HI Absorption in Young Radio Galaxies

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The plan

- Why the neutral hydrogen in radio galaxies?
- What can we learn on the ISM of the host galaxy?
- The HI and the origin of the radio activity

- What are young radio sources?
- HI properties in extremely young radio galaxies
- The goal of high-resolution VLBI observations

Why the HI in Radio Galaxies

- Tracer of physical conditions of the ISM:
  1) settled medium (circumnuclear torus);
  2) unsettled, clumpy medium;

- Tracer of different phenomena:
  a) Jet-ISM interaction;
  b) outflows;
  c) onset of radio activity;

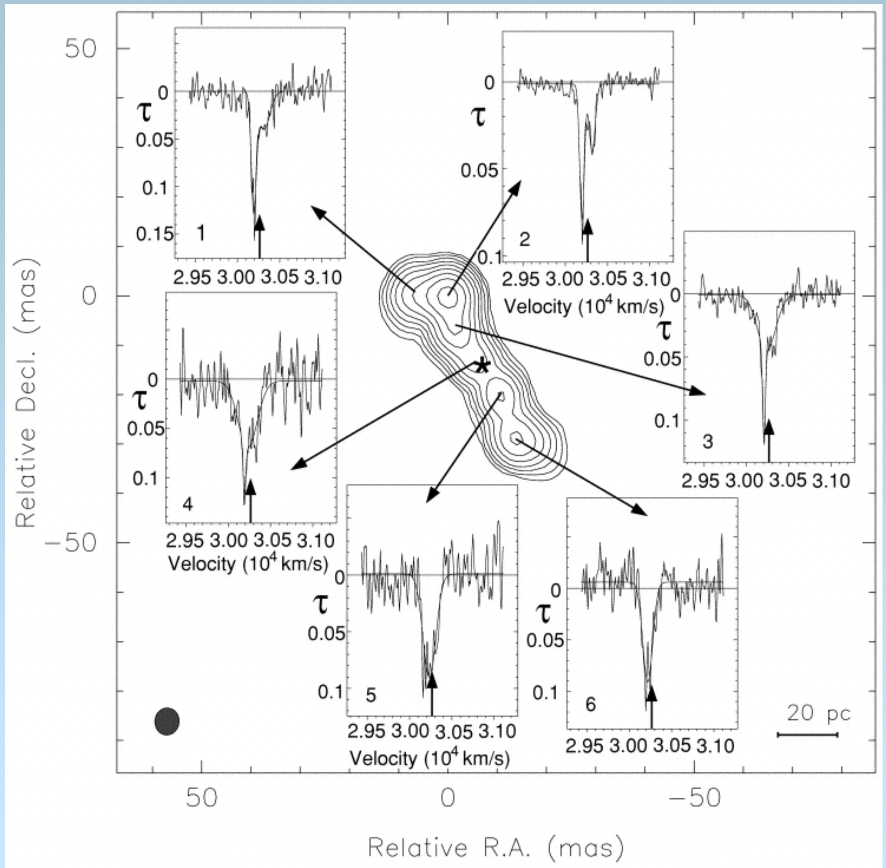
- Tracer of the role played by ISM on growth and evolution of radio source.

Circumnuclear disks and tori

Evidence of HI absorption associated with circumnuclear disks and tori in radio galaxies.

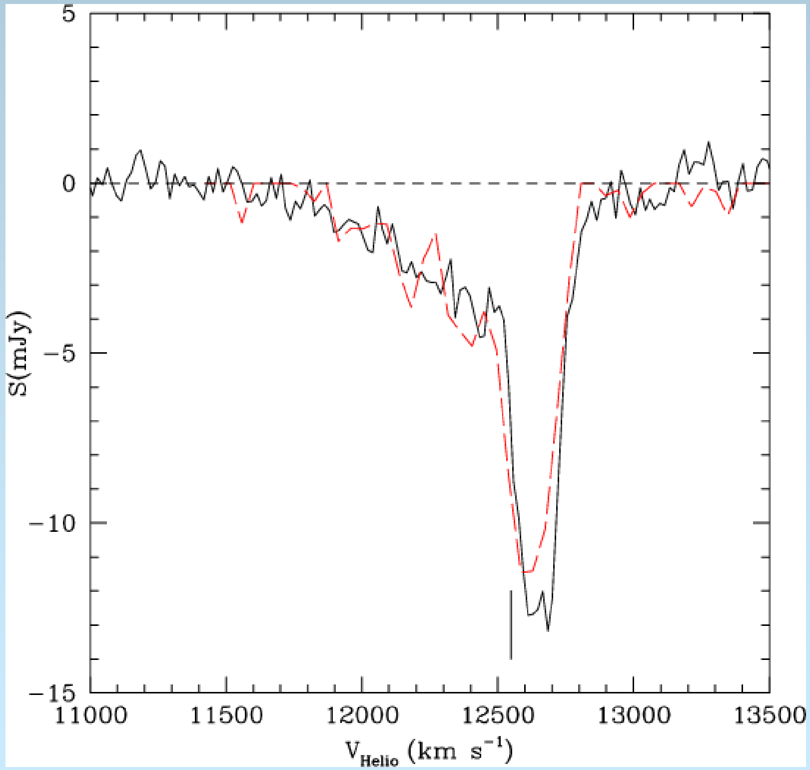
They usually display quite ***broad (> 150 km/s), and deep ($\tau > 0.01$) absorption.***

The HI absorption in 1946+708 (Peck & Taylor 2001), detected throughout the entire continuum source, is due to a ***thick torus*** of 100 pc, $N_{HI} \sim 10^{23}\ cm^{-2}$, with a differential rotation velocity.



