Atomic hydrogen discs as tracers of galaxy transformation in Abell 2626 and beyond

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MeerKAT hunts Jellyfish in A2626

Based on: Deb et al. submitted to MNRAS.

Abstract

We present MeerKAT H I observations of six jellyfish candidate galaxies (JFCGs) in the galaxy cluster, A2626. Two of the six galaxies JW100 and JW103, that were identified as JFCGs from B-band images, are confirmed as jellyfish galaxies (JFGs). Both of the JFGs have low H I content, reside in the cluster core, and move at very high velocities ($\sim 3\sigma_{cl}$). The other JFCGs, identified as non-jellyfish galaxies, are H I rich, with H I morphologies revealing warps, asymmetries, and possible tidal interactions. Both the A2626 JFGs and three other confirmed JFGs from the GASP sample show that these galaxies are H I stripped but not yet quenched. We detect H I, H\alpha, and CO(2-1) tails of similar extent ($\sim 50$ kpc) in JW100. Comparing the multi-phase velocity channels, we do not detect any H I or CO(2-1) emission in the northern section of the tail where H\alpha emission is present, possibly due to prolonged interaction between the stripped gas and the ICM. We also observe an anti-correlation between H I and CO(2-1), which hints at an efficient conversion of H I to H$_2$ in the southern part of the tail. We estimate that 80% of the H I gas has been removed or converted into H$_2$ by RPS. Of the remaining 20%, we find 70% in the tail and 30% still in the disc. This indicates JW100 is already at a very advanced stage of gas removal.

4.1 Introduction

In the dense cluster environment, hydrodynamical interactions such as ram-pressure stripping (RPS) between the inter-stellar medium (ISM) of galaxies and intra-cluster medium (ICM) play an important role in transforming galaxies (Gunn & Gott, 1972) from star forming (SF) and gas rich, to quiescent and gas poor. ‘Jellyfish’ galaxies (JFGs) are extreme examples of RPS with ‘tentacles’ of material that stretch tens of kpcs beyond their stellar discs (Smith et al., 2010; Fumagalli et al., 2014; Ebeling et al., 2014). For example, one of the most studied jellyfish galaxy is ESO137-001 in the nearby Norma cluster, with its long, extended tail observed in multi-wavelength (Sun et al., 2007; Jáchym et al., 2014; Fossati et al., 2016; Jáchym et al., 2019).

The extended, fragile atomic hydrogen (H I) gas discs are not only the reservoirs for star formation, but also serve as diagnostic tracers of gravitational and hydrodynamic environmental processes (Bravo-Alfaro et al., 2001; Chung et al., 2009; Jaffé et al., 2015). Images of the H I gas in galaxies show that the extended H I discs are readily affected by the cluster environment, resulting in H I stripped and H I deficient galaxies compared to field galaxies.
Tab. 4.1: A2626 cluster properties

<table>
<thead>
<tr>
<th>Cluster properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Ascension</td>
<td>23:36:31(^a)</td>
</tr>
<tr>
<td>Declination</td>
<td>+21:09:36.3(^a)</td>
</tr>
<tr>
<td>Redshift (z)</td>
<td>0.055292(^b)</td>
</tr>
<tr>
<td>Velocity dispersion ((\sigma_{cl}))</td>
<td>660 ± 26 km/s(^b)</td>
</tr>
<tr>
<td>Mass ((M_{200}))</td>
<td>3.9 \times 10^{14} M_\odot(^c)</td>
</tr>
<tr>
<td>Radius ((R_{200}))</td>
<td>1.59 Mpc(^b)</td>
</tr>
<tr>
<td>X-ray luminosity ((L_X))</td>
<td>1.9 \times 10^{44} erg/s(^d)</td>
</tr>
</tbody>
</table>

\(\(\sigma_{cl}\)\) \(\sigma_{cl}\)

\(^a\) Cava et al. (2009), \(^b\) Healy et al. (2021c), \(^c\) Biviano et al. (2017), \(^d\) Wong et al. (2008)

(Verheijen & Sancisi, 2001; Oosterloo & van Gorkom, 2005; Chung et al., 2009; Serra et al., 2013; Gogate et al., 2020; Loni et al., 2021). This deficiency and stripping is less conspicuous for the centrally concentrated and more tightly bound molecular hydrogen gas (\(H_2\)). Studies of cluster galaxies often show conflicting results that differ between clusters: low SF in \(H\ I\) stripped but \(H_2\) normal galaxies (Virgo cluster, Brown et al. in press, Kenney & Young 1989; Lee et al. 2017), and normal or slightly enhanced SF in \(H\ I\) deficient but \(H_2\) rich galaxies (JFGs, Moretti et al. 2020b,a). In the Virgo cluster, galaxies are \(H\ I\) deficient and show signatures of RPS, but are only moderately deficient in \(H_2\) (Brown et al. in press, Chung et al. 2009; Kenney & Young 1989). In Fornax, galaxies can be \(H\ I\) or \(H_2\) deficient, or deficient in both gas phases (Zabel et al., 2019; Loni et al., 2021).

Until recently, observations and studies of the environmental impact on the multi-phase ISM have been limited to nearby clusters such as Virgo (Brown et al. in press, Chung et al. 2009; Kenney & Young 1989), Fornax (Zabel et al., 2019; Loni et al., 2021) or Coma (Boselli et al., 1997; Casoli et al., 1996; Healy et al., 2021a). It is still not clear what the relative influence of the ICM pressure is on the \(H\ I\) and \(H_2\) gas. It also remains a puzzle why \(H\ I\) stripped galaxies appear to be quiescent while the \(H_2\) gas, which is the more direct constituent for SF, is not deficient. There are still many other questions without clear answers: How do environmental processes impact the baryon cycle in galaxies? How does SF quench in galaxies: by gas removal or consumption? Therefore, it is very timely to broaden our understanding of environmental processes acting on the multi-phase ISM of galaxies in clusters. JFGs, extreme examples of RPS and often located in the dense cluster core, are excellent objects to investigate environmental effects on the multi-phase ISM.

