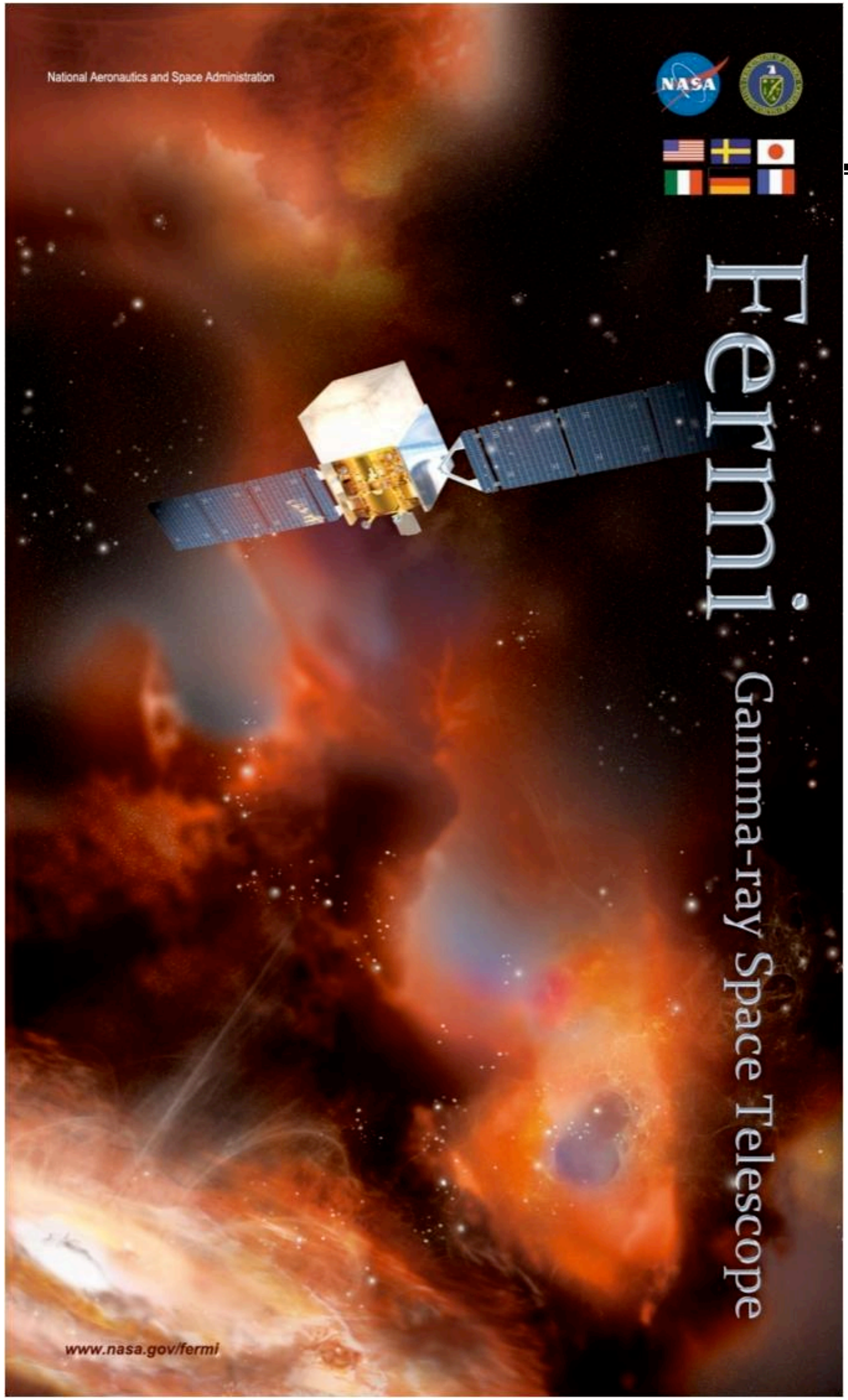


Steep Spectrum Radio Sources with the Fermi-LAT

Elisabetta Cavazzuti
ASI Science Data Center

on behalf of the *Fermi*-LAT collaboration

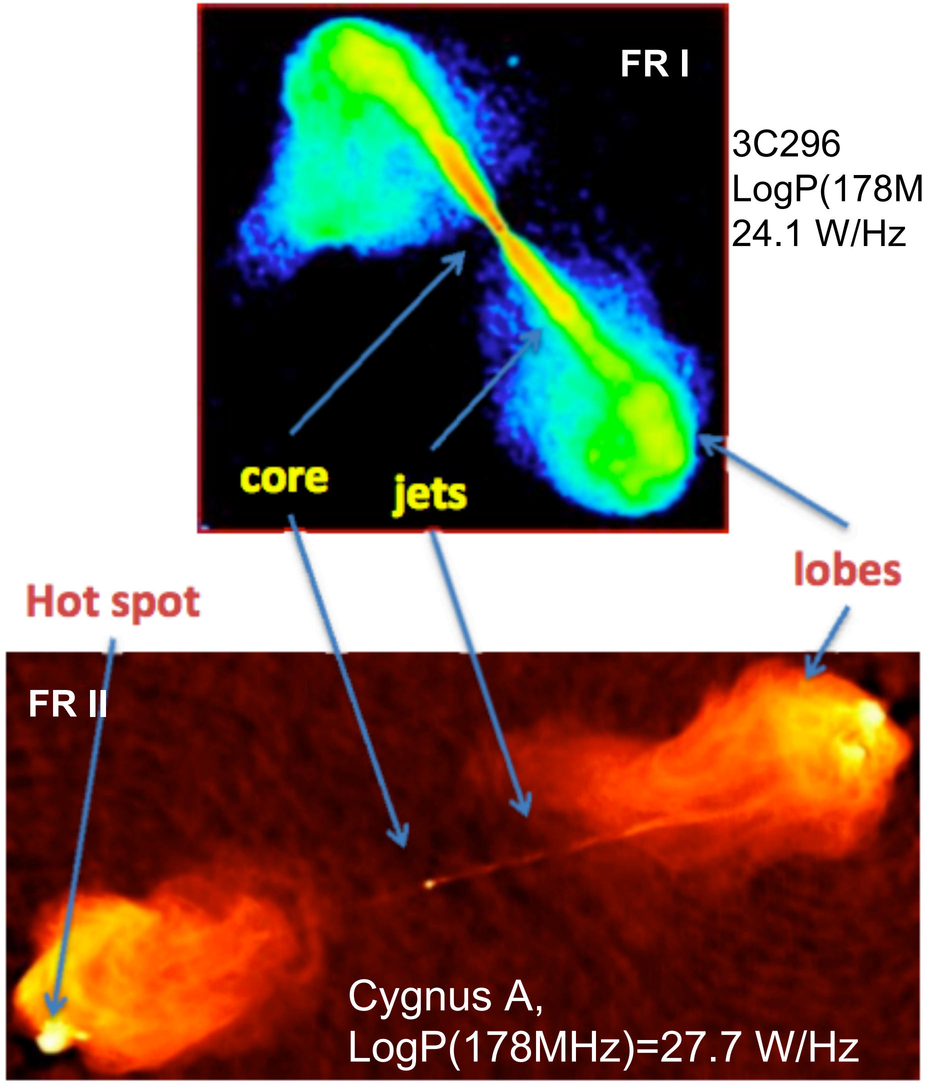
Radio morphological classification

Fanaroff & Riley (1974, MNRAS, 167, 31) divided extended radio sources into the following two structural classes:

FR I: The separation between the points of peak intensity in the two lobes is smaller than half the largest size of the source. (R<0.5) .

FR II: The separation between the points of peak intensity in the two lobes is greater than half the largest size of the source (R>0.5).

