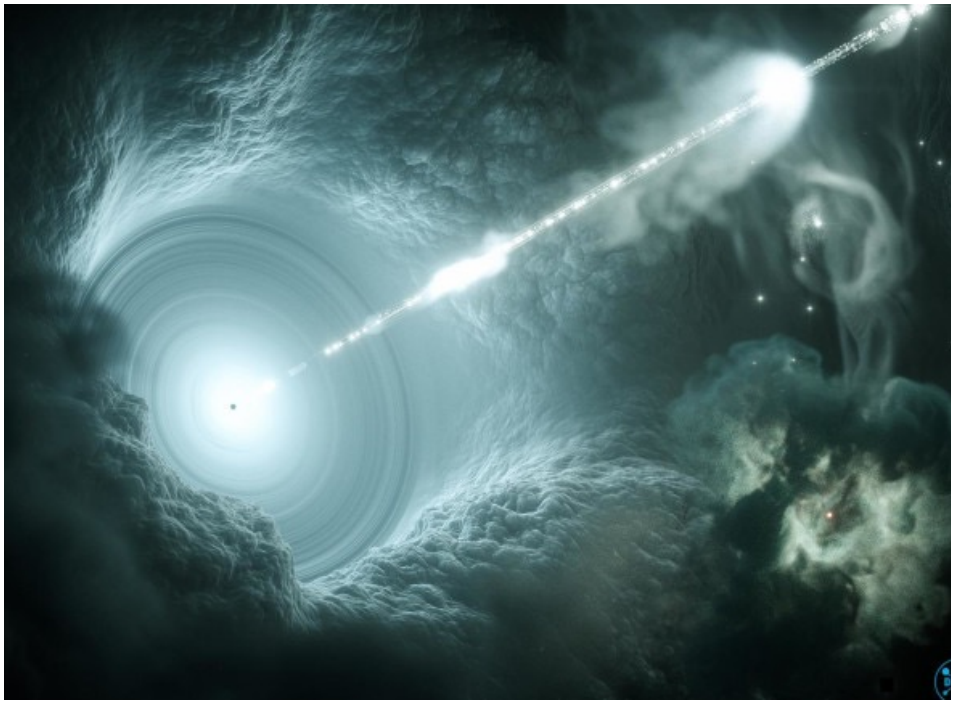
CTAO science perspective on black hole physics

2nd CTAO Science Symposium – Bologna 15-18 April 2024

Elisa Prandini elisa.prandini@unipd.it

Outline

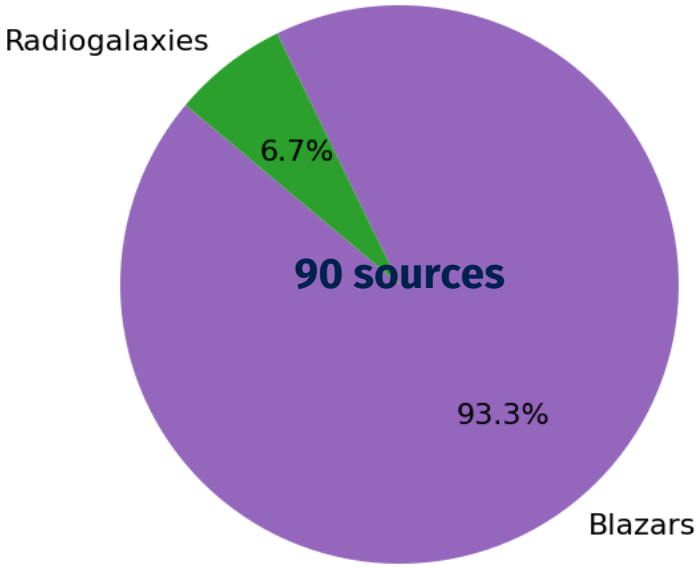


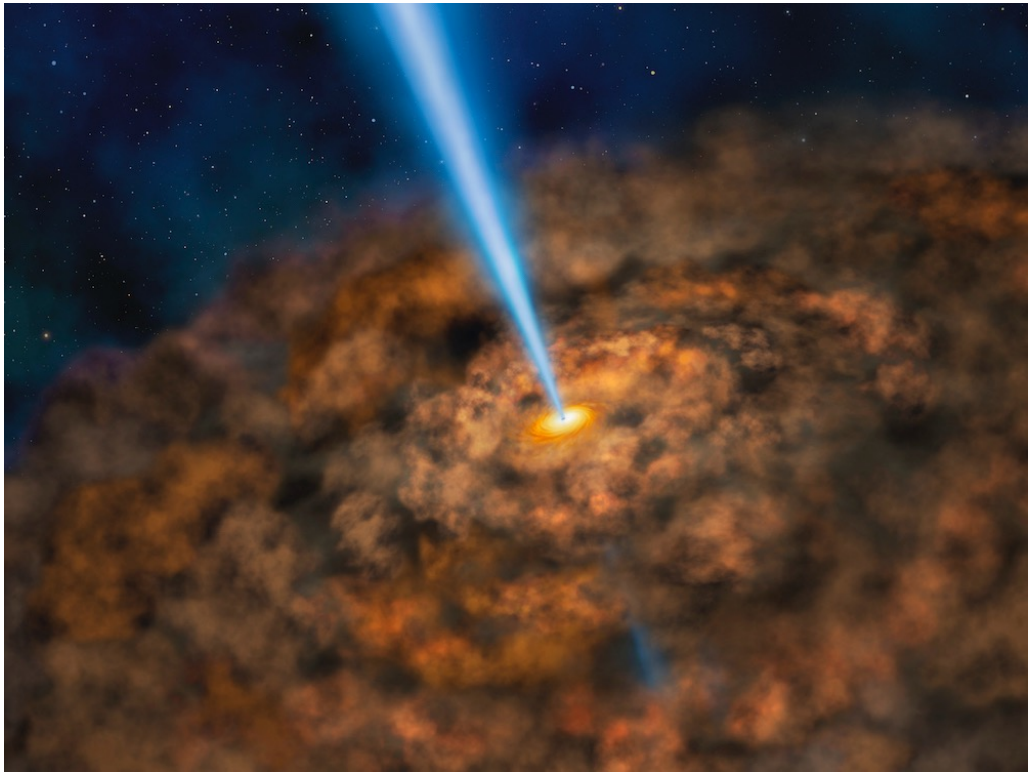
Focus on blazars: selected recent results and studies

- Towards a TeV blazar sequence
  - CTAO Extragalactic survey
- Variability at different scales
  - AGN monitoring and flares

TeV-detected extragalactic black holes

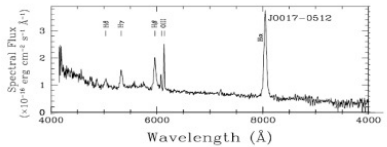
From TeVCAT
http://tevcat2.uchicago.edu/

