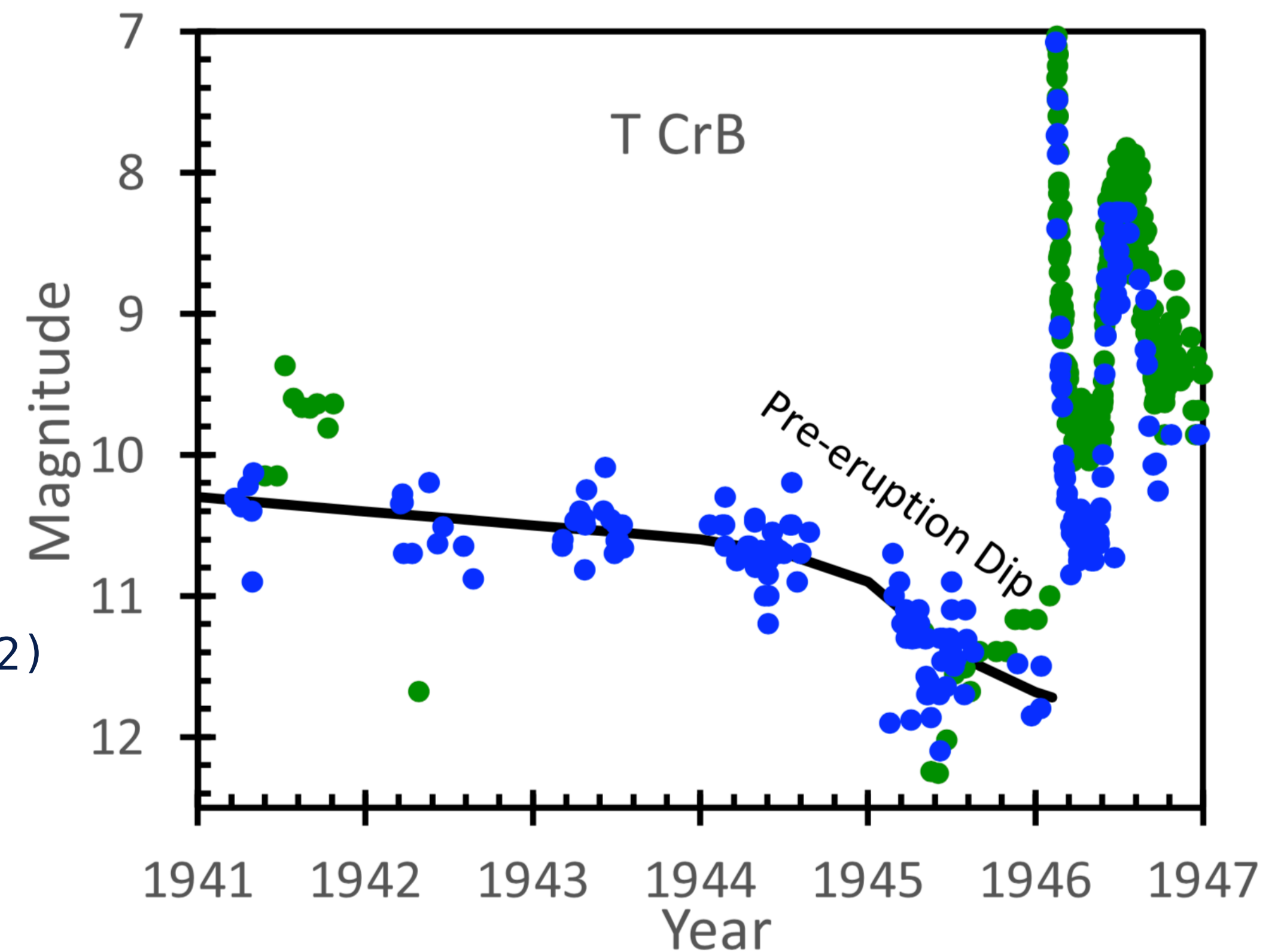
RN Symbiotic nova

M4 III



Data from Schaefer (2022), except V~5 inferred in V959 Mon 2012; added V407 Cyg 2010
From T. Cheung (VGGRS VI)

- **Closest known RN symbiotic nova**, $D = 0.91 \pm 0.02$ kpc (Schaefer 2022)
 - Recurrency period of about **~80 years**
 - Two peaks
- Optical first **peak at mag~2**
- 3x closer than RS Oph; naively scale by distance => ~10x brighter?



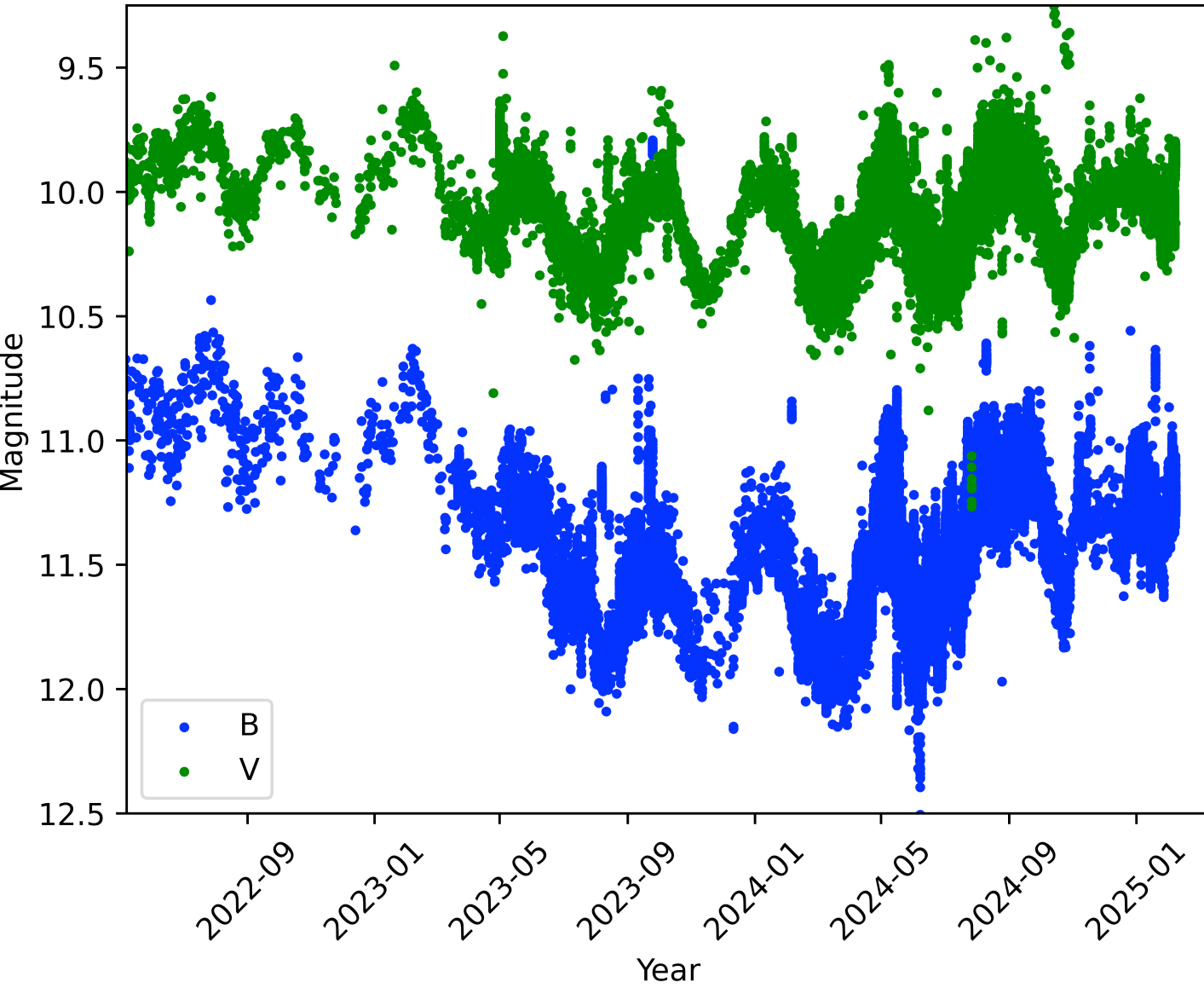
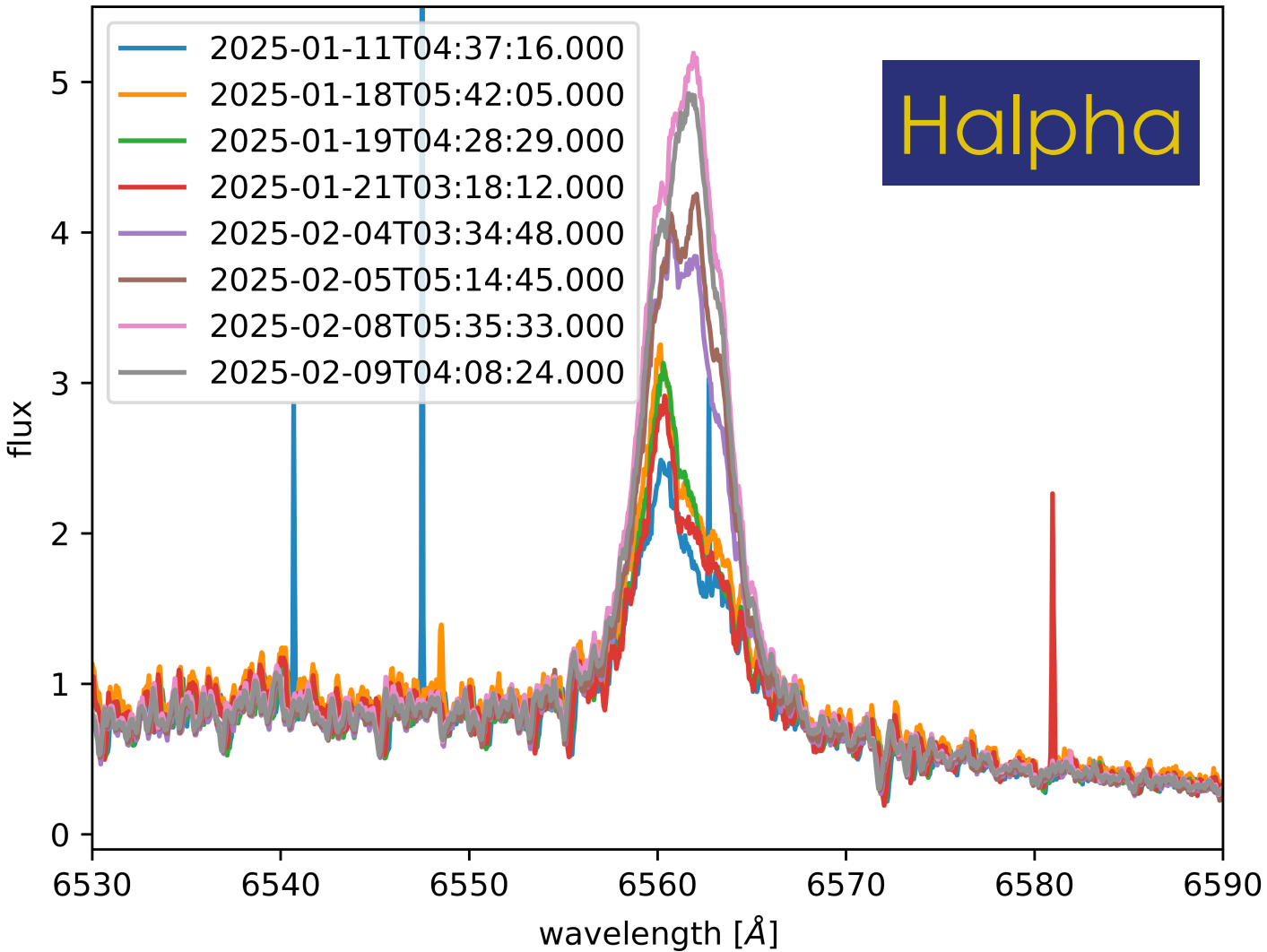
Schaefer 2022

Immediate future: T CrB

- **Increase in the accretion rate, but not in luminosity (ATel #17030)**
 - The equivalent width of the hydrogen lines doubled from 21.01.2025 to 09.02.2025
 - Double-peaked shape with a central absorption to a single emission peak
 - Strong increase in the accretion rate, **which will eventually result in a nova eruption**, as predicted to occur this or next year (e.g., Schaefer et al. 2023).
- **No increase in the light curve** has been observed so far
- When? **Expected eruption date according to literature:**
 - **2024.4 ± 0.3** (Schaefer+ 2023)
 - **2025.5 ± 1.3** (Schaefer 2023)
 - **2025 Nov or June 2026** (Schneider 2025)

