



Virgo Filaments. V. Disrupting the Baryon Cycle in the NGC 5364 Galaxy Group

Rose A. Finn¹ , Gregory Rudnick² , Pascale Jablonka³ , Mpati Ramatsoku^{4,5,6} , Gautam Nagaraj³ , Benedetta Vulcani⁷ ,
Rebecca A. Koopmann⁸ , Matteo Fossati⁹ , James Agostino¹⁰ , Yannick Bahé³ , Santiago Garcia-Burillo¹¹ ,
Gianluca Castignani¹² , Francoise Combes¹³ , Kim Conger² , Gabriella De Lucia¹⁴ , Vandana Desai¹⁵ ,
John Moustakas¹ , Dara Norman¹⁶ , Damien Sperone-Longin³ , Melinda Townsend¹ , Lizhi Xie¹⁷ , Daria Zakharova^{7,18} , and
Dennis Zaritsky¹⁹

¹ Department of Physics and Astronomy, Siena College, 515 Loudon Road, Loudonville, NY 12211, USA; rfinn@siena.edu

² University of Kansas, Department of Physics and Astronomy, 1251 Wescoe Hall Drive, Room 1082, Lawrence, KS 66049, USA

³ Institute of Physics, Laboratory of Astrophysics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Observatoire de Sauverny, CH-1290 Versoix, Switzerland

⁴ INAF—Cagliari Astronomical Observatory, Via della Scienza 5, I-09047 Selargius (CA), Italy

⁵ Department of Physics and Electronics, Rhodes University, P.O. Box 94, Makhanda, 6140, South Africa

⁶ South African Radio Astronomy Observatory, 2 Fir Street, Black River Park, Observatory, Cape Town, 7405, South Africa

⁷ INAF—Osservatorio astronomico di Padova, Vicolo Osservatorio 5, I-35122 Padova, Italy

⁸ National Department of Physics & Astronomy, Union College, Schenectady, NY 12308, USA

⁹ Dipartimento di Fisica G. Occhialini, Università degli Studi di Milano-Bicocca, Piazza della Scienza 3, I-20126 Milano, Italy

¹⁰ Ritter Astrophysical Research Center and Department of Physics & Astronomy, University of Toledo, Toledo, OH 43606, USA

¹¹ Observatorio Astronomico Nacional, Madrid, Spain

¹² INAF—Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, via Gobetti 93/3, I-40129, Bologna, Italy

¹³ Observatoire de Paris, LERMA, Collège de France, CNRS, PSL University, Sorbonne University, 75014, Paris, France

¹⁴ INAF—Astronomical Observatory of Trieste, via G.B. Tiepolo 11, I-34143 Trieste, Italy

¹⁵ IRSA, California Institute of Technology, MS 220-6, Pasadena, CA 91125, USA

¹⁶ National Optical Astronomy Observatory, 950N Cherry Avenue, Tucson, AZ 85750, USA

¹⁷ Tianjin Astrophysics Center, Tianjin Normal University, Binshuixidao 393, 300387 Tianjin, People's Republic of China

¹⁸ Dipartimento di Fisica e Astronomia Galileo Galilei, Università degli studi di Padova, Vicolo dell'Osservatorio, 3, I-35122 Padova, Italy

¹⁹ Steward Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721-0065, USA

Received 2024 September 2; revised 2025 February 22; accepted 2025 March 24; published 2025 May 15

Abstract

The Virgo Filament Survey (VFS) is a comprehensive study of galaxies that reside in the extended filamentary structures surrounding the Virgo Cluster, out to 12 virial radii. The primary goal is to characterize all of the dominant baryonic components within galaxies and to understand whether and how they are affected by the filament environment. A key constituent of VFS is a narrowband H α imaging survey of over 600 galaxies, VFS-H α . The H α images reveal detailed, resolved maps of the ionized gas and massive star formation. This imaging is particularly powerful as a probe of environmentally induced quenching because different physical processes affect the spatial distribution of star formation in different ways. In this paper, we present the first results from the VFS-H α for the NGC 5364 group, a low-mass ($\log_{10}(M_{\text{dyn}}/M_{\odot}) < 13$) system located at the western edge of the Virgo III filament. We combine H α imaging with resolved H I observations from MeerKAT for eight group members. These galaxies exhibit peculiar morphologies, including strong distortions in the stars and the gas, truncated H I and H α disks, H I tails, extraplanar H α emission, and off-center H α emission. These signatures are suggestive of environmental processing such as tidal interactions, ram pressure stripping, and starvation. We quantify the role of ram pressure stripping expected in this group, and find that it can explain the cases of H I tails and truncated H α for all but one of the disk-dominated galaxies. Our observations indicate that multiple physical mechanisms are disrupting the baryon cycle in these group galaxies.

Unified Astronomy Thesaurus concepts: Galaxy groups (597); Galaxy quenching (2040); Galaxy environments (2029); Large-scale structure of the universe (902); Cosmic web (330)

1. Introduction

The physical properties of galaxies are strongly correlated with their environment; galaxies residing in high-density regions tend to host older stellar populations, have lower star formation rates (SFRs), and different morphologies than galaxies in the field (e.g., A. Dressler 1980; M. R. Blanton & J. Moustakas 2009). The alteration of the gas contents and SFRs is invariably linked to the disruption of the baryon cycle, the exchange of gas between the interstellar medium (ISM) and

intergalactic medium (IGM), and its conversion to stars within galaxies (e.g., J. Tumlinson et al. 2017).

Understanding the disruption of the baryon cycle requires mapping all the components of the gas as well as those of the stars, because the abundance and spatial distribution of different components respond differently to physical processes. For example, strong active galactic nuclei and supernova feedback may quench star formation through ejection or heating of the dense gas and the reservoir of atomic gas without impacting the distribution of preexisting stars (e.g., V. Springel et al. 2005; D. J. Croton et al. 2006; A. Dekel & Y. Birnboim 2006). Processes such as tidal interactions and mergers can affect the distribution of both stars and multiple phases of the gas (A. Toomre & J. Toomre 1972; J. C. Mihos et al. 1993; M. Semiczuk et al. 2020), whereas pressure-driven



Original content from this work may be used under the terms of the [Creative Commons Attribution 4.0 licence](https://creativecommons.org/licenses/by/4.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

interactions, such as starvation (e.g., R. B. Larson et al. 1980), remove the hot gas halo and decouple galaxies from their filamentary connections to the cosmic web while leaving the stars untouched. Ram pressure stripping (e.g., J. E. Gunn & J. R. Gott 1972), on the other hand, can remove diffuse neutral gas (J. D. P. Kenney et al. 2004; A. Chung et al. 2007, 2009; Y. L. Jaffé et al. 2015; M. Ramatsoku et al. 2019), ionized gas (R. A. Koopmann & J. D. P. Kenney 2004; B. M. Poggianti et al. 2019), or even potentially dense molecular gas (A. Boselli et al. 2014; T. C. Scott et al. 2015; B. Lee et al. 2017) from the galaxy disk. However, ram pressure can also compress H I and facilitate its conversion into H₂ (A. Moretti et al. 2023). Studying the relative spatial distribution and amounts of different gas phases and of the stars can therefore help identify the dominant processes that deplete gas in galaxies.

While historically attention has focused on how the baryon cycle is disrupted in clusters, groups, and the field, more recently the community has turned its attention to the filamentary network that feeds clusters and groups (e.g., R. Cybulski et al. 2014; D. W. Just et al. 2019; F. Sarron et al. 2019; Y. Lee et al. 2021; G. Castignani et al. 2022a; J. M. Salerno et al. 2022). To further understand how galaxies are altered over the full dynamic range of local environmental densities, we are undertaking a multiwavelength study of galaxies in and around the cosmic filaments surrounding the Virgo cluster, extending up to ~ 12 virial radii in projection from one of the best-studied regions of high density in the local Universe. The first set of papers from the VFS found results that demonstrate that filaments are sites in which galaxies have their gas content and morphology changed (G. Castignani et al. 2022a, 2022b). However, D. Zakharova et al. (2024) found in another VFS paper that gas depletion is being driven primarily by groups embedded within filaments. Additionally, K. Conger et al. (2025) find that late-type galaxies in the densest VFS environments have smaller dust disks than in low-density environments. There is also preliminary evidence of smaller star-forming disks even in intermediate-density environments, i.e., filaments and groups. Given these results, it is still uncertain what relative role filaments, and the groups that are embedded within them, play in transforming galaxies.

A crucial next step in understanding how the gas content of galaxies is modified in the cosmic web is to characterize the detailed spatial distribution of star formation and to link it with the properties of the multiphase ISM. To that end, we have completed a large H α narrowband imaging survey of over 600 galaxies in the extended volume around Virgo, including all the galaxies with CO measurements from G. Castignani et al. (2022a). In this paper, we present the first results from this survey, the Virgo Filament Survey-H α (VFS-H α), focusing solely on the NGC 5364 group. This group was targeted in our H α survey because it is located in the Virgo III filament (S. Kim et al. 2016; G. Castignani et al. 2022b), and we show the location of the NGC 5364 Group relative to the Virgo Cluster and surrounding large-scale structure in Figure 1. We have also obtained spatially resolved H I imaging from MeerKAT (M. Ramatsoku et al. 2025, in preparation). We will present the full VFS-H α survey results in subsequent papers. In this paper we leverage our multiband data for the NGC 5364 group to illustrate the variety of ways in which the baryon cycle can be disrupted in even the lowest-mass galaxy groups.

In Section 2 we describe the group and its place within the larger context of the extended Virgo volume. In Section 3 we describe the H α data and resolved maps of the SFR, stellar mass, and H I. We present our results in Section 4 and discuss them in Section 5. We summarize in Section 6. Throughout this paper we adopt a Λ CDM cosmology with $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$. We assume a G. Chabrier (2003) Initial Mass Function (IMF) throughout.

2. The NGC 5364 Group

The NGC 5364 group is listed in several catalogs (e.g., E. Kourkchi & R. B. Tully 2017; S. H. Lim et al. 2017; E. Tempel et al. 2017). Following G. Castignani et al. (2022b), we adopt the group membership and properties from E. Kourkchi & R. B. Tully (2017). E. Kourkchi & R. B. Tully (2017) identify 17 group members, and the H α image covers eight of these, including the five most massive galaxies within the group (see Table 1 and the layout in Figure 2). In Table 1, we include the Hubble T-type from Hyperleda (D. Makarov et al. 2014) when available, in column 3. Stellar masses and SFRs are derived from spectral energy distribution (SED) fitting using MAGPHYS (E. da Cunha et al. 2008) and custom near-ultraviolet (NUV) through IR photometry. The details of the SED fitting are presented in K. Conger et al. (2025), and the resulting values are listed in Table 1. The group galaxies outside the field of view all have $\log_{10}(M_*/M_\odot) < 8.9$. We calculate the stellar mass-weighted center using all 17 members (R.A. = 208.9912 deg, decl. = 5.11883 deg) and show the location with the cyan X in Figure 3. The center of the group is nicely placed within the H α image.

According to E. Kourkchi & R. B. Tully (2017), the NGC 5364 Group has a line-of-sight velocity dispersion of $\sigma_v = 155 \text{ km s}^{-1}$, and we reach a similar estimate of the velocity dispersion using the biweight scale of the 17 group members (164 km s^{-1}). The dynamical mass given in E. Kourkchi & R. B. Tully (2017) is $\log_{10}(M_{\text{halo}}/M_\odot) = 12.7$. Thus this is an extremely low-mass group. The biweight location of the flow-corrected recession velocities (G. Castignani et al. 2022b) is 1425 km s^{-1} , which corresponds to a distance of $\sim 20 \text{ Mpc}$.

3. Data

3.1. H α Observations

As part of our larger Virgo Filament H α survey, the NGC 5364 group was imaged with the Wide Field Camera (WFC) at the Isaac Newton Telescope on 2019 February 6. The WFC is a mosaic camera containing four 2048×4096 CCDs, and the field of view is $34' \times 34'$. Three of the CCDs are arranged horizontally with the long dimension running east–west, and the fourth CCD is positioned west of the first three and is oriented vertically, with the long dimension running north–south. As a result, the CCDs do not cover the northwest corner of the field of view. We show the WFC footprint with the NGC 5364 group members in Figure 2. The pixel scale of the WFC is 0.333 per pixel , which corresponds to a physical size of $\sim 33 \text{ pc pixel}^{-1}$ at the distance of the NGC 5364 group.