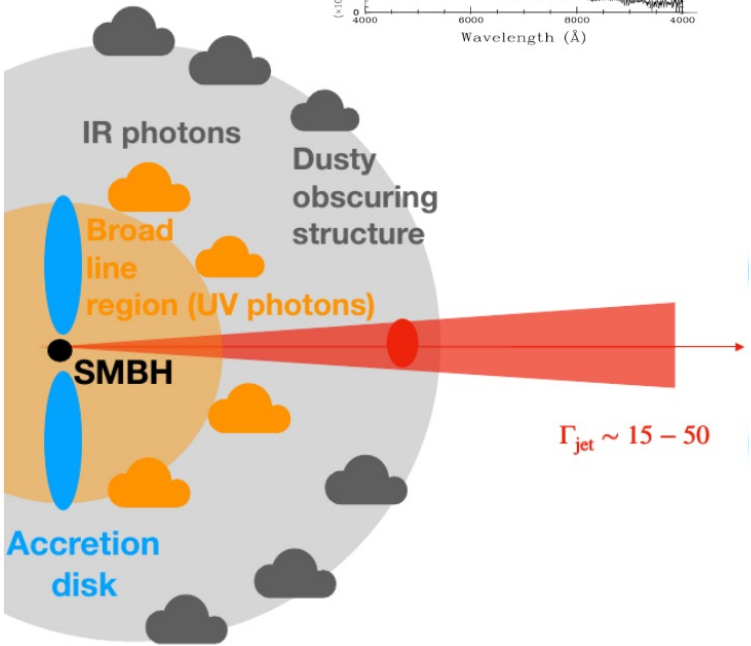




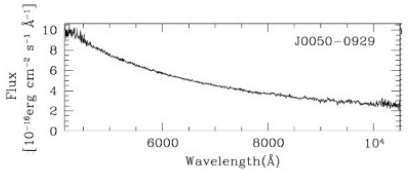
TeV-detected blazars dichotomy

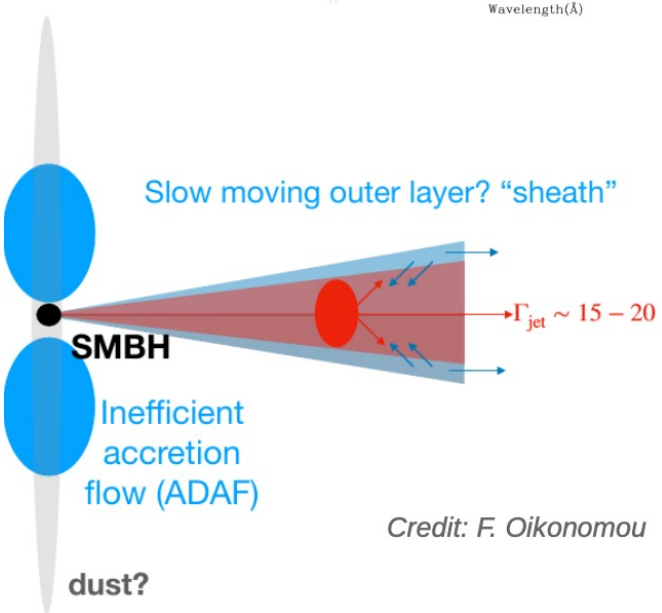
FSRQs





BL Lacs



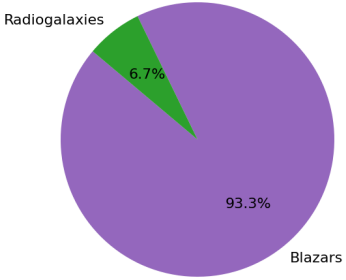


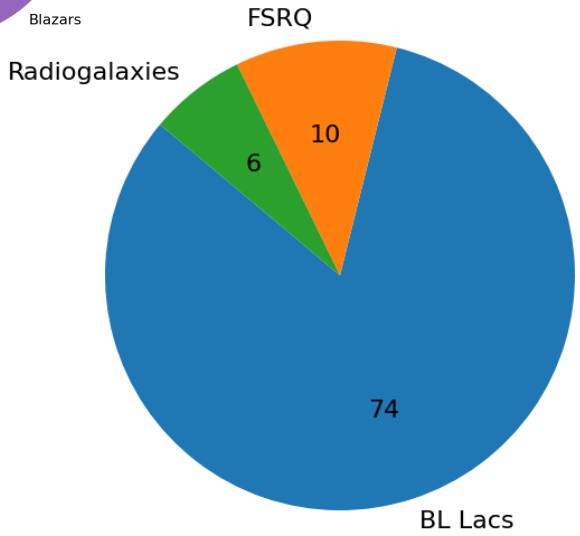
From https://www2.mpia-hd.mpg.de/jets2021/Petropoulou_slides.pdf

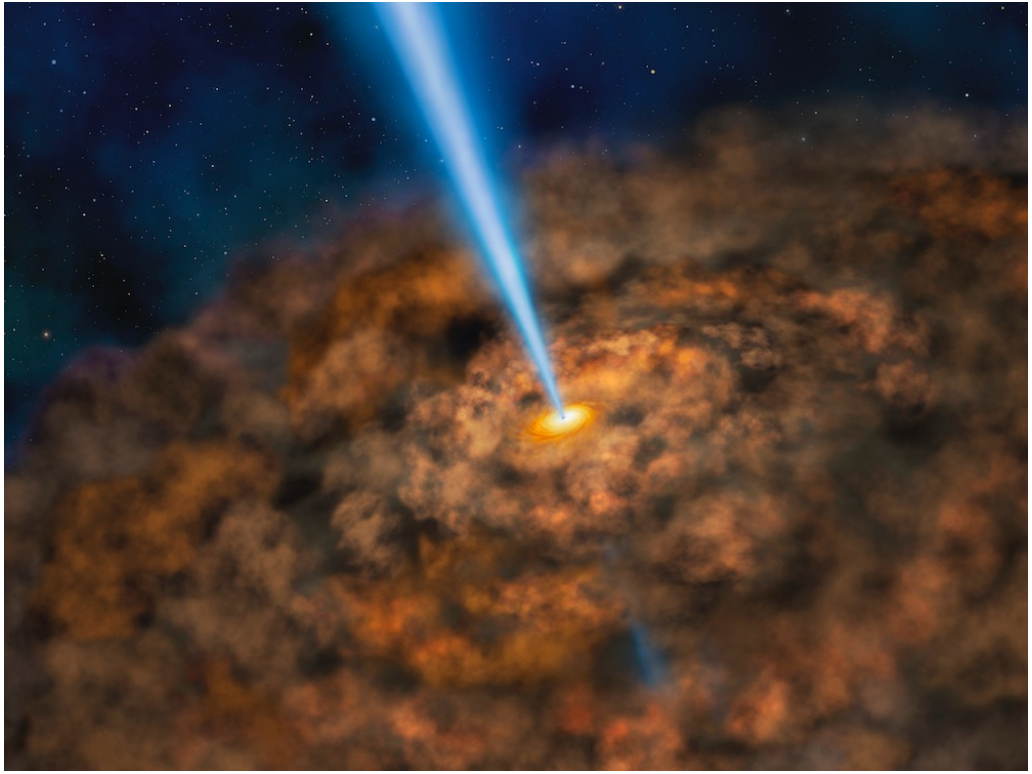
See poster by P. Goldoni Redshift Measurement of Gamma-Ray Blazars for the Cherenkov Telescope Array

TeV-detected extragalactic black holes

From TeVCAT
http://tevcat2.uchicago.edu/



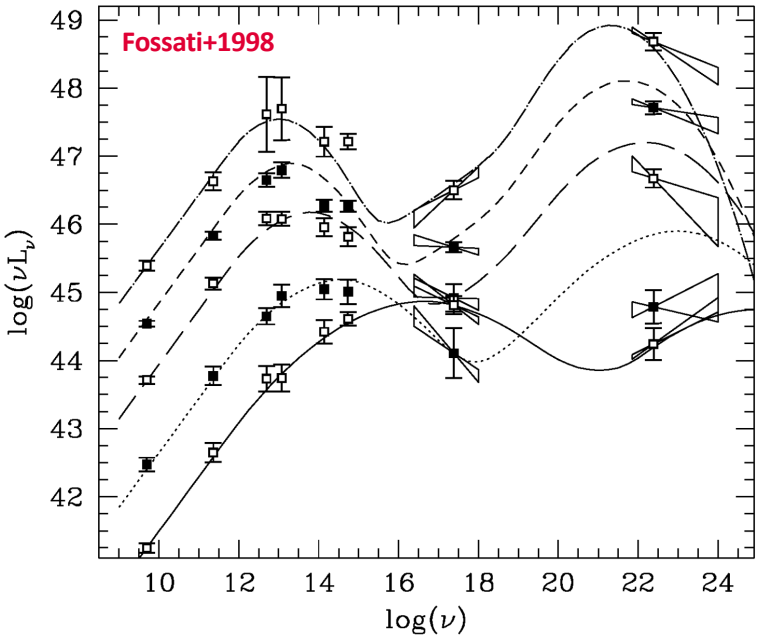




cherenkov telescope array

The TeV blazar population

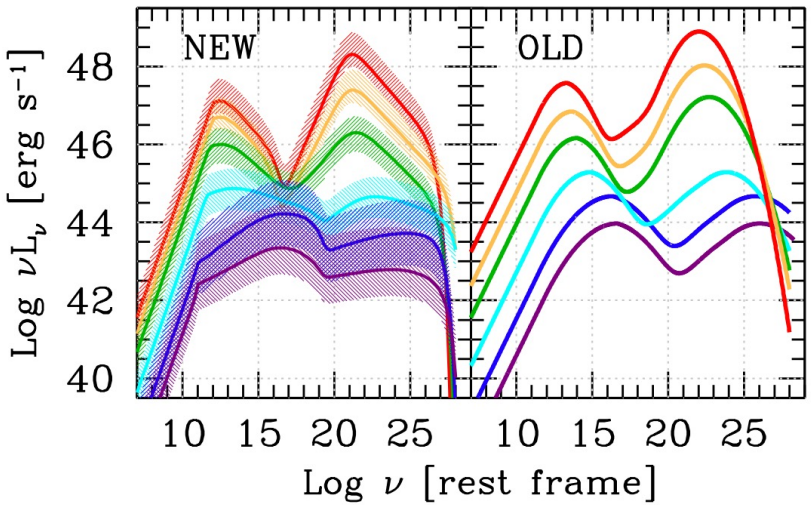
Towards a TeV-blazar sequence



- Anti-correlation between **synchrotron peak** location and radio **luminosity** (Fossati+1998)
  - Debated (Giommi 2012, Potter and Cotter 2015, Fan 2017, Keenan+ 2021, Wan+ 2024)

