H I Observations of Compact Groups of Galaxies

Tom Oosterloo
CSIRO, ATNF, PO Box 76, Epping NSW 2121, Australia
toosterl@atnf.csiro.au

Angela Iovino
Osservatorio Astronomico di Brera, via Brera 28, 20121 Milano, Italy
iovino@brera.mi.astro.it

Abstract

We present preliminary results from H I observations of a new sample of compact groups done with the Parkes telescope, as well as from images made with the Australia Telescope Compact Array (ATCA). These observations confirm earlier claims that a significant fraction of compact groups are deficient in H I, and hence that a significant fraction of groups of galaxies that appear compact on the sky are indeed compact systems. The ATCA observations of a very H I-poor group suggest that this group is a true compact system in an advanced stage of evolution. However, the ATCA observations also show that H I-rich groups exist that are genuinely compact.

1 Introduction

Compact groups of galaxies are small, relatively isolated systems of galaxies with the projected separations between the member galaxies comparable to the diameters of these galaxies (Rose 1977; Hickson 1982). These groups belong to the densest systems of galaxies and they may form an interesting link in the merging process which runs from galaxies in loose groups to the resulting merged systems.

The sample used in most recent studies of compact groups is that defined by Hickson (1982). This sample was selected by visually inspecting Palomar Sky plates, but using quantitative selection criteria. This sample contains about 100 groups, distributed over two-thirds of the sky. The compact groups of this sample typically consists of 4-5 galaxies, and the median separation between galaxies is $40(H_\circ/100)^{-1}$ kpc. About 1% of the visible mass in the universe is estimated to be in such groups. The typical three-dimensional velocity dispersion of a compact group is about 300 $\mathrm{km\,s^{-1}}$, implying that they contain dark matter ($M/L \sim 50(H_\circ/100)$).

Extensive work, both theoretical and observational, has been done on compact groups in the last 15 years, but there is still controversy and debate over their true nature. The crossing time of a typical compact group is only of order 1% of a Hubble time. This means that the galaxies in these groups must merge on a short timescale. In principle, this would fit within the framework of hierarchical formation of structure in the universe: compact groups merge to form elliptical galaxies, while they are replenished by loose groups of galaxies that become more tightly bound. However, it still has to be demonstrated that the required rates follow from realistic initial conditions. The formation rates of elliptical galaxies and compact groups depend on cosmological parameters (e.g. Ω), and some fine-tuning may be required to reproduce the observed number of compact groups (Ramella *et al.* 1994; Hernquist *et al.* 1995).

However, the observational evidence for these high merging rates in compact groups is not very strong. Interactions between galaxies in compact groups occur, but the observed merging rates appear to be smaller than predicted (e.g. Zepf 1993). Several investigators have suggested that a high fraction of the groups in the Hickson sample are not true compact systems, but instead are chance alignments of either loose groups (e.g. Rose 1979; Mamon 1986) or as the result of a filamentary distribution of galaxies (Hernquist *et al.* 1995).

Considering the implications for our understanding of the formation of structure in the universe, it is important to know what fraction of the groups of galaxies that appear compact on the sky are indeed physically dense systems and how these compact groups evolve.

2 Neutral Hydrogen in Compact Groups

Observations of the neutral hydrogen in compact groups can be very useful for studying the nature of these systems in more detail. Rood and Williams (1987) concluded from single dish observations that many compact groups appear to be poor in neutral hydrogen compared to loose groups of galaxies. Although the mechanism responsible for the H I deficiency is not well understood, because these compact groups have different H I properties compared to loose groups, this could indicate that these groups are genuine compact systems and not projected loose groups. High resolution images of the H I provide a very powerful tool for investigating the dynamical state of compact groups since H I is most sensitive to tidal disturbances. However, such data are available only for very few compact groups (e.g. Williams *et al.* 1991). There appears to be a trend that in less dense compact groups, although there are signs of tidal interactions, the H I is still associated with the individual galaxies, while in very compact systems the H I is spread out over the whole group (Williams *et al.* 1991). However, H I images of more compact groups are needed in order to be able to make a firmer statement about this. High resolution H I observations will also help in understanding the reasons for the H I deficiency observed.

