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H I in Elliptical Galaxies

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Abstract: Traditional H I surveys of optically selected elliptical galaxies are time-consuming, and have a low detection rate. The forthcoming Parkes H I multibeam survey offers the exciting possibility of surveying more than 10,000 nearby elliptical galaxies for H I. I argue that this is likely to result in the detection of a large population of small, H I-rich elliptical galaxies which have not previously been studied in any systematic way.

Keywords: galaxies; interstellar matter — galaxies: elliptical — radio sources: 21 cm radiation

1 Introduction

Although the H I content of elliptical galaxies is generally much lower than that of spirals (e.g. Bregman et al. 1992), some ellipticals do contain detectable amounts of neutral hydrogen. Studying the H I distribution and kinematics in these galaxies is interesting for several reasons—it provides the most straightforward and reliable tracer of the mass distribution in the outermost regions of elliptical galaxies, and it can also tell us something about their evolutionary history (since in many cases H I, where present, appears to have been accreted from outside the galaxy; Knapp, Turner & Cunniffe 1985).

2 Large and Small Elliptical Galaxies

Figure 1 shows the local optical luminosity function for elliptical and S0 galaxies (Sadler 1982). Although galaxies with (B band) absolute magnitudes fainter than $M_{\rm B} = -18$ (for $H_0 = 100\ {\rm km\,s^{-1}\,Mpc^{-1}}$) make up only about 10% of most optically-selected samples of elliptical galaxies, their true space density is higher than that of the giant ellipticals.

Several properties of elliptical galaxies appear to change at an absolute magnitude around $M_{\rm B} \sim -18\cdot5$. Large elliptical galaxies (defined here as those with $M_{\rm B}$ brighter than -19) are usually dominated by an old stellar population (e.g. Bressan, Chiosi & Tantalo 1996), and have most of their gas in a hot X ray corona (Forman, Jones & Tucker 1985; Canizares, Fabbiano & Trinchieri 1987). Small elliptical galaxies[1] ($M_{\rm B}$ fainter than -18) are less well studied, partly because they are severely under-represented in magnitude-limited galaxy catalogues, but there are strong hints that many of them contain significant amounts of H I (Lake & Schommer 1984) and are still forming stars (Phillips et al. 1986). There are other differences too—active nuclei are common in the large ellipticals and rare or non-existent in the small ones (e.g. Sadler & Slee 1994); and most large ellipticals have little or no stellar rotation, while many small ones are rotationally flattened (Davies et al. 1983). Since there are many qualitative differences between large and small ellipticals, it is intriguing that their photometric properties define a continuous family. It is usually impossible to tell, based on the light profile alone, whether an individual elliptical galaxy is distant and luminous or nearby and small.

[1] Throughout this paper, 'small ellipticals' are galaxies with surface brightnesses similar to those of the giant ellipticals, i.e. Kormendy's (1985) high-surface-brightness ellipticals, not low-surface-brightness dwarfs.

3 H I in Small Elliptical Galaxies

It has been known for more than a decade that many small elliptical galaxies contain H I. Lake & Schommer (1984) detected 11 (39%) of a sample of 28 low-luminosity elliptical galaxies observed at Arecibo, and suggested that H I was common in these galaxies.

Phillips et al. (1986) found that 5/18 (28%) of the low-luminosity ($M_{\rm B}$ fainter than -18) elliptical and S0 galaxies in their optical emission-line survey had optical spectra characteristic of H II regions. Since these galaxies are currently forming massive stars, they must contain reasonable amounts of cold gas. Parkes H I observations of four of the Phillips et al. (1986) 'star-forming ellipticals' (Sadler & Whiteoak, unpublished) detected all of them, with typical H I masses of a few times $10^8\ M_\odot$.

In summary, the rather sparse data available so far suggest that at least 30% of 'small' elliptical galaxies contain detectable amounts of H I. If so, small H I-rich elliptical galaxies are common objects. They are nevertheless surprisingly hard to find

