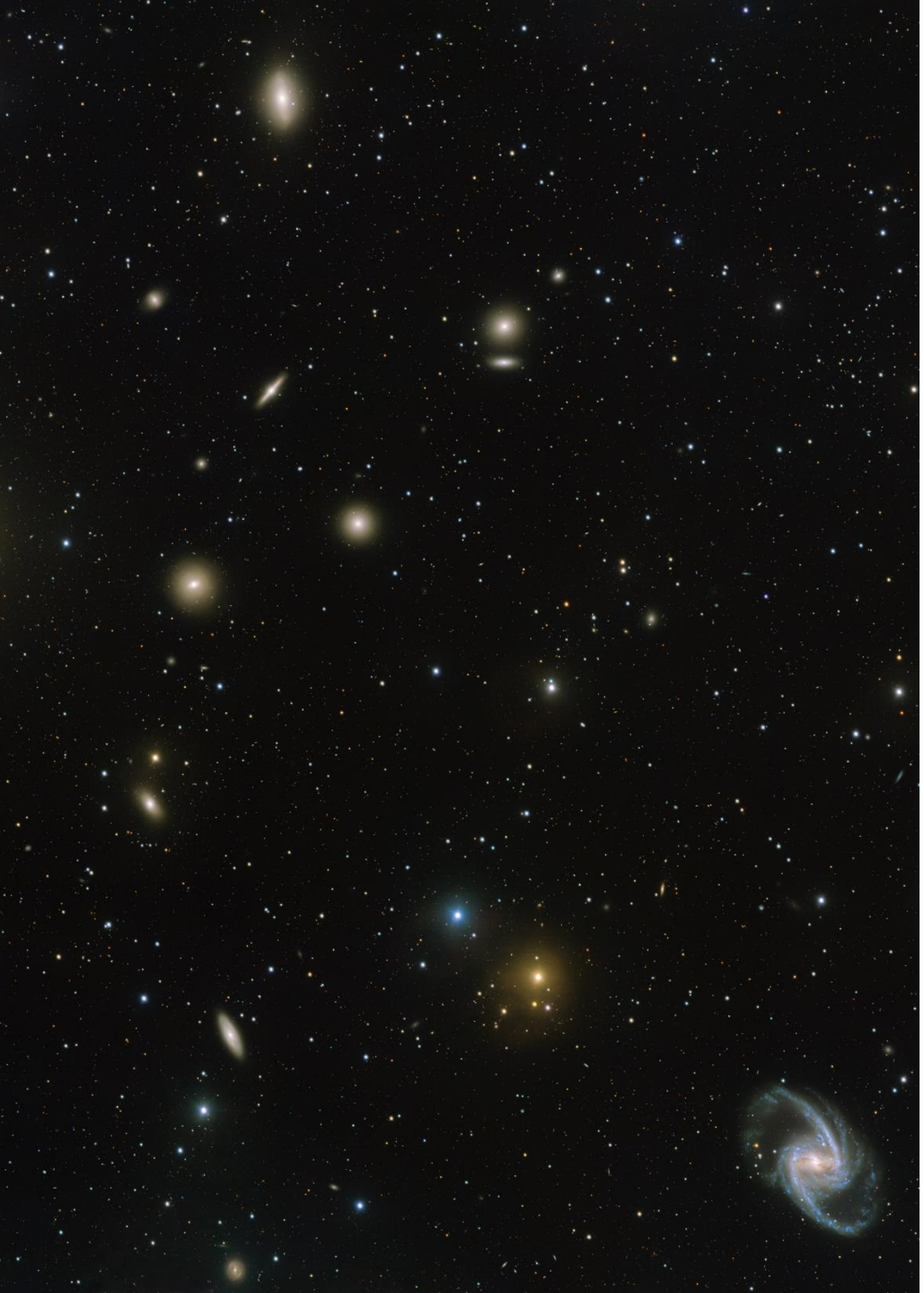


COMPARATIVE ANALYSIS OF THE GALAXIES IN THE **FORNAX MAIN CLUSTER** AND **FORNAX A SUBGROUP**

PhD Candidate: Nabeelah Adam

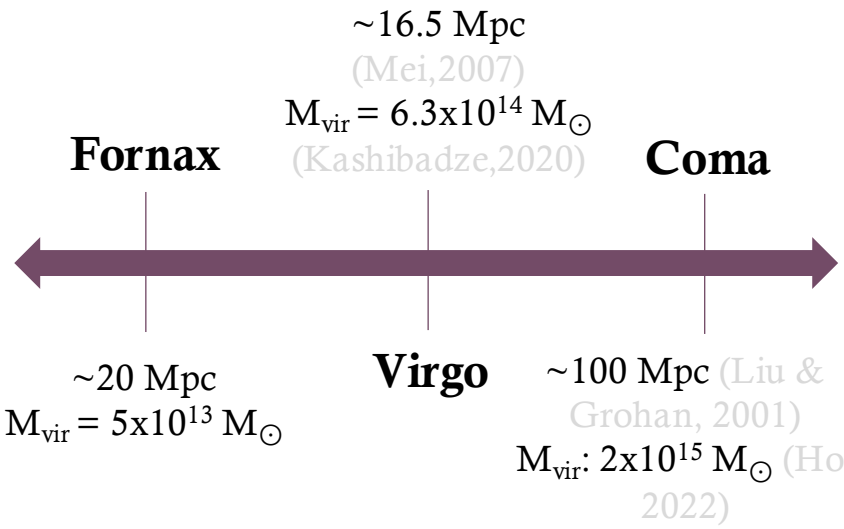
Supervisors: D.J. Pisano & P. Serra

OVERVIEW

- An introduction to Fornax
- A multi-wavelength look into the Fornax cluster and group:
  - Optical
  - X-ray
  - HI
- With regards to the HI,
  - The MeerKAT Fornax Survey
  - Preliminary data
  - HI in the cluster core vs the group

FORNAX

- Distance from us: ~20 Mpc (Scharf,2005)
- M_{vir}: $5x10^{13}$ $M_{\odot}$ (Drinkwater, 2001)
- Velocity Dispersion (σ): 374 $km.s^{-1}$ (Drinkwater, 2001)



