Proceedings of the 7th European VLBI Network Symposium
Bachiller, R. Colomer, F., Desmurs, J.F., de Vicente, P. (eds.)
October 12th-15th 2004, Toledo, Spain

Probing the nature of the ISM in Active Galactic Nuclei through H I absorption

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Abstract. The physical and kinematical conditions of the gas surrounding an active galactic nucleus (AGN) offer key diagnostics for understanding the processes occurring in the inner few kpc around the nucleus. Neutral hydrogen can give important insights on these regions. Apart from probing the presence of gas in relatively settled conditions (i.e. circumnuclear disks/tori) it can also trace the presence of extreme outflows. Some examples of these phenomena are briefly presented. For the study of the neutral hydrogen around AGN the high resolution offered by the VLBI is crucial in order to locate the regions where the absorption occurs and to study in detail the kinematics of the gas. Recent VLBI results are discussed here.

1. Introduction

The presence of neutral hydrogen in the region surrounding the active galactic nuclei (AGN) is known since many years. This gas can be studied via absorption detected against the strong continuum source (see e.g. Heckman et al. 1983; van Gorkom et al. 1989; Morganti et al. 2001, 2002; Vermeulen et al. 2003) and it is now known to be associated with different structures.

Neutral hydrogen can be found in tori very close to the AGN. Although it has been generally assumed that the tori are composed of dusty molecular clouds, it is now clear that, under certain conditions, they can be partly formed by atomic hydrogen (Maloney, Hollenbach & Tielens 1996). The H I can also be associated with larger scale circumnuclear disks (with size ranging from 0.1 and 1 kpc). These structures are similar to the nuclear optical disks detected in a large number of early-type galaxies (both radio-loud and radio-quiet). These disks (mainly detected by HST) can be seen either in ionized gas or through their strong dust absorption (van der Marel 2001, Capetti et al. 2000 and ref. therein).

However, the neutral hydrogen can also be associated with more disturbed structures, like bridges or tails left over from recent mergers. The origin of activity in galaxies is often explained as triggered by merger and/or interaction processes. H I is often seen associated to all these phenomena. The idea of merger is supported by morphological and kinematical evidence (e.g. Smith & Heckman 1989, Tadhunter et al. 1989, Baum et al. 1992). Torques and shocks during the merger can remove angular momentum from the gas in the merging galaxies and this provides injection of substantial amounts of gas/dust into the central nuclear regions (see e.g. Mihos & Hernquist 1996). It is, therefore, likely that in the initial phase of an AGN, this gas, including atomic hydrogen, still surrounds – and possibly obscurs – the central regions. AGN-driven outflows have powerful effects on this dense ISM. Surprisingly, the neutral hydrogen has been recently found associated also with such fast outflows (up to 2000 $\mathrm{km\,s^{-1}}$). This finding gives further information on the physical conditions of the gas in the environment of AGN. Gas outflows generated by the nuclear activity are particularly important because of the effects they can have on the interstellar medium (ISM). This feedback can be extremely important for the evolution of the galaxy, up to the point that it could limit the growth of the nuclear black-hole (e.g. Silk & Rees 1998, Wyithe & Loeb 2003).

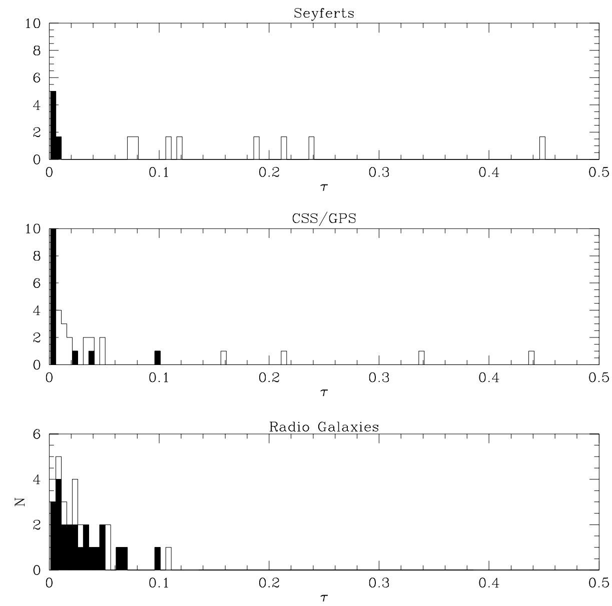

Fig. 1. Histograms of the distribution of optical depth (τ) for Seyfert galaxies (Gallimore et al. 1999), radio galaxies (Morganti et al. 2001, Morganti et al, in prep) and CSS/GPS radio sources (Vermeulen et al. 2003, Morganti et al. 2001). Filled regions indicate upper limits.

