γ-ray emitting AGN and GLAST

Paolo Padovani
European Southern Observatory, Garching, Germany

- The Active Galactic Nuclei (AGN) zoo
- GeV & TeV AGN: numbers and properties
- GLAST AGN: the obvious, the likely, and the less probable
The AGN Zoo: Unified Schemes

Jet

Black Hole

Obscuring Torus

Narrow Line Region

Broad Line Region

Accretion Disk

Urry & Padovani (1995)
The AGN Zoo: Unified Schemes

Type 2

Radio-quiet
- Seyfert 2
- QSO 2

Radio-loud
- high-L RG
- low-L RG

Type 1

- Seyfert 1
- QSO
- SSRQ
- FSRQ
- BL Lacs

\{ blazars \}

decreasing angle to the line of sight

1 radio galaxies
2 steep-spectrum radio quasars
3 flat-spectrum radio quasars
Blazar Properties
BL Lacs and Flat-Spectrum Radio Quasars

- Smooth, broad, non-thermal continuum (radio to $\gamma$-rays)
- Compact, flat-spectrum ($\alpha_r < 0.5$) radio sources ($f_{\text{core}} \gg f_{\text{extended}}$)
- Rapid variability (high $\Delta L/\Delta t$), high and variable polariz. ($P_{\text{opt}} > 3\%$)
- Superluminal motion
- Indication of “beaming” $\implies$ strong flux amplification $= \delta p$, with $\delta = 1/\gamma(1 - [v/c]\cos \theta)$ and $p \sim 2 - 3 \ [\delta \sim (\gamma)^{2-3} \sim 200 - 3,000!]$

Sites of very high energy phenomena:
$E_{\text{max}} \sim \text{TeV} \ (2 \times 10^{26} \text{ Hz})$ and $\gamma_{\text{max}} \sim 40 \ (v \sim 0.9997c)$
Spectral Energy Distributions

High-energy peaked (HBL)
synchrotron $\nu_{\text{peak}}$ in UV/X-rays
X-rays: steep, synchrotron em.

Low-energy peaked (LBL)
synchrotron $\nu_{\text{peak}}$ in opt/IR
X-rays: flat, IC emission

(Padovani et al. 2001)
The GeV sky

Large filled circle, high-confidence blazar; smaller filled circle, plausible blazar; filled star, pulsar; open star, pulsar/plerion candidate; open circle, nonblazar; cross, currently unclassified.

The GeV sky

- 271 EGRET sources
- extragalactic: $\sim 130$ AGN (including possible counterparts) + LMC
- AGN: all radio-loud; $\sim 97\%$ blazars + a few radio galaxies (e.g., Cen A, NGC 6251)
- Mostly FSRQ; FSRQ/BL Lac ratio $\sim 3 : 1$
- Mostly LBL; LBL/HBL ratio $\sim 5 : 1$ (HBL local: $z < 0.12$)

Most ($\sim 93\%$) EGRET detected blazars are of the "low-energy peak" type
All confirmed extragalactic TeV sources are radio-loud AGN: 15 BL Lacs and 1 radio galaxy [M87] (a starburst galaxy is a possible TeV source) ⇒ ~ 94% blazars! No FSRQ, all HBL from D. Mazin, Barcelona Conf., July 2006 (astro-ph/0609152) + L. Costamante, p.c.

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Blazar Rareness

Probability of having a jet pointing at us is small; for $\theta_{\text{max}} \sim 15^\circ$:

$\sim 3\%$ of radio-loud AGN, $\approx 0.3\%$ of all AGN,

$\approx 0.003 - 0.03\%$ of normal galaxies

Only 1 out of $\approx 3,000 - 30,000$ galaxies is a blazar!

Why have then blazars been detected in the $\gamma$-ray band?
Because they have:

1. High-energy particles, which can produce GeV and TeV photons
2. Relativistic beaming, otherwise GeV (Tev) photons would be absorbed through photon-photon collision with X-ray (IR) photons
3. Strong non-thermal jet component
Which AGN will GLAST detect?

• More of the same: flat-spectrum radio quasars, BL Lacs

• How many more? Answer depends on: evolution, intrinsic number density (cf. counts in other bands), γ-ray duty cycle, SED, and background. Simple assumptions:

  ✓ ~ 130 EGRET-detected blazars (likely lower limit)

  ✓ Euclidean number counts \( [N(S) \propto S^{-1.5}] \) (upper limit)

  ✓ GLAST ~ 30 x more sensitive than EGRET

  \[ \Rightarrow \leq 20,000 \text{ blazars} \ (\sim 0.5 \text{ deg}^{-2} = \text{ surface density of DXRBS blazars down to } f_{5\text{GHz}} \sim 50 \text{ mJy}: \text{Padovani et al., ApJ, submitted}) \]

• Giommi & Colafrancesco (2006) predict \( \approx 5,000 \) (Monte Carlo simulations)
MKN 501: a TeV/non-GeV BL Lac

1ES2344+514: a TeV/non-GeV BL Lac

MKN 180: a TeV/non-GeV BL Lac

Radio-galaxies as \( \gamma \)-ray sources?

- Many more radio-galaxies than blazars (\( \approx 30 \) times)
- For angles > 20 – 30° jet emission (\( \propto \delta^{2-3} \)) is de-amplified \( \Rightarrow \) radio-galaxies should be weaker (\( \gamma \)-ray) sources than blazars by factors > 100 – 1,000

- Indeed, the (\( \sim 3 \)) GeV and TeV detected radio-galaxies are very close (\( z < 0.02 \))
- But ...

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Radio-galaxies as γ-ray sources?

- Large scale (> kpc, as opposed to the pc scale) jet emission?
  - Main idea: each component sees enhanced radiation field coming from other component ⇒ inverse Compton (high-energy) radiation gets boosted
  - GeV emission is higher as compared to predictions based on homogeneous jets (but many free parameters)
  - Assuming γ-ray/radio flux ratio observed for 3 sources is typical, Ghisellini et al. (2005) predict ≥ 10 3CR radio-galaxies to be detected by GLAST
Radio-quiet AGN as γ-ray sources??

- Most AGN have very weak radio emission, on average ~1,000 times smaller than in the so-called radio-loud sources.

- What is the nature of radio emission in these sources? Two extreme options:
  1. related to star-formation processes
  2. scaled down version of that present in radio-loud AGN

- If n. 2, then radio-quiet AGN are also expected to be γ-ray sources, but at very low flux levels, on average ~30 below the GLAST limit. Perhaps detection is possible for high radio flux/radio-quiet AGN?? Need core radio flux, say, > 100 mJy

- Even negative detection (supported by detailed calculations) could prove very valuable!
Summary

1. Blazars, although very rare sources, dominate the γ - ray sky
2. GLAST will certainly detect “many thousand” blazars
3. GLAST will most likely detect many “high-energy peaked” blazars (unlike EGRET)
4. GLAST will possibly detect a “fair” number of radio-galaxies
5. Could GLAST detect also radio-quiet AGN???
6. GLAST will constrain (radio-loud) AGN physics and populations (see next talks and posters!!)