MAX-PLANCK-INSTITUT FÜR PHYSIK

MAGIC Major Atmospheric Gamma Imaging Cerenkov Telescopes

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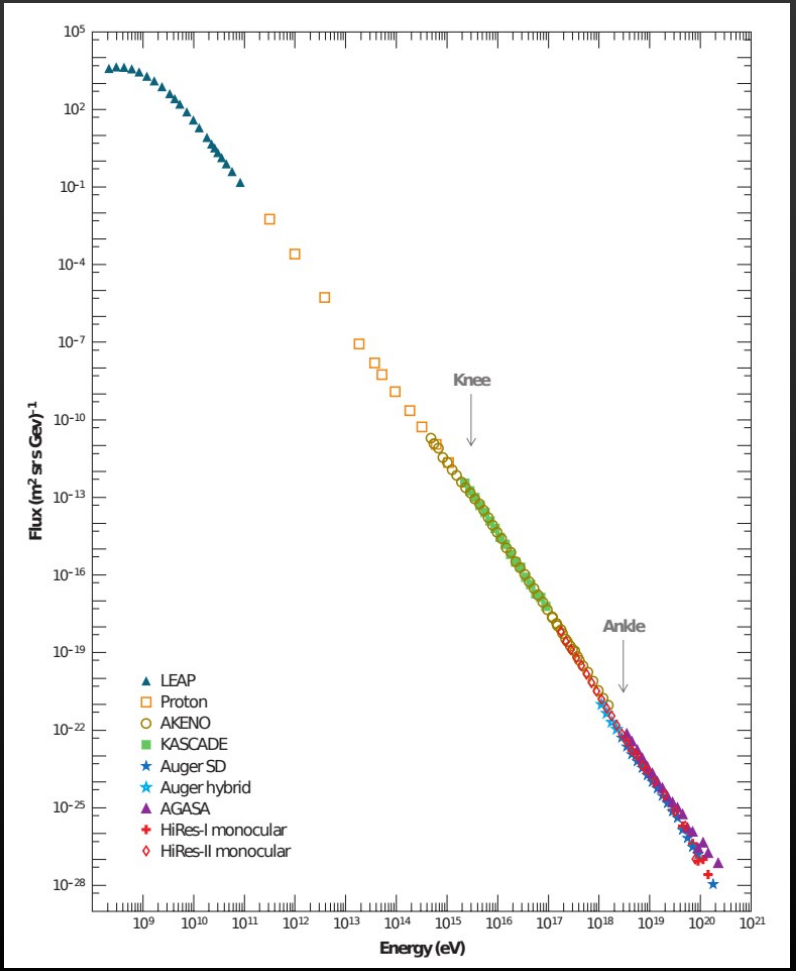
MAGIC observations of M87

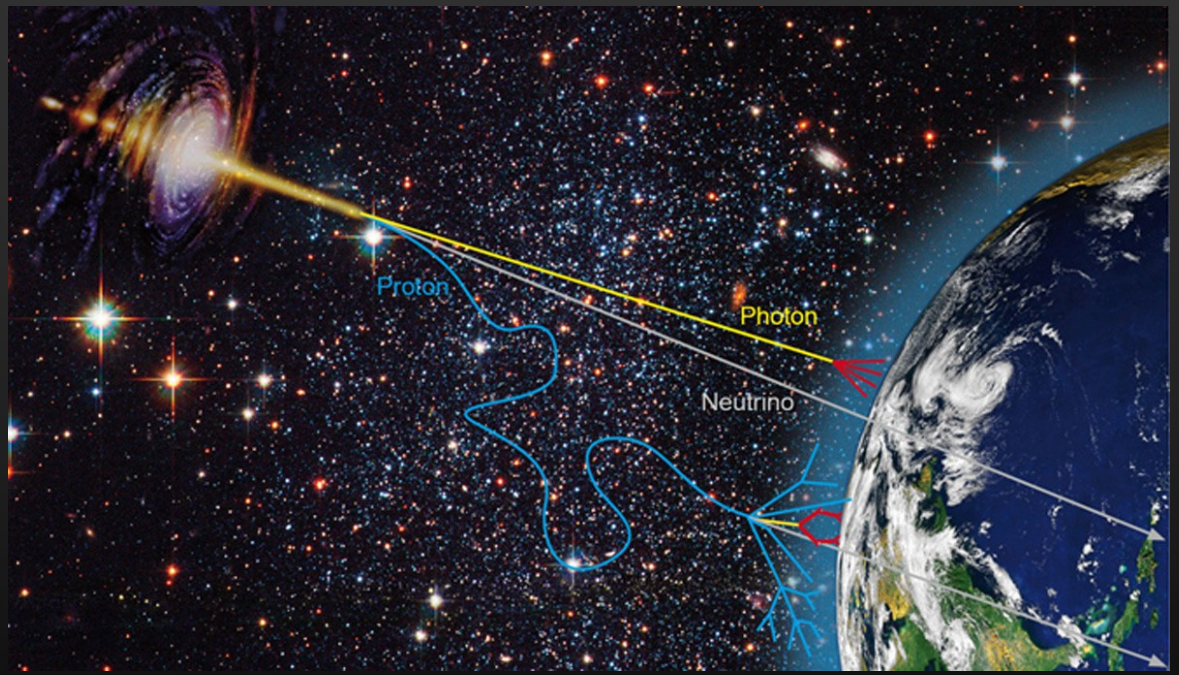
Cosmic-rays measured on Earth

- Origin and acceleration still unknown
- Potential nearby sources (galactic) e.g:
  - Pulsars
  - Supernova Remnants
- Potential distant sources (extragalactic) e.g:
  - Active Galactic Nuclei
  - Gamma-Ray Bursts
- Problem: no direct observation possible

