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Radio observations of bulgeless late type galaxies

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Abstract. We present GMRT 1280 MHz radio observations of a sample of twelve bulgeless spiral galaxies. These galaxies are late type spirals that appear to have no bulge or a very minimal bulge at their center. They are poorly evolved systems with gas rich disks that are often featureless and shrouded in dust. We have detected radio emission from five galaxies in the sample; the emission is mainly associated with disk star formation. For three of the detected galaxies the emission is weak and arises due to localized disk star formation. However, for the other two detections, the emission is relatively strong and extended; both galaxies are closely interacting with nearby companion galaxies and show signs of disk evolution such as spiral arms and weak bar distortions. Our study thus suggests that bulgeless galaxies are generally poor in star formation unless they are interacting with nearby galaxies. Interactions lead to an accelerated rate of disk evolution which may contribute to the buildup of bulges in these galaxies.

Keywords : Galaxies:spiral – Galaxies:individual – Galaxies:active – Galaxies:ISM – Galaxies:kinematics and dynamics

1. Introduction

Bulgeless galaxies are late type spirals that have no bulge or only a very small bulge at their galaxy centers (Boker et al. 2002). The minimal bulge results

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Table 1. Galaxy sample and parameters.

Galaxy Names	Other Names	Type	Distance (Mpc)	Velocity (km s^{-1})	Optical Size
ESO 418-8	PGC 013089	SB(r)d	14.9	1195	$1.2'$
UGC 4499	PGC 024242	SABdm	11.5	691	$1.99'$
NGC 3346	UGC 05842	SB(rs)cd	22	1260	$2.7'$
NGC 3445	UGC 06021	SAB(s)m	30.8	2069	$1.6'$
NGC 3782	UGC 06618	SAB(s)cd	13.2	739	$1.7'$
NGC 3906	UGC 06797	SB(s)d	16.1	961	$1.9'$
NGC 4027	PGC 037773	SB(s)dm	27.9	1671	$3.2'$
NGC 4299	UGC 07414	SAB(s)dm	7.79	232	$1.7'$
NGC 4540	UGC 07742	SAB(rs)cd	22.1	1286	$1.9'$
NGC 4701	UGC 07975	SA(s)cd	14.5	721	$2.8'$
NGC 5584	UGC 09201	SAB(rs)cd	26	1638	$2.45'$
NGC 5668	UGC 09363	SA(s)d	25	1582	$3.3'$

in a nearly pure disk-like morphology. These galaxies are gas rich but the disks usually do not show much star formation activity and are optically low in surface brightness. The dust content is high and results in significant optical extinction (Ganda et al. 2009). However, the galaxy centers often have compact stellar nuclei that appear as bright cores in the the optical images (Walcher et al. 2006). A few such nuclei have also been found to host weak AGN activity (e.g. NGC 4395; Seyfert 1) associated with intermediate mass black holes (e.g. Peterson et al. 2005). This is suprising as most AGN in our nearby universe are associated with bulges. A significant fraction of spirals are bulgeless ; this is most clear in surveys of edge on galaxies where the number is around 15 to 20 % of nearby spiral galaxies. The formation and evolution of these systems is not well understood (Onghia & Burkert 2004) but being low luminosity galaxies they appear to be dark matter dominated systems. In this paper, we investigate the disk star formation in a sample of bulgeless galaxies using radio continuum emission. Radio emission has the advantage that it is not affected by dust obscuration and hence gives a clear picture of the distribution. We also searched for compact nuclear emission associated with AGN activity. In the following sections, we outline our observations and results and then discuss the implications of our findings.

2. Galaxy sample and observations

Our galaxy sample (Table 1) consists of twelve nearby, late type spiral galaxies that appear to be bulgeless or have only a minimal bulge in their optical images (Boker et al. 2002). All the galaxies have compact stellar cores as indicated by their HST I band light profiles. They are all detected at 1.4 GHz in the NVSS

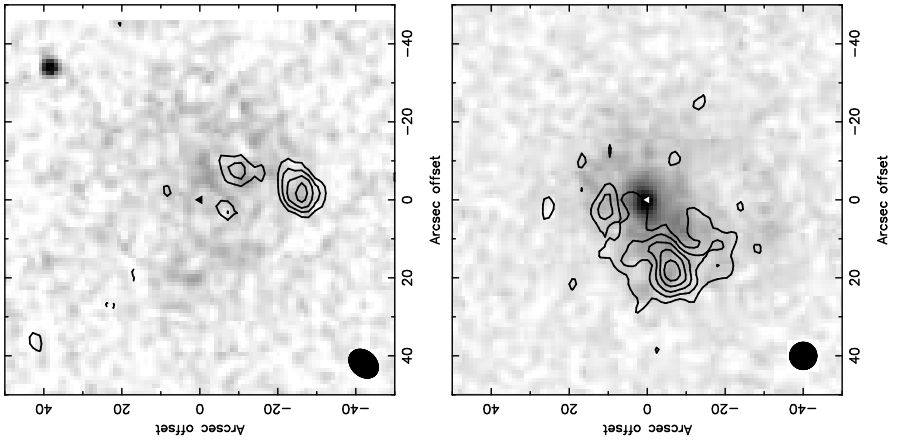

Figure 1. (a) The figure shows the contours of GMRT 1280 MHz radio continuum emission overlaid on the 2MASS near-IR image of the galaxy NGC 4299. The center of the galaxy is marked with a filled triangle. The peak radio flux is 1.4 mJy beam^{-1} and the beam 7.3″. The radio contours are 2, 3, 4, 5, 6 times the noise level which is 0.25 mJy beam^{-1}. The center of the galaxy is marked with a filled triangle. The emission is offset from the center of the galaxy and lies south of the nucleus. (b) The map shows the contours of radio emission overlaid on the 2MASS image of the galaxy NGC 3445. The peak radio flux is 2 mJy beam^{-1} and the beam is 8″. The radio contours are 4, 6, 8, 10, 12 times the noise level which is 0.15 mJy beam^{-1}. The emission is mostly located in the disk and lies east of the nucleus of the galaxy.