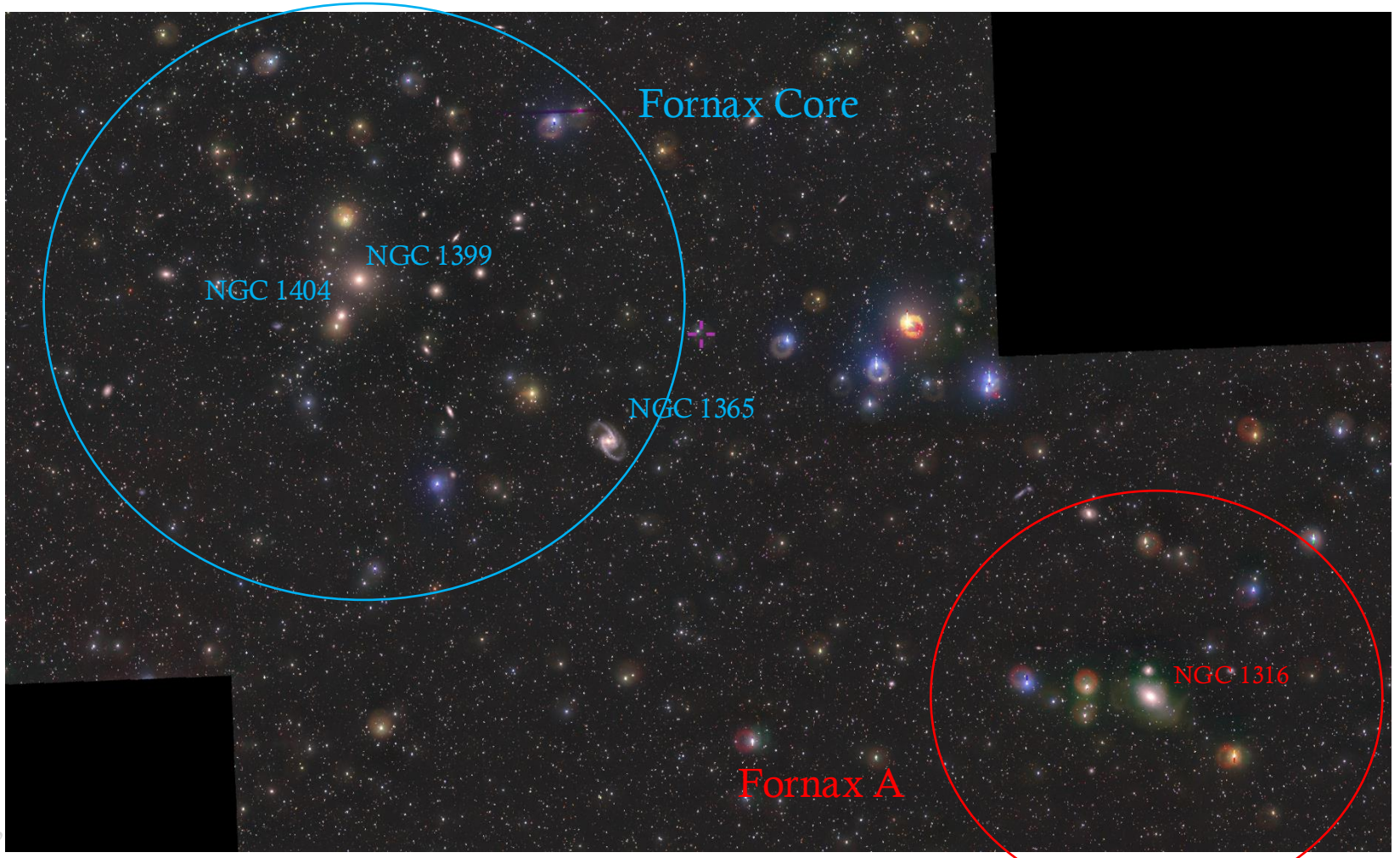


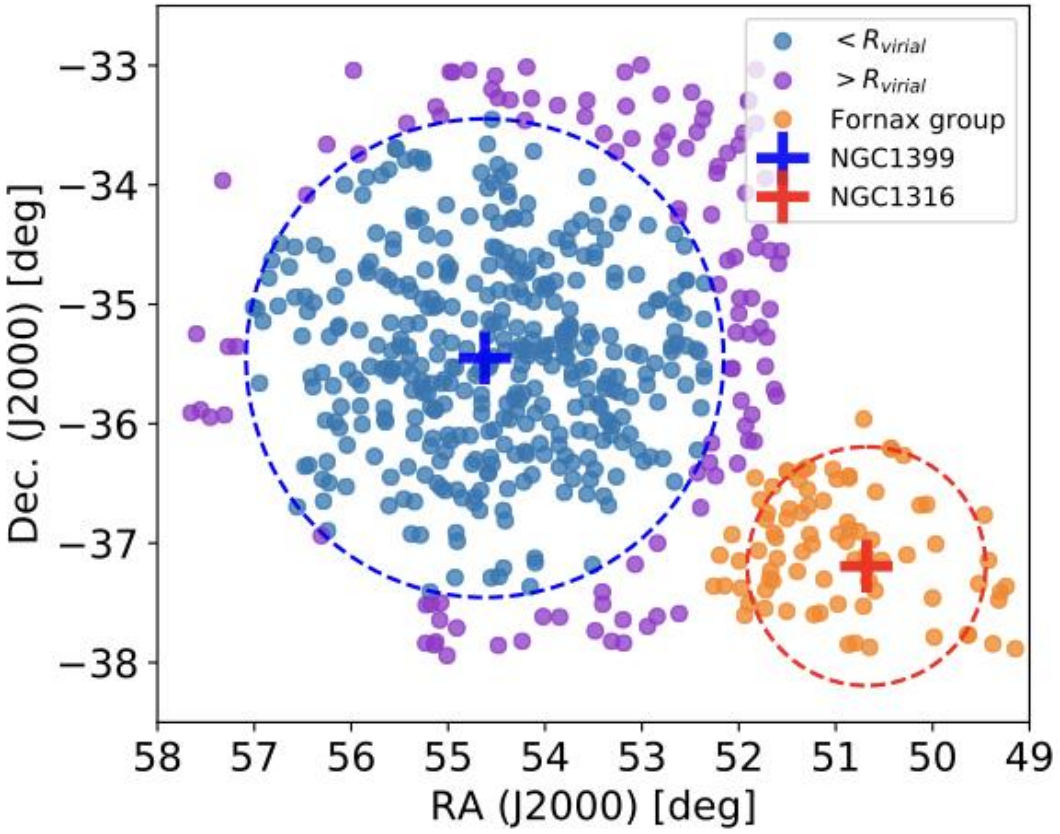
Image Source: FDS HiPS

A LOOK IN THE OPTICAL

Source: Su, 2021

- The Fornax Deep Survey (FDS) – an optical survey covering the Fornax Core and Subgroup region. (Iodice, 2016)
- Survey Area: 26 deg^2
- Optimal surface brightness: μ_g ~ 29-31 $mag/arcsec^2$

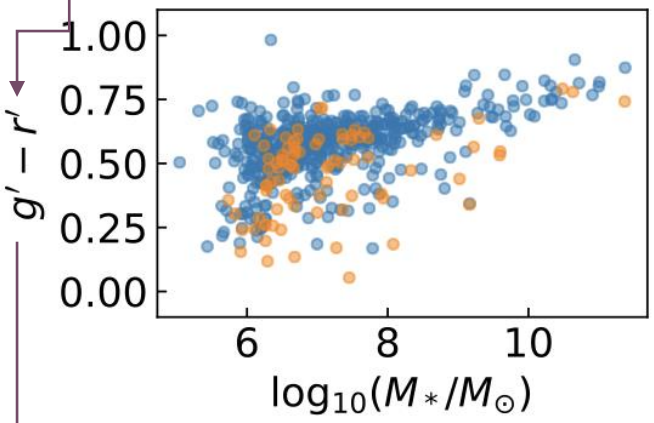
- The points represent 582 galaxies in the FDS sample compiled by Su et al. 2021.



A LOOK IN THE OPTICAL

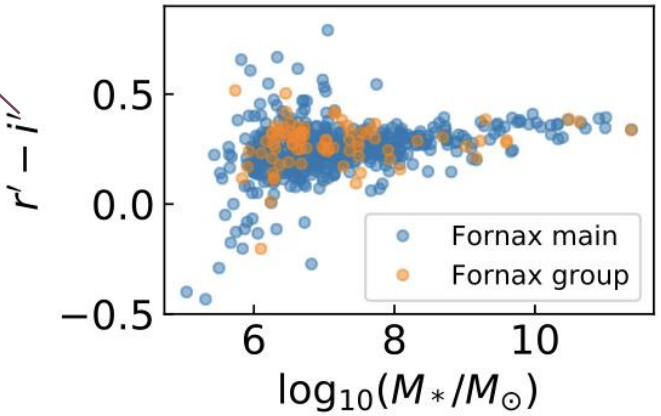
Source: Su, 2021

r' – cool old stars

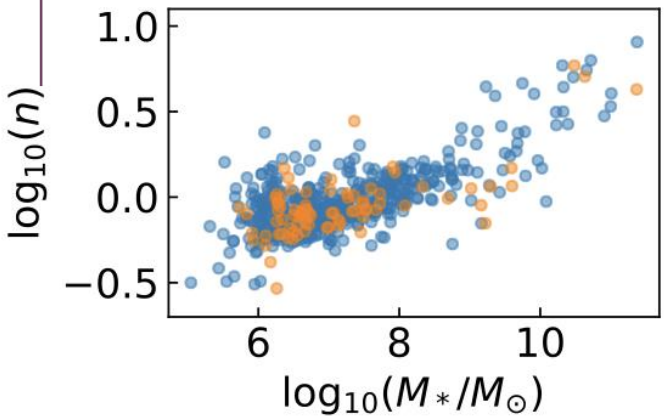


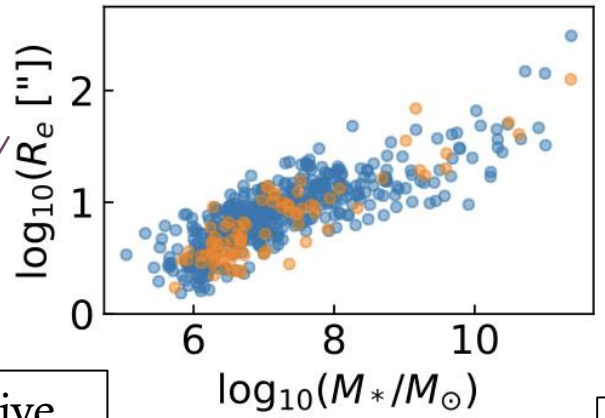
g' – hot young stars

i' – NIR

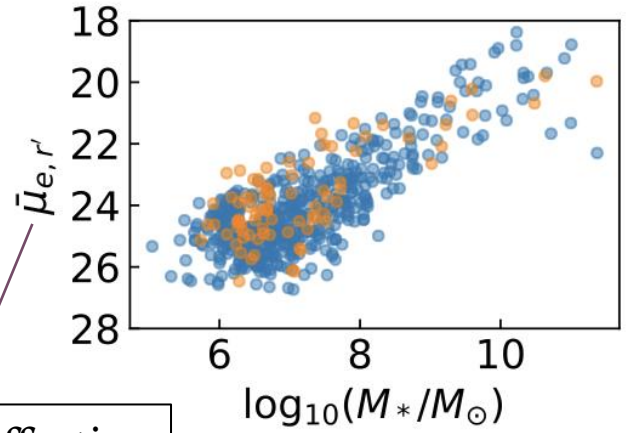


Sérsic index





Sérsic effective radius



Mean effective surface brightness

A BRIEF INTERLUDE: SÉRSIC PROFILES

- A sérsic profile is a function that describes how surface brightness changes with respect to radius.

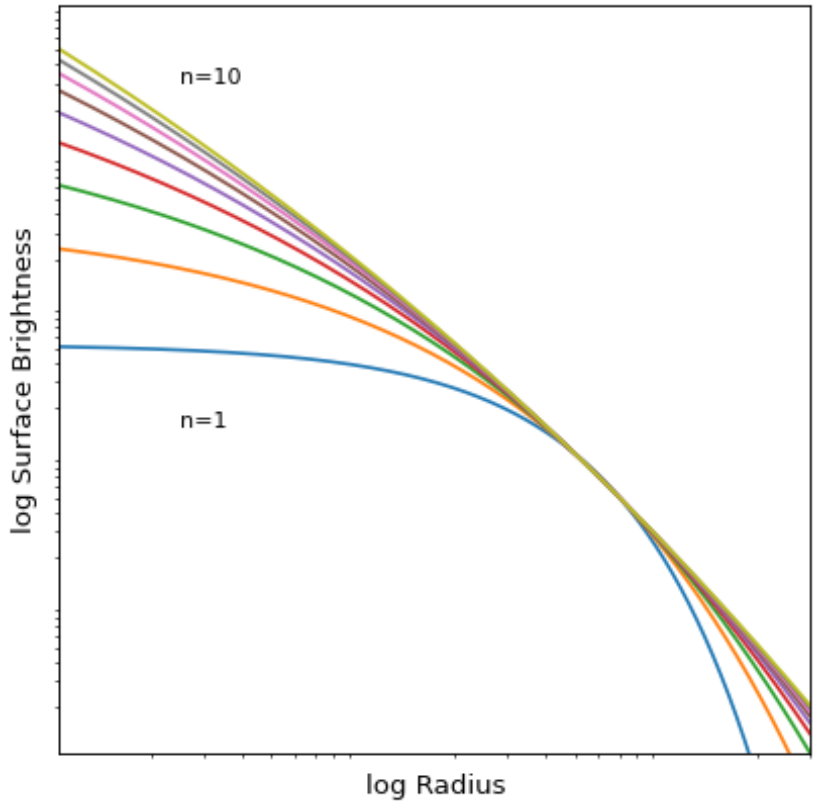
Normalization factor

Sérsic Index

$$I(r) = I_e \exp\left[-b\left(\left(\frac{r}{r_e}\right)^{1/n} - 1\right)\right]$$

