MAGIC
Major Atmospheric Gamma Imaging Cerenkov Telescope

28th Texas Symposium on Relative Astrophysics

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Very fast TeV γ-ray variability from the non-aligned AGN IC 310: Insight into Black Hole Lightning

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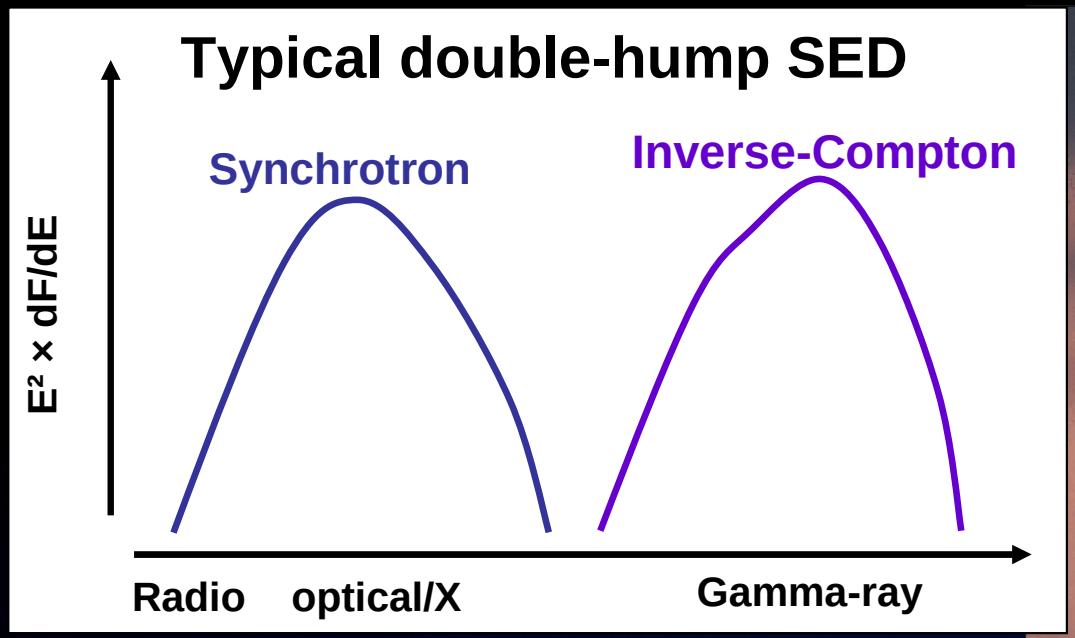
The MAGIC Telescopes

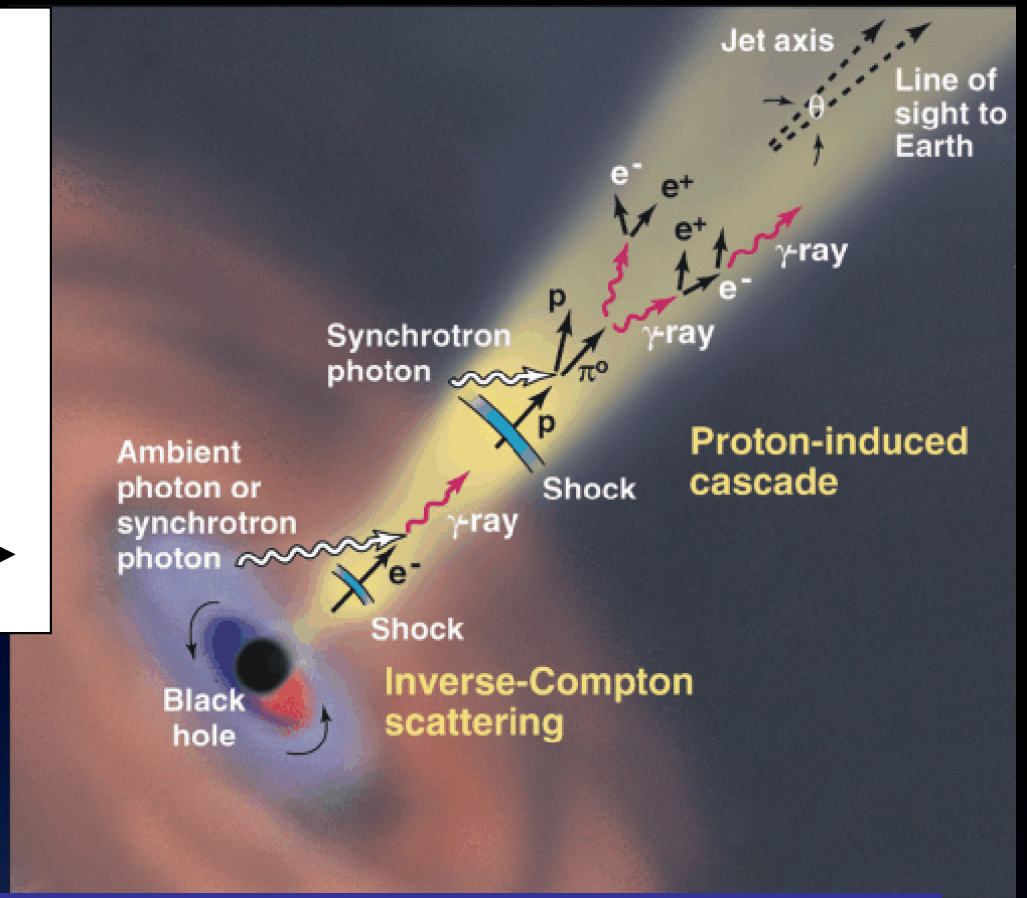
System of 2 Cherenkov telescopes 17m in diameter

- **MAGIC cameras**:
  - Field of view: 3.5°
  - 1039 pixels / camera
- **Stereo Trigger:**
  - Rate: ~300 Hz
  - Energy threshold: ~50 GeV
- **Performance:**
  - Sensitivity (50h): 0.7% Crab
  - Angular resolution: <0.1°
  - Energy resolution: ~15%

Particularly efficient tool to study AGN at Very High Energy:
MAGIC discovered 24 of the 65 known AGNs

