# *Small and young radio sources*

**Monica Orienti**
(IAC - Tenerife)

# *Motivations*

- Information on the origin and evolution of the radio emission;
- Characteristics of the interstellar medium in the innermost region of the host galaxy;
- The role played by the ISM in the source evolution:

  jet-ISM interactions?

# *Outline*

1. **Small radio sources**
2. **Young or frustrated objects?**
3. **Physical conditions in young sources**
4. **Young radio sources: the ambient medium**

# *1. Small Radio Sources*

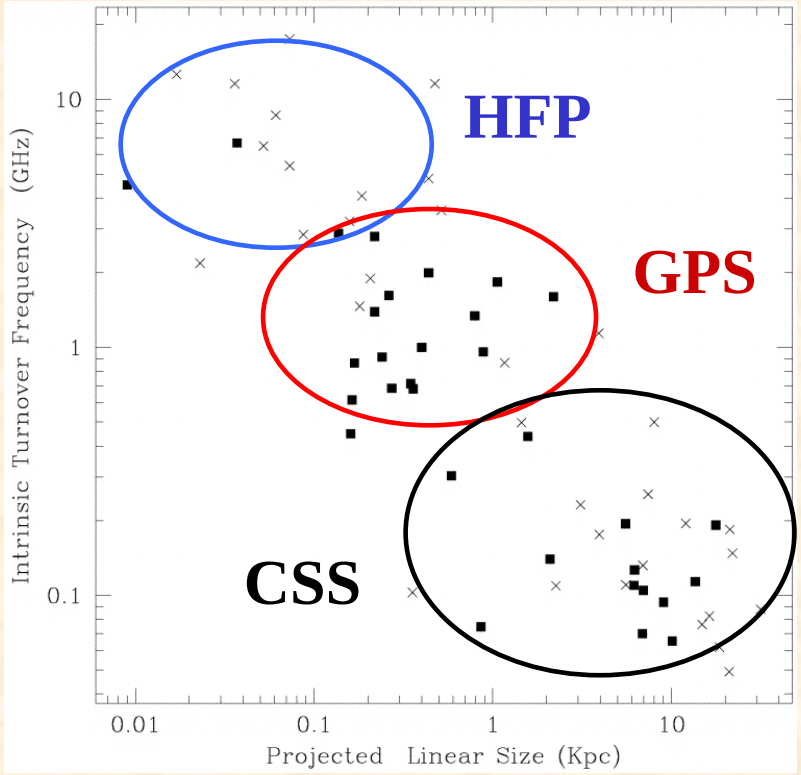
- Compact size (< 1 – 20 kpc);
- High radio luminosity ($P_{1.4\,GHz} > 10^{25}$ W/Hz);
- Significant fraction in radio source catalogues selected at 5 GHz (~15-30%);
- Radio synchrotron spectra with a turnover frequency ranging from ~ 100 MHz to a few GHz.

# *Linear size - turnover*

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

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

**HFP**
- LLS ~ 10 pc
- $\nu_t \geq 4$ GHz

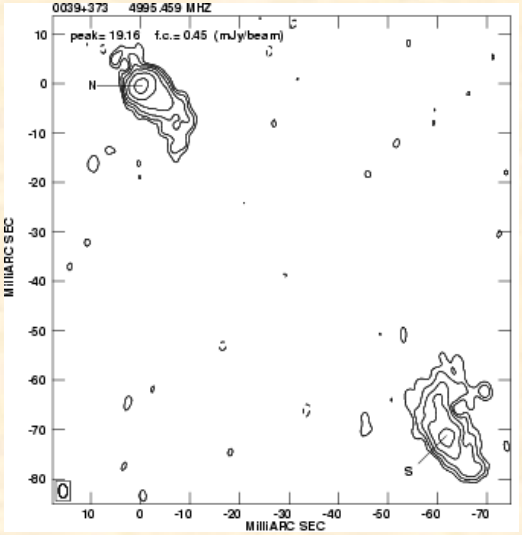



The smaller the source, the higher the turnover frequency (O'Dea 98)

# *Morphology*

When observed with sub-arcsec resolution, they show different structures:

**“Symmetric”**




Majority of small radio galaxies

CSO < 1 kpc

MSO < 20 kpc

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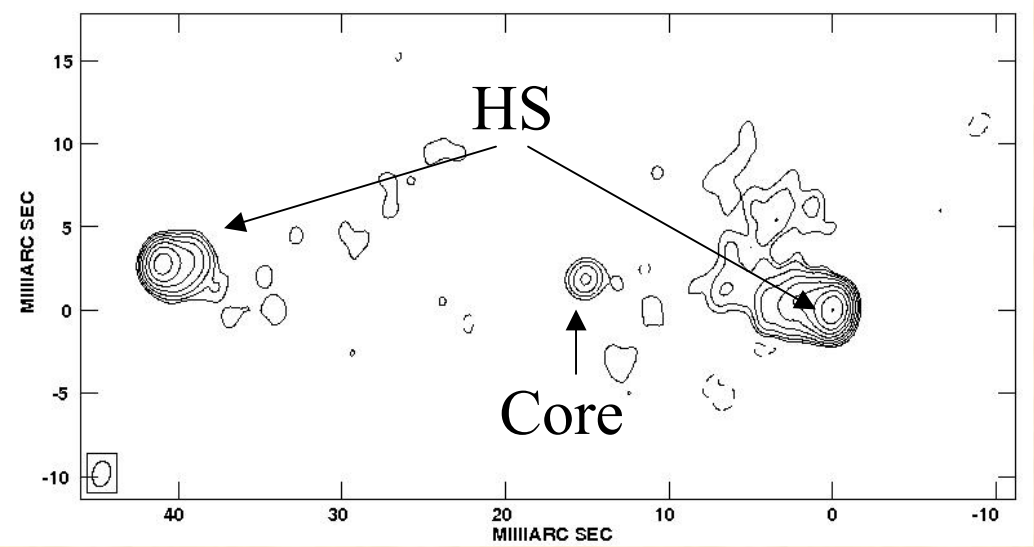


Majority of small radio galaxies

CSO < 1 kpc

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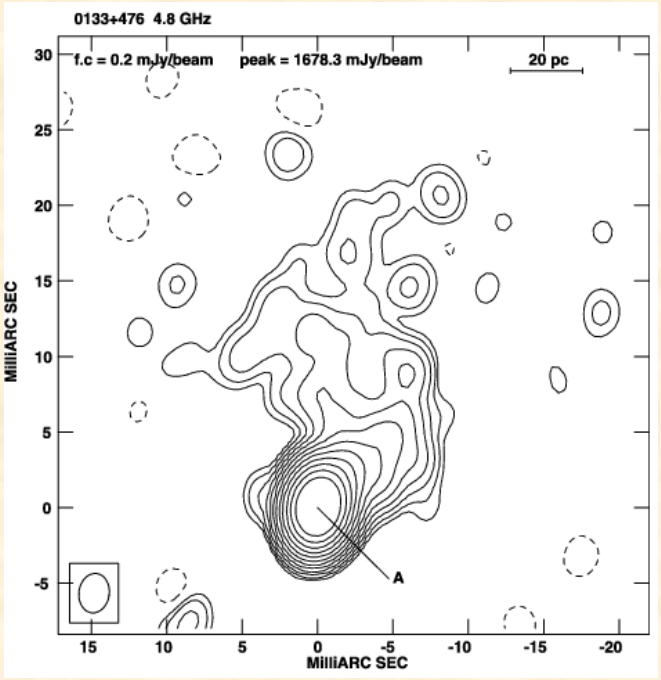
# *Morphology*

When observed with sub-arcsec resolution, they show different structures:

