Investigation of the Extreme Blazar TXS 0210+515

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VERITAS group

The findings in this presentation are embargoed for 12 months

Only the background and project objectives are included

Introduction

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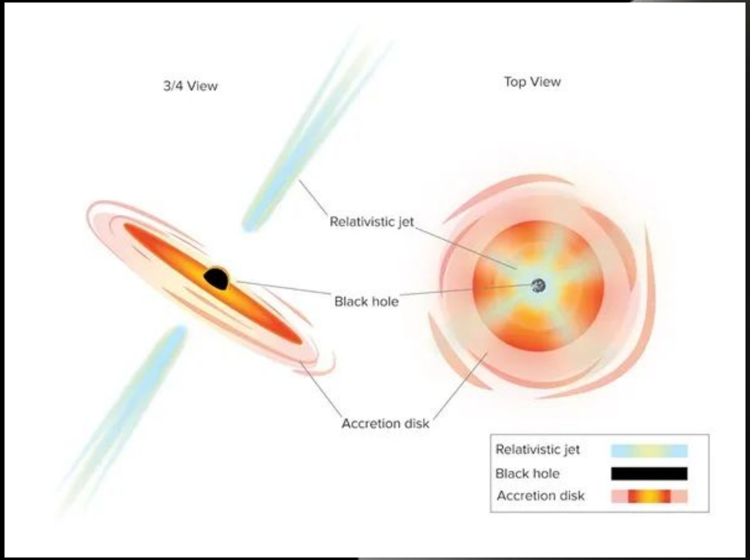
Group: VERITAS

What are blazars?

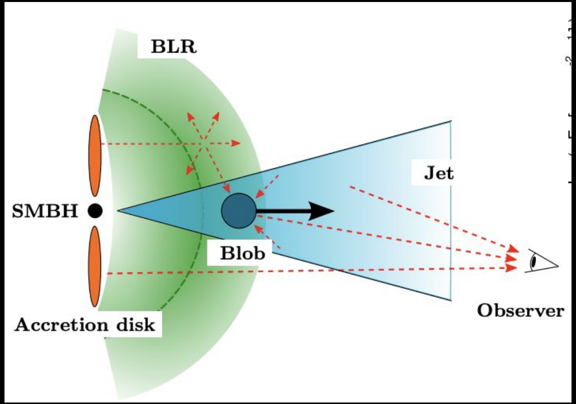


E. Carlson 2023

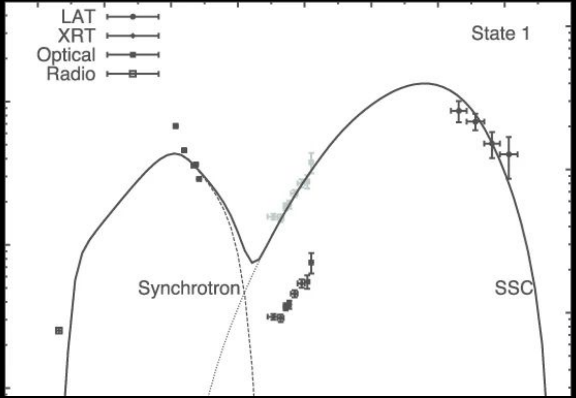
- Supermassive black holes (SMBH) at the center of most galaxies
- Some are **active galactic nuclei (AGN)**
- As AGN accrete, they launch relativistic jets from their poles
- Energetic matter in the jets travels outwards close to the speed of light
- When one of these jets points along our line of sight, the AGN is called a **blazar**
- These jets emit light across the electromagnetic spectrum

Modeling blazar SEDs

- Most blazar spectral energy distributions (SEDs) have 2 peaks
- In simple **one-zone SSC models,** these are explained by
    - **Synchrotron radiation**: emission from relativistic electrons accelerated in a magnetic field
    - **Synchrotron Self-Comptron (SSC):** same population of relativistic electrons scatter synchrotron photons to higher energies
- Deviations from this model could suggest that different fundamental acceleration or emission processes are present in a subset of the blazar population