We use the Sloan Digital Sky Survey (SDSS) r -band filter to measure the stellar continuum and a narrowband filter to detect H α emission. The H α filter has a central wavelength of $6568 \text{ \AA}$ and a bandwidth of $95 \text{ \AA}$, so it can detect H α from galaxies with recession velocities in the range -1942 km s^{-1}

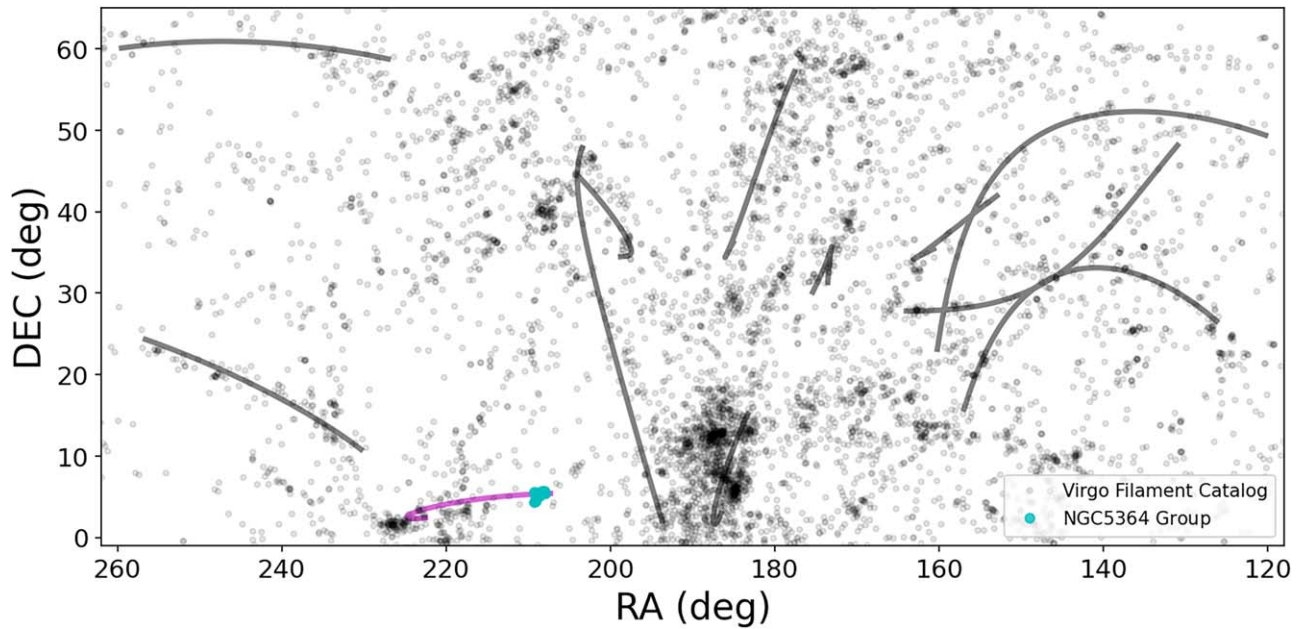


Figure 1. Location of the NGC 5364 Group on the plane of the sky relative to the Virgo Cluster and surrounding large-scale structure covered by the *Virgo Filament Survey*. The magenta line shows the Virgo III filament spine, and the gray lines show the spines of the other filaments identified by G. Castignani et al. (2022b). The NGC 5364 group galaxies are shown with the cyan circles. The group is located at the western end of the Virgo III Filament and approximately 6 Mpc from the center of Virgo. The Virgo cluster is the large overdensity near (R.A. = 185°, decl. = 10°).

$< v_r < 2400 \text{ km s}^{-1}$. The 30 minute $\text{H}\alpha$ integration was comprised of ten 180 s exposures taken in a five-position dither pattern with approximately 30'' offsets. The total r -band exposure was five minutes, consisting of five individual 60 s exposures taken at the same dither positions as the $\text{H}\alpha$ images.

The data reduction follows standard procedures. We complete bias subtraction and flattening with sky flats using the GUI interface for THELI v3 (T. Erben et al. 2005; M. Schirmer 2013), and we combine the bias and flat images for an entire run to maximize the signal-to-noise ratio. We create reference catalogs using Source Extractor (E. Bertin & S. Arnouts 1996) and solve for the astrometric calibration using Scamp (E. Bertin 2010). In Scamp, we used the GAIA EDR3 as the reference catalog and fit the geometric distortion in the WFC images with a fourth-order polynomial. When running Scamp, we set the STABILITY_TYPE=EXPOSURE, MOSAIC_TYPE=FIX_FOCALPLANE. The astrometric rms error with respect to the GAIA EDR3 reference positions is significantly less than a pixel and is typically 0.05 or less. We determine the AB photometric zero-point by comparing instrumental magnitudes with the reference r -band magnitude from PANSTARRS for both the $\text{H}\alpha$ and r -band images. Calibrating both of our images to the same PANSTARRS filter allows us to use the r -band image as our continuum source, as we describe in Section 3.2.

3.2. $\text{H}\alpha$ Star Formation Maps

To create the continuum-subtracted $\text{H}\alpha$ image, we follow the procedure described in detail in A. Boselli et al. (2018; see also, e.g., R. C. Kennicutt et al. 2008). We use a scaled version of the r -band image to estimate the continuum in the $\text{H}\alpha$ image, and to first order, the scale factor is determined from the difference in photometric zero-points in the $\text{H}\alpha$ and r -band images. The exact scale factor also depends on the color of the stellar continuum, so we adjust the scale factor by a term that

scales with the $g - r$ color variations within the galaxy. The $g - r$ color dependence is determined by integrating a large library of stellar spectra over the r and $\text{H}\alpha$ filters (see A. Boselli et al. 2018 for details). We did not obtain our own g -band images, so we constructed a $g - r$ image by reprojecting the Dark Energy Spectroscopic Instrument (DESI) *Legacy Imaging Surveys* (hereafter known as the *Legacy Surveys*) g and r images (A. Dey et al. 2019) to match the field of view (FOV) and pixel scale of the $\text{H}\alpha$ image. The surface brightness corresponding to the standard deviation in the sky noise in the continuum-subtracted $\text{H}\alpha$ image is $2.9 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$.

We convert the continuum-subtracted $\text{H}\alpha$ image to an SFR image using the calibration from R. C. Kennicutt & N. J. Evans (2012). The conversion assumes the IMF as described in P. Kroupa & C. Weidner (2003), which includes a turnover below $\sim 1M_{\odot}$. This IMF produces similar results to the Chabrier IMF (G. Chabrier 2003), as demonstrated by L. Chomiuk & M. S. Povich (2011). We correct for the fact that the $\text{H}\alpha$ emission is within the r -band filter, which means that the scaled r -band image overestimates the continuum (e.g., R. C. Kennicutt et al. 2008). An additional correction arises because the transmission across the $\text{H}\alpha$ filter is not uniform. We use the recession velocity of the galaxy and the filter trace for the $\text{H}\alpha$ filter to determine the filter transmission at the observed wavelength of $\text{H}\alpha$ and use this to correct for the variation in the transmission with wavelength. The filter correction is less than 10%, and we list the correction applied to each galaxy in column 5 of Table 1. Finally, we correct the $\text{H}\alpha$ flux for Milky Way extinction, but not for internal extinction within the galaxy. We note that the uncertainty in the resulting SFR maps can be systematically larger in regions where the SFR is low. As discussed in detail in R. C. Kennicutt & N. J. Evans (2012), the correlation between $\text{H}\alpha$ emission and the SFR can break down at low SFRs and on small spatial

Table 1
NGC 5364 Group Members within the H α Footprint

VFID	NED Name	T^a	v_r^b (km s $^{-1}$)	Virgo d_{3d}^c (Mpc)	$1/T(z)^d$	$\log(M_\star)^e$ ($M_\odot$)	$\log(\text{SFR})^f$ ($M_\odot \text{ yr}^{-1}$)	$\log(\text{sSFR})^g$ (yr^{-1})	H2 def h
VFID5842	NGC 5356	3.8	1370	9.7	1.07	9.96	−0.96	−10.85	−0.29
VFID5844	SDSS J135621.31+051944.2	−2.9	1402	8.9	1.08	7.79	−4.43	−12.22	...
VFID5851	NGC 5363	0.1	1134	6.3	1.04	10.84	−1.83	−12.60	−0.19
VFID5855	NGC 5348	3.8	1450	5.5	1.08	9.52	−0.74	−10.07	0.19
VFID5859	WISEA J135504.45+051121.7	10.0	1405	4.0	1.08	7.68	−1.62	−9.03	...
VFID5879	SDSS J135502.70+050525.1	−5.0	1397	8.8	1.07	8.40	−4.60	−12.90	...
VFID5889	NGC 5364	4.0	1240	5.1	1.06	10.42	−0.37	−10.30	1.06
VFID5892	NGC 5360	0.1	1175	7.9	1.05	9.09	−1.57	−10.56	0.51

Notes.

^a Hubble T-type from Hyperleda (D. Makarov et al. 2014).

^b Heliocentric recession velocity.

^c Flow-corrected, 3D distance from the center of the Virgo Cluster from G. Castignani et al. (2022a)

^d H α flux correction, equal to the inverse of the filter transmission at the redshift of the galaxy.

^e Stellar mass from MAGPHYS SED fitting presented in K. Conger et al. (2025).

^f SFR from MAGPHYS SED fitting presented in K. Conger et al. (2025).

^g sSFR from MAGPHYS SED fitting presented in K. Conger et al. (2025).

^h H $_2$ deficiency from G. Castignani et al. (2022a).

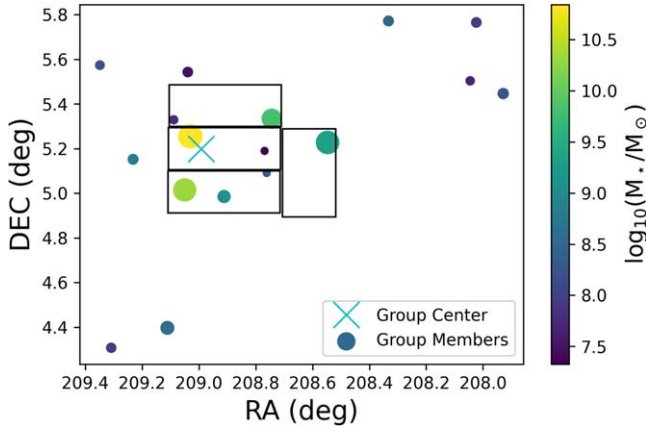


Figure 2. Decl. vs. R.A. for the 17 NGC 5364 group members. Circles are color coded by stellar mass, and the size of the circles scales with the isophotal size of the galaxies. The black rectangles show the approximate location of the four detectors of the Wide Field Camera. The eight group members within the H α field of view are the focus of this paper. The cyan X shows the mass-weighted center of the group.

scales due to the low number density and short lifetimes of the massive O stars that drive the correlation.

3.3. Stellar Mass Maps

We create stellar mass maps from optical imaging and a relationship that predicts the mass-to-light ratio from optical colors (e.g., E. F. Bell & R. S. de Jong 2001; E. F. Bell et al. 2003; S. Zibetti et al. 2009; J. C. Roediger & S. Courteau 2015). In practice, we use the reprojected *Legacy* g and r images described in Section 3.2. We then convert the $g - r$ image to a mass-to-light ratio (M/L) image using the linear relation from J. C. Roediger & S. Courteau (2015):

$$\log_{10}(M_\star/L)_\lambda = m_r \times (g - r) + b_r, \quad (1)$$

where $m_r = 1.629$ and $b_r = -0.792$. This fit assumes a G. Chabrier (2003) IMF. The stellar mass image is created by first converting the r -band image from flux to luminosity and then multiplying by the M/L image. The approximate

uncertainty associated with the resulting stellar masses is ~ 0.2 dex (J. C. Roediger & S. Courteau 2015). Finally, we convert the stellar mass per pixel to units of $\Sigma_\star(M_\odot/\text{kpc}^2)$ using the angular diameter distance that corresponds to the mass-weighted, average recession velocity of the group members.

3.4. H I Maps

We obtained MeerKAT data on this group as part of a larger survey of the Virgo III filament (M. Ramatsoku et al. 2025, in preparation). A single MeerKAT pointing covers this group. The data are primary beam corrected on a channel-by-channel basis and result in a 1σ column density limit of $N_{\text{H I}} = 3.4 \times 10^{19} \text{ cm}^{-2}$. In this paper we focus on the H I morphology and how it relates to the spatial distribution of H α emission. A more detailed and quantitative analysis of the H I data will be presented in M. Ramatsoku et al. (2025, in preparation).

4. Results

4.1. Spatial Distribution of Star Formation

We show the positions of group members that fall within the H α FOV in Figure 3. The dashed line shows the Virgo III filament spine, projected onto the plane of the sky (G. Castignani et al. 2022b). Eight of the 17 group members are located within the footprint of the H α image (see Figure 2), and this paper focuses primarily on these galaxies.

In Figures 4, 5, 6, and 7, we show the relative distribution of the stellar mass and star formation for the eight galaxies within the H α FOV. We present the galaxies in order of decreasing stellar mass. We discuss these results in the context of previous work in Section 5.2.

