RADIO QUIET AND WEAK RADIO SOURCES

A brief introduction

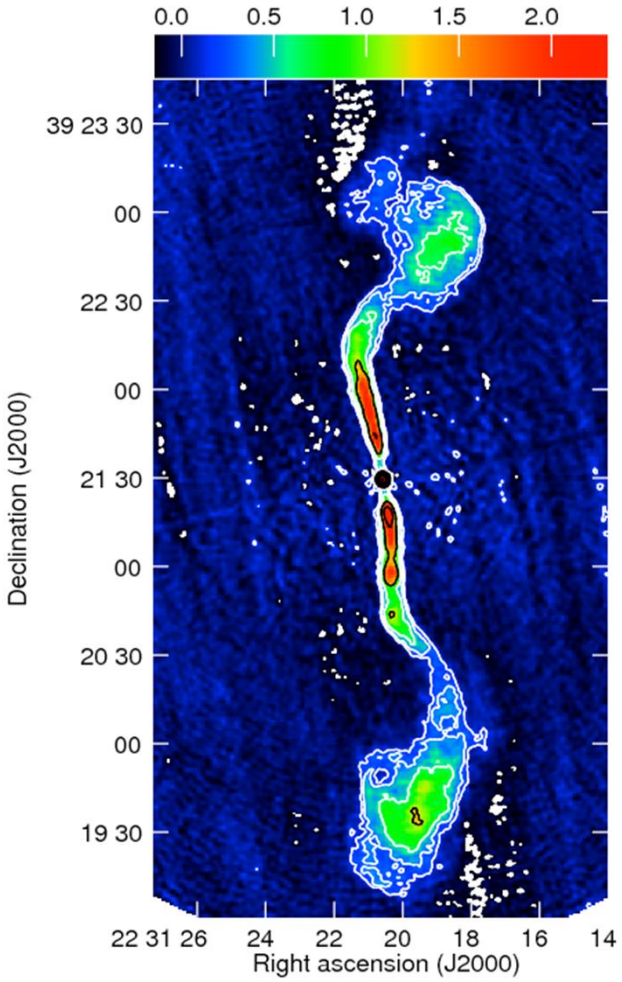
(and not in chronological order)

(High) flux-limited radio surveys (e.g. 3C, $F_{178MHz} > 9$ Jy).

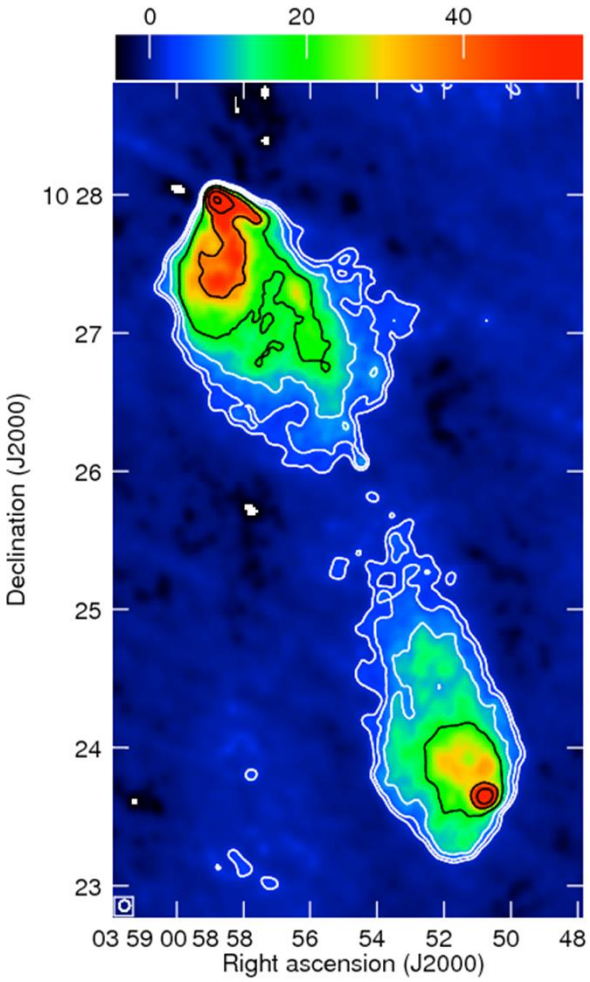
Mostly large FRI and FRII sources (also in B2, 4C…)

Fanaroff & Riley (1974)

FRI



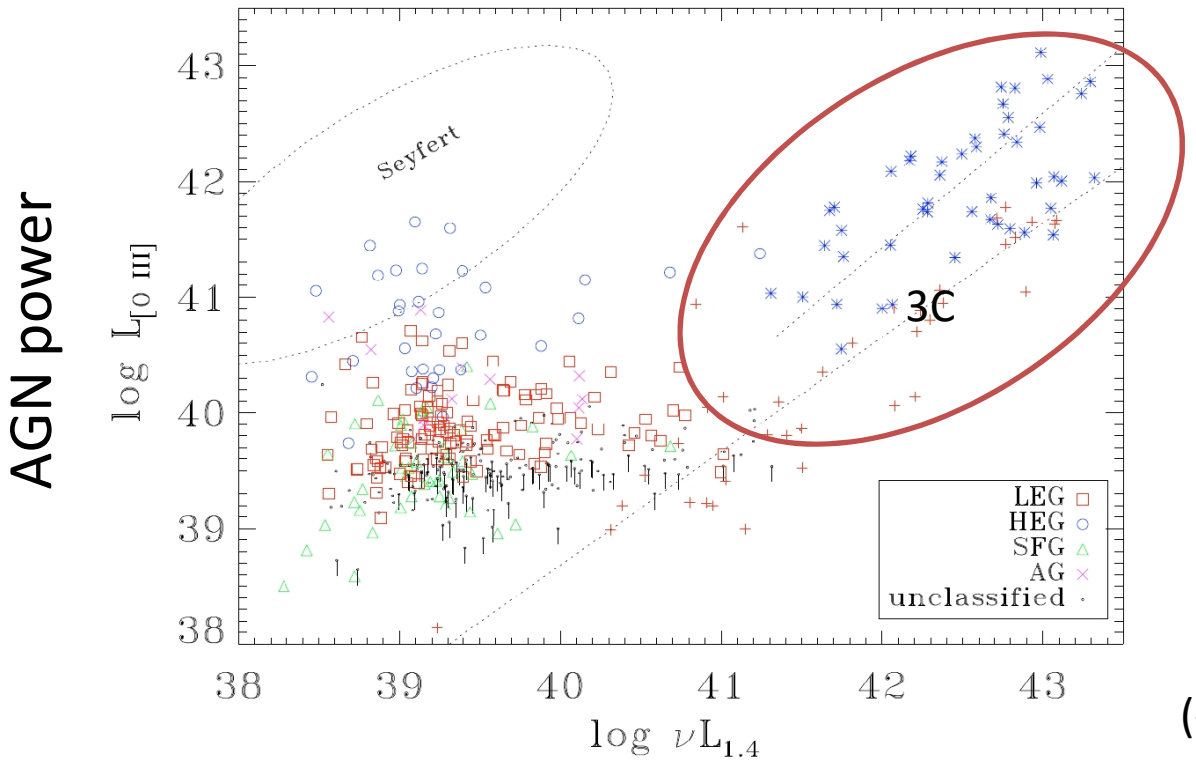
FRII



Only 1 RQ AGN (NGC 1068) and 1 star forming galaxy (M82)

Lowering the radio flux threshold*:

Best et al. (2005/2012) cross-matching SDSS, NVSS, FIRST down to 5 mJy at 1.4 GHz. Only AGN no SF



(-17.1 to W/Hz)

A whole new radio Universe – more later on this

*and/or increasing the survey's frequency (AT20G Sadler et al 2014)

THE OPPOSITE APPROACH:

radio observations of complete optical/IR samples

Rogstad & Ekers 1969: radio observations of 191 nearby (v<10000 km/s) S0 and elliptical galaxies, 14 detected above 0.2 Jy.

