Radio properties of GPS and CSS sources

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Outline

Radio properties of CSS/GPS sources

- Morphology
- Variability
- Polarization

The nature of CSS/GPS sources and their physical properties

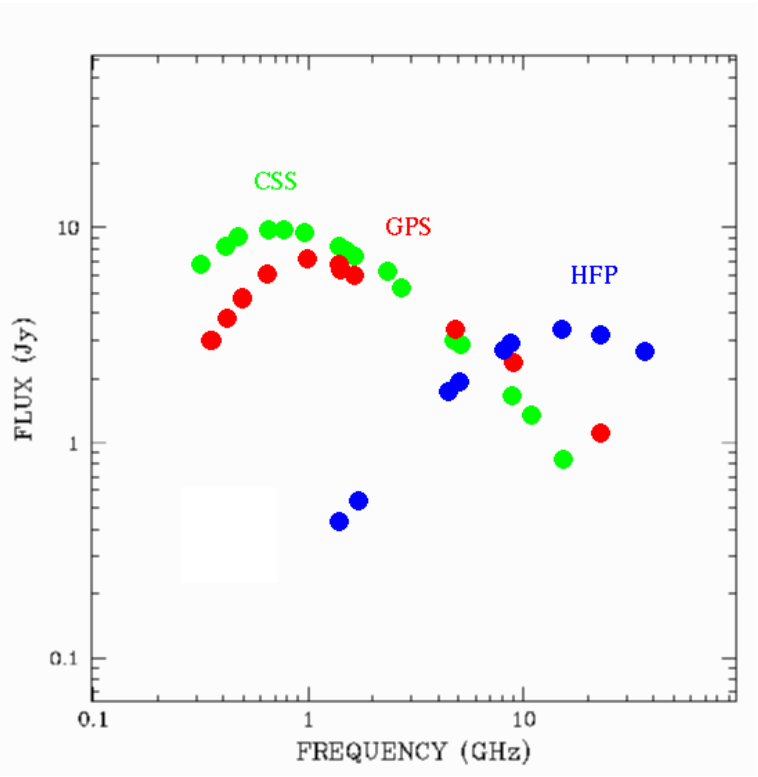
- The duty-cycle of the radio emission
- Luminosity
- Spectral peak

The ambient medium

- Neutral and Ionized gas
- The ambient medium and the source evolution

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

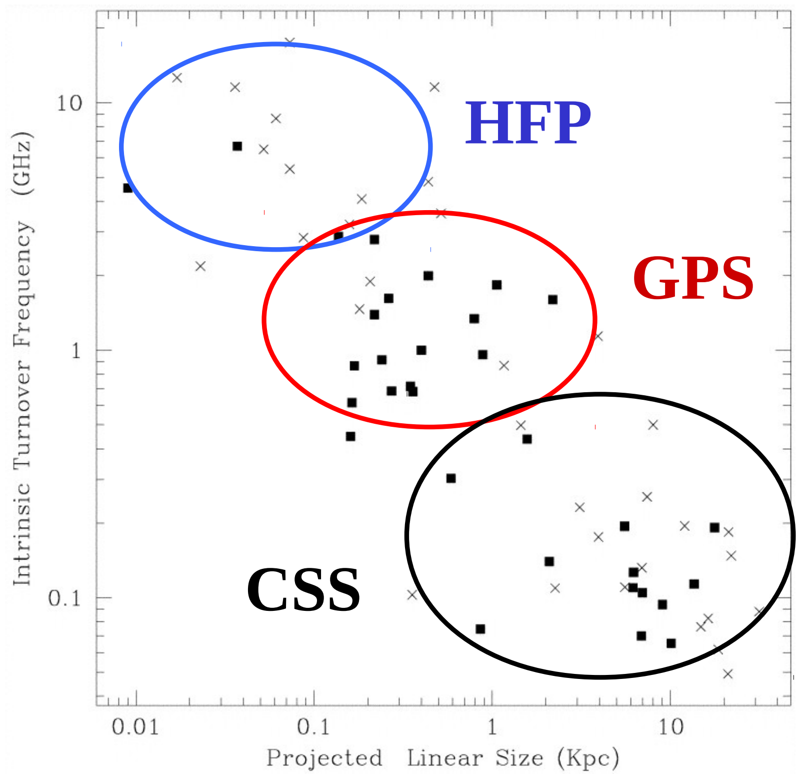


Peak frequency – Linear size

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)

CSS and GPS samples

Selection of CSS and GPS samples from flux density limited radio survey at different frequencies

- **CSS samples:** from 3CRR at 178 MHz, PW at 2.7 GHz, B3 at 408 MHz

  - Spencer+89, Fanti+90, Sanghera+95, Fanti+01, Kunert+02

- **GPS samples:** from 1-Jy catalogue, WENSS at 352 MHz, AT20GHz, Metsähovi at 37 GHz,

  - Stanghellini+98, Snellen+98, Hancock+10, Torniainen+06

- **HFP samples: cross-correlation of GB6, FIRST, NVSS**

  - Dallacasa+00, Stanghellini+09, Partridge+09

- **CSS/GPS selected on the radio structure: COINS, CORALZ, CJB, VIPS**

  - Peck&Taylor00, Polatidis+99, Snellen+04, Taylor&Peck03, Tremblay+09,...

Morphology

Sub-arcsecond resolution is needed for imaging the structure of CSS/GPS objects: VLA, ATCA, MERLIN, VLBI

Credits: Tae-Hyun, Jung (MPIfR, 2004)

CSS/GPS are divided into:

- **Symmetric (i.e. two-sided)**
- **Core-Jet**
- **Complex**

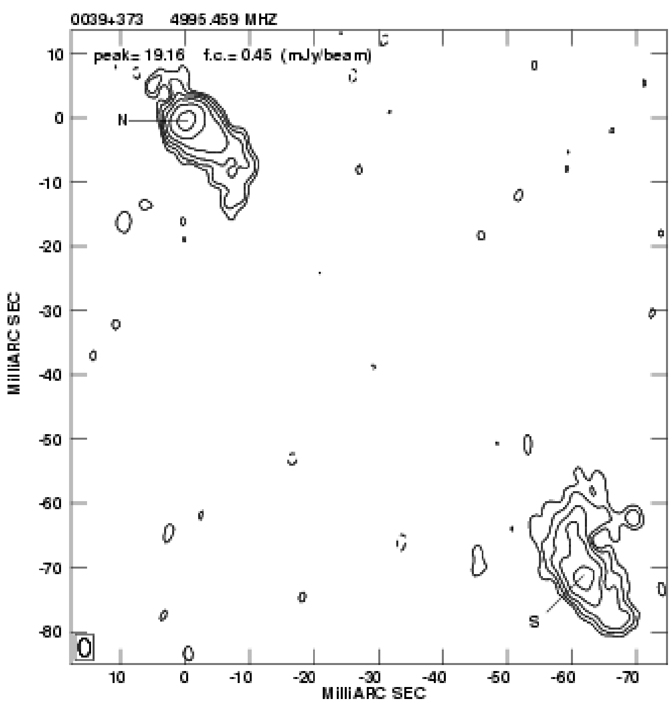
LS > 1 kpc: MSO

LS < 1 kpc: CSO

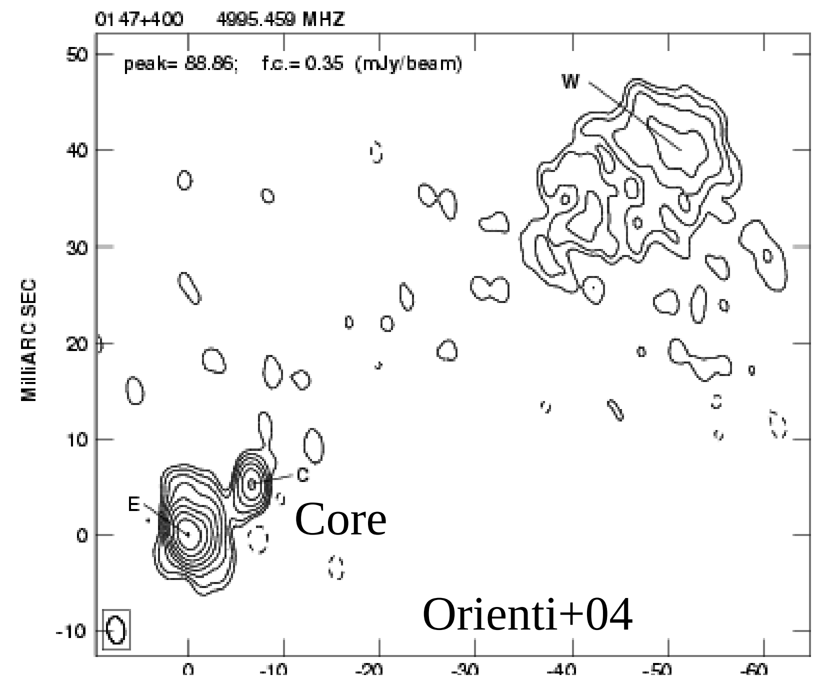
Two-sided structures

The majority of compact **radio galaxies** have a two-sided structure dominated by mini-lobes/hotspots. Sometimes the faint core is detected.

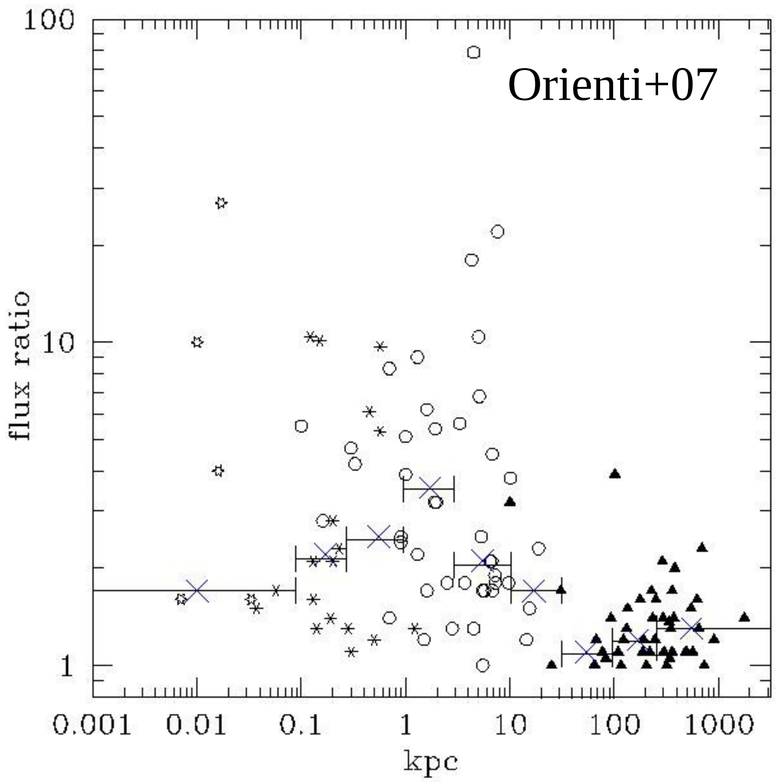
"Symmetric"

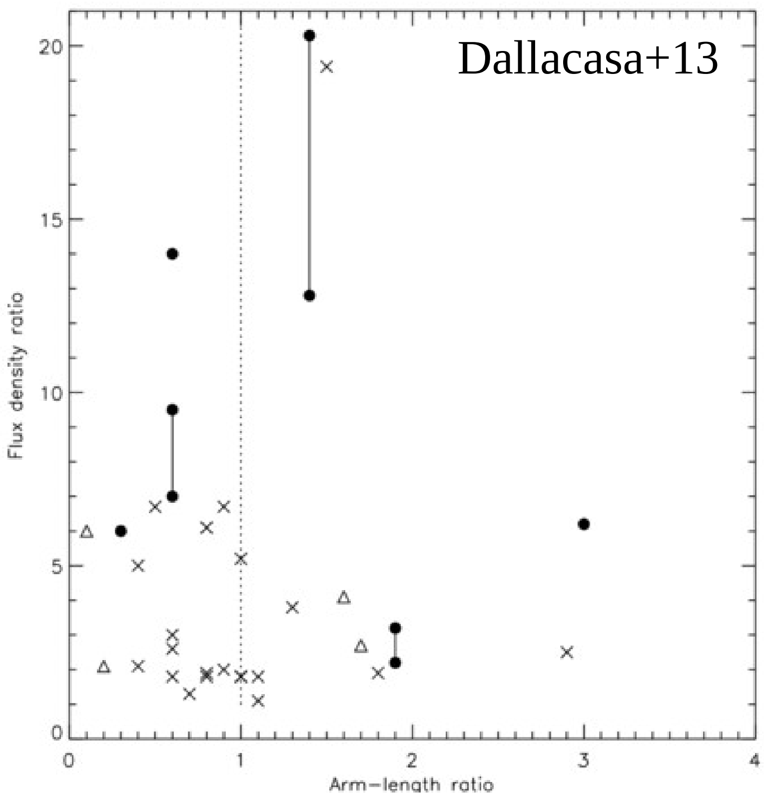


"Asymmetric"



Asymmetries in "symmetric" objects





Large asymmetry in both luminosity and arm-length ratios between the lobes.

