HI gas disks in elliptical galaxies

Elaine M. Sadler
School of Physics, University of Sydney, NSW 2006, Australia

Tom Oosterloo and Raffaella Morganti
NFRA, Postbus 2, 9700AA Dwingeloo, The Netherlands

Abstract. We discuss a class of low–luminosity E/S0 galaxies which have both HI disks and (in contrast to more luminous E/S0s with HI) ongoing star formation. We suggest that such objects are common, but that only a few are known at present because optical magnitude–limited galaxy catalogues are biased against them. The HI Parkes All–Sky Survey (HIPASS) should eventually detect many more. We suggest that ‘boxy’ and ‘disky’ ellipticals are distinct not only in their structure and kinematics, but in their star–formation history.

1. Introduction

Twenty years ago, it might have been surprising to see elliptical galaxies featured at a conference on “Galaxy Disks and Disk Galaxies”. Now, however, it is generally accepted that many elliptical galaxies have stellar and/or gaseous disks. Intermediate–luminosity ellipticals often show ‘disky’ isophotes and/or rapid stellar rotation suggesting the presence of an inner stellar disk (e.g. Bender et al. 1988; Rix & White 1990). Extended disks of gas and dust are often seen around giant ellipticals (e.g. Knapp et al. 1985; Sadler & Gerhard 1986), and are usually ascribed to a recent accretion event or merger. Small central disks of ionized gas are also common in elliptical and S0 galaxies (e.g. Phillips et al. 1986; Buson et al. 1993).

The existence of these disks has implications for our ideas about how early–type galaxies form and evolve. There is no clear photometric boundary between the E and S0 classes (e.g. van den Bergh 1989), and it has been suggested that ‘disky’ ellipticals form a continuous photometric sequence with S0s and spiral bulges and may have a different formation mechanism from the (generally more massive) ‘boxy’ ellipticals (Capaccioli et al. 1990; Kormendy & Bender 1996).

For the past few years, we (and others) have been working to obtain high–quality HI images for a larger sample of early–type galaxies in order to learn more about the relationship between gas content, galaxy evolution, environment and the triggering of an active nucleus. Jacqueline van Gorkom (this meeting) has reviewed what we now know about the HI structure and kinematics in early–type galaxies. In this paper, we focus on two topics — star formation in the HI disks of low luminosity ellipticals, and the likely impact of the HI Parkes All–Sky Survey (HIPASS) on HI studies of early–type galaxies. In the discussion which
follows, we assume $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, and that a ‘low–luminosity’ galaxy has $M_B > -20$ mag.

2. HI disks and star formation in low–luminosity early–type galaxies

Lake & Schommer (1984) first showed that HI was common in low–luminosity E/S0 galaxies, detecting 11/28 such systems (39%) in their HI survey at Arecibo. Four of these galaxies were later imaged with the VLA and shown to have regular velocity fields (Lake et al. 1987). At about the same time, Phillips et al. (1986) found HII region–like emission line ratios in the spectra of 5/18 low–luminosity E/S0s (28%), implying that these galaxies are currently forming massive stars. In contrast, none of the $\sim 200$ luminous E/S0s observed by Phillips et al. showed evidence for the presence of HII regions.

Luminosity functions (e.g. Binggeli et al. 1988) show that low–luminosity E/S0 galaxies are more common than luminous ones in terms of their space density, yet they remain less well–studied because optical galaxy catalogues are strongly biased towards optically–luminous galaxies. Many of the low–luminosity galaxies which have been studied lie in clusters (because they are easier to find there) and may not be typical of the field population.

Sadler et al. (2000) studied the HI distribution and kinematics in four low–luminosity field E/S0 galaxies shown by Phillips et al. (1986) to have HII region–like optical emission–line spectra. The HI typically extended to 2–3 times the optical radius (see Figure 1), and the velocity fields were characteristic of settled disks with regular rotation. In two of the four galaxies the HI rotation axis was misaligned with the photometric axis of the optical galaxy. In all four galaxies the HI was very centrally concentrated, in contrast to early–type spiral bulges and luminous ellipticals which often show central HI holes.