Flux per unit area

Effective radius



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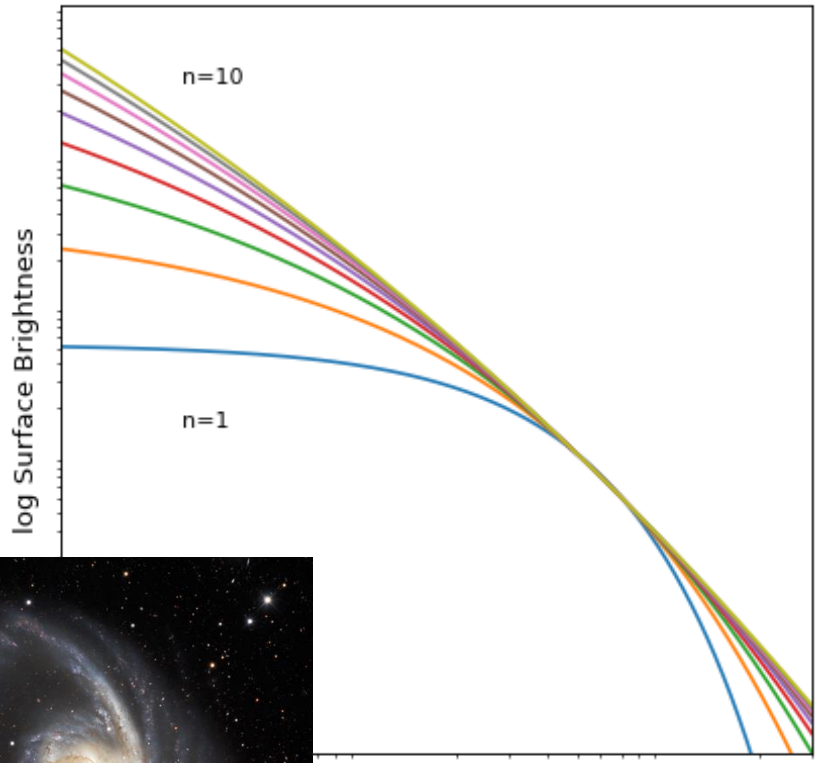

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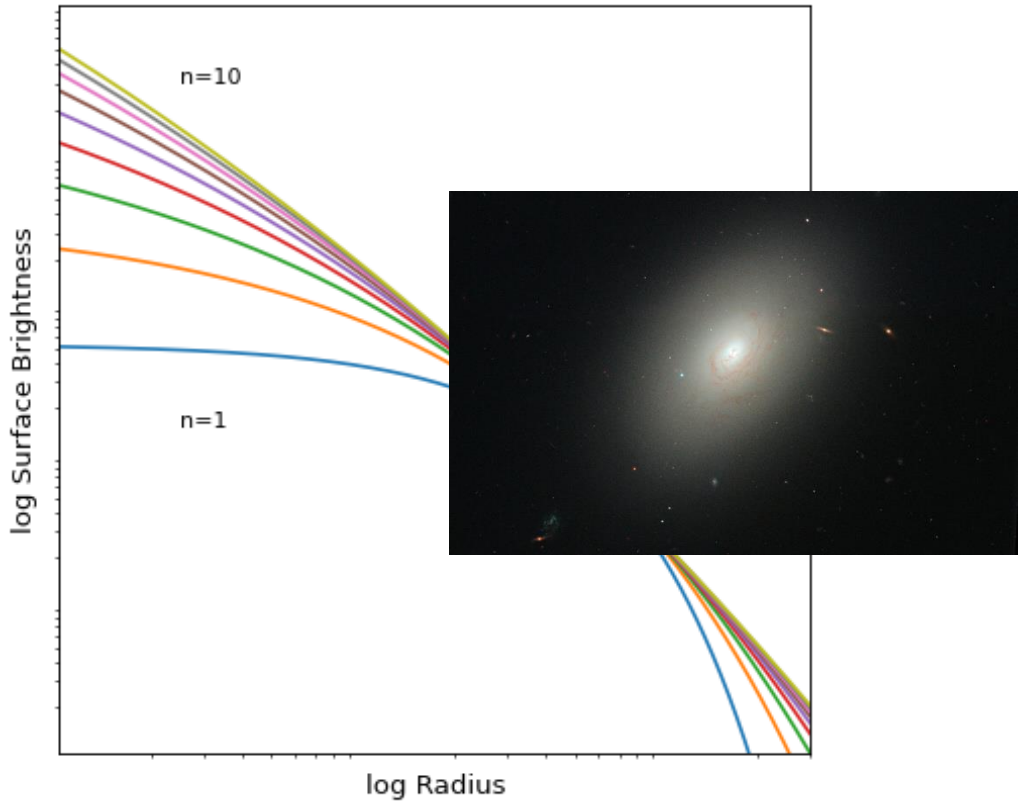

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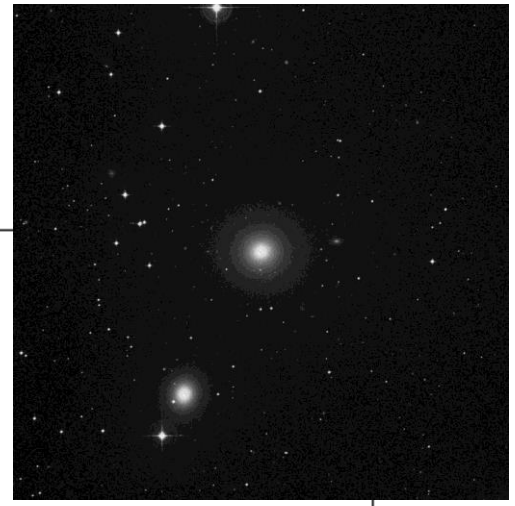

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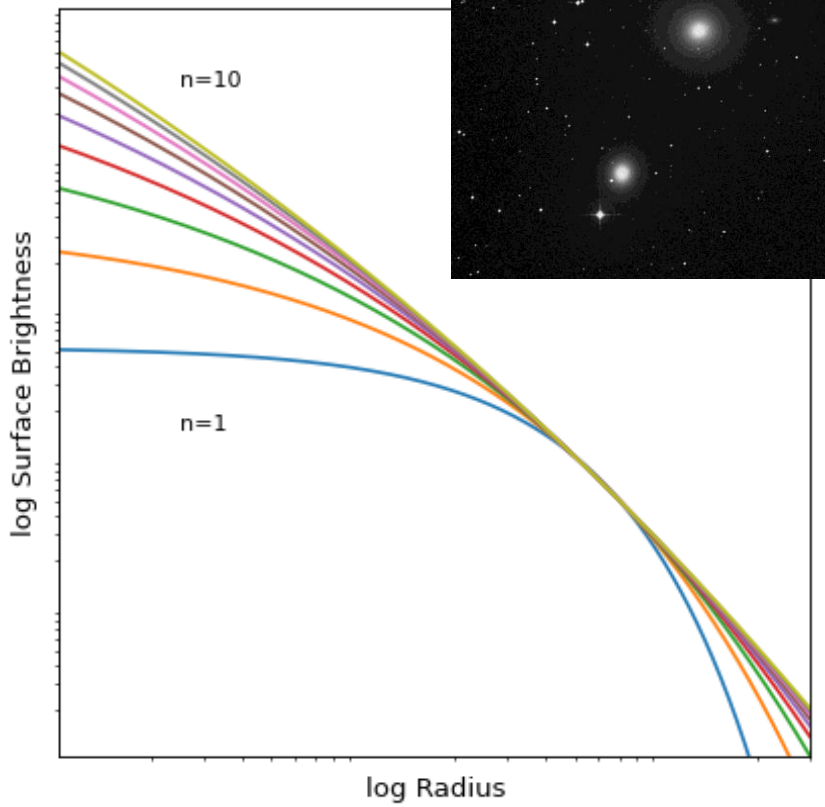
Flux per unit area

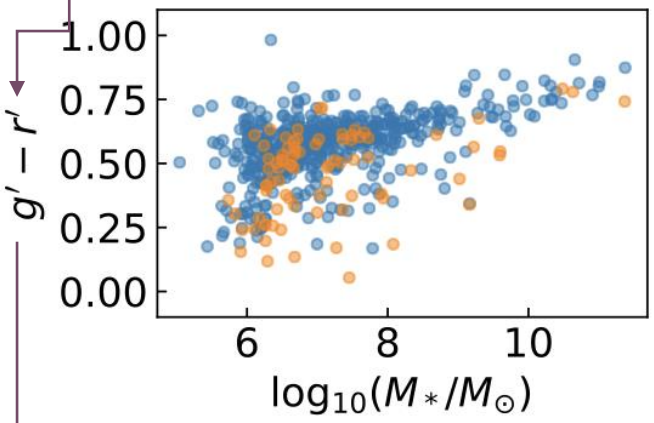
Effective radius



A LOOK IN THE OPTICAL

Source: Su, 2021

r' – cool old stars



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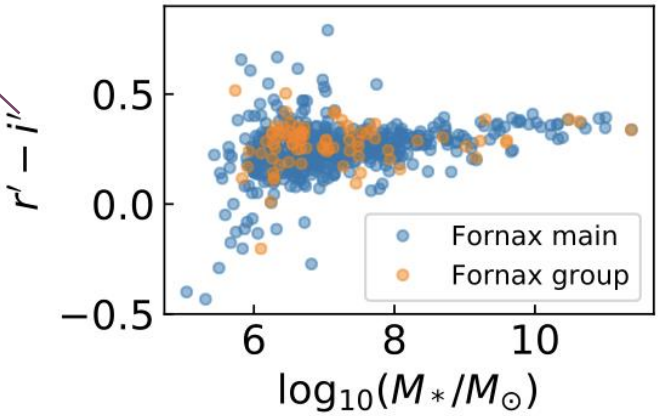
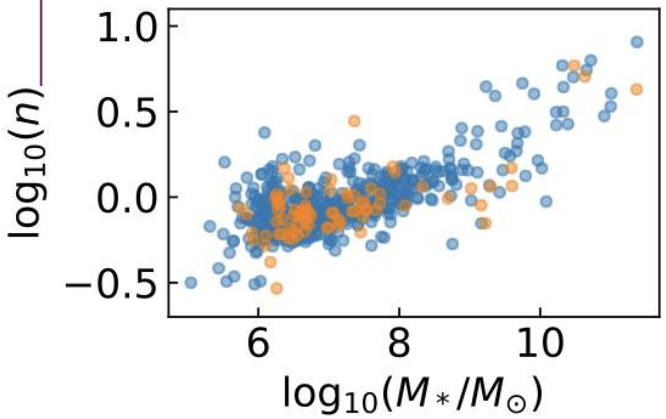
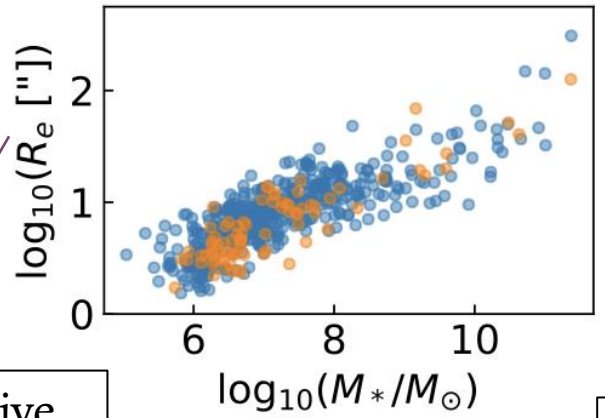
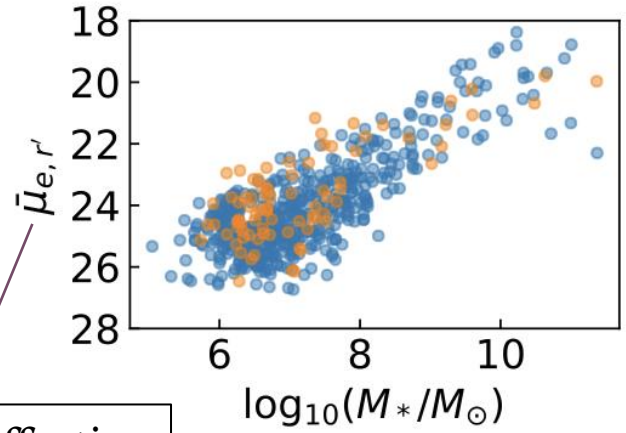


