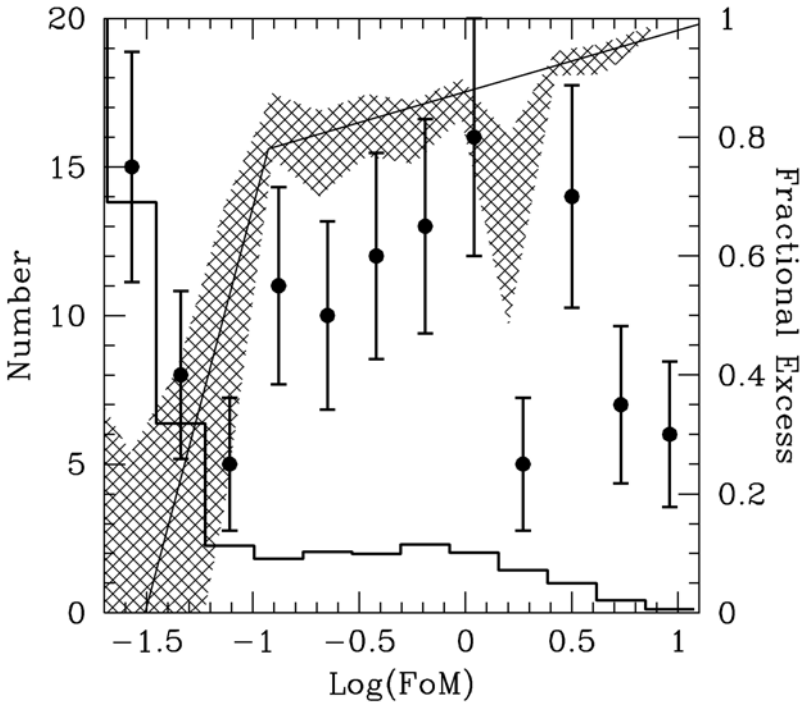
GLAST Blazars: Preparation and Anticipation

w/ L. Greenhill, P. Michelson, T. Readhead,
G. Taylor, J. Ulvestad,
D. Sowards-Emmerd, S.E. Healey, etc.

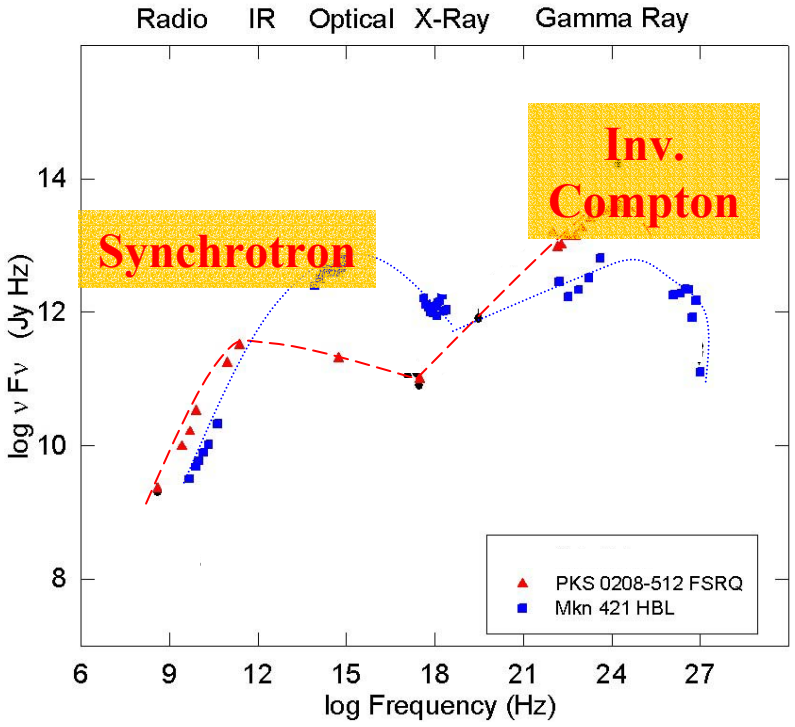
- **Maximize the information from Blazar population in the 3EG**
  - **Train up selection using the EGRET high |b| blazar set**
    - **Find that this selection is complementary to other blazar lists (e.g. GRB, Sed multi-ν, DXRBS)**
  - **Start by improving the EGRET ID fraction**
  - **Develop method for evaluating likelihood of individual source IDs**
- **ID suitable blazar sample to match that expected from GLAST**
  - **Start from flat-spectrum radio sources**
  - **Get optical ID's for the `best' ~1500-1700 sources**
  - **Set up correlated radio/γ-ray population studies**
- **Work up special subsets of the sample in prep. for GLAST**

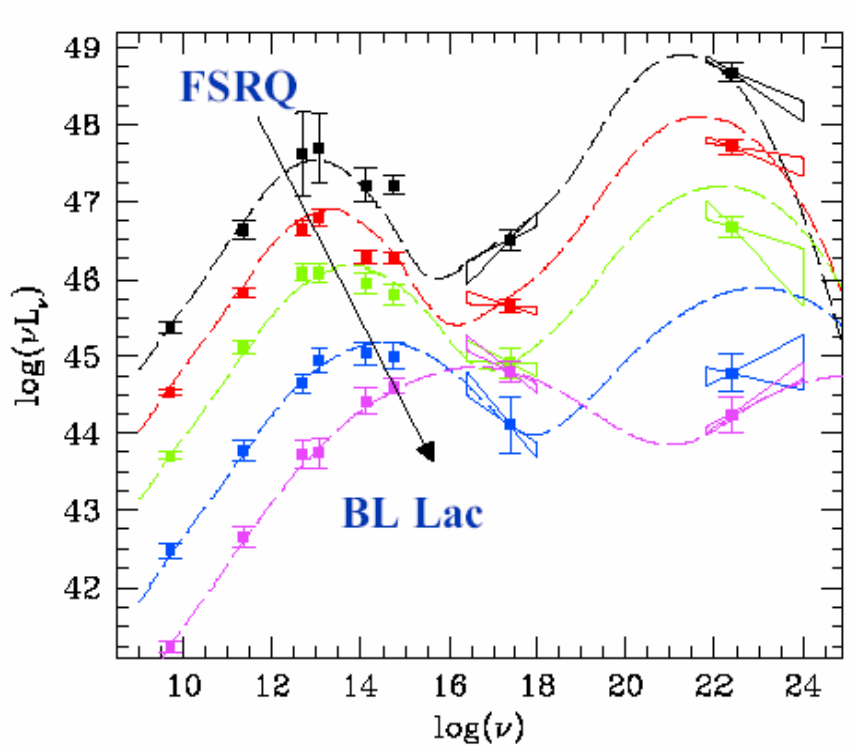
Blazar properties from the EGRET sky

- **Bright EGRET sources clearly assoc. w/ flat spect. radio QSO**
  - **3EG, Mattox, etc. → ~40 IDs, +20 Candidates**
  - **Radio-faint AGN do not show strong >MeV emission**
- **We have worked to quantify this:**
  - **measured excess within 3EG regions as a function of S_{8GHz}, α, f_X**
  - **combined with a probability of being w/in a given 3EG likelihood.**
- **Gives a `Figure of Merit' FoM that the source is the counterpart**
  - Sowards-Emmerd et al '03,'04
  - X-ray correlation is very weak
    - These are often sub-RASS sources
  - High confidence > 92%
  - We take lower confidence to >82%
    - Much better than previous!
  - IDs peter out at ~75mJy