VHE γ-ray emission of AGN





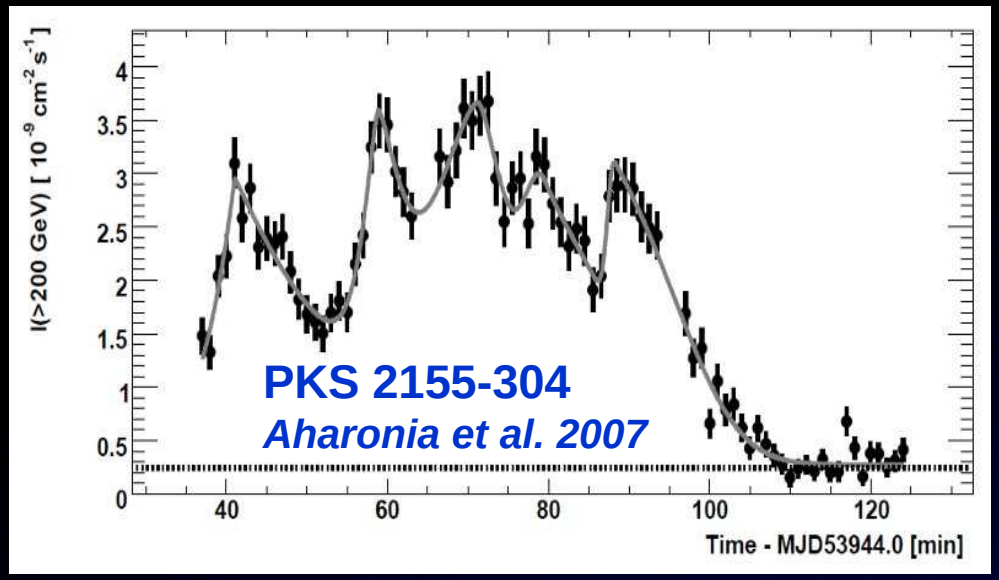
Detection by IACT:
- 60 blazars (θ<5°)
- 5 radio galaxies

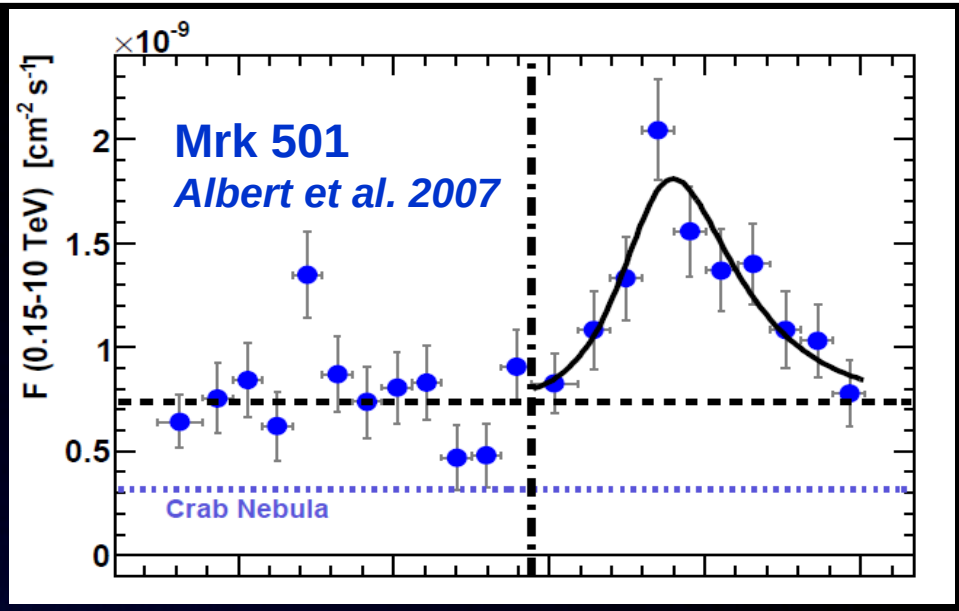
Classical interpretation:

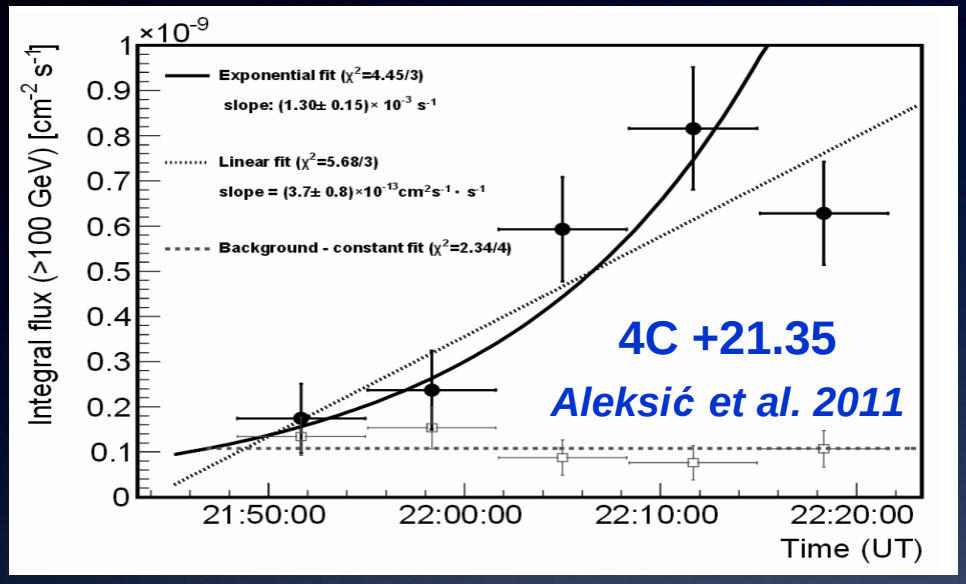
- **Ultra-relativistic particles accelerated in shocks in jet**
- **Emission dominated by HE electrons (synchrotron & IC)**
- **Doppler boosted toward high energies: $\delta = 1 / \Gamma_{bulk}(1-\beta \cos(\theta))$**
- **Shortest variability time-scale: Event horizon light crossing**