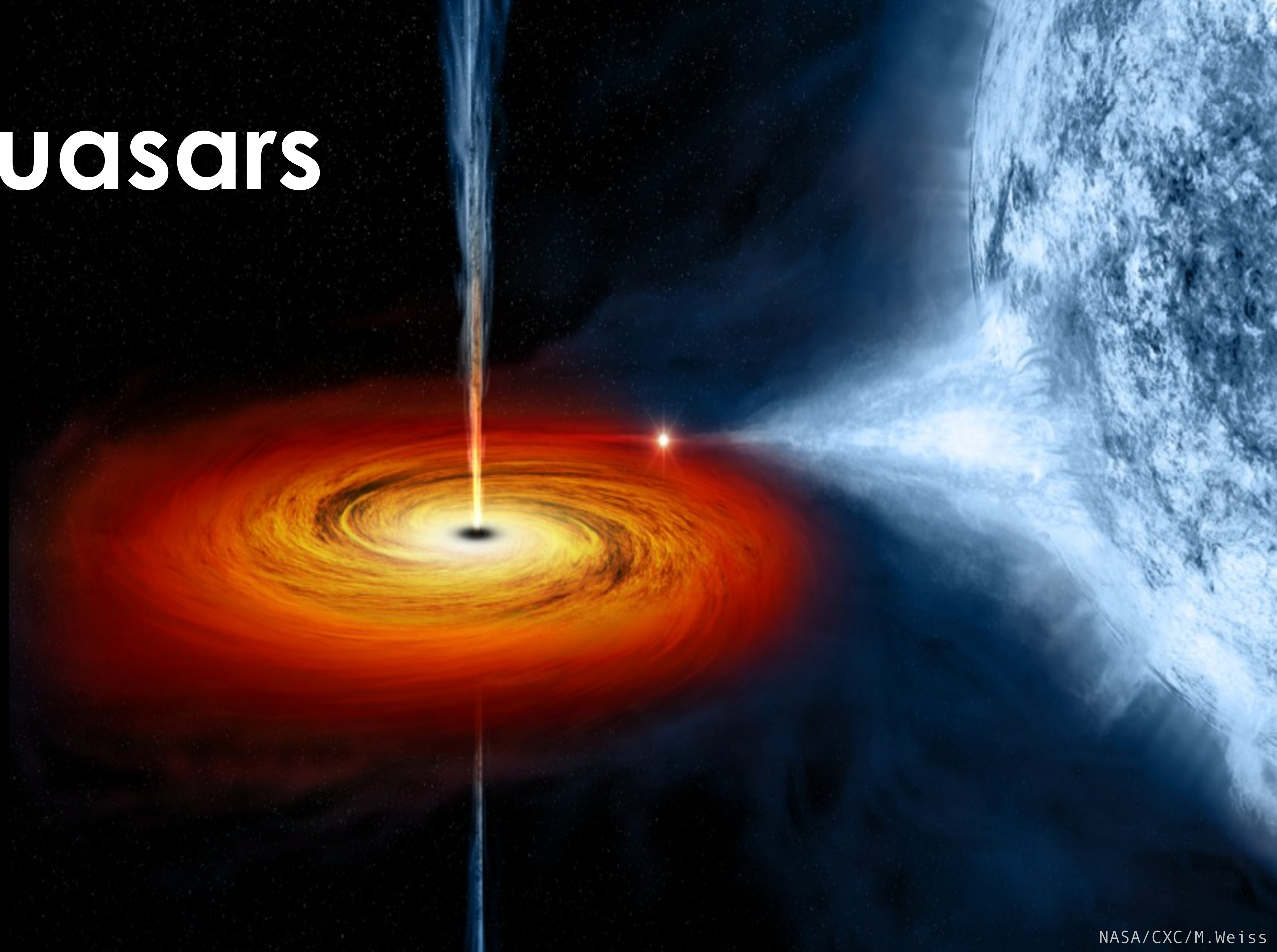
Table 1 Predicted days of eruption occurrence in 2024, 2025, 2026 and 2027 using $2431861 + N \cdot 227.5687$

N	Julian day	Civil date
126	2460535	12 Aug 2024
127	2460762	27 March 2025
128	2460990	10 November 2025
129	2461217	25 June 2026

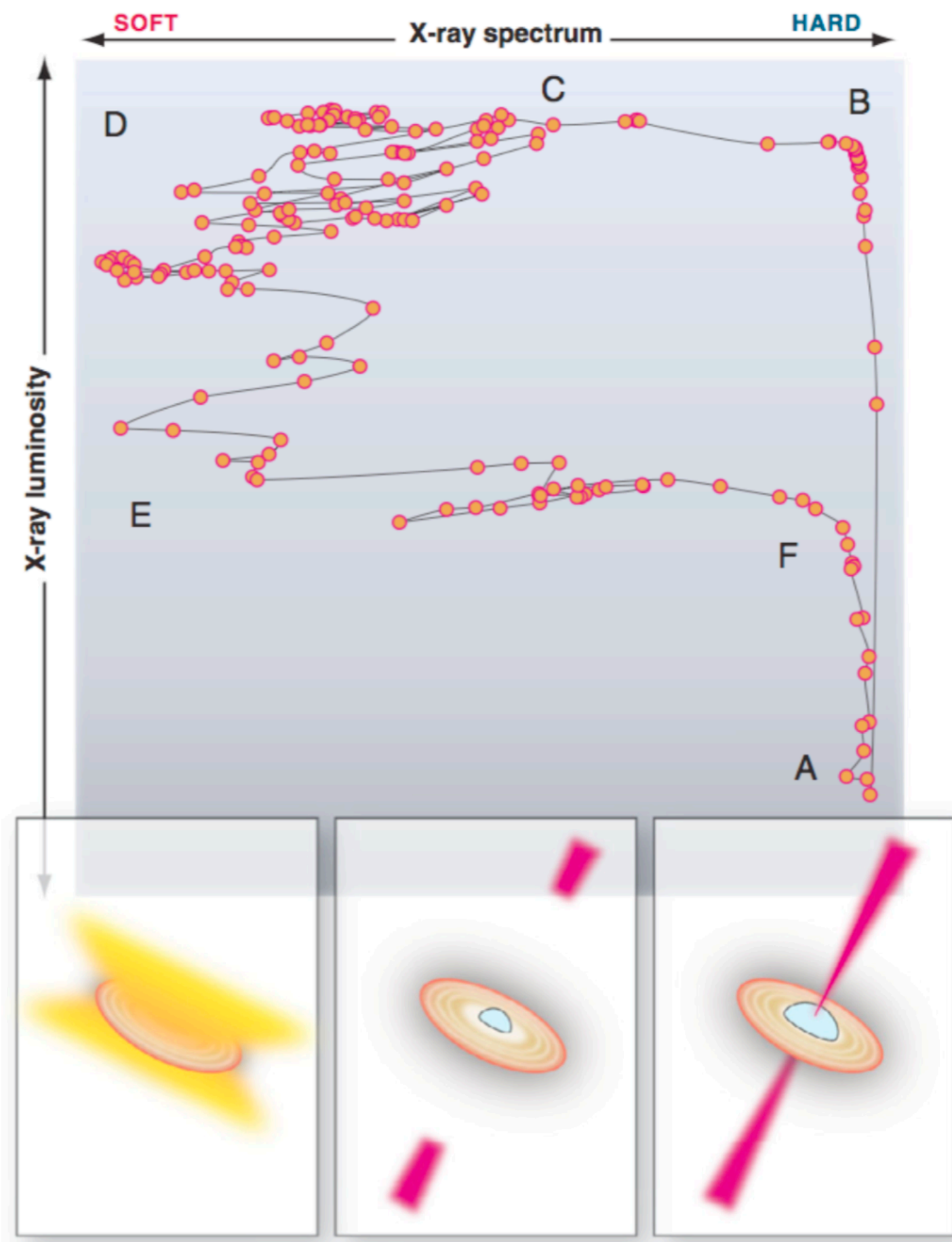


<https://www.tls-tautenburg.de/en/news/tautenburger-wissenschaftler-beobachten-auffaellige-veraenderung-im-spektrum-der-wiederkehrenden-nova-t-crb-und-bleiben-wachsam-2>

