Fast neutral outflows in nearby radio galaxies: a major source of feedback

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AGN and their effect on galaxy evolution: why to look at radio galaxies?

√ Collimated outflows (jets)

√ We can recognize the objects where the radio activity started only recently

- See the immediate effects of a collimated jet on the surrounding medium
- See how important are radio jets in producing gaseous outflows
- Relevant → the radio-loud phase of AGN could happen (although as a short phase) in most early-type galaxies

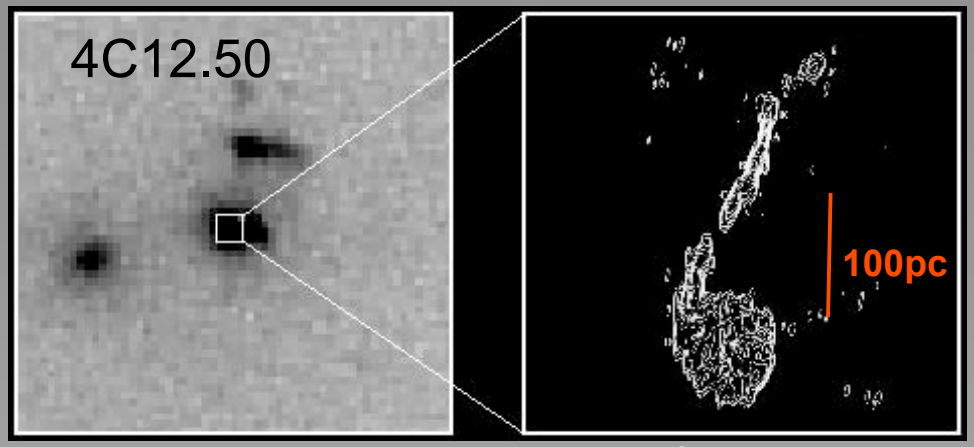
This talk....

♥ **Which radio galaxies:**

- Young or with recently restarted radio activity
- Significant “young” stellar population component
- Rich ISM (CO, FIR, ionised gas)
- One radio-loud Seyfert galaxy

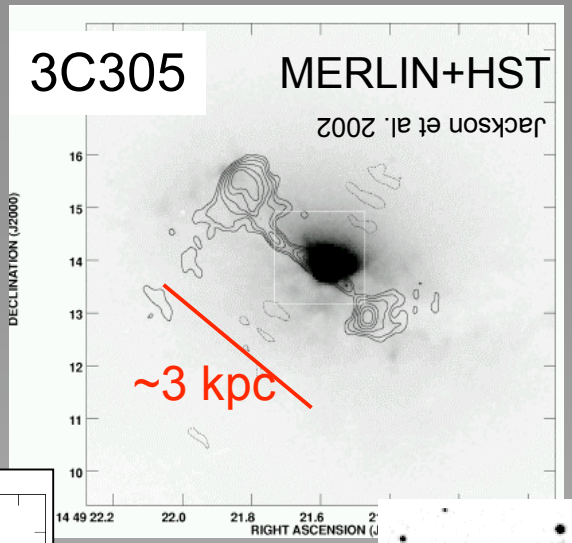
♥ **What do we study**

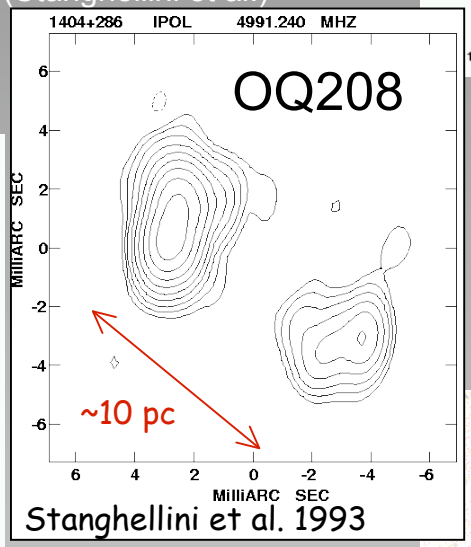
- Study of the gas in the central regions of radio galaxies to investigate their kinematics/physical conditions
- We used both ionized gas (optical) and **HI absorption line (21 cm)**

