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B2 0648+27: A radio galaxy in a major merger*

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Abstract. We present WSRT observations of the neutral hydrogen in the nearby radio galaxy B2 0648+27. In emission, we detect a very large amount of HI ($M_{\rm HI} = 1.1 \times 10^{10}$ $M_\odot$) that is distributed in a very extended disk, or ring-like structure, of about 160 kpc in size. We also detect HI absorption against the central radio continuum component. The detection of the HI, its structure and kinematics, give us key information for building a possible evolutionary scenario. The characteristics of the detected HI are explained as the result of a *major merger event* that is likely to have occurred $\lesssim 10^9$ yr ago. Interestingly, we find that, when observed in radio continuum at higher resolution, this galaxy has a double lobed, steep spectrum structure of about 1 kpc in size. Thus, despite its low radio power, B2 0648+27 bears striking similarities with Compact Symmetric Objects, i.e. objects believed to represent the early phase of radio galaxies ($\lesssim$few thousand yrs old). B2 0648+27 is one of the few nearby radio galaxies where extended neutral hydrogen has been detected so far. This, and other recent results, appear however to indicate that nearby radio galaxies are more often gas rich than commonly assumed. The phenomena described are likely to be much more common at high redshift and galaxies like B2 0648+27 may provide valuable information on the evolution of high redshift radio sources.

Key words. galaxies: ISM – galaxies: active – radio lines: galaxies

1. Mergers and the origin of radio galaxies

Galaxy mergers and interactions are often invoked as trigger of the nuclear activity in radio galaxies. The large number of powerful radio galaxies showing peculiar optical morphology (tails, bridges, shells and dust-lanes; Smith & Heckman 1989; Heckman et al. 1986), together with the detection of large amounts of CO in a number of them (Mazzarella et al. 1993; Evans et al. 1999a,b), can be taken as evidence for this. The increasing evidence that super-massive black holes reside in the centres of many elliptical galaxies (e.g. Kormendy & Richstone 1995) and the detection of potential fuel for AGN (ionized gas and dust) in both radio loud and quiescent galaxies (see e.g. Verdoes Kleijn et al. 2002a and references therein), suggest that radio activity may occur (perhaps as a *short phase*) in the life of *many (or even all)* elliptical galaxies.

The nature of the triggering events remains, however, uncertain. It is not clear whether the activity is mainly triggered by *major mergers* between gas-rich galaxies or by *minor accretion* events. Perhaps either kind of merger plays an important role, as long as the initial conditions are such that the gas will be able to reach the very inner regions (on pc-like scales), see e.g. Hibbard (1995), Wilson (1996). Another uncertain aspect is at which stage of the merger the onset of the radio activity takes place.

Evolutionary sequences linking merger-related objects have been suggested by many authors. The case for a link between ultra-luminous far-IR galaxies (ULIRG) and radio galaxies (e.g. Sanders & Mirabel 1996; Evans et al. 1999a) is perhaps the strongest. ULIRGs are thought to be connected to gas rich mergers. A relation between ULIRGs and radio galaxies would explain, e.g., the large amount of molecular gas and dust detected in some radio galaxies and the starburst component that is visible in the optical spectra of a number of them (Wills et al. 2002). In this sequence, the radio activity is believed to appear late in the evolution of the merger, when the molecular gas finally agglomerates in the nuclear region of the galaxy (Evans et al. 1999a).

The details of the overall evolution are, however, still quite vague. In order to study these, a diagnostic of the conditions and kinematics of the gas on large scales is important. This is because large scales imply longer time scales for this gas to settle in a stable configuration. The signatures and characteristics of the merger can, therefore, be recognised over a longer