Fast outflows

- Broad (600 – 2000 km/s) and shallow (τ ~ 0.006) profiles, (Morganti et al. 2006);
- Optical, UV and X-ray (i.e. Holt et al. 2003);
- Different mechanisms:
  - a) Jet – ISM interaction (Emonts et al. 2005);
  - b) Broad Emission Line Clouds (BELCs; Elvis et al. al. 2002)



The HI and young radio sources

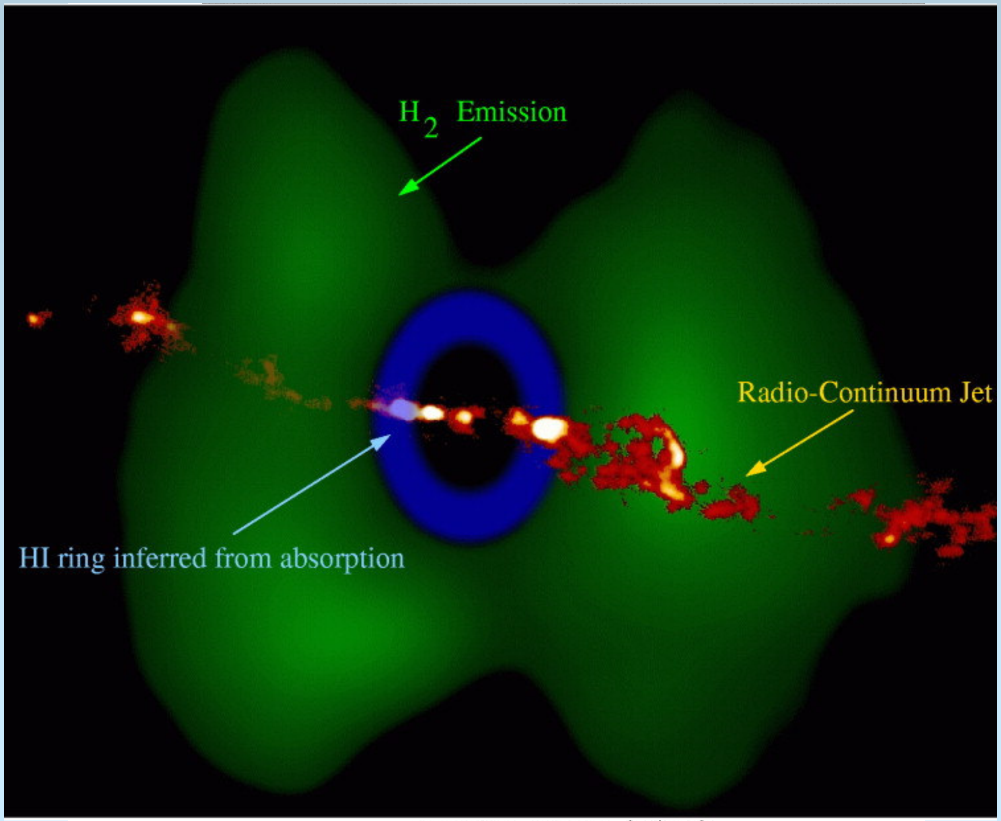
Larger incidence of HI absorption in young radio sources than in "normal" radio galaxies (Morganti et al. 2001);

Anti-correlation LS – N_{HI} (Pihlström et al. 2003; Gupta et al. 2006);

Gas distribution:

• Spherical, radially declining density;