Blazar SEDs and the Blazar sequence





FSRQ -- `Red' Blazar
Flat optical, Faint IC X-ray, High z

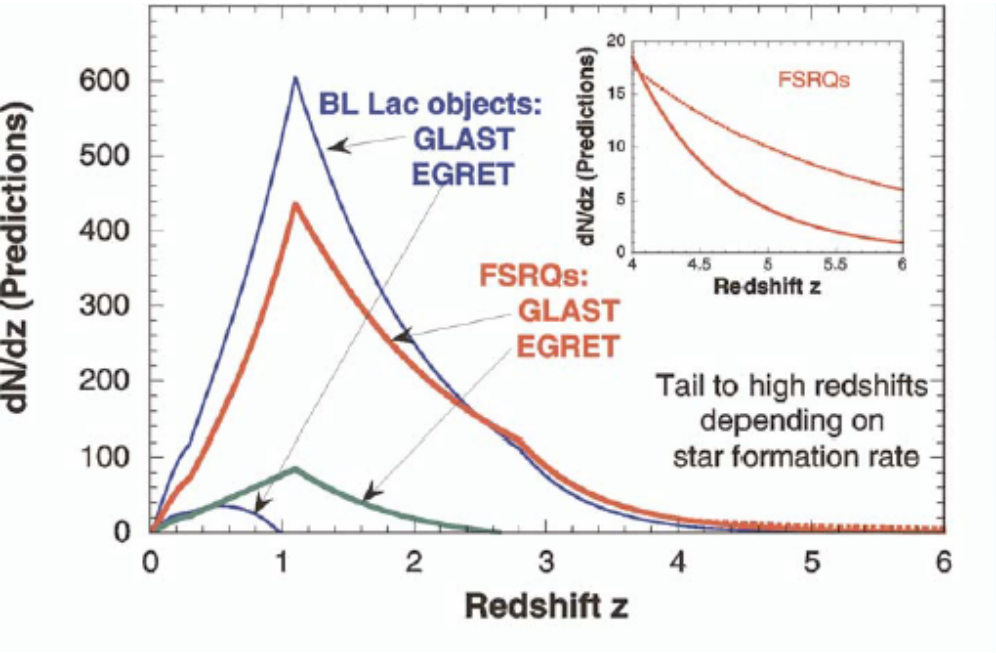
{LBL – intermediate
Low peak BL Lac}

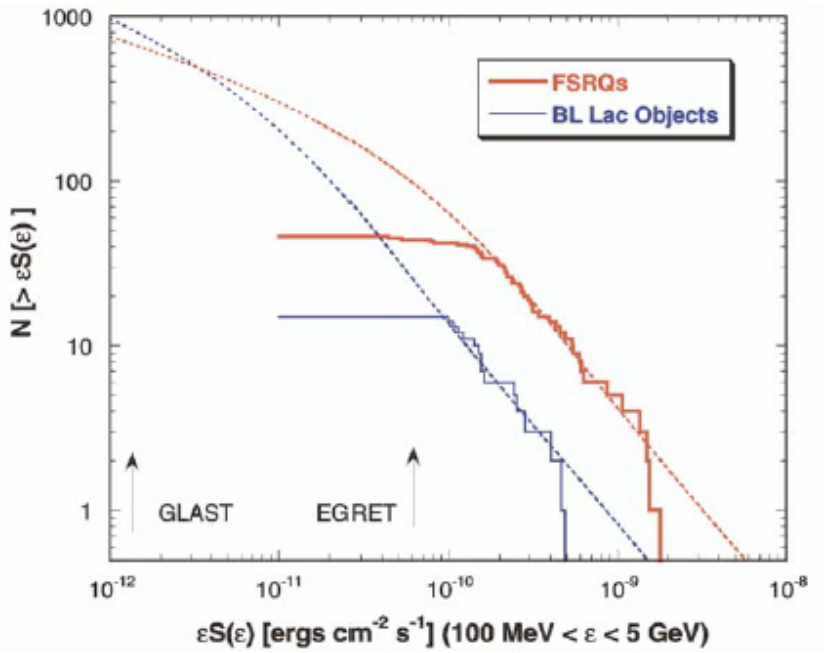
HBL -- `Blue' Blazar
Blue Optical (BL Lac spectrum)
Bright Syn X-ray, Low z

N.B. – Paolo suggests sources outside this sequence (i.e. high radio power, but high peak energy) – would need z's to confirm such sources; could also be beaming effect.

Population – FSRQ & BL Lacs

- **Expect the low L BL Lacs to be increasingly important at low f_γ**
- **Expect these Blazar AGN to peak (like others) at z~1-2 with peak of star formation**
- **Extreme example – Dermer –**





- **Note: population studies probe BL Lacs, but variability, spectral studies still dominated by FSRQ**

