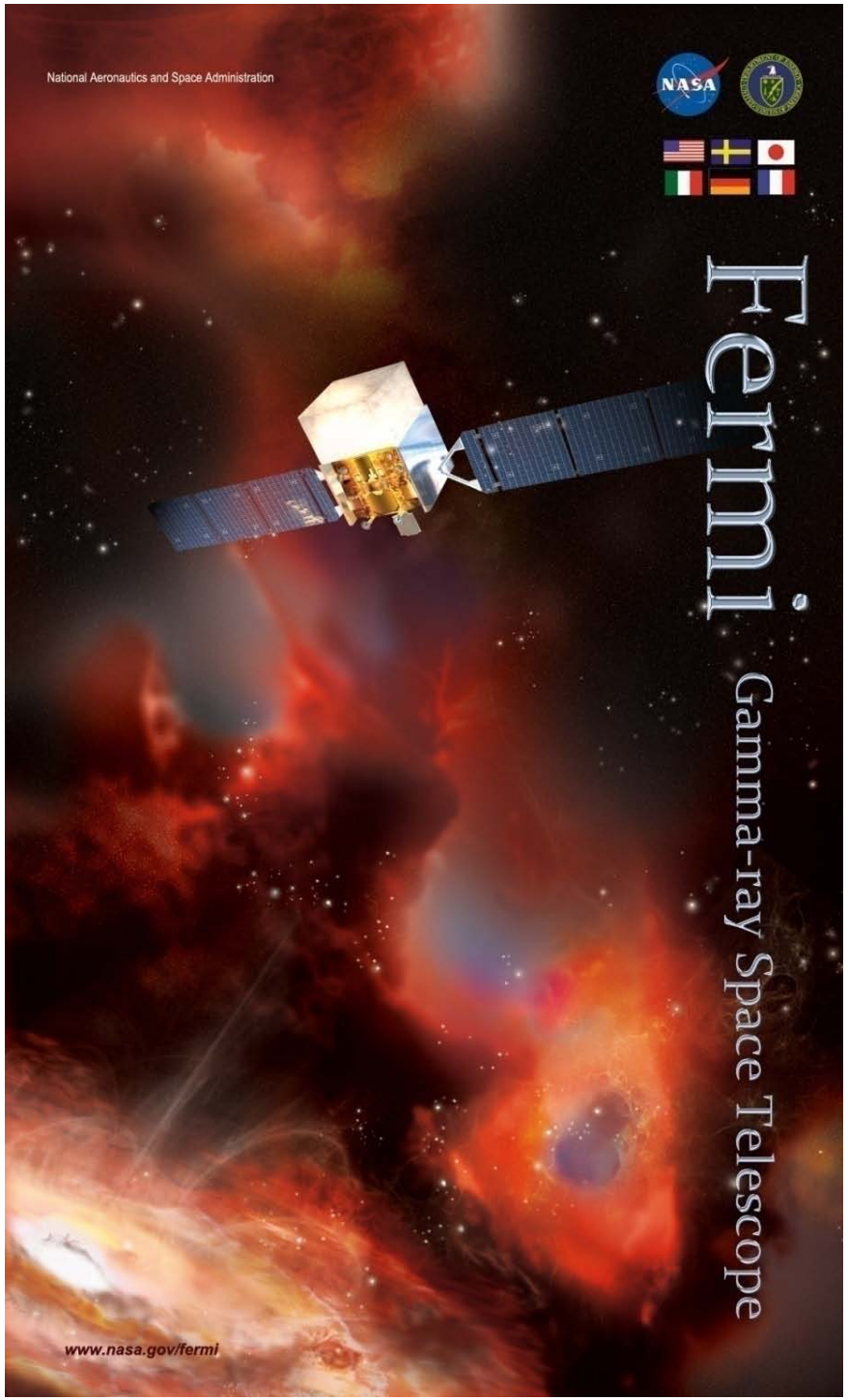


Fermi
Gamma-ray
Space Telescope

Fermi and Non-Blazar AGN

C.C. Teddy Cheung

(NRC/Naval Research Lab)

on behalf of the Fermi-LAT Collaboration

NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

Non-Blazar ("Other") γ-ray AGN

Table 4
Census of 1LAC Sources

AGN Type	Number of AGNs in		
	Entire 1LAC Sample	High-confidence Sample[a]	Clean Sample[a]
All	709	663	599
FSRQ	296	281	248
...LSP	189	185	171
...ISP	3	2	1
...HSP	2	2	1
BL Lac	300	291	275
...LSP	69	67	62
...ISP	46	44	44
...HSP	118	117	113
Other AGN	41	30	26
Unknown	72	61	50

This Talk

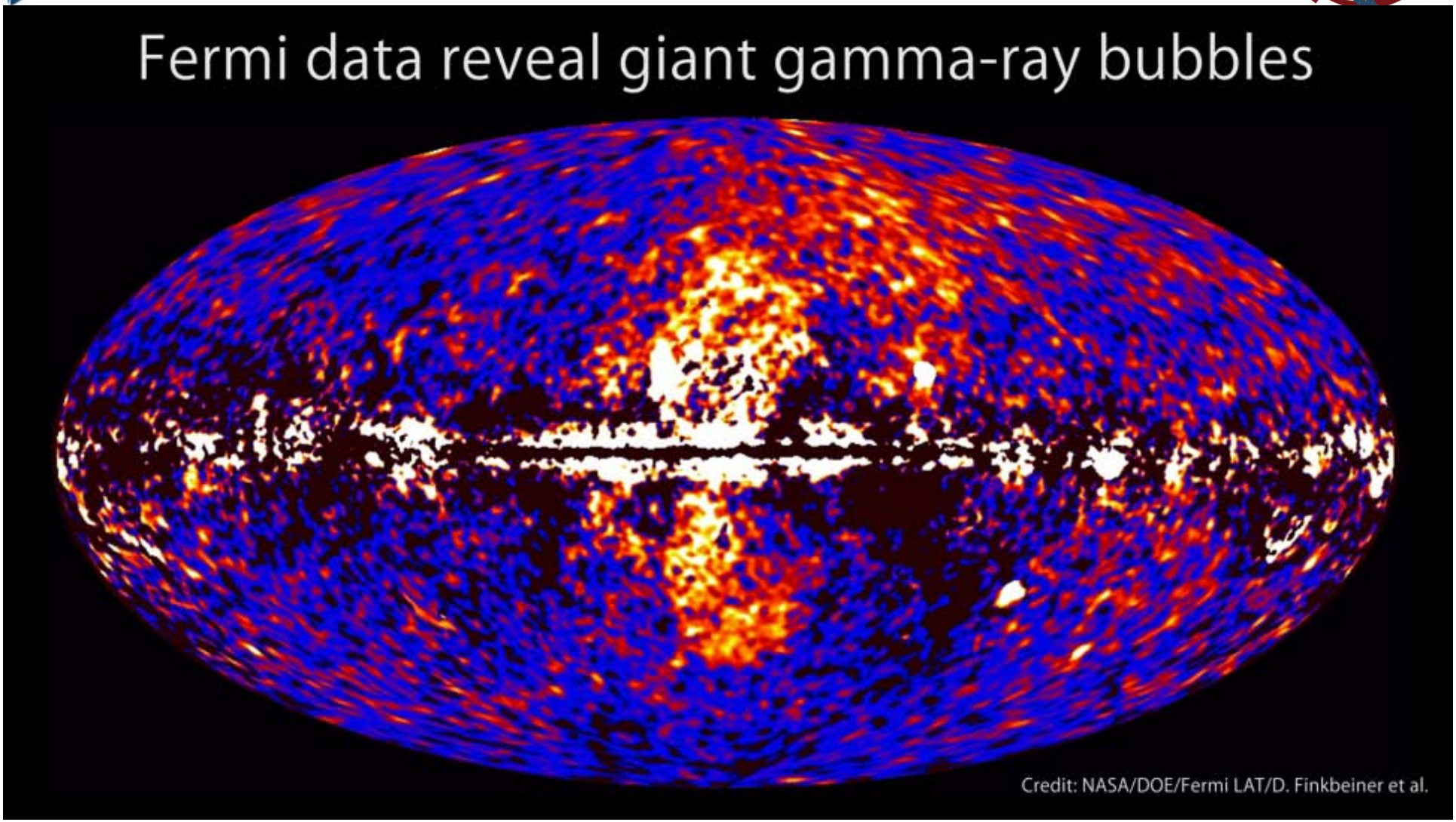
- 1LAC sample contains 709 AGN associated with 671 1FGL gamma-ray sources (|b|>10 deg)
- High-confidence Sample: P>80% assoc. probability
- Clean Sample: P>80% and single AGN/1FGL

1LAC: 2010 ApJ, 715, 429; arXiv:1002.0150

LAT team leads: Healey, Cavazzuti, Gasparrini, Lott, Tosti

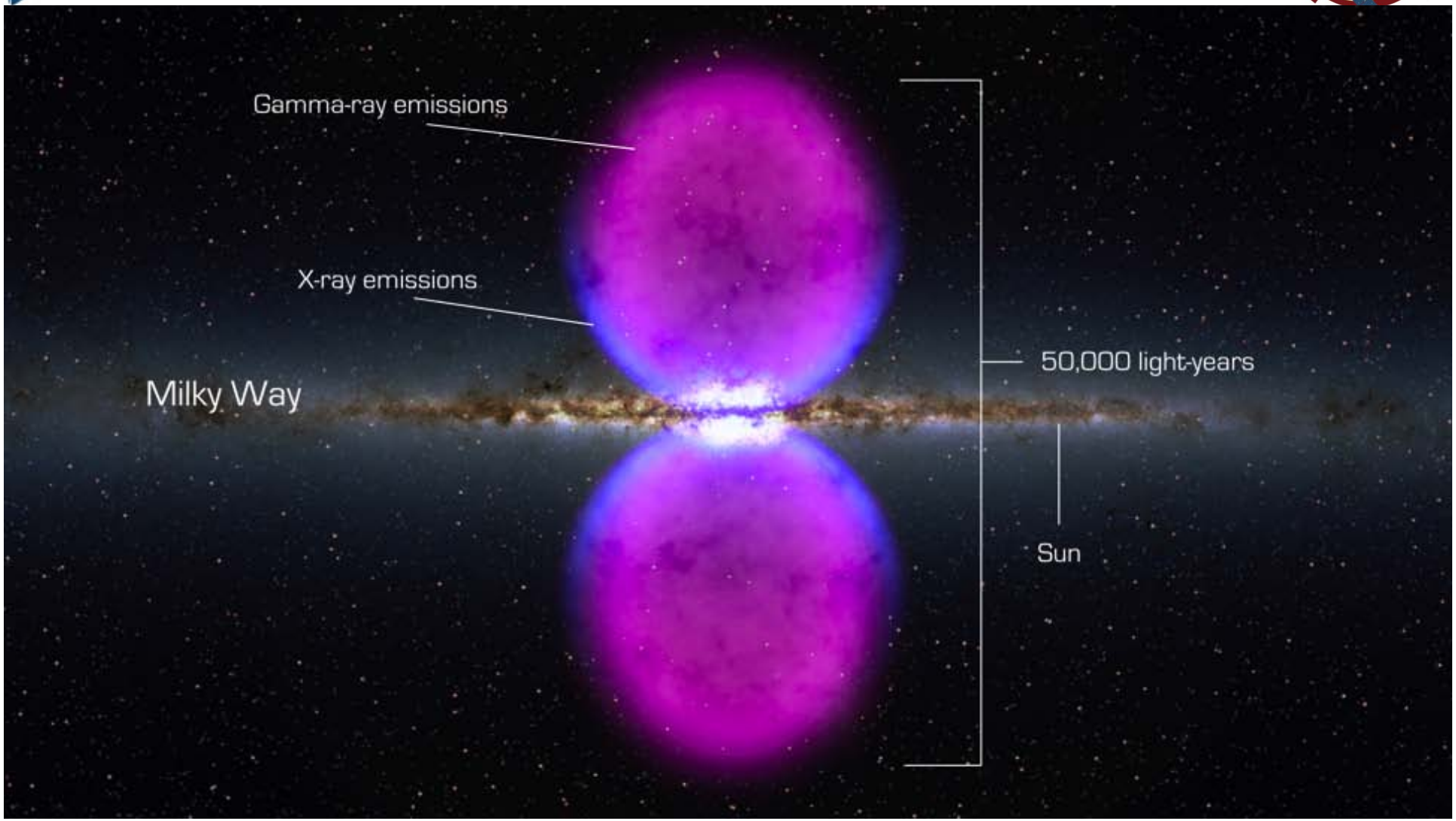
**see E. Cavazzuti et al.'s poster on 2LAC*

Our Nearest Non-blazar AGN

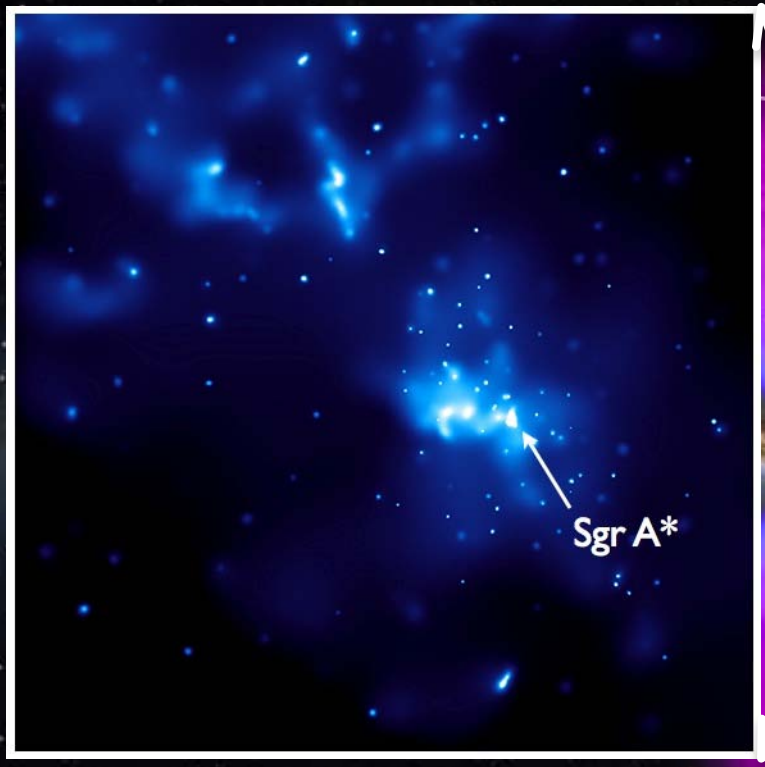


M. Su's talk yesterday

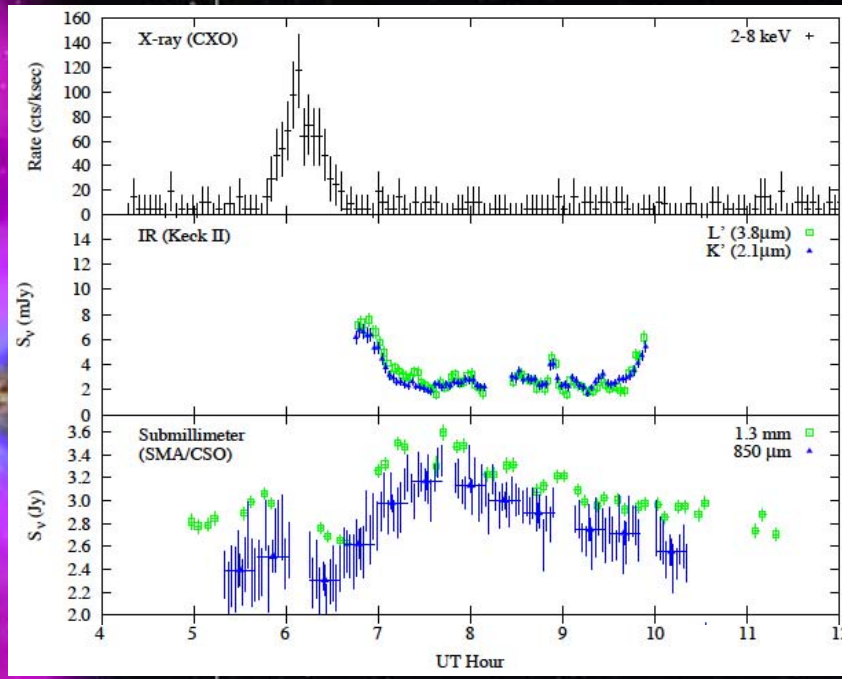
Our Nearest Non-blazar AGN



Flaring in Sgr A*



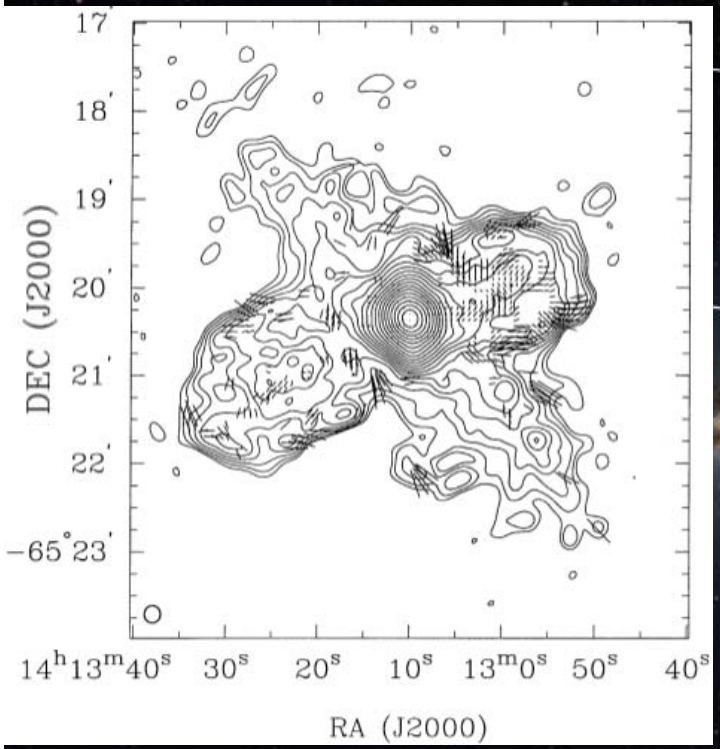
NASA/CXC/Caltech/M. Muno et al.