Heeschen 1970. Two classes: extended steep and compact flat sources.

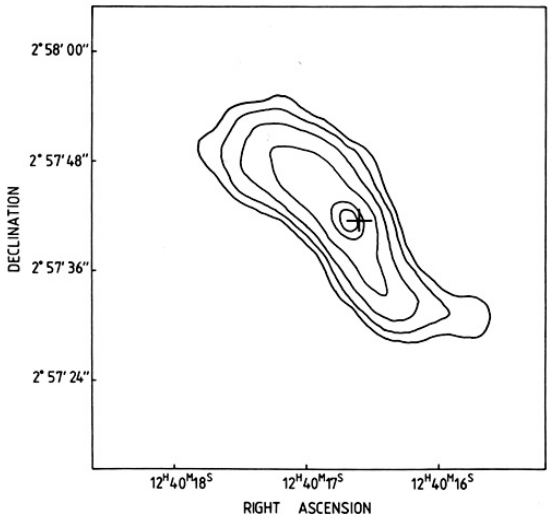
Wrobel (1991), Sadler (1984): deeper radio observations of nearby (v<3000 km/s) galaxies
Luminosity as low as 10^{19} W/Hz.

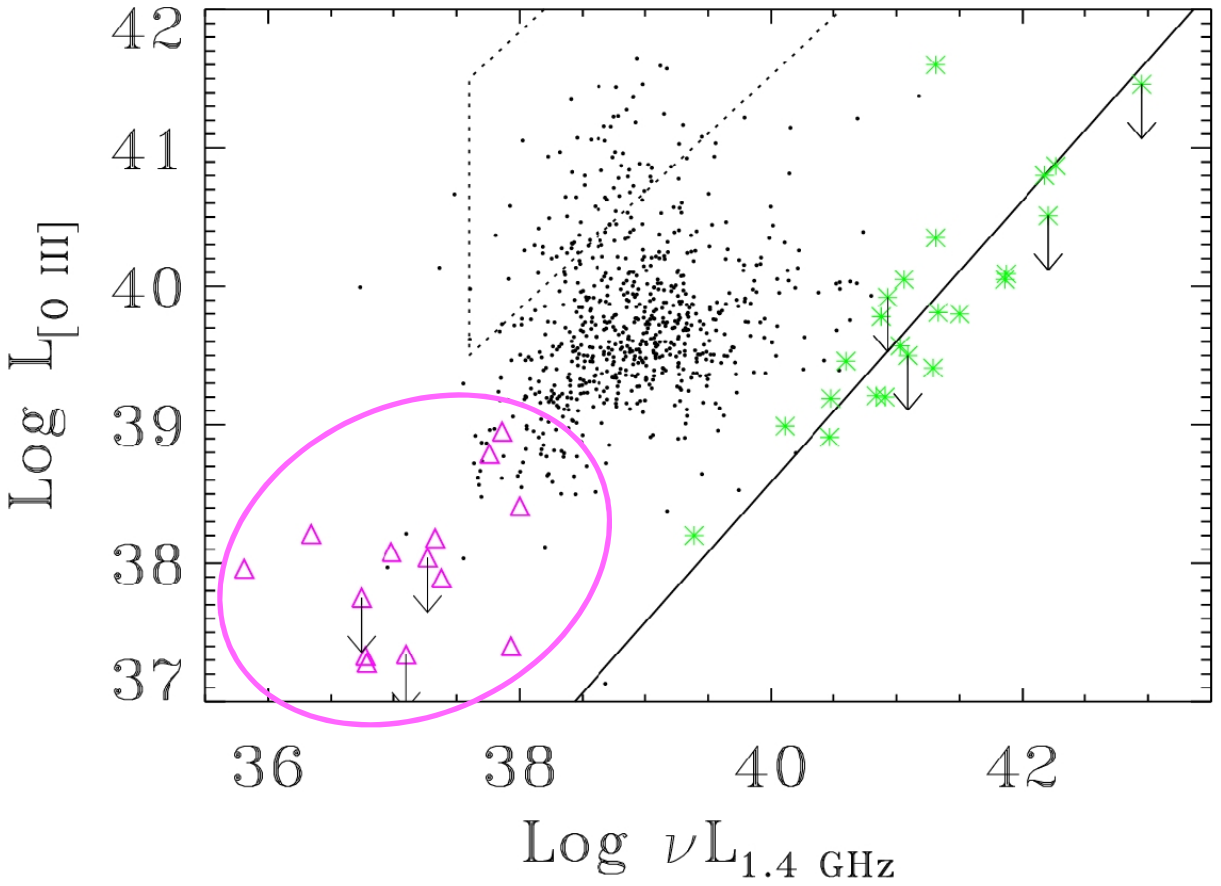
The undetected sources remain in the sample as upper limits!
Essential for population studies

LEMMINGS: deep high resolution observations of local (not just Es and S0) galaxies (Baldi et al. 2018, his talk in less than one hour).

Extremely low luminosity (10^6 times fainter than 3C/FRI) radio loud AGN ($L_r/L_o = 10^3$ -10^5)

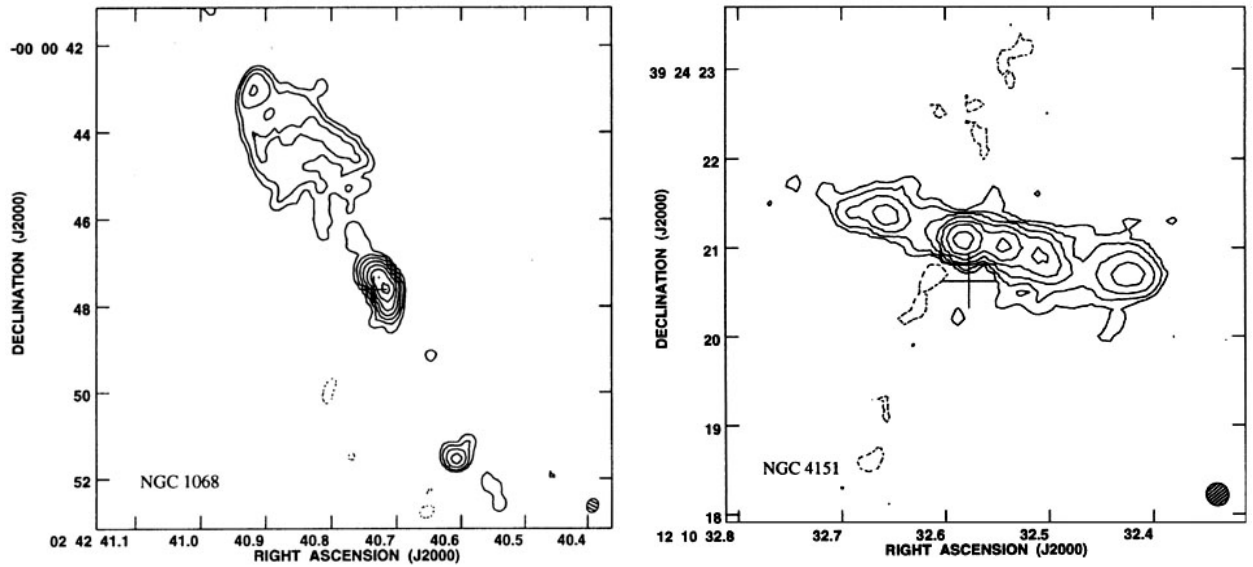
NGC 4636 (FOV 1.5 kpc)