4.1.1. The Two Most Massive Galaxies: VFID5851 and VFID5889

In Figure 4, we show the results for the two most massive galaxies in the group. Each row shows, from left to right, the *Legacy Survey* grz color image with H I contours from M. Ramatsoku et al. (2025, in preparation), the stellar mass

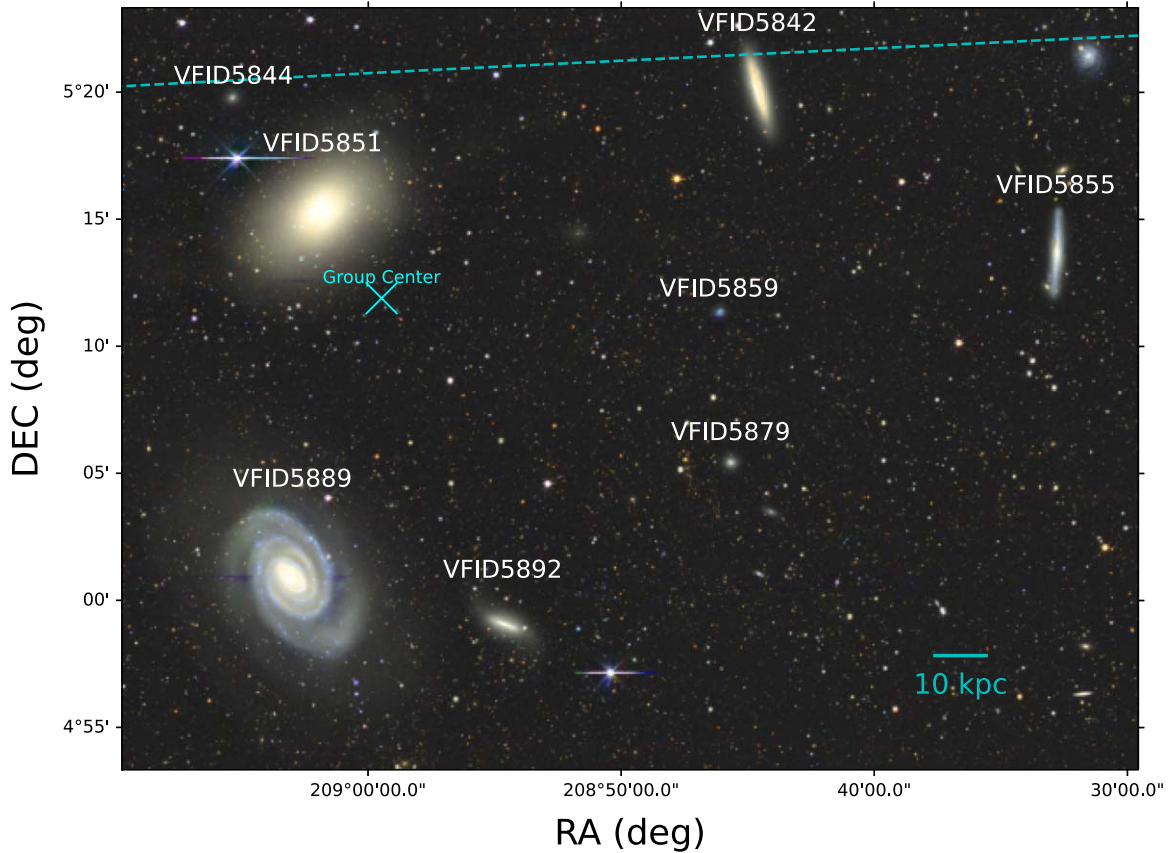


Figure 3. Legacy DR9 *grz* image showing the location of group members. The dashed cyan line shows the location of the Virgo III filament spine, projected in R.A. and decl. Group members are labeled with their VFID (G. Castignani et al. 2022b).

surface density map, the $H\alpha$ star formation surface density map, and radial profiles of the stellar mass and $H\alpha$ SFR. The radial profiles are measured from elliptical aperture photometry, where we fix the ellipse geometry based on the stellar mass distribution and apply the same apertures when measuring the flux in the SFR image. The dashed and solid vertical lines show the radii that enclose 50% and 90% of the flux, respectively, and these are measured from the elliptical aperture photometry.

The top row of Figure 4 shows the results for VFID5851, the most massive member of the group. The *Legacy grz* image reveals its elliptical morphology, and the stellar mass distribution is fairly smooth. Extended $H\alpha$ emission is detected at the center, and the H I contours reveal the presence of atomic gas in the same inner region. The radial profiles confirm that the $H\alpha$ emission is more centrally concentrated than the stellar mass profile, and this is also reflected more quantitatively in the smaller values of R_{50} and R_{90} for the $H\alpha$ –SFR profile.

The bottom row of Figure 4 shows the results for VFID5889, the main spiral galaxy and the namesake of the group (NGC 5364). In this case, the $H\alpha$ emission follows the spiral arms, with no star formation in the interarm region. The $H\alpha$ emission is clumpy, which is likely due to H II regions within the galaxy. Comparison of the Σ_* and Σ_{SFR} images shows that the $H\alpha$ emission is similar in extent to the stellar mass.

4.1.2. Intermediate-mass Spirals: VFID5842, VFID5855, VFID5892

In Figure 5, we show the results for three disk galaxies with $9 < \log_{10}(M_*/M_\odot) \leq 10$, with the galaxies ordered from top to

bottom by decreasing stellar mass. The top row of Figure 5 shows VFID5842, a highly inclined spiral. Comparison of the Σ_* and Σ_{SFR} images shows that the $H\alpha$ emission is clumpy and truncated relative to the stellar component. The radial profiles in the right panel show that the $H\alpha$ emission drops abruptly at a radius of approximately $60''$ or 7.7 kpc. Interestingly, R_{50} is similar for the stellar and SFR profiles, but R_{90} is significantly smaller for the SFR profile. This indicates that the outer part of the star-forming disk is being most affected. The H I contours are truncated relative to the stellar mass but are slightly larger in extent than the $H\alpha$ emission.

The middle row in Figure 5 shows the results for VFID5855, an edge-on spiral. While the $H\alpha$ emission is clumpy, the stellar mass and SFR maps show similar radial extent, and the radial profiles show similar shapes. The Σ_{SFR} image shows that the $H\alpha$ emission is above the plane of the disk on the southern side of the galaxy. Using custom apertures, we estimate that $\approx 15\%$ of the total $H\alpha$ emission is above the plane and that this extraplanar gas is clumpy (G. Nagaraj 2025, in preparation). Interestingly, the H I emission is highly asymmetric and extends beyond the disk on the same side as the extraplanar $H\alpha$ emission. The cyan arrow shows the direction to the group center, and the H I and $H\alpha$ extensions are aligned in this direction. Note that the filament spine is north of the galaxy and runs perpendicular to the disk on the plane of the sky.

In the bottom panel of Figure 5, we show VFID5892. As with VFID5842, comparison of the stellar mass and SFR images shows that the star formation is truncated relative to the stellar disk. The radial profiles show that the $H\alpha$ emission is more concentrated, and in this case, both R_{50} and R_{90} are

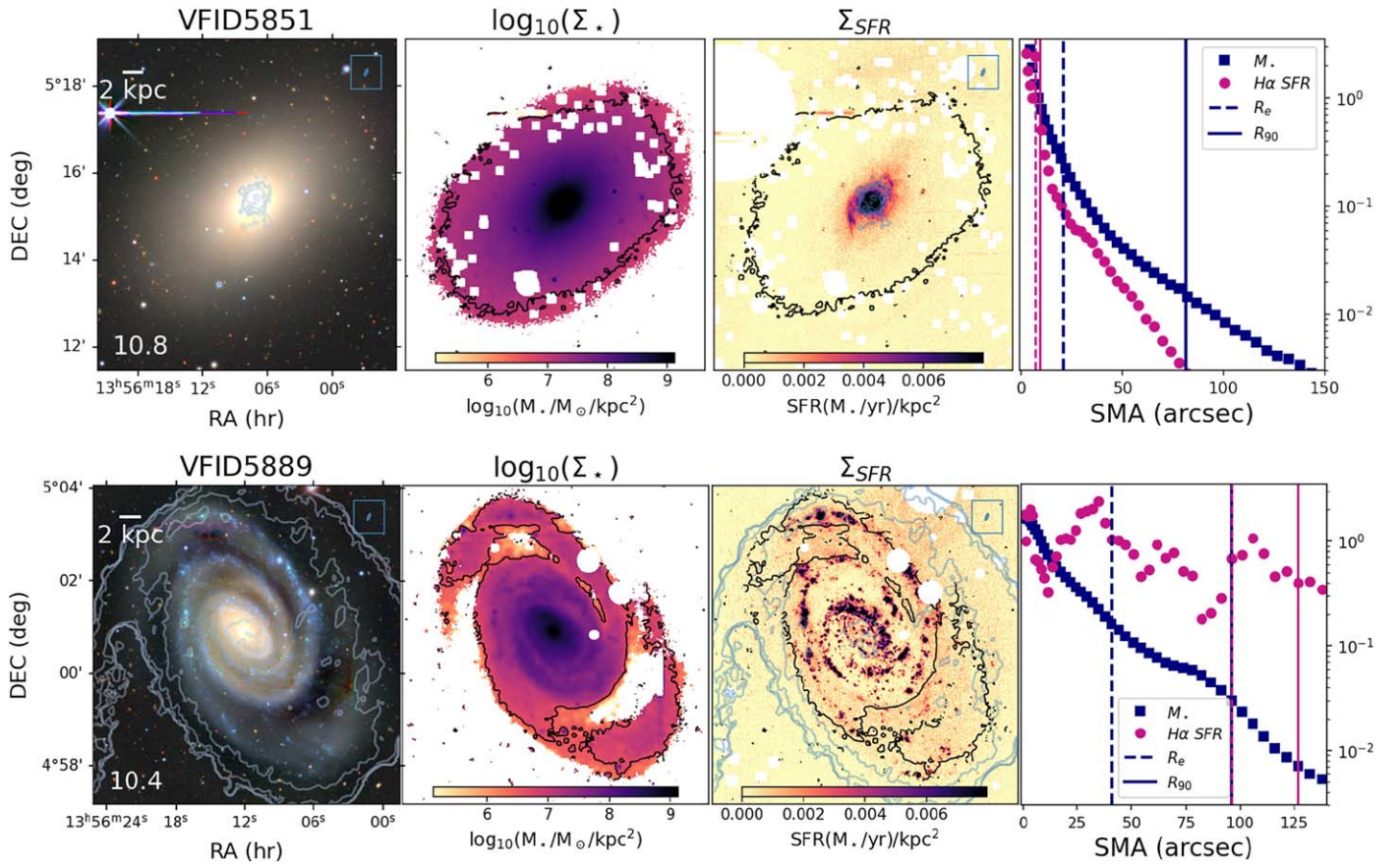


Figure 4. Results for the two most massive ($\log_{10}(M_*/M_\odot) > 10$) galaxies in the group. (Top) VFID5851, the most massive galaxy and central elliptical. The left panel shows the Legacy *grz* color image, with $\log_{10}(M_*/M_\odot)$ written in the lower left and a scale bar in the top left. The second panel shows the stellar mass map, with the color bar showing $\log_{10}(M_*/M_\odot/\text{kpc}^2)$. White regions correspond to foreground stars or background galaxies that are masked for the image analysis. The third panel shows the $\text{H}\alpha$ SFR map, with the color bar showing $\log_{10}(M_*/M_\odot/\text{yr}^{-1})/\text{kpc}^2$. The fourth panel shows the radial profiles of the stellar mass and SFR, normalized to unity in the central $5''$. The MeerKAT H I contours are shown in gray in the first and third panels, and the beam size is shown with the blue ellipse in the top right of the first and third panels. The black contours in the two middle panels show where $\log_{10}(M_*/M_\odot/\text{kpc}^2) \approx 6.6$, and this is included to aid in comparing the spatial extent of the stellar mass and $\text{H}\alpha$ SFR. (Bottom) Same as above, showing results for VFID5889, a large spiral with normal $\text{H}\alpha$ emission.

significantly smaller for the SFR profile. The H I emission is also truncated relative to the stellar disk and shows a similar extent to the $\text{H}\alpha$ emission.

To confirm that VFID5842 and VFID5892 have truncated star formation, we examine the Galaxy Evolution Explorer (GALEX) NUV and Wide-field Infrared Survey Explorer (WISE) W3 $12\ \mu\text{m}$ images, which probe the unobscured and obscured star formation that occurs on slightly longer time-scales. We show the results in Figure 6. While previous work shows that the spatial extents of UV and $\text{H}\alpha$ can differ (e.g., A. Boselli et al. 2006; Q. E. Goddard et al. 2010), the NUV and $12\ \mu\text{m}$ images for VFID5842 and VFID5892 show a similar extent as $\text{H}\alpha$ with a truncation radius that is smaller than the stellar disk. Therefore, we find no evidence that the truncated $\text{H}\alpha$ disks are due to dust obscuration. Thus, it appears that the star formation in these galaxies is truly truncated relative to the stellar disk.

4.1.3. The Lowest-mass Galaxies: VFID5879, VFID5844, VFID5859

In Figure 7, we show the results for the three $7.5 < \log_{10}(M_*/M_\odot) < 8.5$ galaxies that fall within the footprint of the $\text{H}\alpha$ image. In the top and middle rows, we show the results for VFID5879 and VFID5844. The $\text{H}\alpha$ images reveal little to no star formation in these galaxies. In the right panels, we show the radial distribution of the stellar mass but

not the $\text{H}\alpha$ SFR, as these galaxies have no significant $\text{H}\alpha$ emission. Neither VFID5879 nor VFID5844 was detected with MeerKAT. The bottom row of Figure 7 shows the results for VFID5859. In contrast to VFID5879 and VFID5844, VFID5859 shows significant $\text{H}\alpha$ emission. Comparison of the Σ_* and Σ_{SFR} images shows that the star formation is asymmetric with respect to the stellar mass distribution and is concentrated on the east side of the galaxy. We show the radial profiles of the stellar mass and SFR in the right panel, and the radii indicate that the SFR is more centrally concentrated than the stellar mass. However, we note that R_{50} and R_{90} should be interpreted with caution in a case such as this, where the $\text{H}\alpha$ emission is so asymmetric but the photometry is measured in elliptical apertures defined by the stellar mass distribution. The H I emission shows extension to the west of the galaxy, in the opposite direction of where the $\text{H}\alpha$ is concentrated. The cyan arrow shows the direction to the group center, and the signatures in the star formation and H I are consistent with the galaxy moving eastward through the intragroup medium. The H I is much more extended than the $\text{H}\alpha$ emission, and it is difficult to capture the detail in both components in the same image. We therefore show a zoomed-out image of VFID5859 in Figure 8 to show the full extent of the H I tail.