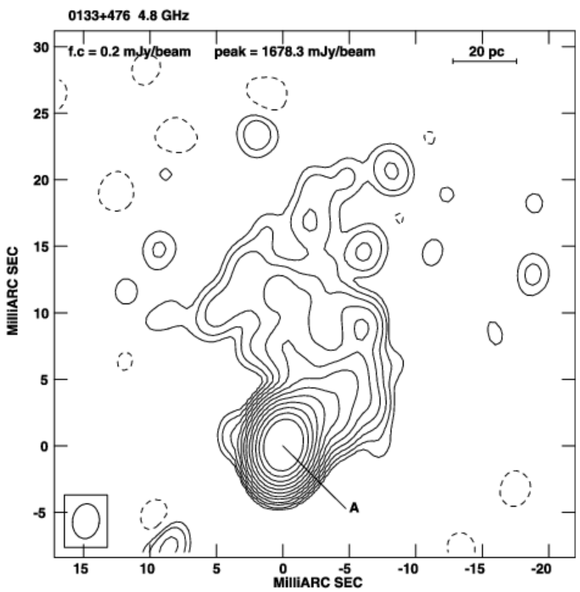
Saikia+ 03, Fanti+ 90, Dallacasa+13

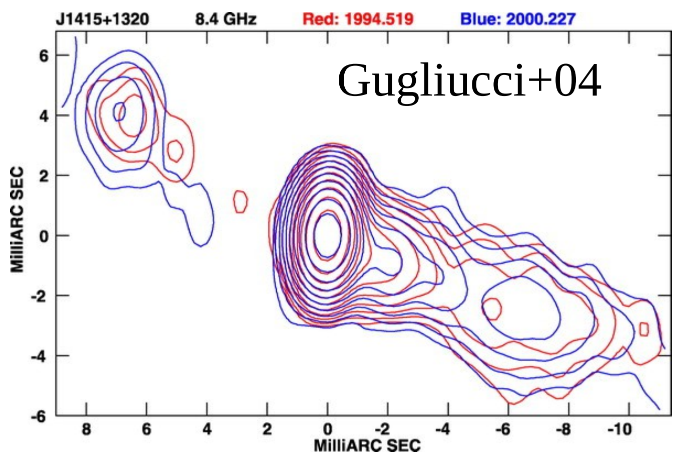
Jet-ISM interaction?

Cj and complex morphology

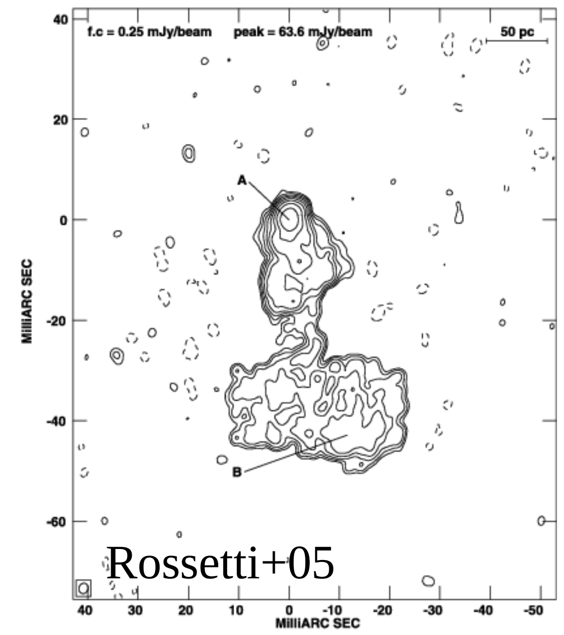
The majority of compact **radio quasars** and some bright CSS have a core-jet structure or very complex morphology (7% of the PW sample).

"Core-jet"





"Complex"

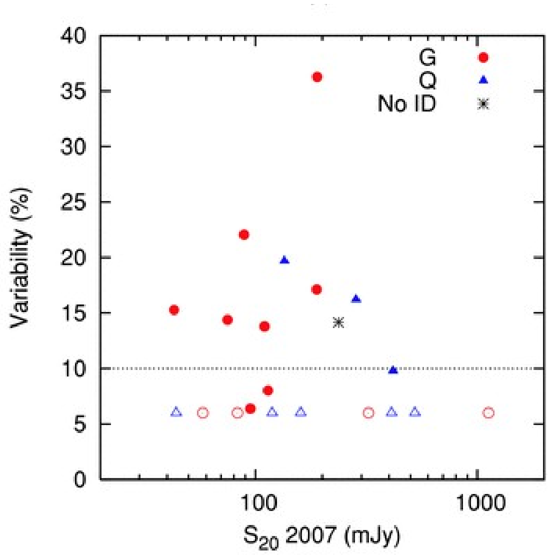


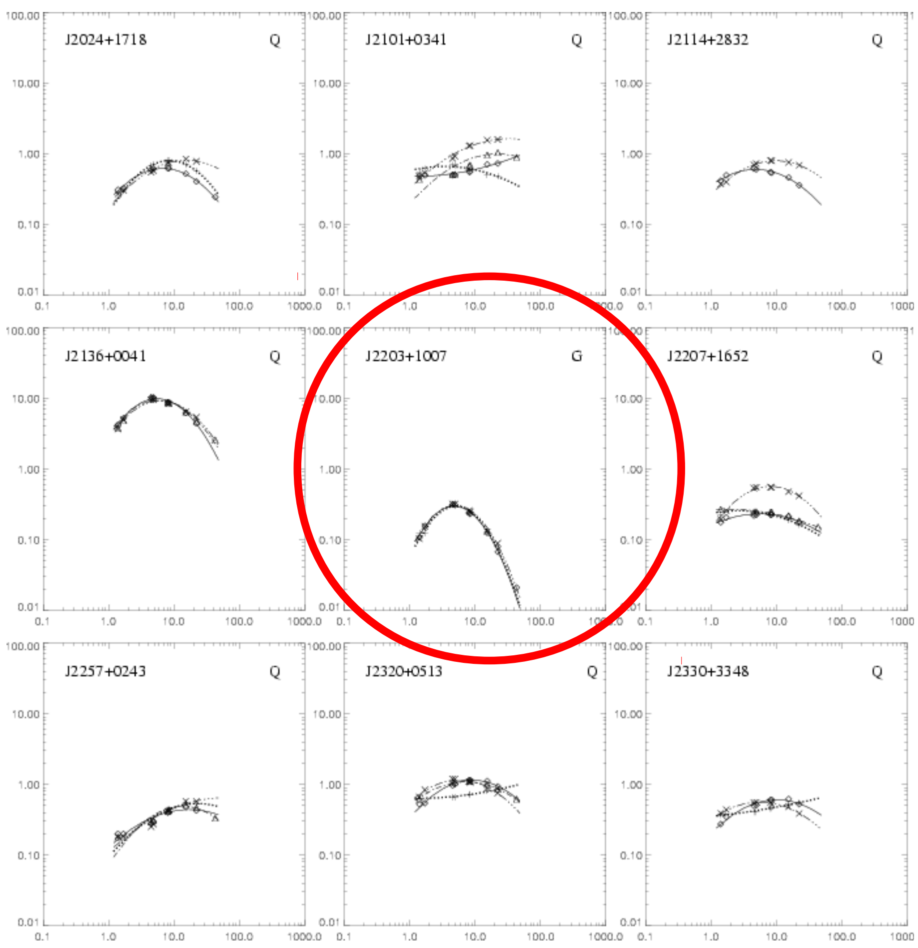
Boosting effects

Variability

The spectral behaviour is investigated by simultaneous multifrequency observations carried out at various epochs.

High fraction of CSS radio **galaxies** are not variable, while only ~30% of GPS galaxies preserve the convex spectrum



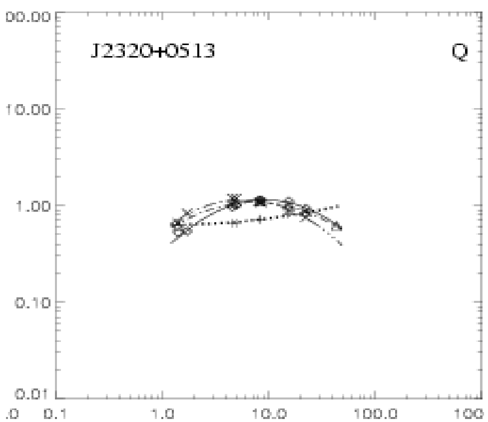


Orienti+07, +10, Torniainen+07, Hancock+10

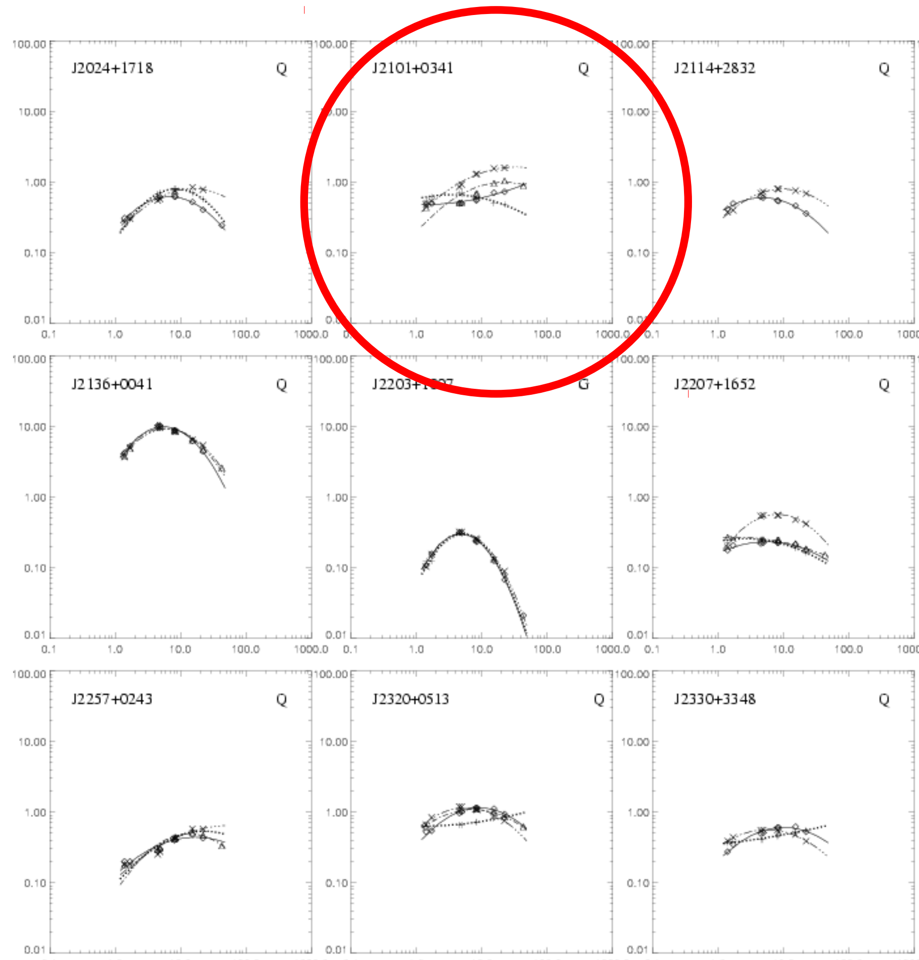
Variability

The spectral behaviour is investigated by simultaneous multifrequency observations carried out at various epochs.

The majority of the CSS and GPS **quasars** show significant flux density and spectral variability



See Dallacasa's talk

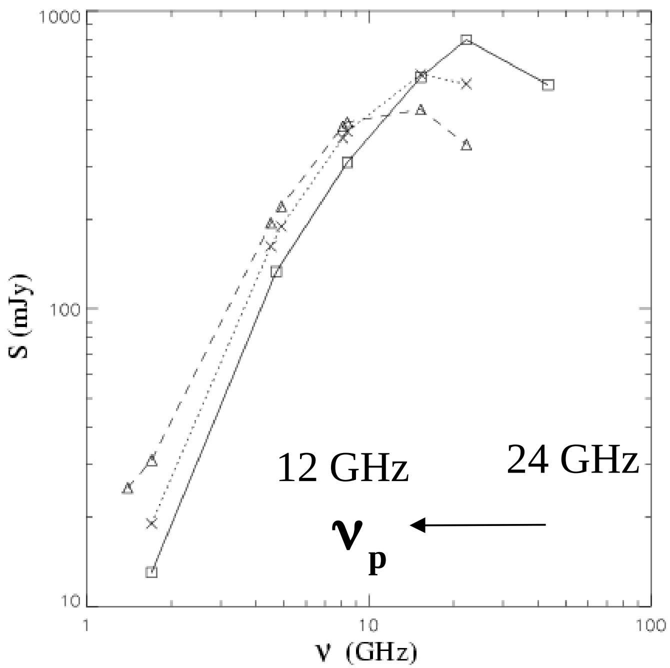


Mingaliev+12, Torniainen+05, Orienti+07

Variability

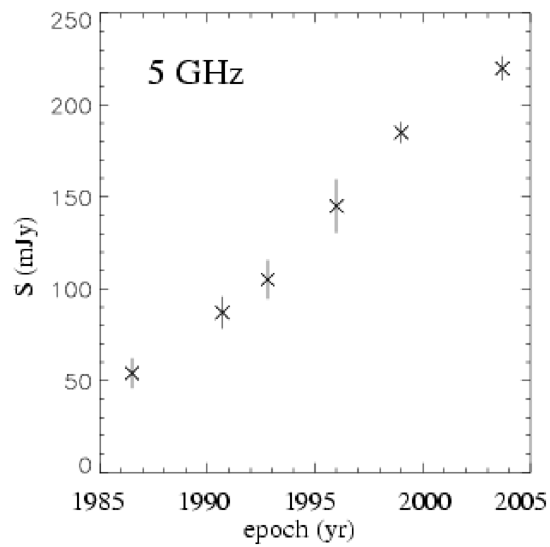
The spectral behaviour is investigated by simultaneous multifrequency observations carried out at various epochs.

