Young radio sources and the duty-cycle of the radio emission

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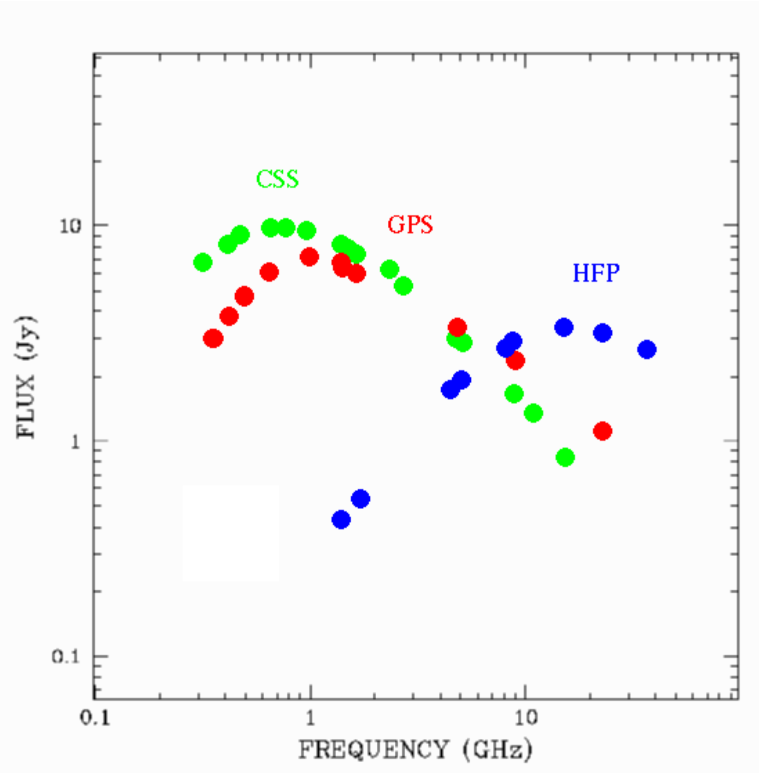
Overview

- Introduction on young radio sources
- Radio properties of very compact radio sources
- Young radio sources: physical properties and evolution
- Searching for short-lived objects

Compact radio sources

- Powerful $L_{1.4\ GHz} > 10^{25}$ W/Hz;
- Steep spectrum $\alpha > 0.7$;
- ν_p~100 MHz to a few GHz
- Compact size LS < 1 – 20 kpc
- High fraction (15%-30%) in flux-density limited catalogues
- Low (<10%) variability

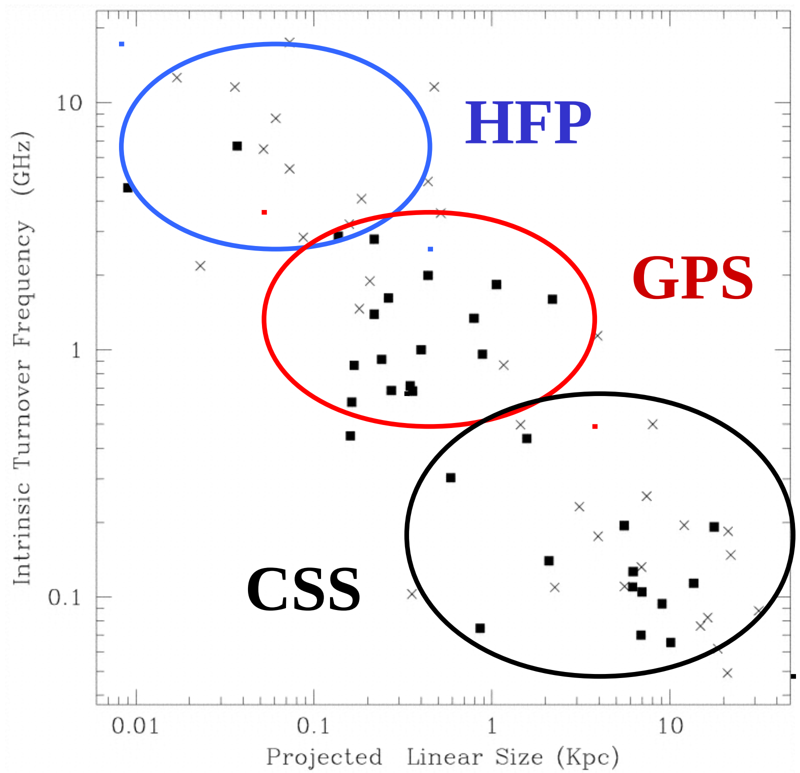


Peak frequency – Linear size

CSS
- LLS < 20 kpc
- $\nu_t \sim 50 - 100$ MHz

GPS
- LLS < 1 kpc
- $\nu_t \sim 1$ GHz

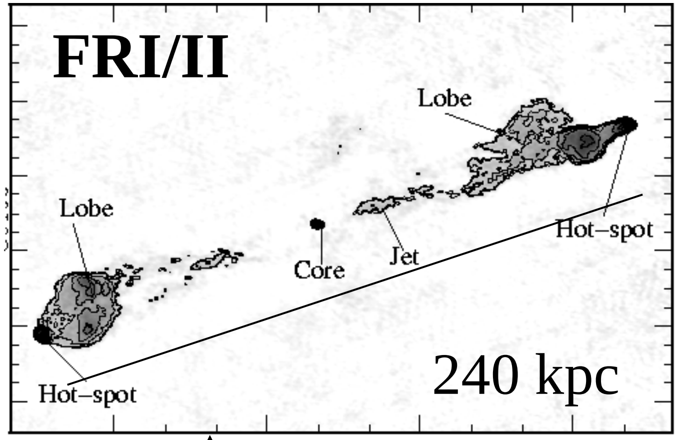
HFP
- LLS < 100 pc
- $\nu_t \geq 4$ GHz



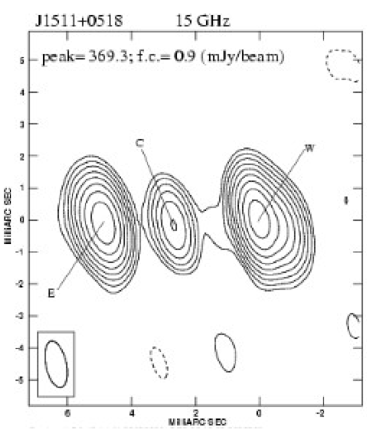
The smaller the source, the higher the turnover frequency (O'Dea 98)

Radio morphology

Scaled-down version of the extended radio sources. They should represent the young stage in the radio source evolution (Phillips&Mutel82)