**Core-Jet**

0133+476

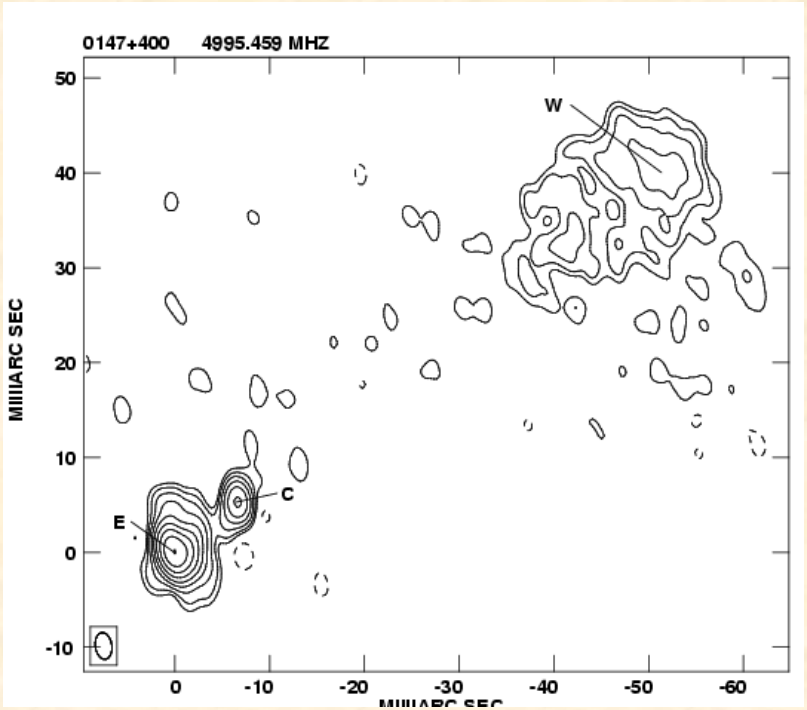



Majority of GPS/HFP and bright CSS identified with quasars

Stanghellini+ 98, Fanti+ 90, Orienti+ 06

Rossetti et al. 2005

# *Asymmetries in "symmetric" objects*




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

Saikia+ 03, Fanti+ 90

Jet-ISM interaction?

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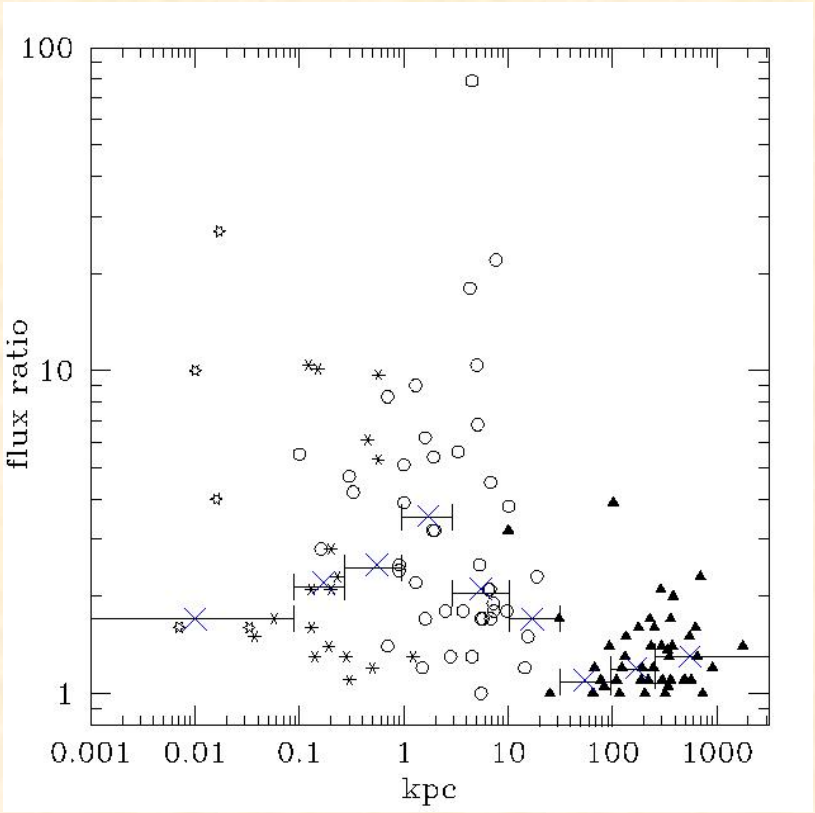



Strong asymmetry in both luminosity and arm-length ratios between the lobes

Saikia+ 03, Fanti+ 90

Jet-ISM interaction?

# *Variability*

- CSS: little or no vararіable

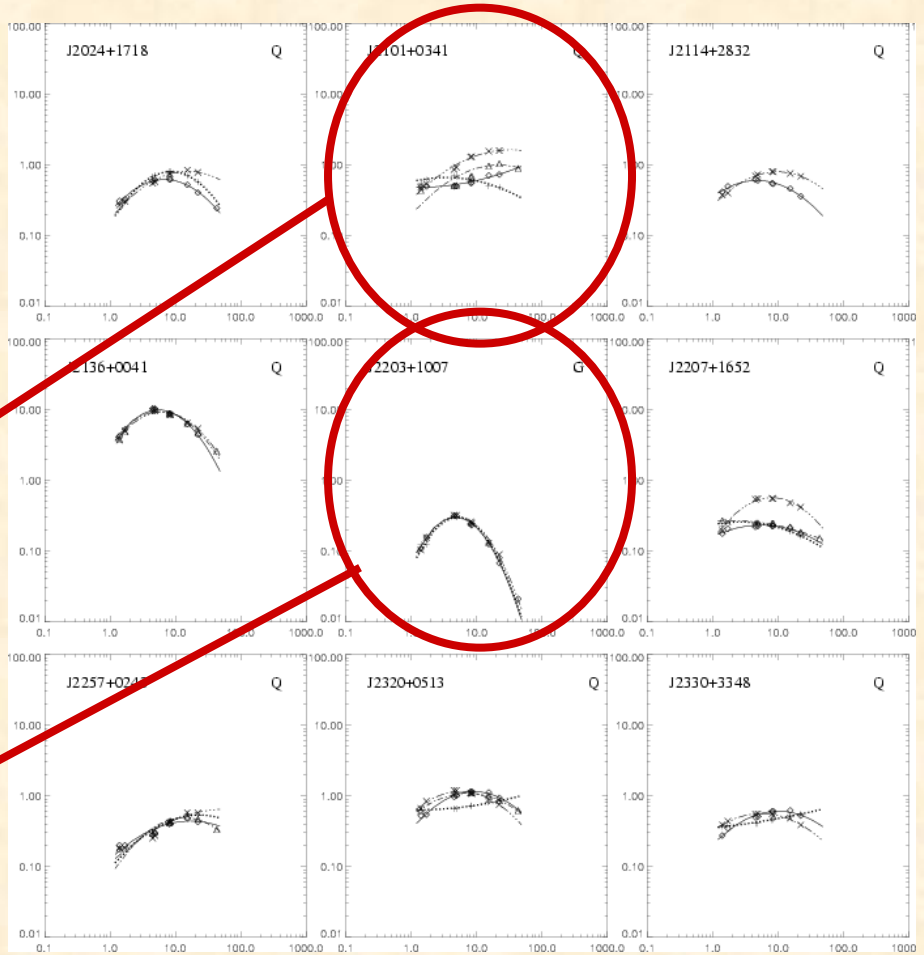
  O'Dea 1998

- GPS/HFP identified with quasars are very variable

  Torniainen+ 05, Tinti+ 05

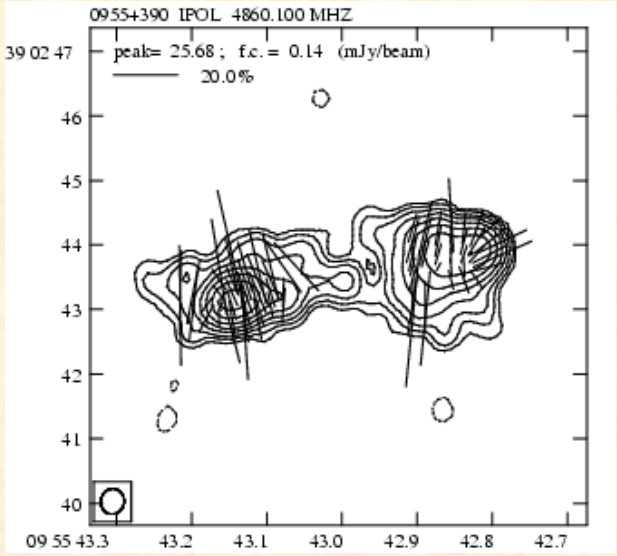
- GPS/HFP galaxies are little or no variable