Table 1 shows the current star–formation rate (SFR) for the four galaxies studied by Sadler et al. (2000), derived from the H$\alpha$ emission–line flux. Optical images and spectroscopy show that massive star formation in these galaxies takes place in the central 0.5–1.0 kpc, where the HI surface density is highest. Thus the bulk of star formation is concealed within the central bulge of these
HI disks in ellipticals

Table 1. Gas content, star–formation rates and gas–depletion times in four low–luminosity E/S0 galaxies

| Galaxy    | $M_B$ (mag) | SFR (M$_\odot$/yr) | HI mass (M$_\odot$) | M(HI)/L$_B$ | HI depletion time (yr) |
|-----------|-------------|---------------------|---------------------|-------------|------------------------|
| NGC 802   | −18.0       | 0.02                | $7.6 \times 10^8$   | 0.42        | $7 \times 10^{10}$     |
| ESO 027–G21 | −19.9      | 0.07                | $4.7 \times 10^8$   | 0.40        | $8 \times 10^{10}$     |
| ESO 118–G34 | −17.9      | 0.29                | $2.5 \times 10^8$   | 0.12        | $7 \times 10^8$        |
| NGC 2328  | −18.7       | 0.41                | $2.0 \times 10^8$   | 0.07        | $2 \times 10^9$        |

3. Finding gas–rich early–type galaxies with HIPASS

HIPASS (Barnes et al. 2000) is an HI imaging survey of the entire southern sky ($\delta < 0^\circ$, but now being extended further north) carried out with a 13–beam receiver on the 64 m Parkes radiotelescope. HIPASS spectra cover the velocity range $−1280$ to $+12,700$ km s$^{-1}$.

A preliminary examination (Sadler 2000) of HIPASS spectra of $≈ 2500$ bright early–type galaxies finds an HI detection rate of at least 5% for ellipticals and 12% for S0 galaxies catalogued in the RC3 (de Vaucouleurs et al. 1991). The detection rate is significantly higher for low–luminosity E and S0 galaxies than for more luminous ones ($22 \pm 5\%$ for early–type galaxies with $−18 > M_B > −20$, versus $10 \pm 2\%$ for those with $M_B < −20$), though the RC3 contains relatively
few low–luminosity galaxies. However, automated galaxy finders will eventually
detect many more uncatalogued galaxies in the HIPASS data cubes.

Predictions based on the optical luminosity function of E/S0 galaxies and
the observed HI detection rate (Sadler 1997) suggest that as many as 100–150
uncatalogued HIPASS detections will be low–luminosity E/S0 galaxies with
apparent magnitudes in the range B=15–18. This will provide a data set large
enough to derive a reliable HI mass function for nearby E and S0 galaxies, and
to explore in detail the effects of both luminosity and environment on the HI
content of early–type galaxies.

4. Conclusions

Luminous (‘boxy’) and low–luminosity (‘disky’) ellipticals appear to differ not
only in their structure and kinematics, but in their HI content and star–formation
history. HI gas disks are much more common in low–luminosity ellipticals than
in high–luminosity ones, and the HI disks in low–luminosity ellipticals commonly
support a modest level of ongoing massive star formation, which is not seen in
the giant ellipticals. This implies that low–luminosity ellipticals form much more
slowly than giant ellipticals, and in many cases are still forming stars today.

References

Barnes, D.G. et al. 2000, MNRAS, in press
Bender, R., Döbereiner, S., & Möllenhof, C. 1988, A&AS, 74, 385
Binggeli, B., Sandage, A. & Tammann, G.A. 1988, ARA&A, 26, 509
Buson, L.M., Sadler, E.M., Zeilinger, W.W., Bertin, G., Bertola, F., Danziger,
J., Dejonghe, H., Saglia, R.P., & de Zeeuw, P.T. 1993, A&A, 280, 409
Capaccioli, M., Caon, N., & Rampazzo, R. 1990, MNRAS, 24P
de Vaucouleurs, G. et al. 1991, ‘Third Reference Catalogue of Bright Galaxies’,
Springer–Verlag
Knapp, G.R., Turner, E.L., & Cunniffe, P.E. 1985, AJ, 90, 454
Kormendy, J. & Bender, R. 1996, ApJ, 464, L119
Lake, G., & Schommer, R.A. 1984, ApJ, 280, 107
Lake, G., Schommer, R.A., & van Gorkom, J.H. 1987, ApJ, 314, 57
Phillips, M.M., Jenkins, C.R., Dopita, M.A., Sadler, E.M., & Binette, L. 1986,
AJ, 91, 1062
Rix, H.-W. & White, S.D.M. 1990, ApJ, 362, 52
Sadler, E.M. & Gerhard, O.E. 1986, MNRAS, 214, 177
Sadler, E.M. 1997, PASA, 14, 45
Sadler, E.M., Oosterloo, T.A., Morganti, R., & Karakas, A. 2000, AJ, 119, 1180
Sadler, E.M. 2000, in ‘Gas and Galaxy Evolution’, ed. J.E. Hibbard, M.P. Rupen
& J.H. van Gorkom, ASP Conf. Series, in press
Searle, L., Sargent, W.L.W. & Bagnumo, W.G. 1973, ApJ, 179, 427
van den Bergh, S., 1989, PASP, 101, 1072