Multi-messenger characterization of Mrk501 during historically low X-ray and gamma-ray activity

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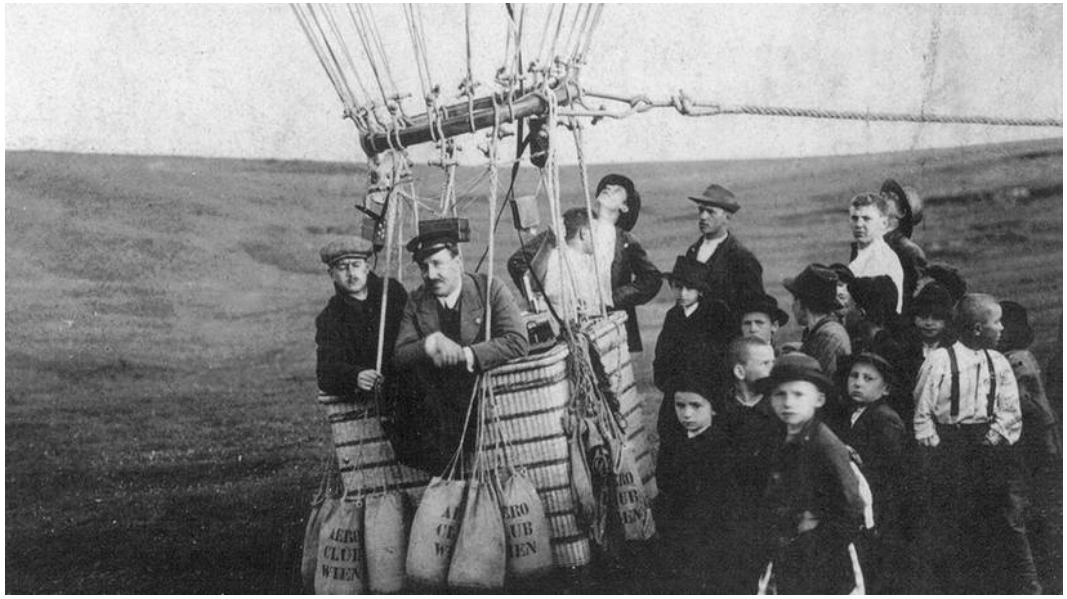
MAGIC

Fermi Gamma-ray Space Telescope

MAX-PLANCK-INSTITUT FÜR PHYSIK

Cosmic Rays

- Discovered by Victor Hess 1912 (Nobel Prize 1936)
- Until now the origin and mechanisms behind cosmic rays and their acceleration are still unknown
- Two main components
  - Galactic
  - **Extragalactic**:
    - Gamma-Ray Bursts
    - **Active Galactic Nuclei**
    - Starburst galaxies
    - Clusters of galaxies