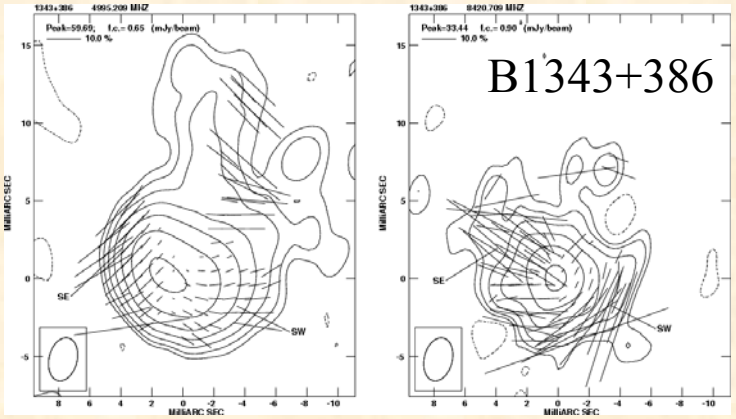
  Tinti+ 05, Orienti+ 07



# Polarization properties

- CSS with LLS > 5 kpc are polarized with H // to the jet axis
  - Fanti+ 01
- CSS with LLS < 5 kpc have high RM
  - Orienti+ 04
- GPS and HFP galaxies are usually unpolarized
  - Stanghellini+ 98
- HFP quasars are strongly polarized
  - Orienti+ 08



