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Large-scale H I structures and the origin of radio galaxies

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Abstract

We present the first results of a study aimed to detect large H I structures in radio galaxies. In two of the three cases presented (Coma A and B2 0648+27), the detection of a large amount of H I distributed over several tens of kpc suggests a major merger as origin of the observed system and allows to infer when this merger must have occurred. The situation is less clear for the third object (3C 433). We propose an evolutionary sequence for one of the radio galaxies studied. The implications of this study of neutral hydrogen in nearby radio galaxies for high- z objects and “normal” (i.e. radio-quiet) elliptical galaxies are also discussed.

Key words: galaxies: ISM - galaxies: active - radio lines: galaxies

1 Why neutral hydrogen?

The study of the formation and the evolution of massive ellipticals is attracting, at present, a lot of attention. Among these systems, an interesting sub-class is represented by those hosting powerful radio sources. The presence of such activity is telling us that the galaxy is in a particular phase in its evolution. Indeed, the increasing evidence given that super-massive black holes reside in the centres of many elliptical galaxies suggests that the period of activity, turning a “normal” elliptical in a radio galaxy, could be a – relatively short – phase in the life of many (or all?) ellipticals. When in the life of the host galaxy this phase takes place and how it is related to the actual formation of the host galaxy and to its evolution, are questions that are still unanswered.

Fig. 1. An example of a large (about 50 kpc diameter), regular HI disk of more than $10^9 M_\odot$ of HI (in contours the total intensity) around the (radio-quiet) elliptical galaxy NGC 3108 (optical image in grey scale). See (11) for more details.

The importance of mergers/interactions in the formation and triggering of radio galaxies has been brought forward already a long time ago. The peculiarities often observed in the optical morphology of radio galaxies (e.g. tails, bridges, shells and dust-lanes, see (2)) is one of the main arguments that has led to this conclusion.

However, new results have been recently obtained from the study of the optical continuum in radio galaxies (with the main goal of investigating the nature of the UV excess). It has been found (14; 16) that a young stellar population component is present in at least 30% of radio galaxies. Interestingly, the galaxies showing this component are also the most luminous in the far-IR, indicating a link between an optical starburst and far-IR activity. These results support the idea of a merger origin for radio galaxies and suggest that, at least some of them, had an (ultra-)luminous far-IR galaxy as progenitor (14). The results also indicate that the activity starts late after the merger event. The existence of galaxies where this young stellar component is not observed indicates that either they are observed at a later stage and/or they originate from *other type* of mergers.

Thus, the study of the stellar population appears to provide some important clues about the origin of radio galaxies. However, some of the information derived in this way is still quite uncertain and it is important to be able to investigate the origin and evolution of these systems in a complementary way. This can be done through the study of *large-scale* structures of neutral hydrogen around radio galaxies. Indeed, HI has been successfully used to study the fate of the gas in a number of cases where interaction/merger is present. The main advantage of the study of neutral hydrogen is, given the long timescales involved, its capability of retaining old signatures of the merger/accretion. Thus, it can be used to derive key information about the *age, size and type* of the merger and about when the AGN phase takes place compared to the starburst phase.

Neutral hydrogen has recently given interesting results also for “normal” (i.e. not necessarily radio-loud) elliptical galaxies (see (11; 12; 13) and refs therein). Interestingly, a small, but significant, fraction, in particular outside clusters of

Fig. 2. (*Left*) HI total intensity contours of the radio galaxy B2 0648+27 superimposed on to an optical image. (*Right*) Position-velocity plot along the major axis. The HI absorption detected against the unresolved continuum is also indicated.

galaxies, contains a sometimes very large amount of HI (i.e. $M_{\text{HI}} > 10^9 M_{\odot}$ ¹, $M_{\text{HI}}/L_B \sim 0.02$) distributed in very extended (tens of kpc in size, see e.g. Fig. 1), and often kinematically regular, structures (see e.g. (8; 11)). These structures are long-lived (no major star-formation is going on) and, because of their large amount of HI and the large size, they are believed to originate from major mergers between two disk galaxies. In addition to this, the often observed decoupling between the gas and stellar content and kinematics is taken as a further indication of the external origin of the HI in ellipticals (6). One obvious question is whether there is any connection between radio galaxies, these gas-rich “normal” elliptical galaxies and other major mergers (like the ultra-luminous far-IR galaxies, ULIRGs).

2 Large-scale HI structures in radio galaxies: new results

For all these reasons, we have begun a study of *large-scale HI structures* (tens of kpc in size) in and around radio galaxies. The presence of neutral hydrogen around radio galaxies was known only for a handful of objects. With this study we plan not only to increase the known number of cases, but also to reach a more complete statistics of its occurrence in order to compare with the situation for “normal” ellipticals.

In our search for large-scale HI structures in radio galaxies, we have already at least three interesting new detections (Coma A, B2 0648+27 and 3C 433). This is quite remarkable given that so far only two radio galaxies of comparable

¹ For $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $q = 0.0$

radio power (Centaurus A and PKS B1718-649, see (10) for an overview) were known to have large-scale HI. For the first time, some of the large-scale HI structures are detected in absorption against the extended radio lobes.

In the radio galaxy Coma A, $10^9 M_\odot$ of HI was detected in a disk-like structure of at least 60 kpc in diameter in absorption against the radio lobes (see (9)). The structure of the gas disk (and the amount of HI) suggests that a merger occurred, involving at least one large gas-rich galaxy, at least a few times 10^8 yr ago. Another example is the nearby radio galaxy B2 0648+27 where HI both in emission and in absorption has been detected (10). In emission, we detect a very large amount of HI ($M_{\text{HI}} = 1.1 \cdot 10^{10} M_\odot$) distributed in a very extended disk, or ring-like structure, of about 160 kpc in size as shown in Fig. 2 (10). We also detect HI absorption against the central radio continuum component. The characteristics of the detected HI and the similarities with some of the “normal” elliptical mentioned above, are explained as the result of a major merger event that is likely to have occurred $\lesssim 10^9$ yr ago.