VLA radio maps. However, the resolution of NVSS is poor (45″) and does not reveal the detailed distribution of radio emission. But, we did use these maps to define a sample for our observations. The observations were done using the Giant Meterwave Radio Telescope (GMRT) which is located near Pune, during May 2008, at 1280 MHz. Nearby sources were used for phase calibration. The data was obtained in the 'lta' format and then converted to fits format. Data analysis was done using AIPS. Both natural and uniform weighted maps of the galaxies were made in order to map the extended disk emission and also to detect any compact emission associated with the nucleus.

3. Results

We detected radio continuum emission from five galaxies in our sample. Of these galaxies, three sources NGC 3782, NGC 4299 and NGC 5668, show weak, patchy emission associated with the disk (e.g. Fig. 1a). The emission is probably due to localized star forming regions in the disk. The remaining two galaxies, NGC 3445 and NGC 4027 have extended disk and nuclear emission (Figs 1b and 2).

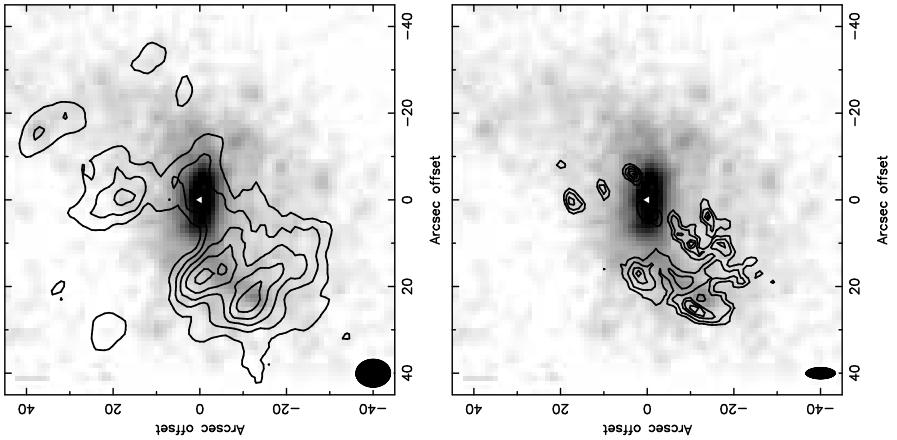

Figure 2. (a) Figure shows the contours of the natural weighted GMRT radio map at 1280 MHz overlaid on the 2MASS image of the galaxy NGC 4027. The peak flux is 3.5 mJy beam^{-1} where beam is 8″. The contours are 8, 10, 12, 14, 16 and 18 times the noise which is 0.21 mJy beam^{-1}. The emission is spread over the disk, the southern arm being more prominent. (b) The plot shows the contours of the high resolution uniform weighted GMRT map overlaid on the 2MASS image. The peak flux is 1.9 mJy beam^{-1} and the beam is 5.7″. The contours are 12, 14, 16, 17, 18 times the noise which is 0.25 mJy beam^{-1}.

(i) NGC 3445 : The radio emission is mainly located along the southern spiral arm (Fig. 2). It is associated with star formation triggered by spiral perturbations in the disk. The IRAS far-infrared flux for this galaxy is quite high, which again suggests ongoing star formation activity. The galaxy appears to be interacting with a nearby companion galaxy and also has an oval distortion or bar at the center.
(ii) NGC 4027 : This galaxy shows the maximum radio emission in our sample. The net flux is $\sim$ 88 mJy and is mainly distributed around the southern spiral arm. The emission north of the center of the galaxy is more patchy but is probably associated with the northern spiral arm (Fig. 2). There is also emission associated with the nucleus of the galaxy, it can be due to nuclear star formation or AGN activity. The far infrared luminosity and radio luminosity ratio q for NGC 4027 is 0.9 which suggests that a significant fraction of the radio luminosity may be due to AGN activity. The rest is due to star formation (Condon et al. 2002).

4. Discussion

(i) Only two galaxies in this sample are bright in radio emission. The remaining ten galaxies have little or no radio flux indicating very little star formation

activity in their disks. The two radio bright galaxies, NGC 3445 and NGC 4027, are closely interacting with neighboring galaxies. NGC 3445 is part of a galaxy triplet. NGC 4027 is part of a group of five galaxies and is closely interacting with NGC 4027A which lies to its south. Our results thus suggest that bulgeless galaxies are low in star formation activity unless interacting with close companions as in NGC 3445 and NGC 4027. **(ii)** Both NGC 3445 and NGC 4027 have relatively strong spiral arms and a small bar in their galaxy centers. These are important indicators of disk evolution and bulge formation. Thus bulgeless galaxies appear to follow an evolutionary track similar to bright galaxies. However only strong galaxy interactions can accelerate the rate of this evolution.

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