H.E.S.S. observations of radio galaxies

Very High Energy Gamma-Ray Astronomy

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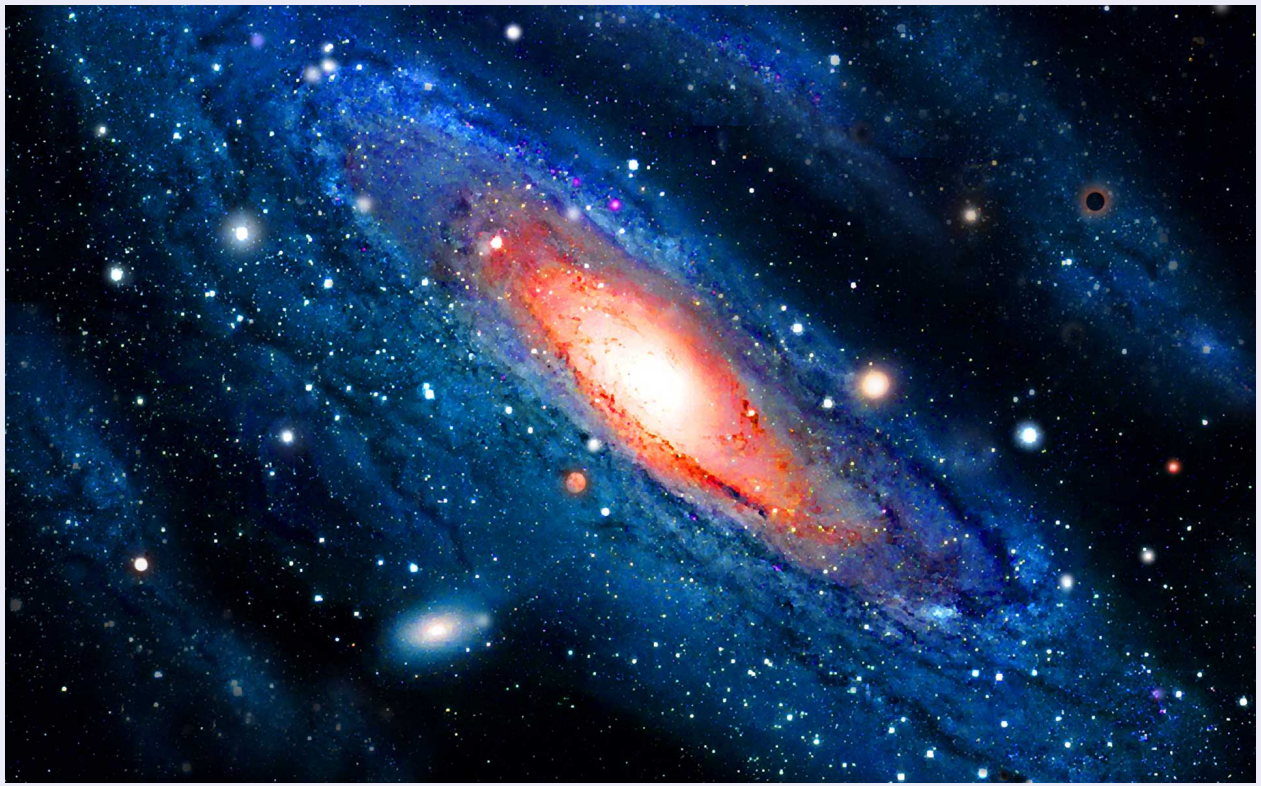
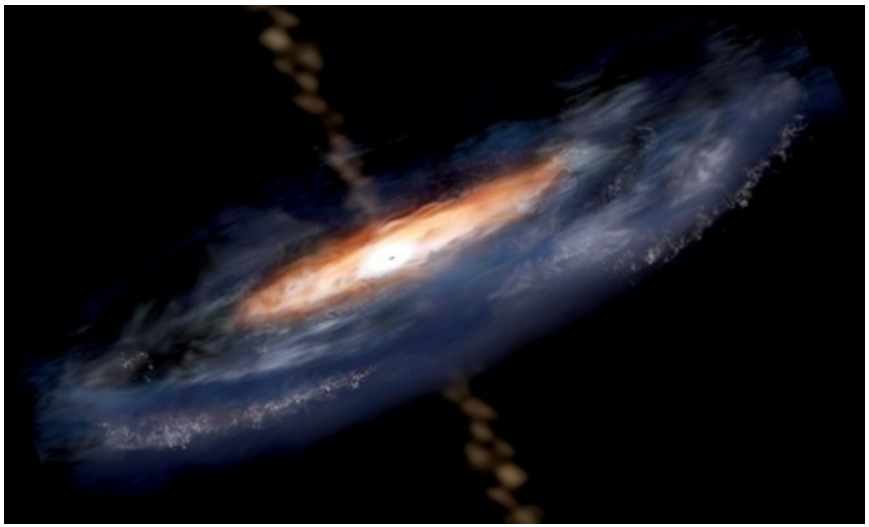
Outline