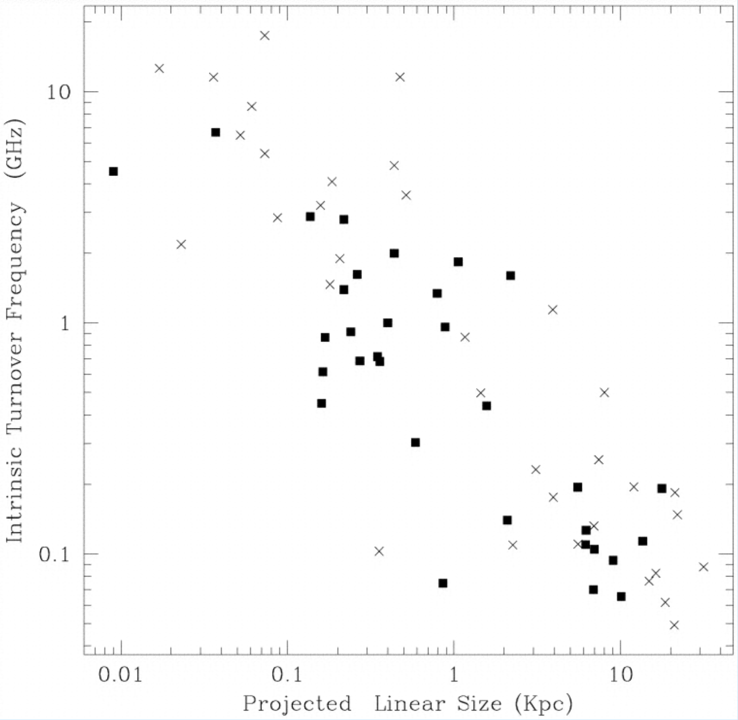
• Circumnuclear disk/tours.



What are young radio sources?

The Compact Steep Spectrum (CSS) and GHz-Peaked Spectrum (GPS) radio sources are:

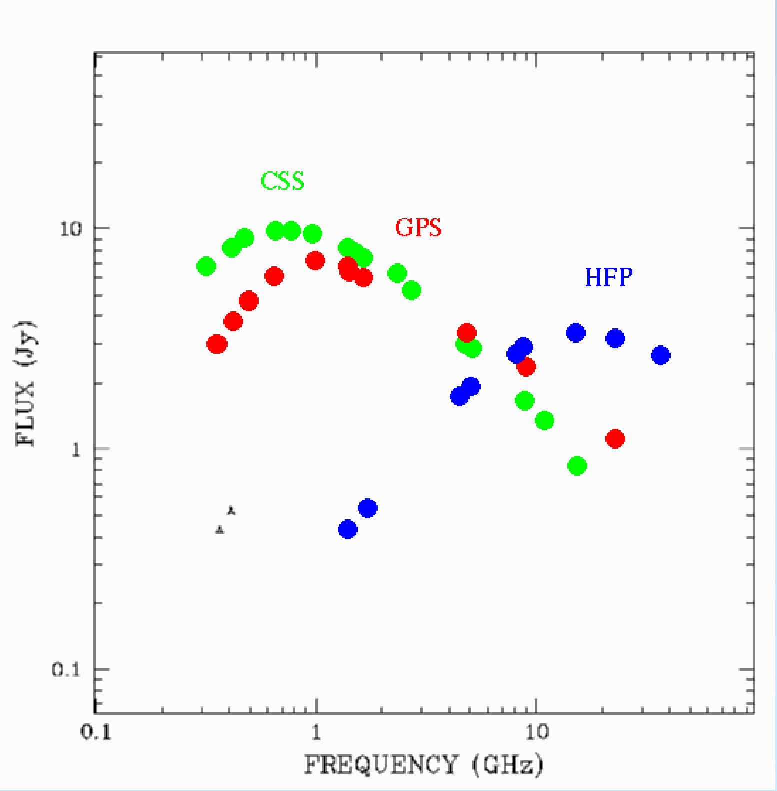
- LLS < 15 kpc;
- $P_{1.4\ GHz} > 10^{25}$ W/Hz;
- $\nu_t \sim 100$ MHz – 1 GHz;
- Anti-correlation between LLS and the turnover (O'Dea et al. 1998);
- t ~ 10^{3-5} yr (Polatidis & Conway 2003; Murgia 2003);
- HI absorption detection rate ~ 54% (Pihlström et al. 2003).



High Frequency Peakers

In the youth scenario the correlation between the turnover frequency and the projected linear size implies that the highest the turnover, the youngest the source is.

High Frequency Peakers (HFPs) objects, characterised by a convex radio spectrum peaking at frequencies higher than 5 GHz, are good candidates to be ***newly born*** radio sources with ages of about 10^2 - 10^3 years.



The sample

- The ***Bright HFP sample*** (Dallacasa et al. 2000) comprises 55 objects with $S_{4.9} > 300$ mJy and $\alpha < -0.5$ ($S \propto \nu^{-\alpha}$).

- VLA and VLBA analysis to avoid blazar contamination (Tinti et al. 2005; Orienti et al. 2006);

- Galaxies and quasars represent different class of objects:

  a) 87% of quasars show a Core-Jet or Unresolved structure;

  b) 78% of galaxies show a CSO-like morphology;

HI Absorption in HFPs

WSRT observations searching for HI absorption in **6 HFP galaxies.**

Redshift: 0.02 – 0.67;