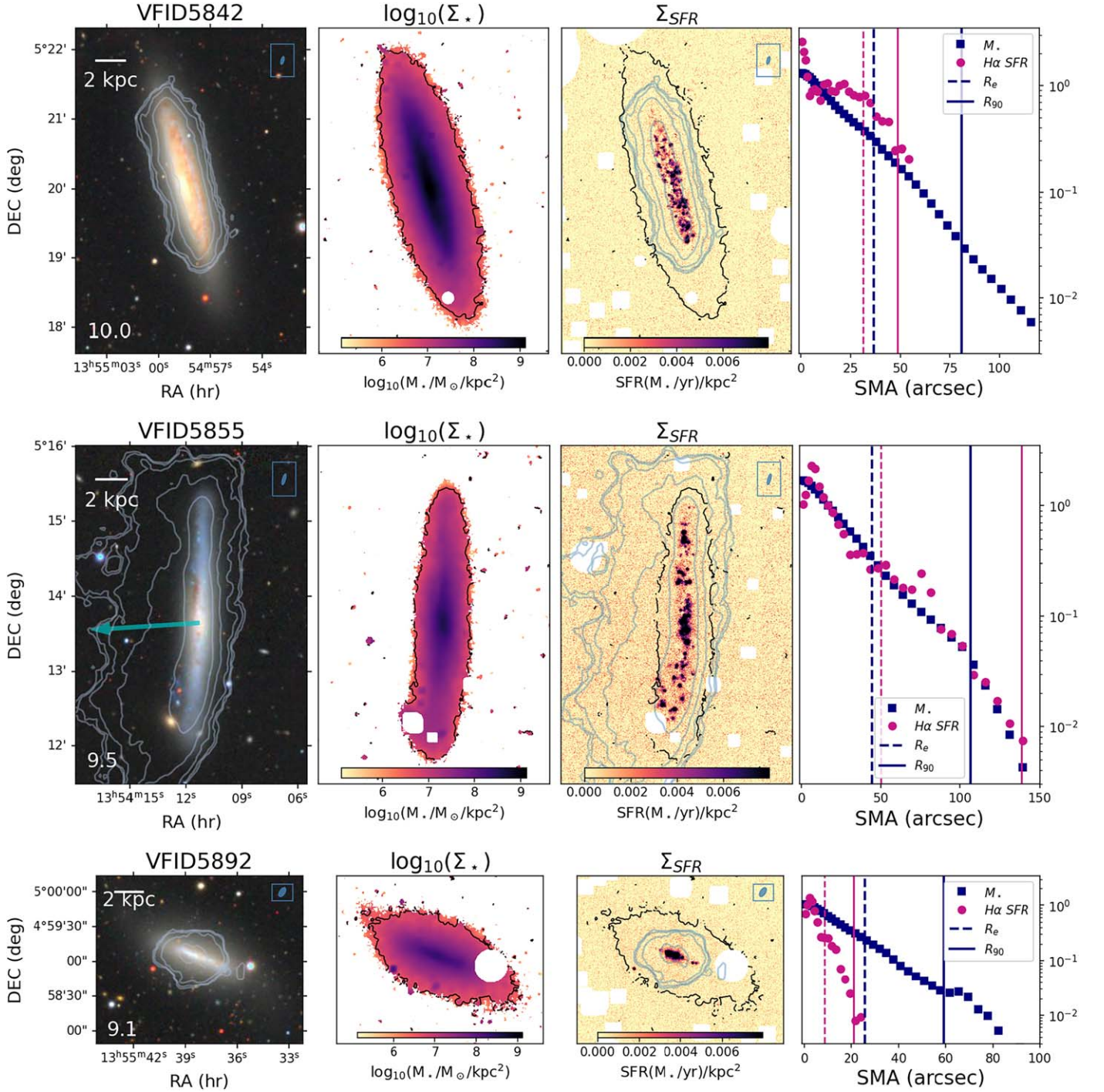


Figure 5. Results for the three $9 < \log_{10}(M_*/M_\odot) \leq 10$ group galaxies: VFID5842 (top), VFID5855 (middle), and VFID5892 (bottom). The left panel shows the Legacy *grz* color image, with $\log_{10}(M_*/M_\odot)$ noted in the lower left and a scale bar in the top left. The second panel shows the stellar mass map, with the color bar showing $\log_{10}(M_*/M_\odot/\text{kpc}^2)$. The third panel shows the $\text{H}\alpha$ SFR map, with the color bar showing $\log_{10}(M_*/M_\odot/\text{kpc}^2)$. The fourth panel shows the radial profiles of the stellar mass and SFR, normalized to unity in the central $5''$. The MeerKAT H I contours are shown in gray in the first and third panels, and the beam size is shown with the blue ellipse in the top right of the first and third panels. The black contours in the two middle panels show where $\log_{10}(M_*/M_\odot/\text{kpc}^2) \approx 6.6$, and this is included to aid in comparing the spatial extent of the stellar mass and $\text{H}\alpha$ SFR.

4.2. Global Properties of Group Galaxies

In the left panel of Figure 9, we show the SFR versus stellar mass for the full VFS sample (gray) and the NGC 5364 group members on the $\text{H}\alpha$ image (squares). The squares are color coded by the size ratio $R_{90}(\text{SFR})/R_{90}(M_*)$ for the group members on the $\text{H}\alpha$ image. We set the ratio to zero for the two dwarf galaxies with no $\text{H}\alpha$ emission (VFID5879 and

VFID5844). The solid line in Figure 9 shows the main-sequence fit from K. Conger et al. (2025), and the dashed line shows the 0.3 dex scatter in the main sequence. The two group galaxies with truncated $\text{H}\alpha$ emission (VFID5892 and VFID5842) have SFRs that are below the main sequence. VFID5859 lies above the main sequence, and this is a low-mass galaxy with asymmetric star formation and an H I tail.

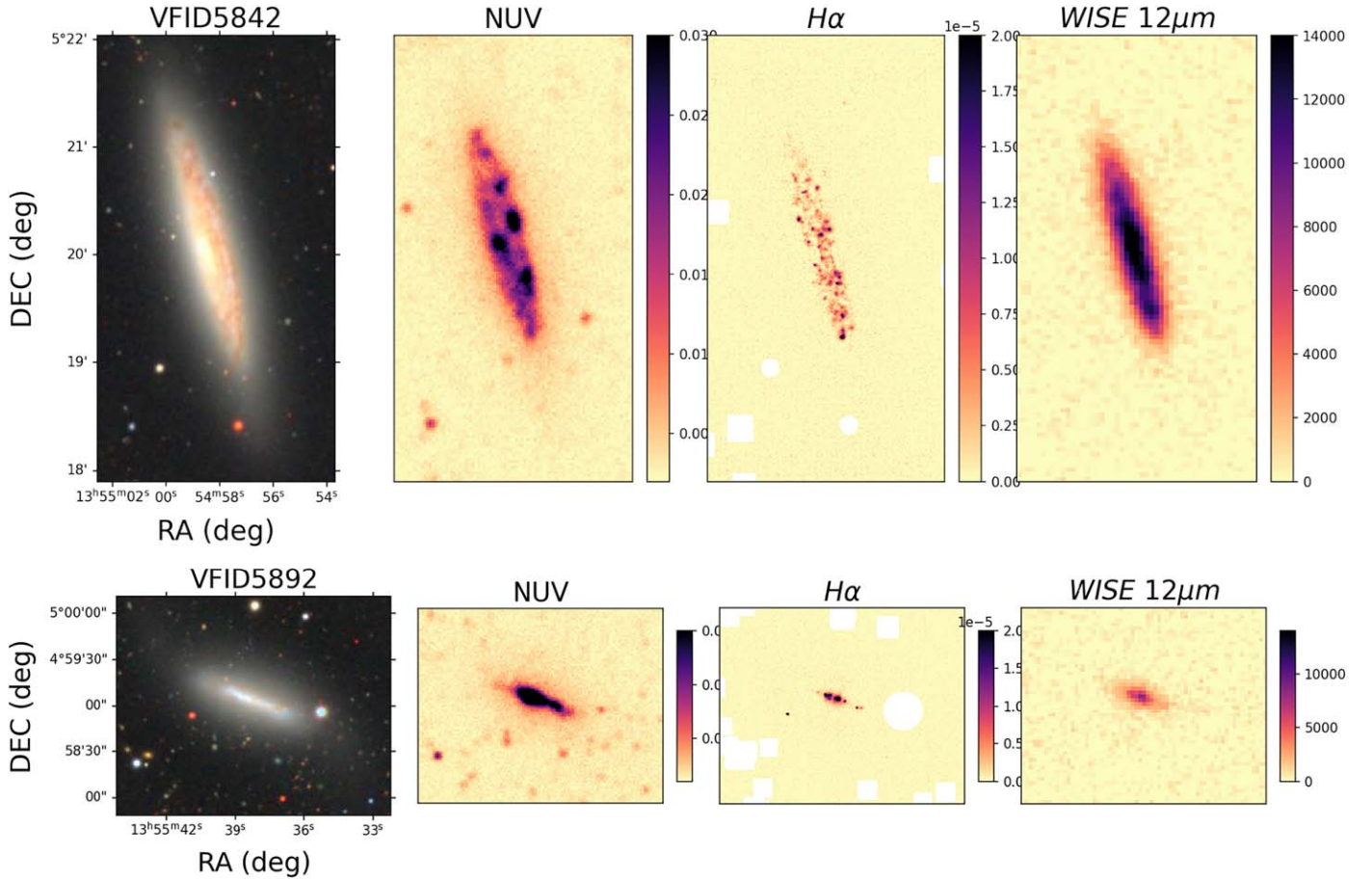


Figure 6. Multiwavelength SFR indicators NUV, $H\alpha$, and Wide-field Infrared Survey Explorer (WISE) $12\ \mu\text{m}$ for (top) VFID5842 and (bottom) VFID5892. Both galaxies show truncated $H\alpha$ emission, and the NUV and IR show a similar extent to $H\alpha$. This indicates that dust is not causing the truncated $H\alpha$ disks.

The galaxies with the lowest size ratios lie well below the main sequence (VFID5851, VFID5844, VFID5879). While this may appear at face value to be expected, since smaller star-forming disks could result in lower SFRs, K. Conger et al. (2025) show that the ratio of WISE $12\ \mu\text{m}$ emission with the stellar mass does not correlate with position relative to the star-forming main sequence. This could either be because the truncation of star formation in the outskirts of galaxies does not significantly affect the total, or it could be that the surface density of star formation is altered at the same time as the size in such a way as to preserve the total SFR. With our full $H\alpha$ sample in a future paper we will determine the statistical relation, if any, between size ratio measured from $H\alpha$ and the SFR.

In the right panel of Figure 9, we show the ratio of H I mass to stellar mass versus the size ratio $R_{90}(\text{SFR})/R_{90}(M_*)$. The H I masses are from MeerKAT (M. Ramatsoku et al 2025, in preparation). The color bar indicates stellar mass, which is not strongly correlated with either variable in the plot. The two galaxies with the lowest values of $\log_{10}(M_{\text{HI}}/M_*)$ (VFID5892, VFID5842) are the two galaxies with truncated $H\alpha$ emission. The two galaxies with H I tails and unusual features in the $H\alpha$ emission (VFID5855, VFID5859) have the highest values of $\log_{10}(M_{\text{HI}}/M_*)$. A Spearman Rank Correlation test indicates that $\log_{10}(M_{\text{HI}}/M_*)$ is not correlated with $R_{90}(\text{SFR})/R_{90}(M_*)$ when considering all five galaxies ($r = 0.56$, $p = 0.32$). However, as noted above, the R_{90} value for VFID5859 is not reliable given the asymmetry of the $H\alpha$ emission. If we run the Spearman Rank test without VFID5859, then the variables are

highly correlated ($r = 1.000$, $p = 0.000$). We will be able to better test the strength of this correlation using the full VFS- $H\alpha$ sample (R. Finn et al. 2025, in preparation), but similar trends have been found between H I deficiency and the relative size of the star-forming and stellar disks (e.g., L. Cortese et al. 2012; M. Fossati et al. 2013; R. A. Finn et al. 2018).

G. Castignani et al. (2022a) present integrated CO measurements of VFID5842, 5851, 5855, and 5889, and we list the H_2 deficiencies from G. Castignani et al. (2022a) in Table 1 for reference. There is no clear trend in H_2 deficiency with $R_{90}(\text{SFR})/R_{90}(M_*)$ or with the offset relative to the $\text{SFR}-M_*$ main sequence. It is of interest that VFID5889 is the most H_2 deficient of any of the galaxies, although it has only slightly lower star formation and is clearly a large star-forming spiral. It may be that the H_2 deficiency for VFID5889 is highly uncertain, as the aperture corrections needed to measure the total H_2 mass from the single-dish CO flux include many assumptions, some of which, e.g., the spatial profile of the molecular gas, may be incorrect.