Microquasars



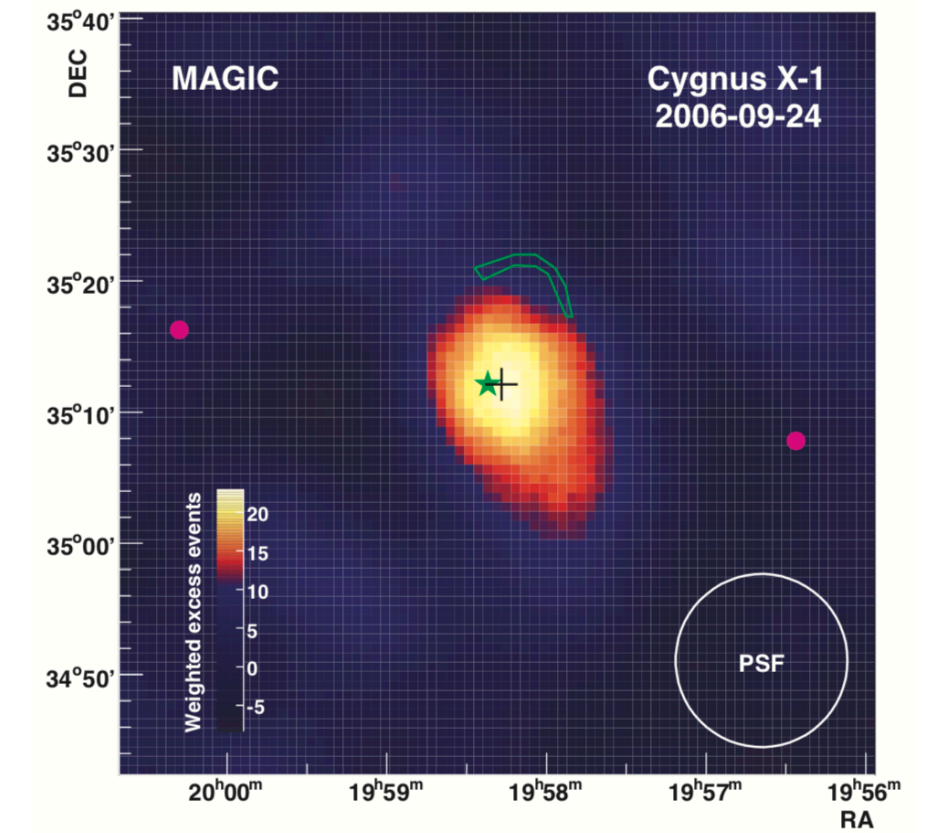
Searching for transient emission



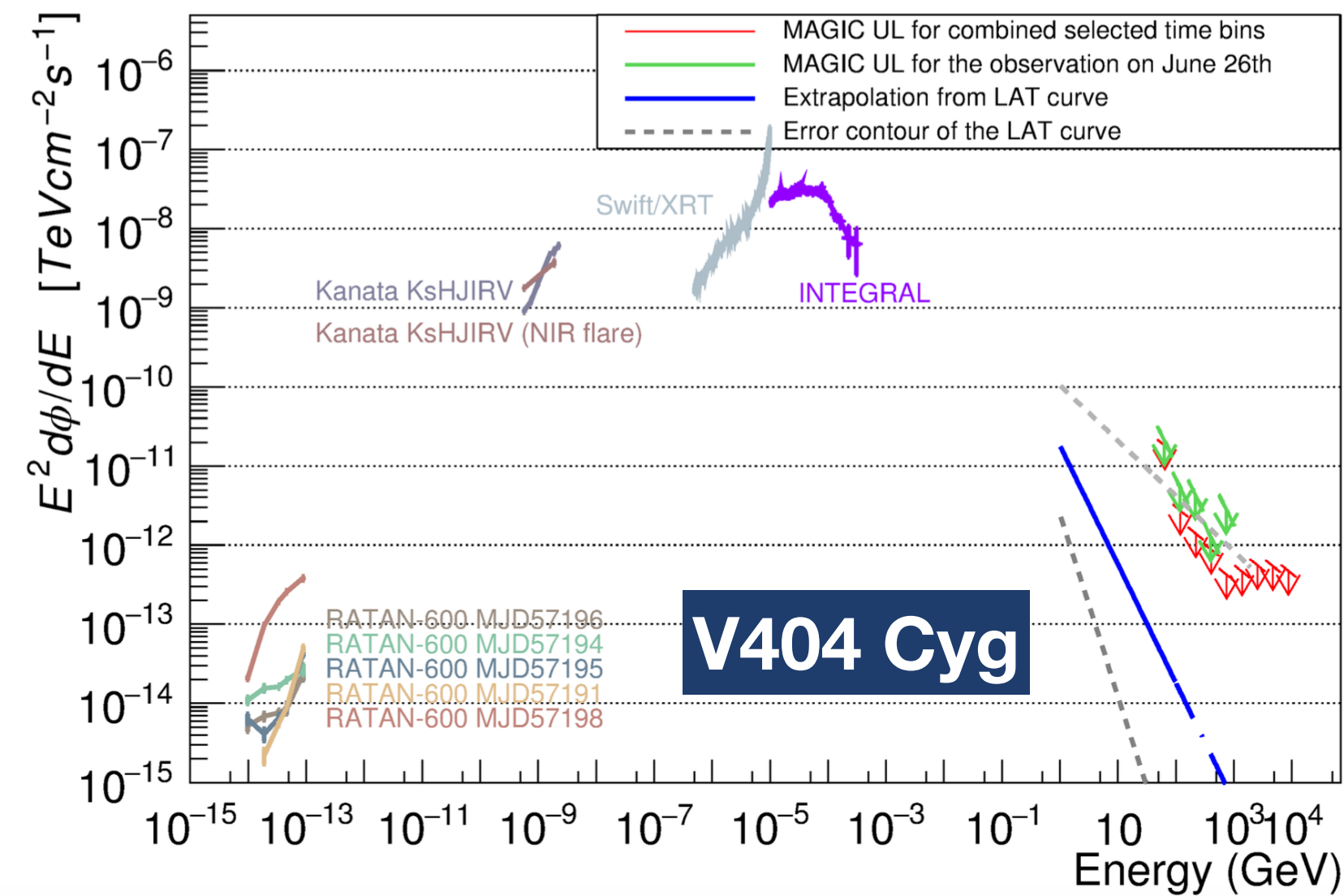
Fender & Muñoz-Darias 2016

• No transient VHE emission from microquasars by MAGIC

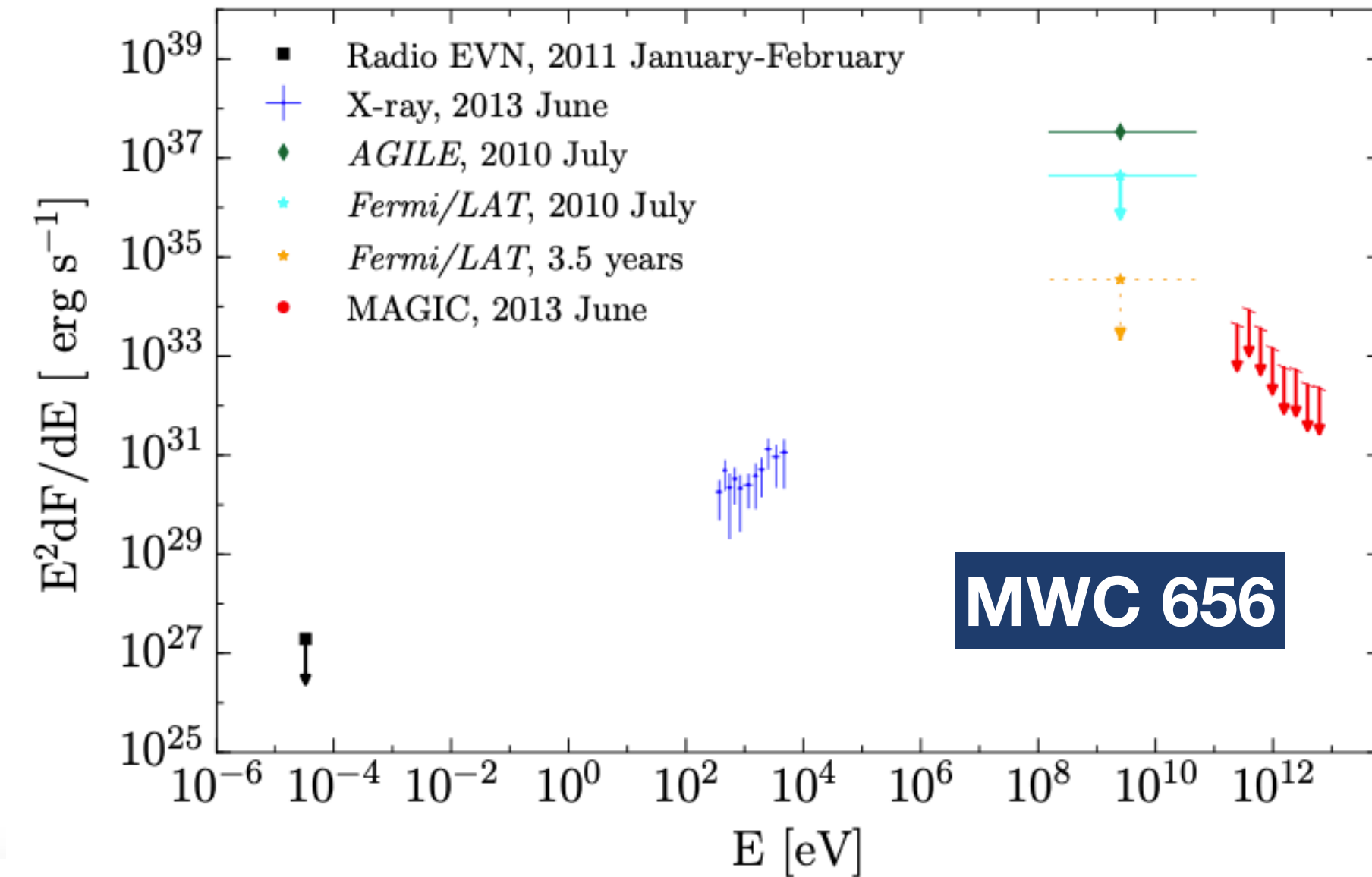
- MWC 656 (Aleksic et al. 2015)
- Cygnus X-1 (Albert et al. 2007)
- Cygnus X-3 (MAGIC 2018)
- Sco X-1 (Aleksic et al. 2011)
- V404 Cygni (Ahnen et al. 2017)
- GRS 1915+105 (Saito et al. 2011)
- MAXI J1820+070 (Abdalla et al. 2018)



