Universidad de La Laguna
GOBIERNO DE ESPAÑA
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AGENCIA ESTATAL DE INVESTIGACIÓN

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)

MAGIC Major Atmospheric Gamma Imaging Cerenkov Telescopes

Variable Galactic Gamma-Ray Sources VII
Barcelona, 6 May 2025

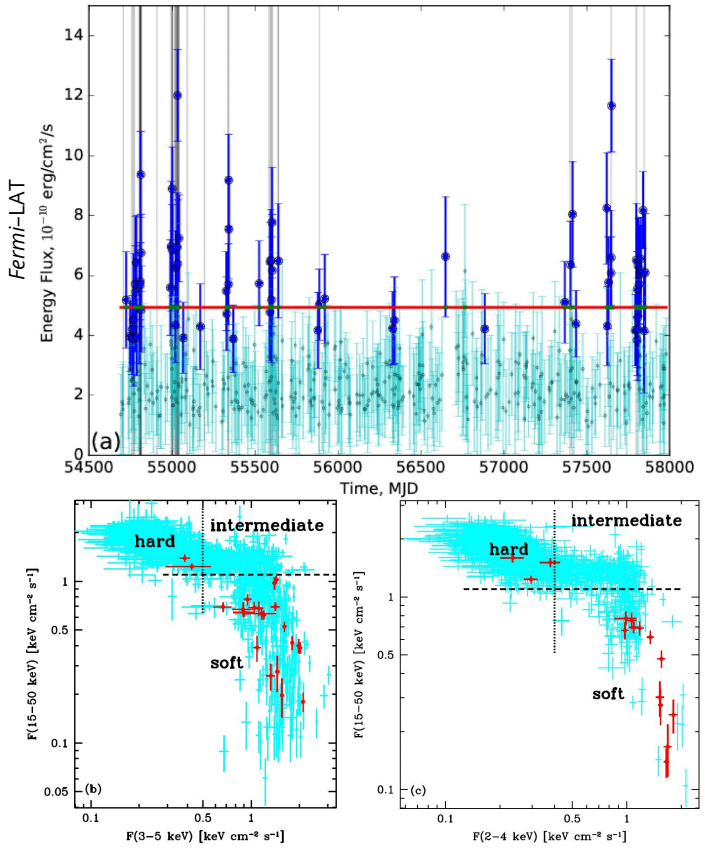
Introduction: Microquasars in gamma rays

Source	HE (0.1 - 100 GeV)	VHE (0.1 - 100 TeV)	UHE (> 100 TeV)	Comments
Cygnus X-1	Yes	4.1σ excess	No	VHE excess in a single observation night. 4.0σ hint above 25 TeV with LHAASO.
Cygnus X-3	Yes	No	No?	UHE emission from a region compatible with the source position.
GRS 1915+105	Yes	No	Yes	Different emitting regions for each energy range.
MAXI J1820+070	No	No	Yes	
SS 433	Yes	Yes	Yes	Different emitting regions for each energy range. Emission far from the binary, except for UHE.
V404 Cygni	4.5σ excess?	No	No	Updated *Fermi*–LAT analysis shows no excess.
V4641 Sgr	No	Yes	Yes	Emission far from the binary.

Acero+09, Aleksić+10, Archambault+13, Loh+16, Ahnen+17, Piano+17, Abeysekara+18, Fang+20, Abe+22, Harvey+22, LHAASO+23, H.E.S.S.+24, Dmytriiev+24, LHAASO+24, Martí-Devesa+24

Introduction: Cygnus X-3

- Cyg X-3 is a **high-mass microquasar** with a black hole or neutron star and a ~11 $M_\odot$ Wolf-Rayet companion. Zdziarski+13, Koljonen+17
  - Distance: 9.7 ± 0.5 kpc Reid+23
  - Orbital period: 4.792354 ± 0.00001 h Parsignault+76
- Consistently detected at HE, mostly during a **soft X-ray state**. e.g. Zdziarski+18
- HE and radio flares are regularly observed when the source is in the **soft state**.
- **No confirmed detection at VHE or UHE**.



