Stellar halos & LSB features from deep VST surveys

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Napoli, Italy

VST color composite image of NGC1316

VST survey of Early-type GAlaxieS (VEGAS)

is a deep, multi-band (*ugri*) imaging survey of early-type galaxies in groups & clusters at VST

VST is a 2.6m wide-field optical survey telescope, located at ESO Cerro Paranal, Chile

<u>VEGAS is based on the GTO assigned at INAF</u>

- 2011-2016, PI: M. Capaccioli, ~55 nights
- 2016-2021, PI: E. Iodice, ~62 nights

http://www.na.astro.it/vegas/VEGAS/Welcome.html

The Fornax Deep Survey with VST

- joint project based on

  VEGAS (P.I. E. Iodice)
  &
  OmegaCam GTO (FOCUS, P.I. R. Peletier)

- new, multi-imaging (u, g, r, i bands) survey of the Fornax Cluster

- FDS aims to cover 26 deg^2 around the core of the Fornax cluster out to the virial radius, including the region of Fornax A

VEGAS & FDS science aims

- **map the light distribution and colors** out to 8-10 Re and down to the faint surface brightness levels of $\mu_g \simeq 31$ mag/arcsec^2 $\mu_r \simeq 28$ mag/arcsec^2 $\mu_i \simeq 27$ mag/arcsec^2

- study of the **galaxy structure and its faint stellar halo**, including the diffuse light component, inner substructures as signatures of recent cannibalism events, inner disks and bars

- detection of the external low-surface brightness structures in galaxies, like **tidal tails, stellar streams and shells** and study the connection with environment

- for those galaxies in the sample with D< 40 Mpc, to **census the GCs and galaxy satellites** in the outermost regions of the host galaxy and to analyse their photometric properties

- the full sample proposed for VEGAS will provide essential **statistical constraints on theoretical models** and enable discrimination among competing galaxy formation theories

VEGAS + FDS publications

- **Iodice E.** et al., **2018**, A&A, submitted: *The Fornax Deep Survey with VST. IV. Surface photometry of the bright ETGs insidee the virial radius*
- **Spavone M.** et al., **2018**, ApJ, accepted: *VEGAS: A VST Early-type GAlaxy Survey III. Mapping the galaxy structure, interactions and intragroup light in the NGC5018 group*
- **Cantiello M.** et al., **2018**, A&A, 611, 93: *VEGAS-SSS II. Comparing the globular cluster systems in NGC3115 and NGC1399 using VEGAS and FDS survey data*
- **Iodice E.** et al., **2017**, ApJ, 851, 75: *Intracluster Patches of Baryons in the Core of the Fornax Cluster*
- **Venhola A.** et al., **2017**, A&A, 608,142: *The Fornax Deep Survey with VST. III. Low Surface Brightness (LSB) dwarfs and Ultra Diffuse Galaxies (UDGs) in the centre of the Fornax cluster*
- **Iodice E.** et al., **2017**, ApJ, 839, 21: *The Fornax Deep Survey with VST. II. FornaxA: A Two-phase Assembly Caught in Act*
- **Spavone M.** et al., **2017**, A&A, 603, 38: *VEGAS: A VST Early-type GAlaxy Survey II. Photometric study of giant ellipticals and their stellar halos*
- **D'Abrusco R.** et al., **2016**, ApJL, 819, 31: *The Extended Spatial Distribution of Globular Clusters in the Core of the Fornax Cluster*
- **Iodice E.** et al., **2016**, ApJ, 820, 42: *The Fornax Deep Survey with VST. I. The Extended and Diffuse Stellar Halo of NGC 1399 out to 192 kpc*
- **Cantiello M.** et al., **2015**, A&A, 576, 14: *VEGAS-SSS. A VST early-type galaxy survey: analysis of small stellar systems. Testing the methodology on the globular cluster system in NGC 3115*
- **Capaccioli M.** et al. **2015**, A&A, 581, 10: *VEGAS: A VST Early-type GAlaxy Survey. I. Presentation and test case on the field of NGC 4472*
- **Iodice E.** et al. **2015**, A&A, 574, 111: *A forming wide polar-ring galaxy at z ~ 0.05 in the VST Deep Field of the Fornax cluster*