All the above illustrates how important is the gas in the study of AGN. The study of the neutral hydrogen is complementary to the studies of the other phases of the gas - molecular and ionized - in these regions. Here, I briefly discuss some of the most recent results in this area. While the detection of the H I is usually done with arcsec resolution observations, the VLBI follow up is crucial in order to be able to understand in wich of the above mentioned structure the gas is located and to derive its physical parameters.

2. Detection of H I in absorption in AGN

Radio galaxies and radio loud Seyferts have been the subject of many H I studies. As result, we know now that about 10-20% of radio galaxies show H I absorption against their nuclei while this fraction goes up to more than 60% for Seyfert galaxies (Gallimore et al. 1999). A group of objects where the fraction of detected absorption is particularly high are Compact Steep Spectrum (CSS) and Gigahertz Peaked-Spectrum (GPS, O'Dea 1997) sources. Vermeulen et al. (2003) found about 50% of detections in these objects. The depth of an absorption line (ΔS) depends on the optical depth (τ), the continuum flux density (S) and the covering factor $c_{\rm f}$ as $\Delta S = c_{\rm f} S(1 - e^{\tau})$. Usually, a covering factor $c_{\rm f} = 1$ is assumed. The distribution of optical depth (τ) for these three groups of AGN is shown in Fig. 1.

The sensitivity of present days radio telescopes is the main limitation for the study of the H I absorption. The typical optical depth observed in the detected objects is $\tau \sim 0.01 - 0.05$ (i.e. the flux absorbed by the H I is few % of the radio continuum of the source at the frequency of the redshifted H I). Thus, for a typical observation with a noise level in every channel of about 0.5 mJy beam^{-1} (1-σ), these values of optical depth (detected at 3-σ level) can be obtained if the continuum is of the order of $\sim 50 - 100$ mJy. It is clear that this is a major limitation for the study of the H I (e.g. in weak radio sources or sources with weak radio cores). Objects with optical depth $\tau \sim 0.10 - 0.20$ or larger do exist but they are rare.

The histograms of Fig. 1 show that the detected Seyfert galaxies have, on average, higher optical depth than radio galaxies. CSS/GPS appear more often detected: the high flux typical of these objects allow to reach very low optical depth. On the other hand, the typical core flux of a radio galaxy is seldom strong enough to reach these limits. Therefore, the higher detection rate of CSS/GPS is affected by this bias. However, it is also the case that objects with high optical depth are missing from the radio galaxies while are observed among CSS/GPS.

In particularly bright radio sources, we are, however, in the position to look for H I with very low optical depth ($\tau \sim 0.001$). Recent observations making use of the broad band (20 MHz) now available, e.g. at the upgraded WSRT, have shown that the kinematics of this gas can be very extreme. Very broad H I absorption features have been discovered in this way. This will be discussed in Sec. 5.3.

The column densities of the neutral hydrogen follow from $N_{\rm HI} = 1.83 \cdot 10^{18} T_{\rm spin} \int \tau dv$ where $T_{\rm spin}$ is the spin temperature in Kelvin and v is the velocity in km s^{-1}. Assuming the canonical $T_{\rm spin} = 100$ K, the column densities typically found are in the range from few times 10^{19} atoms cm^{-2} to few times 10^{21} atoms cm^{-2}. It should be noted, however, that these values of $N_{\rm HI}$ are likely to be lower limits. In fact, in some physical situations, such as close to the nuclei of active galaxies or in outflows, the spin temperature is likely to be as large as a few 1000 K (Maloney et al.1996).

3. Accurate systemic velocities

For a proper interpretation of the kinematics of the H I absorption, it is important to have the systemic velocity of the galaxy as accurate as possible. Although this sounds trivial, it is not always an easy information to have available (at least at the level of accuracy required for the comparison with H I data). It has been often pointed out (Mirabel 1989, Morganti et al. 2001) that the systemic velocity derived from emission lines can be both uncertain and biased by motions of the emitting gas. This is indicated, in the most extreme situation, by the detection in few objects of two different redshift systems, one derived from the low and the other from the high ionization lines. Probably the best example of this has been observed in the radio galaxy PKS 1549-79 (Tadhunter et al. 2001). In this object, the [OIII]5007Å lines appeared to be associated to gas kinematically disturbed, likely an outflow due to the interaction with the radio plasma.