Zdziarski+18

Introduction: The MAGIC telescopes

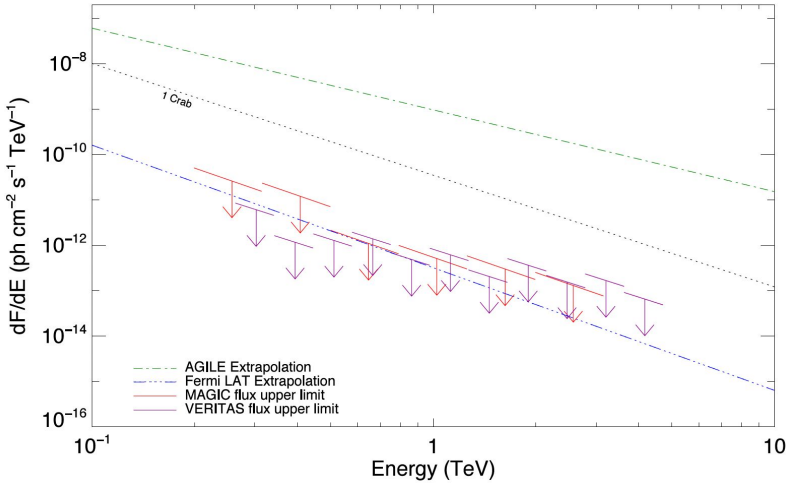
- Two 17-m Cherenkov telescopes located in the Canary island of La Palma, Spain.
- Photomultiplier cameras with a **~3.5º FoV**.
- Energy range: **~30 GeV – 100 TeV**
- Differential sensitivity at hundreds of GeV **below 2% of the Crab Nebula flux in 50h**.
- Energy resolution: **15 – 23%**
- Angular resolution: **~0.09º at 100 GeV**

Aleksić+16

https://magic.mpp.mpg.de/

Previous VHE observations

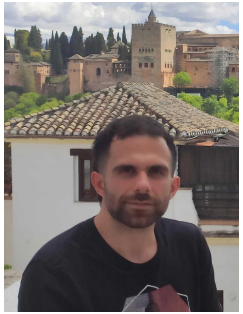
- MAGIC and VERITAS have been observing Cyg X-3 for several years. Publications:
  - MAGIC: **57h** after cuts, between 2006 and 2009 (**mono** data). Aleksic+10
  - VERITAS: **44h** after cuts, between 2007 and 2011. Archambault+13
- No detection or significant hints obtained.



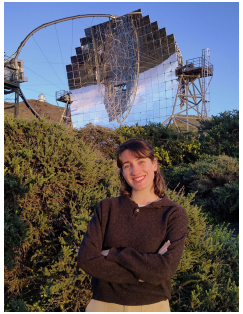
Archambault+13

New(er) VHE observations

- Further Cyg X-3 observations were performed with MAGIC between 2010 and 2024, for a total of 190h.
- After quality selection cuts, **132.2h** of data remain, spanning 12 years of data (2013 – 2024).
  - A **point-like** analysis is performed.
- A significant part of the observations were done **during flaring states at HE**.
- Huge effort by the analyzers.