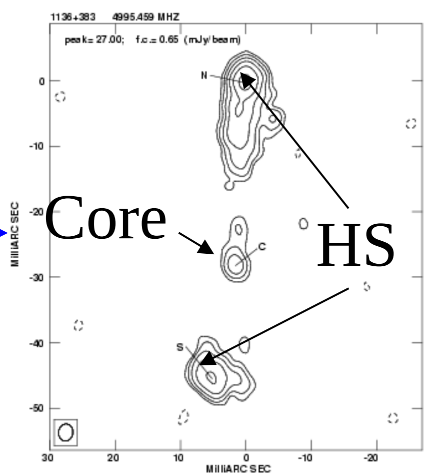


7 pc

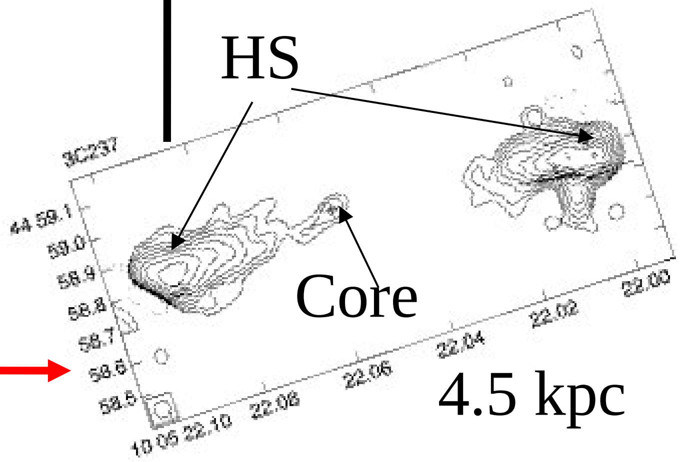


HFP/CSO

350 pc



GPS/CSO



CSS/MSO

The youth scenario

Compact ⟶ **Young**

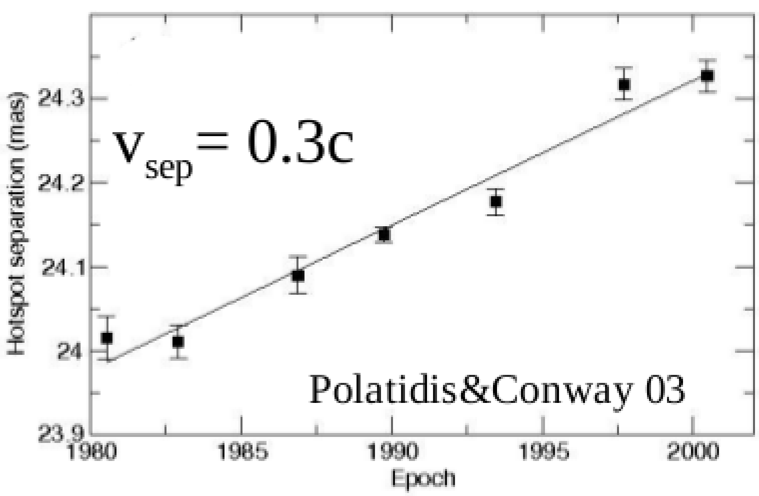
Radiative ages

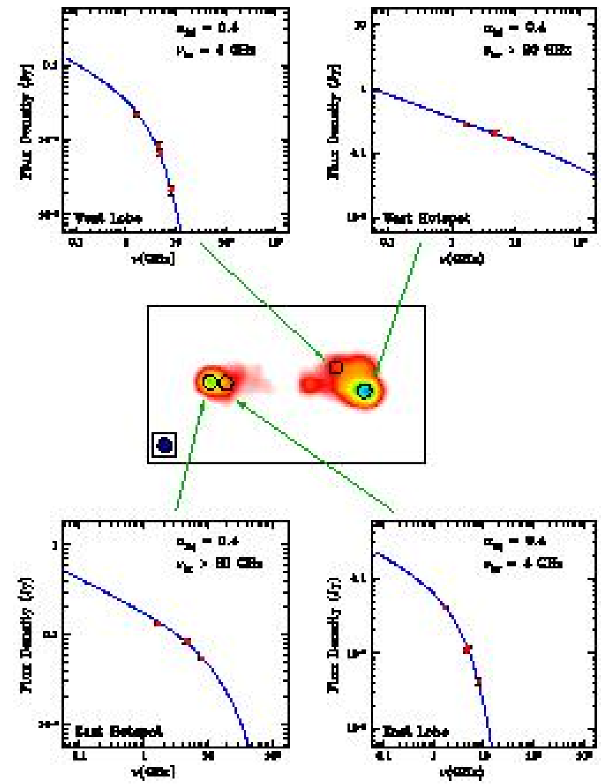
Murgia 2003

Kinematic ages

Polatidis&Conway 2003

} $10^3 – 10^4$ yr

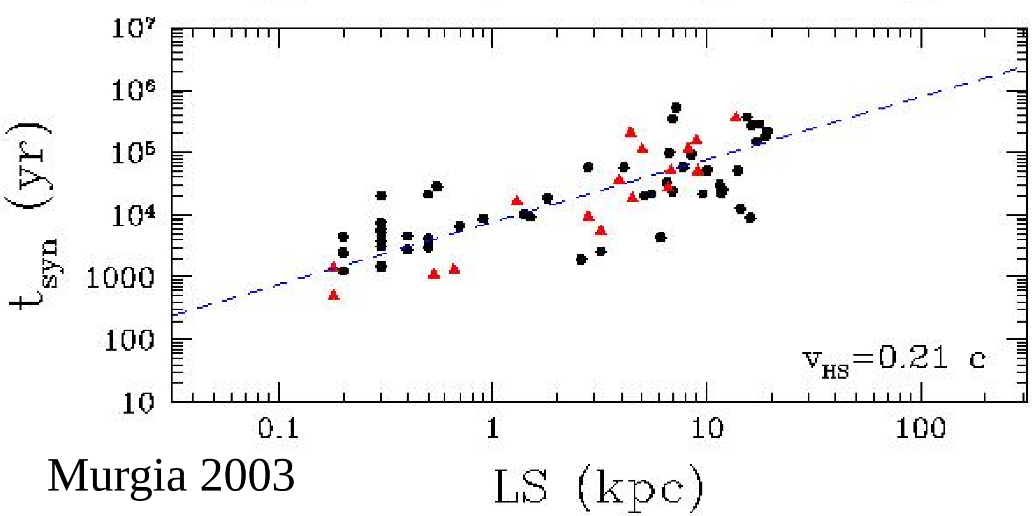




Compact ⟶ **Frustrated**

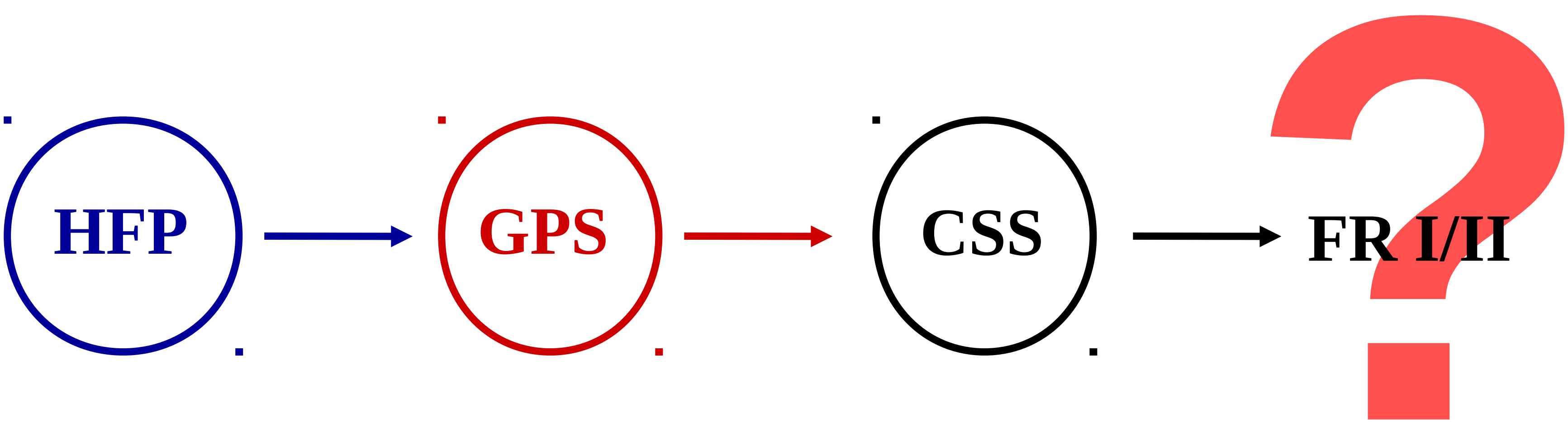
No clear evidence of a particularly dense ISM able to frustrate the source expansion **for its lifetime**