A fiducial power separation between FRI and FRII is assumed to be at P178 MHz = Log 26.3 Watt Hz-1



3C296
LogP(178Mhz)=
24.1 W/Hz

Radio spectral classification

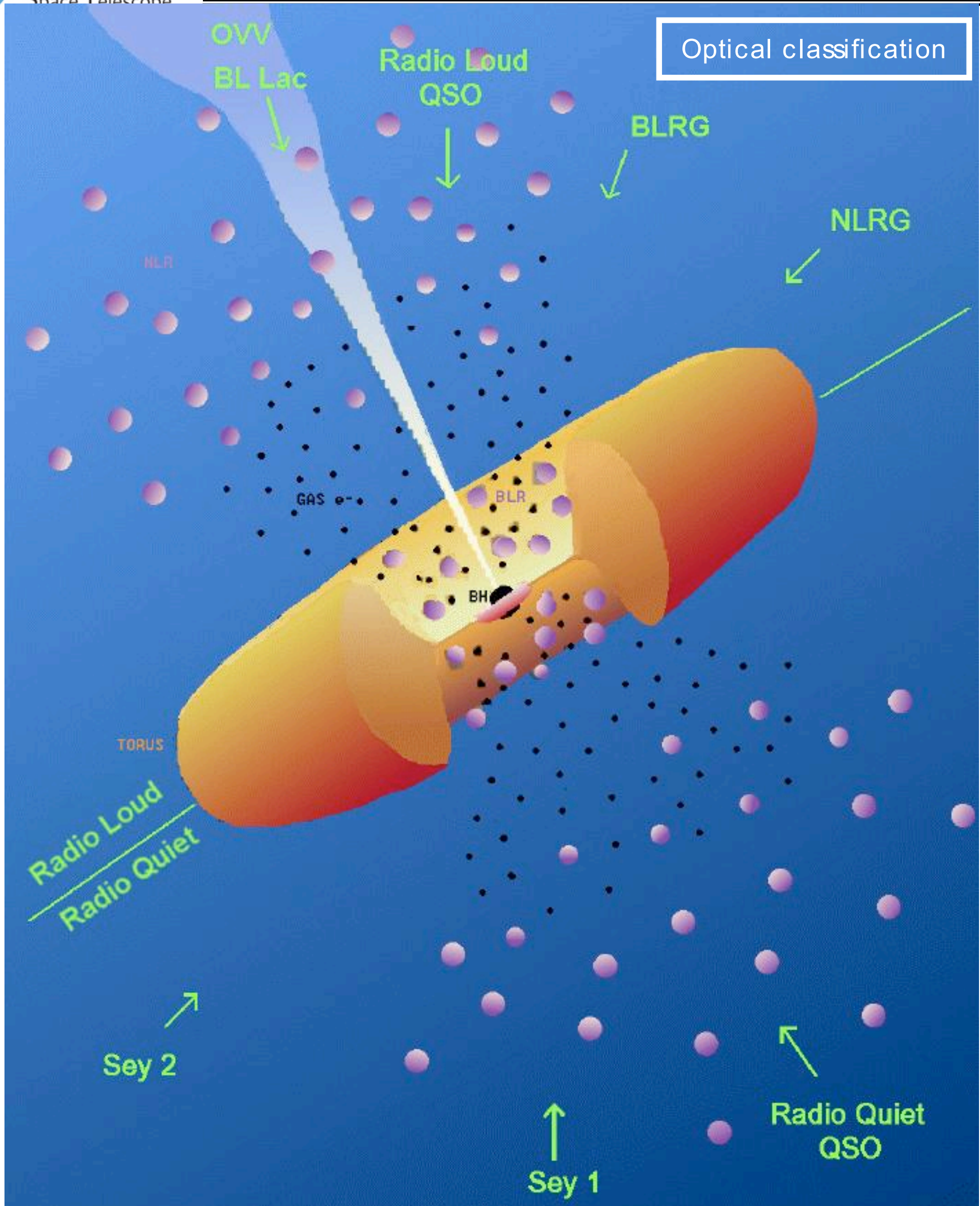
- **Flat-Spectrum Sources (α_r<0.5)**
  - Sources with flat or inverted radio spectrum, signature of a compact radio core
  - Little or negligible jet viewing angle

- **Steep-Spectrum Sources (α_r>0.5)**
  - Typical objects are found in low-frequency surveys, able to capture optically thin synchrotron emission (radio lobes)
  - Larger jet viewing angle

Spectral and morphological classification are complementary. The advantage of the former is that it can be used also to large samples with objects with no radio image available.

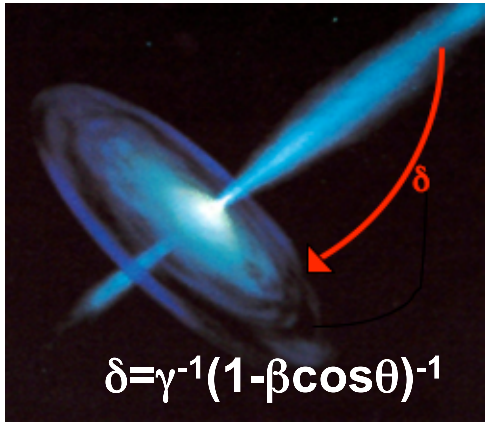
- Both approaches are used in this work

AGN Unified model



[from Urry & Padovani 1995, PASP, 107, 803].

- **small viewing angle**:
  - high Doppler factor (**δ)**
  - Expected gamma-ray emission (BL Lac, FSRQ)
    - **FR I** are considered the parent population of **BL LAC**
    - **FR II** are considered the parent population of **FSRQs**



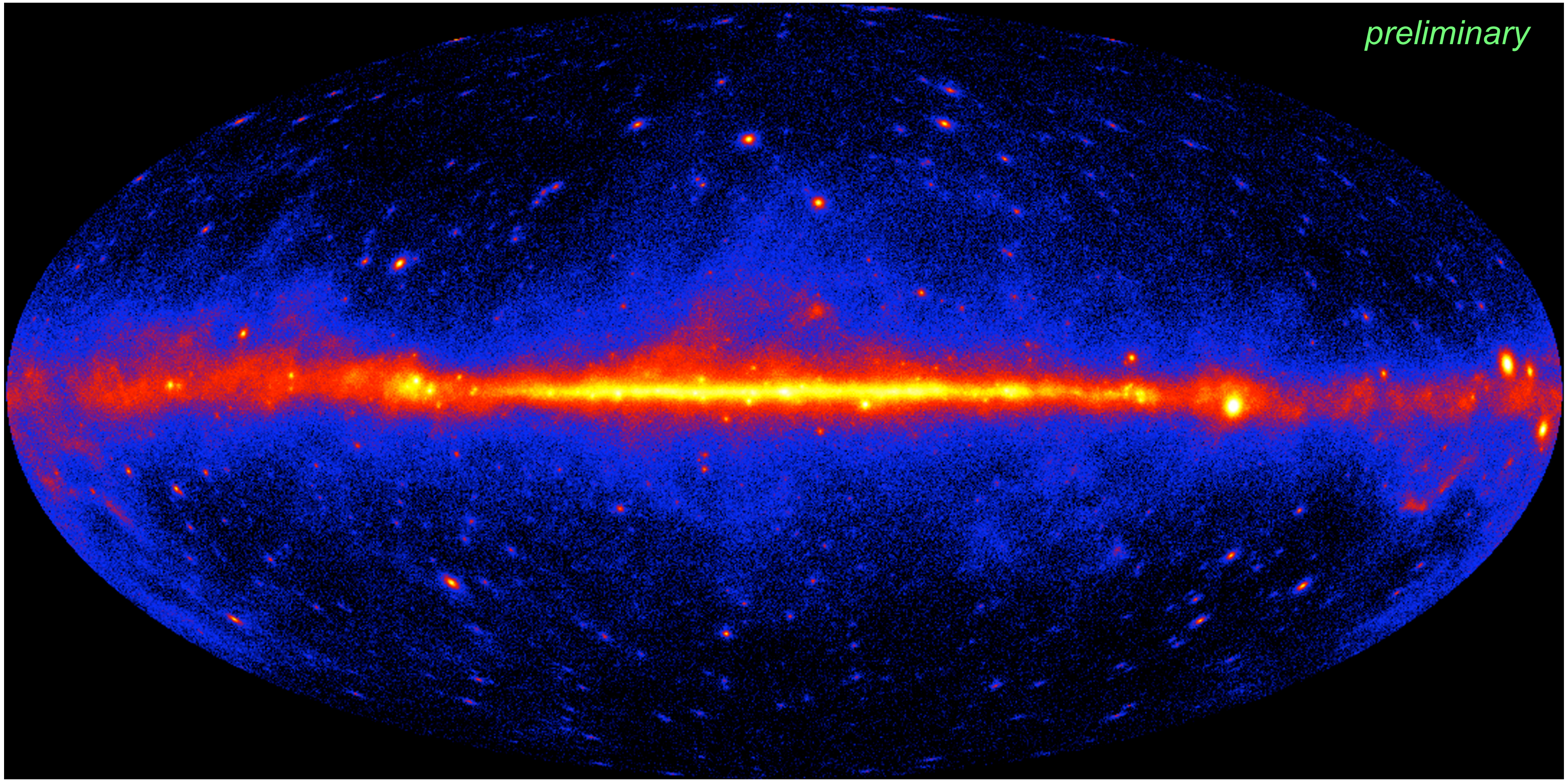
- **large viewing angle**:
  - smaller doppler beaming (FRI, FRII, BLRG/SSRQ, NLRG…)
  - no/little gamma-ray emission ?