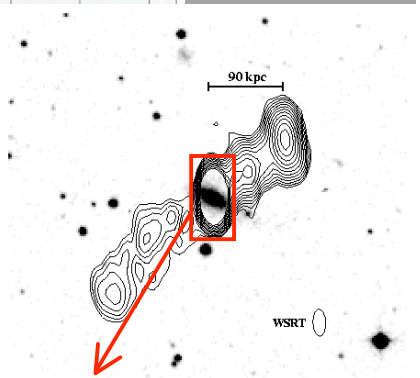


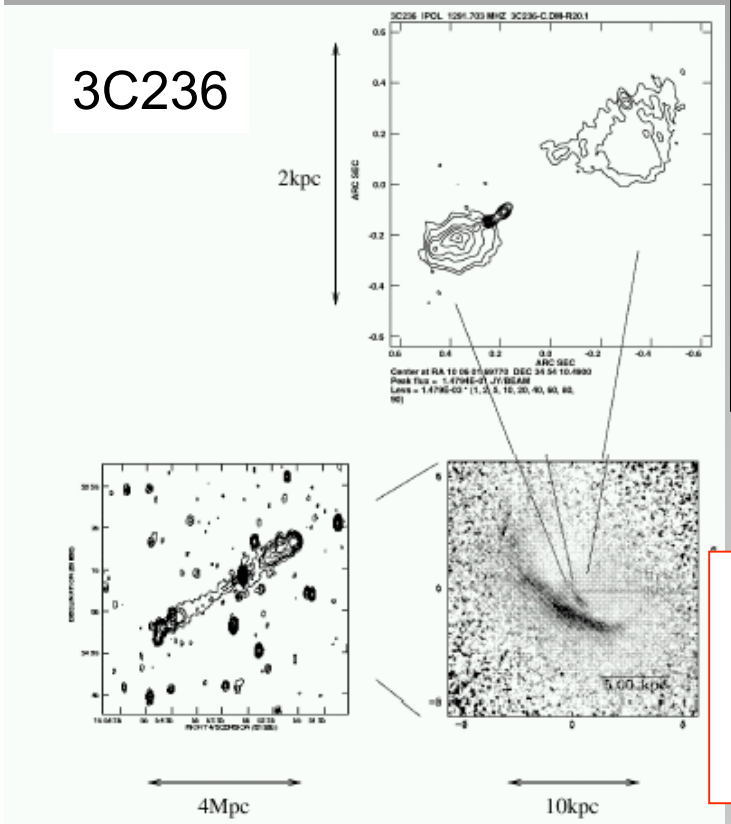
HST image in [OIII] (Axon et al.)

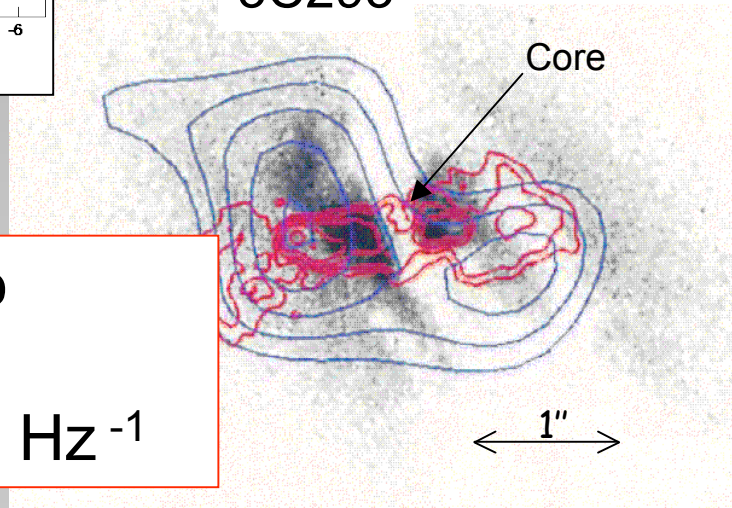
VLBI (Stanghellini et al.)











Powerful radio galaxies

$P_{radio} \geq 10^{24}$ W Hz $^{-1}$

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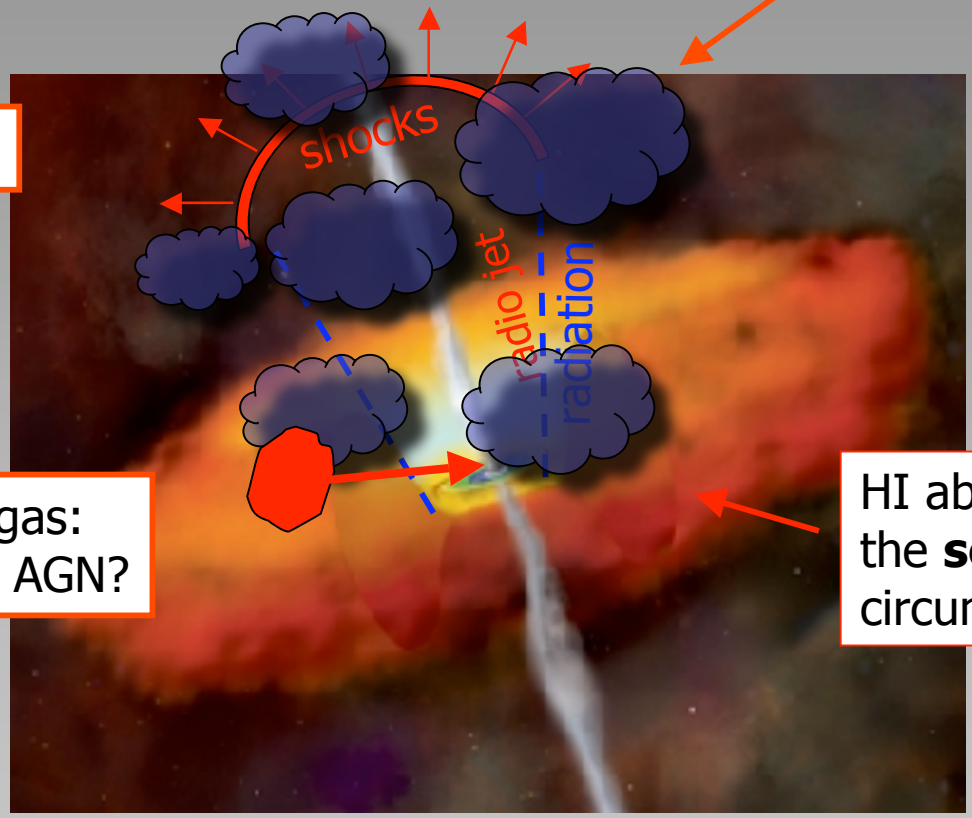
talk J. Holt

Nuclear-scale HI in radio loud AGN

extra-gas surrounding the AGN, e.g. left over from the merger that triggered the AGN

Gas **outflows**



Infalling gas: fueling the AGN?