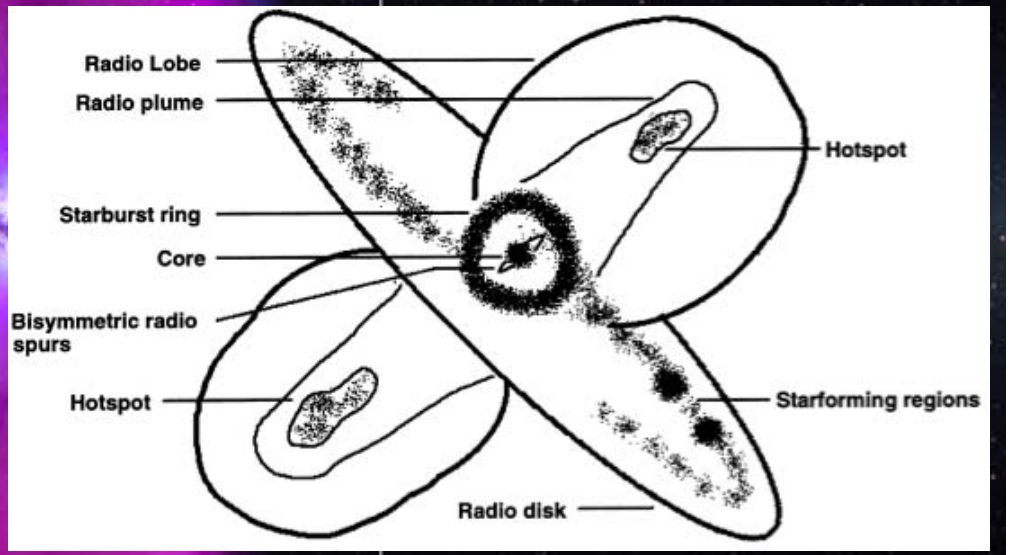
Rapid X-ray/IR/mm/sub-mm variability
Marrone et al. 2008

Radio Jet Activity in Nearby AGN

- Circinus galaxy (D~4 Mpc)
- Radio lobes highly polarized with extent ~6 kpc
- Hosts low-luminosity AGN

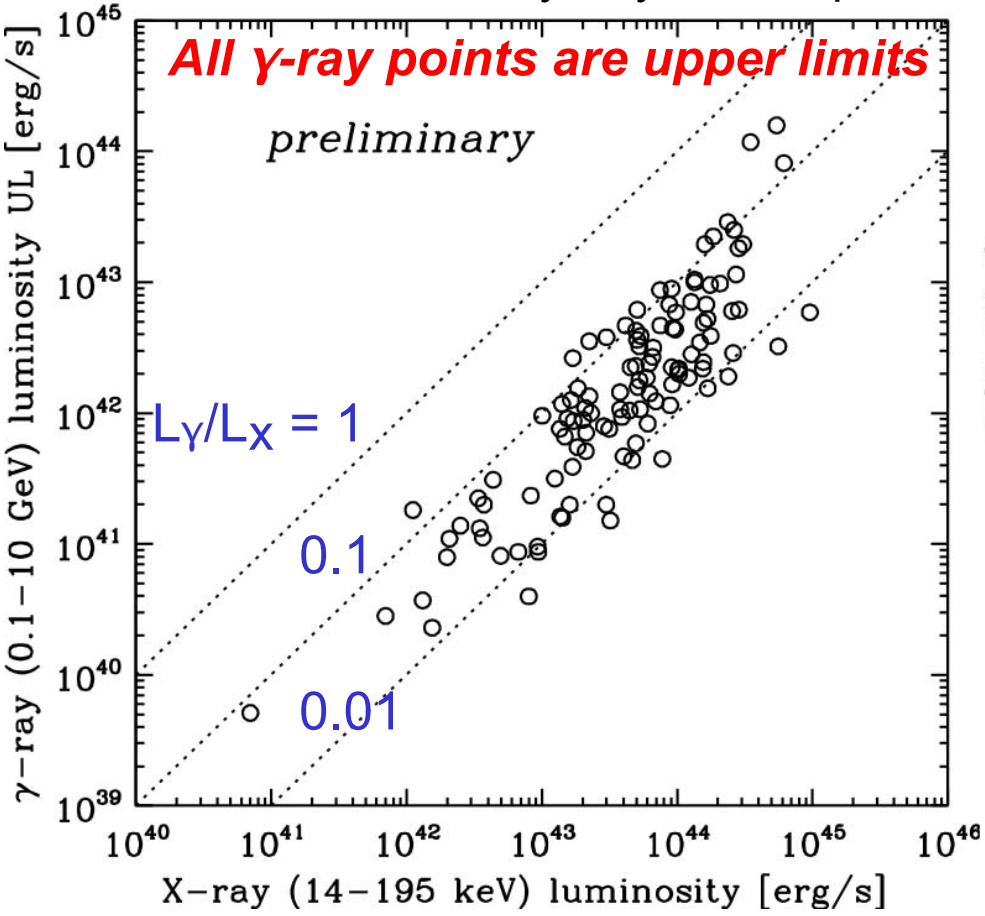


ATCA λ13cm image
Elmouttie et al. (1998)

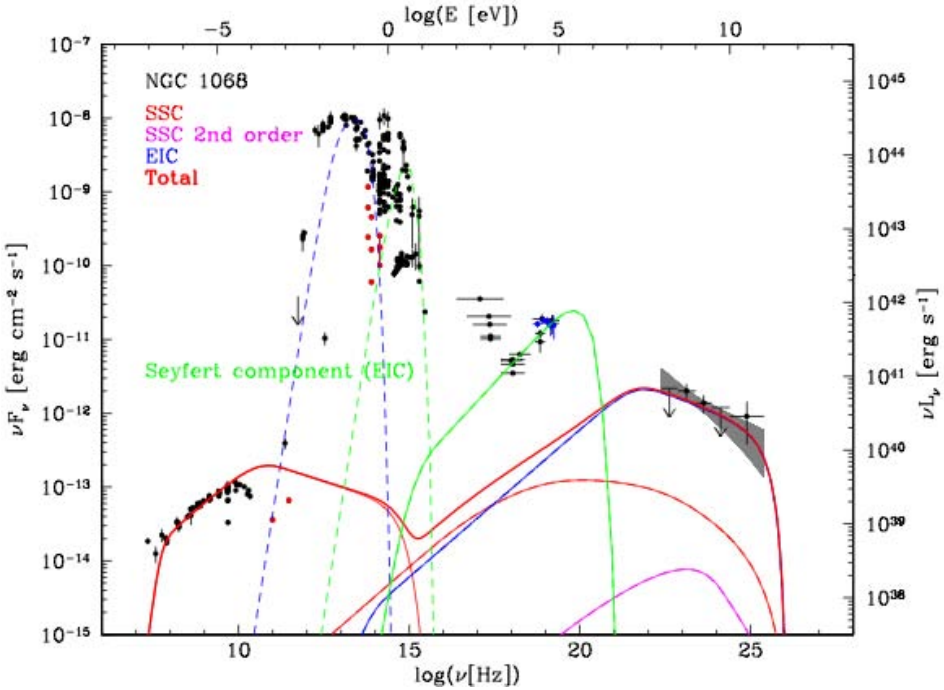


AGN-related Gamma-rays from Seyferts?

BAT hard X-ray Seyfert sample



Jet model for NGC1068

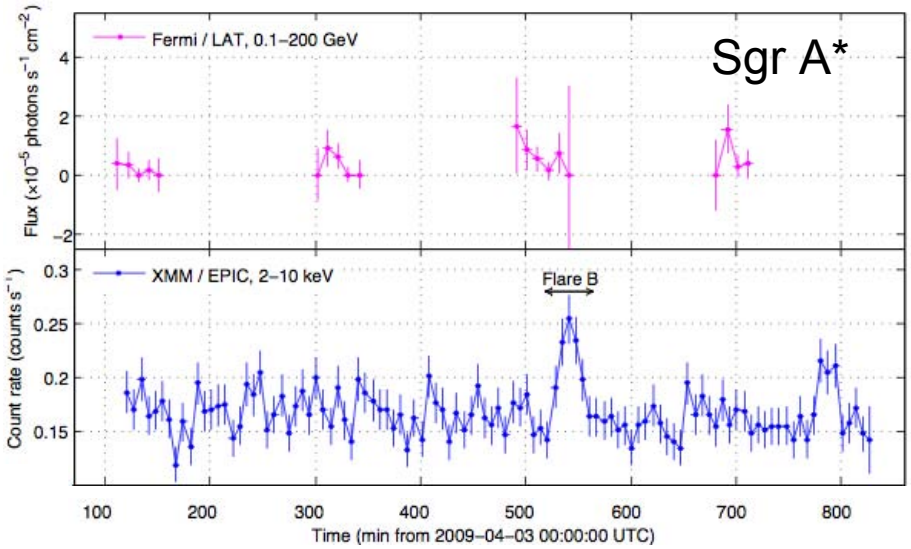


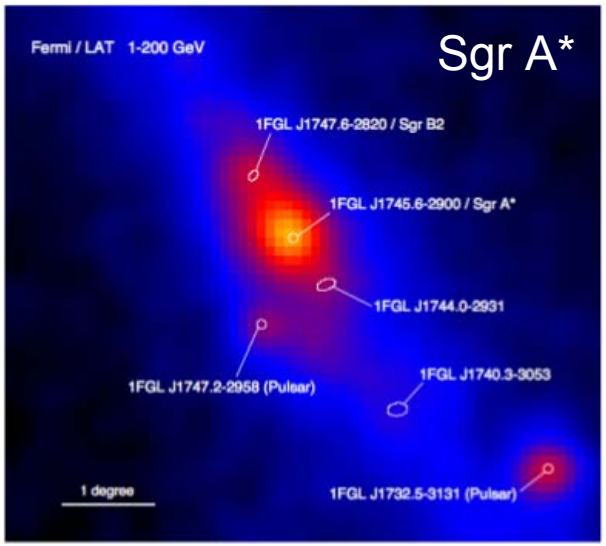
Lenain et al. (2010)

But NGC1068 (and other LAT detected nearby AGN) have prominent starburst emission

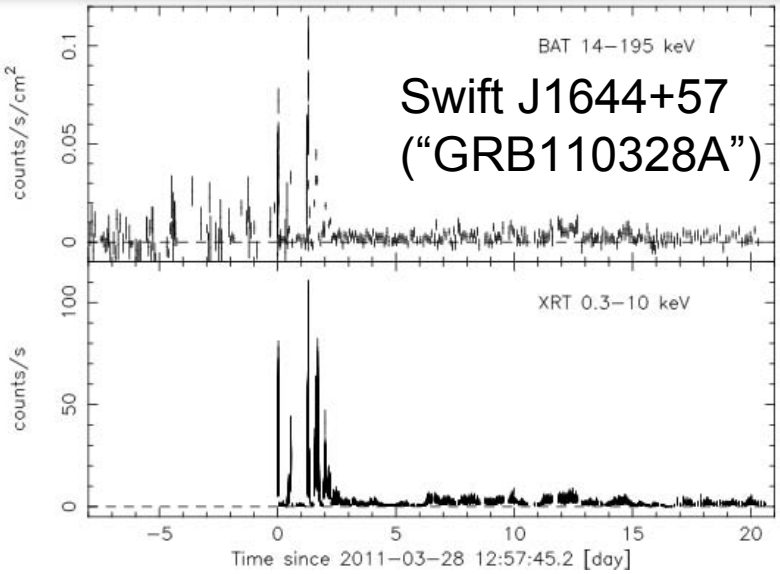
** see M. Hayashida et al. poster*

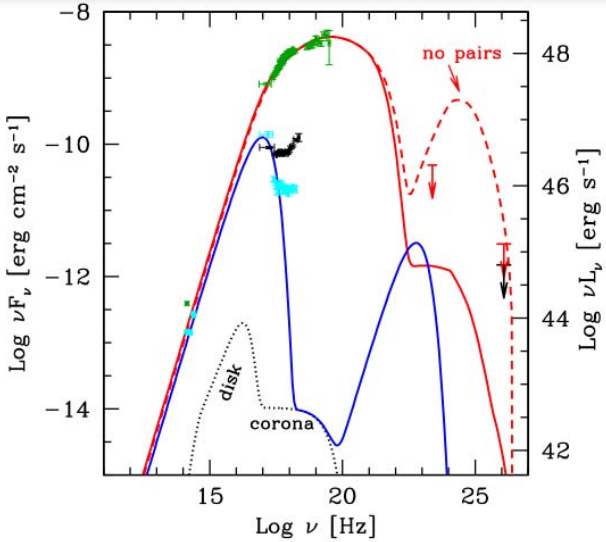
γ-ray Variability Search in nearby AGN





Trap et al. 2011

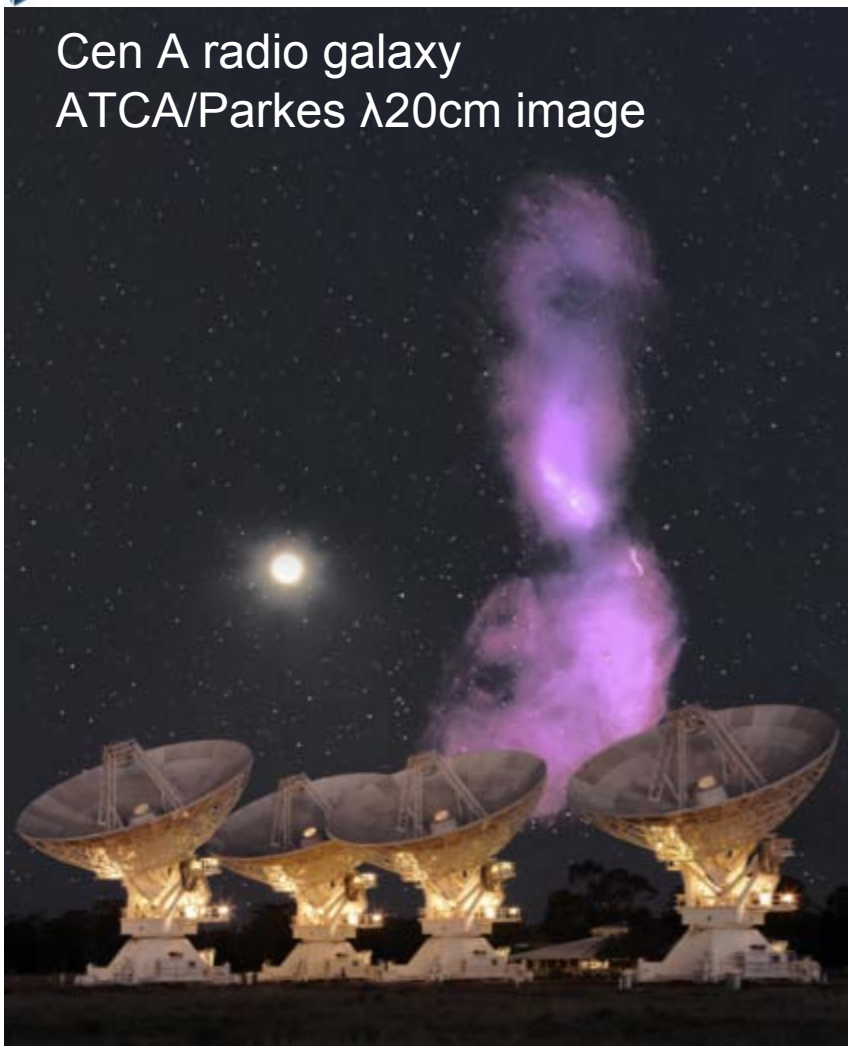




Tidal disruption event in z=0.35 galaxy?

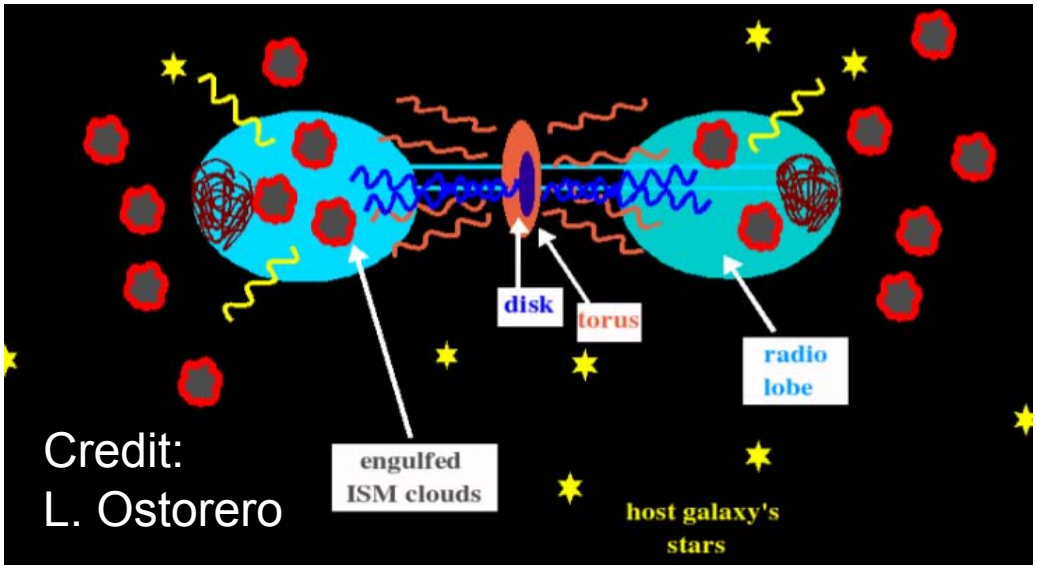
Burrows et al. 2011
see also Bloom et al., Levan et al.