Luis Barrios-Jiménez

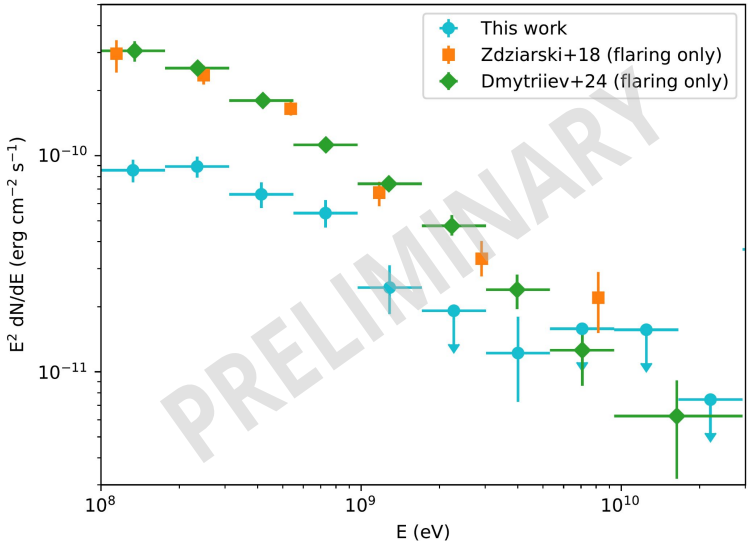


Mar Carretero-Castrillo

Year	Month	Obs. time (h)	Zenith angles (°)
2013	Nov	1.3	32 – 49
2014	May	6.6	15 – 40
	Jun	1.0	13 – 31
	Oct	4.8	11 – 53
2015	Jul	0.8	11 – 47
	Nov	1.3	32 – 47
2016	May	1.0	19 – 31
	Aug	9.6	11 – 45
	Sep	42.8	11 – 52
2018	Jul	2.1	11 – 37
	Aug	6.2	11 – 23
2019	Apr	1.0	38 – 50
	Jun	11.3	11 – 52
2020	Jun	4.4	11 – 25
	Jul	5	11 – 23
	Aug	3.2	11 – 30
	Sep	8.0	10 – 23
	Oct	1.9	22 – 44
2021	Apr	1.2	29 – 46
	Jun	1.9	28 – 51
2024	Apr	0.7	54 – 58
	Jun	2.0	22 – 50
	Jul	14.1	10 – 47
Total		132.2	10 – 58

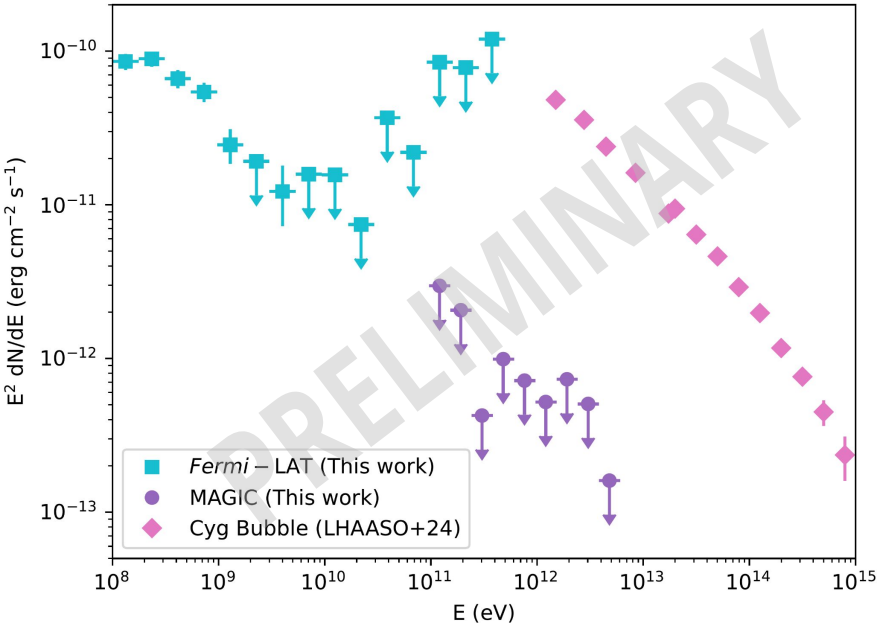
Results: SED – HE

- *Fermi*–LAT data **coincident with the MAGIC observations** were also analysed.
  - To have enough statistics, **daily time bins** centered at midnight UTC are used, for a total of 65 days of LAT data.
- Complex region that needs some care with the analysis.
- Our fluxes are a factor ~2 below those in the literature, which **only use flaring states**.
  - Discrepancies likely explained by **different datasets** and choice of analysis parameters.



Results: SED – VHE

- Still, **no detection at VHE**.
- MAGIC ULs are consistent with an extrapolation of the *Fermi*–LAT spectrum.
- Below 10 TeV, the contribution of Cyg X-3 to the Cygnus Bubble flux **has to be below ~1%**.
- Coming soon:
  - MAGIC VHE excesses seem to show some degree of **correlation with orbital phase and HE flaring state**. Detailed study on its way. Stay tuned!