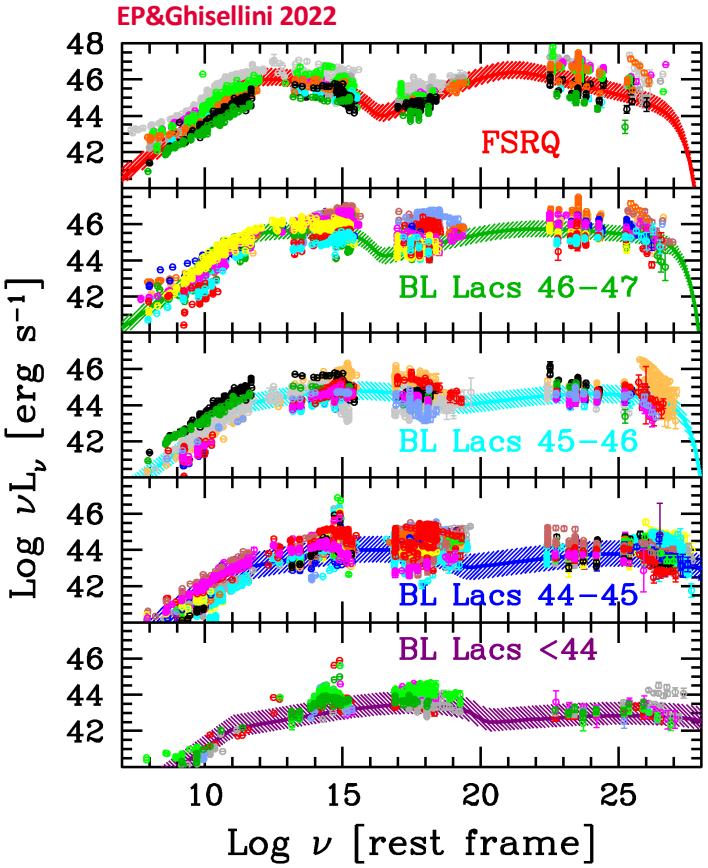
Towards a TeV-blazar sequence

Ghisellini+ 2017



- Anti-correlation between **synchrotron peak** location and radio **luminosity** (Fossati+1998)
  - Debated (Giommi 2012, Potter and Cotter 2015, Fan 2017, Keenan+ 2021, Wan+ 2024)
- Fermi-blazar sequence (Ghisellini+2017):
  - Bins in *Fermi*-LAT luminosity
  - FSRQs: synchro peak stable
  - BL Lacs: synchro peak anticorrelates with luminosity

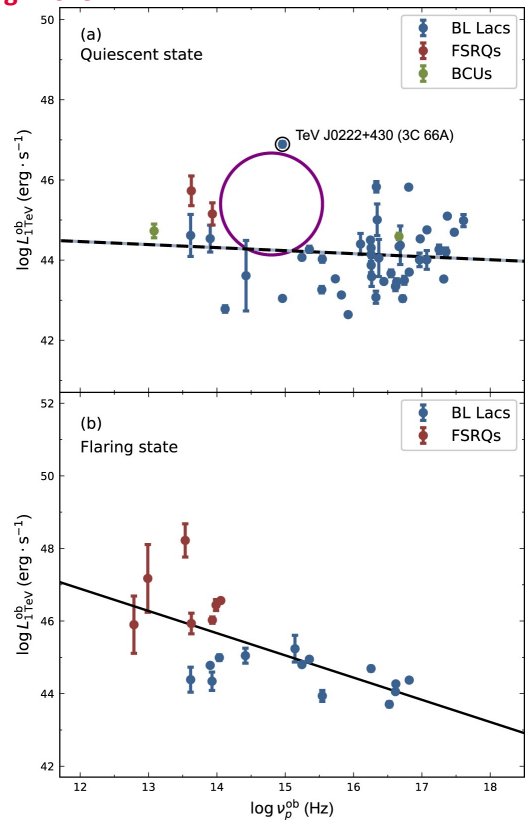
Towards a TeV-blazar sequence



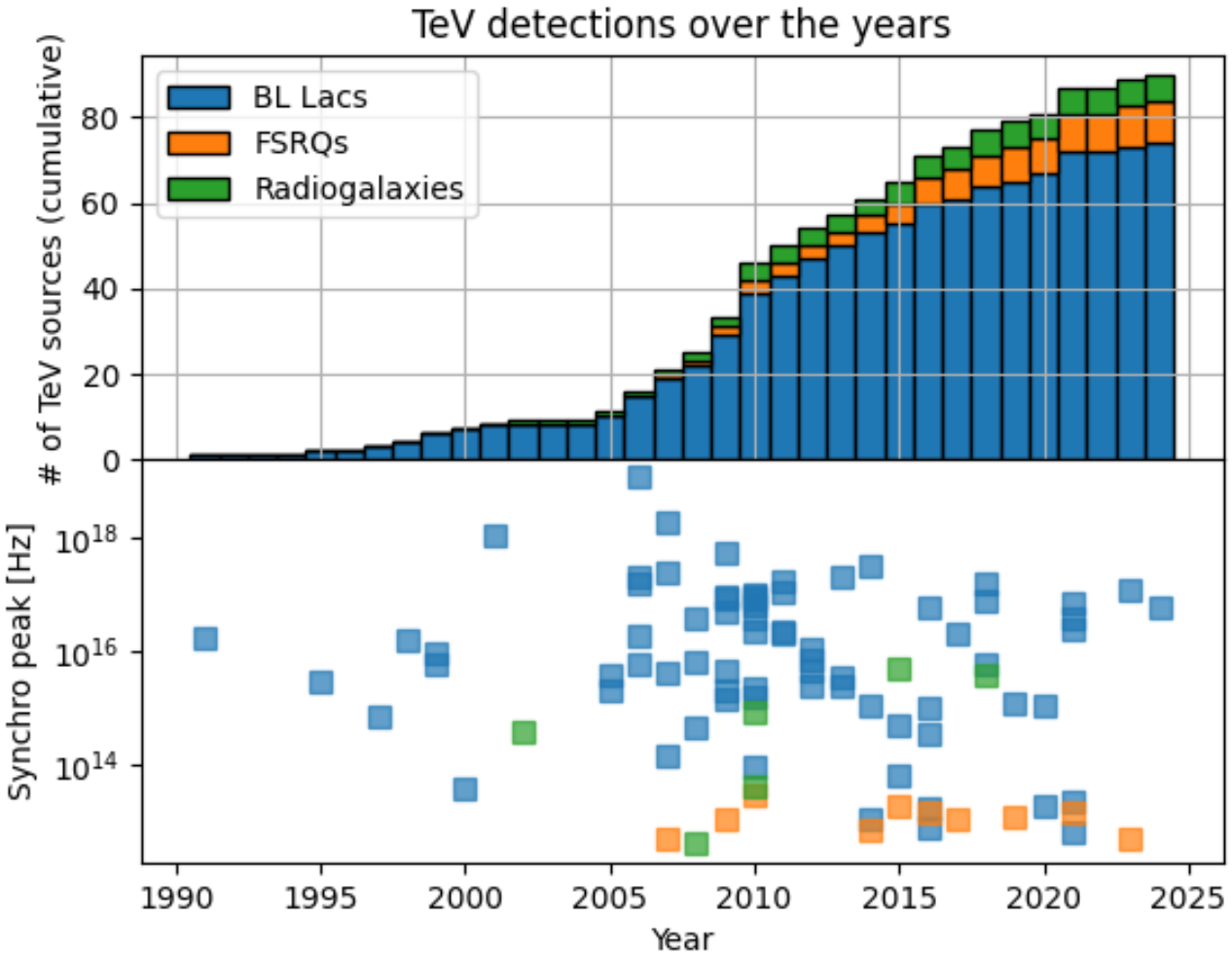
- Anti-correlation between **synchrotron peak** location and radio **luminosity** (Fossati+1998)
  - Debated (Giommi 2012, Potter and Cotter 2015, Fan 2017, Keenan+ 2021, Wan+ 2024)
- Fermi-blazar sequence (Ghisellini+2017):
- TeV blazar sequence (EP&Ghisellini 2022)
  - No strong differences between the SED of *Fermi* blazars and TeV-detected ones
  - X-ray luminosity is generally larger than the average of the *Fermi* blazars

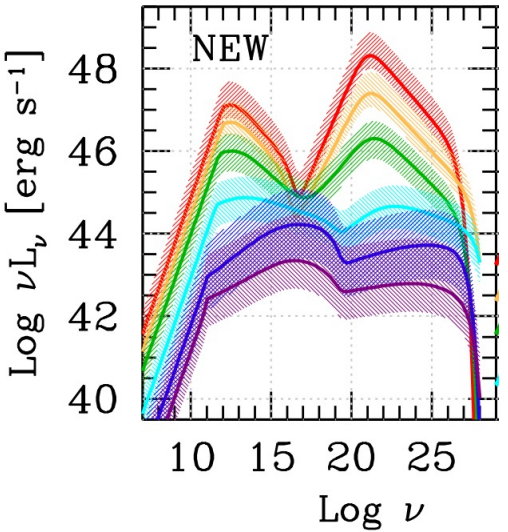
Towards a TeV-blazar sequence

Ouyang+ 2023



- Anti-correlation between **synchrotron peak** location and radio **luminosity** (Fossati+1998)
  - Debated (Giommi 2012, Potter and Cotter 2015, Fan 2017, Keenan+ 2021, Wan+ 2024)
- Fermi-blazar sequence (Ghisellini+2017):
- TeV blazar sequence (EP&Ghisellini 2022)
  - No strong differences between the SED of *Fermi* blazars and TeV-detected ones
  - X-ray luminosity is generally larger than the average of the *Fermi* blazars
- TeV luminosity and variability (Ouyang+ 2023)
  - Anticorrelation only in sources during flaring states