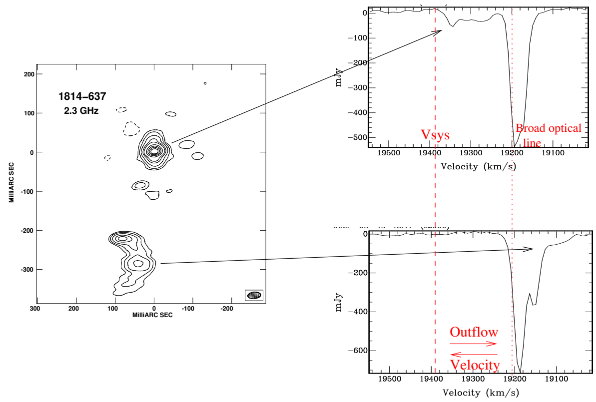

Fig. 2. LBA observations of the southern radio galaxy PKS 1814-63 (Tzioumis et al. in prep.). The nucleus is tentatively identified with the northern component. A blueshifted shallow component of the absorption is detected. The most blueshifted component appear to be located against the southern component. In order to identify this as an outflow, new accurate measurments of the systemic velocity was needed (from optical data, Holt et al. in prep). The new value, derived from the narrow component in the optical emission lines, is indicated with the dashed line. The dotted line indicate the velocity of the broad component detected in the optical emission lines.

In the southern radio galaxy PKS 1814-63 (see Fig. 2), only the detailed analysis of the optical spectrum has shown that the emission lines are actually made of two components: a narrow one that appears to trace the more extended and quiescent and, therefore, more likely to define the systemic velocity and a broader component, likely originating from gas interacting with the radio plasma.

Similar situations have been found in other radio galaxies (e.g. 4C12.50, Holt et al. 2003; 3C 293, Emonts et al. in prep.). Interestingly, these are often radio sources where outflows also associated with the neutral hydrogen are detected (see Sec. 5.3). This further emphasize the importance of study both the ionized and the neutral component of the gas in order build a more complete (and correct) picture of the physical conditions around AGN.

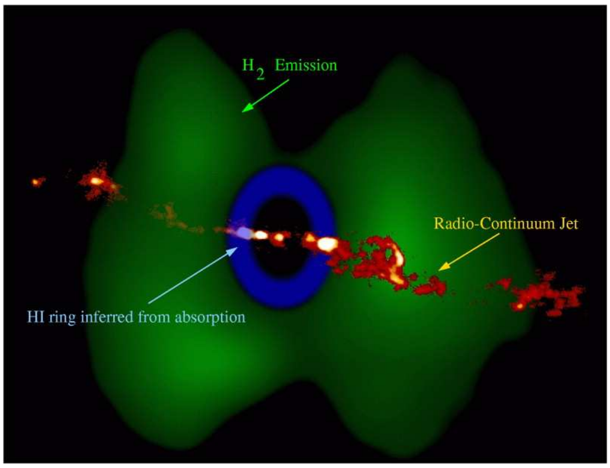

Fig. 3. Montage of the inner 250 pc of NGC 4151 from Mundell et al. (2003), showing torus of H_2 emission in green (from Fernandez et al. 1999), ring of H I inferred from absorption measurements in blue and 1.4 GHz radio continuum emission from radio jet in red. Ionized gas (black) is assumed to fill the torus inside the H I ring. The segments missing to the north and south of the H_2 torus are due to the limited filter width that excluded the high-velocity wings of the H_2 line; this provides evidence for rotation of the torus as the northern and southern segments contain the gas with the highest radial velocities (i.e., line wings) if the torus is rotating.

4. Circumnuclear tori and disks

As described above, H I gas can be associated with circumnuclear disks and tori. To establish whether the H I absorption is coming from these structures is not always easy. Often, given the limited size of the underlying continuum, clear kinematical signatures of a rotation cannot be seen. Thus, one of the criteria to distinguish between these structures is the width of the absorption line. While the H I associated with circumnuclear disks show relatively broad absorption (typically > 150 km s^{-1}), H I associated with larger scale structures is usually observed as narrow absorption features (see e.g. the case of Centaurus A, van Gorkom et al. 1986).

In Seyfert galaxies, Gallimore et al. (1999) found that, with the exception of NGC 4151, the absorbing gas traces 100 pc-scale rotating disks aligned with the outer galaxy disk. In NGC 4151, H I absorption measurements using MERLIN and VLBA indicate a torus ~ 70 pc in radius and ~ 50 pc in height (Mundell et al. 1999, 2003). A cartoon illustrating the geometry of the system is shown in Fig. 3.

Due to the weakness of the radio core in powerful radio galaxies (i.e. Fanaroff-Riley II), evidence for H I associated with tori has been found only in few cases. A possible candidate is Cygnus A. In this object, a 50 pc-scale, rotating, flattened structure has been found from the VLBI observations (Conway 1999). However, recent optical observations have shown that the situation may be more complicated than this and that the H I absorption includes also the signature of an inflowing cloud (see Sec. 5.1).