Recently, a new sample of compact groups was constructed through a purely automated search using digitised galaxy catalogues (Iovino *et al. in prep.*). The algorithm used for the extraction incorporates a slightly modified version of the original Hickson criteria, in order to make it more efficient in rejecting chance projections, a problem that gets very serious at fainter magnitudes. The new algorithm has been tested with Monte Carlo simulations and has proved very fast and reliable, while it avoids some of the biases that are present in the Hickson sample (Prandoni *et al.* 1994; Iovino *et al. in prep.*). To further study the properties of compact groups and to address some of the questions raised above, we have started a program to observe compact groups from this new catalogue. Here we report on H I observations of a first sub-set of this new sample.

2.1 Parkes Observations

To start our observational program, we have observed a first sub-sample of 14 compact groups with the Parkes radio telescope. The aims of these observations were to study the H I content of these groups and to select candidates for observing with the Australia Telescope Compact Array (ATCA). To study the H I content, we do a similar analysis as done by Rood and Williams (1987). In Figure 1 we show the histogram of the H I deficiency, x, for compact groups from the Hickson sample and for the compact groups observed by us. The H I deficiency is here defined as $x \equiv \log(M_{\rm HI,obs}/M_{\rm HI,pred})$, where $M_{\rm HI,obs}$ is the observed neutral hydrogen mass of a group and

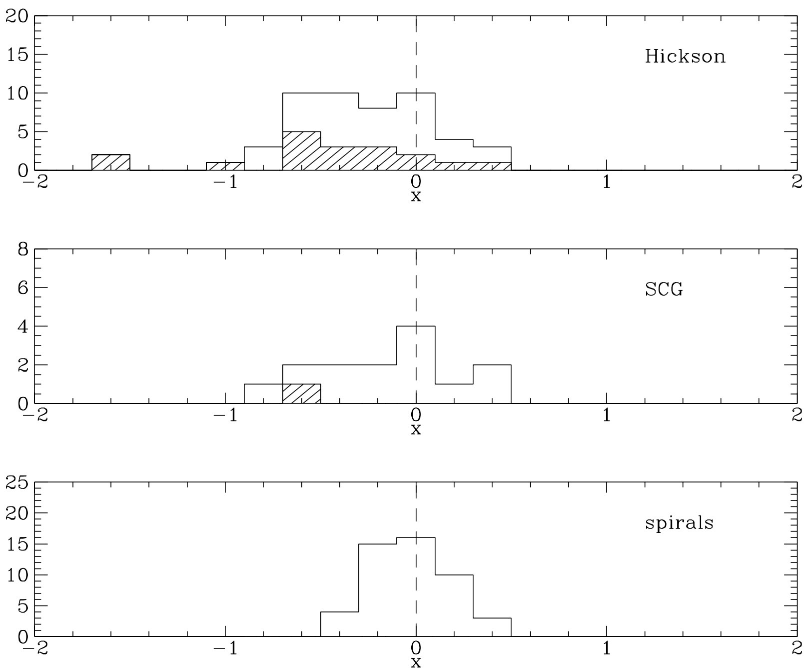

Figure 1: *top:* Histogram of the deficiency of neutral hydrogen, x, in Hickson groups. The shaded area indicates the fraction of upper limits to x. *middle:* as above, but for compact groups observed at Parkes. *bottom:* as above, but for a control sample of field spirals

$M_{\mathrm{HI,pred}}$ is the predicted neutral hydrogen mass for the same group. The predicted H I mass of a group is the sum of the predictions for the galaxies in the group. For spiral galaxies we use the diameter to predict the H I (Roberts & Haynes 1994), while for early type galaxies we assume that they have no H I.