The GAs Stripping Phenomena in galaxies survey (GASP; Poggianti et al. 2017b) was carried out with the Multi Unit Spectroscopic Explorer (MUSE), observing a statistically significant sample of JFGs in nearby clusters (\(z=0.04-0.07\)) over a wide range of stellar masses, morphological asymmetries and environments. The key scientific motivation is to investigate how, where and why gas removal occurs, and to quantify the amount of star formation involved in these processes (Poggianti et al., 2017b). Within GASP, JFGs are defined as the...
galaxies with a $\text{H}\alpha$ tail at least as long as the diameter of the stellar disc. In the context of this paper, we define RPS affected galaxies as JFGs. In the RPS tails of these JFGs, often in situ SF occurs by efficient conversion of $\text{H}\,\text{I}$ to $\text{H}_2$ followed by the collapse of molecular clouds due to thermal instabilities, turbulent motion etc (Poggianti et al., 2019; Müller et al., 2021). $\text{H}\,\text{I}$ gas is also ionised by the young stars that are formed in situ in the tail. Poggianti et al. (2017a) observed a strong correlation between RPS and the presence of an Active Galactic Nucleus (AGNs), hinting at the possibility that ram pressure is causing gas to flow towards the centre thus triggering the AGN activity. Poggianti et al. (2016) identified possible stripped galaxies as jellyfish candidates galaxies (JFCGs) purely based on B-band imaging. JO201, JO204, JO206, and JW100 were confirmed stripped galaxies i.e. JFGs with long tails by MUSE observations (Poggianti et al., 2017b; Gullieuszik et al., 2017; Bellhouse et al., 2017, 2019; Poggianti et al., 2019).

Five of the GASP JFGs (JO201, JO204, JO206, JO194, JO135) were also observed with the Jansky Very Large Array (JVLA; Perley et al. 2009) to investigate their $\text{H}\,\text{I}$ gas content. Ramatsoku et al. (2019, 2020) observed that both JO201 and JO206 show a strong stripping of $\text{H}\,\text{I}$ gas relative to the stellar disc (on the sky and/or in velocity). Both the $\text{H}\,\text{I}$ and $\text{H}\alpha$ tails are of similar extent, and these galaxies have comparable $\text{H}\,\text{I}$ deficiencies, with enhanced SF compared to that of galaxies of similar stellar and $\text{H}\,\text{I}$ mass. However, it is worth noting that JO201 resides in a more massive and dense cluster than JO206 (Bellhouse et al., 2017, 2019; Poggianti et al., 2017b; Jaffé et al., 2018). Deb et al. (2020) observed a much longer (90 kpc) $\text{H}\,\text{I}$ tail compared to the RPS $\text{H}\alpha$ tail (30 kpc, Gullieuszik et al. 2017) in JO204. Deb et al. (2020) also investigated whether RPS is inducing the AGN in JO204 by funnelling $\text{H}\,\text{I}$ gas towards the centre of the galaxy, resulting in a redshifted $\text{H}\,\text{I}$ absorption profile, but the study was inconclusive. Luber et al. (submitted) investigated the $\text{H}\,\text{I}$ properties of non-jellyfish galaxies in clusters with JFGs from GASP sample. Our study will add the $\text{H}\,\text{I}$ picture of the JFCGs in A2626, and will complement the detailed studies of JW100 in other wavelengths (Poggianti et al., 2019).

Healy et al. (2021b) have conducted a blind MeerKAT $\text{H}\,\text{I}$ survey of the galaxy cluster A2626, which hosts six JFCGs including JW100, signifying ongoing environment driven evolution of the galaxies. In this paper, we compare the $\text{H}\,\text{I}$ properties and SF of the A2626 JFCGs with other JFGs from the GASP sample residing in different clusters. In the next sections we will first address the $\text{H}\,\text{I}$ in all six JFCGs and then concentrate on understanding the details of the RPS process in JW100 for which all ISM phases are now available from Poggianti et al. (2019), Moretti et al. (2020b) and our MeerKAT observations. $\text{H}\,\text{I}$ observations of JW100 are the last piece of the puzzle to complete the picture of the interplay of the multi-phase (atomic, molecular, ionised) ISM with itself and with the ICM.

The paper is organised as follows: Sec. 4.2 gives an overview of A2626 and the JFCGs in it. $\text{H}\,\text{I}$ observations and data processing are presented in Sec. 4.3. In Sec. 4.4 we explore the $\text{H}\,\text{I}$ properties of the JFCGs. In Sec. 4.5, we investigate the relation between $\text{H}\,\text{I}$ deficiency and star-formation rate (SFR) in the JFGs. In sec. 4.6, we then focus on JFG JW100 and study the atomic, molecular, and ionised gas phases in different velocity channels. In sec.
Fig. 4.1: The location of jellyfish (candidate) galaxies (JFCGs) JW98, JW99, JW100, JW101, JW102, and JW103 in the A2626 volume (Poggianti et al., 2016). The dashed circle represents the $R_{200}$ of A2626. The black contours represent the X-ray emission in A2626 from ROSAT images. The coloured dots represent the H I detections in different redshift over-densities in the A2626 volume (Healy et al., 2021c). JClass=1 JFCGs (i.e. least probable JFGs from their optical morphologies, JW98, JW99, JW101, JW102) are outside the cluster core, higher JClass (JClass $\geq$ 2) galaxies JW100 and JW103 are residing close to the cluster core in projection. On the side left and right panels we show the optical Dark Energy Camera Legacy Survey (DECaLS, Dey et al. 2019) images of JFCGs in A2626, including the $\Delta cz$ velocity difference with respect to the cluster core.

4.7, we calculate the contribution of different depletion mechanisms to the stripping of the multi-phase gas in JW100. Finally in sec. 4.8, we summarise the findings and conclusions.

Throughout this paper, we adopt a Chabrier initial mass function (IMF; Chabrier 2003), and assume a cold dark matter cosmology with $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ and $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$. At the cluster redshift ($z=0.055292$, Healy et al. 2021c), this yields 1$''$=1.074 kpc.

4.2 A2626 and its jellyfish candidate galaxies

4.2.1 The galaxy cluster A2626

The focus of our study are the JFCGs identified in A2626, one of 77 clusters imaged as part of the Wide-field Nearby Galaxy-cluster Survey (WINGS: Fasano et al. 2006). A2626 is a moderately massive, X-ray emitting cluster at a redshift of $z=0.055292$ (Healy et al., 2021c). The global properties of the cluster are listed in Table 1. It is a cooling-core cluster (Wong et al., 2008; McDonald et al., 2018; Ignesti et al., 2018; Kadam et al., 2019). The X-ray surface brightness and thermodynamic maps show cold fronts and spiral wakes, indicate sloshing
4.2.2 Jellyfish (candidate) galaxies in A2626