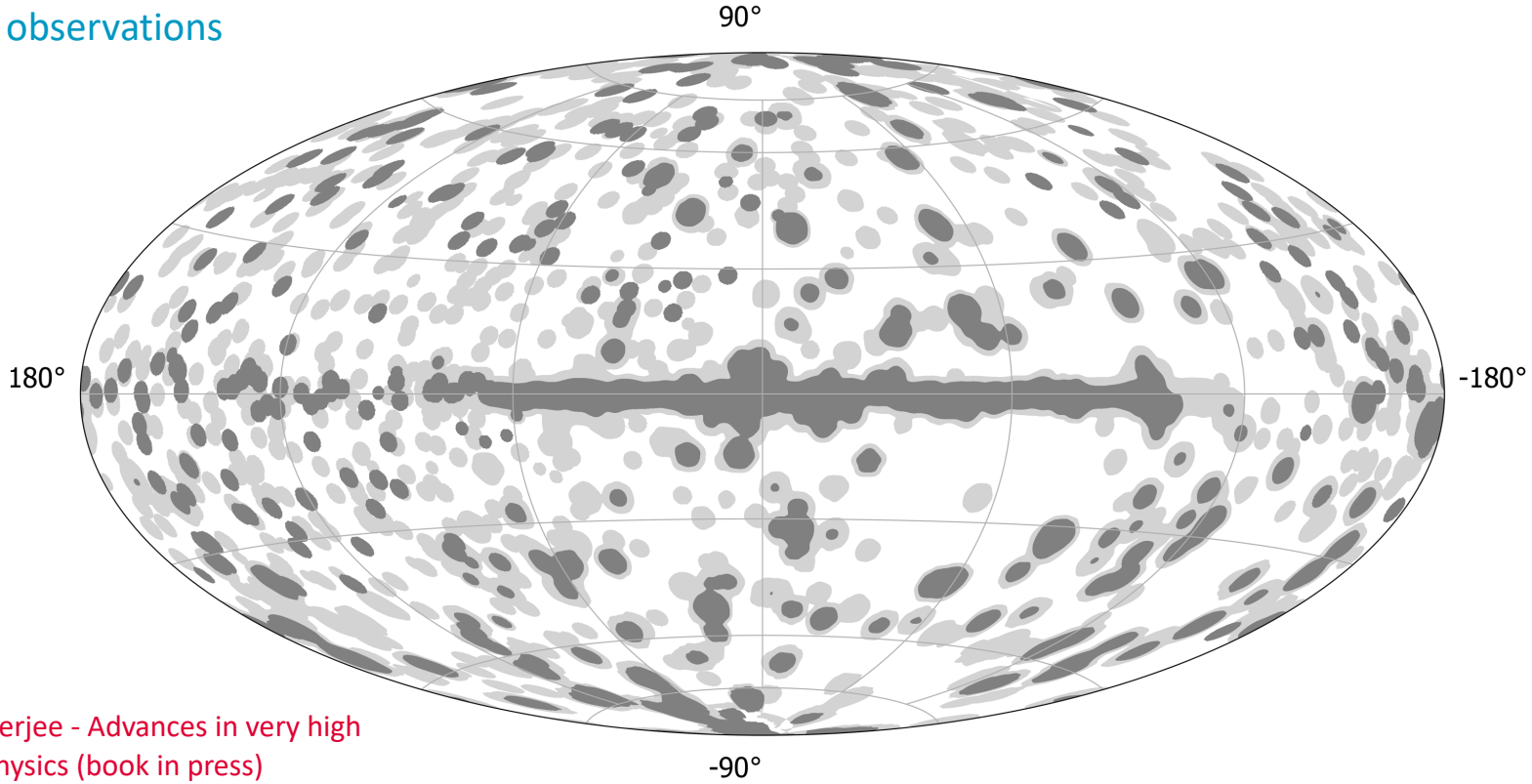




Righi, Prandini, Viale, Bovolon in prep.

Current generation of IACTs: exposure

The current knowledge of the TeV sky is strongly **biased** by a highly non-uniform coverage in the observations

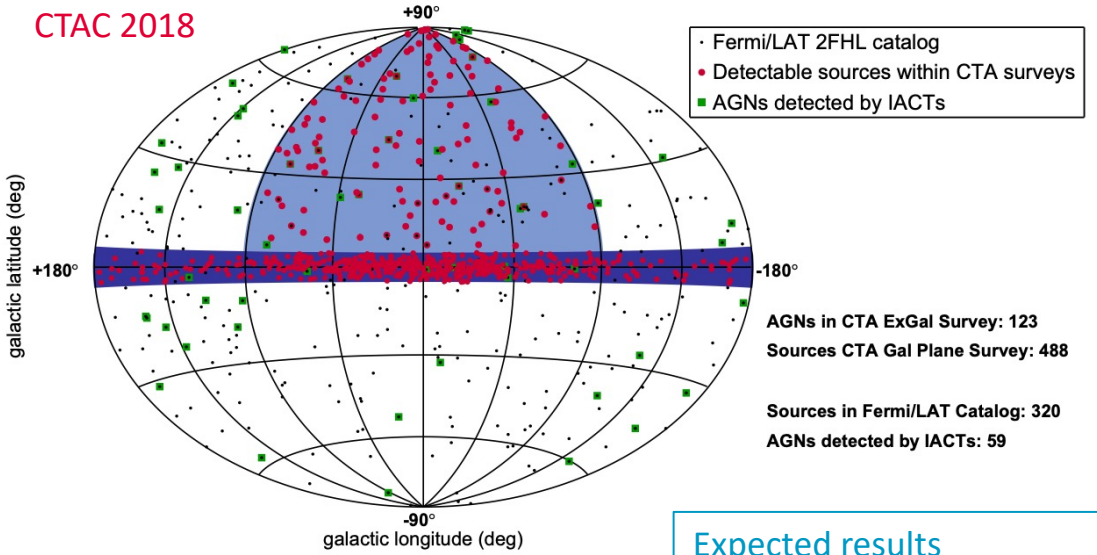


Zanin & Mukherjee - Advances in very high energy astrophysics (book in press)

The extragalactic survey

- Consists of a **survey** with uniform exposure of a contiguous portion of the extragalactic sky
- From the '*Science with CTA*' book:
  - **¼** of the sky
  - **6 mCrab** of integral sensitivity E>125 GeV
- These values and observation strategy could be revised by the CTAC team

CTAC 2018



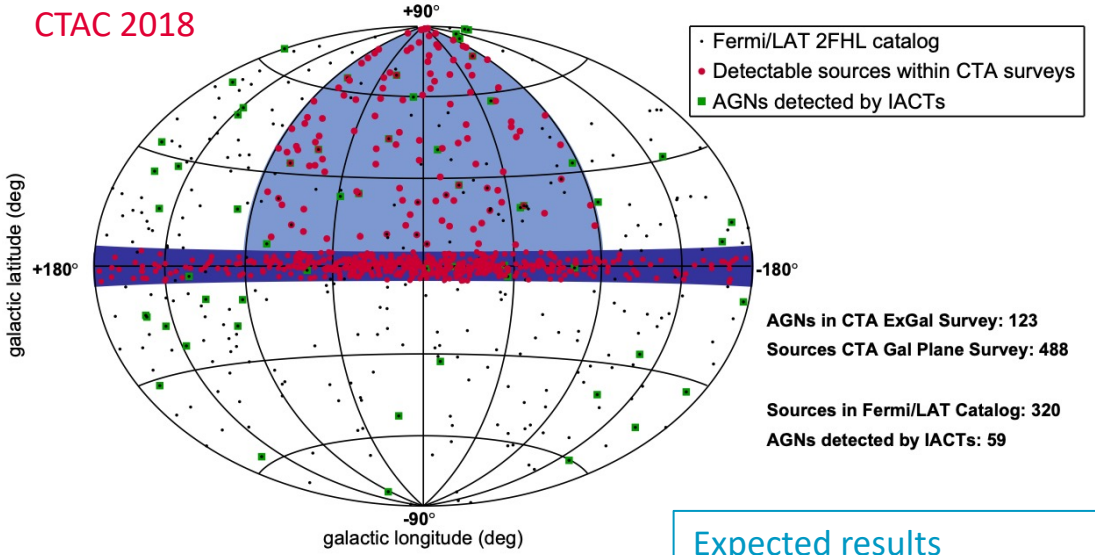
Expected results

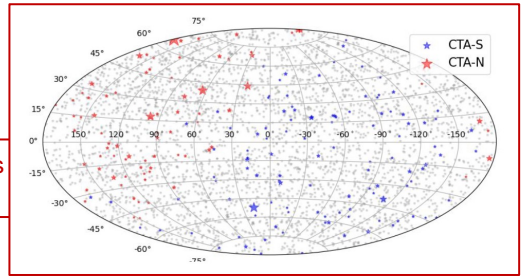
- 1st unbiased VHE catalog
- LogN/LogS
- Serendipitous discoveries
- Variable sources

The extragalactic survey

- Consists of a **survey** with uniform exposure of a contiguous portion of the extragalactic sky
- From the '*Science with CTA*' book:
  - **¼** of the sky
  - **6 mCrab** of integral sensitivity E>125 GeV
- These values and observation strategy could be revised by the CTAC team

CTAC 2018





See Poster By A. Acharyya: Active Galactic Nuclei population studies with the Cherenkov Telescope Array Observatory

