MAGIC Pieces in the Radio Galaxies Puzzle: Fast Flares from IC310 and NGC1275

David Paneque
P. Colin, D. Glawion, K. Mannheim C. Nigro, J. Sitarek,
on behalf of the MAGIC collaboration
and many other scientists
M. Kadler, F. Krauss, K. Pfrang, E. Ros …

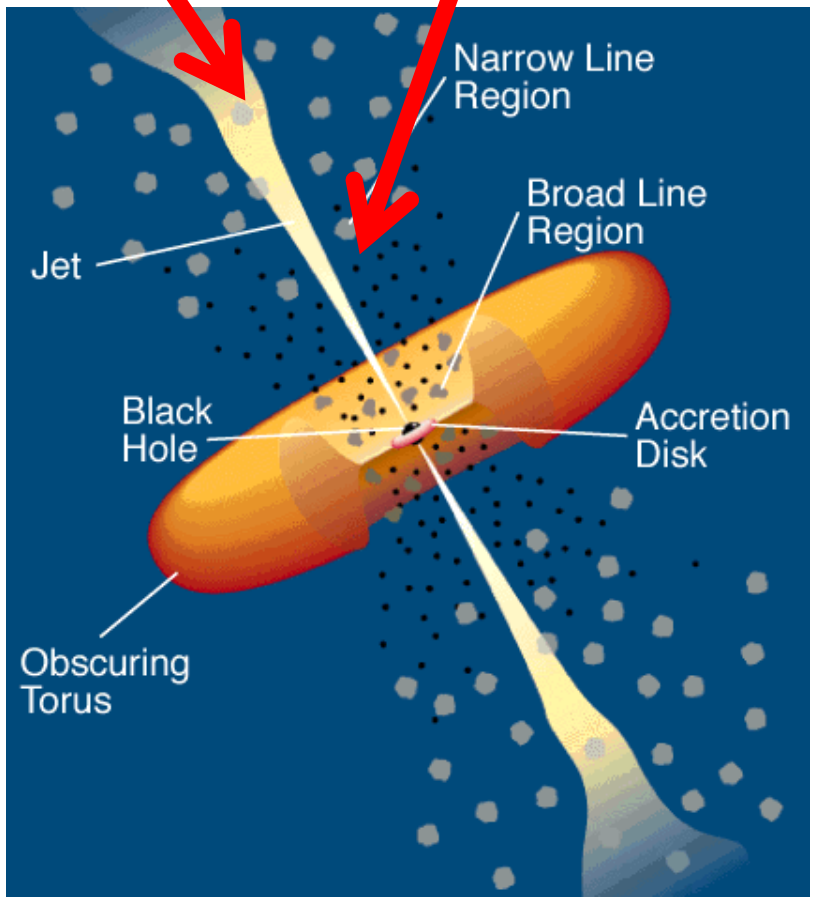
Outline

1- Radio galaxies as gamma-ray emitters
2- MAGIC observations of IC310 and NGC1275
→ Fast variability (comparable to blazars!)
→ implications (puzzles)
3 - Conclusions

1- Radio galaxies as gamma-ray emitters

Blazars are radio loud AGNs with the jet pointing towards the Earth

Radio galaxies are radio loud AGNs where the jet is observed from a large angle (Theta>10 deg)



Pictorial description of an AGN

Image Credit: C.M.Urry & P. Padovani

1- Radio galaxies as gamma-ray emitters

Blazars are radio loud AGNs with the jet pointing towards the Earth

Emission is Doppler boosted.

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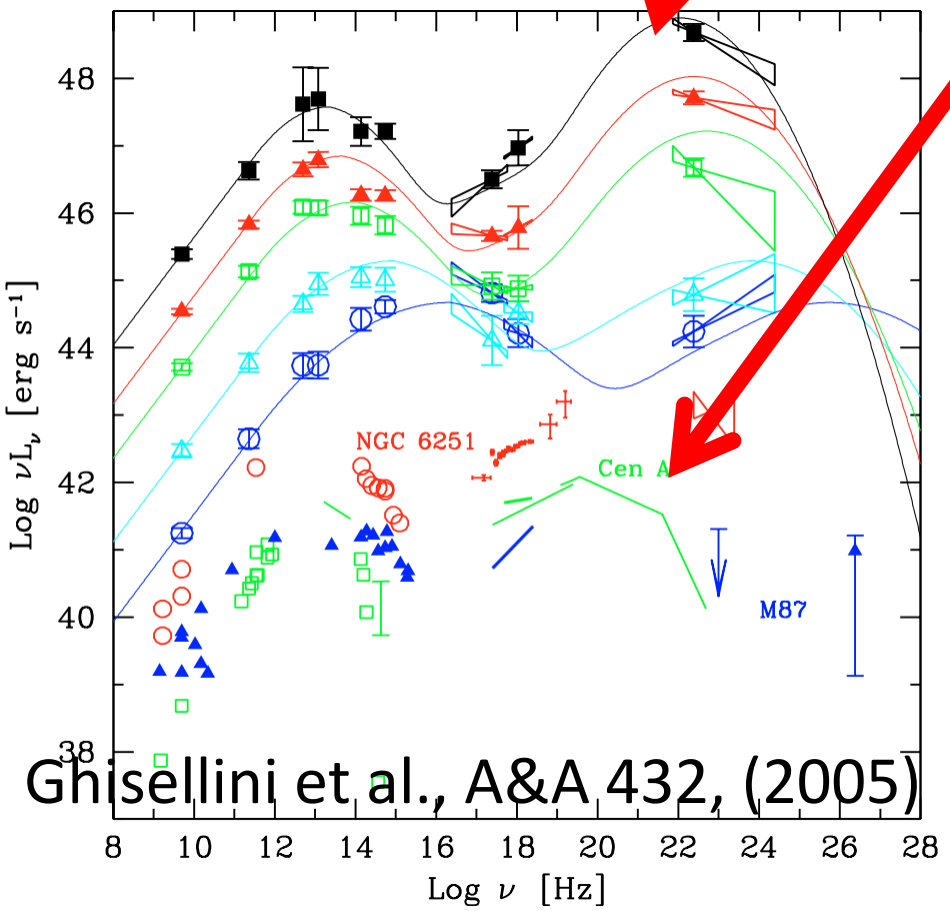
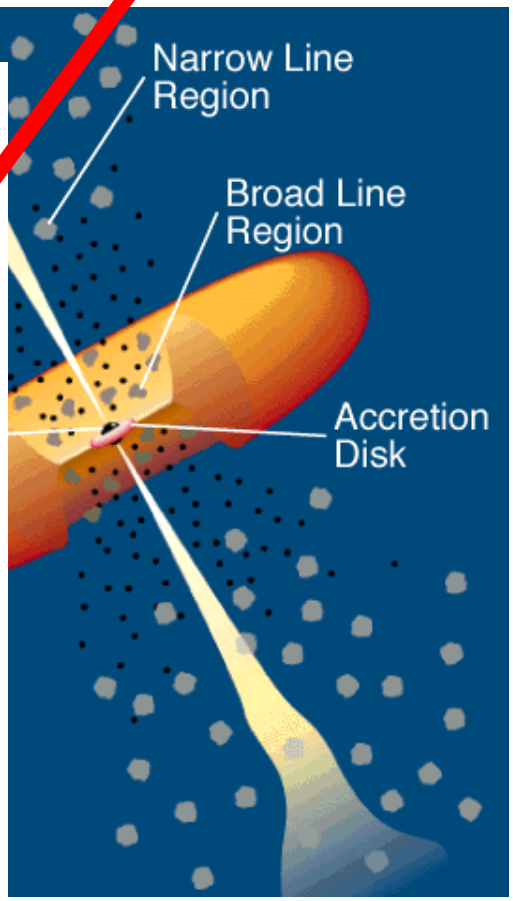


Ghisellini et al., A&A 432, (2005)



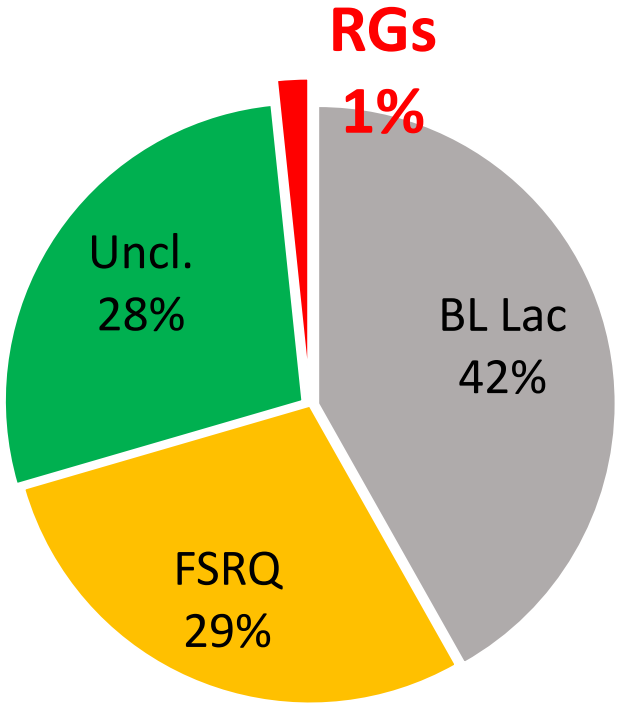
No large Doppler boosting implies less brightness (at all wavelenghts) in comparison to blazars