THE OPPOSITE APPROACH:

radio observations of complete samples (Seyfert)



FR II-like

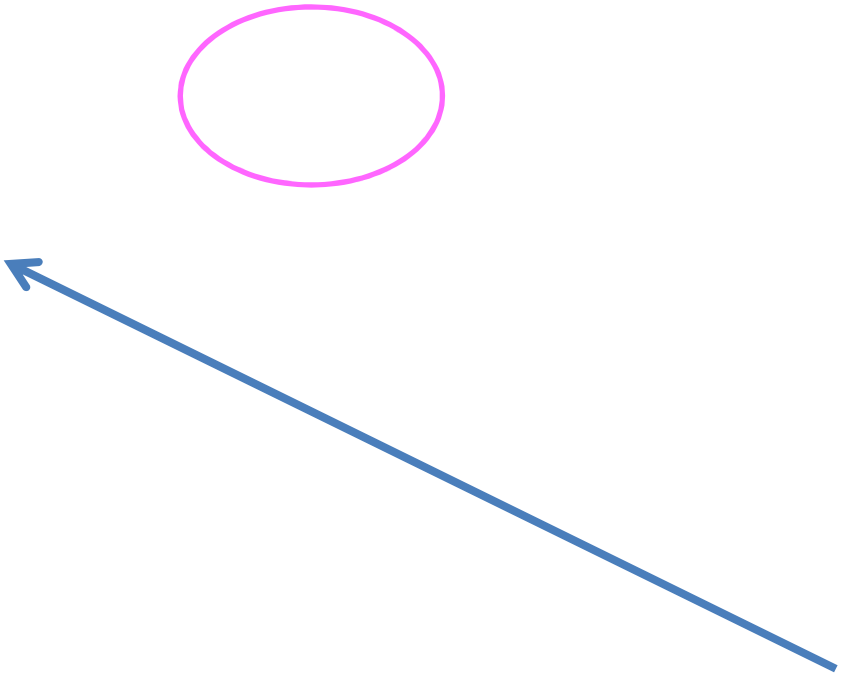
FRI-like

Many papers by Pedlar, Axon, Wilson, Ulvestad, Nagar, et al.

Local Seyfert galaxies are generally detected in the radio (up to 10^{23} W/Hz).

They often show jets or double lobed structures.

Are Seyfert radio loud or radio quiet?



Seyferts have R>10 but there is a trend of R to increase toward low L

Different SED?

The low L radio loud AGN have much larger R

Waiting for the SKA revolution

SKA will detect radio loud AND radio quiet AGN to large redshifts.

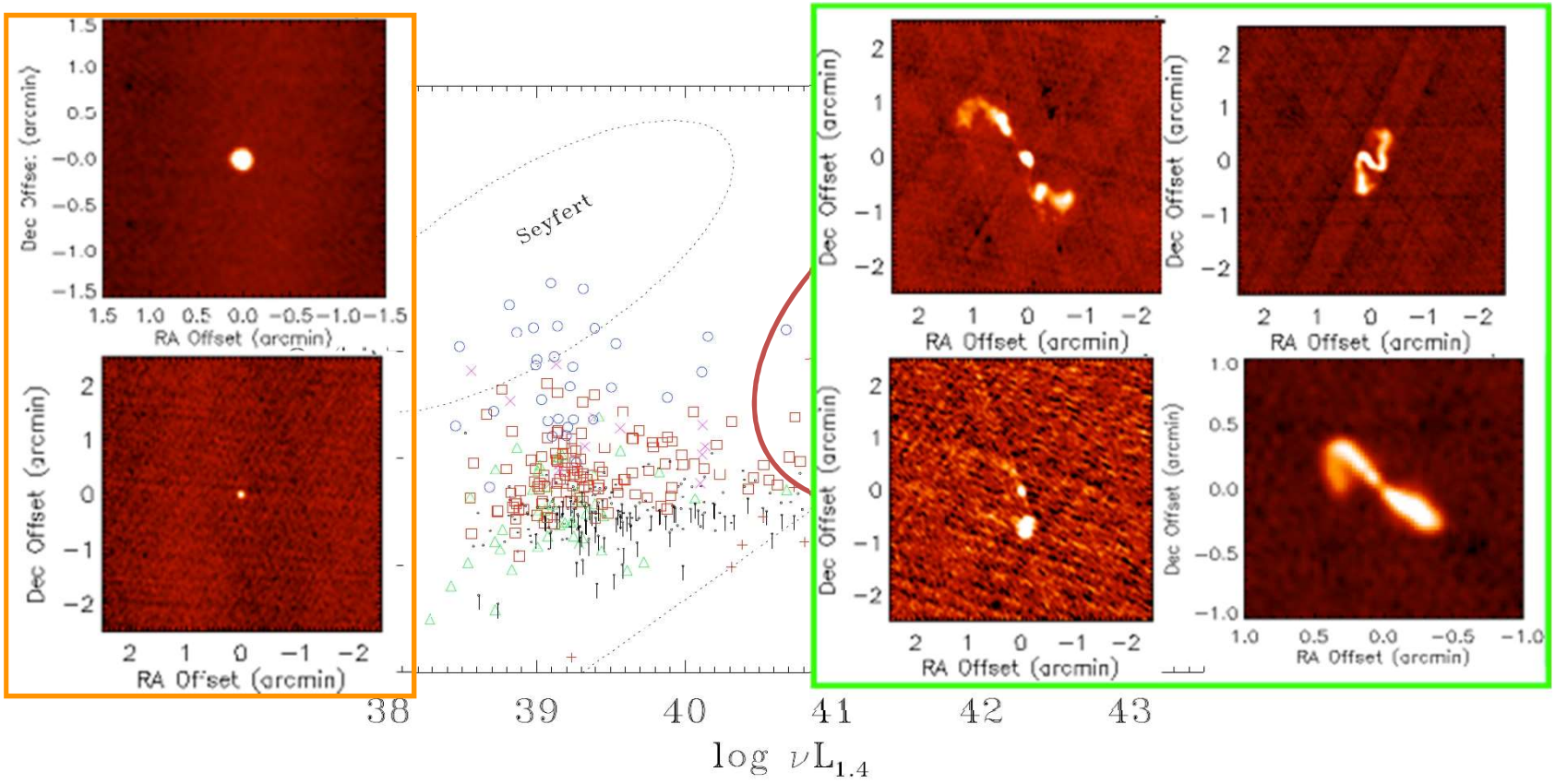
But also «quiescent» galactic nuclei… the radio emission from our Galactic center will be visible to a distance of 10 Mpc, i.e., in a substantial fraction of the LEMMINGs sample.

Exploring the properties of FR 0 radio galaxies

R.D. Baldi, A. Capetti, G. Giovannini

The local population of radio galaxies

SDSS, NVSS, FIRST down to 5 mJy at 1.4 GHz.



At given AGN power ($L_{[OIII]}$) a broad range of L_r and radio morphologies.