- About Active Galaxies and Jets
- Radiation Process
- AGN Classification
- Some Radio Galaxies with HESS
- Outlook

“not-so-active” Galaxies

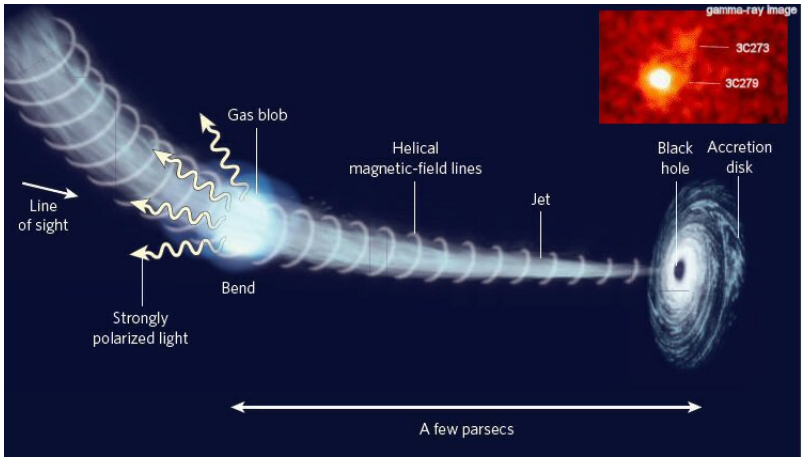


Active Galaxies



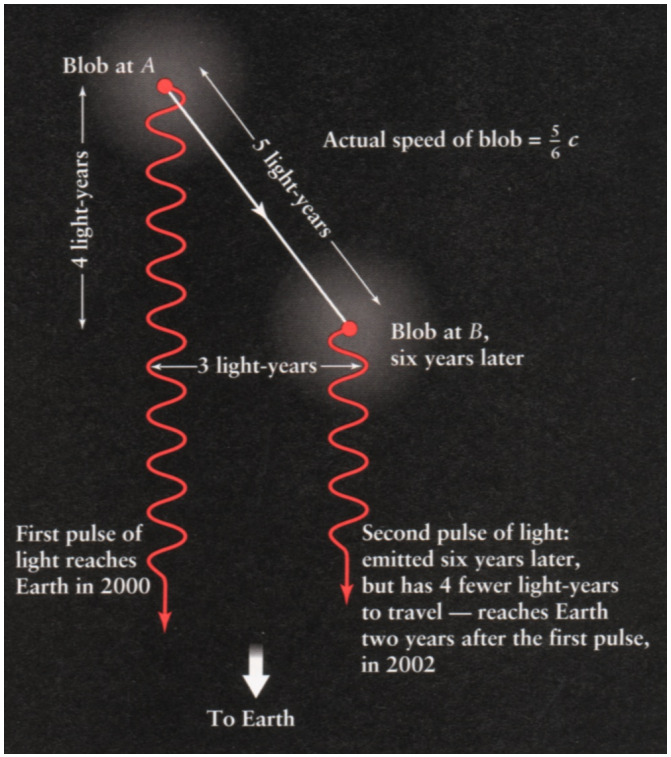
- Given a **supermassive black hole** (SMBH) at galaxy center
- most galaxies have quiet centers
- a few accrete mass and emit radio to gamma
- latter said to be **Active Galactic Nuclei** (AGN)

Astrophysical Jets



- jets are **common** in the Universe
- jets from: pulsars, X-ray binaries, AGN, GRBs
- in AGN: jets due to accretion onto SMBH
- carry particles, energy, B-field
- should be powered by central SMBH