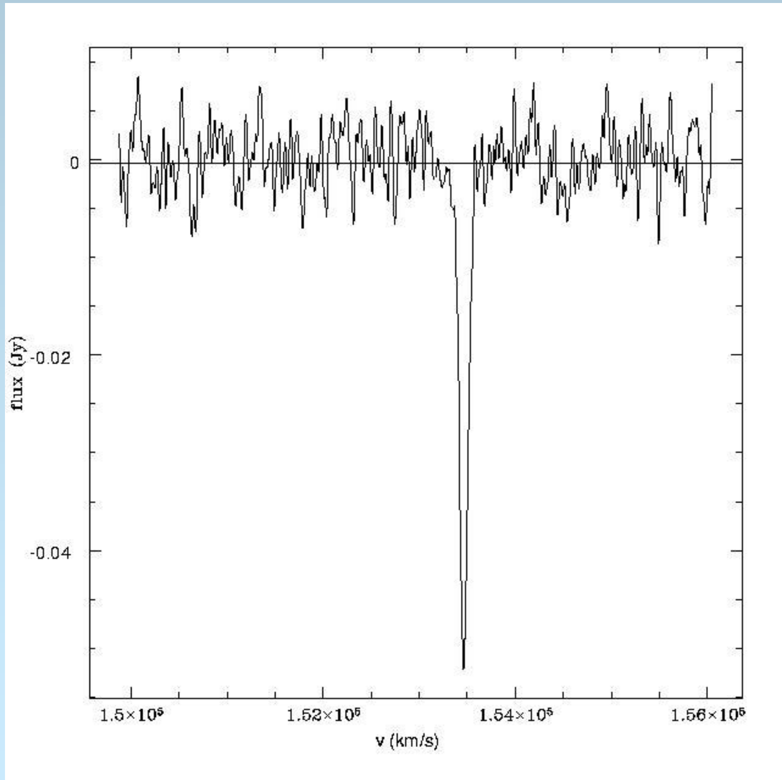
$S_{1.4} > 90$ mJy.

- 2 sources (33%) show HI absorption:
  - 1 with $\tau = 0.44$;
  - 1 with broad (2000 km/s) and shallow $\tau = 0.005$ line;
- 4 sources have not been detected, with **$\mathbf{Log(N_{HI}) < 20.0}$;**
- No evidence of the LLS – N_{HI} correlation (Orienti et al. 2006b).

J0111+3906

Radio galaxy (z = 0.67) with a well known HI absorption line already detected by Carilli et al. (1998):

- Optical depth τ ~ 0.44
- FWHM ~ 100 km/s
- Log(N_{HI}) ~ 21.9



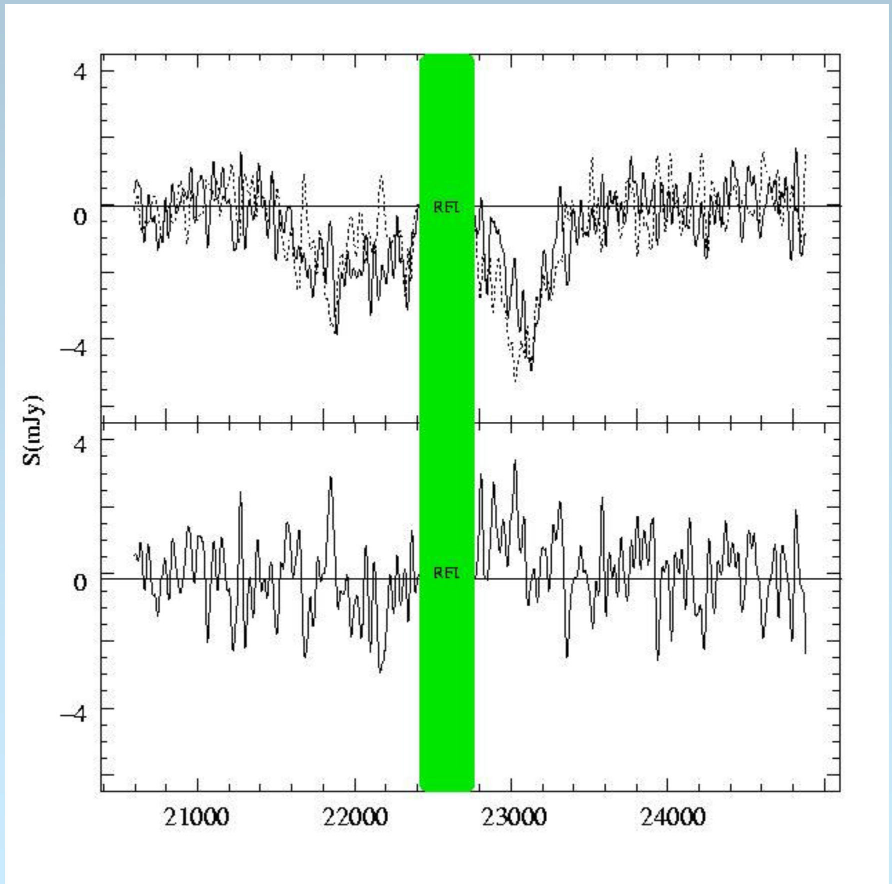
No evidence of variability has been found ($\tau_{2\sigma}$ ~ 0.03).

