The extreme ends of the spectrum: the radio/gamma connection

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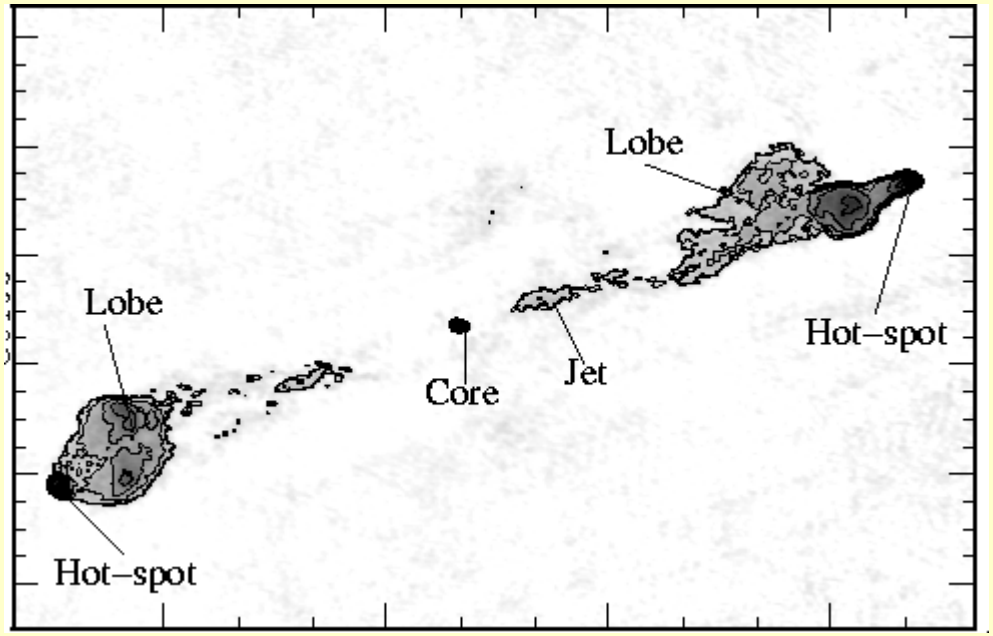
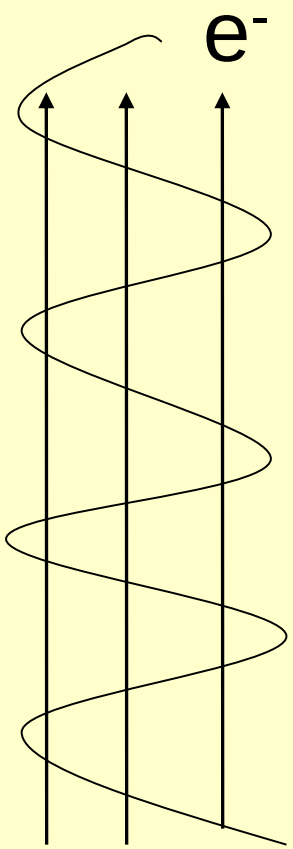
This research has made used of data from the MOJAVE database that is maintained by the MOJAVE team (Lister et al. 2009, AJ, 137, 3718)

Outline

- Radio-loud AGN
- Radio and gamma emission mechanisms
- Radio and gamma correlation in blazars
- Misaligned radio sources

Radio-loud AGN



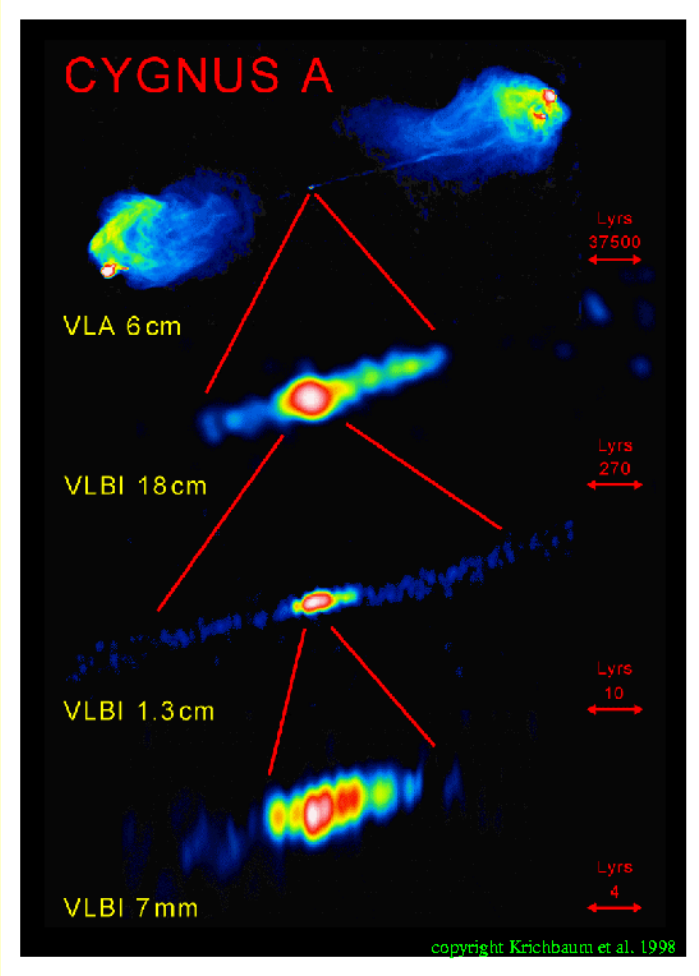


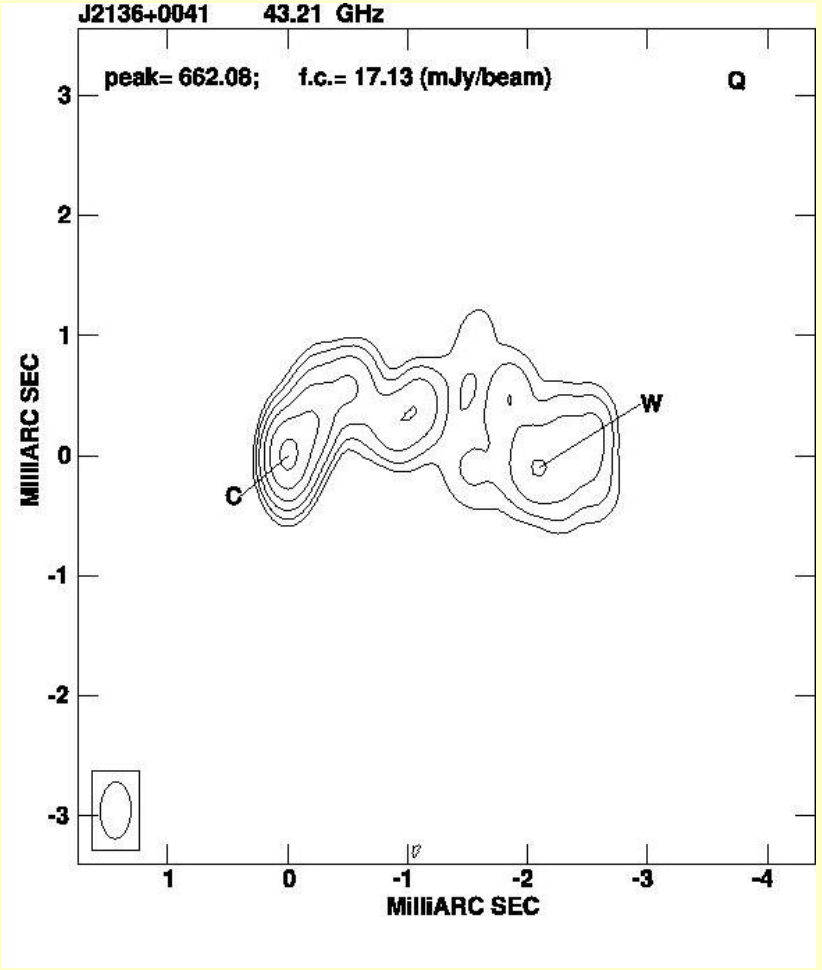
- $L_{0.4MHz} > 10^{23}$ W/Hz
- Size: from pc to a few Mpc
- Elliptical galaxies and quasars;
- 10% of AGN population