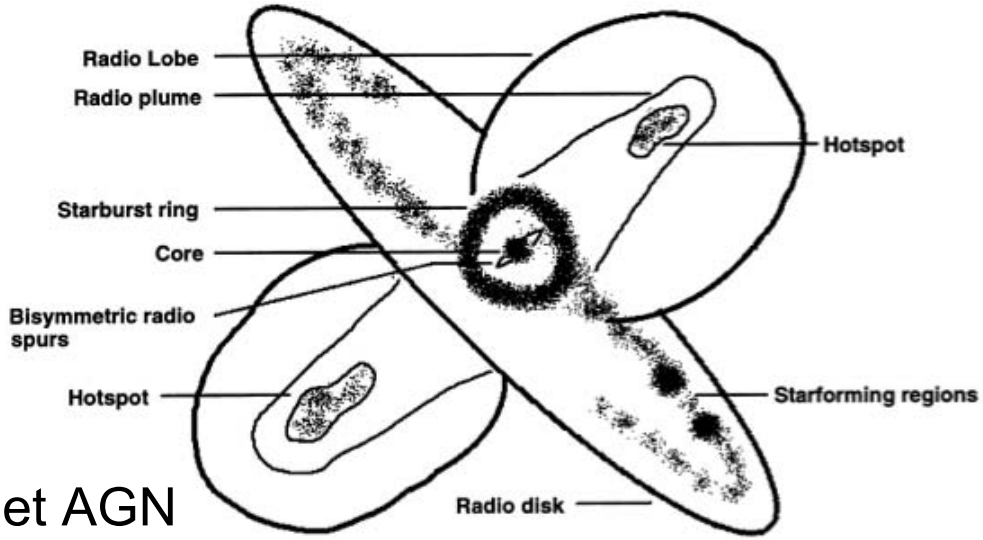
γ-ray Activity in Non-blazar AGN



Feain et al. (2010)

Evolving young radio source





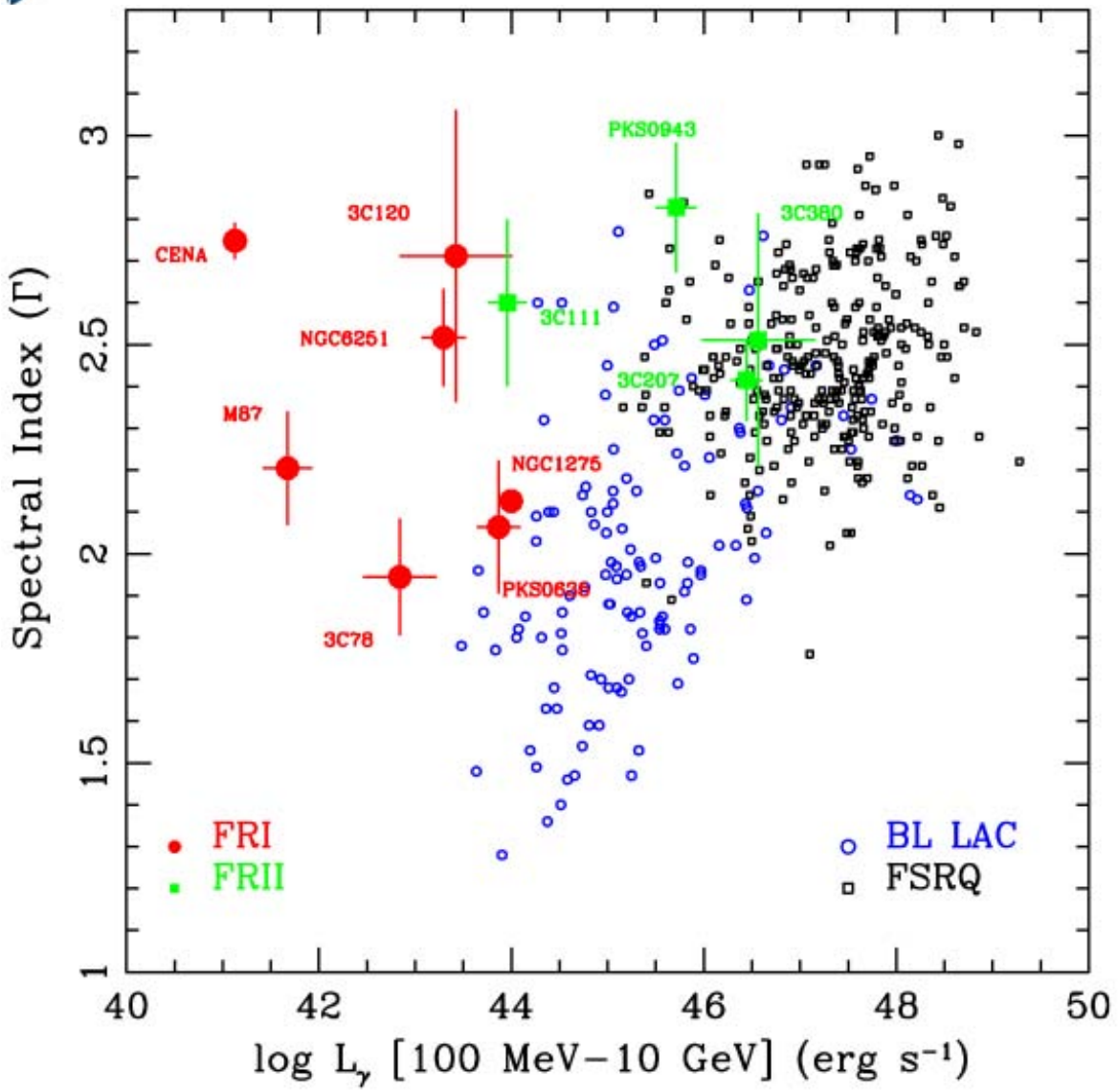
Radio-quiet AGN

Non-Blazar ("Other") AGN

- Radio galaxies as an emerging γ−ray source population from Fermi-LAT
- γ−ray site and emission mechanism from LAT imaging
- Constraints from γ−ray and multi-wavelength variability
- Young radio sources as candidate γ−ray sources
  - see radio galaxy presentations by N. Galante, P. Grandi, J. Kataoka (talk), S. Lombardi, J. Perkins, [others?]
  - see young radio source presentations by W. McConville, M. Orienti
  - RG contribution to MeV background – AGN (Bhattacharya poster, Inoue poster), lobes (Massaro & Ajello poster)
  - UHECRs from nearby LAT AGN (Nemmen poster)

- Radio-loud narrow line Sy1s (Cavazzuti & Ghisellini talk; Foshini talk)
- Nearby AGN with dominant starbursts emitting γ-rays (2010 ApJL 709, L152)
- No clear cluster γ-ray emission detected so far (2010 ApJ 717, L71); Hydra A (poster by M. Ali)

Non-blazar Gamma-ray Population



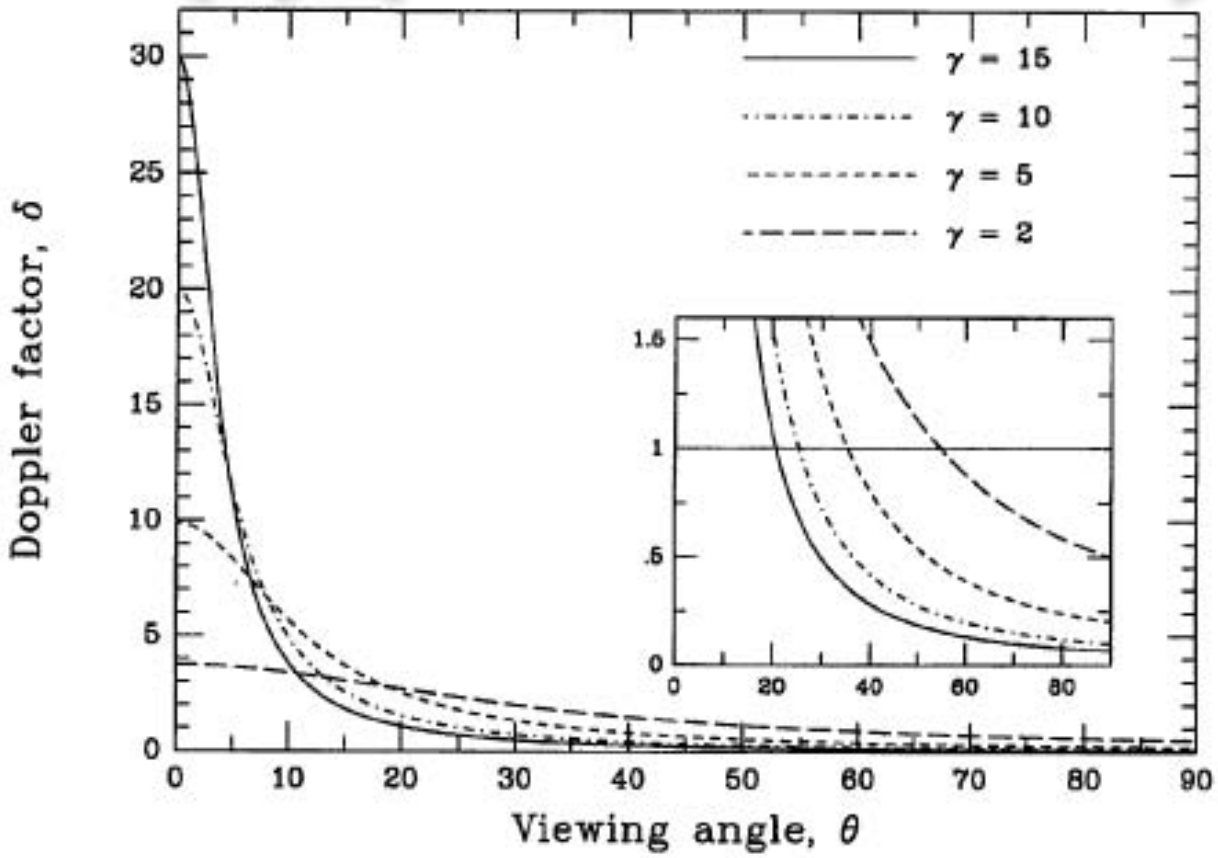
- Glean jet structure from SED modeling including LAT spectra:
  - Are inferred θ larger than blazars?
  - Are inferred jet velocities lower than in blazars?
  - Jet structures?

LAT Mis-aligned AGN paper
2010 ApJ 720, 912
LAT lead: P. Grandi

**see P. Grandi et al.'s poster*

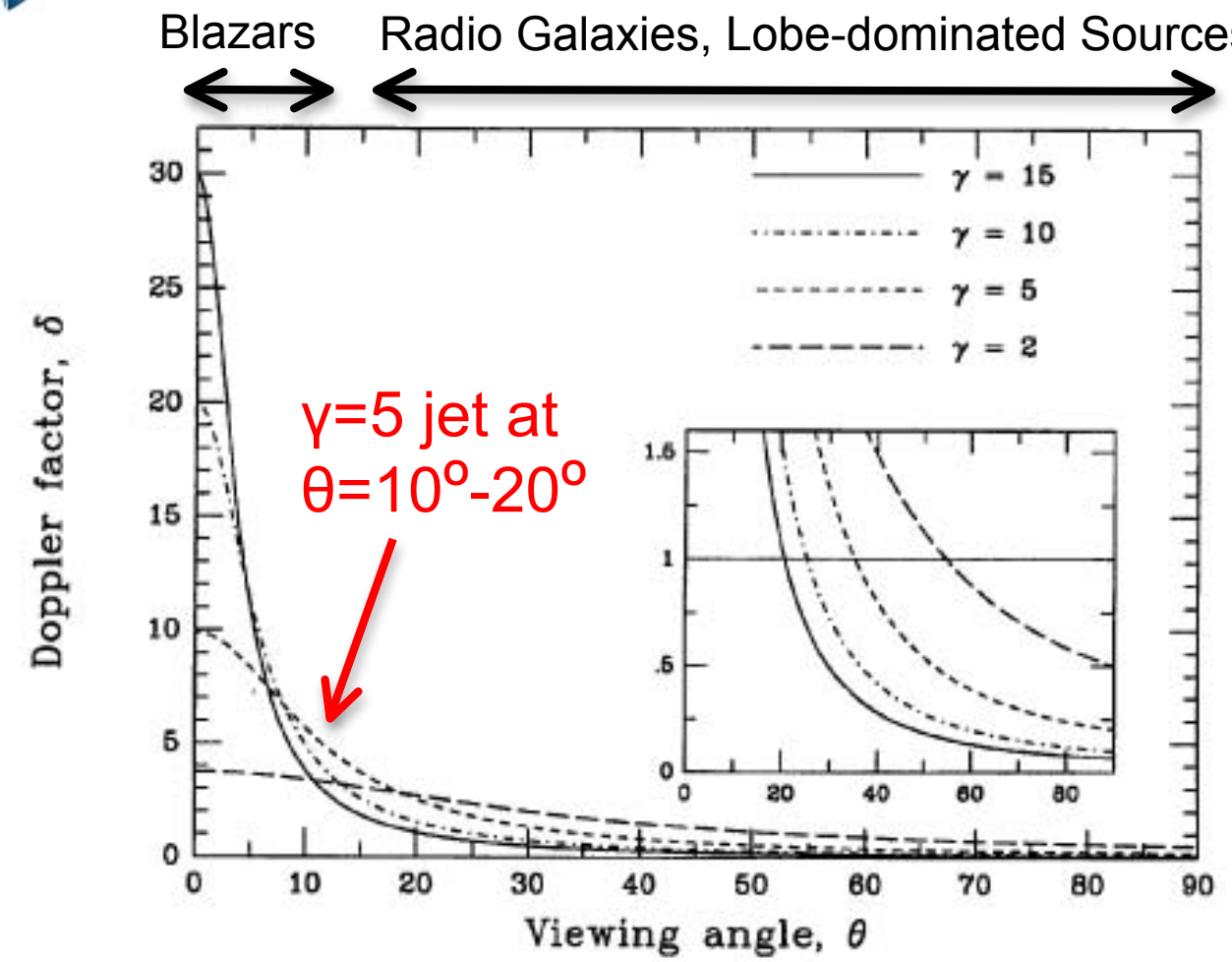
Angle on Classification of Radio Galaxies

Blazars ⟷ Radio Galaxies, Lobe-dominated Sources



from Urry & Padovani (1995)

Angle on Classification of Radio Galaxies



from Urry & Padovani (1995)

- Gamma-ray blazar jets typically characterized by: $\gamma>10$, $\theta<10^{o}$ (rapid variability, superluminal motions); high-E emission from pc-scale or smaller

- At larger θ, "blazar jets" fade; more likely to see slower jet emission
  - spine-sheaths?
  - Unification

- But possible emission from outside of "core" (e.g. extended jet, lobes, cluster)

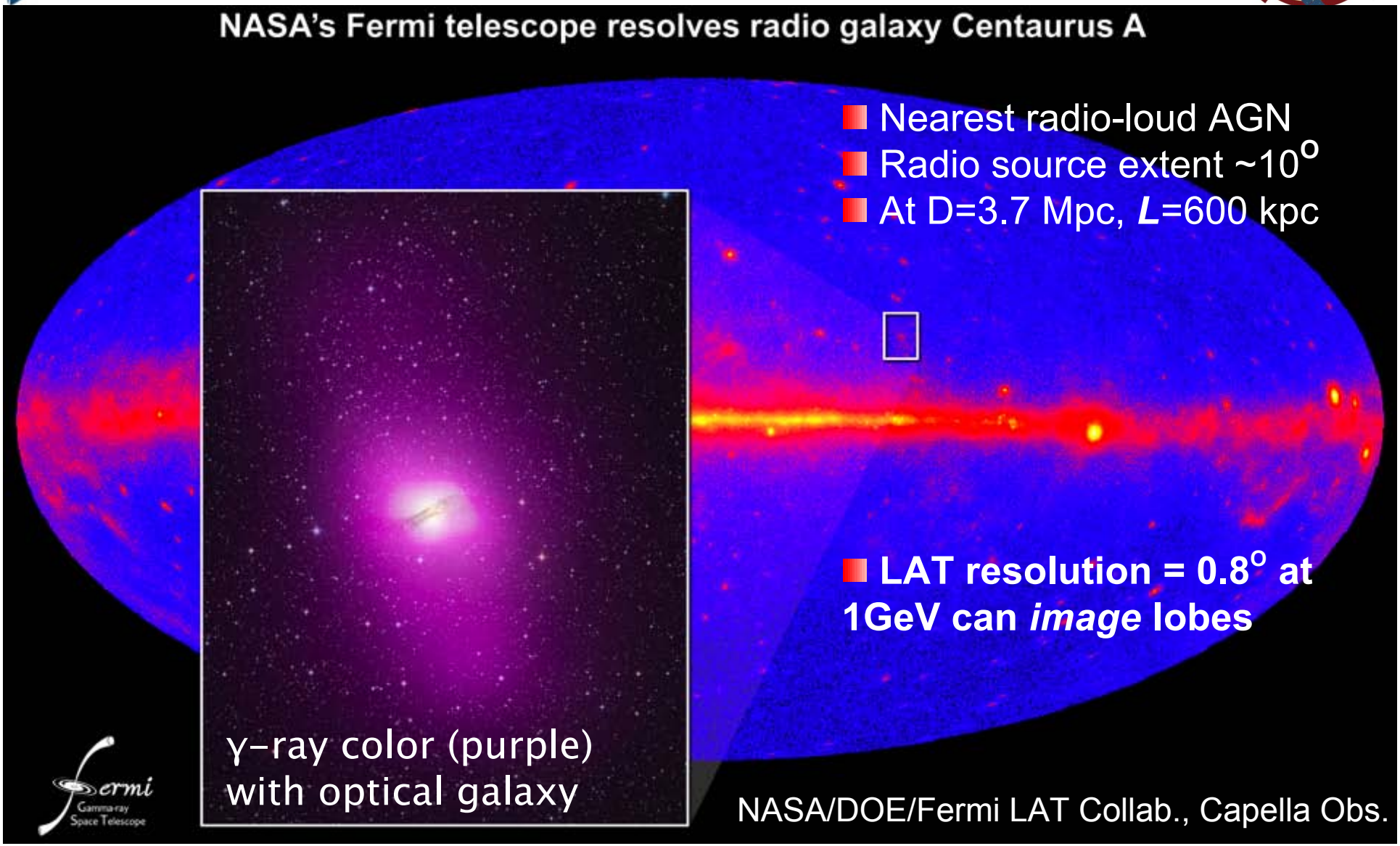
Gamma-ray Radio Galaxies

LAT provides precise γ-ray localizations, *radii* (95%) ~ 1.5 – 5 arcmin (vs. 0.5° in EGRET) correspond to ~5-25 kpc for sources within 100 Mpc