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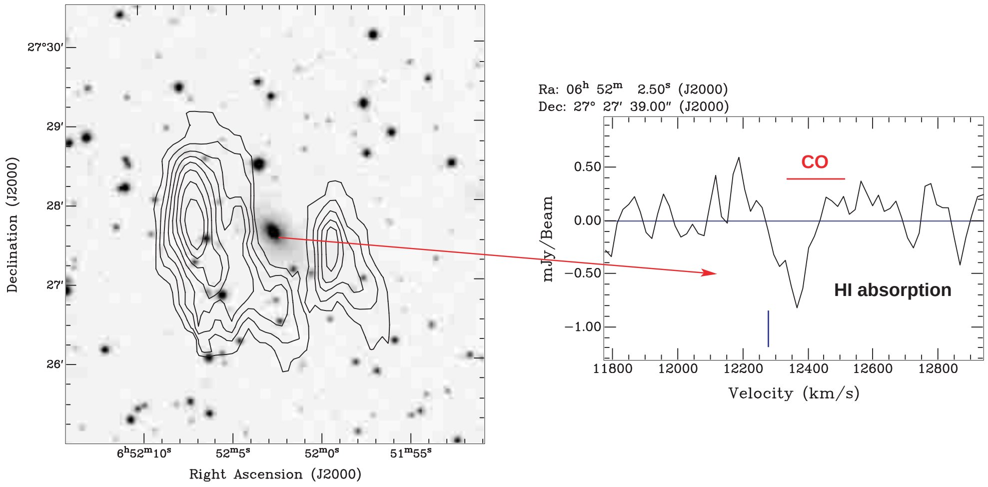

Fig. 1. *Left*: HI total intensity contours of the radio galaxy B2 0648+27 superimposed on to an optical image. *Right*: HI absorption profile, the optical systemic velocity is marked. The range of the CO emission (from Mazzarella et al. 1993) is also indicated. Contour levels: 4.3×10^{19} to 1.9×10^{20} cm^{-2} in steps of 1.8×10^{19} cm^{-2}.

Table 1. Instrumental parameters of the WSRT observations.

Field Centre (J2000)	06:52:02.5 27:27:39
Date of the observations	04 Feb. 01
Shortest spacing (m)	48
Synthesized beam (arcsec)	64 × 27 (PA 0.6°)
Number of channels	128
Bandwidth (MHz)	10
Central frequency (MHz)	1363.8
Velocity resolution (km s^{-1}) (after Hanning)	36
rms noise in channel maps (mJy/beam)	0.22

period. This is an advantage over e.g. imaging studies of the centres of active and non-active galaxies performed with HST (e.g. Verdoes-Kleijn 2002b and ref. therein, Capetti et al. 2000). The dynamical time scales in these central regions are very short and differences between active and non-active galaxies can disappear quickly.

Observations of the neutral hydrogen can be a good tool to study the evolution of mergers. Through the amount of HI (on large scales), its morphology and kinematics, one can obtain a good idea about what kind of galaxies are/were involved as well as about the age of the merger. Large tails of neutral hydrogen signal that the merger is relatively young. On the other hand, the large, regular gas disks found in some elliptical galaxies indicate an older merger, where the gas has had time to settle in such a disk (see Barnes 2002; Oosterloo et al. 2002a; Morganti et al. 1997; van Gorkom & Schiminovich 1997).

In order to obtain more information on the AGN-phase in mergers and to investigate the connection with ULIRGs, gas-rich and normal elliptical galaxies, a thorough study of the HI properties of radio galaxies is essential for radio-loud galaxies. A good candidate for such a study is B2 0648+27, a radio galaxy that has a number of characteristics that indicates that it may be related to ULIRGs or ULIRG-like galaxies. Here we present the results of HI observations carried out with the Westerbork Synthesis Radio Telescope (WSRT).

2. B2 0648+27 and the WSRT observations

B2 0648+27 is a compact radio source ($\log P = 24.02$ W/Hz at 1.4 GHz[1]) hosted by a luminous elliptical galaxy ($M_B = -22.94$ and $\log L_B = 11.34\ L_\odot$). This galaxy has a particularly interesting interstellar medium (ISM). It contains $\sim 6 \times 10^9\ M_\odot$ of molecular hydrogen and it is also an IRAS source ($L_{\rm FIR} \sim 2 \times 10^{11}\ L_\odot$, Mazzarella et al. 1993). It shows warm far-infrared colours and is classified as a 60-μ peaker (Vader et al. 1993; Heisler et al. 1998), likely resulting from the large amount of dust heated by the nuclear activity but also by the star formation (see below). The estimated mass of the dust is $\log M_{\rm dust}/M_\odot = 6.48$. The central regions have been observed with HST and the dust it is found to be distributed both in a regular disk and in patches (Capetti et al. 2000; de Ruiter et al. 2002). The presence of a young stellar population has been determined from optical spectra (Ebneter 1989). The clear deviation from the far-IR/radio correlation (Heisler et al. 1998) and the warm IR colours (i.e. the ratio 25/60 μ) typical of AGN, confirm the classification as radio galaxy.