Pictorial description of an AGN

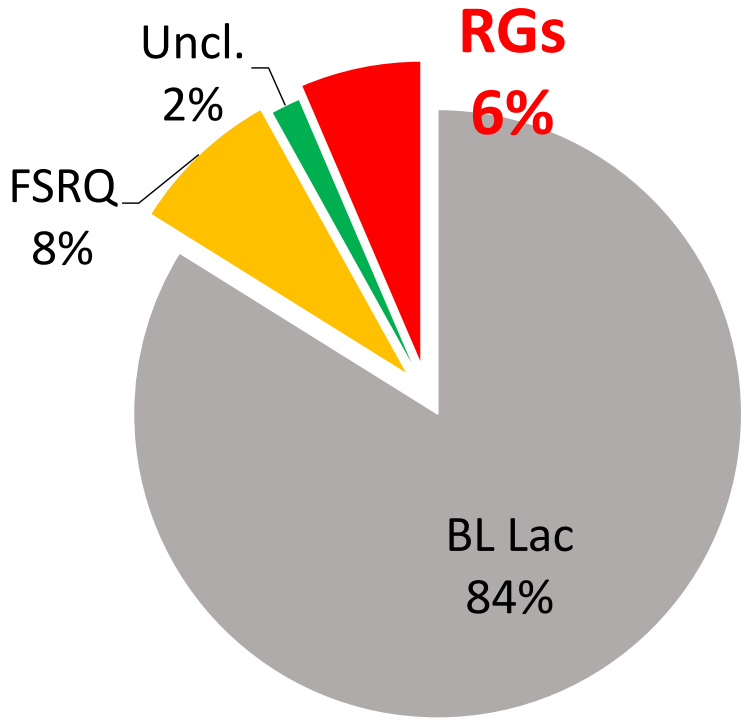
Image Credit: C.M.Urry & P. Padovani

1- Radio galaxies as gamma-ray emitters

Fermi-LAT detects
24 RGs (E>0.1 GeV)
3LAC (Ackermann et al. 2015):



Cherenkov Telescopes detect
5 (+1) RGs (E>0.1TeV)
(TeV Catalogue):



Cen A, M 87, NGC 1275, IC 310, 3c264
(and perhaps PKS 0625-35,
→ nature still under discussion)

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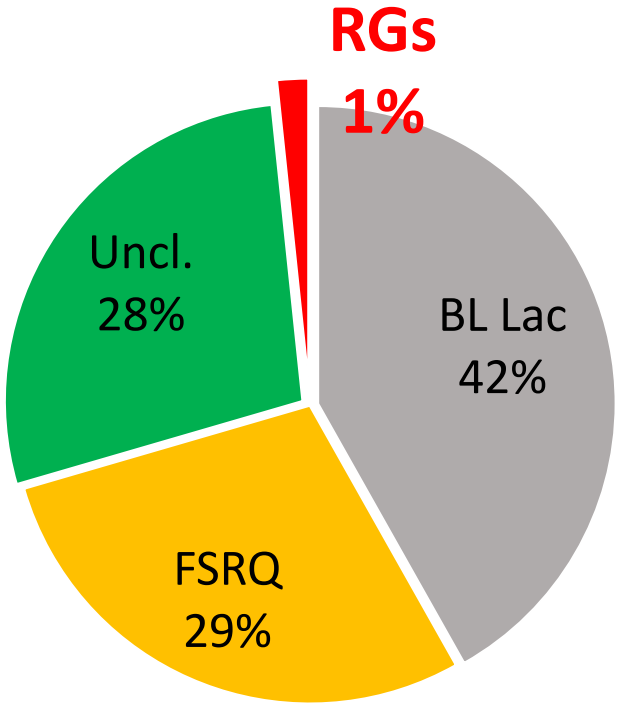

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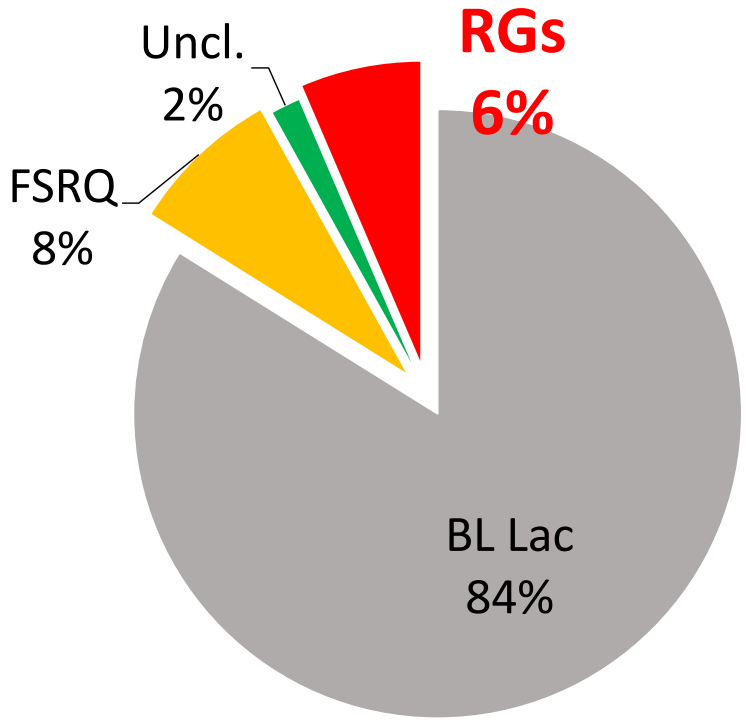
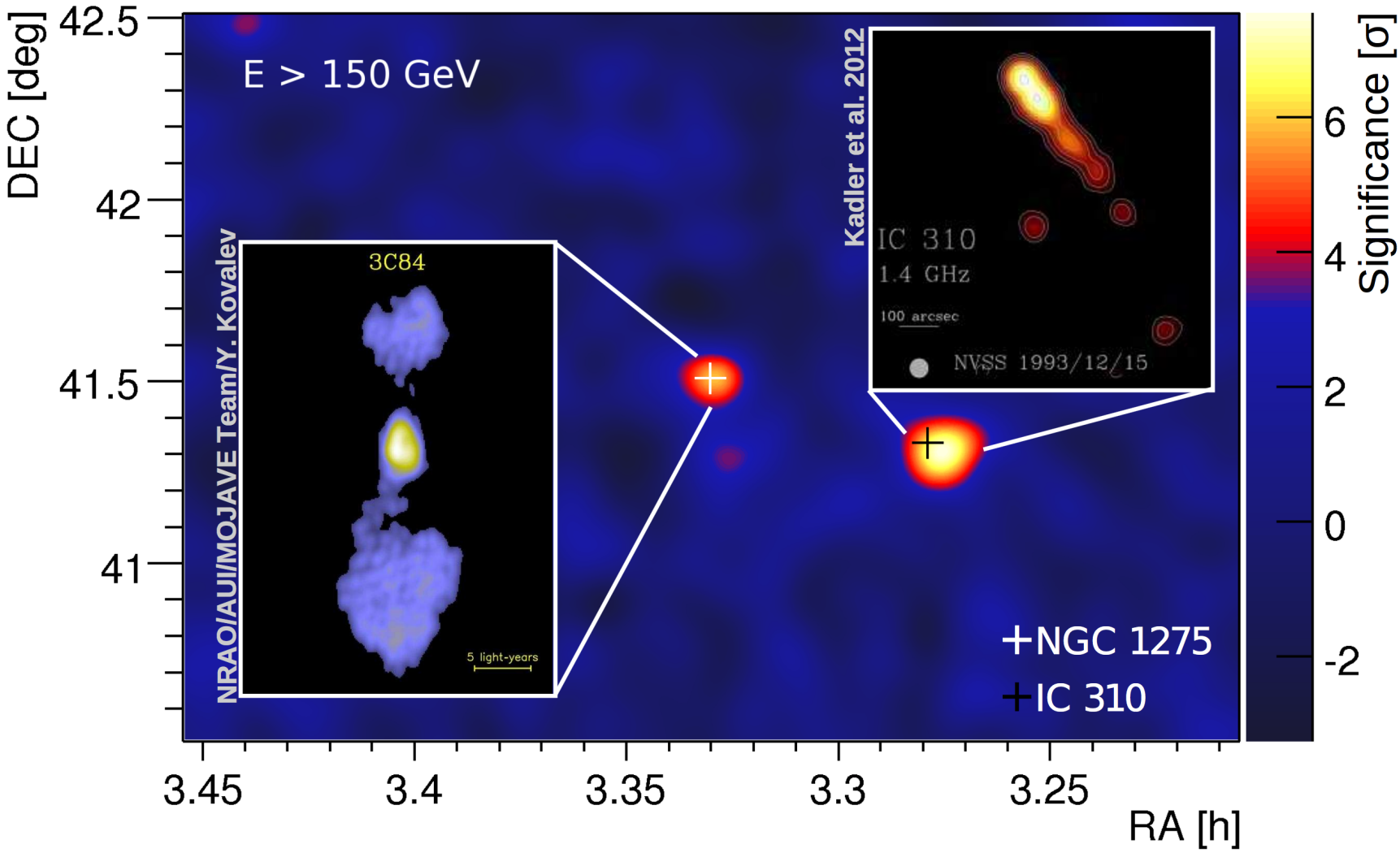


Detected with MAGIC →

Cen A, M 87, NGC 1275, IC 310, 3c264
(and perhaps PKS 0625-35,
→ nature still under discussion)

More difficult to detect at gamma rays, but important to study because they provide a different perspective of the AGN (and good imaging with radio instruments)