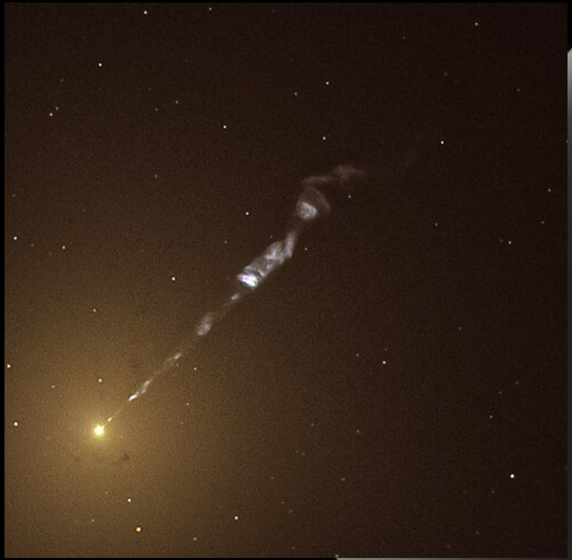


O. Hervet et al. 2024



P. Kushwaha and S. Singh 2013

Describing the “blob”



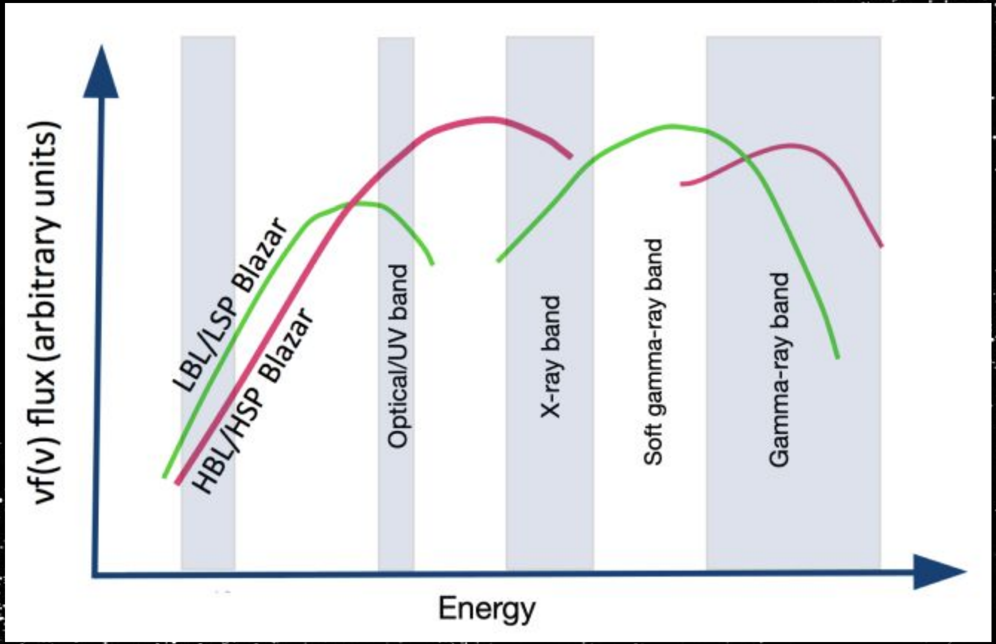
M87 observed by the Hubble space telescope

- The “blob” moves close to the speed of light down the jet
- The **bulk Lorentz factor** measures how relativistically the “blob” is moving: $\Gamma = \dfrac{1}{\sqrt{1-\beta^2}}$
  - where $\beta = \dfrac{v}{c}$
- **The Doppler factor** is given by: $\delta = \dfrac{1}{\sqrt{\Gamma(1-\cos\theta)}}$
- **The particle Lorentz factor** describes the energy of the particles inside the “blob” by: $E = \gamma m_0 c^2$

- **The electron energy distribution** in the blob is represented by a broken power law:

$$N(\gamma) \propto \begin{cases} \gamma^{-n_1}, & \gamma_{\mathrm{min}} < \gamma < \gamma_{\mathrm{break}} \\ \gamma^{-n_2}, & \gamma_{\mathrm{break}} < \gamma < \gamma_{\mathrm{max}} \end{cases}$$

Blazar classification



R. Middai et al. 2022

BL Lacertae objects
(BL Lacs)