# *Galaxies vs quasars*

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

- Galaxies ⟶ Compact sources
- Quasars ⟶ Blazar objects

# *Young or frustrated?*

- **Youth scenario:**

**Compact ⟶ Young**

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

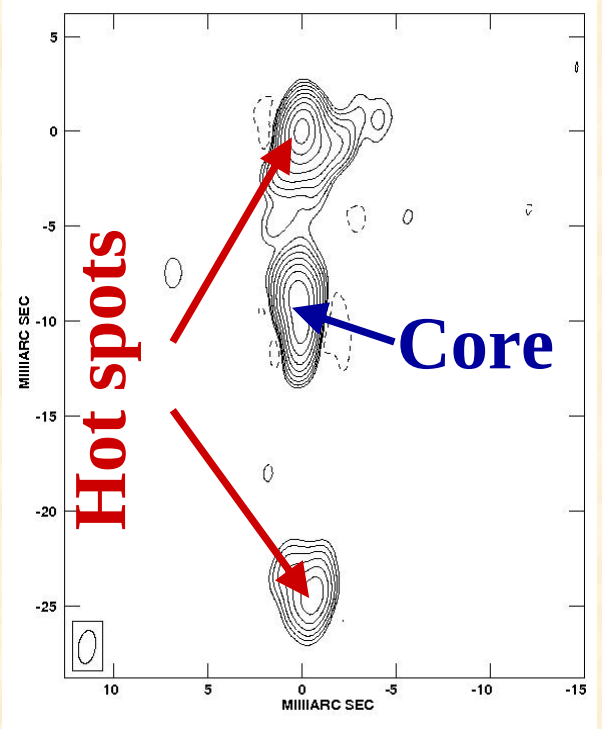
- **Frustration scenario:**

**Compact ⟶ Frustrated**

van Breugel+ 84, Baum+ 90

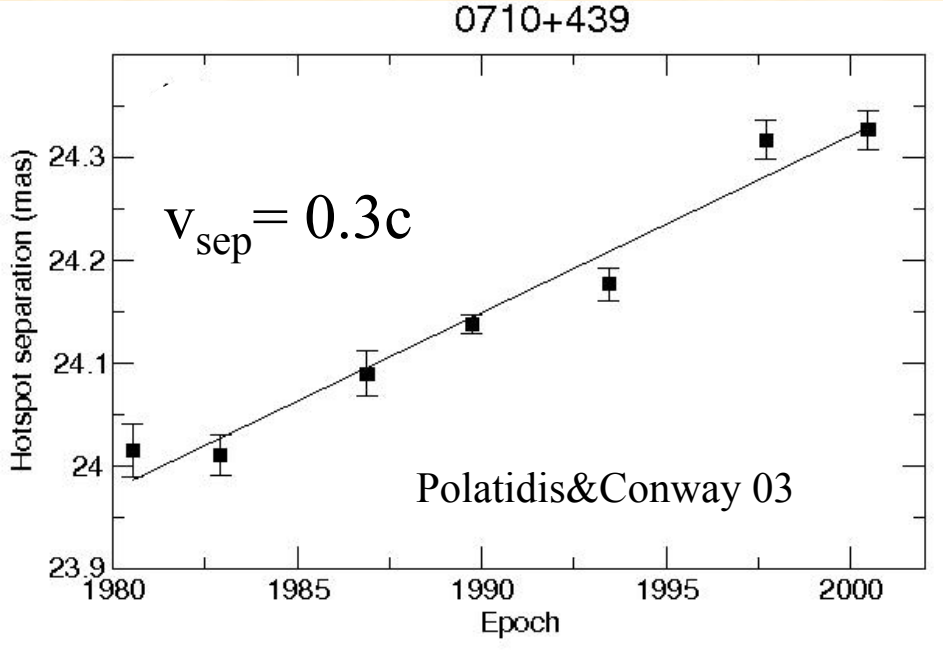
# *Proper motion*

B0710+439




**Compact ⟶ Young**

Kinematic age: $10^3$ yr

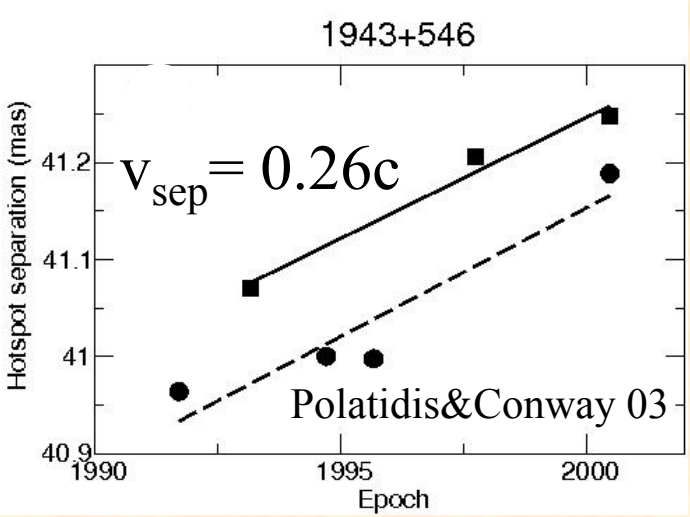


# *Spectral analysis*

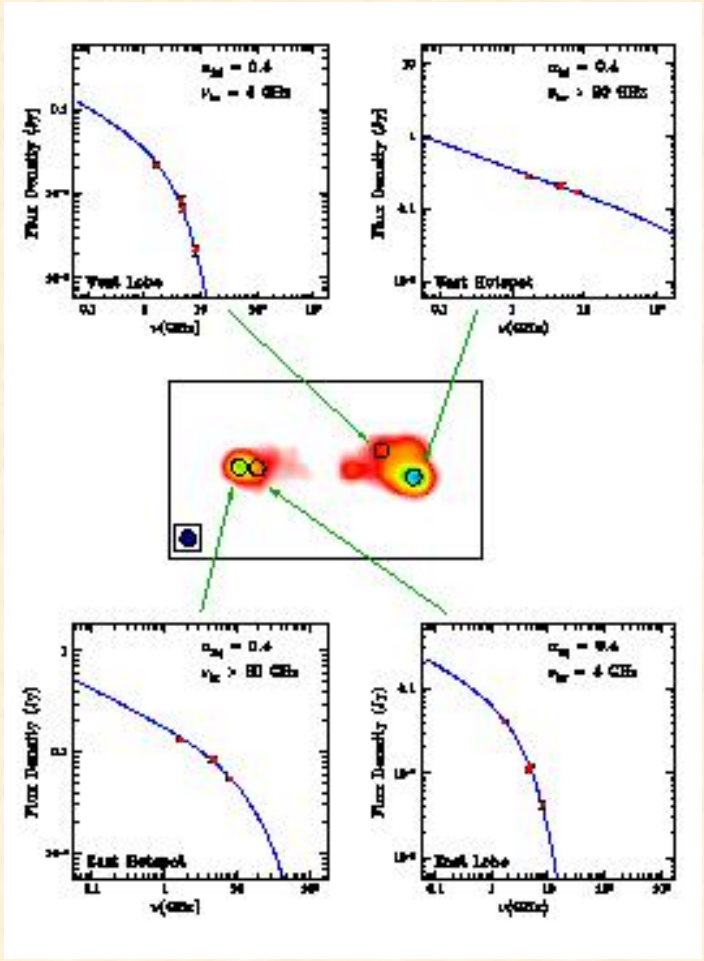
**Compact ⟶ Young**

Spectral age: $10^3$ yr

Kinematic age: $10^3$ yr




B1943+546, Murgia 2003



# *The "frustration" scenario*

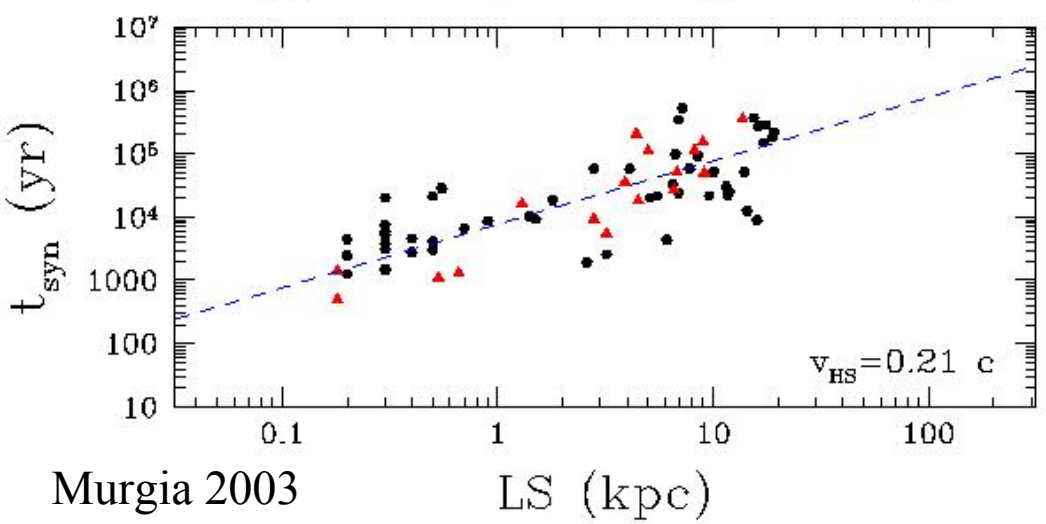
**Compact** ⟶ **Frustrated**

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

Fanti+ 00, Siemiginowska+ 05

**Indirect support to the youth scenario**

# *Evolutionary stages*

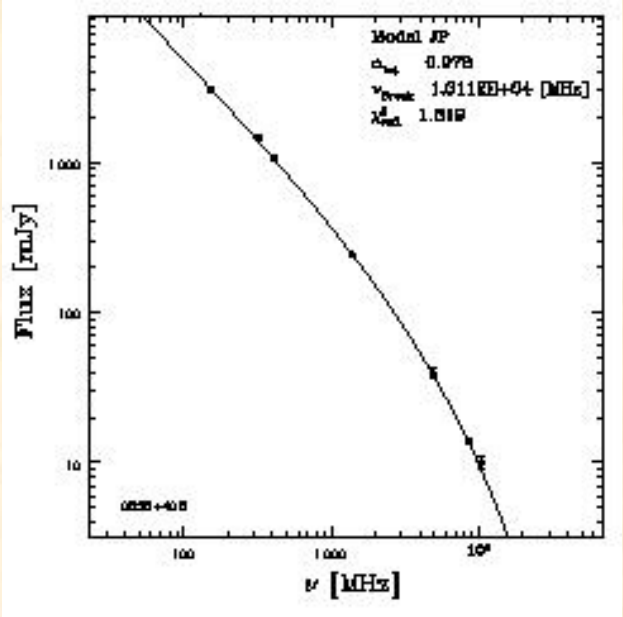



Murgia 2003

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

**HFP** → **GPS** → **CSS** → **FR I/II** ?

# *Dying objects?*




Lack of hot spot and core components in many CSS/GPS

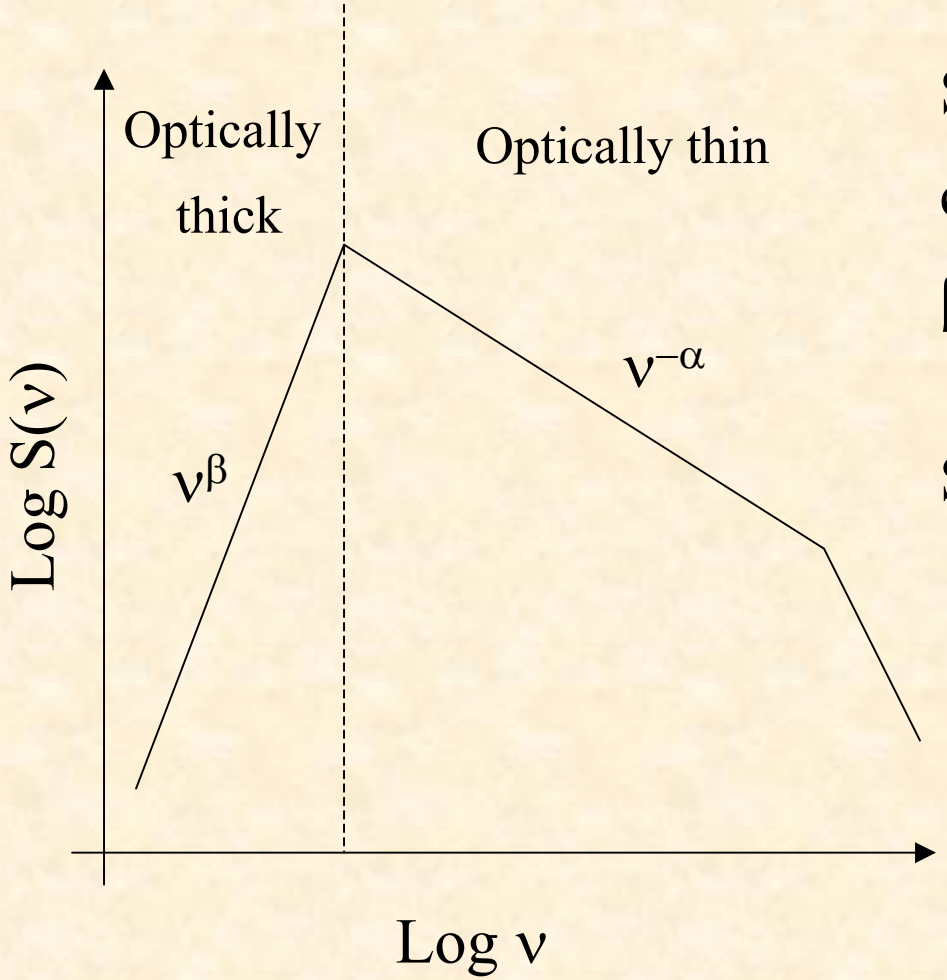
Marecki et al. 03, ….

