Galaxy Disks and Disk Galaxies ASP Conference Series, Vol. 3×10^8 , 2000 J.G. Funes, S.J., and E.M. Corsini, eds.

HI gas disks in elliptical galaxies

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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



Figure 1. Total HI contours overlaid on the optical images of two small E/S0 galaxies: (left) NGC 802 and (right) NGC 2328

follows, we assume H_{\circ} =50 km s⁻¹ Mpc⁻¹, and that a 'low–luminosity' galaxy has $M_{\rm B} > -20$ 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 ~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 α 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

Galaxy	M _B	SFR	HI mass	M(HI)	HI depletion
	(mag)	$({ m M}_{\odot}/{ m yr})$	$({ m M}_{\odot})$	$/L_{B}$	time (yr)
NGC 802	-18.0	0.02	7.6×10^{8}	0.42	7×10^{10}
$\mathrm{ESO}027\mathrm{-}\mathrm{G21}$	-19.9	0.07	4.7×10^{9}	0.40	8×10^{10}
ESO 118-G34	-17.9	0.29	2.5×10^{8}	0.12	7×10^{8}
$\operatorname{NGC}2328$	-18.7	0.41	$2.0{ imes}10^8$	0.07	2×10^9

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

galaxies. The star-formation rates in Table 1 are low compared to those in spiral disks (e.g. around 4 M_{\odot}/yr in the Galaxy), and the currently-available gas supply could sustain the current rate of star formation for many Gyr. The UBV colours of the galaxies in Table 1 can be fitted by stellar-population models with a slowly-declining star-formation rate S $\propto e^{-t}$ (Searle et al. 1973), i.e. intermediate between the giant ellipticals (S $\propto e^{-10t}$ and late-type spiral disks (S \sim constant). Thus all the data so far are consistent with a picture in which these low-luminosity E/S0 galaxies have been forming stars at a slowly-declining rate over a Hubble time. If so, it appears that bulges can be built up slowly over time, and that low-luminosity early-type galaxies may have a very different star-formation history from the giant ellipticals.

However, we are far from having a complete understanding of the evolutionary history of low–luminosity E/S0 galaxies. It is still unclear whether the HI commonly seen in these galaxies is mainly primordial, or whether in some cases at least it has been accreted later on (as the misalignment of HI rotation axes and optical photometric axes might indicate). It is also unclear exactly what triggers star formation, as the current star formation rate does not correlate in any simple way with HI surface density (though stars do seem to form where the HI density is highest). To shed some light on these questions, we would like to have a larger sample of galaxies to study (so that, for example, we could compare the distribution of $M(HI)/L_B$ with that seen in giant ellipticals). Fortunately, the recently–completed HI Parkes All–Sky Survey (HIPASS) offers the possibility of doing this in the near future.

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 ($22\pm5\%$ for early-type galaxies with $-18 > M_B > -20$, versus $10\pm2\%$ 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/SO 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.

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