[1] https://www.br.de/themen/wissen/kosmische-strahlung-victor-hess100.html

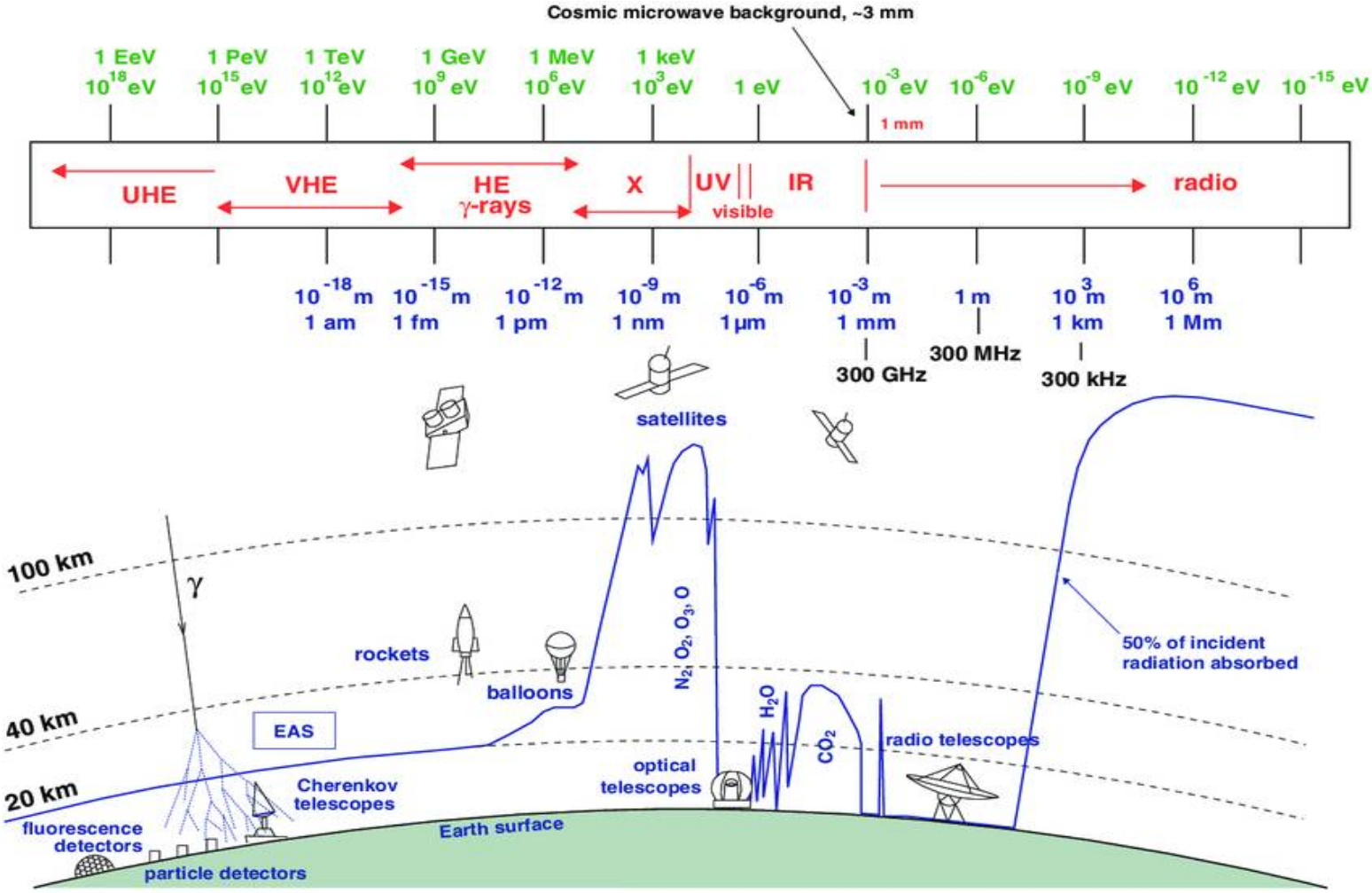
Active Galactic Nuclei (AGN)

- **Bright compact nucleus** in the center of galaxy (supermassive black hole)
- Most luminous persistent sources in the universe
- **Variable in time**
- Often accompanied with two jets
- **Highly energetic physics laboratories**
  (at least 10^{14} eV,
  maybe up to 10^{20})
- When the jet is pointed in our direction we classify them as **blazars**
  → Strong boosting along the jet
  → High observed luminosities

[13] http://www.astro.princeton.edu/~lilew/

Multi-wavelength Astronomy

- Charged particle are deflected by the interstellar medium
- Only **photons and neutrinos (Multi-messenger)** take a direct path



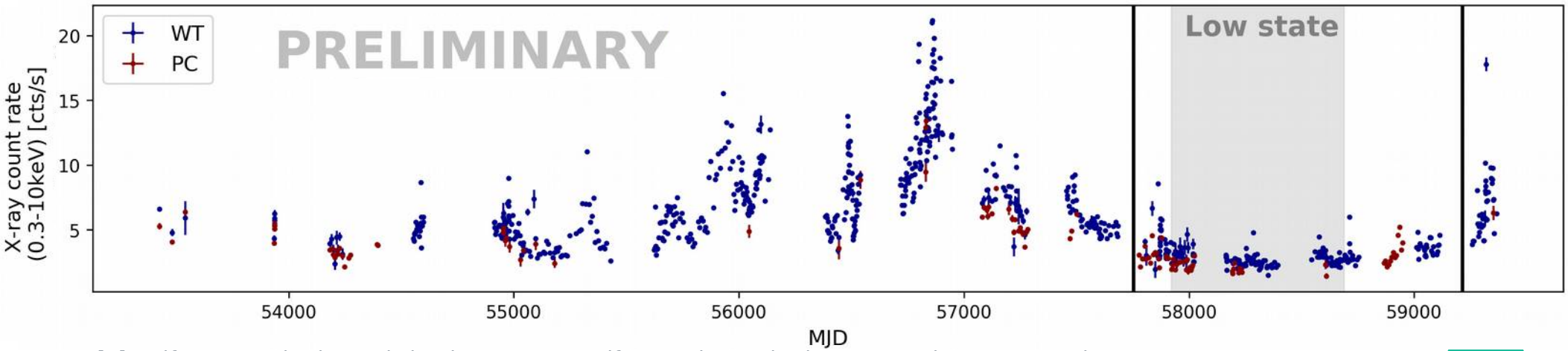
[5] Longair, S. M. (1992)

