The Radio Perspective
(from the fringe)

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GSFC
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The Long Wavelength Demonstrator Array (LWDA) Site on February 18, 2007
"resolution of 2 degrees is poor" - Bob Hartman
LWA Overview:
Far Larger than the VLA

1 “LWA Station” = 256 antennas
Full LWA: 52 stations spread across NM

100 m

400 km

State of New Mexico
3EG Survey Status

186 High $b$:
- 118 Blazar,
- 3 radio galaxies,
- 2PSR/PWN
- 66 Non-Blazar (many questionable SRCs)

>60% High $b$ sources identified as blazars
Gamma-ray flux variations by factor 100, factors of 2 on timescales of ~4 hours

Romani et al
Radio Target List

- Selection $S_{4.8} > 65\text{mJy}$, $|b| > 10^0$, $\alpha < 0.5$ -- CLASS+
  - 11,131 sources - Healey et al. 2007
  - Attempts to fill in PMN holes w/ S5, lower $\nu$-selected sources
  - Combined Radio All-sky Targetted Eight-GHz Survey: CRATES
VLBI 101

- Many jets have $\Gamma > 10$
- Max observed Speed $\sim$ Maximum $\Gamma$
  (e.g. Lister & Marscher 1997)
  $\Rightarrow \Gamma_{\text{max}} \sim 40$ for Blazar Jet Population
- For jet cores, $T_{\text{obs}}$ measurements and limits range from $10^{11} \text{K}$ to $5 \times 10^{13} \text{K}$, a few $> 10^{14} \text{K} \gg T_{\text{eq}}$
- Jet ejection angle wanders around (don’t forget pol’n)
- 3-D field structures of jets?
  - Connection with SMBH/accretion disk system?
  - Do Jets carry a current?

“There may be a great deal more to the jet than we see.” - Dan Homan

“40 or 50 in Astronomy is the same number.” - Al Marscher
Sample Jet Evolution Imaged with VLBA

- Monthly VLBA imaging of radio galaxy 3C 120 at 22 GHz (Gomez et al. 2000)
- What were the gamma rays doing during this period?
- Desire imaging on time scales of weeks or less for $z \approx 0.5$

"Jets are fast and change on a PhD timescale. EGRET jets are faster." - Dan Homan
Questions

- Where are the gamma-rays produced?
- Do gamma-ray blazars have intrinsically faster jets?
- Are there multiple classes of gamma-ray emitting blazars?
- What controls the duty cycle of outbursts?
More Questions

- What makes some blazars brighter in gamma-rays? $\delta$, $L$, $M_{BH}$, Spin, Accretion?
- Do gamma-ray flares coincide with the emission of new components?
- Do gamma-ray flares coincide with jet bending?
- How are jets confined?
- Can we come up with a self-consistent model?

“The combination of GLAST and VLBI presents us with the best chance to answer these questions is the past 30 years (40 for Ken).” - Tony Readhead
Lessons Learned from EGRET/VLBI

(0) gamma-ray loud AGN are radio loud (and blazars)
(1) EGRET blazars are faster (Jorstad et al. 2001)
(2) Gamma-ray flares lag the mm flares (Valtaoja)
(3) Gamma-ray flares lag the ejection of new VLBI components
(4) EGRET detected jets and jet components have higher average fractional polarization (Lister & Homan 2005)
(5) Also have brighter jet components by ~ x 2 (Lister & Homan)
(6) Are more compact overall, more variable (Kovalev)
(7) Have higher core brightness temperatures (Helmboldt)

"What did we not learn from EGRET, and why not?" - Marscher/Kadler
"Energy range of EGRET missed HBLs" - Girolettii
New with GLAST

- Much improved energy range, resolution, & sensitivity
- Much improved sampling of Gamma-ray light curves
- Expect ~ 2/month GLAST flares above $2 \times 10^{-6}$
- List of 22 Famous Blazars
- Radio galaxies? Seyferts?

“The low luminosity AGN deserve attention too.” - Ulvestad
Gamma-Ray Emission Mechanisms for Blazars

Here?

Here?
Radio Monitoring programs

- UMRAO program - ~200 objects at 5, 8, 15 GHz
- OVRO 40 m program - 1000 objects at 15 GHz with noise ~1 mJy and timescales 1-1000 days
- Metsahovi program - ~100 sources 22 and 37 GHz
- ATA, MIRANdA programs?

"Let's include some semi-boring sources also" - Esko Valtaoja
VLBI Programs

- GMVA - 86 GHz
- BU - 43 GHz
  ~10 sources?
- MOJAVE - 192 bright
  monitoring of ~35 blazars
  @ 15 GHz + blazars + AGN
- VIPS - 1127 sources
  @ 5 GHz

"We need a balanced approach." - Readhead/Ulvestad

"We need a central repository of VLBI images." - Dan Homan
J16036+1554: An EGRET blazar that is extremely compact
Evidence for limb brightened jet morphology on the parsec scale is present in some FR I radio galaxies: 1144+35, Mkn 501, 3C 264, M87, 0331+39…….
Requirements for Imaging

Blazar Jets

- High-frequency capability (> 20 GHz) to image jets where they are optically thin
- Full-polarization imaging
- Frequency agility from 330 MHz -> 86 GHz
- Dynamic scheduling for response to gamma-ray flares at any time of year, and for repeated reliable observations
- Sub-milliarcsecond resolution to detect changes on time scales of days to months, sub-pc scales
High Sensitivity Array (add VLA, GBT, Effelsberg, Arecibo) may be desirable for LLAGNs, TeV blazars

"Add in LBA+ to improve imaging of southern sources" - Steve Tingay
“VLBI and GLAST is a marriage made in the heavens.” - Al Marscher

“Save the VLBA! Tell NRAO, tell NSF” - Al Marscher
- Campaigns on individual objects
- Use calibrators from CARMA, SMA, VLA…
- Spitzer, Kepler opportunities early on
- SMARTS, SARA, ROTSE? GTN
- Chandra, XMM
- AGILE, Swift, GLAST
- Veritas, HESS, MAGIC, CANGAROO

“Need your friends and friends’ friends.” - Ann Wehrle