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HI in Early-Type Galaxies

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Abstract.
We briefly discuss the main differences between the H I properties of luminous and low-luminosity early-type galaxies. In luminous early-type galaxies the H I is often irregularly distributed, but in a few cases regular H I disks, of low surface density, are seen. In low-luminosity galaxies, the H I is more often in a disk with high central surface densities. This suggests a different evolution of the gas in these two groups of galaxies.

1. Introduction

Early-type galaxies are generally considered gas poor, but this does not mean that gas is not important for the evolution of these galaxies. Many early-type galaxies, in particular those in the field, do have a long-lived cool interstellar medium, one that is often very similar to that in spiral galaxies. The main difference is that they galaxies have less of it, typically 1-10% compared to what is present in spirals (e.g. Knapp 1999).

Gas content is one of the key elements for understanding the formation and evolution of galaxies. Early-type galaxies constitute quite a heterogeneous group of galaxies. Several of their properties (e.g. stellar rotation, isophotal shape, core properties, ionization characteristics of the ionized gas, star formation history) vary systematically with luminosity and environment. These differences can be partly explained by different amounts of gas present in the formation/evolution. In models for galaxy formation the gas supply is a key factor. To help in understanding the mechanisms and processes behind these systematic differences, it may be worthwhile to study the properties of the neutral hydrogen in early-type galaxies and in particular whether there are systematic differences of the H I properties as function of luminosity and environment.

A few dozen H I data cubes are available now of early-type galaxies, most of them obtained by Van Gorkom and collaborators with the VLA and by us using the Australia Telescope Compact Array, and we will briefly discuss some of the systematics of the H I properties of early-type galaxies.

2. Origin

One key question is "where does the H I come from?". It is generally thought that the H I is due to a recent accretion/merger event. But is this the whole story? If one considers the H I detection rates (e.g. Bregman et al. 1992), one does indeed see that early-type galaxies that, based on their optical morphology, are classified as peculiar, are more often detected than "normal" early-type galaxies. This does indicate that accretion/merging is an important factor. But the statistics also indicate that those early-type galaxies that show some indications for the presence of a (usually small) disk component are more likely to be detected in H I (e.g. Hogg et al. 1993). This suggests that a subgroup of early-type galaxies has regular H I structures. A third factor is also the environment, although there are no good statistics available in order to be able to quantify this.

3. Luminous early-type galaxies

The range in H I morphology in the luminous galaxies ($M_B < -19$) is much broader than that seen in low-luminosity galaxies. In most luminous galaxies the H I shows an irregular morphology, consistent with the idea that the gas is accreting onto the galaxy, or is left over from a recent merger event. Often, these galaxies are found in small groups.

However, as suggested by the detection statistics, there are a few luminous galaxies known that have very regular H I. An example is NGC 807. This galaxy is classified as E4 in the RC3, but is rich in H I. The H I is very extended (going out to several tens of kpc), and shows very regular kinematics. Figure 1a shows the position-velocity plot of the H I along the major axis obtained by us from archival VLA data (Dressel et al.). Another example is NGC 3108 (observed by us with the ATCA and the VLA). Also this galaxy has a H I disk of several tens of kpc in radius. Figure 1b shows the position-velocity map of the H I along the major axis. The H I disk in NGC 3108 has a central hole. Interestingly, this hole is filled up with ionized gas that has the same kinematics as the H I. These data show that the H I in these galaxies is in a regularly rotating disk, that is basically the same as disks in spiral galaxies (including the flat rotation curves). In fact, if one would not know the optical morphology, it would be very difficult to tell from the H I data alone that these are early-type galaxies.

What distinguishes these H I disks from those seen in spiral galaxies is that the surface density of the H I is much lower. The peak surface density is usually below 2 $M_\odot$ pc^{-2} and often the H I distribution has a central hole. These low surface densities imply that no large-scale star formation is occurring and the H I disk will evolve very slowly. At most a very faint optical counterpart to the H I disk will form. Some of these galaxies could perhaps be considered as extremely early-type spirals where the characteristics of the H I are such that an optical disk failed to form from the H I disk ("disk-less disk galaxies").

However, the presence of the H I in these galaxies may still be connected to merging/accretion to some extent. For example, NGC 5266 (Morganti et al. 1997) is a minor-axis dust-lane elliptical with a large amount of H I ($M_{\rm HI}/L_B \sim$ 0.2). Almost all the H I is in a disk-like structure, with more or less regular kinematics, parallel to the optical major axis. However, in the centre, a small

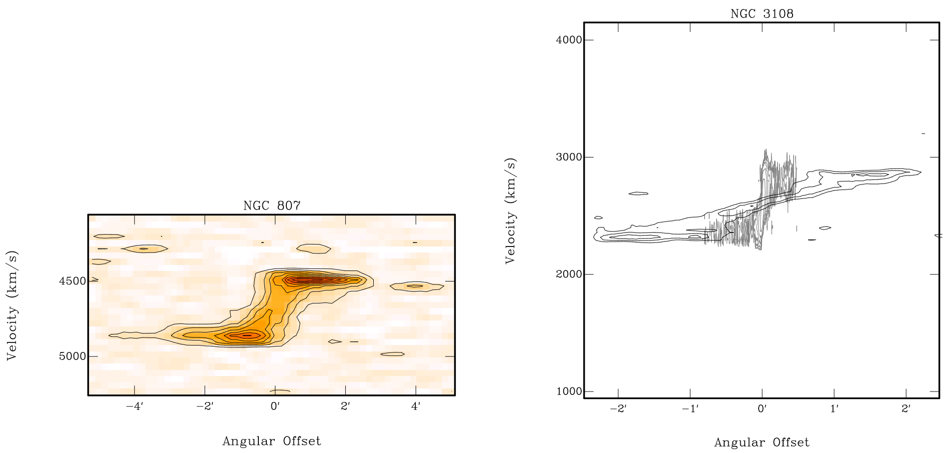

Figure 1. *left:* Position-velocity map along the major axis of the E4 galaxy NGC 807. *right:* Position-velocity map taken along the major axis of NGC 3108. Black contours show the kinematics of the H I, the grey contours near the centre that of Hα