Evolutionary stages



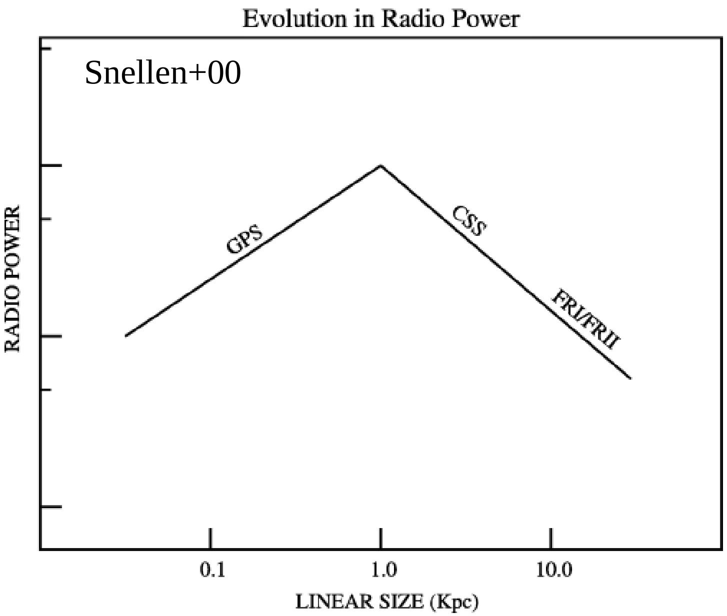
Murgia 2003

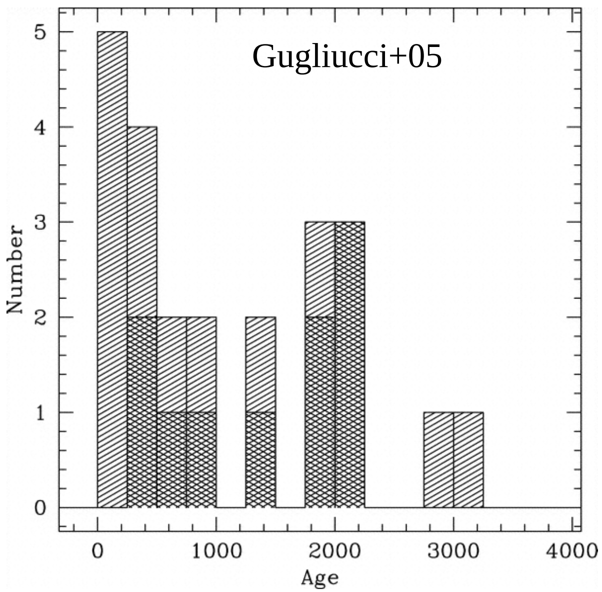
The higher the turnover frequency, the smaller and younger the source is.



Count excess

Excess of young radio sources in flux-density limited catalogs cannot be explained with luminosity evolution.



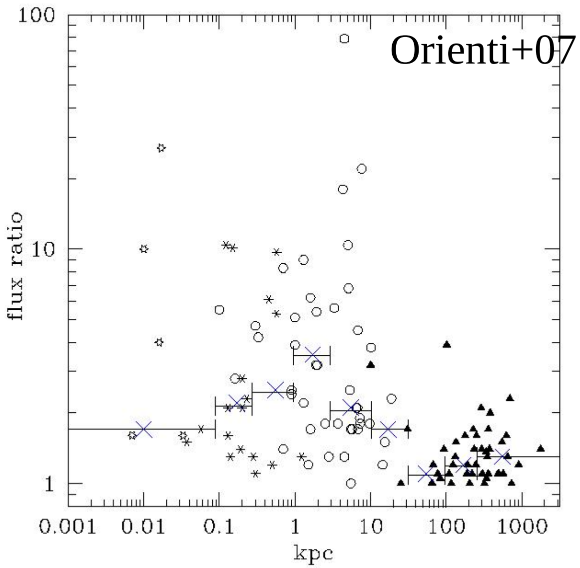


The age distribution of a sub-sample of 13 CSS peaks ~500 yr.

ISM or fading/recurrent radio emission?

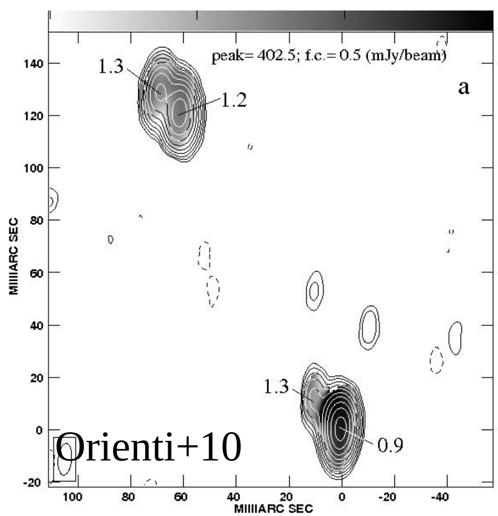
The large fraction of young radio sources may be explained in terms of ISM-jet interaction, short-lived and/or recurrent radio sources

ISM-jet interplay: higher incidence of asymmetric sources than in LSO



High spatial resolution observations are needed

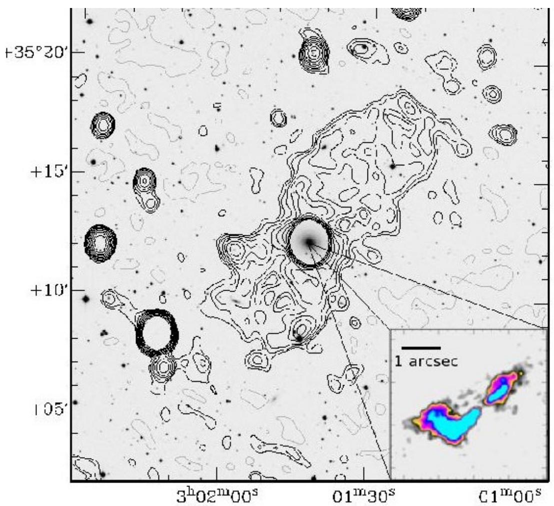
Faders: young sources (t~10[3] yr) with no active regions



