The user wants me to translate a Chinese academic paper title and abstract (or part of it) to English. The text appears to be: "New H i Observations Toward the NGC 5055 Galaxy Group with FAST 后印本"Let me break this down: - "New H i Observations Toward the NGC 5055 Galaxy Group with FAST" - This pa···

Authors: The user has provided a list of names: "Xiao-Lan Liu, Ming Zhu, Jin-Long Xu, Peng Jiang, Chuan-Peng Zhang, Nai-Ping Yu, Jun-Jie Wang and Yan-Bin Yang"

This appears to be an author list for a scientific paper. The task is to translate from Simplified Chinese to English with the highest accuracy and academic tone.

Looking at the content, these are Chinese names. The translation of Chinese names into English typically follows the Pinyin system, which is already what is provided here. The names are already in English format (Pinyin with hyphens for multi-character given names).

Let me check the requirements: 1. Preserve ALL LaTeX commands and placeholders - there are none here 2. Preserve ALL citation commands - there are none here 3. **PRESERVE ALL ···paragraph wrapper tags EXACTLY** - there are none here 4. Maintain academic tone and formal scientific writing style - this is just a list of names 5. Use precise technical terminology - not applicable here 6. Preserve section structure and paragraph organization - it' s just a list 7. Translate all content completely - the names are already in Pinyin, which is the standard English representation

The names are: - Xiao-Lan Liu (刘小兰) - Ming Zhu (朱明) - Jin-Long Xu (徐金龙) - Peng Jiang (姜鹏) - Chuan-Peng Zhang (张传鹏) - Nai-Ping Yu (余乃平) - Jun-Jie Wang (王俊杰) - Yan-Bin Yang (杨燕滨)

Since these are already in proper Pinyin format (which is how Chinese names are written in English academic papers), no translation is needed. The names should be kept exactly as they are.

However, I need to check if there's any specific formatting required. In academic papers, author lists are typically written with commas separating authors, and "and" before the last author, which is already the case here.

The output should be just the translated text, with no explanations, no quotes, no headings. Since the names are already in the correct English format (Pinyin), I should output them exactly as provided.

Wait, let me re-read the instructions carefully. The user has provided what appears to be an author list. The task is to translate from Simplified Chinese to English. But the names are already in Pinyin,

Date: 2024-08-14T00:00:00+00:00

Abstract

The user wants me to translate a scientific abstract from Chinese to English. Let me analyze the requirements:

1. **CRITICAL REQUIREMENTS**:
    - Preserve ALL LaTeX commands and placeholders exactly
    - Preserve ALL citation commands ([**?**], **??**, (**??**), etc.) exactly
    - **PRESERVE ALL ···paragraph wrapper tags EXACTLY**
    - Maintain academic tone and formal scientific writing style
    - Use precise technical terminology - obey the glossary strictly
    - Preserve section structure and paragraph organization
    - Translate all content completely - do not omit any information
2. **OUTPUT RULES**:
    - Return ONLY the translated text
    - Keep one output paragraph per input paragraph
    - **Maintain exact count and IDs of ···tags**
    - Do NOT add Markdown formatting unless present in source
    - Preserve original line breaks within the paragraph when meaningful
3. **FORMATTING GUIDELINES**:
    - Keep mathematical expressions in original LaTeX format
    - Preserve equation numbers and references
    - Maintain proper academic paragraph structure
    - Use formal scientific language
4. **Glossary**:
    - 机器学习 => machine learning
    - 深度学习 => deep learning

Wait, the input text is already in English! Let me re-read the user' s message carefully.

