Mon. Not. R. Astron. Soc. **000**, 1–5 (2010) Printed 23 June 2010 (MN LaTeX style file v2.2)

The curious case of J113924.74+164144.0: a possible new group of galaxies at z = 0.069

Nirupam Roy[1⋆], Chandreyee Sengupta[2,3⋆] and N. G. Kantharia[4⋆]
[1]*National Radio Astronomy Observatory, 1003 Lopezville Road, Socorro, NM 87801, USA*
[2]*Instituto de Astrofisica de Andalucia, C/ Camino Bajo de Huetor, 50, Granada 18008, Spain*
[3] *Calar Alto Observatory, Centro Astronomico Hispano Aleman, C/ Jesus Durban Remon, 2-2, Almeria 04004, Spain*
[4]*National Centre for Radio Astrophysics, TIFR, Post Bag 3, Ganeshkhind, Pune 411 007, India*

Accepted yyyy month dd. Received yyyy month dd; in original form yyyy month dd

ABSTRACT
J113924.74+164144.0 is an interesting galaxy at $z = 0.0693$, i.e. $D_L \sim 305$ Mpc, with tidal-tail-like extended optical features on both sides. There are two neighbouring galaxies, a spiral galaxy J113922.85+164136.3 which has a strikingly similar 'tidal' morphology, and a faint galaxy J113923.58+164129.9. We report H I 21 cm observations of this field to search for signatures of possible interaction. Narrow H I emission is detected from J113924.74+164144.0, but J113922.85+164136.3 shows no detectable emission. The total H I mass detected in J113924.74+164144.0 is 7.7×10^9 M$_\odot$. The H I emission from the galaxy is found to be extended and significantly offset from the optical position of the galaxy. We interpret this as signature of possible interaction with the neighbouring spiral galaxy. There is also a possible detection of H I emission from another nearby galaxy J113952.31+164531.8 at $z = 0.0680$ at a projected distance of 600 kpc, and with a total H I mass of 5.3×10^9 M$_\odot$, suggesting that all these galaxies form a loose group at $z \sim 0.069$.

Key words: galaxies: groups: general — galaxies: interactions — radio lines: galaxies

1 INTRODUCTION

The 21 cm transition has long proved to be an extremely useful tool to probe the neutral hydrogen (H I) in both the local and the distant universe. In particular, the H I 21 cm emission has been used to study, in detail, properties of the interstellar medium (ISM) of the nearby galaxies in the local universe (Briggs 1990; Zwaan et al. 1997, 2005, and references therein). Particularly for gas rich spiral galaxies (at low and moderate distances) where the H I disk is significantly bigger than the stellar disk, H I observations provide information not only on the dynamics of the particular galaxy of interest but also on the galaxy environment and on possible interactions of neighbouring galaxies (e.g., Howard & Byrd 1990; Rots et al. 1990; Kantharia et al. 2005; Hota, Saikia & Irwin 2007; Sengupta, Dwarakanath & Saikia 2009). Cosmic evolution of the properties of neutral gas in galaxies also have important implications on our understanding of star formation and galaxy evolution.

However, it should be noted here that, due to weakness of the emission signal, detecting H I emission from galaxies even at moderate redshift ($z > 0.05$) is a challenging task. Instead, H I absorption has been extensively used to probe ISM at high redshift (e.g., Carilli et al. 1996; de Bruyn, O'Dea & Baum 1996; Kanekar, Chengalur & Lane 2007; York et al. 2007) but only in the intervening gas along a narrow line of sight towards the background source and therefore can not be as informative as H I emission in the kinematics and the dynamics of the gas within galaxies.