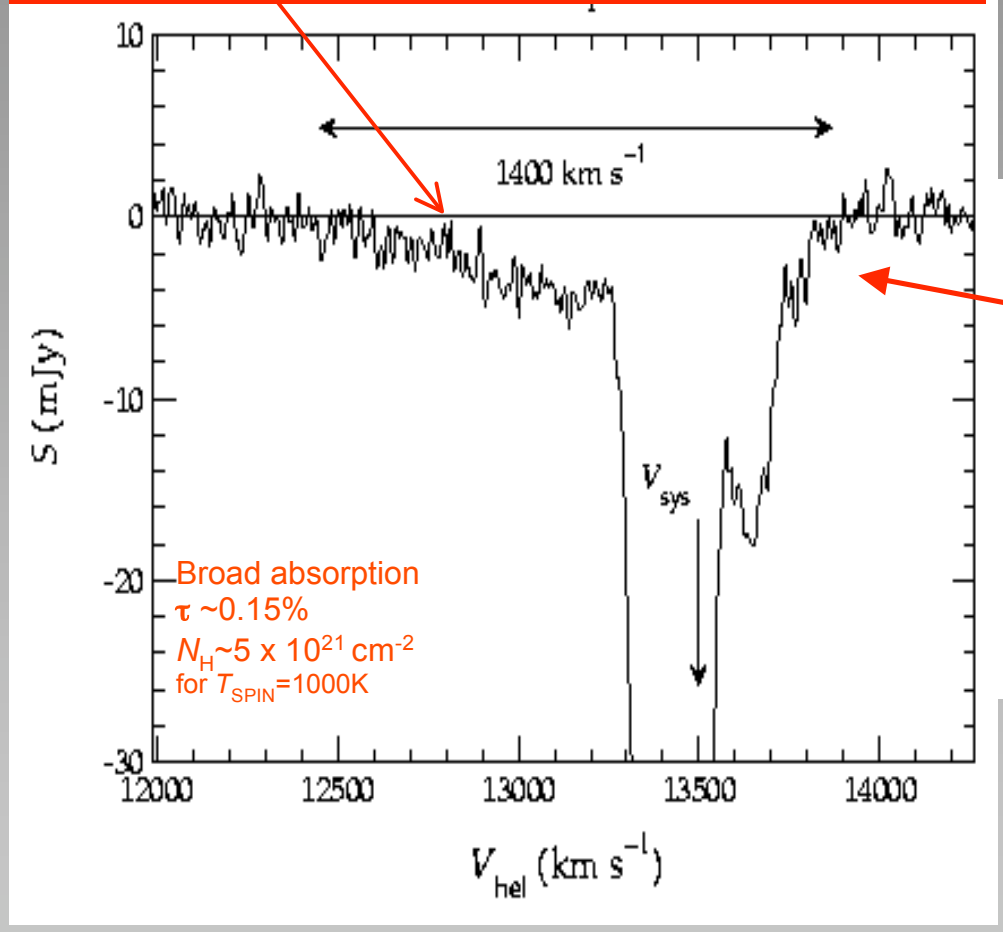
HI absorption from the **settled gas (**torus or circumnuclear disks)

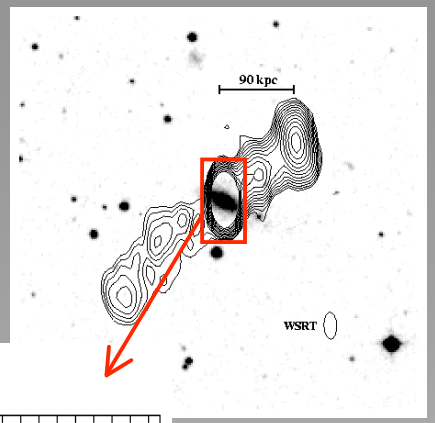
Study of different phenomena using HI <u>in absorption</u> and comparison with ionized gas

