Observing Mrk421 and Mrk501 with the MAGIC telescopes

Francesco Borracci

MAGIC

Major Atmospheric

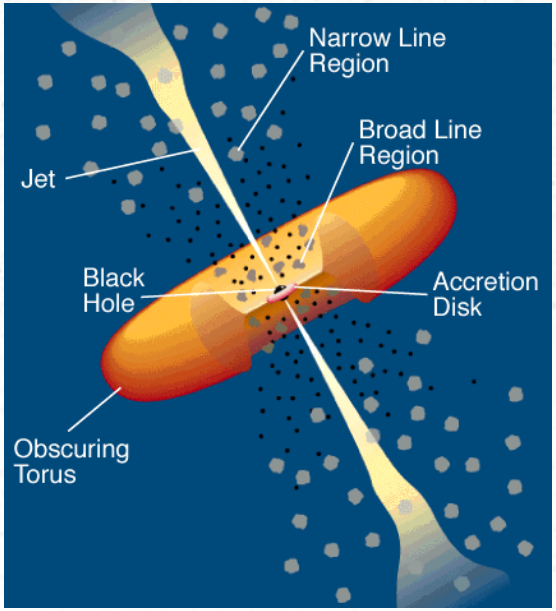
Gamma Imaging

Cerenkov Telescope