Recently, however, attempts to detect H I emission at high z have been made with upgraded or new powerful receivers. Large H I surveys like the ongoing Arecibo Legacy Fast ALFA (ALFALFA) Survey, the H I Parkes All-Sky Survey (HIPASS), the H I Jodrell All-Sky Survey (HIJASS) and the Arecibo Galaxy Environment Survey (AGES) are targeting detailed study of H I only in nearby galaxies at $z \lesssim 0.06$ (Barnes et al. 2001; Lang et al. 2003; Giovanelli et al. 2005a,b; Auld et al. 2006). In the last ten years, sensitive observations with very long integration times using radio telescopes like Arecibo, GMRT, VLA and WSRT have resulted in a few detection of H I emission from galaxies at $z \gtrsim 0.1$: a single galaxy in Abell 2218 at $z = 0.18$ (Zwaan, van Dokkum & Verheijen 2001), one in Abell 2192 at $z = 0.19$ (Verheijen 2004), 19 galaxies in Abell 963 at $z = 0.21$ and 23 galaxies in Abell 2192 at $z = 0.19$ (Verheijen et al. 2007) and 20 optically selected galaxies from the Sloan Digital Sky Survey (Catinella et al. 2008) at redshifts between $z = 0.17 - 0.25$. Additionally, there have been measurements of neutral atomic hydrogen gas content from multiple galaxies using co-adding technique for galaxy clusters Abell 3128 at $z = 0.06$, Abell 2218 at $z = 0.18$, a sample of star-forming galaxies at $z = 0.24$ and Abell 370 at $z = 0.37$ (Zwaan 2000; Chengalur, Braun & Wieringa 2001; Lah et al. 2007, 2009). However, with hundreds of hours of obser-

⋆ E-mail: nroy@aoc.nrao.edu (NR); chandra@caha.es (CS); ngk@ncra.tifr.res.in (NGK)