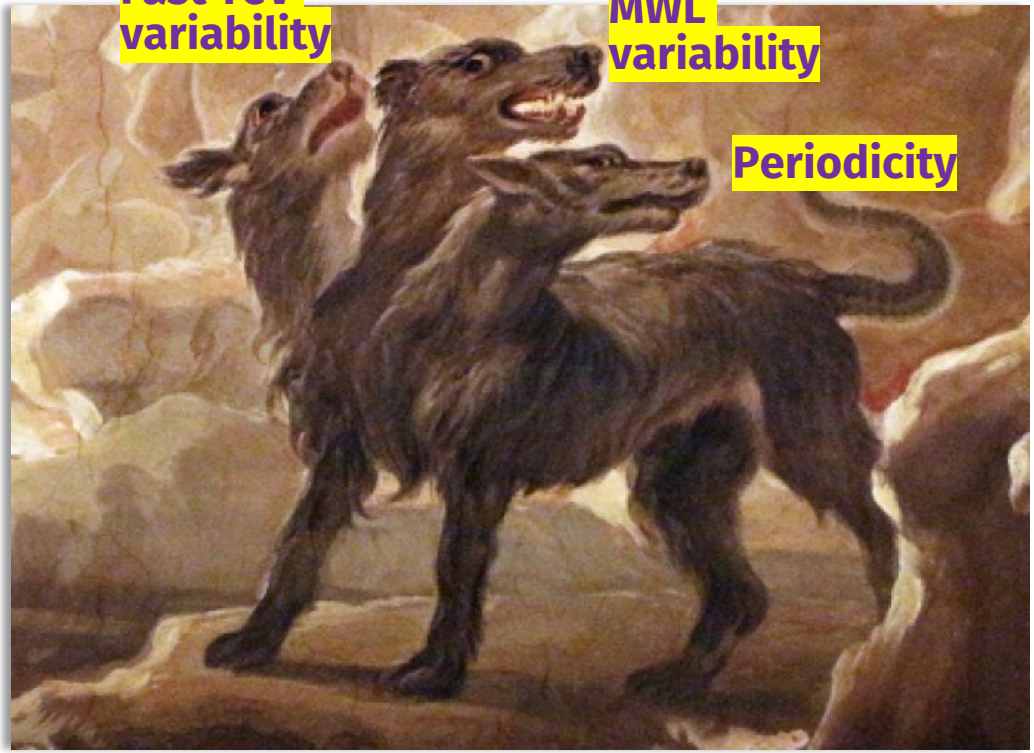
Expected results

- 1st unbiased VHE catalog
- LogN/LogS
- Serendipitous discoveries
- Variable sources

cherenkov telescope array

Blazar variability

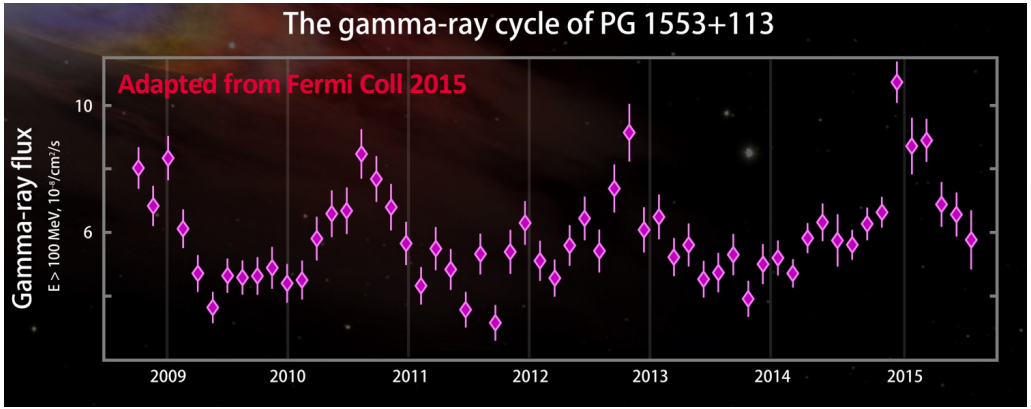
Variability studies



Cerbero the three heads dog from 'Divina Commedia' by Dante Alighieri (1265 – 1321)

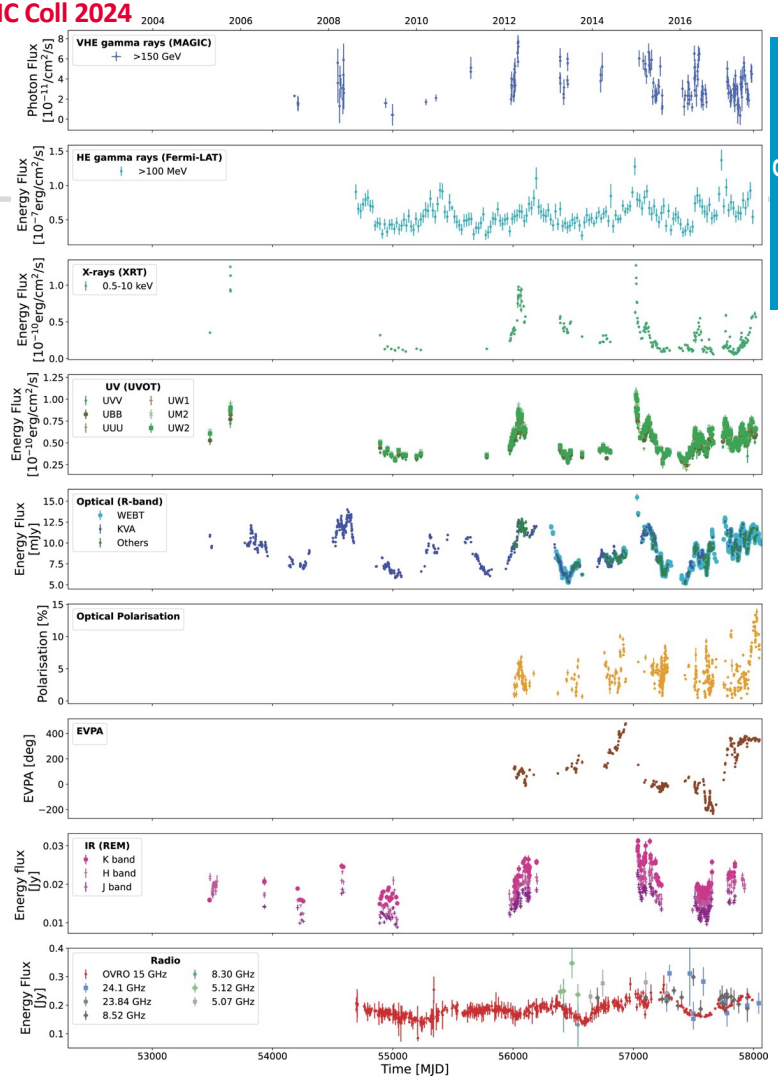
Search for periodicity in PG 1553+113 with MAGIC

- The HBL PG 1553+113 is located at z~0.4 (Dorigo Jones 2021)
- **2.2y periodicity** in *Fermi*-LAT and, possibly, in optical
- Monitored regularly with MAGIC since 2015



MAGIC Coll 2024

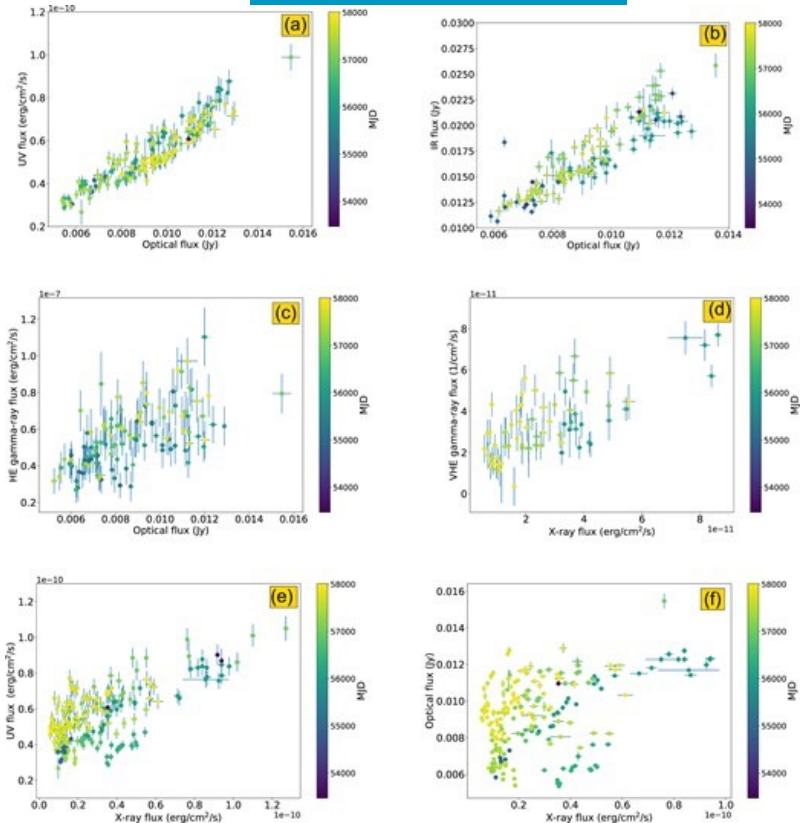
MWL lightcurve



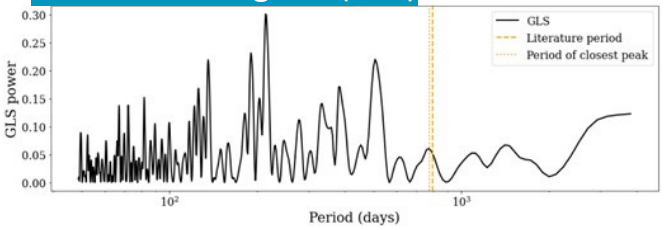
Search for periodicity in PG 1553+113 with MAGIC