A more clear case comes from the study of the kinematics and distribution within the central kiloparsec of the H I in the radio galaxy 3C 293 (Beswick et al. 2003). Strong H I absorption is detected against the majority of the inner kiloparsec of 3C 293. This absorption is separated into two dynamically different and spatially resolved systems. This result is illustrated in Fig. 4. Against the eastern part of the inner radio jet narrow H I absorption is detected and shown to have higher optical depths in areas co-spatial with a central dust lane. Additionally, this narrow line is shown to follow a velocity gradient of ~50 km s^{-1} arcsec^{-1}, consistent with the velocity gradient observed in optical spectroscopy of ionised gas. The narrow H I absorption, dust and ionised gas appear to be physically associated and situated several kiloparsecs from the centre of the host galaxy. Against the western jet emission and core component, broad and complex H I absorption is detected. A possible explanatin for this is that the H I is situated in rotation about the core of this radio galaxy with some velocity dispersion resulting from in-fall and outflow of gas from the core region. If this explanation is correct, then the mass enclosed by the rotating disk would be at least 1.7×10^9 solar masses within a radius of 400 pc.

Powerful compact (steep spectrum) radio sources are uniquely suited for investigations into the physics of the central engines, in particular to study the kinematics of the gas within 100 pc of the core (see e.g. Vermeulen et al. 2003). Pihlström et al. (2003) have studied the distribution of the H I absorbing gas in a sample of these sources. They find that smaller sources (< 0.5 kpc) have larger H I column density than the larger sources > 0.5 kpc) (see Fig.5). This result can be explained both as a spherical and an axi-symmetric gas distribution, with a radial power law density profile, although these authors argue that the disk distribution is the most likely.

Evidence of H I associated with cicumnuclear tori has been reported for some of these compact sources (see e.g. Conway 1997, Peck & Taylor 2001). One of the best examples of this type is the Compact Symmetric Object (CSO) 1946+708. The H I absorption in 1946+708 consists of a very broad line and a lower velocity narrow line which are visible toward the entire ~100 pc of the continuum source, Peck et al. 1999). with thickness of about 100 pc and column density of the order of 10^{23} cm^{-2} (with T_{spin} of several thousand K). The broad line has low optical depth and peaks in column density near the core of the source. This is consistent with a thick torus scenario in which gas closer to the central engine is much hotter, both in terms of kinetic temperature and spin temperature, so a longer path-length through the torus toward the core would not necessarily result in a higher optical depth. The high velocity dispersion toward the core of 1946+708 is indicative of fast moving circumnuclear gas, perhaps in a rotating toroidal structure. Further evidence for this region of high kinetic energy and column density is found in the spectral index distribution which indicates a region of free-free absorption along the line of sight toward the core and inner receding jet. The H I optical depth increases gradually toward the receding jet. The information derived from the H I can be particularly useful to constrain characteristics the central torus when combined with hard X-ray data. This has been done in the case of two possible Compton-thick galaxies studied by Risaliti et al. (2003).

In low luminosity radio galaxies the situation could be different. The high detection rate of optical cores, the lack of large

