Updates on CGRaBS, the Candidate Gamma-Ray Blazar Survey

> Steve Healey GLAST Science Lunch 2 February 2006

# Origins of the Survey

- 3EG counterparts
  - Radio and X-ray properties
  - "Figure of merit" (FoM) statistic
- Optical follow-up on FoM winners
  Type IDs and redshifts
- Repeat for sources across entire sky
  - …well, as much of it as you can

#### Thou Art Radio, and Upon This Rock I Will Build My Survey

- 4.85 GHz single-dish data
  - Impose flux minimum  $S_{4.85} \ge 65$  mJy
- Match against sources from lowfrequency interferometric surveys
- Demand flat spectra
  - Spectral index  $\alpha_{low/4.85} \le 0.5 \quad (S \propto v^{-\alpha})$
- Obtain interferometric data at 8.4 GHz

A Piecewise Function of Declination

- Far North:  $75^{\circ} < \delta < 90^{\circ}$
- North:  $0^{\circ} < \delta < 75^{\circ}$
- Equatorial South:  $-40^{\circ} < \delta < 0^{\circ}$
- Far South:  $-90^{\circ} < \delta < -40^{\circ}$
- Galactic plane ( $-10^{\circ} < b < 10^{\circ}$ ) excluded

#### North: $0^{\circ} < \delta < 75^{\circ}$

- 4.85 GHz single-dish: GB6
- Low-frequency: NVSS (1.4 GHz, VLA)
- 8.4 GHz interferometric: CLASS (VLA)
- Completeness: 99.8%
- Steve's status: Extremely happy, verging on undeservedly smug

#### Equatorial South: $-40^{\circ} < \delta < 0^{\circ}$

- 4.85 GHz single-dish: PMN
- Low-frequency: NVSS (1.4 GHz, VLA)
- 8.4 GHz interferometric: Winn (VLA), Romani (VLA + ATCA)
- Completeness: 88%
- Steve's status: Happy and optimistic

#### Far South: $-90^{\circ} < \delta < -40^{\circ}$

- 4.85 GHz single-dish: PMN
- Low-frequency: SUMSS (0.84 GHz)
- 8.6 GHz interferometric: AT20G, Wright, Romani (ATCA)
- Completeness: 69%
- Steve's status: Thrilled six months ago, but now merely content

## Far North: $75^{\circ} < \delta < 90^{\circ}$

- 4.85 GHz single-dish: S5 (250 mJy!!!!)
- Low-frequency: NVSS (1.4 GHz, VLA)
- 8.4 GHz interferometric: CLASS stragglers, Romani? (VLA)
- Completeness: 77% (to 250 mJy)
- Steve's status: Not entirely satisfied but skeptical that much more can be achieved

## Radio Survey Completeness



#### Tiny dots: Done (i.e., observed at 8.4 GHz) Asterisks: Not

# Radio Wrap-Up

- Significance of the radio campaign
  - As close as possible to uniformity
  - Juicy, delicious list of GLAST blazar candidates
  - Unforeseen utility to the community (a la CLASS)
- Name?

## Generating CGRaBS

- With 8.4 GHz measurements in hand, compute "real" spectral index  $\alpha_{low/8.4}$
- Require that  $\alpha_{low/8.4} \ge -1$  to eliminate the occasional thermal source
- $\cdot$  Compute figure of merit (a function of 8.4 GHz flux,  $\alpha_{low/8.4}$ , and RASS counts)
- Pick a FoM threshold and call the winners CGRaBS

# Optical Follow-Up

- Vet sources against archival IDs (Veron catalogue, Sloan quasars, NED)
- Find optical counterparts
  - USNO B1.0 catalogue
  - SDSS catalogue where available
- Observe targets spectroscopically to establish type ID and redshift

## **Optical Observations**

- North & near Equatorial South: Hobby-Eberly Telescope
- Far North, North, & Equatorial South: McDonald 2.7 m, a tiny bit of Palomar
- Equatorial South & Far South: CTIO 1.5 m, SOAR (sort of), NTT (upcoming)

## Sample Spectrum



J1738+4008 HET LRS 4 July 2005 z = 3.59Type: FSRQ

# **Optical Results**

- 85% of CGRaBS sources are flat-spectrum radio quasars
  - 12% are BL Lacertae objects
  - 3% are narrow-line radio galaxies or other non-blazars
- Just under 1000 redshifts
  - 48% of BL Lacs have well-measured *z*

#### **Redshift** Distribution



Solid: All CGRaBS blazars

Broken: BL Lacs x 2

# **Optical Survey Completeness**



 $R \le 18$   $18 < R \le 20$   $20 < R \le 22$  22 < RFilled: IDed and redshift found Open: Not

# **Concluding Thoughts**

- All-sky flat-spectrum radio survey almost complete! Yay!
- Optical survey is...okay
  - North is in good shape, should exceed 90% by GLAST launch
  - South is not bad; Far South sort of is
- CGRaBS has identified candidates suitable for EBL absorption studies
  - 15% of survey has *z* > 2
  - 30 objects have z > 3