Albert et al. 2007

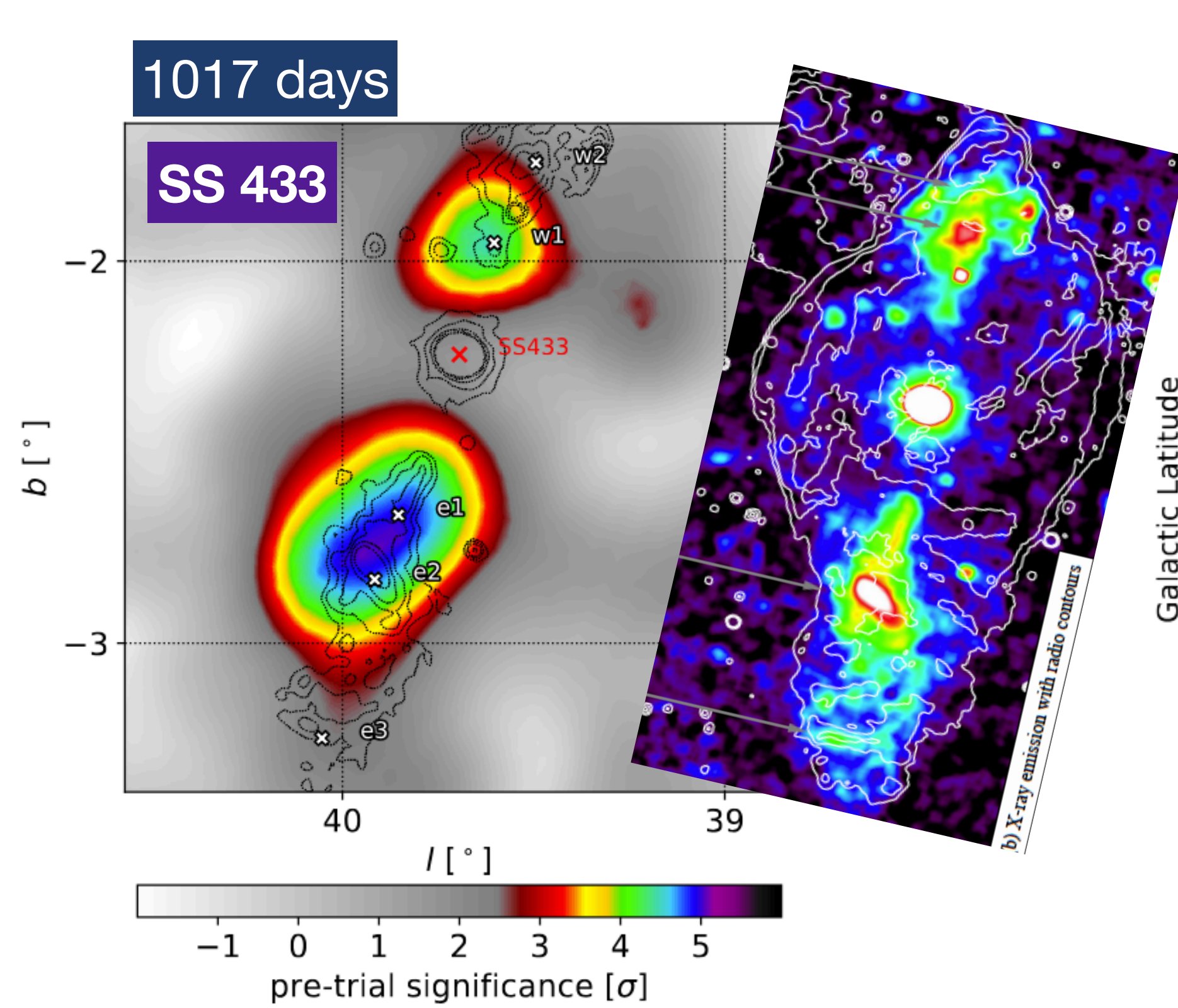


MAGIC Coll. 2017

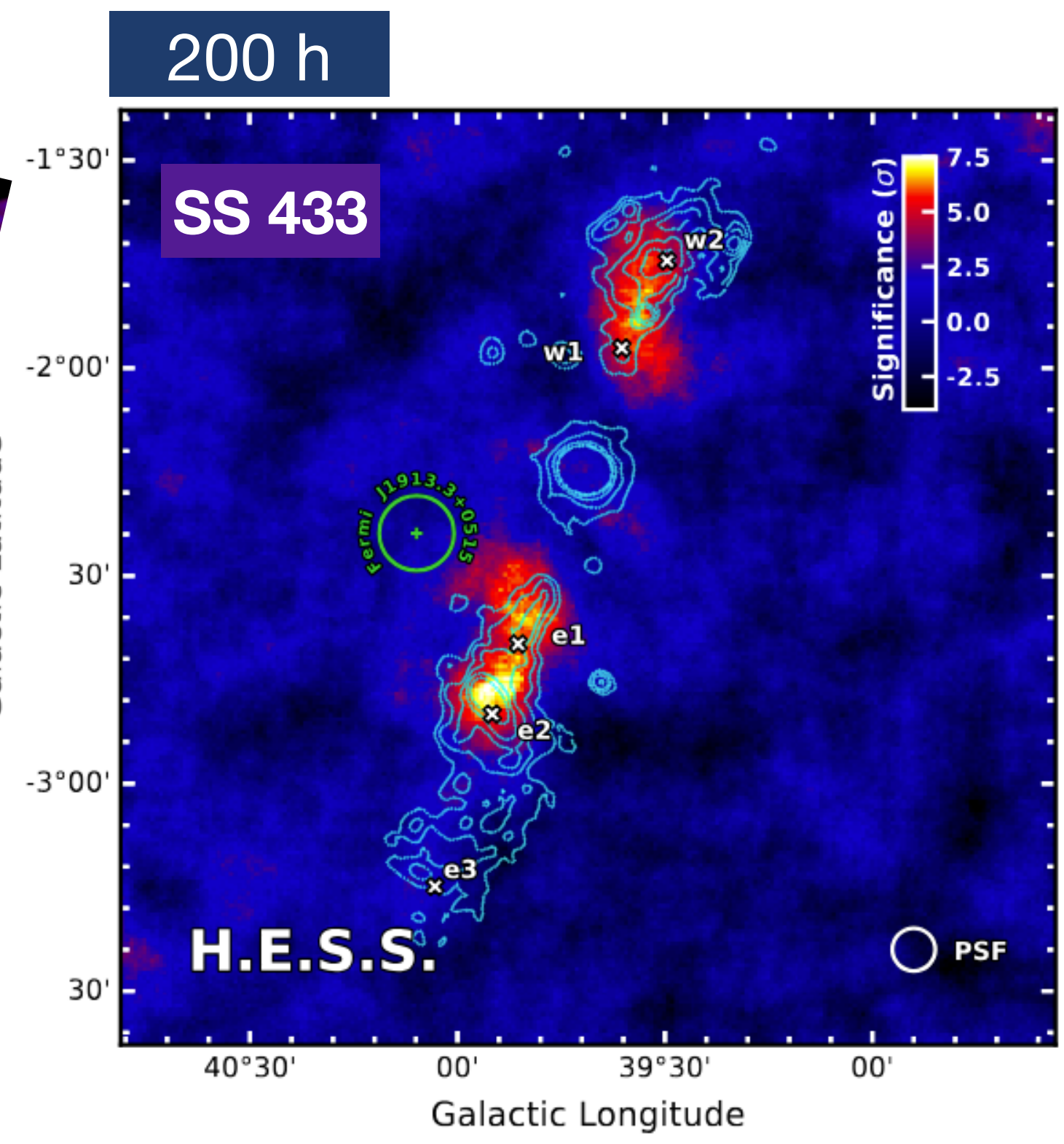


MAGIC Coll. 2015

Persistent TeV emission from **several** microquasars

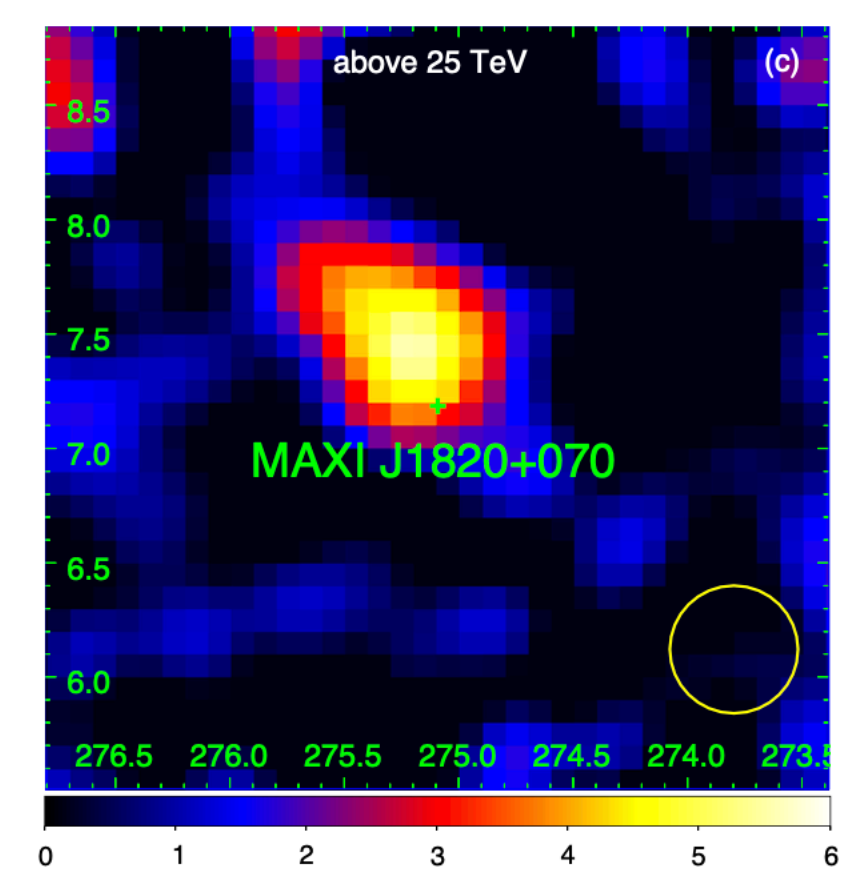


HAWC Coll. 2023

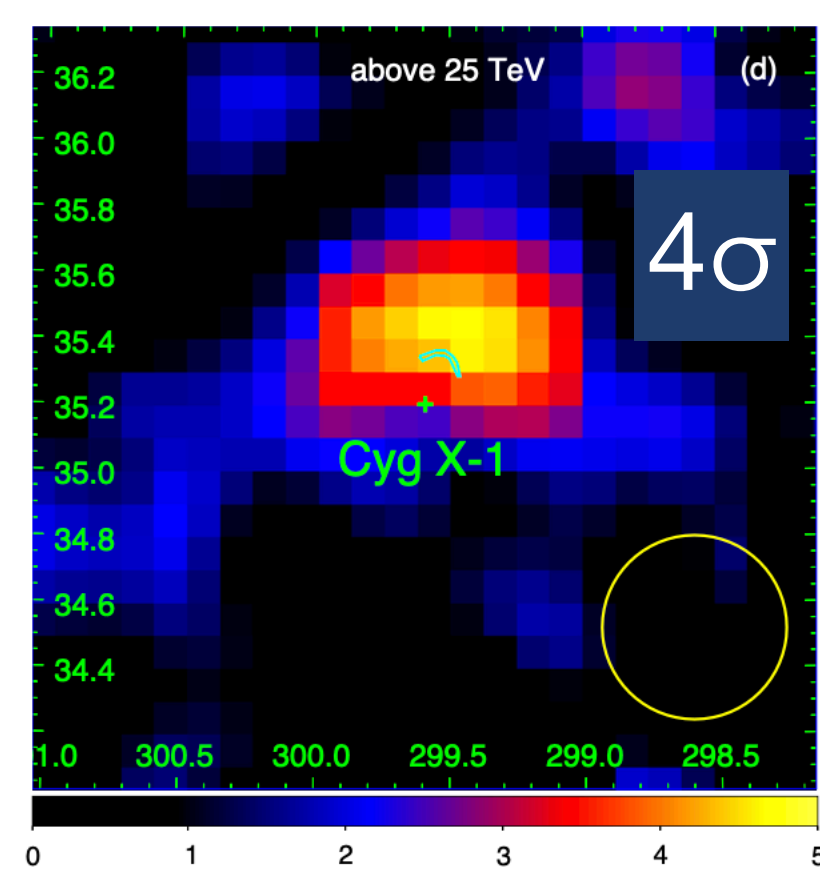


H.E.S.S. Coll. 2024

MAXI J1820+070



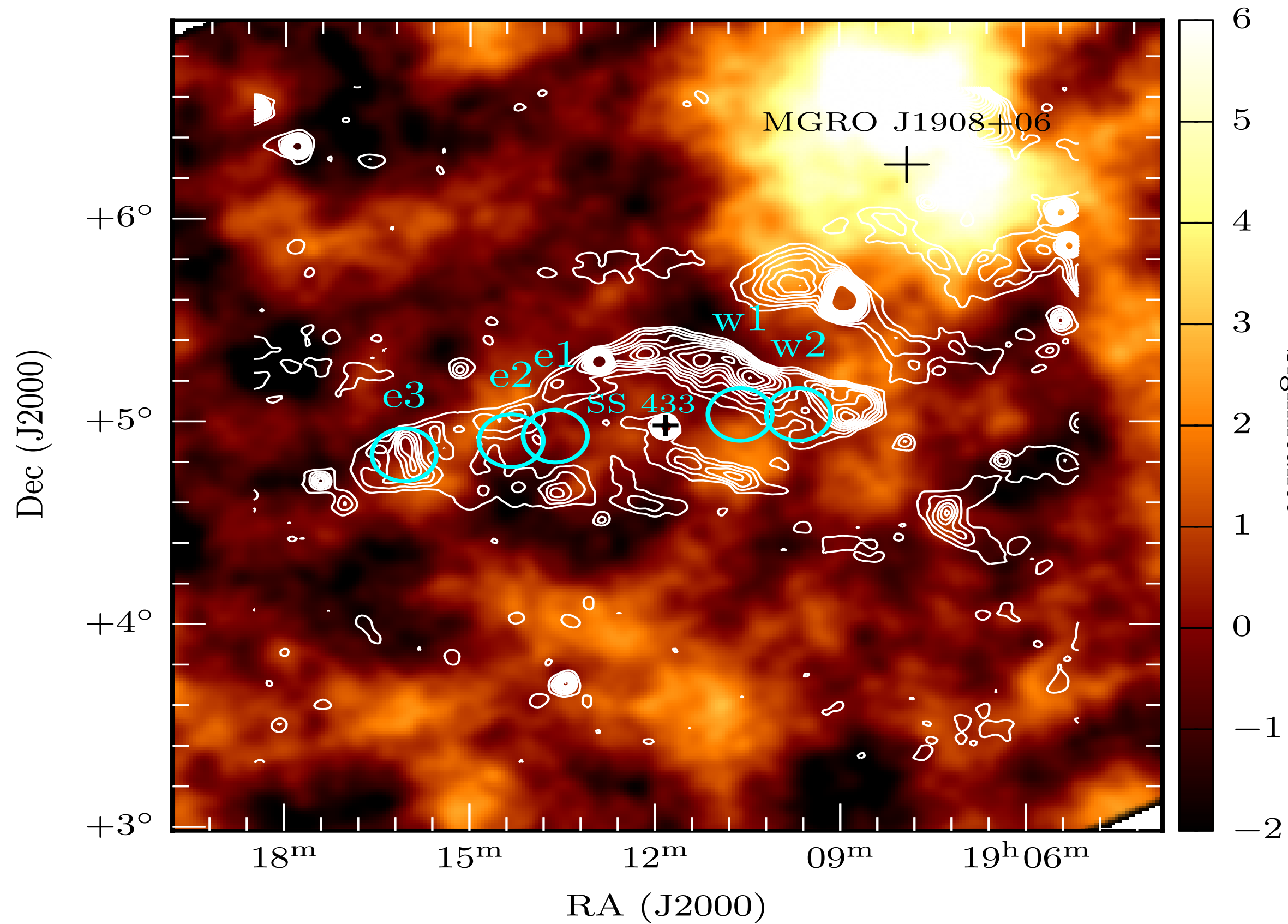
Cygnus X-1



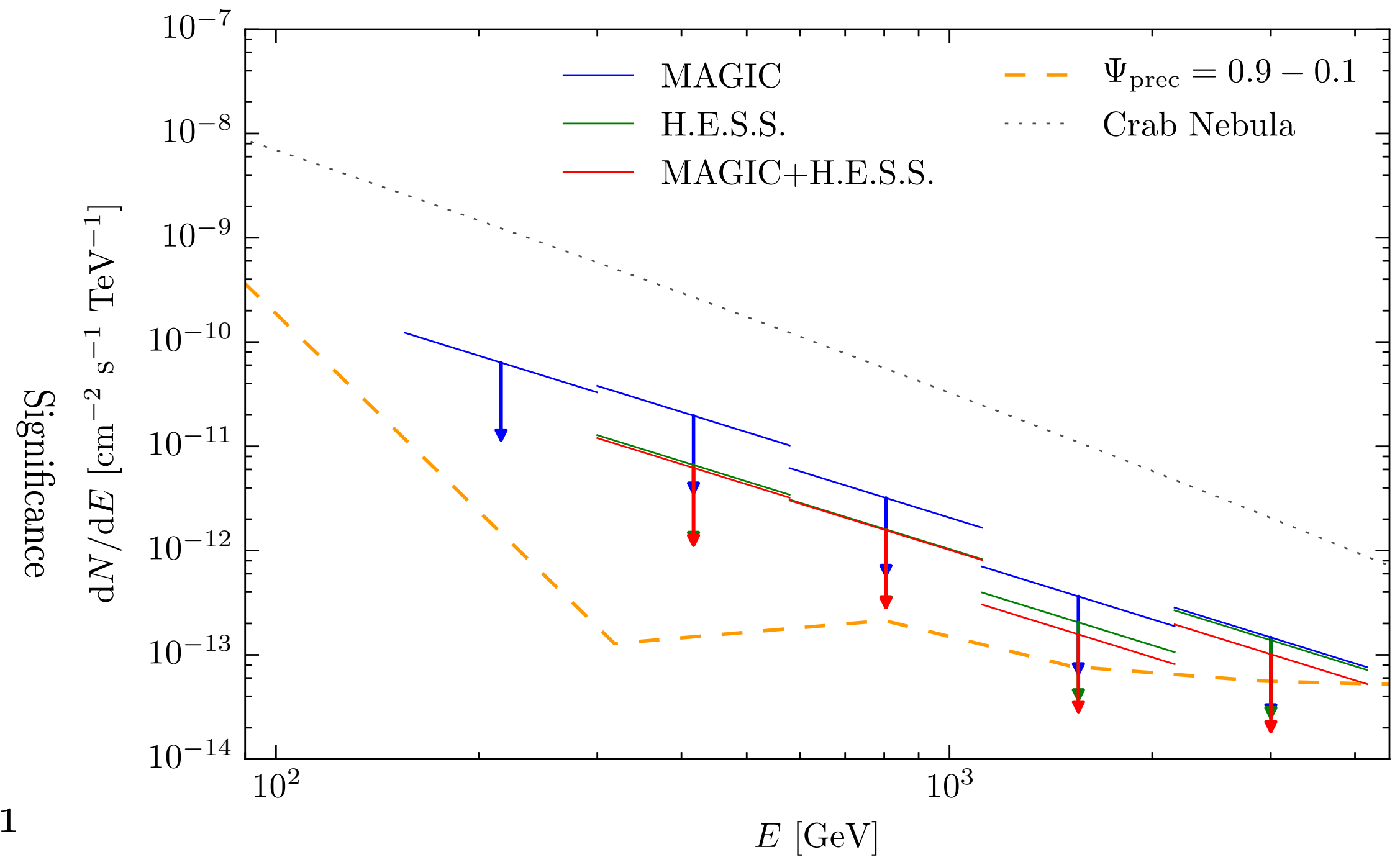
LHAASO 2024

BH-jet binaries
are efficient particle
accelerators

SS 433/W50 at VHE: a very first try



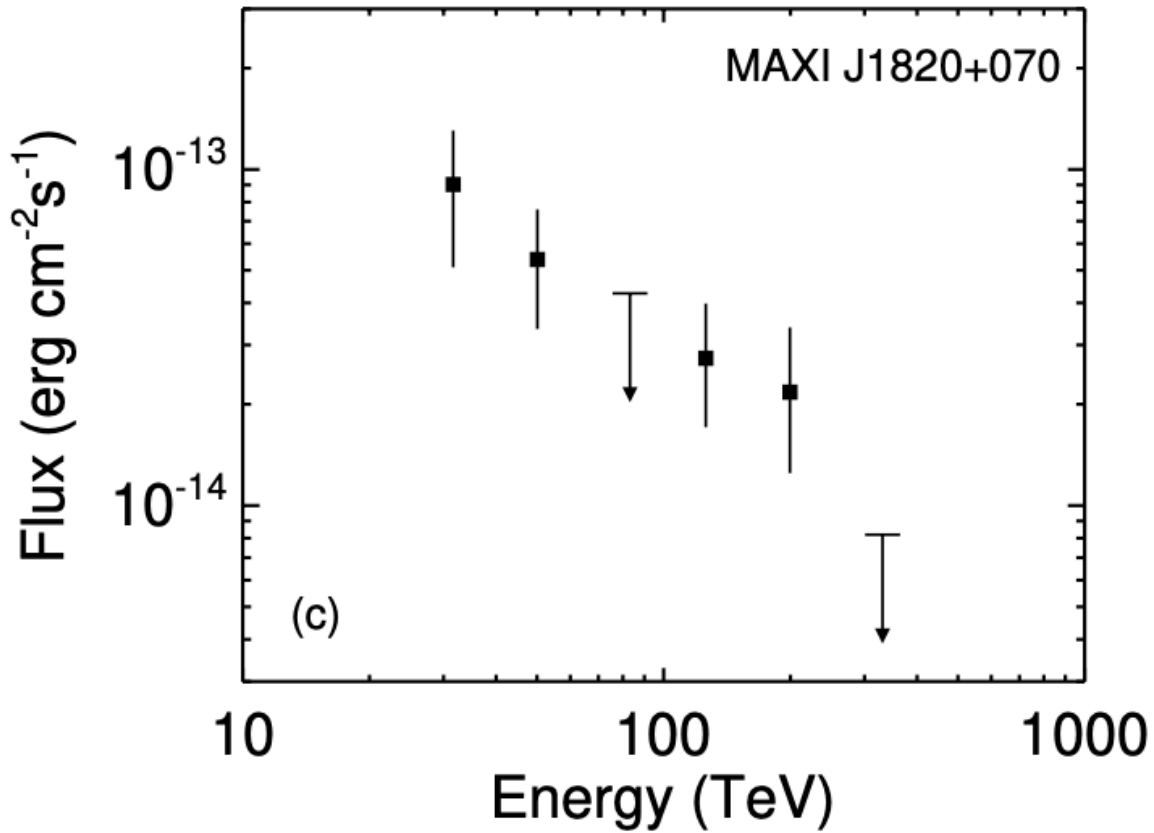
MAGIC & H.E.S.S. 2018



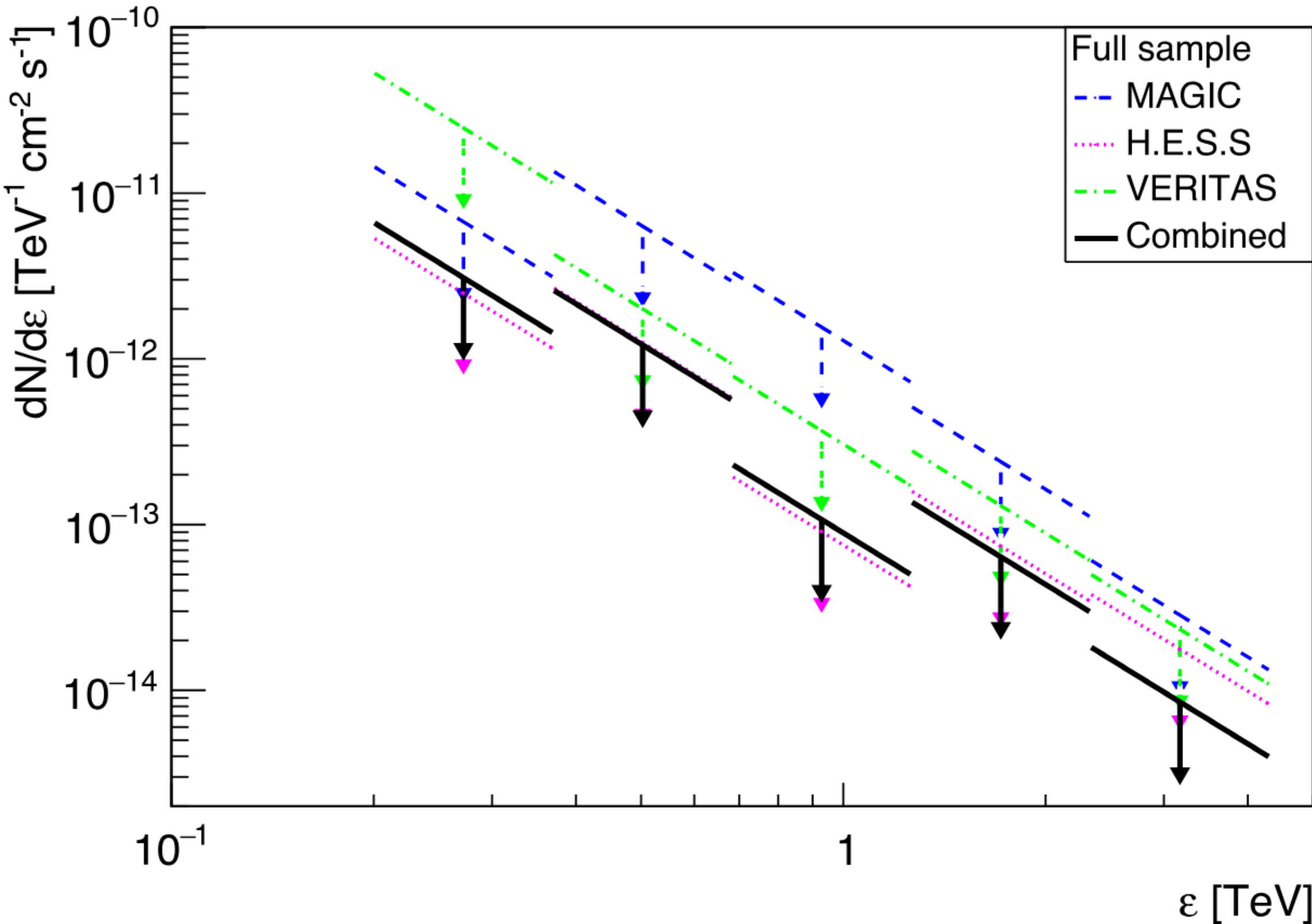
- MAGIC + H.E.S.S. campaign (MAGIC & H.E.S.S. 2018)
 - No significant excess detected