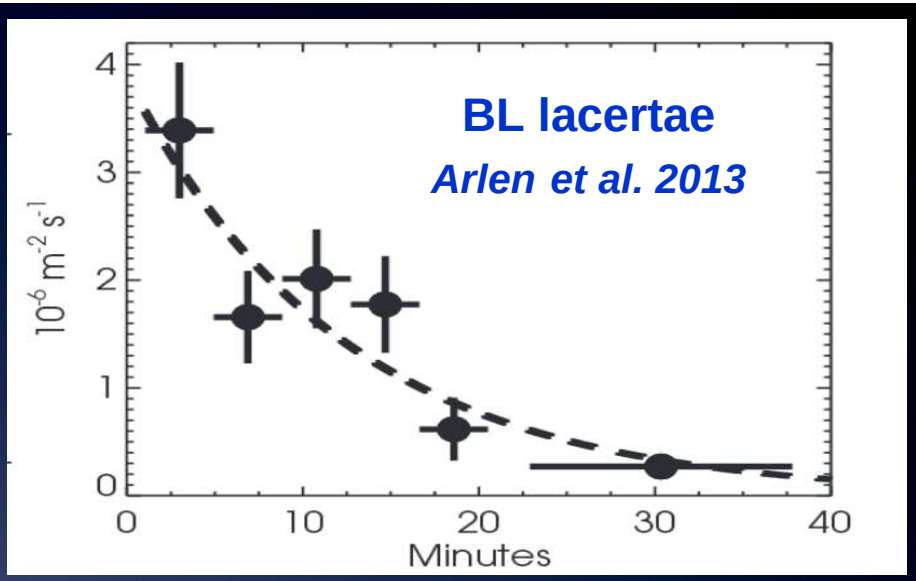
  $\Delta t_{BH} = GM/c^3 = 1.4 \cdot (M/10^9 M_\odot)$ hours

Rapid variability of Blazars









Variability time-scale down to a few minutes (≤ Δt_{BH})
seen in every class of TeV Blazars

The Doppler boost explanation

Main issue of shock-in-Jet paradigm:

Internal VHE gamma-ray absorption by the co-produced synchrotron radiation.

Solution: **A very large Doppler factor**

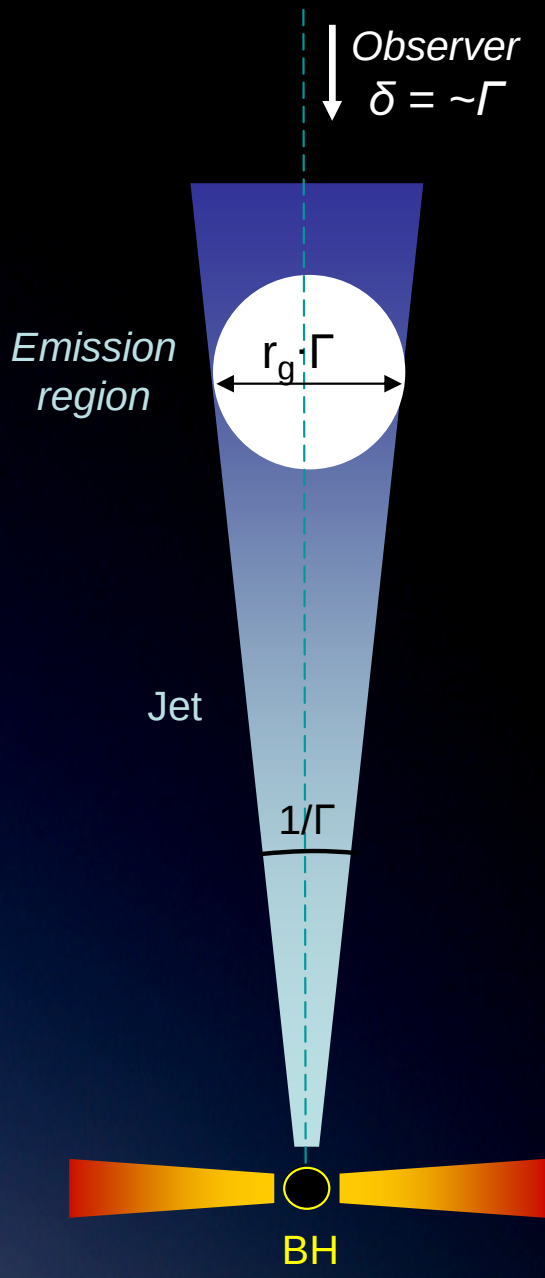
For Mrk501 & PKS 2155-304 minute variability:

- Lorentz factor $\Gamma \geq 50$
- View angle $\theta \leq 1°$

Additional issues:

- If typical blazar Γ>10, we should see much more mis-aligned Blazar than observed
- The origin of the perturbations at the jet injection is not time boosted:

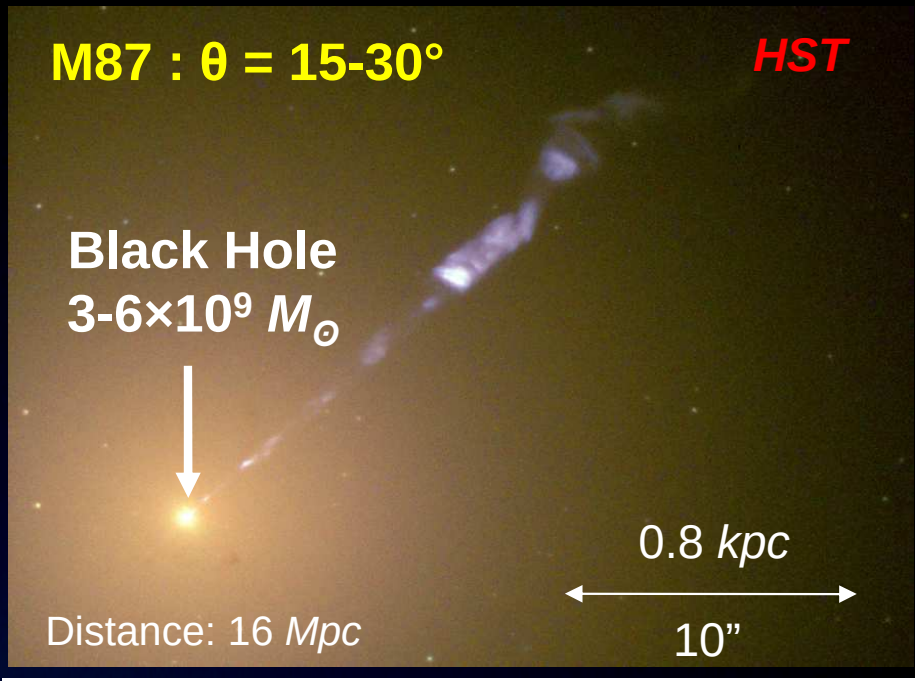
Origin of variability < Δt_{BH} not explained