A2626 hosts six JFCGs as identified by Poggianti et al. (2016). Using WINGS B-band images to search for optical evidence of gas stripping, the JFCGs were identified based on their optical morphology. Poggianti et al. (2016) ranked the galaxies on a scale of 1 to 5, JClass = 1 being the least plausible JFG and JClass = 5 being the most plausible JFG. The six JFCGs identified in A2626 are JW98, JW99, JW100, JW101, JW102, and JW103. Their global properties are listed in Table 4.2 and illustrated in Fig. 4.1 which also indicates their projected locations in A2626. Of these galaxies, JW100 has the highest JClass=5 and is known to be experiencing ram-pressure stripping (RPS) of its ISM. In the top right panel of Fig. 4.1, JW100 clearly displays and extended RPS tail towards the South West that appears as light blue in the optical image that indicating extra-planar star formation activity, which was confirmed by MUSE observations (Poggianti et al., 2019). JW100 has been the subject of many detailed studies (as summarised below) while the other five JFCGs were not part of the GASP MUSE sample. JW103 has a low JClass=2 and it is likely at a later stage of RPS than JW100 due to its
Fig. 4.2: Atlas pages for JW98 and JW99. Clockwise from the top left panel: DECaLS r-band image, the \( \text{H} \text{I} \) column density contours on DECaLS g-band image in greyscale, total \( \text{H} \text{I} \) map in greyscale, signal-to-noise map as a colour map with the different colours representing different levels of signal-to-noise, \( \text{H} \text{I} \) global profile, \( \text{H} \text{I} \) position-velocity (PV) diagram, \( \text{H} \text{I} \) velocity field, and radio continuum map on DECaLS g-band image. The \( \text{H} \text{I} \) column density contours are plotted at the levels \( N_{\text{H} \text{I}}^{3\sigma} \times 2^n \) with \( n=0,1,2,3,... \) with \( N_{\text{H} \text{I}}^{3\sigma} \) - the average 3\( \sigma \) column density for each galaxy. The \( \text{H} \text{I} \) beam size (15") is shown in the bottom left. In the velocity field, the lighter greyscales and blue contours show the approaching side with contour levels 25, 50, 75, 100,...200 km s\(^{-1}\). The systemic velocity \( v_{\text{sys}} \) is shown by the white contour. The darker greyscales and red contours represent the receding side of the \( \text{H} \text{I} \) rotating disc with the contour levels -25, -50, -75, ..., -200 km s\(^{-1}\). The radio continuum contours are plotted at the levels \( 2^n \) of the RMS noise, where \( n=0,1,2,3,... \) Dashed contours are drawn at \(-2\sigma\) the RMS noise. The hatched elliptical beam in the radio continuum map is the beam size of continuum map (14.6" × 9.30", 171.6\(^{\circ}\)). The position-velocity (PV) diagrams are made along the major axis of the optical image, starting at the receding side of the galaxy. The position angles are mentioned on the top of each panel which are determined by visual inspection of the optical image while the receding side with respect to the systemic recession velocity of the galaxy is determined from the three-dimensional \( \text{H} \text{I} \) datacube. The directions of the start and end points of the PV slices are indicated in the bottom left and right corners of each panel respectively. The orange contour outlines the manually made optimum mask. The vertical dashed line indicates the optical centre of the galaxy from the SDSS. The horizontal dashed line corresponds to the central frequency as derived from the global profile. The \( \text{H} \text{I} \) redshift is calculated from this central frequency and reported in the top right of the bottom right panel. The \( \text{H} \text{I} \) spectrum or global profile of each galaxy is constructed by applying the dilated, optimum \( \text{H} \text{I} \) mask for each galaxy to the 20" resolution \( \text{H} \text{I} \) datacube. The vertical black downward arrow in the middle represents the central frequency, corresponding to the systemic velocity, which is the midpoint of the 20% velocity width (\( W_{20} \)). The measured optical redshifts are shown with an orange upward arrow. The method to derive the errorbars as shown on the global profile is described in Section 5.1 in Healy et al. (2021b).
lower stellar mass. It is at a same velocity and similar location at the cluster as JW100 with two extensions of blue light towards the West in the optical image (see top right panel of 4.1). The other four candidate JFGs have JClass=1 and are least likely to be experiencing RPS (see Fig. 4.1).

It should be noted that JW100, JW102 and JW103 have a very similar radial velocity offset with respect to A2626 of $\Delta cz \approx +1800 \text{ km/s} \left( \sim 3 \sigma_{cl} \right)$ indicating that these galaxies are entering A2626 as a group. JW100 and JW103 with JClass $> 1$ are close to the X-ray emitting cluster core while JW102 is still at a substantial projected distance ($\sim 0.6 R_{200}$) and thus not strongly affected by RPS yet.
The optical morphologies of the JFCGs show a wide variety of characteristics, ranging from irregular blue systems like JW98, which Poggianti et al. (2016) suggest to be the result of harassment, to two-armed grand-design spirals with a hint of lopsidedness like JW99, to bulge-dominated like JW101. Notably, the optical image of JW100 shows some reddening of the stellar light just west of its bulge, suggesting that dust is also being removed from the disk of this galaxy. In the lower JClass galaxies, it is not always obvious which blue features hint as ongoing RPS, but their overall disturbed or lopsided optical morphologies classified these galaxies as JFCGs. The spatially resolved H I observations presented in this paper will clarify whether these JClass=1 galaxies are actually experiencing RPS.

Using stellar masses and SFRs determined using WISE photometry (T. Jarrett, private communication), we can compare the A2626 JFCGs to other galaxies in A2626 and different reference samples (see Sec. 4.5). The stellar masses are calculated from the 3.4μm (W1) and 4.6μm (W2) emission. The SFRs are determined from the PAH emission in the 12μm (W3) band; see Cluver et al. (2014, 2017); Jarrett et al. (2013, 2019) for details.

All the above mentioned studies of JFCGs in A2626 lack observational information on an important constituent of the ram-pressure stripped gas, namely the H I gas, and that is what our current study contributes. H I observations of JFCGs in A2626 will provide a diverse picture of H I morphologies of such galaxies that are at different stages of stripping and can confirm whether candidate JFGs are actually experiencing ongoing RPS or not. Particularly, JW100 is one of the most well studied JFGs so far and information about the atomic gas will complete the picture of the multi-phase gas of JW100.

### 4.3 H I observations and data processing

A2626 was observed with the MeerKAT telescope (Jonas & MeerKAT Team, 2016) as one of the first MeerKAT-64 open time observations (project code SCI-20190418-JH-01). A2626 was observed during the nights of 15-17 July 2019 for a total of 15 (3 × 5) hours. The large field-of-view of MeerKAT (61’ × 61’ at a frequency of 1346 MHz where H I emission from z = 0.055 is detected) is adequate to cover the cluster beyond R200 and encompasses all the JFCGs. The sensitivity of MeerKAT enables a 3σ H I mass detection limit of 2 × 10^8 M⊙ in the field centre with a linewidth of 300 km s⁻¹, and a corresponding 5σ column density of 2.5 × 10^{19} cm⁻² at an angular resolution of 30”.

The data calibration and imaging was carried out using CARACa1, (version 1.0, previously known as MeerKATHI, Józsa et al. 2020) to reduce the data and SoFiA-2 (Serra et al., 2015) to detect the H I sources within the MeerKAT cube. For the complete details on the data calibration, imaging, and source finding, see Healy et al. (2021b).