MAGIC telescopes

- **Two imaging atmospheric air Cherenkov telescopes (IACTs)**
- Placed on La Palma (Canary Islands)
- At 2200m above sea level
- Diameter: 17m
- Energy range: **50 GeV to 50 TeV**

Mrk501 – 2017 to 2020

- **Mrk501** is one of our closest & brightest **blazars**
- It can be studied in detail in both during flaring and quiescent states
- Regular **MWL monitoring** is organized to disentangle its complex behavior
- **4 years of very low activity from 2017 to 2020**
- Recognized extremely low state, is it a sort of **baseline**?
  - **2 years of historically low X-ray and gamma-ray (>0.2 TeV) activity**

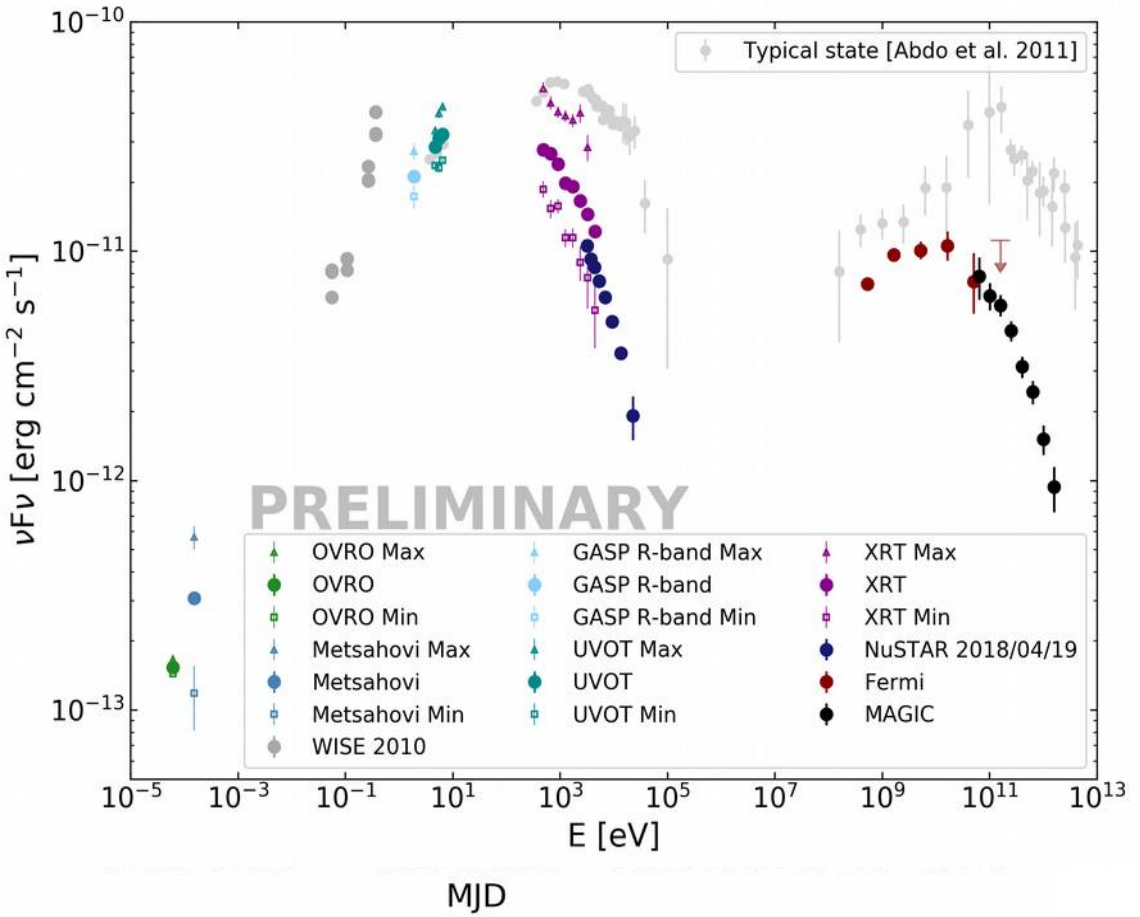


[1] Swift-XRT monitoring website: https://www.swift.psu.edu/monitoring/source.php?source=Mrk501