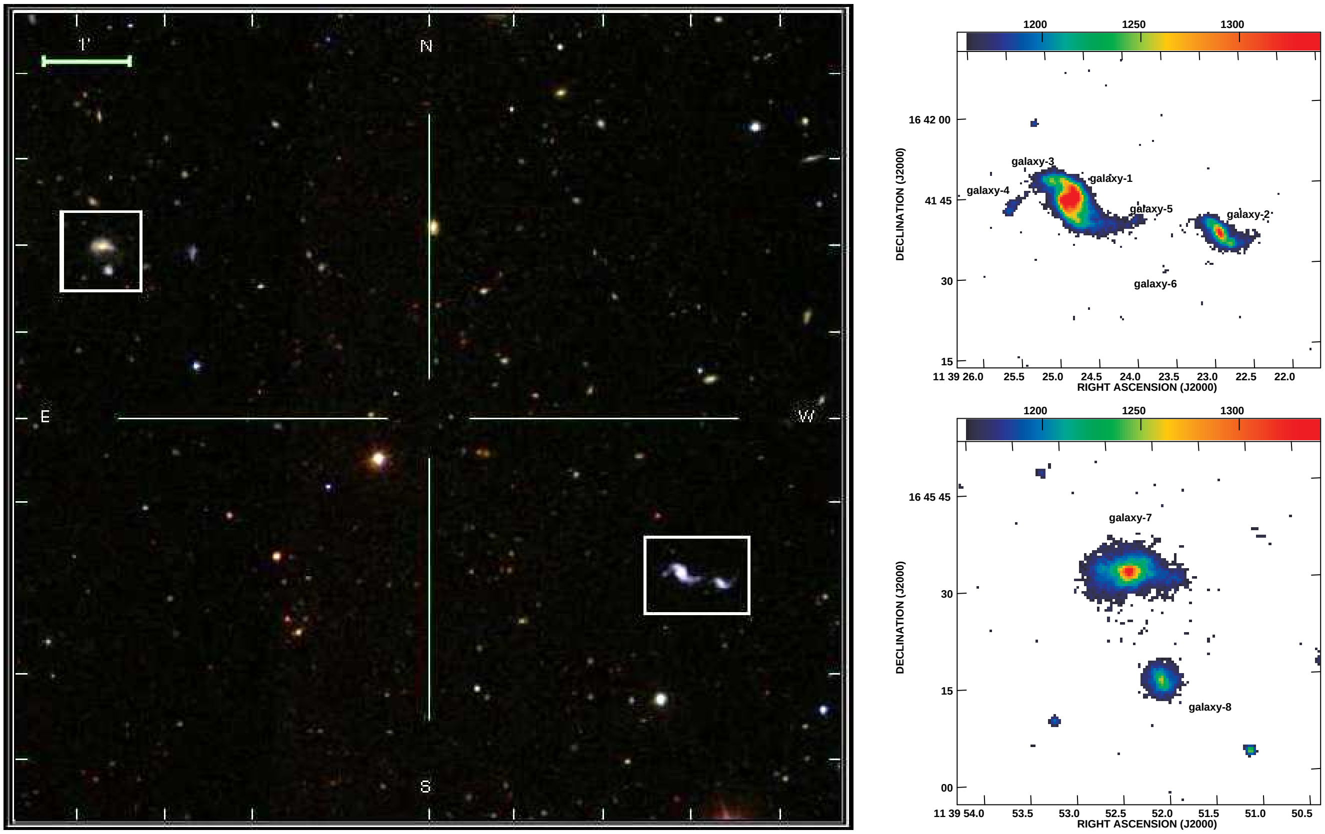

Figure 1. *Left:* SDSS DR6 r-band image of the field ($9.5' \times 9.5'$) centred at RA 11:39:37 Dec. +16:43:32 (J2000) showing two galaxy pairs. *Top right:* Part of the field showing details of the galaxy pair J113924.74+164144.0 and J113922.85+164136.3 (marked 'galaxy-1' and 'galaxy-2' respectively). Note the other four neighbour sources identified as separate galaxies in SDSS ('galaxy-3', 'galaxy-4','galaxy-5' and 'galaxy-6'). *Bottom right:* Part of the field showing details of the galaxy pair J113952.31+164531.8 and J113952.02+164514.8 (marked 'galaxy-7' and 'galaxy-8' respectively). Note the striking morphological similarity of the two spirals (galaxy-1 and galaxy-2) and the disturbed morphology of galaxy-7. The GMRT radio observation field of view was $\sim 25'$ centred at galaxy-1. The optical properties for these sources are listed in Table 1.

vation time, all these are detection of mainly very gas rich systems and the number of H I emission measurements beyond the local universe is still small. Hence H I emission study of galaxies at $z > 0.05$ is challenging but important from many considerations including increasing the number of H I detection in individual galaxies at these redshifts and understanding the galaxy evolution.

Here we present H I observation and results of a particularly interesting galaxy J113924.74+164144.0 at $z = 0.0693$ and its neighbouring galaxy J113952.31+164531.8 at $z = 0.0680$. The details of the field containing these galaxies are outlined in Section §2 while the observation and data analysis method is briefly described in Section §3. Section §4 contains the results, and we present conclusions in Section §5.

2 THE FIELD OF J113924.74+164144.0

The spiral galaxy J113924.74+164144.0 ($m_r = 16.42$) at a spectroscopic redshift of $z_{sp} = 0.069295 \pm 0.000077$ ($cz = 20774$ km s^{-1}, corresponds to a look-back time of ~ 1 billion years) is found to be a very interesting object because of two main reasons. First of all, there are long, tidal-tail-like extended features on both sides of this galaxy (see Figure 1 for r-band image). Though, these features bear strong resemblance to tidal structures, SDSS DR6 (York et al. 2000; Adelman-McCarthy et al. 2008) has identified these structures as three separate faint galaxies: (1) J113925.00+164147.8 ($m_r = 20.49$; photometric redshifts from SDSS $z_{ph} \sim 0.99$, 0.46 and 0.50), (2) J113925.55+164142.5 ($m_r = 20.03$; $z_{ph} \sim 1.00$, 0.47 and 0.30) and (3) J113923.94+164139.5 ($m_r = 19.45$; $z_{ph} \sim 0.04$, 0.13 and 0.12). Derived photometric redshift for these features quoted in SDSS has large error with a overlap around 0.07 indicating that they are probably at the same redshift. Figure 1 shows the SDSS DR6 r-band image of the field containing this galaxy along with a $\sim 2 \times 2'$ image around this main galaxy (marked as 'galaxy-1' in the figure) to show the details of these three neighbouring "galaxies" ('galaxy-3', 'galaxy-4' and 'galaxy-5' in the figure). Other than these three galaxies, there is another faint ($m_r = 21.81$) galaxy ('galaxy-6' in the figure), J113923.58+164129.9 ($z_{ph} \sim 0.22$, 0.60 and 0.58), which is $0.364'$ away and a comparatively bright ($m_r = 17.80$) spiral galaxy ('galaxy-2' in the figure), J113922.85+164136.3 ($z_{ph} \sim 0.00$, 0.05 and 0.09), $0.471'$ away. This corresponds to a projected separation of ~ 37 kpc at $z = 0.069$. Both galaxy-1 and galaxy-2 seems to have open spiral arms and no significant bulge, and so are likely to be Sc or Sd type. The second interesting point is that this smaller spiral galaxy has an optical morphology with tidal-tail-like extended features very similar to that of the bigger spiral galaxy. Given that the errors in photometric redshift measurements are large due to various uncertainties, it is possible that all these galaxies are almost at the same red-