  (this is the question…)

Elisabetta Cavazzuti

Fermi-LAT data

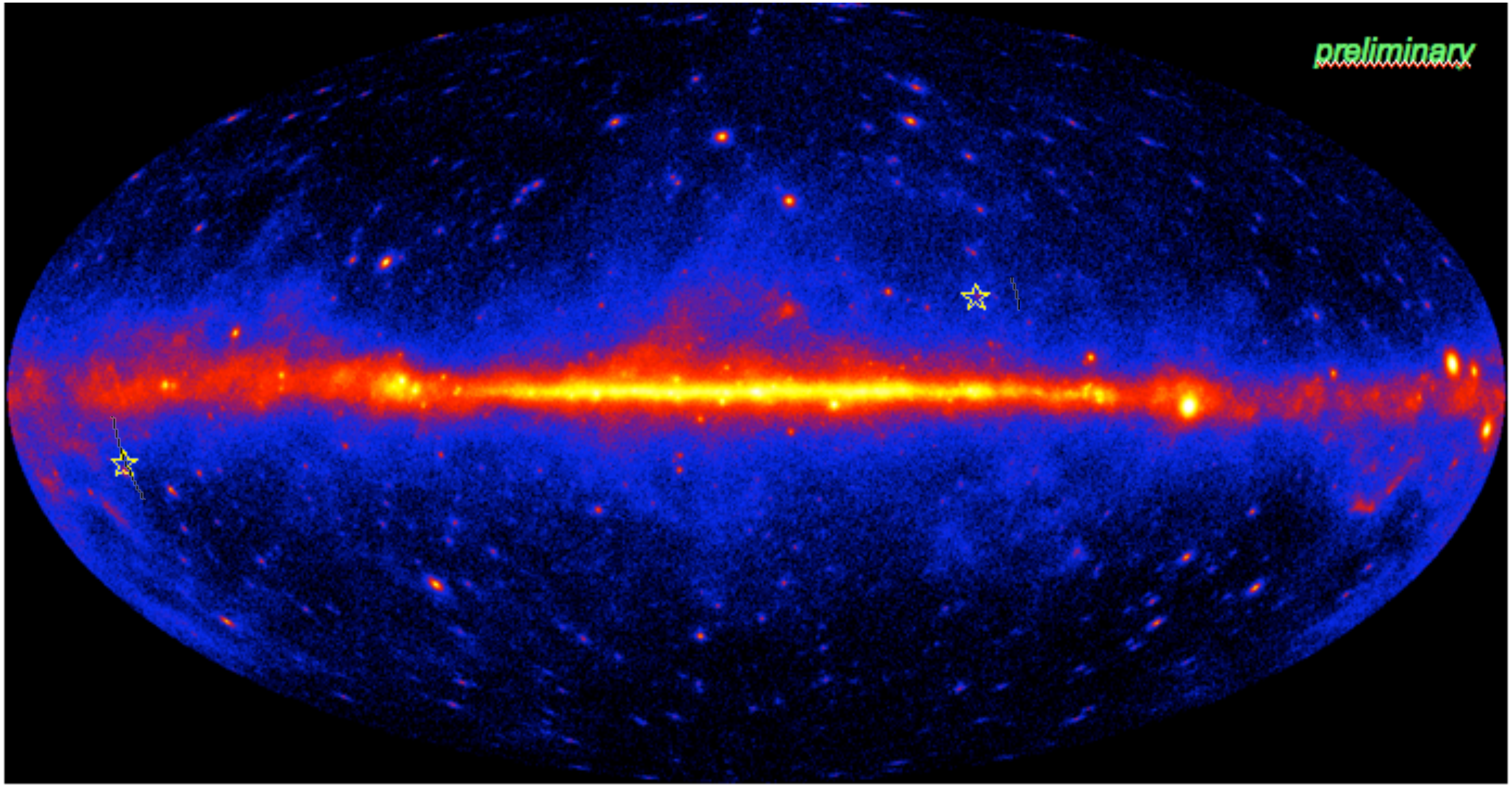
LAT source associations come from the preliminary 1 year source list