fraction of the H I is rotating parallel to the *minor* axis and is coincident with the minor-axis dust lane. Faint traces of H I connecting the two H I structures are also seen. Most likely, NGC 5266 is a system where a large amount of H I has been accreted a relatively long time ago and most of the H I has been able to settle in a disk. Perhaps NGC 5266 is an example of the scenario suggested by Hibbard and van Gorkom (1996) that during a merger of gas-rich galaxies, a large fraction of the H I can be transported to large radii as tidal tails, while at a later stage this gas falls back to form a disk. This would suggest that (some of the) early-type galaxies with regular gas disks are very old merger remnants.

4. Low-luminosity early-type galaxies

In low-luminosity early-type galaxies the situation is quite opposite to that in luminous galaxies. Almost without exception, in low-luminosity early-type galaxies the H I is in a disk with regular morphology and kinematics. In a way, low-luminosity early-type galaxies are also disky in H I. In most low-luminosity galaxies there is no evidence from the kinematics that a recent accretion has occurred. This points to a different accretion history of the H I. As an example, in figure 3 we give the total H I image and the position-velocity map of the galaxy NGC 2328 ($M_B \simeq -18$). The H I in this galaxy is in a nicely rotating disk, aligned with the optical body.

Only in some galaxies there is some kinematics evidence that (part of) the H I may have been accreted recently. For example, in the galaxies NGC 802 (Sadler et al. 2000) and NGC 855 (Walsh et al. 1990), part of the H I is in a polar ring-like structure.

Another characteristic is that in low-luminosity galaxies the H I is very centrally concentrated and that the central surface densities are much higher

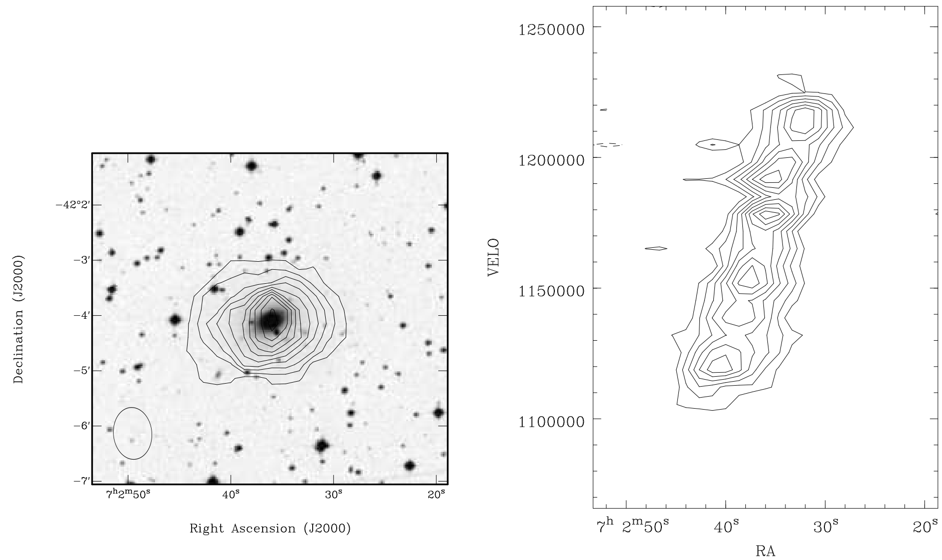

Figure 2. *left:* Total H I image of NGC 2328 as obtained with ATCA. The optical image is taken from the Digital Sky Survey. *right:* Position-velocity map taken along the major axis of NGC 2328

that in luminous early-type galaxies. The central surface densities observed are typically 6 $M_\odot$ pc^{-2} or higher and significant star formation is occurring in the central regions. In fact, these galaxies follow the radio-FIR correlation observed for spiral galaxies, suggesting that the conditions in the central regions are not too different from those in spiral galaxies.

5. Conclusions

Systematics differences are observed between the H I properties of luminous early-type galaxies and those of low-luminosity early-type galaxies. These differences are likely to be connected to systematics differences between the two classes of galaxies seen at other wavelengths and could point to differences in accretion history of the gas and evolution.

References

Bregman, J.N., Hogg, D.E., Roberts, M.S. 1992, ApJ, 387, 484

Hibbard, J. E., van Gorkom, J. H. 1996, AJ, 111, 655

Hogg, D.E., Roberts, M.S., Sandage, A. 1993, AJ, 106, 907

Knapp, G., 1999, in Star Formation in Early-Type Galaxies, eds. P. Carral and J. Cepa, ASP Conf. Proc. 163, 119

Morganti, R., Sadler, E., Oosterloo, T., Pizzella, A., Bertola, F., 1997, AJ, 113, 937

Sadler, E.M., Oosterloo, T.A., Morganti, R, Karakas, A. 2000, AJ, 119, 1180

Walsh, D.E.P., Van Gorkom, J.H., Bies, W.E., Katz, N., Knapp, G.R., Wallington, S. 1990, ApJ, 352, 532