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Thin disks and HI absorption in the centre of low power radio galaxies

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Abstract. We present preliminary results from a global VLBI experiment which aims to study the pc scale structure of HI absorption in radio galaxies. In particular, we discuss here the case of the radio galaxy NGC 315, where two HI absorption systems are present. The narrow, redshifted absorption is extended on a scale larger than 10 pc and the properties are consistent with those of a cloud at large distance from the nucleus, such as tidal debris. A broad absorption line, close to the system velocity, is also detected, although at a very faint level. We interpret it as part of a thin disk close to the nucleus, likely the inner region of the large, dust disk observed by HST. This result confirms the idea that nuclei of low luminosity (i.e. Fanaroff-Riley type I galaxies) appear basically unobscured, i.e. the standard pc-scale, geometrically thick torus is not present in these objects.

1. Introduction

Gas in and around radio galaxies can be used to probe a number of processes occurring in their central regions. Among the different gas components, the neutral hydrogen is particularly suited to study i) the origin of the mechanism that triggers the activity (i.e. merger?); ii) the possible source of fuel for the AGN and iii) the importance of obscuration.

Obscuration is one of the main ingredients in the unification schemes of AGNs. Thick tori are believed to be present in powerful radio galaxies and a combination of beaming and obscuration would explain the lack of broad lines in some powerful radio galaxies. For low power radio galaxies, however, the situation is not so clear yet. The high rate of optical core detections, the lack of large absorption in X-ray and the low detection rate of HI absorption in FRI galaxies (Morganti et al. 2001) suggest that the standard pc-scale geometrically thick torus is not present in these low-luminosity radio galaxies. If this is the case, it can have significant implications for the predictions of unified schemes. In particular, if HI absorption studies indicate no large obscuration against the very central core, the lack or weakness of broad lines in FRI radio galaxies will have to be explained by something other than obscuration effects. Furthermore, the strong correlation that is found between the fluxes of the optical and the radio core (Chiaberge et al. 1999) for FRIs suggests that they have a common non-thermal origin, i.e. synchrotron emission coming from the initial region of the relativistic jet.

To investigate this idea in more detail, we have studied the HI absorption in a sample of radio galaxies selected on the presence of dusty nuclear disks. For these galaxies, HST images, as well as information about the presence of optical cores and nuclear dusty disks/lanes, have been obtained by some of us (Capetti et al. 2000; de Ruiter et al. 2001,2002; Capetti et al. 2001). Thus, the HI observations aim to correlate the presence (or absence) of HI absorption with the optical characteristics. We find HI absorption in 4 of the 9 B2 galaxies observed. In particular, absorption was detected in the two galaxies in the sample that have dust disks/lanes and no optical cores (B2 1322+36 and B2 1350+31 (3C 293)). In these cases, the column density of the absorption is quite high ($> 10^{21}$ cm^{-2} for $T_{spin} = 100$ 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. However, we also find two cases in which HI absorption is detected despite the presence of optical cores: B2 0055+30 (NGC 315) and B2 1346+26. The column density derived from the detected HI absorption is, however, much lower ($\sim 10^{20}$ cm^{-2} for $T_{spin} = 100$ K) and the derived extinction is of the order of only a fraction of a magnitude.

The detected HI absorption could be part (the innermost?) of the dusty disks seen with HST, but VLBI observations are needed to find out what is actually causing the absorption. B2 0055+30 (NGC 315) and B2 1346+26 have been recently observed in a Global VLBI experiment and here we present the preliminary results for one of these galaxies (NGC 315).

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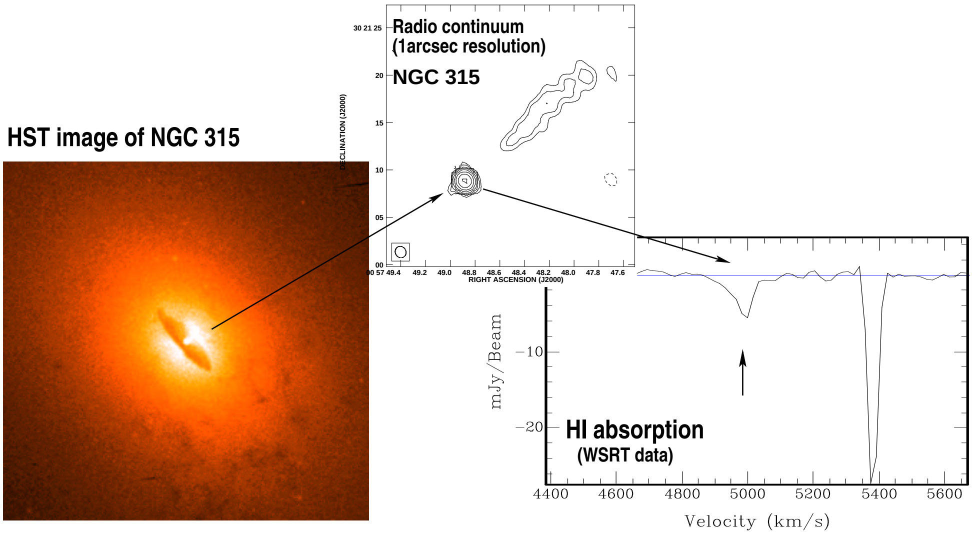