Name	D/Mpc	MeV/GeV Detection	VHE?	Note
Cen A	3.7	EGRET, LAT 2010	yes	Lobes
M87	16	LAT 2009	yes	TeV Var
Fornax A	18	LAT 2011		Preliminary
Cen B	56	LAT 2011		Preliminary
Per A	75	LAT 2009 (COS-B?)	yes**	Variable GeV + TeV
IC310	80	LAT 2010 (Neronov+)	yes	Head-tail, TeV
NGC6251	106	EGRET, LAT 2010		
3C78	124	LAT 2010		
3C120	142	LAT 2010		BLRG*
3C111	213	EGRET, LAT 2010		BLRG*

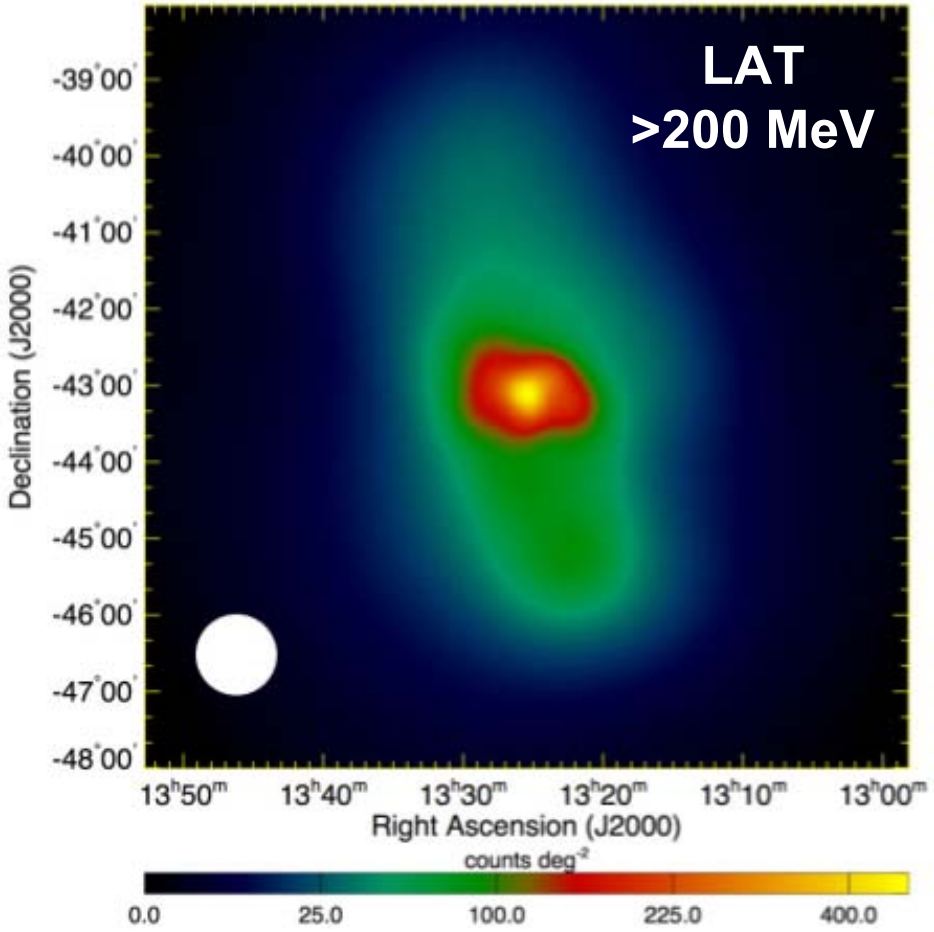
**J. Kataoka's BLRG talk tomorrow, ** S. Lombardi's poster*

Emission Site from Gamma-ray Imaging

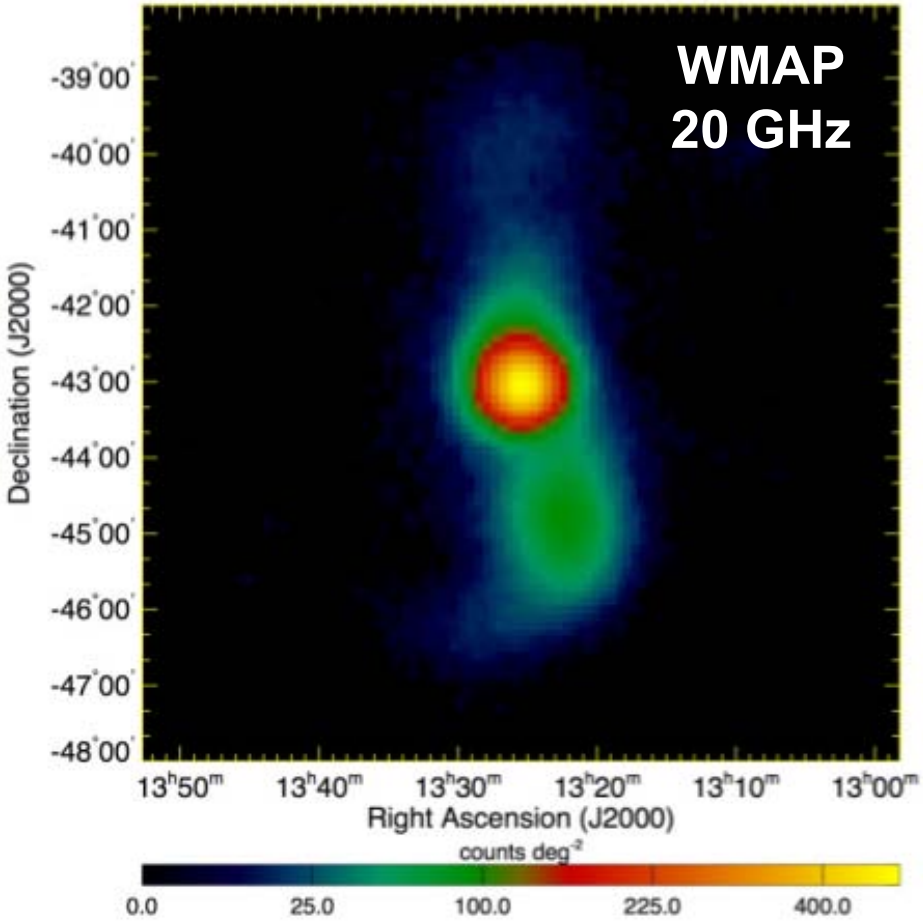


Emission Site from Gamma-ray Imaging

Over ½ of the total >100 MeV observed LAT flux in the lobes



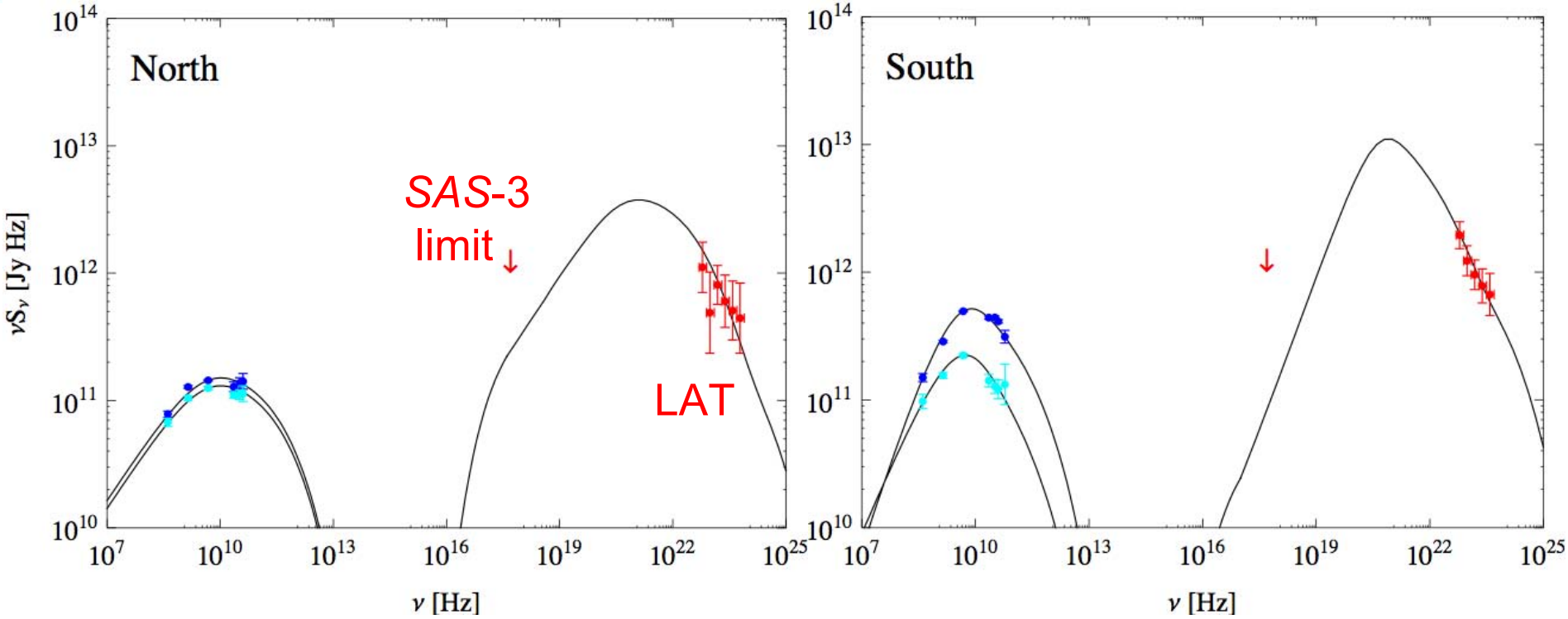
Background & point sources subtracted



From Nils Odegard (GSFC)

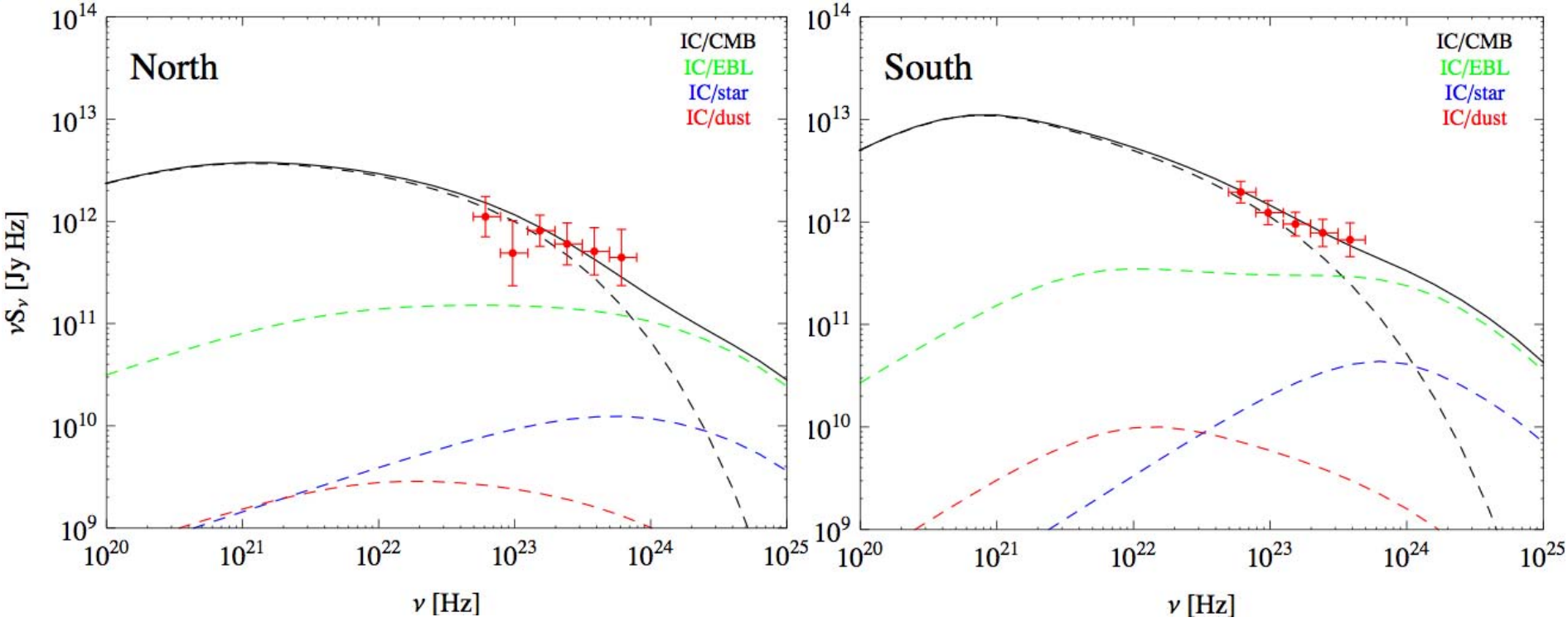
2010 Science, 328, 725; Leads: Cheung, Fukazawa, Knodlseder, Stawarz

Imaging Inverse Compton γ-ray Emission



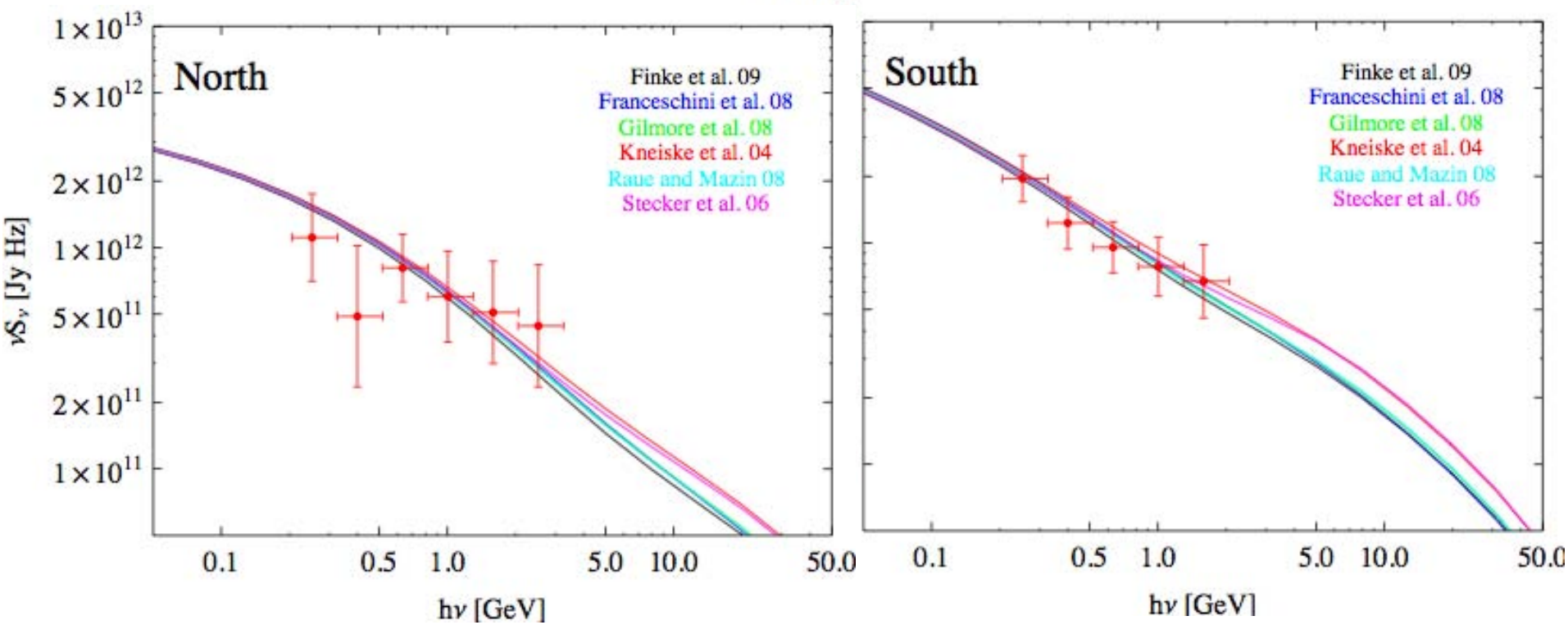
- IC (CMB+EBL) origin of LAT emission with **B ~ 1 μG** in both lobes, near equipartition
- IC component dominant, U_{CMB}/U_B **~ 10** -- 'requires' the lower *B*-field in Cen A lobes than typical in other (more powerful) examples
- Predictions for hard X-ray emission, but not yet detected by INTEGRAL (Beckmann et al. arXiv:1104.4253)

Inverse Compton Emission: Close-up



- LAT γ−ray emission dominated by IC/CMB component for the modeled electron energy spectra (broken power-law + exponential)
- Could probe EBL as IC/EBL dominates here at higher-energies, >GeV

Gamma-ray Probe of EBL at >GeV Energies?