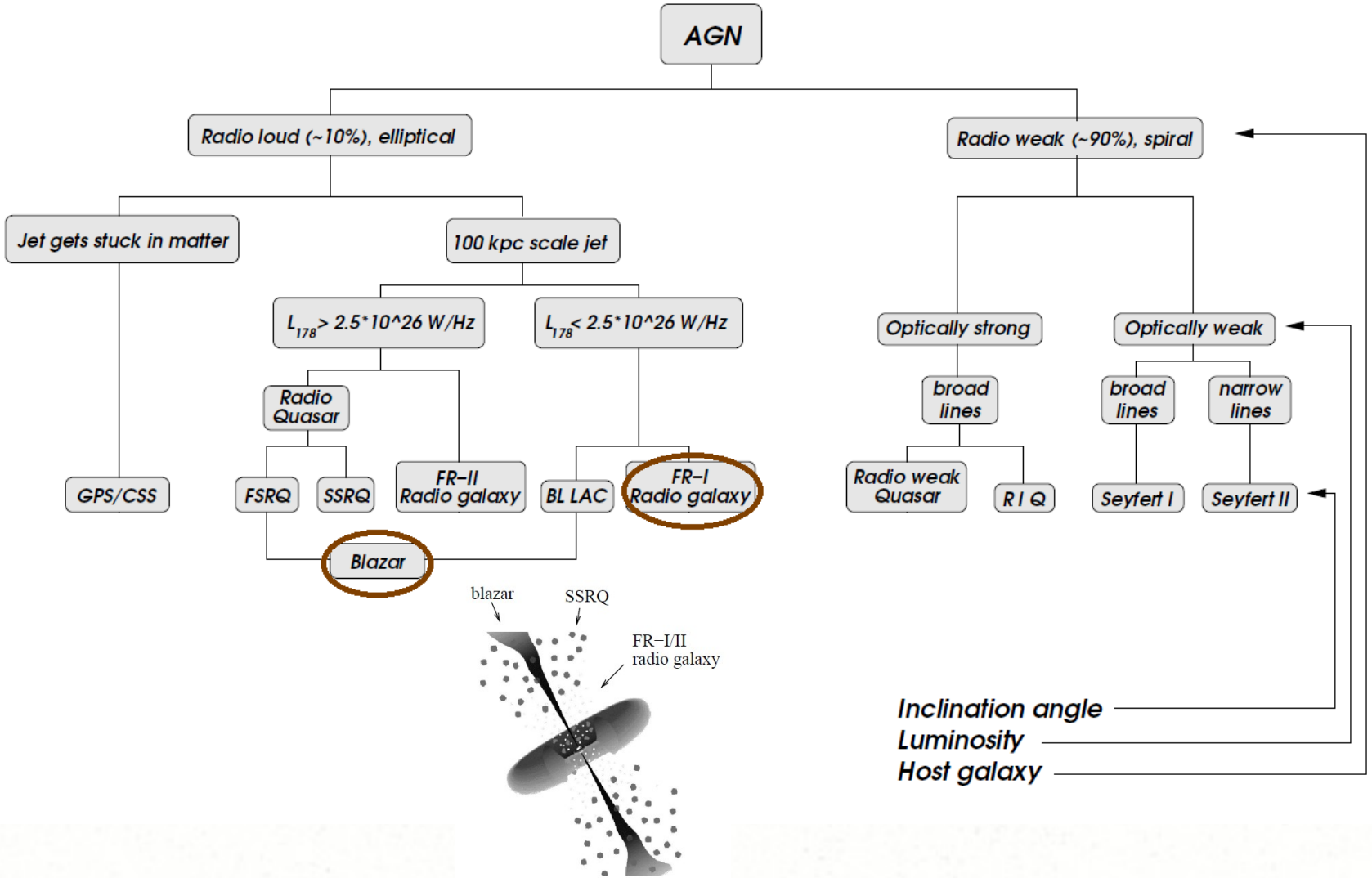
MAX-PLANCK-GESELLSCHAFT

What are Mrk421 and Mrk501?

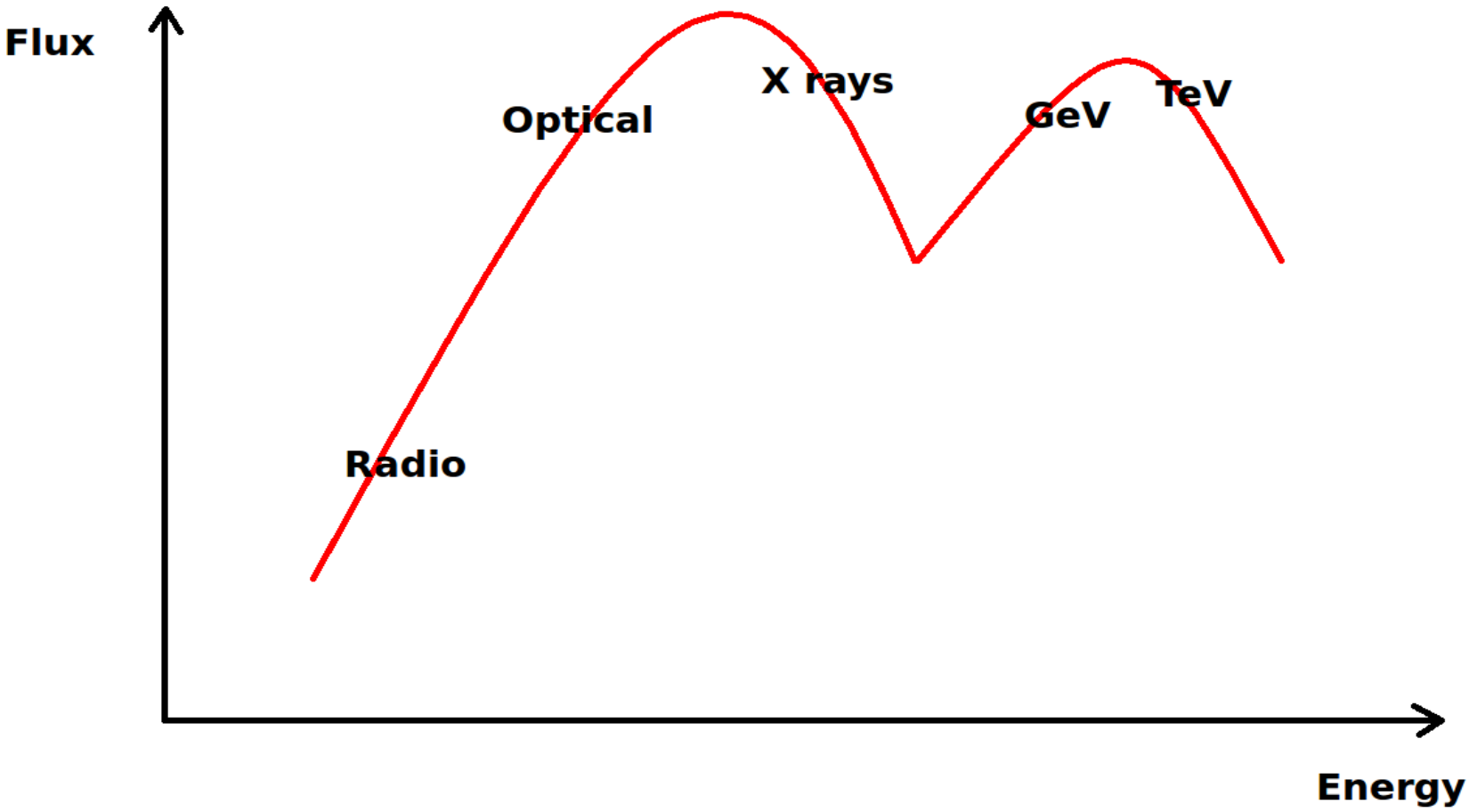
- They are the closest blazars detected in the VHE range