Mrk501 – low activity

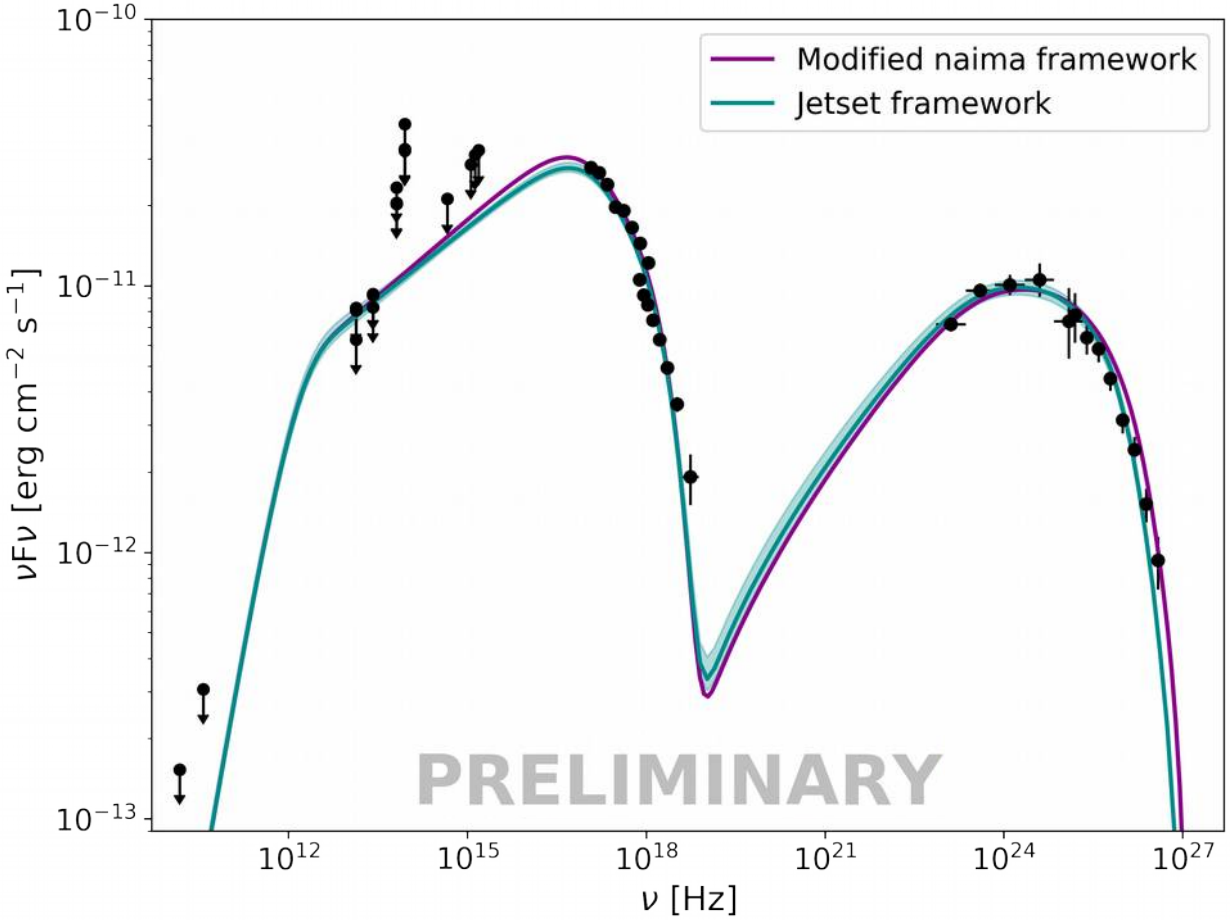
- Recognized extremely low state, is it a sort of **baseline**?
  - **2 years of historically low X-ray and gamma-ray (>0.2 TeV) activity**
  - From mid of 2017 to mid of 2019
  - **VHE flux constant** at ~5% that of the Crab
  - Simultaneous low activity in X-rays