$P \propto E^2B^2$

Synchrotron radiation from relativistic electrons in a magnetic field

Radio jets





Large viewing angles:
The source core and the jet base is detected by VLBI observations

Small viewing angles:
The source core and the jet(s) dominate the radio emission.
Important boosting effects!

High energy emission

Relativistic electrons can scatter low energy photons to high energy bands

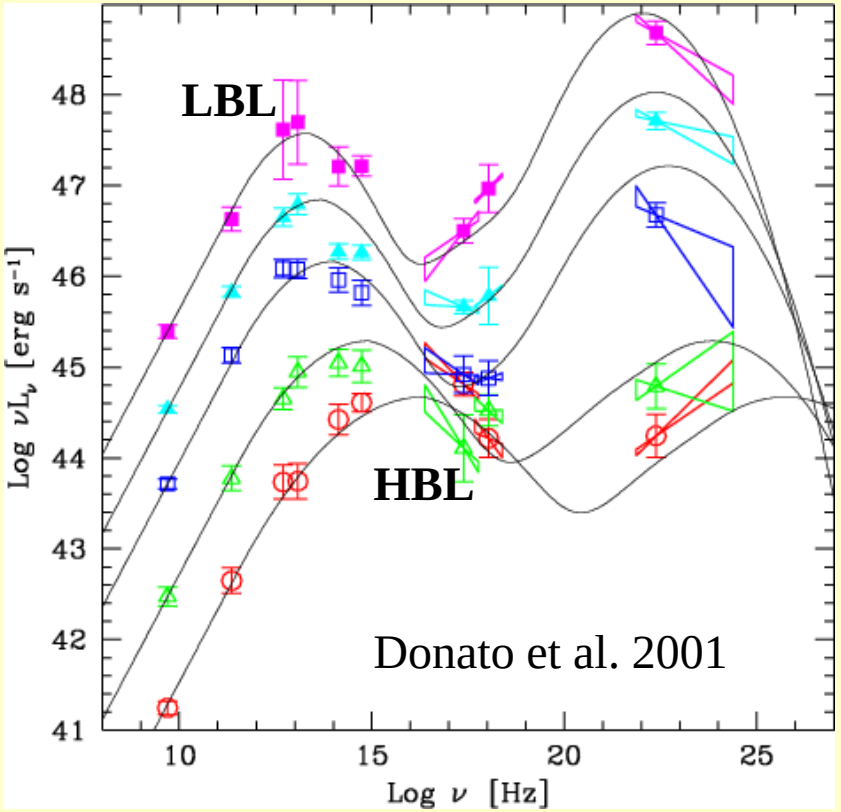
↓

Gamma-ray emission

Radiation mechanisms:

- **SSC** (synchrotron photons)
- **EC** (external photons)

All AGN detected by EGRET are radio-loud objects



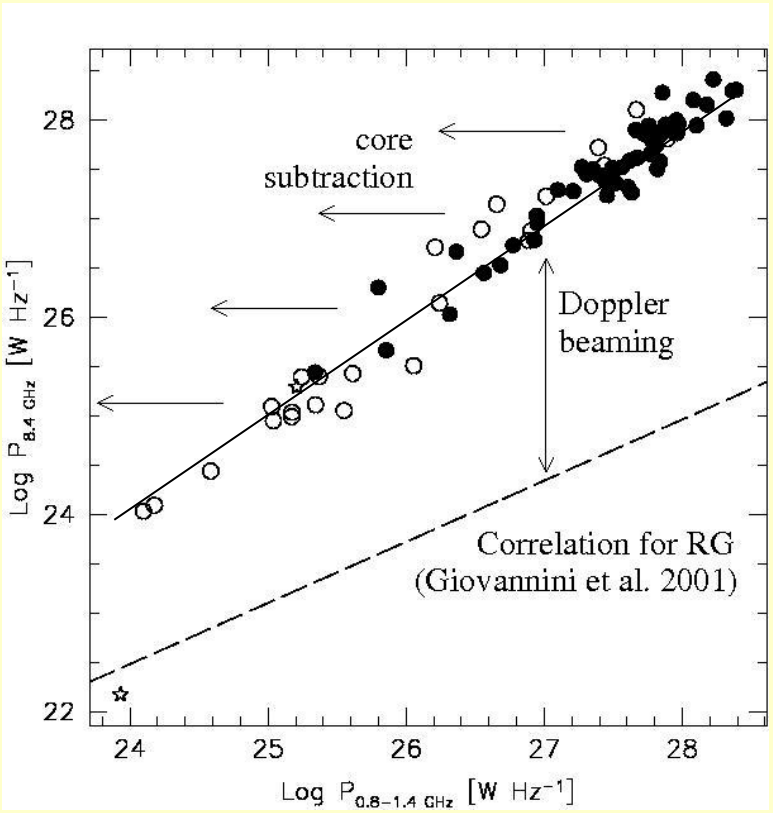
Blazar sequence originally based on the radio luminosity

Blazar population

Almost all the AGN detected in the γ-rays are blazars. Enhanced luminosity by boosting effect.