The four low class (JClass = 1) candidate galaxies turned out to be gas rich and were identified by SoFiA-2 (H I ID=76 (JW98), 88 (JW99), 156 (JW101), 45 (JW102) in Healy et al. 2021b). The atlas pages for JW98 and JW99, and JW101 and JW102 are shown in Fig. 4.2 and 4.3 respectively. JW103 (JClass=2) and JW100 (JClass=5) were not identified by SoFiA-2 with the general parameter settings used in Healy et al. (2021b). Both galaxies have very faint H I emission, and could only be identified visually with the knowledge of their coordinates.
and redshifts from optical observations. The data were smoothed using Gaussian kernels to angular resolutions of 15", 20", 25", 30", and with boxcar kernels to velocity resolutions of \( \sim 135 \), \( \sim 225 \), and \( \sim 315 \) km s\(^{-1} \) to enhance the sensitivity of the data. An angular resolution of 20" and a velocity resolution of \( \sim 135 \) km s\(^{-1} \) resulted in the highest signal-to-noise H I emission for both JW100 and JW103. Masks were constructed manually for each velocity channel containing H I emission with an H I flux of at least three times the rms noise in that channel, and visually detecting spatial coherence in the distribution of the H I emission compared to the neighbouring channels. We have then CLEAN-ed (Högbom, 1974) the ‘dirty’ channels of the 20" H I datacube using the mask made, down to the 0.3\( \sigma \) level. The ‘clean’ components were ‘restore’d with a 20" circular Gaussian beam. The pixels in the ‘clean’ed 20" datacube that are outside the mask were set to zero and pixels inside the mask were summed up along the part of the frequency axis contained within the mask to obtain the total H I maps for JW100 and JW103.

### 4.4 H I properties of the jellyfish candidate galaxies

The H I morphologies of the gas-rich JFCGs JW98, JW99, JW101, and JW102 do not reveal any obvious stripped jellyfish-like gas tails at the angular resolution of our MeerKAT observations (15" corresponding to 16 kpc at the redshift of A2626, see Fig 4.2 and Fig 4.3). The detailed description of the methods used to derive the H I properties of JW98, JW99, JW101, and JW102 can be found in Healy et al. (2021b) and the description of atlas pages of these galaxies are in Fig 4.2 and 4.3. JW98 and JW101 are at higher redshifts (see Table 4.2) than the redshift range of A2626 (0.0475 < \( z \) < 0.0615, Healy et al. 2021c) and thus are not likely members of the cluster. According to Poggianti et al. (2016), JW98 is possibly a harassed galaxy, the radio continuum shows an extension to the west which may support the harassment scenario. JW99 is a somewhat lopsided galaxy, both in the optical and in H I, and displays a mild kinematic asymmetry (see the velocity field in Fig. 4.2). JW101 and JW102 both seem to have warped H I discs, likely due to interactions with their neighbouring galaxies. All of these JFCGs have significant H I masses (\( \sim 10^{10} \) M\(_{\odot} \)), often exceeding their stellar mass.

Fig. 4.4 shows the H I properties of the JFGs JW100 and JW103 in the form of atlas pages. Due East of JW100, at the centre of A2626, is the peculiar, extended radio continuum source known as the “kite” source. For both JW100 and JW103, the optical and HI redshifts are slightly offset (H I redshift is within the error of the optical redshift). MeerKAT H I observations of JW100 reveal a striking H I tail extending south-westwards up to \( \sim 60 \) kpc from the stellar body of the galaxy. Most of the H I emission associated with JW100 is in the tail, which is evident in the PV diagram along the tail (see Fig. 4.4). For JW103 the signal-to-noise of the H I emission is very low and we do not observe any H I tail in the direction of the optical tentacles which are visible in the B-band image. However, the H I emission is mostly on one side of the galaxy (north) and blue-shifted in JW103. The total H I masses of JW100 and JW103 (see equation 5 in Healy et al. 2021b) seen in emission are \( 2.8 \times 10^{9} \) M\(_{\odot} \) and \( 1 \times 10^{9} \) M\(_{\odot} \).
Fig. 4.4: Atlas pages for JW100 and JW103. All the data products except the second and third panel in the bottom row are the same as in Fig. 4.2. The second and third panels of the second row are a H I Position-Velocity (PV) diagram along the optical major axis and a H I position-velocity (PV) diagram across the tail respectively. The H I column density contours are plotted at the levels $N_{\text{HI}} \times 2^n$ with $n=0,1,2,3,...$ while $N_{\text{HI}}$, the average $3\sigma$ column density for each galaxy and the H I beam size ($20''$) is shown in the bottom left of the H I maps. The cyan contour in the PV diagrams outlines the manually made optimum mask as described in the section 4.3.

Interestingly, in both JW100 and JW103, we observe an uni-directional radio-continuum tail in the direction of the optical tail. As pointed out by I ignesti et al. (2022), the majority of the relativistic electrons in the tail were already accelerated in the disc and...
not provided by the star formation activity in the tail, similar to what was found in Coma cluster by Chen et al. (2020).

So, with the combination of H I and optical morphologies of the six the JFCGs in A2626, we infer that only JW100 is an actual JFG while JW103 is a ram-pressure stripped galaxy at a later stage of stripping. Other JFCGs namely JW98, JW99, JW101, and JW102 are identified as non-jellyfish galaxies from their H I morphologies. They are H I rich ($M_{\text{HI}} \sim 10^{10} \, M_\odot$) and do not show signs of RPS, but reveal mildly disturbed H I morphologies consistent with harassment or tidal interactions.

### 4.5 H I deficiency and SFR enhancement in jellyfish galaxies

The relation between stellar masses of galaxies and star formation rates (the ‘star formation main sequence’; SFMS) is a well-known scaling relation (e.g. Brinchmann et al. 2004; Noeske et al. 2007; Elbaz et al. 2007; Speagle et al. 2014; Tomczak et al. 2016). We investigate the location of the JFGs and JFCGs with respect to the SFMS. For that purpose, we use the scaling relation from Cluver et al. (2020). Both the SFMS and quenching threshold relations in Cluver...
et al. (2020) are calibrated using the WISE data and the same methodologies that is used for stellar mass and SFR calculations for our sample galaxies.

