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Neutral Hydrogen in and around Galaxies in the SKA Era
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Searching for UDG and LSBs in the Hydra cluster with MeerKAT HI

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Abstract. Ultra diffuse galaxies (UDGs) are a low surface brightness population of galaxies exhibiting large sizes. Their recent unexpected abundance in clusters has brought into question our understanding of galaxy evolution and the effect of the harsh cluster environment. Using MeerKAT HI observations of the Hydra I cluster, a nearby Southern galaxy cluster with ongoing galaxy interactions and evolution, we explore the neutral hydrogen content in low stellar mass galaxies, specifically investigating UDGs. Detailed observations of these galaxies in HI provide insights into the processes they experience in these harsh and dense environments. We present preliminary results on our search for UDGs in the Hydra cluster with MeerKAT, including HI detections of a UDG near the center of the cluster, a possible LSB galaxy and a dark cloud of neutral hydrogen.

Keywords. ultra-diffuse galaxies, galaxy evolution, cluster environment, low surface brightness galaxies

1. Introduction

Ultra diffuse galaxies (UDGs) are extended, low surface brightness galaxies and typically have low stellar masses. Surprisingly, UDGs have been found to be abundant in galaxy clusters which was not expected due to the harsh cluster environment. Previous studies have shown these faint-extended galaxies in clusters are quenched of starformation and are expected to be deficient of neutral hydrogen.

The primary goal of this study is to detect, image and measure the HI content of previously identified UDGs and LSBs in the Hydra I cluster. The HI redshift will enable us to confirm cluster membership and HI content will provide an insight in the cluster processes affecting UDGs and by extension all galaxies in dense environments. UDGs are an extreme class of LSBs, characterizing their properties within the Hydra cluster will give us an insight into formation mechanisms within dense environments and help us understand the effects of the clusters on the evolution of galaxies.

Table 1. Properties of Hydra I cluster MeerKAT observation.

Observing time	Single pointing 10 hours
Frequency range	1387 - 1419 MHz (312 - 7143 km/s)
Spectral resolution	26.123 kHz (5.5 km/s)
Pixel resolution	4” × 4”
Beam FWHM	21.4” × 14.4”
RMS	0.198 mJy/beam
N_{HI} sensitivity	4.1×10^{18} cm^{-2}

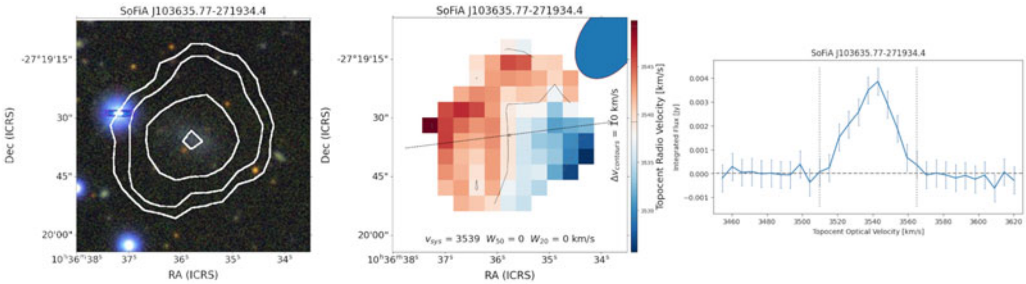

Figure 1. UDG 6 is observed near the center of the cluster. The optical images are DECaLS DR10 images with HI contours plotted in white, a rotation map and HI detection plots using Sofia Imaging Pipeline (Hess et al. 2024).

2. Hydra I Cluster

The Hydra I galaxy cluster is a nearby (z $\sim$ 0.0126, D $\sim$ 55 Mpc) southern galaxy cluster with a virial mass of $M_{vir} \sim 2 \times 10^{14}\, M_{\odot}$ (Girardi et al. 1998) and a recession velocity of 3683 ± 46 km/s (Christlein and Zabludoff 2003). The Hydra I cluster is perturbed and shows substructures which are likely due to recently infalling groups, making it an ideal cluster to study environmentally-driven galaxy evolution (Lima-Dias et al. 2001). The outskirts and core regions also show evidence of gas removal and ram pressure stripping (Reynolds et al. 2021; Hess et al. 2022).

Iodice et al. (2020, 2021) and La Marca et al. (2022) have collectively discovered 24 UDG candidates and 22 other LSB galaxies in the central region of the Hydra I cluster using deep optical imaging from the VLT Survey Telescope (VST). Iodice et al. (2023) have obtained optical spectra for a number of these galaxies with MUSE, confirming the cluster membership for 17 UDGs.