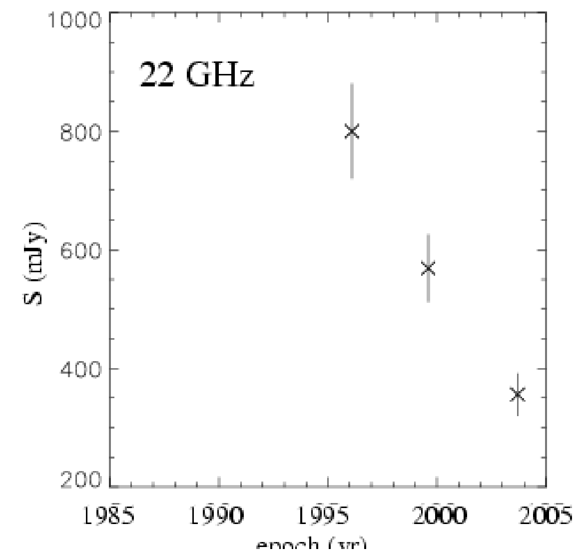
Variability due to adiabatic expansion of very young objects



Edge+96, Orienti+08

RXJ 1459+3337





Optically-thick

S ↑

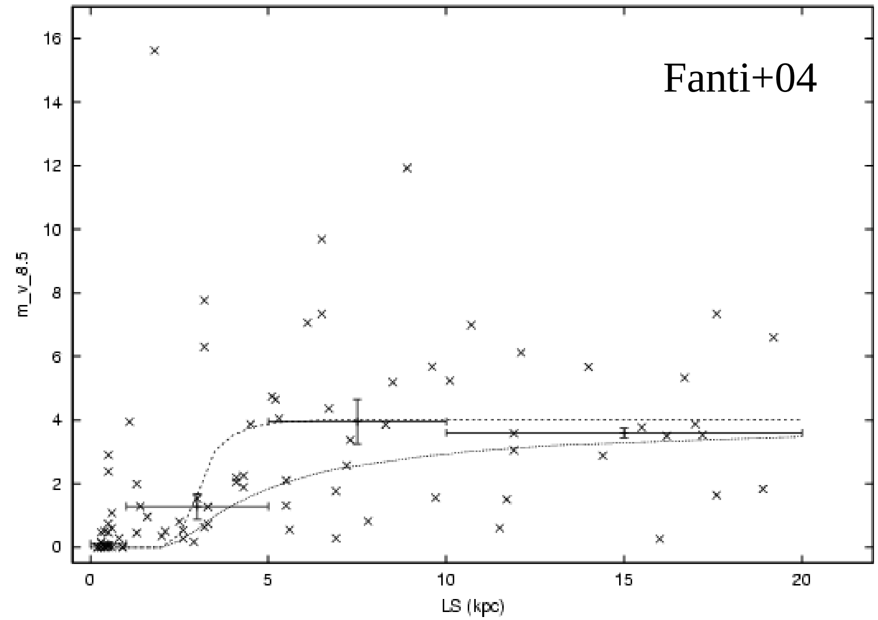
Optically-thin

S ↓

Polarization properties

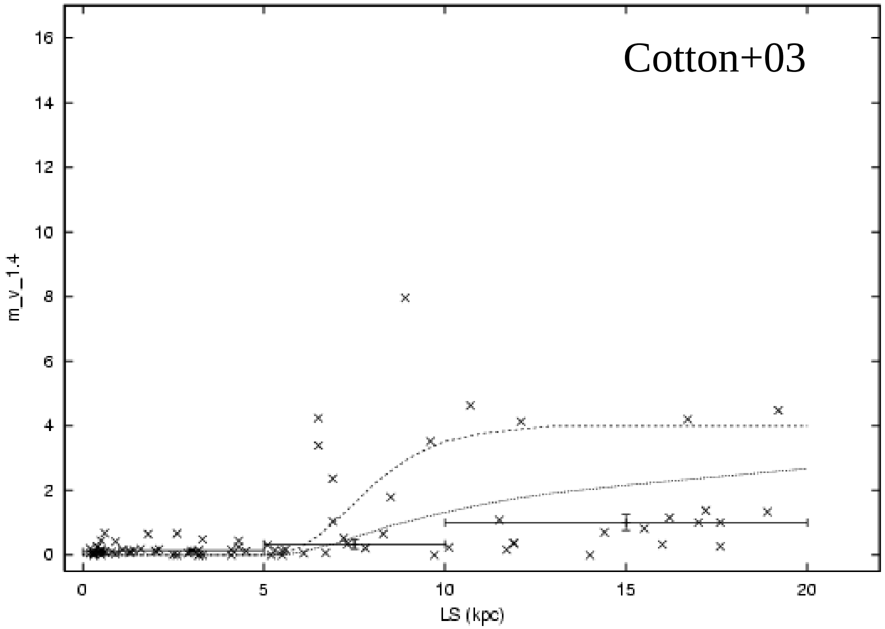
LS < 6 kpc

Unpolarized at 1.4 GHz

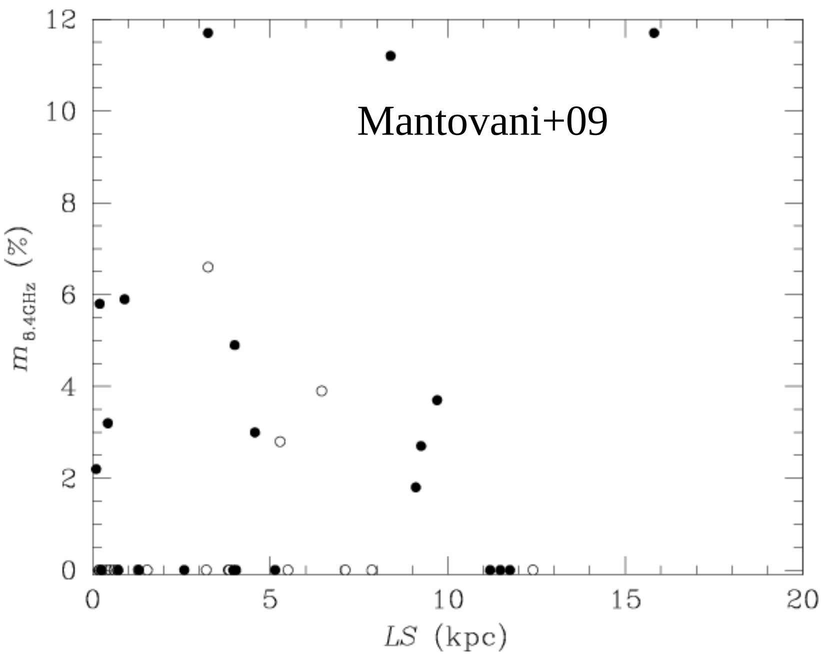


LS < 3 kpc

Unpolarized at 8.4 GHz



Polarization properties



- Polarized emission from quasars, independently from LS

- Polarized emission from galaxies with LS > 3 pc

- Quasars have higher fractional polarization

- Galaxies have larger RM

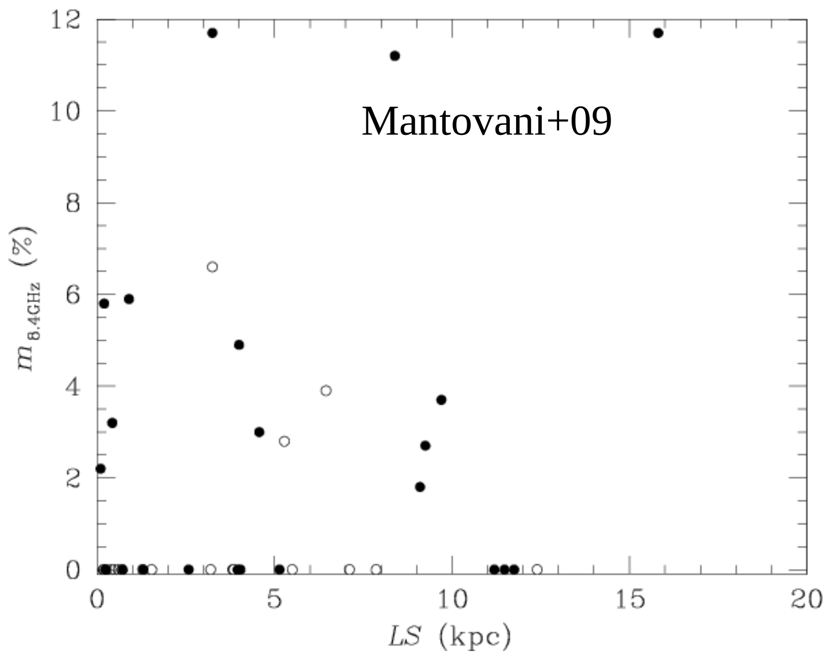
- Higher RM from sub-arcsec observations than from single-dish observations: **blended components?**

- “Re-polarization” at low frequencies: **variability and/or multiple components**

- Larger polarization asymmetry in CSS than in large radio galaxies: **interaction with dense medium?**

Mantovani+09, Rossetti+08, Mantovani+13, Cotton+06, Orienti+08, Saikia+03

Polarization properties



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See Cotton's and Pasetto's talks

- Larger polarization asymmetry in CSS than in large radio galaxies: **interaction with dense medium?**

Mantovani+09, Rossetti+08, Mantovani+13, Cotton+06, Orienti+08, Saikia+03

Galaxies vs quasars

The different characteristics shown by GPS/CSS with different optical identification are consistent with the idea that GPS/CSS **galaxies** and **quasars** represent two **different** radio source populations:

- Galaxies ⟶ Compact sources
- Quasars ⟶ Blazar objects

Young blazars should exist. Boosting effects may hide the lobe structures.

Young or frustrated?

- **Youth scenario:**

Compact → **Young**

Baldwin 82, Fanti+ 95, Readhead+ 96, Snellen+ 00…..

- **Frustration scenario:**

Compact → **Frustrated**

van Breugel+84, Baum+90

The "frustration" scenario

Compact ⟶ **Frustrated**

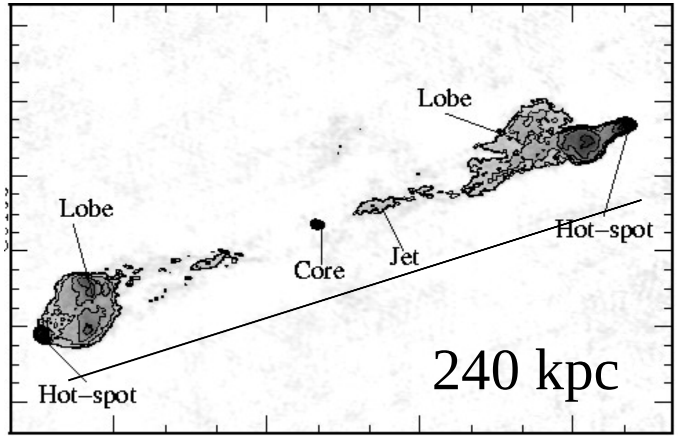
Observations from radio to X-ray searching for an excess of dust, and cold, warm and hot gas did not provide evidence of a particularly dense environment.

e.g. Fanti+00, Siemiginowska+05

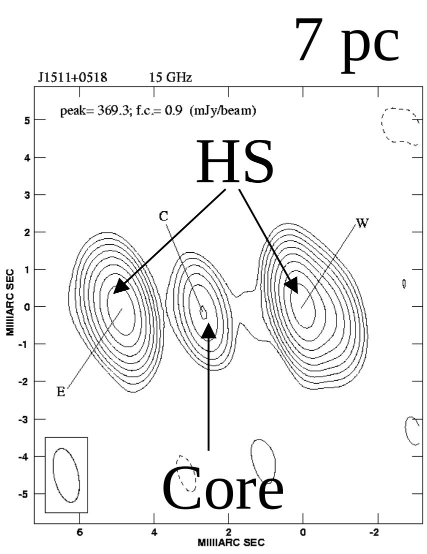
Indirect support to the youth scenario

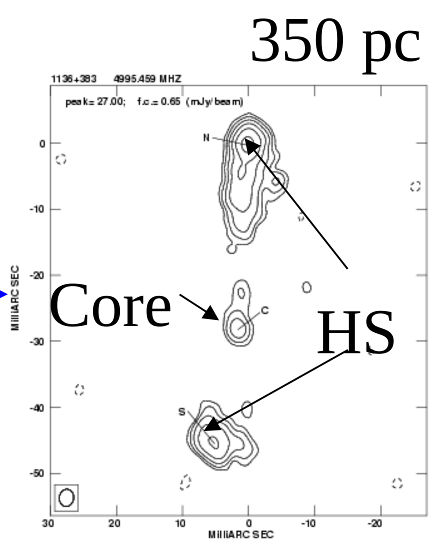
Youth: Radio morphology

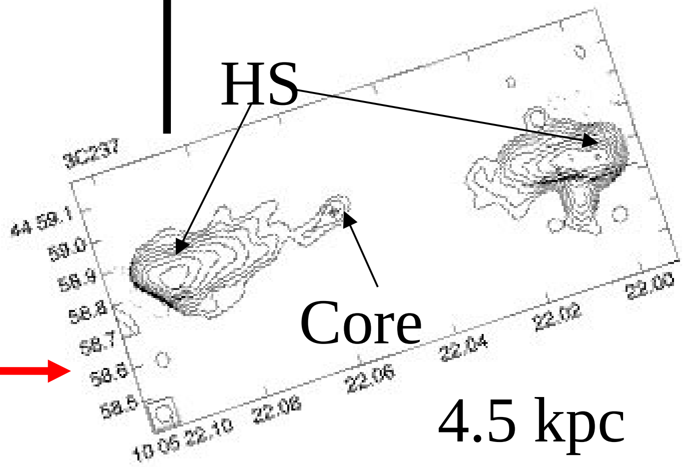
Scaled-down version of the extended radio sources. They should represent the young stage in the radio source evolution