2- MAGIC observations of IC310 and NGC1275



Both sources detected at **VHE for the first time with MAGIC telescopes**

IC 310: Aleksic et al. 2010, ApJ, 723, L207

NGC 1275: Aleksic et al. 2012, A&A, 539, L2

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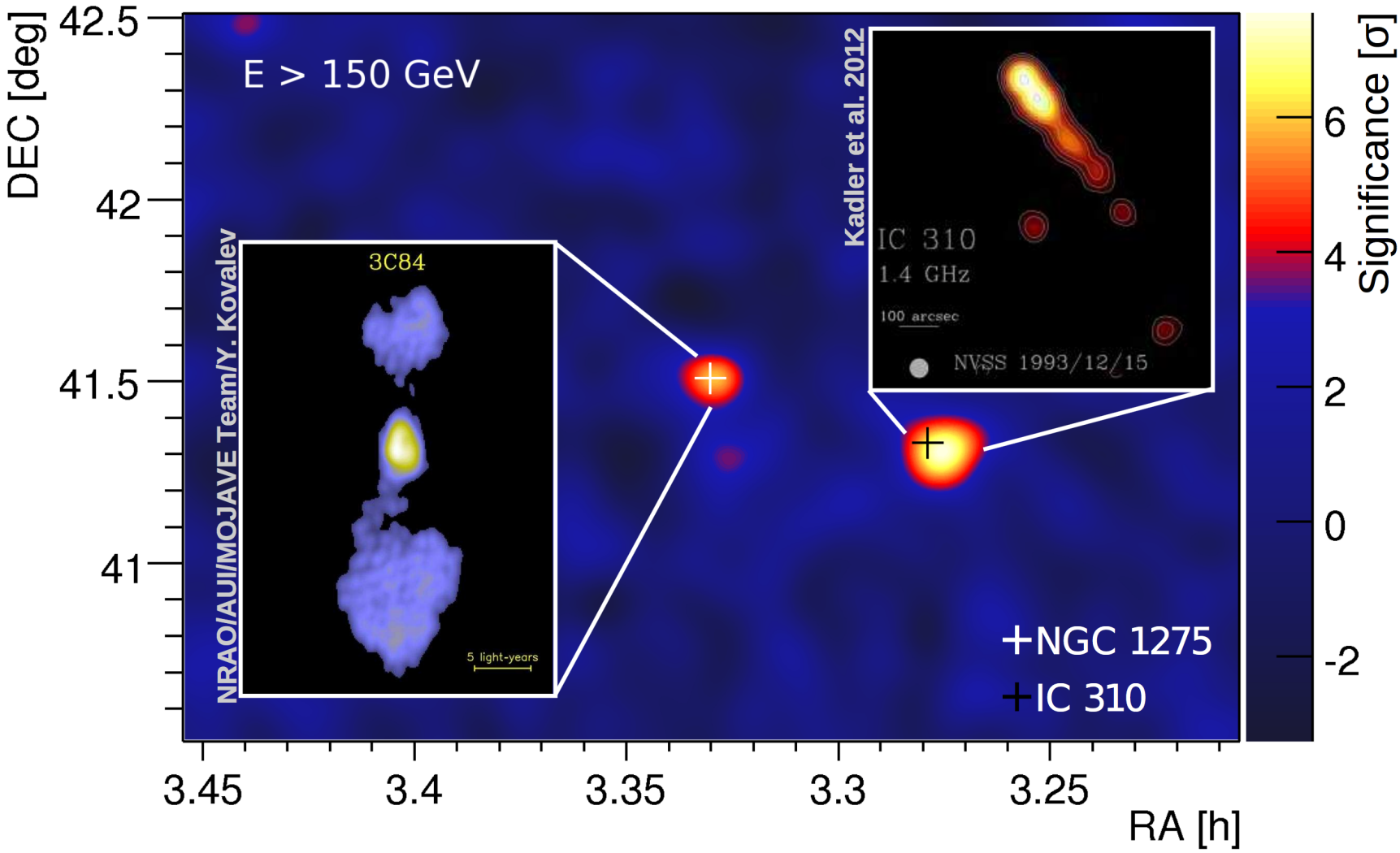

Several publication since then:

NGC 1275: *A&A* **541** (2012) A99, *A&A* **564** (2014) 5, *A&A* **589** (2016)

IC 310 : *Science,* **346** (2014) 1080, *A&A* **563** (2014), *A&A* **603** (2017) A25

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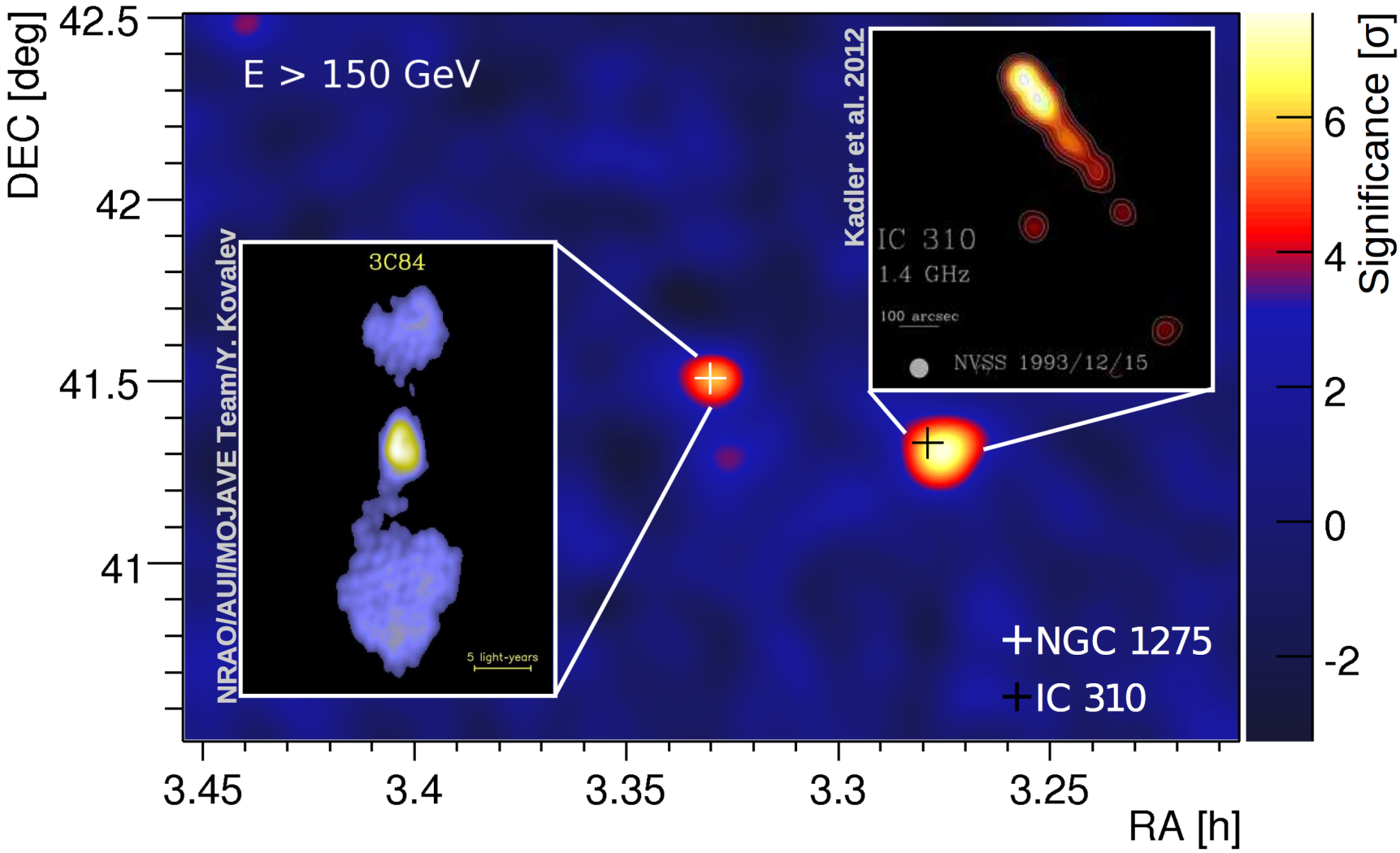

NGC 1275

$M_{BH} = 3\times10^{8} M_{\odot}$ *(Wilman et al. 2005)*

Theta >30 deg

IC 310

$M_{BH} = 3\times10^{8} M_{\odot}$ *(Aleksic et al 2014)*

10 < Theta < 20 deg

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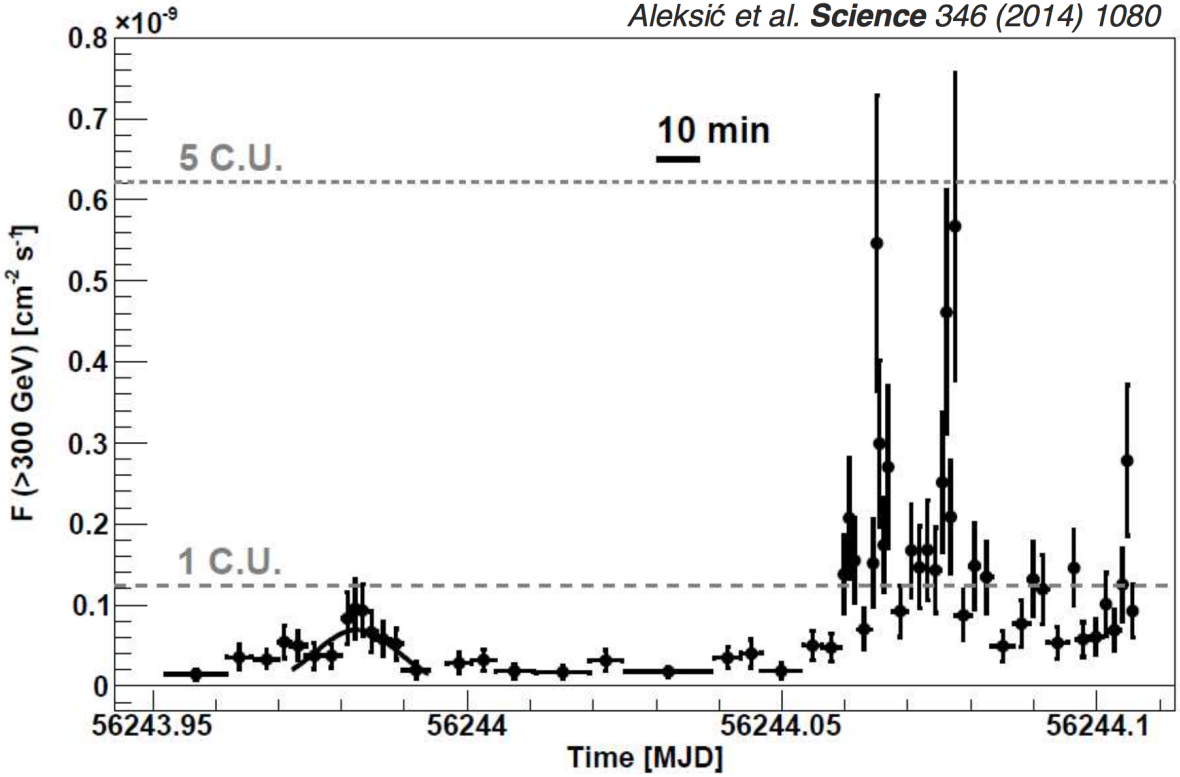