Jet Physics — Superluminal Motion

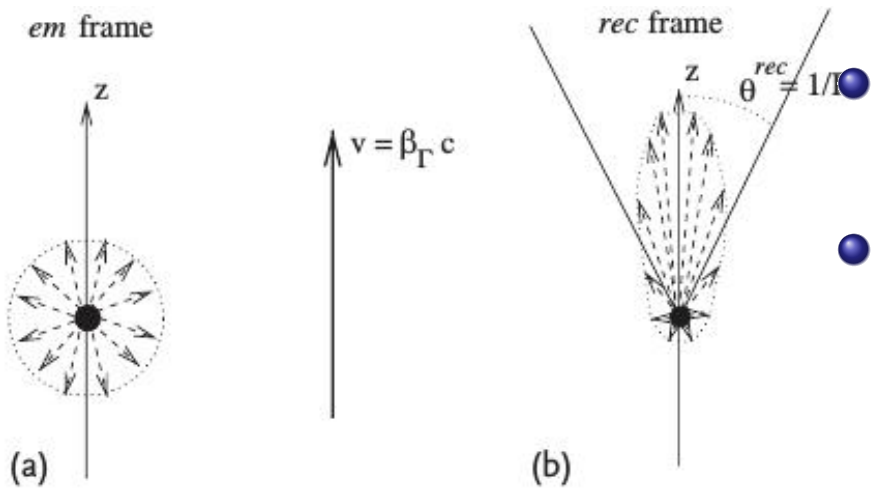


- apparent $v > c$, hence "superluminal"
- only a geometric effect
- arrival time of later pulses enhanced by source motion
- apparent transverse speed

$$v_{\perp_{\rm app}} \leqslant c\,\sqrt{\Gamma^2 - 1}$$

with typical blazars with $\Gamma \sim 10$

Jet Physics — Relativistic Beaming



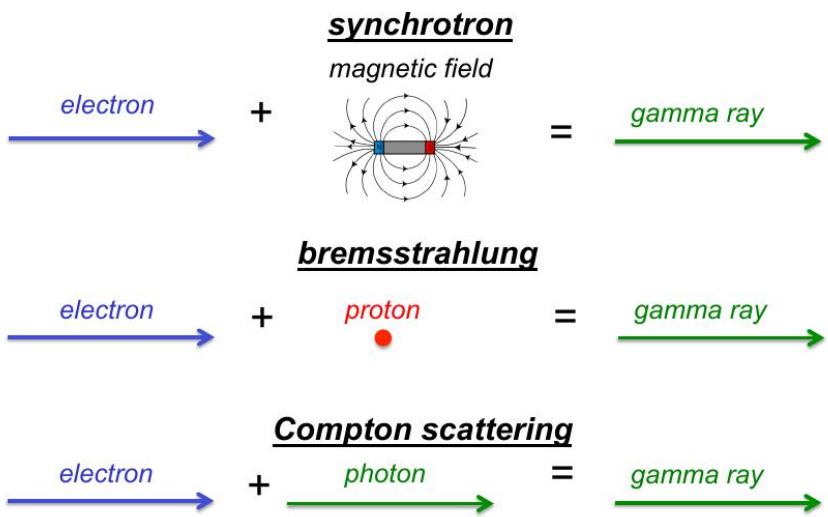
- radiating blob along jet
- blob moves at **relativistic** speed
- blob radiation **beamed** into **forward** direction
- result: Lorentz boosted **headlight effect**