The redshift of B2 0648+27 derived from optical lines is $12\,270 \pm 120$ km s^{-1} ($z = 0.0409 \pm 0.0004$, Falco et al. 2000) while $12\,420$ km s^{-1} ($z = 0.041$) was derived from the CO detection (Mazzarella et al. 1993).

B2 0648+27 was observed using the WSRT at the frequency of the redshifted HI line for 12 hours. The parameters of the observations are summarized in Table 1. The data were calibrated using the MIRIAD package (Sault et al. 1995). The final cube was made with robust–Briggs' weighting equal to 1 (Briggs 1995). The restoring beam is 64 × 27 arcsec (PA 0.6°) and the rms noise is 0.22 mJy beam^{-1}. The velocity resolution is, after the Hanning smoothing we applied, 36 km s^{-1}. At the resolution of our observations, the radio continuum of this galaxy appears unresolved (but see Sect. 4 for the high resolution continuum image).

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[1] For $H_\circ = 50$ km s^{-1} Mpc^{-1} and $q = 0.0$, 1 arcsec = 1.1 kpc.

3. The neutral hydrogen in B2 0648+27

In B2 0648+27 we detect Hi both in *emission* and in *absorption*. The emission comes from a large amount of Hi in a structure around the galaxy, while the absorption is detected against the unresolved central radio continuum component.

3.1. Hi emission

The striking property of the Hi emission is the large amount that is detected. The total Hi mass is estimated to be $M_{\rm HI}$ = 1.1×10^{10} $M_\odot$. This is an unusually large amount for an elliptical galaxy. The optical luminosity of the host galaxy is also high (the RC3 lists B_T^0 = 14.03 which implies L_B = 2.2×10^{11} $L_\odot$ and therefore the relative Hi content is only $M_{\rm HI}/L_B = 0.05\ M_\odot/L_{B,\odot}$.

Figure 1 shows the Hi total intensity superimposed on an optical image taken from the Digital Sky Survey. The Hi emission is very extended, the diameter is about 2.5 arcmin corresponding to ~160 kpc. The surface density of the Hi is quite low, the peak of the emission is only 0.8 $M_\odot$ pc^{-2}. Therefore, in order to get detailed information on the morphology and kinematics of the Hi deeper observations will be required. However, from the available data we can infer some important characteristics of the Hi. Figure 1 shows that the brightness distribution is asymmetric and is much brighter on the E side. The neutral gas shows a smooth velocity gradient that brackets the systemic velocity and this could indicate that rotation is the main component of the observed kinematics. However, the range of velocities is asymmetric with respect to those of the CO which, if we assume that the CO is located in the central regions, indicates that most of the Hi is not in an equilibrium configuration. The position-velocity plots (Figs. 2 and 3) suggest that the Hi is perhaps not in a disk given that the Hi appears almost as a linear feature in these plots. Such a shape is more characteristic of an incomplete ring or annulus (or even a tail-like structure). The apparent lack of Hi emission at the position of the optical galaxy (Figs. 1 and 2) could be partly due to the presence of Hi absorption against the compact radio source (see below). Higher quality data are needed to be able to say more about the structure of the Hi.

3.2. Hi absorption

We also detected Hi in absorption against the unresolved central continuum source of the radio galaxy. The Hi absorption profile is shown in Fig. 1. The peak absorption is ~0.84 mJy beam^{-1}. From the continuum image derived using the data from the line-free channels, we derive a continuum flux of ~147 mJy, comparable to the 156 mJy obtained from VLA data at 1.4 GHz by Fanti et al. 1987. This gives an optical depth of 0.6%.

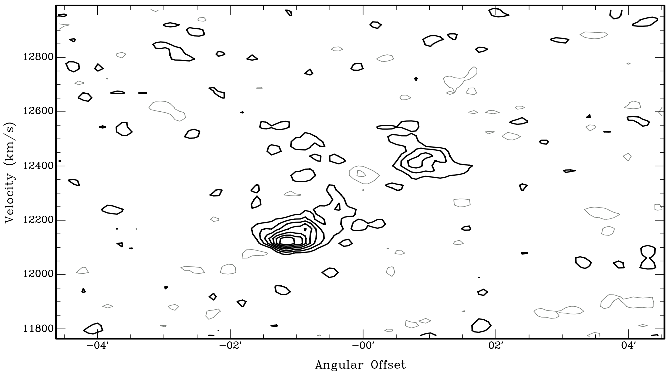


Fig. 2. Position-velocity plot along the major axis (PA = 250°). The contour levels are −0.8, −0.4, 0.4 to 2.8 mJy beam^{-1} in step of 0.4 mJy beam^{-1}.