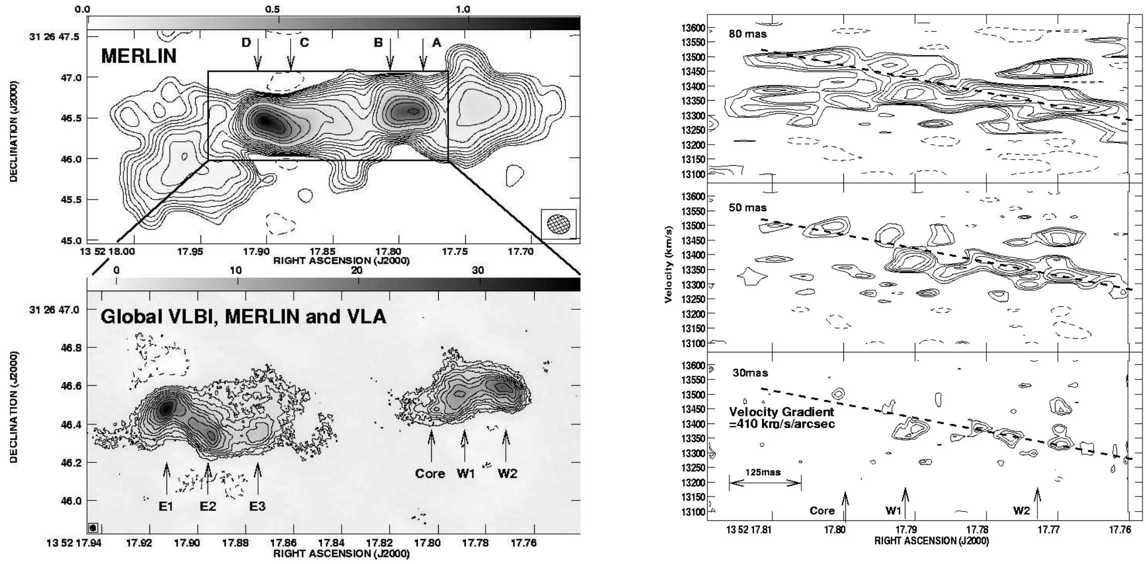

Fig. 4. *(Left)* Sub-arcsecond continuum structure of the inner few kiloparsecs of 3C 293 (from Beswick et al. 2003). The top contour map shows the 1.359 GHz radio continuum structure observed with MERLIN at a resolution of 0.″23×0.″20. The lower panel shows the global VLBI, MERLIN and VLA+PT contoured image of the inner jet of 3C 293 with angular resolution of 30 mas. This map is contoured at multiples of $\sqrt{2}$ times 1.3 mJy beam^{-1}. *(Right)* Multi-resolution position-velocity plots of HI absorption against the western jet component at the centre of 3C 293 (from Beswick et al. 2003). In each of these diagrams the absorption signal has been averaged over the declination range of the continuum source. The dashed line shown on all three plots represents a velocity gradient of 410 km s^{-1} arcsec^{-1}. The spatial position of radio continuum components labelled in the figure on the left are also shown by arrows positioned along the bottom plot. Images and plots are taken from Beswick et al. (2003).

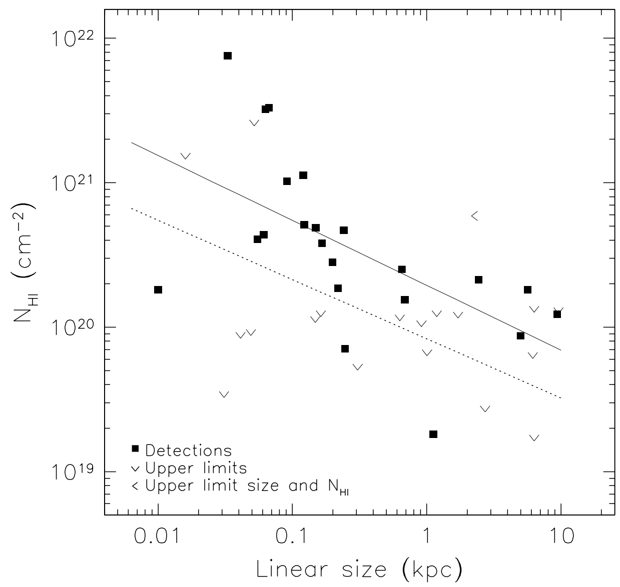

Fig. 5. Absorbed H I column density versus projected linear size for CSS and GPS sources. There is an anti-correlation between the source size and the amount of absorbing gas (from Pihlström et al. 2003).

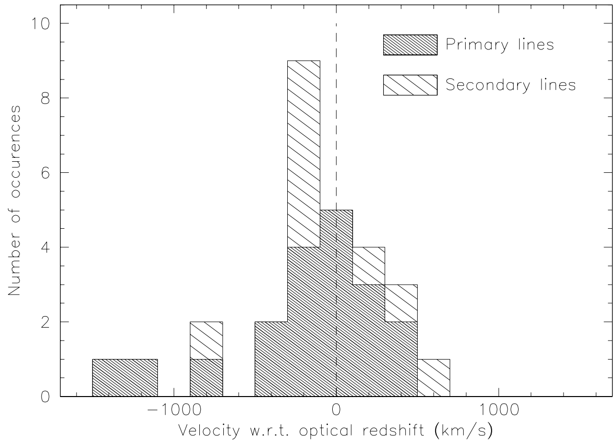

Fig. 6. H I line velocities compared to the optical velocities for CSS and GPS sources from Vermeulen et al. (2003).