The user says: "We report a new high-sensitivity H i mapping observation of the NGC 5055 galaxy group over an area of with the Five-hundred-meter Aperture Spherical radio Telescope (FAST). Our observation reveals that the warped H i disk of NGC 5055 is more extended than what was previously observed by

WSRT, out to (61.7 kpc). The total H i mass of NGC 5055 is determined to be 1.1 × 1010M . We identified three H i clouds with H i masses of the order of 107M at the southeastern edge of the H i disk, as well as a candidate high-velocity cloud with an H i mass of (1.2 ± 0.5) × 106M to the north of NGC 5055. The H i content of UGCA 337 is robustly detected for the first time by the FAST observations. It has a narrow H i linewidth of W50 = 17.4 ± 3.8 km s−1 with a total H i mass of (3.5 ± 0.3) × 106M . Comparing the gas content and g−r color of UGCA 337 with typical low-mass dwarf galaxies, UGCA 337 appears relatively gas-poor despite its blue color. This suggests that UGCA 337 may have undergone gas stripping in the past. We also

Full Text

New H I Observations Toward the NGC 5055 Galaxy Group with FAST

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Abstract

We report a new high-sensitivity H I mapping observation of the NGC 5055 galaxy group over an area of 1.°5 × 0.°75 with the Five-hundred-meter Aperture Spherical radio Telescope (FAST). Our observation reveals that the warped H I disk of NGC 5055 is more extended than previously observed by WSRT, out to 23′.9 (61.7 kpc). The total H I mass of NGC 5055 is determined to be 1.1 × 10^{10} M . We identified three H I clouds with masses of order 10^7 M at the southeastern edge of the H I disk, as well as a candidate high-velocity cloud with an H I mass of (1.2 ± 0.5) × 10^6 M to the north of NGC 5055. The H I content of UGCA 337 is robustly detected for the first time, showing a narrow linewidth of W_{50} = 17.4 ± 3.8 km s^{-1} with a total H I mass of (3.5 ± 0.3) × 10^6 M . Comparing the gas content and g−r color of UGCA 337 with typical low-mass dwarf galaxies, UGCA 337 appears relatively gas-poor despite its blue color. This suggests that UGCA 337 may have undergone gas stripping in the

past. We also analyzed the possible origin of the diffuse H I clouds located at the outskirts of NGC 5055, and speculate that they might be remnant features of a past merger event.

Key words: galaxies: evolution -galaxies: structure -galaxies: individual (NGC 5055) -galaxies: kinematics and dynamics -galaxies: interactions

1. Introduction

Understanding how massive galaxies, such as our Milky Way, accumulate mass to support their nearly constant star formation rates over billions of years is crucial for understanding galaxy evolution. According to the Λ-Cold Dark Matter paradigm of cosmology, galaxies are expected to form hierarchically, with gas and dark matter accumulating in dark matter halos, merging and condensing into larger structures that lead to star formation and galaxy growth. High-sensitivity observations of massive disk galaxies have the potential to provide new insights into their formation and evolutionary history.

NGC 5055, also known as the Sunflower Galaxy M63, is a Milky Way-type SAb(c) galaxy with an optical disk size of about $5'.5$ (R_{25}) (de Vaucouleurs et al. 1976). This spiral galaxy is located at a distance of 8.87 Mpc (McQuinn et al. 2017) and is accompanied by approximately 20 dwarf galaxies identified through deep optical observations (e.g., Karachentsev et al. 2020). The group is relatively isolated, with no large galaxies in the surrounding $3° \times 3°$ region (Müller et al. 2017; Karachentsev et al. 2020). Within the group, only a few dwarfs have radial velocities within \$$\pm 300 kms$^{-1}\$ of NGC 5055, among which UGC 8313 and UGCA 337 have been confirmed as true satellites of NGC 5055 through distance measurements (Carlsten et al. 2022). However, most other faint dwarfs in the group lack velocity or distance information (Karachentsev et al. 2020; Carlsten et al. 2022), making it difficult to determine their role in the evolution of NGC 5055.

NGC 5055 has been extensively studied using high-resolution 21 cm H I line observations with the Westerbork Synthesis Radio Telescope (WSRT) (Battaglia et al. 2006; Kamphuis et al. 2022). These observations revealed a significantly extended H I disk with pronounced kinematic warps beyond the inner optical disk. Deep optical observations have found very faint stellar loops across NGC 5055, some without detected H I associations (Chonis et al. 2011; Karachentsev et al. 2020). Kamphuis et al. (2022) reported three H I sources on the outskirts of NGC 5055 through analysis of the deep WSRT Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) Survey (Heald et al. 2011), including a possible cloud candidate northeast of NGC 5055 and two H I counterparts of nearby dwarf galaxies UGC 8313 and UGC 8365.