5. Discussion

The galaxies in the NGC 5364 group exhibit a large range of $H\alpha$ sizes and $H\alpha$ morphologies. Some have $H\alpha$ emission that is similar in extent to the stellar mass, others have $H\alpha$ emission that is significantly smaller than the stellar mass distribution, and some have no $H\alpha$ emission at all. In addition, the H I morphology is truncated in some galaxies and exhibits clear signs of stripping in others. As we discuss below in Section 5.2,

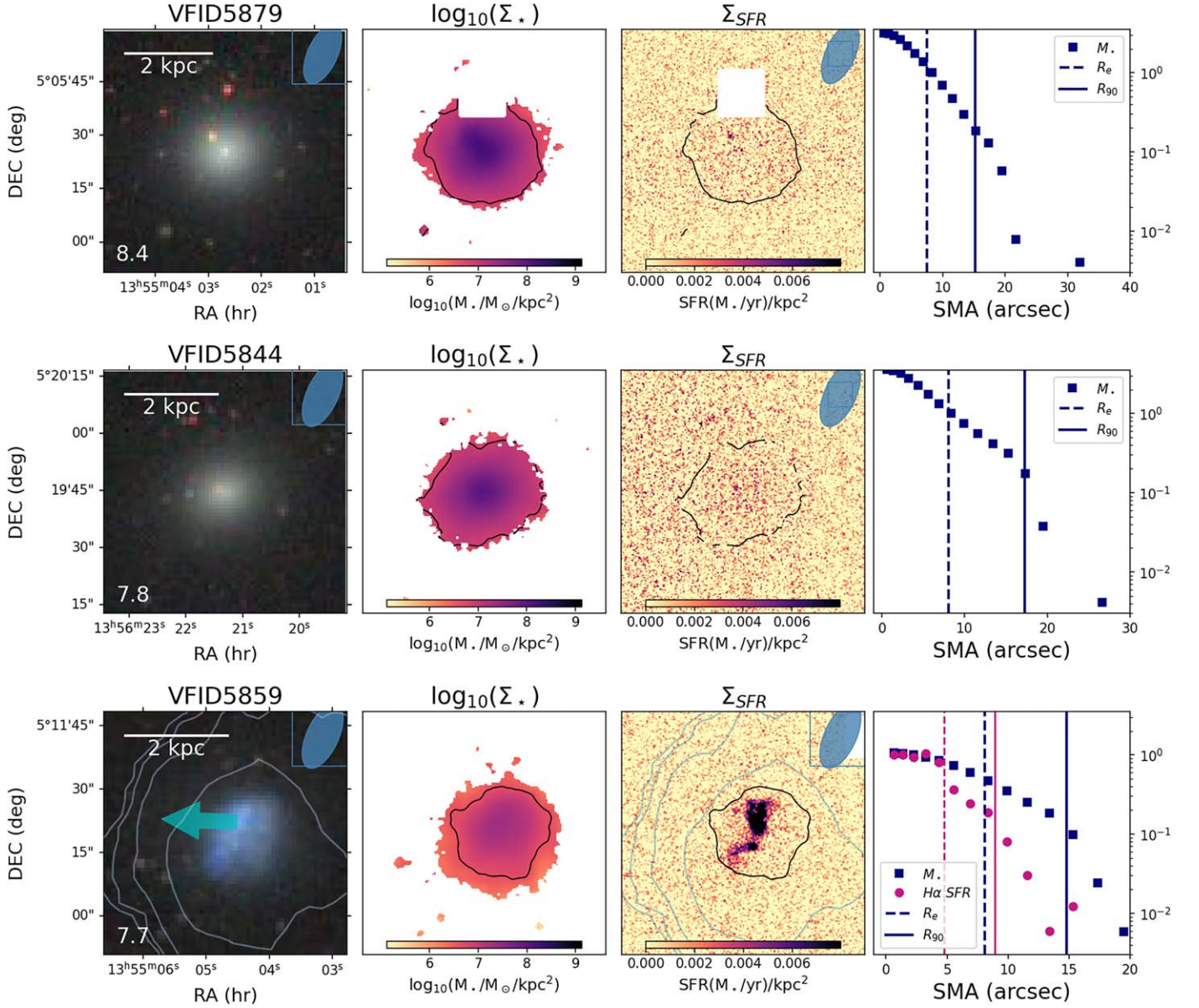


Figure 7. Results for $7.5 < \log_{10}(M_*/M_\odot) < 8.5$ group galaxies, with galaxies ordered from top to bottom by decreasing stellar mass. The left panel shows the Legacy *grz* color image, with $\log_{10}(M_*/M_\odot)$ written in the lower left and a scale bar in the top left. The second panel shows the stellar mass map, with the color bar showing $\log_{10}(M_*/M_\odot/\text{kpc}^2)$. The third panel shows the $\text{H}\alpha$ SFR map, with the color bar showing $\log_{10}(M_*/M_\odot \text{ yr}^{-1}/\text{kpc}^2)$. The fourth panel shows the radial profiles of the stellar mass and SFR, normalized to unity in the central $5''$. The black contours in the two middle panels show where $\log_{10}(M_*/M_\odot/\text{kpc}^2) \approx 6.6$, and this is included to aid in comparing the spatial extent of the stellar mass and $\text{H}\alpha$ SFR. (Top and Middle) VFID5879 and VFID5844, two dwarf galaxies that show little to no $\text{H}\alpha$ emission and no H I . The right panels for these two galaxies show the stellar mass profiles only because they do not have a significant amount of the $\text{H}\alpha$ emission. (Bottom) VFID5859, a star-forming dwarf galaxy. The MeerKAT H I contours are shown in gray in the first and third panels, and the beam size is shown with the blue ellipse in the top right of the first and third panels. The cyan arrow points to the group center.

these data suggest that multiple processes are working to disrupt the baryon cycle in these group galaxies. Before discussing the group-related processes, we first discuss the potential influence of the Virgo Cluster on the evolution of the NGC 5364 group galaxies.

5.1. The Influence of the Virgo Cluster

In Figure 10, we show the location of the NGC 5364 group with respect to the Virgo Cluster. In the left panel, we show sky coordinates of the NGC 5364 group with colored circles, and the color shows the 3D distance from Virgo. Starred points show the Virgo cluster members from G. Castignani et al. (2022b), and the dashed line shows the projected location of

the Virgo III filament spine. The alternate x and y -axis labels show how the angular distance translates into physical separation at the distance of the Virgo cluster, and from this we can infer that the group members are at least 6 Mpc away from the center of Virgo, which is significantly larger than Virgo’s virial radius ($R_{200} \approx 1$ Mpc; D. E. McLaughlin 1999). We note that the virial radius may not be the best to describe the sphere of influence of Virgo, as the distribution of galaxies is clearly not spherically symmetric but is instead elongated in the north–south direction.

To assess the possibility of hydrodynamic effects from the Virgo Cluster, we attempt to estimate the density of the intracluster medium (ICM) at a projected radius of $6R_{200}$ from

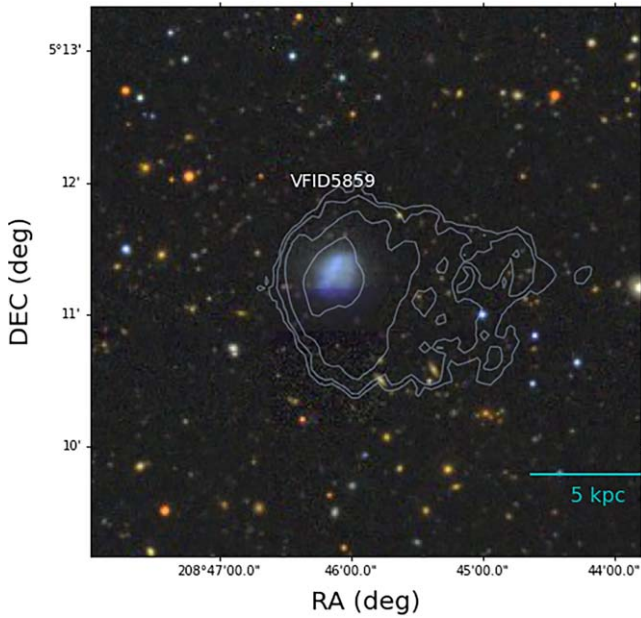


Figure 8. Legacy *grz* color image of VFID5859 with MeerKAT H I contours shown in gray. This figure provides a zoomed-out image that includes the full H I tail that is not captured in Figure 7.

the Virgo cluster using the eROSITA-derived ICM density profile from H. McCall et al. (2024). They only measure the profile out to $3R_{200}$ and give a power-law fit to the density profile that is only valid out to $0.4R_{200}$. Toward the east and southeast, the profiles flatten out beyond R_{200} . This flattening is attributed to the “eROSITA Bubble” (P. Predehl et al. 2020), which extends far out of the plane of the Milky Way and is attributed to energy injected into the galactic halo from the galactic center. Nonetheless, as a rough estimate of the ICM density, we extrapolate the density profile out to $6R_{200}$, with the understanding that this is very uncertain. The projected ICM density at this radius is ~ 10 times lower than at R_{200} . This is roughly 1.5 dex less than the intragroup medium density expected for groups of this mass (Section 5.3). We therefore feel that any ram pressure effects on galaxies in the NGC 5364 group are dominated by the intragroup medium and not by interactions with Virgo’s ICM. This supposition is supported by the observation that the passive fraction of galaxies drops monotonically toward the outskirts of nearby clusters and is nearly at the field value by $3 \times R_{200}$. No studies measure the passive fraction out to $6 \times R_{200}$ in $z \sim 0$ clusters, but I. Pintos-Castro et al. (2019) find that the passive fraction around clusters at $0.3 < z < 0.5$ reaches the field value by $\sim 2 \times R_{200}$. This implies that clusters themselves do not quench galaxies significantly beyond $\sim 2 \times R_{200}$.

A similar result is illustrated in the right panel of Figure 10, which shows a phase-space diagram with recession velocity versus projected angular separation (in both degrees and Mpc). The caustics are from G. Castignani et al. (2022b) and show the radial dependence of the escape velocity as computed using the prescription from Y. L. Jaffé et al. (2015). The group has a low velocity offset with respect to the Virgo cluster. In addition, the NGC 5364 galaxies are not in the regions where one would expect to see backplash galaxies—galaxies that have already passed through the center of the cluster—as the backplash population in clusters dominates between 1 and 2 virial radii (M. L. Balogh et al. 2000). Therefore, we conclude that the

observed trends in star formation and H I properties are not due to the Virgo cluster.

5.2. Observing the Disruption of the Baryon Cycle in Galaxy Groups

There are multiple ways that the baryon cycle in group galaxies can be disrupted (K. George et al. 2018; B. M. Poggianti et al. 2019; A. Boselli et al. 2022). Thanks to the high densities and low relative velocities, tidal interactions are common in groups and can remove gas from the halos and outskirts of galaxies. For example, D. Williamson et al. (2016) used hydrodynamic simulations to show that tidal interactions within a group can preferentially remove gas in the outer parts of disks in dwarf galaxies, which can then lead to truncated disks. These tidal interactions can also result in extraplanar star-forming gas (Y. Stein et al. 2017). While ram pressure stripping in clusters can remove dense molecular gas from galaxies (B. Vollmer et al. 2008), purely hydrodynamical effects can also occur via a galaxy’s passage through the intragroup medium (I. D. Roberts et al. 2021). In its weak manifestation, hydrodynamic stripping from the intragroup medium can remove gas from the hot halo and also strip the loosely bound gas on the edges of galaxy disks. The intragroup medium can also interfere with gas recycling within a galaxy. For example, galactic fountains that are ejected from galaxies can extend to large distances (60–100 kpc), and up to 30% of that material can be reaccreted onto galaxies (B. D. Oppenheimer & R. Davé 2008). Y. M. Bahé & I. G. McCarthy (2015) found that this gas can also be stripped if it travels far enough away from the disk, thus removing a major source of gas replenishment and causing a reduction in the SFR (K. A. Oman et al. 2021). These physical mechanisms can also interplay in complex ways. For example, tidal interactions and supernova feedback can make the gas more susceptible to ram pressure stripping (A. Marasco et al. 2016; P. Serra et al. 2023). Given how conducive the group environment is to multiple processes, trying to identify a single dominant mechanism is not well motivated.

Indeed, the main spiral (VFID5889) and the spiral located to its southwest (VFID5892) show evidence of both gravitational and hydrodynamical interactions. VFID5889 has a significantly lopsided stellar, H I, and $H\alpha$ disk, which can be caused by weak tidal interactions (I. R. Walker et al. 1996; D. Zaritsky & H.-W. Rix 1997; G. Rudnick & H.-W. Rix 1998). It also has very extended diffuse stellar emission, but the H I only extends to the edge of the spiral arms. Isolated galaxies often have H I disks that extend well beyond r_{25} of the stellar light (e.g., F. Bigiel et al. 2008), and the lack of extended H I emission in VFID5889 could indicate that the outer H I has been removed. VFID5892 shows signs of a tidal interaction with VFID5889, as evidenced by a warped stellar disk. The gas and SFR distribution in VFID5892 have also been modified. The H I disk is truncated, and this galaxy has the highest H I deficiency and the smallest size ratio of $H\alpha$ to stars of the entire sample (Figure 9). The $H\alpha$ and H I disks are also off-center with respect to the stellar disk (Figure 5), which is what is naively expected from hydrodynamic processes. It is not clear if such a feature can also be caused by tidal interactions.

Two galaxies, VFID5855 and VFID5859, show asymmetric H I distributions that are compressed on one side and extended on the other (Figures 5 and 7), forming tails that match the qualitative expectation for ram pressure stripping. Indeed, the H I contours for VFID5855 show streamers of H I trailing

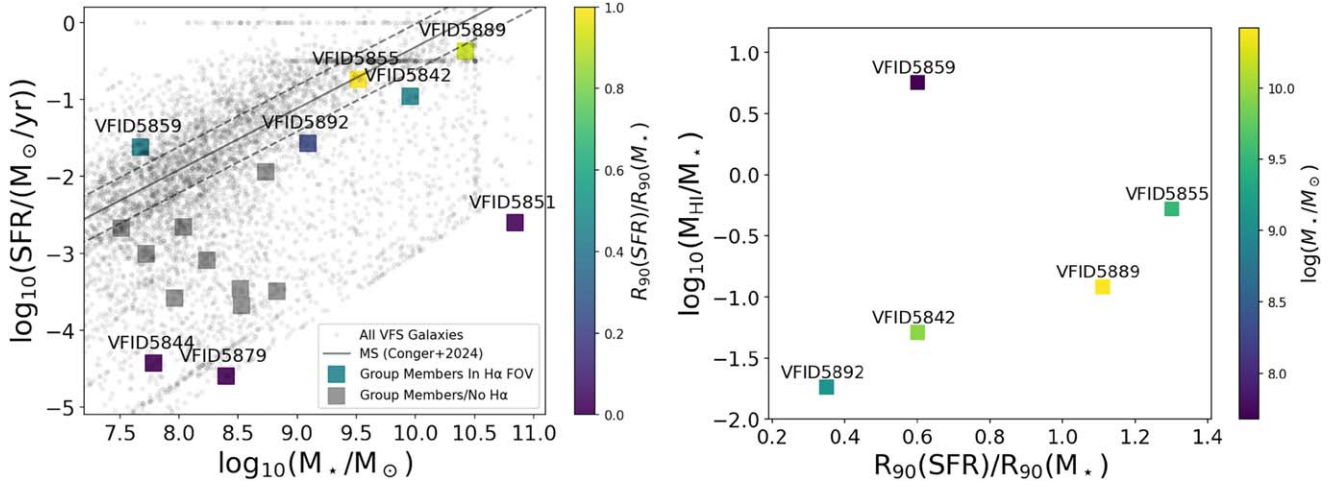


Figure 9. (Left) SFR vs. stellar mass for the full Virgo Filament Survey sample (gray) and the group members (squares). For group members on the $\text{H}\alpha$ image, the squares are color coded by the ratio of $R_{90}(\text{SFR})/R_{90}(M_{*})$. The remaining group members are shown with the gray squares. The solid line shows the main-sequence fit from K. Conger et al. (2025), and the dashed line shows the 0.3 dex scatter in the main sequence. (Right) Ratio of H I mass to stellar mass vs. the size ratio of the $\text{H}\alpha$ SFR profile to the stellar mass profile for the group galaxies with H I detections from MeerKAT.