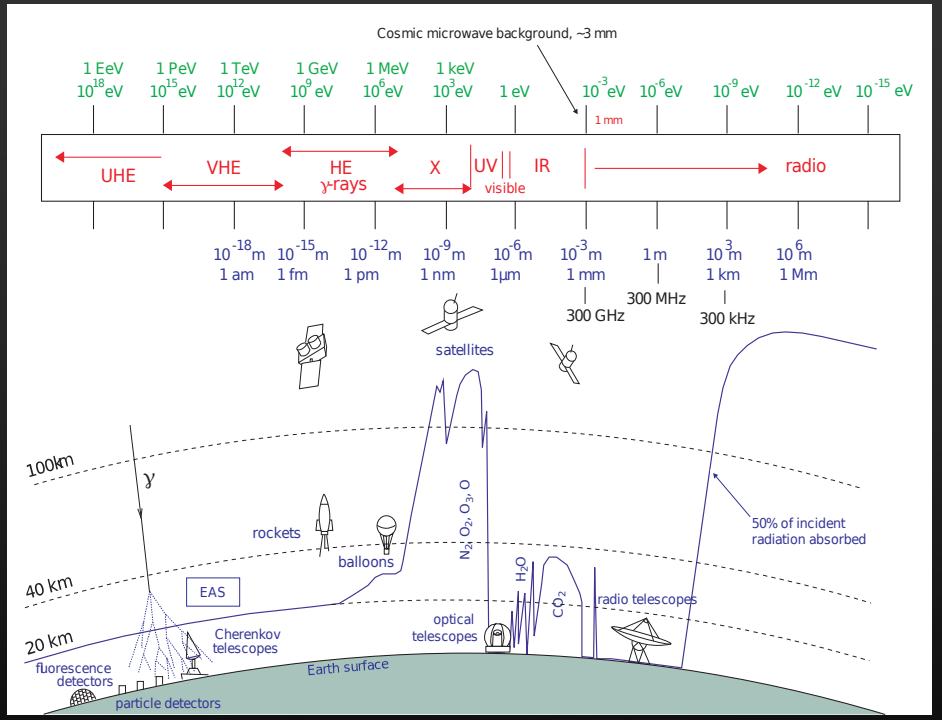


Astroparticle physics

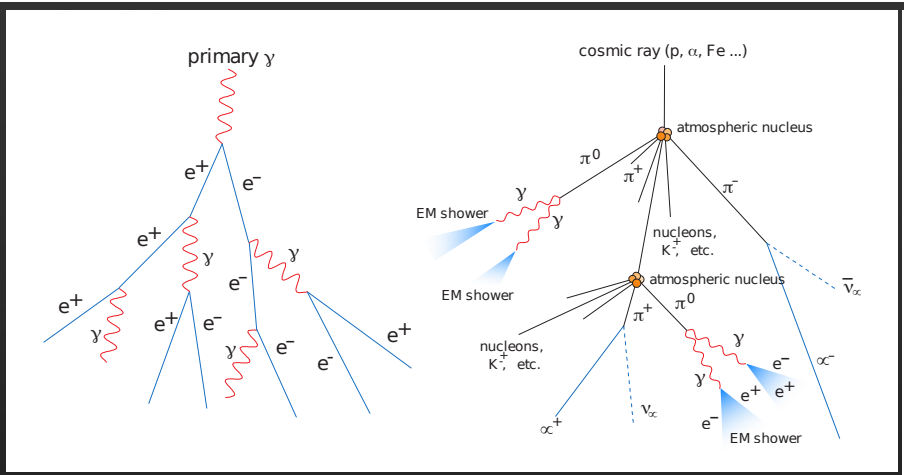
- Observations of specific sources only with photons and neutrinos
- Charged particles are deflected

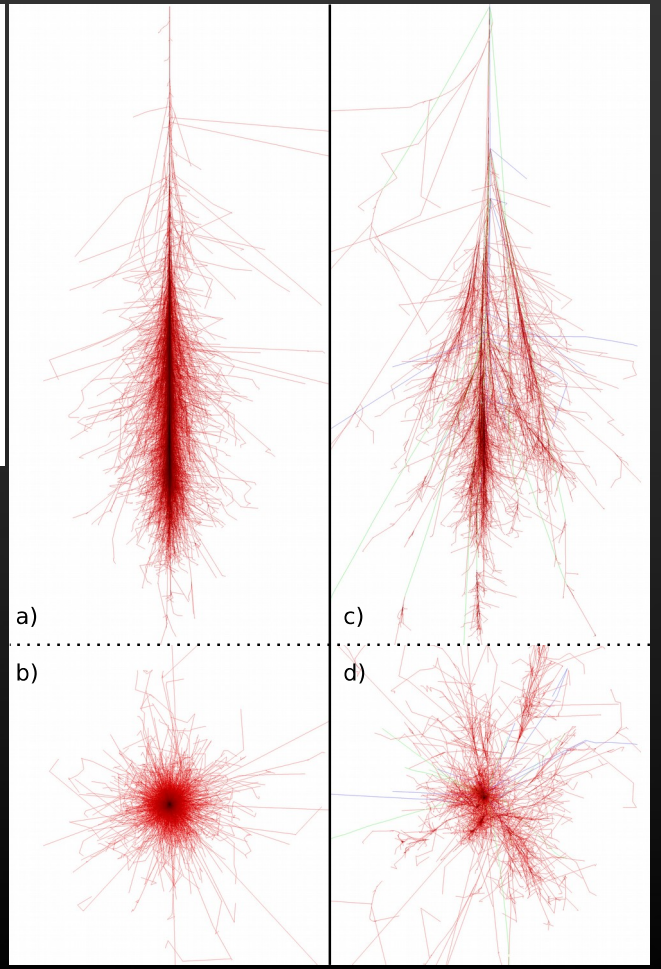


- Wavelength dependent transmission of atmosphere
- Atmosphere is not transparent for gamma rays
- How can MAGIC observe gamma rays?