Majority lack spectral index studies

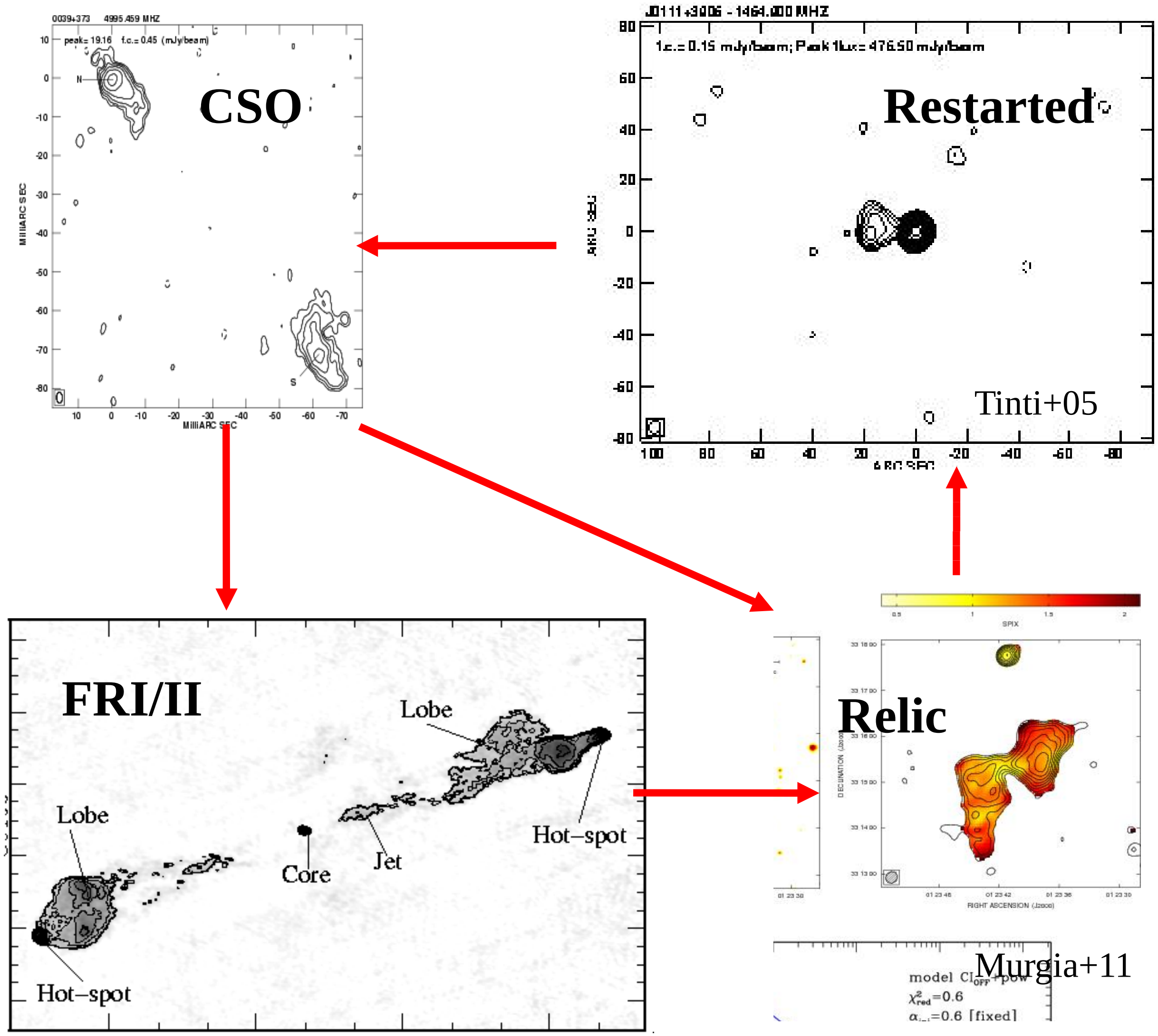
Recurrent activity

Shulevski+12



Old steep-spectrum emission hard to find

The duty-cycle of the radio emission



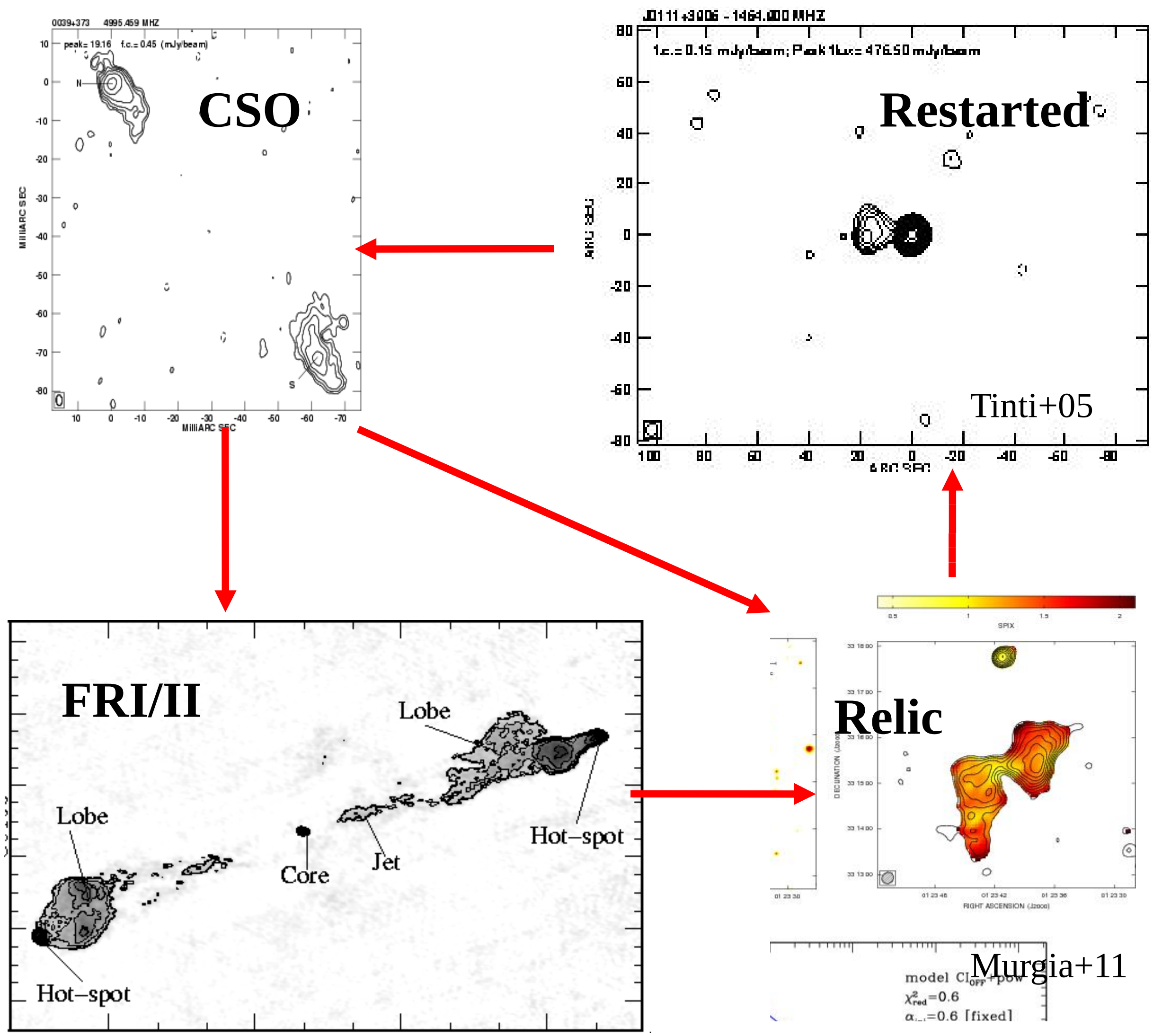
Source evolution:

- Luminosity
- Magnetic field
- Velocity expansion
- Energetics

Influencers:

- ISM
- Jet power

The duty-cycle of the radio emission



Source evolution:

- **Luminosity**
- Magnetic field
- Velocity expansion
- Energetics

Influencers:

- **ISM**
- Jet power

CSS/GPS: physical properties

We select a sample of bona-fide young radio sources from different CSS/GPS samples (Fanti+90,01, Dallacasa+95,00, Snellen+98, Stanghellini+98,09, Peck&Taylor00)

- Clear core detection
- Known z (spectroscopic/photometric)