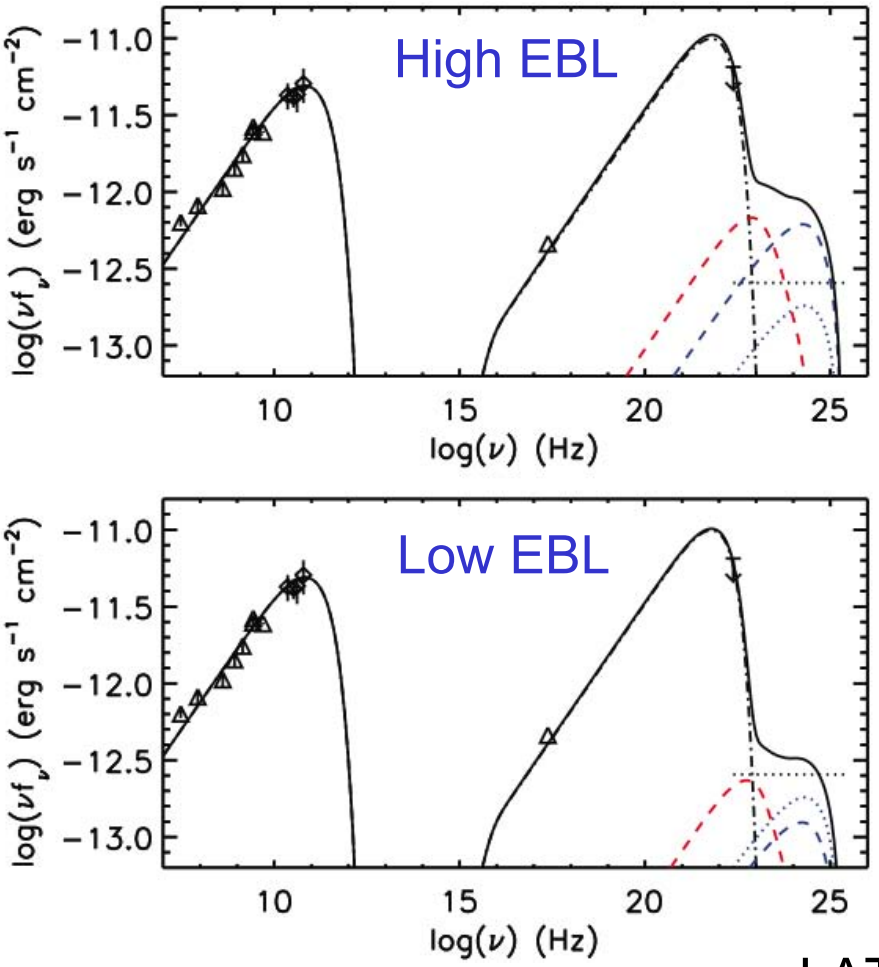


- LAT γ−ray emission dominated by IC/CMB component for the modeled electron energy spectra (broken power-law + exponential)
- Could probe EBL as IC/EBL dominates here at higher-energies, >GeV

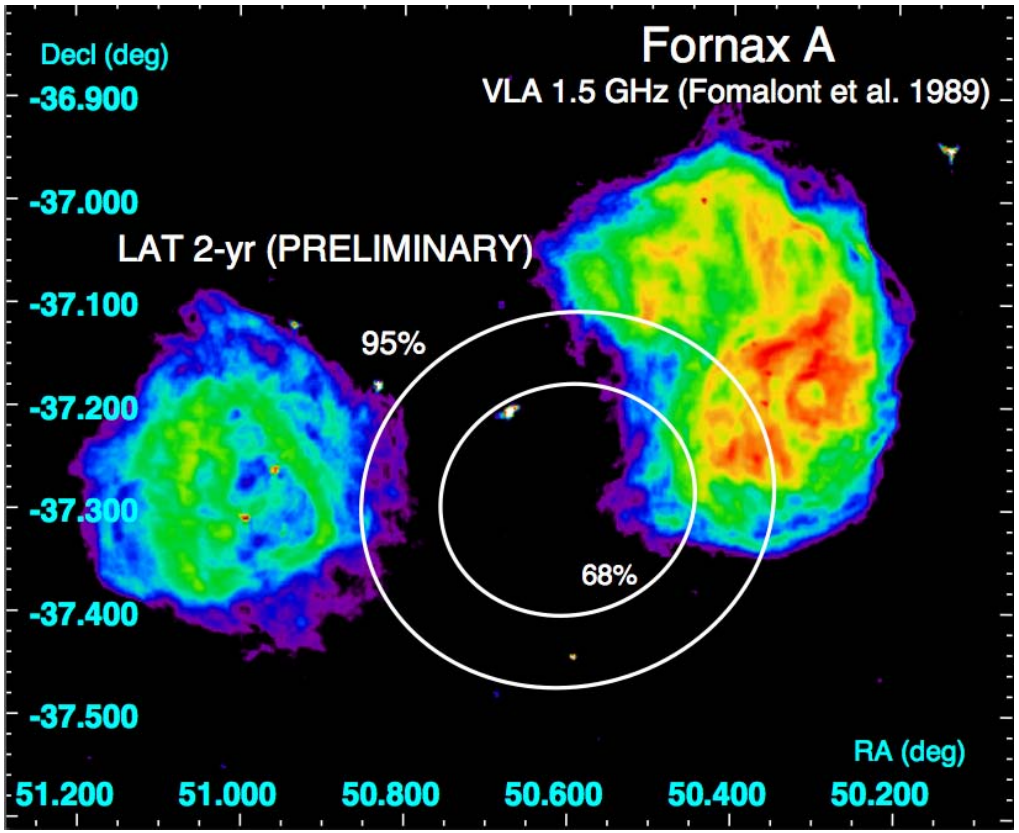
**See J. Perkins et al. poster for improved statistics and expanded energy coverage in analysis 29-months of LAT data analysis*

Inverse-Compton γ-ray Lobes in Fornax A?

IC/X-ray lobe B-field ~1.5 μG (Feigelson et al. 1995, Isobe et al. 2006)



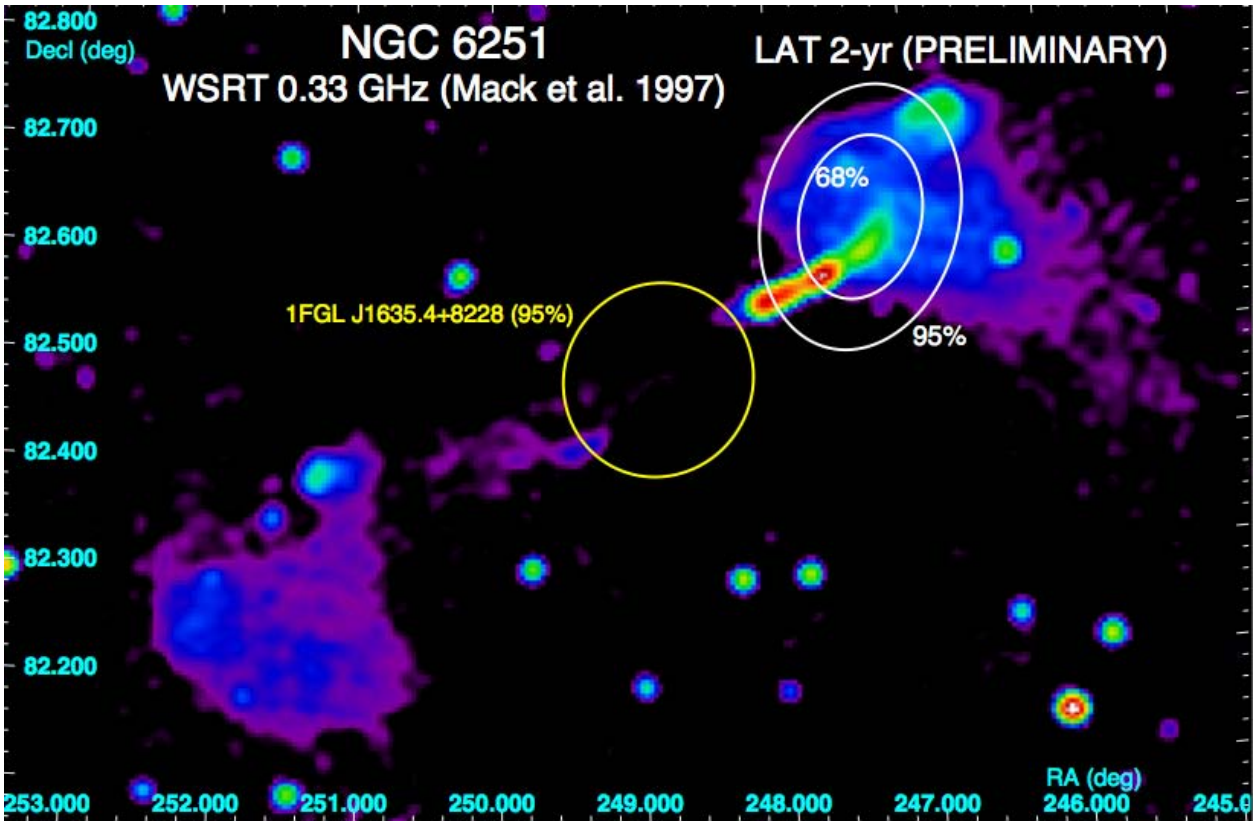
Georganopoulos et al. (2008)



LAT 68% and 95% confidence ellipse on radio image

LAT team leads: McConville, Georganopoulos

γ-rays from NGC6251: inverse-Compton Lobes?

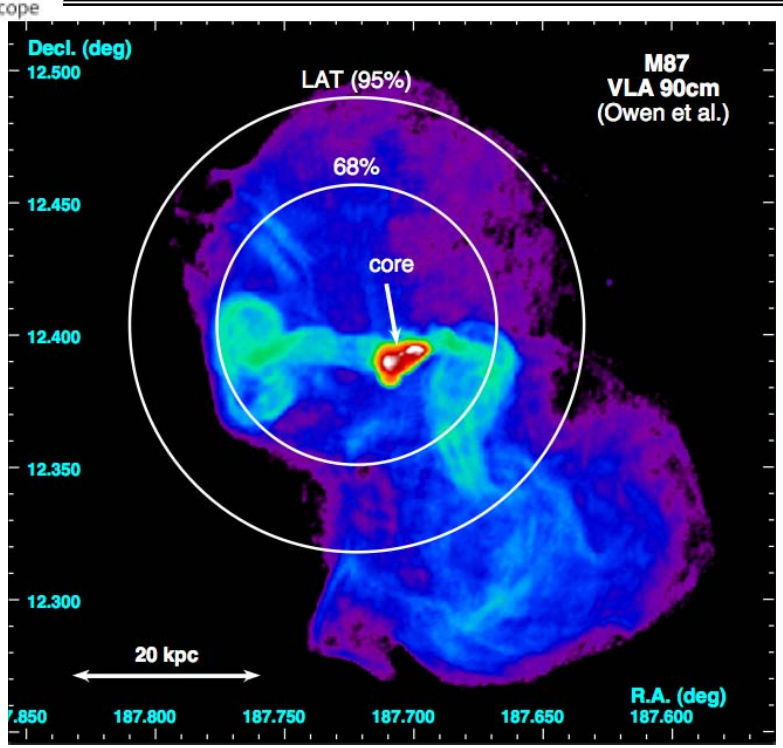


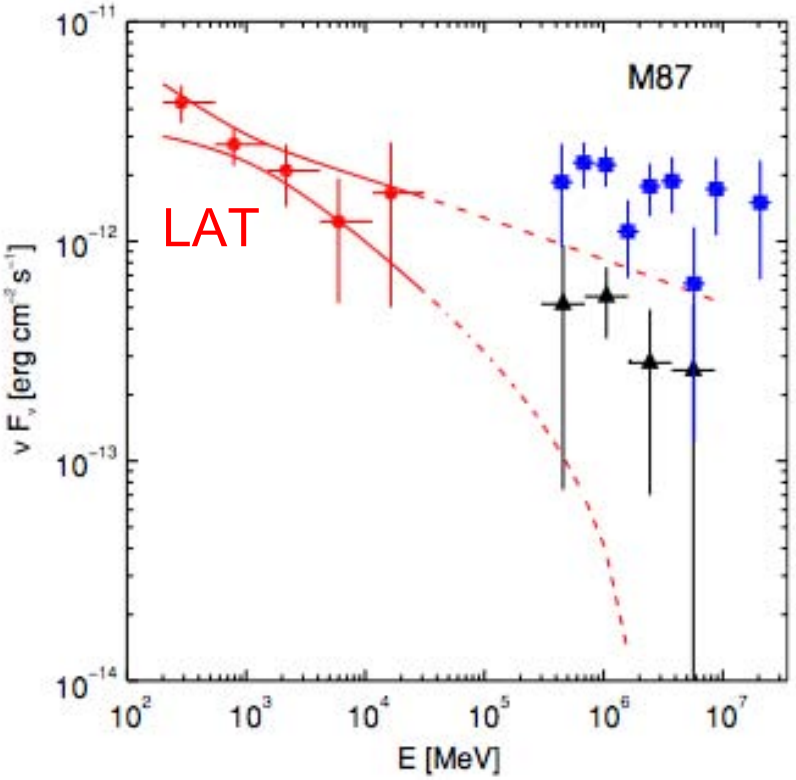
LAT 68% and 95% confidence ellipse on radio image

1FGL/15-month LAT analysis in
2010 ApJ 720, 912 (LAT lead: P. Grandi)
also Migliori et al., submitted

- Associated with 3EG J1621+8203 (Mukherjee et al. 2002) with large error circle
- Large radio galaxy (1.2^{o} ~ 1 Mpc) so LAT capable of spatially separating lobe from AGN emission
- Lobe equipartition B-field ~0.3 μG (Mack et al. 1996); cf. ~1 μG for Cen A

Gamma-ray Emission Site from Variability

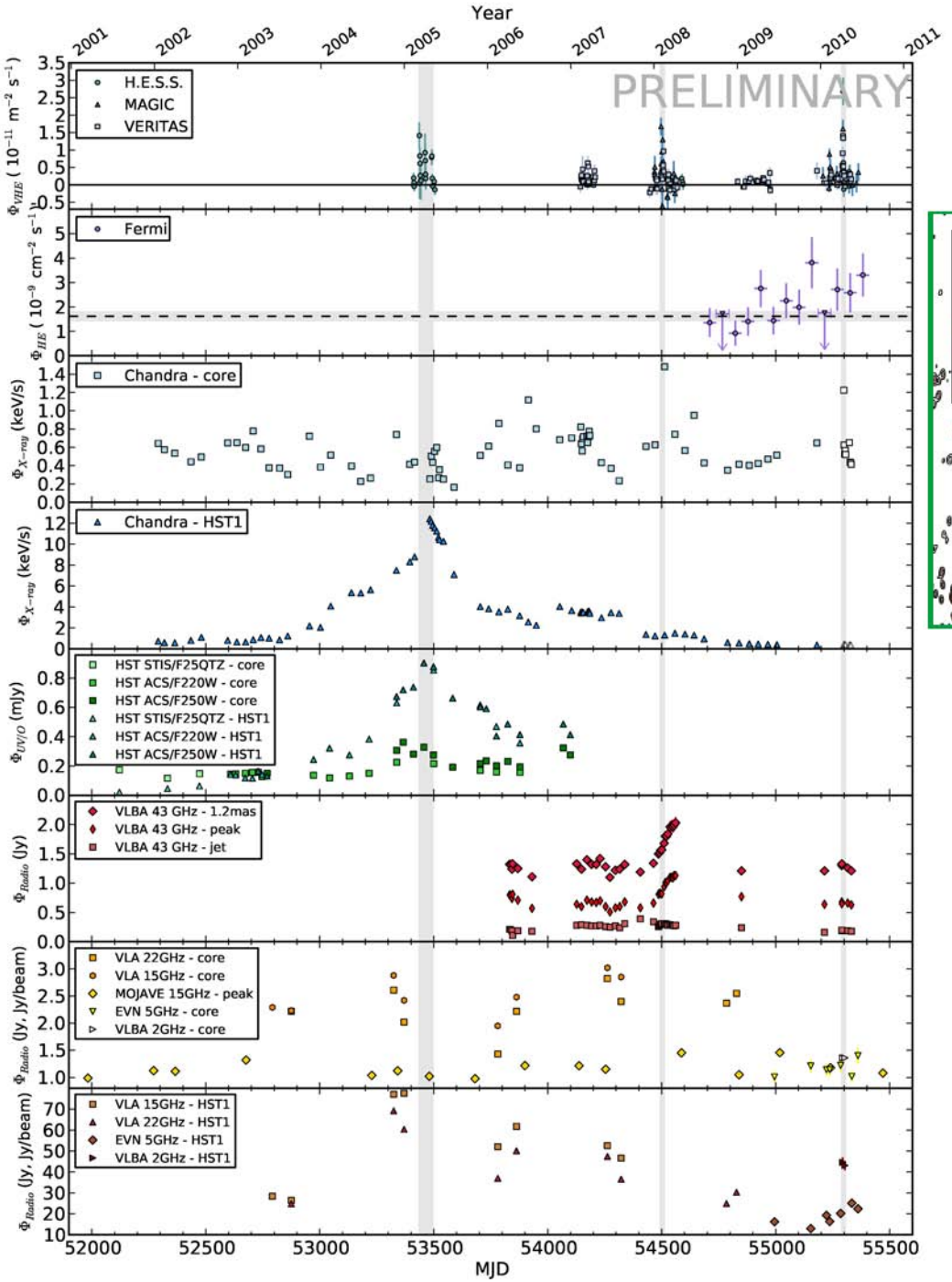


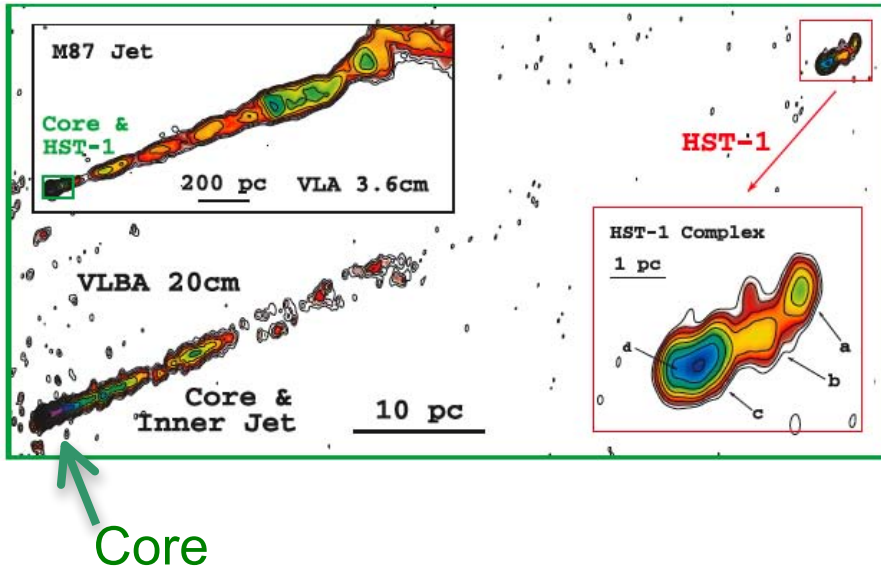


- MeV/GeV emission can be modeled as 1-zone synchrotron self-Compton from core with moderate jet beaming: δ~2-4
- Does not preclude γ−rays from outside the radio core