Air shower

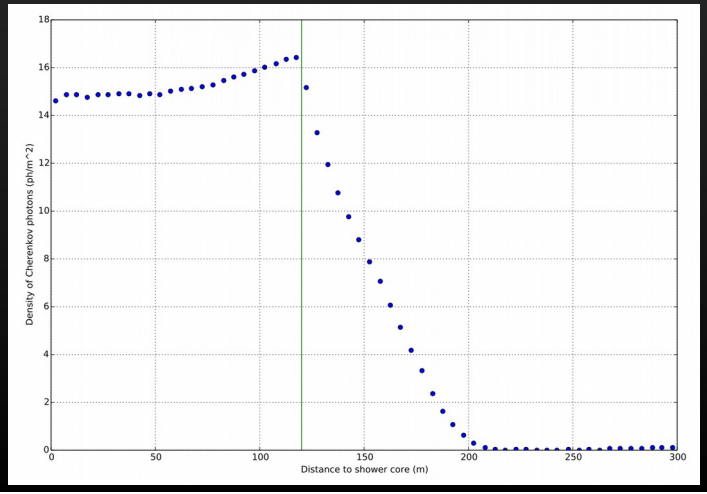


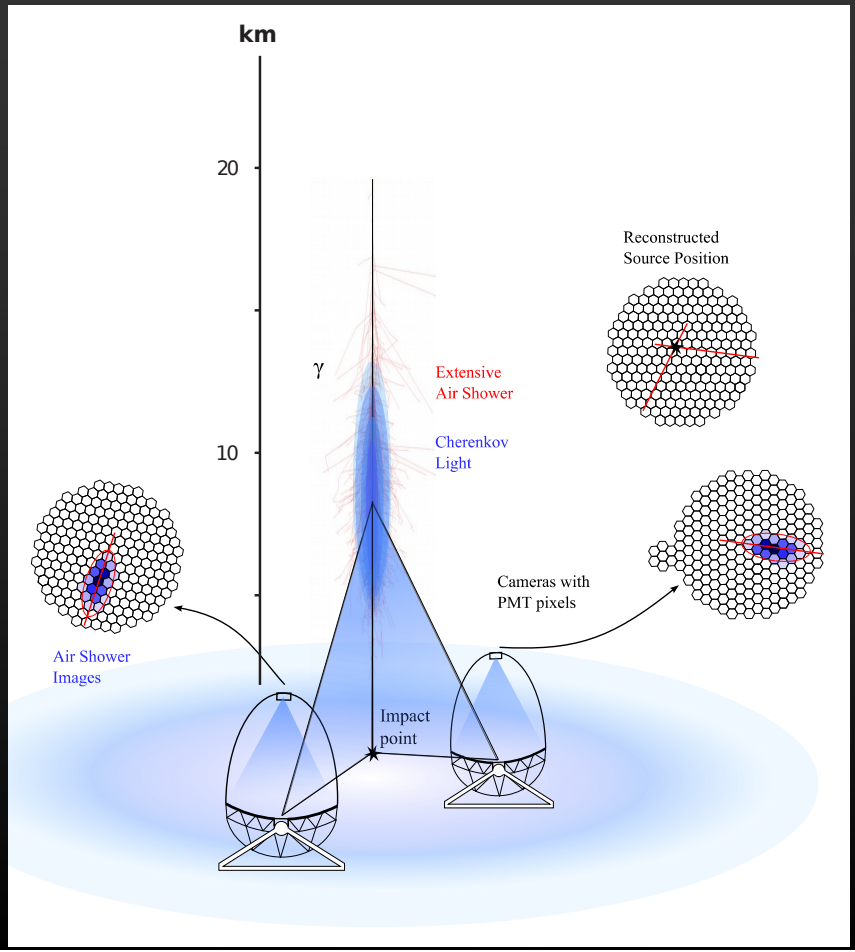


- EM shower
  - pair creation → Bremsstrahlung → pair creation →...
  - narrow, few ns duration
- Hadronic shower
  - $\pi^0 \Rightarrow$ EM shower
  - wide, ~10 ns duration

Cherenkov telescopes

- Charged particles of air shower v>c
  ⇒ Cherenkov light emission
- Superposition of Cherenkov light rings
- Cherenkov light pool r ~120m on ground
- Collect light with large surface
- Stereo reconstruction