We have also included the galaxies detected in the volume-limited H I surveys of the Ursa Major (UMa, Verheijen & Sancisi 2001; Busekool et al. 2021), Perseus-Pisces (PP, Bilimogga et al. in prep), and the entire A2626 volumes as reference samples. The UMa volume is defined as a ‘supergroup’ that lacks any central concentration while still being gravitationally bound (Wolfinger et al., 2013). At a distance of 18.6 Mpc, the volume is characterised by mostly late-type galaxies with a normal gas content (Tully & Fisher, 1977b). We use the H I detections from a blind H I imaging survey of the volume with the JVLA-D configuration (for more details see Busekool et al. 2021) supplemented by targeted observations of 50 UMa galaxies (described in Verheijen & Sancisi 2001). The PP volume is a section of a ridge embedded in the PP supercluster. A blind H I imaging survey of this volume has been performed with the JVLA-C configuration (Bilimogga et al. in prep). At a distance of 66 Mpc, the volume consists of several loose groups of galaxies that follow the large-scale structure of the PP supercluster (see Trasarti-Battistoni 1998). Since the UMa and PP observations are also volume limited H I surveys like the MeerKAT A2626 survey, we used those galaxies to compare with our JFCGs. For A2626, 97 H I sources other than JW100 and JW103 are detected in our MeerKAT observations (see Healy et al. 2021b), and they are also used in this paper as a reference sample. Stellar masses and SFRs for PP and UMa galaxies have also been calculated from
WISE photometry using the same prescription as for the A2626 galaxies as mentioned in Sec. 4.2.2. The left panel of Fig 4.5 shows H I vs stellar masses for the JFCGs and the reference sample galaxies. Three other H I detected JFGs namely JO201, JO204, and JO206 (Ramatsoku et al., 2019, 2020; Deb et al., 2020) from the GASP sample (Poggianti et al., 2017b) are also plotted with JW100 and JW103 in coloured star markers. Four non-stripping JFCGs are plotted with pentagon coloured star markers. Together with PP, UMa, and A2626 galaxies, we have also plotted the results from the Arecibo Legacy Fast ALFA- Sloan Digital Sky Survey (ALFALFA–SDSS) galaxy sample of field galaxies with errorbars from Maddox et al. (2015), which spans a large range in stellar and H I masses. All five JFGs (JO201, JO204, JO206, JW100, and JW103) have relatively low H I masses for their stellar masses when compared to the reference sample galaxies (also found by Luber et al. submitted). Especially, when compared with the ALFALFA field galaxies, all five JFGs are almost 1 dex below the typical H I masses of the galaxies of similar stellar masses.

The right panel of Fig 4.5 shows SFR vs stellar masses for the JFGs, the reference sample galaxies and the SFMS relation. For all but JW103, the SFRs are measured with MUSE (Vulcani et al., 2018). The SFR calculations from MUSE and WISE observations are verified to be consistent (within ~ 10% scatter). For JW103, we use the SFR calculated from the 12μm (W3) emission. Interestingly, both JFGes and JFCGs which are later identified as non-jellyfish galaxies do not stand out with respect to the SFMS of Cluver et al. (2020), i.e. they do not necessarily have enhanced SFR compared to their stellar masses, this is contrary to what is found by Vulcani et al. (2018). However, we note that JW100 below the quenching threshold as defined by Cluver et al. (2020), signifying a strongly reduced star formation activity for its stellar mass.

Finally, we inspect how the atomic gas content is linked to the global star formation activity of the JFGs as compared to usual field or cluster galaxies following Fig 6 in Ramatsoku et al. (2020). We have prepared a reference sample of field galaxies with the same stellar mass range as the five JFGs (9.7 ≤ logM_* ≤ 11.5) from the Extended GALEX Arecibo SDSS Survey (xGASS; Catinella et al. 2010). Fig. 4.6 displays SFR vs M_H for the xGASS sample (Doyle & Drinkwater, 2006; Huang et al., 2012; Saintonge et al., 2016) in addition to the PP, UMa and A2626 cluster galaxies. The coloured star and pentagon markers represent the JFGs and other JFCGs respectively. Intriguingly, all the five JFGs lie above the distribution of the reference samples. In other words, the JFGs have higher star formation rates compared to their H I masses for galaxies with similar stellar masses (Ramatsoku et al., 2019, 2020). This suggests that these galaxies are being H I stripped but are not yet quenched. Furthermore, this also implies that the little H I gas these galaxies retain, is more efficiently transformed into H2 gas, as concluded by Moretti et al. (2020a), resulting in a high SFR for their H I masses, compared to normal galaxies of similar H I masses. Given that these JFGs are H I deficient and often do not have enhanced SFR for their M_*, they must evolve from right to left in Fig. 4.6, and not from bottom to top. We note in the right panel of Fig. 5, that the JFGs do not lie significantly above the SFMS and therefore, do not currently have an enhanced SFR for their stellar mass. Therefore, we conclude that the JFGs have not moved upwards significantly in
Fig. 6. However, we cannot entirely rule out that a mild enhancement of the SFR may have occurred during a short period of time since these galaxies entered the clusters.

### 4.6 The Multi-phase ISM of JW100

#### 4.6.1 Previous studies on JW100

JW100 is the proto-typical JFG. It is a nearly edge-on spiral galaxy with an AGN in its centre (Poggianti et al., 2019; Radovich et al., 2019). JW100 resides in A2626 under optimal conditions for ram-pressure stripping (Jaffé et al., 2018; Gullieuszik et al., 2020), with a particularly high line-of-sight velocity of 2000 km s\(^{-1}\) with respect to the cluster rest frame and a projected distance of 83 kpc from the cluster centre (Poggianti et al., 2019). It is the most massive JFG in the entire GASP sample with a stellar mass of \(3.2 \times 10^{11} \ M_\odot\) (Poggianti et al., 2019). JW100 is one of the most spectacular JFGs with extra-planar RPS tails of ionised and molecular gas, UV stellar light, X-ray and radio continuum emission (Poggianti et al., 2019; Moretti et al., 2020b; Ignesti et al., 2020).

In the northern part of the tail, there is a lack of extra-planar clumpy CO gas and star formation while only diffuse H\(\alpha\) is observed, with a high [O\(I\)]/H\(\alpha\) ratio and X-ray emission. This suggests that the excess H\(\alpha\) emission in the northern part of the tail is possibly a result of a complex ICM-ISM interplay triggered by RPS (e.g. Ferland et al. 2009; Fossati et al. 2016; Cramer et al. 2019; Campitiello et al. 2020). We note here that the northern, diffuse H\(\alpha\) emission has a recession velocity that is inconsistent with the rotational velocity of JW100, suggesting that the ionised gas is decelerated along the orbit and longer exposed to interaction with ICM (see Sec. 4.6.2 for more details). The radio continuum emission from the tail of JW100 is mainly synchrotron emission caused by relativistic electrons ejected by supernovae explosions, indicating the presence of magnetic fields pervading the stripped gas (as in e.g. Chen et al. 2020; Müller et al. 2021; Roberts et al. 2021).