 - Upper limits (95% C.L.) compatible with predictions by Reynoso et al. 2008

MAXI J1820+070

- **Multi-IACT campaign in 2018 during outburst (discovery)**
- Combined of 59.5 h of observations with H.E.S.S., MAGIC and VERITAS at $E > 200$ GeV (Abe et al. 2022)
 - No VHE detection



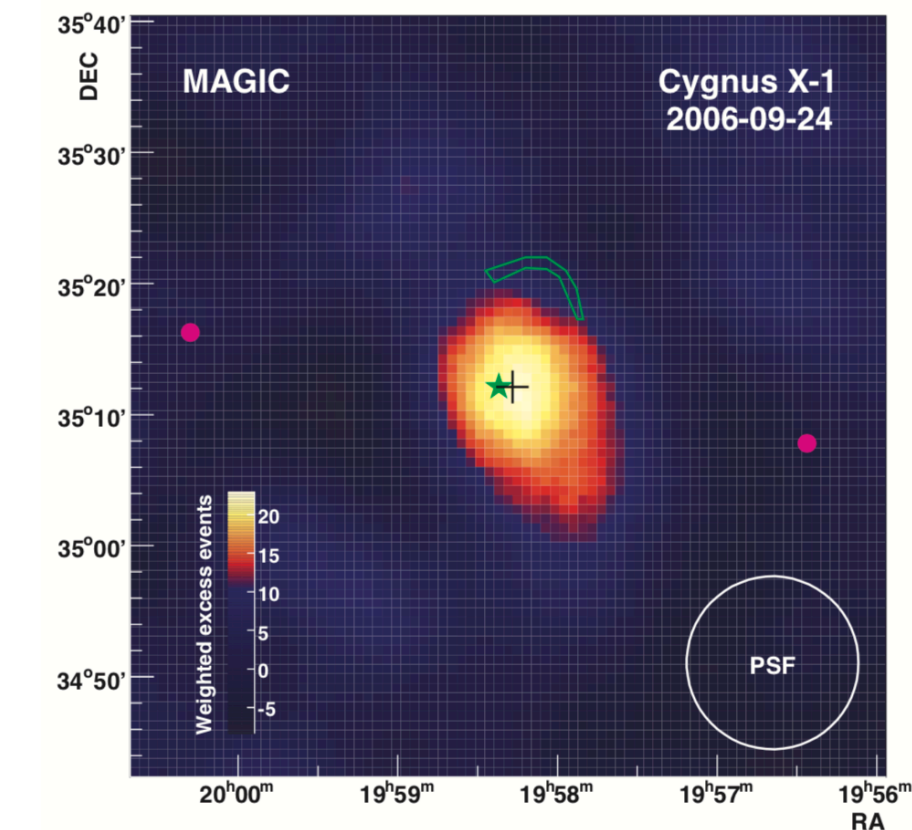
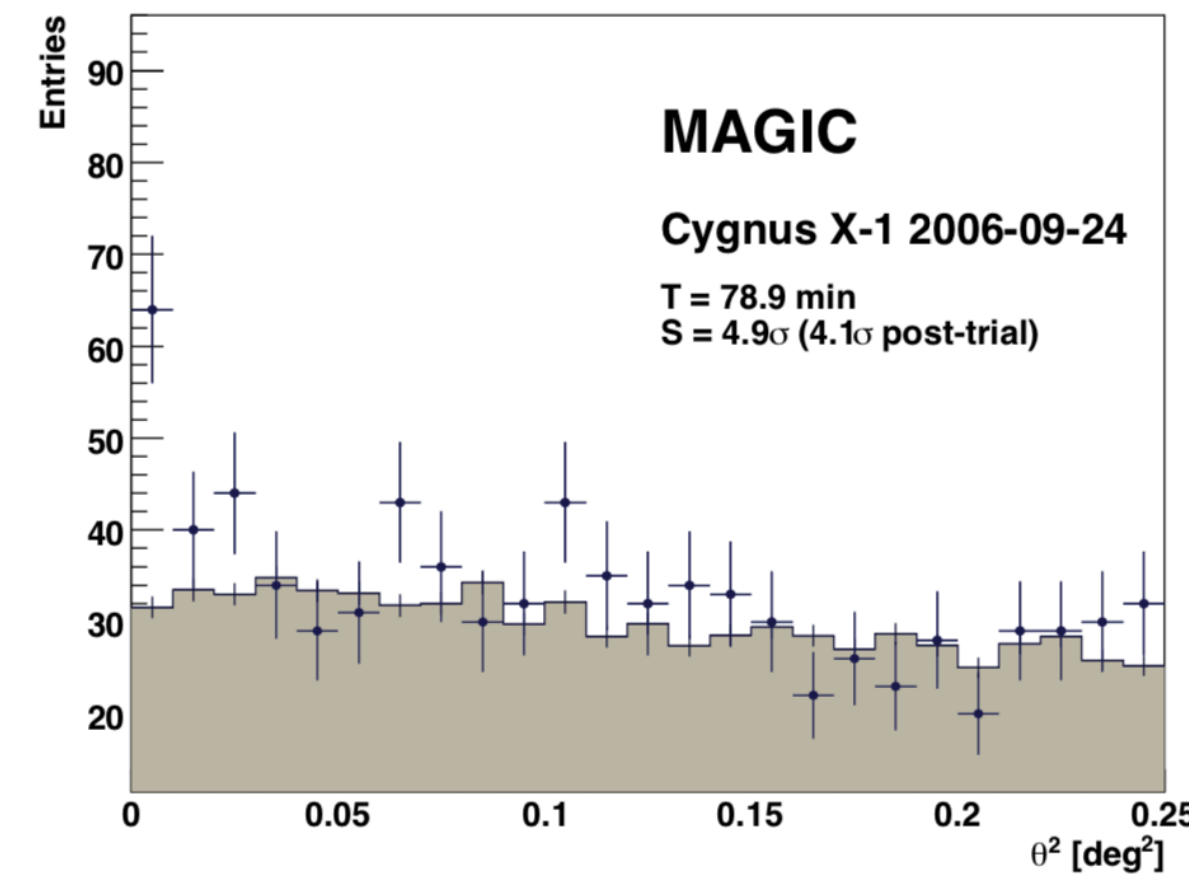
LHAASO 2024 arxiv: 2410.08988



Source state	<i>Fermi</i> -LAT UL (0.1–500 GeV) (ph cm ^{−2} s ^{−1})	IACT UL (>200/300 GeV) (ph cm ^{−2} s ^{−1})
Hard State I	3.1×10^{-8}	9.5×10^{-13}
HS → SS	1.6×10^{-7}	9.5×10^{-13}
Soft State	2.5×10^{-8}	1.6×10^{-12}
SS → HS	5.2×10^{-8}	2.2×10^{-12}
Hard State II	6.0×10^{-8}	—
TOTAL	1.8×10^{-8}	7.2×10^{-13}