Phillips&Mutel82

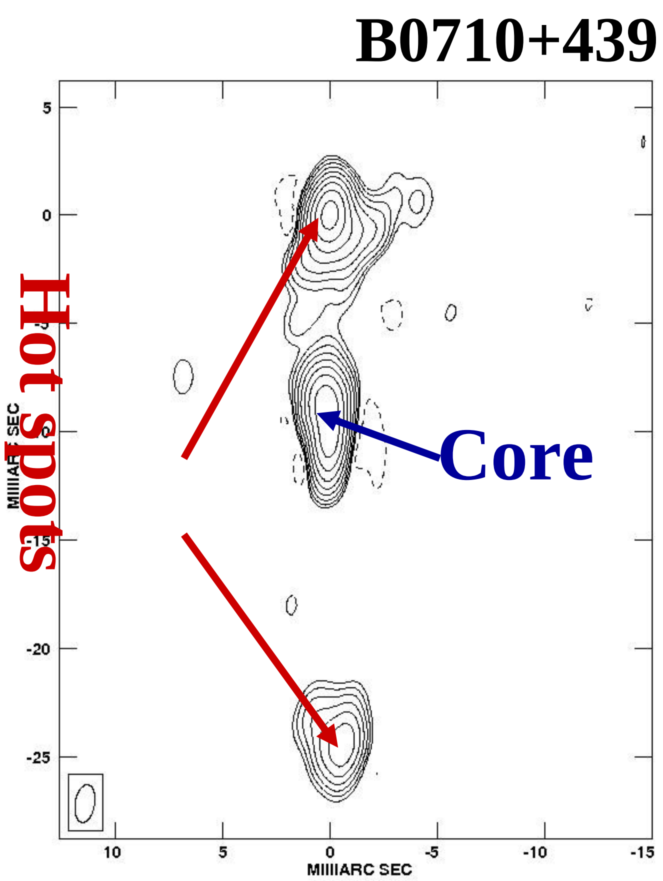


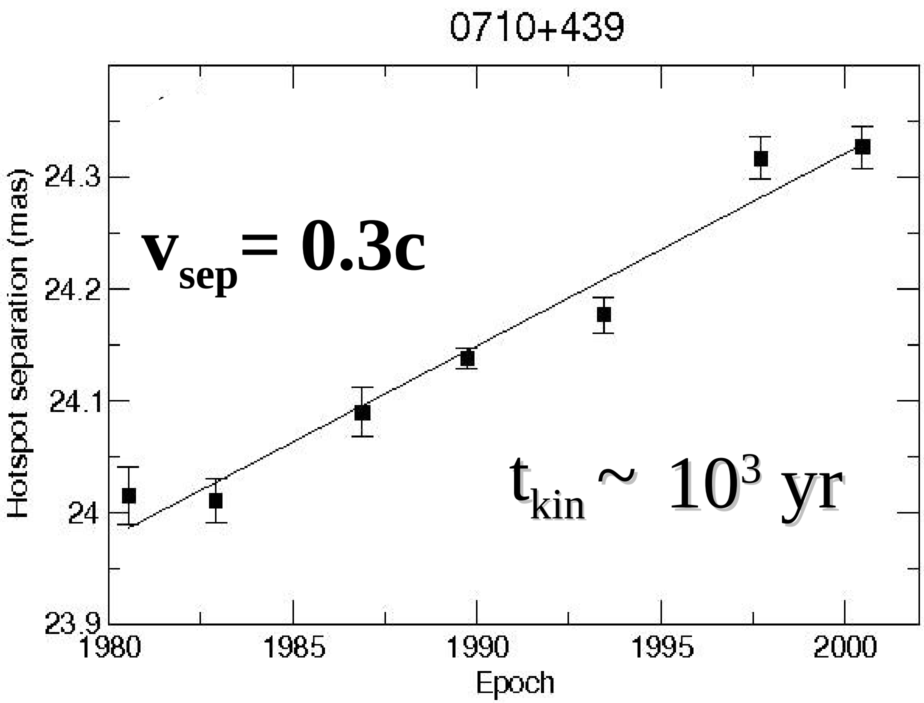




Youth: Proper motion

Detection of hot-spot separation by means of multi-epoch VLBI observations spanning a decade or more



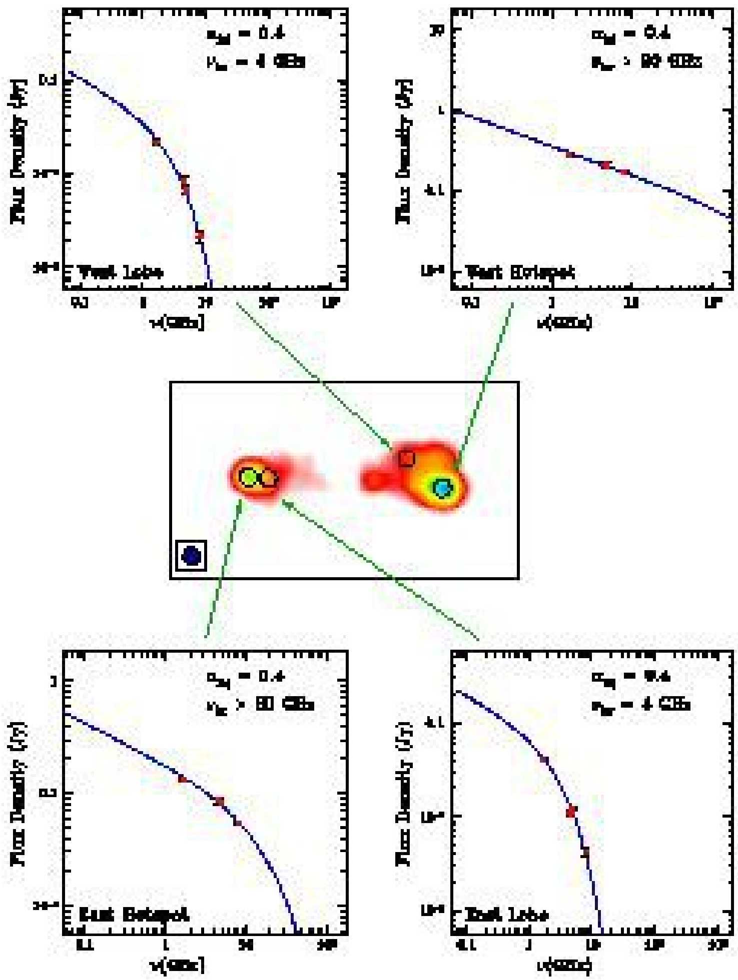


Polatidis&Conway 03

See Rastello's talk

Youth: spectral analysis

B1943+546, Murgia 2003



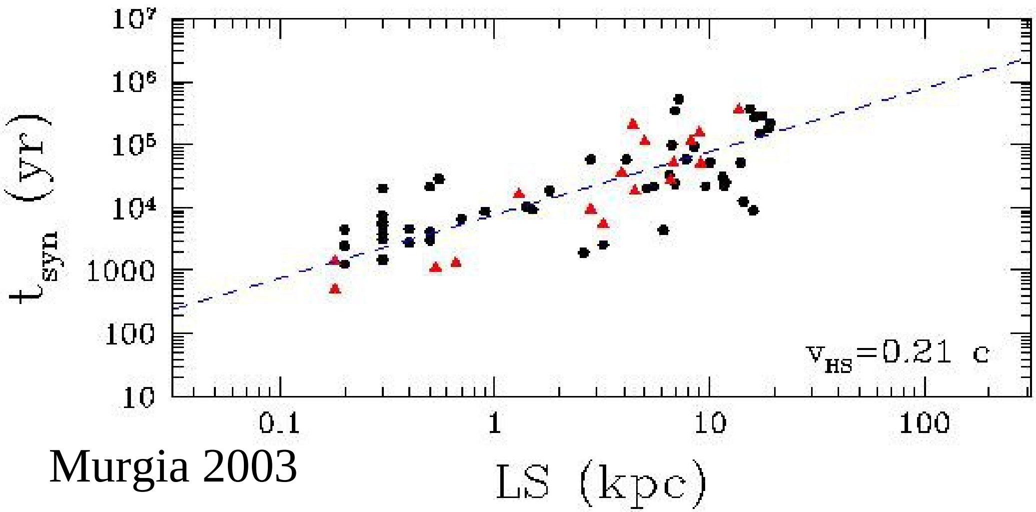
The radiative age of the electron population can be derived by the break frequency ν_b and the magnetic field H

$$t_{rad} \propto \nu_{br}^{-1/2} H^{-3/2}$$

From ν_{br} in the lobes:

$$t_{rad} \sim 10^3 \text{ yr}$$

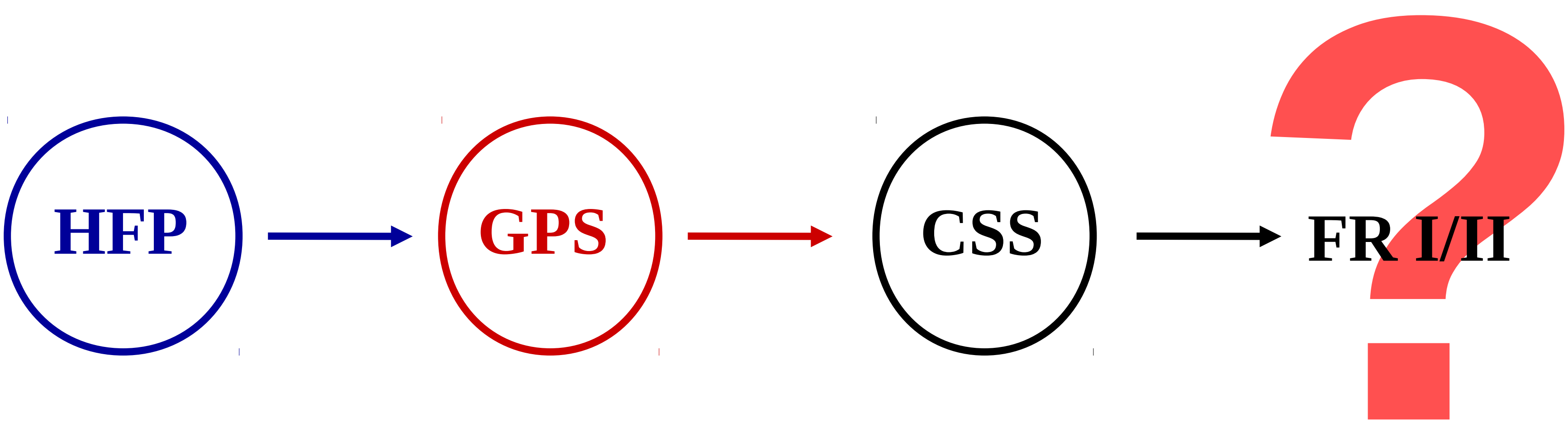
Evolutionary stages



Murgia 2003

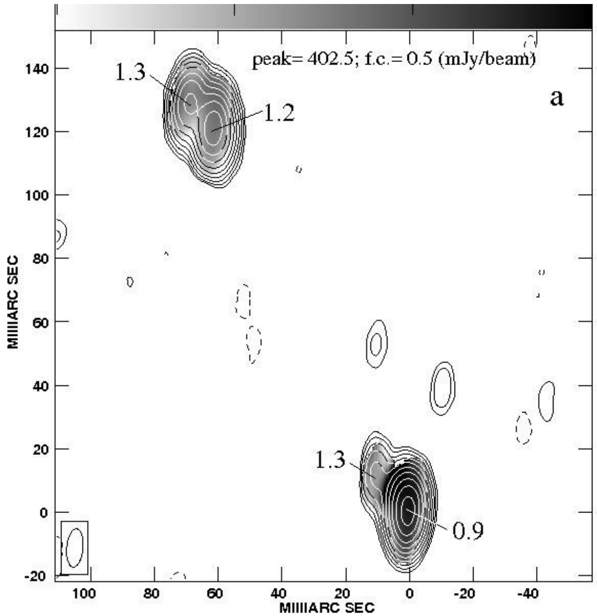
The higher the turnover frequency, the smaller and younger the source is.