Variability of TeV radio galaxies

Radio galaxies

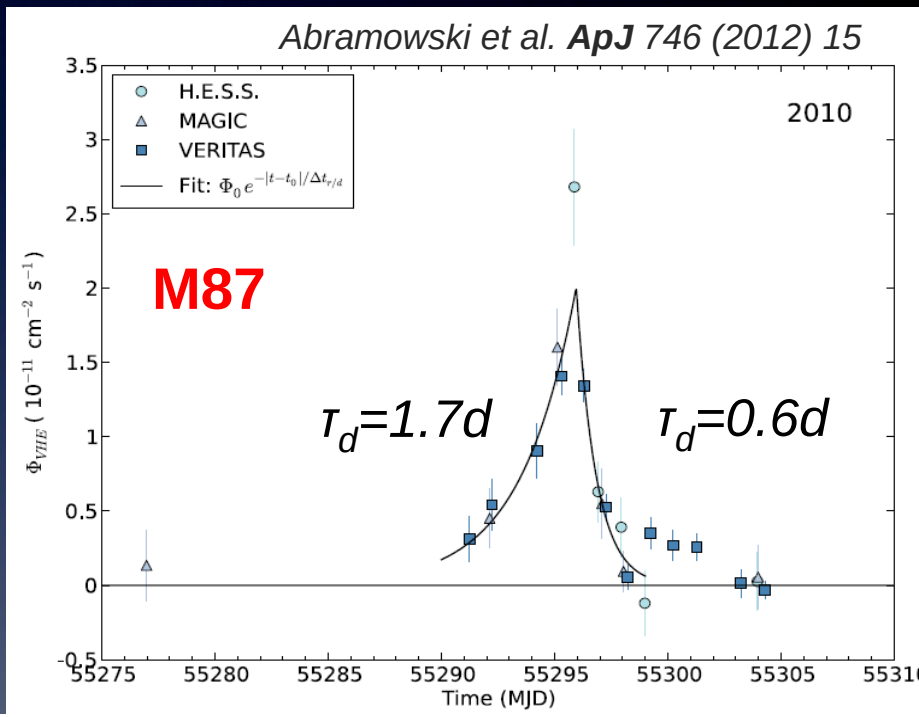
- Jet not pointing toward us
- Limited Doppler boost δ
- Weaker signal
- Only a few detected at VHE



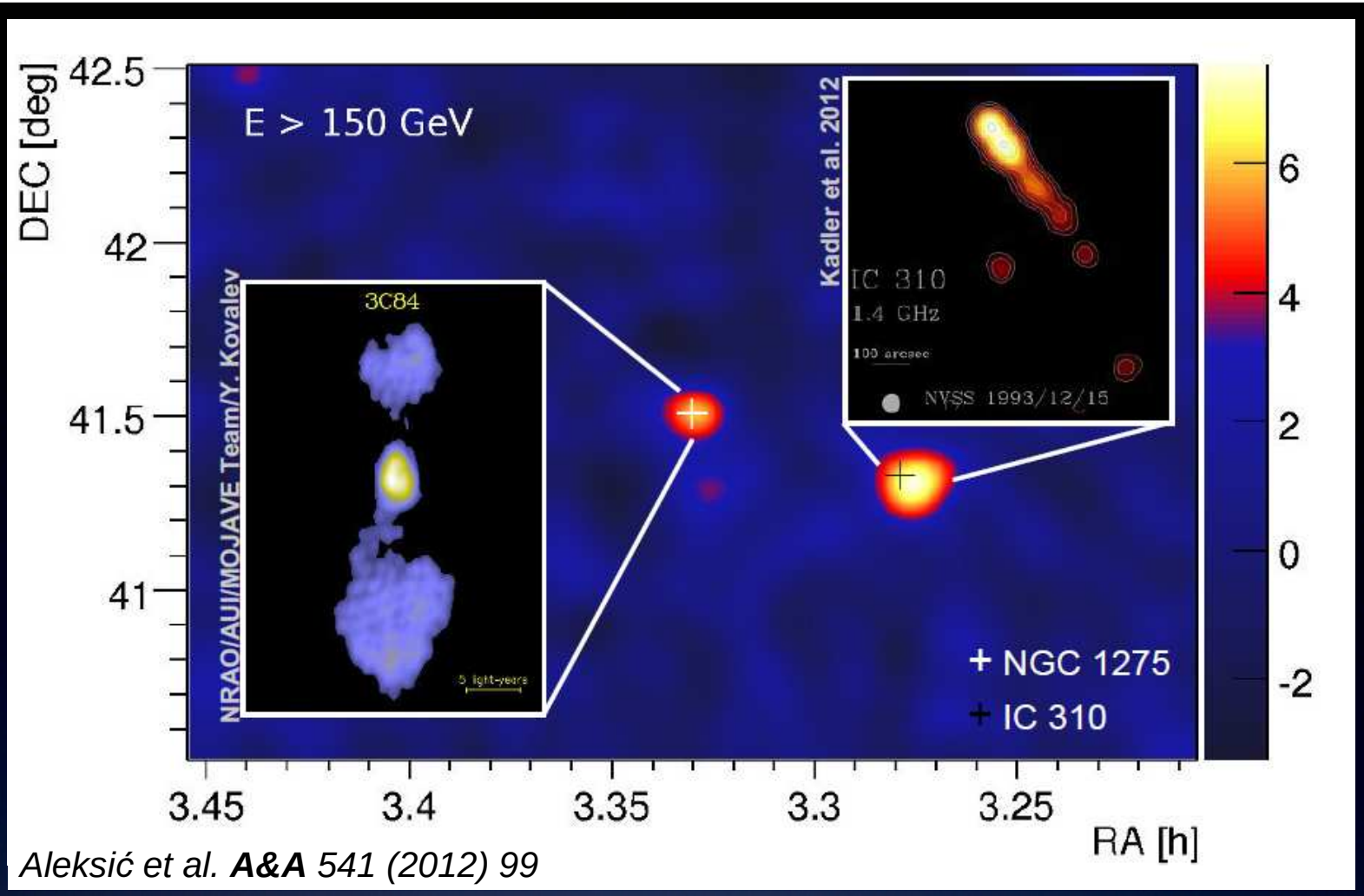
Best studied case: M87

- Viewing angle θ ≈ 20° (δ≤3)
- M_{BH} = 3-6·10⁹ $M_\odot$
- **Δt_{BH} = 0.2-0.4 day**