- 1-yr AGILE detection (Pittori et al. 2009):
  - 7 FSRQ
  - 4 BL Lacs
  - 2 Unclassified
- LBAS Fermi detection (Abdo et al. 2009):
  - 58 FSRQ;
  - 42 BL Lacs;
  - 2 RG

Objects with flat spectral index, **$\langle\alpha\rangle = 0.06+/-0.23$** with the exception of Cen A



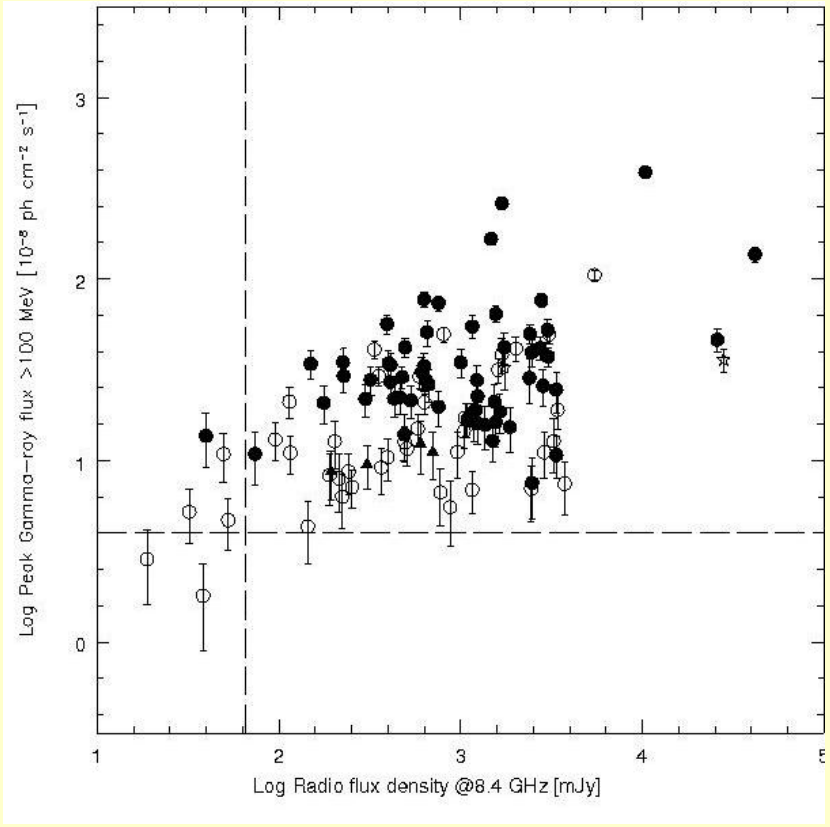
● FSRQ ○ BL Lacs

☆ RG

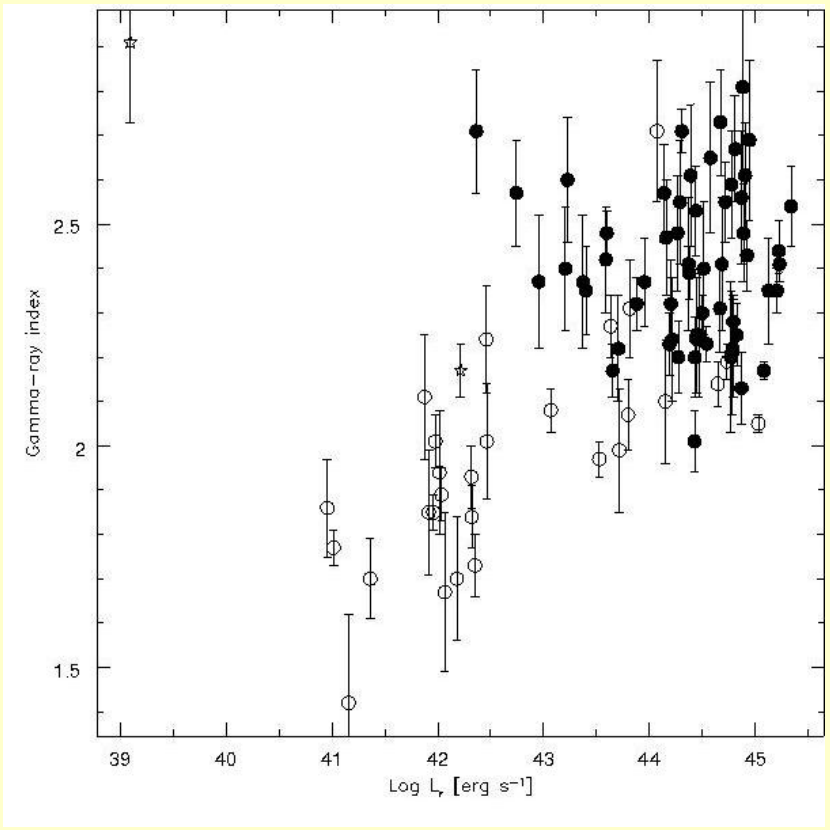
FSRQ usually at higher luminosity

Radio-gamma correlation – I. CRATES

Abdo et al. 2009



Abdo et al. 2009



FSRQs high radio and γ-ray luminosity, softer γ-ray index

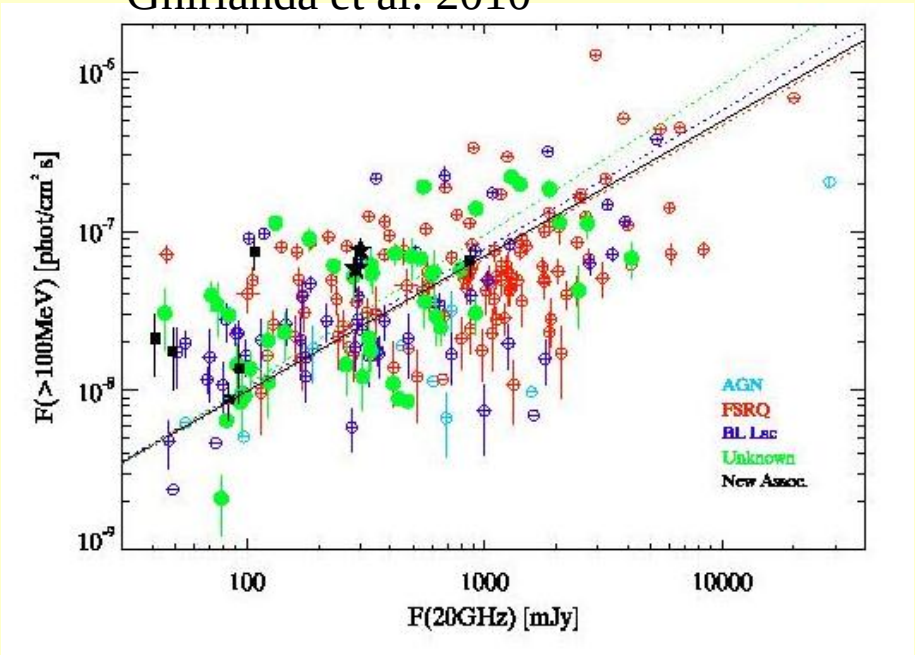
BL Lacs low radio and γ-ray luminosity, harder γ-ray index

Tentative radio-gamma rays correlation, stronger in BL Lacs
(Kovalev 2009, Giroletti et al. 2010)