See Perucho's talk

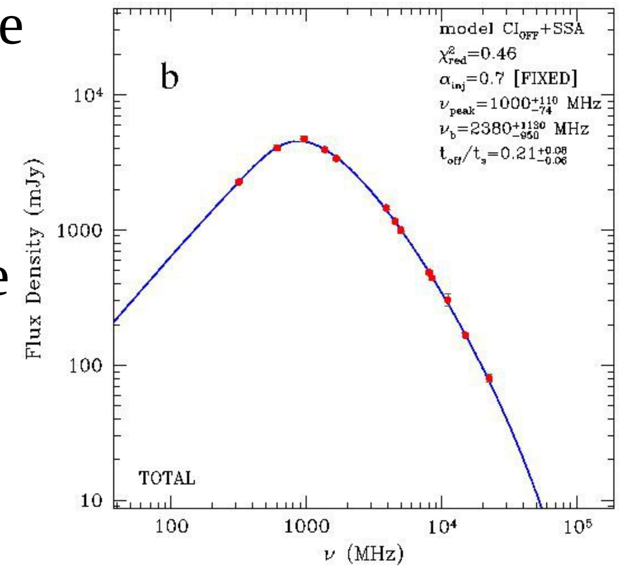


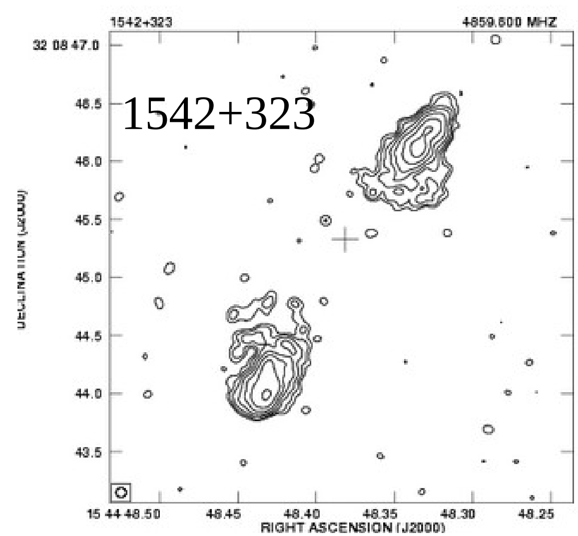
Dying objects?

PKS 1518+047



- Lack of hot spots and core components in many CSS/GPS
- Steep spectrum across the whole source
- No injection of fresh particles





See Brienza's and Kino's talks

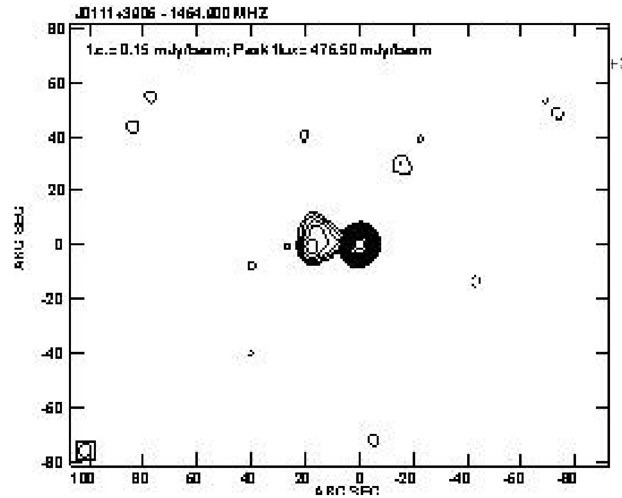
Orienti+10, Kunert-Bajraszewska+10, Kunert-Bajraszewska+10

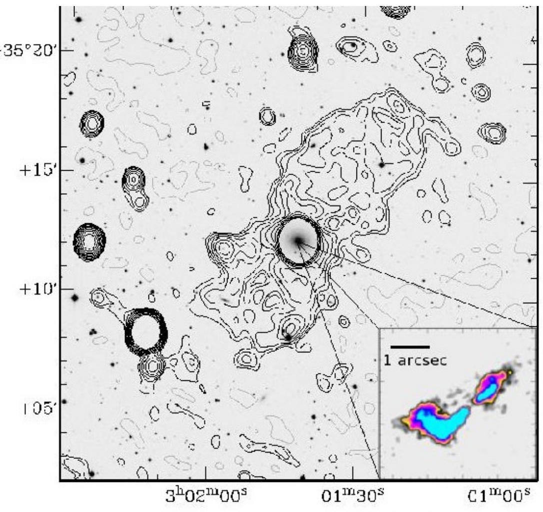
Recurrent activity?

- On kpc scales:
  - J0111+3906: 128 kpc
  - B2 0258+35: 160 kpc

t_{relic} ~ 10^7 – 10^8 yr

(Baum+90; Tinti+05, Shulevski+12)



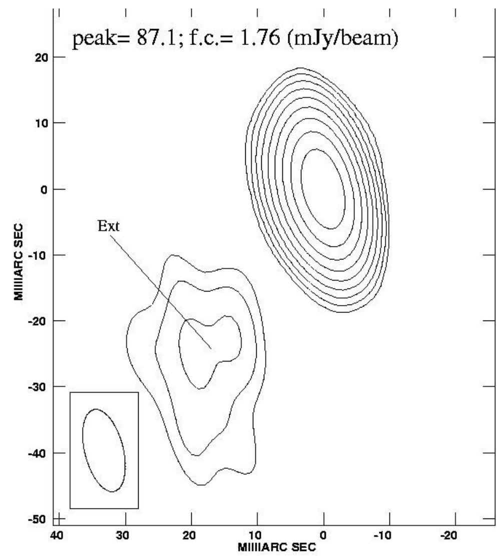


- On pc-scales:
  - J1511+0518: 50 pc
  - OQ208: 43 pc

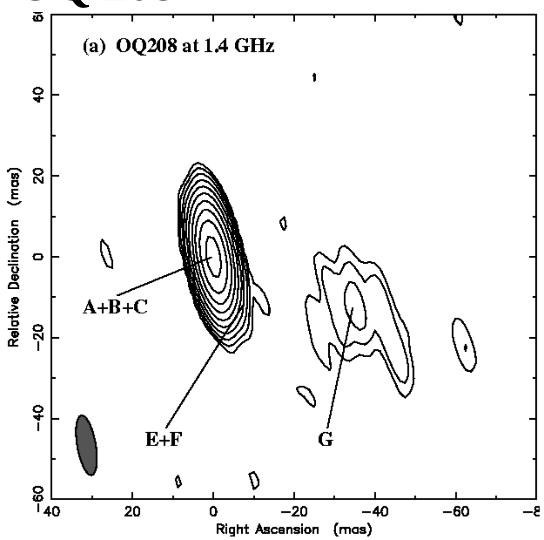
t_{relic} ~ 10^3 – 10^4 yr

(Orienti&Dallacasa08, Lu+07)

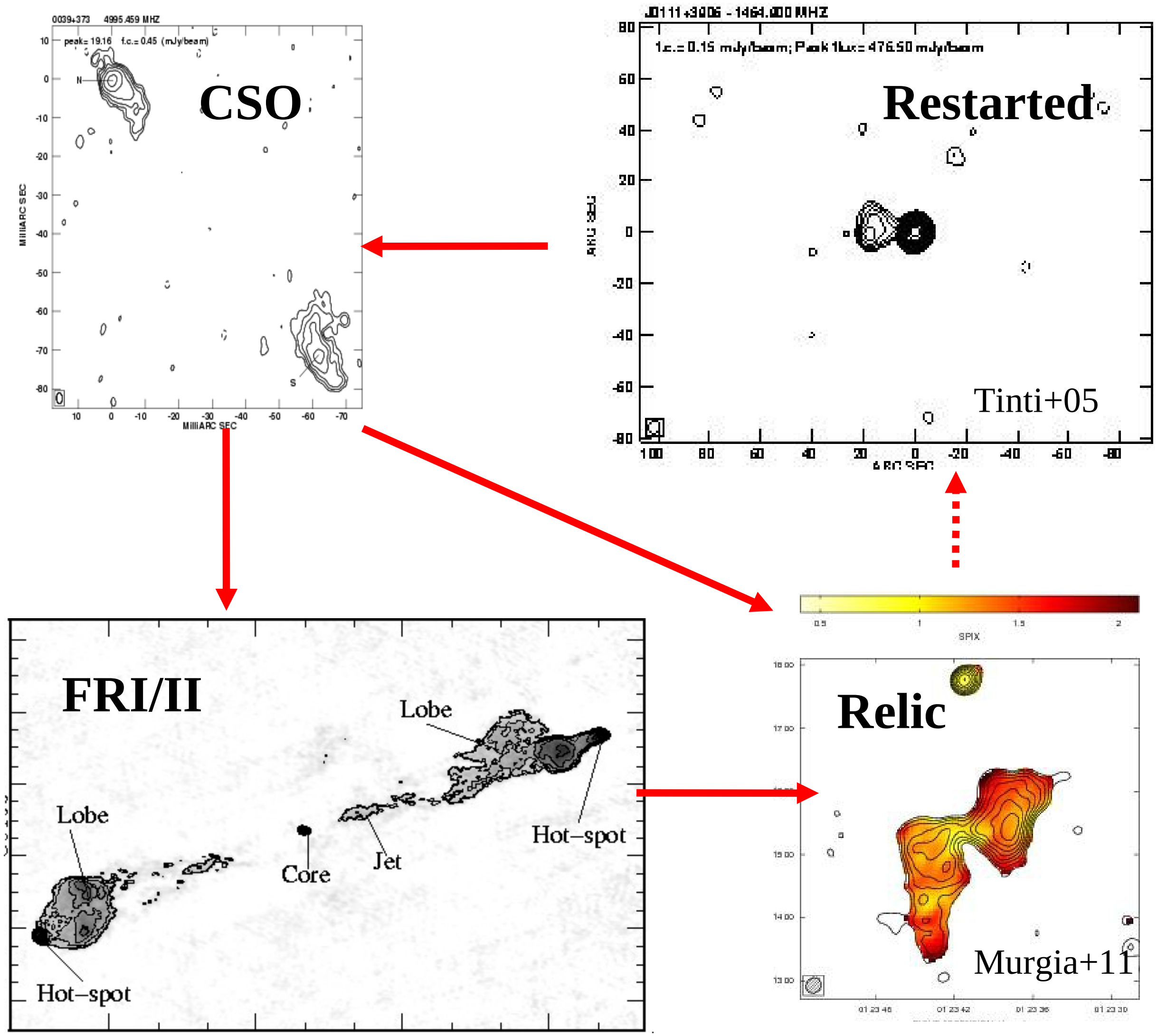
J1511+0518



OQ 208



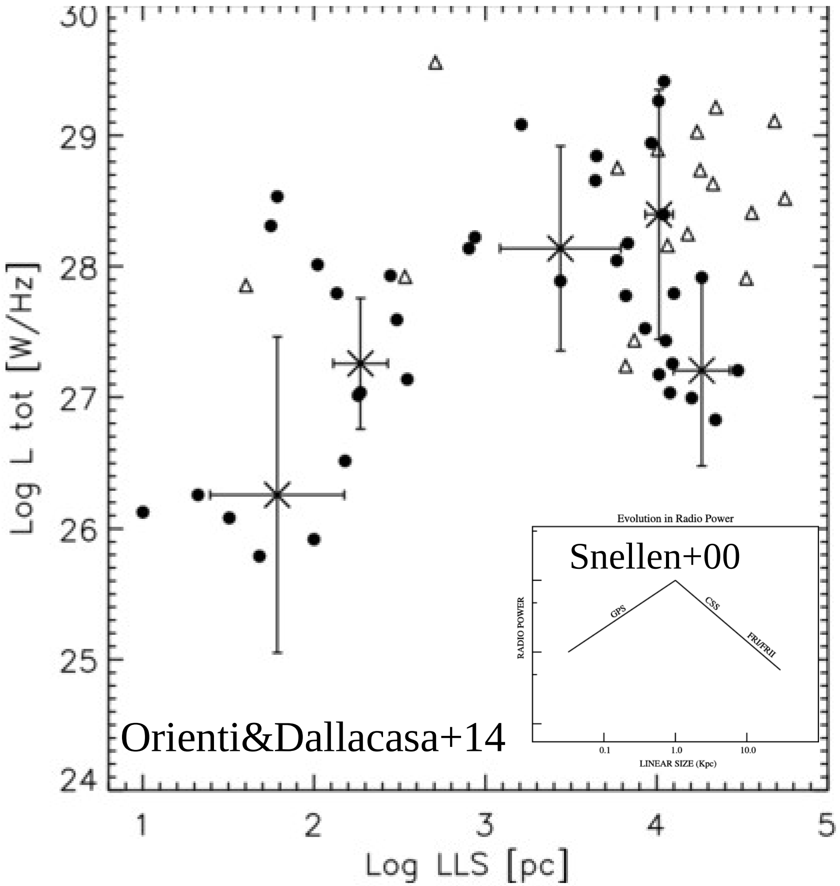
The duty-cycle of the radio emission

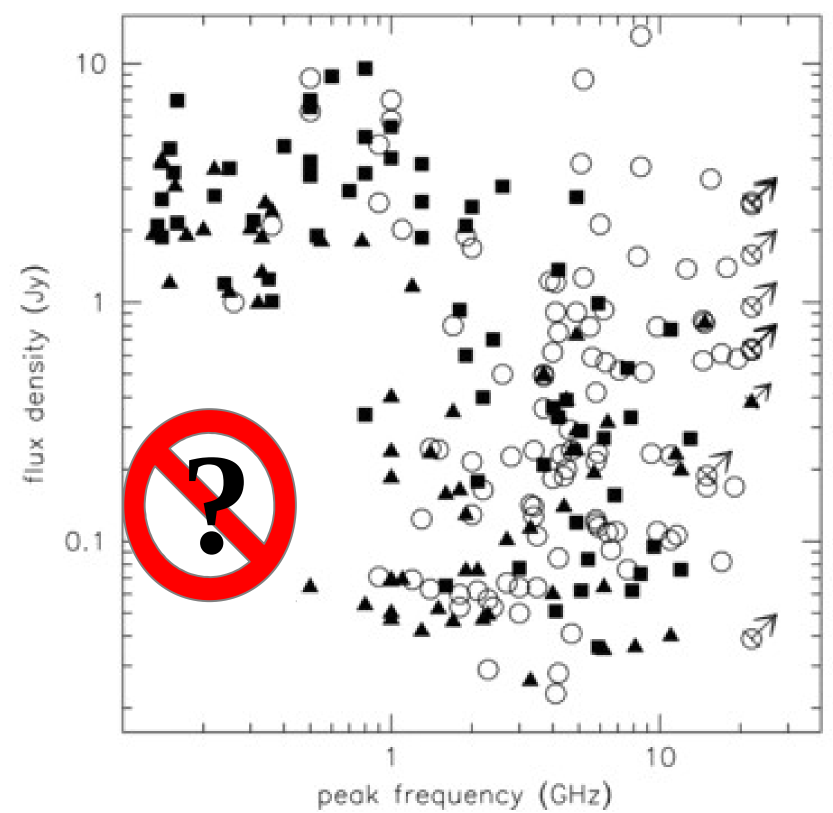


High angular resolution at low frequency is necessary to detect remnant from previous radio activity around young radio sources to find how many and how long the various phases may last