Interferometer arrays have the advantage of resolving small structures in galaxies in principle, but can suffer from "negative bowl" artifacts indicating loss of short-spacing information (Wang et al. 2023). In contrast, single-dish radio telescopes can compensate for this deficiency. In recent years, radio telescopes with large collecting areas, such as the Five-hundred-meter Aperture Spherical radio Telescope (FAST), have detected faint gas in and around several large spiral galaxies (e.g., Zhu et al. 2021; Xu et al. 2021; Wang et al. 2023; Yu et al. 2023). These findings have shed new light on galaxy formation and evolution. In this paper, we present new H I observations of the NGC 5055 galaxy group using FAST. We describe the observations and data reduction in Section 2, present the results and kinematic analysis of NGC 5055 in Section 3, discuss the possible origin of the observed H I around NGC 5055 in Section 4, and summarize our main results in Section 5.

2. Observation and Data Reduction

We carried out a high-sensitivity H I observation of NGC 5055 and its surroundings over an area of $1.^\circ5 \times 0.^\circ75$ in July 2022 as part of the FAST All Sky H I survey (FASHI, Zhang et al. 2024). We adopted the multi-beam on-the-fly (MultiBeamOTF) observation mode with the 19-beam array receiver, which provides a half-power beamwidth (HPBW) of $2'.9$ at 1.4 GHz per beam (Nan et al. 2011; Jiang et al. 2019, 2020). The on-sky scanning speed was set to $15''$ per second with an integration time of 1 s. Spectra were observed in dual polarization mode and digitized by the backend Spec(W) in 65,536 channels over a bandwidth of 500 MHz, providing a frequency resolution of 7.629 kHz at 1.4 GHz, corresponding to a velocity resolution of 1.611 km s^{-1}. During the observation, the mean system temperature was 20 K. The pointing accuracy of FAST is better than $8''$.

We observed NGC 5055 twice with a total observation time of 1.28 hr. For calibration, a standard noise signal, T_{cal} (typically 10 K), was regularly injected into the signal path every 32 s for a duration of 1 s. The raw data were reduced using the Python-based pipeline HIFAST (Jing et al. 2024). The reduced data cube has a pixel scale of $1'$ and a spectral resolution of 1.611 km s^{-1}. The final data cube has a mean noise of about 1.04 mJy $beam^{-1}$ per channel, corresponding to a 3σ H I column density of 5.2×10^{17} cm^{-2} for a linewidth of 20 km s^{-1} (Wang et al. 2023).

In addition, we utilized SOFIA (Serra et al. 2015) to create a detection mask for the H I emission in the final data cube, which was applied during the analysis of the H I moment maps. The smooth+clip source-finding algorithm was implemented using a 5σ threshold and smoothing kernels of 0, 3, and 5 pixels in both spatial and velocity dimensions. The final detection mask was generated to ensure a detection reliability of 0.99.

3.1. H I Map of the NGC 5055 Galaxy Group

Figure 1 Figure 1: see original paper presents the H I column density map of the NGC 5055 galaxy group in contours overlaid on the SDSS g-band optical image. The column density is derived from the moment-0 map integrated over the velocity range of 276.0–718.8 km s^{-1}. Three dwarf galaxies are located adjacent to NGC 5055. UGC 8313 and UGCA 337 have been recognized as satellites of NGC 5055 (Carlsten et al. 2022) at projected distances of 61.7 kpc to the northwest and 90 kpc to the southwest, respectively. UGC 8365 is located to the east of NGC 5055 and has a systemic velocity of 1260 km s^{-1} (van Driel et al. 2016; Kamphuis et al. 2022). We estimated the distance to UGC 8365 as 20.8 $\pm$ 2.1 Mpc using the Cosmicflows-3 method (Kourkchi et al. 2020), which is not associated with NGC 5055. Thus, we suggest that UGC 8365 is a background galaxy relative to NGC 5055.