AGN classification



Typical blazar spectrum



Mrk421 and Mrk501 as laboratories

- We can only observe, but what we observe are extreme processes
- These objects are still not well understood
- Difficulty to understand caused by no proper VHE coverage in the past and variability
- Mrk421 and Mrk501 are the easiest TeV blazars to study since detailed studies are much more difficult to do with any other blazar

How to understand?

- We can use a new technique to observe what we could not observe before
- New instruments and coordination of different instruments always open a new window
- We can not reproduce the processes in labs (as in particle physics!), but only understand them with continuous observations

Understanding extreme phenomena in astrophysics (an example)

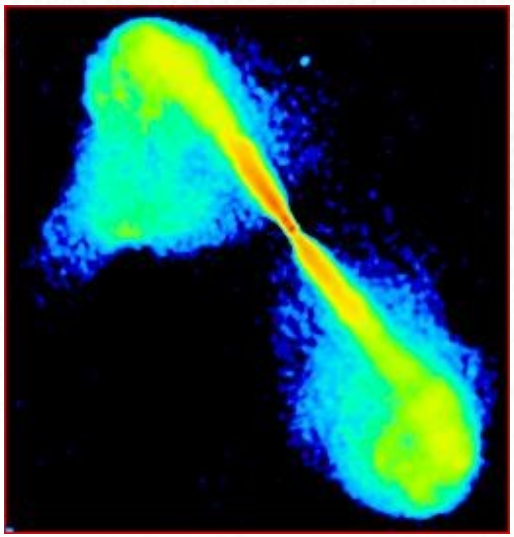
- Tycho Brahe observes the planetary motion (1585)
- Kepler establishes the laws of planetary motion (1620)
- Newton establishes the universal gravitation law (1665)

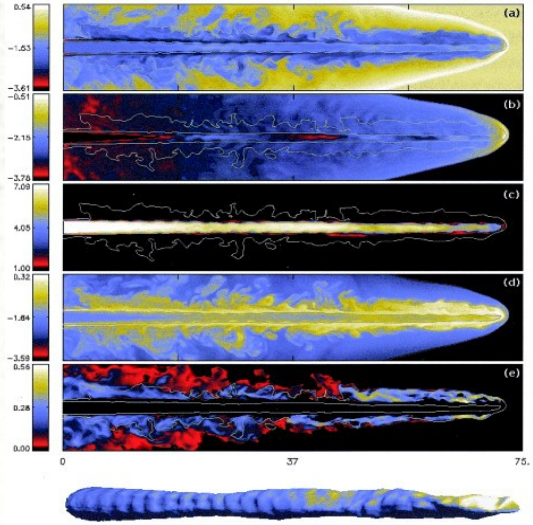
What we want to understand?