$$F_\nu^{\rm obs} = \delta_D^3 F_\nu^{\rm em}$$

where $\delta_D = \frac{1}{\Gamma(1-\beta cos\theta)}$

Radiation Processes

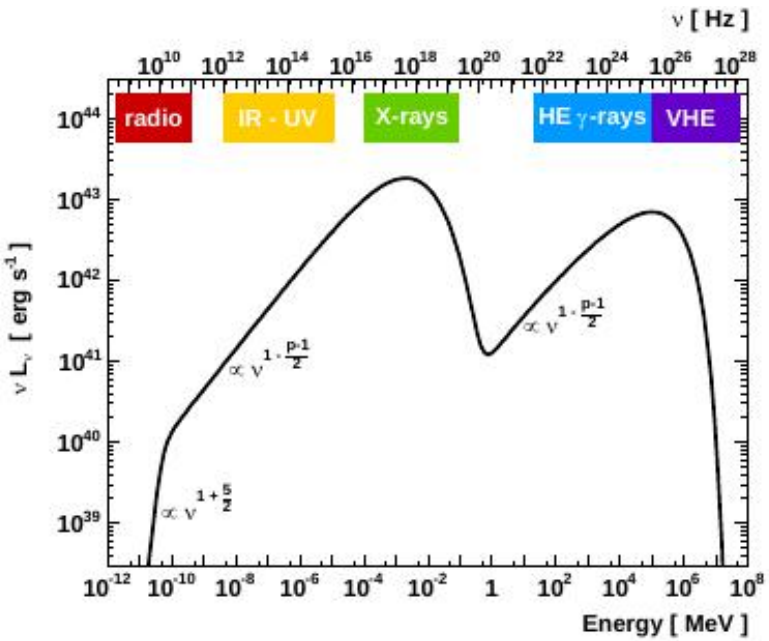
Non-thermal process involving electrons



- flux depends on electron energies, B, volume, photon density, etc.
- Inverse-compton upscattering of low-energy photons
- Syn. Self-Compt. (SSC): seed photons from synchrotron
- External Compt. (EC): seed photons from CMB, disk, etc.

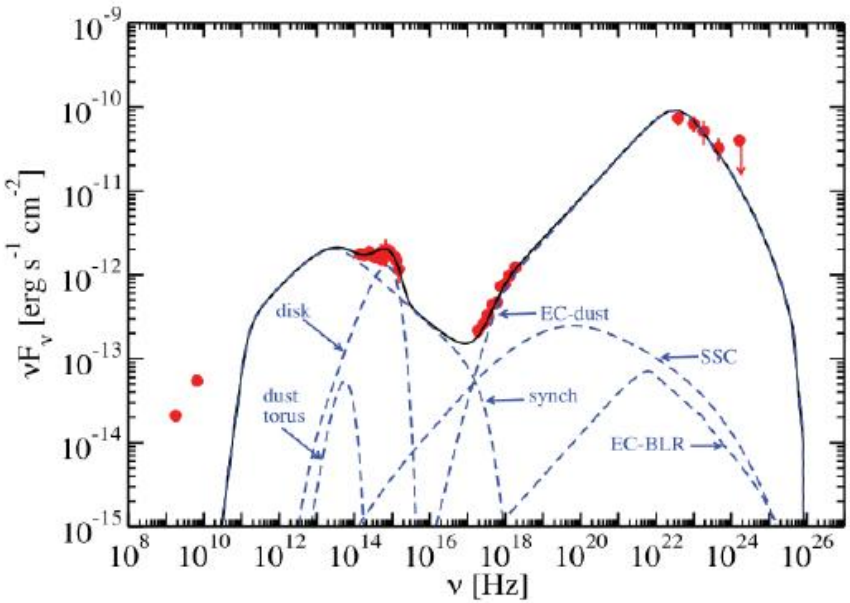
$$\nu_{\mathrm{Compt}} \sim \nu_0 \gamma^2$$

Radiated Spectra



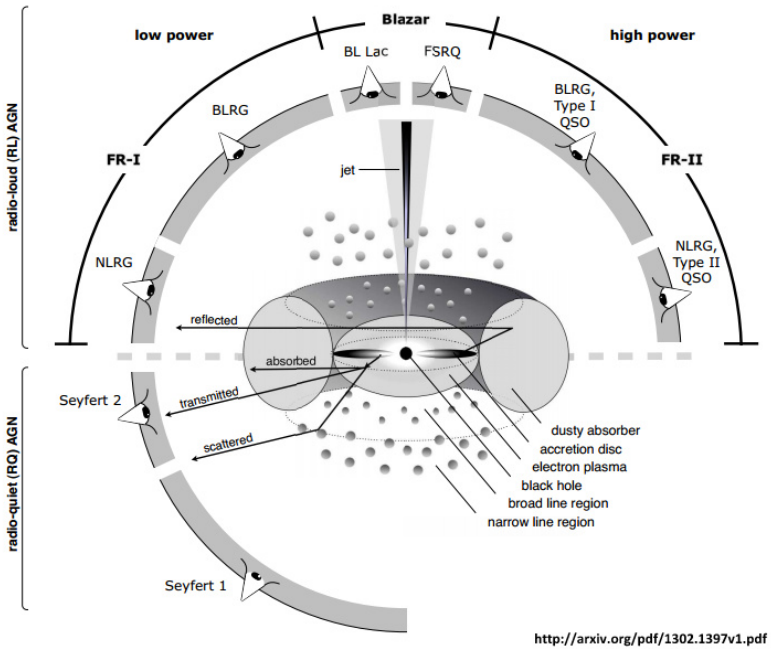
- Synchrotron peak in lower energies up to X-rays
- Inverse-compton peak in γ-rays