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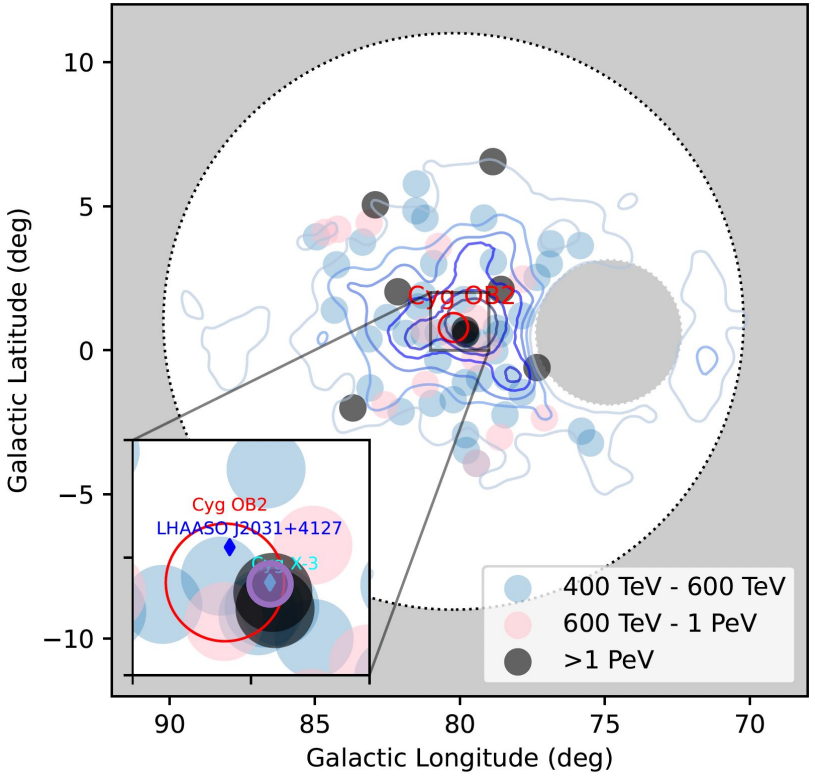
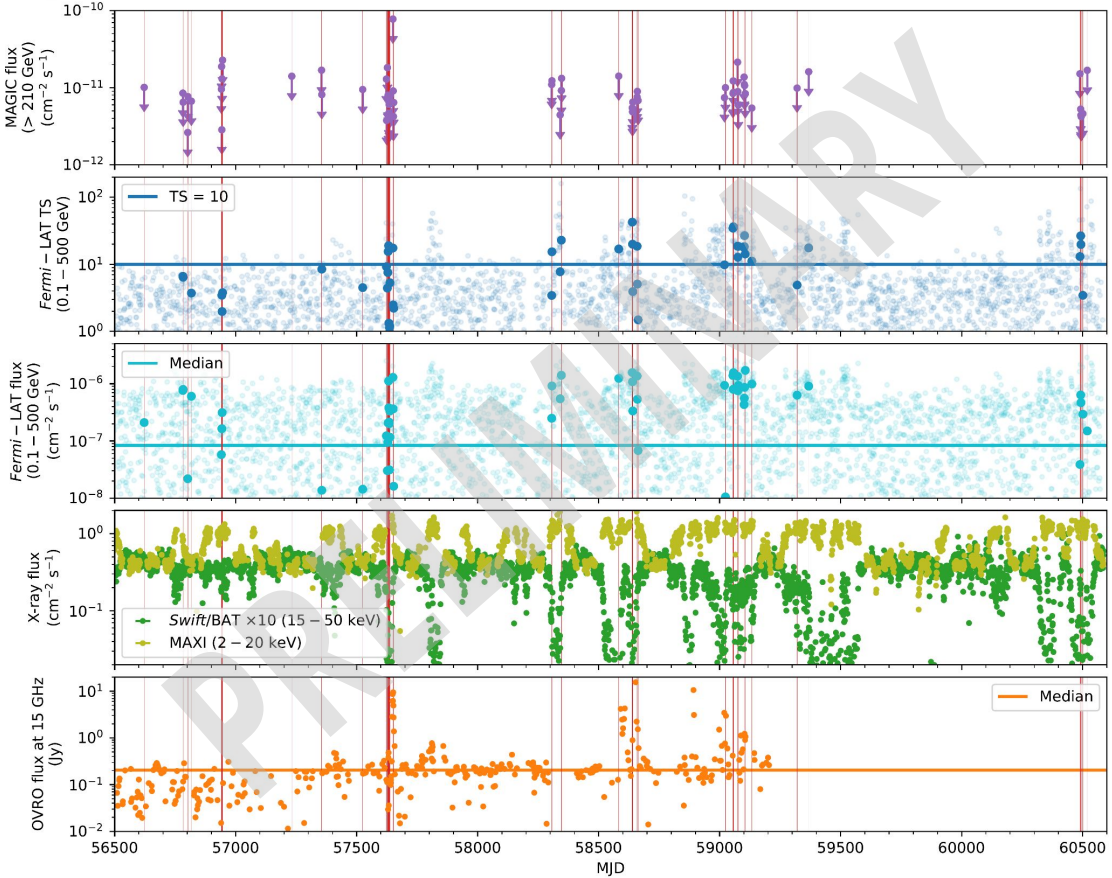