Observed VHE variability: ~Δt_{BH}



The Perseus Cluster seen by MAGIC

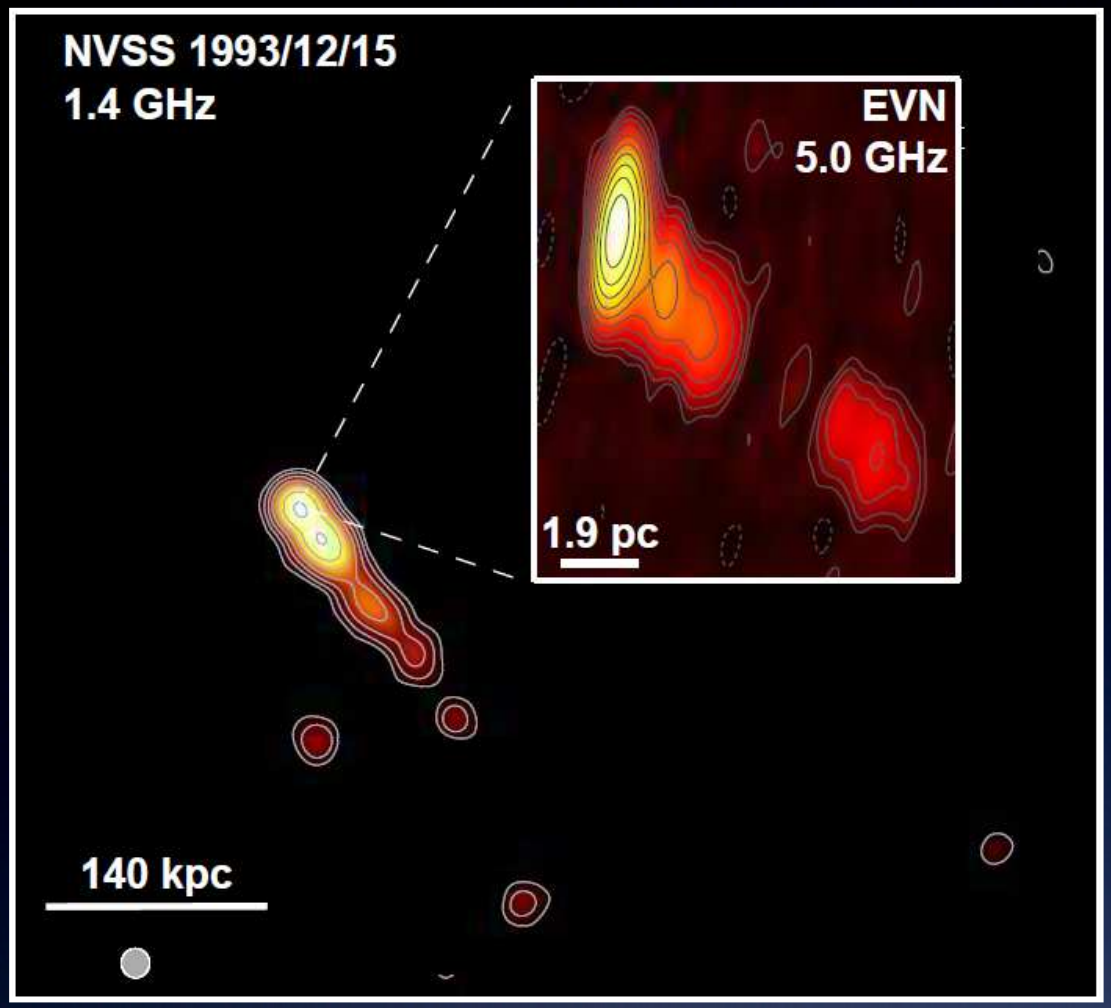


Aleksić et al. ***A&A*** *541 (2012) 99*

Detection of two new AGNs:

- **NGC 1275: The Central dominant radio galaxy**
- **IC 310: a peculiar radio galaxy**