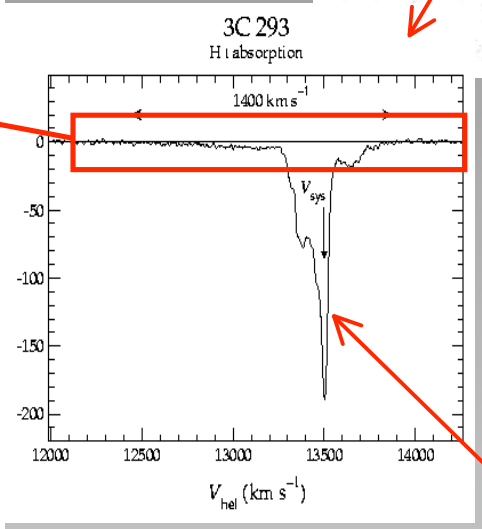
Broad HI absorption in 3C293

Westerbork Synthesis Radio Telescope observations

New broad, shallow absorption





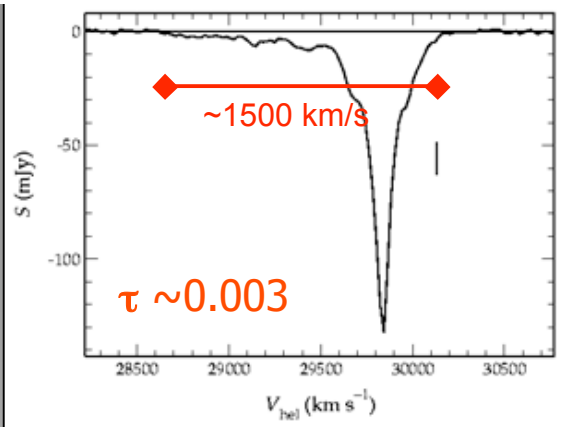


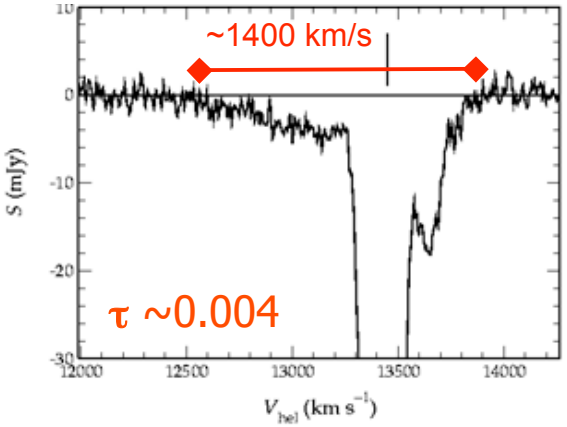
Deep absorption: Haschick & Baan (1985)
Beswick et al. (2002)

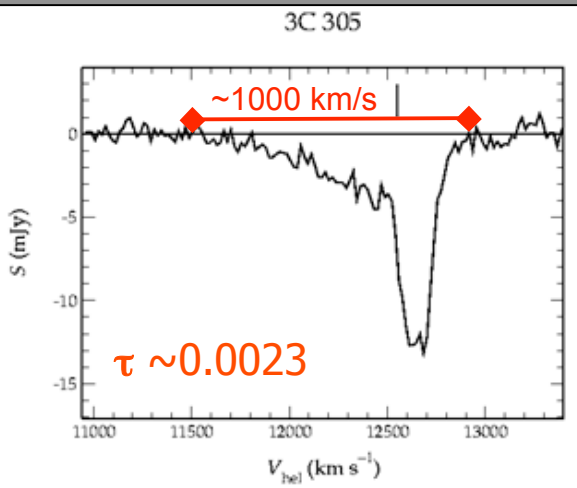
Morganti, et al. ApJL 2003
Emonts et al. A&A 2005

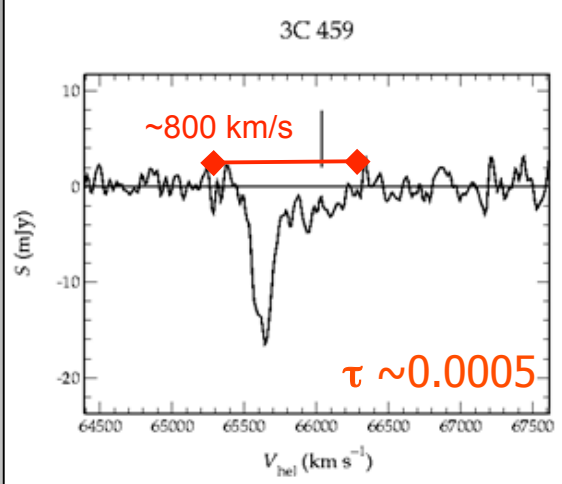
WSRT observations of broad HI absorption