ApJ 2009, 707, 55
LAT leads: Cheung, McConville

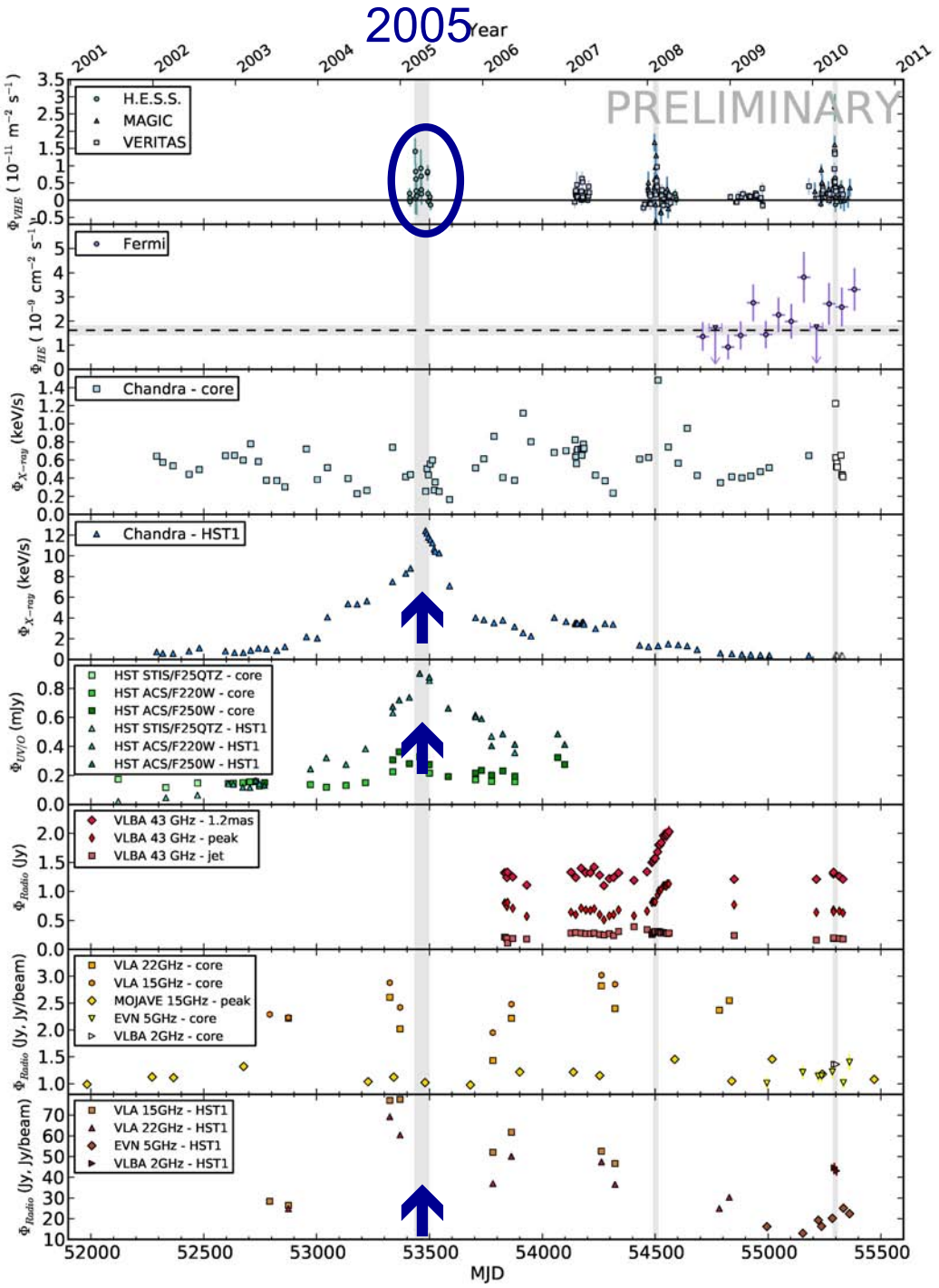
M87: 3 TeV Events





Credit: HESS, MAGIC, VERITAS, Fermi-LAT, many MWL partners

**see N. Galante's poster*



M87: 3 TeV Events

- 2005 TeV flare (HESS) coincided with X-ray/UV/radio flaring in knot HST-1 (>120 pc); Cheung et al. 2007

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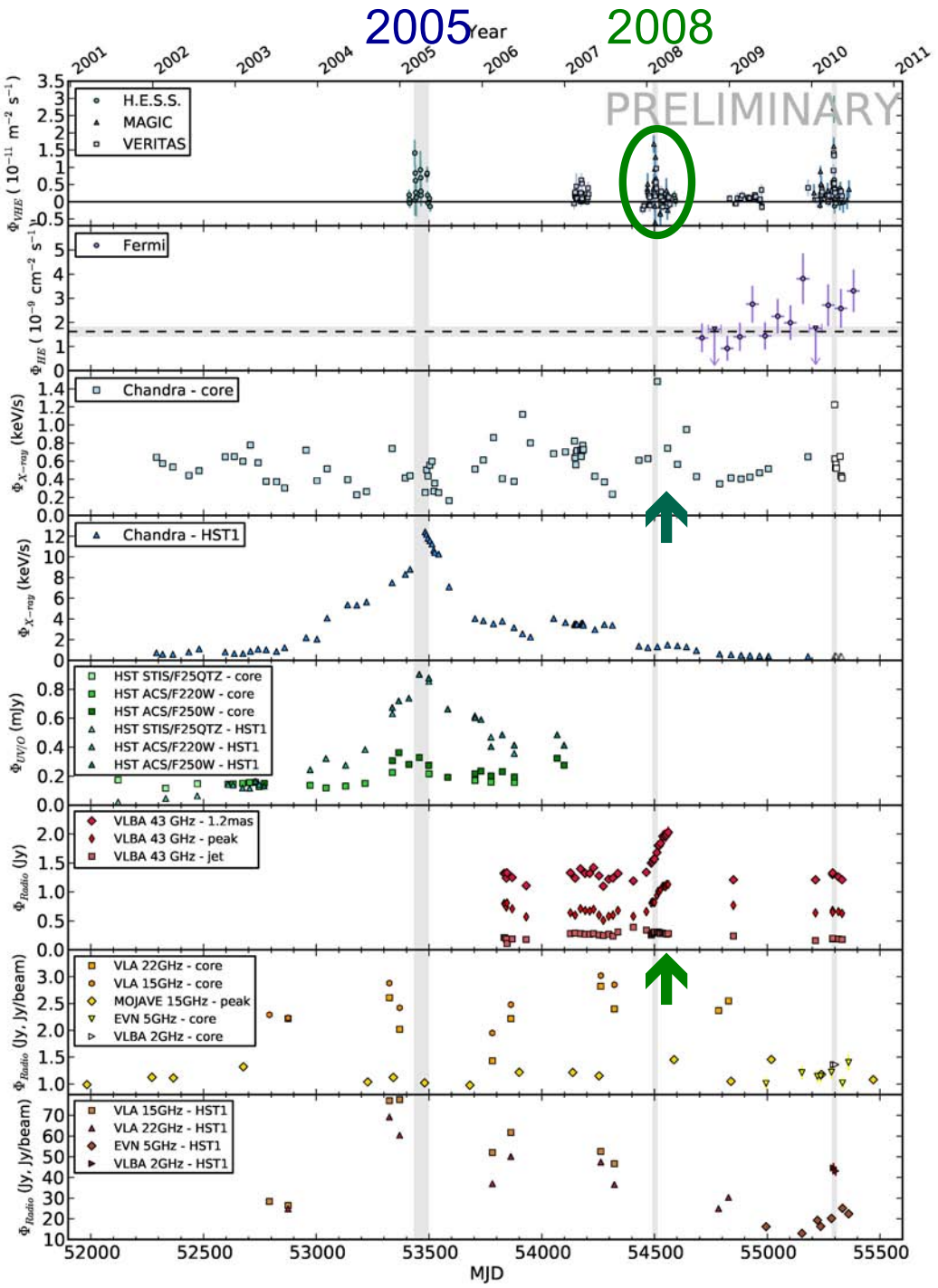
**see N. Galante's poster*



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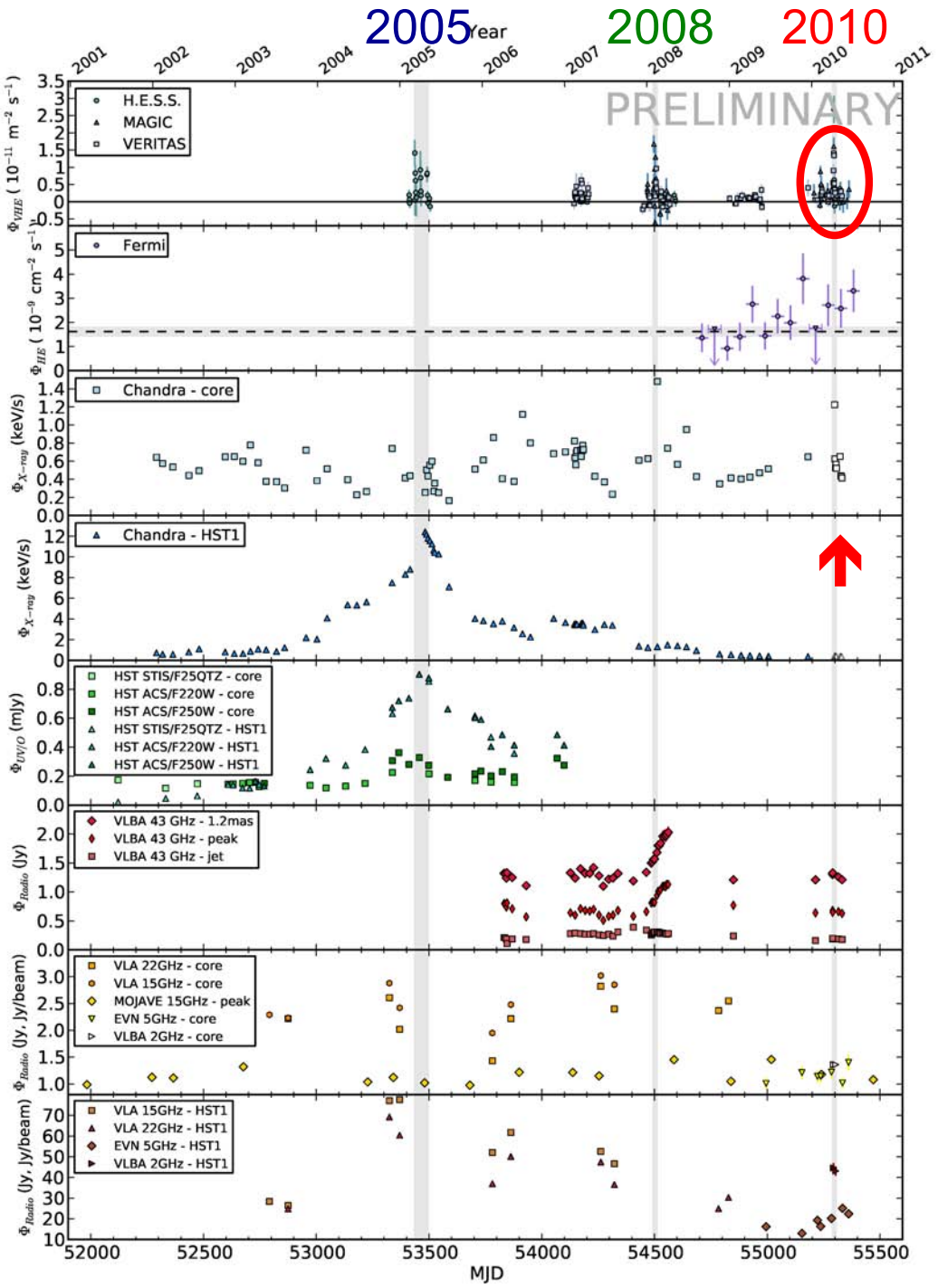
- 2008 TeV flare (VERITAS, MAGIC, HESS) coincided with radio flaring in core (sub-pc); Acciari et al. 2009

Credit: HESS, MAGIC, VERITAS, Fermi-LAT, many MWL partners

**see N. Galante's poster*



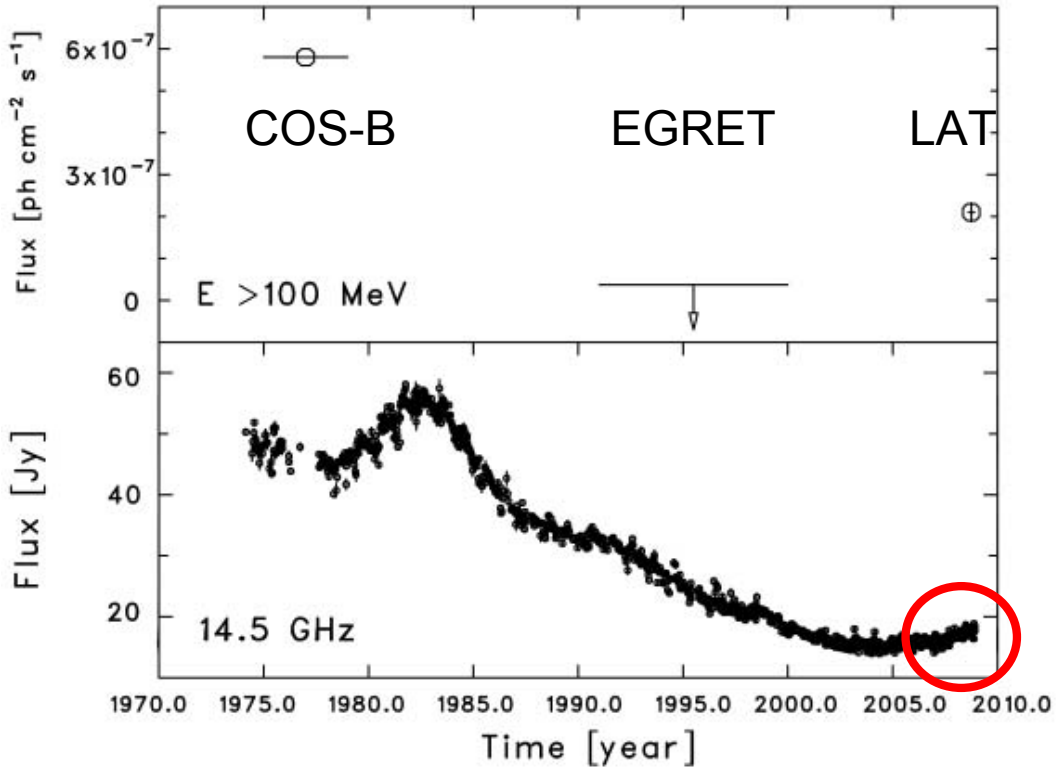
M87: 3 TeV Events

- 2005 TeV flare (HESS) coincided with X-ray/UV/radio flaring in knot HST-1 (>120 pc); Cheung et al. 2007
- 2008 TeV flare (VERITAS, MAGIC, HESS) coincided with radio flaring in core (sub-pc); Acciari et al. 2009
- 2010 TeV ~20% Crab (historical high) now with Fermi-LAT, VLBA, and Chandra coverage

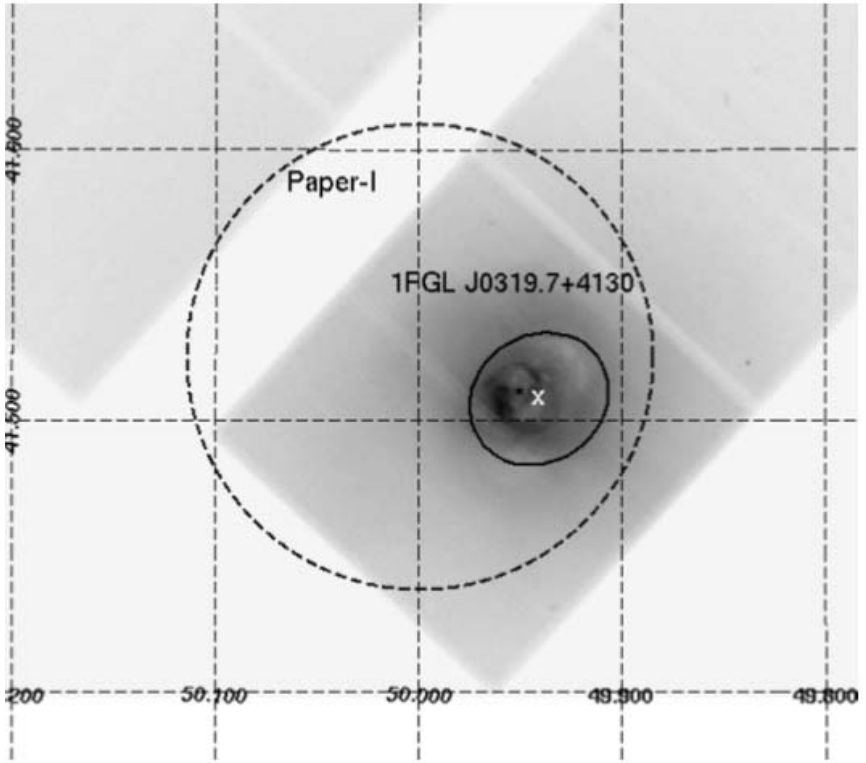
Credit: HESS, MAGIC, VERITAS, Fermi-LAT, many MWL partners

