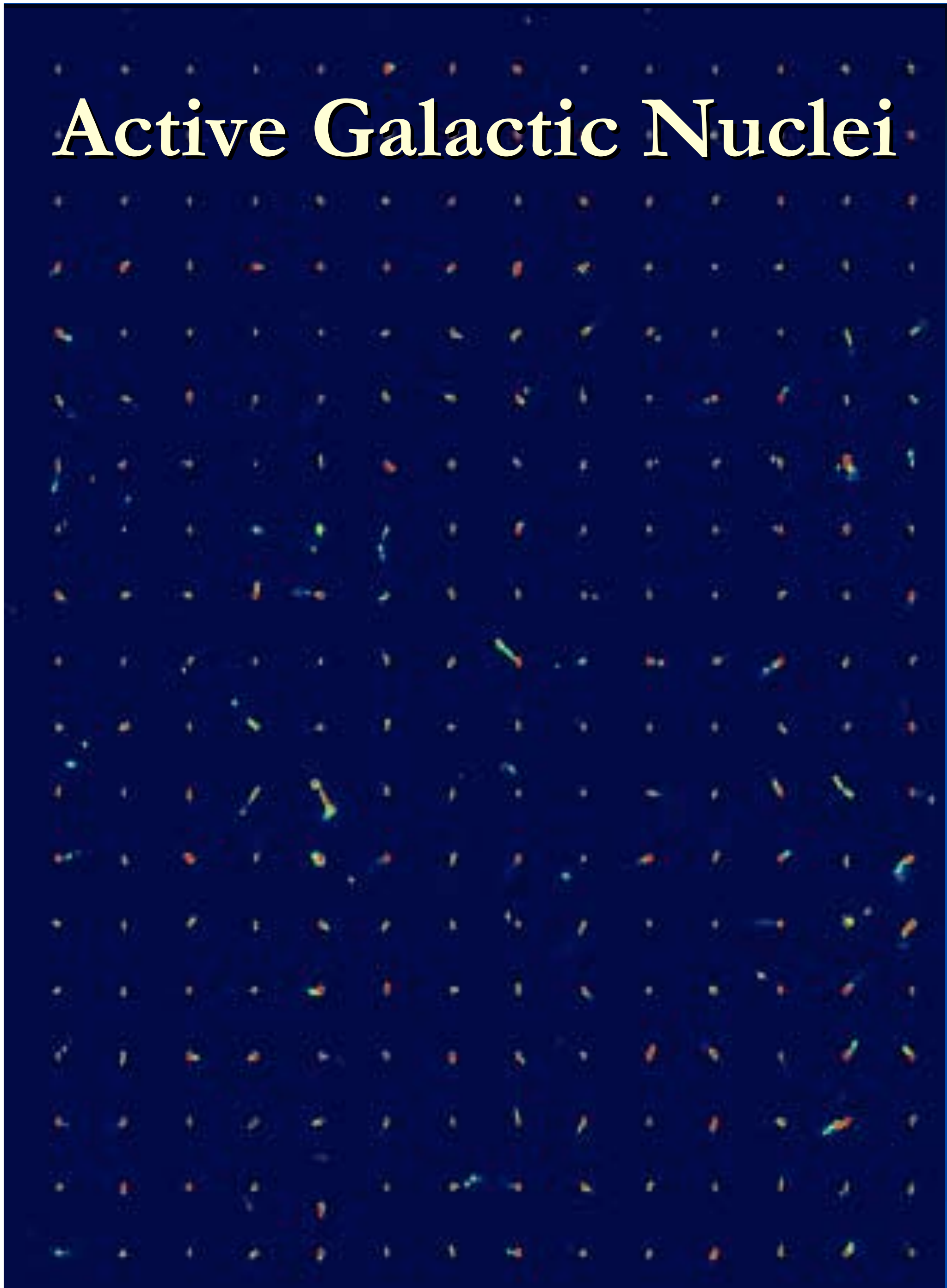


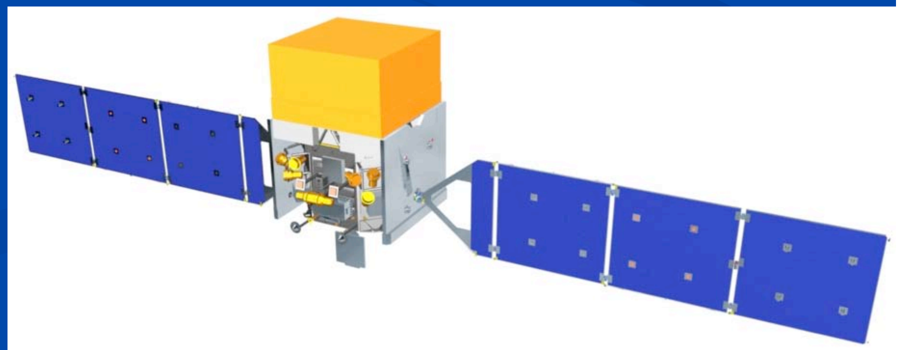
Active Galactic Nuclei

Radio Observations and GLAST

Greg Taylor

University of New Mexico

First GLAST Symposium
Feb. 5, 2007



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Roger Romani
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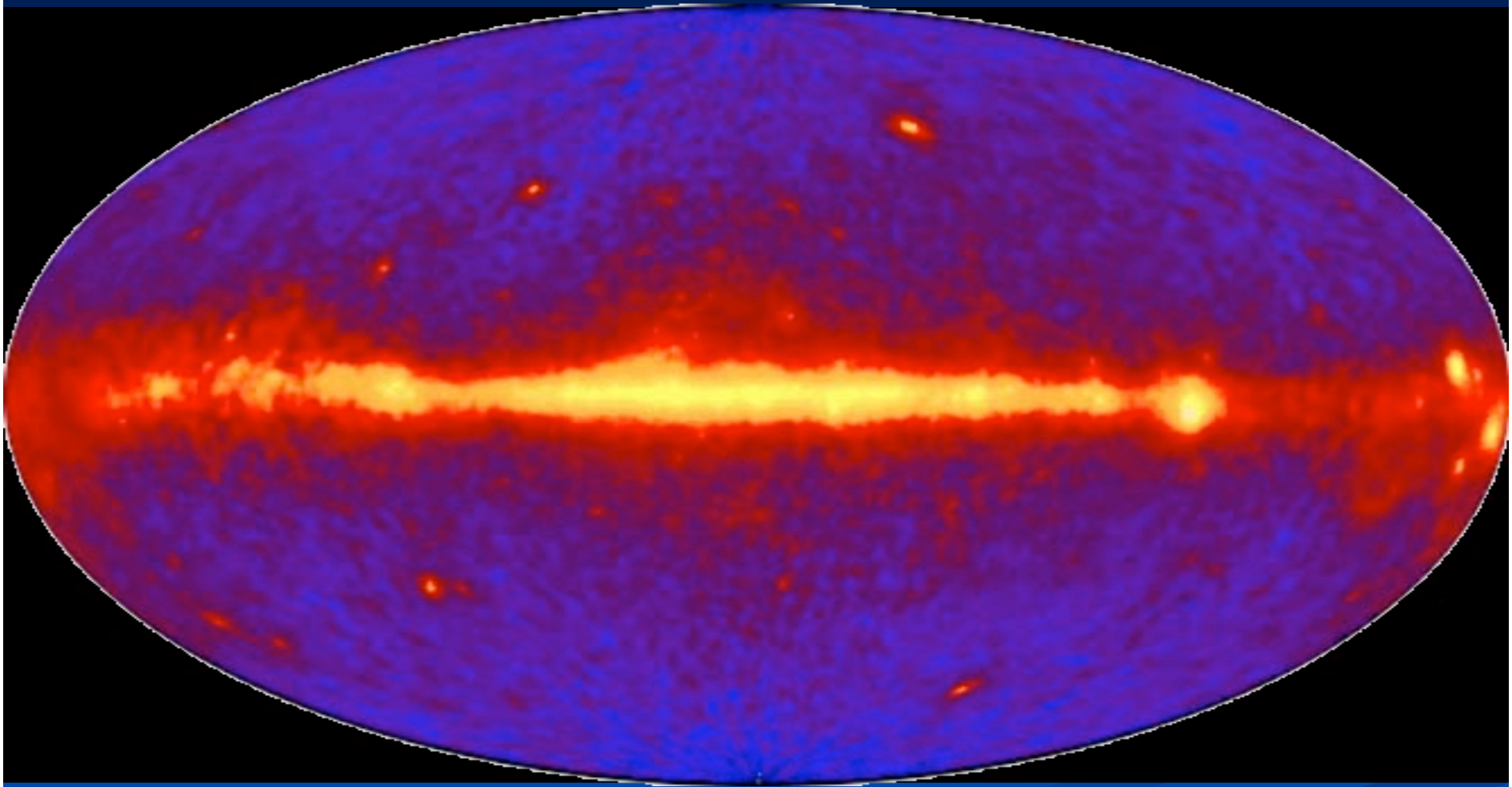
Larry Weintraub
Ann Wehrle
Bob Zavala

GLAST Gamma-Ray Sky

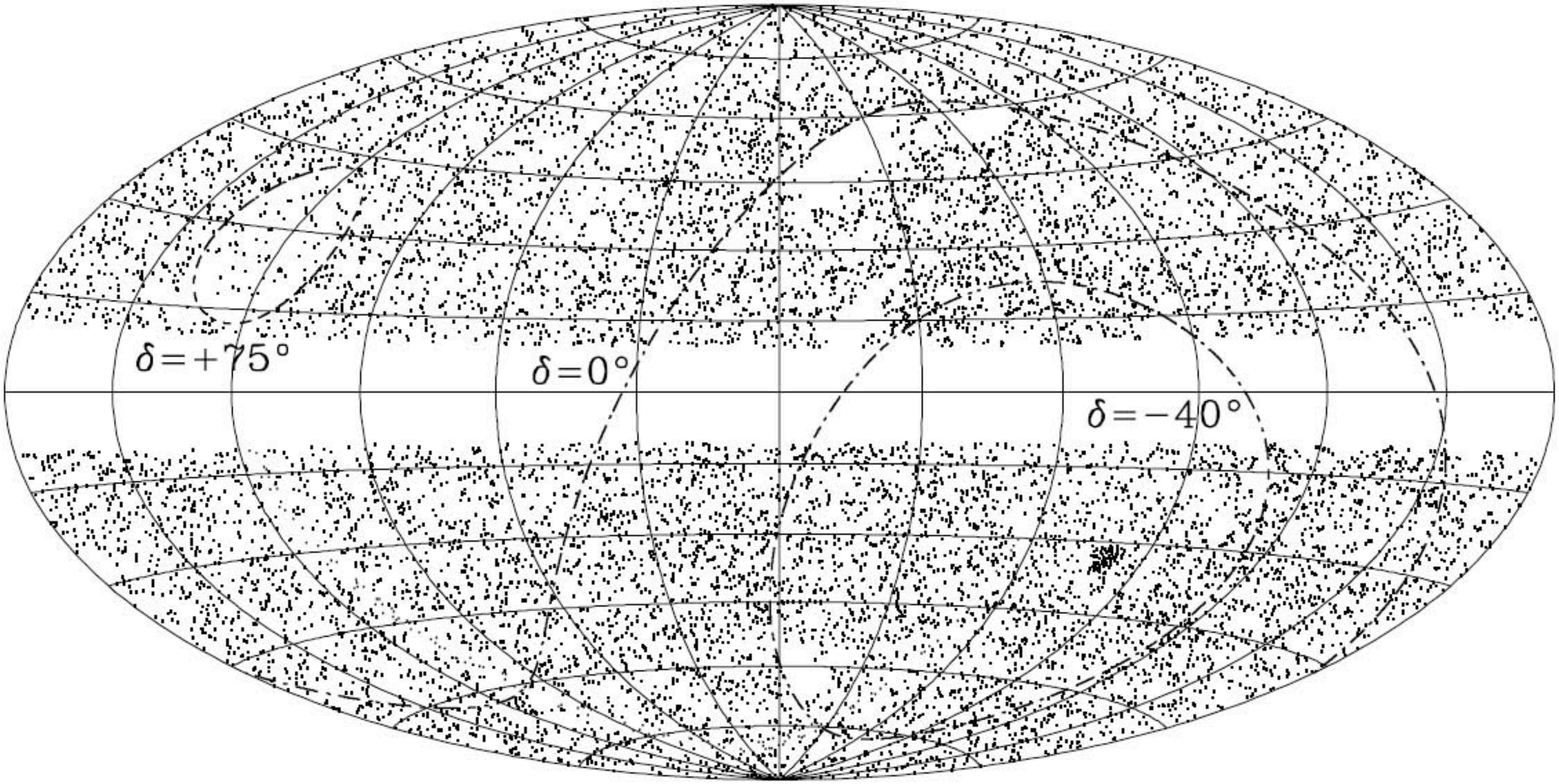


GLAST (Launch in late 2007)