Sérsic index





Sérsic effective radius

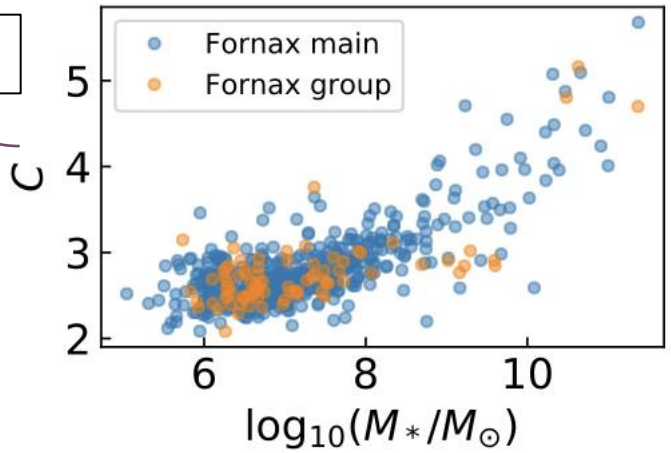


Mean effective surface brightness

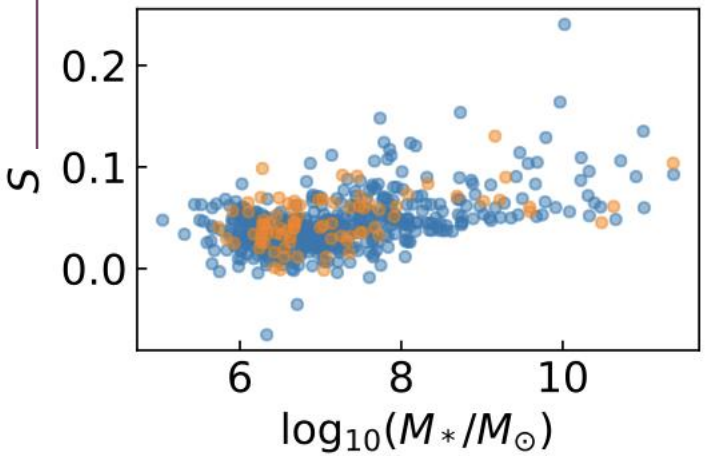
A LOOK IN THE OPTICAL

Source: Su, 2021

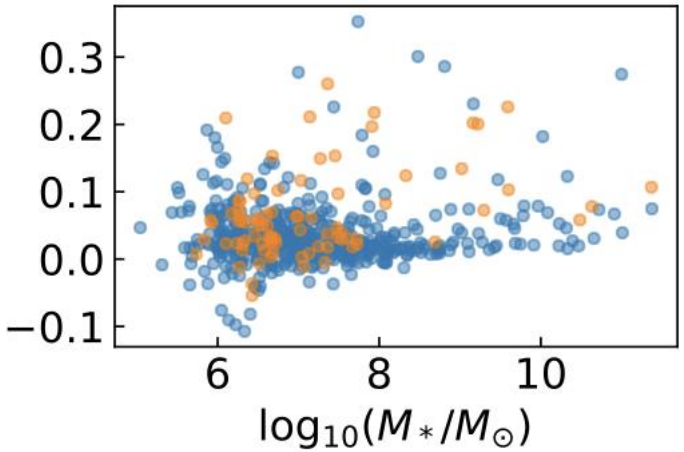
Concentration

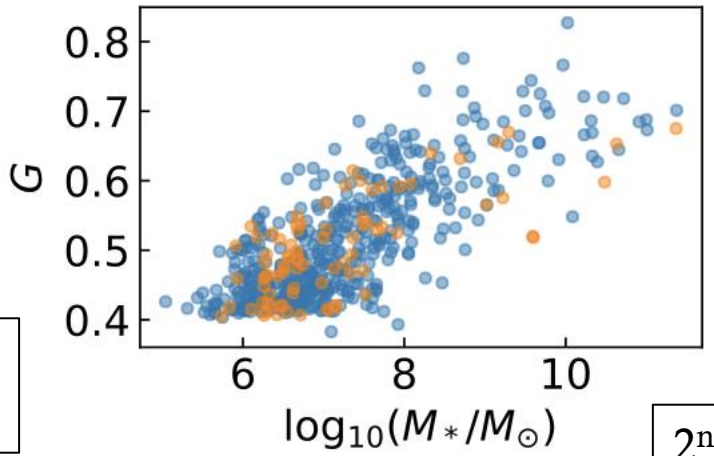


Clumpiness

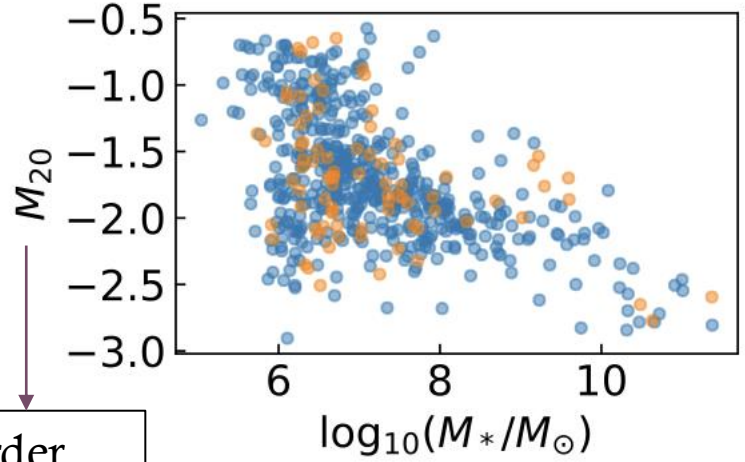


Asymmetry





Gini Coeffiecient



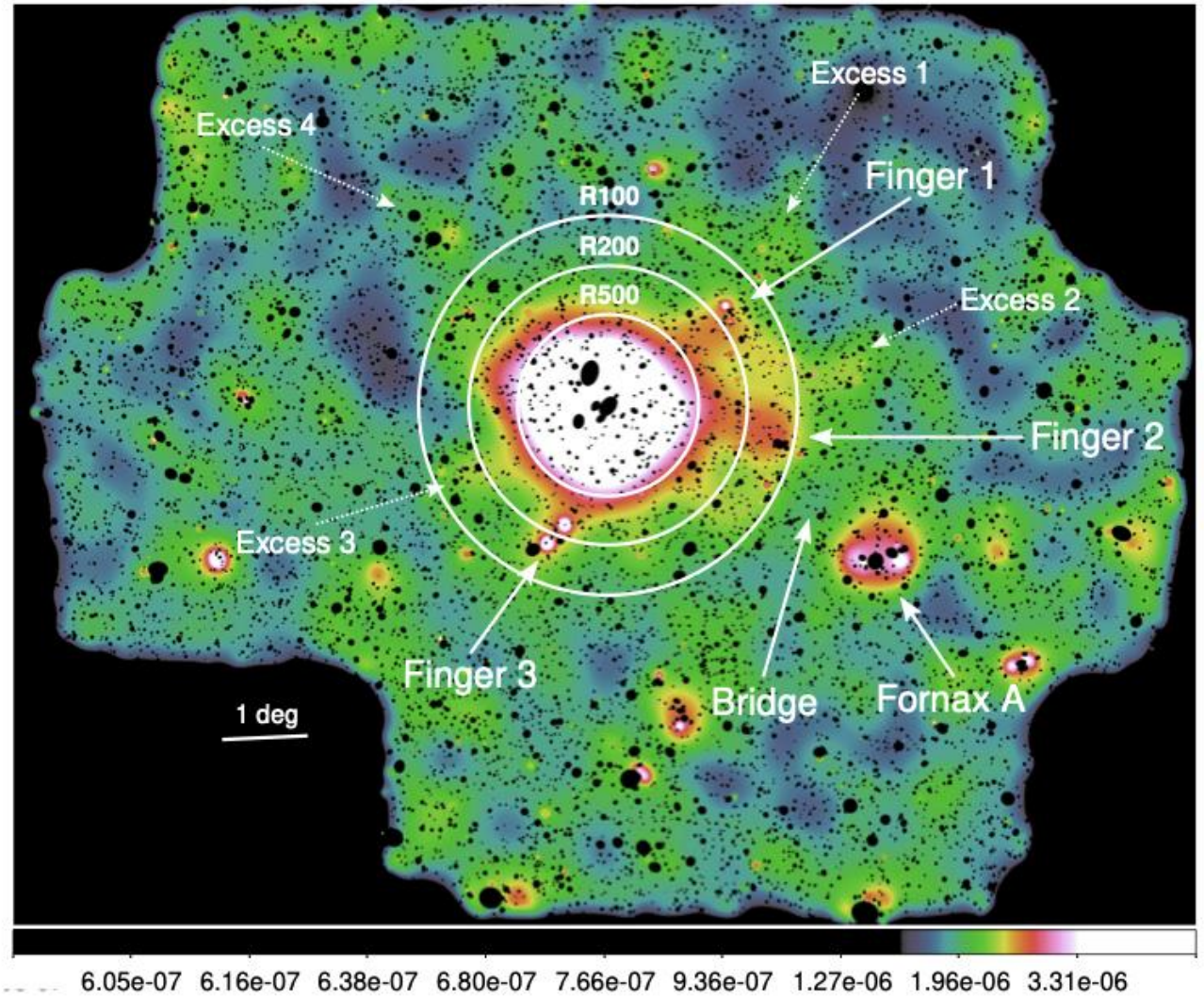
2nd order moment of light

A LOOK IN THE X-RAY

Source: Reiprich,2025

- eRosita all-sky survey

- Discovery of **x-ray 'fingers'** extended beyond the virial radius of Fornax to the west and SE.
- **Excessses 1,2,3,4** – broader regions of excess x-ray emission.
- Bridge joining Fornax to Fornax A.