- Formation and collimation of the jets
- Underlying mechanism for acceleration
- Particles responsible for gamma-ray emission
- Location of the acceleration and radiation zones
- Origin of the variability

Jets

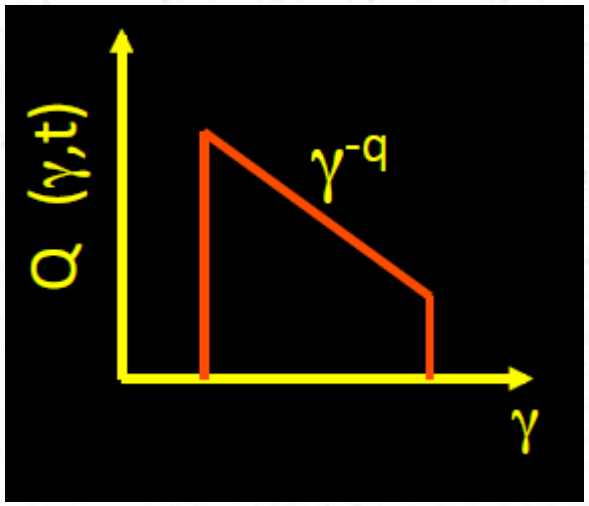
- Largest structures in the universe
- Collimated magnetized collisionless plasma propagating with relativistic velocities
- Shocks and turbolence
- Extremely efficient accelerators of particles

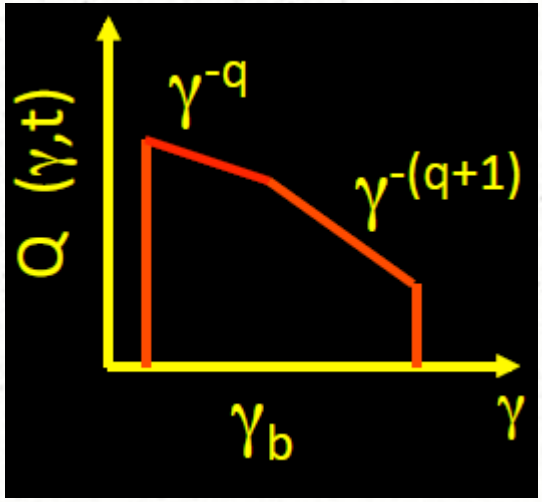




Which particles can be accelerated?