Lessons from 3EG IDs

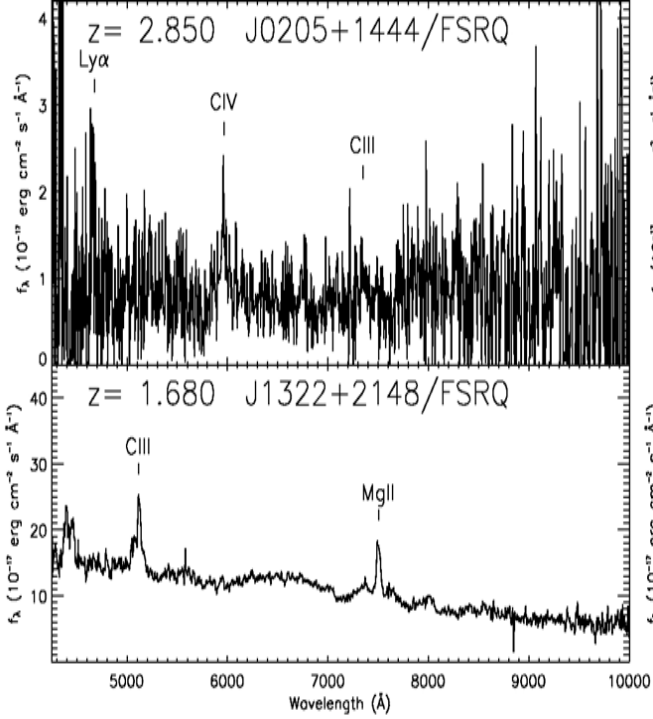
- **FSRQ dominate the bright source population**
  - **Need to get more FSRQ (down to ~100mJy) to complete census**
  - **Note this does not mean BL Lacs will not be very important at fainter flux levels!**
- **These FSRQ will be X-ray, optically faint at given radio flux level, but γ-ray luminous**
  - **Typical f_X ~50-100x times fainter than BL Lac (below RASS)**
  - **Optical r, +4-5 mag -- need to work to r~23**
- **Radio-IDs: compact (interferometric) high ν core flux helps greatly in getting positive IDs**
- **Issues:**
  - **Spurious γ-ray sources: 5-10 3EGs do not survive data re-processing**
  - **False Positives: ~10 in present sample, but mostly at lower FoM**
  - **Variability – especially 8GHz variability affects α estimates**
  - **Looking under the lamppost….**
  - **Properly speaking, these are blazar `candidates' w/o 3EG association**

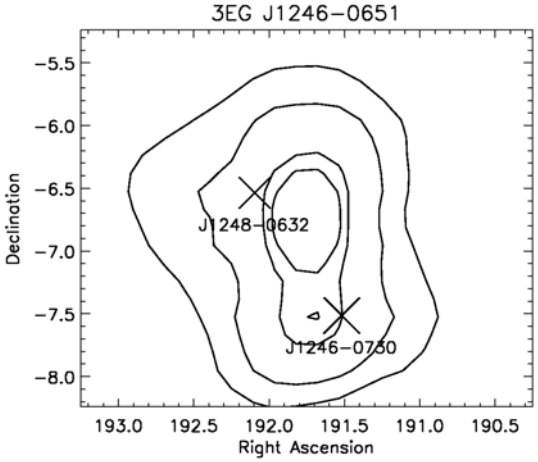
HET 3EG Blazar Survey

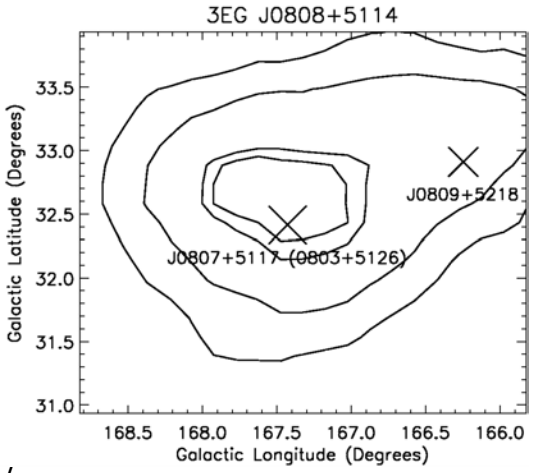
- EGRET sources -- start from 3EG (some are spurious!!)
  - **Select flat spectrum (NVSS+CLASS or new VLA 8.4GHz A-array)**
    - **FoM approach: increasing weight with large S_ν, small α**
  - **Including X-ray, γ-ray position:**
    - **Total FoM has weak X-ray weight, uses 3EG TS maps**
  - **Optical ID of high FoM, R<23 w/ Hobby*Eberly Telescope**
    - **Optical Arecibo → DEC>-10**
    - **Bright (<19.5) sources >-40 w/ 2.7m**