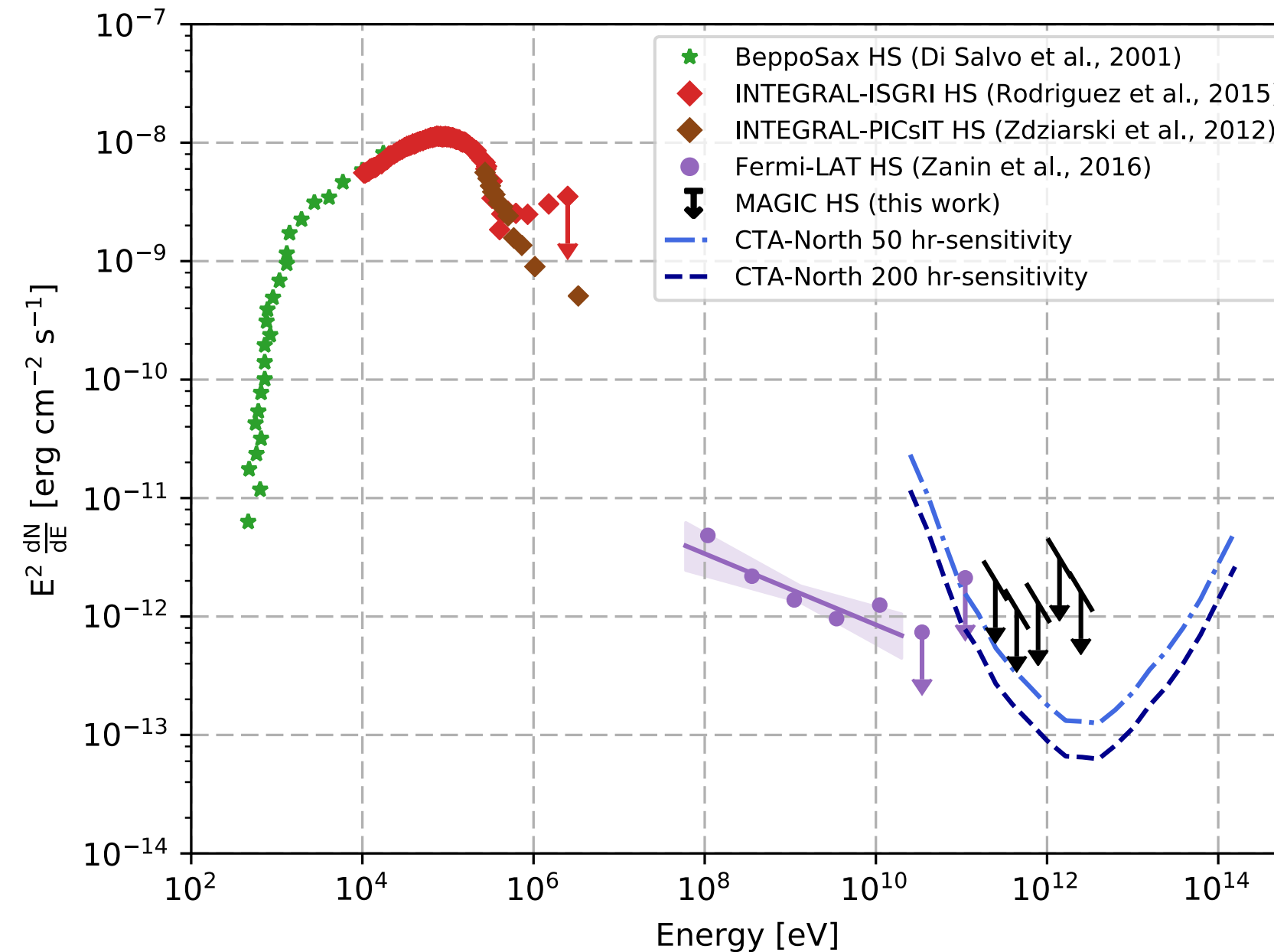
Cygnus X-1 at VHE

- **Hint of transient emission** with MAGIC:
4 σ in 80 min (Albert et al. 2007)
- Simultaneously with
hard X-ray flare
- During hard state (HS) and SUPC

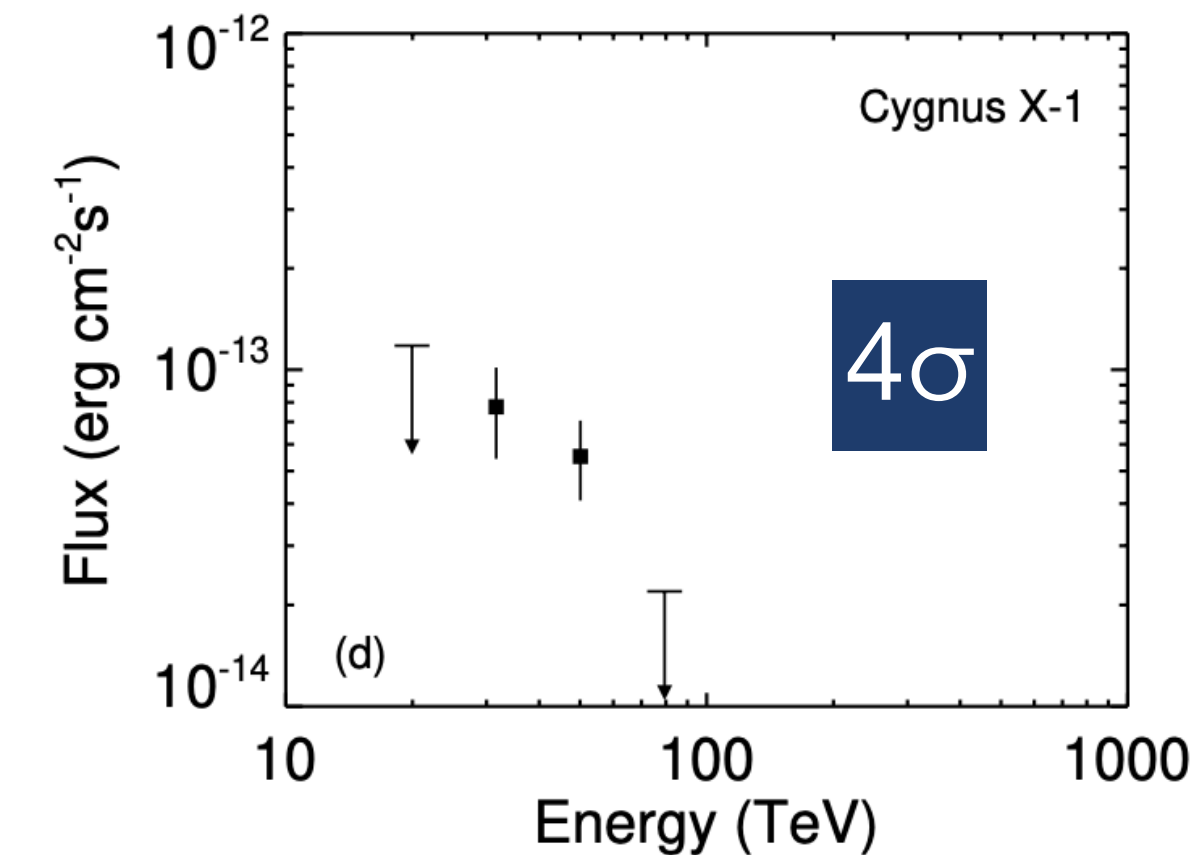


Albert et al. 2007

- **Search for persistent signal** (Albert et al. 2007)
- **100 h** (2007-2014) of MAGIC observations **mainly at HS** (83h)
- **No significant excess** at either X-ray state for steady, orbital or daily basis emission
- **Transient emission** (Albert et al. 2007) **still possible** at binary scale