absorption in X-ray (Chiaberge et al. 1999) and possibly also the relatively low detection rate of H I absorption (Morganti et al. 2001) suggest that the standard pc-scale geometrically thick torus is not present in these radio galaxies. The presence of thin disks has been claimed from H I observations in the case e.g. NGC 4261 (van Langevelde et al. 2000). For this object, the VLBI data suggest that the H I absorption is due to a disk of only ∼1.3 pc thick projected against the counter-jet. In NGC 4261, evidence for the presence of such nuclear disk are also found in HST images. The idea of thin disks can be investigated in more detail by correlating the presence (or absence) of H I absorption with the optical characteristics. This has been done for a sample of radio galaxies (selected from Capetti et al. 2000) for which information about the presence of optical cores and nuclear dusty disks/lanes (from HST images) is available. Interestingly, H I absorption was detected in the two galaxies that have dust disks/lanes and *no* optical cores. In these cases, the column density of the absorption is quite high ($> 10^{21}$ cm^{-2} for $T_{\rm spin} = 100$ K) and the derived optical extinction A_B (between 1 and 2 magnitudes) is such that it can, indeed, produce the obscuration of the optical cores. In the other two cases, H I absorption has been detected despite the presence of optical cores. However, the column density derived from the detected absorption is much lower (~ 10^{20} cm^{-2} for T_{spin} = 100 K) and the derived extinction is of the order of only a fraction of a magnitude. This is, therefore, consistent with what expected if the circumnuclear disk are thin in these radio galaxies.

5. Unsettled gas

5.1. Any evidence for infall?

Evidence for infalling gas was reported by van Gorkom et al. (1989). In a sample of radio galaxies, H I absorption was detected either close to the systemic velocity or systematically redshifted, indicating therefore a prevalence of gas falling into the nucleus. This result does not appear to be confirmed by more recent observations. For example, the study of H I absorption in compact radio sources by Vermeulen et al. (2003) shows that there is evidence for significant gas motions and not only positive but even more negative H I velocities (up to more than $v = -1000$ km s^{-1} compared to the systemic velocity) are found (see Fig. 6). This is indicating that gas flowing out of the galaxy is also present. Indeed, clear cases of fast gas outflows have now been detected as described below (see Sec. 5.3).

One of the most promising case of infalling gas was found in the radio galaxy NGC 315. A very narrow and highly redshifted (~ 500 km s^{-1}) H I absorption was reported by Heckman et al. (1983) and Dressel et al. (1983). VLBI observations (Peck 1999, Morganti et al. in prep.) are now showing that this absorption appears to cover a region of about 9 pc of the source, from the core to the first part of the jet. A likely explanation for this absorption is that of a cloud at large distance from the nucleus (like tidal debris, Wakker et al. 2002) detected, in projection, against the nucleus. This seems to be more favorable over the possibility of a small cloud falling into the nucleus and feeding the AGN.

An interesting case of cloud falling into the nucleus has been recently suggested for Cygnus A (Bellamy et al. 2004). Near-IR data show the existence of an off-nucleus molecular cloud, that is redshifted respect to the systemic velocity (measured accurately from stellar features). This suggests the presence of a giant molecular cloud falling though the “heart” of Cygnus A. Interesting, the redshift of this cloud is in agreement with that of the H I absorption (or part of it) indicating, therefore, that the two phenomena may be linked.

5.2. Gas cocoon around AGN

As mention in the introduction, H I absorption can also trace gas distributed in a more complex way around the AGN. In the low luminosity active galactic nucleus, NGC 1052, the VLBI study of the H I has revealed atomic gas in front of the approacing jet as well as the receding jet (Vermeulen et al. 2003b). The gas appeared to be associated with three velocity systems. One system can be as close as 1-2 pc from the core. The other systems could be local to the AGN environment or distributed on galactic scales.

H I absorption can be used to trace a particularly rich medium that is characteristics of some radio galaxies – perhaps those resulting from major mergers or in which a merger happened not so long ago. One example is the radio galaxy 4C 12.50 (see Fig. 7, Morganti et al. 2004a), a galaxy that has often been suggested to be a prime candidate for the link between ultraluminous infrared galaxies and young radio galaxies. In this object, deep and relatively narrow H I absorption (observed at the systemic velocity) is associated with an off-nuclear cloud (~ 50 to 100 pc from the radio core) with a column density of ~ 10^{22} $T_{spin}/(100\ \mathrm{K})$ cm^{-2} and an H I mass of a few times 10^5 to 10^6 $M_\odot$. There are more examples of objects where the H I traces the rich medium surrounding the active nucleus. Examples of off-nuclear H I absorption are found in 3C 236 (Conway & Schilizzi 2000) and, more recently, in the CSO 4C 37.11 (Maness et al. 2004) where a broad (~ 500 km s^{-1}) absorption line was found in the region of the southern hot-spot.

This may have important implications for the evolution of the radio jets. Although this gas will not be able to confine the radio source, it may be able to momentarily destroy the path of the jet as shown also by numerical simulations (Bicknell et al. 2003). Thus, this interaction can influence the growth of the radio source until the radio plasma clears its way out.