→ **SED with good MWL coverage**
→ Averaged SED very well suited to **investigate the nature** of this **extremely low-state emission (baseline)**



Mrk 501: nature of the low state

- **Leptonic Scenario**
  - Main source of the emission: **Electrons**
  - Synchrotron peak + Inverse Compton Scattering



Mrk 501 low state

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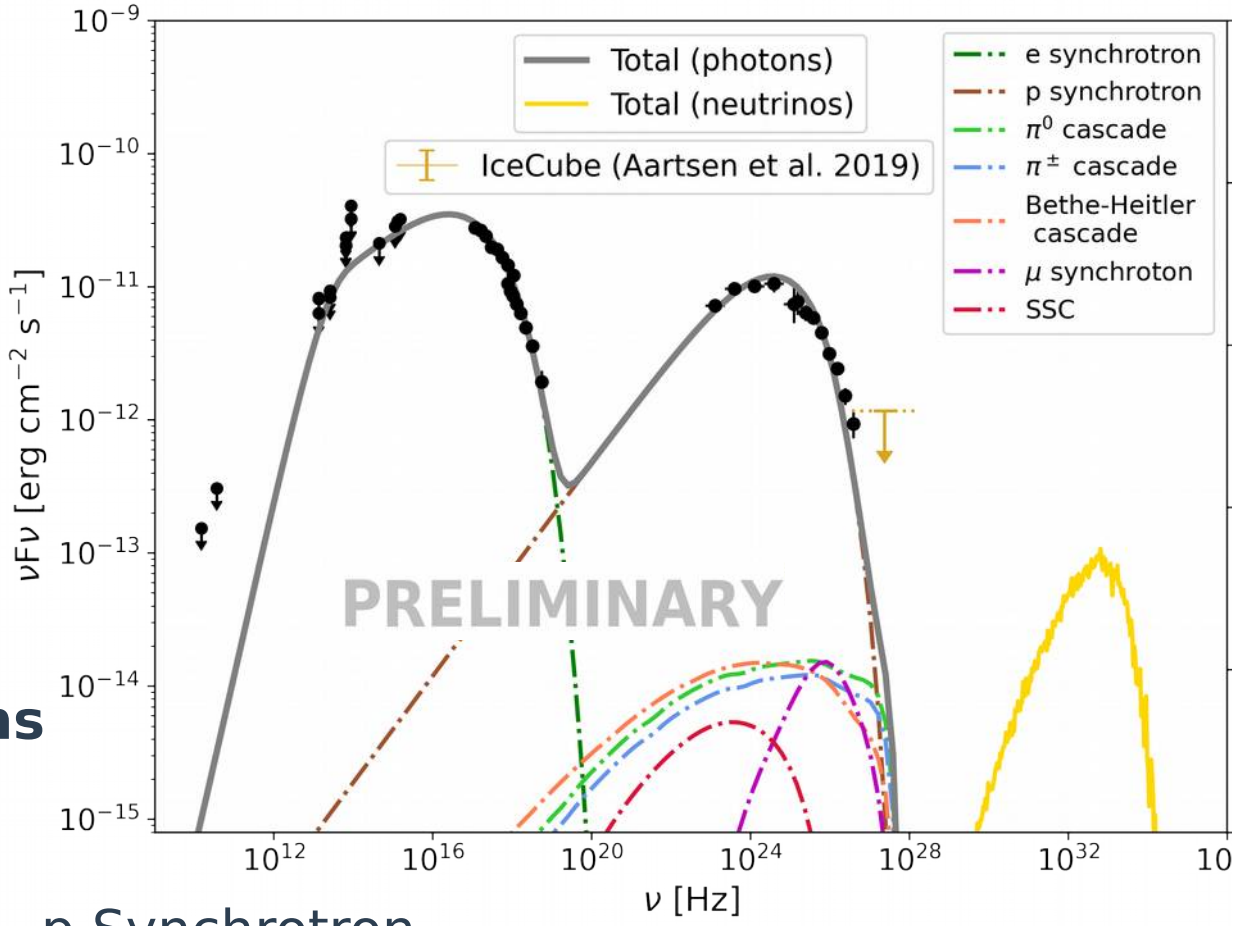