Figure 1(b) shows an H I column density overlay map of NGC 5055 from both FAST and HALOGAS survey data. Compared to the HALOGAS survey, the FAST observations reveal more extended H I structures around NGC 5055, extending the observed H I disk of NGC 5055 out to $23'.9$ (i.e., 61.7 kpc). This size is corrected for resolution using the expression R_{HI} = √(R_{obs}^{2} - R_B^2), where R_{HI} is the length of the semimajor axis measured from the H I column density map at the 3σ level and R_B is half the HPBW of FAST. This H I disk measured by FAST is 25% larger than that from the full WSRT data observed by Battaglia et al. (2006).

Figure 2 [Figure 2: see original paper] compares the total H I flux of NGC 5055 from the FAST observation (black line) and the primary beam-corrected HALOGAS survey (blue line). We find that the primary beam-corrected HALOGAS survey revealed 22.4% $\pm$ 0.6% less H I flux compared to FAST (see Table 1). Taking into account the 10% systematic difference between the two telescopes and the 10% flux calibration uncertainty (Wang et al. 2023), our observed H I flux for NGC 5055 is still in excess of the HALOGAS survey. This is because the HALOGAS survey was performed with the interferometer array WSRT, which could suffer from the zero-spacing problem and miss flux from extended gas components. This effect has been studied in detail for NGC 4631 (Wang et al. 2023).

3.2. H I Kinematics of NGC 5055

In Figure 3 [Figure 3: see original paper], we explore position–velocity (PV) slices along five directions indicated by the cyan dashed arrows labeled a through e (the same labels apply to the panels). The slice thickness is taken as 3 spaxels, i.e., $3'.0$, corresponding to the beam size. In each PV diagram, the position axis is centered on NGC 5055 and increases along the arrow direction. These slices were selected to investigate the kinematic behavior of dwarf galaxies and possible substructures (i.e., c1, c2, c3, and H1) in the H I map around the main H I disk (within an elliptical radius of $0°.3$) of NGC 5055.

Panel (a) shows a PV slice passing through possible substructure c1, which appears as a detached component with noticeably lower velocity than the main H I disk emission. In the positive part of the PV diagram, c1 shows some broad spatial connections to the main H I disk over a wider velocity range. One may also notice the counterpart of c1 (at the same symmetric distance) in the negative part of the PV diagram, which does not appear detached from the main H I disk but shows strong velocity lag (over about 50 km s^{-1}). Although these spatial and kinematic features could result from beam smearing at high inclination, it is important to note that the ridge line of the disk flux in panel (a) points toward c1, indicating that they are likely tidal gas features around NGC 5055.

In panel (b), UGC 8313 is seen at a counter-rotating velocity relative to the disk of NGC 5055 and is well detached. The possible substructure c2 appears more connected to the main H I disk, and its counterpart shows good continuity with the main H I disk. Panel (c) demonstrates that possible substructure c3 has similar properties to c2. Panel (d) depicts the clear detection of H I gas associated with the low surface brightness (LSB) galaxy UGCA 337. In panel (e), we see that substructure H1 appears not only as an extra structure beyond the main H I disk but also as separated in velocity by -170 km s^{-1} relative to the systemic velocity of NGC 5055, suggesting that it is either a satellite or a high-velocity cloud (HVC) of NGC 5055 (Westmeier et al. 2008; Hess et al. 2009; Chynoweth et al. 2011b).

Figure 4 [Figure 4: see original paper] presents the velocity field of NGC 5055 (excluding UGC 8313, as it is superimposed in position but at a different velocity). Similar to the PV slices in Figure 3, the main H I disk of NGC 5055 shows a regular warped velocity field. At the outskirts of NGC 5055, c1, c2, and c3 exhibit overall velocity continuity with the main H I disk; however, there appears to be a slightly perturbed velocity field at their junctions. In addition, a velocity gradient is present between the isolated H1 and the northern edge of the H I disk of NGC 5055, possibly due to projection effects.