MAGIC Coll 2024

Intra-band correlations

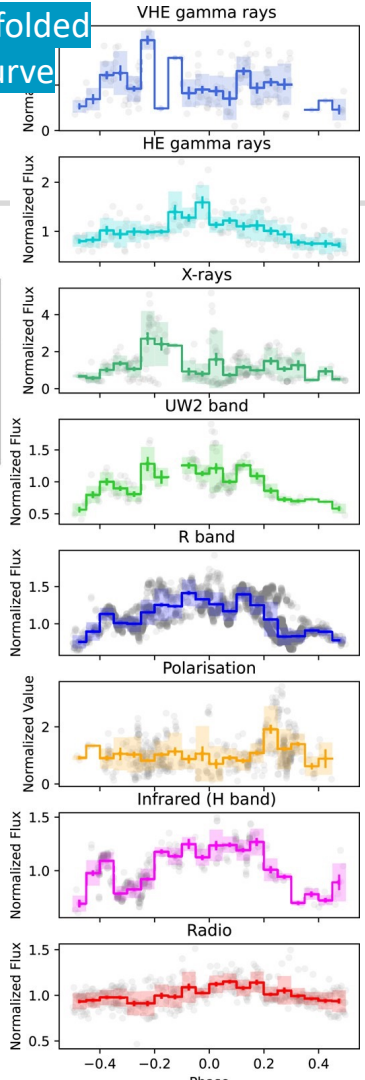


MAGIC Periodgram (GLS)



- **No periodicity** in VHE gamma rays and X-rays, confirmed periodicity in HE gamma rays
- Intra-band correlations: complex interplay between bands
  - Multiple zone emission model

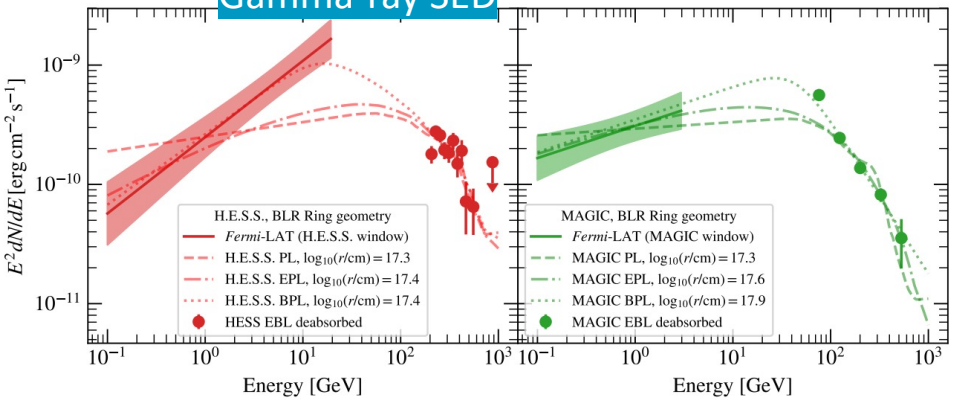
MWL folded lightcurve



FSRQ PKS 1510-089: intranight variability (in the currently best monitored FSRQ)

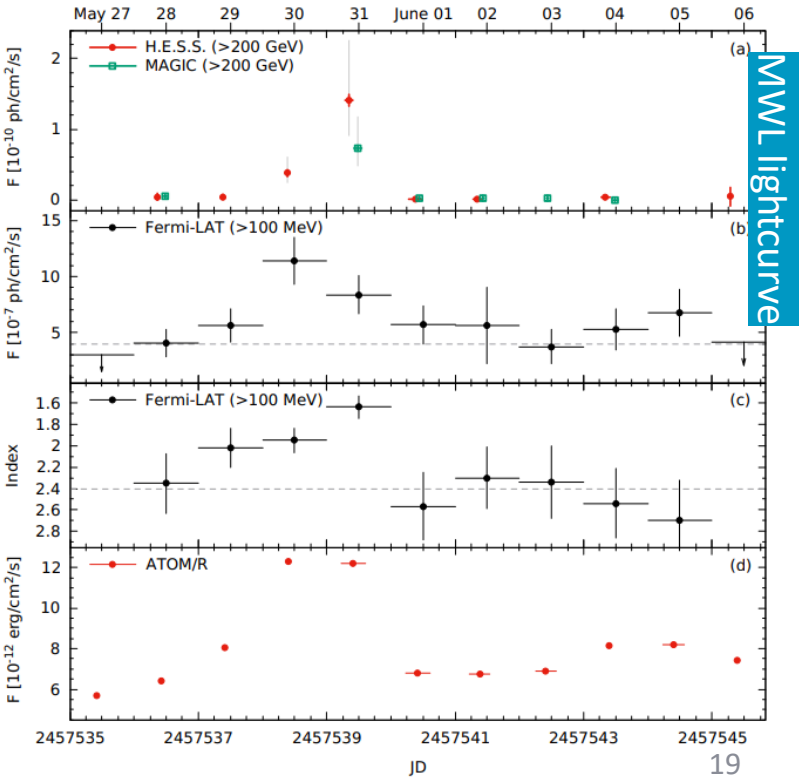
- PKS 1510-089 is the only FSRQ detected at TeV both in low and high-state
- H.E.S.S. and MAGIC: during regular **monitoring** in 2016, found a common intra–night variability timescale of **1.5hr**
- Combined with radio and MWL observations: **emission constrained outside the BLR**