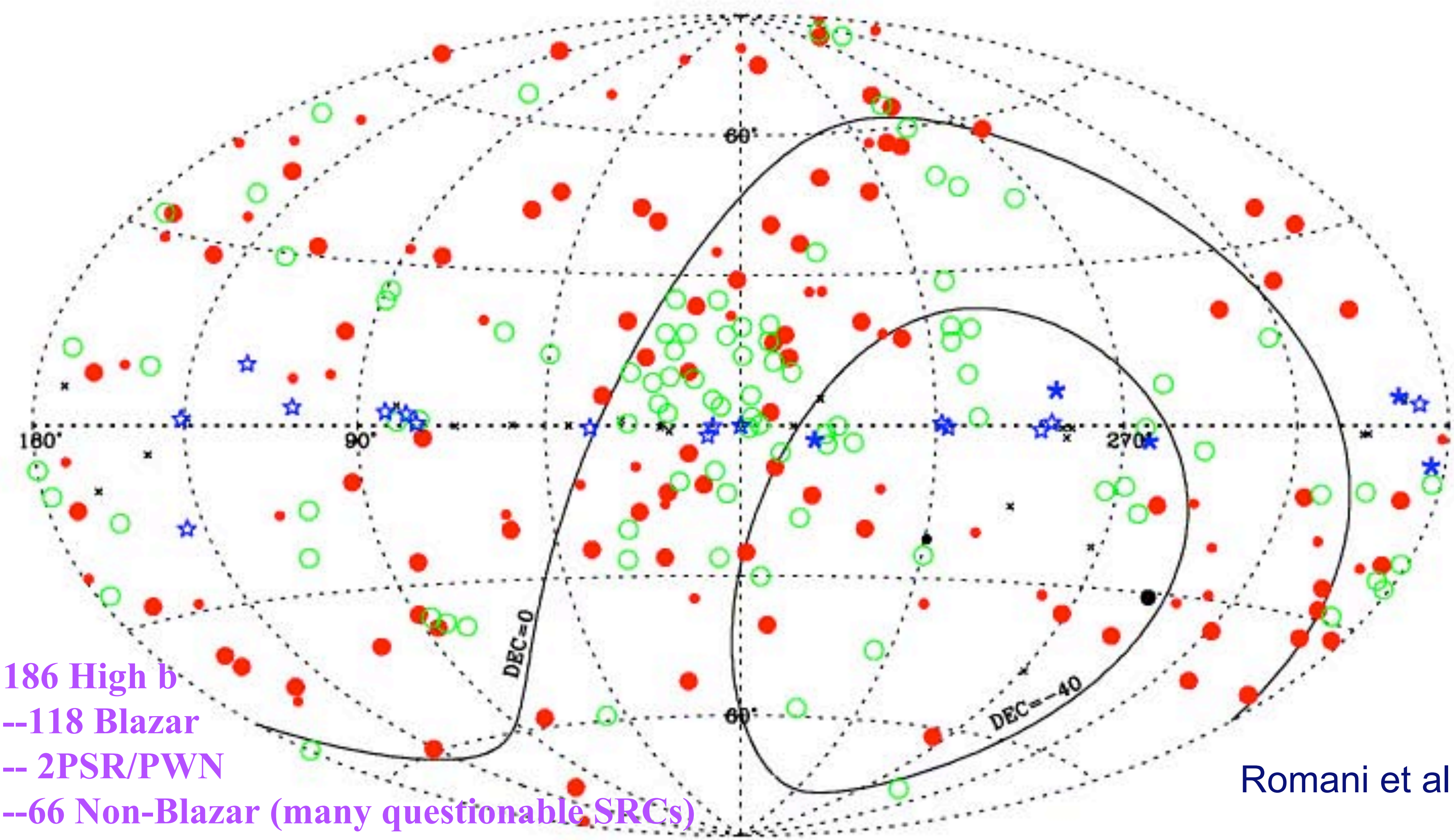
- >30x EGRET sensitivity
- Expect 4000-10,000 Blazars, >200 Pulsars

Radio Target List

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



3EG Survey Status

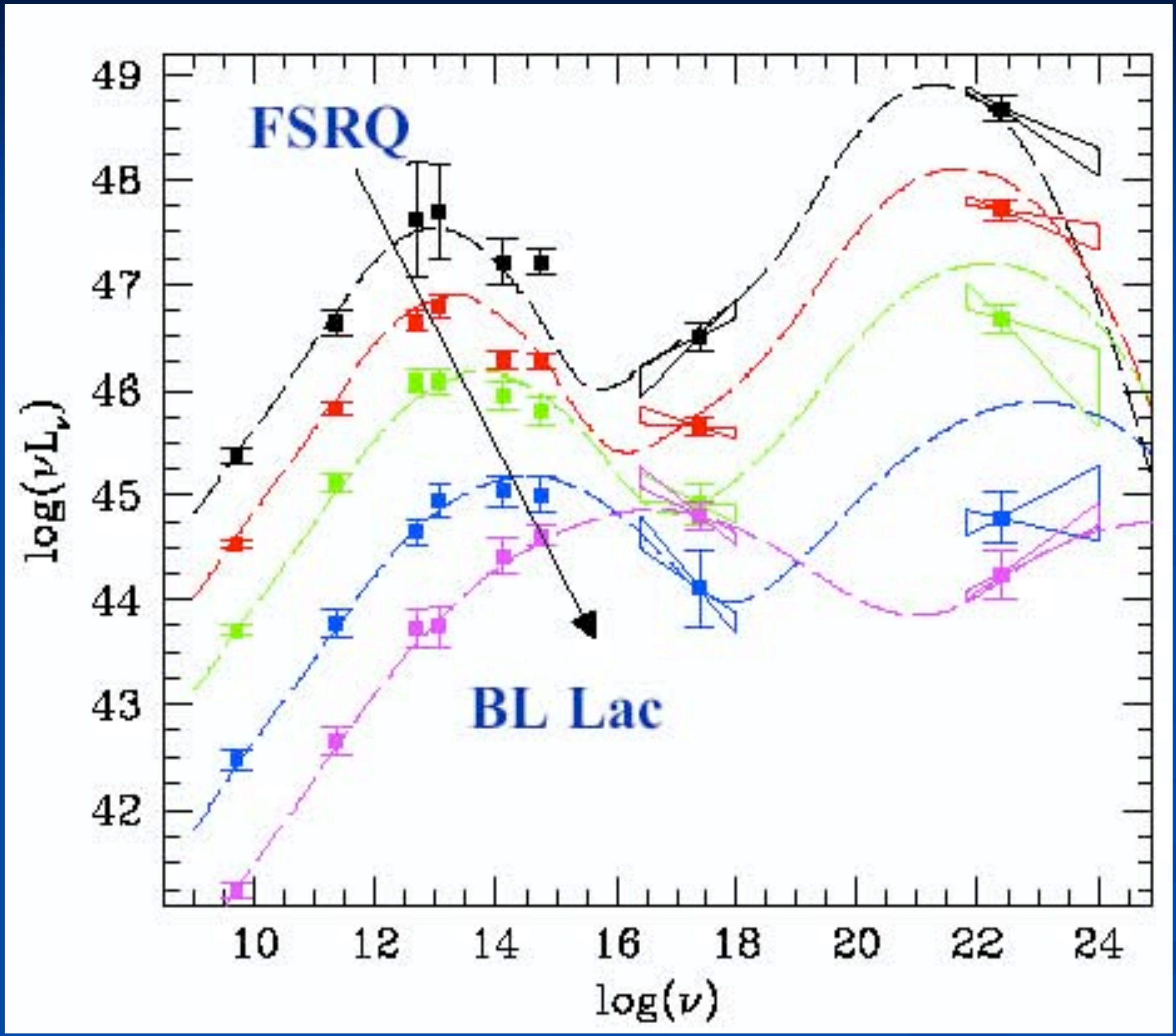


Romani et al

186 High b
--118 Blazar
-- 2PSR/PWN
--66 Non-Blazar (many questionable SRCs)

>60% High b sources identified as blazars

AGN spectra

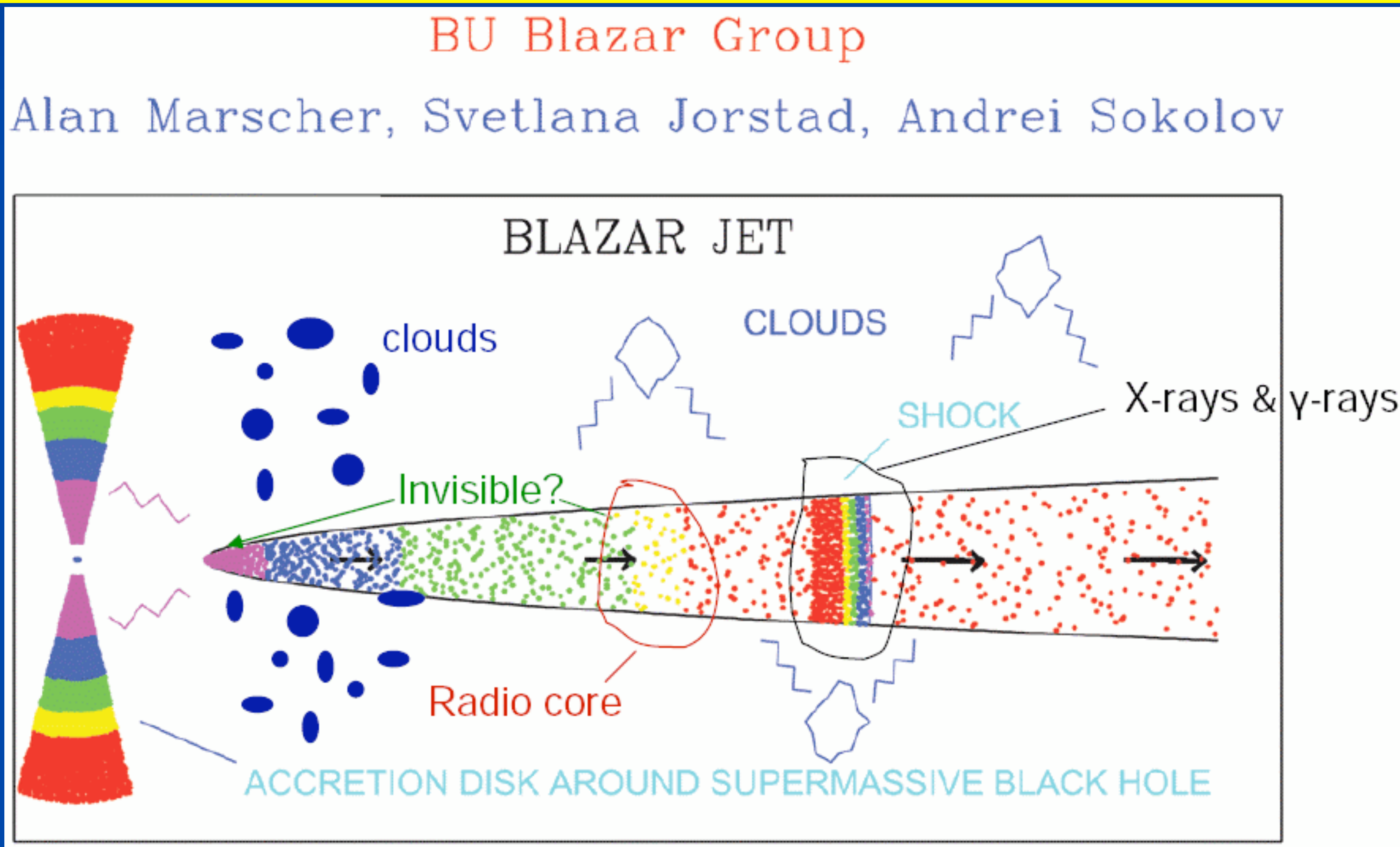


Blazar sequence

Ghisellini et al.