We follow up on the previously discovered UDGs and LSBs in the Hydra I cluster with MeerKAT radio observations. The pilot 10h observation is a single pointing at the center of the Hydra cluster, detailed in table 1. A survey of the remaining region of the cluster up to the virial radius was undertaken with MeerKAT to reach a uniform depth across the Hydra cluster and enable studies of the environmental effects of clusters on UDGs.

3. Preliminary Detections

The MeerKAT radio data were reduced on the ilifu cloud computing facility using CARACal (`https://caracal.readthedocs.io`) and SoFiA (Serra et al. 2015; Westmeier et al. 2021) was used for source finding. We have identified numerous HI sources, including UDGs (see figure 1) and LSBs (see figure 2) as well as dwarfs and a possible dark cloud of neutral hydrogen in the cluster (figure 3). The optical and HI properties of these sources are listed in table 2.

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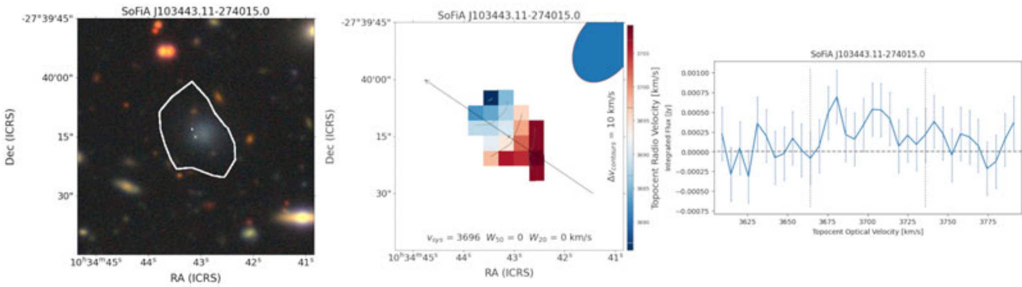

Figure 2. LSB 15 is detected at the recession velocity of the Hydra cluster, approximately 30 arcmin from the cluster center. The additional observations will improve the HI mass estimation.

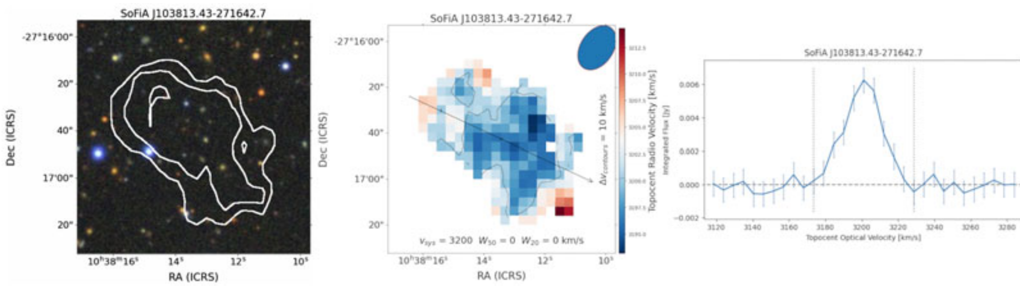

Figure 3. GAL-HI has been detected in HI with no clear optical counterpart in the DECaLS data. The recession velocity and proximity to the Hydra cluster center suggests association.

Table 2. The measured HI properties of the UDG, LSB and optically dark galaxy in the Hydra I cluster and their optical parameters as reported in Iodice et al. (2020, 2023) and La Marca et al. (2022).

Object	$\mathbf{M_r}$ [mag]	$g-r$	$\mu_0(g)$ [mag arcsec^{-2}]	$\mathbf{R_e}$ [kpc]	$\mathbf{V_{sys}}$ [kms^{-1}]	$\mathbf{W_{50}}$ [kms^{-1}]	$\mathbf{M_{HI}}$ log(M$_\odot$)
UDG 6	-14.38	0.32	24.08	1.37	**3542**	**29**	**7.96**
LSB 15	-14.96	0.6	23.1	0.89	**3692**	**43**	**7.34**
GAL-HI	-	-	-	-	**3200**	**22**	**8.12**

4. Conclusion and Outlook

In our preliminary study we have identified several UDGs, LSBs and a possible dark cloud of neutral hydrogen in the central region of the Hydra I cluster, suggesting that faint extended galaxies may have significant HI content within the harsh environment of clusters.

The next step is to characterise the remaining LSBs in the Hydra cluster, determine their redshifts and HI masses. We will also estimate the mass limits on non-detections and perform stacking on UDGs and LSBs with the available optical redshifts.

We have obtained an additional 120 hours of MeerKAT data on the Hydra cluster with coverage up to the virial radius. The processing of this data is underway. The study of HI-UDGs and their evolution within the cluster environment up to the clusters virial radius (where we expect to find more HI sources) will be pursued to further our understanding of environmentally-driven galaxy evolution.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1743921324003429

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