Modelling the VHE Spectra



- leptonic or hadronic
- gamma-gama pair production
- Spine-sheath model: two flow in jet
- Multi-blob SSC models

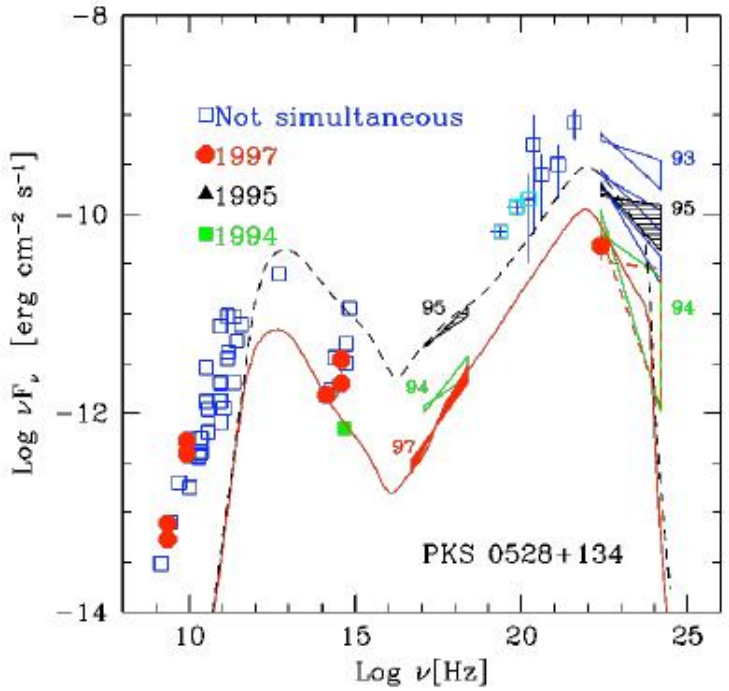
Classifying AGN by Viewing Angle



- Viewing angle $\theta_{\rm view}$ b/w LoS and jet direction
- for small $\theta_{\rm view}$: **blazar**
- for large $\theta_{\rm view}$: **radio galaxy**
- can be radio-loud or radio-quiet
- can have broad/narrow line emission
- **BL Lacs** have a narrower than **FSRQs**