IC 310

Light curve from ~4 hour observations performed in Nov. 12/13, 2012

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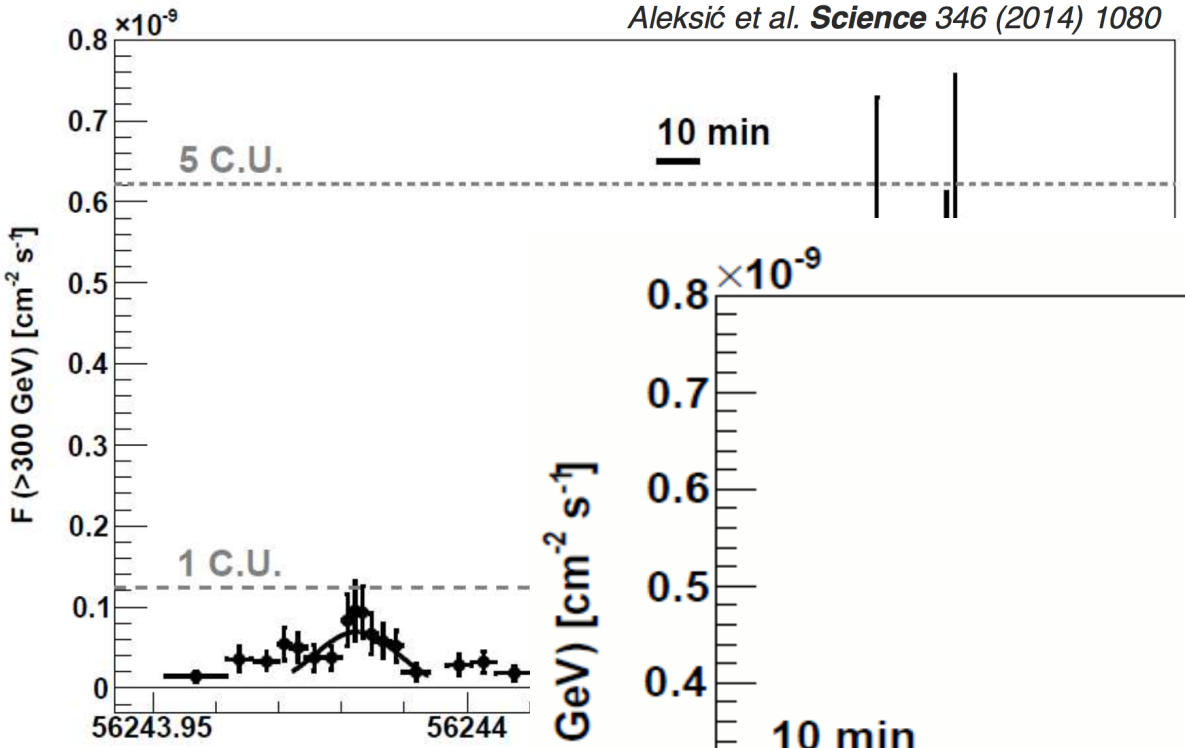
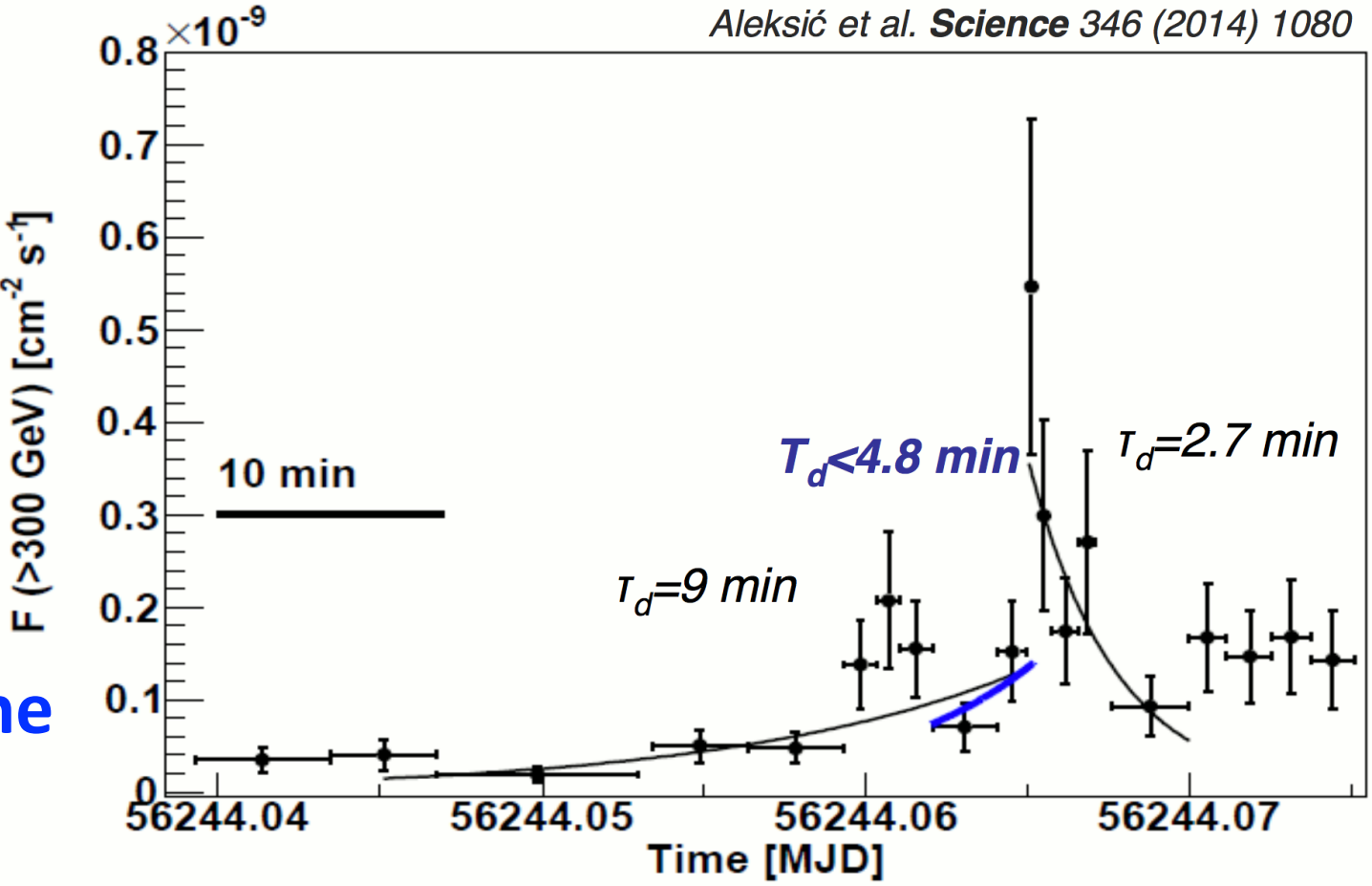


IC 310

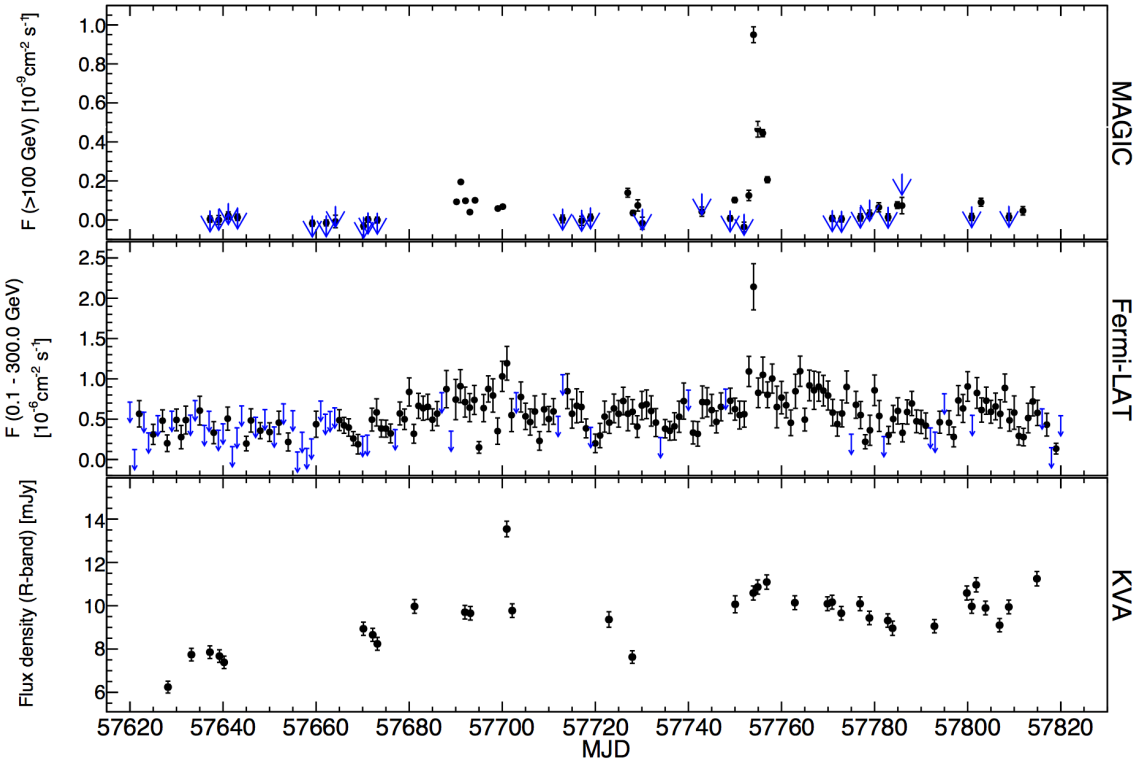


Flux doubling time less than 5 min.