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- **Spavone M.** et al., **2018**, Ap *and intragroup light in the NGC501*
- **Cantiello M.** et al., **2018**, A&A *and FDS survey data*
- **Iodice E.** et al., **2017**, ApJ, 851
- **Venhola A.** et al., **2017**, A&A, *xies (UDGs) in the centre of the Forn*
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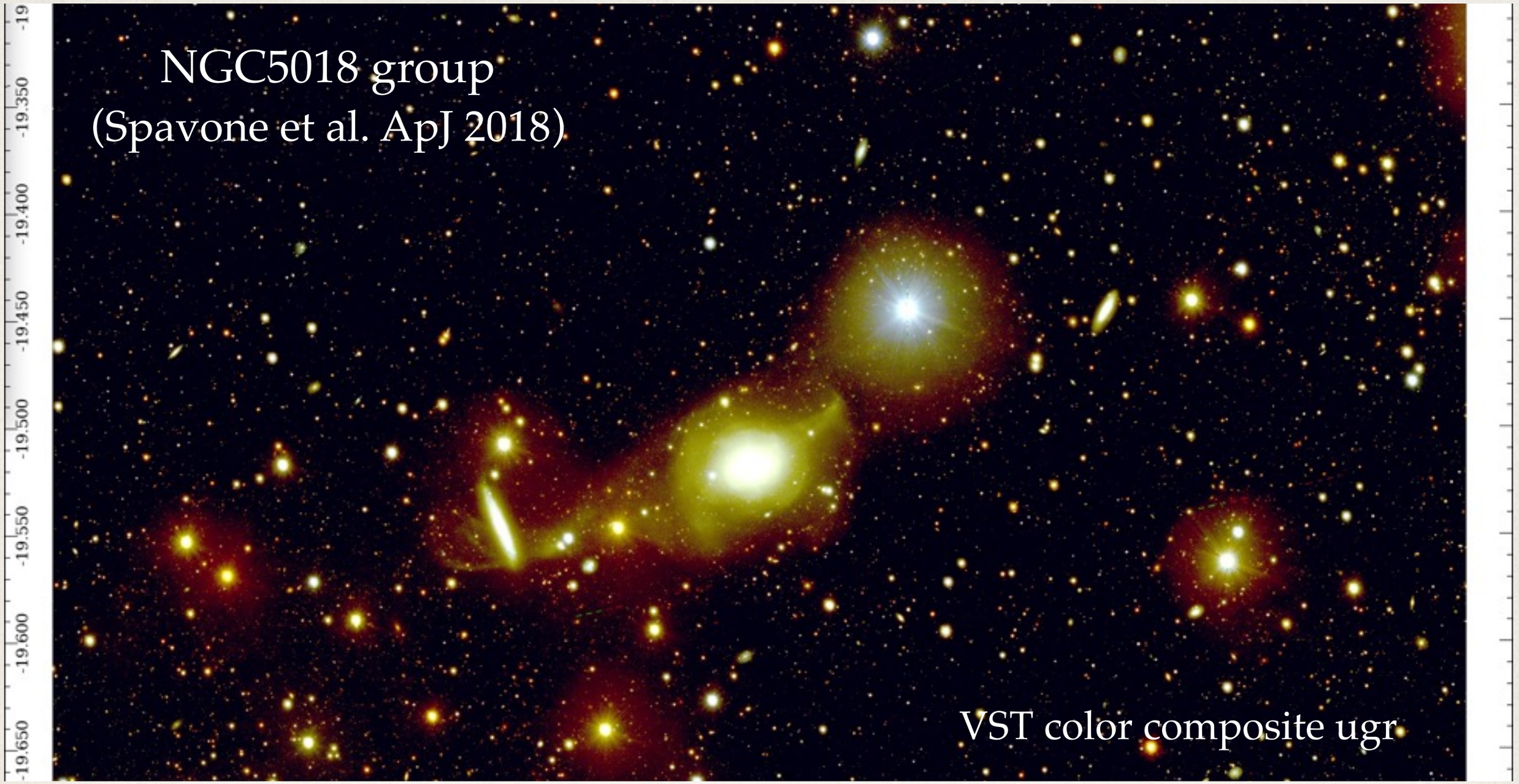
this talk