Classifying Blazars by Synchrotron Peak

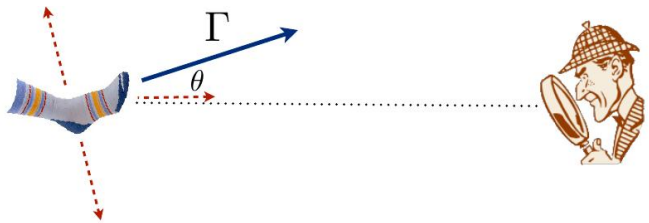
Blazer



Blazar

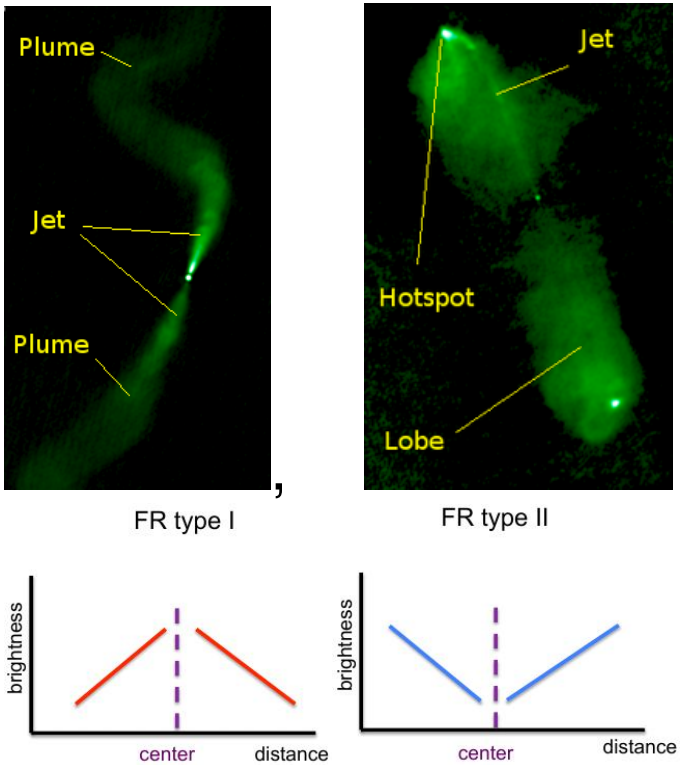
Classifying Blazars by Synchrotron Peak

From Low to High-energy peaked Blazars:
FSRQ - LBL - IBL - HBL - Extreme BL



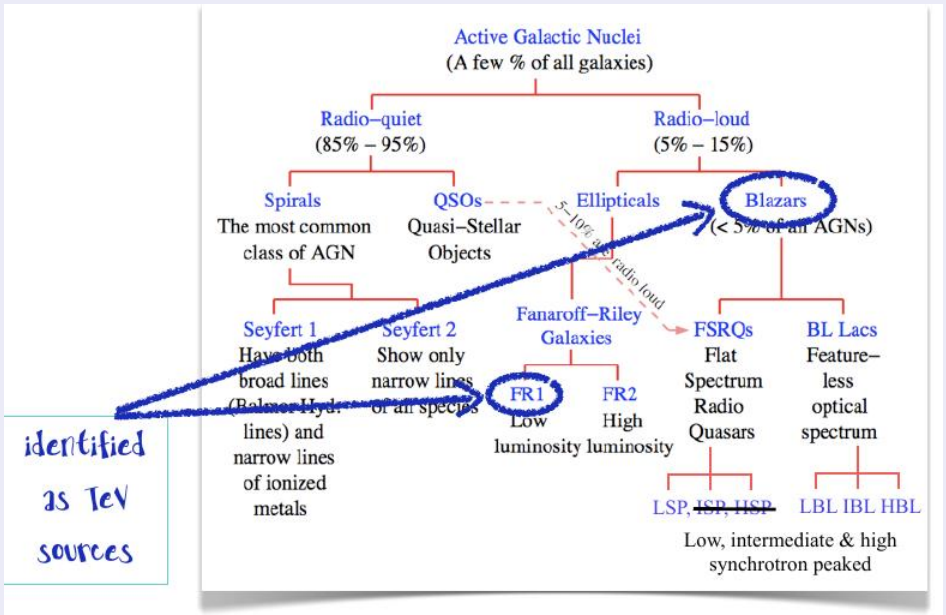
- check frequency at which "Synchrotron Peaks" (SP)
- LSP (Low): $\nu < 10^{14}$ Hz
- ISP (Intermediate) :10^{14} Hz $< \nu < 10^{15}$ Hz
- HSP (High): $\nu > 10^{15}$ Hz

Classifying Radio Galaxies by Morphology

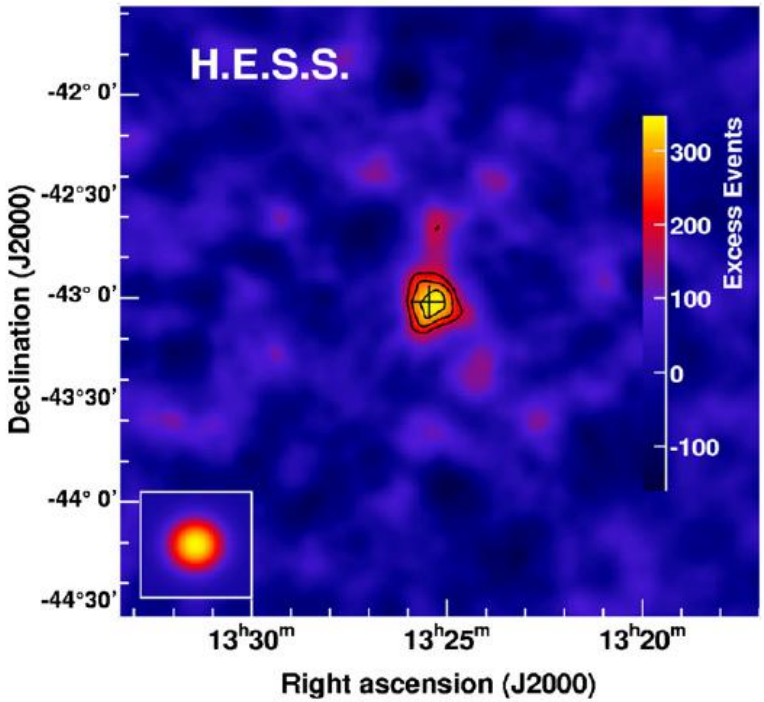


- study morphology of extended **double** radio structures
- classify by **structural features**: jets, lobes & hotspots
- 1974: Fanaroff & Riley proposed FR I and FR II types
- FR I e.g. Cen A | FR II e.g. 3C 47
- FR I: spectra steeper, aged radiating particles
- FR II: often giant elliptical host