See Mahony's talk

Luminosity evolution



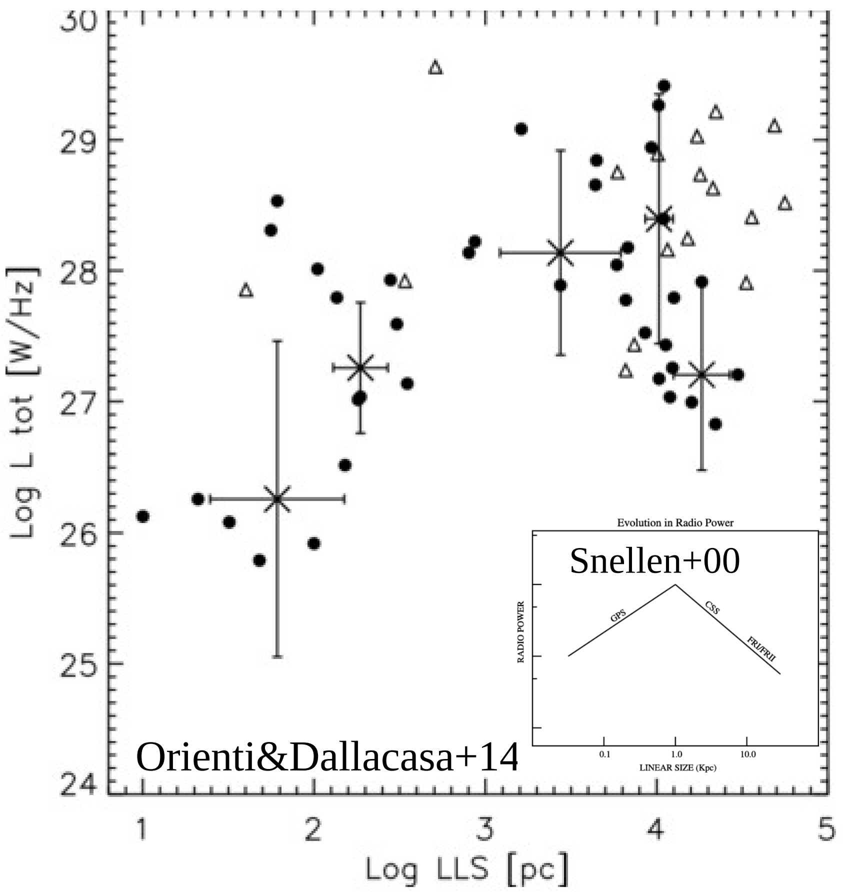


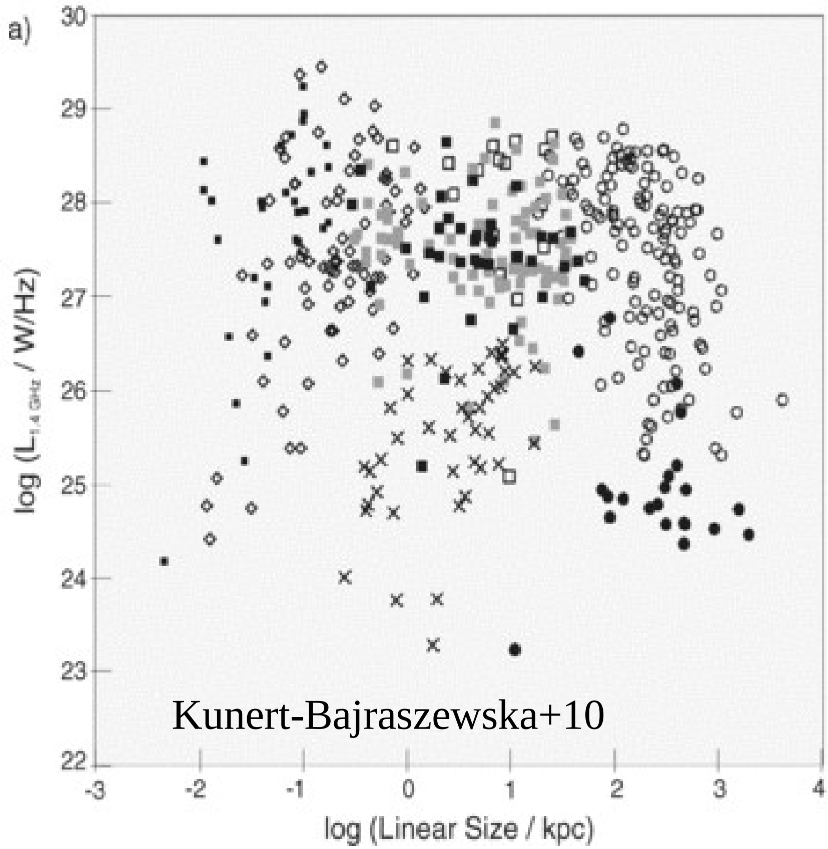
Orienti+12,

Luminosity increases for LS < a few kpc, then decreases

No faint CSS objects.
Sensitivity limitation?

Luminosity evolution



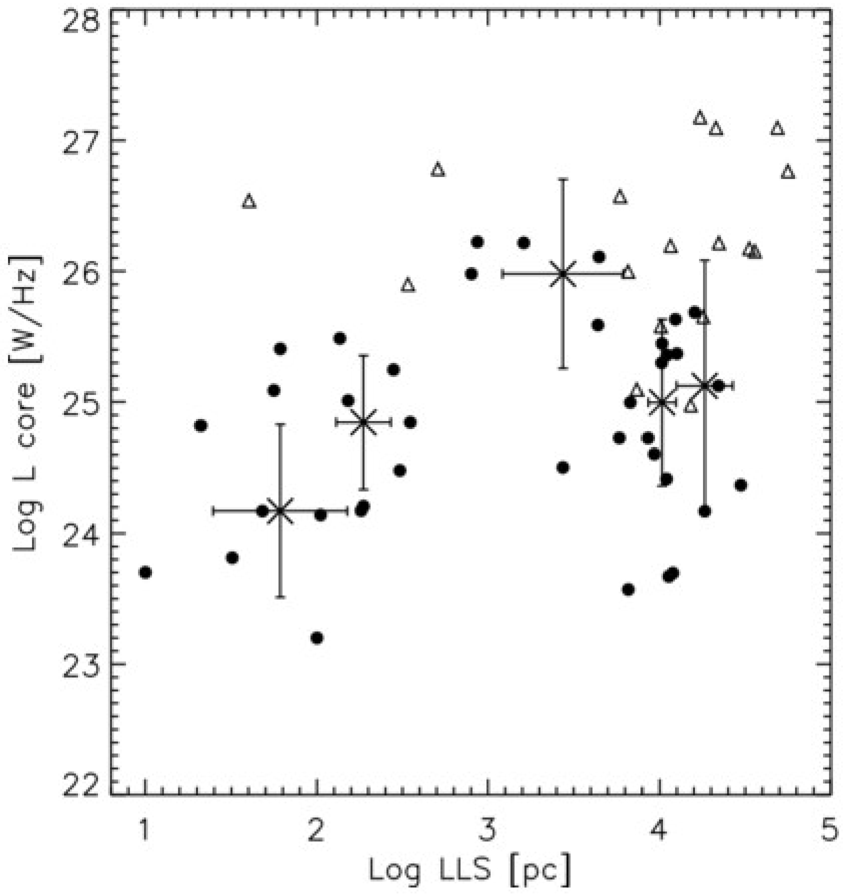


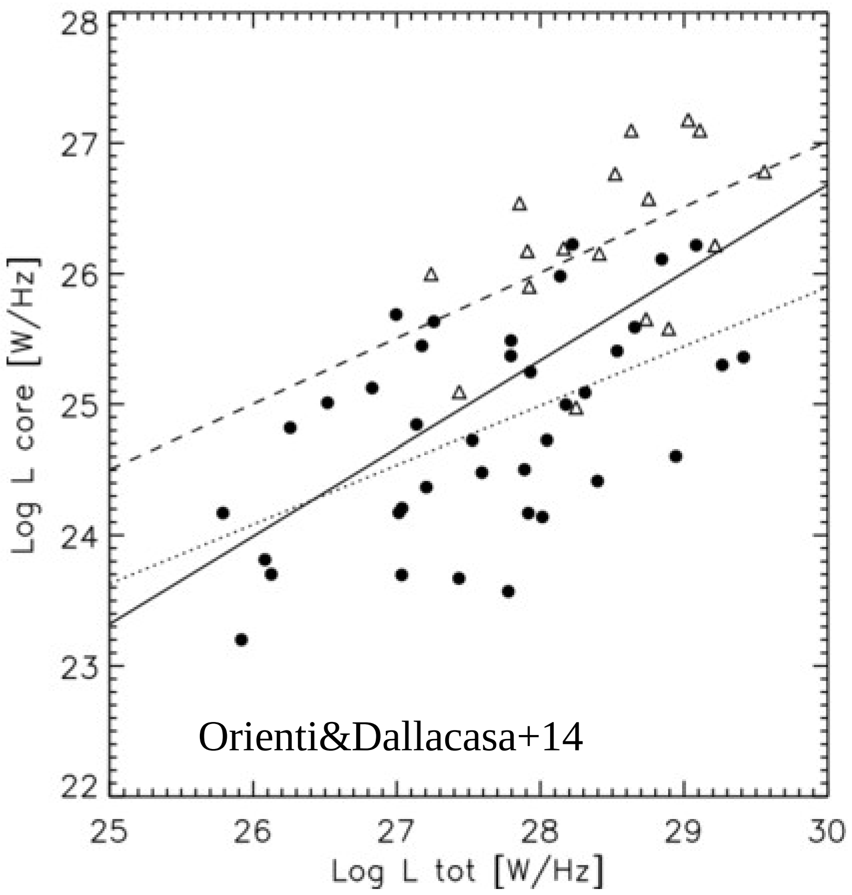
Low-luminosity CSS

Luminosity increases for LS < a few kpc, then decreases

See also Baldi's talk

Core Luminosity



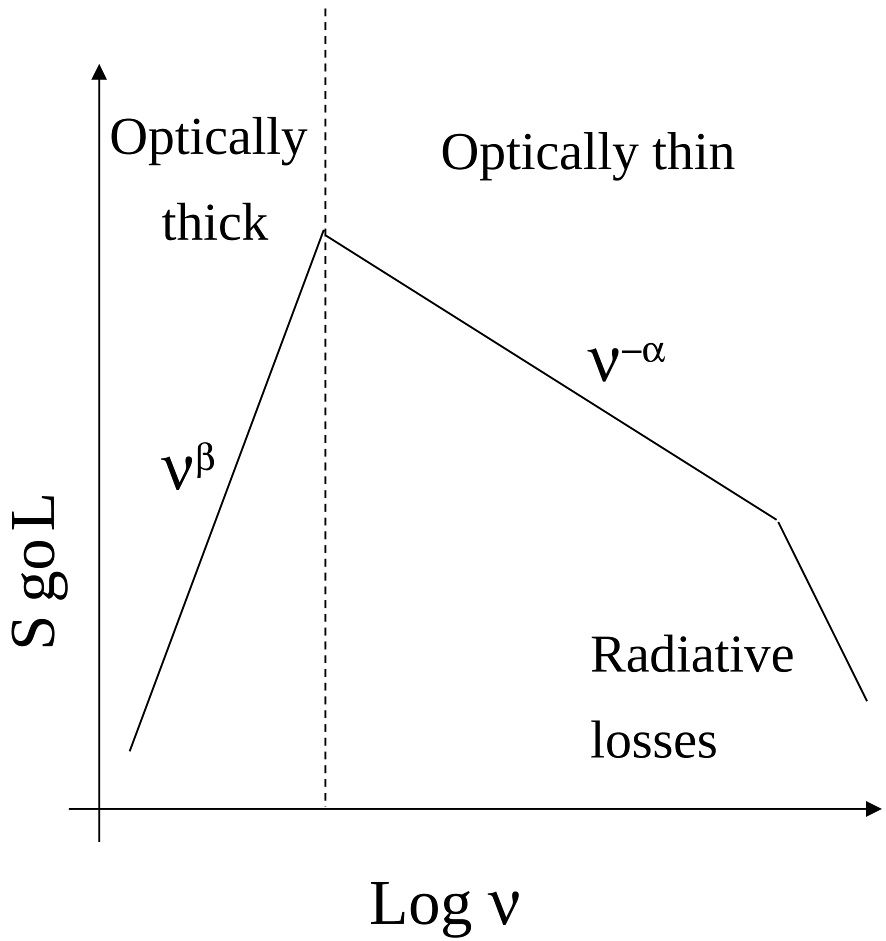


Luminosity increases for LS < a few kpc, then decreases

Peak frequency

The turnover in the spectrum is likely due to synchrotron self absorption

Snellen+00, Tingay&de Kool03, Orienti&Dallacasa08



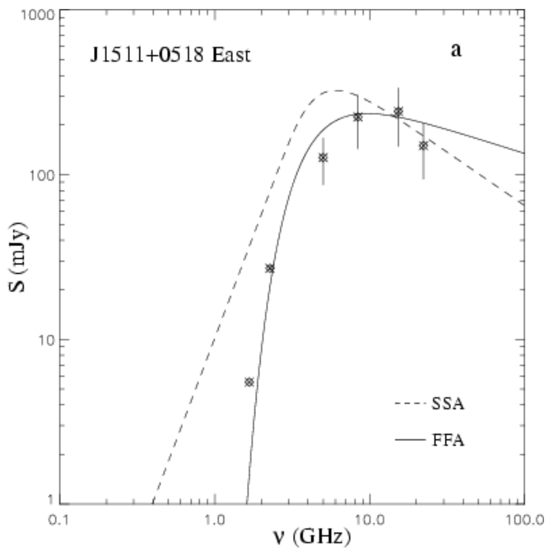
SSA in a homogeneous component: $\beta = 2.5$