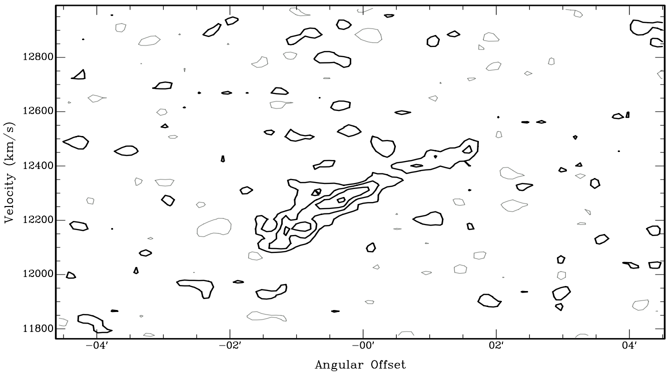


Fig. 3. Position-velocity plot along the PA of the major axis (PA = 250°) but ~40 arcsec offset to the south. The contour levels are −0.8, −0.4, 0.4 to 1.6 mJy beam^{-1} in step of 0.4 mJy beam^{-1}.

The *FWHM* of the absorption profile is ~100 km s^{-1} and the central velocity (~12 370 km s^{-1}). The *FWHM* of the CO appears to be broader (*FWHM* = 220 km s^{-1}, Mazzarella et al. 1993) than the Hi. The column density is ~1.1×10^{20} cm^{-2} for $T_{\rm spin}$ = 100 K. This is similar to what found in some other radio galaxies (see e.g. Morganti et al. 2001; Pihlström 2002) when sensitive observations are available. It is also very similar to the column densities of the Hi seen in emission. The Hi seen in absorption is likely to be part of the same system as the gas detected in emission but happens to be in front of the radio source, hence it is gas at large radius. Thus, the difference in width between the Hi and the CO likely reflects the difference in location of these two gas components, with the CO closer to the nucleus compared to the neutral hydrogen. Unfortunately, no image of the distribution of the CO emission is available.

3.3. Other objects in the field

Three other objects are detected in Hi emission in the field of B2 0648+27. Their total Hi images are presented in Fig. 4. The three galaxies are separated from each other between 300 and 800 kpc and they form a small group, situated about 27 arcmin (or 1.8 Mpc) east of B2 0648+27. Moreover, the average redshift of the galaxies is about 1000 km s^{-1} different from B2 0648+27. Ongoing or recent interactions between these galaxies and B2 0648+27 can therefore be excluded, because the group is quite distant from B2 0648+27 while it also appears to be at a somewhat lower redshift.

A summary of their characteristics is given in Table 2. The brightest one (J0652+2721) is identified with a 2MASS galaxy (2MASXi J0652557+272157) and the systemic

Table 2. Other galaxies in the B2 0648+27 field.

Name	α (J2000)	δ (J2000)	$V_{\rm hel}$ (km s^{-1})
J0652+2721	$06^{\rm h}52^{\rm m}56^{\rm s}$	27°21′57″	11320
J0652+2719	$06^{\rm h}52^{\rm m}45^{\rm s}$	27°19′28″	11620
J0652+2709	$06^{\rm h}52^{\rm m}48^{\rm s}$	27°09′45″	11455

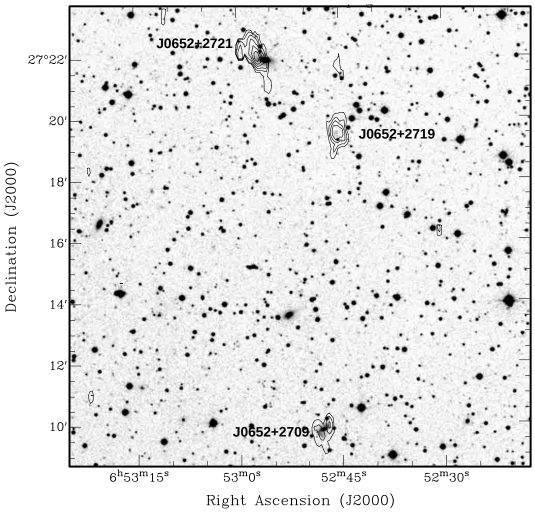


Fig. 4. Total HI intensity (contours) of the three galaxies detected in the field of B2 0648+27 superimposed on an optical images taken from te Digital Sky Survey. Contour levels: 4.3×10^{19} to 1.3×10^{20} cm^{-2} in steps of 1.8×10^{19} cm^{-2}.