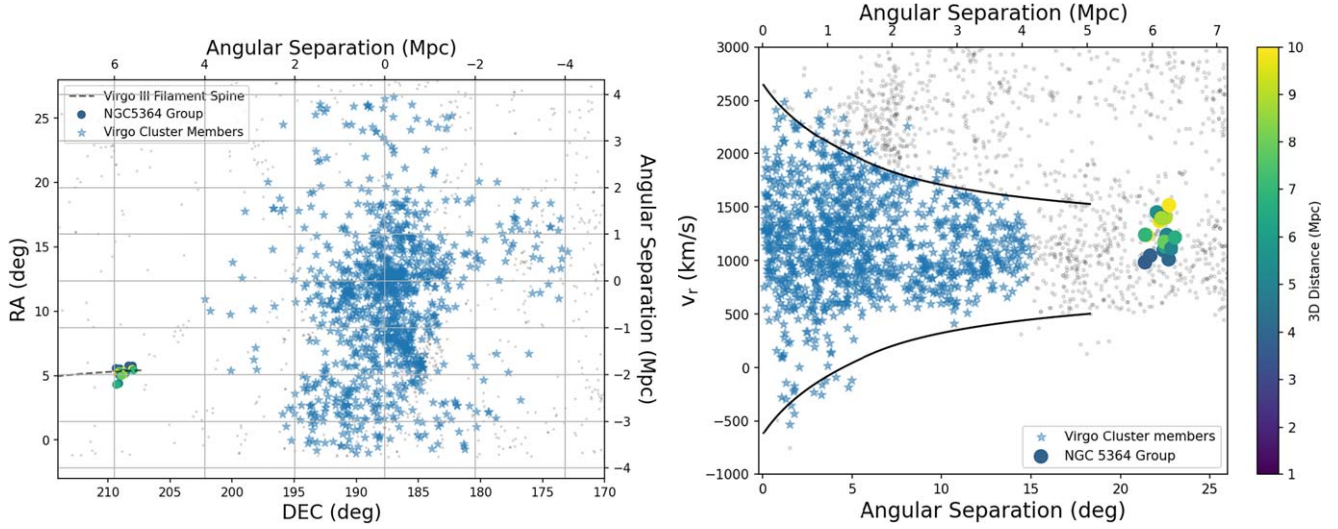


Figure 10. (Left) decl. vs. R.A. of NGC 5364 group members compared to Virgo Cluster members. (Right) Recession velocity vs. projected angular separation from the center of Virgo. Black lines show the model for the escape velocity from G. Castignani et al. (2022b).

behind the disk. VFID5855 also shows extraplanar $\text{H}\alpha$ emission, and the H I contours on that side of the disk trace the $\text{H}\alpha$ and are curved in the direction of the tail on the leading edge of the disk. The tails for VFID5855 and VFID5859 point in opposite directions. It may also be possible that the two galaxies recently experienced an interaction and that this partly explains the extraplanar $\text{H}\alpha$ emission at the southern end of VFID5855. The distortion in the stars of VFID5855 is not strong enough to conclusively establish the presence of an interaction using published diagnostic criteria (B. Vollmer et al. 2005; B. Vulcani et al. 2021). We will discuss the stripping in VFID5855 in detail in Section 5.3, but if an interaction is indeed occurring, it could boost the susceptibility of the gas to ram pressure stripping, as discussed in P. Serra et al. (2023).

The only galaxy with a clearly truncated H I profile and $\text{H}\alpha$ disk, but with no evidence of tidal interaction, is VFID5842. This galaxy has a symmetric distribution of stellar mass, H I, and SFR, but the $\text{H}\alpha$ and H I disks

are clearly truncated. As noted in Section 4.1, while $R_{50}(\text{SFR})/R_{50}(M_{*}) \sim 1$, the R_{90} values for SFR and the stellar mass differ significantly. Within the truncation radius, the stellar and SFR profiles have a similar slope, indicating naively that whatever affected the gas distribution preferentially modified the outskirts of the galaxy. We will discuss this object and its susceptibility to RPS in detail in Section 5.3.

The elliptical VFID5851 has little H I and $\text{H}\alpha$ emission, and the $\text{H}\alpha$ profile is significantly steeper than that of the stars. The origin of the observed gas is unclear. Work on the properties of nearby early-type galaxies has revealed that the H I detection fraction depends strongly on environment (P. Serra et al. 2012) but that the CO detection rate is independent of environment (L. M. Young et al. 2011). The presence of $\text{H}\alpha$ emission in this galaxy could have many sources, including mass loss from existing stellar populations or accretion from the cosmic web, though it is not clear how the latter is modified by the low-mass group environment (G. Rudnick et al. 2017).

The remaining two galaxies within the $H\alpha$ FOV are the dwarf galaxies VFID5879 and VFID5844, and these are not detected in $H\alpha$ or H I (Figure 7). Both galaxies are detected in the GALEX NUV images. If this NUV emission is due to the most recent episode of massive star formation, then this indicates fairly recent quenching (longer than $H\alpha$ timescale of 10 Myr but less than NUV timescale of 100 Myr, e.g., R. C. Kennicutt 1998). There are no signs of tidal interaction in these galaxies. They are low mass ($\log_{10}(M_*/M_\odot) < 8.5$), and therefore ram pressure stripping could be effective in quenching these galaxies, as could starvation.

The passive fraction for the eight galaxies in the $H\alpha$ image of this group is $3/8 = 0.375$. This is significantly higher than the passive fraction for isolated galaxies, which is at most 0.05 for the highest masses and falls to 0.01 at $\log(M_*/M_\odot) < 9.5$ (M. Geha et al. 2012). Given the small numbers in our sample, we can use binomial statistics to rule out the field value at the 90%–99% level, depending on the mass limit adopted. When comparing to the passive fractions of satellite galaxies, the passive fraction of the $\log(M_{\text{halo}}/M_\odot) = 12.7$ NGC 5364 group falls between those of Milky Way analogs with $\log(M_{\text{halo}}/M_\odot) = 12$ –12.3, which are almost entirely star-forming (M. Geha et al. 2017), and groups with $\log(M_{\text{halo}}/M_\odot) = 13$ –14, which have passive fractions at these masses of ~ 0.5 (D. C. Baxter et al. 2021). The observed passive fraction of 0.375 implies that the NGC 5364 group may indeed be conducive to galaxy quenching.

5.3. Quantifying the Role of Ram Pressure Stripping

In this section, we use the classical description of ram pressure stripping (J. E. Gunn & J. R. Gott 1972) to explore its potential role in the ongoing evolution of the four disk-dominated galaxies (VFID5842, VFID5855, VFID5851, VFID5892). Several other studies have found ram pressure candidates in groups based on the presence of X-ray tails (e.g., G. R. Sivakoff et al. 2004; J. Rasmussen et al. 2006), H I tails (I. D. Roberts et al. 2021; E. K. Maina et al. 2022), and optical signatures of stripping, such as jellyfish galaxies (e.g., B. Vulcani et al. 2018, 2021; T. Kolcu et al. 2022). B. Vulcani et al. (2018) also find multiple signatures of environmental processing, including truncated star-forming disks, in four galaxies that are part of the same group ($z = 0.06359$). However, their group has a mass of $\sim 5 \times 10^{13} M_\odot$, which is at least a factor of 5 greater than the mass of the NGC 5364 group. Therefore, we want to explore the potential influence of RPS in a group with a much lower halo mass.

The strength of ram pressure stripping depends on both the density of the intracluster or intragroup medium (hereafter ICM for simplicity and to avoid confusion with IGM $\equiv$ intergalactic medium) and the velocity of the galaxy with respect to this hot intergalactic gas:

$$P_{\text{RPS}} = \rho_{\text{ICM}} \Delta v^2, \quad (2)$$

where P_{RPS} is the pressure exerted by the ICM, ρ_{ICM} is the density of the ICM, and Δv is the velocity of a galaxy with respect to the ICM. The effectiveness of RPS also depends on the mass and structure of the infalling galaxy because this determines the galaxy’s ability to keep its gas gravitationally bound. According to the classical treatment of ram pressure stripping presented in J. E. Gunn & J. R. Gott (1972), the

restoring force per area in a disk galaxy is given by:

$$F/A = 2\pi G \Sigma_* \Sigma_g \quad (3)$$

where Σ_* is the surface density of stars and Σ_g is the surface density of gas. When ram pressure exceeds this restoring force, the gas can be pushed off the disk. We note that the effectiveness of RPS also depends on the details of a galaxy’s orbit (e.g., S. Tonnesen & G. L. Bryan 2009; S. Tonnesen 2019) as well as the angle of the galaxy disk with respect to the wind (e.g., B. Vollmer et al. 2021). However, we do not consider these additional factors here for the sake of simplicity.

If a galaxy shows a clear truncation of either the $H\alpha$ or H I emission, then we can use the outer radius to estimate the density of the ICM if the truncation is in fact due to RPS. Specifically, if we assume that the outer disk gas has been removed by ram pressure, then the truncation radius, R_{trunc} , indicates the location where the restoring force per unit area is equal to the ram pressure:

$$\rho_{\text{IGM}} \Delta v^2 = 2\pi G \Sigma_*(R_{\text{trunc}}) \Sigma_g(R_{\text{trunc}}). \quad (4)$$

At smaller radii, the restoring force exceeds ram pressure, and at larger radii, ram pressure dominates. We calculate the stellar and gas mass surface densities by assuming exponential profiles for the stellar and gas distributions (e.g., W. Domainko et al. 2006; Y. L. Jaffé et al. 2015):

$$\Sigma_*(R_{\text{trunc}}) = \frac{M_*}{2\pi R_{d,\text{stars}}^2} e^{-R_{\text{trunc}}/R_{d,\text{stars}}}, \quad (5)$$

and

$$\Sigma_g = \frac{M_{\text{HI}} + M_{\text{H}_2}}{2\pi R_{d,\text{gas}}^2} e^{-R_{\text{trunc}}/R_{d,\text{gas}}}, \quad (6)$$

where $R_{d,\text{stars}}$ is the scale length of the stellar disk and $R_{d,\text{gas}}$ is the scale length of the gas (see also M. Gullieuszik et al. 2020). We have estimated the half-light radius R_{50} in Section 4.1, and the half-light radius and scale length are related by $R_{50} = 1.67 R_d$. We assume the scale length of the gas disk is 1.7 times greater than the scale length of the stellar disk ($R_{d,\text{gas}} = 1.7 R_{d,\text{stars}}$; e.g., V. Cayatte et al. 1994; Y. L. Jaffé et al. 2015). It is in theory possible to use the $H\alpha$ emission to estimate the extent of the molecular gas using the Schmidt law (F. Bigiel et al. 2008). However, H I can extend well beyond the $H\alpha$ emission even for galaxies undergoing RPS, as for VFID5855 (Figure 5), and $H\alpha$ would underestimate the gas scale length in this case. This could even be true for truncated galaxies, depending on exactly how the gas is being modified. In G. Castignani et al. (2025, in preparation), we will examine the detailed spatial profiles of the molecular gas, atomic gas, and star formation for a set of galaxies, including some of those in this paper.

To estimate the restoring force, we first determine the outer radius of each galaxy, which we hereafter call the truncation radius. For VFID5889, VFID5842, and VFID5892, the $H\alpha$ and H I are similar in spatial extent, and we use the outer radius of this emission as the truncation radius. For VFID5855, the H I extends beyond the $H\alpha$ emission, and so we use the extent of H I along the major axis to determine the truncation radius. To estimate the surface density of atomic and molecular gas, we use the H I masses from MeerKAT observations (M. Ramatsoku et al. 2025,

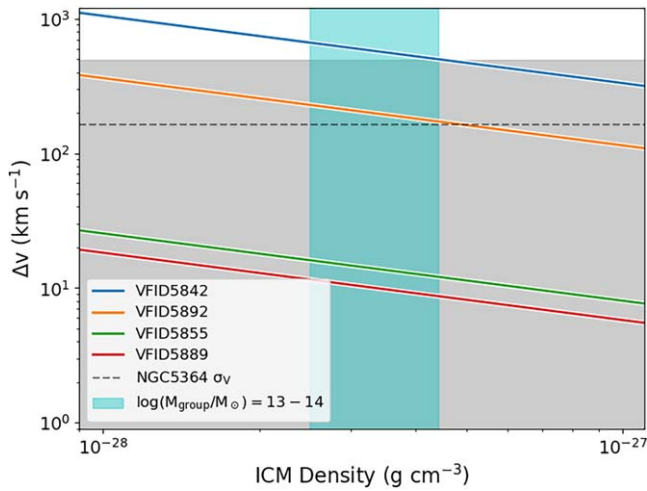


Figure 11. To illustrate the potential influence of ram pressure stripping, we plot the relative velocity of the galaxy with respect to the group center vs. the density of the ICM. The solid diagonal lines show lines of constant pressure, and each line reflects the pressure required to remove mass at the observed truncation radius. The horizontal dashed line shows the group velocity dispersion from E. Kourkchi & R. B. Tully (2017), and the gray shaded region shows $+3\sigma_v$. The shaded cyan region shows the approximate ICM density measured for a sample of $13 < \log_{10}(M/M_\odot) < 14$ galaxy groups (M. Sun et al. 2009) as presented in A. Boselli et al. (2022, see their Figure 1).

in preparation) and the molecular gas mass estimates from G. Castignani et al. (2022a). We then combine the truncation radius, the stellar mass, and the gas mass according to Equation (3) to estimate the restoring force per area.