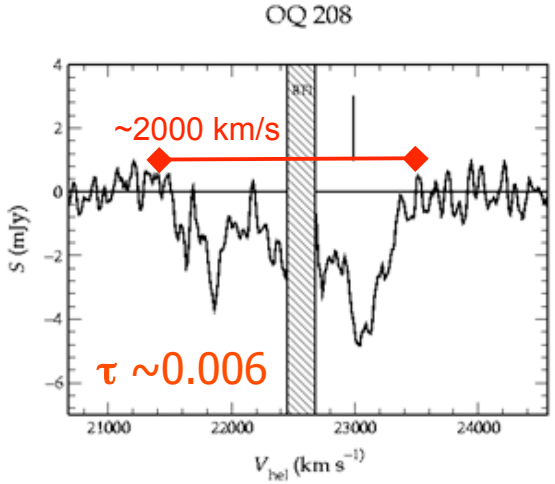
Morganti, Oosterloo, Tadhunter A&A 2005

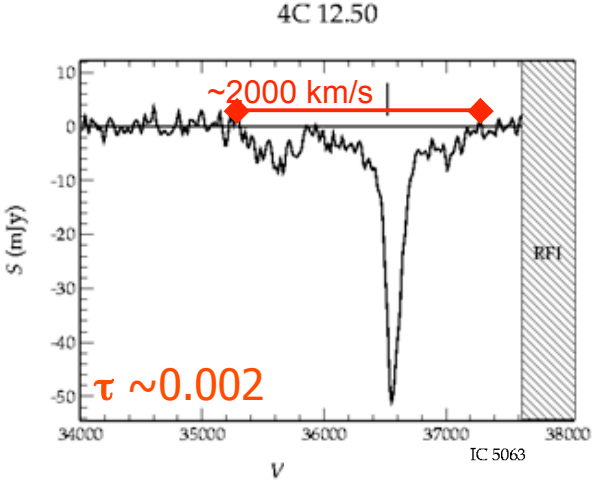


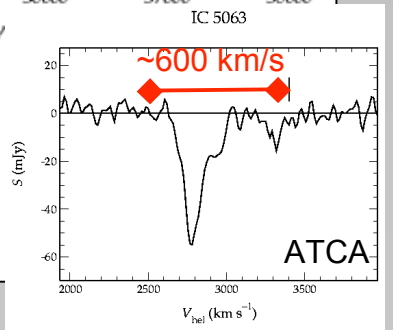












Up to 2000 km/s width, optical depth <<1%

Column density: few times 10^{21} - 10^{22} cm^{-2}

(for T_{spin} = 1000 K but could be higher!!)

Mostly blueshifted → outflows

Main questions

- What is the origin of the HI outflows?

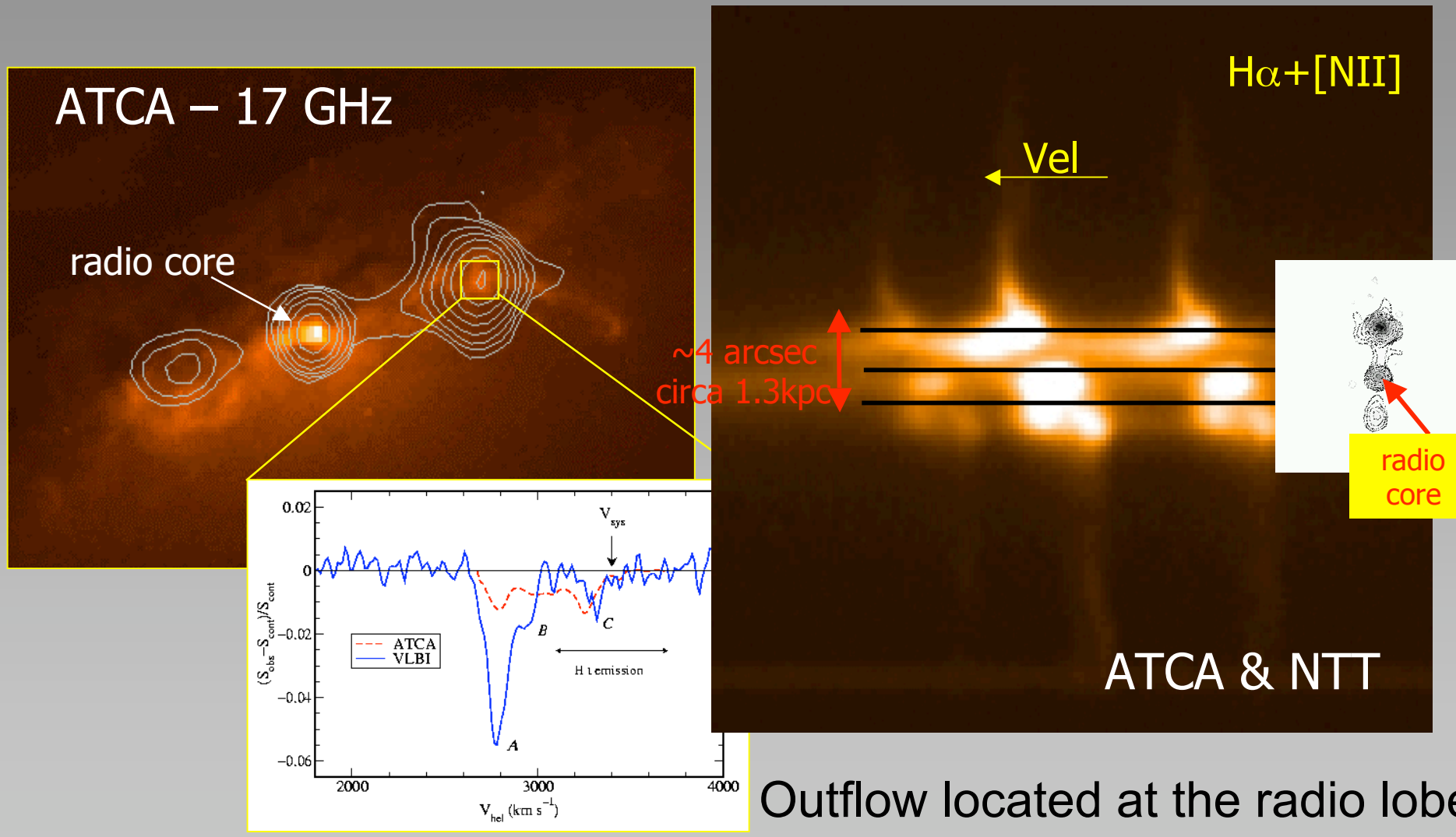
What is the location of the outflows?

What is the relation with the ionised gas

- What is the effect on the galaxy?