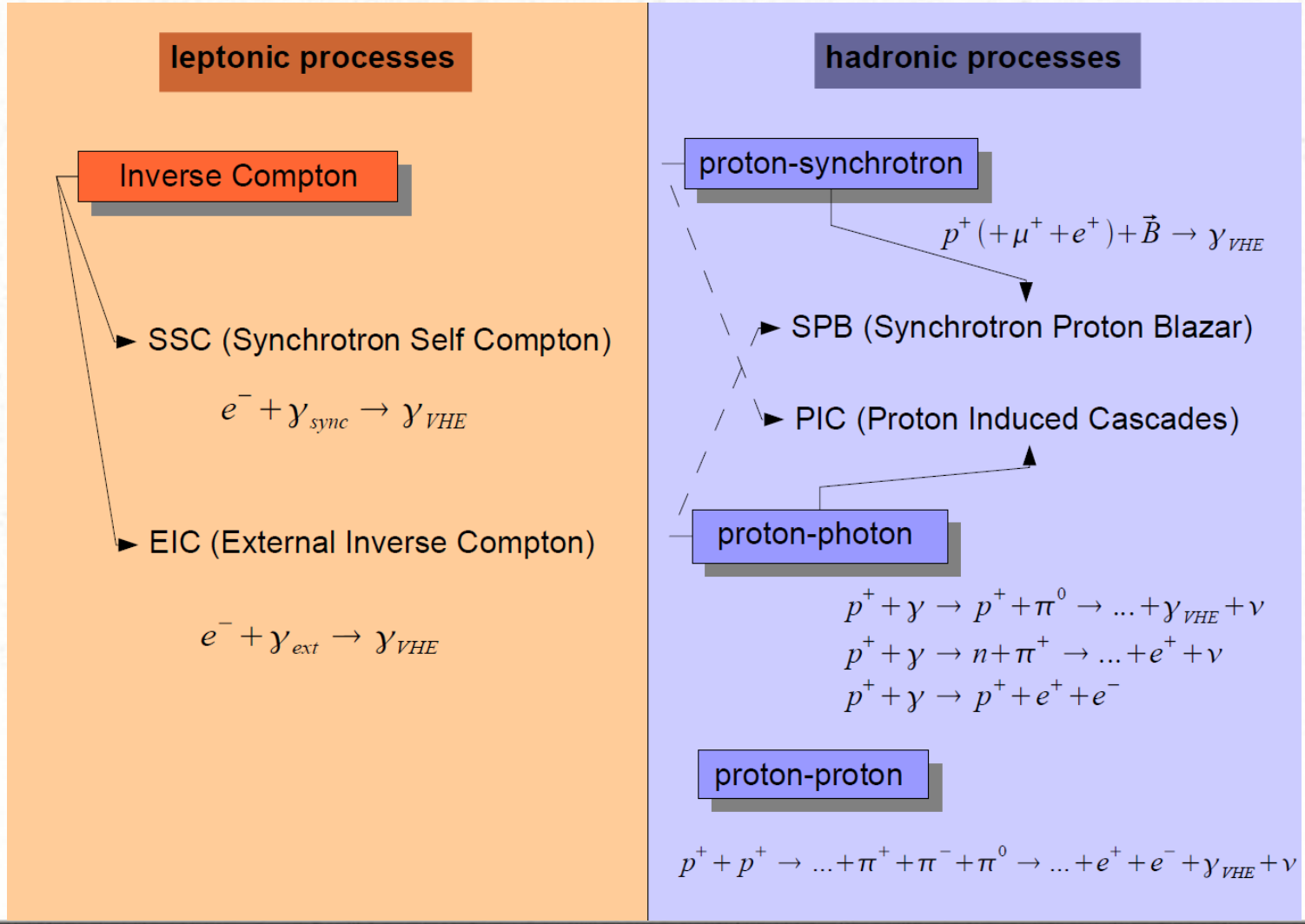
- Electrons up to PeV energies (proved)
- Protons up to ZeV energies (claimed)





γ_b:
$\tau_{cool}(\gamma_b) = \tau_{esc}$

How particles radiate?



What we need to understand those extreme objects?

- Temporal coverage

- Broad band coverage

Temporal coverage

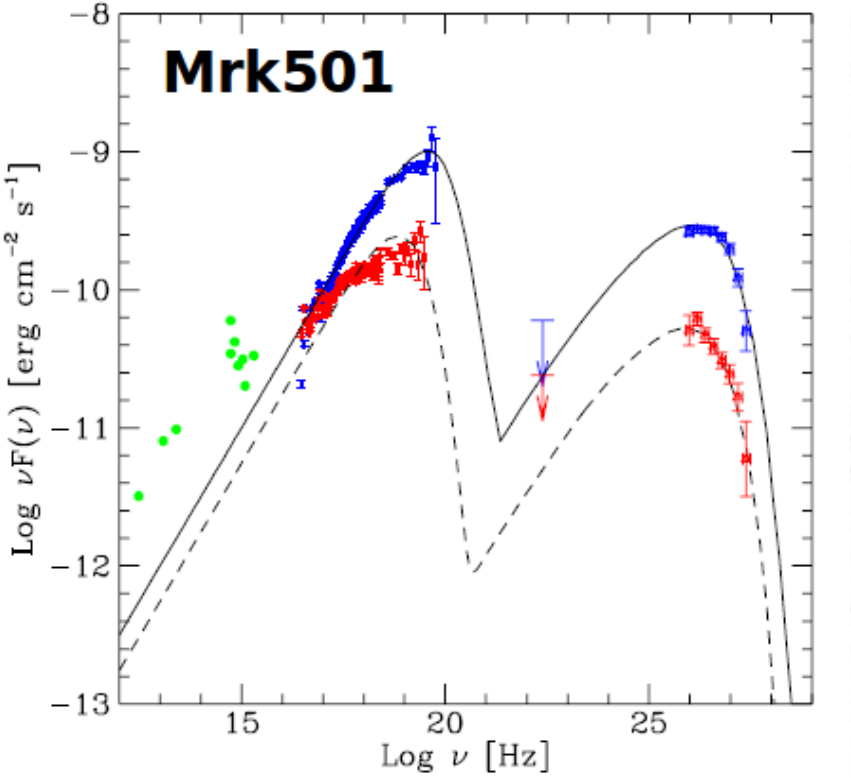
- Most of our knowledge of Mrk421 and Mrk501 comes from the high state of those sources
- Only a good temporal coverage over years can guarantee a complete and not biased picture of the sources
- Year after year, the sensitivity and the number of the instruments increases!