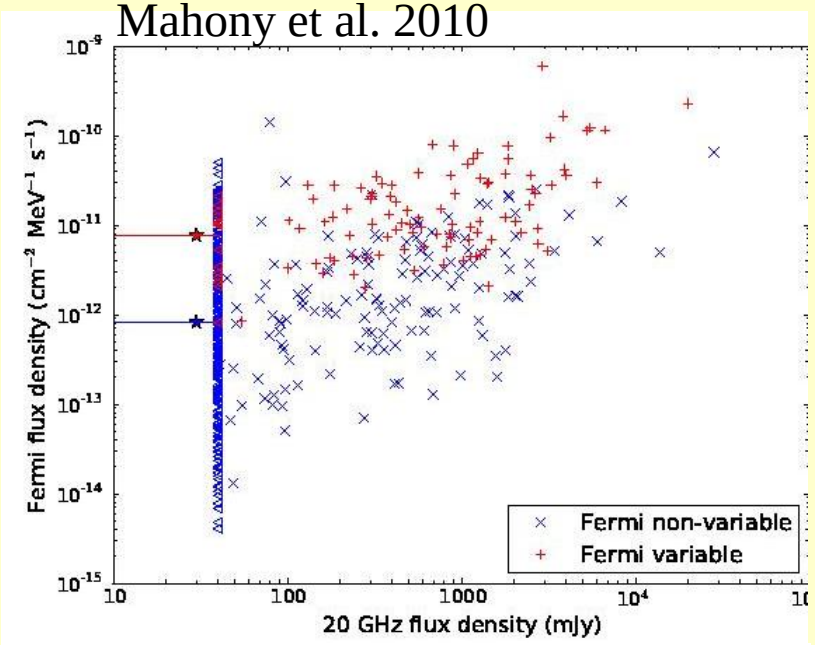
WARNING: No simultaneous radio and γ-ray data!

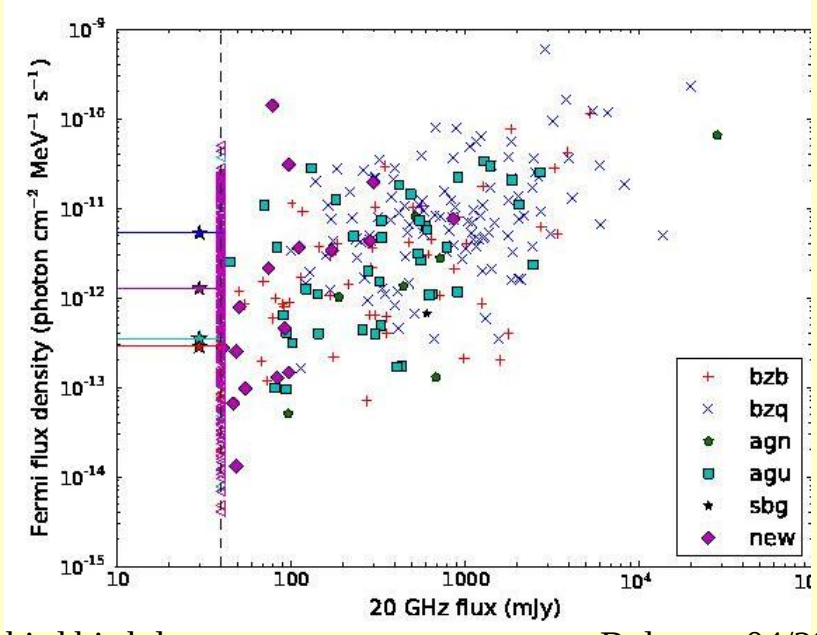
Radio-gamma correlation - II. AT20G

Ghirlanda et al. 2010



Mahony et al. 2010





Cross-correlation with the AT20G catalogue (Murphy et al. 2010):