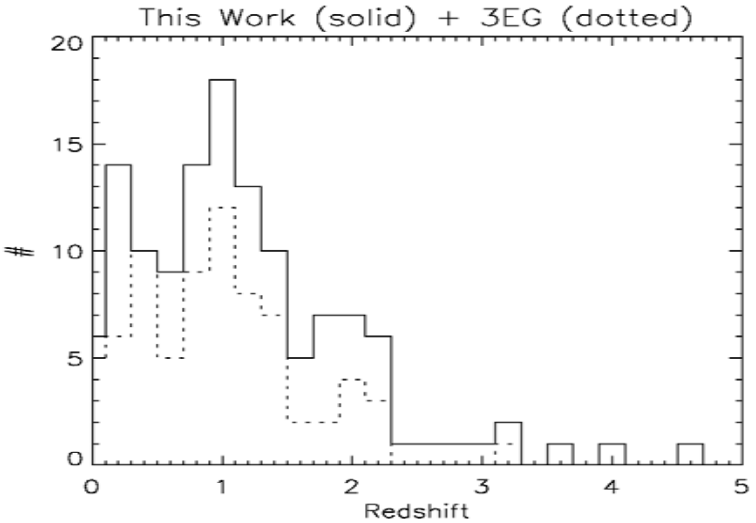
HET 3EG Blazar Survey

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

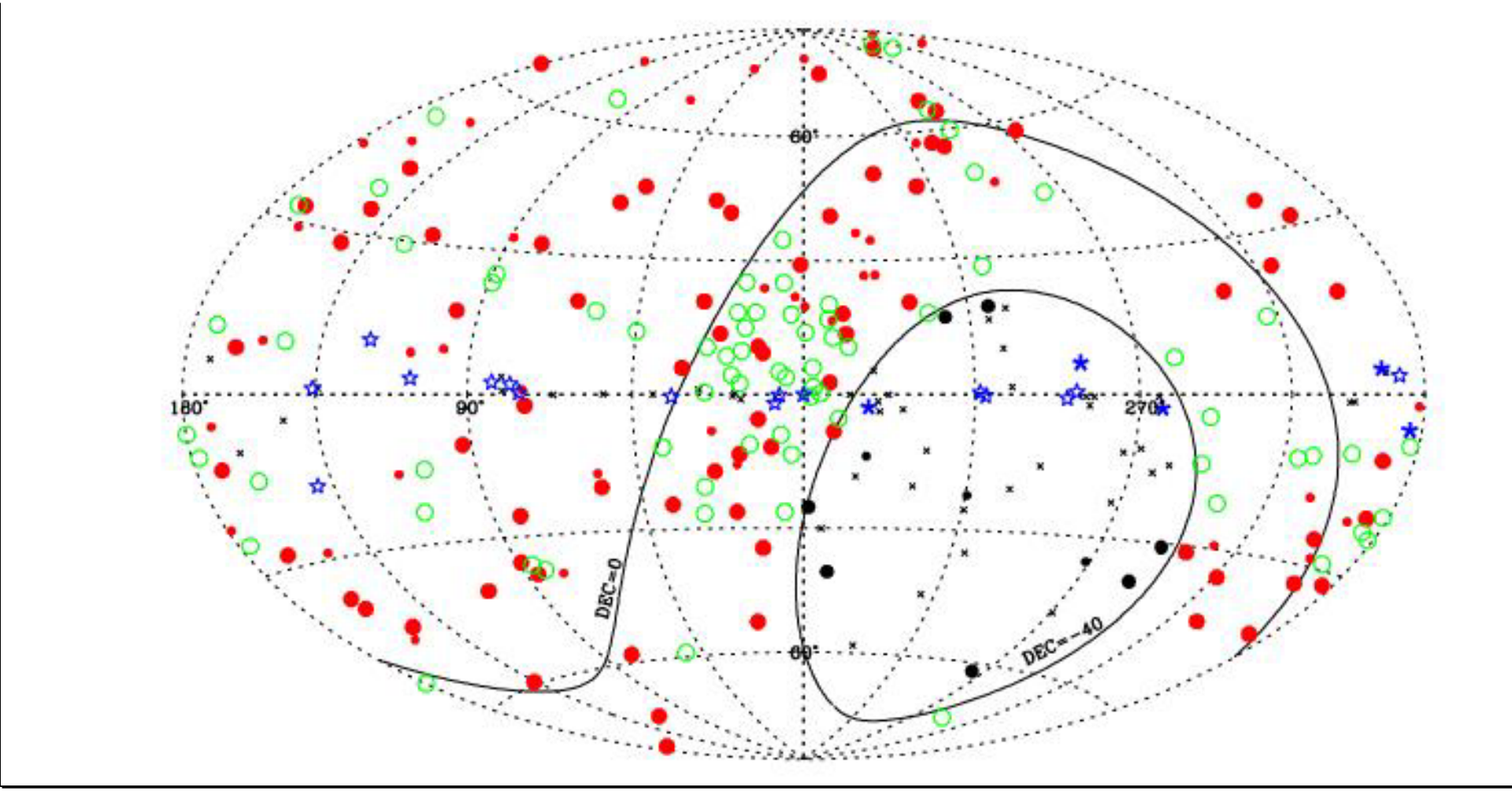




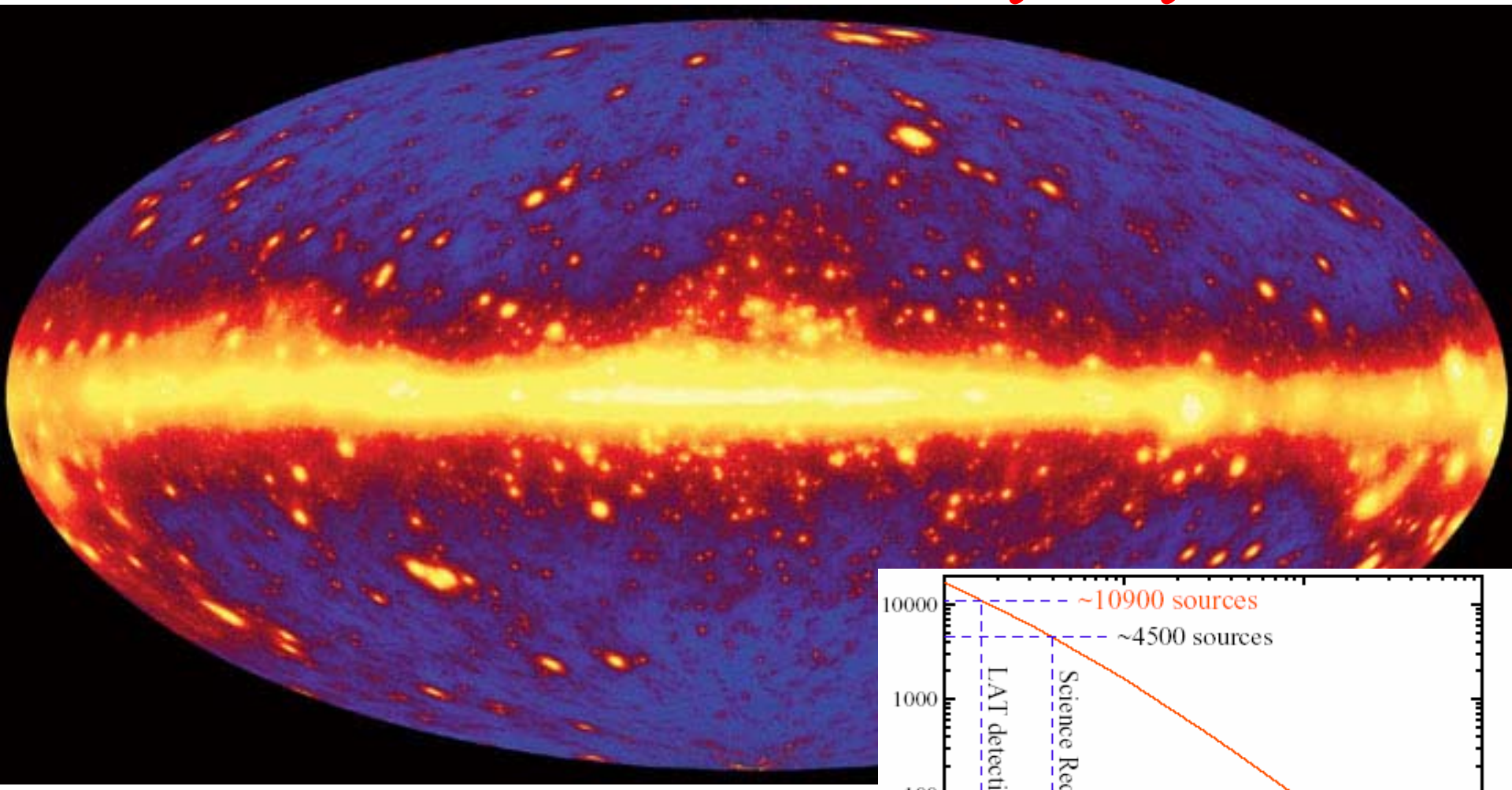


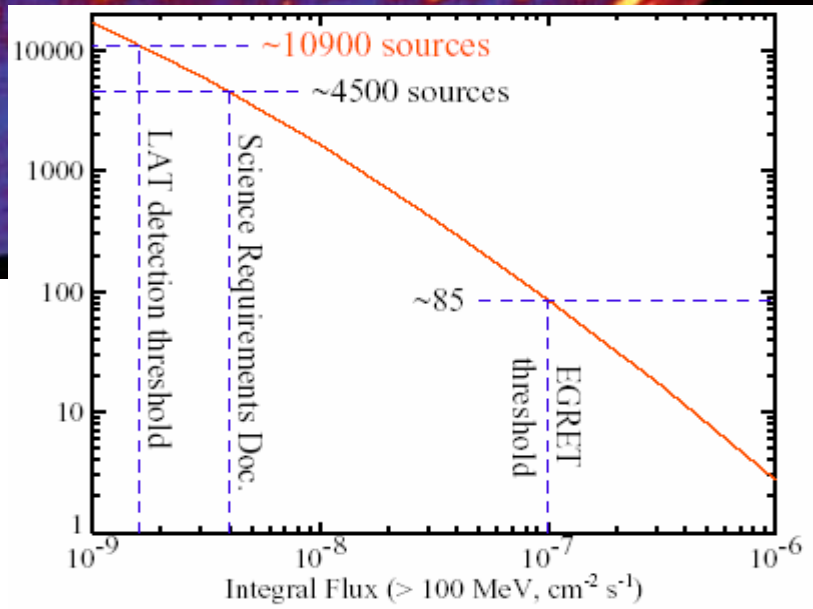


3EG Survey Status



GLAST Gamma-Ray Sky





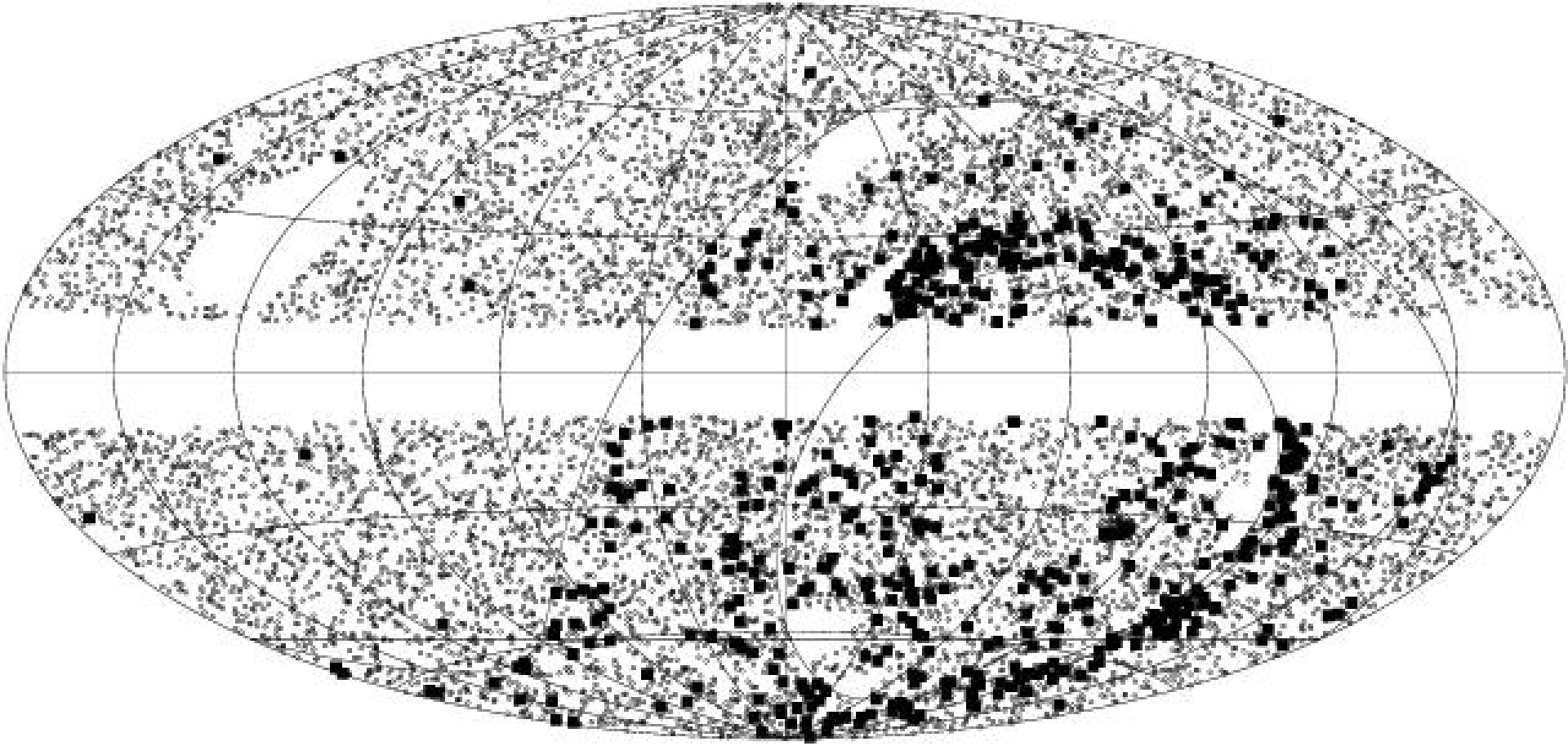
3,000-10,000 blazars – not all active in 1st year survey….

GLAST-sized samples

- **Note: 3EG was a pointed, intermittent survey**