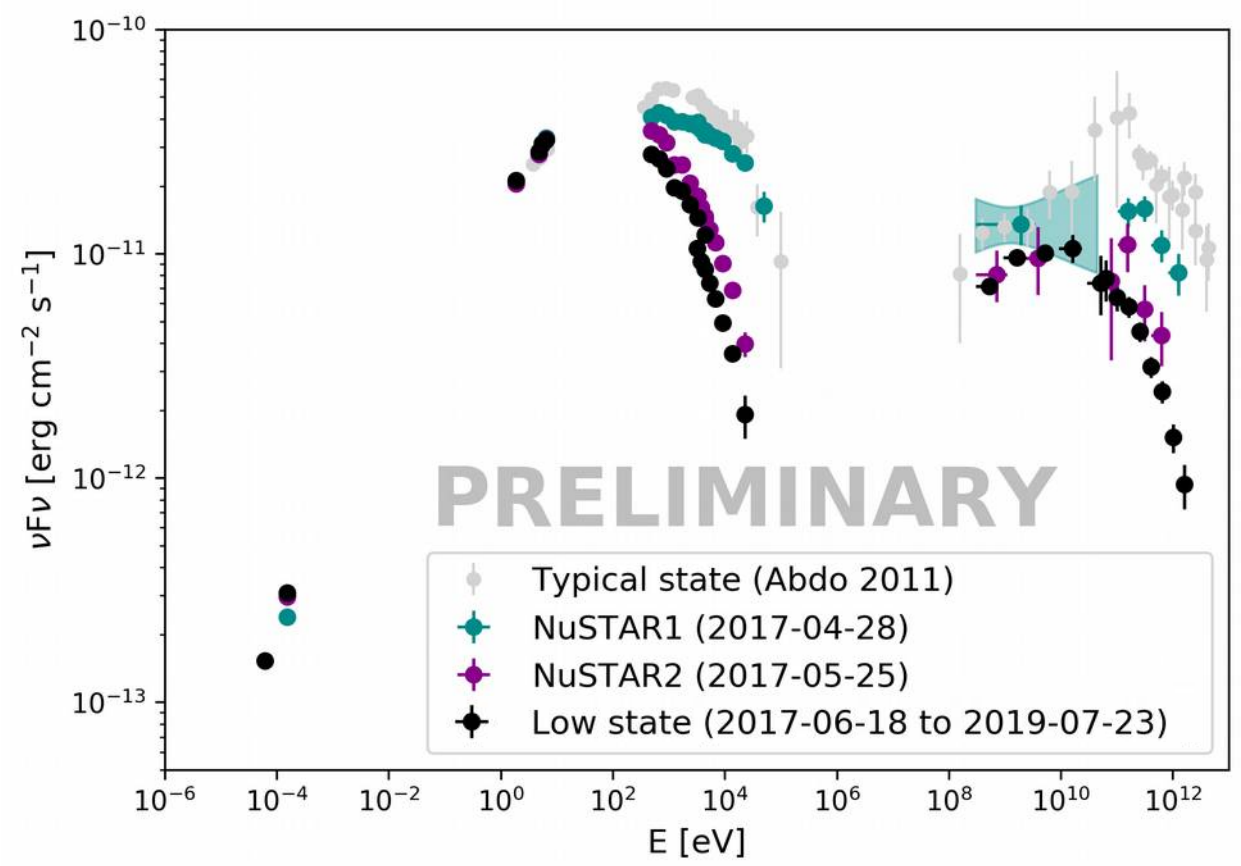
- **Hadronic Scenario**
  - **Protons and electrons** contribute to the emission
  - Mainly e Synchrotron + p Synchrotron
  - Framework using the LeHa code (Cerruti et al. 2015)
  - **In agreement** with Icecube upper limits on the **neutrino** rate