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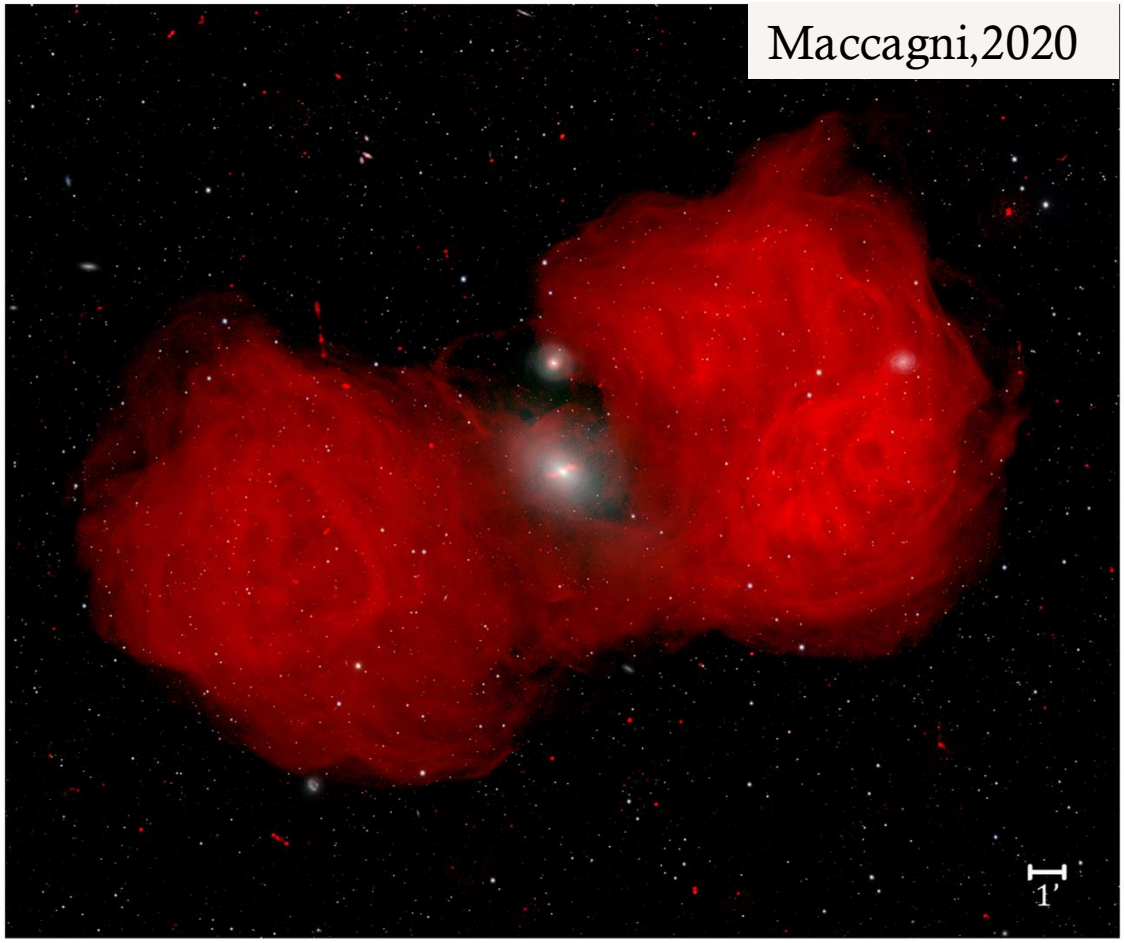


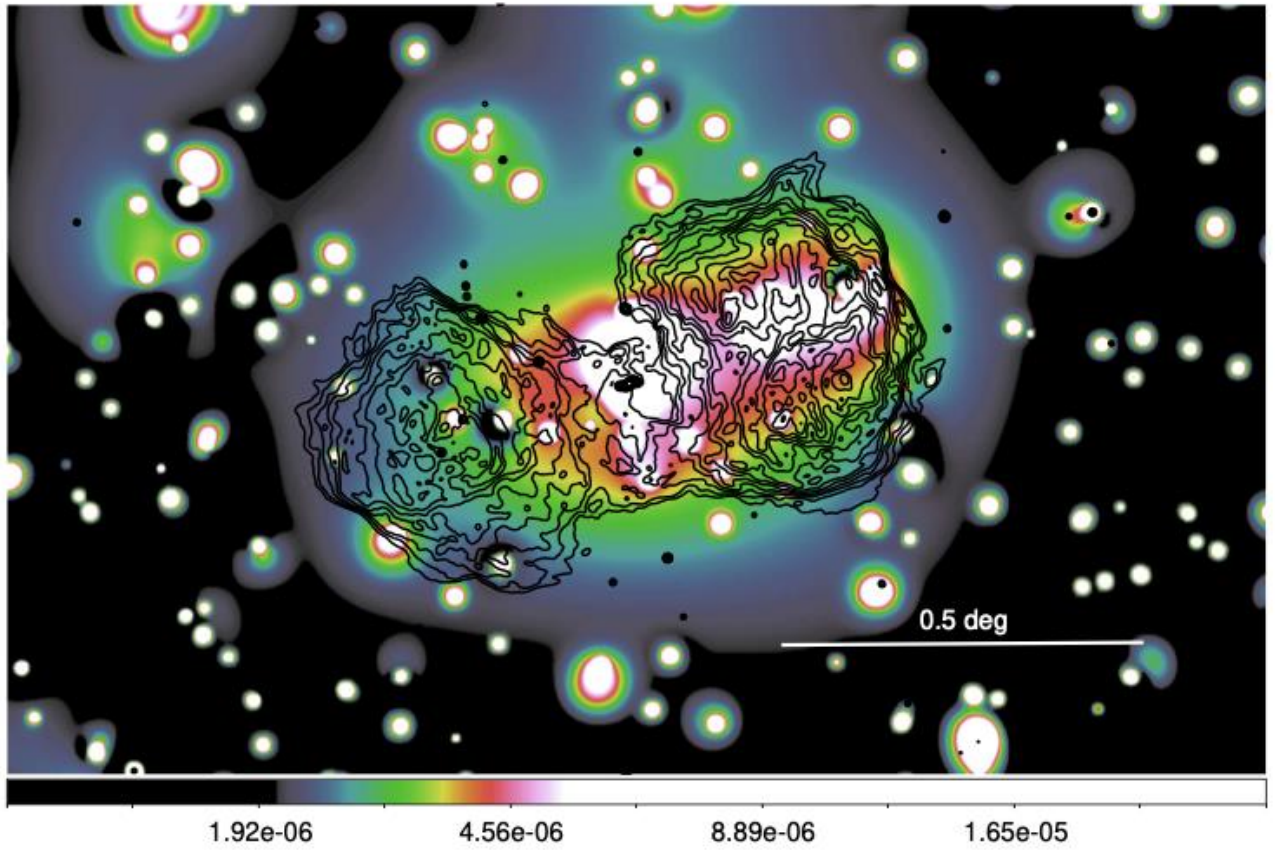


Fig. 1. Fornax A seen by MeerKAT at 1.44 GHz. The radio emission is in red, as well as the background and foreground sources. The three-colour composite image (from the *gri* bands) of the same field of view is taken from the Fornax Deep Survey (Iodice et al. 2017).

THE MEERKAT FORNAX SURVEY

- 21cm HI observations (L-band)
- Survey Footprint: 12 deg^2

- Goals:
  - Detection of diffuse HI
  - Studying the HI mass function
  - Detection of HI gas tails

Angular Resolutions	Velocity Resolutions	HI column density sensitivity limit (3σ over 25 km/s)
11''	1.4, 7, 21 km/s	$5x10^{19}$ cm^{-2}
21''	1.4, 7, 21 km/s	$1.2x10^{19}$ cm^{-2}
41''	1.4, 7, 21 km/s	$2.7x10^{18}$ cm^{-2}
66''	1.4, 7, 21 km/s	$1.3x10^{18}$ cm^{-2}
98''	1.4, 7, 21 km/s	$7.6x10^{17}$ cm^{-2}