  - **average exposure ~9.5 x 2wk 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 (3×10^{-9} $\gamma/cm^2/s$ 5σ; 1.5×10^{-8} $\gamma/cm^2/s$ in two weeks) get**
    - **4500 all sky (5σ. 1yr), 3700 $|b|>10^0$**
    - **About ½ 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 ~1750 all sky, $|b|>10^0$**
  - **Only ($1 > \alpha > -0.5$) FSRQ**
  - **(0.05 is likely if at 95% CL)**
  - **Gives flux floor $S_{8.4GHz} > 85mJy$**

Parent Radio Population

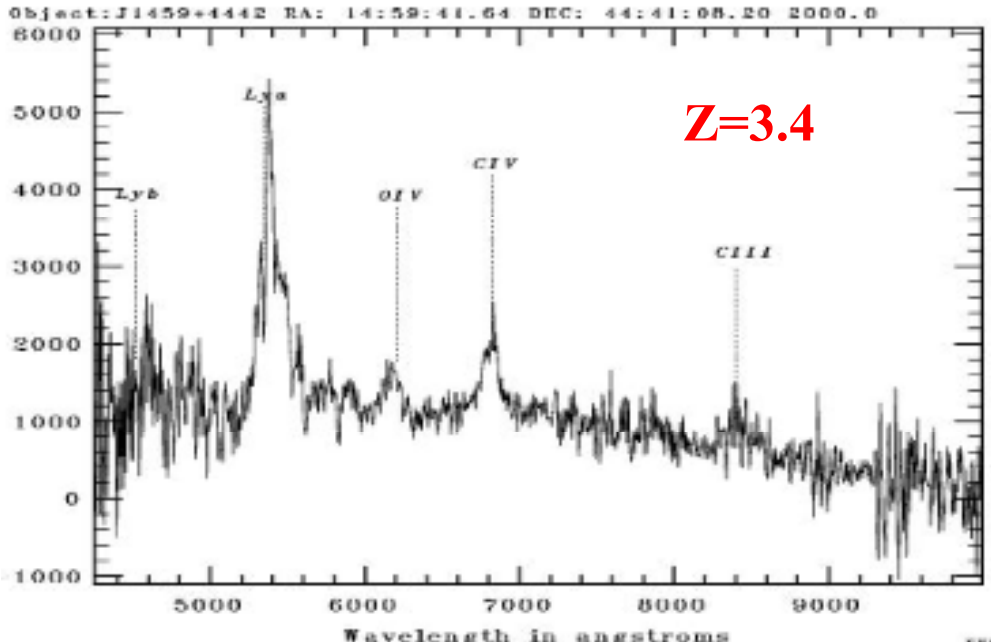
- ~11,000 sources $S_{4.8}$GHz > 65 mJy. Black squares need interferometric confirmation