SED evolution

- **Additional NuSTAR observations → Evaluation of the SED evolution**

- **NuSTAR1:** 2017-04-28
  - **~2 months before** the low state

- **NuSTAR2:** 2017-05-25
  - **~1 month before** the low state

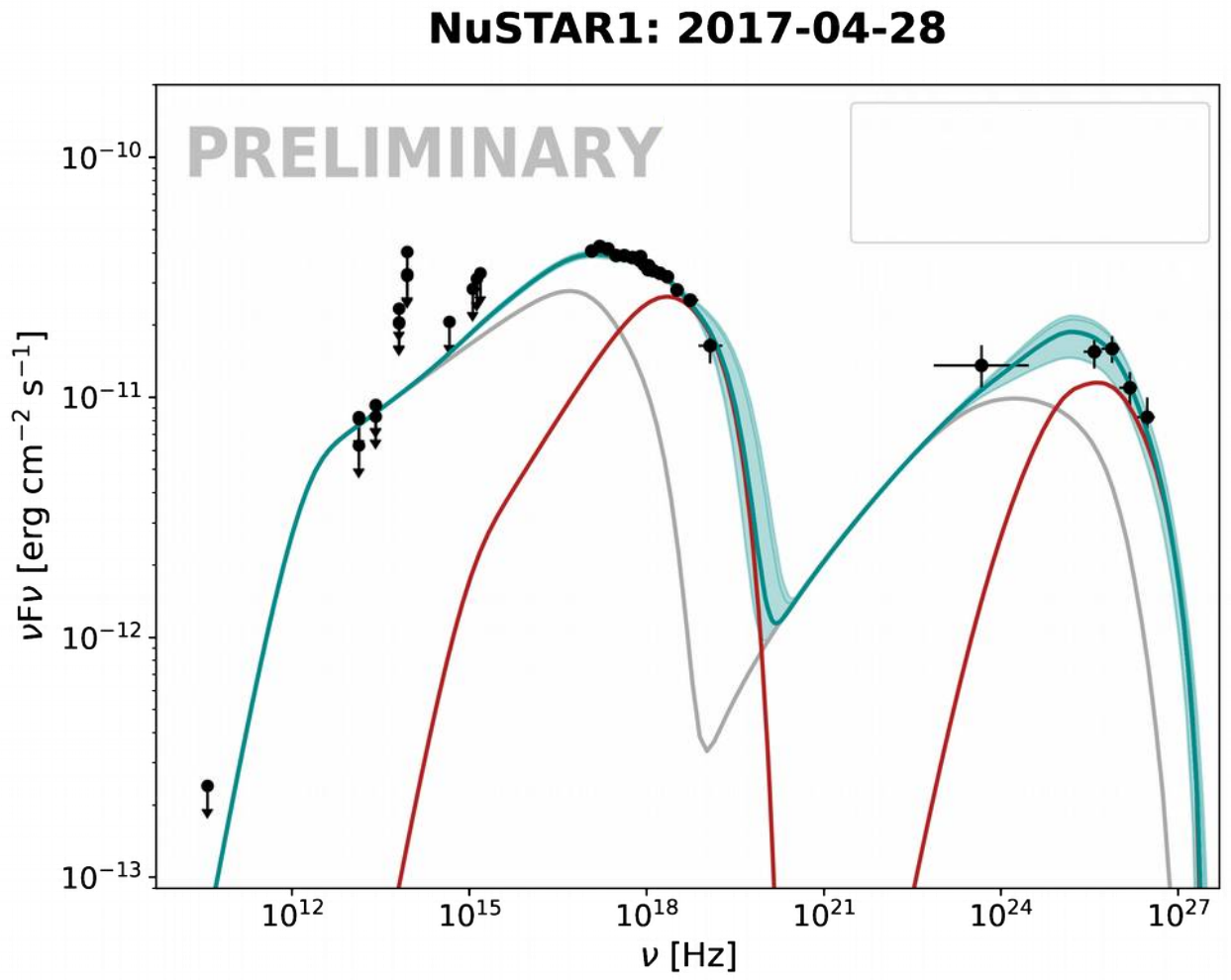


Two-zone scenario

- Assumption:
  - **Stable & always present baseline emission**

    → use our low state model
  - Usually outshone by a **more dominant and variable region ,** that dominates at the highest energies

    → Combination reproduces the observed blazar emission



Summary & Outlook

- Within the new multi-messenger era, data from MAGIC aim to shed some light on the origin of cosmic rays
- Blazars are especially interesting because their jets accelerate particles to extremely high energies
- Mrk501, one of our closest blazars, showed **historically low activity in X-rays and VHE gamma rays from mid of 2017 to mid of 2019**
- The nature of this extremely low state (baseline emission?) can be explained by both **standard leptonic and hadronic scenarios in agreement with additional multi-messenger data**
- These studies aim to evaluate the **potential existence of a steady baseline component** in the blazar emission, which is often **outshone by the emission of more variable and active region**
- More details will follow soon in a **dedicated publication**

Thank you for your attention!