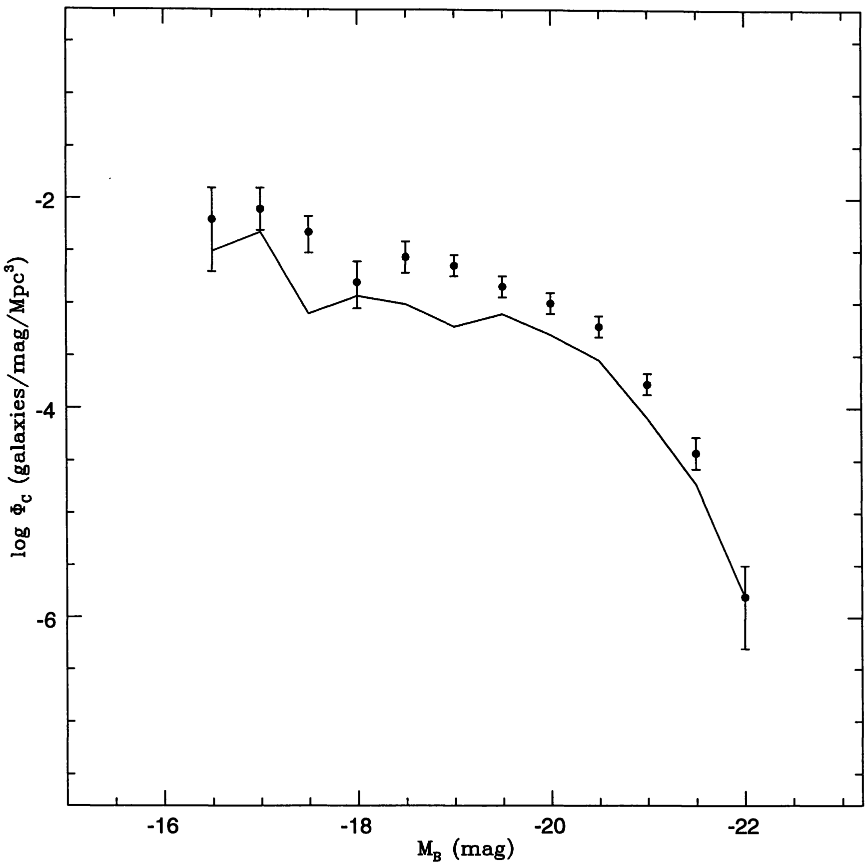

Figure 1—The local optical luminosity function for a combined sample of elliptical and S0 galaxies (points), and for elliptical galaxies alone (solid line). Since elliptical galaxies with dust lanes or other 'peculiar' features are often classified as S0s, the true space density of ellipticals probably lies somewhere between the two sets of points. The faint end of the luminosity function is not well defined for field galaxies, but studies of nearby clusters (Binggeli, Sandage & Tammann 1988) suggest that it turns over near $M_{\rm B} = -14$.

optically, since on photographic plates they are indistinguishable from more distant and luminous giant ellipticals.

4 What Will the H I Multibeam Survey See?

The Parkes H I multibeam survey (Staveley-Smith 1997, present issue p. 111) will cover the entire southern sky, and thus will include many early-type galaxies.

The number of new H I detections for 'large' elliptical galaxies is difficult to predict, because the H I content of these galaxies is largely decoupled from any other observable property. The multibeam survey volume (out to 100 Mpc) will contain at least 5000 giant elliptical galaxies. A spectacular H I-rich elliptical like NGC 5266 (Morganti et al. 1997), with more than 10^{10} $M_\odot$ of neutral gas, should be detectable throughout this volume. NGC 5266 has an apparent magnitude of $B_{\rm T} = 12{\cdot}1$, making it one of the 100 brightest early-type galaxies in the southern sky. If we therefore assume that ~1/100 ellipticals in a randomly-chosen sample will contain as much H I as NGC 5266, we would expect the multibeam survey to detect up to 50 H I-rich giant elliptical galaxies. These would be a valuable resource for follow-up dynamical studies.

The number of H I detections for 'small' elliptical galaxies can be estimated if we make the following assumptions:

- The survey covers the region south of declination 0°, i.e. half the sky.
- Within this region, the space density of 'small' early-type galaxies ($M_{\rm B}$ −16 to −18) is $9{\cdot}5{\times}10^{-3}$ Mpc^{-3} based on Figure 1.
- We can make rough estimates (see col. 4 of Table 1) of the likely detection rates for various H I mass limits, based on the few galaxies for which H I data are available.

This calculation is probably somewhat conservative, since it neglects the smallest galaxies ($M_{\rm B}$ fainter than −16) whose optical luminosity function is uncertain. It nevertheless suggests that the multibeam survey should detect at least 300 H I-rich, low-luminosity, early-type galaxies. Since most of these galaxies will have apparent magnitudes brighter than $B_T \sim 18$, their optical identification, classification and follow-up optical spectroscopy should be straightforward.

Table 1. Estimated multibeam detections for small early-type galaxies (M_B −16·0 to −18·0)

Assuming an H I velocity width $\Delta V = 100\,\mathrm{km\,s^{-1}}$, 600 s integration time, 3σ detection limit and $H_0 = 100\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$

d (Mpc)	H I limit ($M_\odot$)	N_{gal} (total)	H I det. rate (est.)	N_{det}	Typical B_T (mag)
<10	3×10^7	20	30%	6	13–14
10–20	$1{\cdot}2\times10^8$	139	20%	28	14–15
20–30	$2{\cdot}7\times10^8$	378	10%	38	15–16
30–50	$7{\cdot}5\times10^8$	1950	3%	58	16–17
50–100	3×10^9	17,400	~1%	~170	17–18
Total				~300	

5 Conclusions

The rough estimates presented here suggest that the Parkes H I multibeam survey will detect some new H I-rich giant elliptical galaxies, as well as a large population of small, gas-rich, early-type galaxies which have not previously been studied in any systematic way. Some of the questions which might be answered by follow-up studies of this population include:

- How common is star formation in small early-type galaxies, and what acts as a trigger?
- How do the properties of small elliptical galaxies compare with those of spiral bulges of similar mass?
- How are the small elliptical and S0 galaxies related to the blue compact dwarfs (BCDs)? Can we set up a classification system for small galaxies which is based on their physical properties rather than their appearance?
- How many of these galaxies contain dark matter, and how is it distributed?
- Why do large and small elliptical galaxies appear structurally similar when so many of their other properties are different?

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