R < Doppler x 0.2 x r_g

2- MAGIC observations of IC310 and NGC1275

*Ansoldi et al (**accepted in A&A**, arXiv:1806.01559)*



NGC 1275

Multi-instrument campaign from 2016/2017

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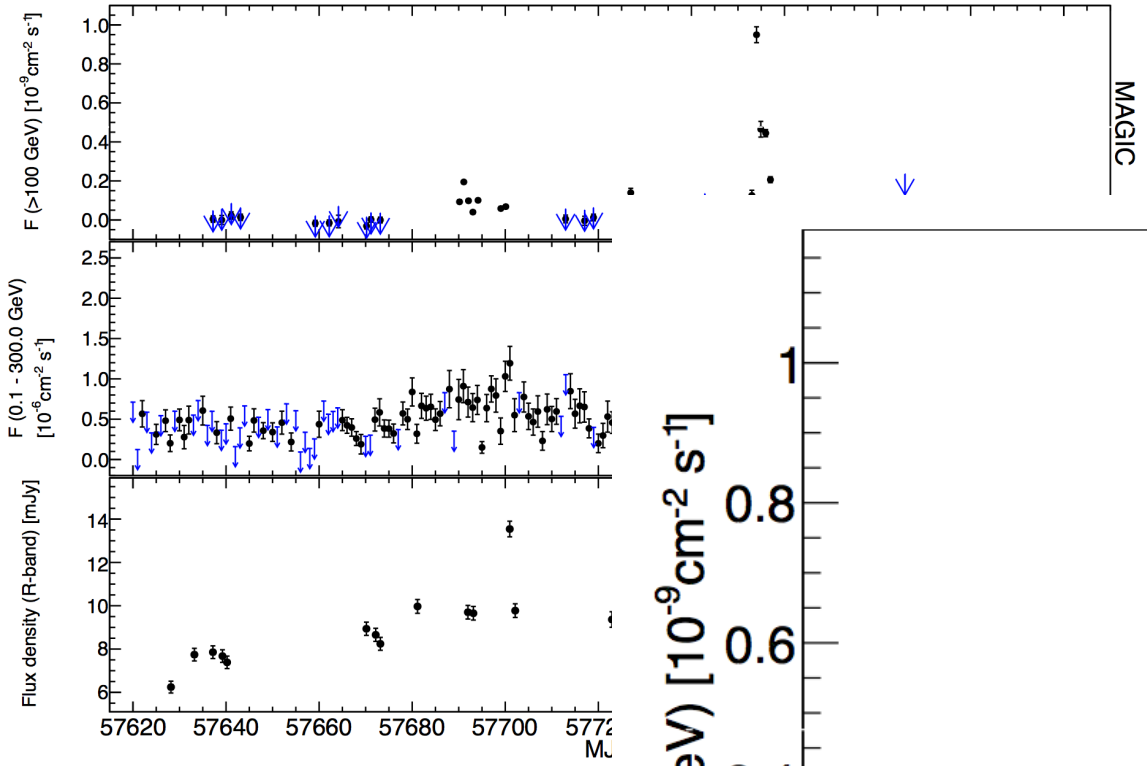
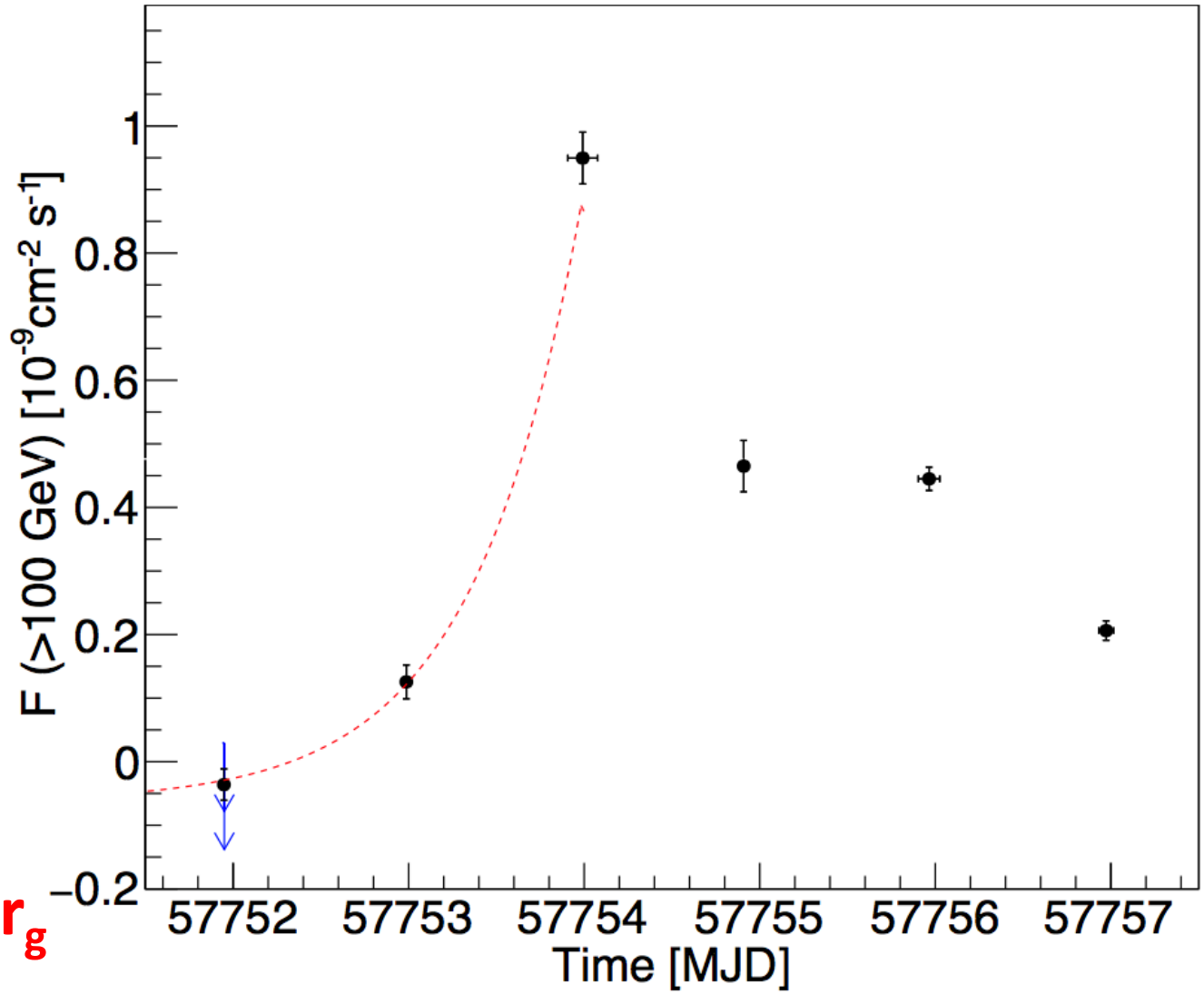


