GLAST Blazars: Preparation and Anticipation
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The GeV sky – persistent point sources

• To date only pulsars, blazars securely identified
  – Individual variability to cement ID w/ lower energy
  – Statistical association for population as a whole
  – other candidates: HMXB, clusters, SNR, …

• Common Physics of $\gamma$-ray dominated sources:
  – Flywheel – bulk storage of mechanical energy
  – Strong magnetic field coupling to a low density ($\gamma$ and $\rho$) environment
  – Pair production + weak cascading to lower energy
Looking forward to GLAST (2007)

- >30x EGRET sensitivity
- Expect 4000-10,000 Blazars, >200 Pulsars
Lessons from EGRET

• The bright blazar population is decently characterized
  – Nominally, expect population surprises at the few % level
  – Luminosity, high duty cycle bias
  – w/ 2,000-10,000 expected, we can do serious work with rare sub-sets of the blazar population

• Pulsars are much less well characterized
  – Expect surprises at the 30% level
  – Geminga’s, MSP, B star binaries…

• Beyond this we revel in lightly constrained speculation...
Blazars Dominate the known EGRET sky

- Blazars:
  - Bright EGRET Sources clearly assoc. w/ flat spectrum radio QSO
    - 3EG, Mattox, etc. → ~40 IDs, +20 Candidates
  - Blazar definition heuristic, blazar studies are heterogeneous
  - Striving to be more physics based: (from at least some direction) a jet-dominated AGN with a bimodal, synchrotron+Compton SED (Giommi)
Blazar SEDs

GLAST MW Team
(D Thompson)

FSRQ -- `Red' Blazar
Flat optical
(FSRQ spectrum)
Faint IC X-ray
High z

LBL – intermediate
Low peak BL Lac

HBL -- `Blue' Blazar
Blue Optical
(BL Lac spectrum)
Bright Syn X-ray
Low z

Inv. Compton
Synchrotron

FSRQ: PKS 0208-512
HBL: Mkn 421
Evaluating Blazar counterparts

• Need deep all-sky samples.
• Train SED FoM against clear EGRET counterparts
• Radio: flux, spectrum, compactness
• X-ray: (RASS) weak selection for detection
• Position w/in 3EG uncertainty contour
• Issues:
  – False Positives
  – Confusion
  – Variability
  – Looking under the lamppost
HET 3EG Blazar Survey

- EGRET sources -- start from 3EG (some are spurious!!)
  - Select flat spectrum radio counterparts (NVSS+CLASS or new VLA 8.4GHz A-array)
    - FoM approach: increasing weight with large $S_{\nu}$, small $\alpha$
  - Including X-ray, $\gamma$-ray position:
    - Total FoM has weak X-ray weight, uses 3EG TS maps
  - Optical ID of high FoM, $R<23$ w/ Hobby*Eberly Telescope
    - Optical Arecibo $\rightarrow$ DEC>-10
HET 3EG Blazar Survey

- Results
  - >70% IDs at high b
  - 18% are BL Lac, almost all of rest are FSRQ
  - Multiple IDs (composite \( \gamma \)-ray sources)
  - ~Doubled maximum z
  - Found 2 radio faint (non-blazar) populations

- Isotropic, bulge
3EG Survey Status
GLAST-sized samples

- Note: 3EG was a pointed, intermittent survey
  - Average exposure $\sim 9.5 \times 10^{\text{wk VP}}$
  - Some fainter sources only in one VP i.e. $< 10\%$ duty cycle
  - After correcting for VP exposure, the flux dist'n/VP is good PL
  - Extrapolation to GLAST 1yr sensitivity ($3 \times 10^{-9} \gamma / \text{cm}^2 / \text{s} \sigma$; $1.5 \times 10^{-8} \gamma / \text{cm}^2 / \text{s}$ in two weeks) get
    - 4500 all sky (5 $\sigma$, 1yr), 3700 $|b| > 100$
    - About $1/2$ of these bright enough for spectral, temporal study
    - Remove spatial part of FoM – select a threshold giving the desired # of sources
      - We take FoM > 0.04 – gives 1742 all sky, $|b| > 100$
        - Only ($1 > \alpha > -0.5$) FSRQ
        - Gives flux floor $S_{8.4 \text{GHz}} > 85 \text{mJy}$
`CGRaBS’: ID fractions