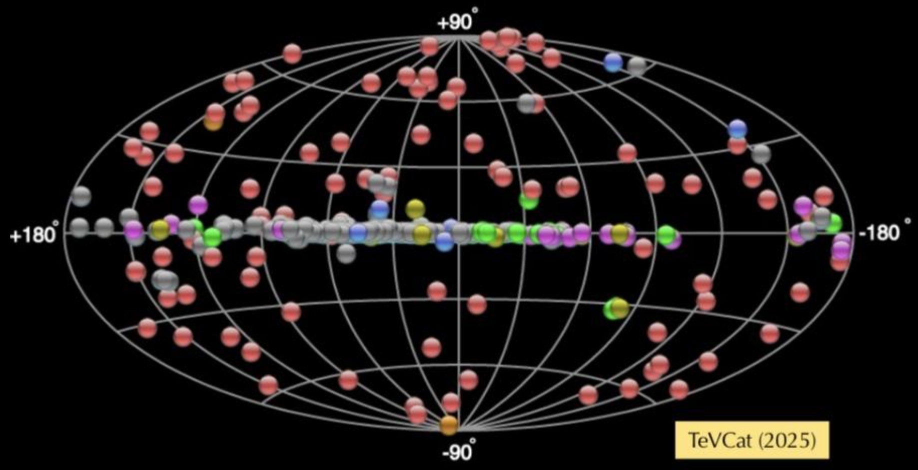
Characterised by weak emission lines or featureless spectra

1) Low frequency peaked BL Lacs (LBLs)
2) Intermediate frequency peaked BL Lacs (IBLs)
3) High frequency peaked BL Lacs (HBLs)
4) **Extremely high frequency peaked BL Lacs (EHBLs)**

Soft vs. Hard

- Soft: flux drops off at highest energies
- Hard: flux remains high at high energies

The VHE gamma-ray sky

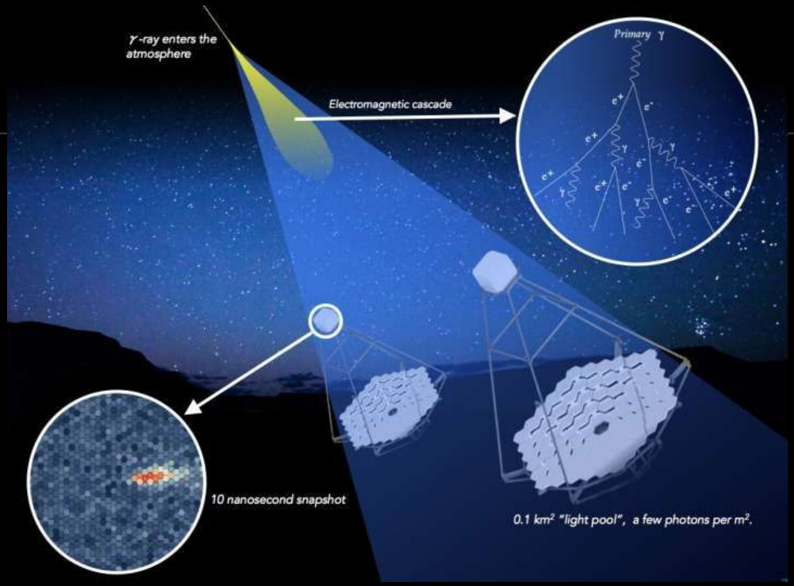


The VHE gamma-ray sky 2025

Source Types

- PWN TeV Halo/TeV Halo TeV Halo Candidate
- XRB Nova Gamma BIN Binary
- **HBL IBL GRB FSRQ LBL AGN (unknown type) FRI blazar**
- Shell Giant Molecular Cloud SNR/Molec. Cloud composite SNR Superbubble SNR
- Starburst
- Dark UNID Other
- Star Forming Region Globular Cluster Masssive Star Cluster BIN uQuasar Cat. VAr. BL Lac (class unclear) WR

Detecting gamma rays: Cherenkov light



CTAO collaboration

- Indirectly detect gamma rays from the ground with imaging of atmospheric-Cherenkov telescopes (IACTs)
- Gamma rays cause **electromagnetic cascades** or **particle showers** in the atmosphere
- These produce **Cherenkov light**
  - When particle travels through medium faster than the speed of light in that medium producing a flash of blue light
- Gamma ray electromagnetic cascades can be differentiated from others using their morphology