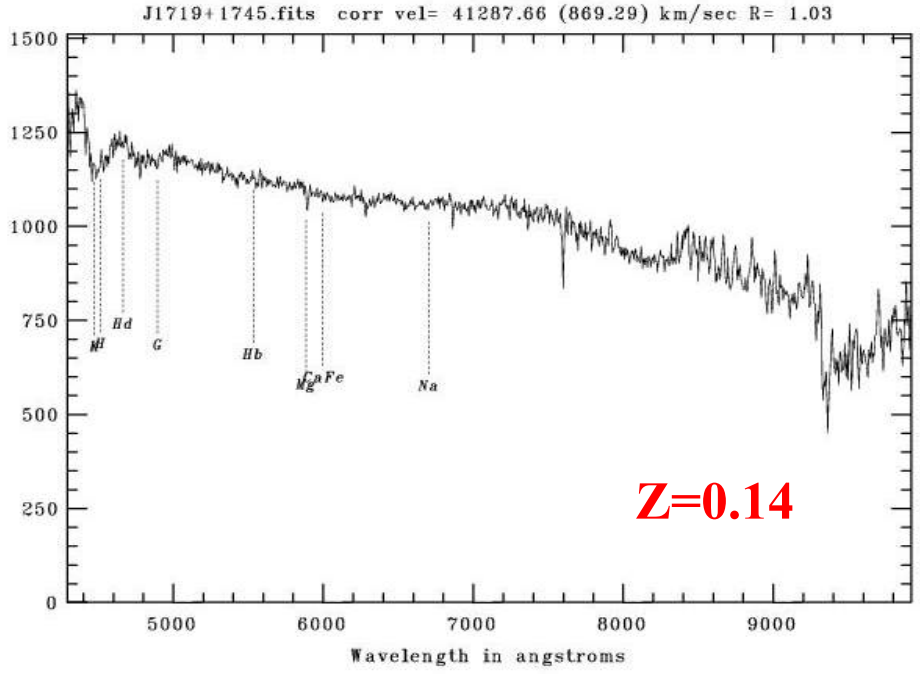


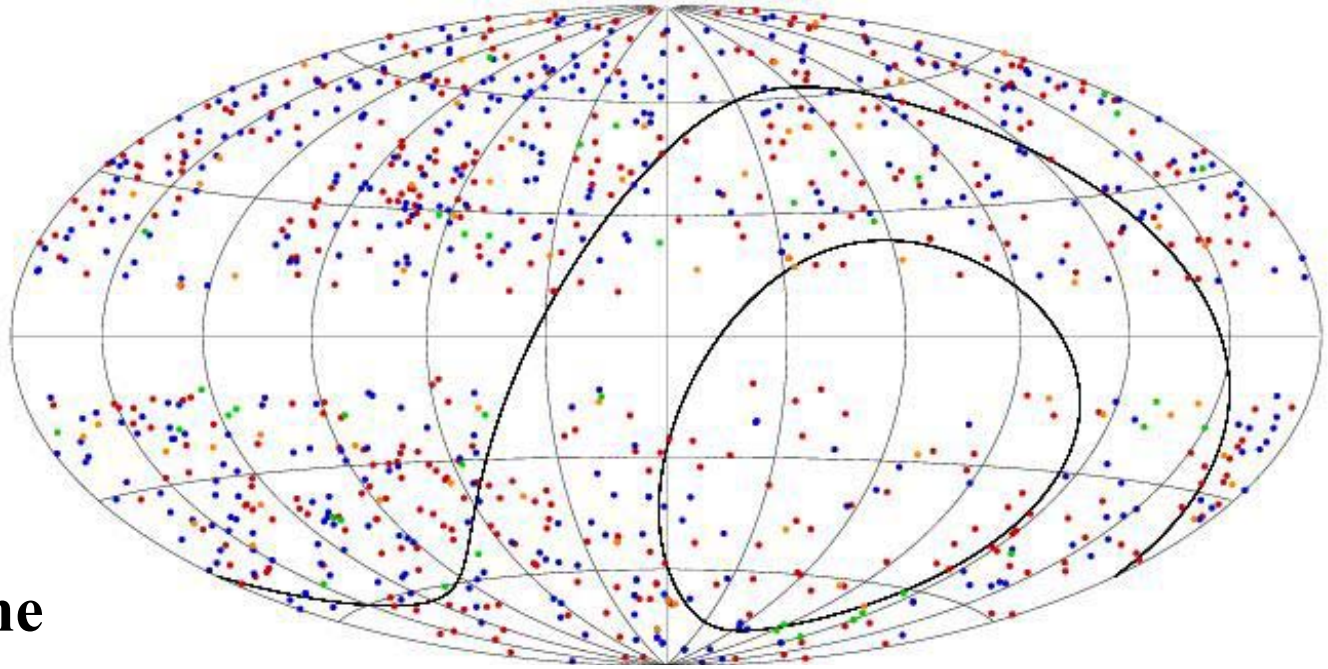
- We target a sample of 1500-2000 of the most EGRET-like