Gamma-Ray Emission Mechanisms for Blazars

GLAST will detect thousands of gamma-ray blazars that can only be resolved by VLBI techniques

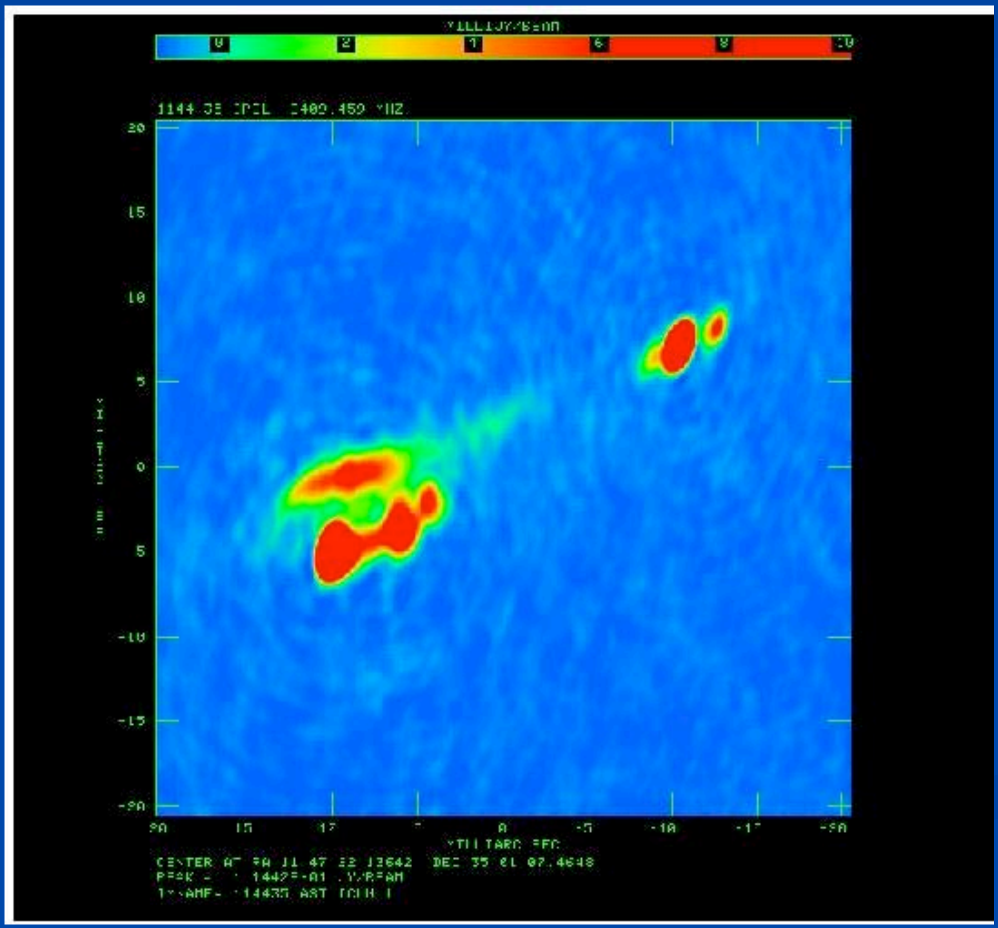


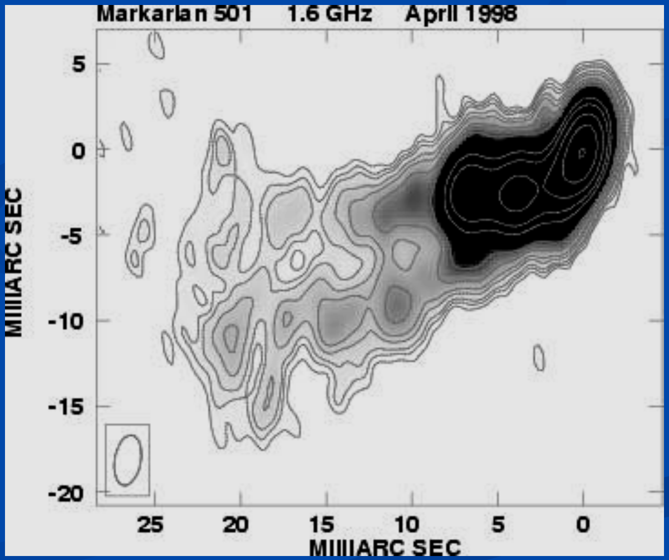
Questions

- Where are the gamma-rays produced?
- Do gamma-ray blazars have intrinsically faster jets?
- Are there multiple classes of gamma-ray emitting blazars?

Velocity Structures

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…….





Slide courtesy M. Giroletti

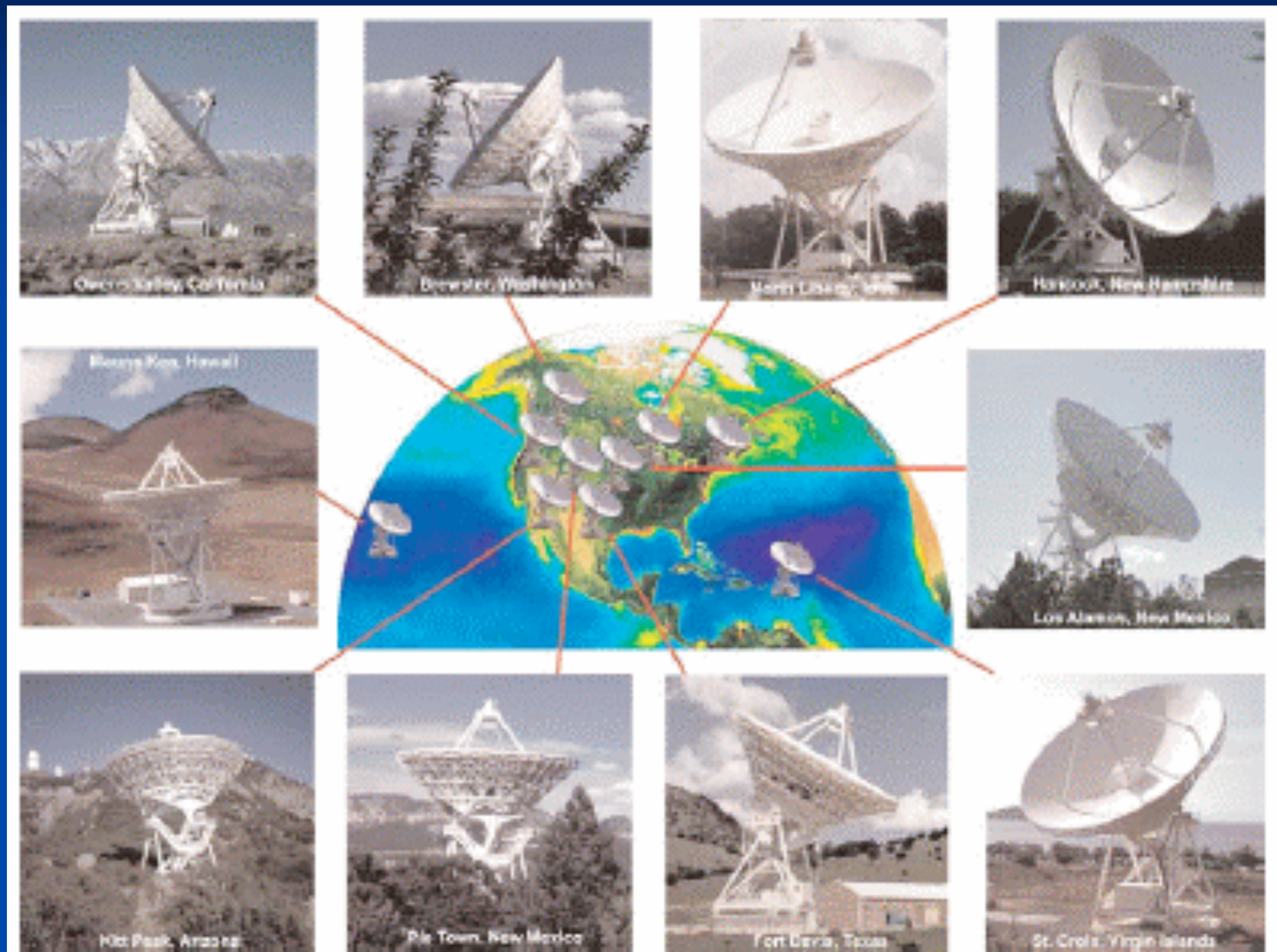
More Questions

- What makes some blazars brighter in gamma-rays? δ? 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?

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

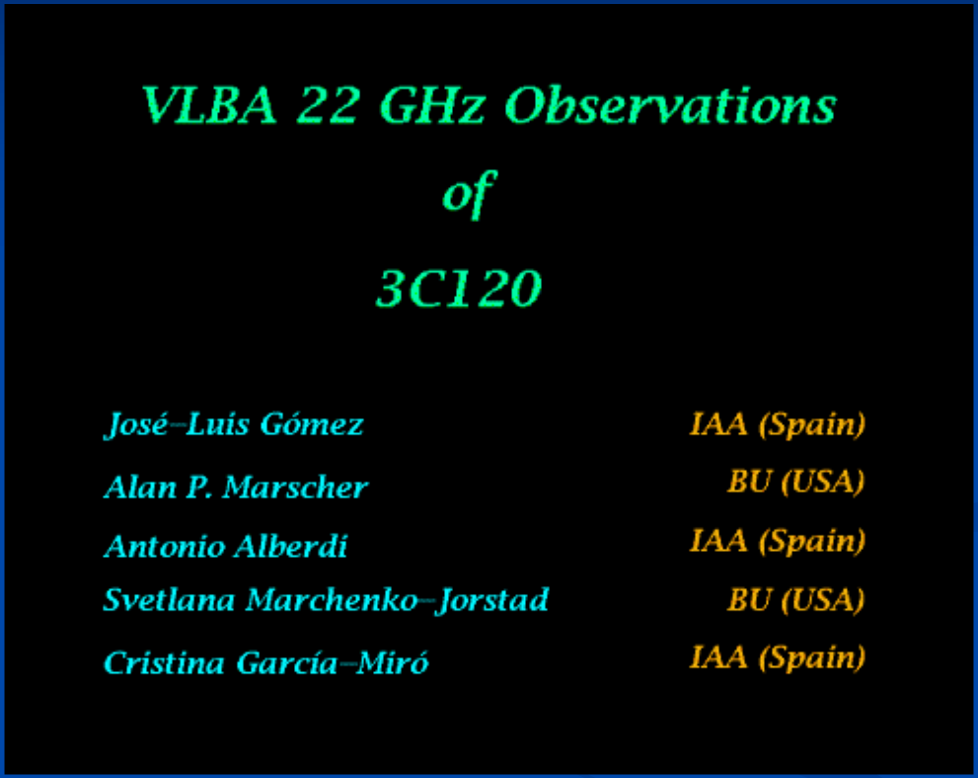
VLBA



- High Sensitivity Array (add VLA, GBT, Effelsberg, Arecibo) may be desirable for LLAGNs, TeV blazars