Broad band coverage

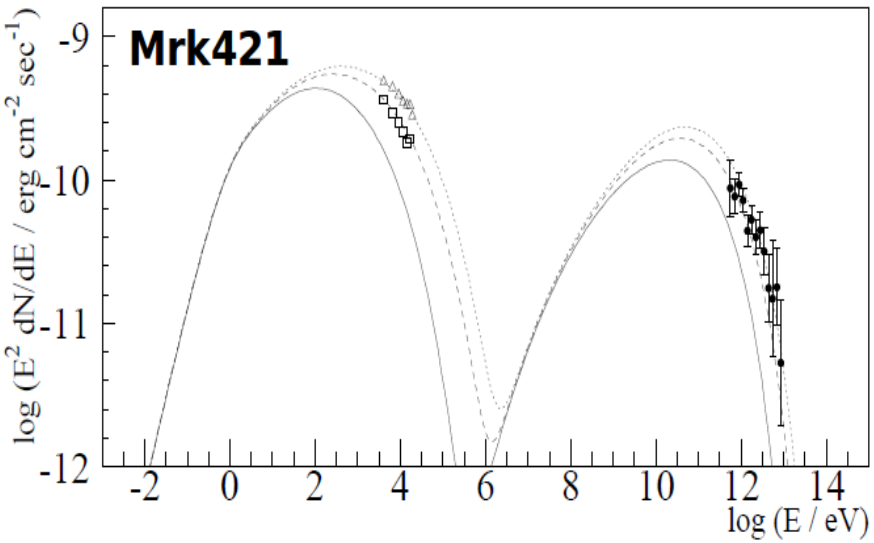
- Coordination of instruments covering different energies simultaneously is needed
- It is not so easy to obtain simultaneous data
- New generation of gamma ray telescopes (LAT, MAGIC...) guarantees a performance jump respect to the past

Why we can do better now? (1)

Tavecchio 2001 (ApJ 554)