1 year all sky map with the Fermi-LAT SSRS preliminary detected sources

Fermi-LAT data

LAT source associations come from the preliminary 1 year source list



1 year all sky map with the Fermi-LAT SSRS preliminary detected sources

Fermi-LAT data

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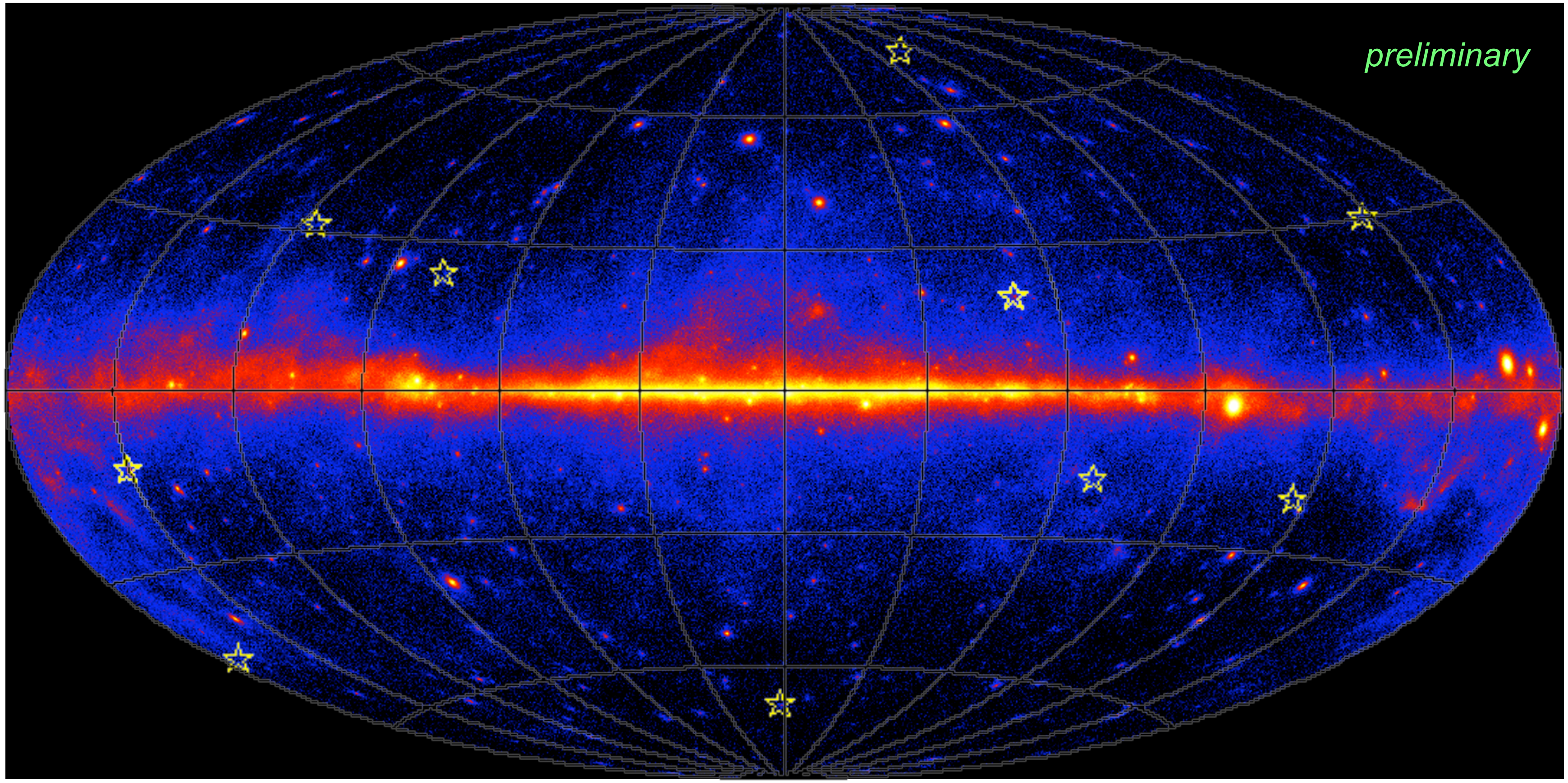
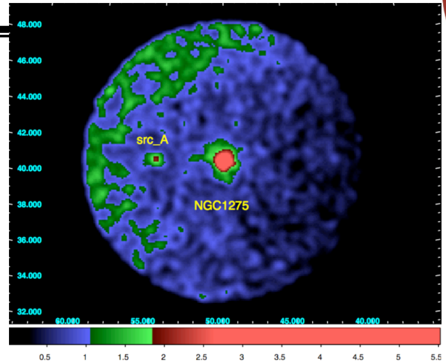


1 year all sky map with the Fermi-LAT SSRS preliminary detected sources

Fermi-LAT SSRS preliminary associations

preliminary

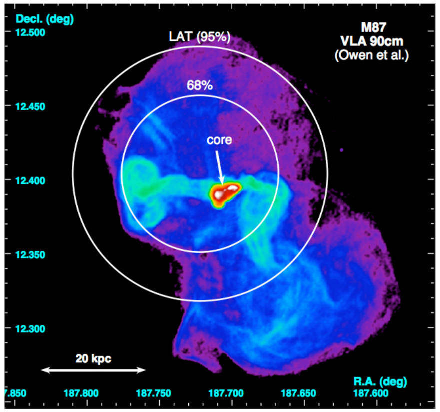
Name	Former gamma	Morphol. class
HIGH CONFIDENCE		
NGC 1275	COS-B	FRI
Cen A	EGRET	FRI
M 87		FRI
PKS 0625-354		FRI
NGC6251	EGRET	FRI/II
3C 207		FRII
3C 380		FRII
3C 407		FRI/II
3C 120		FRI
LOW CONFIDENCE		
3C 78		FRI
PKS 0943-76		FRII
PKS 1257-326		FRI

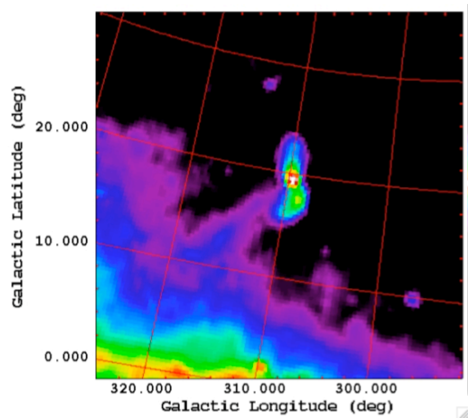


See J. Kataoka poster

See J. Fink poster and T. Cheung talk

See W. McConville poster



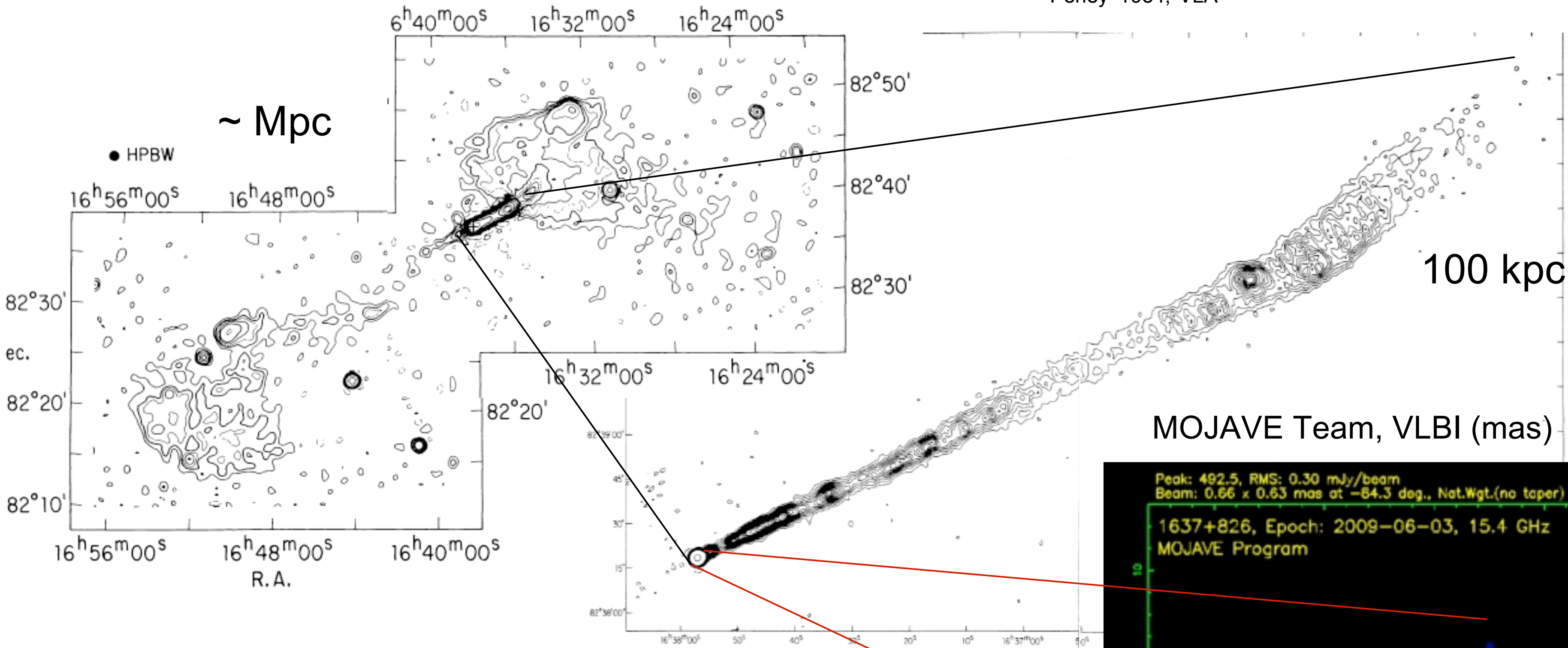


In the next slides I will discuss only on those sources for which we were able to evaluate a spectrum