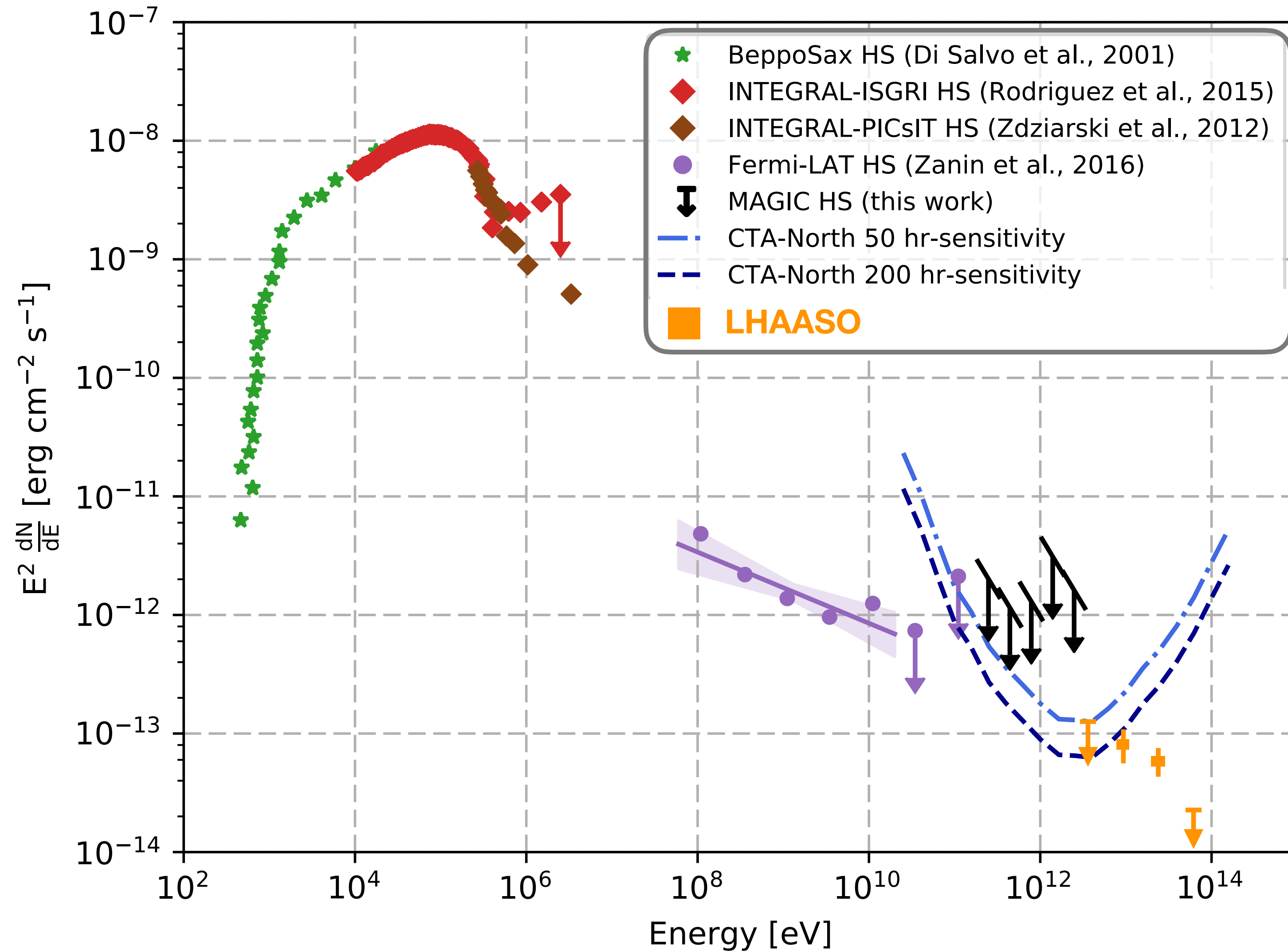


Ahnen et al. 2017



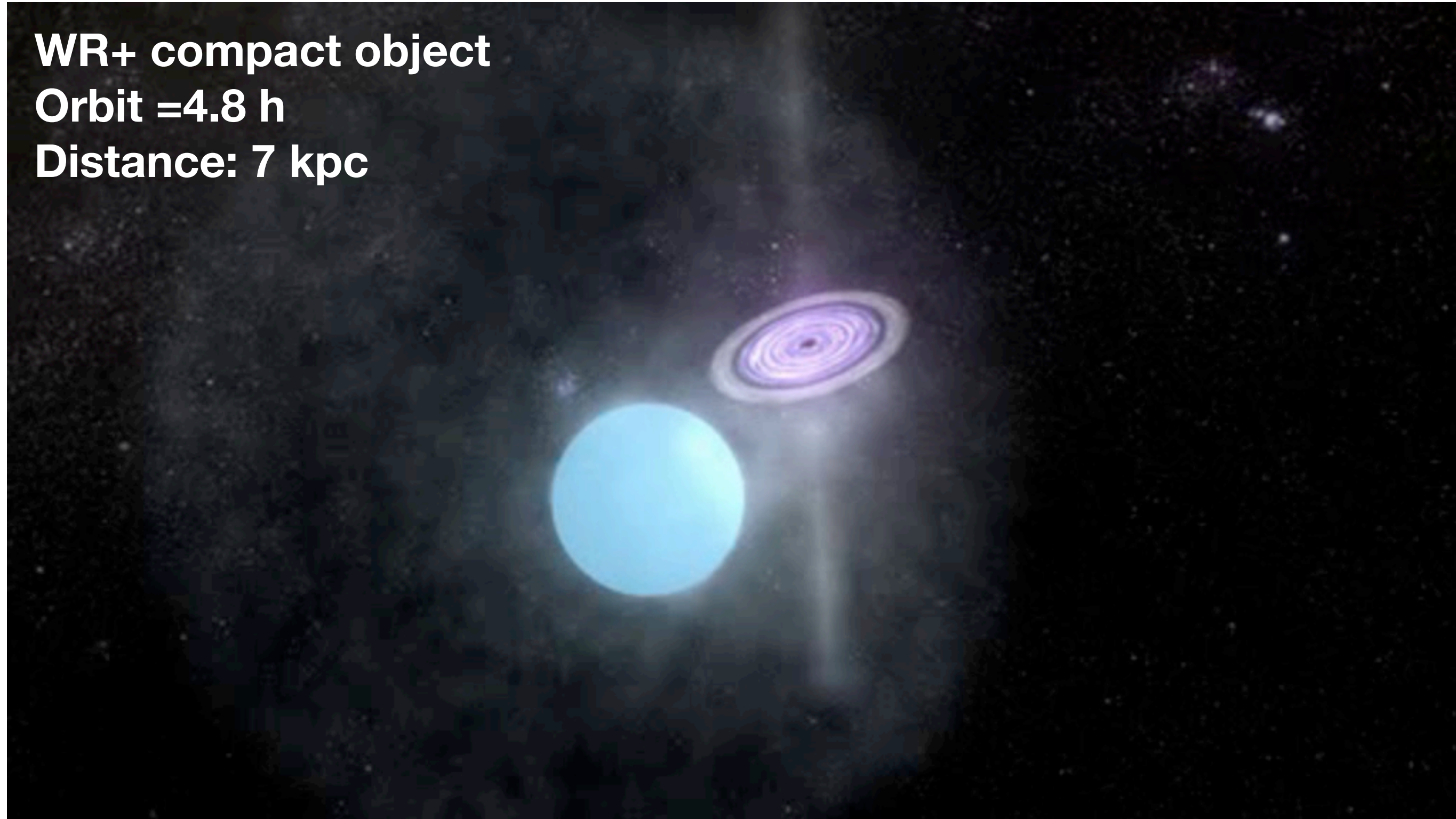
LHAASO 2024 arxiv: 2410.08988

Cygnus X-1 at VHE



Cygnus X-3

WR+ compact object
Orbit = 4.8 h
Distance: 7 kpc



See dedicated talk by
Edgar Molina



Universidad
de La Laguna



Cofinanciado por
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Results of the long-term campaign on Cygnus X-3 by MAGIC

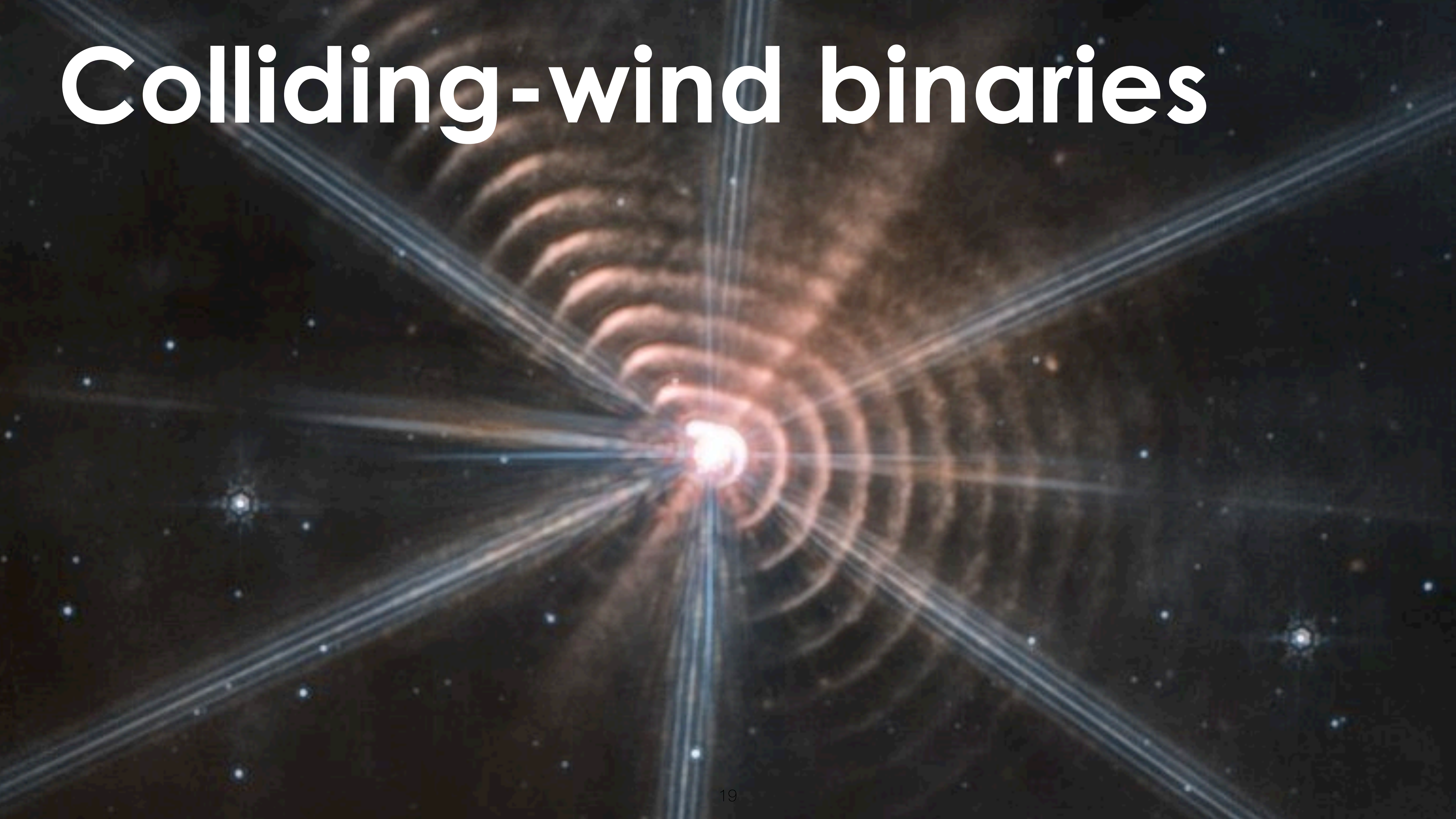
E. Molina*, L. Barrios-Jiménez, M. Carretero-Castrillo, J. Becerra González, M.
Ribó and J.M. Paredes, for the MAGIC Collaboration

*Instituto de Astrofísica de Canarias (IAC)