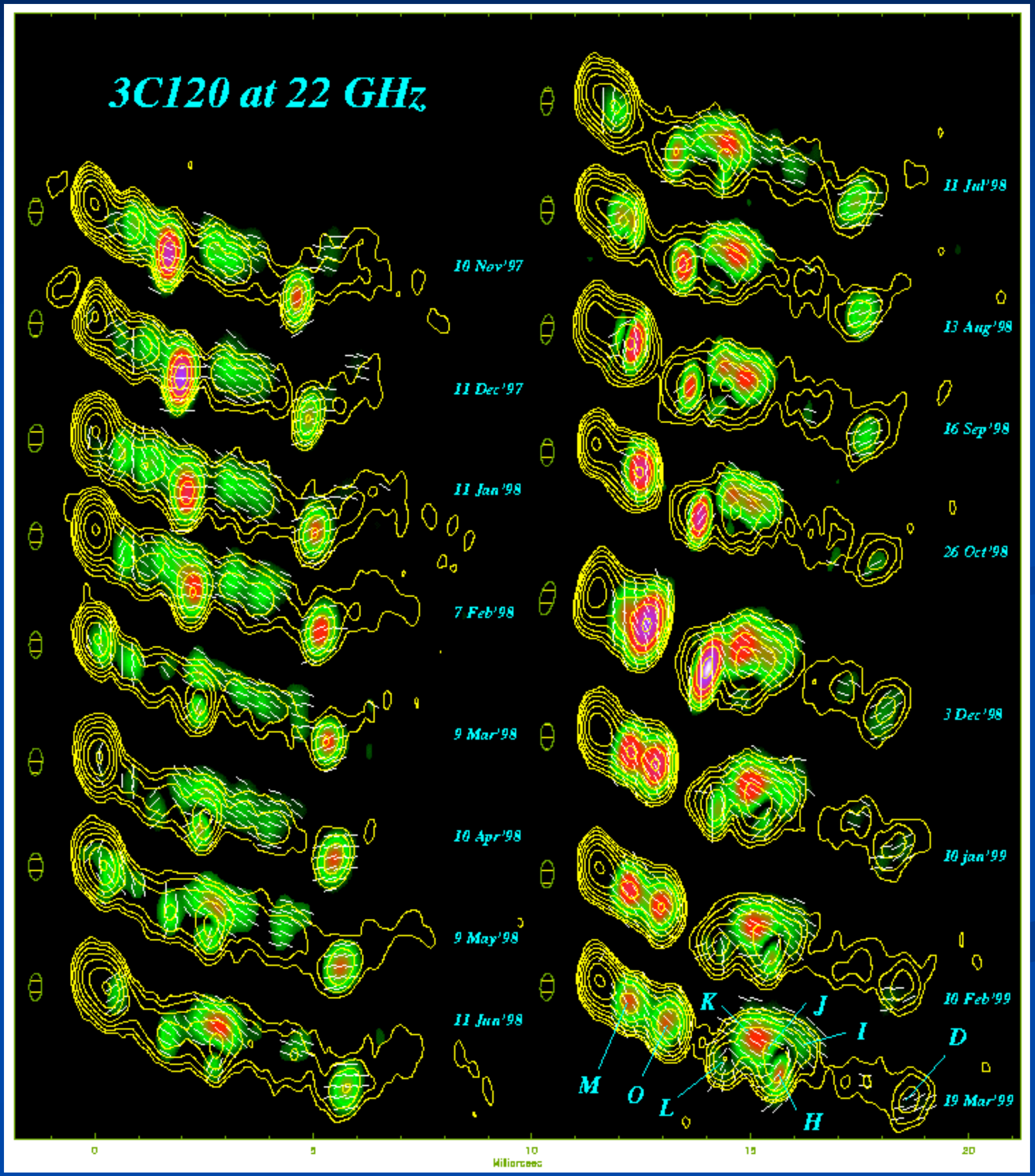
Sample Jet Evolution Imaged with VLBA

- Monthly VLBA imaging of radio galaxy 3C 120 at 22 GHz (Gomez et al. 2000)



Sample Jet Evolution Imaged with VLBA

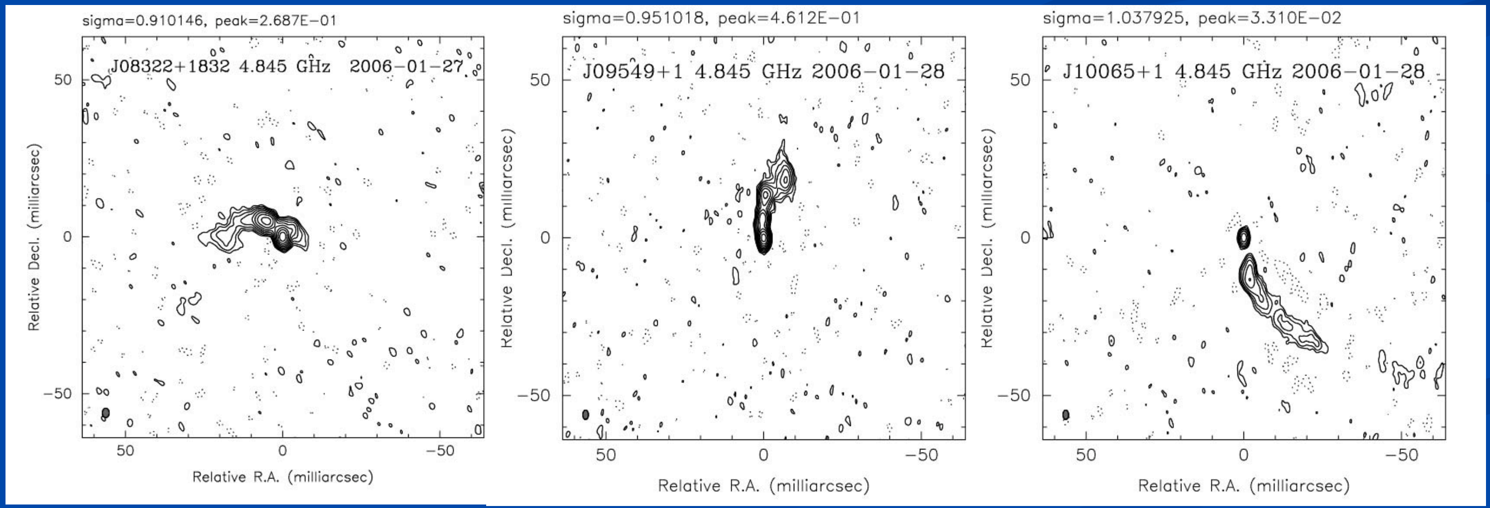
- Monthly VLBA imaging of radio galaxy 3C 120 at 22 GHz (Gomez et al. 2000)
- What were the gamma rays doing during this period?
- Desire imaging on time scales of weeks or less for z~0.5



VLBI Imaging of Active Galactic Nuclei

VLBA Imaging Polarimetry Survey (VIPS)

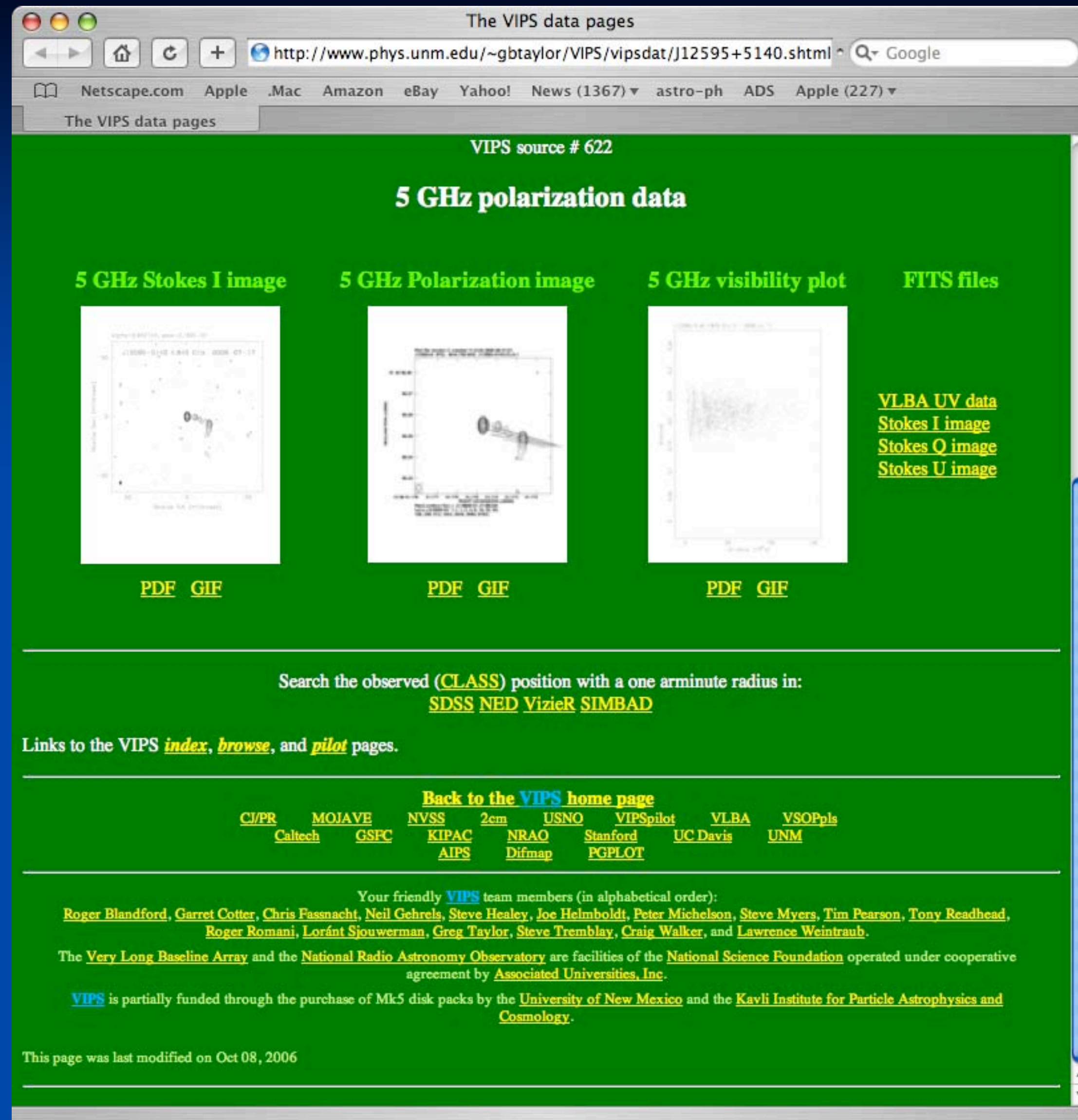
- 1127 sources: S > 85 mJy, 65 > dec > 20, |b|>10 at 5 GHz
  in SDSS northern cap
- First epoch observations on the VLBA in 2006
- Identifications and redshifts from SLOAN, HET, Palomar, Keck, …
- Goals:
  - Characterize GLAST sources
  - Study Evolution of Radio Sources
  - Study AGN environments
  - Find more compact supermassive binary black holes



http://www.phys.unm.edu/~gbtaylor/VIPS/

VIPS on the web

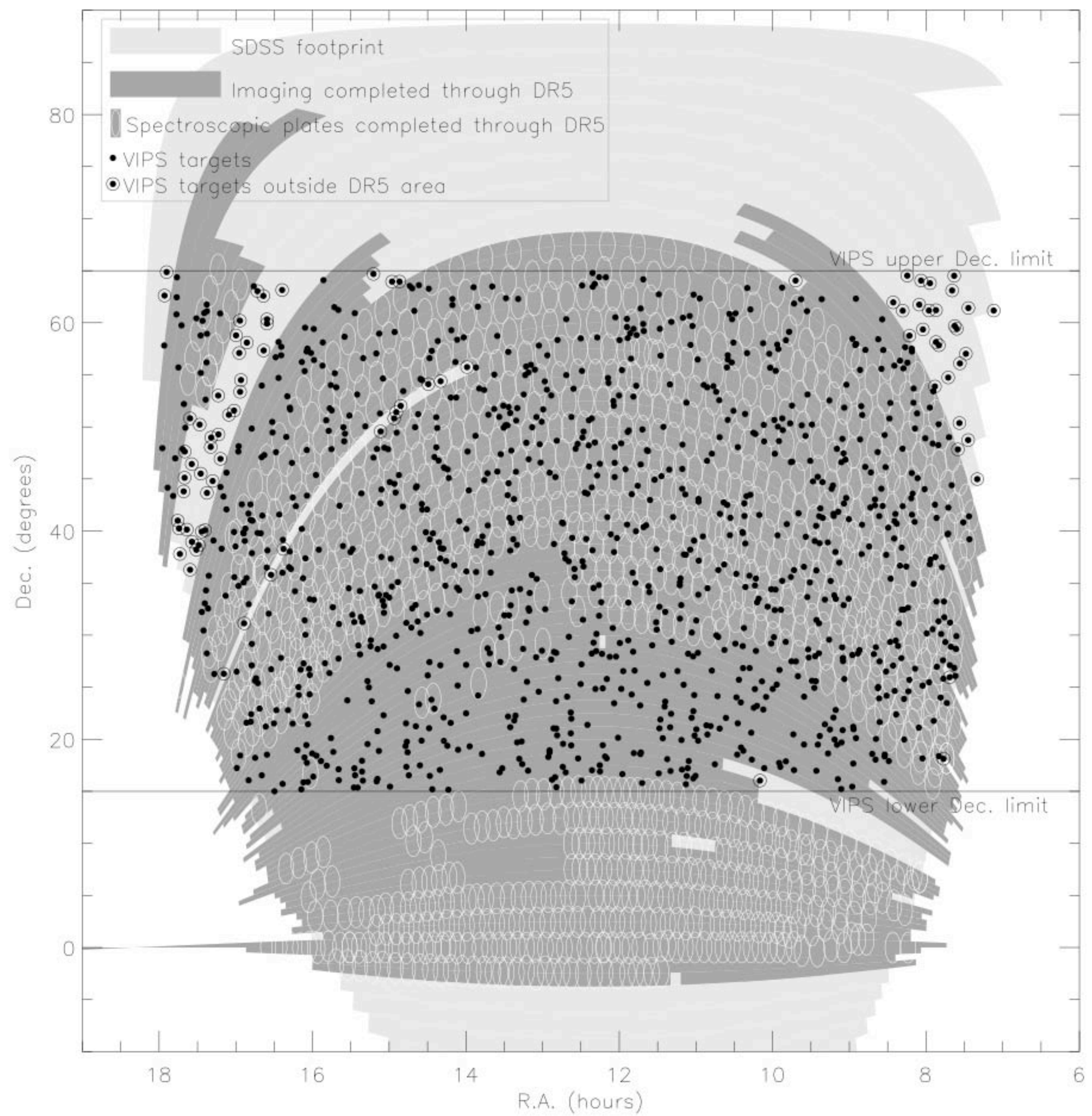
1127 in sample
11 not detected
169 previously imaged
------
947 newly imaged