3.3. Integrated H I Properties of the H I Clouds

Using the associated velocity ranges from the PV diagrams (see Table 1), we created H I column density maps and measured integrated fluxes for the H I substructures c1, c2, c3, and H1, presented in Figure 5 [Figure 5: see original paper]. The H I column density maps above 3σ are superimposed on SDSS g-band optical images to identify optical counterparts. In Figure 5, each of the four H I substructures exhibits a coherent structure with a Gaussian component and appears to lack any visible optical counterpart. Therefore, we conclude that the H I substructures c1, c2, c3, and H1 are likely coherent gas clouds (Chynoweth et al. 2011a) located on the outskirts of the extended gaseous disk of NGC 5055.

We compute their total H I mass using the standard relation M_{HI} = 2.36 $\times$ 10^5 D^2 S_ dV, where D is the distance in Mpc and S_ dV is the integrated H I flux in Jy km s^{-1}. Assuming the same distance as the host galaxy NGC 5055, clouds c1, c2, c3, and H1 are determined to have total H I masses of (2.7 $\pm$ 0.06) $\times$ 10^7 M , (2.3 $\pm$ 0.05) $\times$ 10^7 M , (1.2 $\pm$ 0.06) $\times$ 10^7 M , and (1.2 $\pm$ 0.5) $\times$ 10^6 M , respectively, as shown in column (2) of Table 1. Their combined H I mass contributes less than one percent of that of NGC 5055, which is about

1.1×10^{10} M as derived from the integrated H I flux presented in Table 1.

3.4. Integrated H I Properties of the LSB Dwarf Galaxy UGCA 337

Figure 6 [Figure 6: see original paper] shows the H I column density contours overlaid on the SDSS g-band optical image and the integrated H I spectrum (including the fit from the busy function code) for UGCA 337. From the fitting results of the integrated H I spectrum (Table 1), FAST detected a narrow single-Gaussian H I component with a systemic velocity of 550.0 ± 1.0 km s^{-1} and a linewidth of W_{50} 17.4 ± 3.8 km s^{-1}. This is in agreement with the optically measured heliocentric radial velocity of 529 ± 40 km s^{-1} (Alam et al. 2015) and therefore can be identified as the counterpart of UGCA 337. This H I component is missing from the HALOGAS survey. However, in previous studies of UGCA 337, Huchtmeier et al. (2009) reported a double-horn H I profile with a systemic velocity of 460.0 ± 5.0 km s^{-1} and a linewidth of $W_{50} = 234$ km s^{-1}, observed with the 100 m Effelsberg radio telescope at a spatial resolution of $9'$. Given that UGCA 337 is comparable to the FAST beam size but much smaller than the Effelsberg beam, and that the H I component detected by FAST exhibits a higher signal-to-noise ratio, we believe the FAST H I results for UGCA 337 are more reliable, representing the first clear H I detection of this galaxy.

The H I detection by Huchtmeier et al. (2009) may have been affected by H I emission from NGC 5055 leaking in through an Effelsberg sidelobe (Reich et al. 1978), thus producing the apparent double-horned profile. Cold gas typically dominates the baryon content in low-mass dwarfs (Lelli 2022). We determine the total H I mass of UGCA 337 to be $(3.5 \pm 0.3) \times 10^6$ M using Equation (1) and the integrated H I flux of 194.7 ± 17.5 mJy km s^{-1}. The total gas mass, M_{gas}, can be calculated as $(4.7 \pm 0.4) \times 10^6$ M after accounting for helium by multiplying the above value by a factor of 1.33. The stellar mass (M_*) of UGCA 337 is determined to be $(1.7 \pm 0.5) \times 10^8$ M after correcting for the distance of 8.87 Mpc (Carlsten et al. 2022). The resulting M_{gas}/M_* for UGCA 337 is about 0.03 ± 0.008, implying that this dwarf galaxy is extremely gas-poor. Additionally, the dwarf galaxy exhibits a g−r color of 0.61 ± 0.13 (Carlsten et al. 2022) and a star formation rate of 4.8×10^{-5} M yr^{-1} estimated from Hα observations, indicating a rather low level of star formation despite its blue color. These findings differ from typical low-mass dwarfs (Lisker et al. 2006; Lelli 2022), suggesting that UGCA 337 may have been stripped of gas in the past.