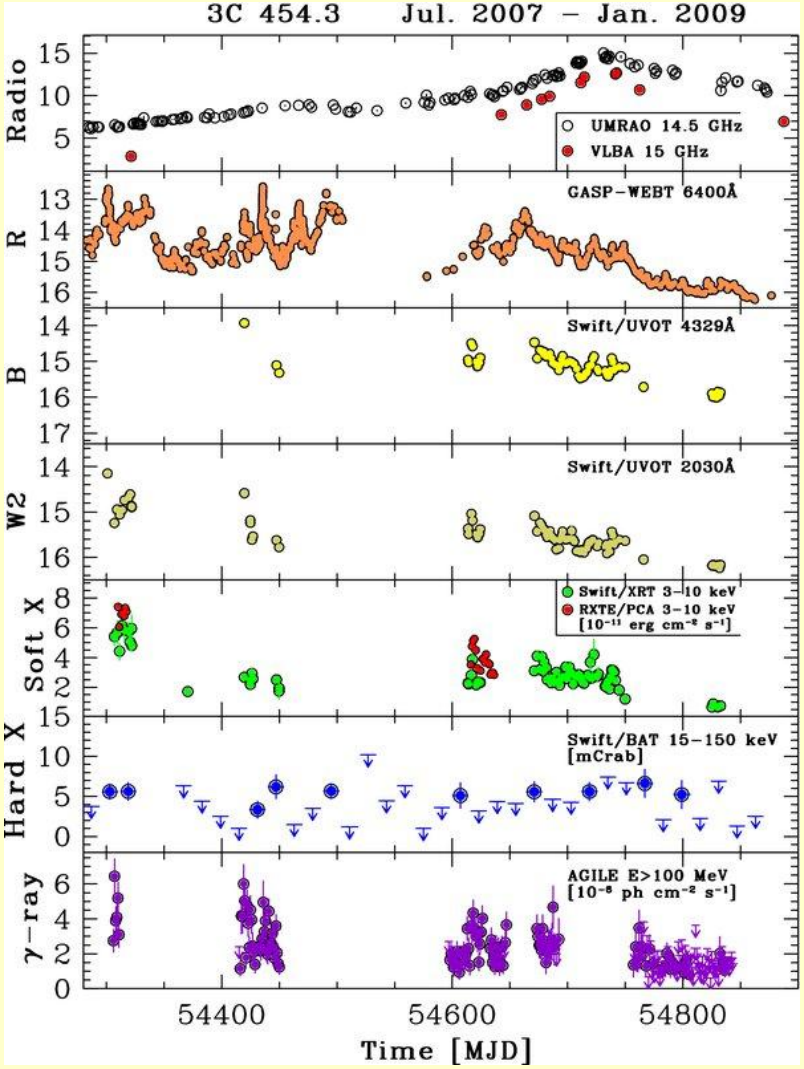
- 112 FSRQ, 54 BL, 10 RG, 46 Un

Existence of radio-gamma correlation for both BL Lacs and FSRQ

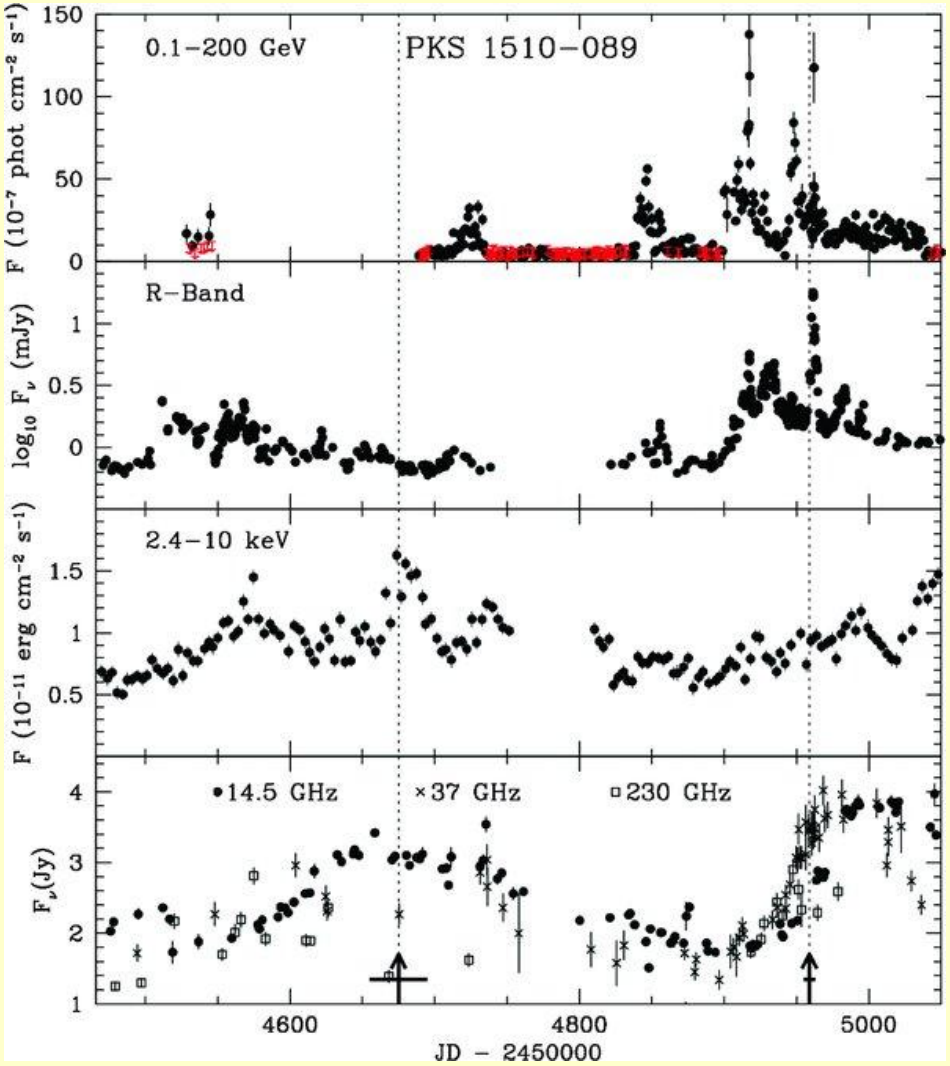
Correlation is stronger for non-variable sources

Variability

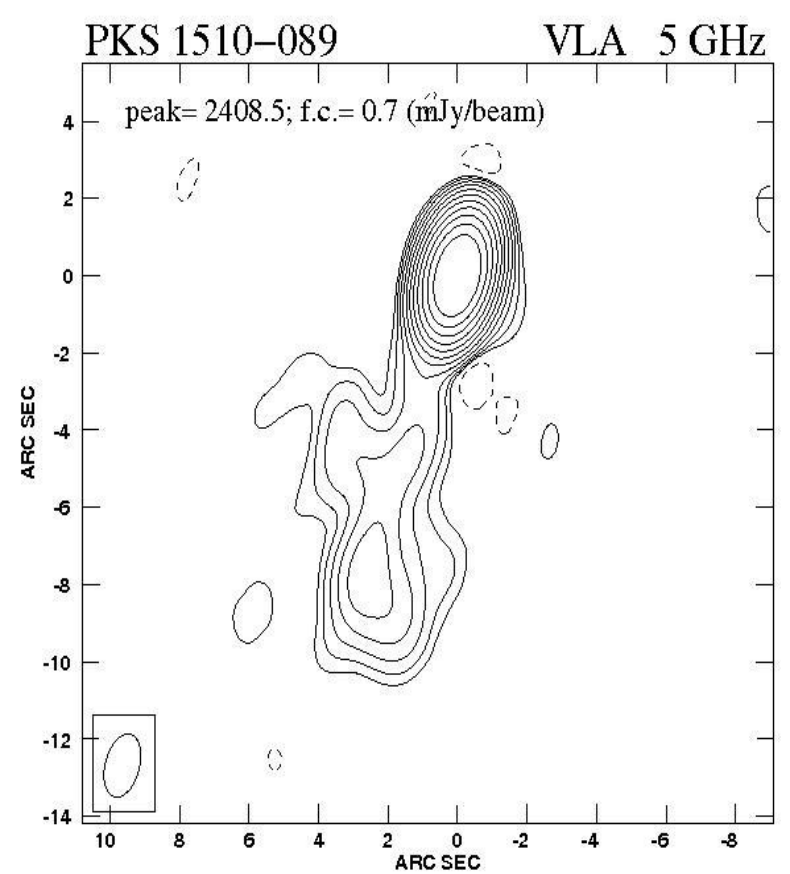
3C 454.3, Vercellone et al. 2010

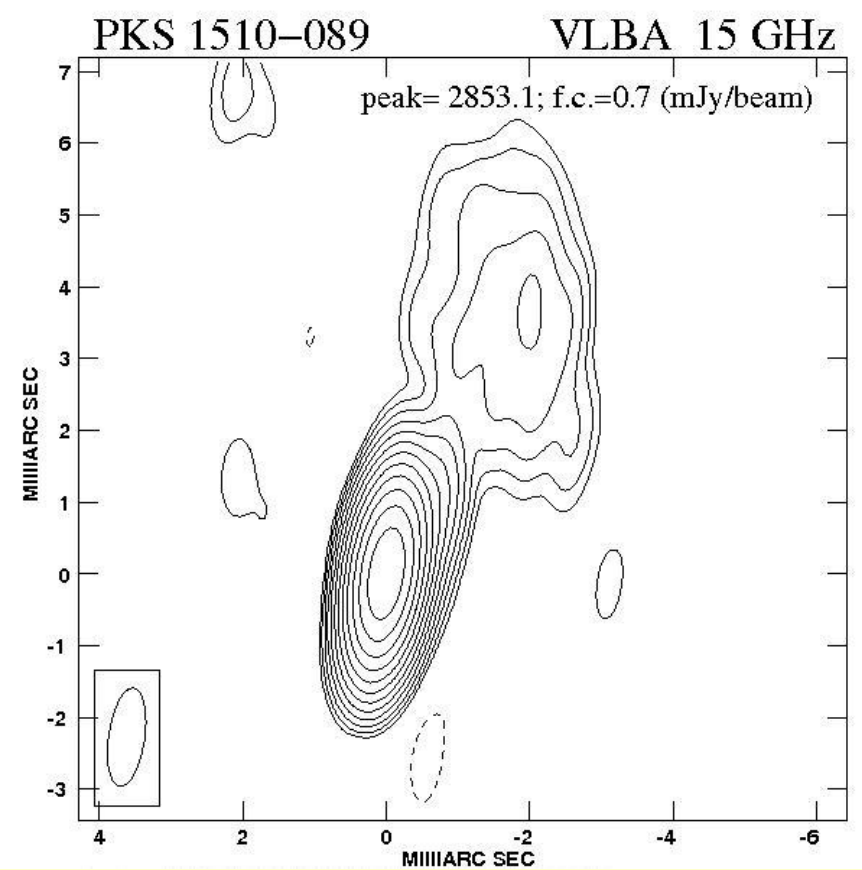


PKS 1510-089, Marscher et al. 2010



PKS 1510-089





- Highly polarized FSRQ;
- z = 0.361;
- Core-jet morphology on kpc and pc scales;
- Strong radio-to-γ variability.