48 objects, 31 galaxies and 17 quasars with LS ~ 10 pc to 30 kpc

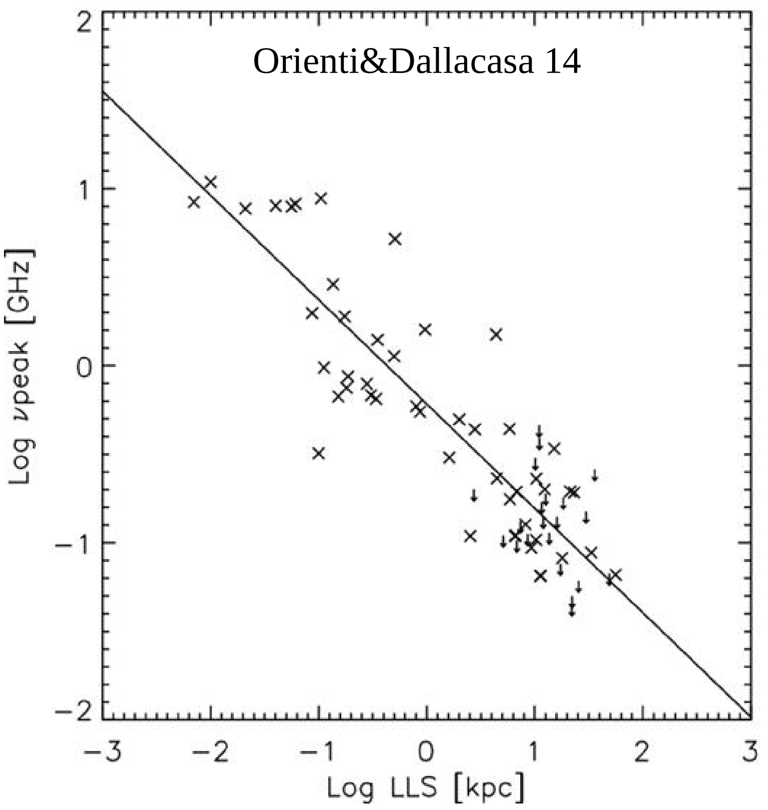
Suitable for investigating radio emission at different evolutionary stages

Turnover frequency - LLS

Empirical correlation

log ν_p ~ -0.21 – 0.59 log LLS

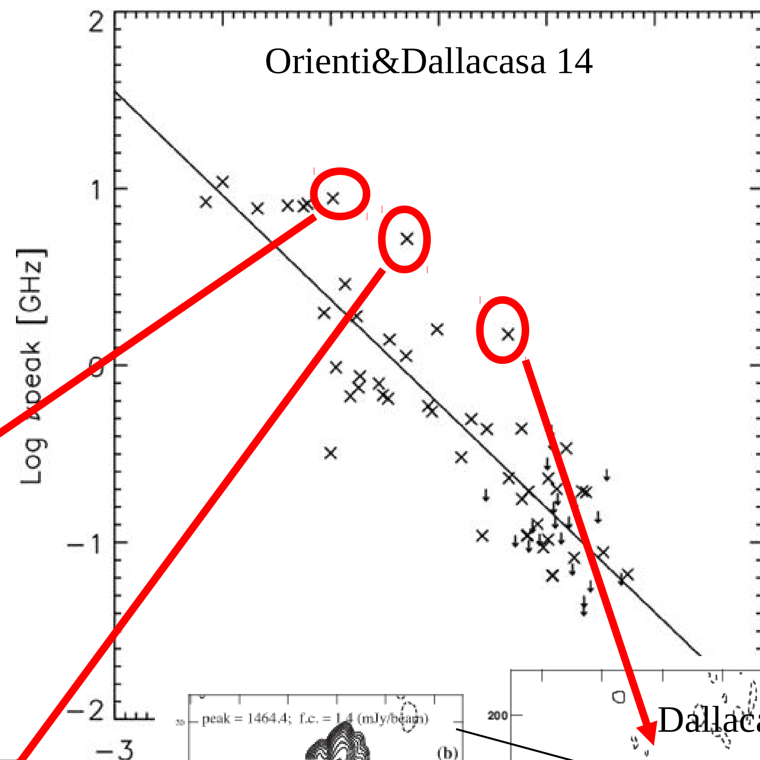
Deviation at small LLS

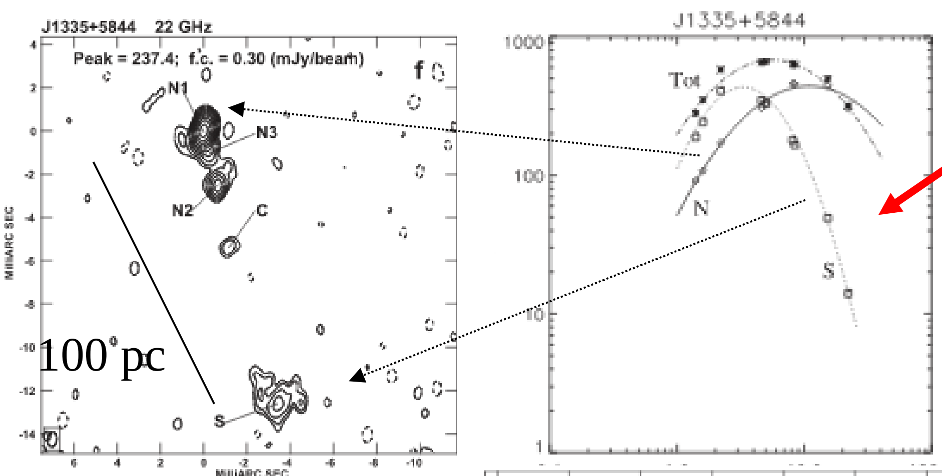


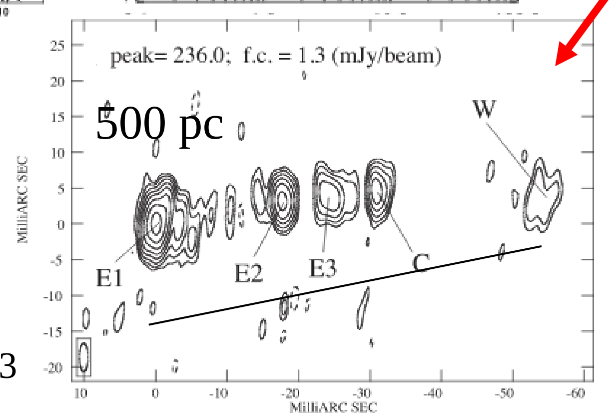
Turnover frequency - LLS

Deviation at small LLS

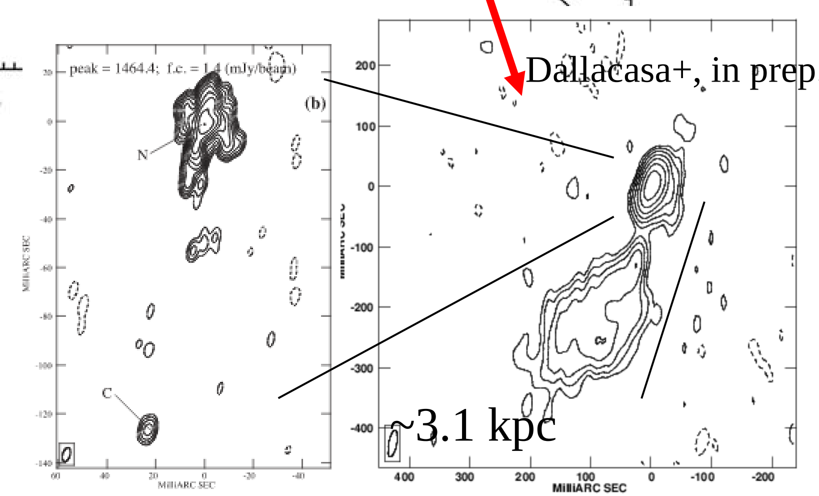
Overall spectrum not representative of the source LLS







Dallacasa+13



Luminosity

Total luminosity at 375 MHz

Absorbed sources: 375-MHz flux extrapolated using the optically-thin spectral index

Core luminosity at 5 GHz

No 5-GHz data: flux extrapolated assuming a flat spectrum

Galaxies + Quasars, similar to FRI/FRII:

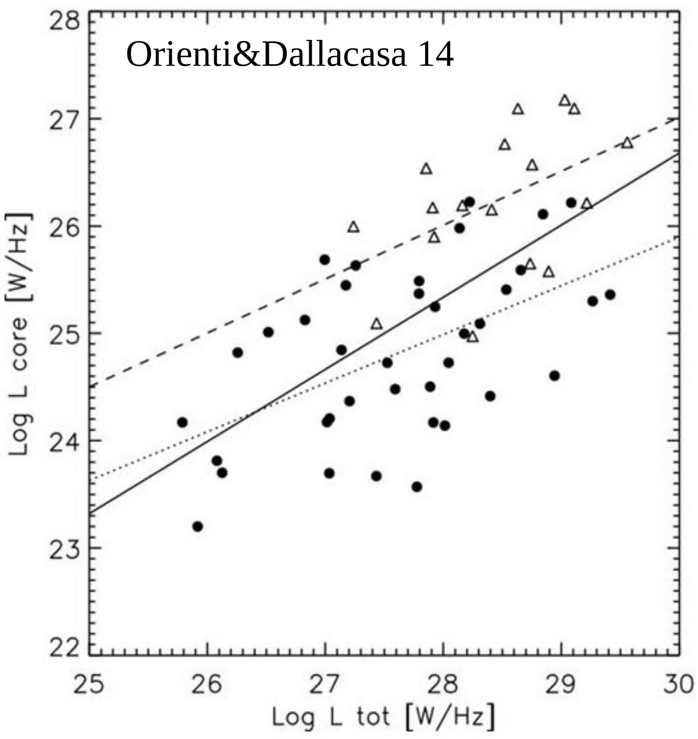
$$L_{core} \sim 6.5 + 0.67\, L_{tot}$$

Galaxies only

$$L_{core} \sim 12.28 + 0.5\, L_{tot}$$

Quasars only

$$L_{core} \sim 11.94 + 0.5\, L_{tot}$$



Quasars and galaxies have same slope and an offset in Lcore

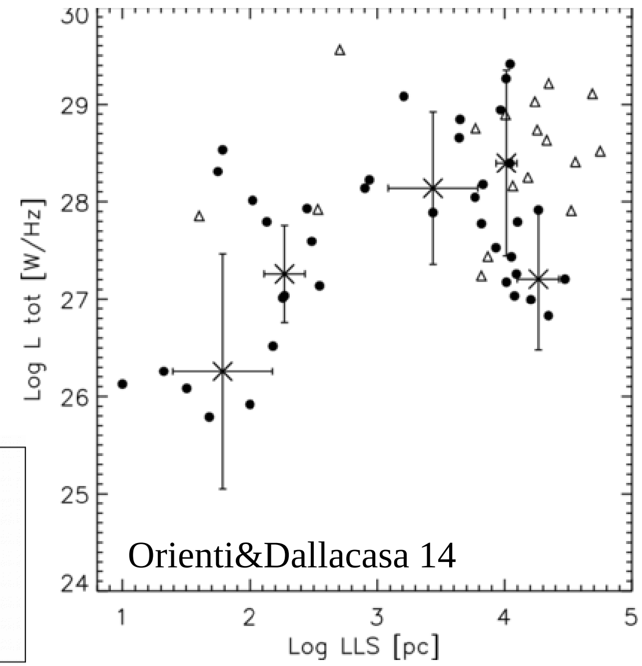
Quasars+galaxies: steeper slope driven by segregation in Lcore and Ltot

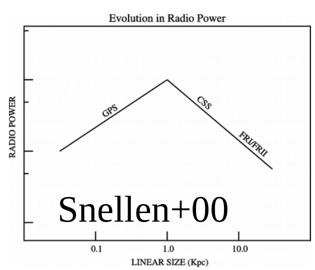
Luminosity - LLS

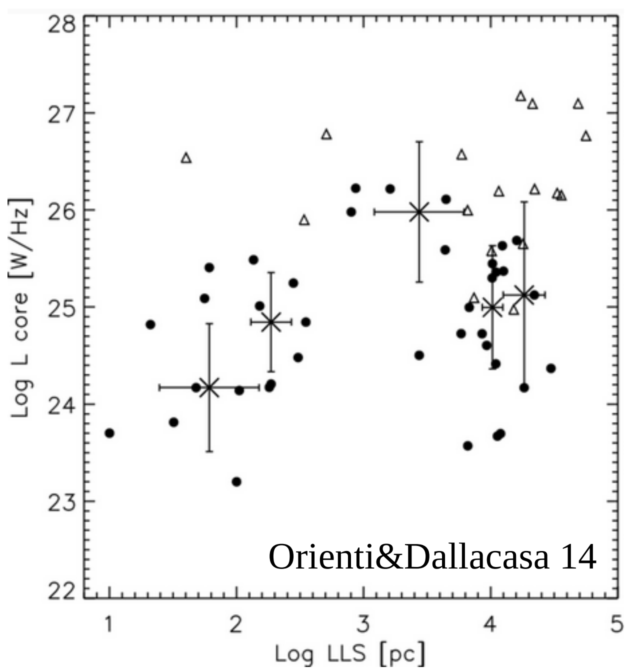
Galaxies only: luminosity evolution consistent with models

$$LS \leqslant 4\,kpc : L_{tot} \uparrow$$

$$LS \geqslant 4\,kpc : L_{tot} \downarrow$$







$$LS \leqslant 1\,kpc : L_{core} \uparrow$$

Low statistics for LLS ~ 1 kpc

Quasars cluster at high Ltot and Lcore

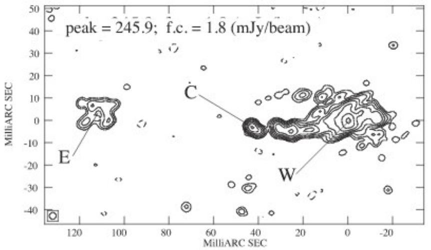
Quasars may suffer from projection

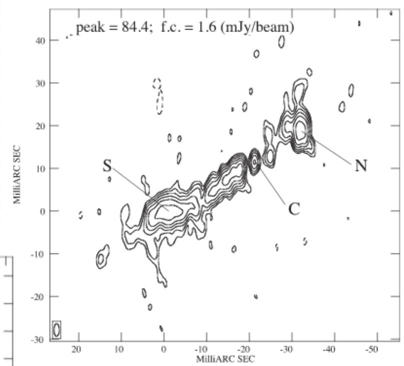
Role of ISM in young radio sources

AIM: determine the morphology and spectral index distribution in GPS sources

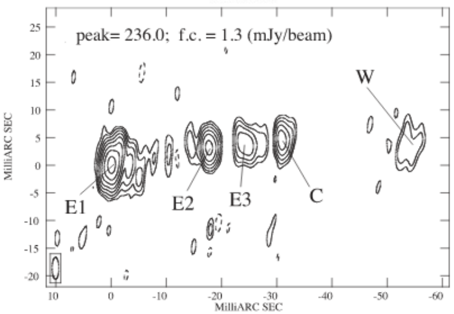
HOW: multi-frequency VLBI observations of 10 GPS + 9 HPF (from Dallacasa+95, Dallacasa+00)