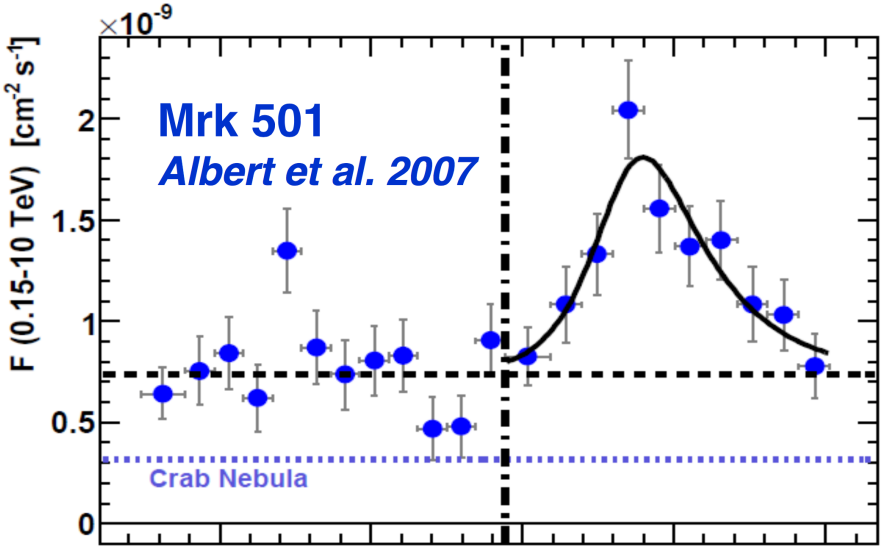
NGC 1275

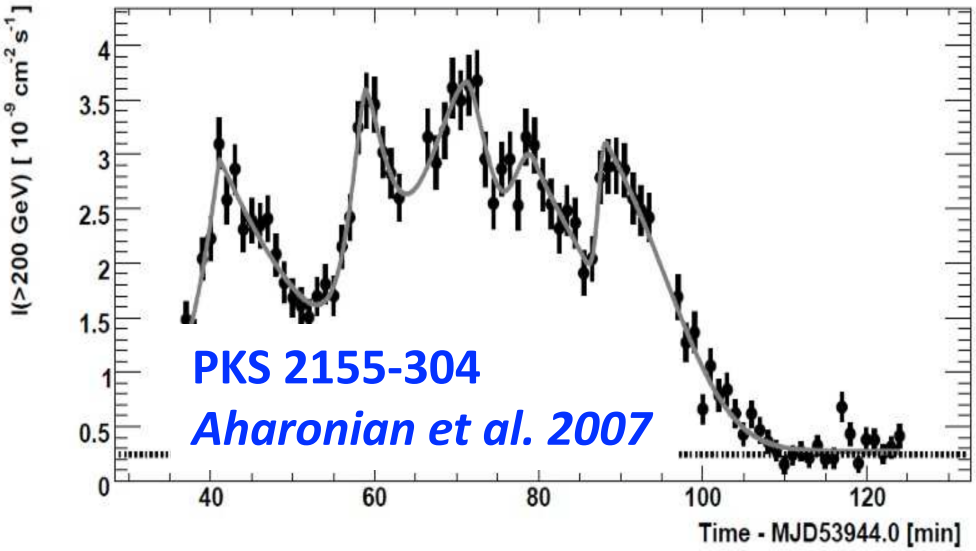


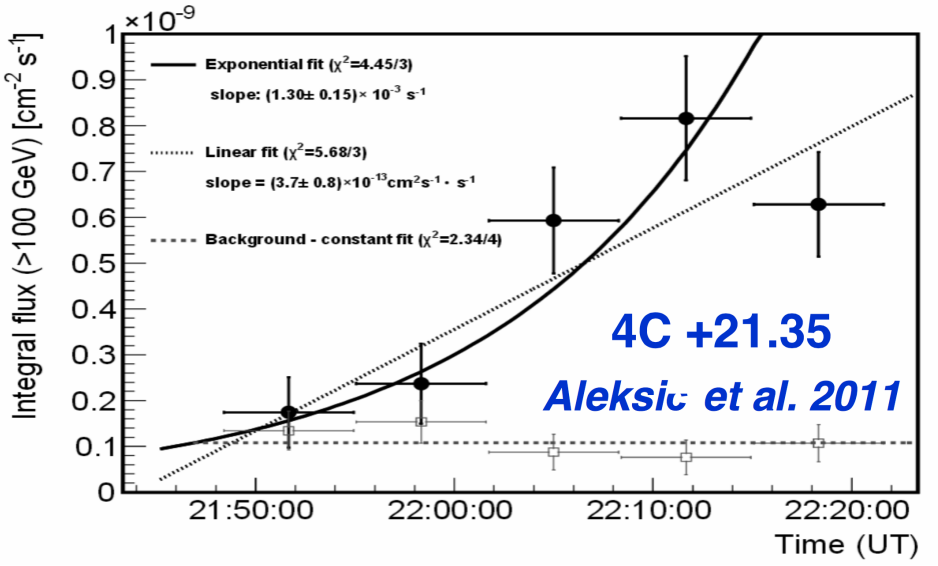
Flux doubling time in ~10 hours

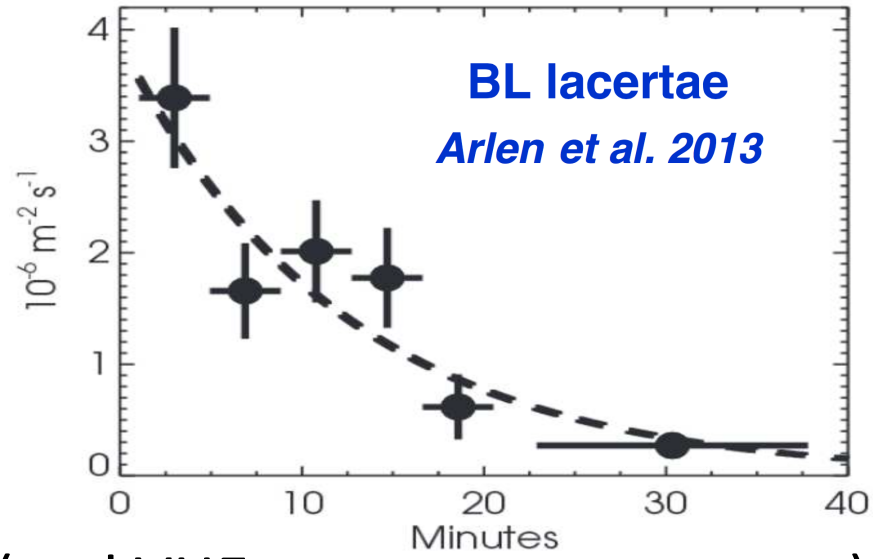
R < Doppler x 22 x r_g

Gamma-ray blazars show short variability timescales







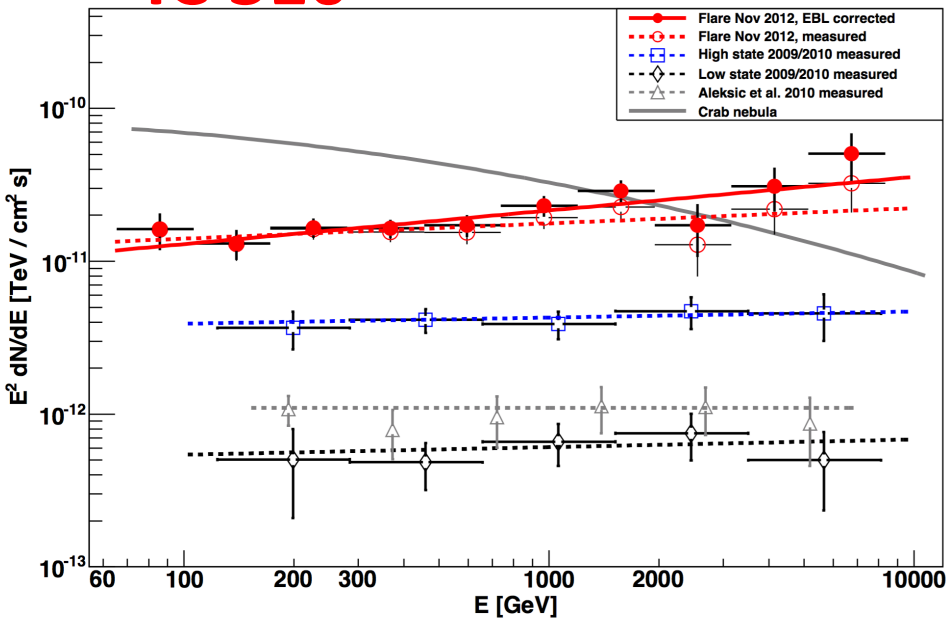


Variability as short as a few minutes (and VHE gamma transparency) is typically explained with very large beaming (Doppler >50)

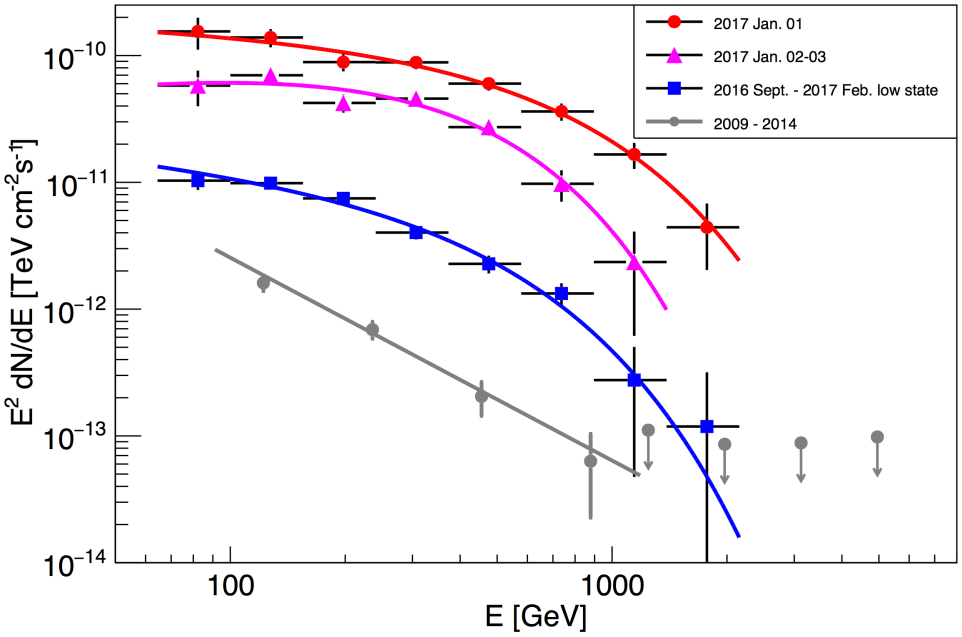
→ **This explanation is not possible for radio galaxies !**

Spectra during these fast flares show gamma rays with energies larger than 1 TeV

IC 310



NGC 1275



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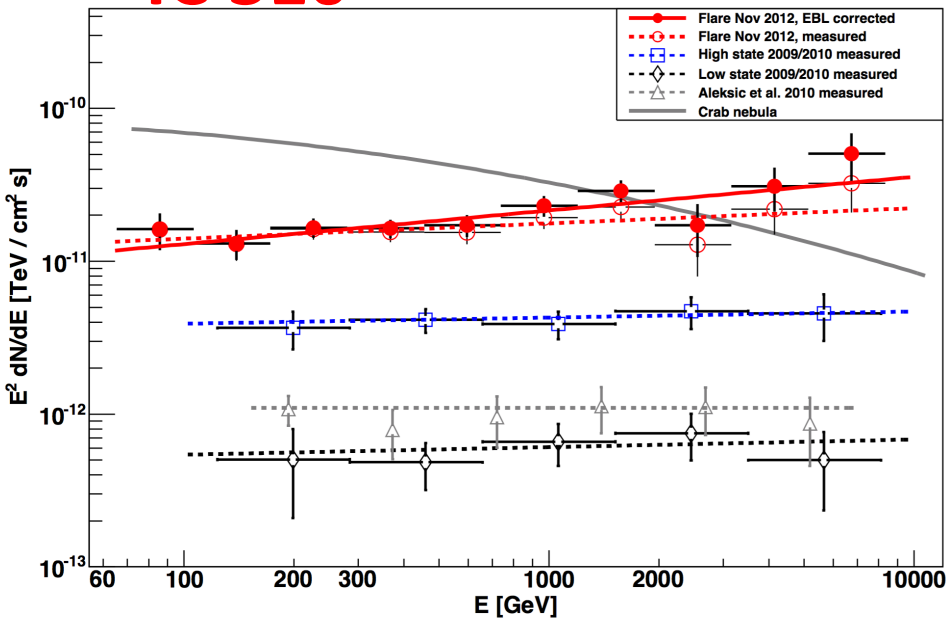