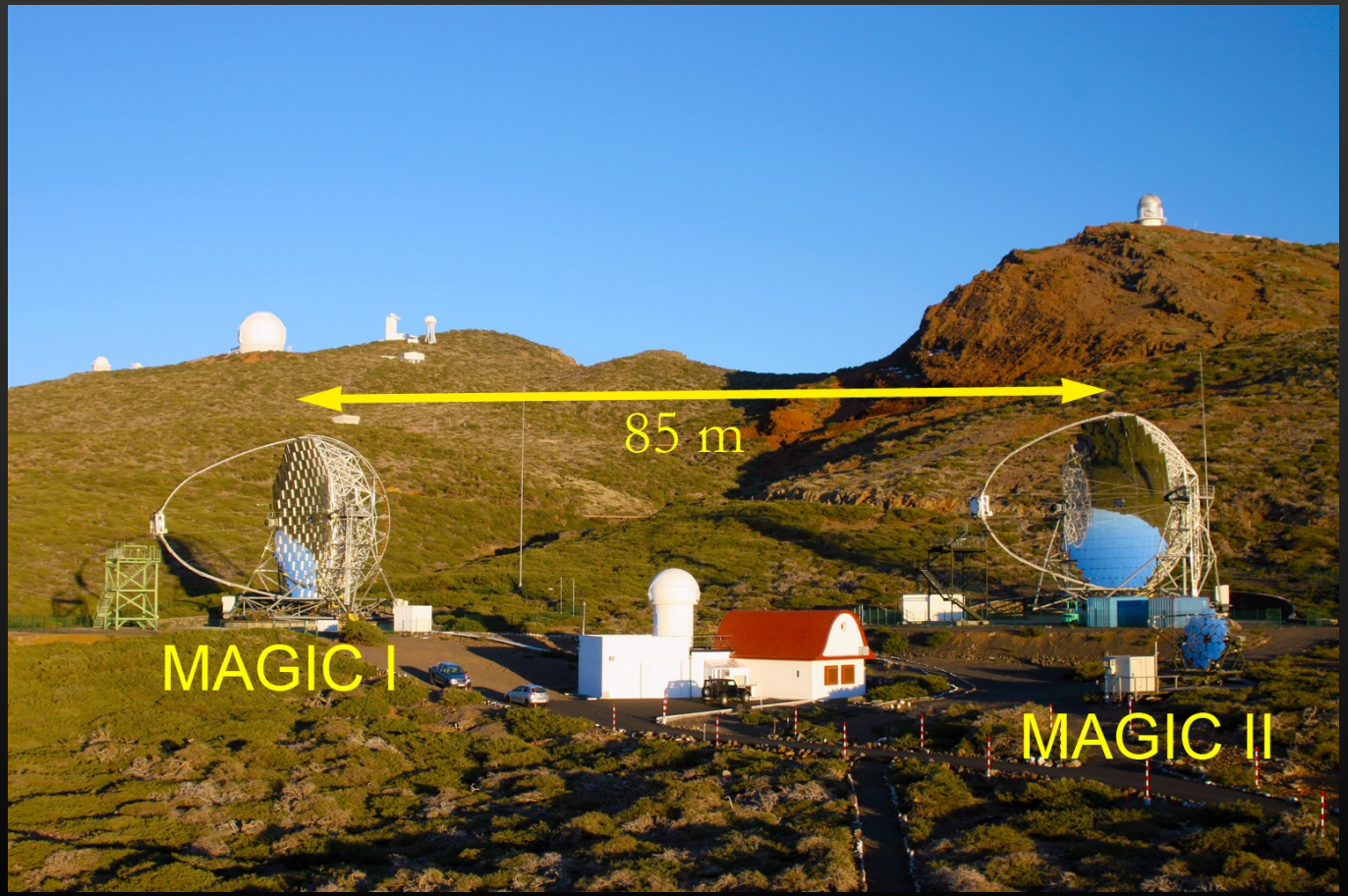


La Palma - HEGRA

- High-Energy-Gamma-Ray Astronomy
- Lowest energy threshold due to atmospheric Cherenkov telescopes
  10 m^2 mirror
- Burned down in bush fire
- Insurance payout was seed funding for MAGIC
- Wanted larger telescope for lower threshold
  ~ 200 m^2

La Palma - MAGIC

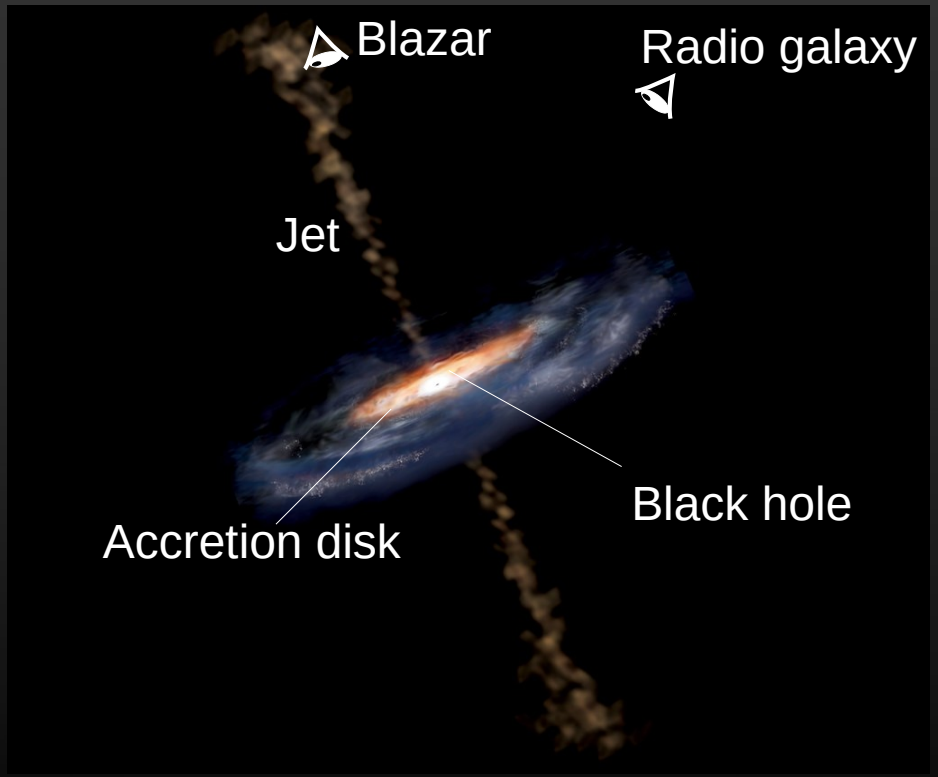
- Major Atmospheric Gamma Imaging Cherenkov
- 236m² mirror (17m Ø)
- light weight ~70 tons
- Fast rotation
- Operation and DAQ in counting house