For the Hickson groups we have used the H I data from Rood and Williams (1987), but we have redone their analysis since better optical images are now available for morphological classification (Hickson *et al.* 1989), as well as complete redshift information for the galaxies in Hickson groups (Hickson *et al.* 1992), although the overall conclusion about the H I content of Hickson groups remains the same. For comparison, we also give the histogram of x for a small sample of field spirals (data taken from Broeils 1992). A Kolmogorov-Smirnov (KS) test (using the upper limits as detections) gives that the distribution of x for the Hickson groups differs from that of the field sample at a level $< 0.1\%$.

Figure 1 shows that the distribution of x has a tail towards negative values, both for the Hickson sample (as expected) and for the 14 groups observed at Parkes. Although a KS test gives that the distribution of x for our sample of compact groups differs from that of the field sample only at the 15% level, also in our new sample there are a few compact groups that are deficient in H I. It can also be seen from Figure 1 that quite a large fraction of compact groups have normal H I content. It is tempting to identify the H I-poor compact groups as the true compact systems. If we do this, this would mean that about a third of the groups studied are true compact systems. But, as we will see below, the situation is somewhat more complicated.

2.2 ATCA Observations

¿From the 14 compact groups observed with the Parkes telescope, we have observed 7 with the ATCA. In Figure 2 we show the total H I maps of two of these groups. The compact group on

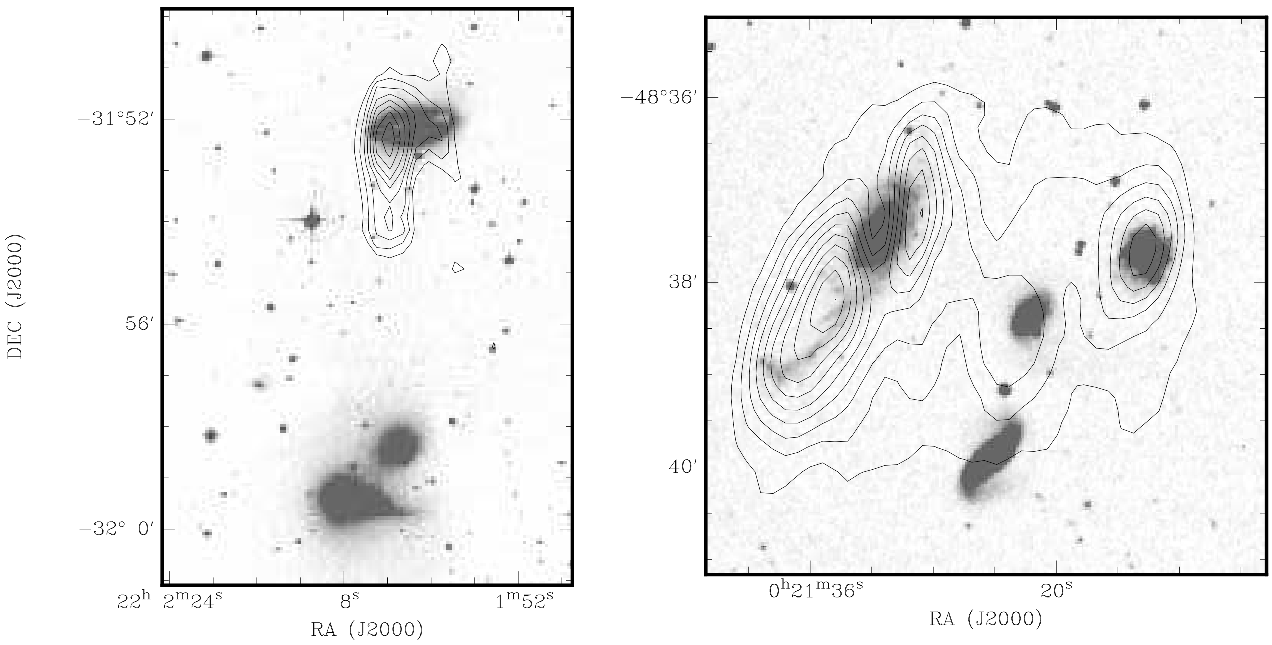

Figure 2: Total H I map (contours) superposed on an optical image for two of the compact groups observed with ATCA. The group shown on the left is also part of the Hickson sample (HCG 90). The depression in the H I of the largest galaxy in the panel on the right is due to absorption against the central continuum source of this galaxy