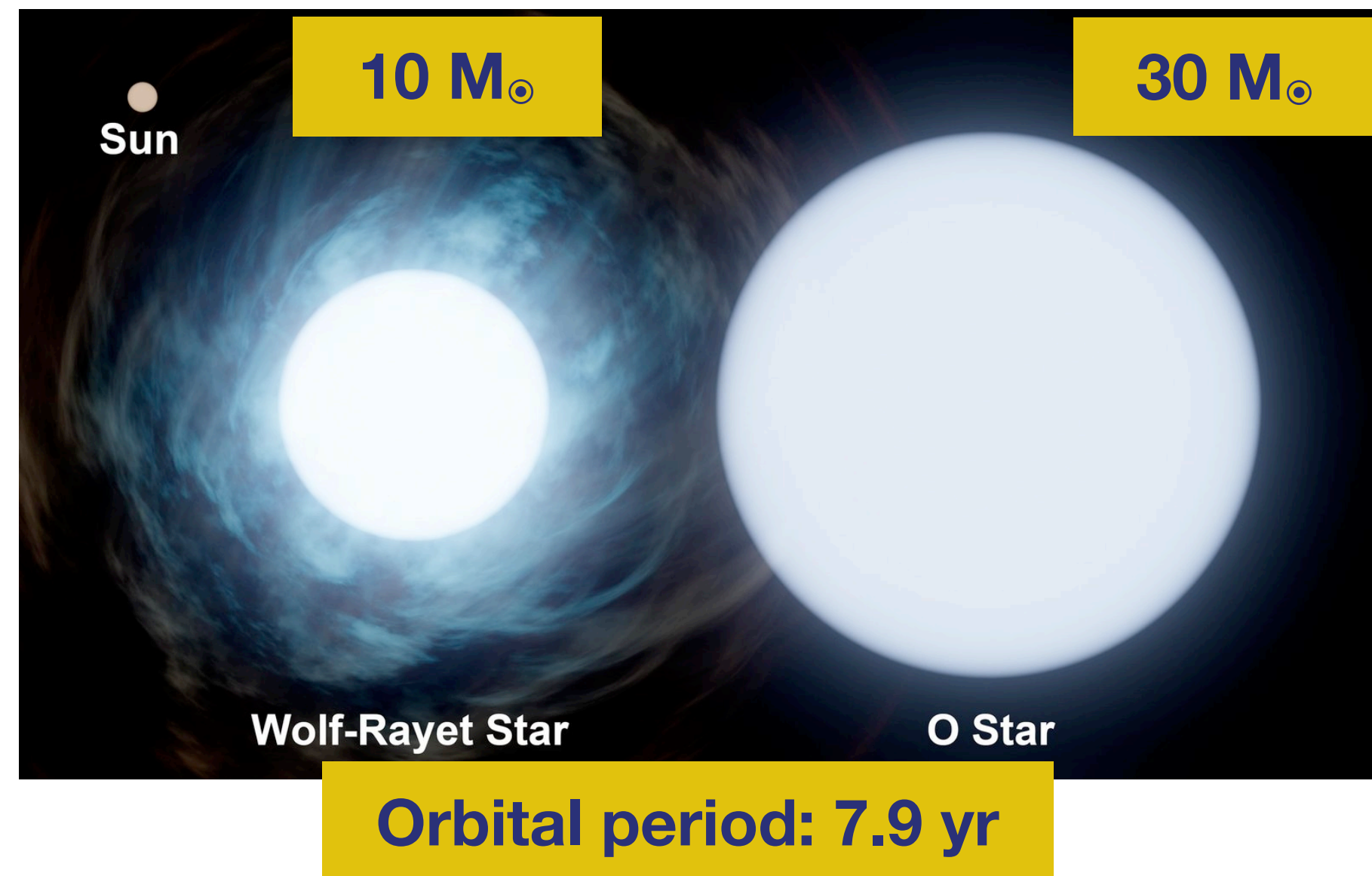


Variable Galactic Gamma-Ray Sources VII
Barcelona, 7 May 2025

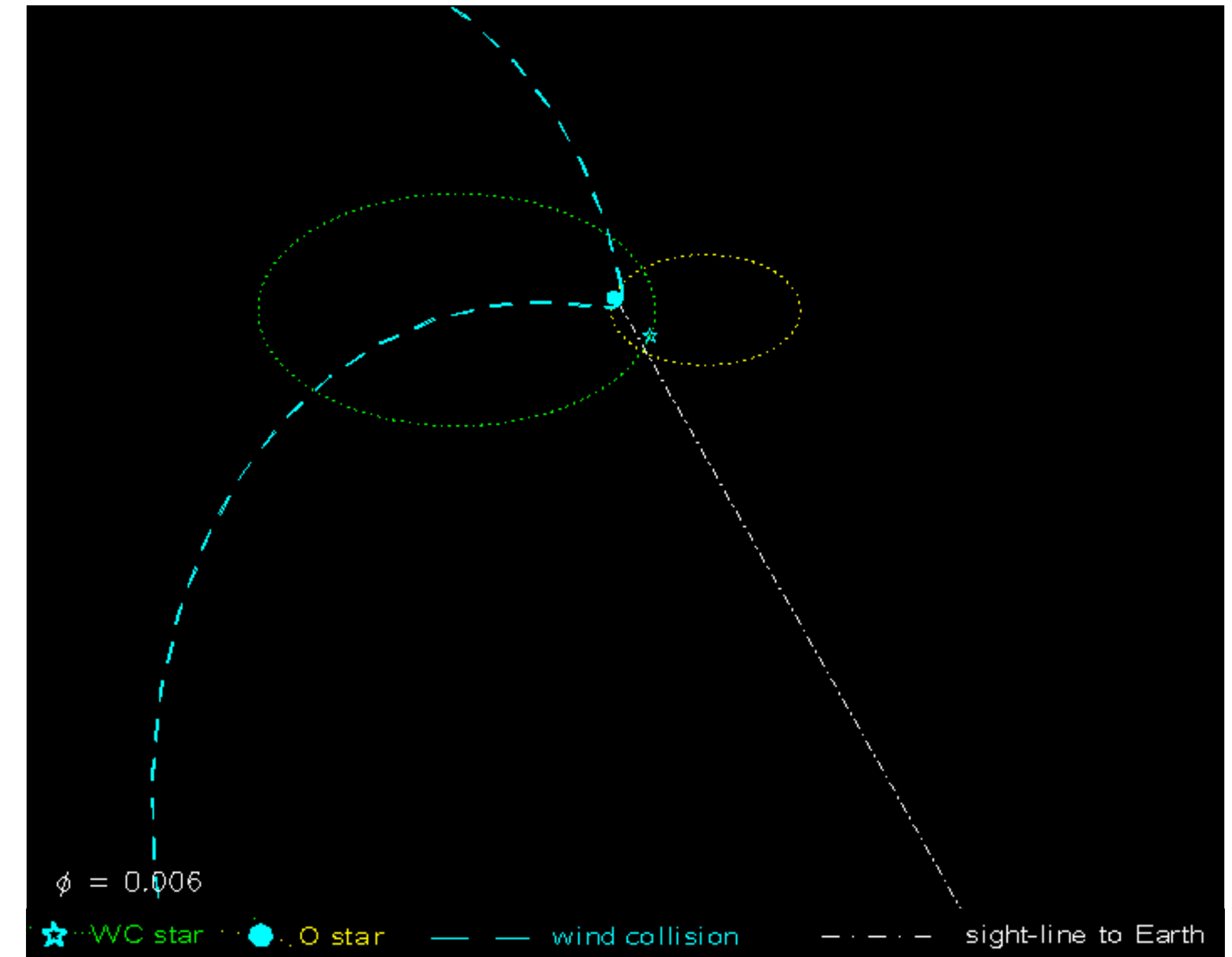
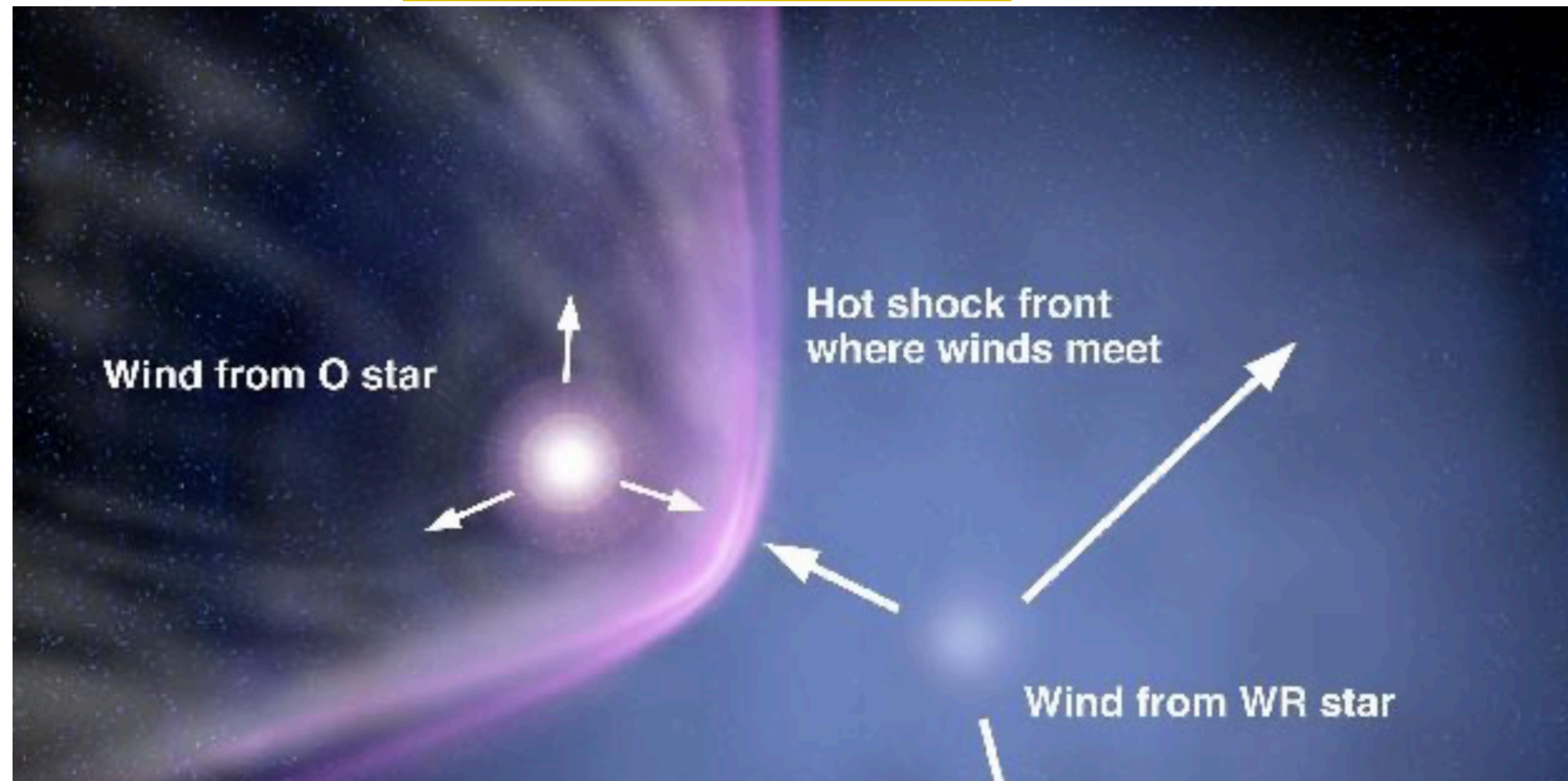
Colliding-wind binaries



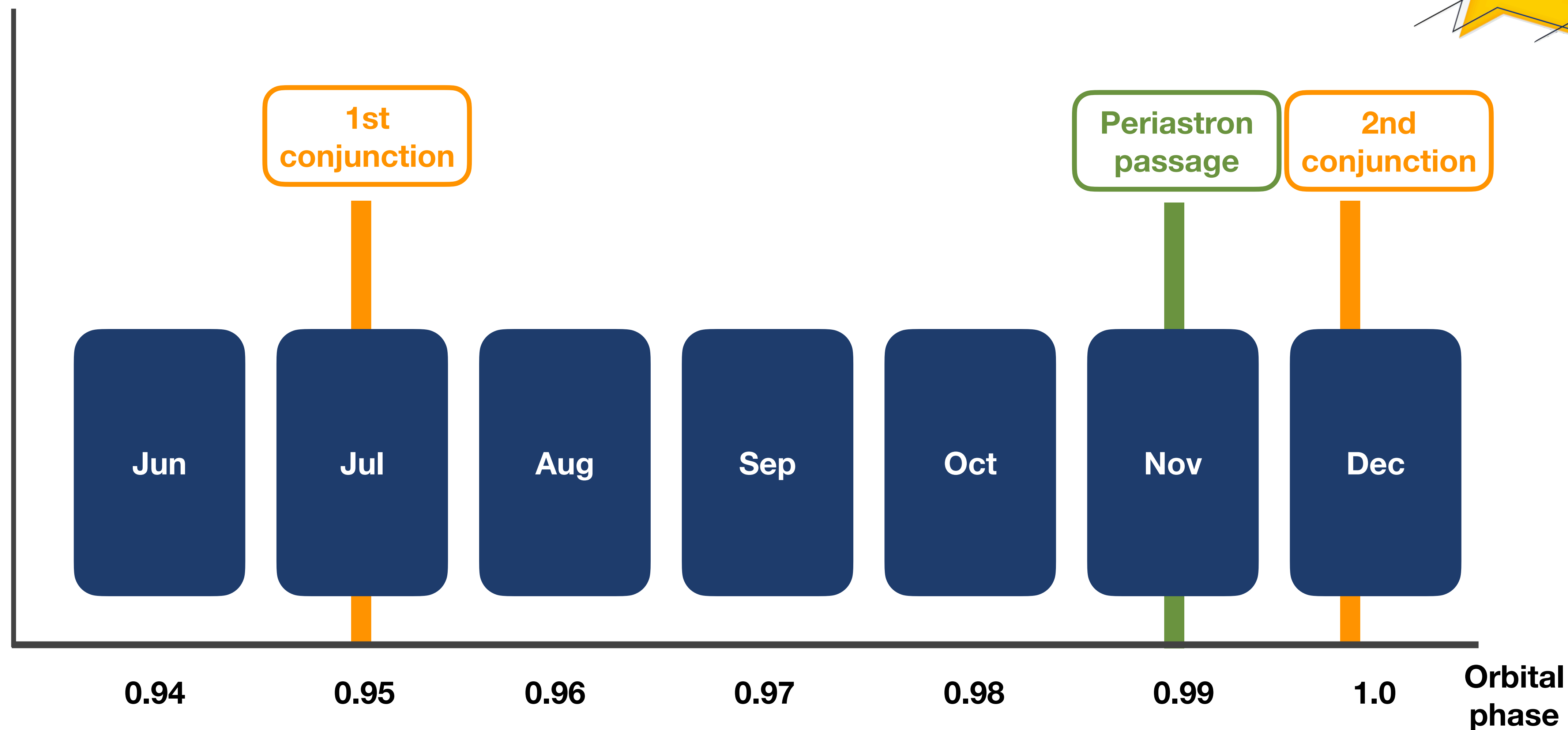
WR 140: a CWB in the northern hemisphere

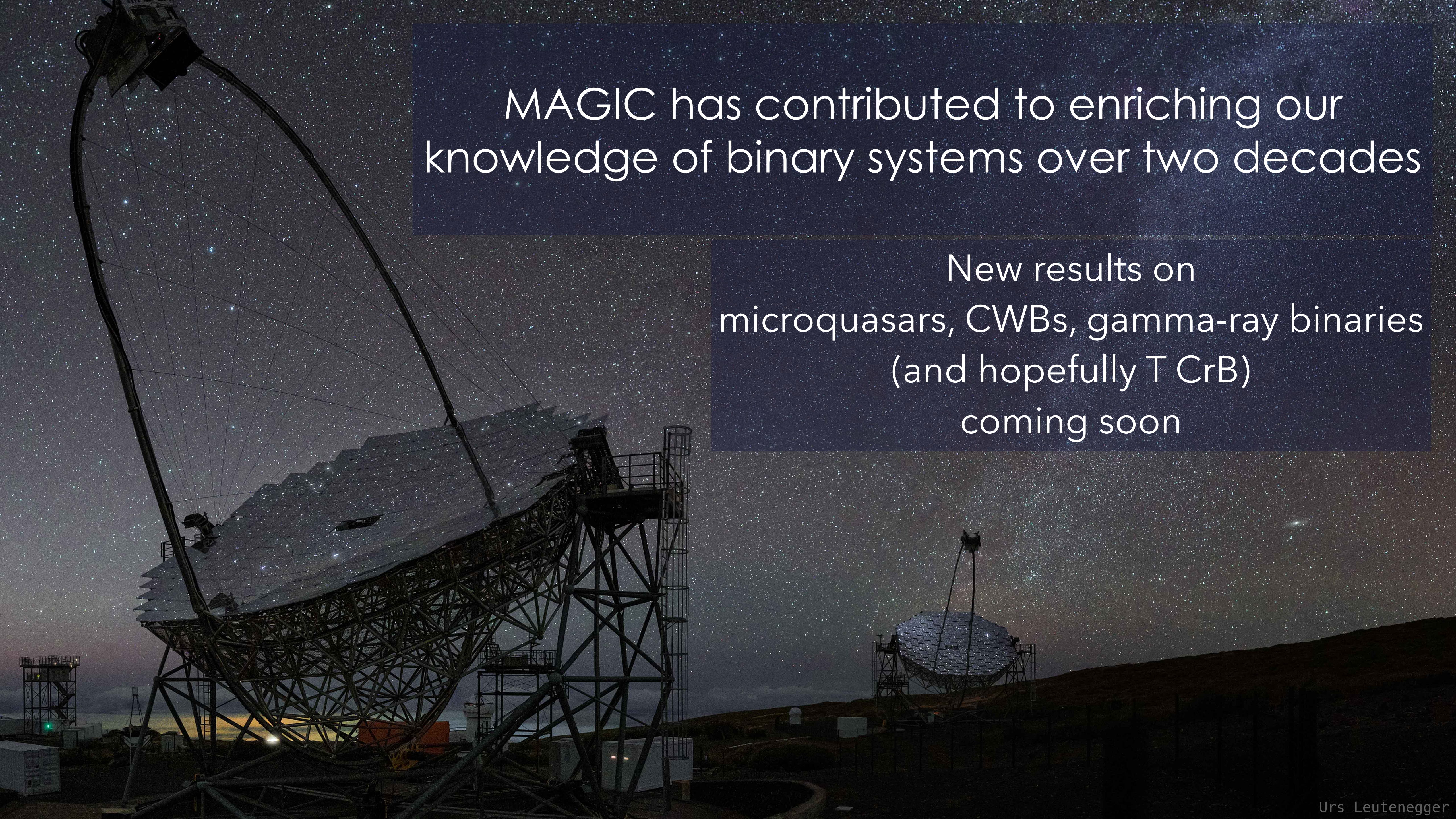


- Periastron passage: November 2024



WR 140: 2024 periastron passage



A large radio telescope dish is shown at night, illuminated by its own lights. The dish is made of many small panels and is supported by a complex metal structure. In the background, another smaller dish is visible on a hill. The sky is dark and filled with stars.

MAGIC has contributed to enriching our
knowledge of binary systems over two decades

New results on
microquasars, CWBs, gamma-ray binaries
(and hopefully T CrB)
coming soon



MAGIC view on binary systems

Alicia López Oramas
(Instituto de Astrofísica de Canarias)
for the **MAGIC Collaboration**

Thanks

✉ alicia.lopez@iac.es

Antonio González



EXCELENCIA
SEVERO
OCHOA



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MINISTERIO
DE CIENCIA
E INNOVACIÓN



Financiado por
la Unión Europea
NextGenerationEU



Plan de Recuperación,
Transformación
y Resiliencia



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