Higher resolution radio data

The location of the HI outflows: the case of the radio-loud Seyfert IC 5063

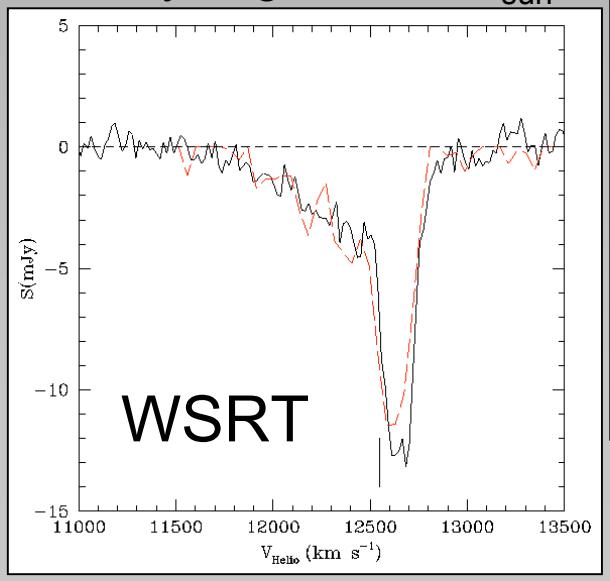


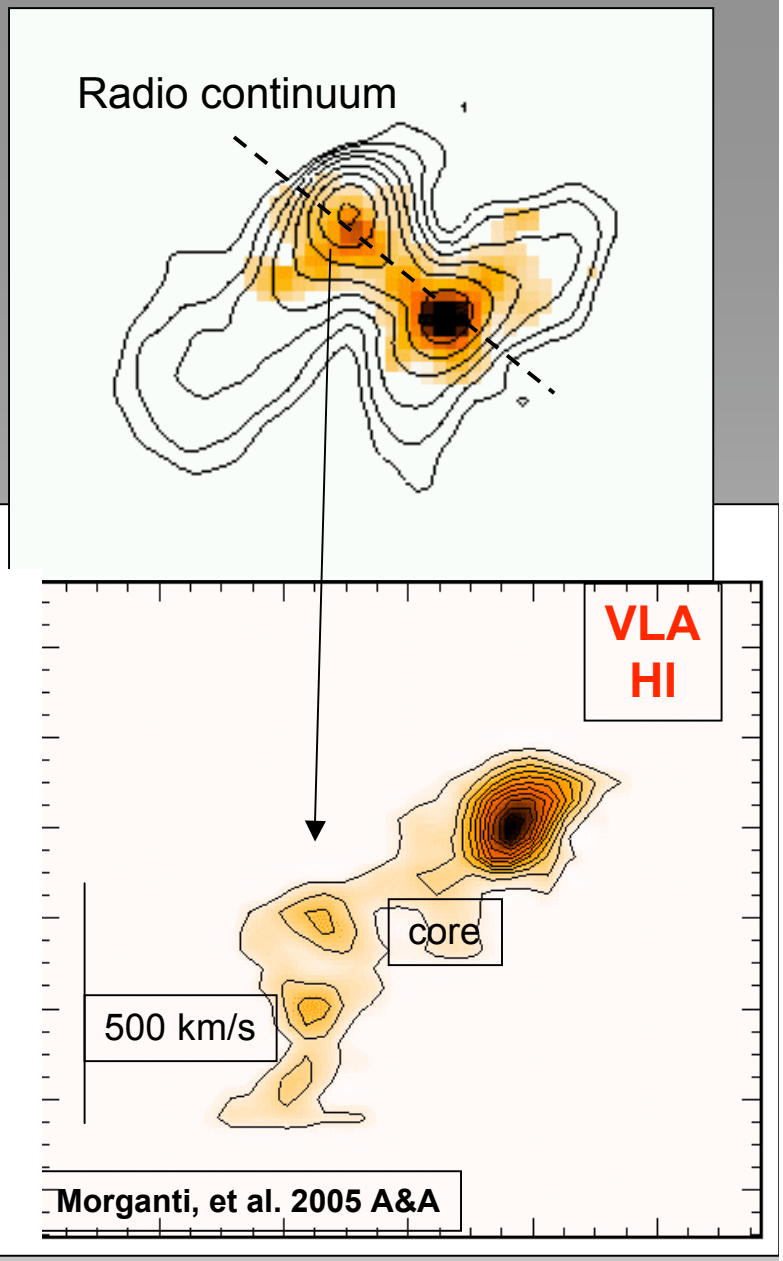
Morganti, Holt et al. in prep

Outflow located at the radio lobe (0.5 kpc from the nucleus): **jet-induced outflow**?

The case of 3C305

- Again the broad HI absorption is found **off-nucleus** at the location of the radio lobe:
  ~1.6kpc from the nucleus
- column density 2×10^{21} cm^{-2}
  (for T_{spin}=1000K)
- Mass outflow neutral hydrogen ~10^6 M_{sun}