Based on ALMA observations, Moretti et al. (2020b,a) found a large amount of molecular gas \((\sim 2.5 \times 10^{10} \ M_\odot)\), i.e. 8% of the stellar mass, a value more than an order of magnitude higher than that found in typical Virgo cluster galaxies (Corbelli et al., 2012) and in the local xCOLD GASS sample (Saintonge et al., 2017) for galaxies of similar stellar mass. The ALMA data reveal a 35 kpc long RPS tail of clumpy and diffuse molecular gas from the centre of JW100 (Moretti et al., 2020b). The high values of the CO line ratio \(r_{21} \geq 1\) in the southern part of the tail, the narrow, single-component CO emission lines, and low velocity dispersion hint that the tail in that region is composed of dense star forming molecular gas. The time required to produce a such a long stripped tail \((\sim 30 \ Myr)\) is much longer than the typical lifetime of a dense molecular cloud \((\sim 5 \ Myr, \ Chevance \ et \ al. \ 2020)\). This signifies that these clouds are formed in situ, either from the stripped H\(\text{I}\) or the diffuse molecular gas (Moretti et al., 2020b,a).
4.6.2 The distribution of \( \text{H} \text{} \text{I} \) in JW100 in comparison with \( \text{H} \alpha \) and CO

Fig. 4.7 shows the multi-phase gas in the RPS tail of JW100. The left and right panel of Fig. 4.7 show the \( \text{H} \text{} \text{I} \) emission (red, 20” resolution) on \( \text{H} \alpha \) (white, 1” resolution) and \( \text{H} \text{} \text{I} \) emission (red, 20” resolution) on CO(2-1) (blue, 1” resolution) respectively with the DECaLS (Dey et al., 2019) color image in the background. The atomic, molecular, and ionised gas tails are almost of similar extent (\( \sim 50 \) kpc), this small difference of the tail lengths could be also due to the different sensitivities and resolutions of the \( \text{H} \text{} \text{I} \), \( \text{H} \alpha \), and CO(2-1) data.

We then inspect the distribution of gas at different recession velocities through channel maps in Fig. 4.8. We compare the \( \text{H} \text{} \text{I} \) contours (red), CO(2-1) contours (blue), and the \( \text{H} \alpha \) emission (greyscale) at different velocities in JW100 in ten panels. The top two rows of Fig. 4.8 show \( \text{H} \alpha \) emission at the original MUSE angular and velocity resolution (1” \( \times \) 1”, 57.1 km s\(^{-1}\), Poggianti et al. 2019), CO(2-1) emission at the original ALMA resolution (1.4” \( \times \) 1.1”, 44.1 km s\(^{-1}\), Moretti et al. 2020b) and \( \text{H} \text{} \text{I} \) emission smoothed to 20” and \( \sim 135 \) km s\(^{-1}\). The high resolution ALMA channel maps indicate the location of small CO(2-1) clumps. In the bottom two rows of Fig. 4.8, the CO(2-1) emission is also smoothed to an angular resolution of 20” to compare the atomic and molecular gas phases on the same spatial scales.

\( \text{H} \alpha \) emission is visible already in the top-left panels where \( \text{H} \text{} \text{I} \) and CO(2-1) are not yet visible. CO(2-1) and \( \text{H} \text{} \text{I} \) emission are detectable from the 4th and 5th panel respectively. In the 6th, 7th, and 8th panel of Fig. 4.8, \( \text{H} \text{} \text{I} \) emission is found further down the tail (away from
Fig. 4.8: Hα, CO(2-1), and H i channel map overlays for JW100. In the bottom two rows, the CO(2-1) emission is smoothed to the same angular resolution as the H i emission (20") to compare the atomic and molecular gas phases on the same spatial scales. The red solid contours represent the H i emission with contour levels of (2, 3, 4, 5,..) ×σ or RMS and the dotted red contour represents the −2σ level. The blue contours indicate CO(2-1) emission with contour levels (2, 4, 8, 16,..) ×σ where σ= 0.28 mJy/beam for the high resolution ALMA cube and 0.67 mJy/beam for the 20" ALMA cube. The central light-grey rectangle represents the area in which Hα emission is observed with MUSE, after substraction of the [NII] emission lines and the stellar continuum emission. The image is larger than the field of view of MUSE, so the DECaLS g-band image is shown in the background. The black contour represents the stellar disc and the hatched circle on the bottom left of each panel shows the size of the 20" H i beam. Hα emission is seen in the northern part of the RPS tail but no CO(2-1) or H i emission while Hα and CO versus H i emission are anti-correlated on small scales.
the centre of JW100) than the CO(2-1) clumps. In the bottom two rows of Fig. 4.8, though the CO(2-1) clumps are smoothed in those panels, the centres of the CO(2-1) emission are still offset from the H I emission. The 3σ H I ‘appendix’ at the bottom left in the 8th panel, the 3σ H I peaks in the 9th and 10th panels, and the -2σ H I peaks in the 1st and 2nd panels are consistent with the noise behaviour and plausibly not associated with the H I emission or absorption of JW100. These peaks are not included in the H I mask that is used to make the H I map and the global profile.

The H I and CO(2-1) emissions in the channel maps (4-8th panel) are not exactly co-located, or anti-correlated, which suggests several possibilities. It could be because of a high rate of ionisation of the H I gas by the young massive/OB stars, or due to an efficient conversion of H I to H₂.

Hα emission is extended over larger velocity range than H I and CO(2-1). The systemic velocity of JW100 is $\sim 18500 \text{ km s}^{-1}$ ($z=0.06189$, Poggianti et al. 2019). Towards the lower velocities, the $\sim 1000 \text{ km s}^{-1}$ velocity difference with respect to the systemic velocity for Hα emission can not be accommodated by the rotation of JW100, irrespective of JW100 being a very massive galaxy (3.2 $\times$ 10$^{11}$ M$_\odot$, Poggianti et al. 2019). And based on the TF relation, we would expect a rotational velocity of 400 km/s. Therefore, due to pure rotation of the galaxy, we would expect gas emission at velocities in the range of 18100-18900 km/s. Indeed, the channel maps show the maximum recession velocity of 18800 km/s, consistent with the rotation of the galaxy. However, the lowest velocities where the Hα emission becomes visible, is roughly 17400 km/s. This difference of 1100 km/s from the systemic velocity of the galaxy can not be accommodated by the rotation of the galaxy. Furthermore, this low recession velocity is closer to the systemic velocity of the cluster, suggesting that the Hα emission is lagging behind the galaxy along its orbit through the cluster. This is observed in other GASP galaxies falling along the LOS, such as JO201 in A85 (Bellhouse et al., 2017, 2019).

4.7 H I depletion channels

In what follows, we sketch a qualitative picture of possible H I depletion channels. We estimated the relative importance of the several potential H I depletion mechanisms that act on a galaxy undergoing RPS. We identify three main depletion channels for H I gas in JW100 (see schematic diagram Fig. 4.9):

4.7.1 Stripping (ram pressure)

One of the pivotal depletion mechanisms is ram-pressure stripping of the diffuse H I gas from disc and tail while JW100 is falling into the centre of A2626 cluster and interacting with the hot, X-ray emitting ICM.