IACTs around the world

S. Shankland 2019

VERITAS

Tucson, Arizona, USA

Max-Planck Institute

MAGIC

La Palma, Canary Islands

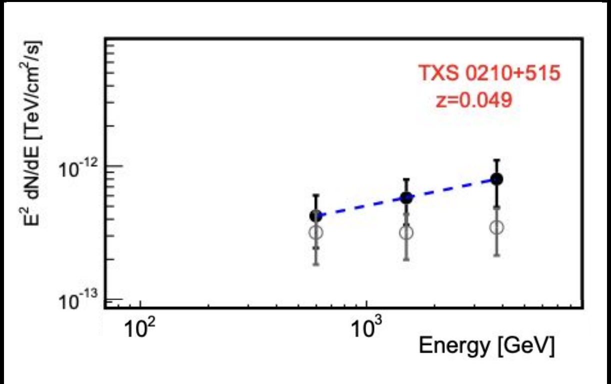
G. Diaz et al. 2020

CTAO

La Palma, Spain, and Paranal, Chile

TXS 0210+515

New hard-TeV extreme blazars detected with the MAGIC telescopes



Gamma-ray SED from MAGIC
Acciari et al. 2019

Redshift:

$z = 0.049$

First official detection with MAGIC in:

2019

Photon index of

1.6 ± 0.3

- MAGIC data showed emission in VHE gamma rays
- Classified as an Extremely High peaked BL Lacertae object (EHBL)
- Is it still emitting at these energies?

To answer this question, VERITAS collected data from this source in

2024

Objectives

The projects goals were to perform the first detection and detailed modeling of TXS 0210+515 with VERITAS

Harvard Smithsonian Center for Astrophysics 2011

1) Data quality selection

Data from VERITAS was analyzed using the standard VERITAS analysis pipeline

An additional layer of data quality checks were performed to finalize the data set

2) Generate skymaps and SEDs

Generate flux points and fit best-fit models

Confirm detection of a VHE source with VERITAS

Objectives

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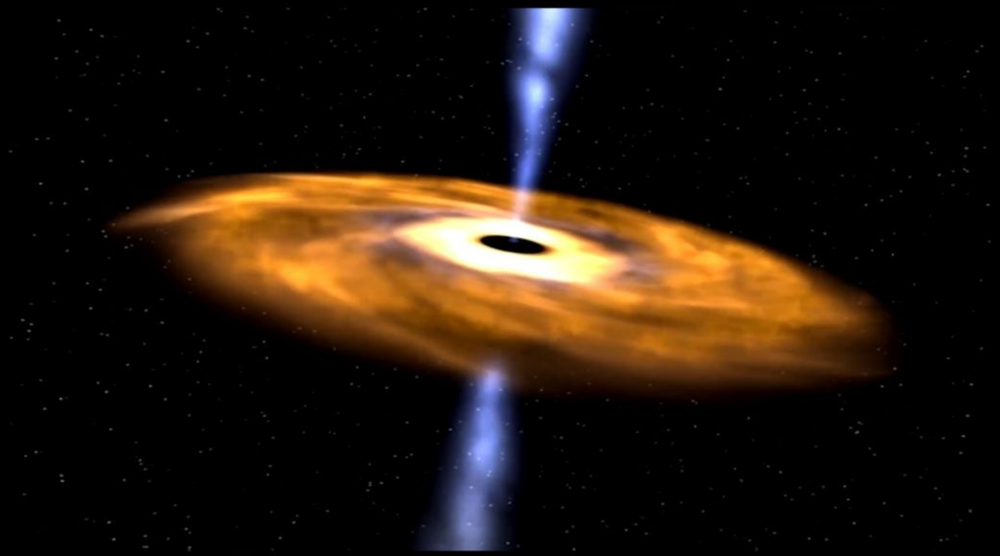


A. Grennell 2018

3) Carry out spectral analysis

Use BJet MCMC, a one-zone SSC model, to model and fit multiwavelength spectral energy distributions (SEDs)