velocity for this galaxy is $V_{\rm hel}\sim$ 11 320 km s^{-1}. The HI profile has a *FWHM* of only ~50 km s^{-1}, probably also due to the fact that the emission is situated at the very edge of our observing band and we could be missing some emission coming from this object. We also detect HI in coincidence of an anonymous low-surface brightness galaxy, J0652+2719, with a systemic velocity of $V_{\rm hel}\sim$ 11 620 km s^{-1} and the HI profile has a *FWHM* ~ 80 km s^{-1}.

The third HI detection is coincident with an anonymous galaxy, J0652+271509, with a velocity of $V_{\rm hel}\sim$ 11 455 km s^{-1} and a *FWHM* of ~60 km s^{-1}.

Because of their large distance from the field center, the HI flux of these galaxies is very much affected by the attenuation of the primary beam. Therefore any estimate of the HI mass would be very uncertain.

4. VLA 8 GHz observations

VLA observations at 8 GHz using the A-array configuration where obtained on 03-May-2002 in order to understand the sub-arcsec structure of this galaxy. The final image is shown in Fig. 5. The restoring beam is 0.2 × 0.19 arcsec (PA = −12°) and the rms noise 26 μJy beam^{-1}. The peak of the continuum emission is 10.7 mJy.

At this sub-arcsec resolution, B2 0648+27 is resolved into a double-lobed structure. This is consistent with the fact that the overall radio spectrum of the source is steep ($\alpha^{5}_{0.4}$ = 0.6, $S\sim\nu^{-\alpha}$), similar to that of large scale radio sources, and not typical of radio cores. The overall structure is about 1 kpc in size. The radio morphology of B2 0648+27 is therefore similar to the so-called Compact Steep Spectrum sources and Compact Symmetric Objects (see O'Dea 1998 for a review), objects that are believed to have a small size, not due to beaming effects, but because of the young age of their radio emission ($\lesssim$ few thousand yrs old). B2 0648+27 could be, therefore, a low-power example of this group of sources. The possibility that the radio emission in B2 0648+27 started not so long ago is interesting in the light of the time scales of the merger that can be derived from the HI and the evolutionary sequence that will be discussed in Sect. 5.3.

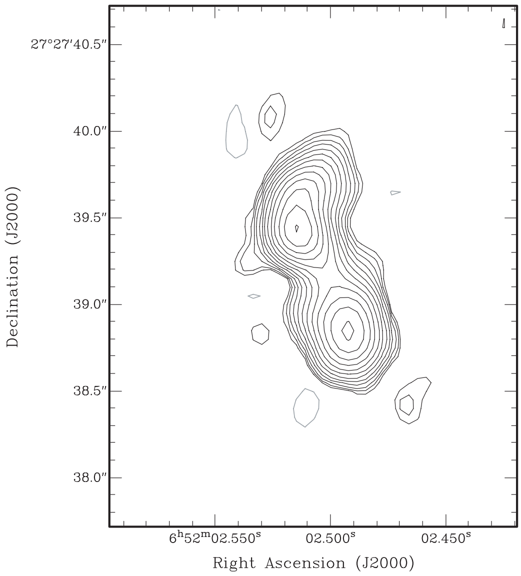


Fig. 5. VLA image of B2 0648+27 at 8 GHz. The contour levels are −0.08, 0.08 to 11 mJy beam^{-1} increasing with a factor 1.5.

5. A radio galaxy in a major merger

5.1. Origin of the HI

The main result of this study is that in the radio galaxy B2 0648+27, HI has been detected not only in absorption, as often is the case in radio galaxies, but also in emission. The amount of gas detected is large (~10^{10} $M_\odot$) and distributed in a very extended structure (~160 kpc in diameter) of which the kinematics suggest that it is not entirely in equilibrium. Large amounts of HI, distributed over a large region, have now been found in a number of nearby radio-quiet elliptical galaxies, sometimes, but not always, distributed in a relatively regular disk-like structure (see e.g. Morganti et al. 1997; van Gorkom & Schiminovich 1997; Oosterloo et al. 2002b and references therein). In these systems the neutral hydrogen is explained as originating from a major-merger event, involving at least one gas-rich, disk galaxy, that occurred, in some cases, more than 10^9 yr ago. This appears also to explain the characteristics of the detected HI in B2 0648+27.