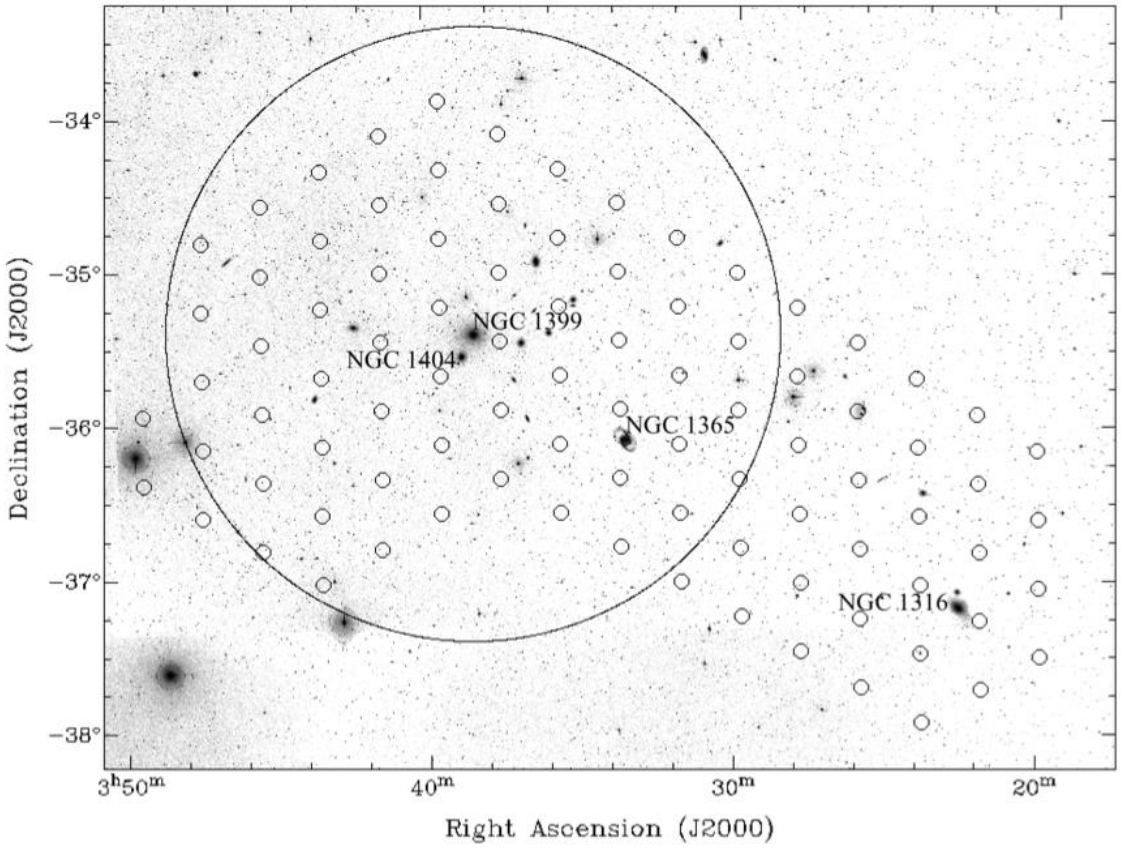
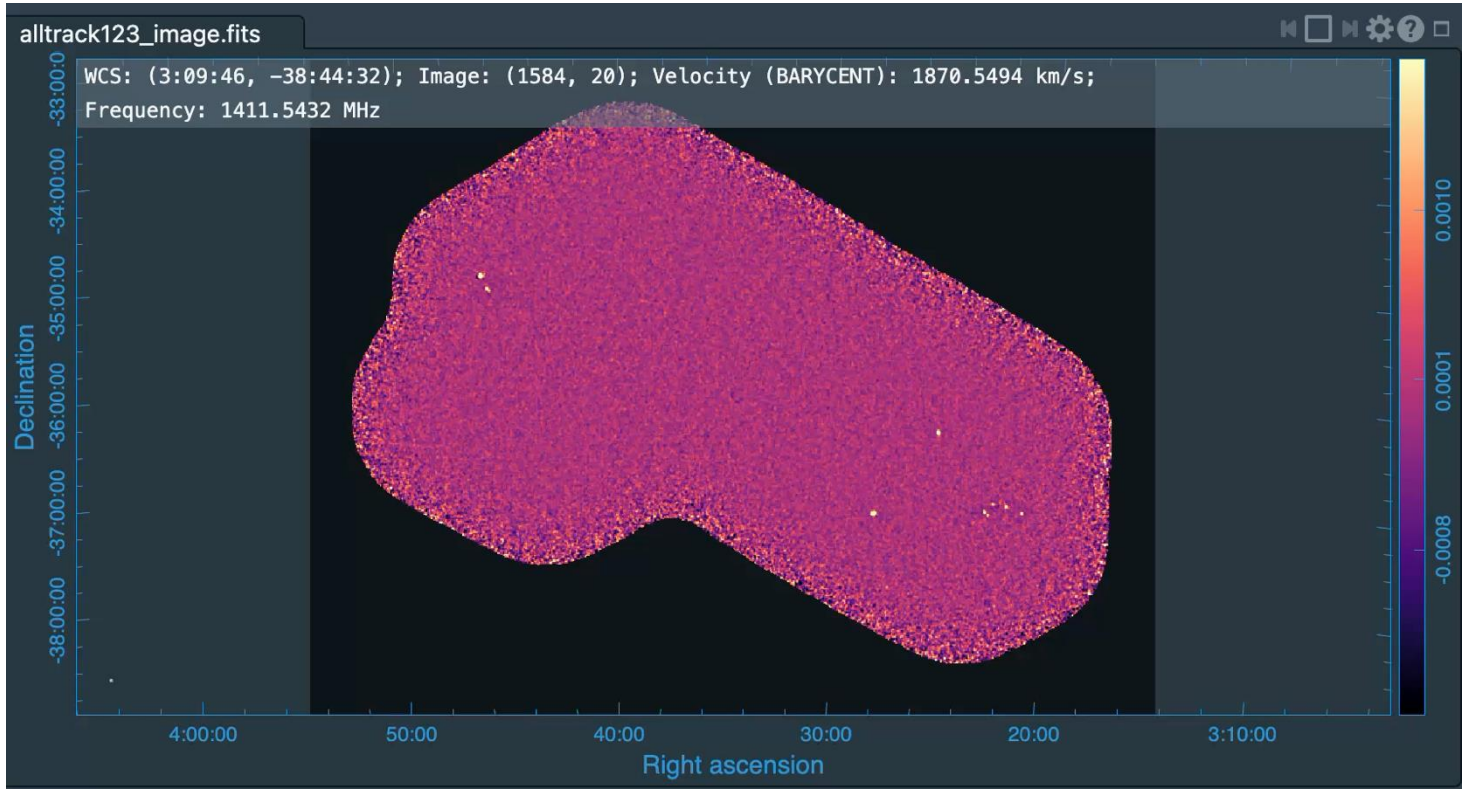


Image Source: Serra, 2023

DATA

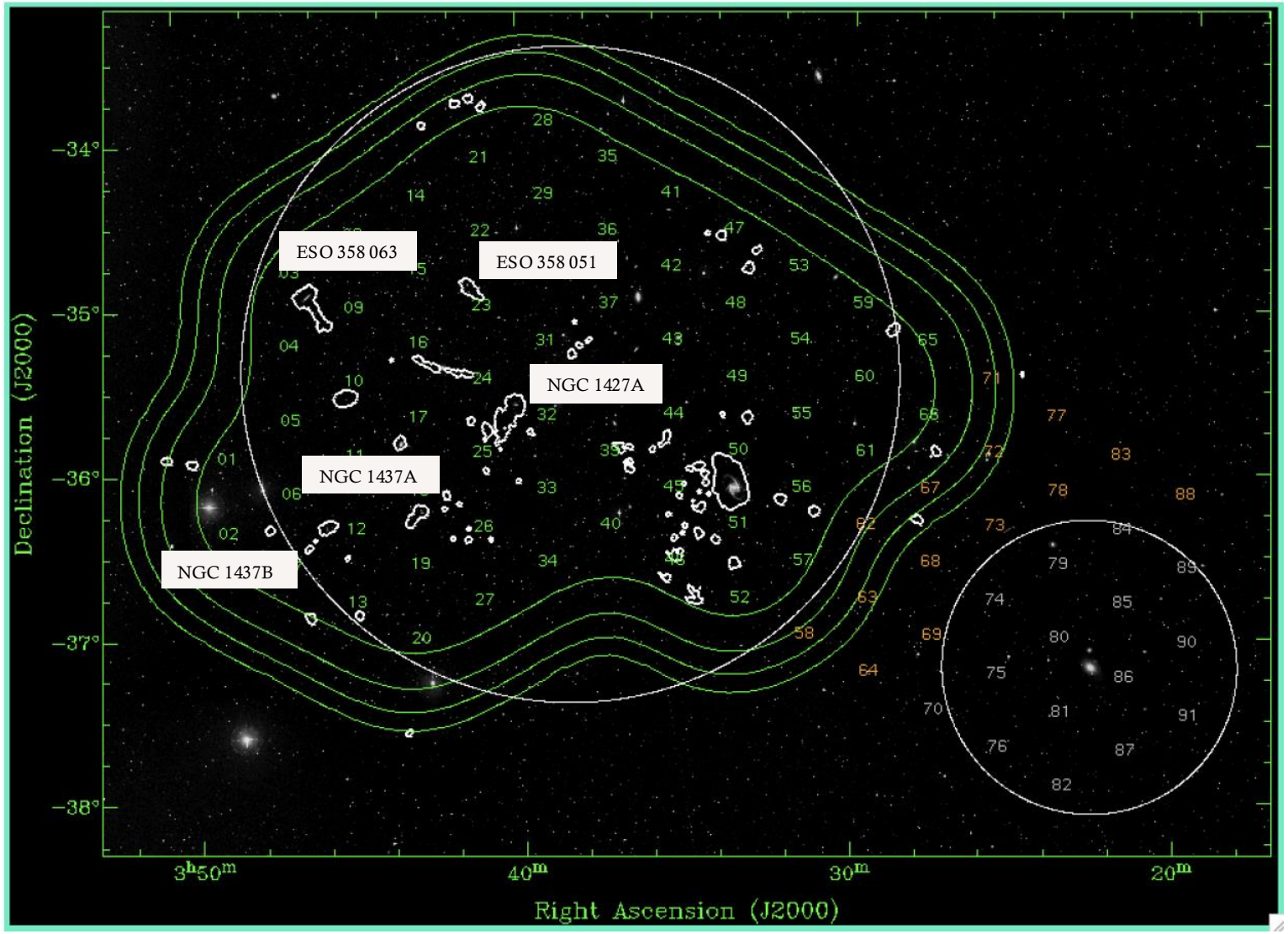
- A preliminary cube of the complete survey area.
- A single MeerKAT pointing = 2x 5hr tracks.

Frequency Range	**[1.3998,1.4194] GHz**
Spectral Resolution	4.1 km/s (19.6 kHz)
Pixel Size	20'' x 20''
RMS noise	~ 0.33 – 0.6 μJy/beam
Restoring beam	63.3361'' x 59.743'', PA = -63.0027 deg



HI IN THE CLUSTER CORE

- N_{HI} contour ~ $1x10^{18}$ cm^{-2}
- Cloud complex associated with NGC 1365.
- 6 of the detections have long one-sided tails (Serra, 2023):
  - ESO 358-51
  - ESO 358-63
  - FCC 306
  - NGC 1427A
  - NGC 1437A
  - NGC 1437B