HI absorption associated to a ***circumnuclear torus*** (Marr et al. 2001).

OQ 208

Radio galaxy at z = 0.07;

LS = 10 pc (Stanghellini et al. 1998);

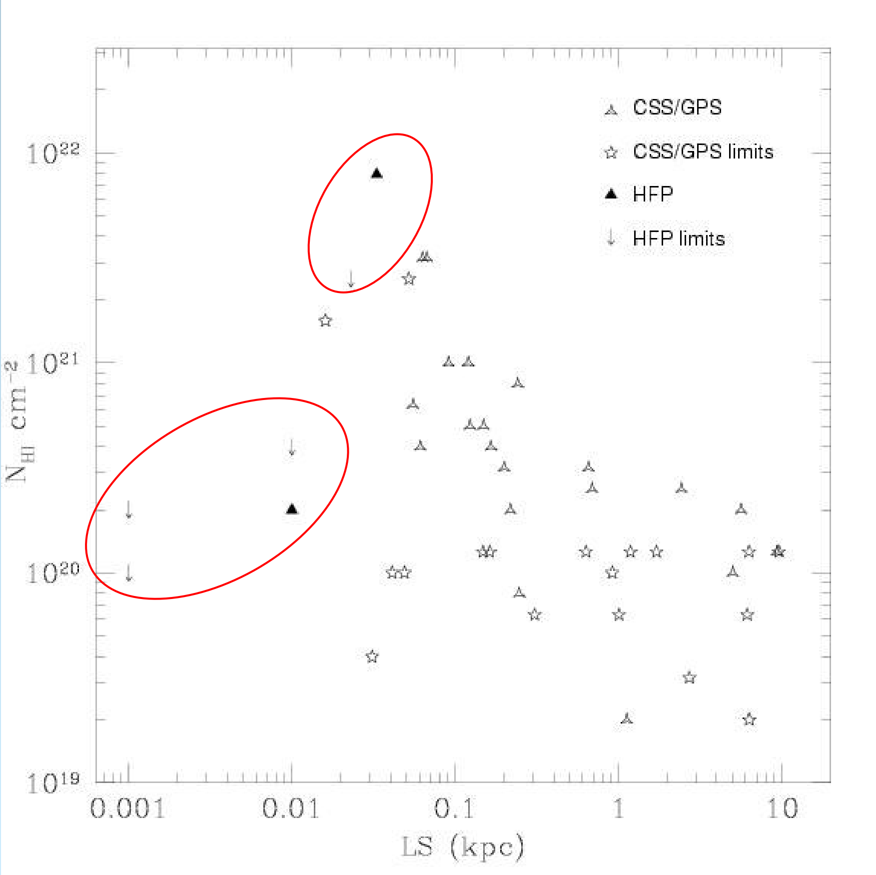


- Broad (~ 2000 km/s);
- Blueshifted;
- Shallow ($\tau \sim 0.005$) ;
- $\mathrm{Log}(N_{HI}) \sim 20.9$;
- No variability ($\tau_{2\sigma}$. ~ 0.002).