Extended HI in emission was also found by Lim & Ho (1999) associated with three quasars host galaxies.

The Hɪ detected there exhibit ongoing or remnant tidal Hɪ disruptions possibly tracing galactic encounters or mergers. These objects are perhaps in a early stage of their evolution. Unlike B2 0648+27 they are radio-quiet objects. Also in these cases the amount of Hɪ mass is quite high (between 0.5 and 2.5×10^{10} $M_\odot$).

The structure of the Hɪ and the asymmetric density distribution suggest that in B2 0648+27 the Hɪ is unlikely to be in a settled configuration. A rough indication of the age of the merger is R/V where R is the size of the system and V a characteristic velocity. For B2 0648+27 we find $R/V \simeq 3 \times 10^8$ yr.

It is interesting to note that in B2 0648+27 the column density of the Hɪ detected in emission is relatively low as in the other gas-rich elliptical galaxies mentioned above (see e.g. Oosterloo et al. 2002a). The peak of the Hɪ surface density is only ~0.8 $M_\odot$ pc^{-2}, well below that found in the inner regions of most spiral disks. Because of this low surface density, no significant star formation is, at present, occurring in the regions coincident with the Hɪ. The galaxy can, therefore, remain gas rich for a very long period.

5.2. Gas disks and radio activity

The interesting element, compared to many other gas rich elliptical galaxies, is that B2 0648+27 is also a relatively strong radio source. With the sensitivity of present day radio telescopes it is very difficult to detect neutral hydrogen in emission at the typical distance of radio galaxies. Hɪ in emission is detected only in an handful of very nearby radio galaxies, for example IC 1459 (Oosterloo et al. 1999), NGC 4278 (Raimond et al. 1981; Lees 1994), NGC 1052 (van Gorkom et al. 1986), PKS B1718-649 (Véron-Cetty et al. 1995) and Centaurus A (van Gorkom et al. 1990; Schiminovich et al. 1994). With the exception of the last two objects, these radio sources are at the lower end of the distribution of radio power for radio galaxies and they are more than an order of magnitude less powerful than B2 0648+27. Among the objects listed above, the one that shows characteristics very similar to B2 0648+27 is the southern radio galaxy PKS B1718-649. This is a compact steep spectrum source (Tingay et al. 1997) around which a large (~180 kpc diameter) Hɪ disk of ~3.1×10^{10} $M_\odot$ has been found (Véron-Cetty et al. 1995).

In addition to this, by using Hɪ absorption against the radio lobes (i.e. tens of kpc in size), extended neutral hydrogen has been detected in the radio galaxy Coma A (Morganti et al. 2002a). In this object at least 10^9 $M_\odot$ of Hɪ have been detected in a disk-like structure of at least 60 kpc in diameter. Other examples have also been recently found where the Hɪ absorption is not limited to the nuclear region but extend tens of kpc, e.g., 3C 433 (Morganti et al. 2002b) and 3C 234 (Pihlström 2001) although they have not yet been studied in detail. Thus, the case of B2 0648+27, together with these other recent results, indicates that extended structures of neutral hydrogen in radio galaxies may actually be more common than thought so far. A systematic study of these systems is now essential.