Fig. 1. In the left panel, an HST image of NGC 315 shows the dusty nuclear disk, the scale of which is about 1.5 kpc (3 arcsec). The central panel shows our VLA A-array observations, with a continuum peak of 360 mJy. The right panel shows the HI absorption detected using the Westerbork Synthesis Radio Telescope. The arrow in the right panel indicates the approximate systemic velocity.

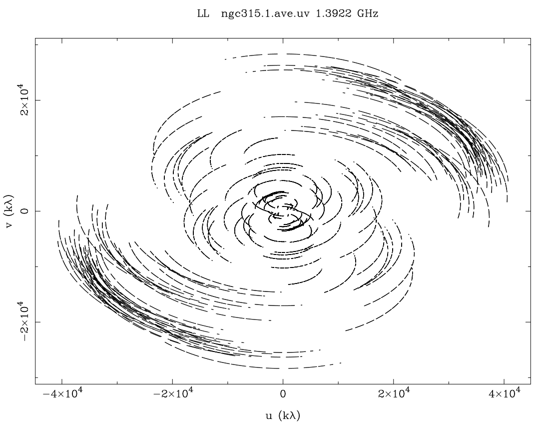

Fig. 2. (u, v)-coverage of the Global VLBI observations of NGC 315.

Throughout this paper we use a Hubble constant H_o= 50 km s^{-1} Mpc^{-1} and $q_0 = 0$. At the redshift of NGC 315 ($z = 0.167$) 1 arcsec = 0.47 kpc.

2. The case of NGC 315

The radio galaxy NGC 315 appears to be particularly interesting for this study because it shows two HI absorption systems. It was already known from Arecibo observations (Dressel et al. 1983) to have very deep and narrow (FWHM $\sim$ 3 km/s) absorption, redshifted by about 500 km/s with respect to the systemic velocity, which is very unusual for radio galaxies. In addition to this, recent observations with the Westerbork Synthesis Radio Telescope (WSRT) have shown that a second absorption system is present (see Fig. 1). This second absorption line is broader (FWHM $\sim$ 80 km/s) and situated close to the systemic velocity of the galaxy (for which both 5007 km/s and 4921 km/s are quoted by Colla et al. 1975 and Dressel et al. 1983 respectively). The peak optical depth of the broad absorption is about 1 % in the WSRT observations and the derived column density is $1.4 \times 10^{18} \times T_{spin}$ cm^{-2}/K. This galaxy was also observed by us with the VLA in A-array configuration (Morganti et al. in prep.). At the resolution of about 1 arcsec the absorbed flux measured in the narrow component is *comparable to what measured in the Arecibo observation*, therefore indicating that the region causing the absorption must have a smaller size than the VLA beam.

3. The new VLBI observations

NGC 315 was observed for 6 hours with the Global VLBI Network in November 2001. The *uv* coverage of the observations is shown in Fig. 2. We used an 8 MHz bandwidth, 512 channels centered on 1397 MHz in order to include both HI absorption systems. The velocity resolution after Hanning smoothing is $\sim$ 6 km/s. The rms noise is $\sim$ 0.7 mJy/beam in the continuum image and $\sim$ 1.2 mJy/beam/chan in the line cube (after Hanning smoothing).