Table 1. Details of the sources in the SDSS field with J113924.74+164144.0

ID	SDSS galaxy	Distance^a		Photometry					Redshift	cz
		$'$	kpc^b	u	g	r	i	z	z_{sp}	km s^{-1}
galaxy-1	J113924.74+164144.0	—	–	17.83	16.82	16.42	16.14	16.05	0.0693	20774
galaxy-2	J113922.85+164136.3	0.471	37	19.21	18.26	17.80	17.57	17.53	–	–
galaxy-3^c	J113925.00+164147.8	0.088	7	20.63	20.23	20.49	20.14	19.76	–	–
galaxy-4^c	J113925.55+164142.5	0.195	15	20.41	20.02	20.03	19.67	19.89	–	–
galaxy-5^c	J113923.94+164139.5	0.206	16	20.29	19.57	19.45	19.11	19.03	–	–
galaxy-6	J113923.58+164129.9	0.364	28	22.19	22.50	21.81	21.59	23.38	–	–
galaxy-7	J113952.31+164531.8	7.615	595	19.35	17.60	16.82	16.42	16.08	0.0680	20386
galaxy-8	J113952.02+164514.8	7.415	580	19.86	18.67	18.24	17.96	17.91	–	–

^{a} Distance from the spiral galaxy J113924.74+164144.0; ^{b} Projected separation at $z = 0.069$; ^{c} Most likely to be part of galaxy-1

shift and interacting with each other. Apart from these, $\sim 7'$ away from the source ($\sim$ 600 kpc at $z = 0.069$) there are two galaxies, J113952.31+164531.8 ($m_r = 16.82$) with a spectroscopic redshift of $z_{sp} = 0.068000 \pm 0.000090$ ($cz = 20386$ km s^{-1}) and its close neighbour J113952.02+164514.8 ($m_r = 18.24$; $z_{ph} \sim 0.04$, 0.06 and 0.07). SDSS DR6 r-band image of the field containing these two galaxies (marked 'galaxy-7' and 'galaxy-8') is also shown in Figure 1. Clearly, the optical morphology of galaxy-7 is "disturbed" with tidal features. The photometry and redshift measurements for these sources are summarized in Table 1.

3 DATA AND ANALYSIS

The Giant Metrewave Radio Telescope (GMRT) L-band (1.4 GHz) receiver was used to observe the H I emission in this field. The observations were carried out on July 11 and 12, 2009 (GMRT observing cycle 16). Total observation duration was about 20 hours (10 hours on each day) with on-source time of about 12 hours. VLA calibrator source $1120 + 143$ ($\sim 5^\circ$ away from the target source) with $S_{1.4\mathrm{GHz}} = 2.4$ Jy was used for phase calibration. This calibrator was observed for 7 minutes for every 45 minutes observation of the target field centred at galaxy-1. A standard flux calibrator (3C147 or 3C286) was observed for about 10-15 minutes in every 2 hours during the observation. The flux calibrator scans were also used for bandpass calibration. A total baseband bandwidth of 8.0 MHz divided into 128 frequency channels centered at 1328.35 MHz, which corresponds to redshifted H I 21 cm frequency at $z = 0.0693$, was used for the observation. This gives a velocity resolution of ~ 15 km s^{-1} per channel and a total velocity coverage of ~ 1800 km s^{-1}. Data analysis was carried out using standard AIPS. After flagging out bad data, the flux density scale, instrumental phase and frequency response were calibrated. The calibrated visibility data from the two days were combined and used to make an image cube and check for H I emission. The line-free channels were used to make continuum images at various resolution by weighting down different long baseline data points with Gaussian function using UVTAPER and UVRANGE in IMAGR. The high resolution continuum map has an rms noise of $\sim 142\mu$Jy beam^{-1} for a synthesized beam size of $3.49'' \times 2.78''$. No continuum emission was detected in either high or low resolution images at the optical positions coinciding with that of these galaxies. The continuum emission from other sources in the field was subtracted from the data cube in the visibility domain. This continuum subtracted data cube, which contains signal only from the line emission, was imaged at different resolution to get the H I emission spectra and the H I maps. The H I mass detection limit for this observation ($\sim 4 \times 10^9 M_\odot$) is better than that of the ALFALFA survey ($\sim 1.2 \times 10^{10} M_\odot$) and comparable to that of the AGES for galaxies at a distance of $\sim$ 300 Mpc (Cortese et al. 2008).