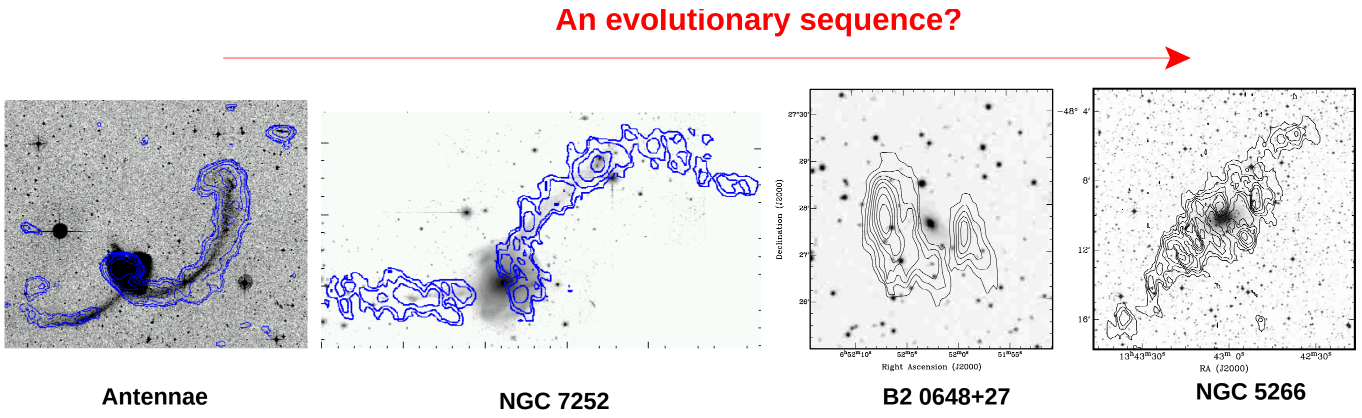
Although these objects may represent only a relatively small subset in the group of radio galaxies, they may have an extra relevance as link to high-z objects. Extended Hɪ absorption (observed against the Lyα emission) has been found in a high fraction of high-z radio galaxies (van Ojik et al. 1997). This is considered an indication that high-z radio galaxies are located in dense environments and is a diagnostic for the effects of radio jet propagation in this dense medium. Moreover, a low surface brightness Lyα halo with quiescent kinematics has also been found in the case of the distant radio galaxy USS 0828+193 (Villar-Martín et al. 2002).

Although these phenomena may be occurring more frequently and more efficiently at high redshifts, in the Hɪ-rich, low redshift radio galaxies we may witnessing a similar situation. Indeed, Villar-Martín et al. (2002) indicate the possibility that the low surface brightness Lyα halo in USS 0828+193 is the progenitor of the Hɪ discs found in low redshift galaxies.

Finally, as mentioned above (Sect. 4), B2 0648+27 could be a young radio source. For this and other characteristics (high far-IR luminosity, Hɪ absorption, young stellar population component), B2 0648+27 bears a strong similarity with two other radio galaxies, namely PKS 1547–79 and 4C 12.50 (see also Sect. 5.3). The properties of these sources have been explained by that they are young sources still enshrouded in a cocoon of material left over from the event which triggered the nuclear activity. The radio source, during its evolution, is sweeping away large amounts of obscuring material present along the radio axis. In PKS 1547–79 and 4C 12.50 the interaction between the radio plasma and the ISM is evidenced by the presence of two redshift systems (see Tadhunter et al. 2001 and Morganti et al. 2003 for a detailed discussion). Good quality optical spectra are necessary to investigate whether B2 0648+27 also shares these characteristics. Unfortunately, given their higher redshift, the search for extended neutral hydrogen is particularly difficult for PKS 1547–79 and 4C 12.50. The finding of Hɪ in B2 0648+27 confirms, nevertheless, the trend of an higher probability of detecting neutral hydrogen in starburst/far-IR bright radio galaxies as found by Morganti et al. (2001). Although B2 0648+27 is actually the first case where Hɪ is detected also in emission, this result can be taken as a further indication that the interstellar medium is indeed, on average, richer in these objects than in other radio galaxies.

5.3. The merger and the order-of-events

The relevance of major vs minor mergers as trigger for the radio activity and the time of the onset of this activity in the life of a galaxy, are not yet well understood. Major mergers have been proposed to explain, e.g., the large amount of CO observed in some radio galaxies. The spread in the CO properties observed in radio galaxies (Mazzarella et al. 1993; Evans et al. 1999a,b) is used to argue that *the radio activity appears late in the life of the merger and a long time after the start of the starburst phase* (as late as it takes for the molecular gas to agglomerate in the very nuclear regions). Depending on such a delay, the consumption of the left-over gas (both molecular and neutral) by extended star formation could be well underway even before the radio activity starts and this will explain the large range in CO values (see the case of 4C 12.50, Evans et al. 1999a).



Antennae **NGC 7252** **B2 0648+27** **NGC 5266**

Fig. 6. Possible evolutionary sequence linking gas-rich mergers with radio galaxies and gas-rich ellipticals (described in text). The images of the Antennas and NGC 7252 have been taken from Hibbard & van Gorkom (2001), B2 0648+27 from this paper, NGC 5266 from the data presented in Morganti et al. (1997).

Lim et al. (2000), however, have argued that the fact that most of the radio galaxies lie very close to the fundamental plane (unlike merging systems), is better explained by cannibalizing of smaller gas-rich galaxies by the pre-existing galaxy that therefore retains its gross morphological and dynamical properties.