**see N. Galante's poster*

Gamma-ray Variability in NGC 1275 = 3C84



Year timescale γ-ray & radio variability

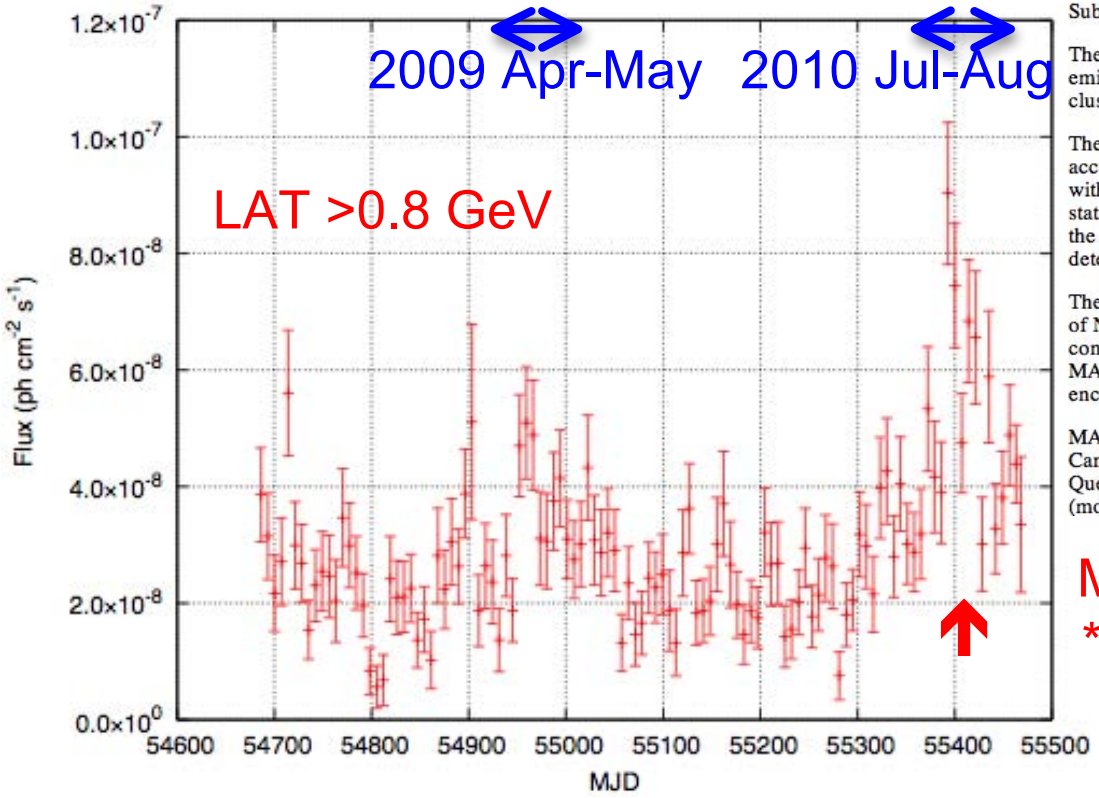


LAT 3-month & 11-month localizations (95%)

ApJ 2009, 699, 31: Lead: J. Kataoka, with MOJAVE team

NGC 1275: LAT 2-year View

- Flaring in 2009 with >GeV hardening (Kataoka et al. 2010)
- Brighter flare in 2010 (Donato et al. Atel 2737) with VHE detection



Brown & Adams (2011)

Discovery of Very High Energy Gamma-Ray Emission from NGC1275 by MAGIC

ATel #2916; *Mose Mariotti (INFN and Univ. of Padova) on behalf of the MAGIC Collaboration*
on 10 Oct 2010; 15:00 UT
Distributed as an Instant Email Notice Request For Observations
Credential Certification: Mosè Mariotti (mariotti@pd.infn.it)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Blazar, Cosmic Rays

The MAGIC Collaboration reports the detection of Very High Energy (VHE) gamma-ray emission from a position consistent with NGC 1275, the central radio galaxy of the Perseus cluster of galaxies.

The MAGIC observations were carried out in stereoscopic mode starting from August 2010, accumulating 14 h of good quality data. Preliminary analysis using the standard analysis chain with a energy threshold of 100 GeV, shows an excess of 280 gamma-rays, corresponding to a statistical significance of 5.2 standard deviations. The observed flux is estimated to be ~3% of the Crab nebula flux above 100 GeV, and it decreases rapidly with energy. No signal is detected above 400 GeV.

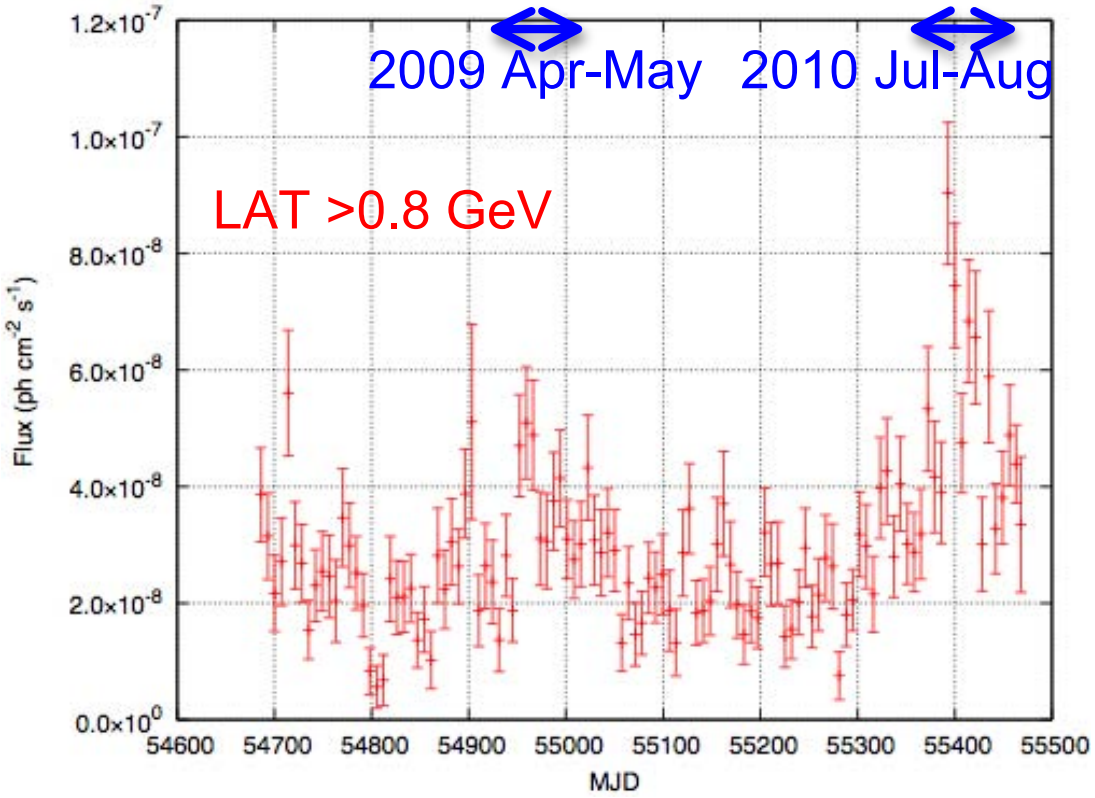
The MAGIC VHE detection happened during a period of increased high gamma-ray activity of NGC 1275, as reported in July 2010 by the Fermi/LAT collaboration, ATel#2737, and continuing until October, according to an analysis of public Fermi/LAT data.
MAGIC will continue observations of NGC1275. Observations at other wavelengths are encouraged.

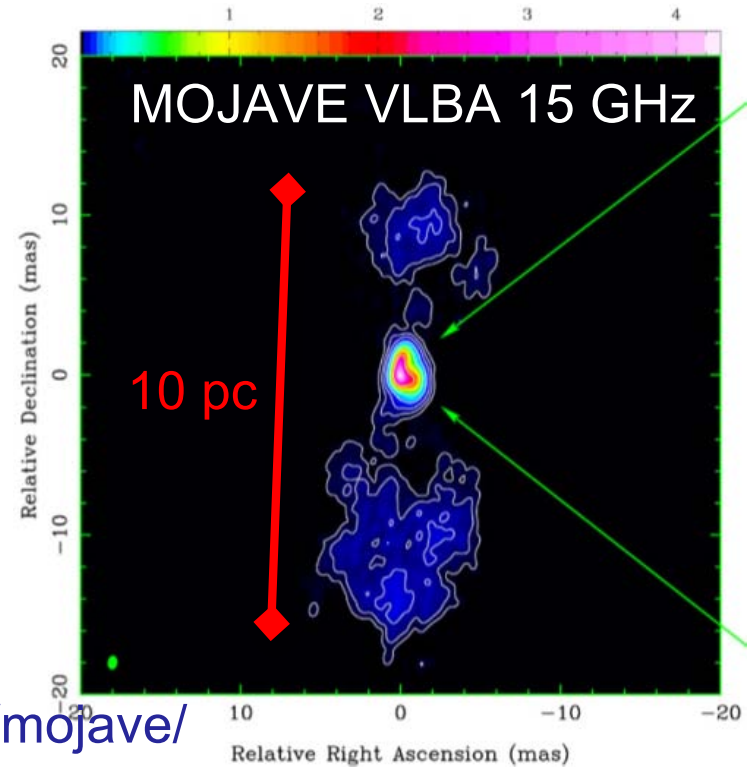
MAGIC consists of two 17m diameter imaging air Cherenkov telescopes located on La Palma, Canary Islands, Spain.
Questions regarding the MAGIC observations should be directed to Mose Mariotti (mose.mariotti@pd.infn.it)

MAGIC VHE detection
** See Lombardi et al. poster*

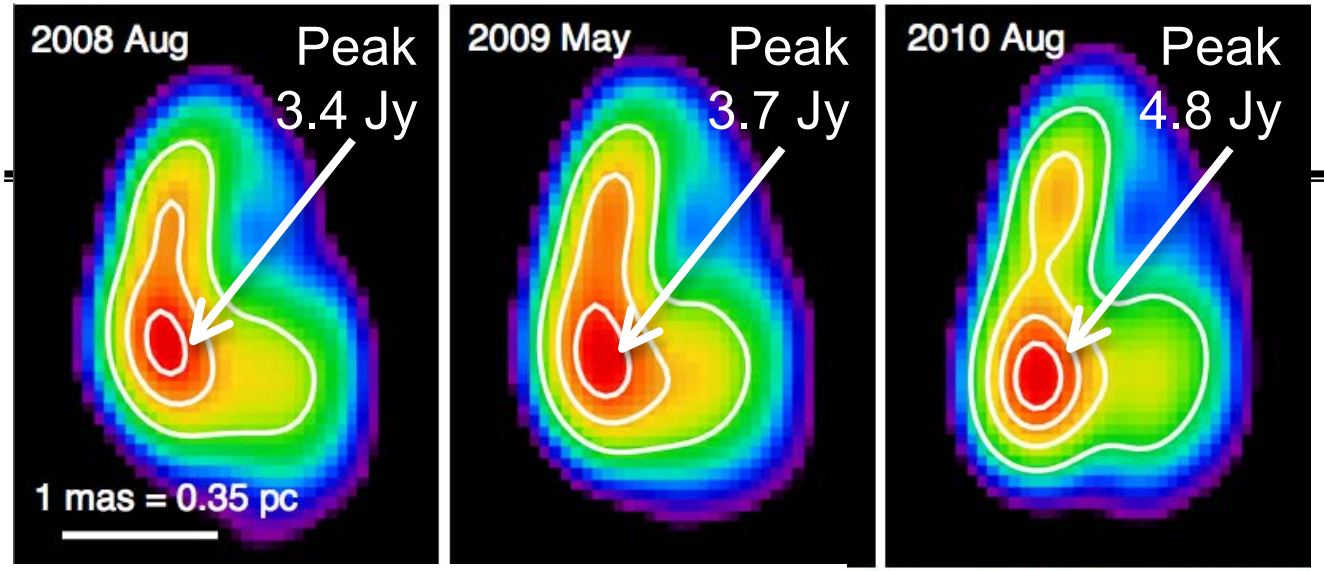
Previous VERITAS and MAGIC limits
Acciari et al. 2009, Aleksic et al. 2010

Correlated Radio Flares?

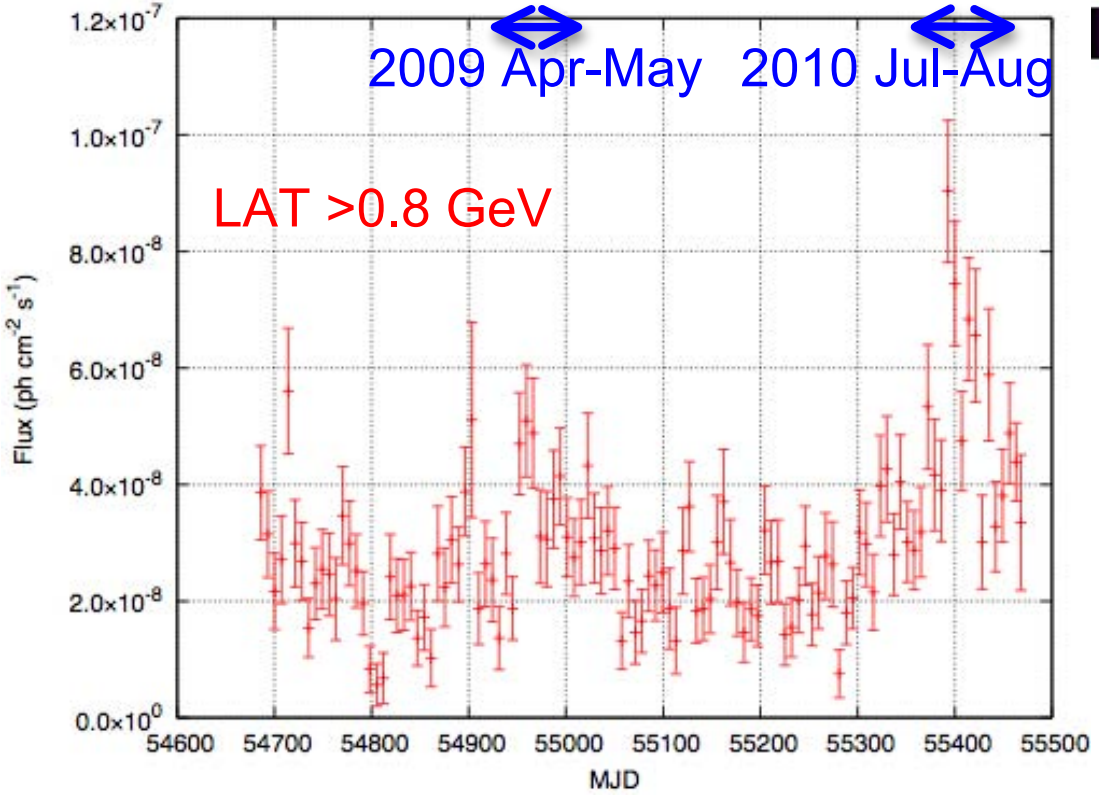


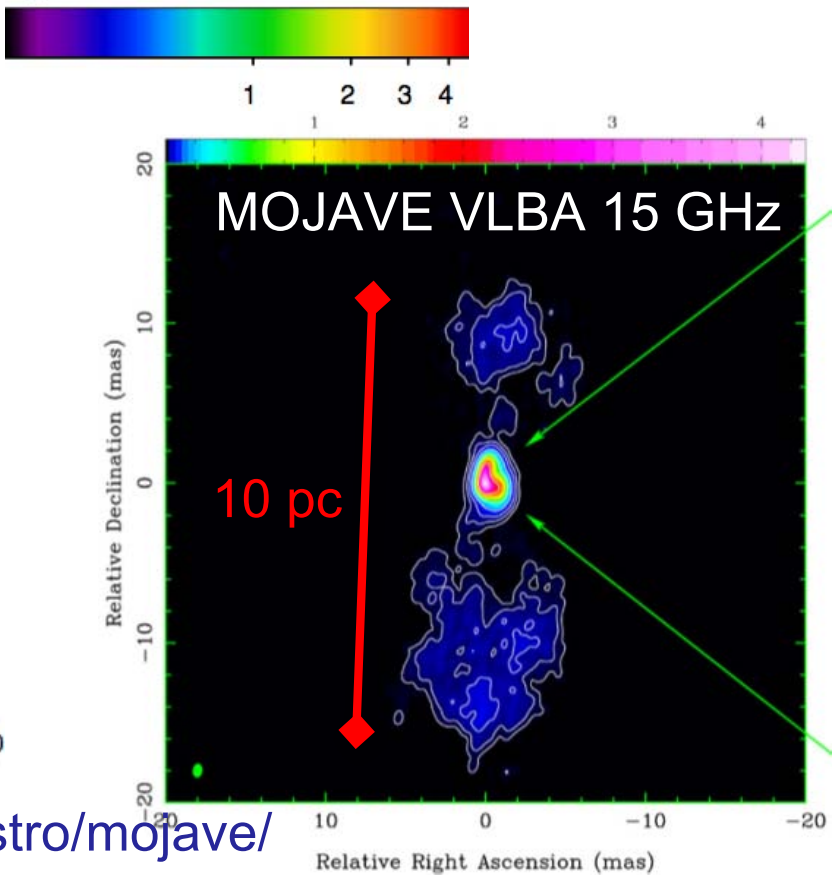


MOJAVE: https://www.physics.purdue.edu/astro/mojave/



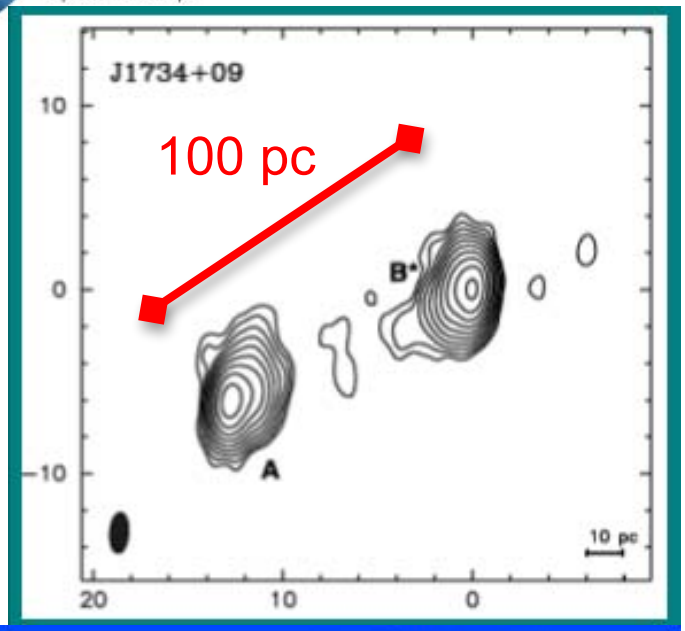
Young Radio Source?