Most of them are compact

FR 0 radio galaxies

Ghisellini (2014) and Sadler (2016) «a convenient way of linking the compact radio sources … into the canonical FR classification scheme»

Are they a new class? NO.

Compact radio-sources at the center of early type galaxies (ETG) has been already recognized in the ’70s (Ekers & Ekers 1973) and later (Wrobel & Heeschen 1991, Sadler 1984, Slee et al. 1994)

Are they a well defined class? NO.

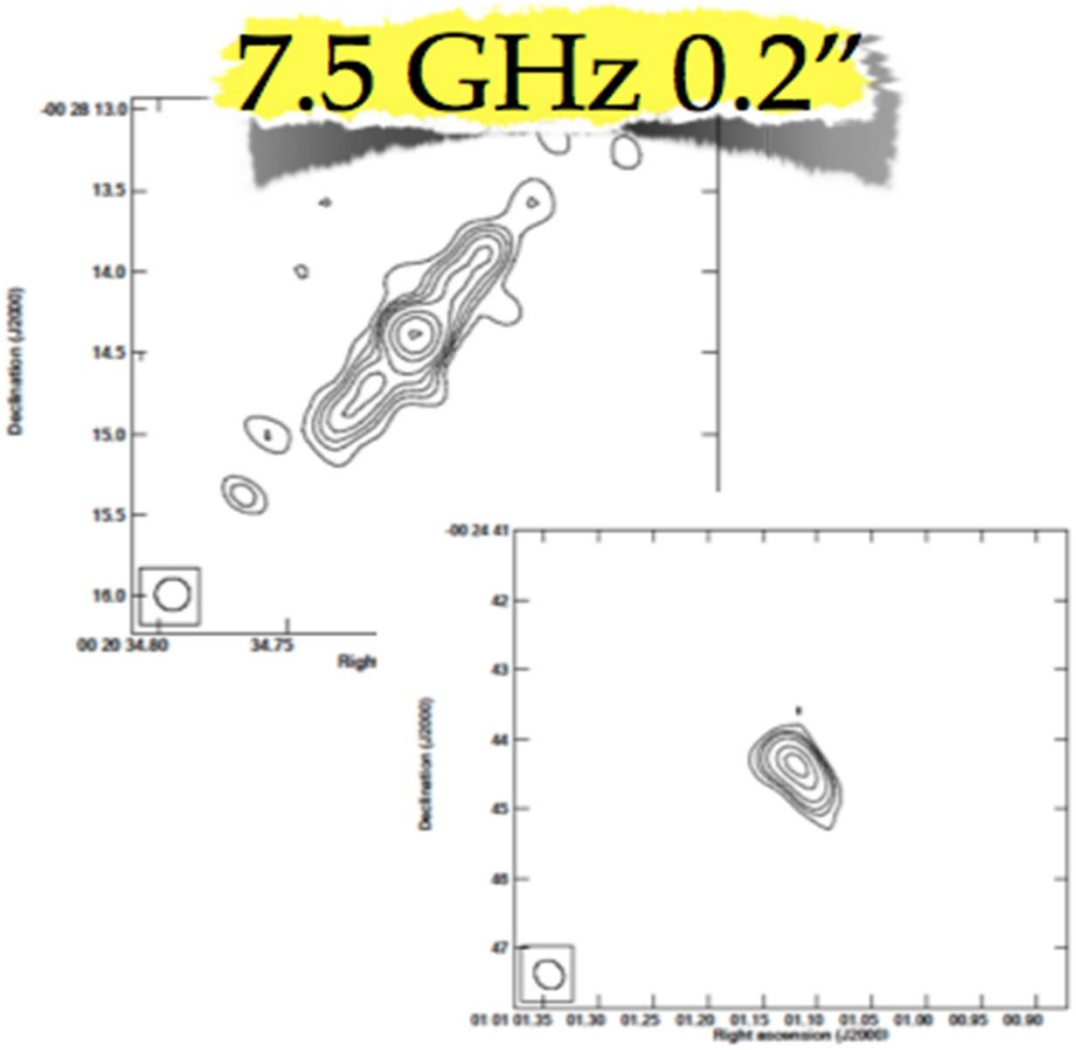
The «compact source» definition depends on the survey depth and resolution and on the source distance.

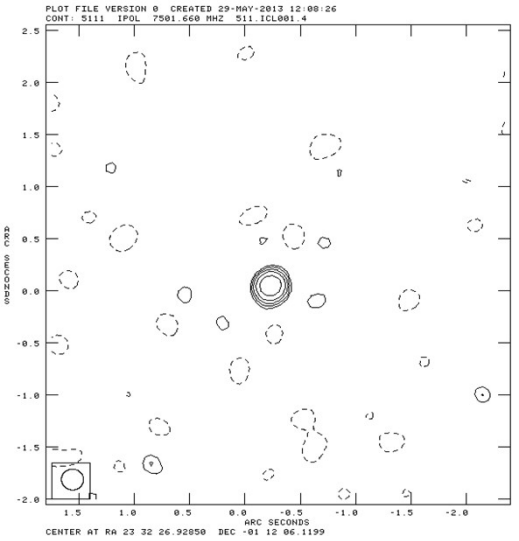
Are they an interesting class? YES (I think so…).

Why most radio galaxies extend to, at most, a few kpc? How are they connected to the large objects? Are they small because they are young? Or are they different?

A pilot project of high resolution radio imaging of FR0

Baldi, Capetti, Giovannini (2015)