The broader picture

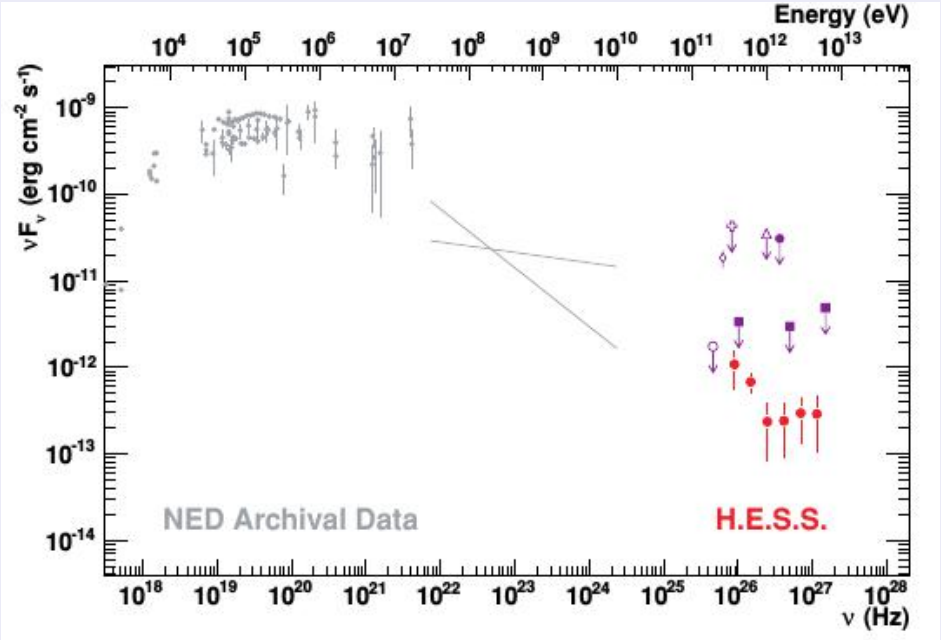


Centaurus A

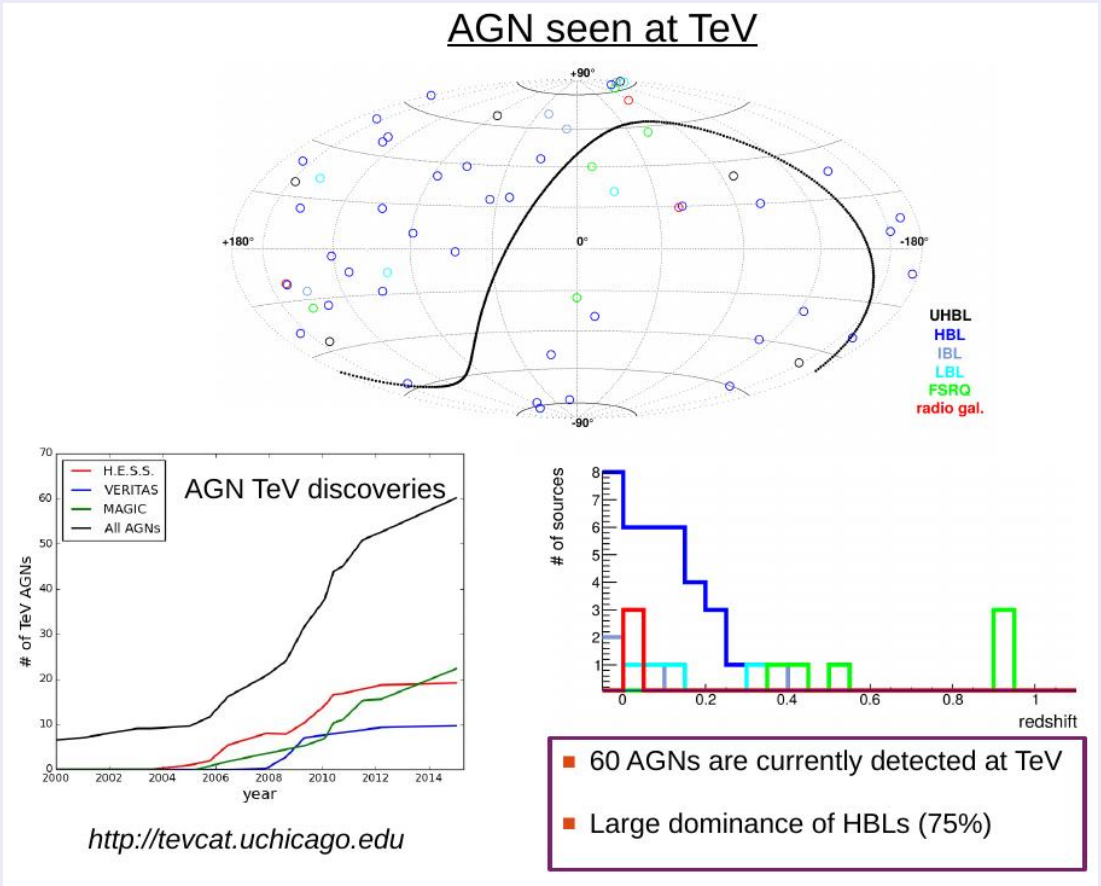


- giant elliptical host galaxy NGC 5128
- FR I and closest AGN to Earth at $\sim 13 \times 10^6$ ligth years
- SMBH $\sim 55 \times 10^6\ M_\odot$
- large viewing angle $\sim 70^\circ \Rightarrow$ weak/no relativistic boosting
- hence not expected as up to TeV emitter
- HESS obs.: seen in TeV $\Rightarrow$ "puzzle"

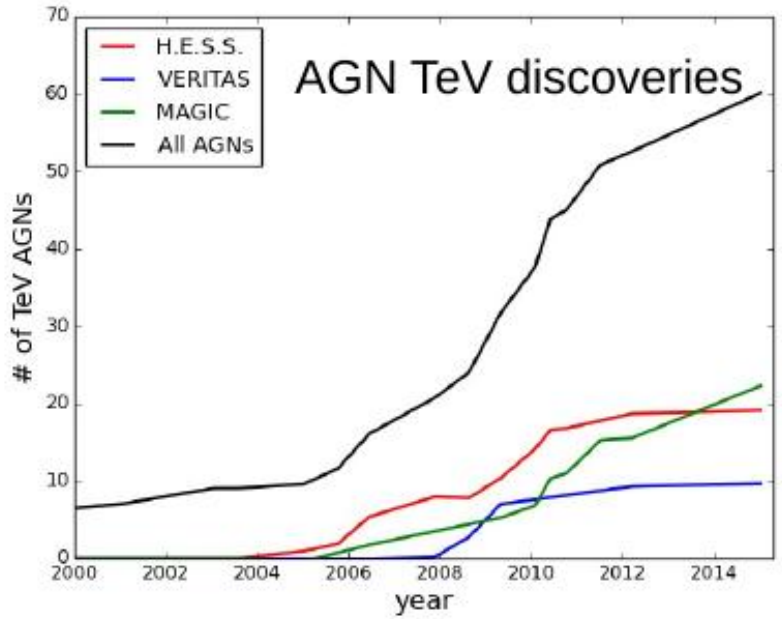
Spectrum: Centaurus A with H.E.S.S.



Current TeV AGN Sky



Other Radio Galaxies with HESS



- M 87 in Virgo cluster — extensively studied since start of HESS
- supergiant NGC 6251 in constellation Ursa Minor — far too north (dec $+82^\circ$)
- 3C 236 an FR II — also a northern source
- 3C 111 – Seyfert 1 Galaxy
- 3C 320 – A broad line radio galaxy
- radio galaxies are handful at

Ongoing AGN Observations

- Currently: analyzing 3C 120, PKS 1510-089 with HESS tools
- Performing FERMI analysis — Pass 8 one week old in public
- revisit Cen A VHE spectra and do hard-X-ray analysis (Swift)
- In general: Looking forward to CTA regime: next-generation VHE-γ-ray Observatory


Thank
You!