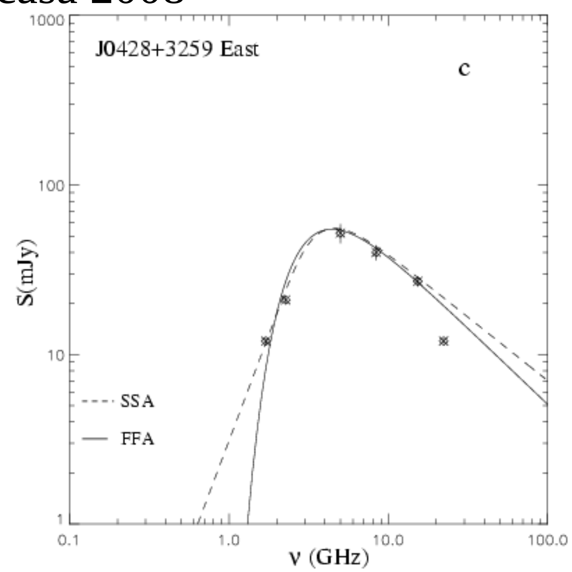
SSA is present BY DEFAULT!

SSA or free-free absorption?

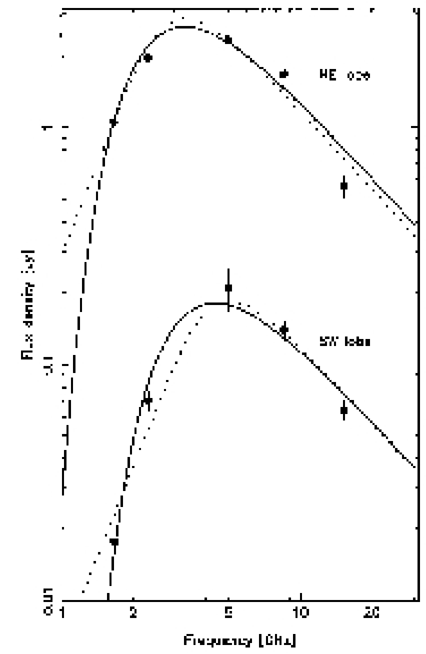
Optically-thick part of the spectrum is too steep to be due to SSA.
An additional contribution from FFA is needed to model the spectrum

Orienti&Dallacasa 2008





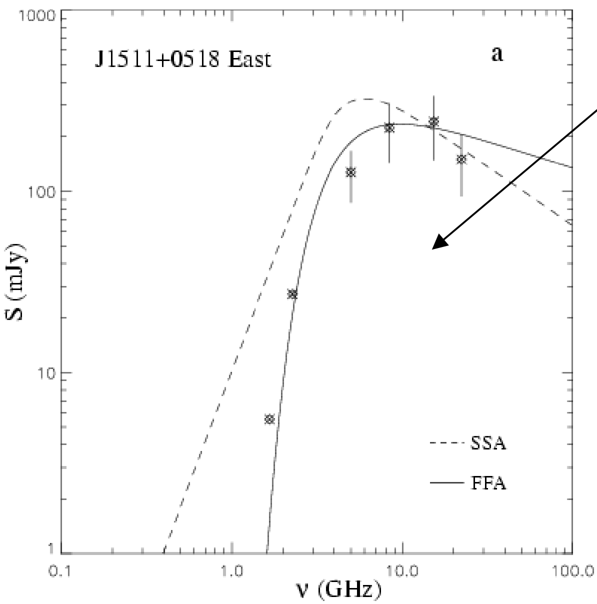
Kameno et al.2000

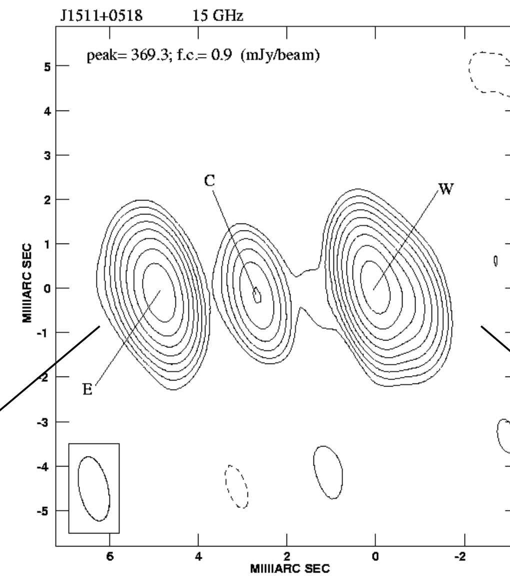


H_{SSA} cannot be derived

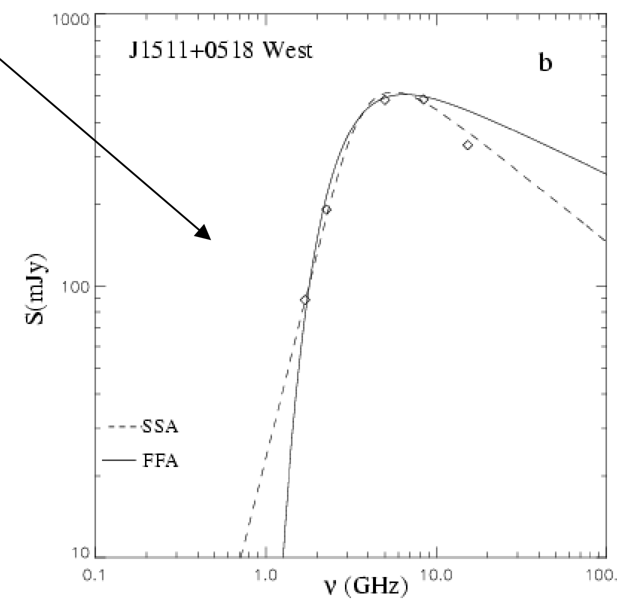
SSA or FFA?

FFA





SSA



Inhomogeneous ambient medium

Rich environment

As a consequence of the merger at the origin of the radio emission, the ambient medium surrounding a radio source is rich of gas.

- High incidence of ionized gas (FFA);
  Marr+01, Orienti&Dallacasa08

- Highly depolarized;
  Cotton+03, Fanti+04

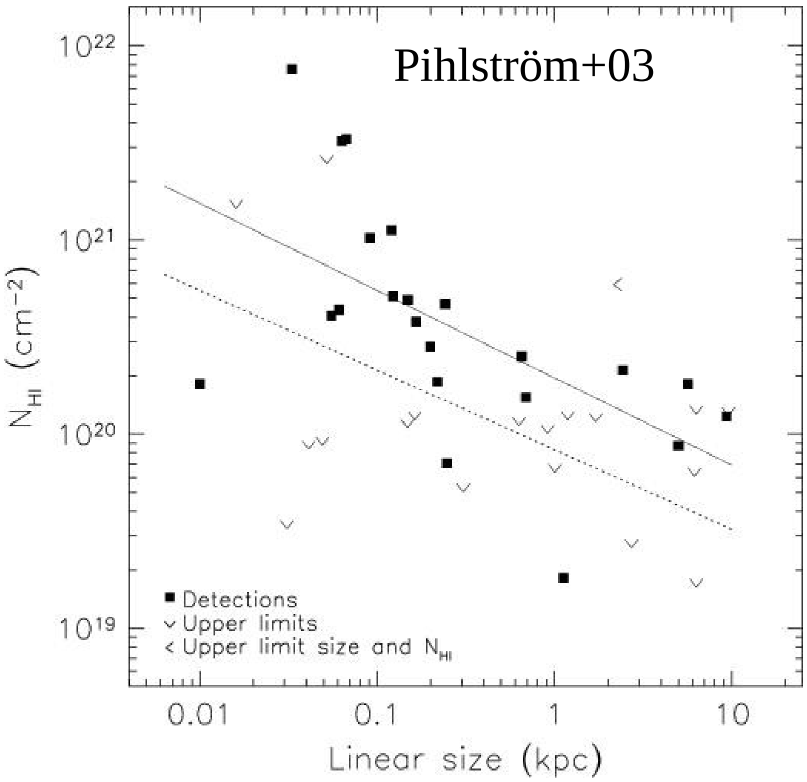
See Allison's, Ostorero's and Chandola's talks

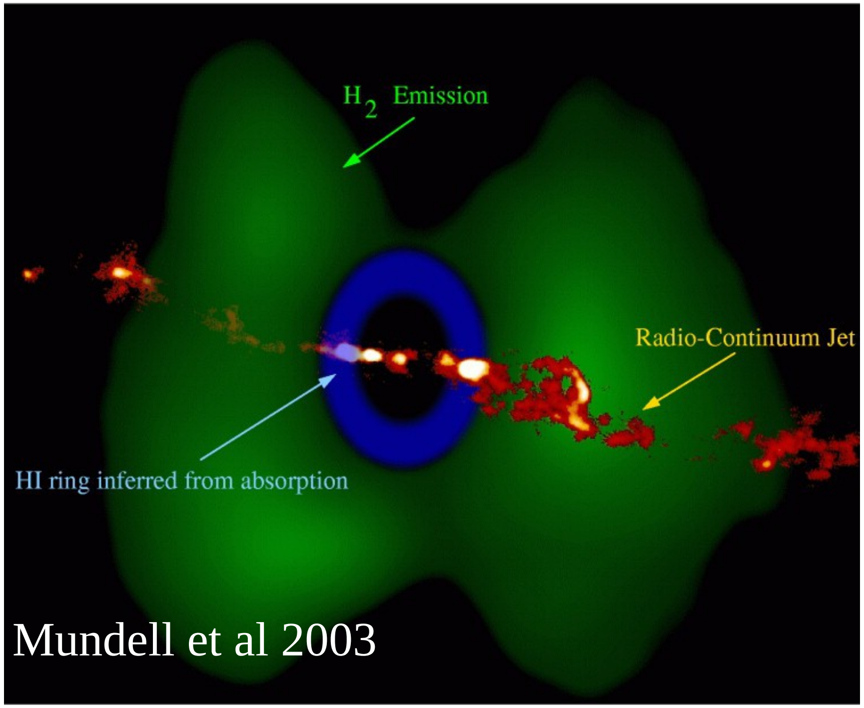
- High incidence of HI absorption;
  Pihlström+03, Gupta+05, Morganti+05

- High detection rate of CO emission
  Mack+09

The atomic hydrogen

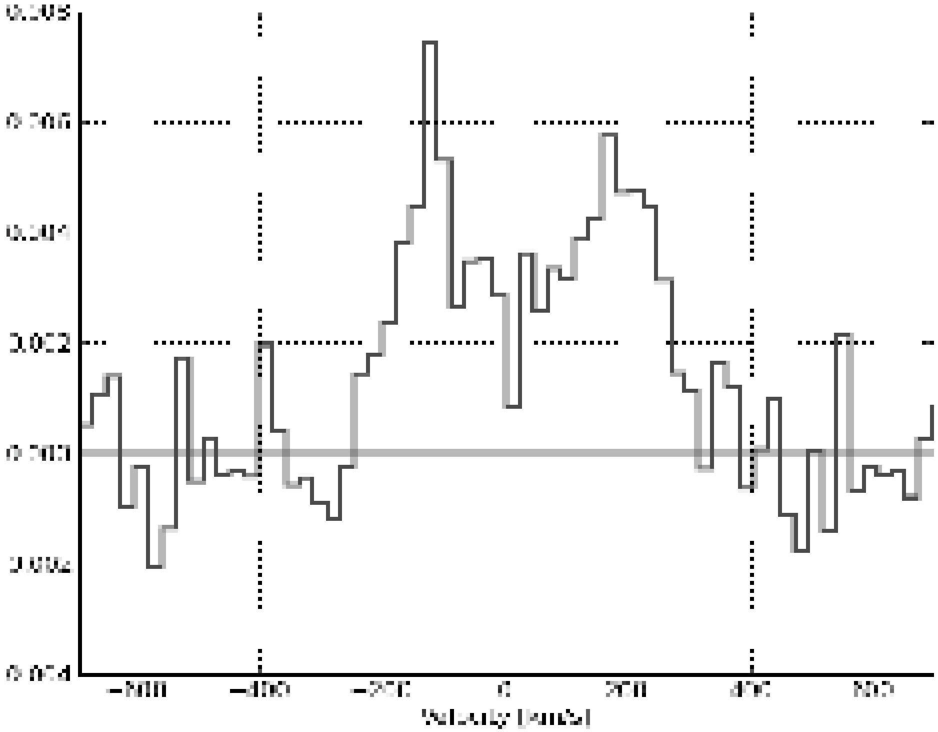
Anti-correlation between the HI column density and the linear size may be produced by circumnuclear gas with a radially declining density profile





