AGN STUDIES WITH GLAST

Mitch Begelman
JILA, University of Colorado
**UNIFIED PICTURE OF AGN**

**Generic features:**
- Power supply: BH accretion
- Outflows: jets/winds/breezes
- Dependence on viewing angle: obscuration and/or Doppler beaming

**Variations:**
- Radiative efficiency of disk
- Prominence of relativistic jet: “blazars” (~10% AGN)
- Ambient radiation field: BL Lacs vs. quasars

*Padovani & Urry*
SITES OF AGN $\gamma$-RAY EMISSION

- BLAZAR JETS
  - Orientation - beaming
  - Intrinsic differences (mass-loading, composition, $\Gamma$)

- NON-BLAZAR JETS

- ACCRETION FLOW & JET-LAUNCHING REGION

- STEADY EMISSION

- FLARES
  - 66 disc. by EGRET
  - ~13 seen in TeV

- Hints from HESS
WHAT DO WE WANT TO KNOW?

• How do jets form?
  - Magnetic propulsion?
  - Driven by disk or BH spin?

• What are they made of?
  - Baryonic vs. pair plasma?

• How efficiently do they transport energy?
  - Bulk Lorentz factor
  - Dissipation: internal shocks vs. reconnection?
  - Particle acceleration mechanisms

• How do they interact with their surroundings?
  - Gas: Boundary layers, entrainment
  - Ambient radiation field
WHAT DO WE WANT TO KNOW?

• How do jets form?
• What are they made of?
• How efficiently do they transport energy?
• How do they interact with their surroundings?
BLAZARS

• “Two-component” spectrum
  - Lo freq. peak ranges from IR → X
  - Hi freq. peak at GeV → TeV
  - Both components can be hard
BROADBAND BLAZAR SPECTRA:
Two Components

Bright EGRET-detected GeV-blazar: 3C279
(Wehrle et al. 1998)

First TeV-emitting blazar: Mkn 421
(data from Macomb et al. 1995)
BLAZARS

• “Two-component” spectrum
  - Lo freq. peak ranges from \(<\ IR \Rightarrow X\)
  - Hi freq. peak at GeV \(\Rightarrow\) TeV
  - Both components can be hard

• Rapid variability
  - \(~1 \ day \ with\  EGRET,\ limited\ by\ sensitivity\)
  - Shorter var. seen at TeV in brightest cases
  - Light travel time argument \(\Rightarrow\) \(\gamma\ \gamma\) absorption of \(\gamma\)-rays
    - Avoid by Doppler beaming from \(\Gamma^\sim 10\) jet
    - Emission from \(R\sim\) lt-mo. can vary in \(~\) days

• Multi-\(\lambda\) correlations?
  - Sometimes - esp. shorter flares
  - Sub-mm/IR coverage poor
BROADBAND BLAZAR SPECTRA:
Two Components

Bright EGRET-detected GeV-blazar: 3C279
(Wehrle et al. 1998)

First TeV-emitting blazar: Mkn 421
(data from Macomb et al. 1995)
**BLAZAR MODELING**

- **“Best guess”:** Same electrons produce both peaks
  - Lo freq. peak \(\sim\) synch \((\text{IR} \Rightarrow \text{UV})\), synch. or IC \((X)\)
  - Hi freq. peak IC

- **Different sources of Compton seed photons**
  - Synchrotron Self–Compton (SSC) vs.
  - External Radiation Compton (ERC)
Fig. 2.—Geometry of the source. The radiating region, denoted by short cylinder of dimension $a$, moves along the jet with pattern Lorentz factor $\Gamma_p$. Underlying flow moves with Lorentz factor $\Gamma$, which may be different.

(Sikora, Begelman, and Rees 1994)
3C 279: Realization of an ERC Model

SIKORA, BEGELMAN, & REES 1994
BLAZAR MODELING

- “Best guess”: Same electrons produce both peaks
  - Lo freq. peak ~ synch (< IR ⇒ UV), synch. or IC (X)
  - Hi freq. peak IC
- Diff. sources of Compton seed photons
  - Synchrotron Self–Compton (SSC) vs.
  - External Radiation Compton (ERC)
- Distinguishing the models
  - Multi–wavelength correlations
    - Strong for SSC, weaker for ERC
    - Sikora bump
    - Time–lags: propagation of jet disturbances, mapping ambient radiation field
  - “Hadronic” models less likely, but not ruled out
2 CLASSES OF BLAZARS?

Inter-peak correlations:

WEAK

STRONG

<table>
<thead>
<tr>
<th>Wehrle et al. 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUASAR: Strong ambient radiation</td>
</tr>
<tr>
<td>BL LAC: Weak ambient radiation</td>
</tr>
</tbody>
</table>

Macomb et al. 1995

 ERC?  
 SSC?
WHAT CAN GLAST DO?

• Larger collecting area track flares on timescales < 1 day
• Wide FOV continuous monitoring of many sources, better chance to catch flares in multiple bands (e.g., if X-ray precursor is spotted)
• Overlap with groundbased TeV arrays
  - Better handle on absorption by NIRB
  - Klein–Nishina effects?
    • Constrain Comptonization models
    • Leptonic vs. Hadronic models
NON-BLAZAR JETS

• “Quiescent” emission from beamed jets
  - Need higher sensitivity than EGRET
  - TeV evidence from HESS
  - Clues to underlying jet physics (MHD turbulence vs. shock heating, boundary layers…)

• “Unbeamed” jets
  - Test unification: FR I → BL Lacs, FR II quasars

• Diagnose beaming patterns
  - Do “misaligned” jets sometimes spray relativistic matter in our direction?
  - HESS: rapid TeV variability in M87
So far, γ-ray astronomy has probed AGNs on 0.1 pc scales. Can GLAST extend our view spatially?

• Central engines & jet launching pads
  - Scales ∼ 100 AU
  - Need sufficiently low compactness - radiatively inefficient accretion flows
  - HESS: rapid TeV variability in M87

• Kpc-scale jets
  - Chandra saw surprisingly large X-ray emission from extended regions in jets - mechanism controversial
  - Sites likely “hotspots”: internal shocks, collisions with obstacles
SUMMARY

• GLAST will provide key insights into the physics of relativistic jets from AGNs...

• On blazar (pc) scales...
  - Will go well beyond EGRET to explore faster variability, non-flaring emission
  - Need adequate multi-wavelength coverage
  - Link to groundbased TeV experiments

• May reveal new energetic phenomena...
  - Scales ranging from the inner accretion fbw to kpc scales