Spectacular Flares of the Radio Galaxy NGC 1275 measured with MAGIC

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ICRC 2017
Relativistic Jets in AGN

- Particle acceleration to extreme energies – origin of UHE cosmic rays ($E > 10^{18}$ eV)?
- Emission mechanisms at high energies: hadronic or leptonic?
- Location of the (fast) gamma-ray emission region?
- Black hole – jet connection?
- Jet structure & jet formation?
NGC 1275 in a Nutshell

- Distance of galaxy: ~73 Mpc (z=0.018)
- Host a compact AGN:
  - FR I radio galaxy (Vermeulen et al. 1994, Buttiglione et al. 2010)
  - Seyfert 1.5 (Humason 1932, Khachikan & Weedman 1974)
  - Strong variability: BL Lac classification (Veron 1978)
  - Radio Counter-jet visible
    → Viewing angle = 30°- 55° (Walker et al. 1994); 65° ± 16° (Fujita & Nagai 2017)
- Monitoring of pc-scale jet
  - New radio knot ejected in 2005
  - Fast γ-ray variability of time scale of (1.51±0.02) d found with Fermi (Brown & Adams 2011)
The Perseus Cluster seen with MAGIC

Mean flux 7-9 times higher than in 2009-2011 of 3% C.U. (Aleksić et al. 2014)
Oct./Nov. 2016 16% C.U. (ATel #9689) and Jan. 2017 150% C.U. (ATel #9929)
Rise in January 2017 within a few days
\[ \rightarrow \text{Doubling time scale of } (10.2 \pm 1.7) \text{ h from exponential fit} \]
- Harder spectrum w.r.t. Aleksić et al. 2014 and curved
- Significant signal found above 1 TeV
- Power-law fits plus exponential cutoff indicate cutoff at ~500 GeV (e.g. EBL cutoff expected at 10 TeV, see Ahnen et al. 2016)
Theoretical aspects from variability

- Size of emission region:
  \[
  R > \delta c \tau_{\text{var}} = 22 \cdot \delta \cdot R_G
  \]
  for \( \tau_{\text{var}} = 10.2 \) h and \( M_{\text{BH}} = 3 \times 10^8 M_\odot \) (Wilman et al. 2005)

  No problem with shock-in-jet model
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  ![Checkmark]
  
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- Internal \( \gamma \gamma \)-pair production for 1 TeV photons:
  \[
  \tau_{\gamma \gamma} \sim \frac{\sigma_T D_L^2 F_0 \varepsilon_\gamma (1+z)}{10 R m_e^2 c^5 \delta^5} < 1 \rightarrow \delta \approx 7 \text{ for } F_0 = F_{\text{2MASS,2\text{\mu m}}} \text{ (Jarrett et al. 2003)}
  \]
  \[
  \quad \quad \quad \rightarrow \delta \approx 3.5 \text{ for } F_0 = F_{\text{HST,1.6\text{\mu m}}} \text{ (Baldi et al. 2010)}
  \]

  ![X]
  Constrains viewing angle to \( \theta < 9 \) or \( \theta < 16 \) for any \( \Gamma_B \)
Spine-layer model

- Geometry of SSC emission region defined with:
  - Spine $\Gamma_{\text{spine}} = 10 - 20$ in red
  - Layer $\Gamma_{\text{layer}} = 2 - 4$ in blue

- Evidence found in radio band:
  - Limb-brightened structure in inner pc-scale jet (Nagai et al. 2014)

- But for energies $> 1$ TeV $\rightarrow \tau_{\gamma\gamma} \gg 1$
  - Strong internal absorption at TeV energies

Data: Aleksić et al. 2014
Model: Tavecchio, F. & Ghisellini 2014
Summary

TeV observation of radio galaxies

Fast variability
Preliminary
Detection at TeV energies and maybe cutoff
Preliminary