The peculiar radio galaxy IC 310

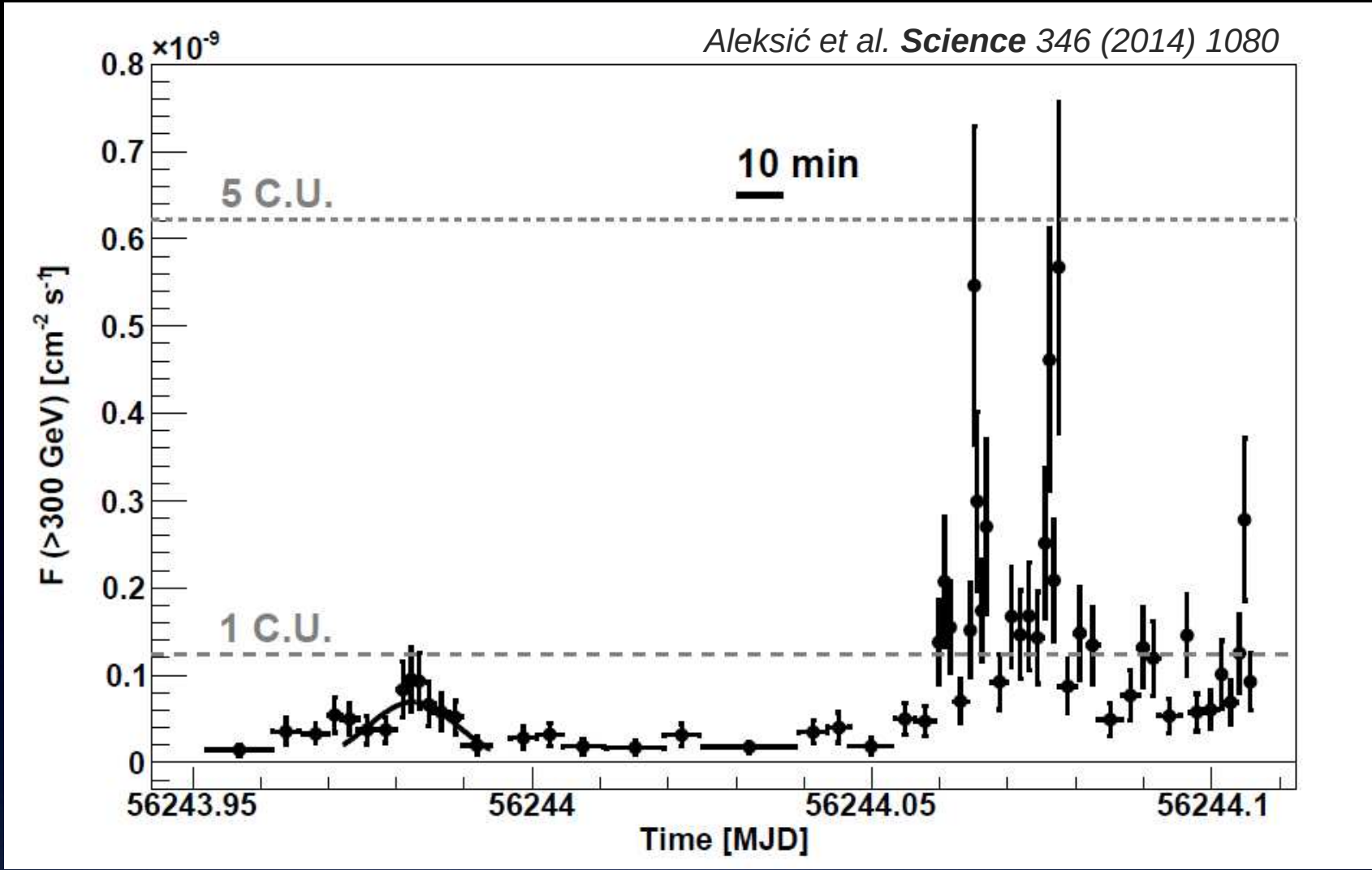


Nearby galaxy: z=0.0019

Intermediate object between BL Lac and **FRI radio galaxy**

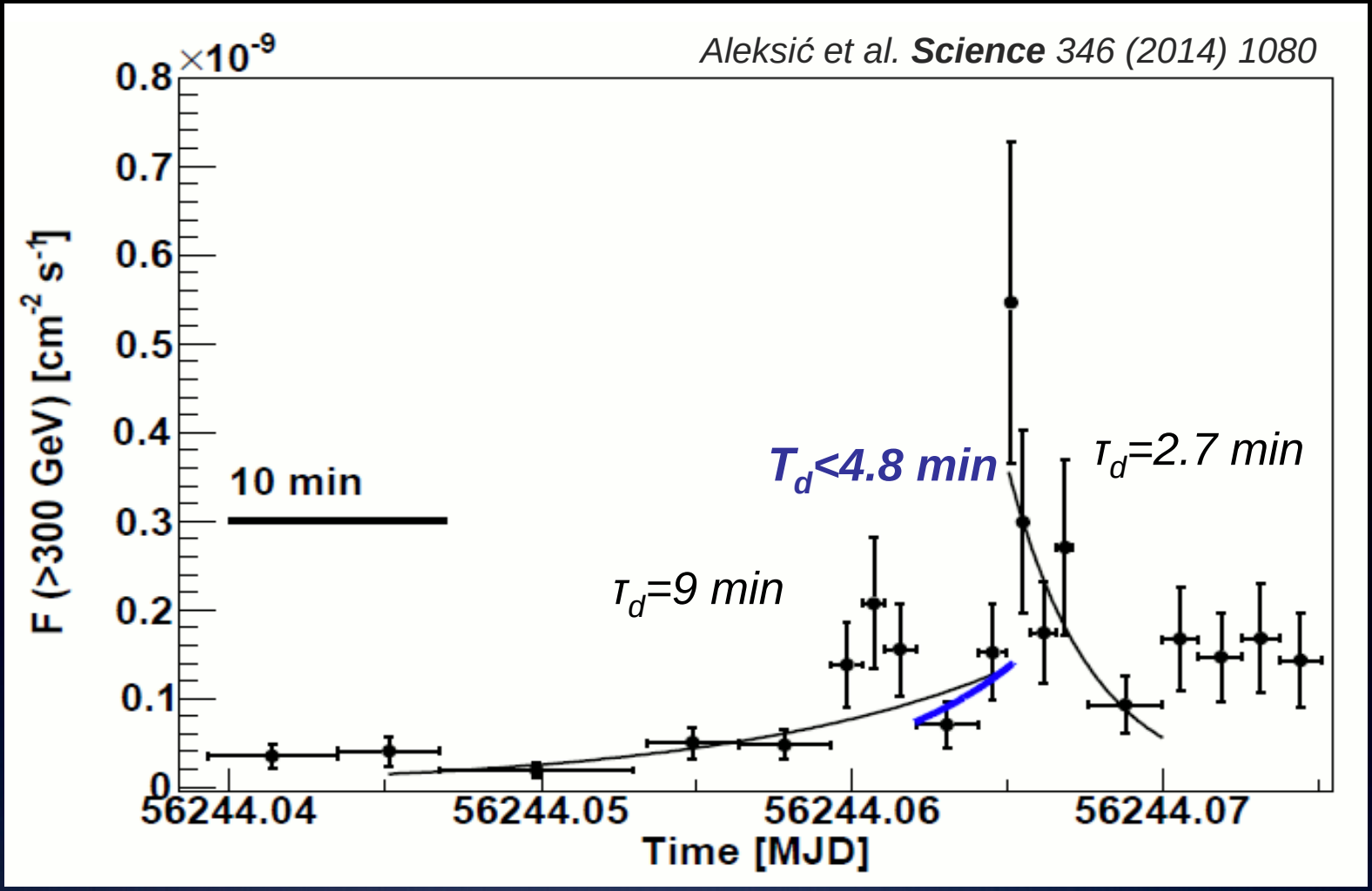
- No counter-jet detected.
  Limit from VLBI (5GHz):
  $\theta \leq 20°$
- 300 kpc long jet observed.
  Limit from the de-projected jet length: **$\theta \geq 10°$**
- No hint of bending between the kpc and pc scale jet
- $M_{BH} = 1\text{-}7 \cdot 10^8 M_\odot$
  Δt_{BH} = 8 min – 1 hour