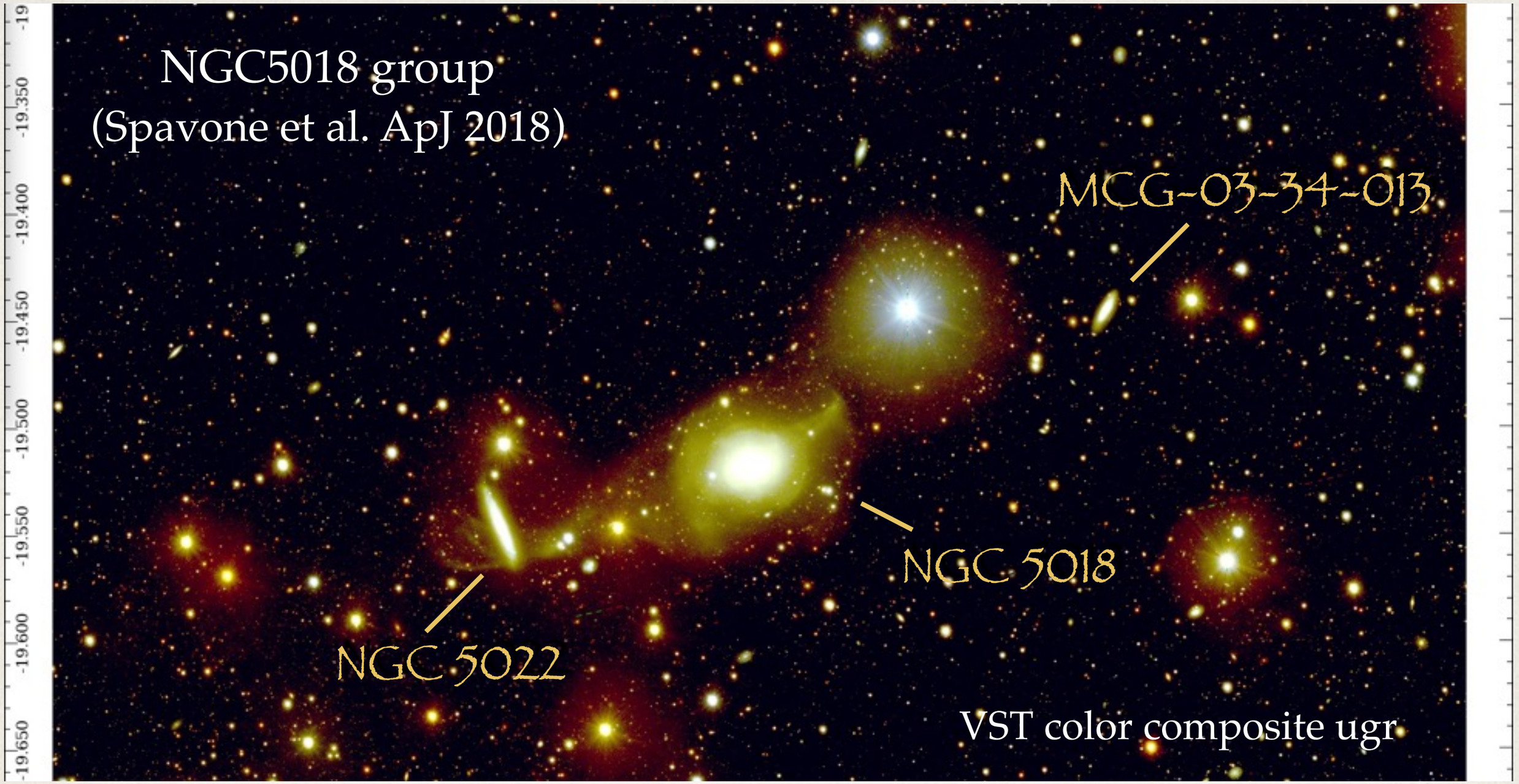
- images from VEGAS
- results on stellar halos & LSB
- observations vs theoretical predictions



VEGAS ongoing projects:

Mapping the galaxy structure, interactions and intra-group light in the NGC5018 group