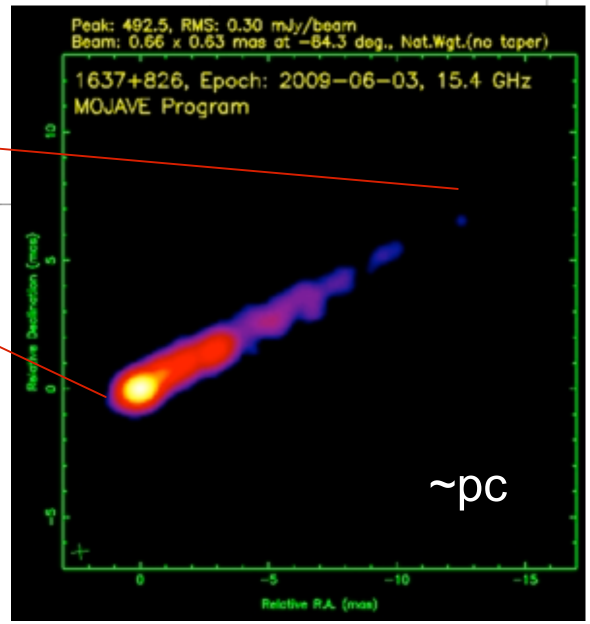
NGC 6251: an example of detected FR I

Radio map at 610 MHz with 50' resolution (from Willis et al. 1982)

Perley 1984, VLA



MOJAVE Team, VLBI (mas)



Viewing angle ~45° (Sudou & Taniguchi 2000)

S5 1637+82, 3EG J1621+8203 (Mukherjee et al. 2002)

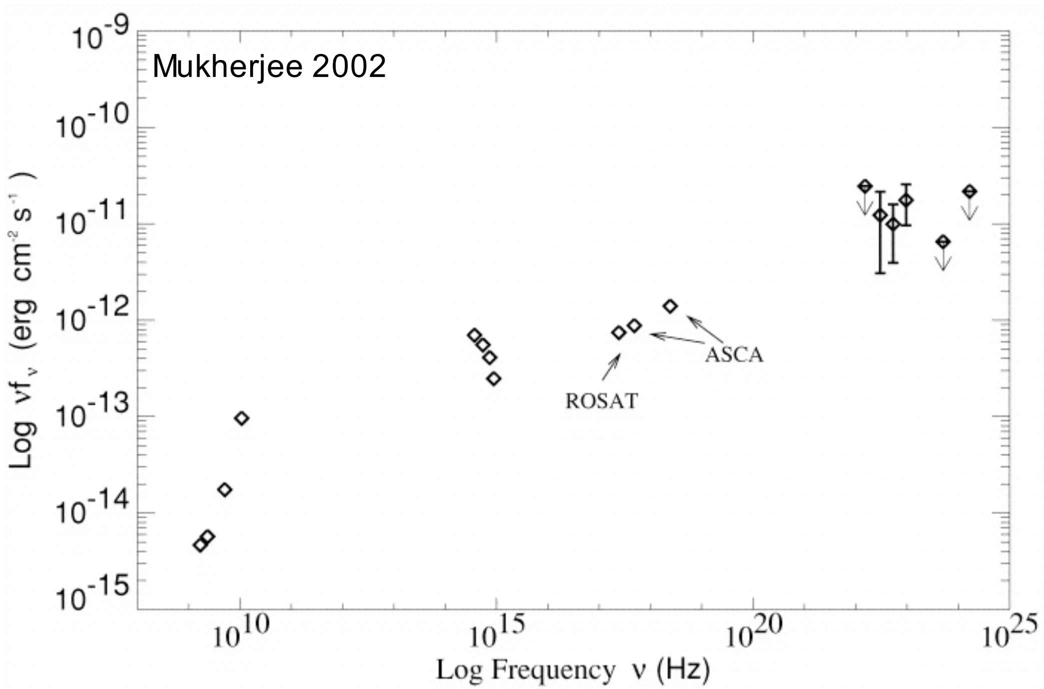
z=0.0247

S_VLA_1.4 GHz: 2.3 Jy

S_178 MHz: ~10.9 Jy (LogP=23.98)