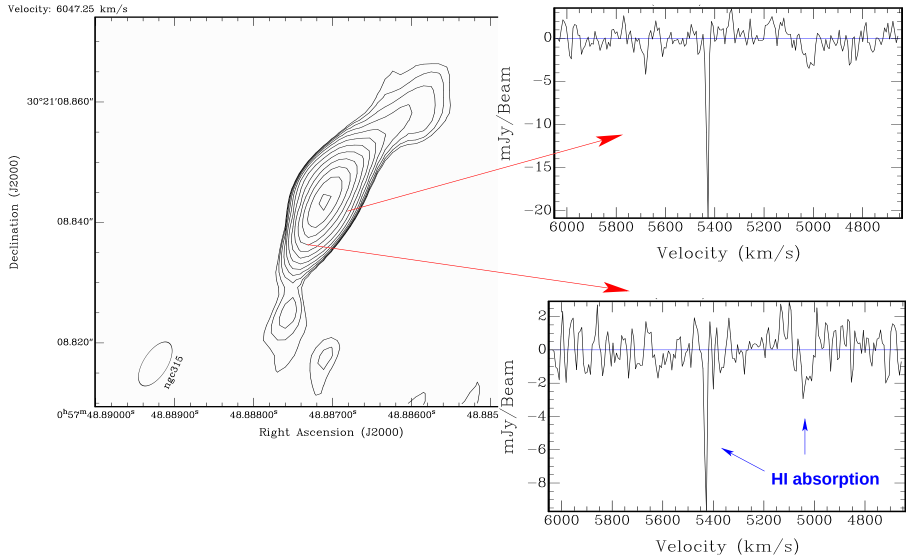

Fig. 3. Continuum image (obtained from the line-free channels, left) obtained from our global VLBI data together with the spectra (right) obtained from two positions against the radio source.

The continuum image obtained from the line-free channels (beam 12×3 mas using natural weighting) is shown in Fig. 3. A strong core and a jet structure are detected, consistent with the previous observations (see e.g. the detailed observations presented in Cotton et al. 1999). The position angle of the jet is about 43°, consistent with that of the large scale jet and perpendicular to dust disk observed by HST (see Fig. 1). The peak of the continuum is about 190 mJy. In the following sections we present the preliminary results obtained from the line data.

4. The narrow, redshifted HI absorption component

The narrow, redshifted HI absorption is clearly detected in our data as can be seen in the two profiles presented in Fig. 3. The absorption appears to be extended. This was also found in previous VLBA observations (Peck 1999) as shown in Fig. 4. From those data, the narrow absorption appears to cover about 20 mas of the source, ~ 9 pc, from the core to the first part of the jet. In addition to this, we note that we detect only about half of the integrated flux density of the HI absorption detected in the VLA data reported above.

4.1. Tidal debris

The narrow HI absorption is extended on a scale larger than 10 pc and the properties are consistent with those of a cloud at large distance from the nucleus (like tidal debris, Wakker et al. 2002). We therefore favor this explanation over the possibility of a small cloud falling into the nucleus and feeding the AGN. Other evidence also points to this explanation. At least four companions have been detected near NGC 315 in HI emission in the WSRT data. Tidal interactions between NGC 315 and the environment are therefore likely to occur. Moreover, irregular patches of gas and dust have been observed in the southern side of the galaxy (Butcher et al. 1980), that are also clearly visible in the HST images (see e.g. Capetti et al. 2000). The velocity difference of 500 km/s is not inconsistent with such an explanation.

5. The broad HI absorption

The broad HI absorption is probably also detected, although at a very faint level, in our VLBI observations. This absorption is mainly detected SE of the core as shown in Fig. 3. This absorption is more likely to be caused by gas situated relatively close to the nucleus and distributed in a disk/torus. The optical depth is about 1.7%, i.e. only slightly higher than in the WSRT data, and the FWHM$\sim$ 40 km/s: the derived column density is $\sim 10^{18} \times$ T$_{spin}$ cm^{-2}/K.

In trying to interpret the HI absorption detected in NGC 315, it is worth noticing the parameters derived from the HST data (de Ruiter et al. 2002). The dust disk observed with HST (see Fig. 1) has an inclination of $\sim 73°$ and the column density derived from the dust is $\sim 2.7 \times 10^{20}$ cm^{-2}. On the other hand, from ASCA observations mild absorption is detected in the nucleus of NGC 315, corresponding to a column density of $9^{+6}_{-5} \times 10^{21}$ cm^{-2} (Matsumoto et al. 2001).