We show the results in Figure 11, where we plot the restoring force for each galaxy relative to the two factors that affect the strength of ram pressure stripping: Δv and ρ_{ICM} . For a particular galaxy, any combination of Δv and ρ_{ICM} that falls along its line indicates conditions where ram pressure is equal to the restoring force, or where RPS can produce the observed truncation radius. The regions in Δv – ρ_{ICM} space that fall below a galaxy’s line indicate conditions where RPS is insufficient to produce the observed truncation radius. We can constrain the likely range of Δv using the group’s velocity dispersion ($\approx 150 \text{ km s}^{-1}$, see Section 2), which we show with the horizontal dashed line. The horizontal shaded region shows $\Delta v \leq 3\sigma$ to denote the region along the Δv axis where we expect most group members to lie.

We use information compiled by A. Boselli et al. (2022) to estimate the range of ICM densities for galaxy groups. The ICM density decreases as the distance from the group/cluster center increases. We calculate the projected distance of the four galaxies from the group center and find an average distance of approximately $0.4R_{\text{virial}}$, where $R_{\text{virial}} = 222 \text{ kpc}$ comes from E. Kourkchi & R. B. Tully (2017). From A. Boselli et al. (2022) Figure 1, the density of the ICM for a sample of 43 galaxy groups (M. Sun et al. 2009) ranges from $\rho_{\text{ICM}} = 2.5\text{--}4.4 \times 10^{-28} \text{ g cm}^{-3}$. We note that the groups in that study have $13 < \log_{10}(M/M_\odot) < 14$, so they are likely more massive than the NGC 5364 group. We show the range of ICM densities expected at $0.4R_{\text{virial}}$ for these galaxy groups with the cyan region in Figure 11. For comparison, the central gas mass density for Coma would be off the right edge of the plot at $\rho_{\text{ICM}} = 7.8 \times 10^{-27} \text{ g cm}^{-3}$ (J. E. Gunn & J. R. Gott 1972).

The calculations of restoring force shown in Figure 11 are based on a number of assumptions and should only be considered as approximate. However, the comparison of

restoring force and ram pressure is instructive. If the curves in the figure reside where the gray and cyan regions overlap, then RPS could be effective. The pressures required for VFID5892, VFID5855, and VFID5889 are consistent with the range of Δv and ρ_{ICM} values expected for this group. The blue curve in Figure 11 shows the restoring force at the truncation radius for VFID5842, and this galaxy requires both a high relative velocity and high ICM density to explain the truncation radius using RPS. Thus, the truncation observed in VFID5842 implies an external pressure that is at the upper edge of what is expected from the classical treatment of RPS. However, it should be noted that the effectiveness of RPS can be increased by density variations in the ISM (e.g., V. Quilis et al. 2000; S. Tonnesen & G. L. Bryan 2009) and ICM (e.g., S. Tonnesen & G. L. Bryan 2008). In addition, RPS can be enhanced due to the group’s location within a filament. For example, Y. M. Bahé et al. (2013) show that in simulations, RPS can be enhanced by a factor of 100 in filaments compared to isolated galaxies. On the other hand, D. Zakharova et al. (2024) attributed gas depletion processes of galaxies in VFS filaments primarily to the groups embedded in the filaments; they did not find evidence of filaments alone affecting galaxy gas contents. Without a larger sample of galaxies in groups and filaments, it is not possible to more precisely isolate the additional effect that filaments have on group galaxies. Likewise, there are not enough direct studies of the intragroup medium for groups inside and outside of filaments to determine if filaments can enhance the RPS in groups. With this in mind, the main takeaway from Figure 11 is that RPS from the intragroup medium is a reasonable explanation for the truncated H I and H α profiles observed in most of the disk-dominated group galaxies, perhaps with the exception of VFID5842.

5.4. Additional Processes That Can Truncate Disks

While we explore in detail the potential role of RPS in creating the truncated H α and H I disks in Section 5.3, from a theoretical perspective, several additional physical processes can lead to truncated H α and H I disks in the group environment. For example, as mentioned in Section 5.2, simulations show that tidal interactions within a group can lead to truncated disks (D. Williamson et al. 2016). Additionally, it is possible that starvation can reduce the size of the star-forming disk. In the most straightforward implementation of starvation, accretion is halted, and the remaining gas is consumed through star formation. The gas content should reduce uniformly across the disk as a consequence of the relatively constant depletion time of 2–3 Gyr throughout galactic disks (F. Bigiel et al. 2008). This could in principle result in a truncation of the star-forming disk as the gas near the galaxy outskirts drops below the threshold for star formation of $3\text{--}4 M_\odot \text{ pc}^{-2}$ (A. K. Leroy et al. 2008). However, this simple scenario ignores the impact of recycling and redistribution of gas in the disk. For example, the GAEA simulations (L. Xie et al. 2017, 2020; G. De Lucia et al. 2024) divide each galaxy into a set of annuli and track the consumption, recycling, expulsion, and stripping, as well as the redistribution of gas among these annuli. The gas that is ejected via a galactic fountain is retained, and because the ejected gas has low angular momentum, it is added back at small galactocentric radii. When galaxies in GAEA become satellites, they are cut off from accretion of new gas; the new gas should have higher angular momentum than gas accreted at earlier cosmic epochs

and is therefore accreted at preferentially larger radii. The net result of both outflows and accretion makes the gas, and hence star formation, more concentrated in the presence of starvation. While this scenario has not been thoroughly explored through zoom-in hydrodynamic simulations except for the work by D. Kawata & J. S. Mulchaey (2008), the implication is that it is possible to have a reduction in the H α and H I profiles just in the presence of starvation.

6. Summary

We present the first results from the VFS-H α , an H α imaging survey of over 600 galaxies that reside in the large-scale structure around the Virgo Cluster. In this paper, we focus on the NGC 5364 group, a low-mass group located at the western end of the Virgo III filament and over 6 Mpc from the center of the Virgo Cluster. We analyze the H α star formation maps for eight group galaxies that were obtained with the WFC at the 2.5 m Isaac Newton Telescope, and we combine these with new high-resolution MeerKAT imaging of the H I in these group galaxies. The combination of H α and high-resolution, sensitive H I imaging is an extremely powerful tool for understanding the way different gas phases are affected in the intermediate-density environments that host most galaxies.

We find that eight group members within the H α image footprint show a range of properties. We summarize these results in order of decreasing stellar mass.

1. The most massive galaxy in the group (VFID5851, an elliptical) shows diffuse, smooth, extended H α and H I in the central region (Figure 4).
2. The most massive spiral (VFID5889) shows H α over the entire stellar disk. The H I emission is comparable in extent to the H α emission but does not extend beyond the stellar disk (Figure 4). Both the H α and H I are lopsided, as is the stellar disk.
3. Two galaxies in this group show some evidence of mutual tidal interaction (VFID5889 and VFID5892), as indicated by a lopsided stellar distribution in VFID5889 and a stellar warp in VFID5892.
4. Two additional galaxies have clear H I tails indicative of ram pressure stripping and have potentially just completed a close interaction. One of these galaxies (VFID5855; $\log(M_*/M_\odot) = 9.5$) has extraplanar H I and H α (Figure 5). Both of these galaxies appear to have H I that is compressed on the side opposite the tail.
5. There are two galaxies (VFID5842, VFID5892) with clear H I and H α truncation. One of these galaxies is likely interacting with a nearby large spiral galaxy, but the galaxy with the most significant truncation has no evidence of tidal interaction (Figure 5).
6. Two low-mass galaxies (VFID5879, VFID5844) show no detectable H α and H I emission (Figure 7).

Despite the group's low mass ($\log(M/M_\odot) \sim 13$), we find multiple signatures of environmental processing that are disrupting the baryon cycle in a variety of ways. In addition, we find that the ratio of H I mass to stellar mass is correlated with the normalized size of the H α disk. We examine the quantitative relevance of RPS and find that it is sufficient to explain the truncated H α and H I emission observed for all but one of the disk-dominated galaxies. The NGC 5364 group in this paper is significantly lower in mass than those with prior

RPS detections and/or truncated star-forming disks. Thus, our results imply the ubiquitous modification of multiple phases of the gas content in group galaxies.

In future work, we will analyze our entire MeerKAT H I sample (M. Ramatsoku et al. 2025, in preparation) and the full H α imaging survey (R. Finn et al. 2025, in preparation). The latter contains comparable H α images for >600 galaxies in the filaments and groups surrounding Virgo, ~ 240 of which have integrated CO fluxes and H I fluxes. Analysis of H α images for an additional ~ 40 groups ($12 < \log_{10}(M/M_\odot) < 13.7$) in the VFS will help quantify the prevalence of these signatures in group galaxies.

Acknowledgments

R.A.F. gratefully acknowledges support from NSF grants AST-1716657 and AST-2308127 and from a NASA ADAP grant 80NSSC21K0640.

G.H.R. acknowledges the support of NASA ADAP grant 80NSSC21K0641, and NSF AAG grants AST-1716690 and AST-2308127. G.H.R. also acknowledges the hospitality of the Hamburg Observatory, which hosted him during parts of this work.

The authors thank the International Space Sciences Institute (ISSI) in Bern, Switzerland, which hosted collaboration meetings as part of the ISSI COSWEB team. They also thank the Institute for Fundamental Physics of the Universe (IFPU) in Trieste, Italy, for hosting a group workshop. G.H.R., R.A.F., and B.V. thank Padova Observatory for hosting them during a team meeting.

D.Z. and B.V. acknowledge support from the INAF Mini Grant 2022 “Tracing filaments through cosmic time” (PI Vulcani).

G.C. acknowledges the support from the Next Generation EU funds within the National Recovery and Resilience Plan (PNRR), Mission 4—Education and Research, Component 2—From Research to Business (M4C2), Investment Line 3.1—Strengthening and creation of Research Infrastructures, Project IR0000012—“CTA+ - Cherenkov Telescope Array Plus.”

The Legacy Surveys consist of three individual and complementary projects: the Dark Energy Camera Legacy Survey (DECaLS; Proposal ID #2014B-0404; PIs: David Schlegel and Arjun Dey), the Beijing–Arizona Sky Survey (BASS; NOAO Prop. ID #2015A-0801; PIs: Zhou Xu and Xiaohui Fan), and the Mayall z-band Legacy Survey (MzLS; Prop. ID #2016A-0453; PI: Arjun Dey). DECaLS, BASS, and MzLS together include data obtained, respectively, at the Blanco telescope, Cerro Tololo Inter-American Observatory, NSF’s NOIRLab; the Bok telescope, Steward Observatory, University of Arizona; and the Mayall telescope, Kitt Peak National Observatory, NOIRLab. Pipeline processing and analyses of the data were supported by NOIRLab and the Lawrence Berkeley National Laboratory (LBNL). The Legacy Surveys project is honored to be permitted to conduct astronomical research on Iolkam Du’ag (Kitt Peak), a mountain with particular significance to the Tohono O’odham Nation.

NOIRLab is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. LBNL is managed by the Regents of the University of California under contract to the U.S. Department of Energy.

This project used data obtained with the Dark Energy Camera (DECam), which was constructed by the Dark Energy

Survey (DES) collaboration. Funding for the DES Projects has been provided by the U.S. Department of Energy, the U.S. National Science Foundation, the Ministry of Science and Education of Spain, the Science and Technology Facilities Council of the United Kingdom, the Higher Education Funding Council for England, the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign, the Kavli Institute of Cosmological Physics at the University of Chicago, Center for Cosmology and Astro-Particle Physics at the Ohio State University, the Mitchell Institute for Fundamental Physics and Astronomy at Texas A&M University, Financiadora de Estudos e Projetos, Fundacao Carlos Chagas Filho de Amparo, Financiadora de Estudos e Projetos, Fundacao Carlos Chagas Filho de Amparo a Pesquisa do Estado do Rio de Janeiro, Conselho Nacional de Desenvolvimento Científico e Tecnológico and the Ministerio da Ciencia, Tecnologia e Inovacao, the Deutsche Forschungsgemeinschaft and the Collaborating Institutions in the Dark Energy Survey. The Collaborating Institutions are Argonne National Laboratory, the University of California at Santa Cruz, the University of Cambridge, Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas-Madrid, the University of Chicago, University College London, the DES-Brazil Consortium, the University of Edinburgh, the Eidgenössische Technische Hochschule (ETH) Zurich, Fermi National Accelerator Laboratory, the University of Illinois at Urbana-Champaign, the Institut de Ciències de l'Espai (IEEC/CSIC), the Institut de Física d'Altes Energies, Lawrence Berkeley National Laboratory, the Ludwig Maximilians Universität München and the associated Excellence Cluster Universe, the University of Michigan, NSF's NOIRLab, the University of Nottingham, the Ohio State University, the University of Pennsylvania, the University of Portsmouth, SLAC National Accelerator Laboratory, Stanford University, the University of Sussex, and Texas A&M University.

BASS is a key project of the Telescope Access Program (TAP), which has been funded by the National Astronomical Observatories of China, the Chinese Academy of Sciences (the Strategic Priority Research Program “The Emergence of Cosmological Structures” Grant # XDB090000000), and the Special Fund for Astronomy from the Ministry of Finance. The BASS is also supported by the External Cooperation Program of the Chinese Academy of Sciences (Grant # 114A11KYSB20160057) and the Chinese National Natural Science Foundation (Grant # 12120101003, # 11433005).