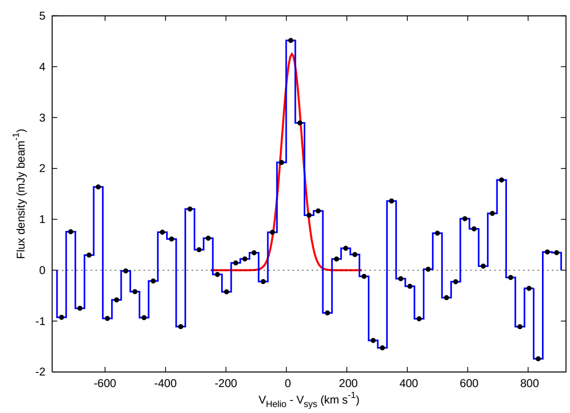

Figure 2. H I emission spectrum for galaxy-1 (blue) and the best fit Gaussian function to the observed spectra (red). The linewidth (σ) is only 33 km s^{-1} (full width at zero intensity $\sim$ 200 km s^{-1}).

4 RESULTS

H I emission from galaxy-1 is detected at $> 6\sigma$ in the spectral channels with velocity close to the systemic velocity of the source. Figure 2 shows the H I emission spectrum with a spectral resolution of ~ 30 km s^{-1} for this galaxy and the best fit Gaussian function to the data. The linewidth (σ) of the component is only 33 km s^{-1} (full width at zero intensity ~ 200 km s^{-1}). Luminosity distance D_L of this galaxy for standard ΛCDM cosmology ($H_0 = 73$ km s^{-1}, $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$) quoted in the NASA/IPAC Extragalactic Database (NED) is 305 Mpc. Hence, the total H I mass for the galaxy is found to be

$$M_{HI} = 2.36 \times 10^5 \; D_L^2 \int S_v dv \;\; M_\odot = 7.7 \pm 0.8 \times 10^9 M_\odot \quad (1)$$

where the distance to the galaxy $D_L = 305$ Mpc, S_v is in Jy and the velocity interval is in km s^{-1}. No H I emission is detected from the smaller spiral galaxy (galaxy-2) for which the 3σ upper limit of H I mass assuming a similar distance and linewidth is $2.4 \times 10^9 M_\odot$. Since galaxy-2 is about factor of two smaller in size than galaxy-1, for a similar H I surface density, the total mass is expected to be $\sim 1.9 \times 10^9 M_\odot$, consistent with the derived upper limit. Figure 3

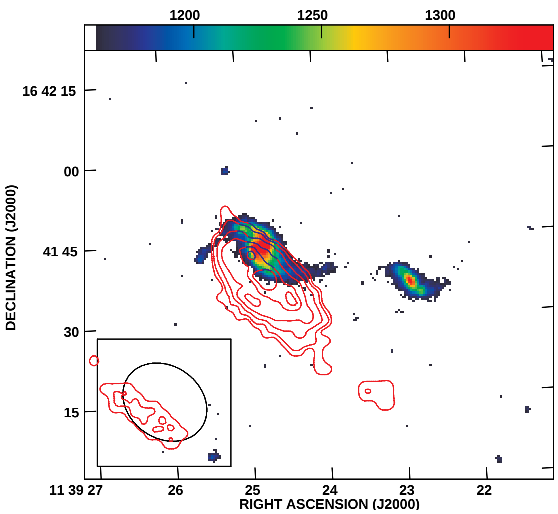

Figure 3. SDSS DR6 r-band image of the galaxy pair J113924.74+164144.0 and J113922.85+164136.3 (galaxy-1 and galaxy-2) overlaid with the integrated H I emission in contours. For the H I map, the synthesized beam size is $16.6'' \times 13.5''$ and the contour levels are for column densities of (3, 7, 15, 25, 35, 40) times 3.95×10^{19} cm^{-2}. The low level H I contours are likely to be artifacts.