Extended HI in absorption against the radio lobes has been observed also in 3C 433. In this radio galaxy (Fig. 3), the preliminary analysis of the data shows that $\sim 5 \times 10^8 M_\odot$ of (extended) HI is detected at about 60 kpc from the radio core. The gas shows a velocity gradient, but at the moment it is not clear whether the detected HI is part of an extended gas disk/tail or whether it corresponds to a region of interaction between the ISM and the radio lobe. Given the lower amount of HI detected so far in this object, the origin of this galaxy might be different from the major-merger suggested in the two previous cases. Finally, it is important to notice that both B2 0648+27 and 3C 433 have a clear young stellar population component visible in their optical spectra. The final goal will be to compare the information obtained from the HI data and those obtained from the stellar population.

3 Can we use the HI to define an evolutionary sequence?

For B2 0648+27 we have attempted, using the information obtained from the HI, to include this object in an evolutionary sequence, partly already proposed for other gas-rich systems (see e.g. (4)). This could provide a possible scenario for the origin of at least some radio galaxies.

The sequence, depicted in Fig. 5, begins with systems like The Antennae (left) as representative of an ongoing merger where two galaxies are still identifiable and where a starburst is occurring. 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 (4). 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. The 3rd stage with AGN activity is represented in the sequence by B2 0648+27. From

Fig. 3. The preliminary total intensity image (black contours) of the HI absorption in 3C433, with superimposed the radio continuum (grey contours) and the optical image (grey scale). In the middle, is shown the position-velocity plot taken along the line marked on the left image and on the right the HI profile of the peak absorption (the velocities are in radio definition).

the time-scale derived both from the HI and from the stellar population, (and given the shorter time-scale of the AGN phase compared to mergers) the AGN activity must occur at a late stage of the merger while a young stellar population is still observable in the optical spectrum. The final stage (NGC 5266; 4th panel), shows a galaxy that has become a genuine early-type galaxy (8). In NGC 5266 the HI is falling back from the large tidal tails to the galaxy and is in the process of forming a large disk or ring-like structure of low surface density. Star formation is occurring at a much reduced rate and no AGN is detected.

This is, of course, likely to be an oversimplified scenario as a number of other “free parameters” are also playing a role. For example, the genesis of the merger depends also on the type of encounter (e.g. prograde vs retrograde) and the relative size of the two galaxies is making the story more complicated. The environment is also likely to play a very important role.

4 Implication for nearby and high- z radio galaxies

The initial results obtained in the study of extended structures of neutral hydrogen in and around radio galaxies indicate that these structures may actually be more common than thought so far. Thus, the HI can be used to study the likely origin of these systems and the time scales involved. Two of the three galaxies described above show a young stellar population components. The parameters obtained from the study of the optical continuum and from the HI can be therefore complementary in order to obtain a full picture. It is important to note that galaxies with a young stellar population appear to be the best candidates for detecting HI. This may further support the idea that they come from particularly gas-rich mergers or they are mergers that occurred recently.

Fig. 4. Possible evolutionary sequence linking gas-rich mergers with radio galaxies and gas-rich ellipticals. The contours represent the total HI superimposed to the optical image. The images of the Antennas and NGC 7252 have been taken from (4), B2 0648+27 from (10), NGC 5266 from the data presented in (8).

Finally, an important connection is between nearby and high- z galaxies. Although interactions and mergers are likely to occur more frequently and more efficiently at high redshifts, in the HI-rich, low redshift radio galaxies we may witness similar phenomena. Particularly relevant is the finding ((15) and Villar-Martín these Proceedings) of a low surface brightness Ly α halo with quiescent kinematics in the case of the high- z radio galaxy USS 0828+193. One possible way suggested to explain this structure is that the low surface brightness Ly α halo is the progenitor of the HI discs found in low redshift galaxies.

If this is the case, the wealth of details that we can learn at low- z may be crucial for understanding the structures at high- z .

References

- [1] Barnes J.E. 2002, MNRAS 333, 481
- [2] Heckman T.M. et al. 1986 ApJ, 311, 526
- [3] Hibbard J.E. 1995, PhD Thesis Columbia University
- [4] Hibbard J.E. & van Gorkom J.H. 1996, AJ 111, 655
- [5] Hibbard J.E. et al., 2002 in "Gas & Galaxy Evolution", J.E. Hibbard et al. (eds.), Vol. 240, also available at <http://www.nrao.edu/astrores/HIrogues/>
- [6] Knapp G.R., Turner E.L., Cuniffe P.E. 1985 AJ 90, 454
- [7] Kormendy J., Sanders D.B. 1992, ApJ 390, L53
- [8] Morganti R. et al., 1997, AJ, 113, 937
- [9] Morganti R. et al. 2002, A&A 387, 830
- [10] Morganti et al. 2002, A&A in press (astro-ph/0212323)
- [11] Oosterloo T.A. et al. 2002, AJ 123, 729
- [12] Oosterloo et al. 2002 in "Gas & Galaxy Evolution", J.E. Hibbard et al. (eds.), Vol. 240, p. 251
- [13] Sadler E.M., Oosterloo T.A., Morganti R., 2002 *The Dynamics, Struc-*

ture & History of Galaxies ASP Conference Series, in press (astro-ph/0205151)

- [14] Tadhunter C.N. et al. 2002, MNRAS 330, 977
- [15] Villar-Martín M. et al. 2002, MNRAS in press (astro-ph/0206118)
- [16] Wills K.A. et al. 2002, MNRAS 333, 211