the left in Figure 2 is the group that is most deficient in H I as found in the Parkes observations. H I is only detected in one of the galaxies and the morphology of the H I suggest a strong tidal interaction. Interestingly, a deep optical image of this group shows that the galaxies in this group have a common envelope (D. Malin *priv. comm.*). This suggests that this group is a real compact system and that it is in a quite advanced stage of evolution. Observations with SEST (Oosterloo & van Moorsel *in prep.*) reveal that CO is not only present in the galaxy we also detect in H I, but also in the southern galaxy in the group. So this southern galaxy appears to be a galaxy that originally was gas rich, but now has lost most of its neutral hydrogen. This is the first example where we can study the H I deficiency in compact groups in much more detail and these observations will help in understanding the mechanisms responsible for the H I deficiency observed in some compact groups. These observations also lend support to the idea the H I deficiency observed in some compact groups could mean that these groups, like the group in Figure 2, are indeed genuine compact systems.

The group on the right in Figure 2 is a compact group that is *rich* in H I. The interesting feature here is that a significant fraction of the H I is not associated with the galaxies, but instead appears to form a common envelope. This indicates that also this group is very likely a physically compact system. This is also suggested by the morphology of the galaxies, as well as by the fact that one of the galaxies has a relatively strong continuum source in the centre. The observations of this group show that it is not correct to identify only the compact groups that are H I poor with the true compact systems, but that a genuine compact group can also be rich in H I.

In the remaining 5 compact groups observed with ATCA, the morphology of the H I suggests interactions occur in 2 more groups, while in 3 groups the H I does not indicate that the galaxies in these groups are particularly disturbed by interactions.

3 Conclusions

We have started a project to study the properties of the neutral hydrogen for a new sample of compact groups of galaxies. Parkes observations of a first sub-sample confirm earlier observations that a significant fraction of compact groups are poor in H I, suggesting that at least a third of the groups that appear compact on the sky, are in fact true compact systems. ATCA observations of some of these groups suggest that a low H I content of a compact group does indeed indicate that this group is a compact system, possibly in an advanced stage of evolution. However, the ATCA observations also show that H I-rich groups exist that are likely to be true compact systems. We conclude that a significant fraction of the groups that are selected as compact groups are genuine compact systems. This high number of true compact groups provides an important constraint on the models for the formation of structure in the universe.

References

Broeils A.H., 1992, PhD thesis, Rijkuniversiteit Groningen
Hernquist L., Katz N. & Weinberg D.H., 1995, ApJ, 442, 57
Hickson P., 1982, ApJ, 255, 382
Hickson P., Auman J.R. & Kindl E., 1989, ApJS, 70, 687
Hickson P., De Oliveira C.M., Huchra J.P. & Palumbo G.G., 1992, ApJ, 399, 353
Mamon, G.A., 1986, ApJ, 307, 426
Prandoni I., Iovino A. & MacGillivray H.T., 1994, AJ, 107, 1235
Ramella M., Diaferio A., Geller M.J. & Huchra J.P., 1994, AJ, 107, 1623
Roberts M.S. & Haynes M.P., 1994, ARA&A, 32, 115
Rood H.J. & Williams B.A., 1987, ApJS, 63, 265
Rose J.A., 1977, ApJ, 211, 311
Rose J.A., 1979, ApJ, 231, 10
Williams B.A., McMahon P.M. & van Gorkom J.H., 1991, AJ, 101, 1957
Zepf S.E., 1993, ApJ, 407, 448