No injection of fresh particles

Murgia 03

**HFP** → **GPS** → **CSS** → **FR I/II** ?

# The spectral peak




SSA in a homogeneous component:

$\beta = 2.5$

SSA is present by default

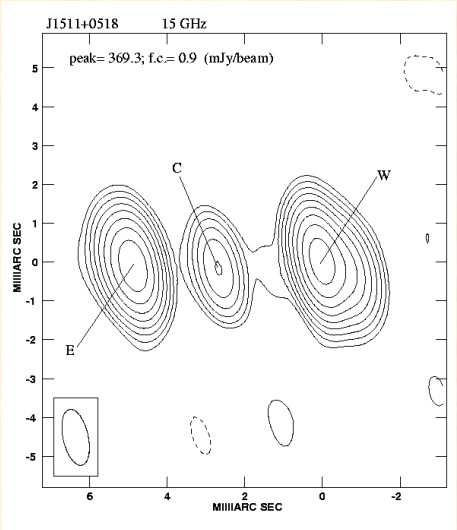
Radiative losses

# *Magnetic field*

In the presence of SSA from homogeneous component:

$$H_{SSA} = \frac{\theta^2_{max}\ \theta^2_{min}\ \nu^5_p}{f(\alpha)^5\ S^2_p\ (1+z)}$$

Kellermann&Pauliny-Toth 81




$H_{SSA}$ derived in CSS objects have high uncertanties (factor 16)

Scott&Readhead 77, Spangler+ 82

# Magnetic field

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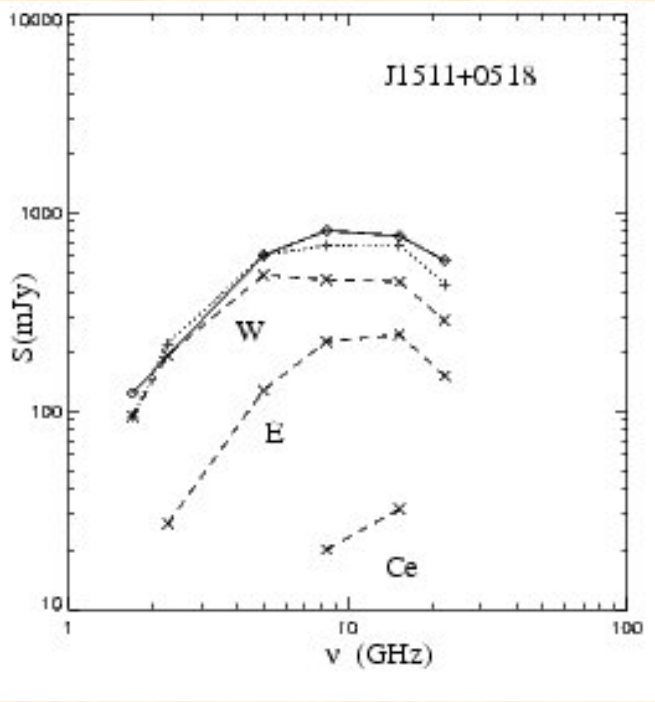



The VLBI has the ideal frequency coverage and the resolution to "observe" the spectral peak in HFP

# *Are young objects in equipartition?*

In case of equipartition:

$$H_{eq} \propto (1+k)^{2/7}\ \phi^{-2/7}\ P^{2/7}\ V^{-2/7}$$

Pacholczyk 1970

$$H_{eq} \approx H_{SSA}$$

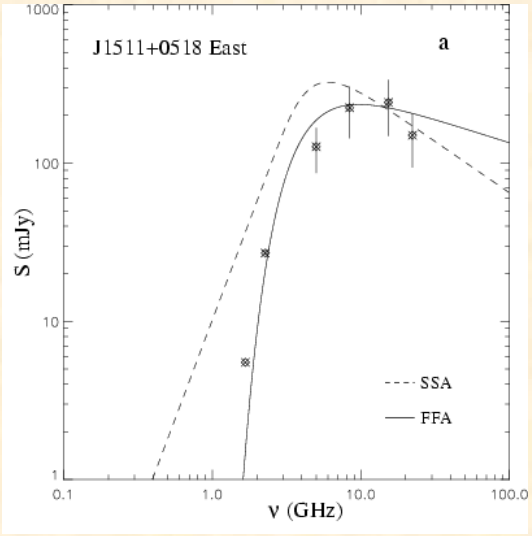
with some exceptions…

| Source | Component | H (mG) | $H_{eq}$ (mG) |
|---|---|---|---|
| J0003+2129 | E | 33 | 30 |
| J0005+0524 | E | | 18 |
| J0428+3259 | E | >>1000 | 34 |
| | C | 59 | 65 |
| J0650+6001 | N | 29 | 77 |
| | S | 10 | 54 |
| J1511+0518 | W | 104 | 95 |
| | E | >>1000 | 70 |
| J1459+3337 | ... | 160 | 160 |

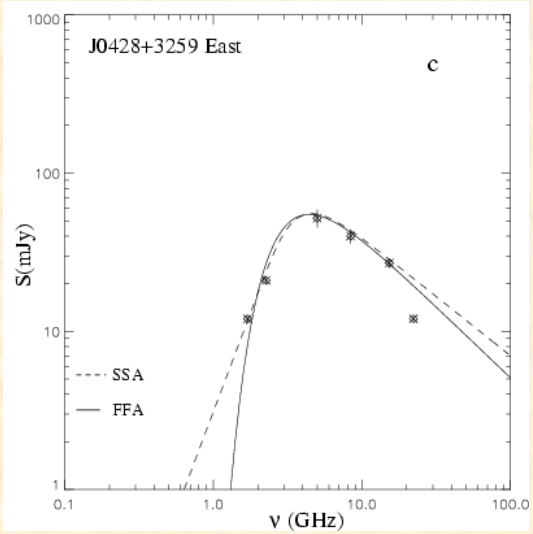
Orienti&Dallacasa 08

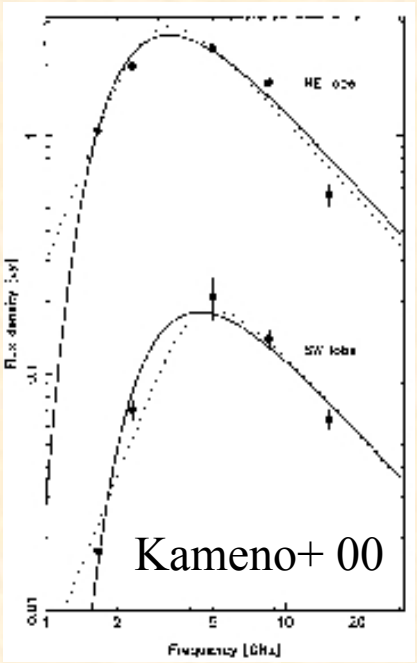
# *SSA or FFA?*

Optically-thick part of the spectrum is too steep to be described by SSA only. Additional contribution from FFA