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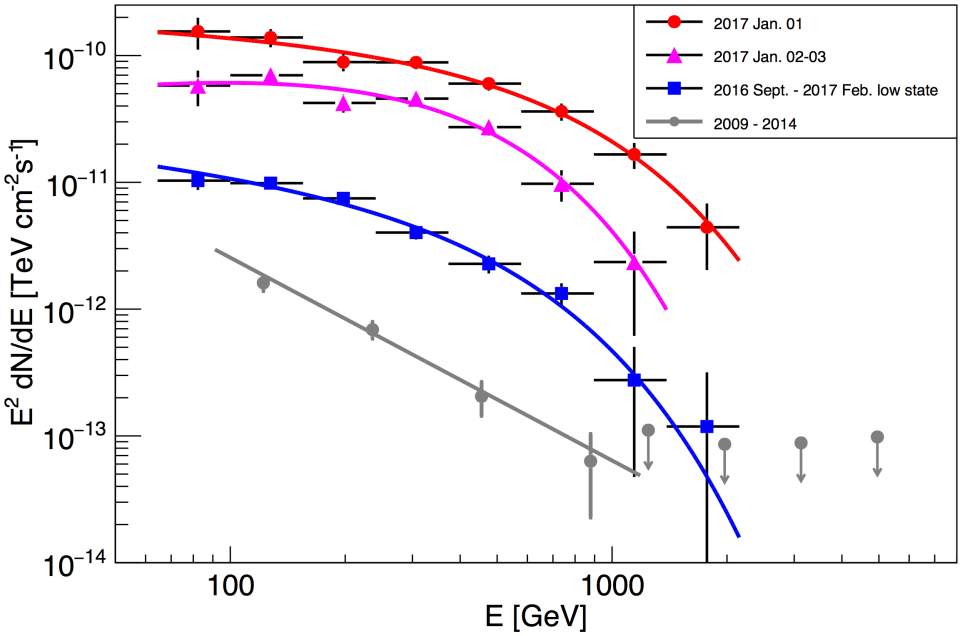


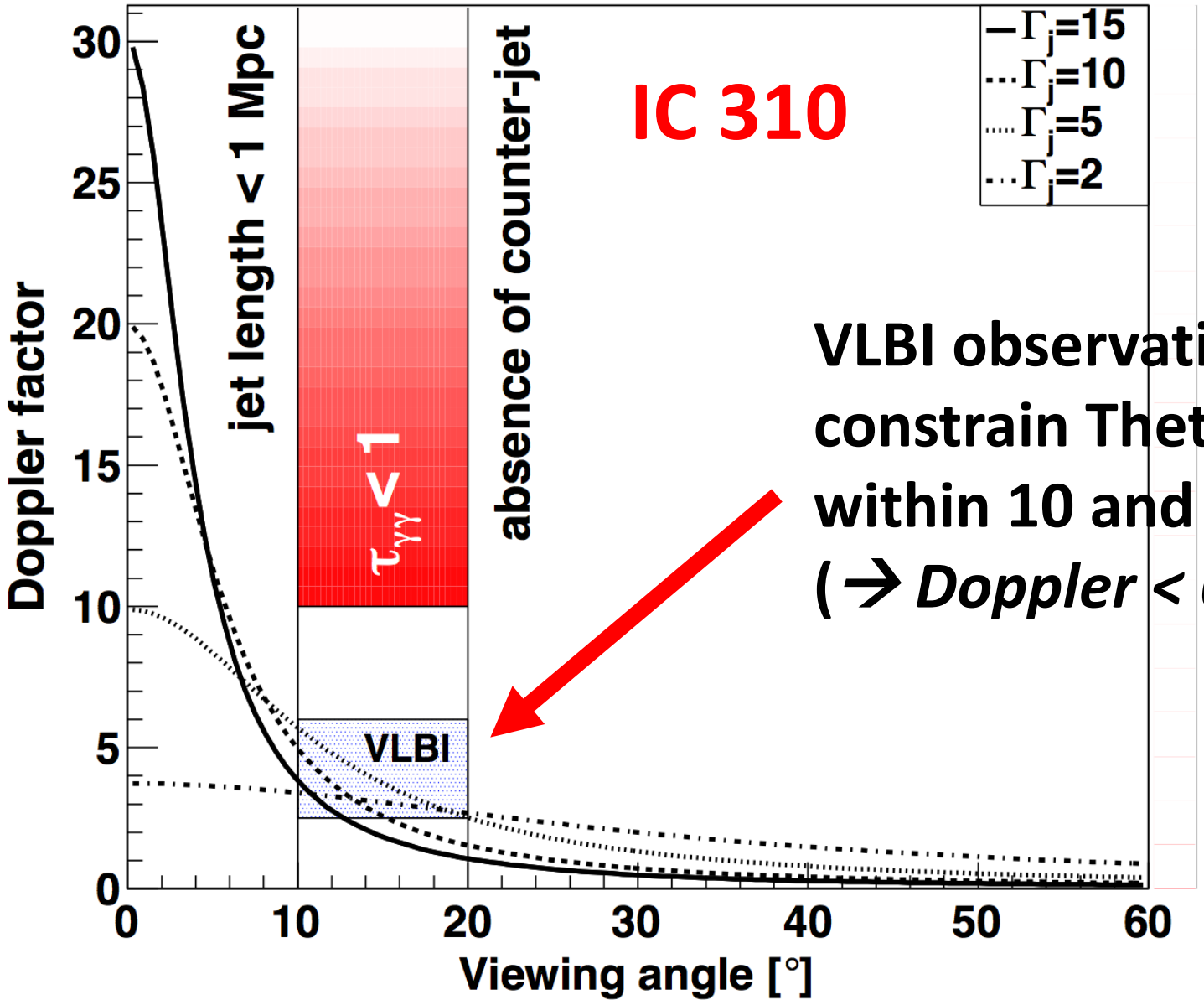
Opacity due to gamma-gamma absorption in the source

$$\tau_{\gamma\gamma} \sim \frac{\sigma_T D_L^{\,2} F_0 \varepsilon_\gamma (1+z)}{10 R m_e^{\,2} c^5 \delta^5}$$

IC 310: $\tau_{\gamma\gamma}$ **(10TeV) < 1 → Doppler >10 → Theta < 6 deg**

Constraints on viewing angle from radio observations

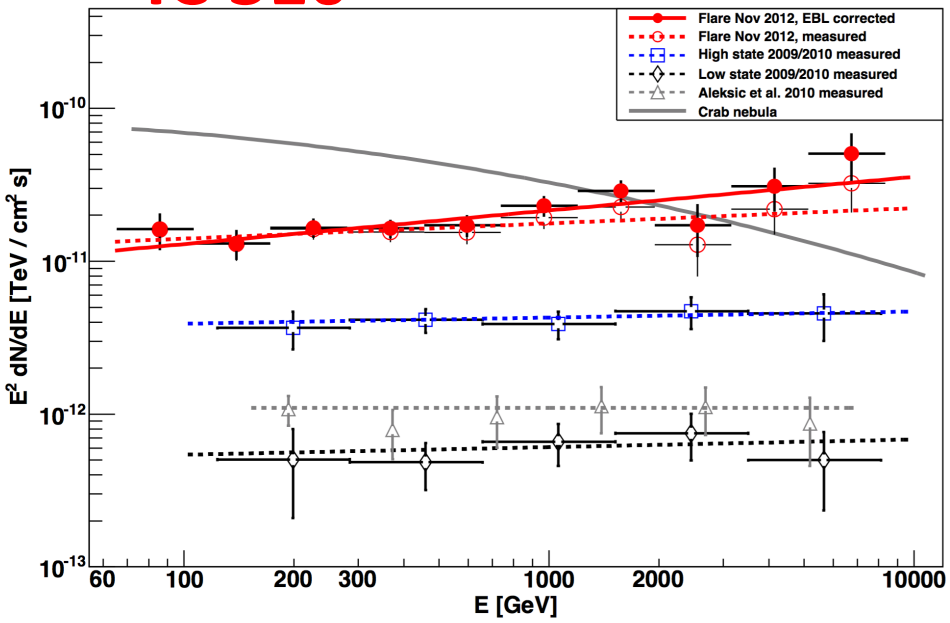
MAGIC Collab. Science, **346** (2014) 1080



VLBI observations constrain Theta to be within 10 and 20 deg (→ *Doppler < 6*)

Spectra during these fast flares show gamma rays with energies larger than 1 TeV

IC 310



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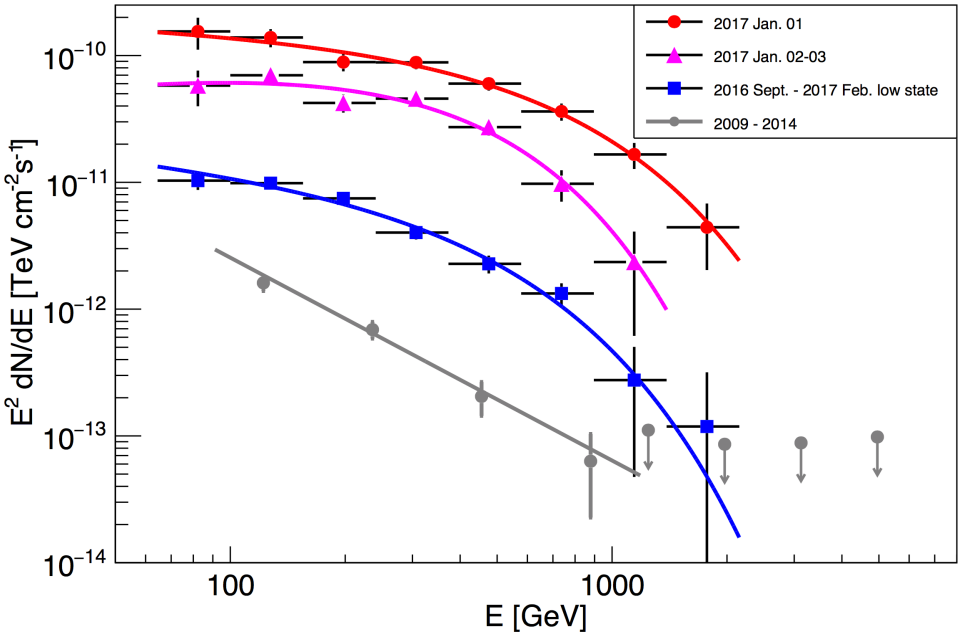