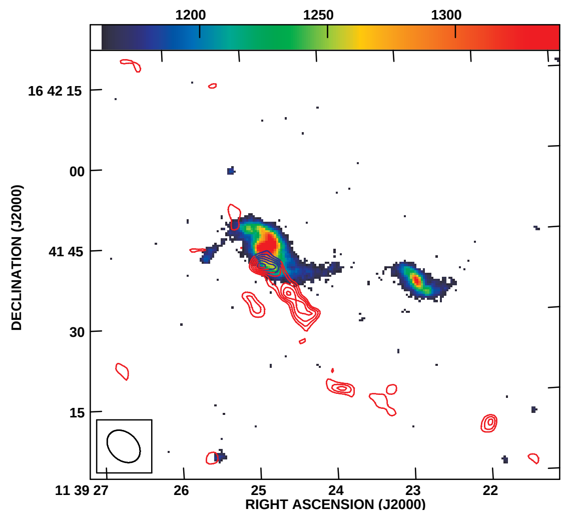

Figure 4. SDSS DR6 r-band image of the galaxy pair J113924.74+164144.0 and J113922.85+164136.3 (galaxy-1 and galaxy-2) overlaid with the integrated H I emission in contours. For the H I map, the synthesized beam size is $6.9'' \times 5.1''$ and the contour levels are for column densities of (5, 7, 9, 11, 13, 15) times 2.51×10^{20} cm^{-2}. The low level H I contours are likely to be artifacts.

and 4 show the SDSS DR6 r-band image of the field overlaid with the integrated H I emission contours for synthesized beam size of $16.6'' \times 13.5''$ and $6.9'' \times 5.1''$ respectively. Both these H I maps show the emission to be extended and significantly offset from the optical position of the galaxy.

Figure 5 shows the H I emission spectrum for galaxy-7 with a spectral resolution of ~ 45 km s^{-1} and a $> 4\sigma$ peak flux density of ~ 2.8 mJy. This marginally significant emission feature at the expected systemic velocity of the galaxy coinciding with the optical position makes it most likely to be H I emission from this galaxy. The emission profile shows weak indication of asymmetry and the total estimated H I mass is $5.3 \pm 1.3 \times 10^9 \mathrm{M}_\odot$ for a luminosity distance of 299 Mpc quoted in NED. Figure 6 shows the SDSS DR6 r-band image of the field overlaid with the H I emission contours for a synthesized beam size of $25.2'' \times 23.0''$. Apart from the disturbed optical morphology, for this galaxy also there is some hint that the H I emission is extended and offset from the optical position. But this offset is smaller than the beam size and hence needs to be confirmed. This low surface brightness emission is resolved in the high resolution map, making it difficult to draw any definitive conclusion on interaction between this pair of galaxies.

One intriguing thing here is the striking similarity in the morphology of the central object of our study (galaxy-1) and that of the other spiral galaxy (galaxy-2) in the field. The small spiral galaxy-2 looks like a scaled down image of galaxy-1 with similar tidal-tail-like extended features. The total H I mass estimated for galaxy-1 from the GMRT observations is 7.7×10^9 M$_\odot$. As has been mentioned earlier, the H I mass is mostly concentrated on galaxy-1 and seems to have an offset with respect to the optical position which can be due to a tidal interaction between the two neighbours. From the optical image, the galaxy diameter quoted in NED is $\sim 22''$. Assuming the entire H I is only from galaxy-1, the H I surface density of this galaxy turns out to be $\log(M_{\mathrm{HI}}/d_l^2) = 6.86$ M$_\odot$ kpc^{-2}, where d_l is the linear diameter of the galaxy. The quantity $\log(M_{\mathrm{HI}}/d_l^2)$ is known to be a good diagnostic of the H I content of galaxies. Comparing the derived H I surface density for this galaxy with the expected surface density for spiral galaxies of similar size