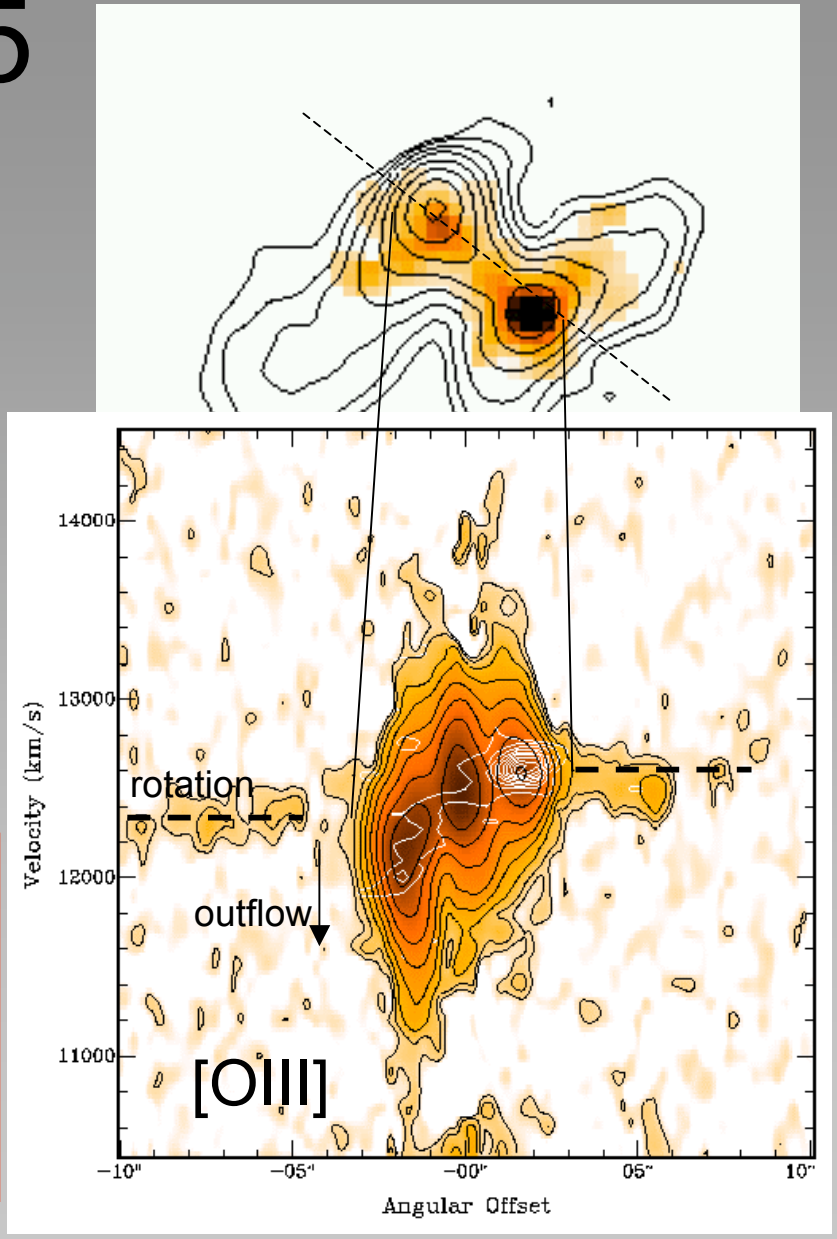




The case of 3C305

- **Comparison with the ionized gas**

- Outflow of ionized gas seen at the same location (Jackson et al. 2003)
- **Explained as a strong interaction between the radio plasma and the surrounding ISM at the location of the lobe → confirming HI result**
- Mass outflow ionized gas ~10^5 M_{sun}



Similar kinematics of the neutral and ionised gas (although HI not as broad as ionised gas):

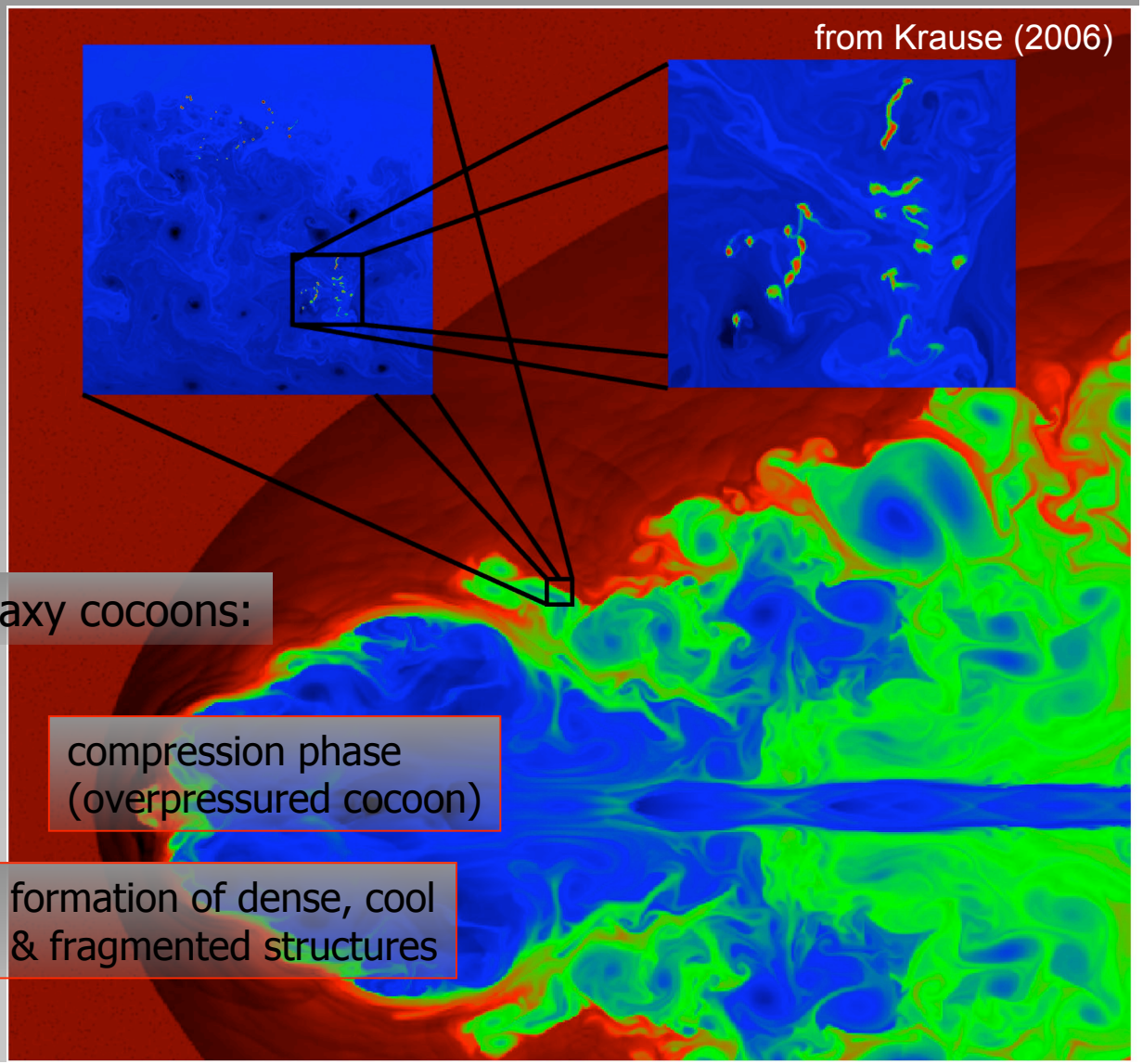
The two components of the gas are the result of a gaseous outflow produced **by the same mechanism**