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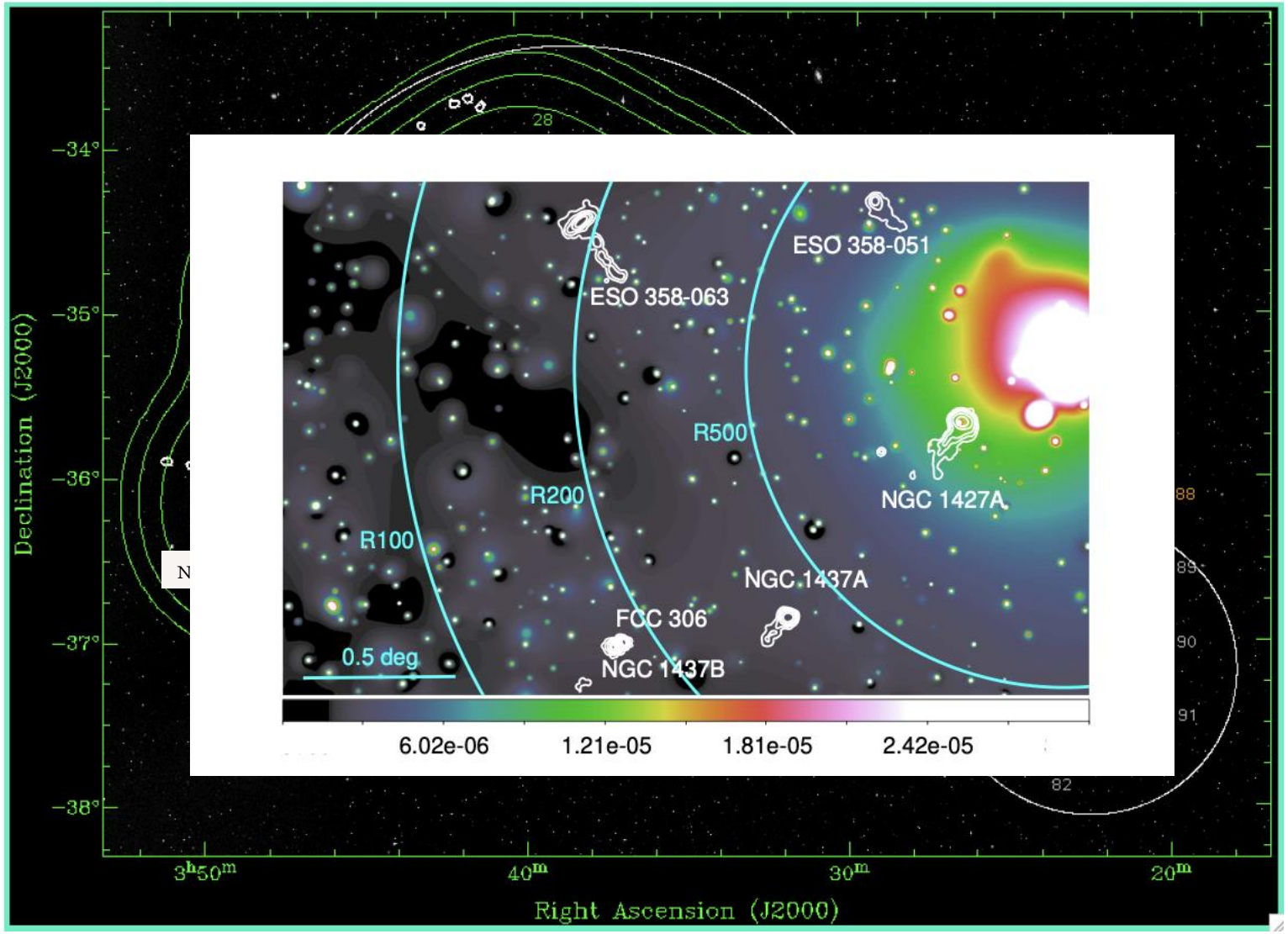


HI IN THE SUBGROUP

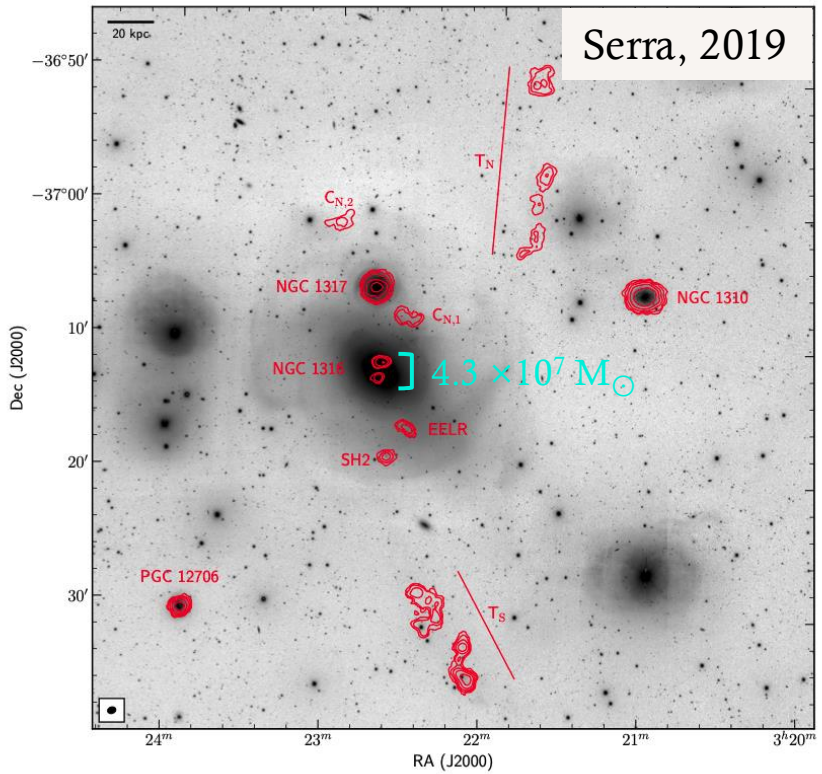


Fig. 2. Primary-beam corrected, constant column density H I contours overlaid on a *r*-band image from the Fornax Deep Survey (Iodice et al. 2017). The contour levels are $2.7 \times 10^{19} \times 2^n$ cm^{-2} ($n = 0, 1, 2, ...$). The lowest contour corresponds to a 3σ signal in a single channel at the centre of the H I cube (coincident with NGC 1316) but has lower significance further out. The Gaussian restoring PSF in the bottom-left corner has a FWHM of 36.7″ × 28.1″ and position angle 109 deg. The scale bar in the top-left corner represents 20 kpc (~3.5′ at a distance of 20 Mpc). The H I properties of the labelled sources are listed in Table 2.