- Segmented mirror with tiltable tiles
- 1039 photomultiplier tube (PMT) pixels
  + open spots for prototyping (my last IMPRS talk)
- Each pixel connected via optical fibre to DAQ in counting house
- 1.64 GHz readout frequency
- Trigger logic and sampling in counting house
- Sum-trigger for lowest possible threshold
  → Giovanni's talk

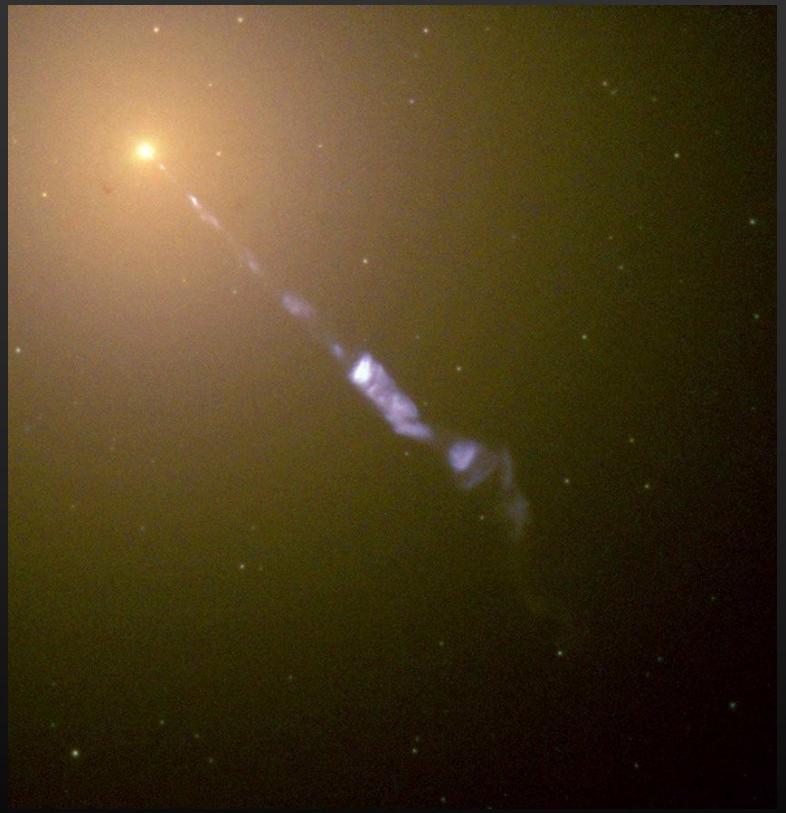
AGN

- Active Galactic Nuclei (AGN)
  (very simplified)
- Super-massive black hole in the centre
- Accretion disc
- Relativistic jet
- multi-size scales ⇒ multi-wavelength studies
- Many different, overlapping classifications
  - Blazar: jet directed to observer
    - ⇒ Strong boosting
    - 81 known in VHE
  - Radio galaxy: view from the side
    - ⇒ little boosting
    - Structures observable in radio/X-ray
    - 3 known in VHE



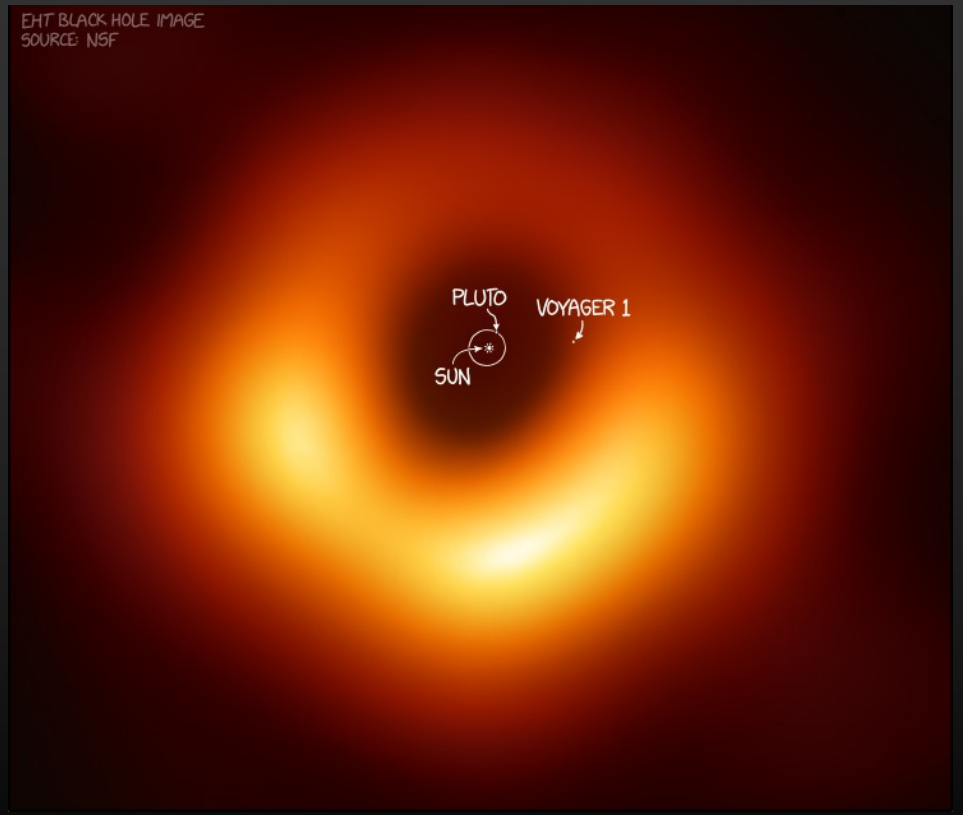
M87

- Supergiant elliptical galaxy in the Virgo cluster
- Distance only 16.8 Mpc
- Supermassive BH in centre (6.5 x 10 9 M ⊙)
- Relativistic collimated jet (with knots)
- Viewing angle 163° (17°)
- Jet extends 65 kpc (~ 14“)
  Jet age ~ 40 Myr
- First radio galaxy detected in VHE
- Studied in all wavebands
- Previous flux variability ⇒ small emission region
- Target:
  - Origin of quiescent γ-ray emission
  - Variability of M87 and its possible correlation with new components emerging close to jet base
  - MWL data to distinguish between emission 20-100 R_s or further down the jet