The study of the stellar population is also giving a complex view of what may be the trigger mechanism of radio activity and that we are probably dealing with not a single type of merger as trigger of the activity (Wills et al. 2002). A young stellar population component has now been detected in about 30% of the observed radio galaxies (Wills et al. 2002; Tadhunter et al. 2002) and in some of them the mass of this component is large, suggesting its origin to be related to a major merger event. If this is the case, the merger is estimated to be relatively old (>0.1 Gyr, see e.g. Tadhunter et al. 2002; Wills et al. 2002), supporting the idea that al least in those objects the radio activity starts in these galaxies quite late after the merger.

The case of B2 0648+27 has shown as the neutral hydrogen can be a good tool to answer some of the above open questions and derive key information, not only about the origin, but also about the evolution of the system and the time-scales involved. In the case of B2 0648+27, the likely origin of the system is a major merger. This supports the idea of a link between, at least some, radio galaxies and ULIRGs, as already suggested by the characteristics of the ISM in this galaxy. The prototype of this class of objects is the radio galaxy 4C 12.50 (Evans et al. 1999a) and the similarities between the two objects have been already mentioned above (Sect. 5.2).

Although this could be the case for only a limited group of radio galaxies, nevertheless we can attempt, using the information obtained by the Hi, to include B2 0648+27 in the evolutionary sequence already proposed for other gas-rich systems (see e.g. Hibbard & van Gorkom 1996; Wilson 1996; Mihos & Hernquist 1994; Morganti et al. 1997) This is presented in Fig. 6.

The Antennae (left) illustrates an ongoing merger where two galaxies are still identifiable and where a starburst is occurring (Hibbard et al. 2001). Part of the Hi is found in two long tidal tails. NGC 7252 (2nd from left) represents a somewhat later stage where the central remnant has already more or less taken the shape of an elliptical galaxy (Hibbard et al. 1996). The Hi is mainly in large tails at large radii, while the gas in the centre, where much star formation is still occurring, is mainly molecular. NGC 7252 is a strong emitter in the far infrared. After an intermediate stage with AGN activity (B2 0648+27, see below), the final stage (NGC 5266; 4th panel), shows a galaxy that has become a genuine early-type galaxy (Morganti et al. 1997). The Hi is falling back from the tails to the galaxy and is in the process of forming a large disk or ring-like structure of low surface density. In NGC 5266, in fact, two such systems, that are orthogonal to each other, are observed (Morganti et al. 1997). In the outer regions Hi filaments are still visible. Star formation is occurring at a much reduced rate and no AGN is detected.

The new Hi data allow us to place B2 0648+27 on the evolutionary sequence illustrated in Fig. 6. The, admittedly very rough, estimate of the age of the merger, based on the size and the kinematics of the Hi, is several times 10^8 yr. This suggests that this galaxy can be placed between NGC 7252 and NGC 5266. Considering that the timescale over which AGN activity occurs is at least an order of magnitude smaller, in this object the AGN activity occurred at a late stage of the merging process. This is particularly interesting when considering that the radio emission, indeed, appears to be relatively recent in B2 0648+27. This is therefore consistent with the fact that the Hi has not yet completely settled and therefore that the merger is not too old.

A final word of caution is that the first-order kind of scenario proposed above will have to be further investigated using different kind of observations. In particular, it will be important to derive the age of the young stellar population from optical spectroscopy, while deep optical images will have to show whether indeed a stellar conterpart of the Hi structure is present (as found in NGC 5266 and NGC 2865; Morganti et al. 1997 and Schiminovich et al. 1995 respectively).

6. Summary

We have presented Hi observations of the radio galaxy B2 0648+27 where Hi both in absorption and in emission has been detected. The neutral hydrogen is distributed in a large, disk or ring-like structure of $M_{\rm HI} = 1.1 \times 10^{10}\ M_{\odot}$ in mass and about 160 kpc in diameter. This result, together with what recently found in other objects, indicates that extended structures of neutral hydrogen in radio galaxies may actually be more common than thought so far. The HI can be used to study the likely origin of these systems and the time scales involved. In the case of B2 0648+27, the large amount of neutral gas suggests a major-merger event. From the kinematics and the size of the HI we estimated the age of the merger to be several times 10^8 yrs. Gas-rich, low redshift systems like B2 0648+27 could be the nearby examples of phenomena that are more common in high redshift radio galaxies, therefore they may help us in better understanding these far-away systems.

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