Candidate Gamma-Ray Blazar Survey
`CGRaBS': ID fractions

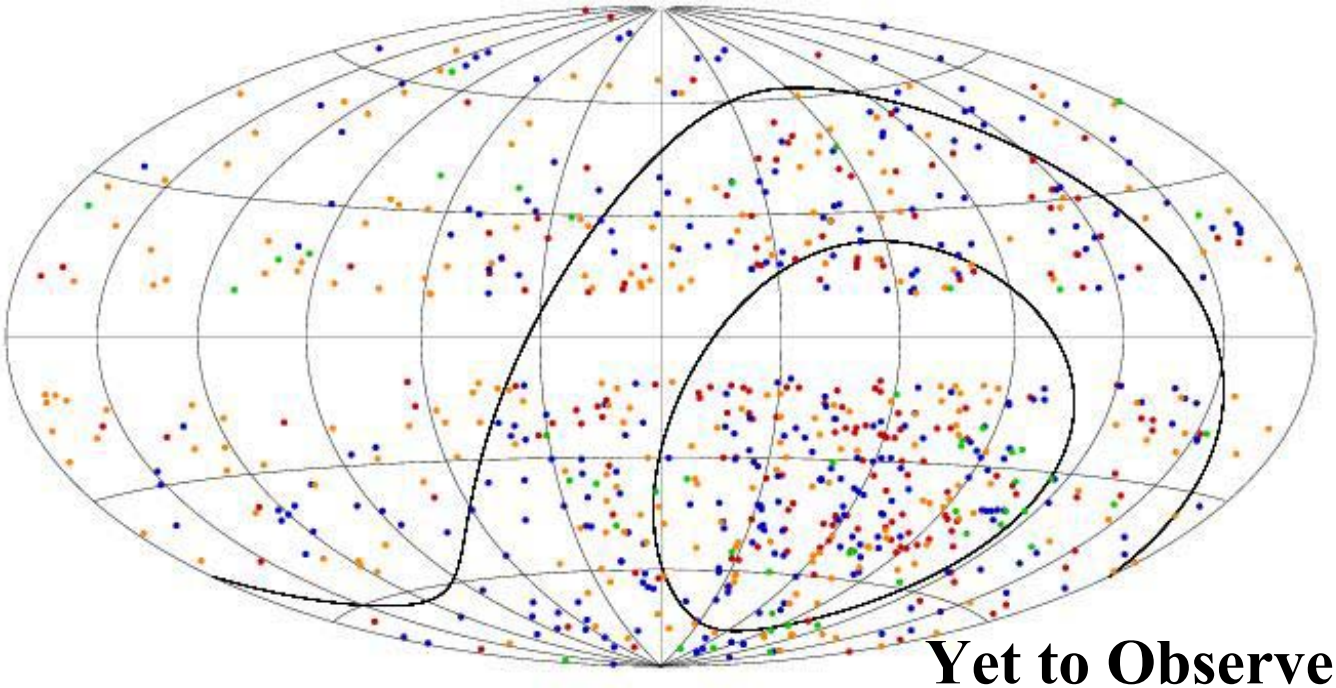
- **All-sky |b|>10^0**
  - **1035/1745 optically classified (59%)**
  - **964 (94%) of these w/ z – *we've contributed 60% of the z***
  - **115 (11%) are IDed as BL Lac (about ½ w/ redshifts)**
- **Above DEC= 0^0**
  - **672/837 optically classified (80%)**
  - **624 (94%) with z**
  - **81/672 (12%) are BL Lacs**