The molecular gas

Ocaña-Flaquer et al. 2010



OQ 208 CO(1-0)

Symmetric Doubled-peak profile

Disk structure

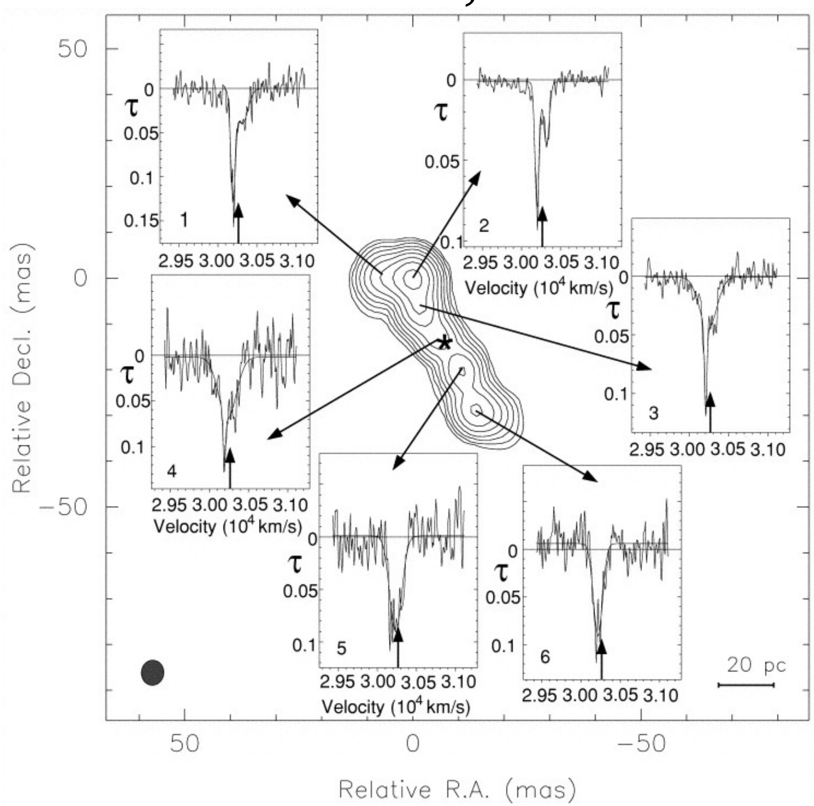
$M_{disk} \sim 1.4\cdot10^{10}\ M_{\odot}$

Similar result for 4C31.04 HCO^{+}(1-0 and CO (2-1)

Garcia-Burillo+10

HI distribution: VLBI observations

1946+708,   Peck+ 99



$\Delta v = 350$ km/s

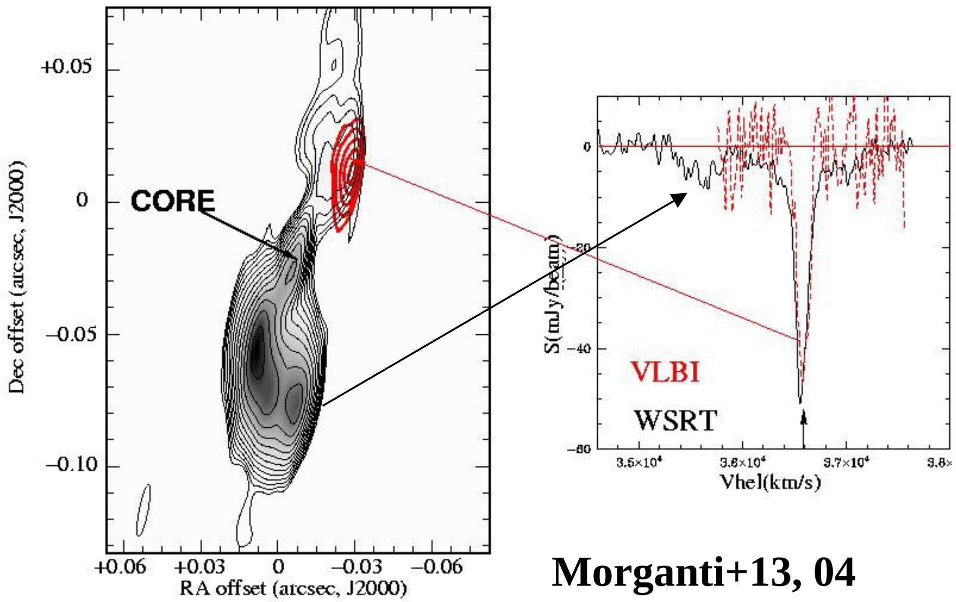
$N_H \approx 2x10^{23}$ cm $^{-2}$ (T_s = 8000 K)

HI detected against

the whole source

Central disk

HI distribution: VLBI observations



Morganti+13, 04

HI located ~100 pc from the core, where the jet bends

Off-nuclear clouds

$\Delta V = 150$ km/s

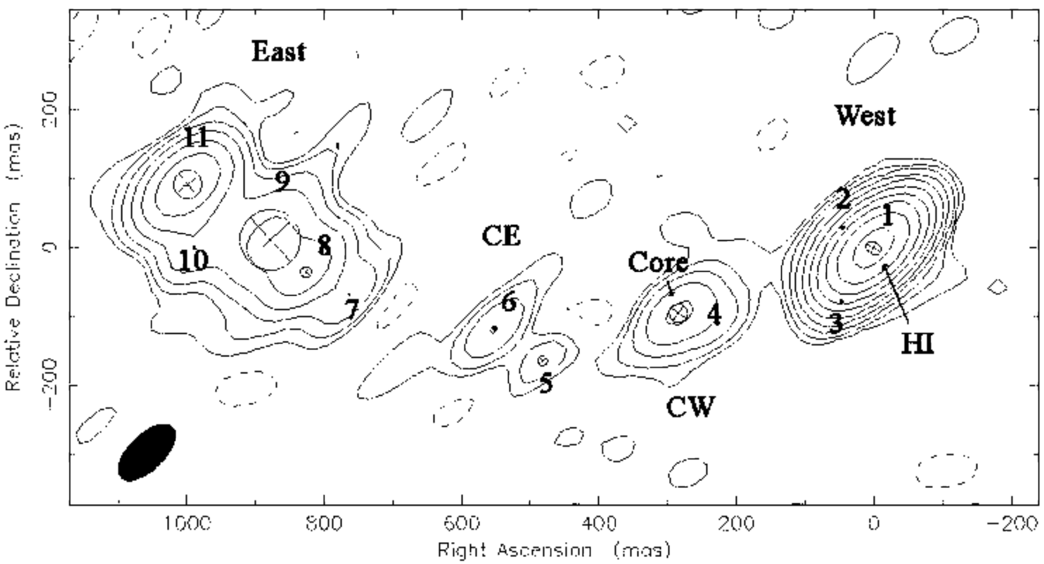
$N_H \sim 10^{22}$ cm $^{-2}$ ($T_s = 100$ K)

But see also Labiano's talk

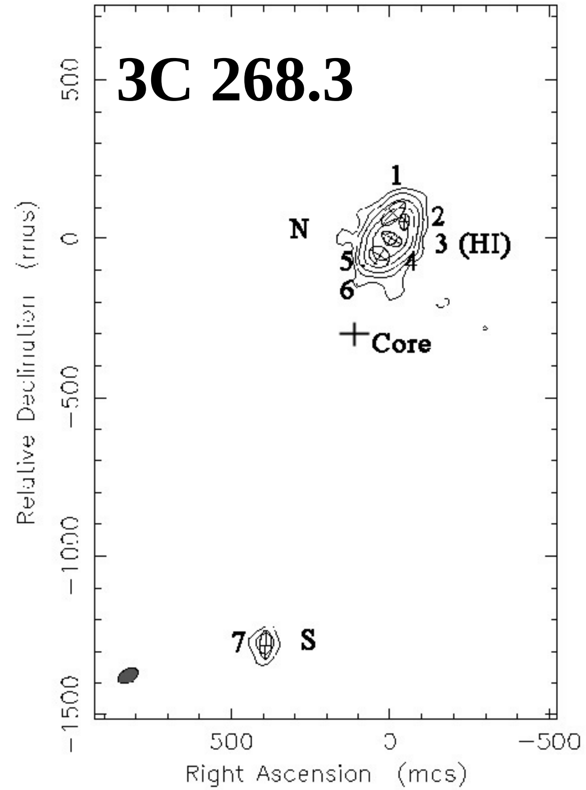
Jet-cloud interaction?

They may influence the source evolution, slowing down its expansion and enhancing the luminosity. They may be responsible for the asymmetries in arm-length and luminosity.

3C 49

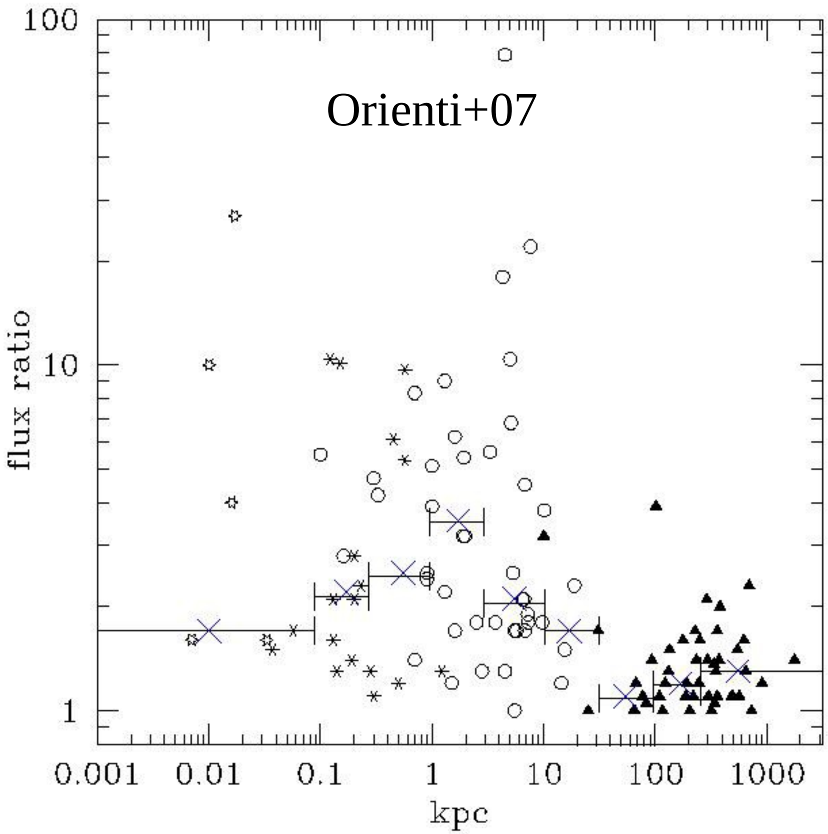


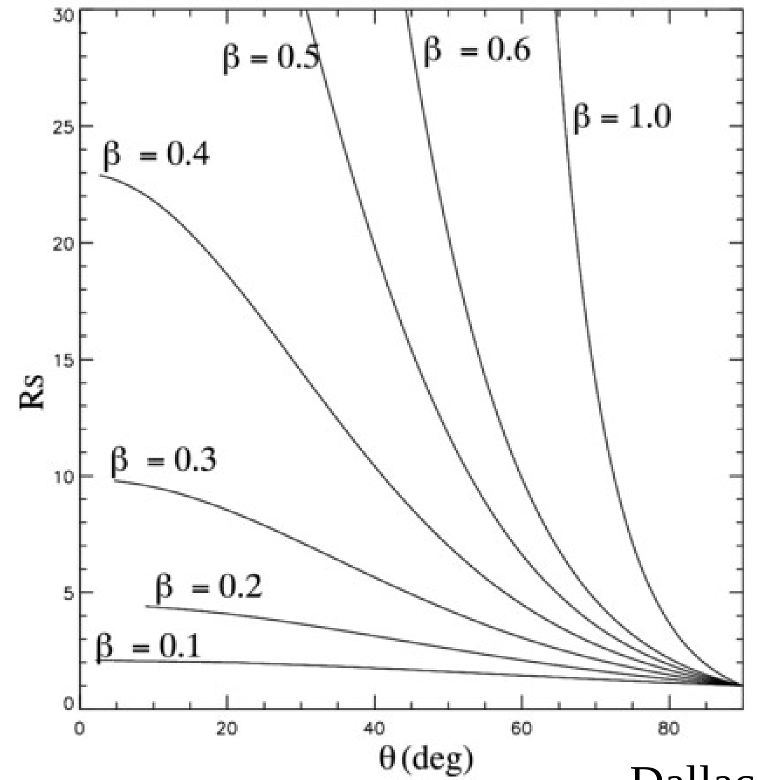
Labiano+06



The statistic is still too poor…..

Asymmetries in "symmetric" objects





Dallacasa+13

High flux density ratios cannot be explained by geometrical effects

Excess of asymmetric objects in flux density limited samples?

Jet-ISM interaction?

Conclusions

- Steep-spectrum compact radio sources represent an early stage in the radio source evolution

- Quasars and galaxies have different properties: different sub-classes?

- The peak in their synchrotron spectrum is generally due to SSA, although an additional contribution of FFA is found in the most compact sources

- The ambient medium surrounding young radio sources is inhomogeneous and dense and jet-cloud interaction can take place

- Flux density asymmetries may explain some number excess in flux limited sample

- Not all the CSS/GPS may evolve in extended FRI/FRII galaxies, or many short “radio” phases occur in the same AGN


Thank you