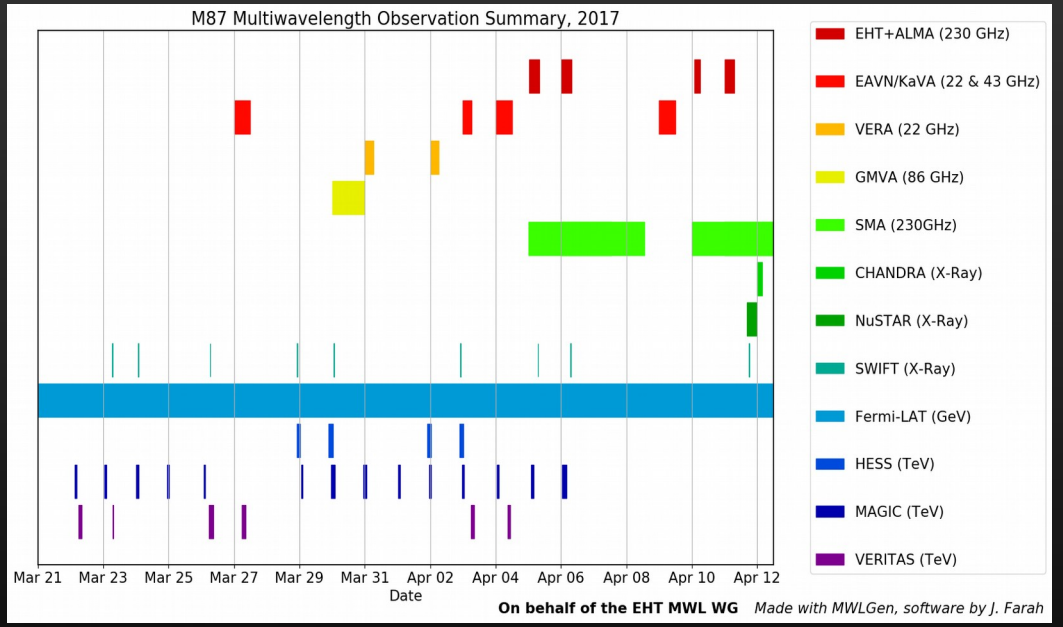
M87

- Event Horizon Telescope (EHT)
- Global network of radio telescopes
- 2017 data revealed the first “photo” of a black hole (BH) event horizon
  - BH shadow is observed
  - BH rotating clock-wise
  - Consistent with a magnetised accretion flow orbiting a Kerr BH
  - jet is launched in the vicinity of the BH (~100 μas)
  - Multiwavelength (MWL) observations nedded for more physics



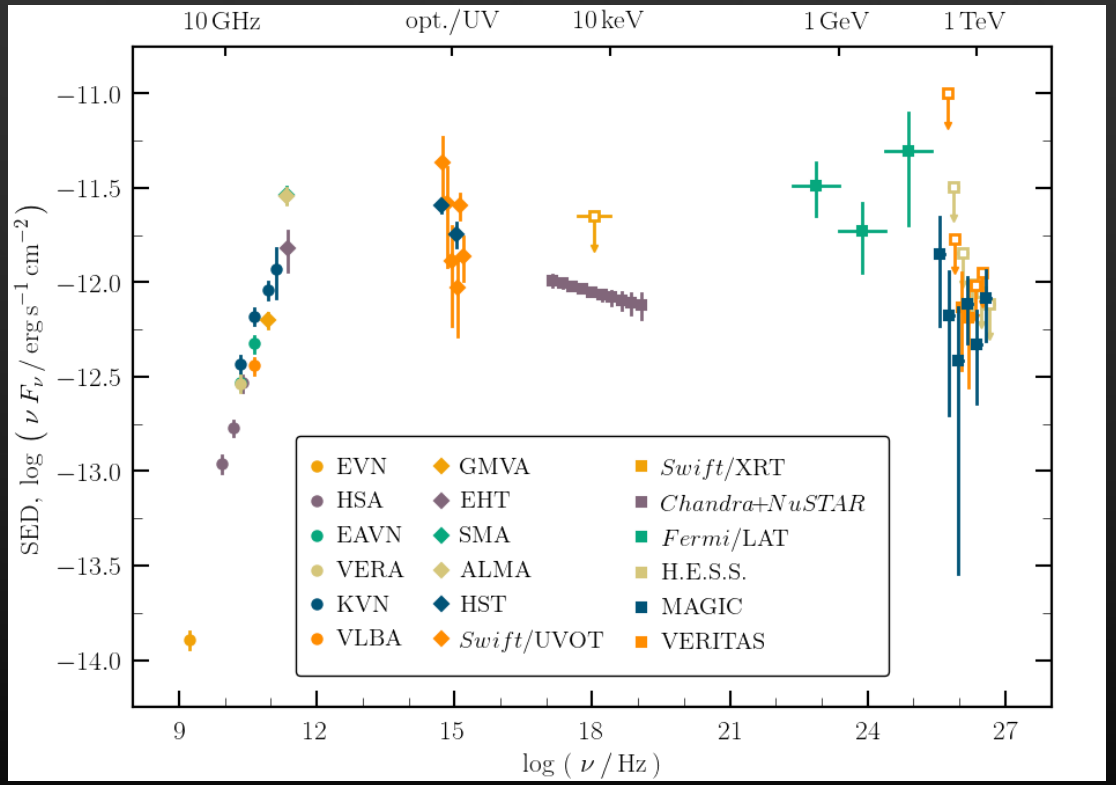
M87 MWL

- 2017 EHT-MWL campaign
- MWL is essential to understand the source
- Get as much MWL as possible
- Spanning the range from radio through TeV gamma rays
- Instruments include: MAGIC, EAVN, Chandra, NuSTAR, EHT, ….