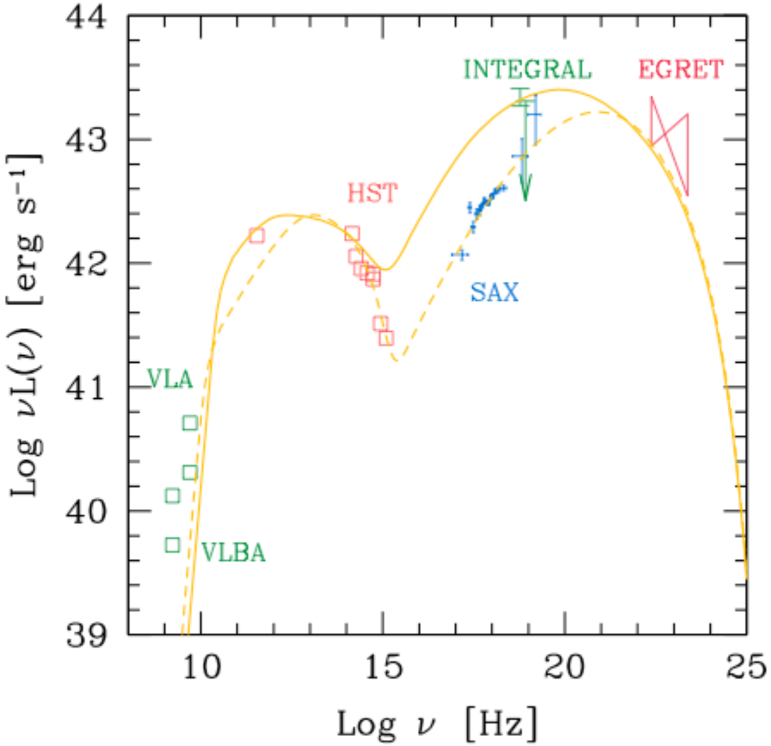
S_MOJAVE 15 GHz: 0.80 Jy

NGC 6251: an example of detected FR I



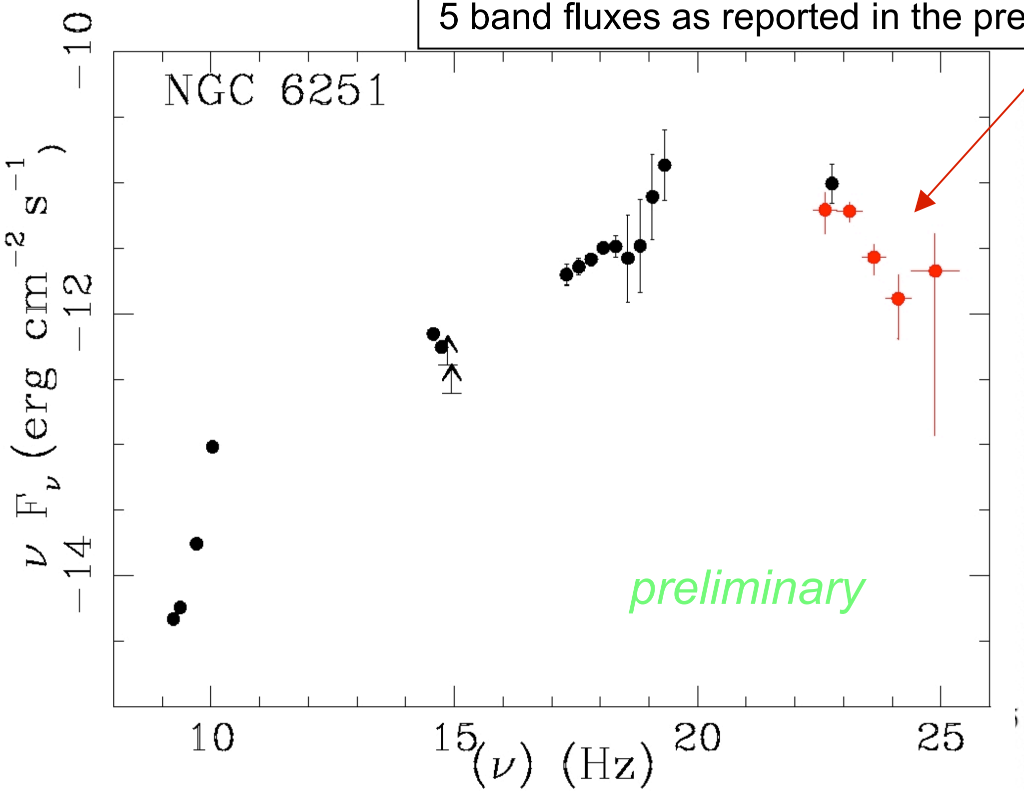
NGC 6251: an example of detected FR I

Foschini et al A&A 433, 515, 518 (2005)

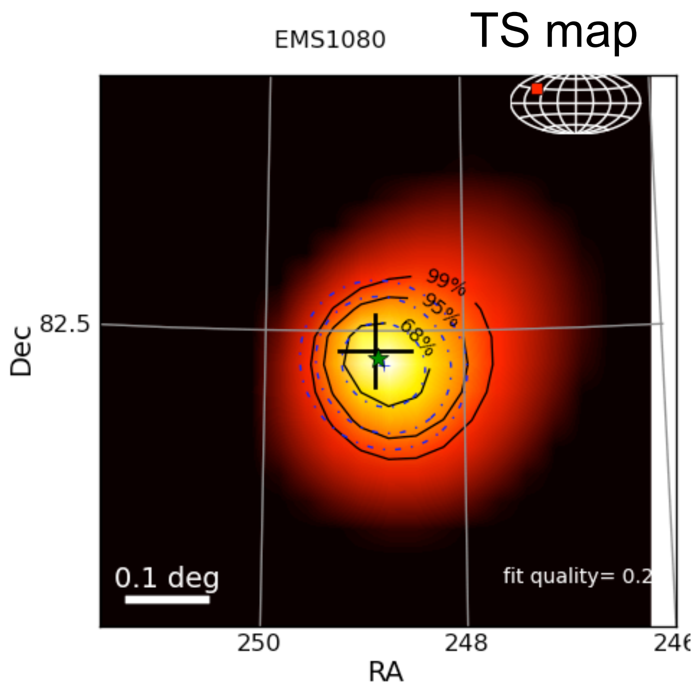


NGC 6251: an example of detected FR I

5 band fluxes as reported in the preliminary 1st year source list



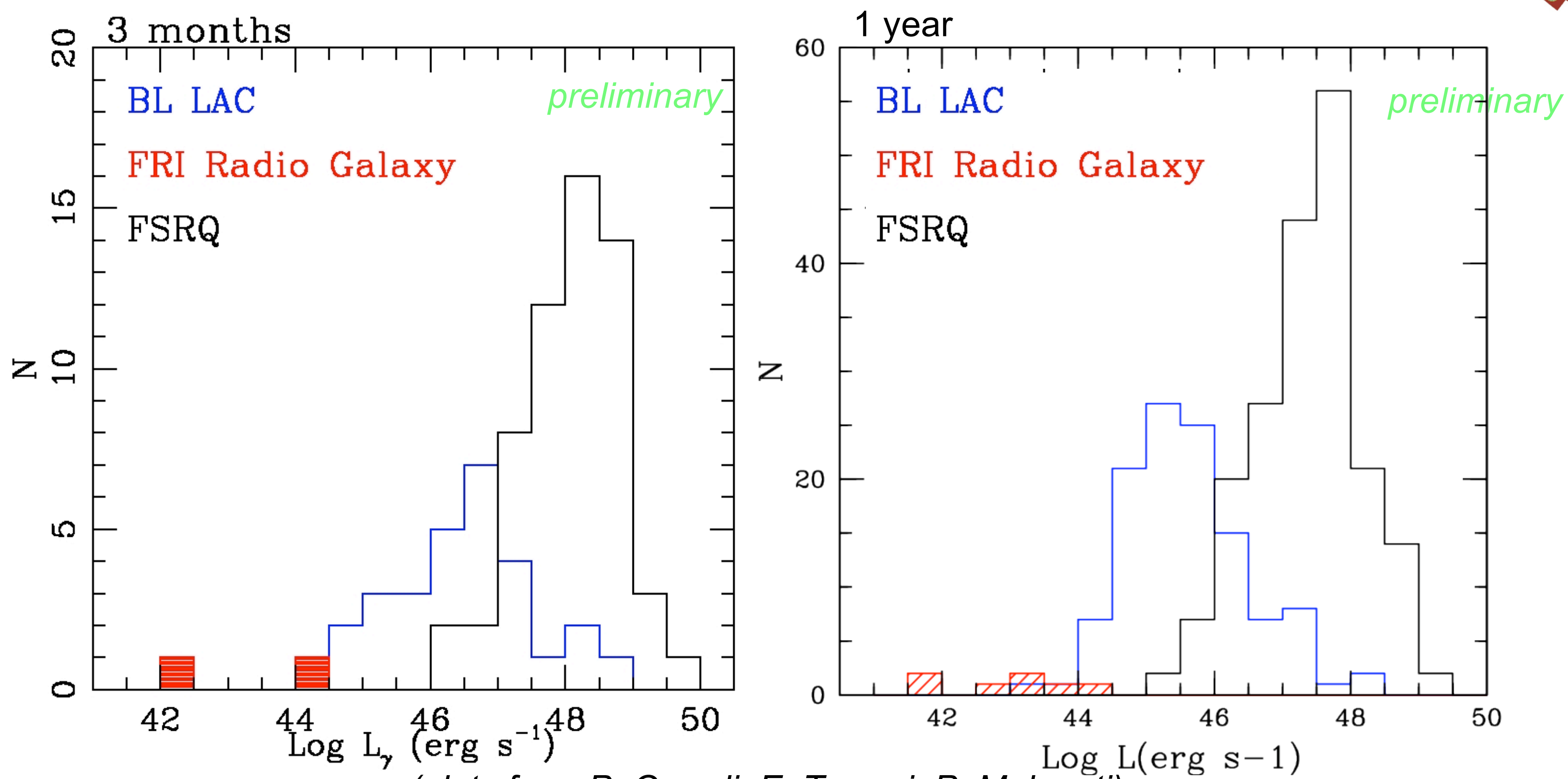
(SED from P. Grandi, E. Torresi, P. Malaguti)



(see poster T. Burnett)

Their overall **SED** appears **dominated by double-peaked non-thermal emission**, **in spite of the misalignment** between the jet axis and the observer line-of-sight suggested by the extended radio morphology.