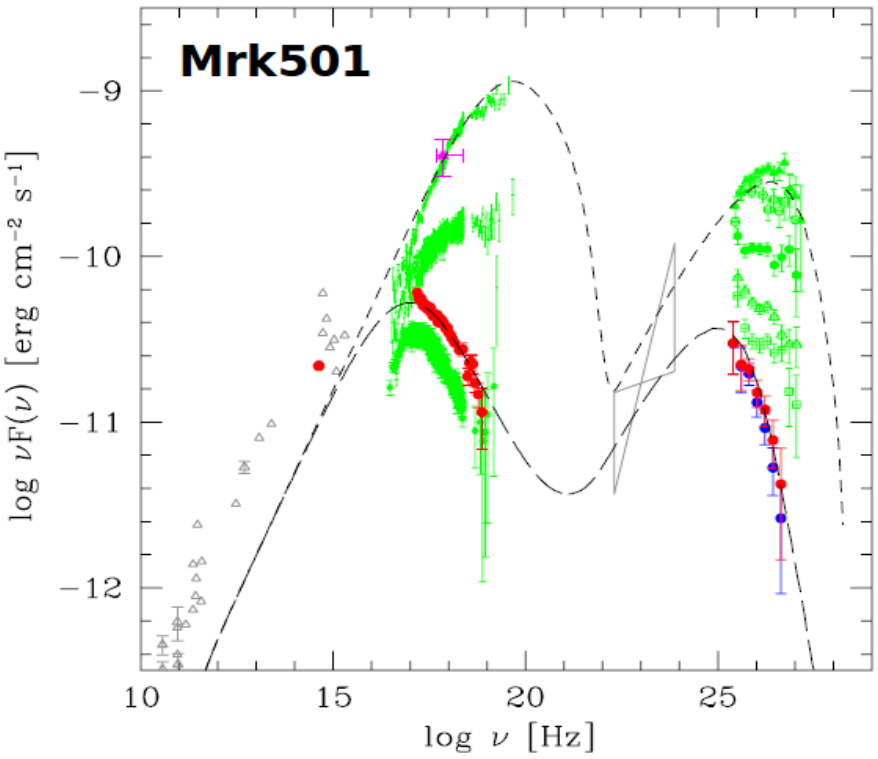


Krawczynsky 2001 (ApJ 559)

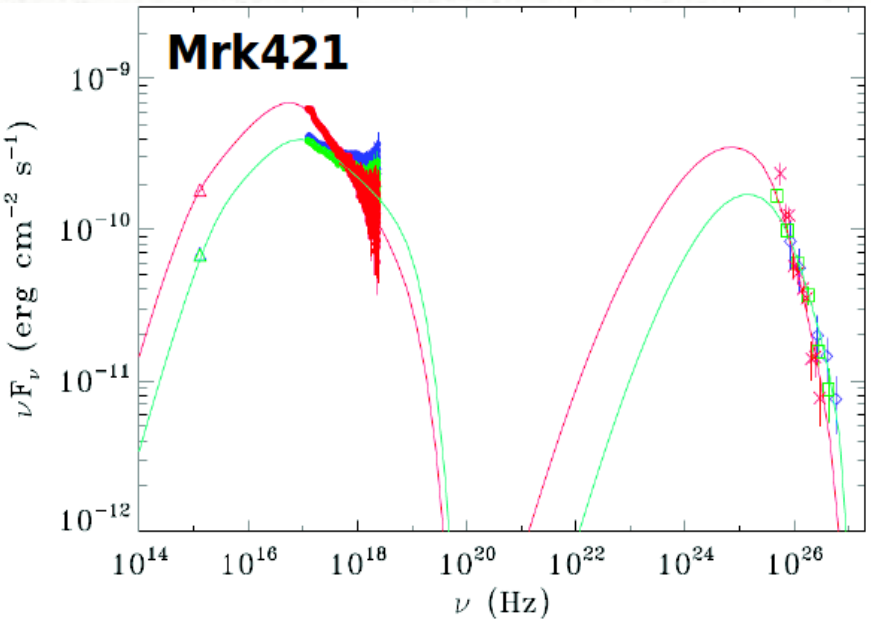


Why we can do better now? (2)

Acciari 2009 (ApJ 703)



Anderhub 2009 (ApJ 705)



Better coverage from 2009 multiwavelength intensive campaigns

- Temporal coverage + broad band coverage allow for multifrequency variability and multifrequency correlation studies
- Monitoring reguardless of activity
- Easier to do with Mrk421 and Mrk501 since they are bright sources and close to the Earth

Why bright sources?