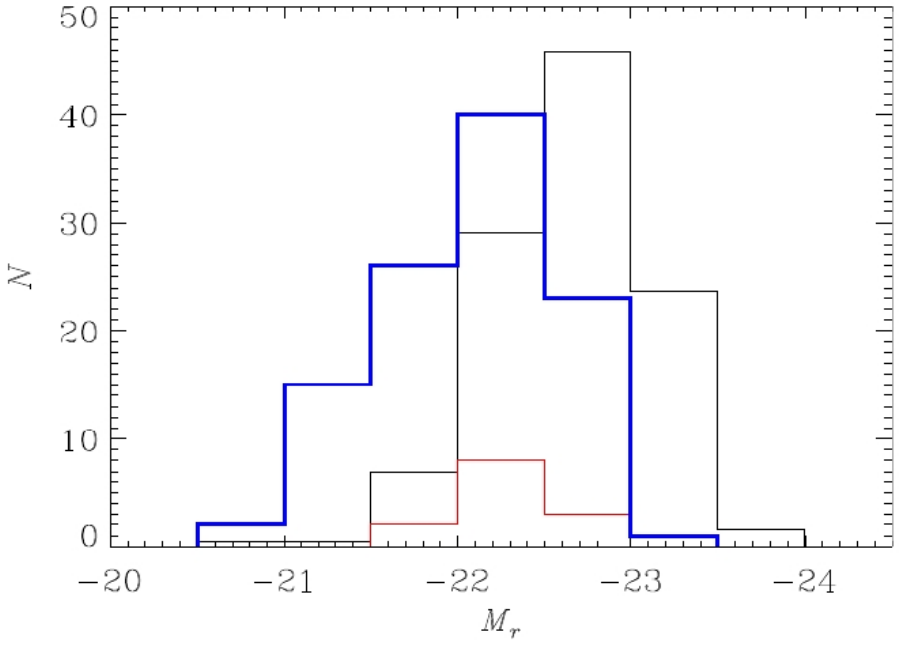


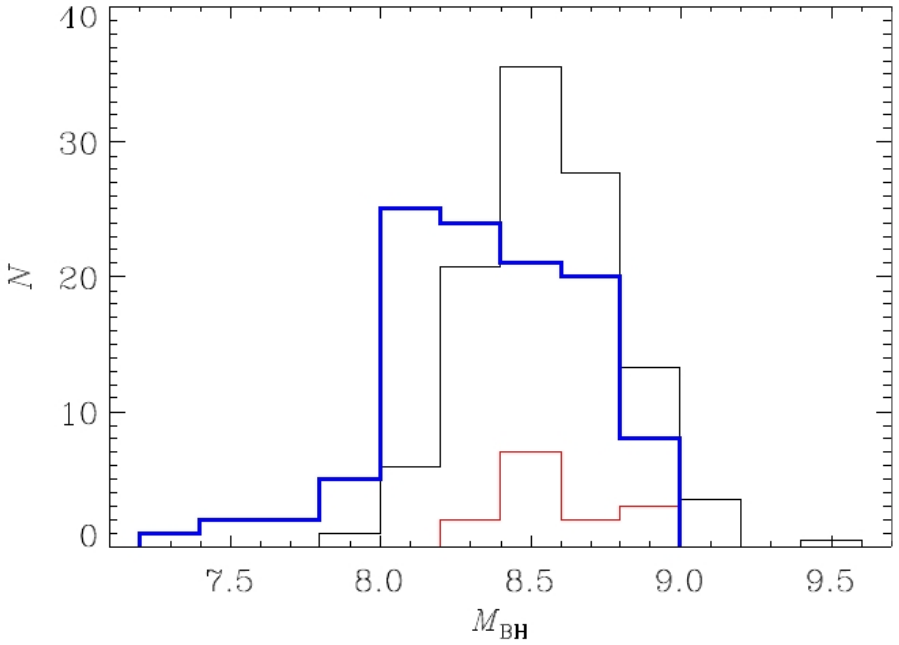
A few small jets and many cores!

A systematic study of FR0: FR0CAT

(Baldi Capetti Massaro 2018)

108 compact (size <5 kpc) sources in FIRST at z<0.05 , L radio 10^{38} – 10^{40} erg/s

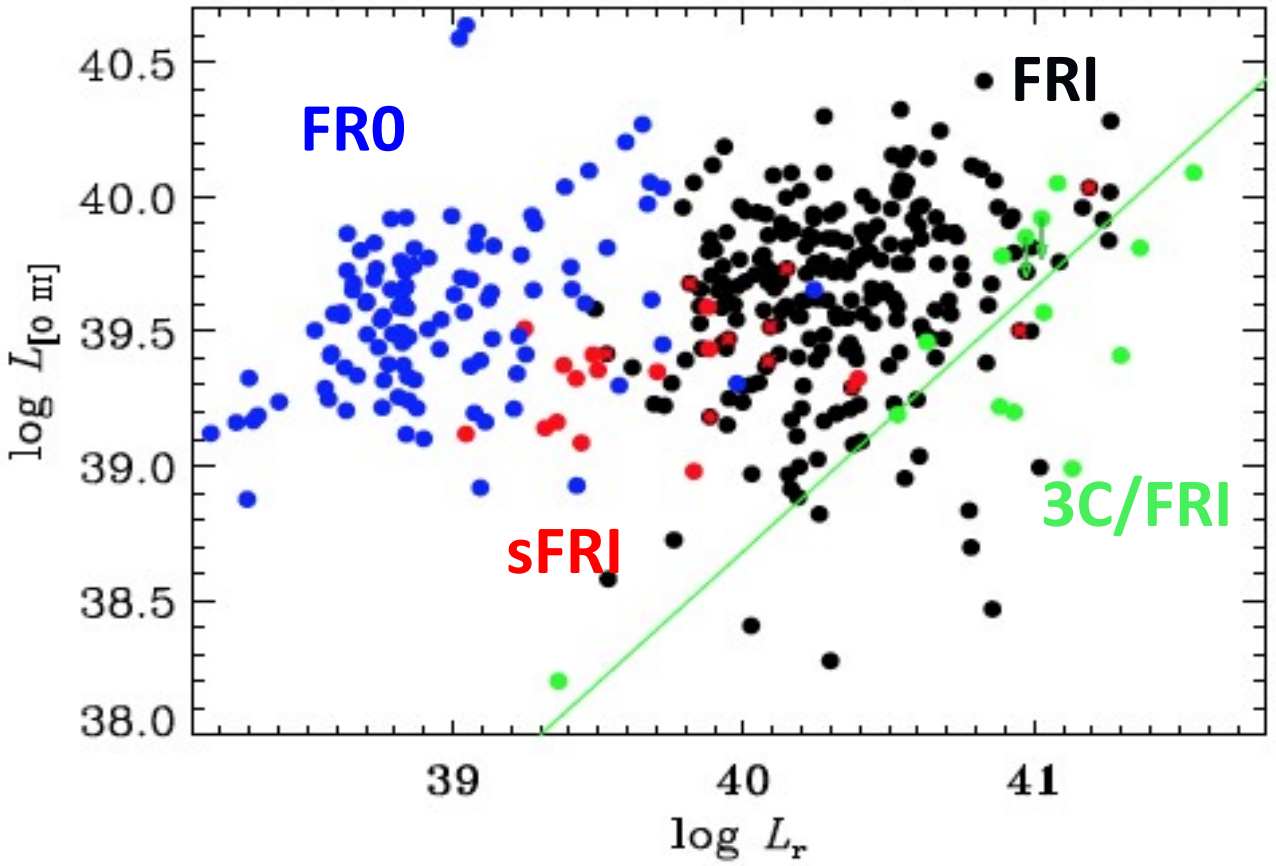




All LEG (except 4 HEG), luminous red elliptical hosts.

Very similar to the FRI hosts (black), just slightly less massive. A small low M_{BH} tail.

FR0 vs FRI IN FIRST



A continuous distribution of radio power at given AGN power from the 3C/FRI, to the FRI in FIRST, the sFRI (FRI with z<0.05) and the FR0.

Baldi, Capetti & Massaro (2018)

JVLA observations of a random sub sample of 18 FR0

Three bands (1.5, 4.5, and 7.5 GHz). A array, resolution 0.2 – 1 arcsec.

Four are extended, sizes 2-8 kpc. NO CSO!! 14 are still compact.

RADIO SPECTRA

In most sources the FIRST and NVSS flux is fully recovered: no lost diffuse emission.