MWL SED

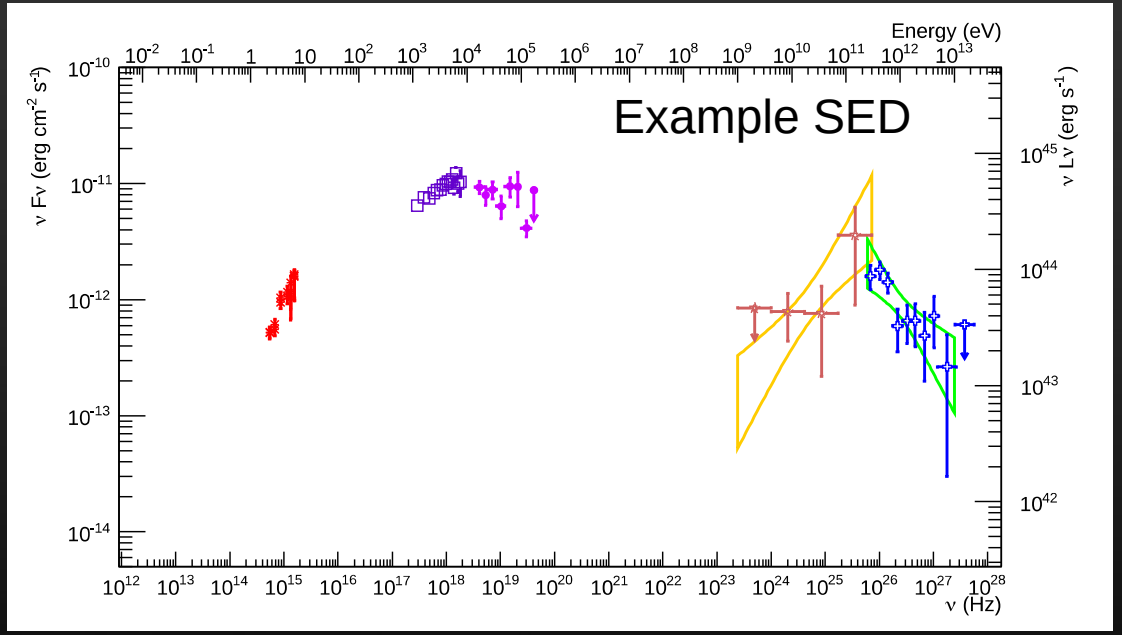
- Broad-band spectral energy distribution
- 2-humped structure
- Usually MWL data has large time spans
- This is all quasi-simultaneously
- Spanning ~ 15 decades in energy ⇒ Converging very different size scales !
- Model fitting to extract physical source parameters (of that model)
  - e.g. with one-zone synchrotron self-Compton (SSC) model



SED Models

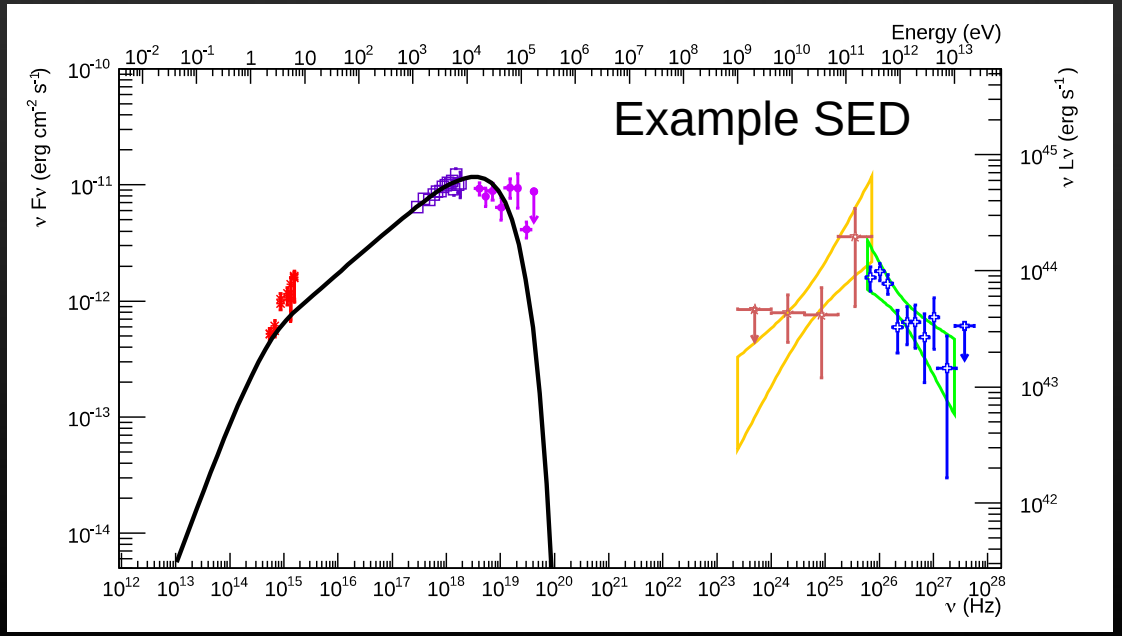
One-zone models

- Simple model with only one emitting region
- Radiating particles:
  - Leptonic
  - Hadronic
  - Hybrid