Gamma-ray SED



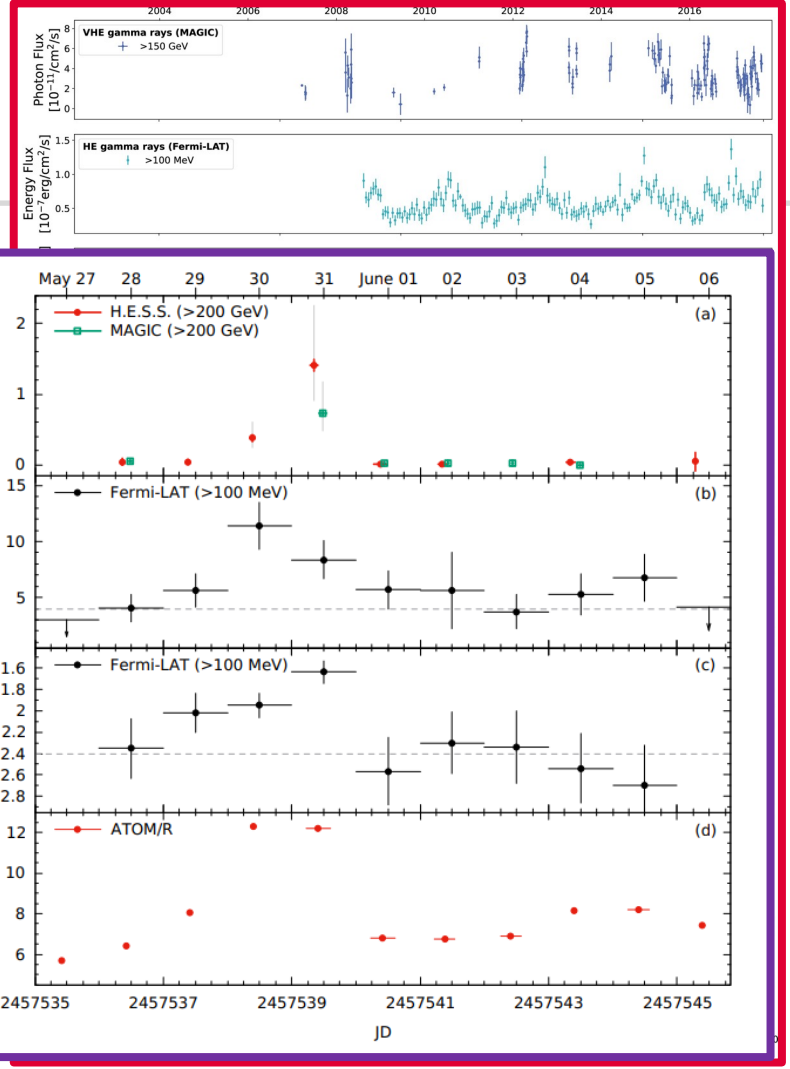
H.E.S.S. and MAGIC Coll. 2021

MWL lightcurve



Source monitoring with CTAO

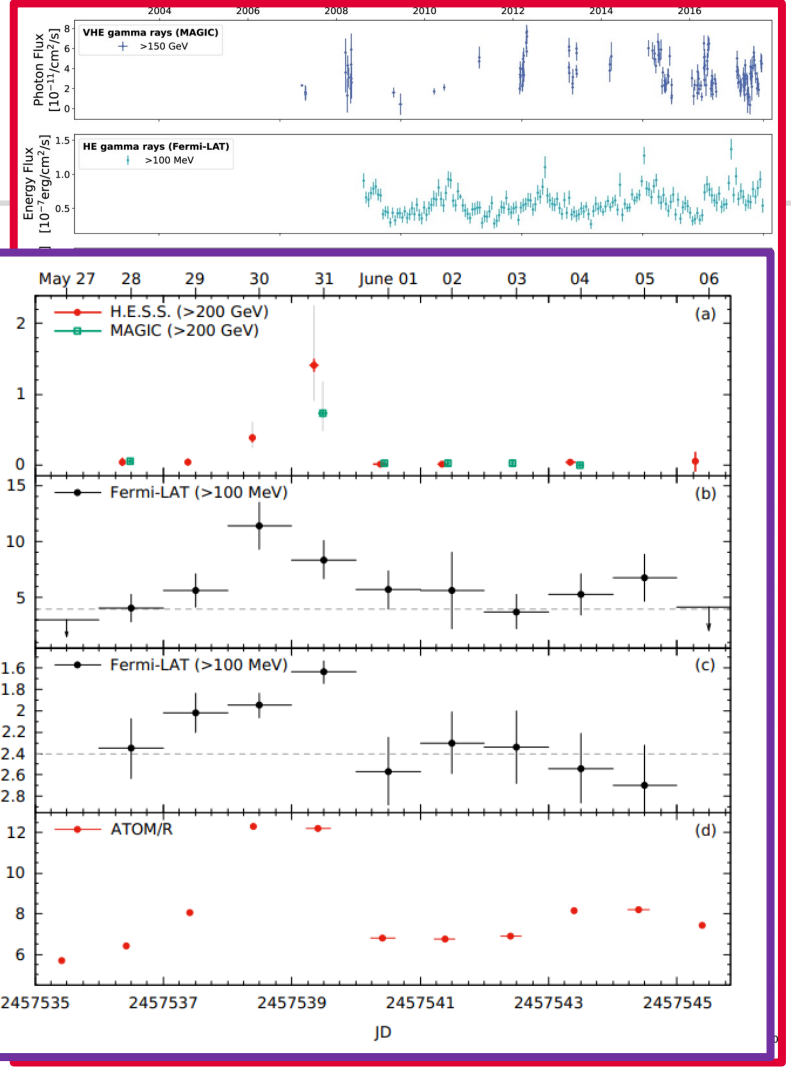
- Part of the AGN KSP: monitoring of selected sources, covering different source classes and variability patterns
- Regular sampling and unprecedented sensitivity
  - Extremely accurate and unbiased correlation studies
  - Precise SED modeling
  - Intranight variability



Source monitoring with CTAO

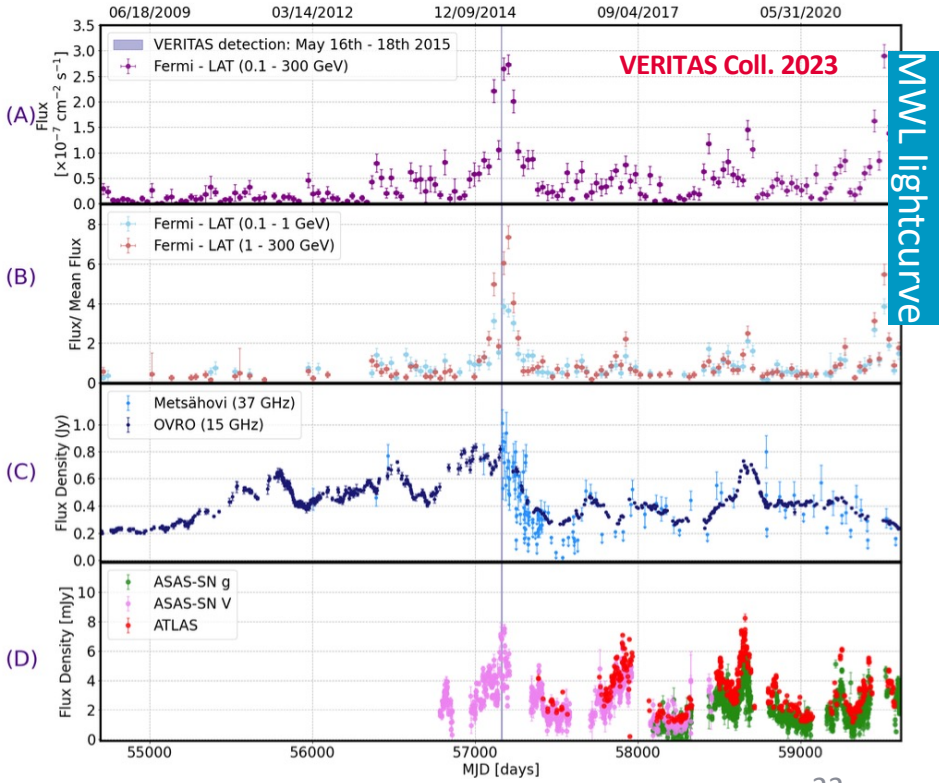
- Part of the AGN KSP: monitoring of selected sources, covering different source classes and variability patterns
- Regular sampling and unprecedented sensitivity
  - Extremely accurate and unbiased correlation studies
  - Precise SED modeling
  - Intranight variability

Require MWL coverage and simultaneity



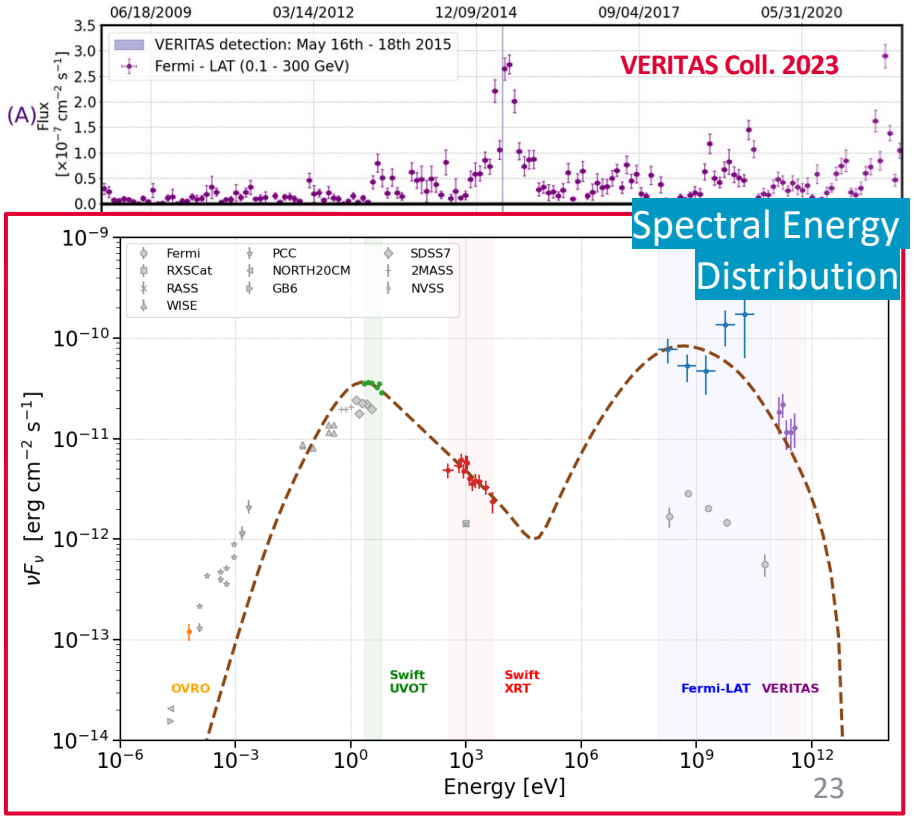
Detection of rare VHE emitters during MWL flares

- IBL source S3 1227+25 located at redshift 0.325 (debated)
- *Fermi*-LAT hard state **triggered** VERITAS observations and detection
- MWL campaign initiated
- Fast variability of timescale 6.2 hours
  - Compact region



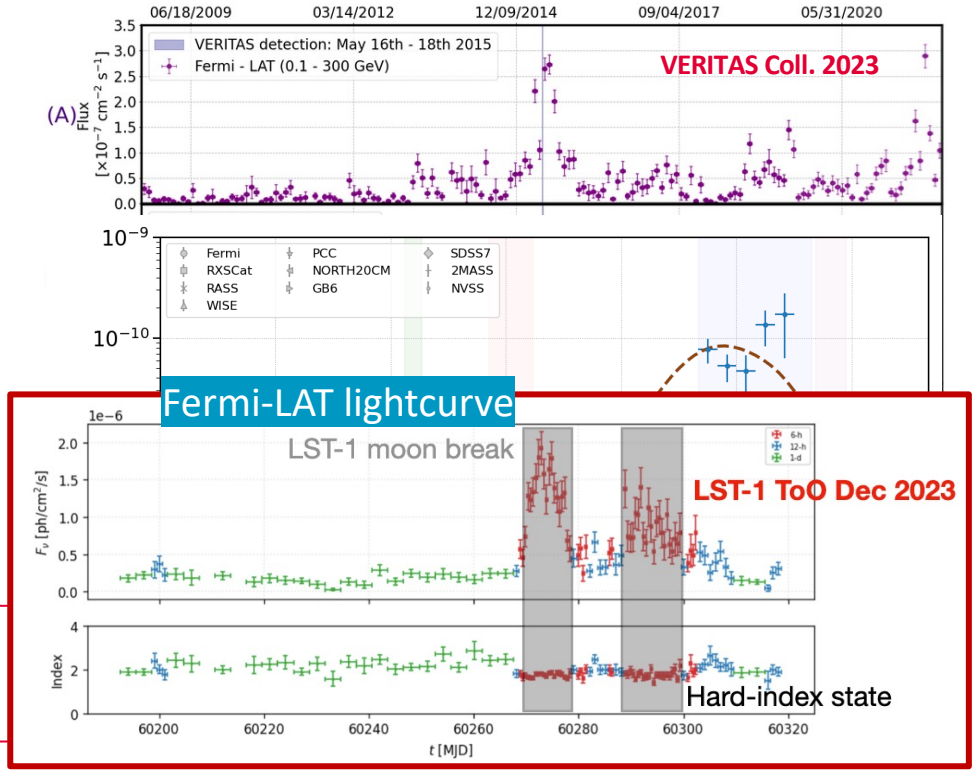
Detection of rare VHE emitters during MWL flares