- Mrk421: 0.5 Crab Unit

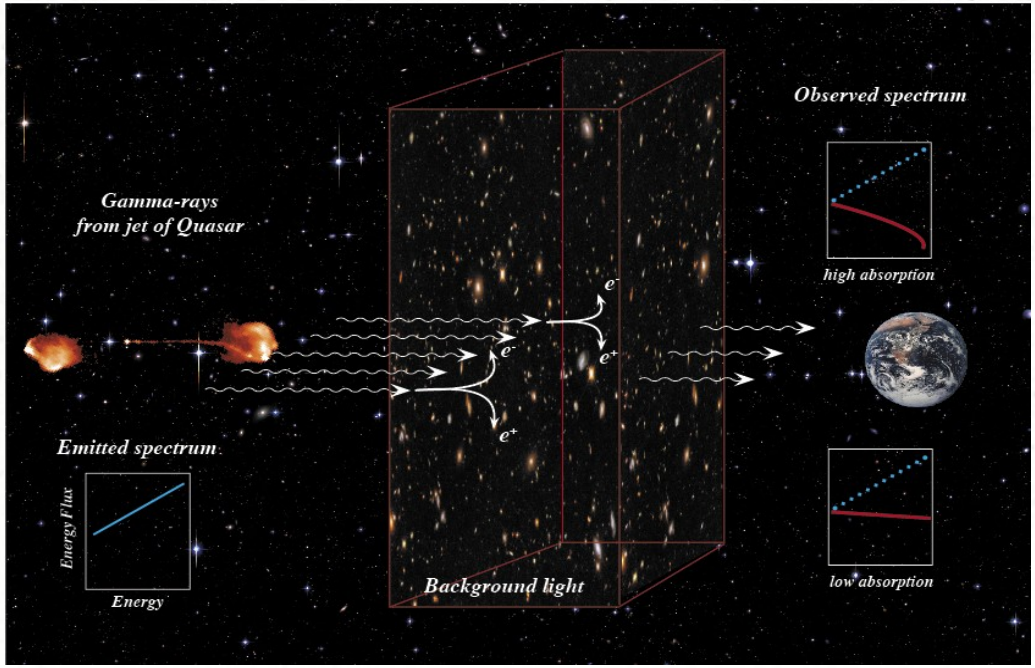
  5 sigma detection in 3 minutes with MAGIC
- Mrk501: 0.2 Crab Unit

  5 sigma detection in 20 minutes with MAGIC
- Most of the VHE sources need to be observed for many hours in order to be detected!

- Crab Nebula is the standard candle in VHE astrophysics

Close to the Earth … why is it so important?

- Low EBL (Extragalactic Background light) absorption via electron positron pair production
- EBL includes starlight, dust and CMB emission



Importance of MAGIC observations

- Mrk421 and Mrk501 can be seen only by two IACT telescopes with high sensitivity and low energy threshold (MAGIC and VERITAS)

- IACTs are quite sensitive to non-optimum weather

- Most of the other energy bands are well explored since years!

Multifrequency variability studies

- Mrk421 and Mrk501 are so variable that they change significantly in time, looking like different sources (TeV intra-night variability!)
- Variability is a extraordinary opportunity to break degeneracies among the different models
- Different models produce flux variations with particles of different energies, cooling times and cross sections for different processes which are in principle distinguishable (Time Modelling)

Multifrequency correlation studies

- TeV flux can increase by more than one order of magnitude during Mrk421 and Mrk501 flares
- Correlation of flaring activity with blobs ejected by the core (which can be imaged in the radio)
- Correlation of flaring activity with a change in the optical flux polarization degree and angle
- Orphan flares
- In absence of flares, we can still achieve a complete characterization of the SED

Evolution studies of the SED

- Mrk421 and Mrk501 are easy to detect not only with MAGIC but also in other wavelenghts
- In principle, it is possible to have a SED for each day of observation
- We can quantify multi energy variability patterns, find features that can be reproduced over time
- Long term project producing fundamental results slowly over time

Observing again and again

- This overall picture is the main driver of the observations
- Since 2009, every year we have 6 months long observing campaigns with 25-30 instruments
- This leads to 3 MAGIC papers on multiwavelenght analysis of Mrk501 and Mrk421, 8 MAGIC papers in preparation, 7 Phd thesis
- Nevertheless...the unexpected is always behind the door!

Thank you!