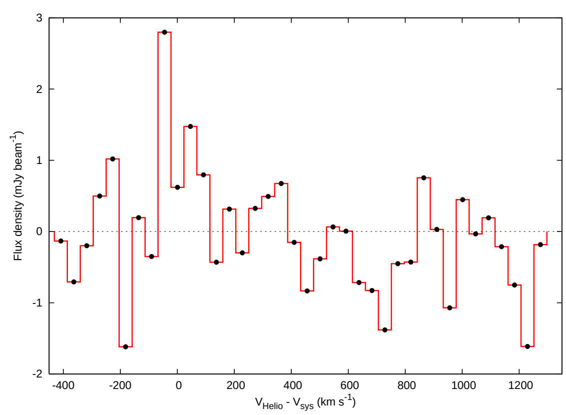

Figure 5. H I spectrum for galaxy-7 with a resolution of ~ 45 km s^{-1}.

(Haynes & Giovanelli 1984), we find no H I deficiency in this particular case. Thus even if we detect a reasonably disturbed and displaced H I disk in the main galaxy of the system possibly due to an ongoing interaction, we do not see any signs of gas loss from the system. This conclusion is based on the assumption that the entire H I detected belongs to galaxy-1 and there is no contribution from the other galaxy. But, its external origin can not be ruled out completely. A possible explanation of the disturbed and displaced H I disk of galaxy-1, presumably used to be a nicely rotating spiral, is tidal interaction with galaxy-2. Based on the absence of $m = 2$ symmetry and the fact that its center being too off from the optical center, it is less likely to be caused only through tidal interaction. Gas accretion from satellites (potentially including galaxy-2) may also contribute to the origin of this displaced H I gas.

These two systems at $z_{sp} = 0.0680$ and 0.0693 are most likely to be distinct and evolving independently. However, the other possibility is that they have been involved in an interaction. The projected separation is ~ 600 kpc which is a reasonable size for a moderate group. Assuming the true distance to be few times 600 kpc and typical velocity to be few hundred km s^{-1}, the correspond-

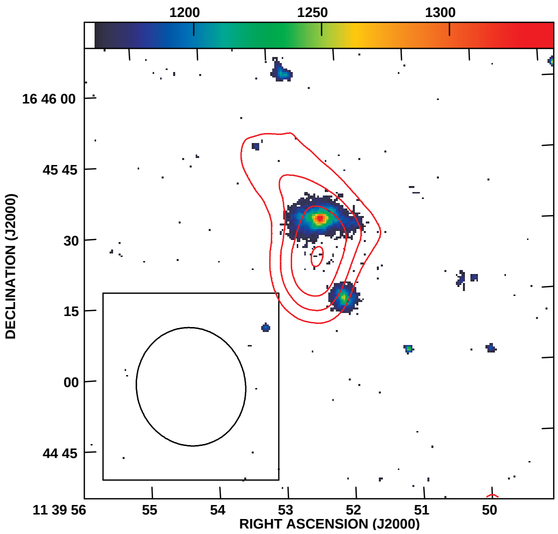

Figure 6. SDSS DR6 r-band image of the galaxy pair J113952.31+164531.8 and J113952.02+164514.8 (galaxy-7 and galaxy-8) overlaid with the H I emission in contours for the channel at $V \approx 20350$ km s^{-1} and channel width ~ 45 km s^{-1}. For the H I map, the synthesized beam size is $25.2'' \times 23.0''$ and the contour levels are for flux densities of (2.5,3.0,3.4,3.8) times 400 μJy beam^{-1}.

ing timescale is ~ 6 Gyr. So, if there was any interaction, the close approach would have happened ~ 6 Gyr ago. It is also worth mentioning that since the photometric redshift measurements often have large errors, it is possible that all these galaxies almost at the same redshift are in a loose group and interacting with each other.