Dallacasa+13

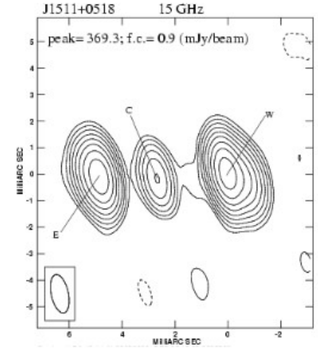


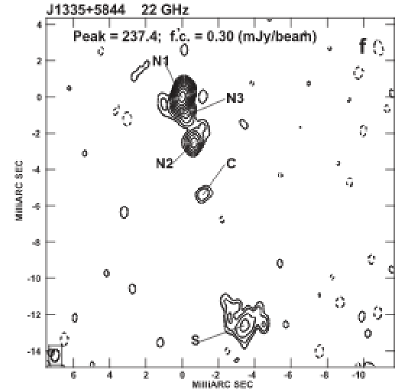


Results: 7/10 GPS have core identification
6/7 have two-sided structure
3/6 asymmetry caused by projection



Results: 5/9 HFP have core identification
4/5 have two-sided structure
2/4 asymmetry caused by projection



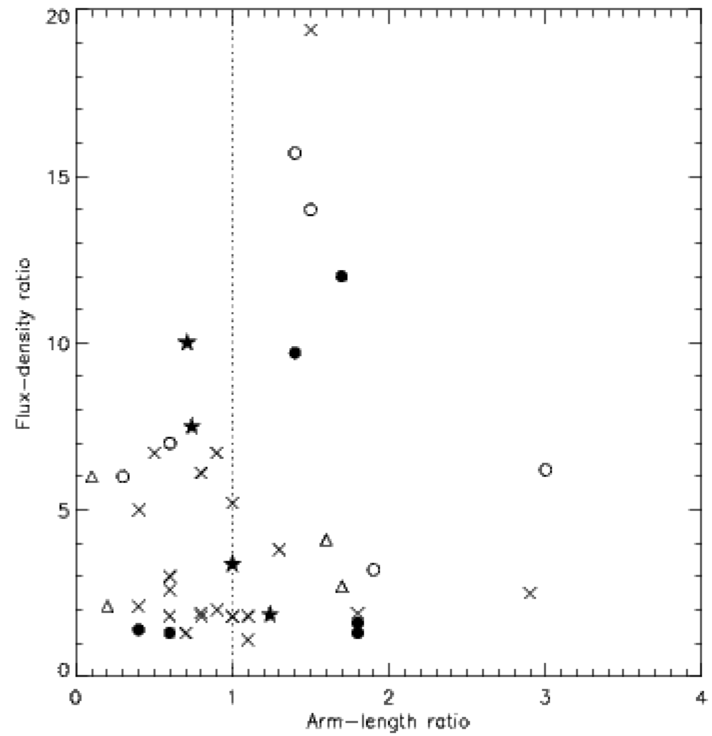


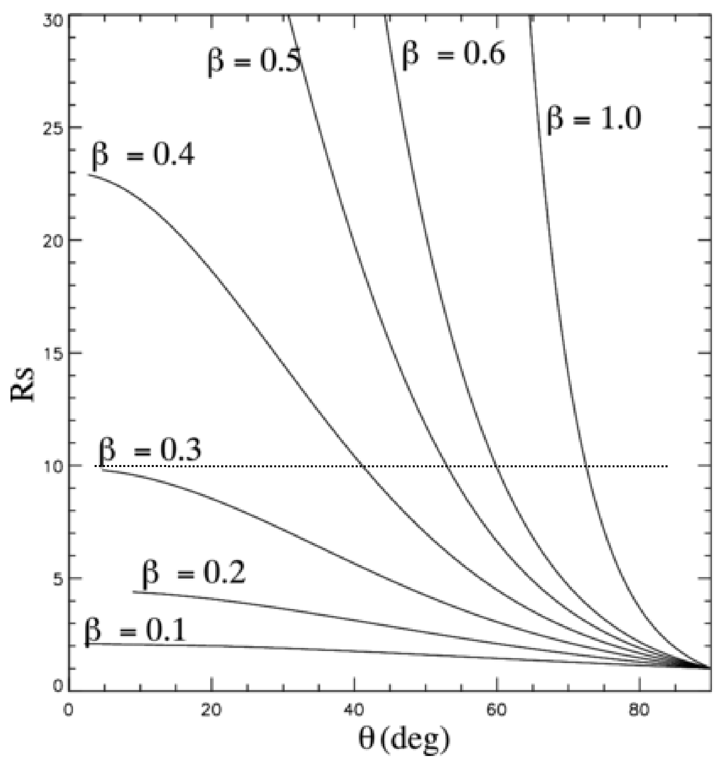
Orienti&Dallacasa 14

Asymmetries in “symmetric” objects

We complemented our results with those from other samples of CSS/GPS with LS up to a few kpc.

Brighter-when-closer in >50% of sources





Dallacasa+13

$$R_S = \left(\frac{1 + \beta \cos\theta}{1 - \beta \cos\theta} \right)^{(3+\alpha)}$$

Rs > 10 need either large β or small viewing angle θ

Fading radio sources

AIM: constraining the incidence of fading objects at different evolutionary stages

MODELS:

1) intermittent radio emission lasts 10^{4-5} yr and recurs 10^{5-6} yr (Reynolds&Begelman97)

2) intermittent radio emission lasts $<10^{3-4}$ yr and recurs 10^{4-5} yr (Czerny+03)

EXPECTATIONS:

1) excess of MSO (LS > 1 kpc) (Reynolds&Begelman97)

2) excess of CSO (LS < 1 kpc) (Czerny+97)

Searching for faders

Looking for candidate faders from the Fanti+01 B3-VLA CSS sample

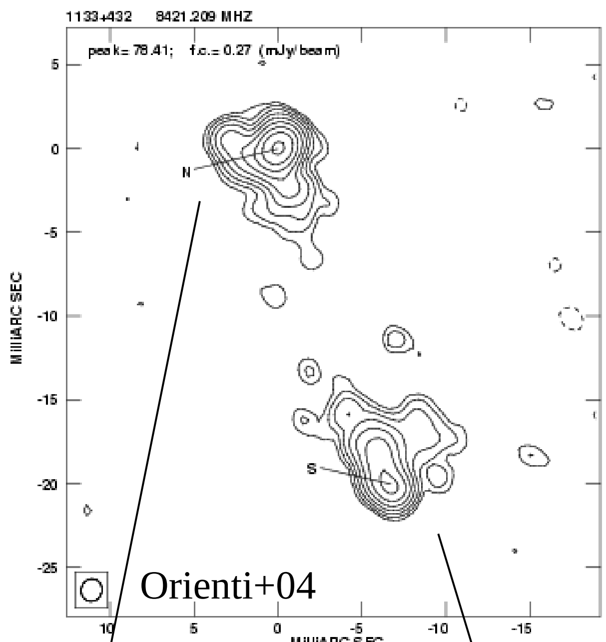
Selection criteria:

- Steep spectrum with $\alpha > 1.0$
- No evindence of active regions

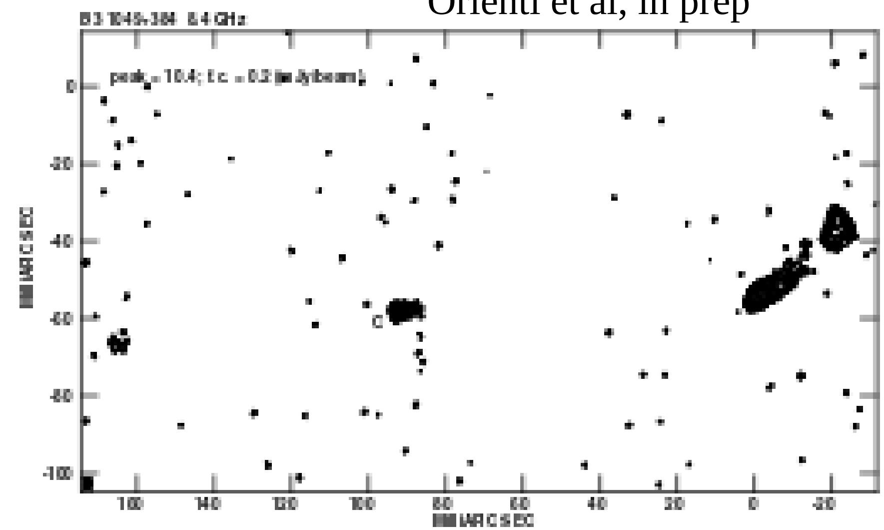
18 CSS source: 12 with LLS > 1 kpc, 6 with LLS < 1 kpc