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IC 310: $\tau_{\gamma\gamma}$ **(10TeV) < 1 → Doppler >10 → Theta < 6 deg**

→ Inconsistent with measured Theta>10 deg at radio

NGC 1275: $\tau_{\gamma\gamma}$ **(1TeV) <1 → Doppler >4-7 → Theta < 9-16 deg**

→ Inconsistent with measured Theta>30 deg at radio

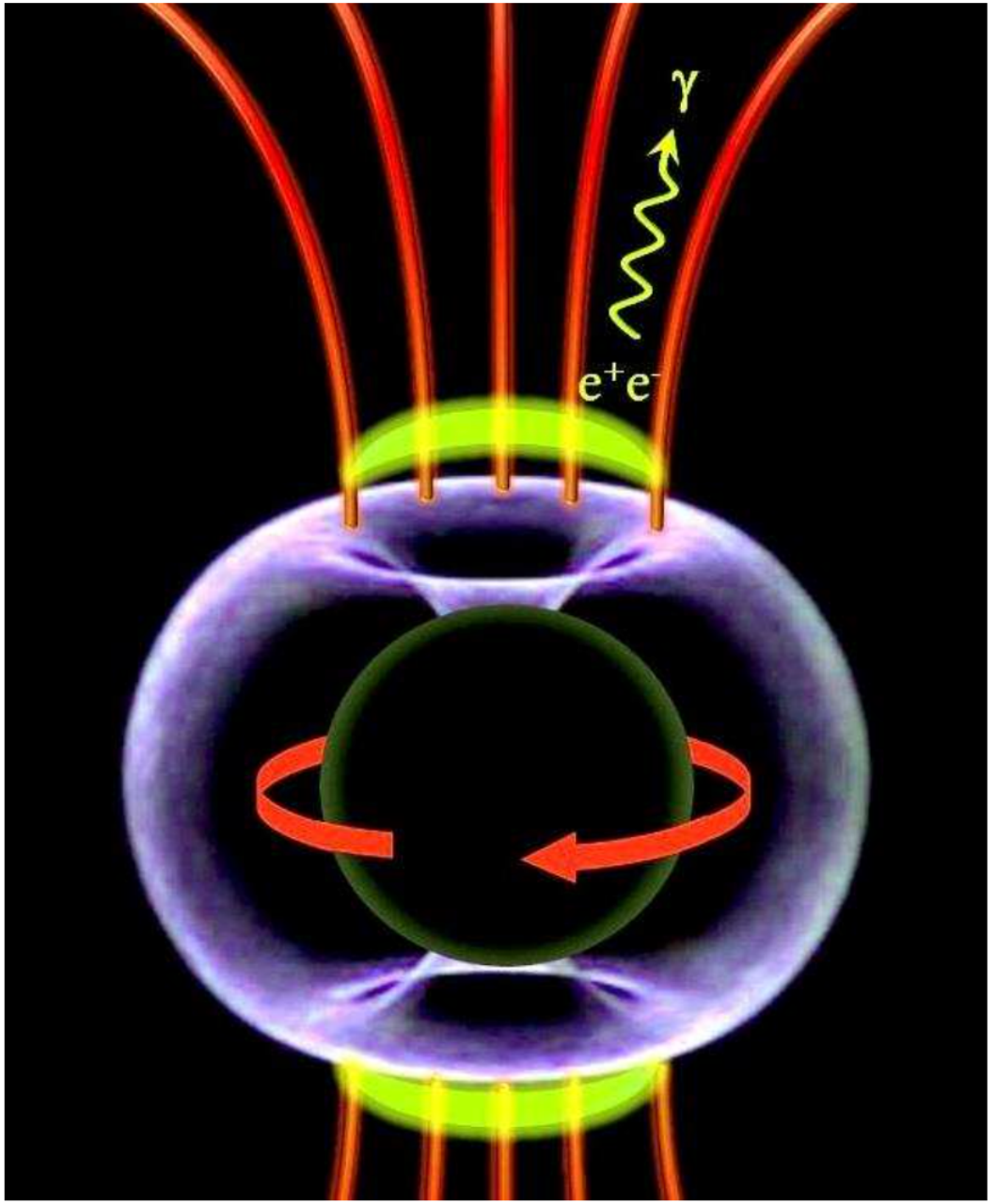
MAGIC puzzle for radio galaxies … how to explain it ?

Data could be explained with "**Magnetospheric models**": by e.g. Levinson & Rieger 2011; Aleksic et al. 2014, *Science* Hirotani & Pu 2016

e+e− accelerated in an electric field in vacuum gap regions

Similar to "aligned magnetic rotator models" for pulsars

Could produce anisotropic particle beams at angles 10-20 deg to the jet axis



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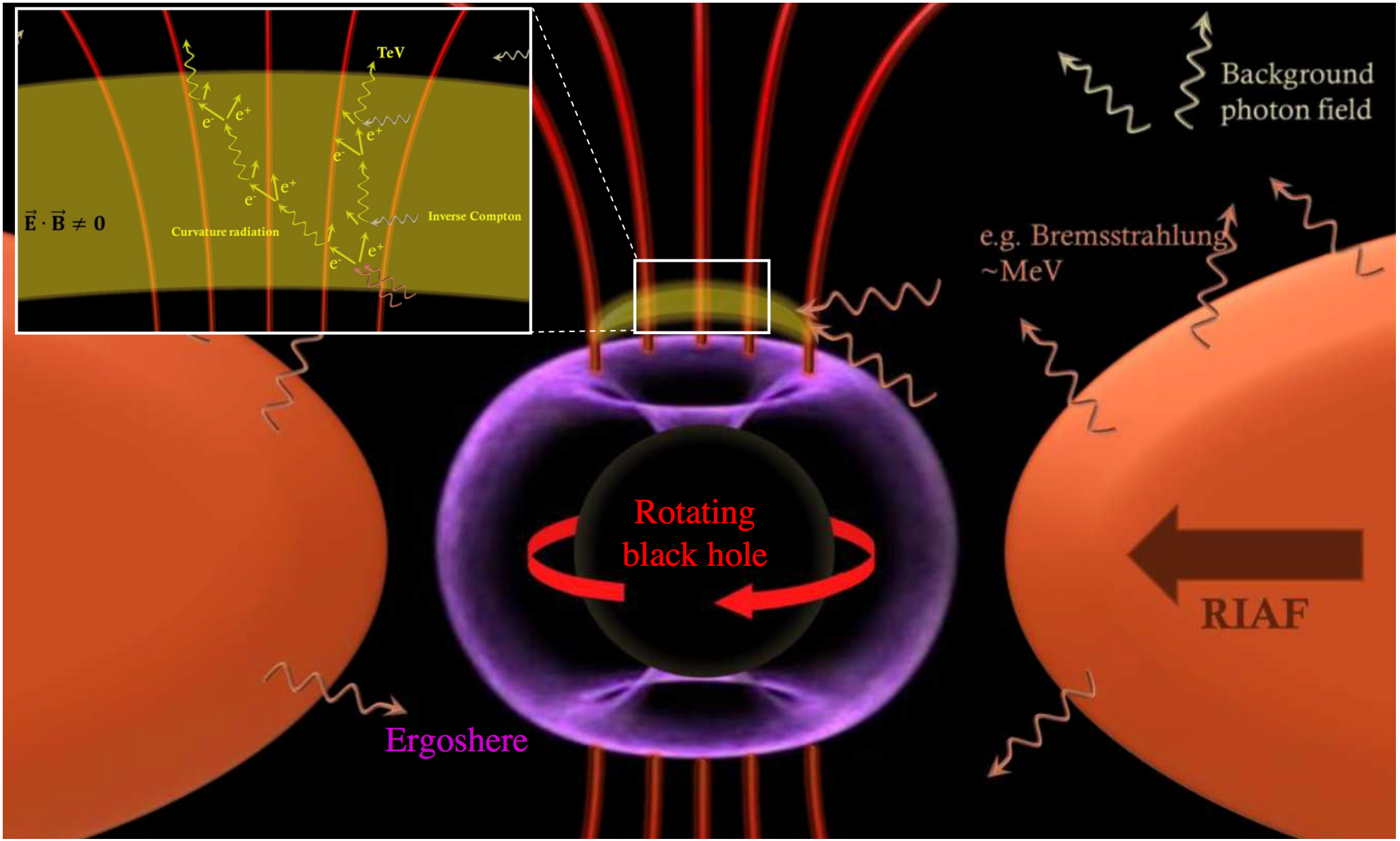

Conclusions

The MAGIC telescopes have detected short variability timescales (minutes to hours) and VHE gamma rays beyond 1 TeV from the non-aligned AGNs IC310 and NGC1275, where direct (radio) imaging observations indicate large viewing angles (θ>10deg and θ>30deg)

These observations challenge the standard emission models:

→ Shock-in-Jet model cannot use large Doppler factors

Alternative (non-standard) models are required

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Alternative (non-standard) models are required

Jets in Jet (Magnetic reconnections)	Solve limited Doppler factor Problem with total jet energy
Star or cloud Entering in the jet	Solve problem of gamma absorption (gammas produced through p-p interactions) Problem with fast variability

Magnetospheric models appear to be a viable option

what about other radio galaxies ? Future IACT obs. will tell …

BAckup