The exceptional flare of Nov. 2012



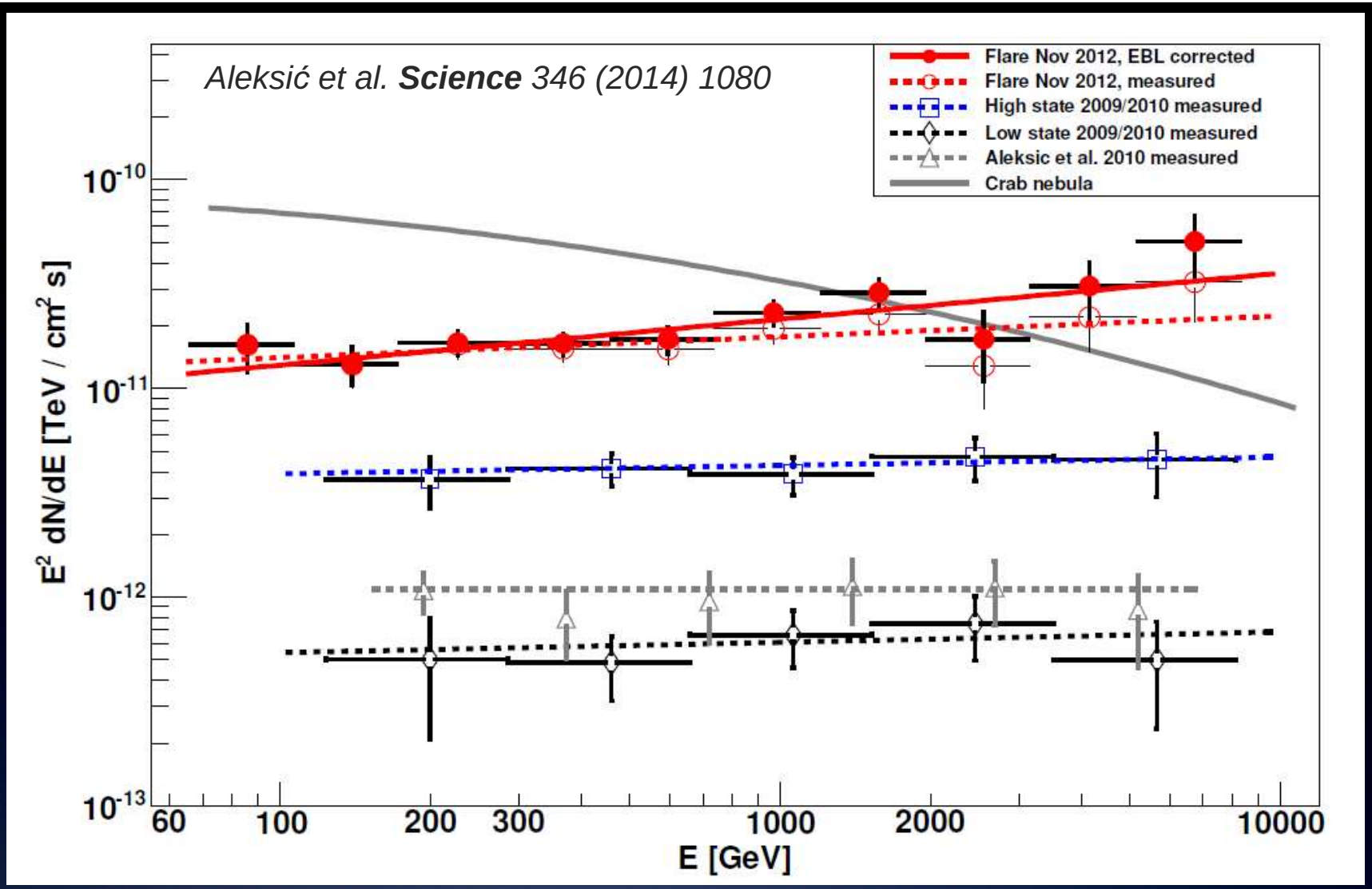
- 4 hours of observation during the night 12/13 of Nov. 2012
- **Detections of several flares with very fast variability**

Variability time-scale of the 2012 flare



- Exponential fit: Increase doubling-time < 4.8 min (95% c.l.)
- Fast flickering with Δt ~1min