Orienti&Dallacasa 08

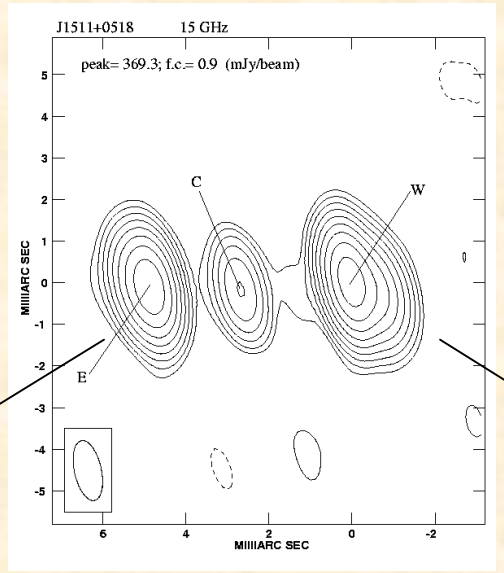


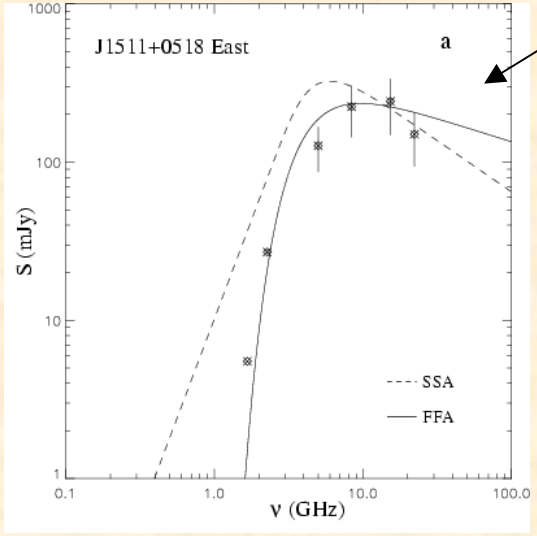

$H_{SSA}$ cannot be derived

## *3. Physical conditions*

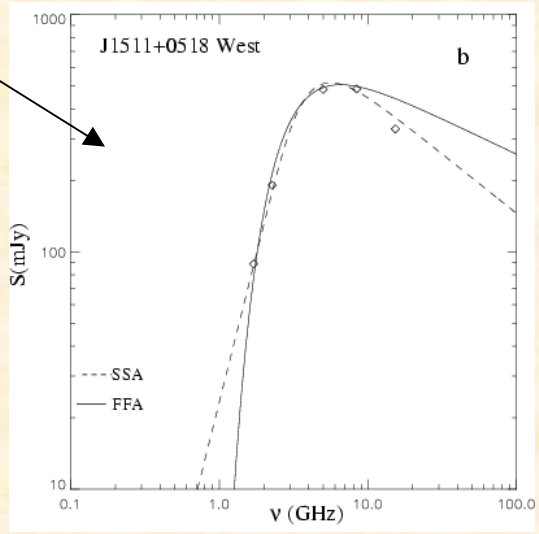
# *SSA or FFA?*




FFA




SSA



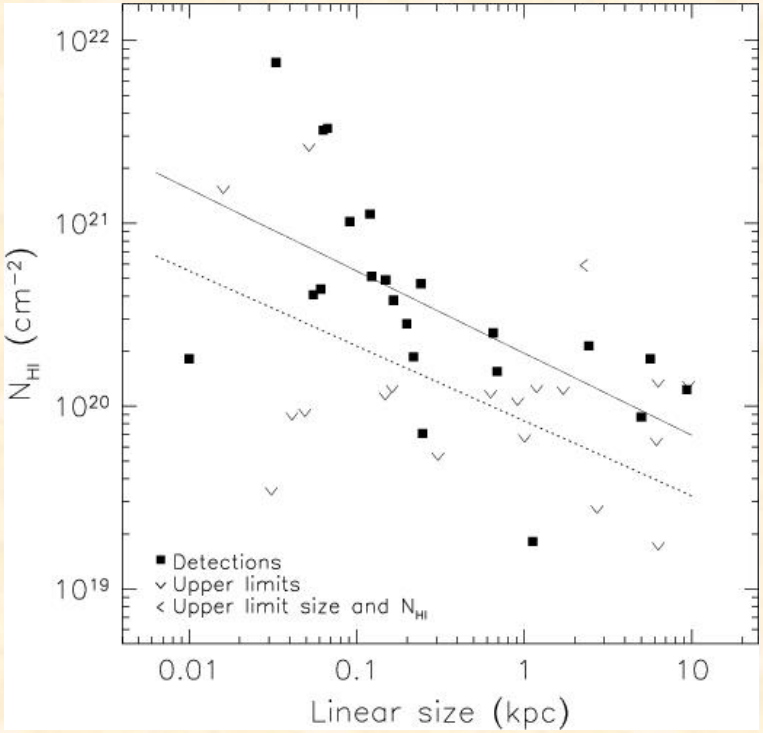

Inhonogeneous ambient medium

# *The HI in young radio sources*

Larger incidence of HI absorption in young radio sources than in "normal" radio galaxies (Morganti et al. 2001);

- Anti-correlation LS – $N_{HI}$

(Pihlström+ 03; Vermeulen+ 03 Gupta+ 06);



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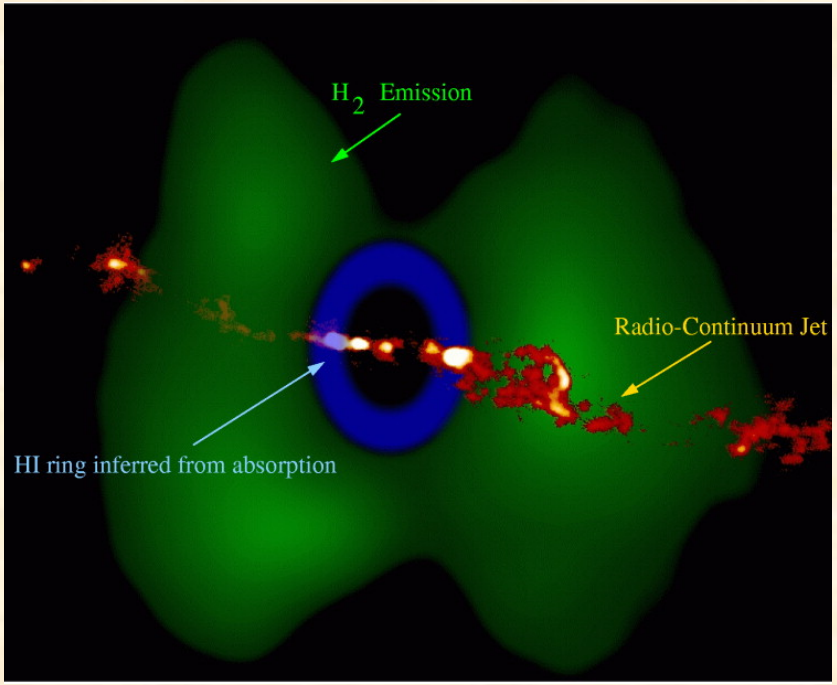
- Gas distribution:

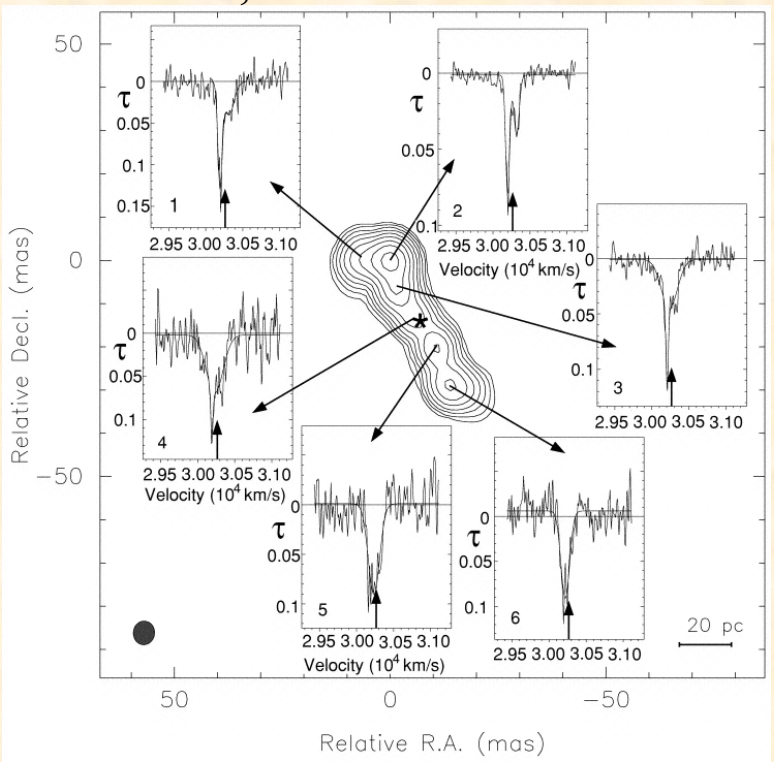
- Spherical, radially declining density;

- Circumnuclear disk/tours (Mundell+ 03).



# *VLBI observations*

1946+708, Peck et al. 1999



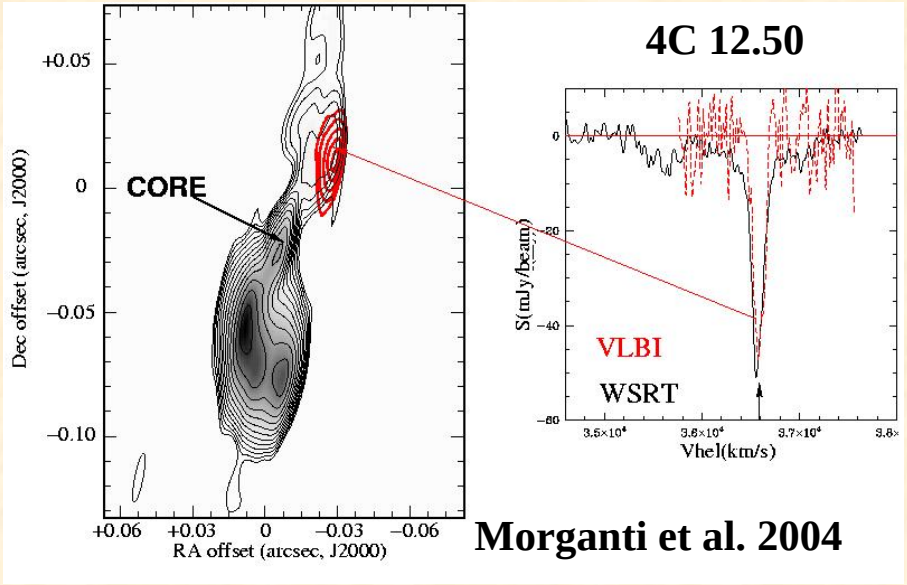

HI detected against the whole source

**Central disk**

$\Delta V = 350$ km/s

$N_H \approx 2 \times 10^{23}$ cm $^{-2}$ ($T_s = 8000$ K)

# *VLBI observations*




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

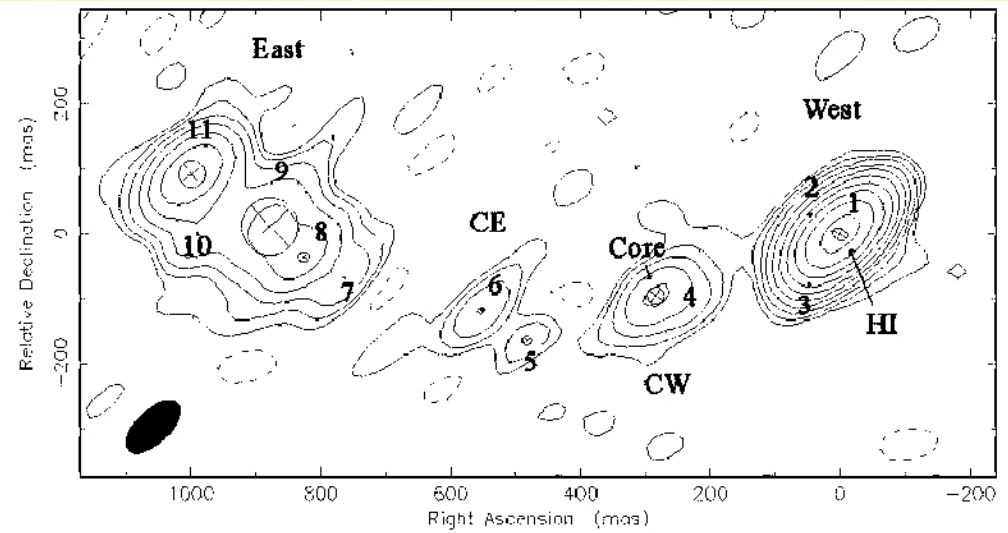
**Off-nuclear cloud**

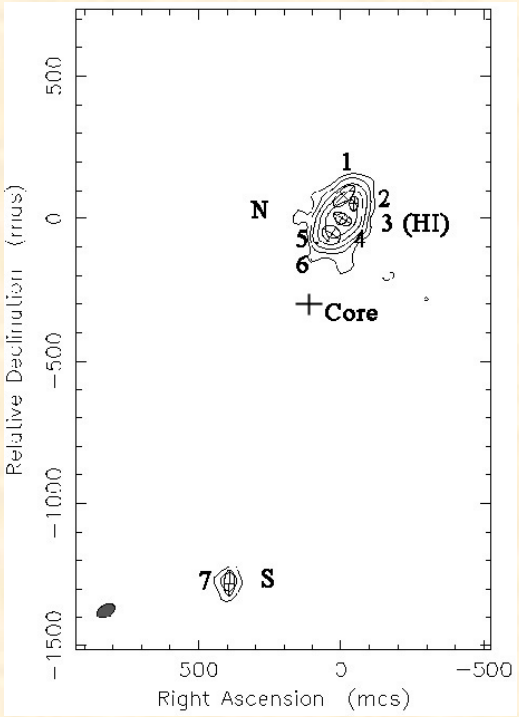
$\Delta V = 150$ km/s

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

# *Jet-cloud interactions?*

They may be responsible for the asymmetries in arm-length and luminosity found in compact objects




The statistic is still too poor…..