Compare best-fit parameters to those expected for EHBLs

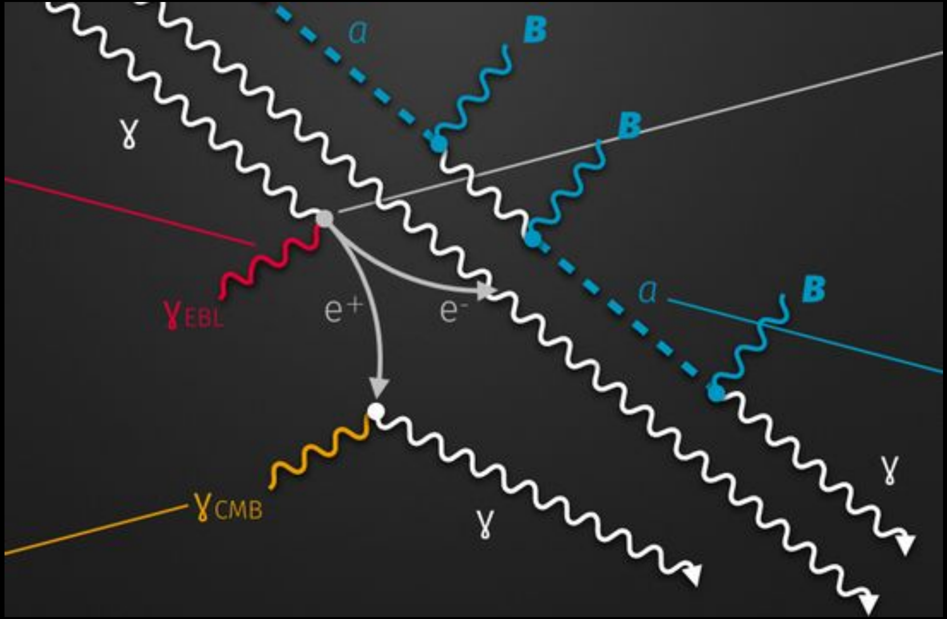
4) Compare findings to previous analysis

Compare VERITAS and MAGIC flux points

Determine if TXS 0210+515 is a persistent EHBL

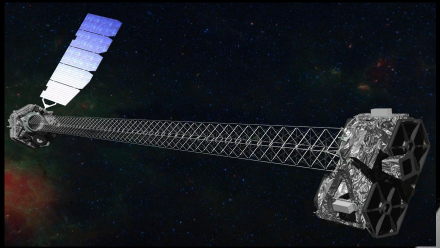
Extragalactic background light

- Integrated intensity of **all the light emitted** throughout the history of the universe **across the whole EM spectrum**
  - Cosmic microwave background (CMB)
  - Photons emitted by stars, galaxies, and AGN due to nucleosynthesis or other processes
  - High-energy photons associated with dark matter particle decays or annihilation
- **Reacts with gamma rays**, producing pairs
  - Higher energy gamma rays are absorbed more
  - Further blazars are more attenuated
  - Observed spectrum is **softer** and **dimmer** than the intrinsic one
- Must correct for EBL when modeling intrinsic blazar spectra in gamma rays



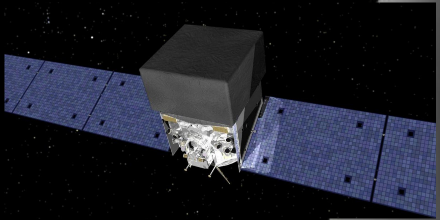
J. Biteau and M. Meyer 2018

SED modeling: Bjet MCMC



NuStar, NASA

TELAMON,
TELAMON database



Fermi-LAT, Stanford University

- Takes input of flux points from different energy ranges
- Models the emitting region of the jet as an expanding blob described by SSC parameters
- Markov-Chain Monte Carlo method
  1) Picks random SSC parameters
  2) Runs and generates SED model
  3) Compares SED model to data
  4) Computes χ^2
  5) Converts χ^2 into a probability
  6) Decides whether to accept or reject the new parameter set
  7) Repeats until converging on best-fit parameters
- Generates a multiwavelength SED and best-fit parameters

References & Acknowledgements

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