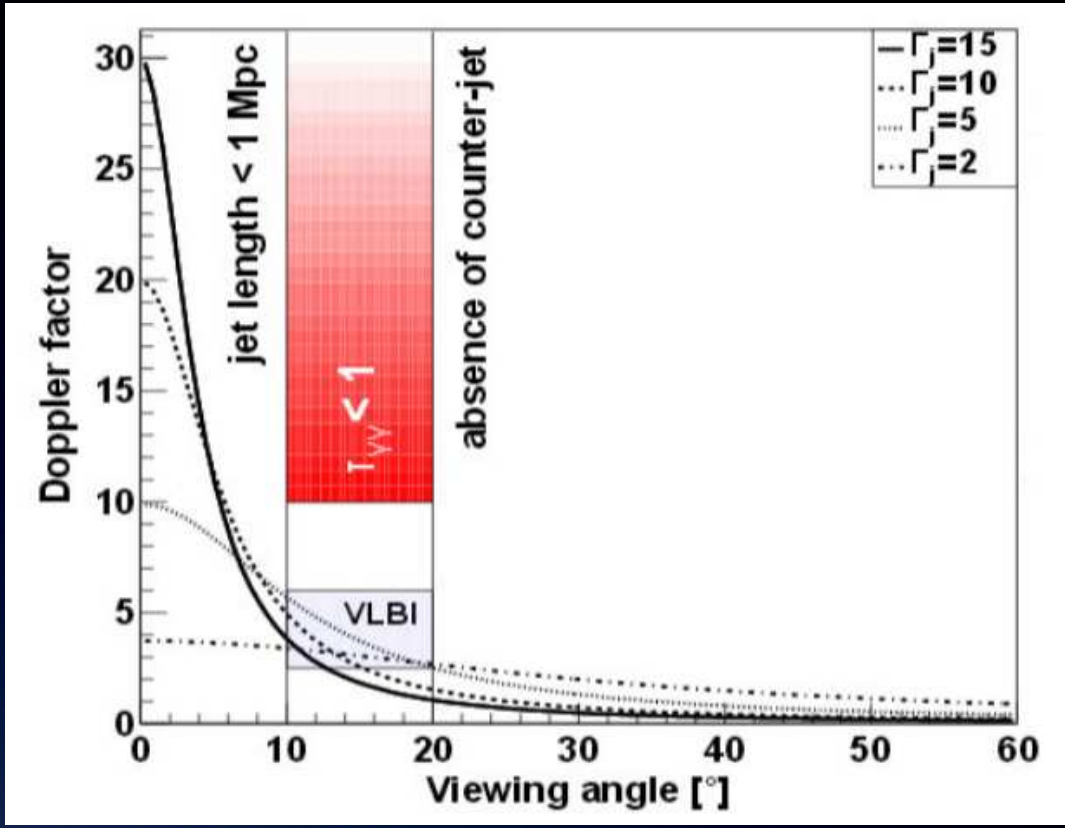
VHE spectrum of IC 310



- Very Hard spectrum: Power-law with index < 2 (no break)
- Spectrum similar to previous flares

Tension with the shock-in-jet model

- Variability < Δt_{BH}
- Hard spectrum up to 10 TeV
  Opacity problem solved
  only with δ >10
- Jet view angle: δ ≤ 6

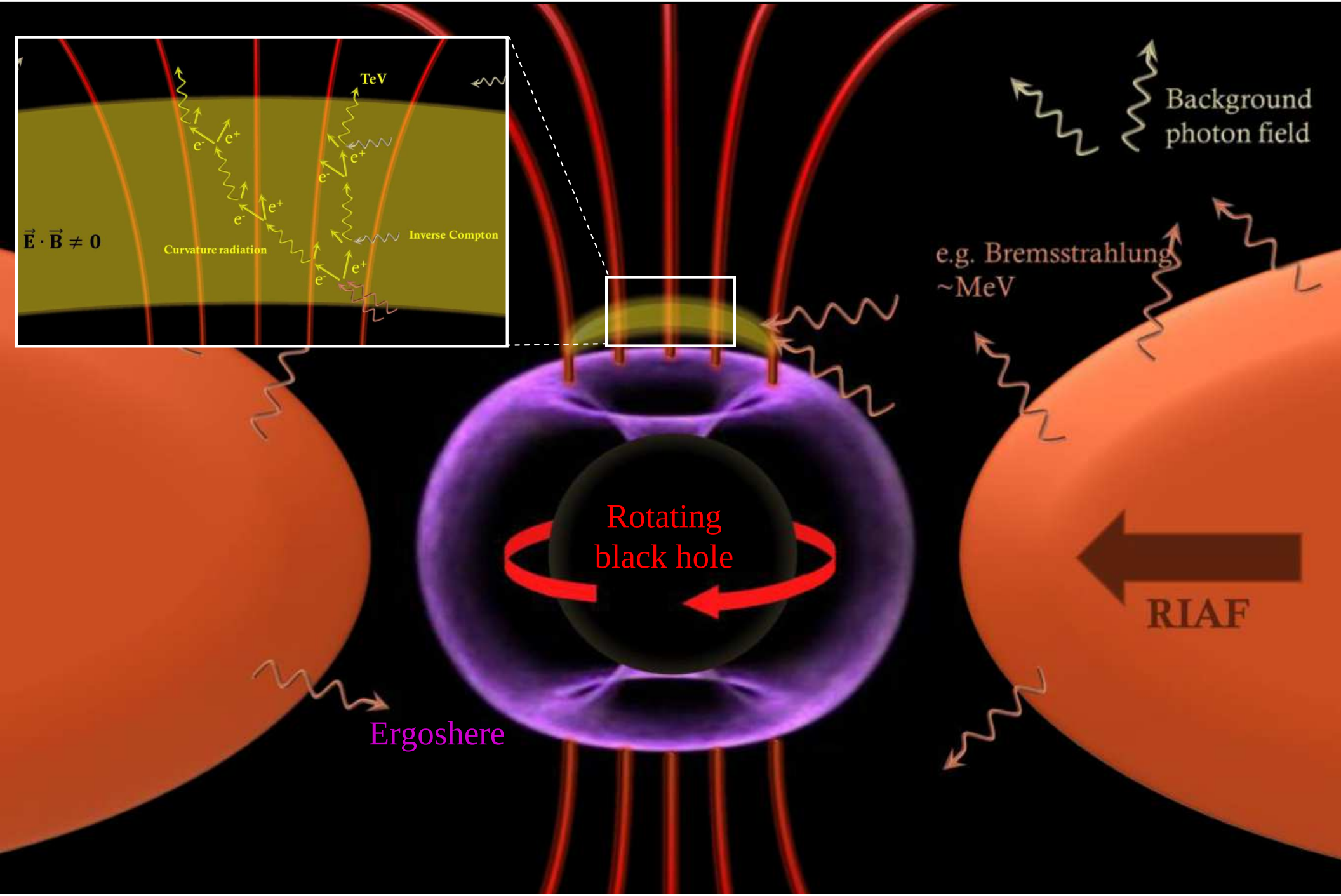


Emission region ≤ δ·0.2 r_g ≤ ~r_g

Alternative models

- Jets in jet (Magnetic reconnections)
  - Solve the limited δ issue
  - Problem with the total jet energy
- Star or cloud entering in the jet
  - γ rays from P-P hadronic interaction
  - (no absorption by synchrotron radiation)
  - Issue with the Proton cooling time
- Magnetospheric model
  - Particle acceleration in the electric field of vacuum gaps in the BH magnetosphere
  - Similar to "aligned magnetic rotator model" of pulsars
  - Match well the IC 310 minute-scale flares

Magnetospheric models



Summary

- MAGIC detected fast variability from a non-aligned AGN (θ = ~10-20°)
- Shock-in-Jet model cannot use the huge Doppler boost trick to explain this observation
- The origin of the fast VHE flare could be different. Alternative model:
  - **Black-Hole lighting !?**