- **All-sky |b|>10°**
  - 1030/1742 optically classified (59%)
  - 964 (94%) of these w/ z – we’ve contributed 60% of all z
  - 115 (11%) are IDed as BL Lac (about ½ w/ redshifts)

- **Above DEC= 0°**
  - 672/837 optically classified (80%)
  - 624 (94%) with z
  - 81/672 (12%) are BL Lacs
Redshift Dist’n

- 60 $z > 2.5$ (8 in 3EG)
- 30 $z > 3.0$ (5 in 3EG)
CGRaBS optical

Done  Yet to Observe

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Why Now?

- GLAST sky will be \textit{variable}
- A externally selected sample complements `triggered’, i.e. γ-selected, objects.
- Important (e.g. high $z$) sources need to be pre-selected for correlated study
- Secure IDs may still require \textit{simultaneous} monitoring
Blazar Jet Monitoring

- VLBI monitoring to get $\delta$
  - Comparison of $\delta$ at $\gamma$-ray (0.1pc) and VLBI (~1pc) scales
  - HBL: VLBI $\delta < 4c$ (Giroletti et al. 03)
    - But $\delta \sim 50$–100 needed to model TeV!
  - FSRQ (EGRET Blazars): VLBI $\delta$ peaks at 10-12 (Marscher & co)
    - Compare w/ 2-3 for RQSO in general

- Key Question: VLBI ejection vs. $\gamma$ flare
  - GLAST cont. coverage essential
  - Secondary issue: $\delta$ vs. GeV power
    (Macomb, Ulvestad, et al.)
We do all this zoology to enable some Physics

• Probing the acceleration of the AGN jets
  – Step 1 – get $\beta$
    • (expect high speeds Kellerman, et 04….)
  – Step 2 – $\beta \Rightarrow \theta, \Gamma$
    • Multi-n component studies (Blandford & Koenigl `79 $\Rightarrow$ Marscher `83 $\Rightarrow$ e.g. Piner et ’03,…)
  – Step 3 – field structure of jet, relate activity to $\gamma$ outbursts

• Probing the EBL and the onset of star formation
  – Step 1 – find high $z >10$GeV sources (CGRaBS is a start)
  – Step 2 – monitor $>10$GeV flux
    • With attendant low energy study
  – Step 3 – look for systematic $\tau(z)$ cutoff independent of $f$ source, flaring,…

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**EBL Absorption (Madau & Phinney)**

- Encouraging successes with optical/IR absorption of TeV Blazars at $z < \sim 0.15$ (e.g. Dwek & Krennrich)
  - Snapshot of the integral stellar content today
  - Expect such studies will make robust measurements in next few years…
- With $>10\text{GeV}$ photons from $z>3$ can probe optical/UV absorption through the peak of star formation $z\sim$
  - Time-resolved monitoring of the onset and growth of star formation

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*Primak et al 04*
EBL Absorption – Can GLAST measure it?

- Present blazar LF, evolution very uncertain: e.g. Salomen&Stecker (a) and Chiang&Mukherjee (b) differ by >10x in # at z>3
- To get time evolution, need follow systematic with z, flare state.
- Improved SSC models, coupled w. optical/X-ray monitoring will greatly improve the prospects
Summary

• Radio-selected Blazars will likely dominate GLAST sky
  – But presently we know of far too few…

• Pre-launch efforts to ID powerful blazars can reasonably match the well-measured GLAST sample.
  – Helps with IDs in early GLAST catalogs
  – Down-selects interesting (i.e. high z, powerful jet) sources for intensive multi-ν study during the GLAST prime mission.
  – GeV physics will be substantially aided by low energy modeling, improved SSC, EC models.

• Sorting the wheat from the chaff…
  – Identify new radio-faint ex-gal populations
  – Search for high latitude Galactic (eg. MSP) sources.