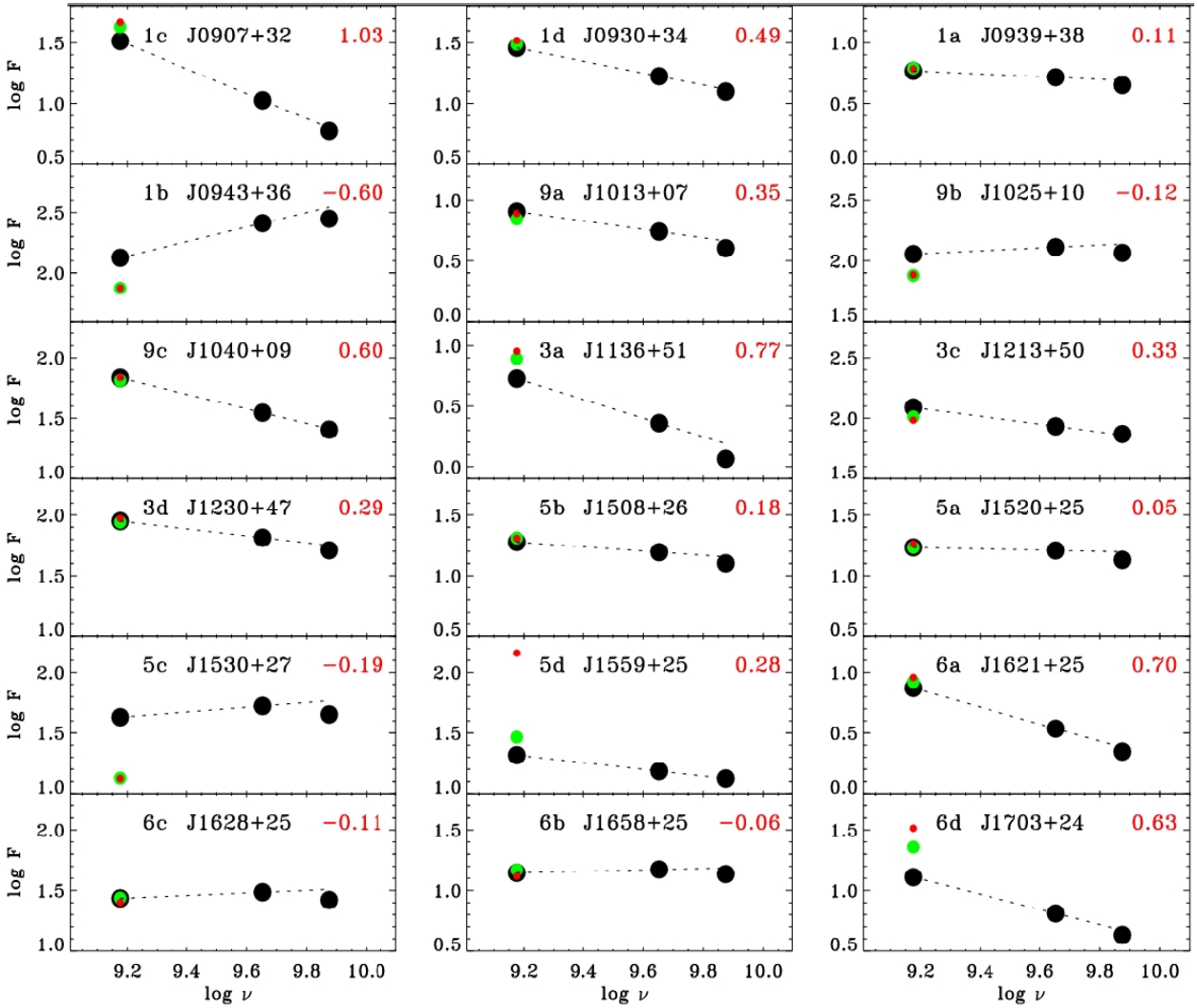
The two sources with the highest deficit are extended.

12 are flat spectrum (<0.5)

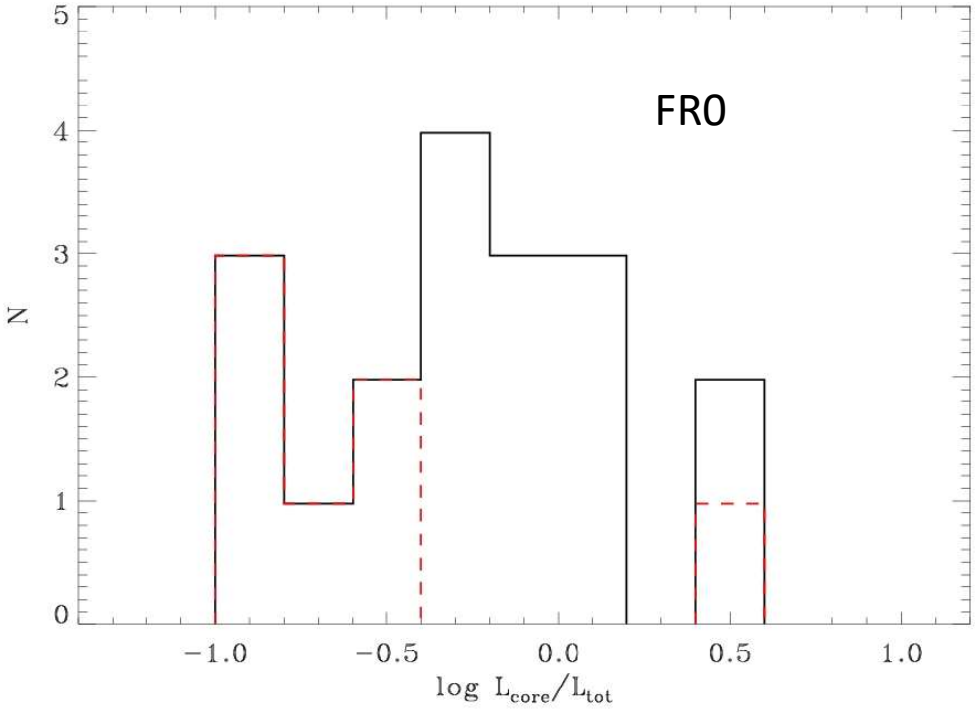
5 are steep spectrum

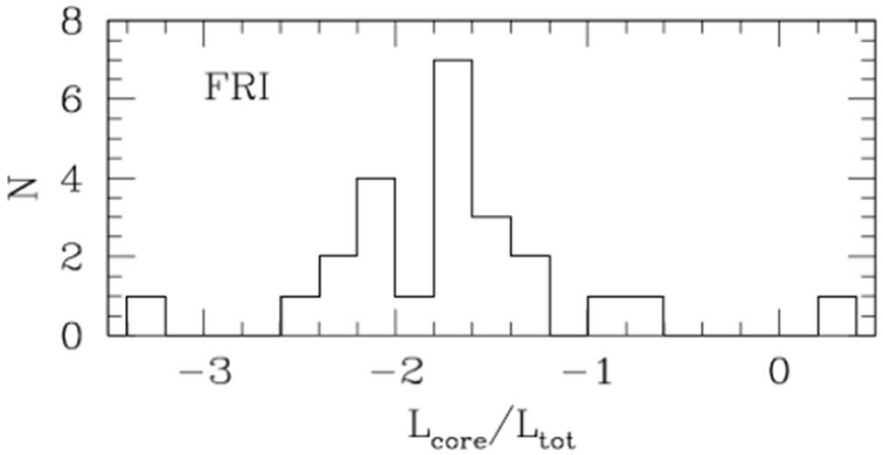
1 is inverted, a GPS/HFP source, flux almost doubled in 15 years.

Radio core (or upper limit) from the 7.5 GHz data.