4.1. Origin of the Possible Tidal Gas

Our new high-sensitivity H I mapping observations with FAST toward NGC 5055 reveal faint H I clouds (c1, c2, c3, and H1) at the edges of the H I disk of NGC 5055. Clouds c2 and H1 were detected for the first time in our study, and cloud c3 was also identified for the first time. These four H I clouds have a combined H I mass of 6.3×10^7 M , contributing less than one percent of the H I mass of NGC 5055. In terms of kinematics, clouds c1, c2, and c3 appear as extensions of the spiral arms of NGC 5055 (Figures 3 and 4), resembling tidal tails observed in other galaxies (e.g., Xu et al. 2021; Zhou et al. 2023). In this section, we discuss their possible origins.

Tidal features generally indicate recent or past gravitational interactions and disruptions of galaxies (Sancisi et al. 2008; Xu et al. 2021; Zhou et al. 2023). However, UGC 8313 and UGCA 337 appear to lack the necessary mass to extract gas from their host galaxy NGC 5055, as indicated by the significant stellar mass ratios of about 274 and 306 between NGC 5055 and UGC 8313 and UGCA 337, respectively, since NGC 5055 and UGC 8313 have total stellar masses of 5.2 $\times$ 10^{10} M and 1.9 $\pm$ 0.6 $\times$ 10^{8} M at the distance of 8.87 Mpc, respectively (Carlsten et al. 2022). In addition to UGC 8313 and UGCA 337, Chonis et al. (2011) proposed that NGC 5055 may have disrupted a missed dwarf galaxy in the last few Gyr, as they found a faint, huge, coherent stellar stream with a dim break to the north and northeast of NGC 5055. Chonis et al. (2011) roughly estimated a total mass of approximately 10^{8} M for this disrupted dwarf satellite, which also appears insufficient to extract gas from the host galaxy NGC 5055. Therefore, clouds c1, c2, and c3 seem unlikely to result from minor interactions between the disrupted dwarf galaxy, UGC 8313, or UGCA 337 with NGC 5055.

Alternatively, the tidal tails of NGC 5055 might be remnants of a past merger event that formed the galaxy itself. This is supported by the presence of notable warped features, which may have resulted from such an event (Barnes 2002). Furthermore, the H I kinematic features in NGC 5055 resemble those observed in M94 (Zhou et al. 2023), where a central, isolated host galaxy is surrounded by diffuse H I tidal features and isolated H I clouds. This similarity suggests a common origin for the diffuse H I features outside the host galaxy, indicating that these clouds could be part of the remnant of a major merger event in the past.

5. Conclusions

We have performed a high-sensitivity H I mapping observation toward the NGC 5055 galaxy group over an area of 1.°5 $\times$ 0.°75 with FAST. We discovered a more extended gaseous disk of NGC 5055 compared to the WSRT H I maps. The FAST observation allows us to probe the H I disk of NGC 5055 out to 23′.9 (61.7 kpc) and measure a total H I mass of 1.1×10^{10} M . The latter is approximately 22.4% larger than that revealed by the primary beam-corrected HALOGAS survey, because FAST is a single-dish telescope that does not suffer from the zero-spacing problem and therefore does not miss flux from extended components.

We identified three H I clouds with tidal features on the southeastern edge of the H I disk of NGC 5055. They have total H I masses of 2.7×10^{7} M , 2.3×10^{7} M , and 1.2×10^{7} M , respectively, and may be remnants of a past merger event. A candidate HVC, H1, is confirmed to the north of NGC 5055 near the minor axis, with a total H I mass of 1.2×10^{6} M .

In addition, the H I content of the dwarf galaxy UGCA 337 is robustly determined by FAST for the first time, showing a narrow linewidth of W_{50} = 17.4 ± 3.8 km s^{-1} with a total H I mass of (3.5 ± 0.3) × 10^6 M . Comparing the gas content and g−r color of UGCA 337 with typical low-mass dwarf galaxies, it appears relatively gas-poor despite its blue color, suggesting that UGCA 337 may have undergone gas stripping in the past.

Acknowledgments

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Note: Figure translations are in progress. See original paper for figures.