- IBL source S3 1227+25 located at redshift 0.325 (debated)
- *Fermi*-LAT hard state **triggered** VERITAS observations and detection
- MWL campaign initiated
- Fast variability of timescale 6.2 hours
  - Compact region
- SED well fitted by a single-zone SSC model



Detection of rare VHE emitters during MWL flares

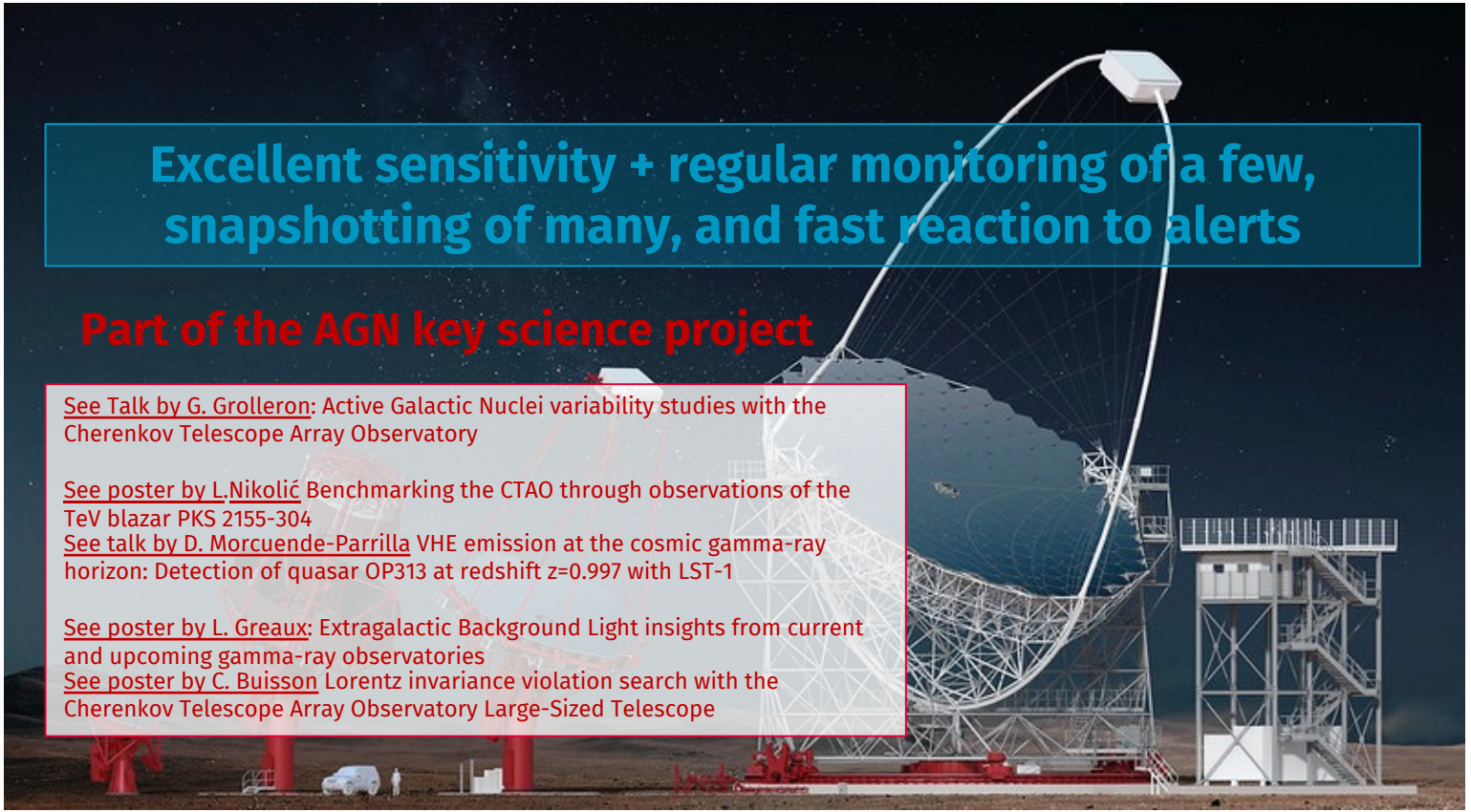
- IBL source S3 1227+25 located at redshift 0.325 (debated)
- *Fermi*-LAT hard state **triggered** VERITAS observations and detection
- MWL campaign initiated
- Fast variability of timescale 6.2 hours
  - Compact region
- SED well fitted by a single-zone SSC model



See talk by D. Morcuende-Parrilla VHE emission at the cosmic gamma-ray horizon: Detection of quasar OP313 at redshift z=0.997 with LST-1

Ingredients for groundbreaking variability studies

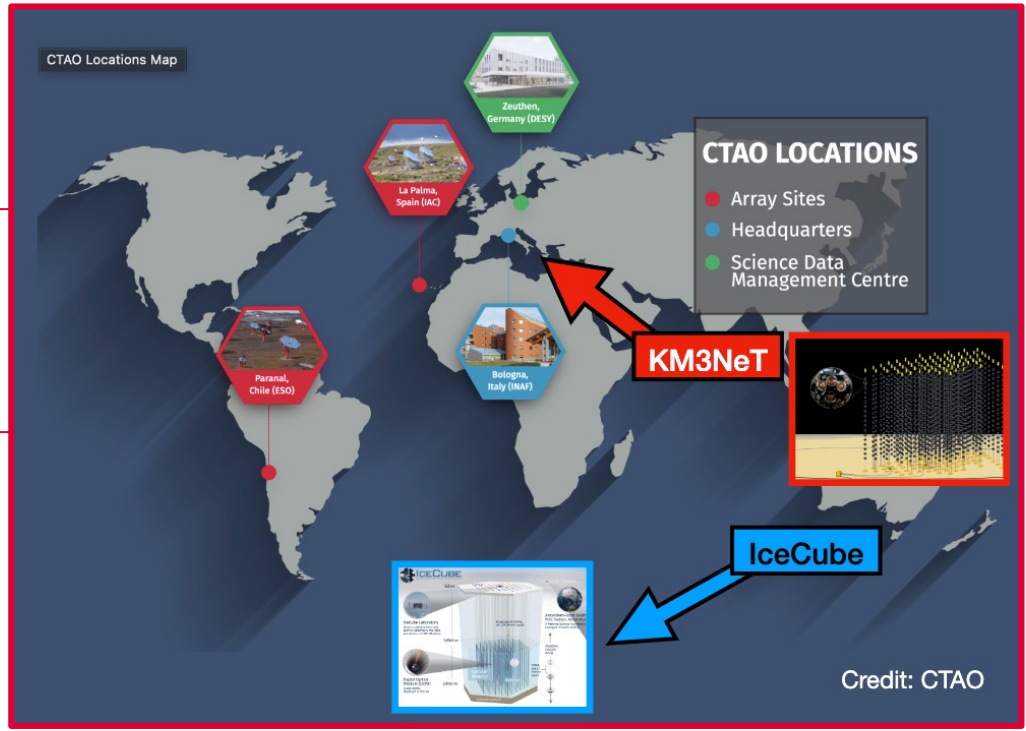
Ingredients for groundbreaking variability studies



TeV blazars and their role in neutrino astronomy

See talk by G. M. Cicciari Evaluation of the Cherenkov Telescope Array Observatory performance to the gamma-ray emission from neutrino sources detectable by the IceCube and KM3NeT neutrino telescopes

See poster by O. Sergijenko Sensitivity of the Cherenkov Telescope Array Observatory to the gamma-ray emission from neutrino sources detected by IceCube



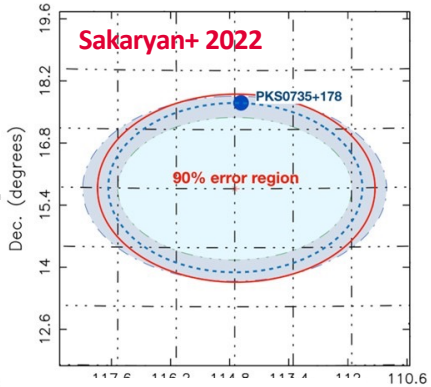
Thank you!

Dante Alighieri in Heaven – Divina Commedia

cherenkov telescope array

Extra slides

TeV blazars and their role in neutrino astronomy: PKS 0735+178



Neutrinos from extragalactic sources:

- TXS 0506+056 (Aartsen et al. 2018),
- Seyfert galaxy NGC 1068 (Aartsen et al. 2020; Abbasi et al. 2022)

Source PKS 0735+178 (z = 0.45)

- Several neutrino alerts (IceCube Coll. 2021, Dzhilkibaev et al. 2021, Filippini et al. 2022, Petkov et al. 2021)
- Multifrequency campaign in December 2021, including NuSTAR
- Broadband, leptonic and lepto-hadronic models
  - Severe constraints from X-ray and gamma rays
  - Gamma-ray spectra requires external photon field (in agreement with Sahakyan 2022, Prince 2023)
  - Lepto-hadronic model explains reasonably well the observations, including neutrinos, by requiring a **high jet power**