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

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With extra help from Joanna Holt & Bjorn Emonts
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.)

100pc

~3 kpc

MERLIN+HST

Jackson et al. 2002

Core

~10 pc

Stanghellini et al. 1993

Powerful radio galaxies

$P_{\text{radio}} \geq 10^{24} \text{ W Hz}^{-1}$
This talk....

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talk J. Holt
Nuclear-scale HI in radio loud AGN

Gas outflows

Infalling gas: fueling the AGN?

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

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

Study of different phenomena using HI in absorption and comparison with ionized gas
Broad HI absorption in 3C293

Westerbork Synthesis Radio Telescope observations

New broad, shallow absorption

Broad absorption
\( \tau \sim 0.15\% \)

\( N_H \sim 5 \times 10^{21} \text{ cm}^{-2} \)

for \( T_{\text{SPIN}} = 1000\text{K} \)

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

Emonts et al. A&A 2005
Up to 2000 km/s width, optical depth <<1%
Column density: few times $10^{21} - 10^{22}$ cm$^{-2}$
(for $T_{\text{spin}} = 1000$ K but could be higher!!)
Mostly blueshifted $\rightarrow$ 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

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

Morganti, Holt et al. in prep
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 $2 \times 10^{21} \text{ cm}^{-2}$ (for $T_{\text{spin}} = 1000 \text{K}$)

- Mass outflow neutral hydrogen $\sim 10^6 \text{ M}_{\odot}$
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 $\sim 10^5 M_{\text{sun}}$

**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 2000)

- **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 $M_{\text{sun}}$/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)
  - $\sim 10^{57}$ - $10^{58}$ 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$_{\text{sun}}$/yr $\rightarrow$ 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.