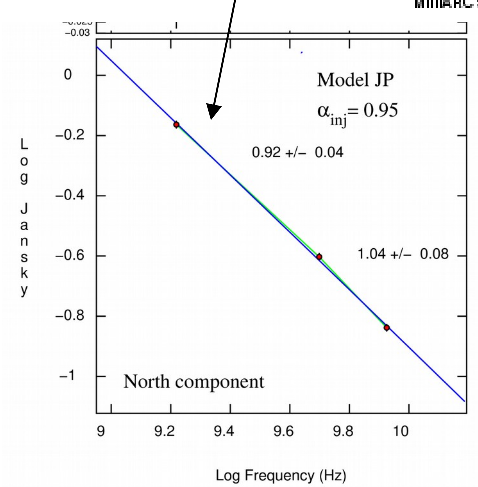
LS < 1 kpc: preliminary results

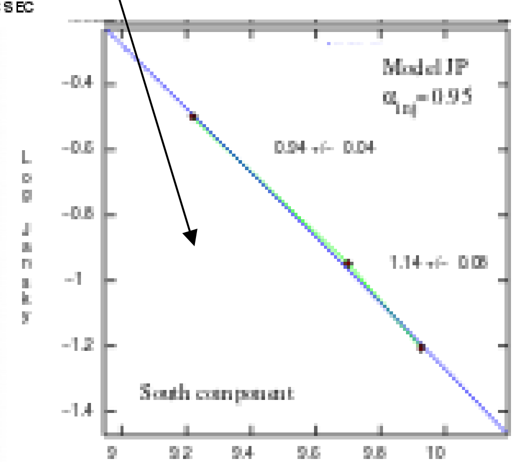
VLBA observations at 1.4, 5, 8.4 GHz



Orienti et al, in prep







4 out of 25 sources (~16%) with LS < 1 kpc in the Fanti et al. sample do not show active regions

2 sources with clear detection of the core

LS > 1 kpc: preliminary results

VLA observations from 1 to 17 GHz

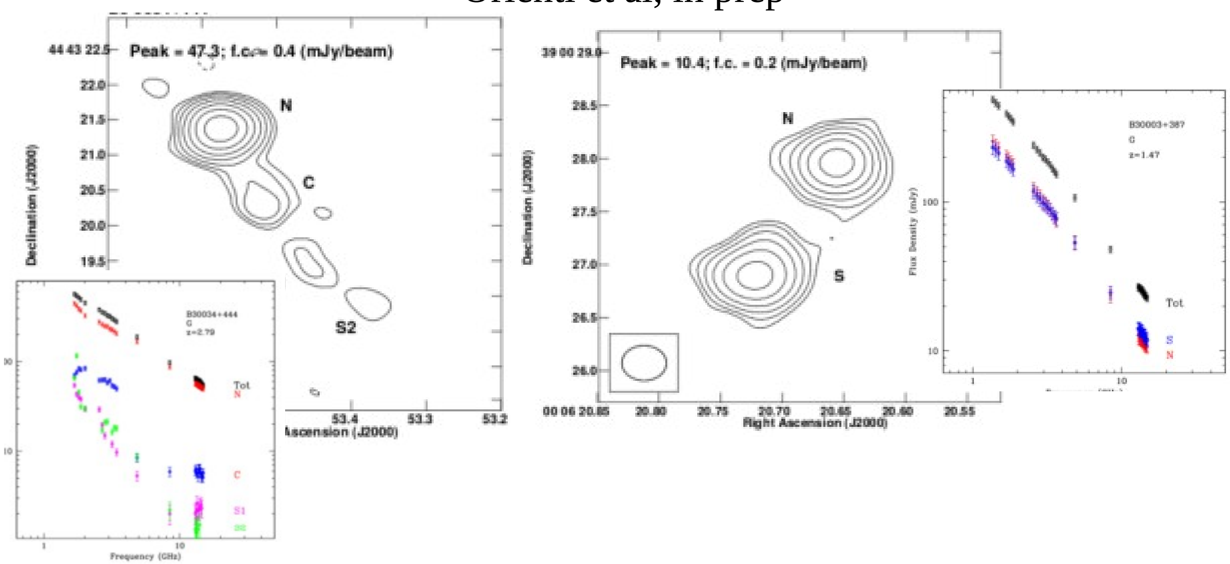
Orienti et al, in prep

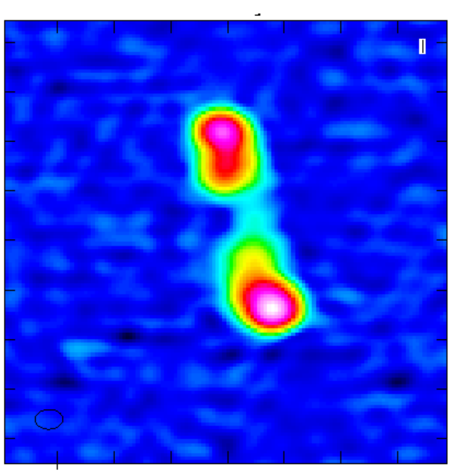
4 sources fully calibrated

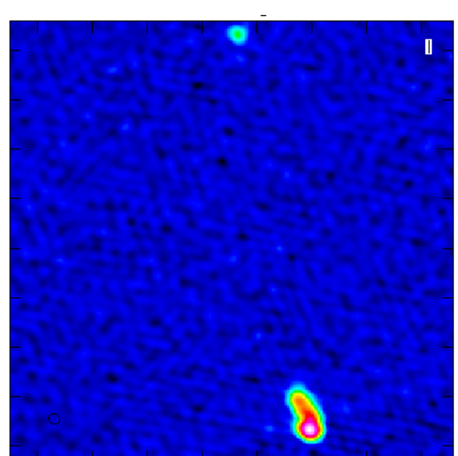
3 sources with active regions

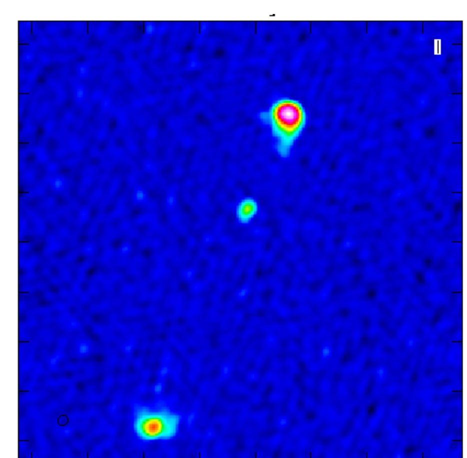
1 source with no active regions

8 sources analysis in progress









Conclusions

- Young radio sources provide insight on the initial conditions of the evolution of the radio emission
- Luminosity evolution of high-power young radio galaxies agrees with the expectation from evolutionary models
- Incidence of asymmetric morphology likely produced by ISM interaction is high in young radio sources
- Over-abundance of young radio sources indicates the existence of a population of short-lived/recurrent objects
- The time scale of recurrent activity is still far to be constrained
- The high sensitivity and resolution at low frequencies are crucial for our knowledge of the life cycle of the radio emission