We infer the amount of ram-pressure stripped H I gas based on the mass of H I gas in the tail of JW100. The mass of H I gas in the tail is derived by subtracting the amount of H I gas inside the stellar disc from the total H I gas seen in emission. The stellar disc is derived from the MUSE observations (Poggianti et al., 2019). Hence, the total H I mass in the tail is: (2.8 $\times$
Fig. 4.9: Cartoon of H I depletion channels. There are three principal depletion channels: ram-pressure stripping of the diffuse H I gas, H I to H2 conversion in the tail, and ionisation of H I gas.

$10^9 - 0.8 \times 10^9 \ M_\odot = 2 \times 10^9 \ M_\odot$. At least 70% of the H I gas has been removed from the disc.

4.7.2 H I to H2 conversion

Moretti et al. (2020a) found an over-abundance of molecular gas in the tail of JW100. Hence, another significant H I depletion channel seems to be H I to H2 conversion in the disc and tail of JW100 due to the collapse of turbulent atomic gas.

We have calculated the spatially resolved atomic to molecular gas fraction for both the disc and the tail of JW100 to investigate the H I gas depletion efficiency of the ISM due to H I to H2 conversion. The amounts of H2 gas in the disc and tail are also calculated within the stellar disc defined by the MUSE observations (Poggianti et al., 2019; Moretti et al., 2020b). This will also reveal whether the atomic to molecular conversion is more efficient in JFG tails due to the collapse of turbulent atomic gas in the ISM. The left panel in Fig. 4.10 is the ratio map for H2 vs H I surface mass density (both measured in units of $M_\odot/pc^2$). The map is constructed by smoothing the H I and H2 column density maps to 20” resolution and regridding the maps to the same pixel sizes (0.2”). Though we are limited by the resolution of the H I data, evidently, there is a negative gradient along the tail, implying there is more H I compared to H2 in the extended tail. For field galaxies, depending on their stellar masses ($9.18 \leq \log M_\star/M_\odot \leq 11.2$), the ratio of H I and H2 mass varies in the range of 0.03-1.3, as
Fig. 4.10: $\text{H}\alpha/\text{HI}$ and $\text{H}_2/\text{HI}$ ratio maps of JW100. The maps are constructed by smoothing the $\text{H}_1$, $\text{H}_2$, and $\text{H}\alpha$ column density maps to 20” resolution and regridding the maps to the same pixel sizes (0.2”). The black curved contour inside represents the stellar disc. The black solid contours represent the $\text{HI}$ emission with contour levels (3, 4, 5,..) × $\sigma$ or RMS. The beam size is shown in the bottom left. The negative gradient in both the maps show that there is an abundance of $\text{HI}$ over $\text{H}_2$ or $\text{H}\alpha$ along the extended tail.

found in the xGASS sample (Catinella et al., 2018). In the Fornax cluster, Loni et al. (2021) found $\text{M}_{\text{H}_2}/\text{M}_{\text{HI}}$ in the range of 0.1-10 for galaxies with stellar masses $10^9 \leq M_*/M_\odot \leq 10^{11}$ (Zabel et al., 2019; Loni et al., 2021). In the case of JW100, $\text{M}_{\text{H}_2}/\text{M}_{\text{HI}}$ is 8.9, higher than the field galaxies, but within the higher end of the range of $\text{M}_{\text{H}_2}/\text{M}_{\text{HI}}$ in Fornax galaxies (Zabel et al., 2019; Moretti et al., 2020b; Loni et al., 2021).

We calculate the amount of $\text{HI}$ gas that is converted into $\text{H}_2$ in the tail, by considering the amount of clumpy molecular gas in the tail. We assume the clumpy molecular gas is formed \textit{in situ} in the tail from the stripped $\text{HI}$ gas. We also assume that the diffuse CO gas in the tail is ram-pressure stripped diffuse CO gas from the disc and part of it will eventually blow out without forming clumps and stars subsequently. And a part of diffuse CO will end up in CO clumps. Since JW100 is over-abundant in CO (Moretti+ 2020), it is unlikely that the CO clumps in the tail are mainly formed out of the diffuse CO in the tail. Combining LOFAR-MeerKAT-JVLA radio continuum observations of JW100, Ignesti et al. (submitted) estimated the strength of the magnetic field $\leq 10 \mu \text{G}$, that could potentially be strong enough to shield the stripped ISM gas from the ICM (Müller et al., 2021). The draping of the magnetized environmental plasma around the tail is possibly preventing thermal
conduction and hydrodynamic turbulence by the hot ICM, enabling the stripped H I gas to cool and condense in molecular clumps (e.g., Sparre et al. 2020; Ge et al. 2021; Müller et al. 2021). In Table 2 from Moretti et al. (2020b), the CO flux in the ALMA 12m observations represents the clumpy molecular gas while the 12m + ACA or APEX observations stand for the total molecular gas emission (diffuse + clumpy). From this we infer that one-third of the molecular gas is clumpy and formed in situ in the tail, mostly from the H I gas. From Table 2 in Moretti et al. (2020a), the total amount of H₂ gas in the tail is 0.6% of the stellar mass. Therefore, the total amount of clumpy H₂ gas in the tail is: \( \frac{1}{3} \times 0.6\% \times 3.2 \times 10^{11} = 6.4 \times 10^{8} \) M\( \odot \). Thus, there is three times more diffuse H I gas than clumpy H₂ gas in the tail.

4.7.3 H I to H\( \alpha \) conversion

Ionisation of H I owing to radiation from young stars that are formed in situ in the tail in the molecular gas clumps and due to complex ICM-ISM interplay is another depletion channel for H I gas.

We have investigated the spatially resolved ionised to atomic gas fraction for both the disc and the tail of JW100 using the same strategy we used for the molecular to atomic gas fraction. The left panel in Fig. 4.10 shows the ratio map for H\( \alpha \) vs H I surface mass density (surface mass density is measured in units of M\( \odot \)/pc² and H\( \alpha \) emissivity in erg/s/cm²/pc²) for JW100. In this case also, there is a gradient along the tail, implying there is more H I compared to H\( \alpha \) toward the tip of the tail. The lower limit of H\( \alpha \) gas estimated from the MUSE observations is \( 4.6 \times 10^{6} \) M\( \odot \).

4.7.4 Summary of depletion channel efficiencies

We estimate the total amount of H I gas before the onset of gas depletion mechanisms as the sum of H I gas in the disc + H I gas in the tail + clumpy H₂ gas in the tail + H\( \alpha \) gas in the tail. Thus, the minimum amount of H I gas with which JW100 would have entered the A2626 cluster is \( (2.8 \times 10^{9} + 0.64 \times 10^{9} + 4.6 \times 10^{6}) M_{\odot} = 3.4 \times 10^{9} M_{\odot} \).