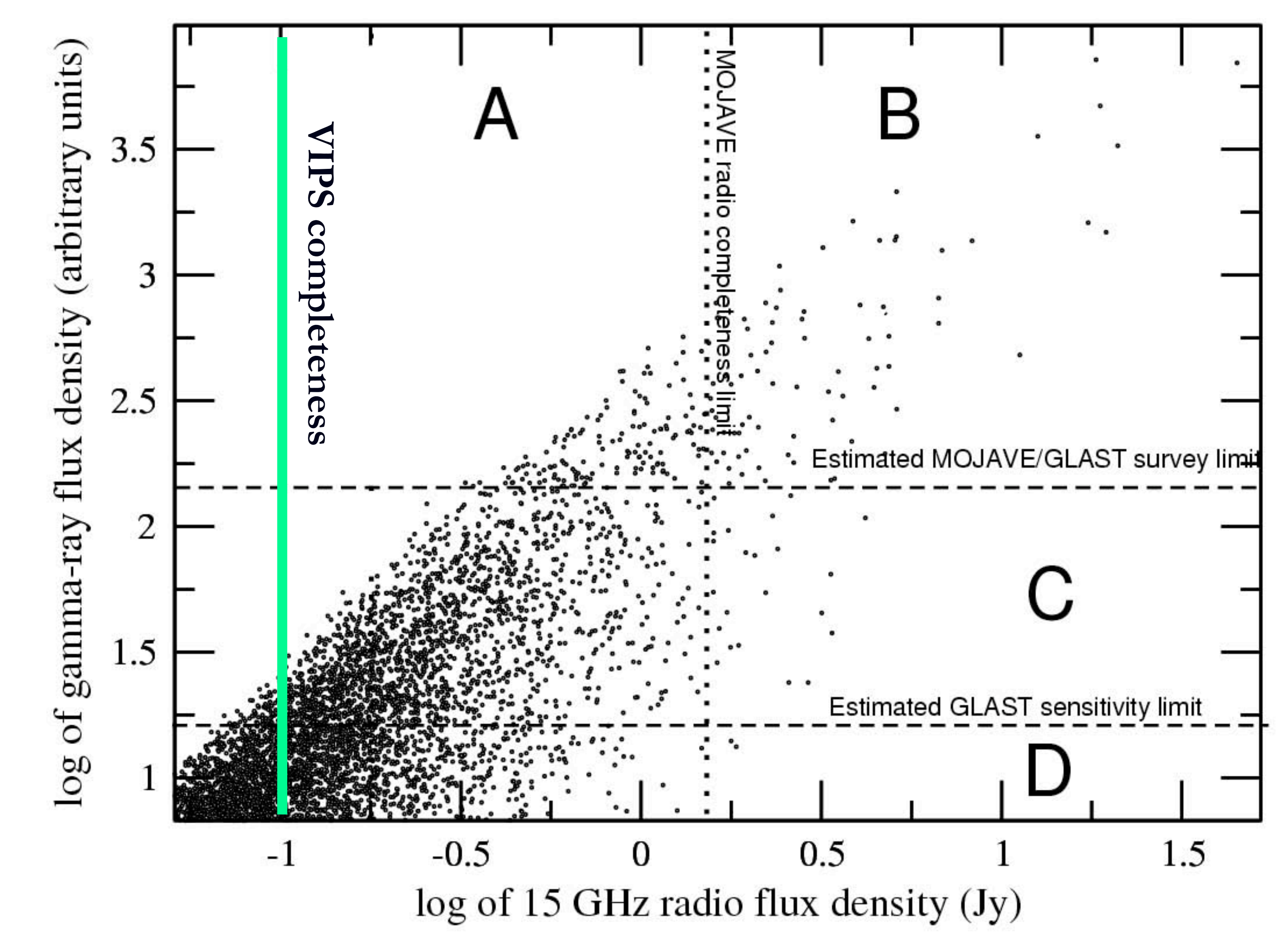
http://www.phys.unm.edu/~gbtaylor/VIPS/

Sky Coverage

- through DR5, 1,043 have SDSS images; 356 have SDSS spectra
- will get more optical spectra from SDSS-II and ongoing follow-up with Palomar, HET, and Keck - currently about 50% complete in redshifts