The Legacy Survey team makes use of data products from the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), which is a project of the Jet Propulsion Laboratory/California Institute of Technology. NEOWISE is funded by the National Aeronautics and Space Administration.

The Legacy Surveys imaging of the DESI footprint is supported by the Director, Office of Science, Office of High Energy Physics of the U.S. Department of Energy under Contract No. DE-AC02-05CH1123, by the National Energy Research Scientific Computing Center, a DOE Office of Science User Facility under the same contract; and by the U.S. National Science Foundation, Division of Astronomical Sciences under Contract No. AST-0950945 to NOIRLab.

ORCID iDs

Rose A. Finn <https://orcid.org/0000-0001-8518-4862>
 Gregory Rudnick <https://orcid.org/0000-0001-5851-1856>

Pascale Jablonka <https://orcid.org/0000-0002-9655-1063>
 Gautam Nagaraj <https://orcid.org/0000-0002-0905-342X>
 Benedetta Vulcani <https://orcid.org/0000-0003-0980-1499>
 Rebecca A. Koopmann <https://orcid.org/0000-0002-3144-2501>
 Matteo Fossati <https://orcid.org/0000-0002-9043-8764>
 James Agostino <https://orcid.org/0000-0002-8122-3032>
 Yannick Bahé <https://orcid.org/0000-0002-3196-5126>
 Santiago Garcia-Burillo <https://orcid.org/0000-0003-0444-6897>
 Gianluca Castignani <https://orcid.org/0000-0001-6831-0687>
 Francoise Combes <https://orcid.org/0000-0003-2658-7893>
 Kim Conger <https://orcid.org/0009-0005-0303-0330>
 Gabriella De Lucia <https://orcid.org/0000-0002-6220-9104>
 Vandana Desai <https://orcid.org/0000-0002-1340-0543>
 John Moustakas <https://orcid.org/0000-0002-2733-4559>
 Lizhi Xie <https://orcid.org/0000-0003-3864-068X>
 Daria Zakharova <https://orcid.org/0009-0001-1809-4821>
 Dennis Zaritsky <https://orcid.org/0000-0002-5177-727X>

References

- Bahé, Y. M., & McCarthy, I. G. 2015, *MNRAS*, **447**, 969
 Bahé, Y. M., McCarthy, I. G., Balogh, M. L., & Font, A. S. 2013, *MNRAS*, **430**, 3017
 Balogh, M. L., Navarro, J. F., & Morris, S. L. 2000, *ApJ*, **540**, 113
 Baxter, D. C., Cooper, M. C., & Fillingham, S. P. 2021, *MNRAS*, **503**, 1636
 Bell, E. F., & de Jong, R. S. 2001, *ApJ*, **550**, 212
 Bell, E. F., McIntosh, D. H., Katz, N., & Weinberg, M. D. 2003, *ApJS*, **149**, 289
 Bertin, E. 2010, SCAMP: Automatic Astrometric and Photometric Calibration, Astrophysics Source Code Library, ascl:1010.063
 Bertin, E., & Arnouts, S. 1996, *A&AS*, **117**, 393
 Bigiel, F., Leroy, A., Walter, F., et al. 2008, *AJ*, **136**, 2846
 Blanton, M. R., & Moustakas, J. 2009, *ARA&A*, **47**, 159
 Boselli, A., Boissier, S., Cortese, L., et al. 2006, *ApJ*, **651**, 811
 Boselli, A., Cortese, L., Boquien, M., et al. 2014, *A&A*, **564**, A67
 Boselli, A., Fossati, M., & Sun, M. 2022, *A&Arv*, **30**, 3
 Boselli, A., Fossati, M., Ferrarese, L., et al. 2018, *A&A*, **614**, A56
 Castignani, G., Combes, F., Jablonka, P., et al. 2022a, *A&A*, **657**, A9
 Castignani, G., Vulcani, B., Finn, R. A., et al. 2022b, *ApJS*, **259**, 43
 Cayatte, V., Kotanyi, C., Balkowski, C., & van Gorkom, J. H. 1994, *AJ*, **107**, 1003
 Chabrier, G. 2003, *PASP*, **115**, 763
 Chomiuk, L., & Povich, M. S. 2011, *AJ*, **142**, 197
 Chung, A., van Gorkom, J. H., Kenney, J. D. P., Crawl, H., & Vollmer, B. 2009, *AJ*, **138**, 1741
 Chung, A., van Gorkom, J. H., Kenney, J. D. P., & Vollmer, B. 2007, *ApJL*, **659**, L115
 Conger, K., Rudnick, G., Finn, R. A., et al. 2025, *ApJ*, **978**, 113
 Cortese, L., Boissier, S., Boselli, A., et al. 2012, *A&A*, **544**, A101
 Croton, D. J., Springel, V., White, S. D. M., et al. 2006, *MNRAS*, **365**, 11
 Cybulski, R., Yun, M. S., Fazio, G. G., & Gutermuth, R. A. 2014, *MNRAS*, **439**, 3564
 da Cunha, E., Charlot, S., & Elbaz, D. 2008, *MNRAS*, **388**, 1595
 De Lucia, G., Fontanot, F., Xie, L., & Hirschmann, M. 2024, *A&A*, **687**, A68
 Dekel, A., & Birnboim, Y. 2006, *MNRAS*, **368**, 2
 Dey, A., Schlegel, D. J., Lang, D., et al. 2019, *AJ*, **157**, 168
 Domainik, W., Mair, M., Kapferer, W., et al. 2006, *A&A*, **452**, 795
 Dressler, A. 1980, *ApJ*, **236**, 351
 Erben, T., Schirmer, M., Dietrich, J. P., et al. 2005, *AN*, **326**, 432
 Finn, R. A., Desai, V., Rudnick, G., et al. 2018, *ApJ*, **862**, 149
 Fossati, M., Gavazzi, G., Savorgnan, G., et al. 2013, *A&A*, **553**, A91
 Geha, M., Blanton, M. R., Yan, R., & Tinker, J. L. 2012, *ApJ*, **757**, 85
 Geha, M., Wechsler, R. H., Mao, Y.-Y., et al. 2017, *ApJ*, **847**, 4
 George, K., Poggianti, B. M., Gullieusik, M., et al. 2018, *MNRAS*, **479**, 4126
 Goddard, Q. E., Kennicutt, R. C., & Ryan-Weber, E. V. 2010, *MNRAS*, **405**, 2791
 Gullieusik, M., Poggianti, B. M., McGee, S. L., et al. 2020, *ApJ*, **899**, 13
 Gunn, J. E., & Gott, J. R., III 1972, *ApJ*, **176**, 1

- Jaffé, Y. L., Smith, R., Candlish, G. N., et al. 2015, *MNRAS*, **448**, 1715
- Just, D. W., Kirby, M., Zaritsky, D., et al. 2019, *ApJ*, **885**, 6
- Kawata, D., & Mulchaey, J. S. 2008, *ApJL*, **672**, L103
- Kenney, J. D. P., van Gorkom, J. H., & Vollmer, B. 2004, *AJ*, **127**, 3361
- Kennicutt, R. C., Jr. 1998, *ARA&A*, **36**, 189
- Kennicutt, R. C., Jr., Lee, J. C., Funes, J. G., et al. 2008, *ApJS*, **178**, 247
- Kennicutt, R. C., & Evans, N. J. 2012, *ARA&A*, **50**, 531
- Kim, S., Rey, S.-C., Bureau, M., et al. 2016, *ApJ*, **833**, 207
- Kolcu, T., Crossett, J. P., Bellhouse, C., & McGee, S. 2022, *MNRAS*, **515**, 5877
- Koopmann, R. A., & Kenney, J. D. P. 2004, *ApJ*, **613**, 866
- Kourkchi, E., & Tully, R. B. 2017, *ApJ*, **843**, 16
- Kroupa, P., & Weidner, C. 2003, *ApJ*, **598**, 1076
- Larson, R. B., Tinsley, B. M., & Caldwell, C. N. 1980, *ApJ*, **237**, 692
- Lee, B., Chung, A., Tonnesen, S., et al. 2017, *MNRAS*, **466**, 1382
- Lee, Y., Kim, S., Rey, S.-C., & Chung, J. 2021, *ApJ*, **906**, 68
- Leroy, A. K., Walter, F., Brinks, E., et al. 2008, *AJ*, **136**, 2782
- Lim, S. H., Mo, H. J., Lu, Y., Wang, H., & Yang, X. 2017, *MNRAS*, **470**, 2982
- Maina, E. K., Mohapatra, A., Józsa, G. I. G., et al. 2022, *MNRAS*, **516**, 2050
- Makarov, D., Prugniel, P., Terekhova, N., Courtois, H., & Vauglin, I. 2014, *A&A*, **570**, A13
- Marasco, A., Crain, R. A., Schaye, J., et al. 2016, *MNRAS*, **461**, 2630
- McCall, H., Reiprich, T. H., Veronica, A., et al. 2024, *A&A*, **689**, A113
- McLaughlin, D. E. 1999, *ApJL*, **512**, L9
- Mihos, J. C., Bothun, G. D., & Richstone, D. O. 1993, *ApJ*, **418**, 82
- Moretti, A., Serra, P., Bacchini, C., et al. 2023, *ApJ*, **955**, 153
- Oman, K. A., Bahé, Y. M., Healy, J., et al. 2021, *MNRAS*, **501**, 5073
- Oppenheimer, B. D., & Davé, R. 2008, *MNRAS*, **387**, 577
- Pintos-Castro, I., Yee, H. K. C., Muzzin, A., Old, L., & Wilson, G. 2019, *ApJ*, **876**, 40
- Poggianti, B. M., Gullieuszik, M., Tonnesen, S., et al. 2019, *MNRAS*, **482**, 4466
- Predehl, P., Sunyaev, R. A., Becker, W., et al. 2020, *Natur*, **588**, 227
- Quilis, V., Moore, B., & Bower, R. 2000, *Sci*, **288**, 1617
- Ramatsoku, M., Serra, P., Poggianti, B. M., et al. 2019, *MNRAS*, **487**, 4580
- Rasmussen, J., Ponman, T. J., & Mulchaey, J. S. 2006, *MNRAS*, **370**, 453
- Roberts, I. D., van Weeren, R. J., McGee, S. L., et al. 2021, *A&A*, **652**, A153
- Roediger, J. C., & Courteau, S. 2015, *MNRAS*, **452**, 3209
- Rudnick, G., & Rix, H.-W. 1998, *AJ*, **116**, 1163
- Rudnick, G., Jablonka, P., Moustakas, J., et al. 2017, *ApJ*, **850**, 181
- Salerno, J. M., Muriel, H., Coenda, V., et al. 2022, *MNRAS*, **517**, 4515
- Sarron, F., Adami, C., Durret, F., & Laigle, C. 2019, *A&A*, **632**, A49
- Schirmer, M. 2013, *ApJS*, **209**, 21
- Scott, T. C., Usero, A., Brinks, E., et al. 2015, *MNRAS*, **453**, 328
- Semczuk, M., Łokas, E. L., D’Onghia, E., et al. 2020, *MNRAS*, **498**, 3535
- Serra, P., Oosterloo, T., Morganti, R., et al. 2012, *MNRAS*, **422**, 1835
- Serra, P., Maccagni, F. M., Kleiner, D., et al. 2023, *A&A*, **673**, A146
- Sivakoff, G. R., Sarazin, C. L., & Carlin, J. L. 2004, *ApJ*, **617**, 262
- Springel, V., Di Matteo, T., & Hernquist, L. 2005, *MNRAS*, **361**, 776
- Stein, Y., Bomans, D. J., Ferguson, A. M. N., & Dettmar, R. J. 2017, *A&A*, **605**, A5
- Sun, M., Voit, G. M., Donahue, M., et al. 2009, *ApJ*, **693**, 1142
- Tempel, E., Tuvikene, T., Kipper, R., & Libeskind, N. I. 2017, *A&A*, **602**, A100
- Tonnesen, S. 2019, *ApJ*, **874**, 161
- Tonnesen, S., & Bryan, G. L. 2008, *ApJL*, **684**, L9
- Tonnesen, S., & Bryan, G. L. 2009, *ApJ*, **694**, 789
- Toomre, A., & Toomre, J. 1972, *ApJ*, **178**, 623
- Tumlinson, J., Peebles, M. S., & Werk, J. K. 2017, *ARA&A*, **55**, 389
- Vollmer, B., Braine, J., Combes, F., & Sofue, Y. 2005, *A&A*, **441**, 473
- Vollmer, B., Braine, J., Pappalardo, C., & Hily-Blant, P. 2008, *A&A*, **491**, 455
- Vollmer, B., Fossati, M., Boselli, A., et al. 2021, *A&A*, **645**, A121
- Vulcani, B., Poggianti, B. M., Jaffé, Y. L., et al. 2018, *MNRAS*, **480**, 3152
- Vulcani, B., Poggianti, B. M., Moretti, A., et al. 2021, *ApJ*, **914**, 27
- Walker, I. R., Mihos, J. C., & Hernquist, L. 1996, *ApJ*, **460**, 121
- Williamson, D., Martel, H., & Romeo, A. B. 2016, *ApJ*, **831**, 1
- Xie, L., De Lucia, G., Hirschmann, M., & Fontanot, F. 2020, *MNRAS*, **498**, 4327
- Xie, L., De Lucia, G., Hirschmann, M., Fontanot, F., & Zoldan, A. 2017, *MNRAS*, **469**, 968
- Young, L. M., Bureau, M., Davis, T. A., et al. 2011, *MNRAS*, **414**, 940
- Zakharova, D., Vulcani, B., De Lucia, G., et al. 2024, *A&A*, **690**, A300
- Zaritsky, D., & Rix, H.-W. 1997, *ApJ*, **477**, 118
- Zibetti, S., Charlot, S., & Rix, H.-W. 2009, *MNRAS*, **400**, 1181