CORE DOMINANCE

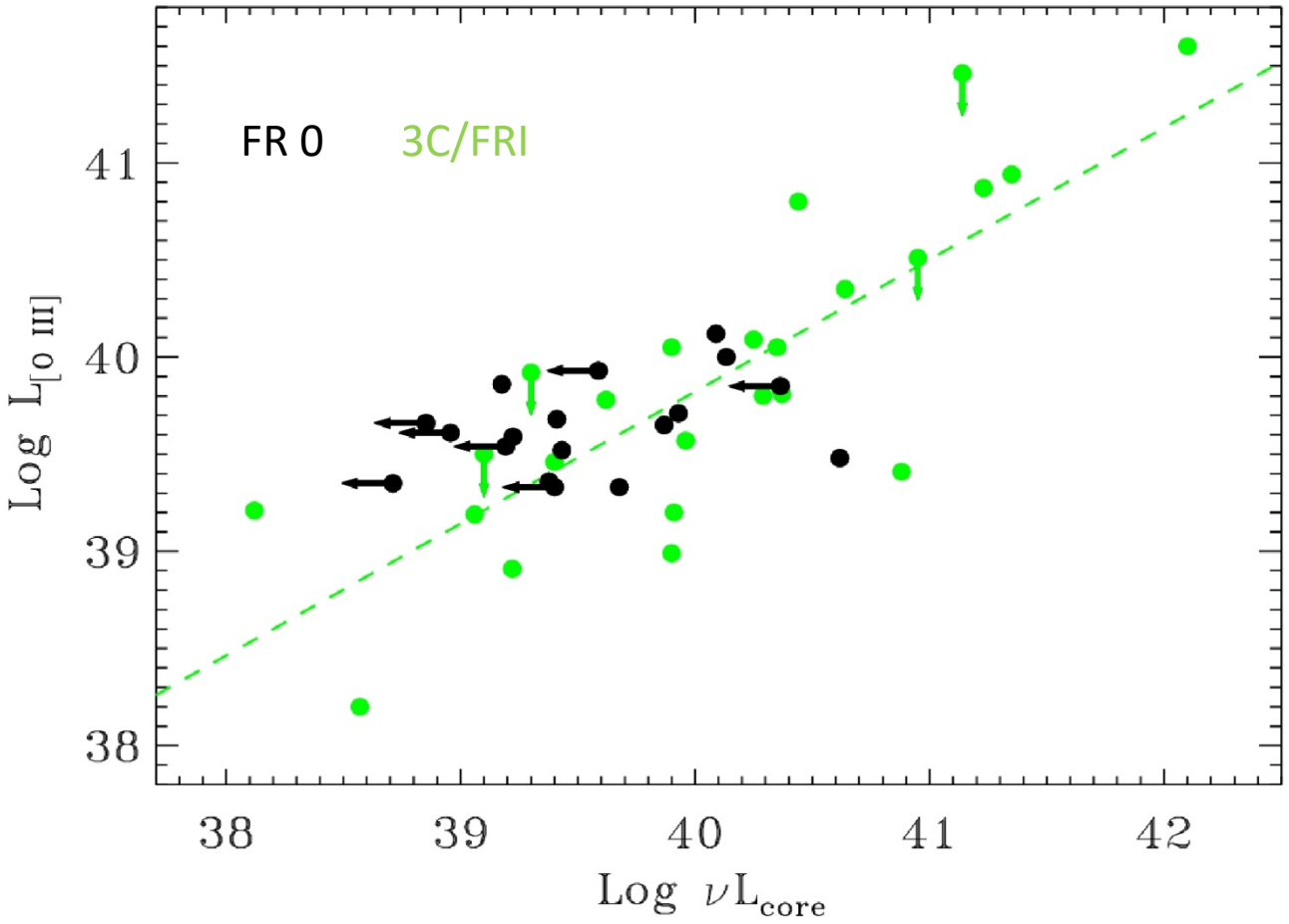




The core dominance of FR 0 is >30 times larger than in the 3C/FRI.

Their lower radio luminosity is due to a paucity of extended emission.

CORE vs AGN POWER (I)



The core emission of FR 0 is the same of the 3C/FRI of similar AGN power.

SAME CENTRAL ENGINE BUT LESS EXTENDED EMISSION

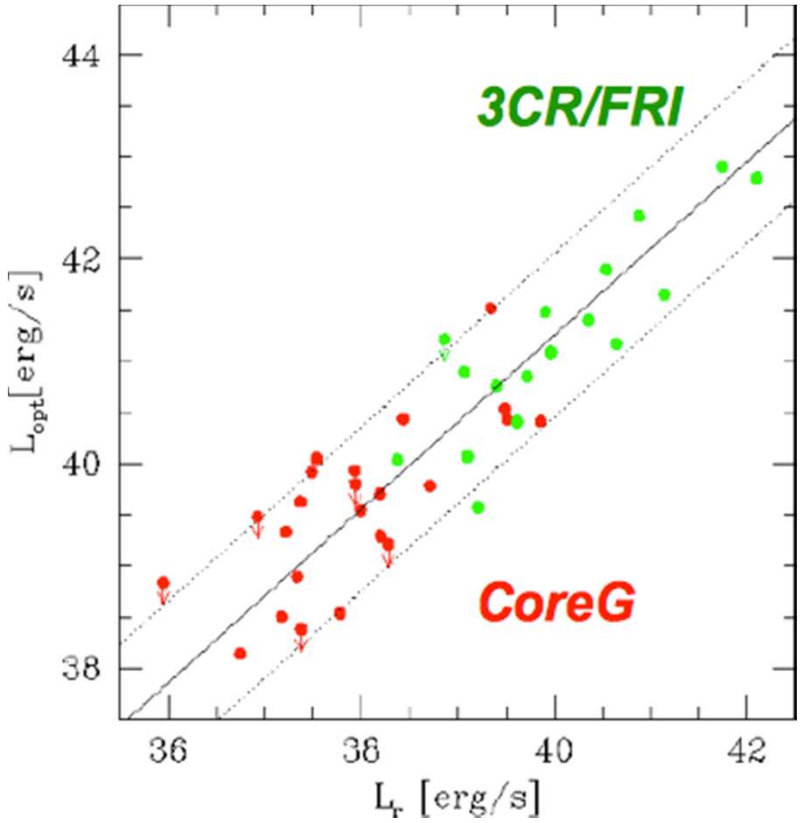
12 years ago:

Radio sources in nearby (v<3000 km/s) elliptical galaxies

(extracted from the Wrobel 1991 sample)

Selection of «core galaxies» based on the optical profile

(Balmaverde Capetti 2005, 2006)