5.3. Fast Outflows

Gas outflows associated with active galactic nuclei (AGN) provide energy feedback into the ISM that can profoundly affect the evolution of the central engine as well as that of the host galaxy. The mass-loss rate from these outflows can be a substantial fraction of the accretion rate needed to power the AGN.

Fast outflows have now been detected in a large fraction of nearby AGN via observations at visible, X-ray and UV wavelengths associated to ionized gas (see e.g. Veilleux et al. 2000, Kriss 2004, Elvis, Marengo & Karovska 2002 and ref. therein for an overview). It is, therefore, not too surprising to find such outflows also in radio galaxies (see Morganti et al. 2003a for a summary of recent results). However, it is extremely intriguing the discovery of a number of radio sources where the presence of fast outflows (up to 2000 km s^{-1}) is associated not only with ionized but also with *neutral* gas. This finding gives new and important insights on the physical conditions of the gaseous medium around an AGN. The best examples so far are the radio galaxies 3C 293 (Morganti et al. 2003b, see Fig.8a) and 4C 12.50 and the Seyfert galaxy IC 5063 (Oosterloo et al. 2000). It is also worth noticing that outflows of ionized gas are also associated with these neutral outflows (see Morganti et al. 2003a).

An other interesting object where an H I outflow has been detected is the Compton-thick, broad-line and GPS radio galaxy OQ 208. The H I spectrum of this source (that is only 10 pc in size) is shown in Fig. 8b. Guainazzi et al. (2004) suggest that in this source we coulld be seeing the jets piercing their way through a Compton-thick medium pervading the nuclear environment. The outflow detected in H I (see Fig.8b) would be an other indication of this process. Guainazzi et al. (2004)

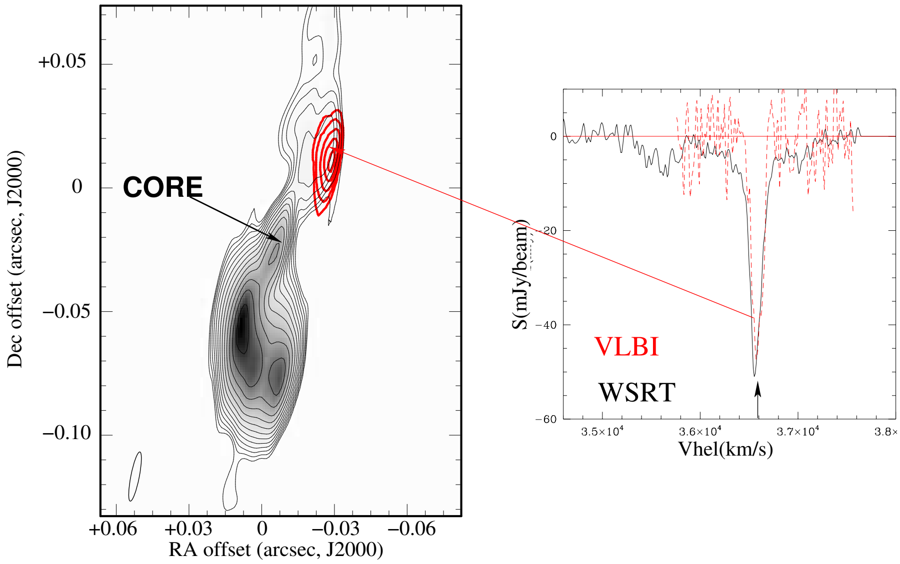

Fig. 7. *(Left)* VLBI continuum image (grey scale and thin contours) of 4C 12.50 (from Morganti et al. 2004a) superimposed onto the total intensity of the (narrow) H I absorption observed at the systemic velocity (thick contours). The position of the radio core is also indicated. The contour levels for the continuum image are: 5 mJy beam^{-1} to 800 mJy beam^{-1} in steps of factor 1.5. *(Right)* H I absorption profile observed with the WSRT (black) and VLBI (red). A broad, shallow H I absorption is detected in the WSR Tobservations. Due to the narrower band, this broad absorption is not detected in the VLBI observations.

also suggest that if the jets have to interact with such a dense medium, one could largely underestimating the radio activity dynamical age determinated for this kind of sources from the observed hot-spot recession velocity. A similar situation could be occuring the the GPS 4C12.50 described above.