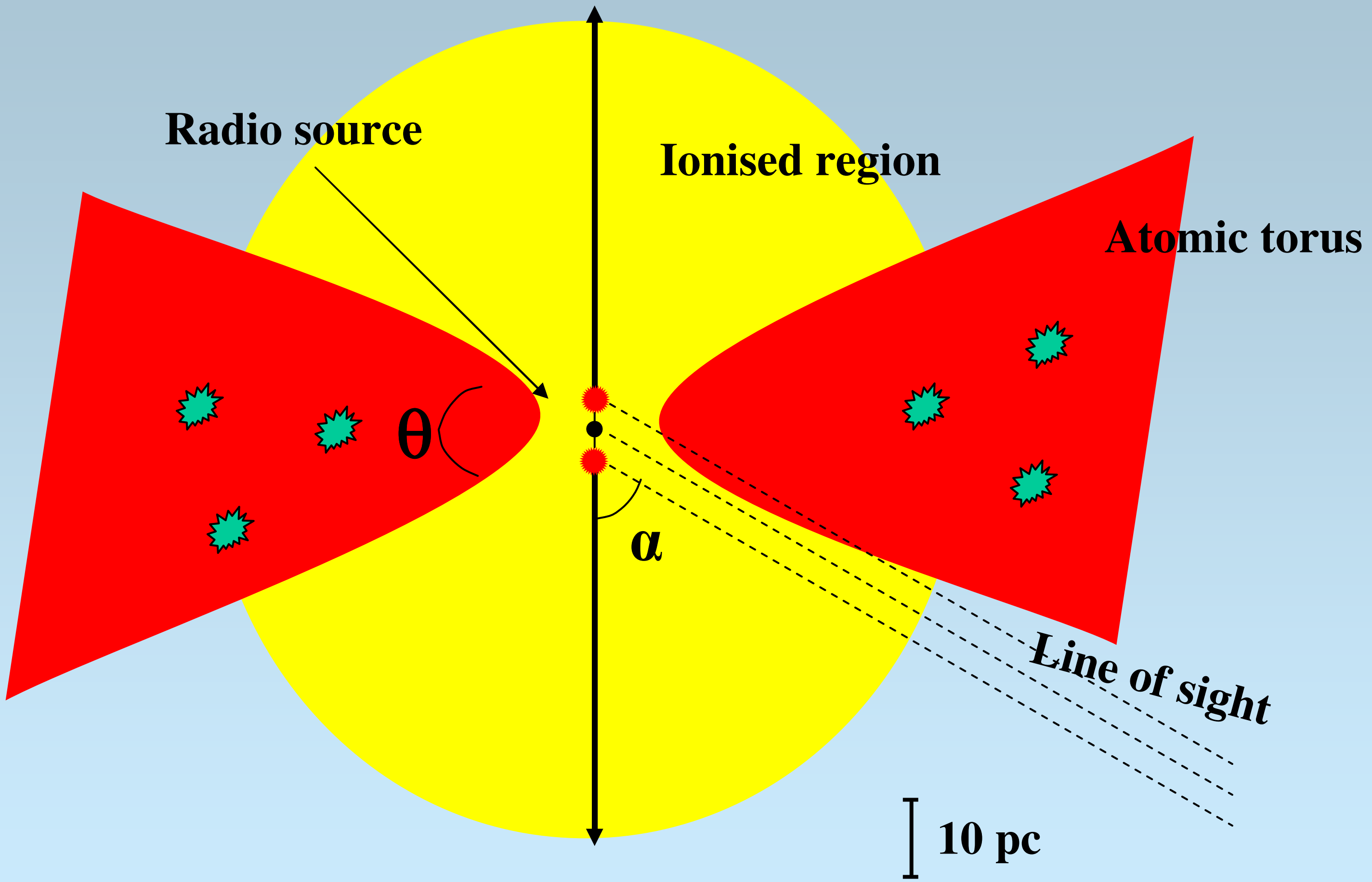
Linear size vs Column Density

The HFP sources do not seem to follow the extrapolation to smaller LLS of the correlation found by Pihlström et al. (2003).

The absence of high HI column density can be explained in a torus/disk scenario, by geometrical and orientation effects.



Low detection in a torus scenario



$\theta \sim 60^{o}$

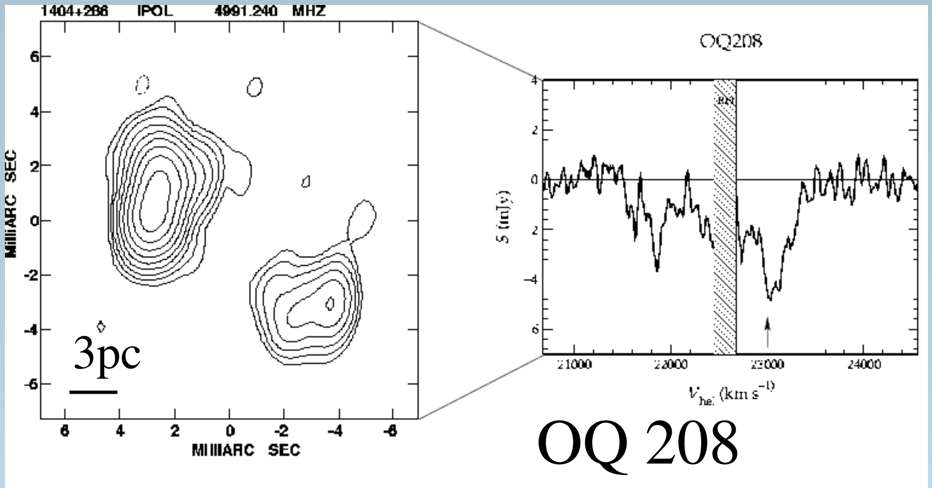
$\alpha \sim 70\ ^{o}$

Conclusions

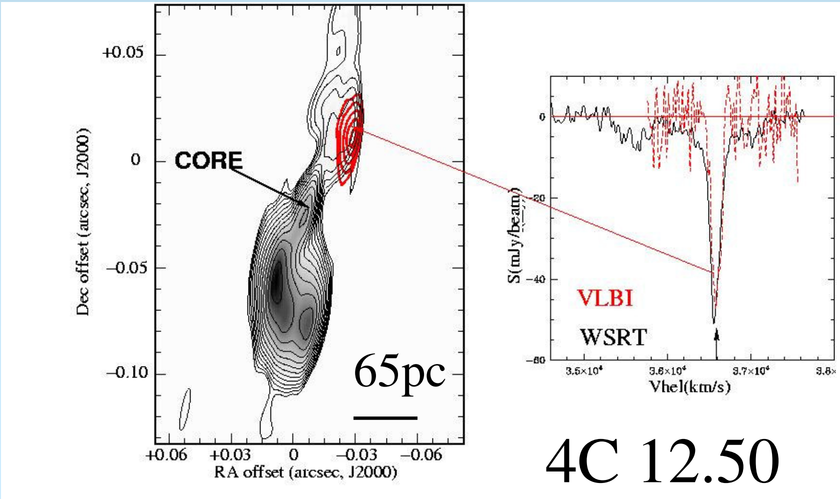
- 2 (33%) HFPs show HI absorption;
- 1 galaxy has a narrow and strong line with $\tau \sim 0.44$;
- 1 galaxy has a very broad (2000 km/s) and shallow ($\tau \sim 0.005$) absorption;
- No evidence of variability;
- No evidence of correlation between LLS-N_{HI} on small scales;