Labiano et al. 2006

# *Square Kilometer Array*

- Frequency range:

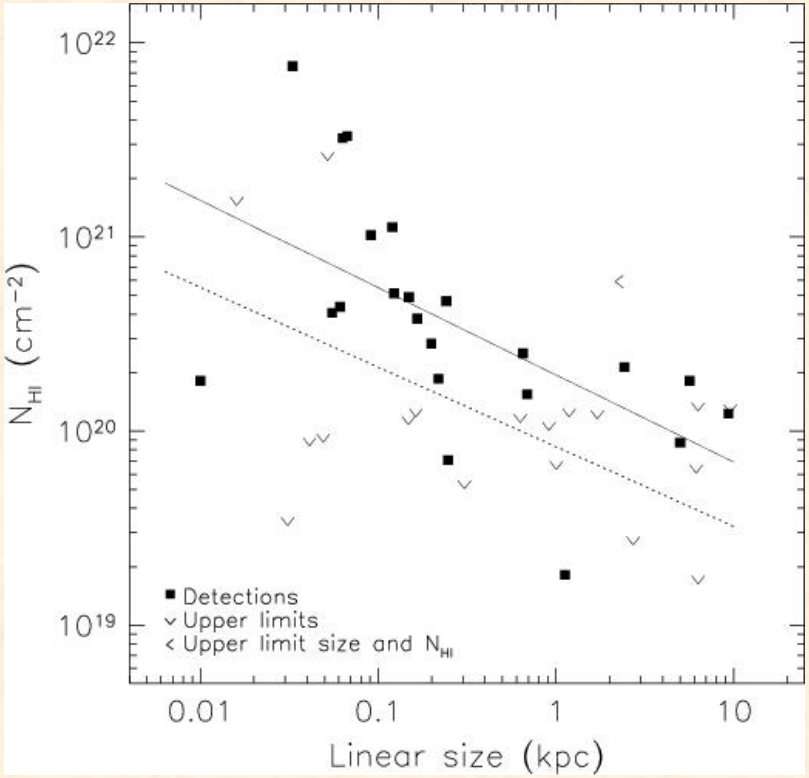
  - 0.1 – 25 GHz

- Sub-arcsec resolution:

  - 0".1 @ 1.4 GHz

  - 0".2 @ 0.7 GHz

- High dynamic range: $10^6$



# *Summary*

- **Small radio galaxies represent the young phase in the radio source evolution;**
- **The spectral turnover is due to SSA, but an additional contribution of FFA is found in the most compact objects;**
- **Young radio sources are found in equipartition condition;**
- **The ambient medium plays an important role in the evolution of the radio emission;**
- **Future telescopes with good sensitivity and resolution as SKA will give us new important information on the environment**

**A better knowledge of the ambient medium will enable us to draw a more reliable picture on the fate of the source evolution**

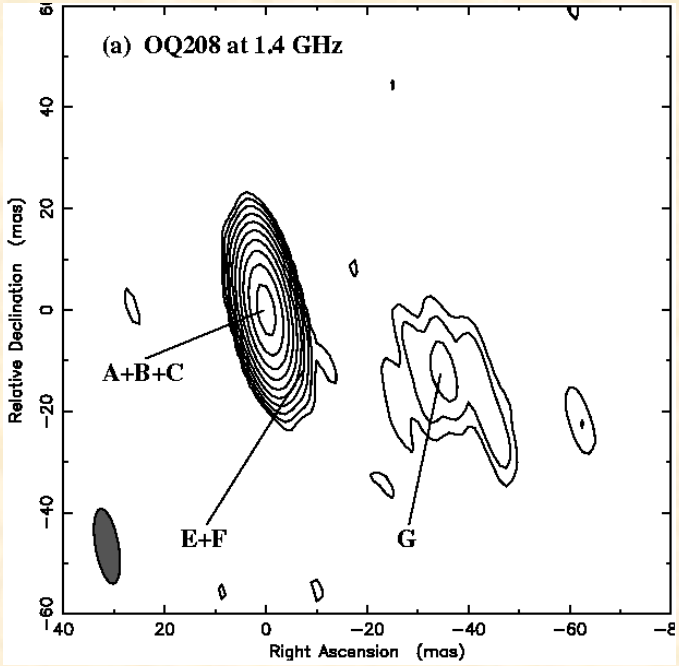
# *Extended emission in HFP galaxies*

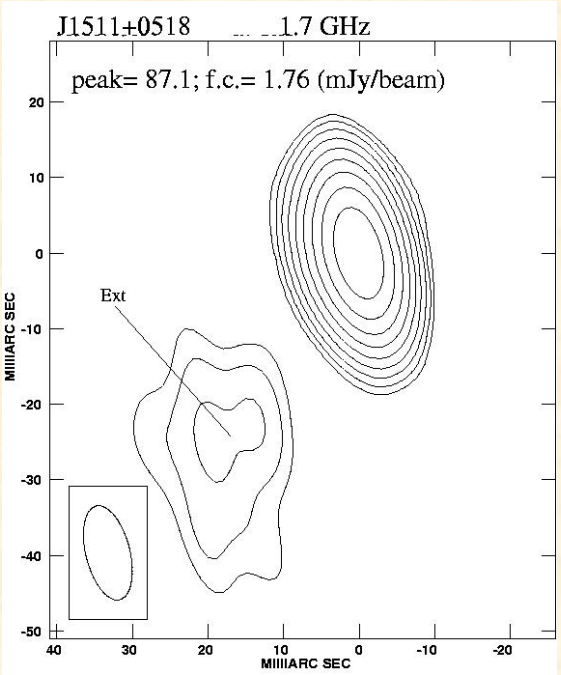
- On kpc-scales:

  - J0111+3906 (Baum+ 90); J0428+3259 (Tinti+ 05)

- On pc-scales:

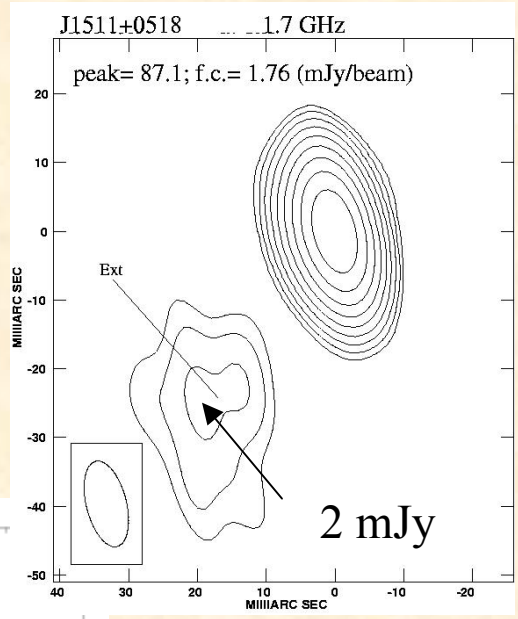
  - OQ 208 (Luo+ 07); J1511+0518 (Orienti&Dallacasa 08)

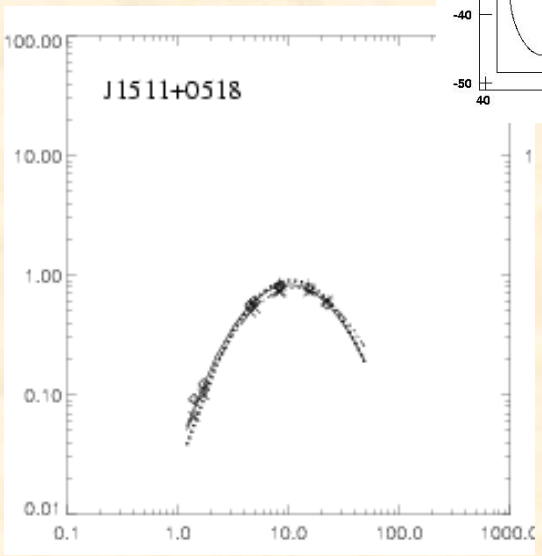


# *(E)-LOFAR*

Recurrent activity in the first stages of the radio emission?




$\alpha = 1.0$

- 23 mJy @ 120 MHz
- 37 mJy @ 75 MHz
- 47 mJy @ 30 MHz