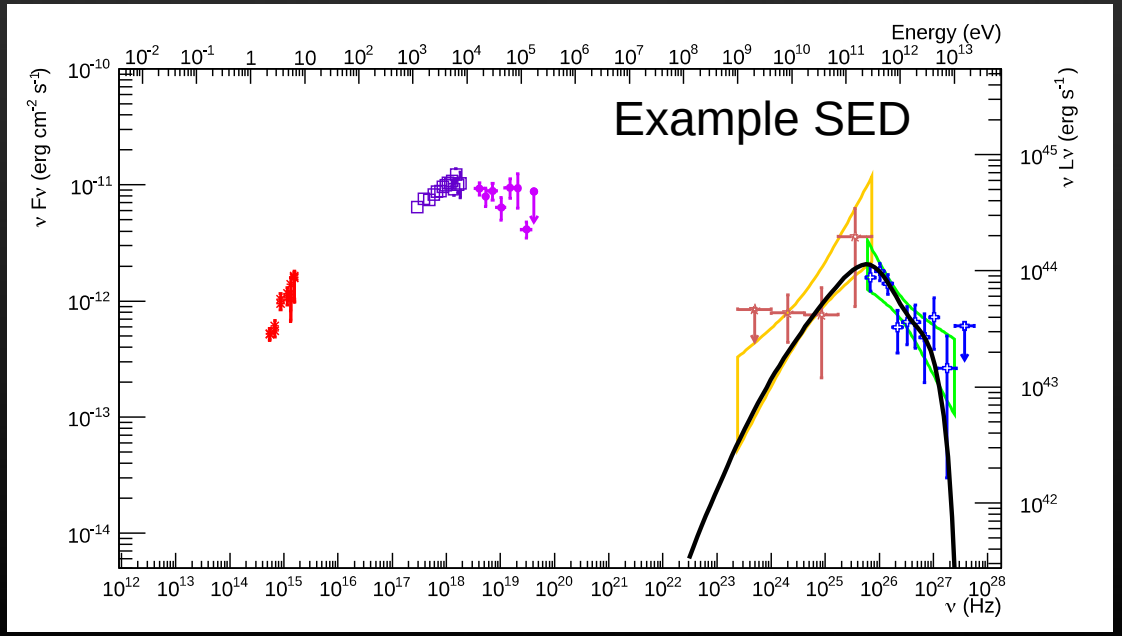
Synchrotron

- Synchrotron peak
  - Charged particle moving at relativistic speed in B-filed
  - ⇒ Circular Lorentz motion
  - ⇒ Emission of photons



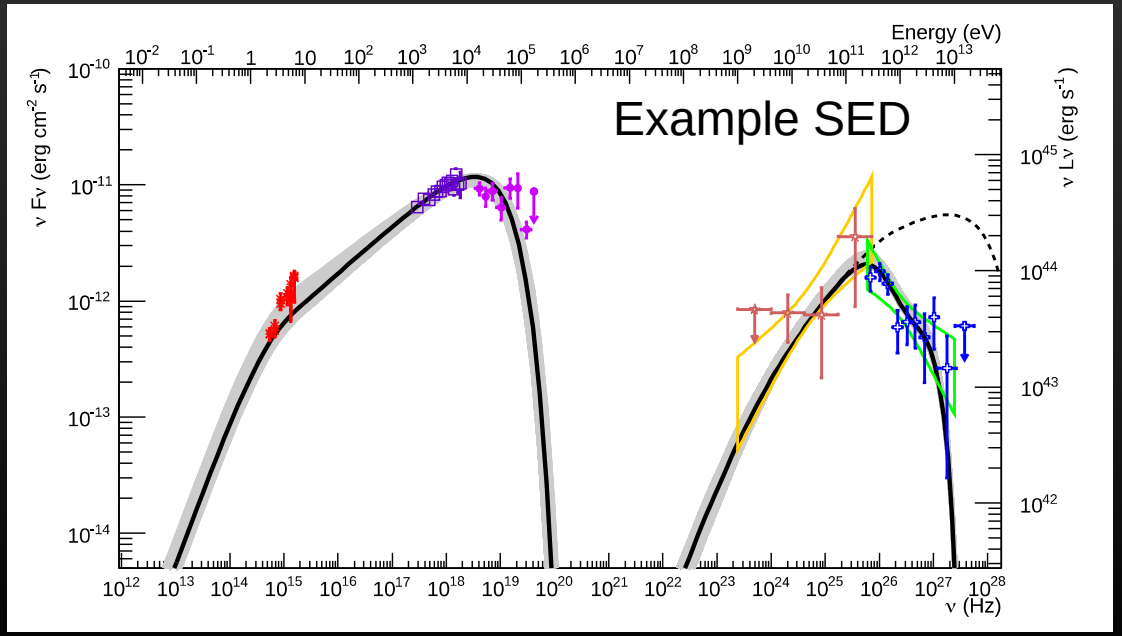
Inverse Compton

- Synchrotron peak
  - Charged particle moving at relativistic speed in B-filed
  - ⇒ Circular Lorentz motion
  - ⇒ Emission of photons
- Inverse Compton peak
  - A low energy photon scatters of a relativistic electron
  - ⇒ Photon gains energy (electron losses energy)



Inverse Compton

- Synchrotron self-Compton (SSC) model
  - Relativistic electrons in the jet
  - Low energy peak: Synchrotron radiation
  - High energy peak: Inverse Compton radiation
  - Seed photons for the IC are the original synchrotron photons




Thank you for your attention