PKS 1510-089 – Variability & Proper motion

In 2009/2010 strong γ-ray activity detected by AGILE

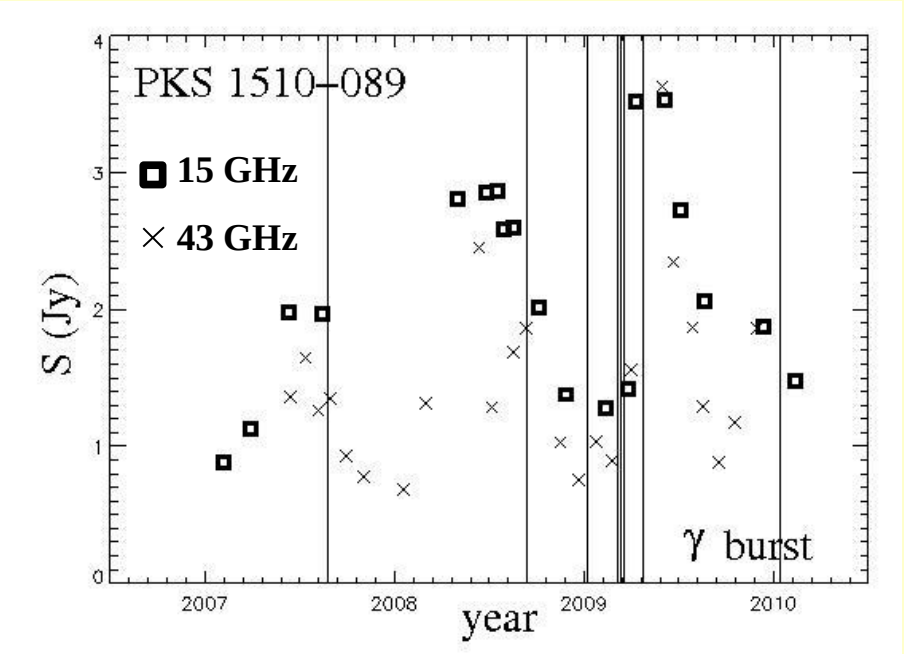
Ejection of a superluminal knot (Marscher et al. 2010)

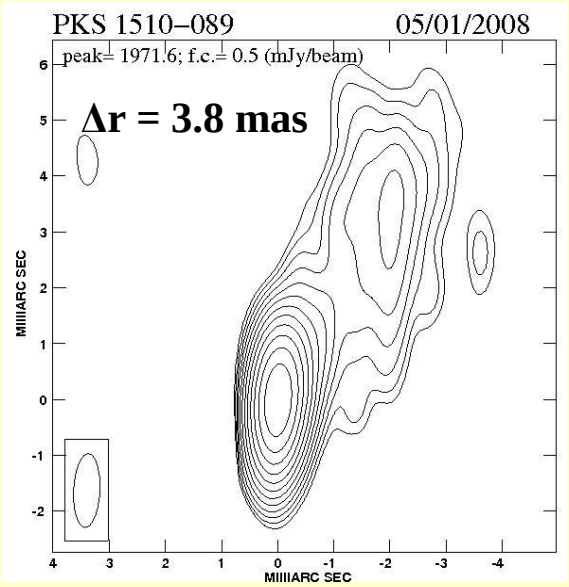
D'Ammando et al. 2009

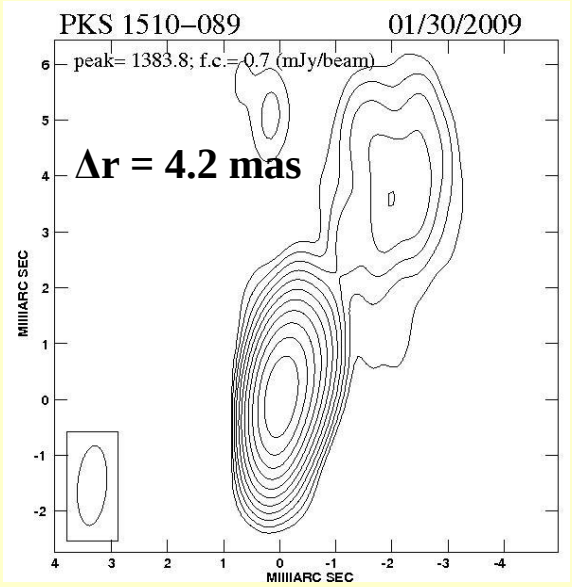
V_{sep}=1.1±0.1 mas/yr

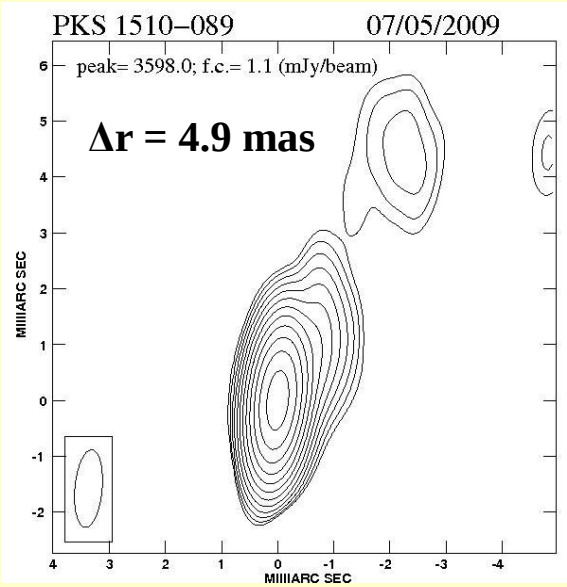
β_{app}= 21±2

→ $\beta > 0.9989$, $\theta < 5°$









Radio-to-gamma connection: misaligned objects

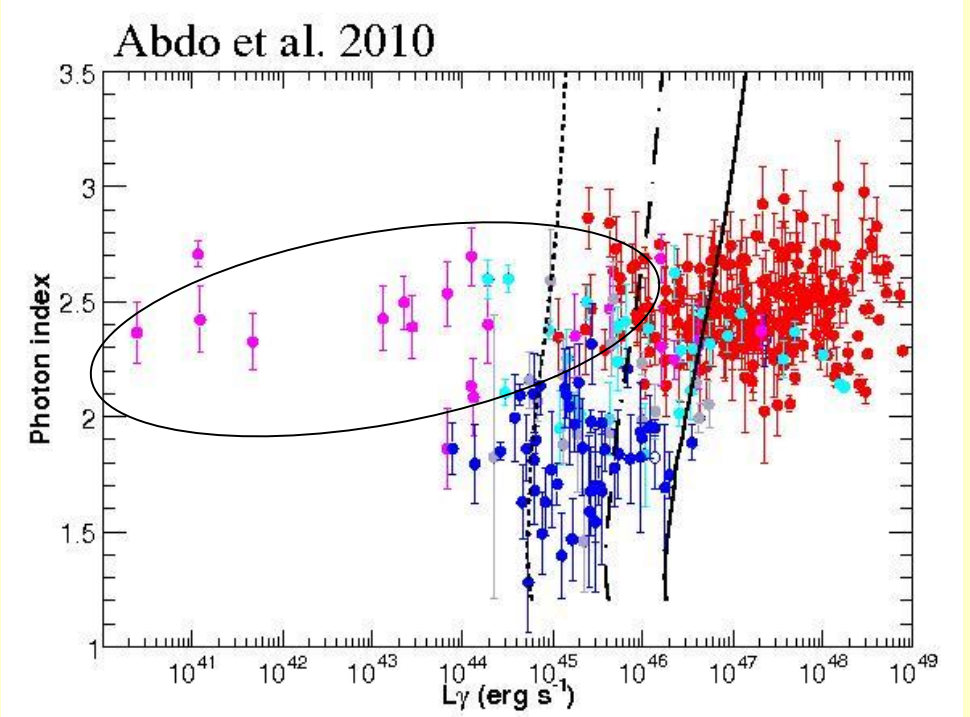
Detection of non-blazar objects:

- nearby radio galaxies
  - Cen A (EGRET), Abdo et al 2009
  - NGC 1275, Abdo et al. 2009
  - M 87(EGRET), Abdo et al. 2009

γ-ray emission due to SSC

- FR I radio galaxies;
- steep spectrum quasars;

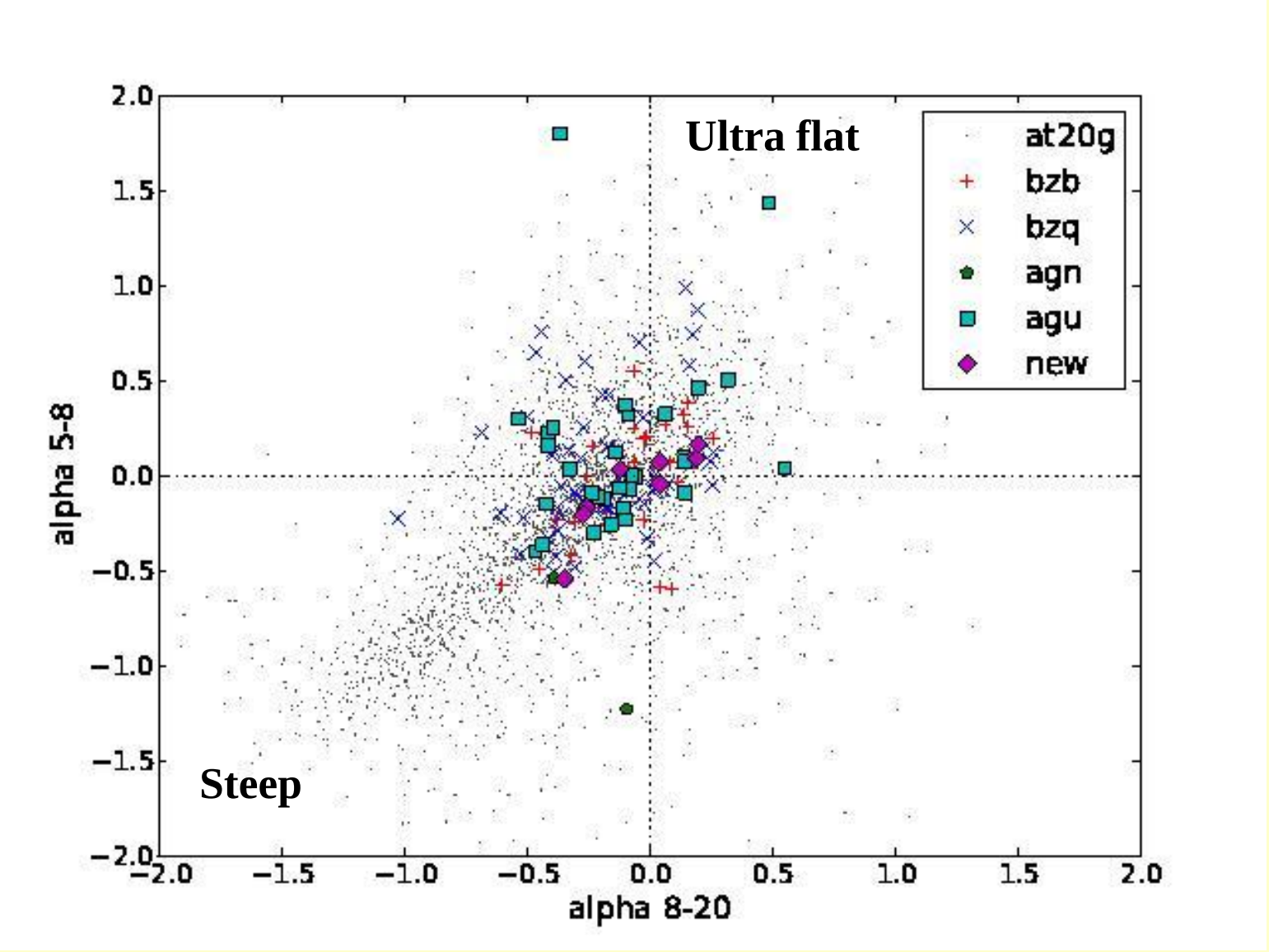
Abdo et al. 2010



- Lower gamma luminosity: marginal boosting effects
- Soft photon index

→ Deeper and deeper observations are needed to detect misaligned objects at higher redshift!

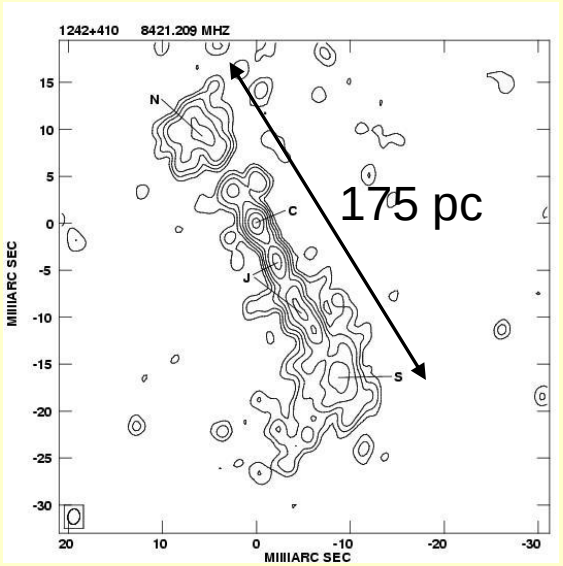
Misaligned objects: spectral index distribution