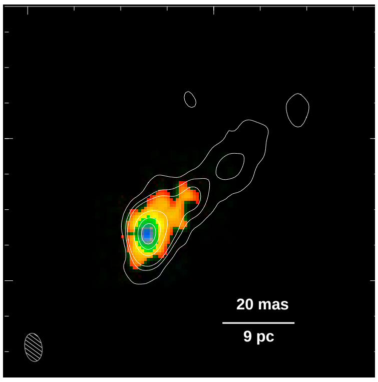

Fig. 4. HI absorption amplitude (grey scale, ranging from 10 to 80 mJy) of the narrow HI absorption in NGC 315 superimposed to the contours of the total intensity obtained in prev ious VLBA observations from Peck (1999)

5.1. Thin disk

If we assume that the disk/torus responsable for the broad HI absorption is part of the same disk structure observed by HST, we can assume they have the same inclination. The fact that in our preliminary data analysis we do not detect the HI absorption against the northern part of the jet appears to be consistent with this assumption and indicates an opening angle not larger than $\sim 20^{\circ}$ is characteristic of the HI disk/torus. At this stage we cannot say how close the HI is to the nucleus. However, if it is only a few parsecs this will affect significantly the value of the spin temperature and the estimate of the column density. The presence of a strong continuum source near the HI gas may significantly increase the spin temperature because the radiative excitation of the HI hyperfine state can dominate the usually more important collisional excitation (see e.g. Bahcall & Ekers 1969). If the gas producing the HI absorption is in a circumnuclear torus (i.e. at a distance ≤ 100 pc from the nucleus), it will be irradiated by the hard X-ray emission from the nucleus. According to Maloney et al. (1996, and references therein), purely atomic gas in these conditions has a stable equilibrium temperature of ~8000 K. Thus, the value of T_{spin} will be likely to be or the order of few thousand K in the case of the broad absorption of NGC 315.

Using this value we can get an upper limit to the column density of the HI of the order of $\sim 10^{22}$ cm^{-2}, which would be consistent with what has been derived from the X-ray observations. The inclination and the small opening angle would ensure that the optical core, i.e. the nonthermal synchrotron emission from the initial region of the relativistic jet, is not obscured.

One more caveat to keep in mind, however, is that no accurate systemic velocity is known for this galaxy. This is important information that will need to be measured in order to have the correct interpretation for the HI absorption.

So far, only a few low-luminosity radio galaxies have been observed in HI absorption with VLBI. The best cases are NGC 4261 (van Langevelde et al. 2000) and Hydra A (Taylor 1996). In the case of NGC 4261, the HI absorption has been detected only against the counter-jet. For this galaxy it has also been explained as the result of a thin, disk-like structure with the same inclination as the one observed with HST.

Thus, with the (limited) cases we have so far, nuclear HI disks/tori are found close to the nuclei of FRI radio galaxies. These disks appear to be thin, exactly like what is found in the optical data. They therefore support the idea that the nuclei of low-luminosity FRI radio galaxies are basically unobscured.

References

Barth A. et al. 1999, ApJ 525, 673;
Butcher H.R., van Breugel W., Miley G. 1980, ApJ 235, 749
Bahcall J.N., Ekers R.D. 1969, ApJ, 157, 1055
Capetti A., de Ruiter H.R., Fanti R., Morganti R., Parma P., Ulrich M.-H. 2000, A&A 362, 871;
Capetti et al. 2001, in Issues in Unification of AGNs, Maiolino R., Marconi A., Nagar N. eds., ASP Conf. Series in press
Chiaberge et al. 1999, A&A 349, 77;
Cotton et al. 1999, ApJ, 519, 108;
Giovannini et al. 2001, ApJ 552, 508 (astro-ph/0101096);
van Gorkom, J. H., Knapp, G. R., Ekers, R. D., Ekers, D. D., Laing, R. A., Polk, K. S. 1989, AJ 97, 708;
Heckman T.M., Balick B., van Breugel W.J.M., Miley G.K. 1983, AJ 88, 583;
Maloney P.R., Hollenbach D.J., Tielens A.G.G.M. 1996, ApJ 466, 561
Matsumoto Y., Fukazawa K., Iyomoto N., Makishima K. 2001, Publ. Astr. Soc. Japan 53, 475
Morganti et al. 2001, MNRAS 323, 331 (astro-ph/0010636);
Oosterloo et al. 2000, AJ 119, 2085
Peck, A. B. 1999, PhD Thesis, New Mexico Inst. of Mining and Technology;
de Ruiter et al. 2001, in The central kpc of starburst and AGN, Knaper, Beckman, Shlosman & Mahoney eds., ASP Conf. Series in press (astro-ph/0106490)
de Ruiter et al. 2002 A&A submitted
Taylor, G. B. 1996, ApJ, 470, 394;
van Langevelde H.J., Pihlström Y.M., Conway J.E., Jaffe W., Schilizzi R.T. 2000, A&A 354, 45
Wakker B., Oosterloo T.A., Putman M. 2002 AJ 123, 1953