5 CONCLUSIONS

We have reported H I observation of the field with an interesting galaxy J113924.74+164144.0 at $z = 0.0693$, and two other neighbouring galaxies, a spiral galaxy J113922.85+164136.3 which has a strikingly similar 'tidal' morphology, and a faint galaxy J113923.58+164129.9. Narrow H I emission is detected from J113924.74+164144.0, but J113922.85+164136.3 shows no detectable emission. The total H I mass detected in J113924.74+164144.0 is about 7.7×10^9 M$_\odot$. The H I emission from the galaxy is found to be extended and offset from the optical position of the galaxy. This, along with the long, tidal-tail-like extended optical features indicate possibility of interaction with the neighbouring spiral galaxy. About $7'$ away from these sources there is another galaxy J113952.31+164531.8 at $z = 0.0680$ with a close neighbour J113952.02+164514.8. There is a possible H I detection of the galaxy J113952.31+164531.8 with an estimated H I mass of about 5.3×10^9 M$_\odot$. The scenario, that all these galaxies are almost at the same redshift and interacting with each other, can not be ruled out due to possible large uncertainties of photometric redshifts. Deep optical spectroscopic measurements are required to ascertain the redshifts of all the galaxies.

ACKNOWLEDGEMENTS

We thank the staff of the GMRT who have made these observations possible. GMRT is run by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research. We are grateful to the anonymous referee for useful comments and for prompting us into substantially improving this paper. NR is also grateful to Jacqueline H. van Gorkom and Eric W. Greisen for useful discussions. NR is a Jansky Fellow of the National Radio Astronomy Observatory (NRAO). The NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

REFERENCES

Adelman-McCarthy J. K., Agüeros M. A., Allam S. S. et al., 2008, ApJS, 175, 297
Auld R., Minchin R. F., Davies J. I. et al., 2006, MNRAS, 371, 1617
Barnes D. G., Staveley-Smith L., de Blok W. J. G. et al., 2001, MNRAS, 322, 486
Briggs F. H., 1990, AJ, 100, 999
Carilli C. L., Lane W. M., de Bruyn A. G., Braun R., Miley G. K., 1996, AJ, 111, 1830
Catinella B., Haynes M. P., Giovanelli R., Gardner J. P., Connolly A. J., 2008, ApJ, 685, L13
Chengalur J. N., Braun R., Wieringa M., 2001, A&A, 372, 768
Cortese L., Minchin R. F., Auld R. R. et al., 2008, MNRAS, 383, 1519
de Bruyn A. G., O'Dea C. P., Baum S. A., 1996, A&A, 305, 450
Giovanelli R., Haynes M. P., Kent Brian R. et al, 2005a, AJ, 130, 2598
Giovanelli R., Haynes M. P., Kent Brian R. et al, 2005b, AJ, 130, 2613
Haynes M. P., Giovanelli R., 1984, AJ, 89, 758
Hota A., Saikia D. J., Irwin J. A., 2007, MNRAS, 380, 1009
Howard S., Byrd G. G., 1990, AJ, 99, 1798
Kanekar N., Chengalur J. N., Lane W. M., 2007, MNRAS, 375, 1528
Kantharia N. G., Ananthakrishnan S., Nityananda R., Hota A., 2005, A&A, 435, 483
Lah P., Chengalur J. N., Briggs F. H. et al., 2007, MNRAS, 376, 1357
Lah P., Pracy M. B., Chengalur J. N. et al., 2009, MNRAS, 399, 1447
Lang R. H., Boyce P. J., Kilborn V. A. et al., 2003, MNRAS, 342, 738
Rots A. H., Bosma A., van der Hulst J. M., Athanassoula E., Crane P. C., 1990, AJ, 100, 387
Sengupta C., Dwarakanath K. S., Saikia D. J., 2009, MNRAS, 397, 548
Verheijen M. A. W., 2004, in Diaferio A., ed., Proc. IAU Colloq. 195, Galaxy Evolution in Dense Environments: a Concise H I Perspective, Cambridge Univ. Press, Cambridge, p. 394
Verheijen M., van Gorkom J. H., Szomoru A., Dwarakanath K. S., Poggianti B. M., Schiminovich D., 2007, ApJ, 668, L9
York D. G., Adelman J., Anderson Jr. J. E. et al., 2000, AJ, 120, 1579
York B. A., Kanekar N., Ellison S. L., Pettini M., 2007, MNRAS, 382, L53
Zwaan M. A., 2000, PhD thesis, Univ. Groningen
Zwaan M. A., Briggs F. H., Sprayberry D., Sorar E., 1997, ApJ, 490, 173
Zwaan M. A., Meyer M. J., Staveley-Smith L., Webster R. L., 2005, MNRAS, 359, L30
Zwaan M. A., van Dokkum P. G., Verheijen M. A. W., 2001, Sci, 293, 1800