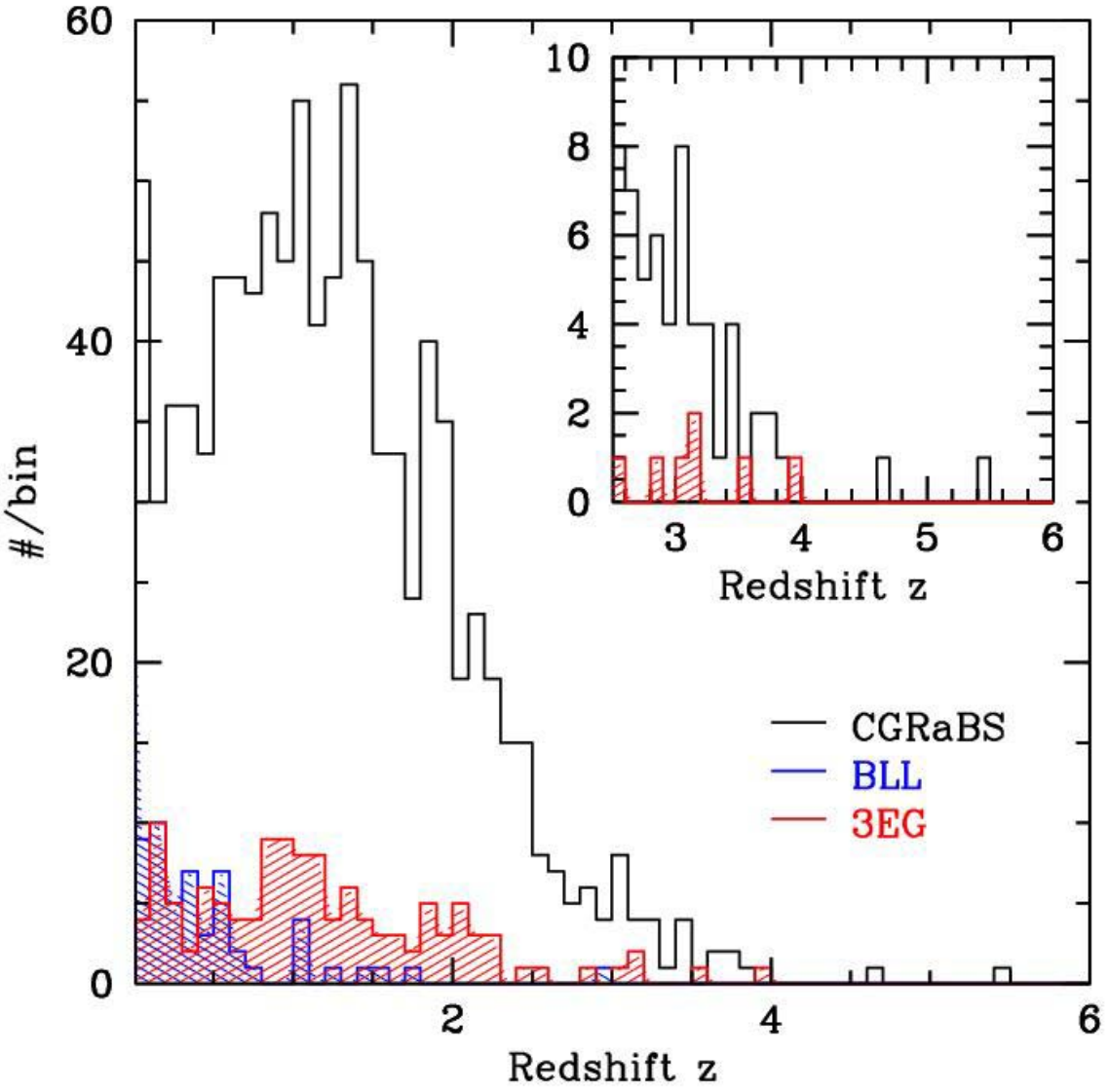
Done



Yet to Observe

Redshift Dist'n

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

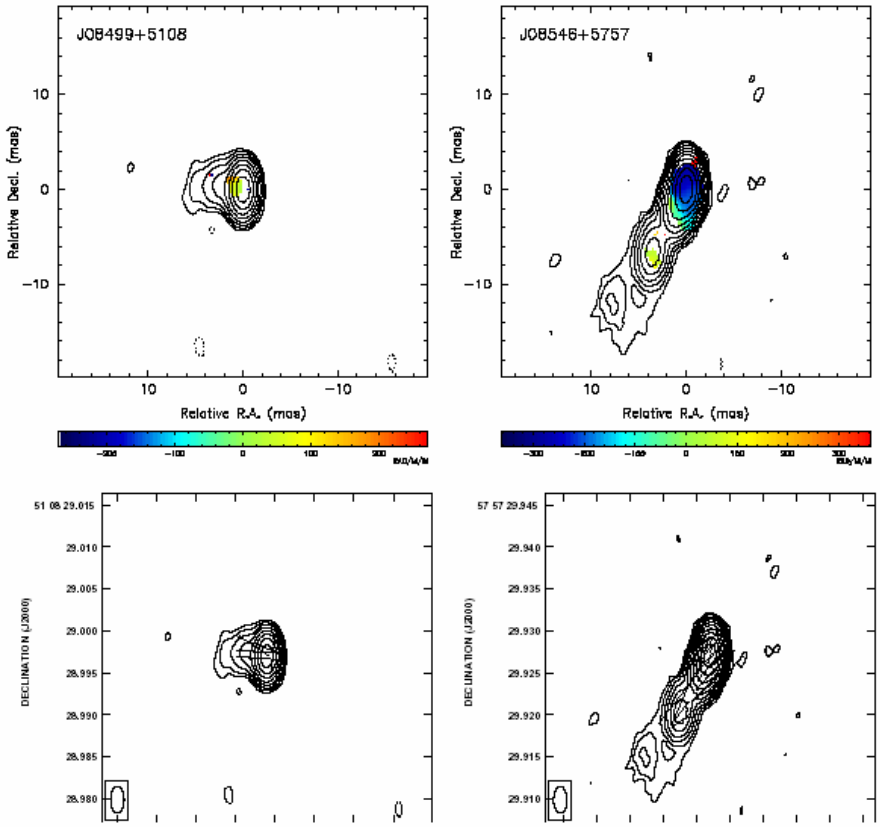


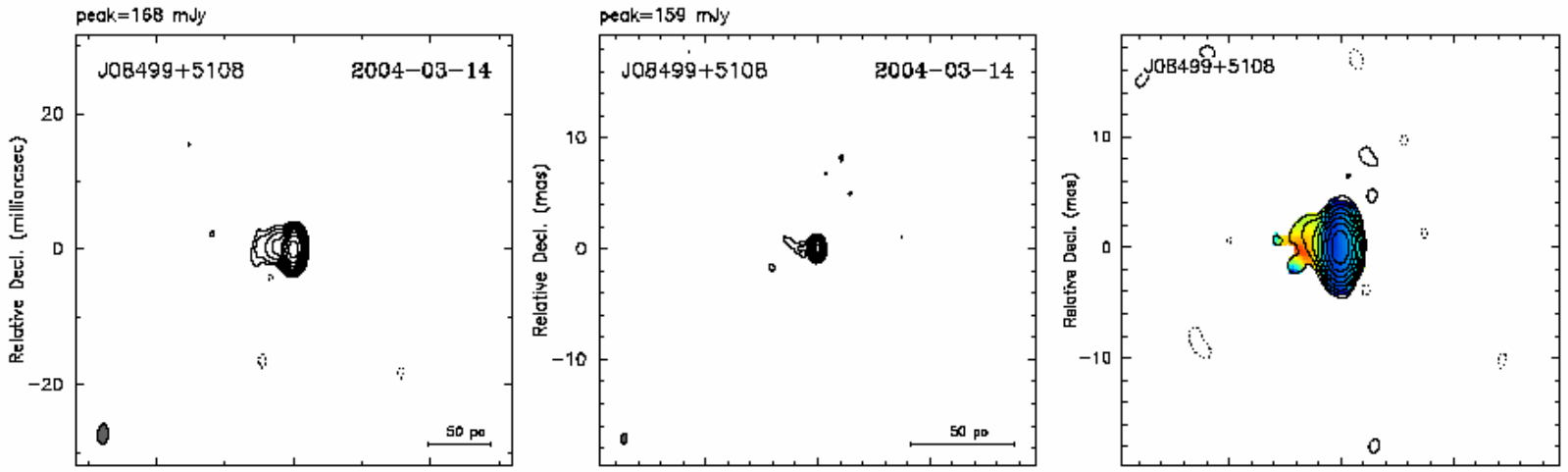
To finish off CGRaBS

- Getting <-40^0 8GHz interferometric fluxes w/ ATCA
  - Note AT20G survey (w/ Sadler) provides high ν info
- Have been observing w/ 2.7m at McDonald (>-40)
- Also small CTIO telescopes
- w/ Readhead and colleagues 5m, Keck time
- In South, w/ European GLAST colleagues: ESO NTT, VLT proposals
  - (Giommi/ASI & Grenier/Saclay joining in this effort…)
- Should be done to R~23 by launch

Other Radio Efforts -- VIPS: VLBA Imaging Polarization Survey

- Greg Taylor (UNM, NRAO) PI
  - 1200 flux limited α>-0.5 sources in SDSS footprint
  - 5/15GHz VLBA, full Pol'n
  - Somewhat deeper than CGRaBS
  - Pure radio flux selection to allow study of systematics





Summar

Other Efforts: Monitoring during the mission

- w/ Readhead, Owen's Valley 40m @15GHz
- Lower (ATA?) and higher (Torun?) frequency measurements
- Cement IDs
- Alerts for VLBI, optical/IR/X-ray flux monitoring campaigns
- Improved connection between jet dynamics and γ-ray activity

Why CGRaBS?

- Get a major fraction of high latitude sky pre-IDed
  - **Suitable catalog for positional cross-correlation studies**
  - **Larger flat spectrum radio catalog helps check for other AGN classes**
  - **Radio-selected sample complements X-ray selected (BLL) samples**
  - **Isolates a sample of radio-faint, high |b| sources ← something new!**
- **Evaluate GLAST samples potential for physics studies**
  - **EBL probes (high z sample)**
  - **Jet studies (polarized, variable sample)**

Why Now?

- GLAST sky will be **variable**
- externally selected sample complements γ-selected, objects.
- Important (e.g. high z) sources pre-selected for correlated study
- Secure IDs may still require **simultaneous** monitoring