Future work

Global VLBI observations have been carried out for the HFP OQ208 and the GPS 4C12.50 radio galaxies.



The location of the broad component will provide information on its nature (Jet-cloud interaction; BELCs) and the role of the ISM on the source evolution.



Why the HI in Radio Galaxies

The presence of large amount of gas and dust is often found in the central regions of galaxies harbouring an Active Galactic Nucleus (AGN).
Indeed, the ***onset of nuclear activity*** is often thought to be link to the abundant fuel provided by ***accretion or merger event*** in the host galaxy.

A component of this gas, the ***neutral hydrogen*** detected in absorption against the the radio continuum, provides important insights on phenomena common to radio galaxies, such as jet-ISM interaction, presence of fast outflows…

HI can be found in settled structures, as ***circumnuclear tori and disks***, or in unsettled ***clumpy medium***, tracing, thence, different physical and dynamical conditions of the medium enshrouding the AGN, and becoming an important tool in understanding the role played by the medium itself on the growth and evolution of the radio source.

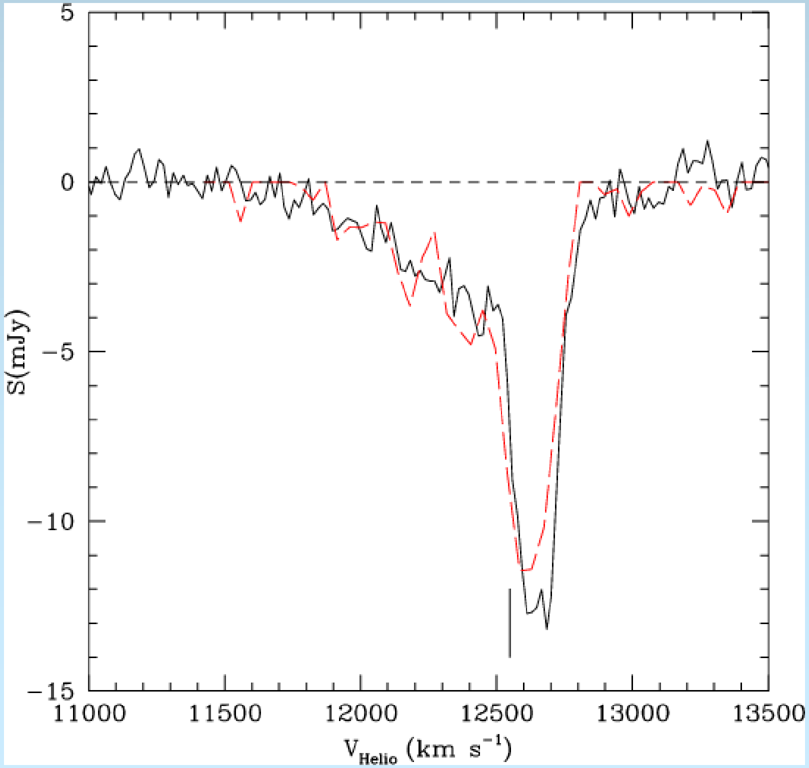
Fast outflows

Fast outflows of ***ionized*** gas associated to AGN have been detected in optical, UV and X-ray observations (i.e. Holt et al. 2003).

The availability of the new WSRT broad-band reciver has led to the discovery of ***broad (600 - 2000 km/s) and shallow (*** τ ***< 0.006) HI absorption***, interpreted in terms of fast outflows of neutral gas (Morganti et al. 2005, 2006).

Depending on their location, they can be interpreted in terms of different mechanisms.