However, as a result of these several depletion mechanisms, some amount of H I gas might already have been stripped and diffused into the ICM such that we are unable to measure it from our observations. To have an estimation of the expected H I mass of JW100, we used a scaling relation of M\( \text{HI} \)/ M\( \star \) of the field galaxies from ALFALFA survey (Maddox et al., 2015). The expected H I mass for a galaxy with similar stellar mass as JW100 is \( 1.4 \times 10^{10} M_{\odot} \). So, almost 80% of the H I gas is already entirely removed from JW100 and its tail. We conclude that the depletion mechanisms are very efficient in JW100, and the galaxy is already in a very advanced stage of gas removal.

A rough estimation of the time for H I gas to reach the tip of the tail of JW100 is 33 Myrs, assuming a velocity of 1980 km s\(^{-1}\) (velocity of JW100 with respect to the cluster) and a maximum extent of the tail of 60 kpc. The stripping time should be shorter if the galaxy is subject to acceleration as it undergoes RPS. Since the typical lifetime of a dense molecular cloud is \( \sim 5 \) Myrs (Chevance et al., 2020), there were \( \sim 6 \) different molecular clump formation cycles by the time the stripped atomic gas reached the tip of the tail. Therefore, the gas loss rate of JW100 is (atomic gas mass in the tail+ clumpy molecular gas mass in the tail)/stripping

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time = (2 \times 10^9 \, M_\odot + 6.4 \times 10^8 \, M_\odot)/(33 \, \text{Myr}) = 80 \, M_\odot \, \text{yr}^{-1}. \) If 10% of the molecular gas is converted into stars, the SFR in the tail is 10% of 20 \, M_\odot \, \text{yr}^{-1} \sim 2 \, M_\odot \, \text{yr}^{-1}, which is consistent with the observed SFR in the tail of JW100 (Vulcani et al., 2018). RPS started to affect JW100 when the galaxy was at a distance of \sim 250 \, \text{kpc} from the cluster centre, based on the method described in Jaffé et al. 2018, thus JW100 is under influence of RPS for (250 \, \text{kpc}/1980 \, \text{km} \, \text{s}^{-1}) \sim 125 \, \text{Myrs}. Hence, the amount of atomic gas already removed from JW100 is, (80 M_\odot \, \text{yr}^{-1}) \times 125 \, \text{Myrs} \sim 10^{10} \, M_\odot. Thus, indeed, almost \sim 65% of the atomic gas is depleted from JW100. However, these calculations are a rough approximation, showing that our approach of investigating different depletion channels is consistent with the observed quantities.

4.8 Summary

In this work, we have presented MeerKAT H I observations of the JFCGs in the A2626 galaxy cluster. Among the six JFCGs as identified by Poggianti et al. (2016) from their optical morphologies in WINGS B-band images, only JW100 is identified as a JFG from its optical and H I morphologies. JW103 is probably a ram-pressure stripped galaxy at a later stage of stripping. Both JW100 and JW103 are moving at a very high similar velocity (cz \sim +1800 \, \text{km} \, \text{s}^{-1}, \sim 3\sigma_{cl}) with respect to the ICM of A2626, suggesting that these galaxies are entering as a group, confirmed by Healy et al. (2021c). Both of these galaxies are higher class JFCGs (JClass > 1, Poggianti et al. 2016) and reside close to the X-ray emitting cluster core, thus in the most favourable conditions for RPS. In our upcoming work, taking advantage of these MeerKAT H I observations, we expect to identify more RPS galaxies in the A2626 volume that could not be identified from their optical morphologies.

- The four JFCGs namely JW98, JW99, JW101, JW102 have significant H I masses (\sim 10^{10} M_\odot). Their H I imaging reveals warps, morphological and kinematic asymmetries, possible tidal interactions and no convincing signature of RPS.

- JFG JW103 is barely detected in H I and very H I deficient (M_{H I} = 10^9 M_\odot). While in the optical image of JW103, we observe blue tentacles towards the west, we do not detect any H I tails in the direction of the optical tail, possibly because the H I emission is below the detection limit. Interestingly we see a radio continuum tail in the direction of the optical tail, which is possibly due to the relativistic electrons that were already accelerated in the disc, rather than the star formation activity in the tail (e.g. Ignesti et al. 2022; Chen et al. 2020).

- We investigated H I vs stellar masses for JFCGs compared to a reference sample of galaxies from the PP, UMa, A2626 and ALFALFA surveys of field galaxies (Maddox et al., 2015). All JFGs have lower H I masses for their stellar masses compared to most field or cluster galaxies while other JFCGs are H I rich. We then plotted SFR vs stellar masses for the JFCGs, the reference sample galaxies and the SFMS relations. None of the JFCGs and previously studied GASP JFGs stand out with respect to the SFMS of Cluver et al. (2020).

- Finally, when we compared the H I content vs the SFR in the JFCGs and the reference sample, all five JFGs stand out in the relation because of the lower H I masses for their SFRs. It means that these galaxies are H I stripped but not yet quenched.
- H I observations of JW100 reveal an extended H I tail towards the south-west up to ∼ 50 kpc from the stellar body of the galaxy. Comparing the Hα, CO(2-1), and H I channel maps in JW100, we detect Hα emission in the northern part of the RPS tail with no CO(2-1) or H I counterpart (but where X-ray emission is present, Poggianti et al. 2019) possibly because of complex ISM-ICM interaction due to prolonged RPS. Moreover, we observe an anti-correlation between Hα and CO(2-1) versus H I, hinting at an efficient conversion of H I to H2 in the tail. We hypothesize that the draping of the magnetic plasma around the tail is preventing thermal conduction and hydrodynamic turbulence by the hot ICM, enabling the stripped H I gas to cool and condense into H2 clumps (e.g. Müller et al. 2021).

- The spatially resolved Hα/H I and H2/H I ratio maps of JW100 show a gradient along the tail, implying there is more H I compared to H2 or Hα toward the tip of the extended tail. We estimated the relative importance of the different depletion mechanisms of the H I gas in JW100 and we identify three main depletion channels: RPS removal, conversion of H I to H2, and ionisation of the H I. We found that RPS has removed at least 70% of the H I gas from the disc. There is one-third of the clumpy H2 gas than the diffuse H I gas in the tail that is converted in situ from H I. Thus, JW100 has already lost 80% of the expected H I mass based on the M_HI/ M_⋆ scaling relation of field galaxies (Maddox et al., 2015). Thus we conclude that JW100 is in very advanced stage of gas removal and the depletion mechanisms have removed most of the H I gas from it already.
Where the mind is without fear and the head is held high
Where knowledge is free
Where the world has not been broken up into fragments
By narrow domestic walls
Where words come out from the depth of truth
Where tireless striving stretches its arms towards perfection.
Where the clear stream of reason has not lost its way
Into the dreary desert sand of dead habit
Where the mind is led forward by thee
Into ever-widening thought and action
Into that heaven of freedom, my Father, let my world awake.

- Rabindranath Thakur