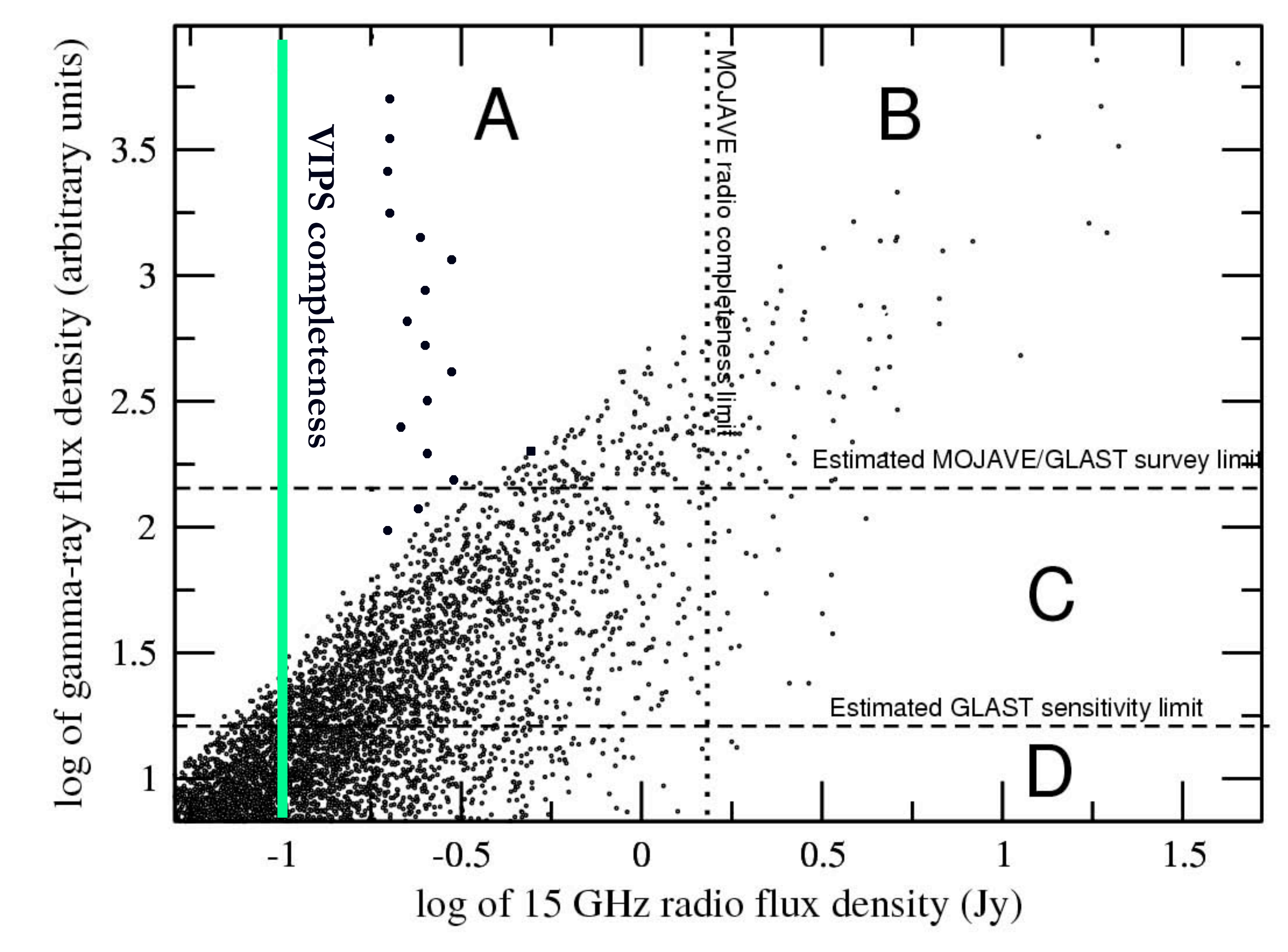


Simulation of Blazars



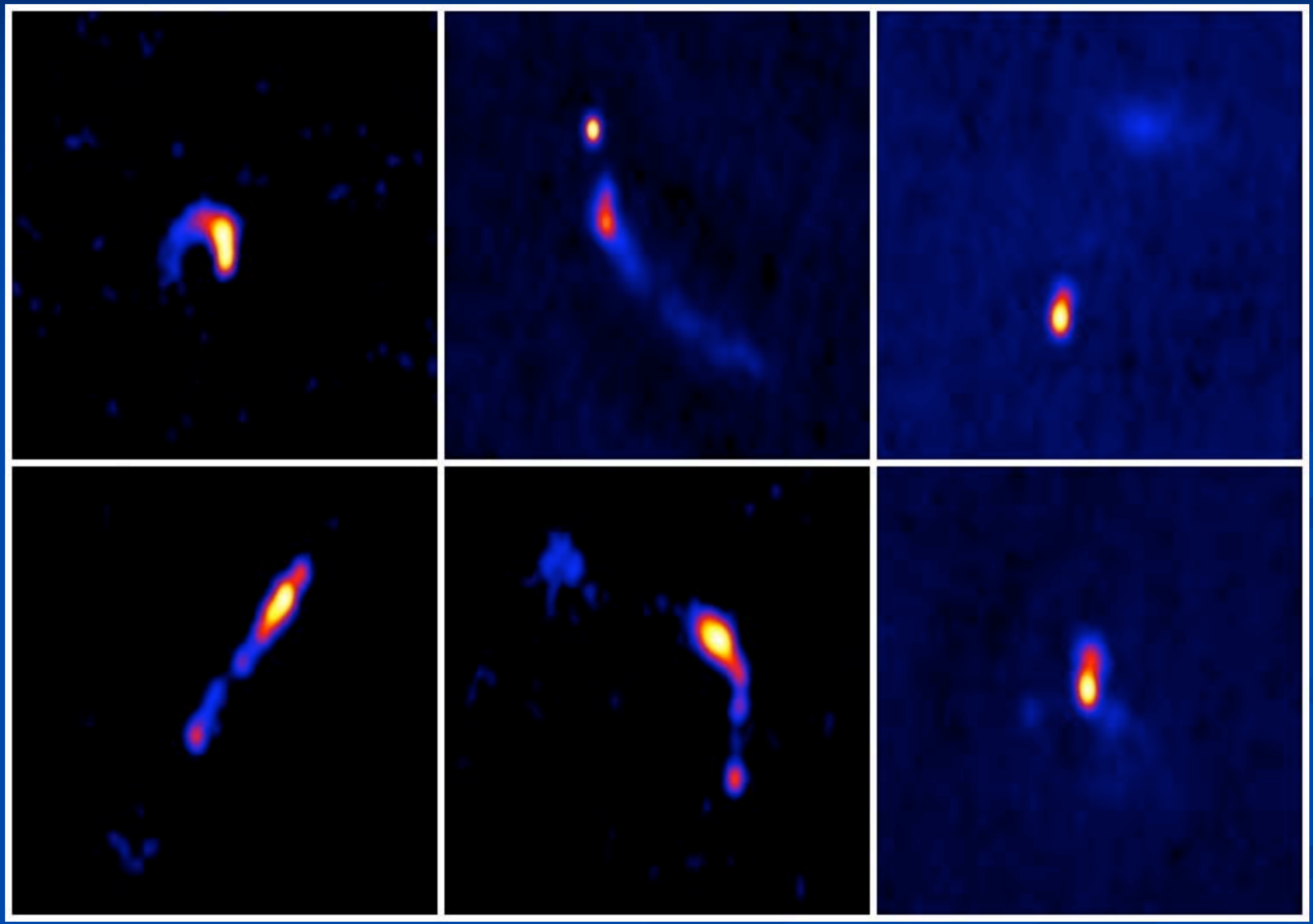
Adapted from M. Lister

Simulation of Blazars



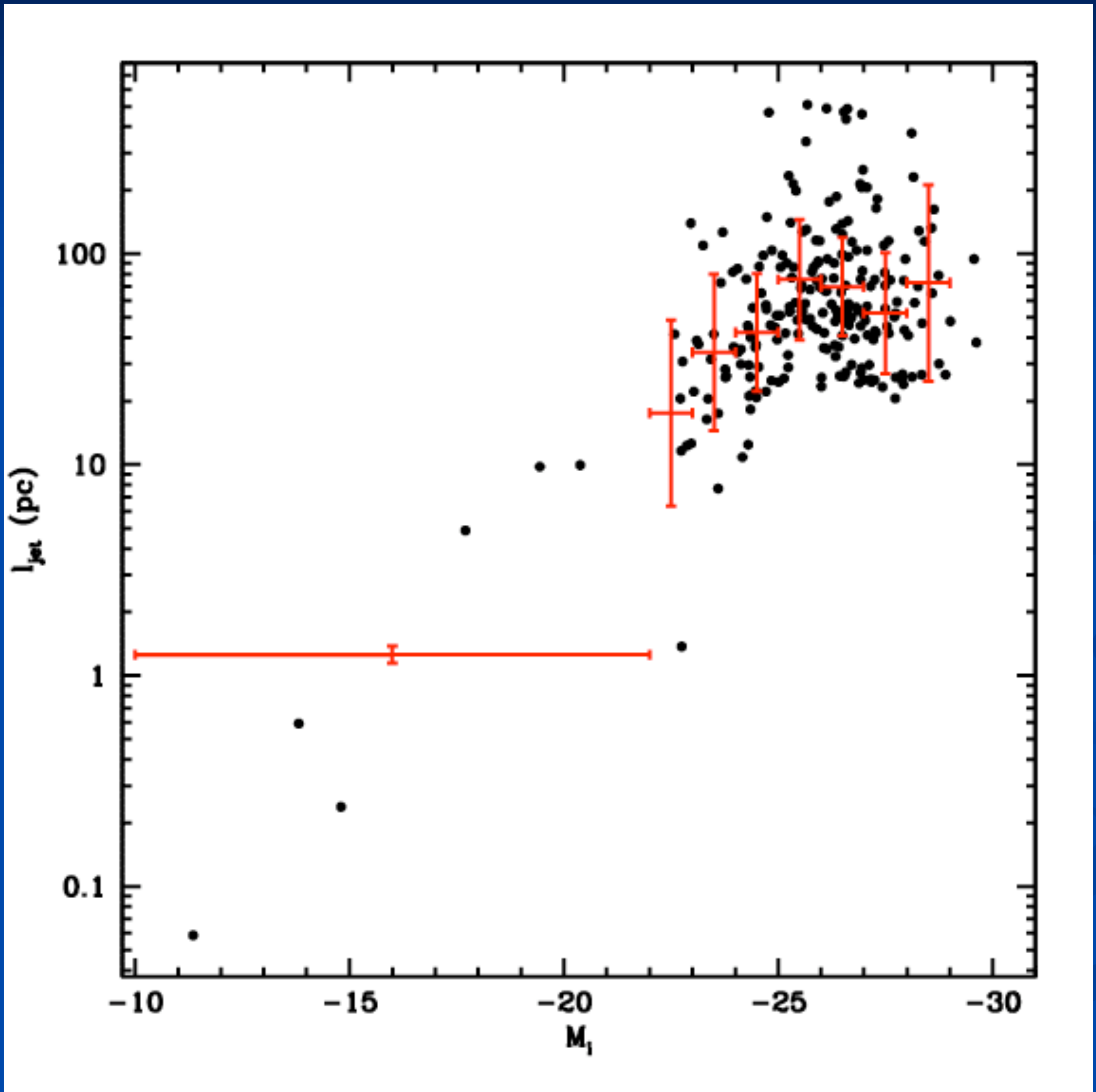
Adapted from M. Lister

Which one of these Jets will be detected by GLAST?



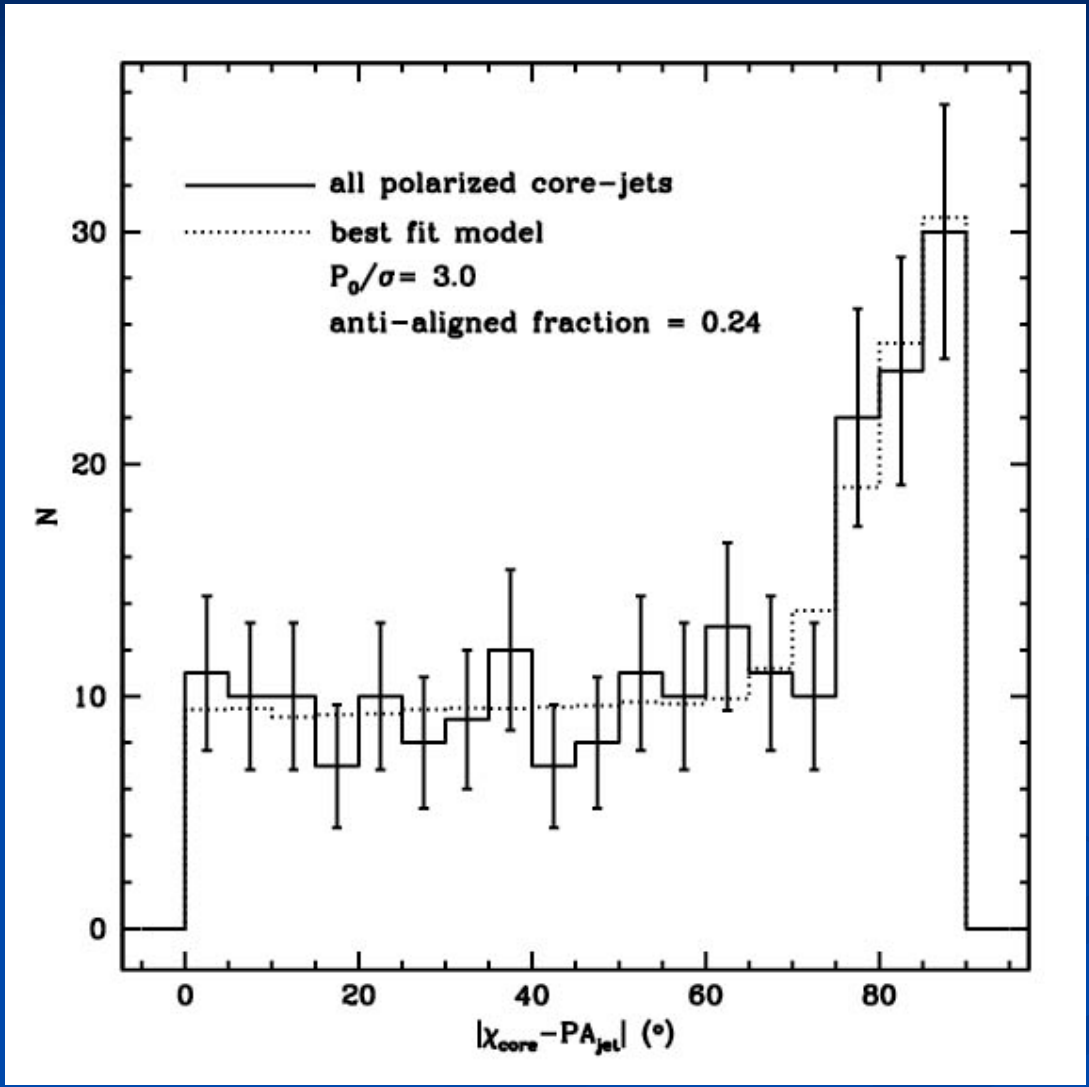
Helmboldt et al. 2007

Jet length correlates with host galaxy magnitude



Helmboldt
et al. 2007

At their base, Jets tend to have magnetic fields aligned with the jet axis.

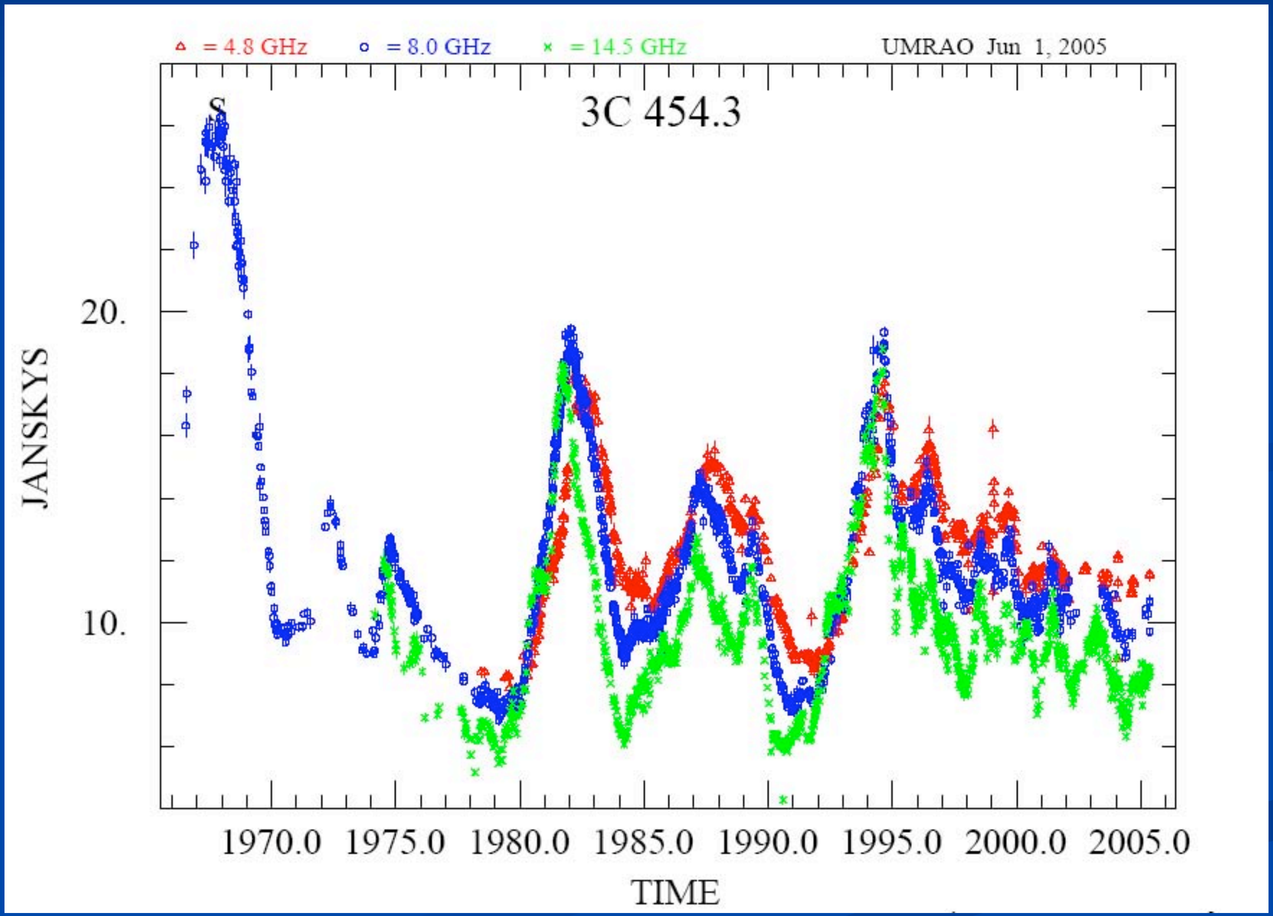


Helmboldt et al. 2007

This trend should become more pronounced once we can correct for Faraday rotation