FR I: preliminary results (1)

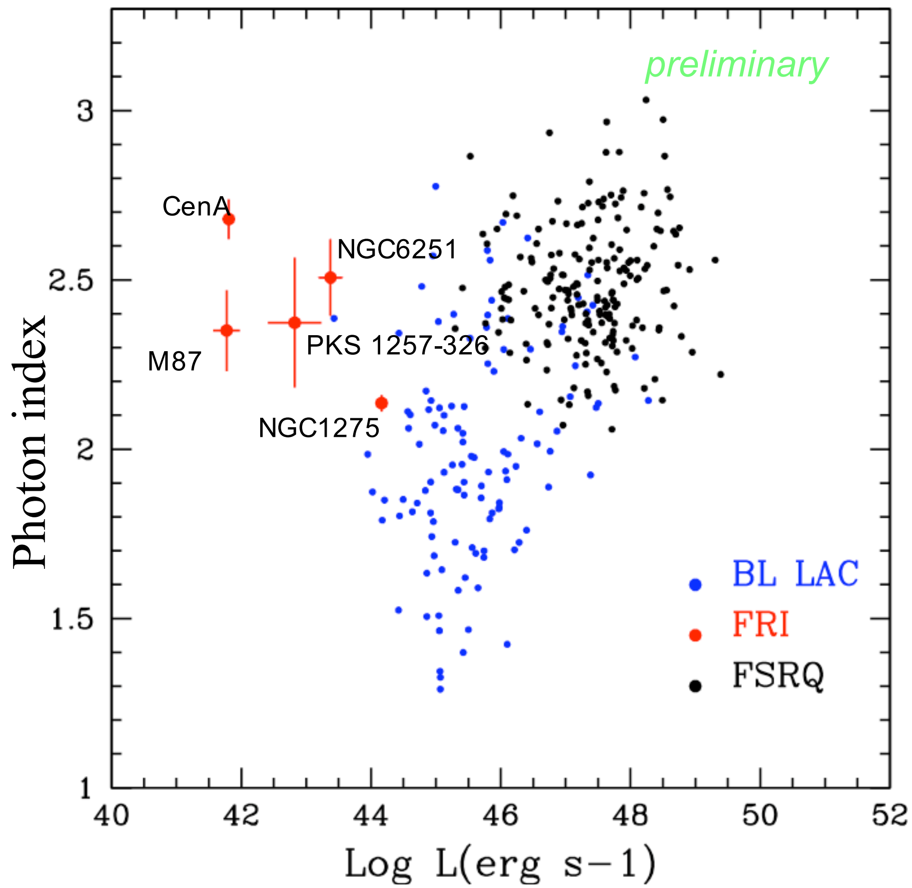


(plots from P. Grandi, E. Torresi, P. Malaguti)

FR I in these plots come from cross-correlations with known radio-catalogues (the revised **3CR sample** (Bennett A. S. 1962, MNRAS, 125,75; Spinrad et al. 1965, PASP, 97, 932) , the **3CRR sample** (Laing et al. 1983, MNRAS, 204,151) and the **Molonglo Southern 4 Jy sample** (MS4; Burgess & Hunstead 2006, AJ 131, 100).

When compared to **BL LAC** objects the **FR I** radiogalaxies occupy the low tail of the gamma-luminosity distribution.

FR I: preliminary results (2)



preliminary

Table 1: *PROPERTIES OF THE FRI SOURCES DETECTED IN 11 MONTHS*

Observables	Min value	Max value
Log L_γ (erg s^{-1})	42.02	44.33
Γ	2.40	2.68
F>100 MeV (phot cm^{-2} s^{-1})	4.6×10^{-9}	2.1×10^{-7}
Redshift	0.002	0.055
TS*	37	>10000

* TS= -2 (ln L_0- ln L_1), where L_0 and L_1 are likelihood values with and without a possible source. $\sqrt{TS}$ is roughly equal to σ.

1

(plot and table from P. Grandi, E. Torresi, P. Malaguti)

(adapted from Abdo et al. 2009, ApJ, 700, 597).

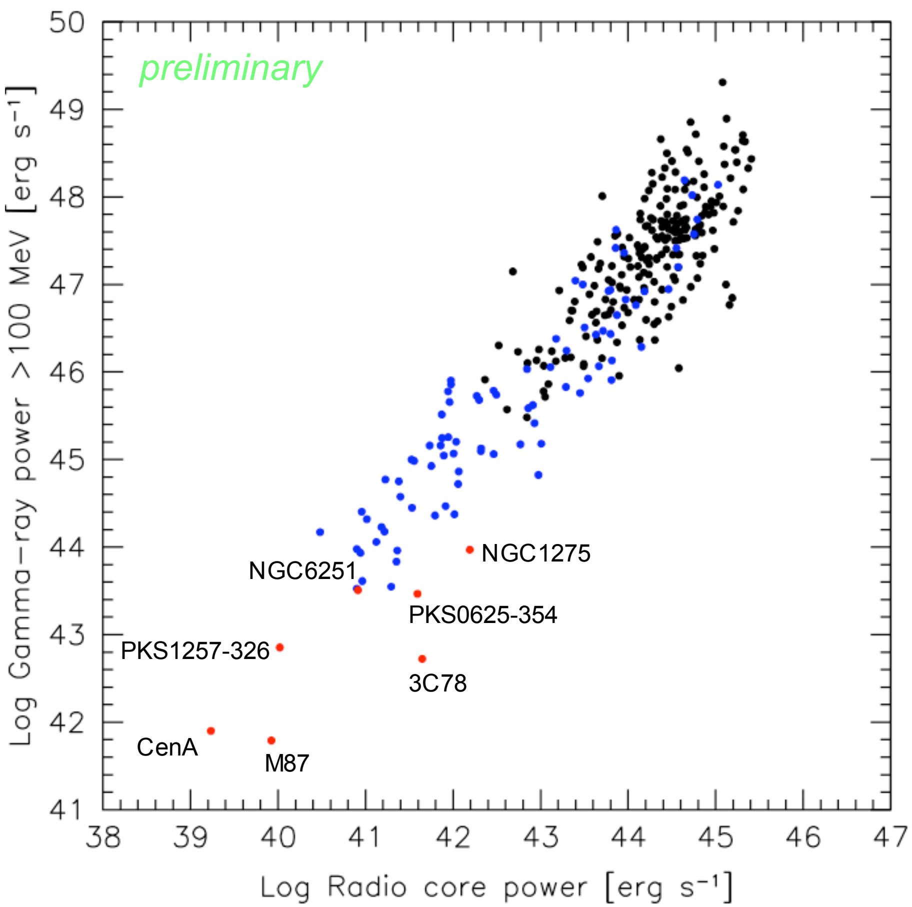
The (3CR, 3CRR, MS4) **FR I** are nearby sources (z≤0.055), with low γ-luminosity with an indication of a steep gamma-ray spectrum.

FR I are plotted together with the other extragalactic radio sources detected in the first three months of the *Fermi* all-sky survey (Abdo et al. 2009, ApJ, 700, 597).

The **FR I** appear to occupy a separate region in the Γ_γ vs L_γ plot.