What is the origin?

- **Broad emission line clouds** (BELC) will expand and cool adiabatically and will reach 1000K at ~3pc where they will form dust (Elvis, Marengo & Karovska 200) → possibe in some objects?
- **Jet interaction:** Cool gas can be produced and/or survive in jet-cloud interactions

Simulations show that cooled, fragmented clouds do form as result of the interaction

Krause 2006, Mellema et al. 2002, Fragile et al. 2003



Evolution of clouds in radio galaxy cocoons:

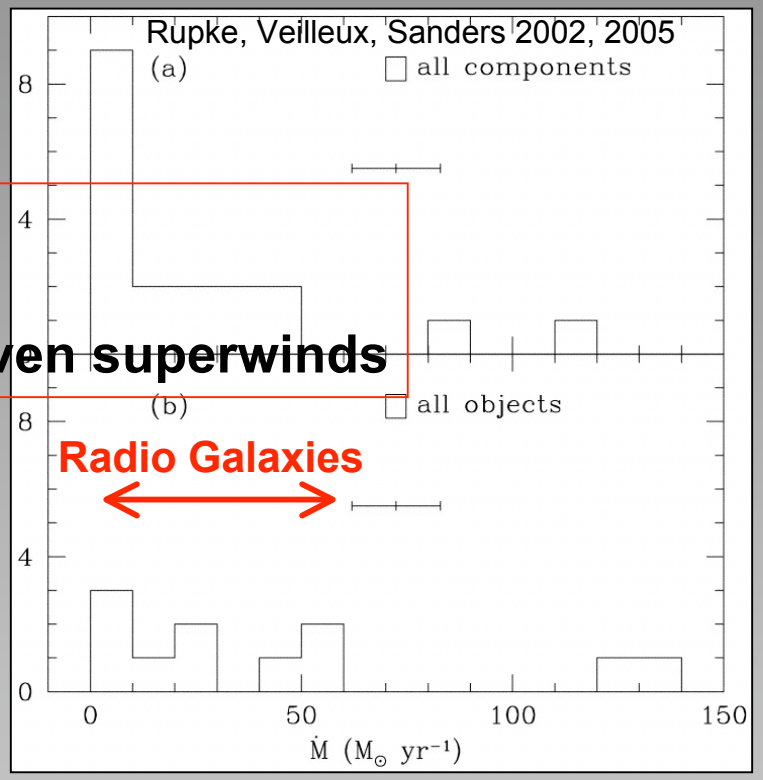
shock runs over a cloud → compression phase (overpressured cocoon)

→ fragmentation & **cooling** → formation of dense, cool & fragmented structures

Mass outflow rate between a few and ~50 M_{sun}/yr

comparable (lower end) to that found in Ultraluminous IR galaxies

Jet-driven outflows can have an impact on the evolution of a galaxy comparable to starburst-driven superwinds



• Bulk kinetic energy+turbulent motion (over a lifetime of a radio jet)

~ 10^{57} -10^{58} erg

Close to the binding energy of the gas in the galaxy

Results from fast HI outflows

- Fast outflows of neutral hydrogen can be produced by the interaction between the radio jet and the surrounding dense medium
  (few examples 3C305, IC5063, 3C293).

- The presence of neutral gas indicates that the gas can cool very efficiently following a strong jet-cloud interaction.

- Mass outflow rate between a few and ~50 M_{sun}/yr → comparable (lower end) to that found in Ultraluminous IR galaxies.

- Jet-driven outflows can have a similar impact on the evolution of a galaxy as starburst-driven superwinds.