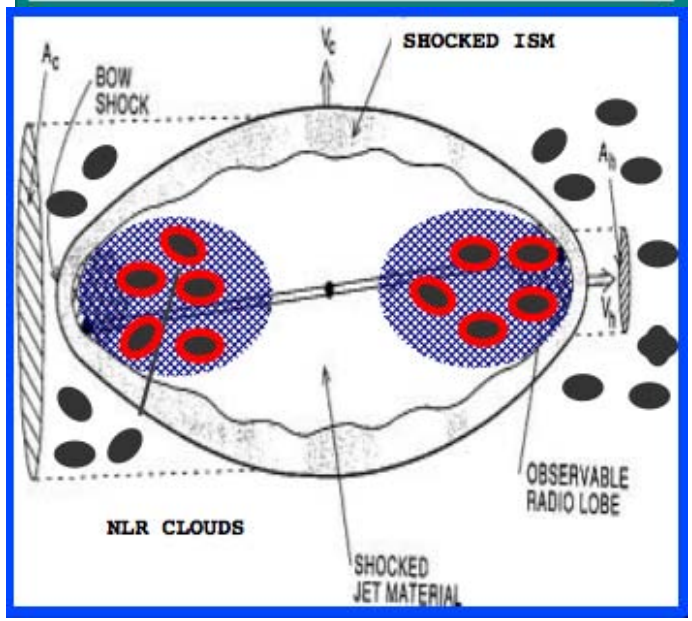




MOJAVE: https://www.physics.purdue.edu/astro/mojave/

Gamma-rays from Young Radio Sources?



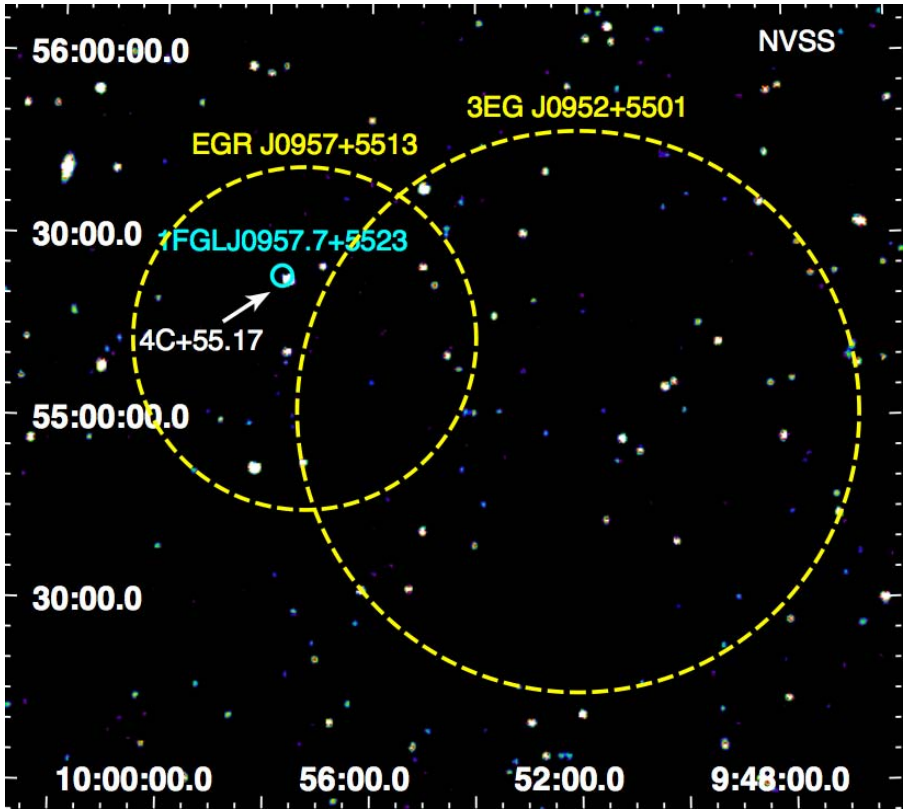


- Compact (<1 kpc – 10's kpc) radio sources constitute large fraction in cm-wavelength surveys
- These "GPS/CSS" sources are powerful, $L_{5\ GHz} > 10^{25}$ W/Hz (FR-II radio galaxies in miniature)
- Intrinsically small and powerful (negligible projection and Doppler effects)
- Model expectations for gamma-rays in lobes – leptonic (Stawarz et al. 2008) and hadronic (Kino et al. 2007, 2009)

Gugliucci et al. (2005), Begelman & Cioffi (1989)

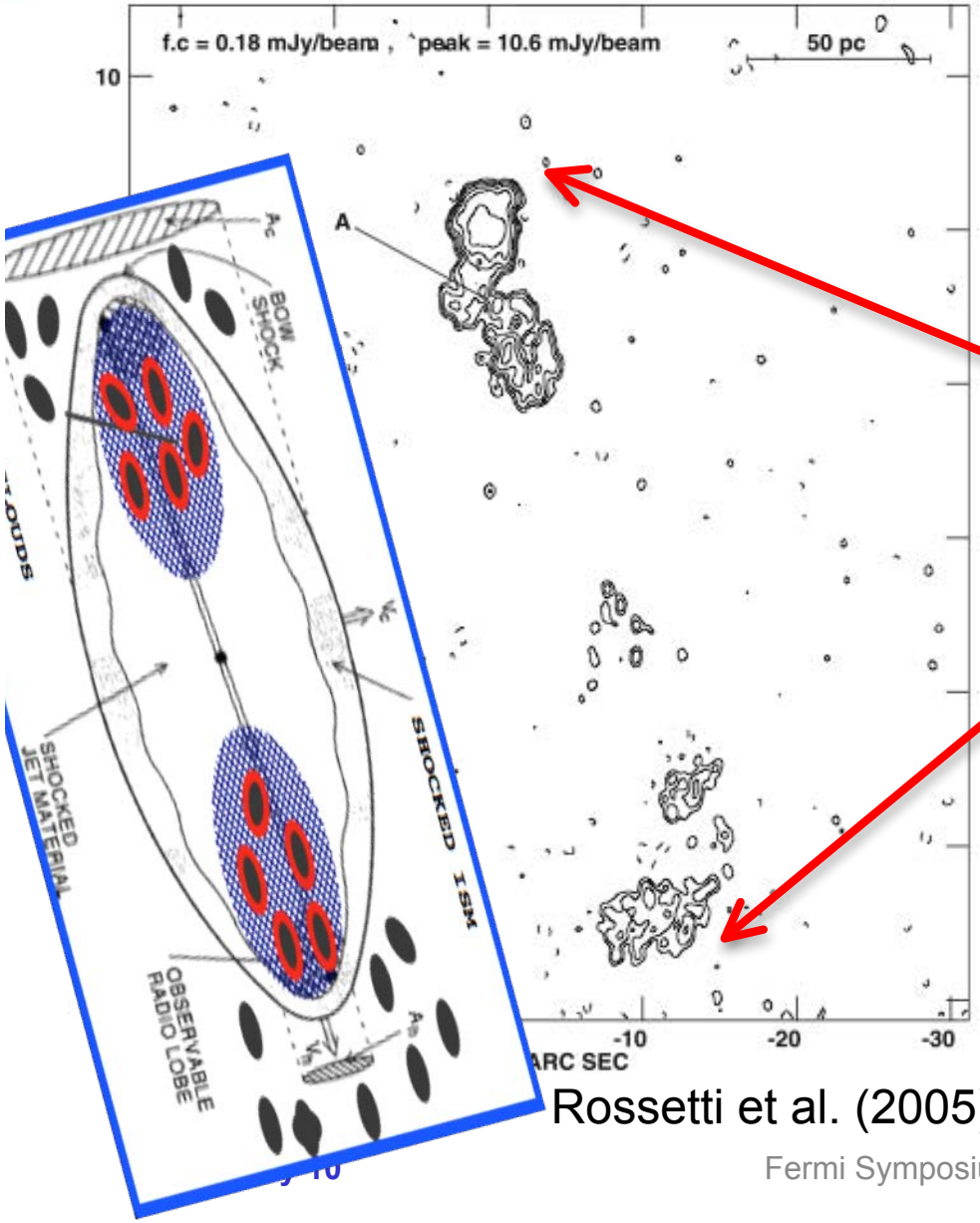
4C+55.17: a Young Radio Source?

- Flat-spectrum radio quasar, z=0.9
- VLBI extent ~400 pc, projected



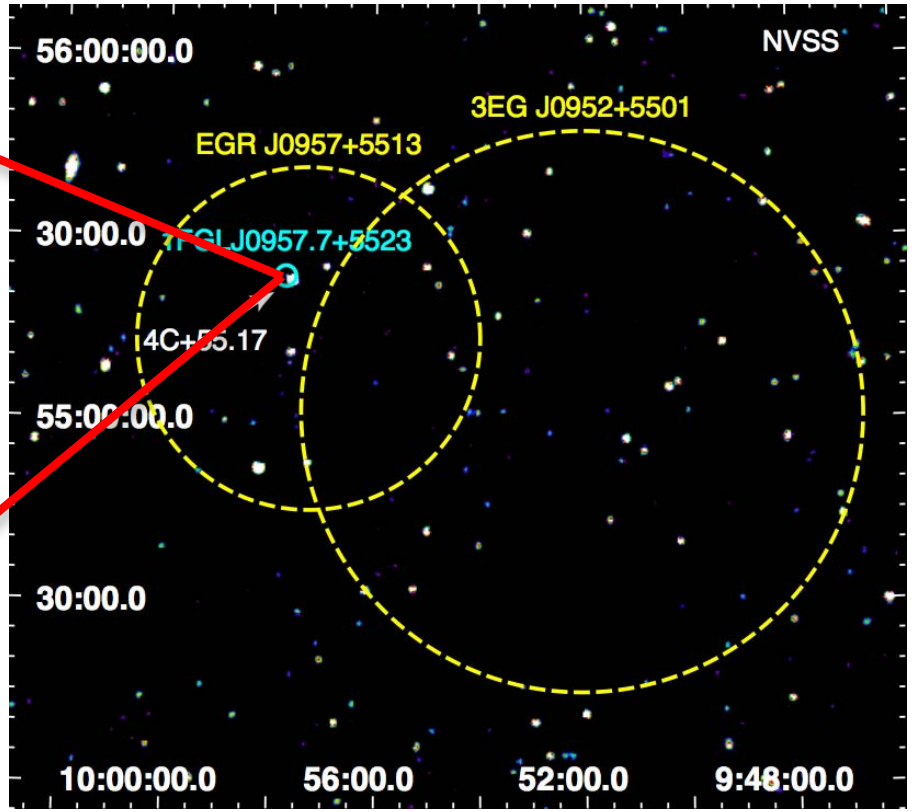
*see W. McConville poster

4C+55.17: a Young Radio Source?



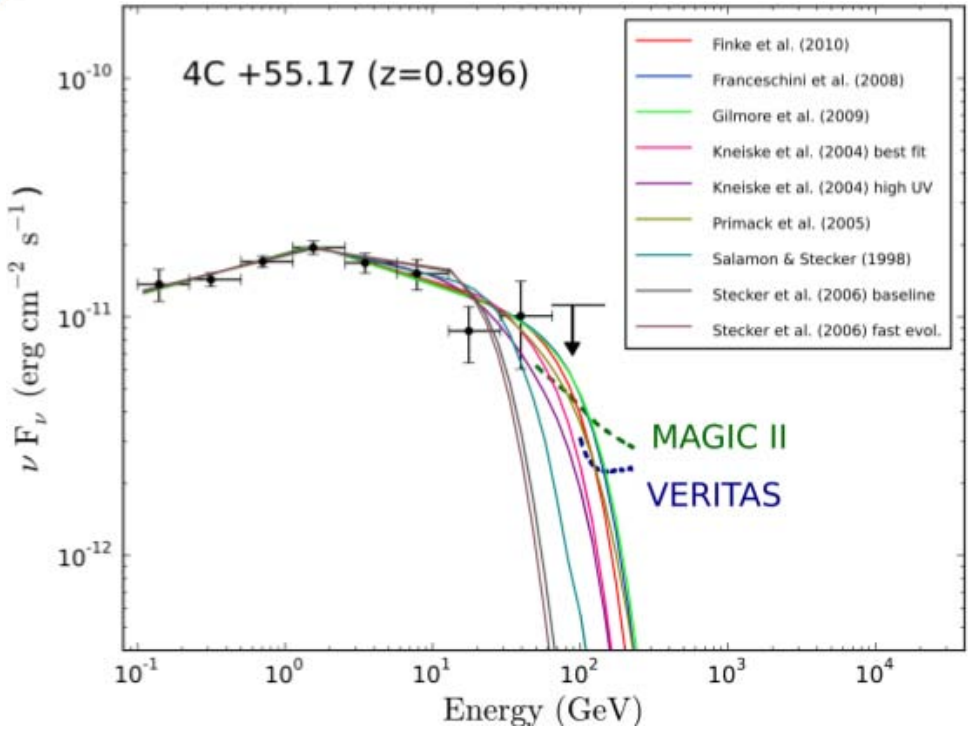
Rossetti et al. (2005)

- Flat-spectrum radio quasar, z=0.9
- VLBI extent ~400 pc, projected

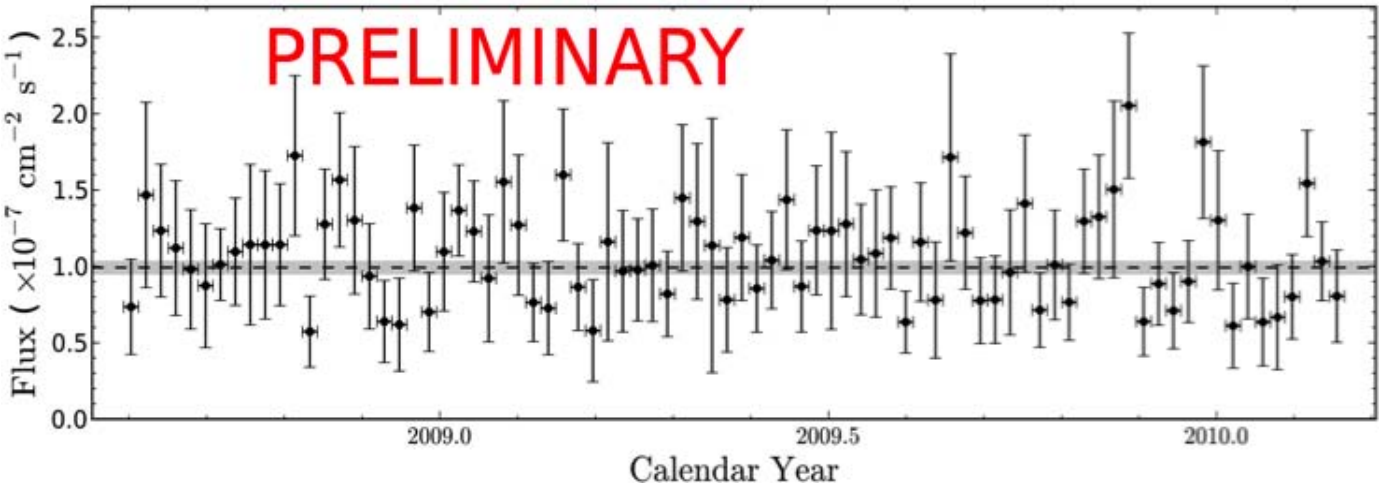


*see W. McConville poster

4C+55.17: an Unusual LAT AGN



- Brightest steady LAT detected γ-ray AGN, after Cen A
- Hard MeV/GeV spectrum (especially for a quasar)
- LAT VHE detection of 145 GeV photon (275 GeV rest frame)
- Gamma-ray lobe emission?



McConville et al., submitted

Non-Blazar ("Other") AGN

- Radio galaxies as an emerging γ−ray source population from Fermi-LAT
- γ−ray site and emission mechanism from LAT imaging
- Constraints from γ−ray and multi-wavelength variability
- Young radio sources as candidate γ−ray sources
  - see radio galaxy presentations by N. Galante, P. Grandi, J. Kataoka (talk), S. Lombardi, J. Perkins, [others?]
  - see young radio source presentations by W. McConville, M. Orienti
  - RG contribution to MeV background – AGN (Bhattacharya poster, Inoue poster), lobes (Massaro & Ajello poster)
  - UHECRs from nearby LAT AGN (Nemmen poster)

- Radio-loud narrow line Sy1s (Cavazzuti & Ghisellini talk; Foshini talk)
- Nearby AGN with dominant starbursts emitting γ-rays (2010 ApJL 709, L152)
- No clear cluster γ-ray emission detected so far (2010 ApJ 717, L71); Hydra A (poster by M. Ali)