A number of possible hypotheses can be made about the origin of the gas outflow (e.g., starburst winds, radiation pressure from the AGN, adiabatically expanded broad emission line clouds). In some cases, the possibility that they are driven by the interaction of the radio jet with the ISM seems to be favored. To investigate whether this is indeed correct, high-resolution (VLBI) studies are in progress to find the exact location of the ouflowing gas. So far these outflows have been found in objects that are either in the early-stage of their evolution (like 4C 12.50) or, perhaps, in a phase of re-started activity (as might be the case for 3C 293). Another characteristic of these galaxies is the presence of a "young" stellar population (from their optical spectra, see e.g. Tadhunter et al. 2002). Such a component (with ages between 0.5 and 2 Gyr) can be considered an indication that the galaxy is indeed in a stage of its evolution, when large amounts of gas/dust - likely from the merger that triggered the activity - are still present in the inner region and the radio jet is strongly interacting with it. A more systematic search for fast gas outflows in radio galaxies is now in progress and has already revealed more cases of broad, blueshifted H I absorptions.

6. Conclusions

The H I is an important tool to study the physical conditions of the gas around AGN. Although the main limitation of these studies is the sensitivity of present day radio telescopes, the possibility now becoming more and more available of broad band observations allows to explore the presence of kinematically disturbed H I. This may represent a relatively common phenomena, perhaps related with the evolutionary stage of the radio sources. The importance of understanding the physical conditions of the gas in the environment of the AGN (both in the circumnuclear tori as well as in the AGN-driven outflow) is illustrated by the interest and the wealth of observations performed, e.g., in the optical and X-ray bands. However, the possibility of imaging this gas at very high resolution – by obtaining H I absorption with milli-arcsec resolution – is unique to the radio band and the VLBI technique. This combined with the broad band (i.e. to instanteneously cover up to ~ 4000 km s^{-1}) is providing an extremely powerful tool to investigate the conditions (including the extreme one that now we know can exist) of the atomic gas around AGN.

The next step is, however, the dramatic improvement and possibilities that the new generation of radio telescope will offer. A summary of the possibilities that the Square Kilometer Array will open for the study of the environment of the AGN are summarized in Morganti et al. (2004b). Apart from the more detailed study of the H I in single objects, the SKA will provide the possibility of performing large surveys and understand the occurence of the phenomena described above and their relation with the properties of the host galaxy. The SKA will allow to investigate an unexplored region of parameter space. At present, serendipitous H I surveys can already be carried out in every deep field, for example by using spectral-line mode, in which continuum observations (see e.g. Morganti et al. 2004c for the case of the Spitzer Space Telescope First-Look Deep survey done with the WSRT).

With the high sensitivity expected from the SKA, we will be able to search for H I absorption at $\tau \sim 0.01$ level (the typical absorption found in cases of circumnuclear tori) on every

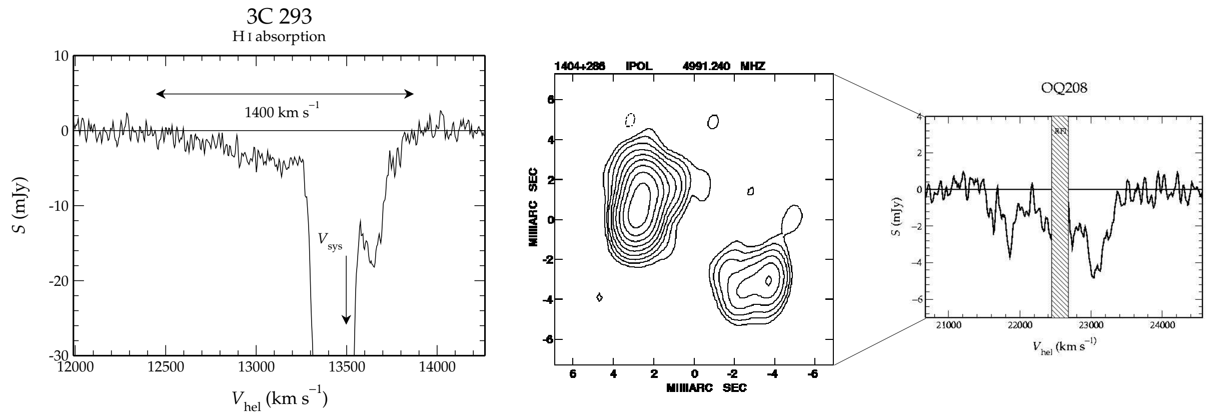

Fig. 8. *(Left)* The H I absorption profile detected in 3C 293 from the WSRT observations. The spectrum is plotted in flux (mJy) against optical heliocentric velocity in km s^{-1} (from Morganti et al. 2003). *(Right)* Broad H I absorption detected (using the WSRT) against the compact source OQ 208. The systemic velocity derived by Marziani et al. (1997) is also indicated. The VLBI radio continuum (that is only ∼ 10 pc in size) is taken from Stanghellini et al. (1997).

source stronger than only a few mJy of any observed field. It will be like searching every source of the NVSS catalogue for H I absorption. The large instantaneous bandwidth will ensure that a large range in redshift is covered to detect this absorption.

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