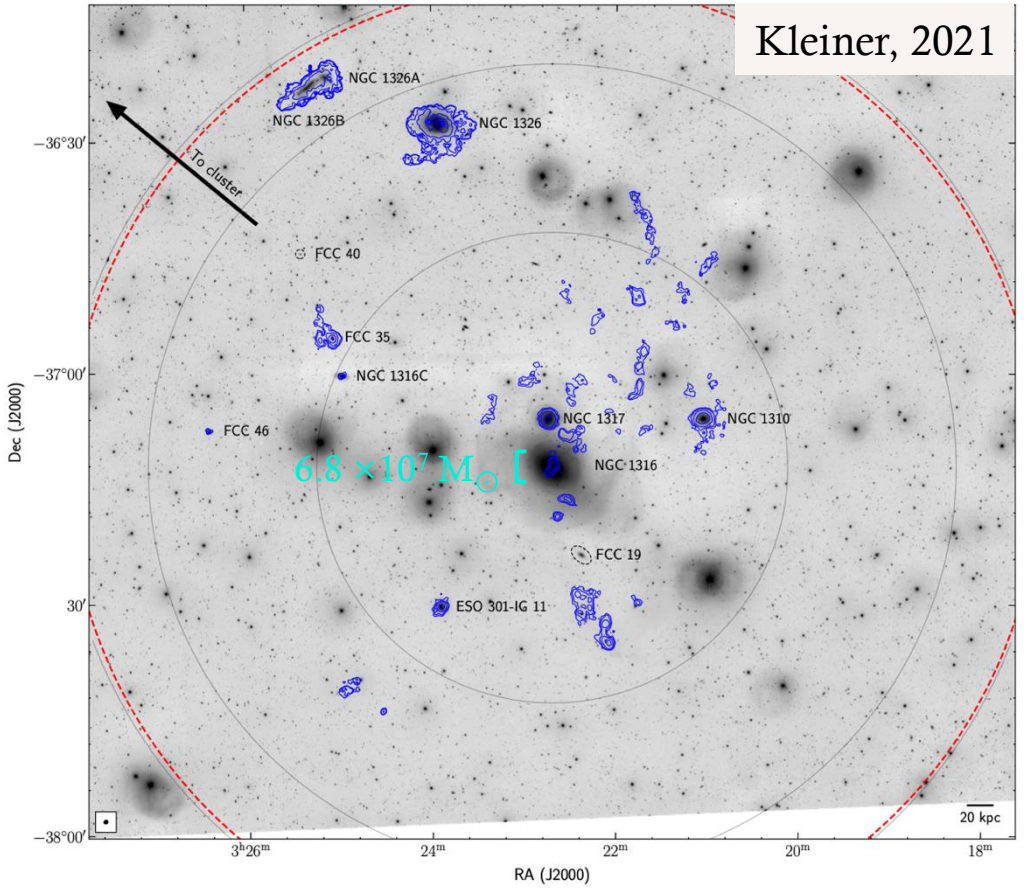


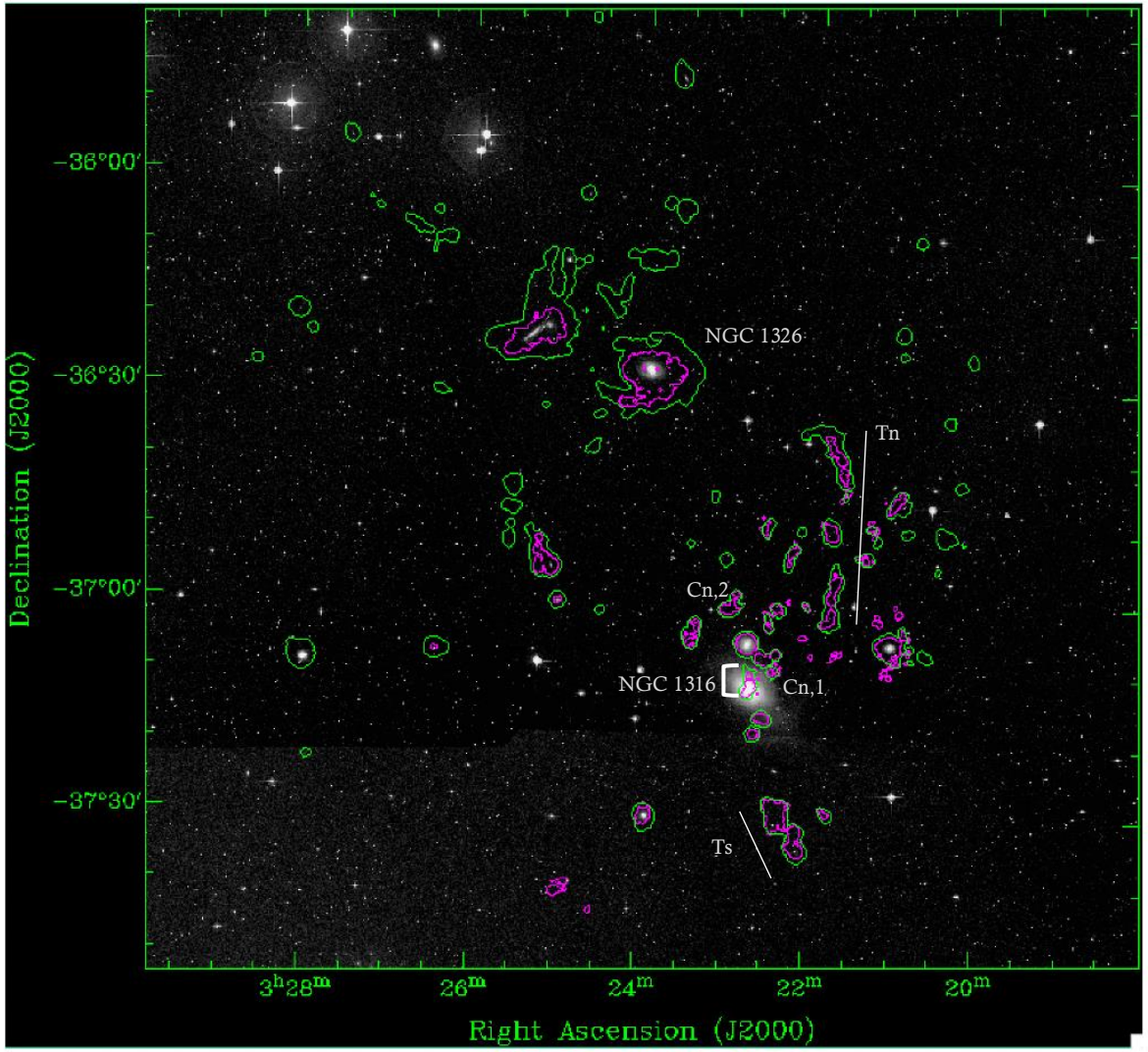
Fig. 2. Primary beam-corrected constant H I contours from MeerKAT (blue) overlaid on a FDS (Iodice et al. 2016) *gri* stacked optical image. The lowest contour represents the 3σ column density level of $N_{H\,I} = 1.4 \times 10^{19}$ atoms cm^{-2} over a 44.1 km s^{-1} channel, where the contours increase by a factor of 3^n ($n = 0, 1, 2, \ldots$). The group galaxies are labelled and the galaxies not detected in H I are outlined by a dashed black ellipse. The grey circles indicate the sensitivity of the primary beam (Mauch et al. 2020) at 50%, 10%, and 2%. The red dashed circle denotes the 1.05° (0.38 Mpc) virial radius of the group as adopted in Drinkwater et al. (2001), where the restoring beam (33.0″ × 29.2″) is shown in the bottom left corner and a scale bar indicating 20 kpc at the distance of Fornax A in the bottom right corner. The direction to the Fornax cluster is shown by the black arrow. In H I, we detect 10 (out of 12) galaxies, previously known clouds and streams in the IGM and a population of new H I clouds in the IGM. The previously known IGM H I structures are labelled in Fig. 4 for clarity.

HI IN THE SUBGROUP

- Preliminary cube: mosaicking of each pointing 5 x 5 hr tracks
- Larger survey area than previous HI maps

- Magenta Contours: Kleiner, 2021
- Green Contours: preliminary work

- Key features:
  - Tn extension
  - Cloud complex to the right of Tn
  - Potential stripped gas associated with FCC 35



HI IN THE SUBGROUP

Fornax A

- The third brightest nearby radio galaxy after Centaurus A and M 87.
- Large double-lobed radio lobes, spans 290 kpc
- Central s-shaped jets, spans 6kpc

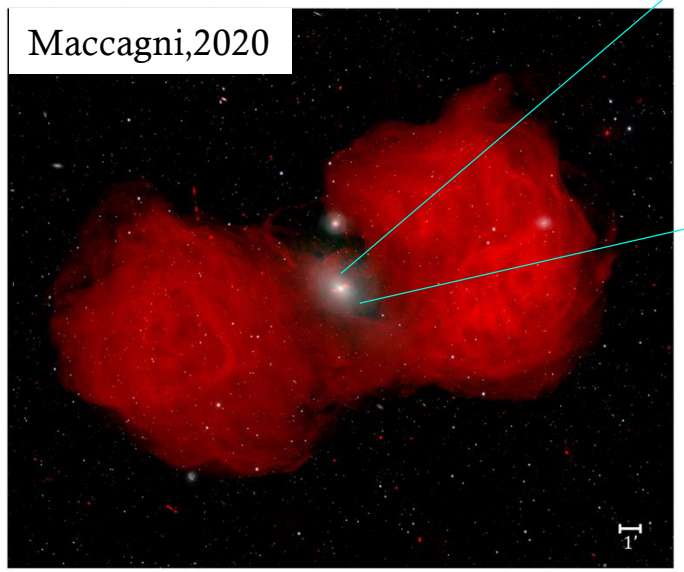


Fig. 1. Fornax A seen by MeerKAT at 1.44 GHz. The radio emission is in red, as well as the background and foreground sources. The three-colour composite image (from the *gri* bands) of the same field of view is taken from the Fornax Deep Survey (Iodice et al. 2017).

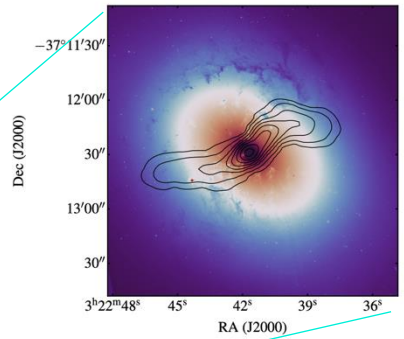
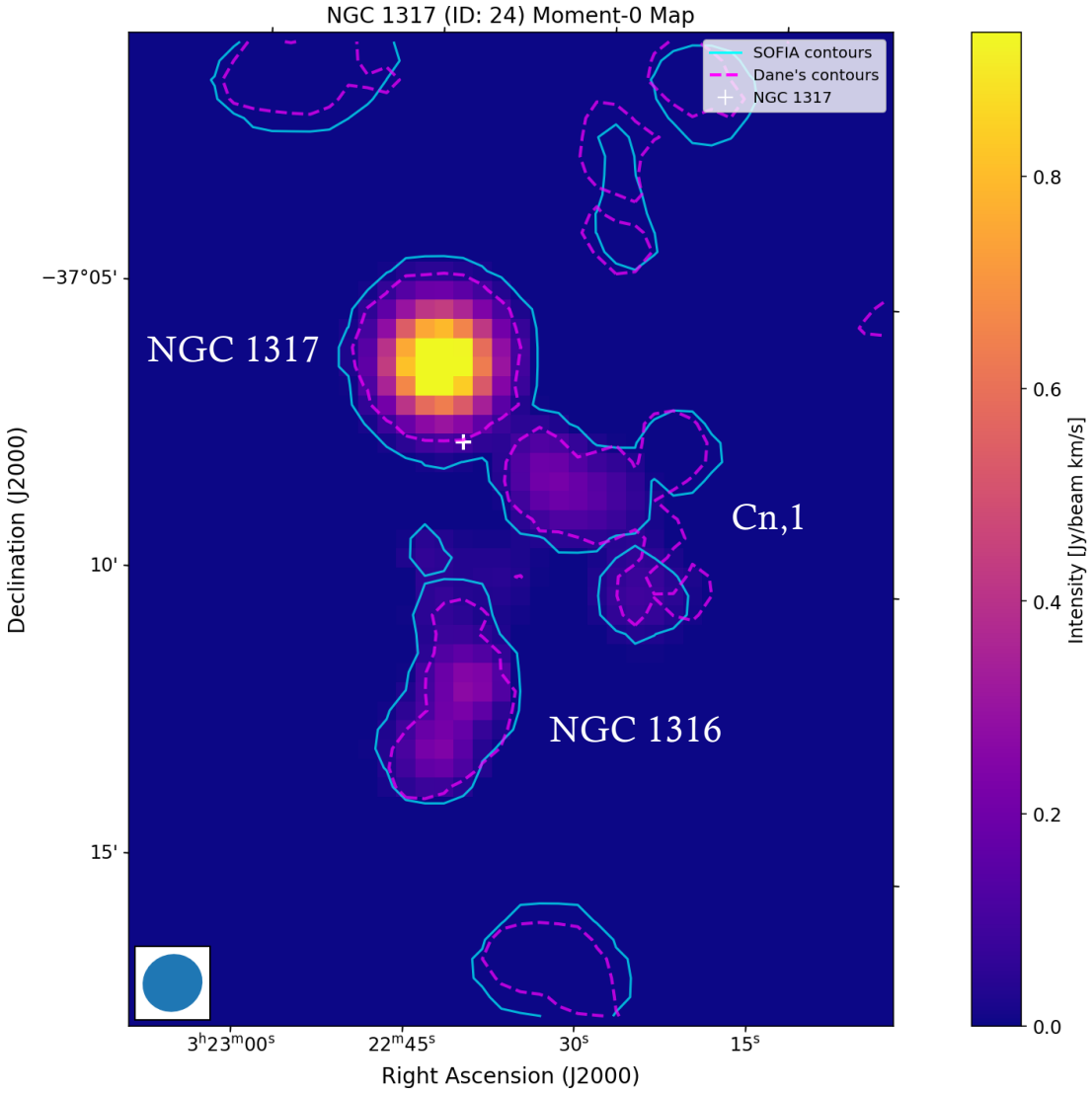


Fig. 1. *Hubble* ACS visible emission (535 nm) of the centre of Fornax A, radio jets seen by MeerKAT at 1.4 GHz are overlaid in black. Contour levels are $5 \times 10^{-4} \times 2^n$ Jy beam^{-1} (n = 0, 1, 2, ...) (Maccagni et al. 2020).



IN SUMMARY

- Optical:
  - Fornax A group galaxies are typically bluer, smaller, brighter, and more asymmetric and clumpy.
  - This implies that galaxies falling towards the centre of the Fornax main cluster become fainter, more extended, and generally smoother in their light distribution.
- X-ray:
  - There is an apparent bridge of low-surface-brightness emission beyond the virial radius connecting to the Fornax A galaxy group, which is also traced by the member galaxy and globular cluster distribution.
  - Reiprich et al.2025 concluded that they witnessed the growth of a cluster along large-scale filaments.
- HI:
  - With the unprecedented resolutions provided by the MeerKAT interferometer, we are able to investigate the HI associated with galaxies in these diverse environments in incredible detail.
  - We see, even in our preliminary results, a remarkable complex of HI morphologies depicted.