Variability brightness temperature

$D < c\,\tau$
$\theta < D/R$
$T_{var} > S\lambda^2/2k\,\theta^2$
$T_{var} = \delta^3 T_{int} >> T_{eq}$
$\delta_{var} = (T_{var}/T_{int})^{1/3}$

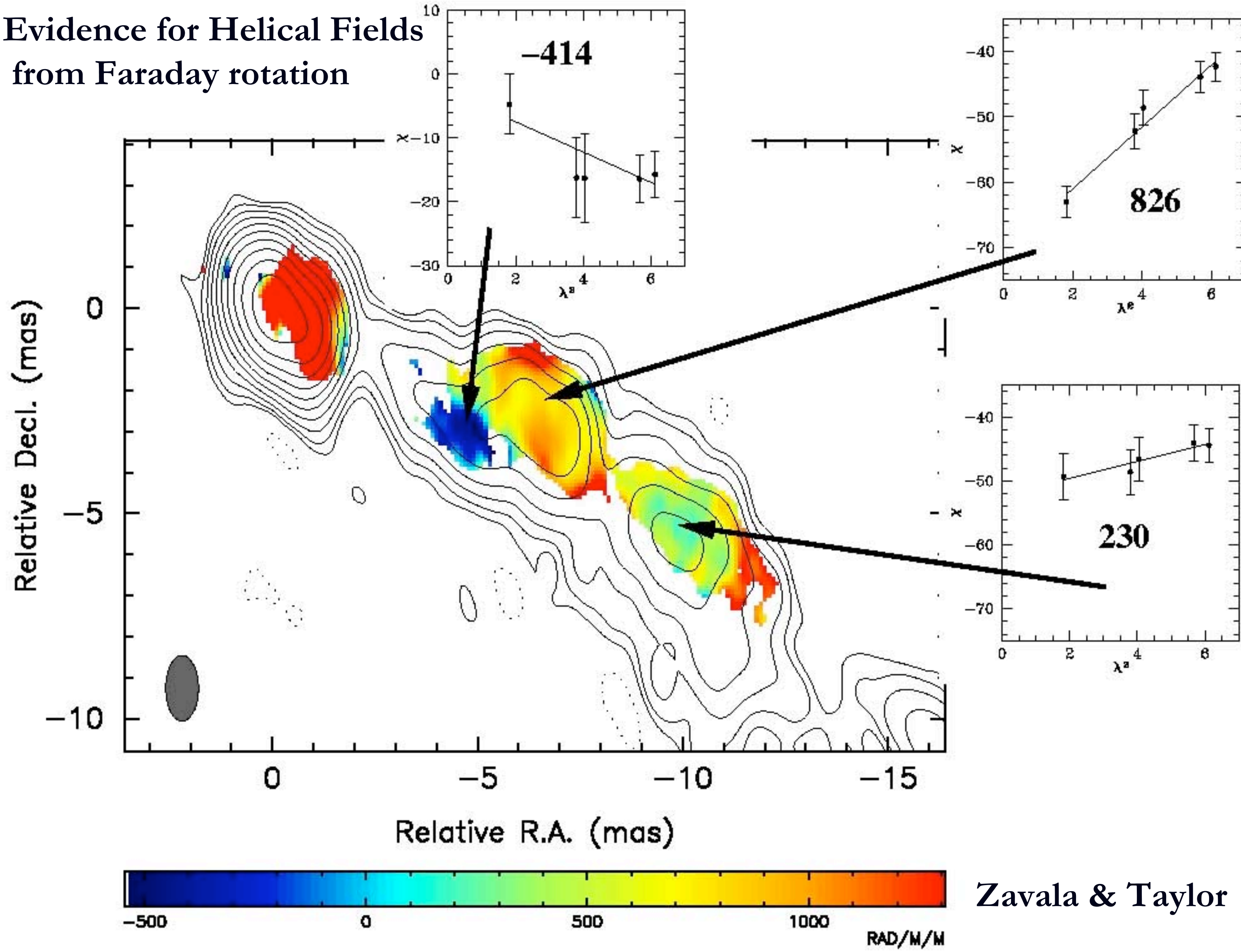


Radio Monitoring programs

- 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 - 22 and 37 GHz
- ATA program?

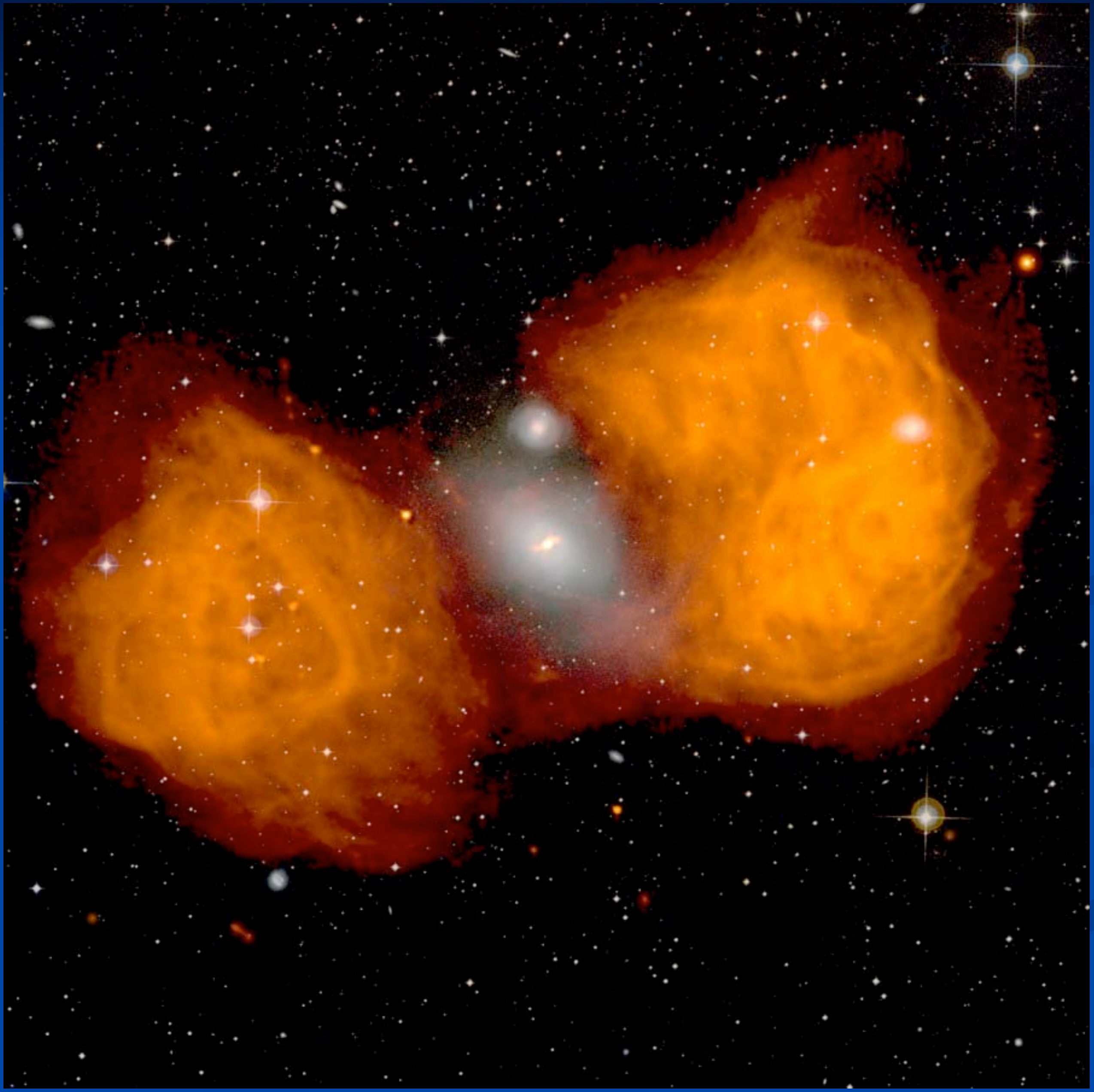
Evidence for Helical Fields from Faraday rotation