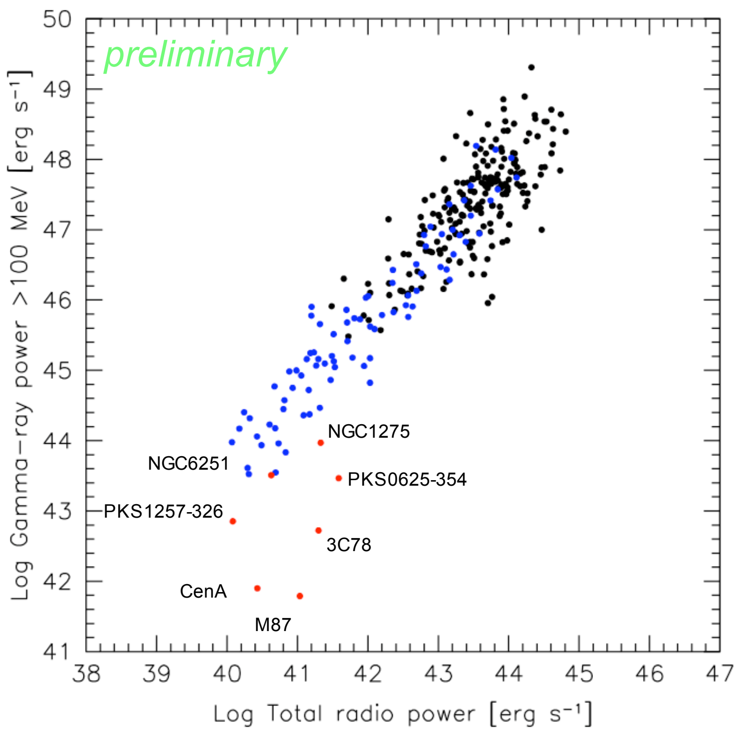
FR I: preliminary results (3)

(plot by M. Giroletti)



Steep Spectrum Radio Sources are less luminous than FSRQs and BL Lacs, being less beamed objects.

There is room for discovery in the lack of detected SSRS. We are working on this.



Summary

SSRS are considered elusive gamma targets

Their **MeV-GeV emission** is expected to be **less amplified when compared to blazars**, as the **SSRS jets** are **seen at larger inclination angles**.

COS-B detected NGC1275, EGRET detected CenA and NGC6251

In spite of this

Fermi-LAT preliminary 1st year AGN catalog contains a few SSRS

Many of them have

- FRI radio morphology
- low gamma ray luminosity ($L_\gamma<10^{44}$ erg/s)
- steep gamma-ray spectra

The more extensively studied FRI radio sources exhibit **non-thermal SED**, produced by synchrotron and Inverse Compton mechanisms probably occurring in the pc-scale inner region.
FR I are γ-ray faint objects when compared to BL LAC, as expected if they are the BL LAC parent population: **increasing the angle of view, the Doppler factor decreases shifting the sources towards lower luminosities.**

Open questions

Which are the gamma-ray emission mechanisms?
Where does the gamma-ray emission come from?

There is **not**, up to now, a **unique interpretation for the gamma-ray emission** process.

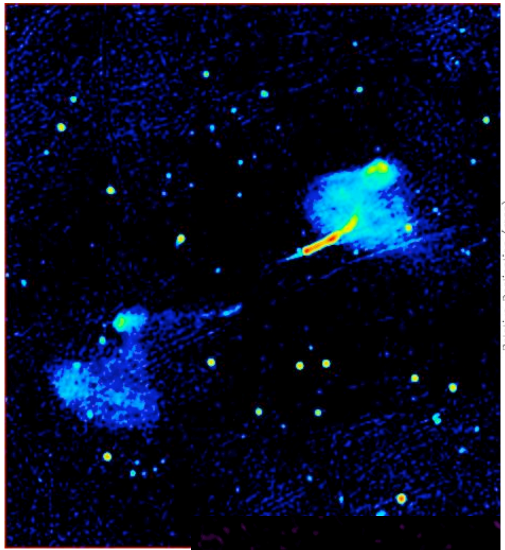
The well studied NGC1275, CenA and M87 are quite different from each other.

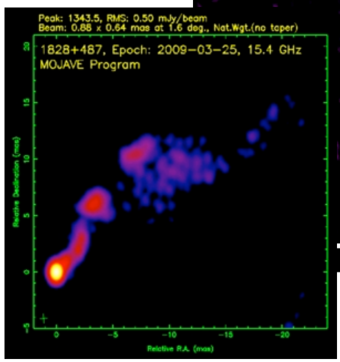
In CenA the gamma-ray emission comes also from the lobes.

This scenario makes these sources even more interesting in the understanding of their nature.

The preliminary few Fermi-LAT detections wrt to past missions are already a big step ahead.

Thank you





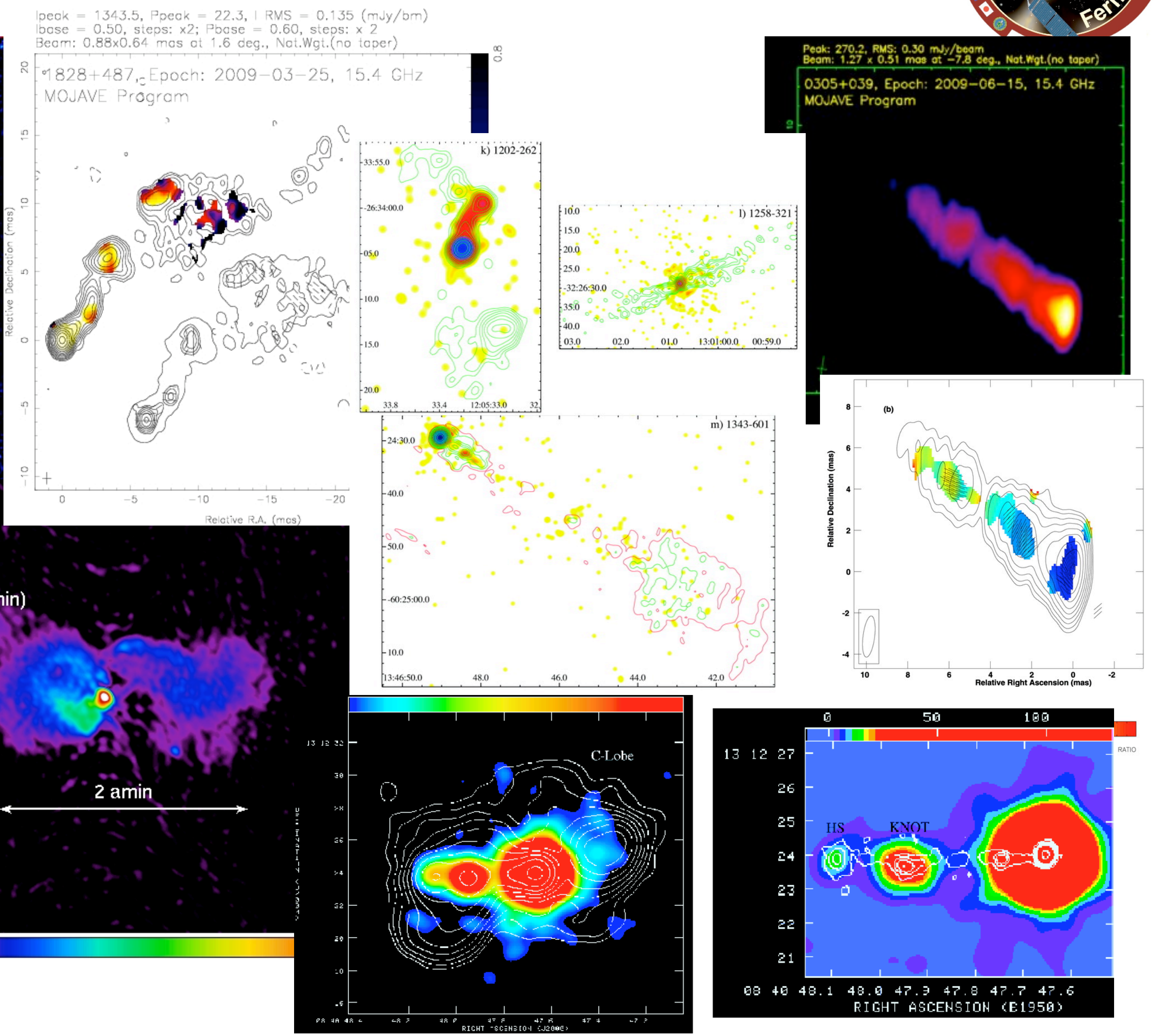


Image courtesy of Mojave Team, Mack96, T. Cheung, G. Brunetti, Marshall05