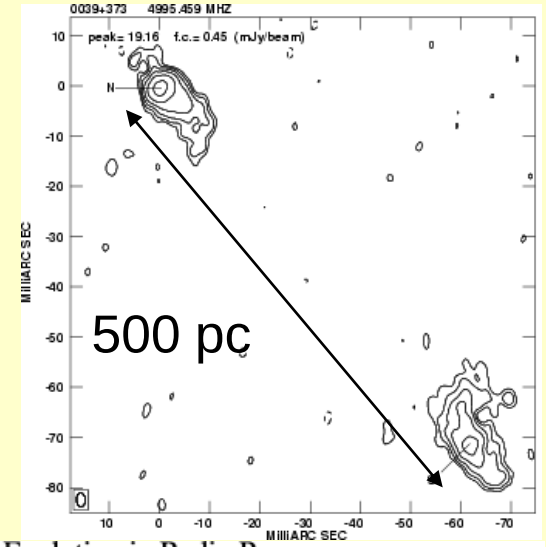


Mahony et al. 2010

Misaligned objects: young radio source population

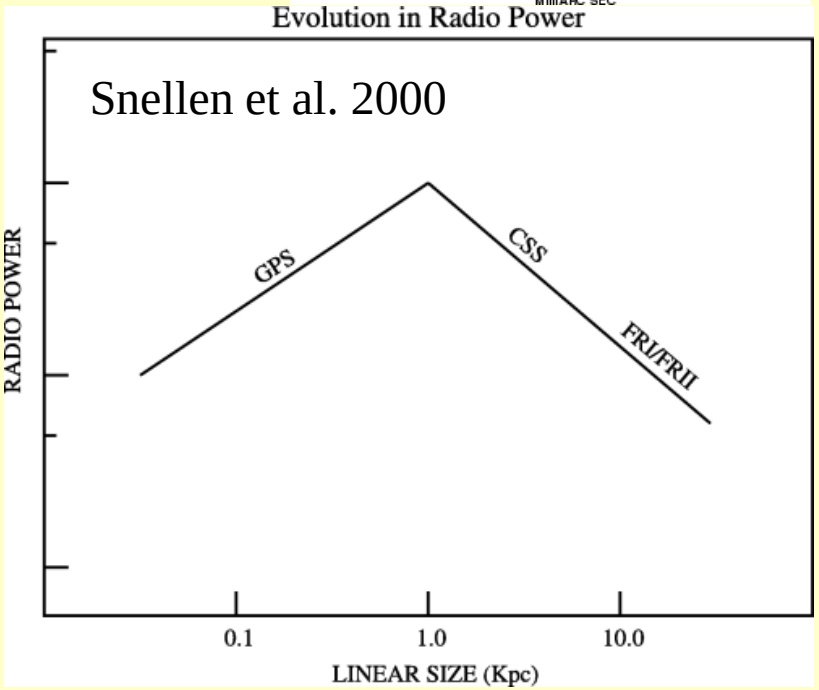
- $P_{1.4\,GHz} > 10^{25}$ W/Hz;
- ν_p 0.1-10 GHz;
- LS < 1 – 20 kpc;
- Scaled-down version of FR II RG;
- 10% - 30% in radio samples;





Luminosity evolution:

High radio power, BUT....
....higher redshift than FRII RG (z > 0.2)

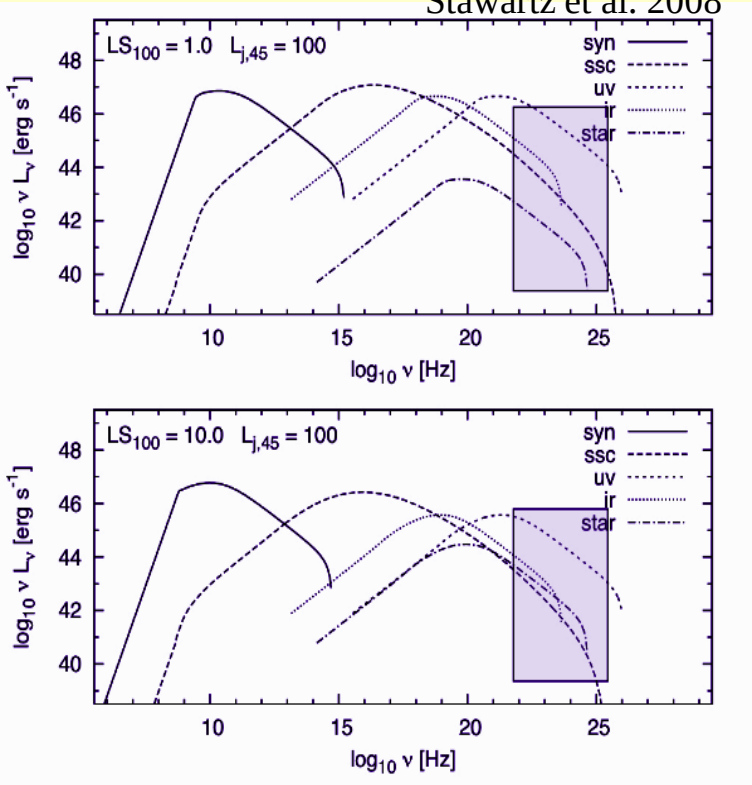


Young radio sources: a γ-ray perspective

Compact radio sources are still embedded in nuclear and galactic photon fields, which can provide the seed photons for the IC emission.

Galaxies

Stawartz et al. 2008

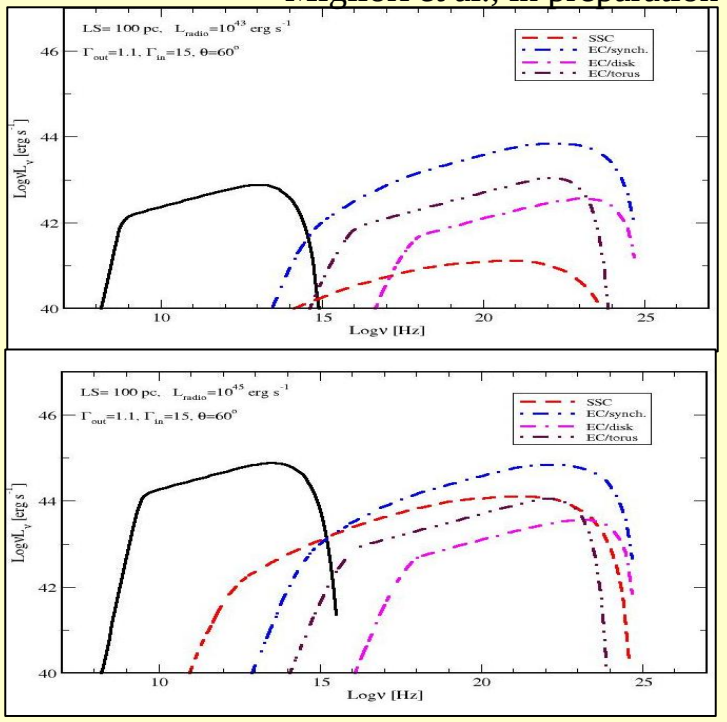


IC by **lobes**' electrons with IR/torus UV/disk photon seeds

Stawartz et al. 2008

Quasars

Migliori et al., in preparation



IC by **jet**'s electrons with synchrotron photon seeds from the core.

Projection effects are needed!

Migliori, PhD thesis

Summary

- Gamma-ray emission is dominated by blazar population;

- Radio-gamma connection seems to exist, but variability may play a role!

- A few nearby misaligned steep spectrum sources are detected;

- In steep spectrum objects the origin of the gamma rays is still an open question.