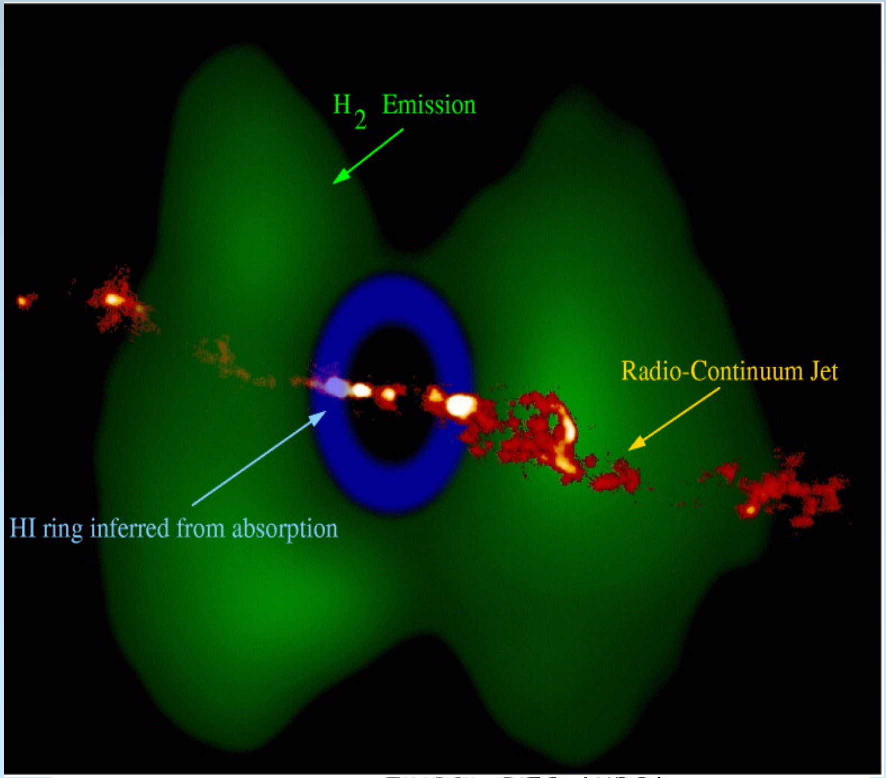
In the case of 3C 305 and 3C 293, high-resolution observations allow to locate the outflows at kpc distance from the nucleus, and explained by a ***jet-ISM interaction*** (Morganti et al. 2005; Emonts et al. 2005).



The HI and young radio sources

Galaxies harbouring a radio source have quite a rich ISM, at least during the initial phase of the AGN, as a consequence of merger event.

Evidence of significant amount gas in young radio sources is supprted by larger incidence of HI absorption, and higher optical depth, than in “normal” radio galaxies (Morganti et al 2001).



Pihlström et al. (2003) found that smaller sources (< 0.5 kpc) have larger HI column density, than larger (>0.5 kpc) sources.
It can be explained by both a spherical and axi-symmetric gas distribution.

The sample

The only exsisting sample of candidate HFP is the ***Bright HFP sample*** from Dallacasa et al. (2000), obtained cross-correlating the 87GB and the NVSS, and comprising 55 objects with $S_{4.9} > 300$ mJy and $\alpha < -0.5$ ($S \propto \nu^{-\alpha}$).

To avoid contamination from blazar objects, multi-frequency VLA monitoring (Tinti et al. 2005; Orienti et al., in prep) and VLBA observations (Orienti et al. 2006a) have been carried out.

Galaxies and quasars are likely to represent different class of objects (Orienti et al. 2006a):

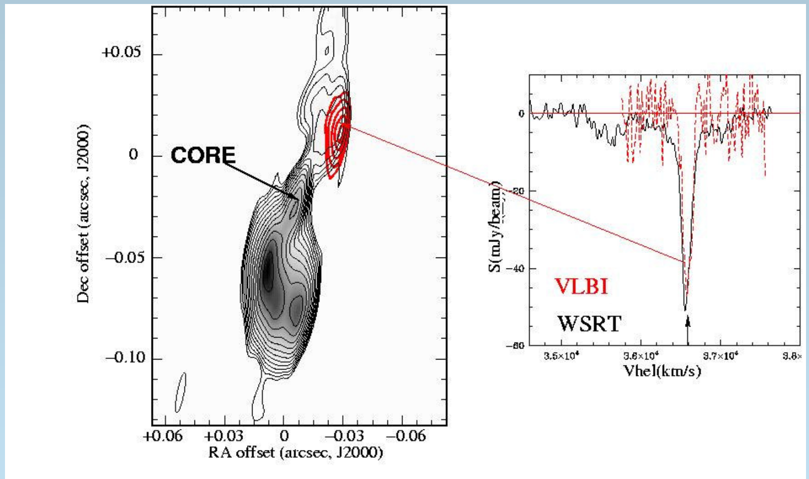
• 87% of quasars show a Core-Jet or Unresolved structure;

• 78% of galaxies show a CSO-like morphology;

In agreement with previous works on GPS (Stanghellini et al. 2005) and bright CSS samples (Fanti et al. 1990; Dallacasa et al. 1995).

Future work

Global VLBI observations have been carried out for one HFP and one GPS radio galaxies, to locate the position of the broad component of the HI absorption and, thence, its nature.
If they are due to jet-cloud interaction, this can provide important information on the role played by the ISM on the source growth and evolution.



In 4C12.50 the narrow component of the HI absorption is localized in the bending of the jet (Morganti et al. 2004).

And the broad component?