LHAASO+24

Results: Light Curve

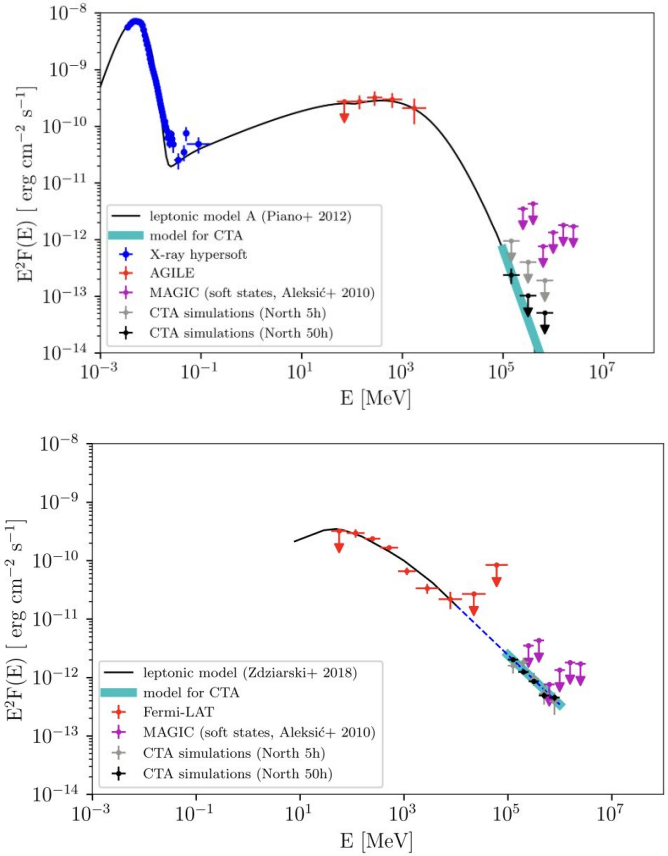
MAGIC observations



PRELIMINARY

Prospects with CTA

- Based on the HE data, a detection of Cyg X-3 in flare with CTA may be possible in a few (tens of) hours.
- Highly dependent on the assumed model, and in particular on the extrapolation of the HE flux to VHE.
- Alternatively, one may focus on the higher energies to bridge the gap with LHAASO.
    - High zenith angle observations?



Abe+24

Interpretation and summary

- Cyg X-3 is not detected after analyzing more than 130h of MAGIC observations.
- The non-detection may be explained by a high background “veiling” the emission of the source.
- MAGIC ULs are compatible with the *Fermi*-LAT spectrum, and limit to < 1% the contribution of Cyg X-3 to the LHAASO Bubble flux below 10 TeV.
- Excess hints are present during HE flares and changing with orbital phase.
- Stay tuned for a more detailed VHE study.

THANK YOU FOR YOUR ATTENTION

Edgar Molina
(emolina@iac.es)

in collaboration with:
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