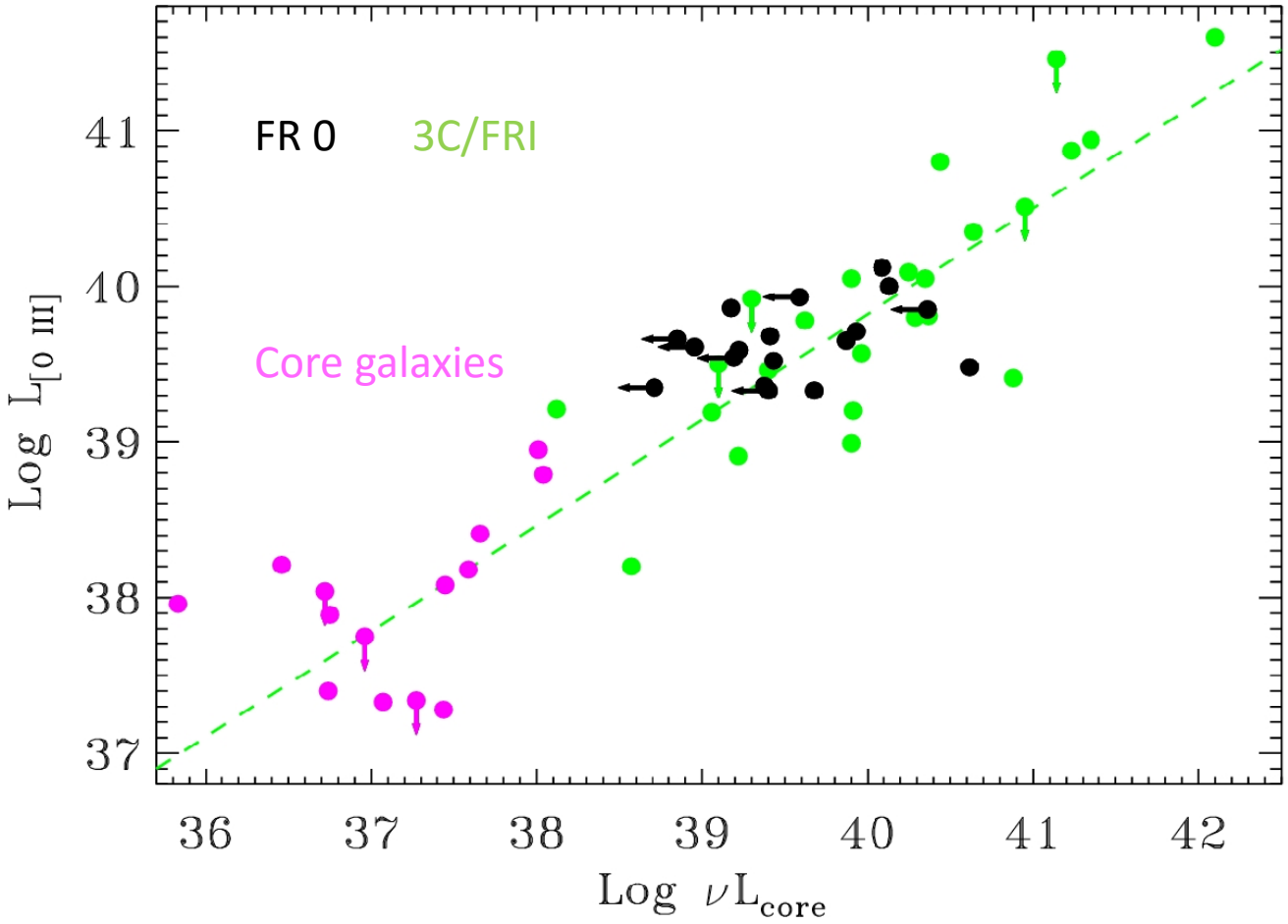


The optical nuclear continuum (HST) in CoreG follows the same linear relation with the radio core defined by the 3C/FRI. Up to 100 times less luminous.

Synchrotron emission from faint radio loud nuclei.

Is there a miniature radio galaxy in every core galaxy?

CORE vs AGN POWER (II)

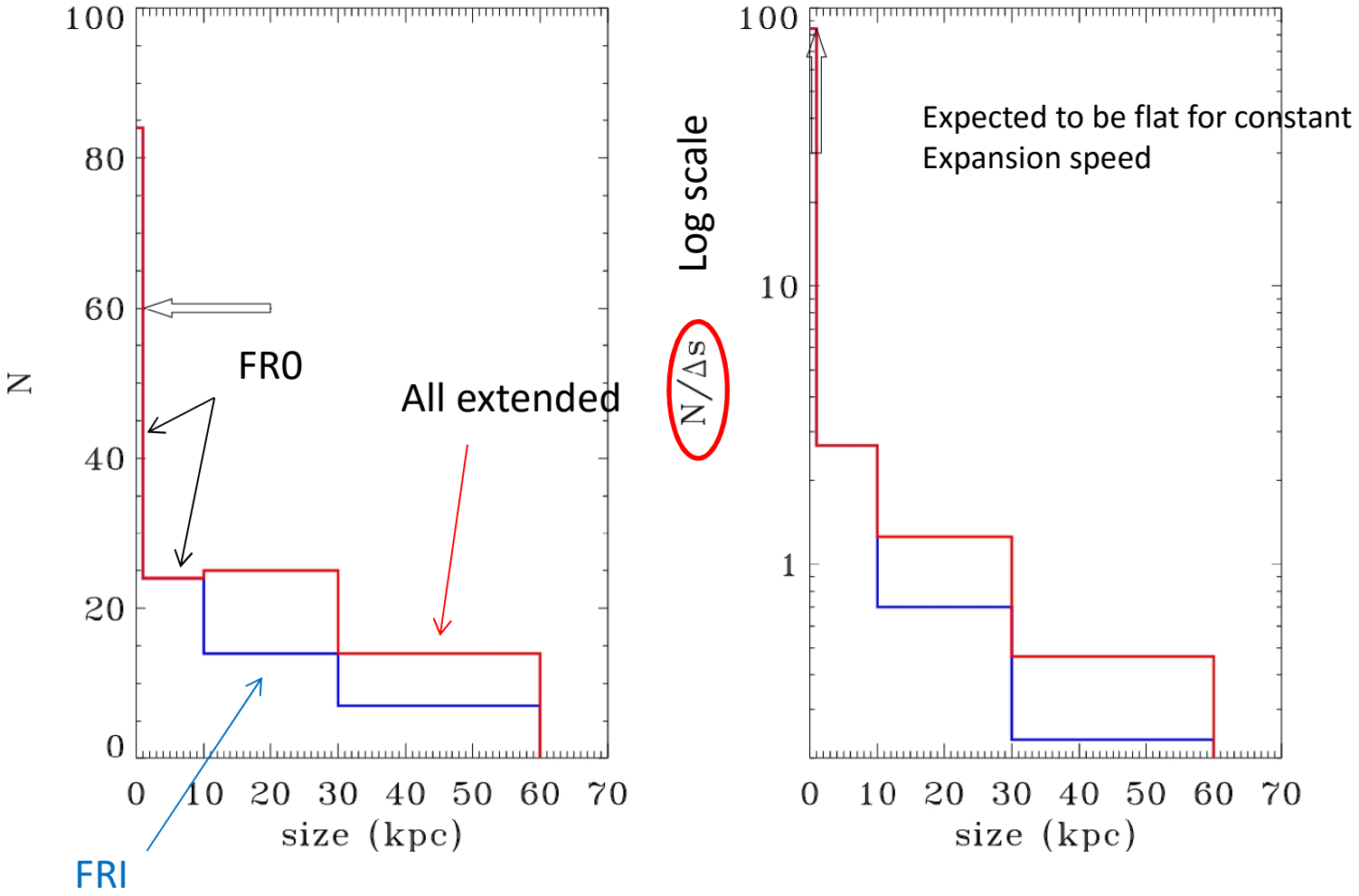


The ratio between core and line emission is almost constant over 6 order of magnitude in luminosity.

SAME CENTRAL ENGINE BUT LESS/NO EXTENDED EMISSION

Are FR0 young FRI?

Clues from number densities



FR0 can not ALL evolve into FRI because their relative number density is too high.

SUMMARIZING:

Are they a well defined class? YES. The «compact source» definition is «almost» independent on the survey characteristics.

FRO and FRI have very similar hosts (massive red Es, LEG) and BHs.

FR0 are essentially FRI cores without extended emission (same radio power at given AGN power, also in X-rays, Torresi et al. 2018).

Same central engine with a range of 10^6 in luminosity.

FR0 can not be ALL young, but some of them MUST be young.

FR0 jets might be slow and disrupt within the host.
1 highly asymmetric jet (out of 4, not enough statistics) .
(and the jetted FR0s might be the few genuine young RGs)

They can be short lived($<10^5$ years) and recurrent radio galaxies.

THE FUTURE

Looking for pc jets in FR0: VLBI observations (in progress)

Are we missing something? A LOFAR view of FR0

The role of environment: comparison of environment of complete samples of FRI and FR0 (in progress)

THANK YOU