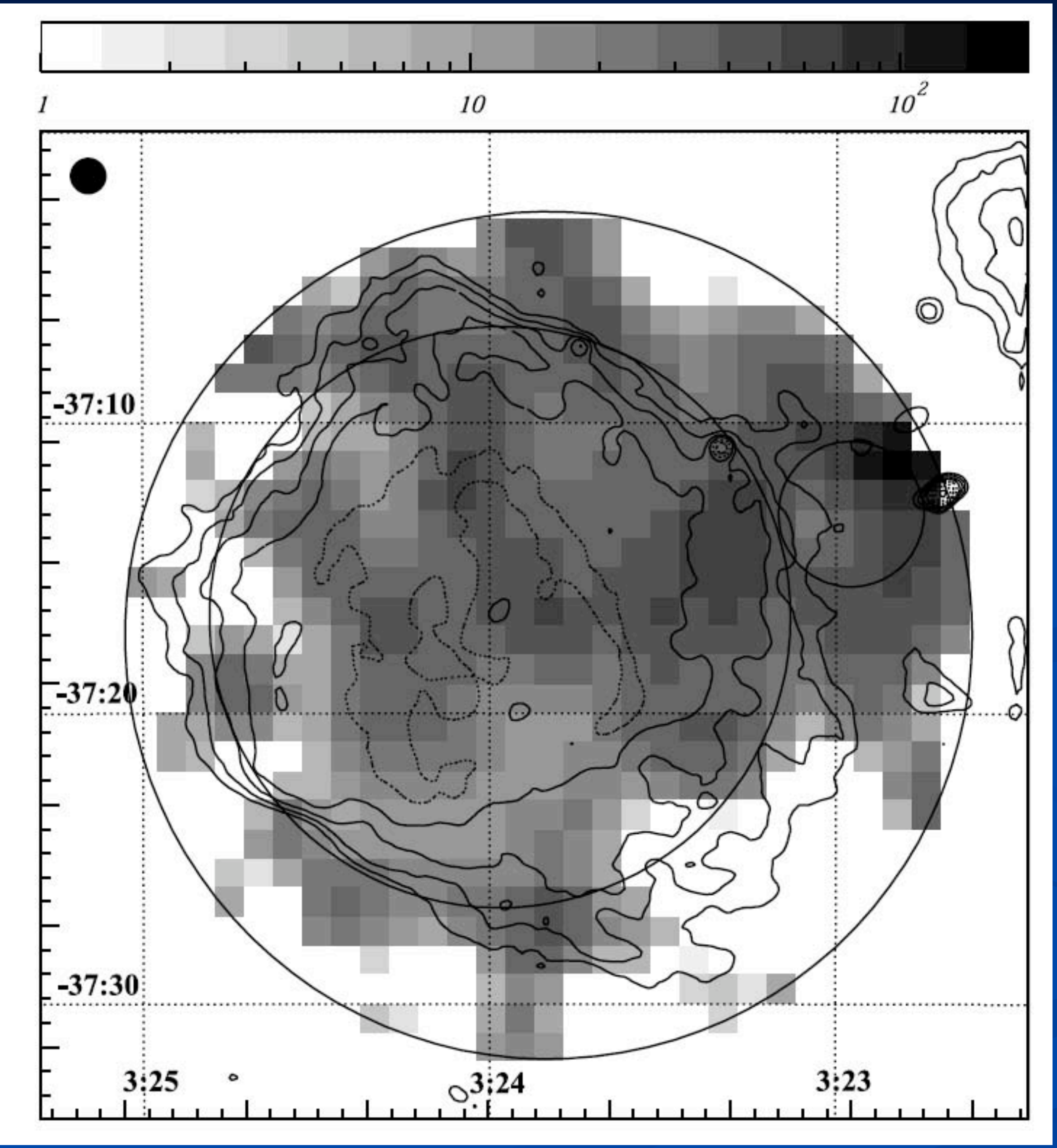
Zavala & Taylor 2005

The Very Large Array - 74 MHz -> 50 GHz

Fornax A



Radio Emission from the Lobe of a Nearby Radio Galaxy - Fornax A



100 kpc

Isobe et al. 2006

XMM: Fx = 6 x 10^{-13} erg cm-2 s-1 at 1 keV

Summary

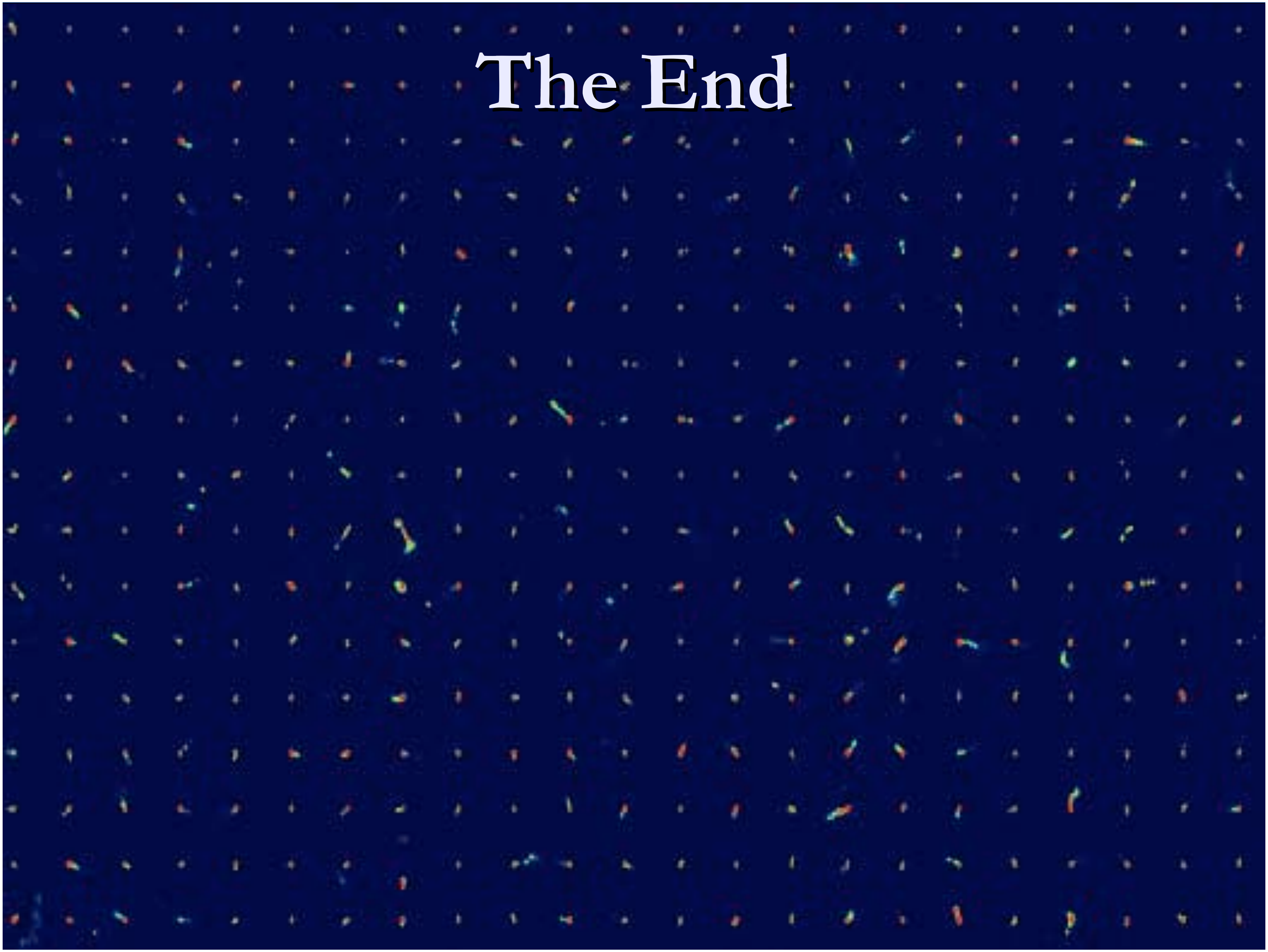
- GLAST will increase the γ-ray source catalog by a factor > 30
- Efficient observing mode, improved sensitivity and increased effective area combine to provide superb monitoring of the GeV sky on timescales from hours to years
- Knowledge of the AGN population (and which ones tend to be loud in gamma-rays) will be essential to identify GLAST sources.
- There are hints that EGRET blazers are faster (Jorstad et al. 2001) and more strongly polarized (Lister & Homan 2005)
- GLAST observations combined with complementary radio observations will result in a deeper understanding of:

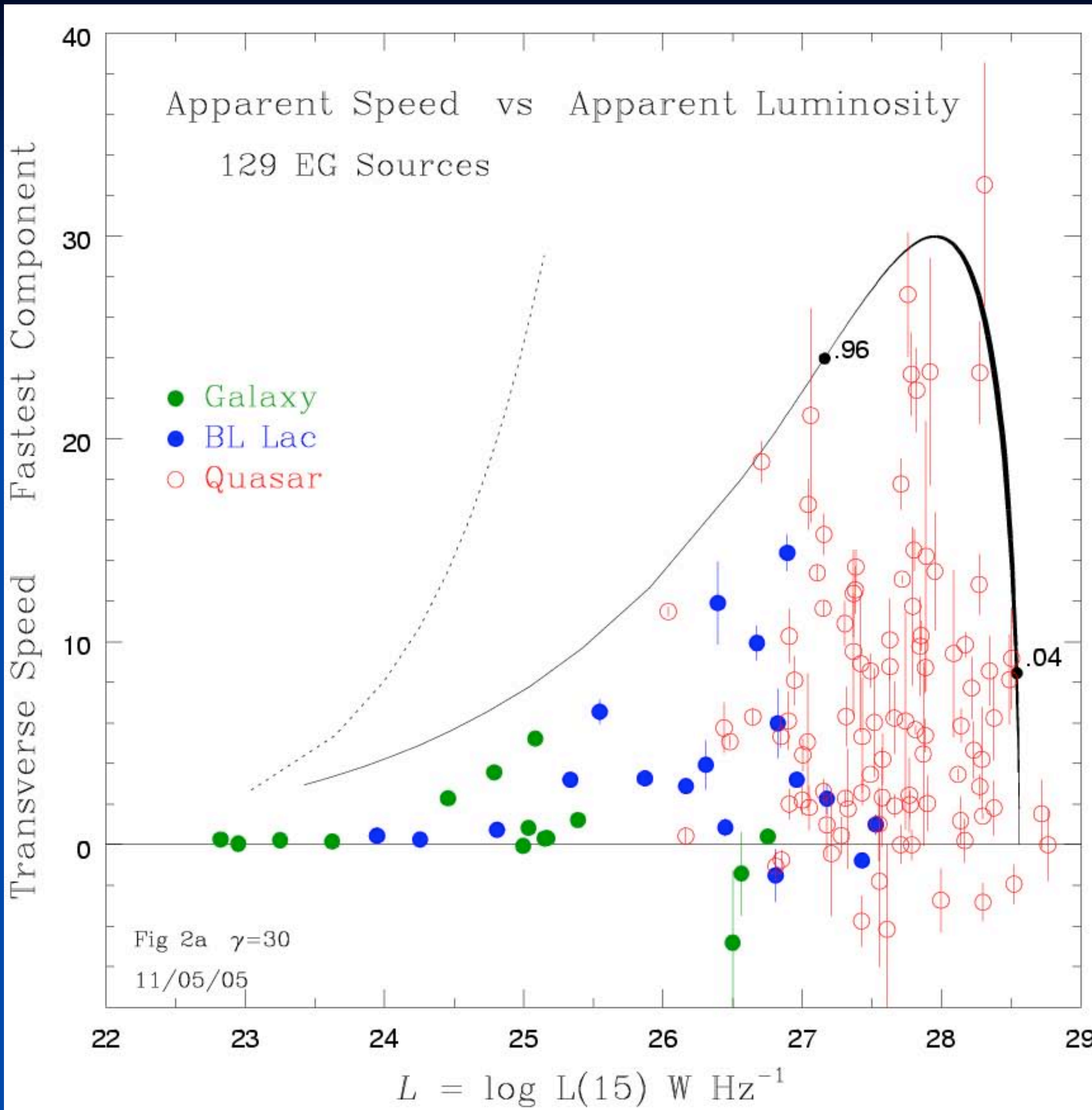
  - Acceleration and emission mechanisms of Jets

  - Test of the unification model and blazar sequence

  - Jet interactions with the environment
- Many studies mentioned here make heavy use of the VLBA of the NRAO. Additional operations support will be needed to keep this unique facility open.

The End



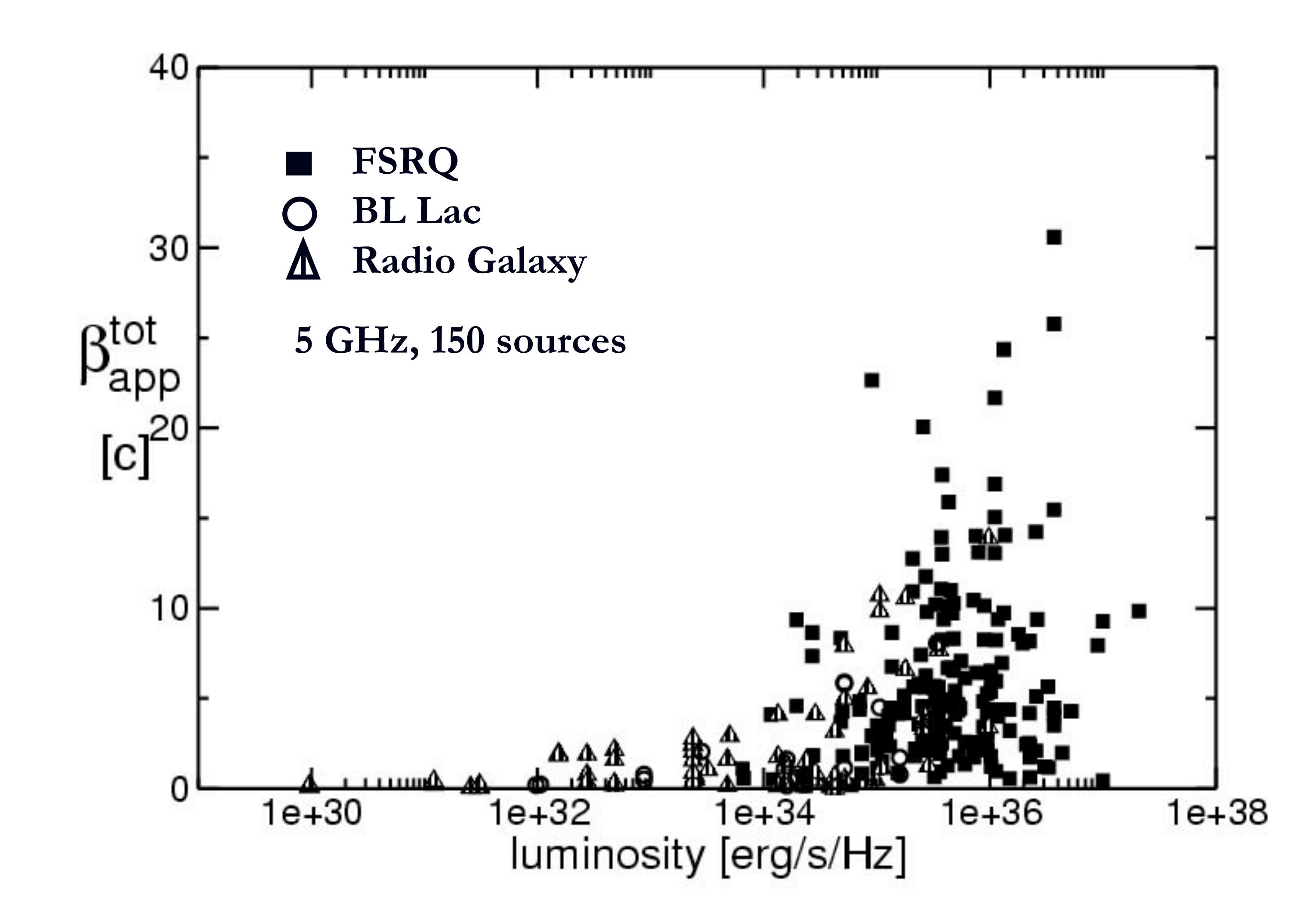


Maximum γ ~ 30

Low luminosity, low speed sources are not blazers beamed in the plane of the sky.

Cohen et al. ApJ, in press (astro-ph 0611642)

Superluminal motion (β) correlates with core luminosity



Britzen et al. 2007