Spavone et al. 2018, ApJ, accepted



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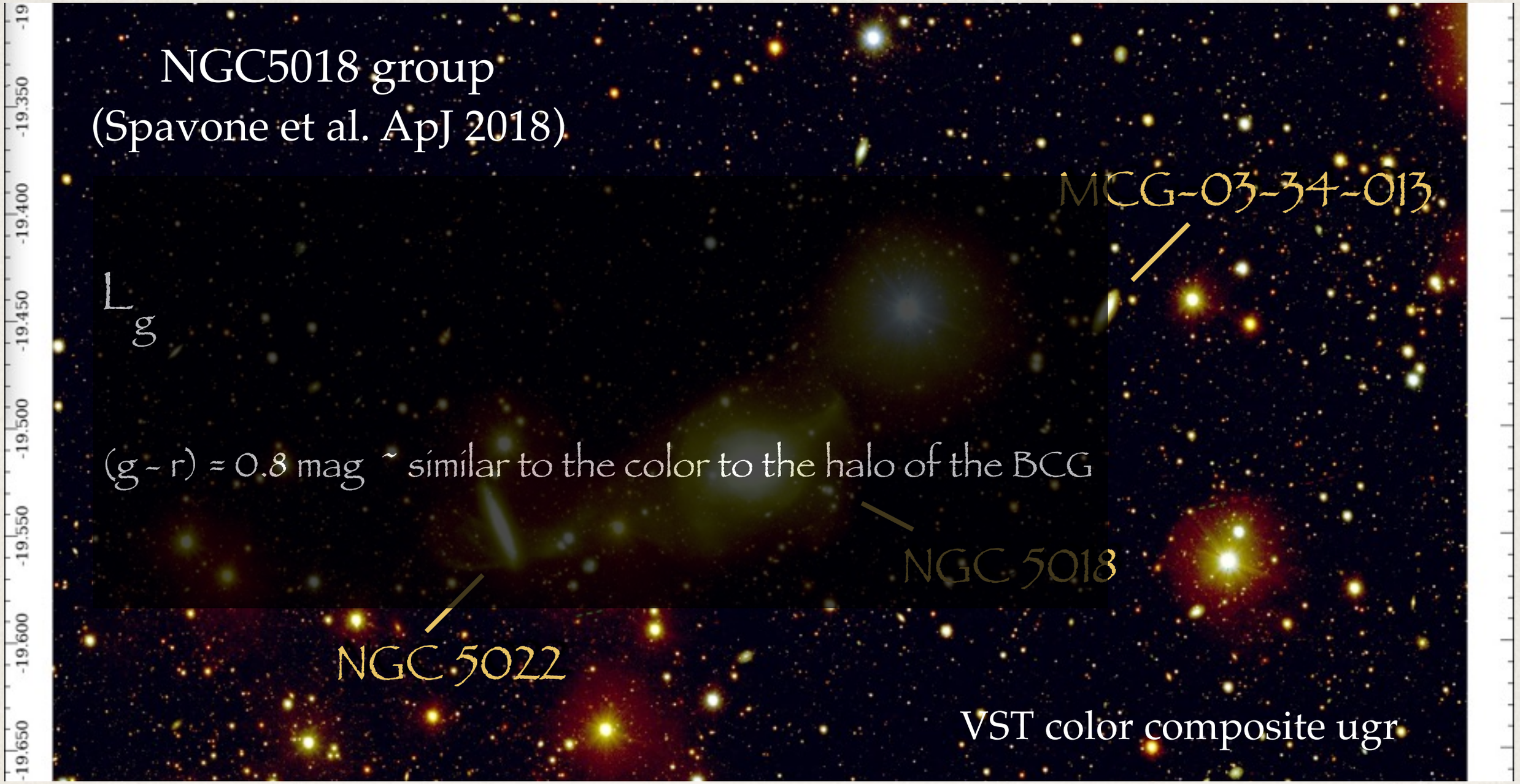

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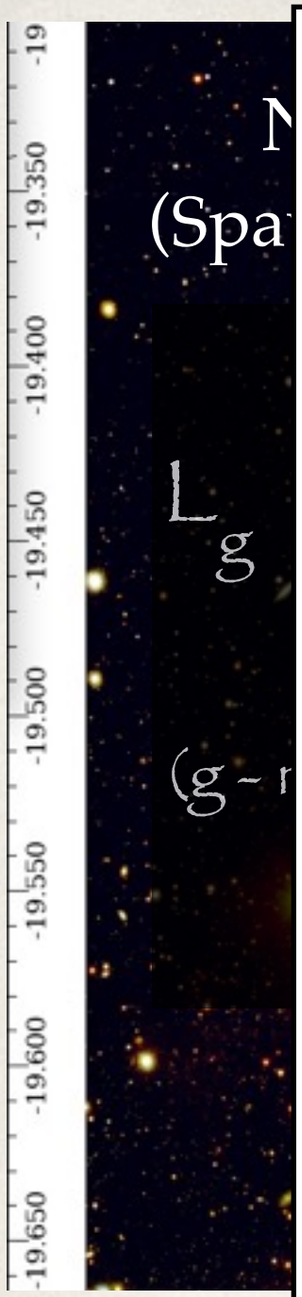

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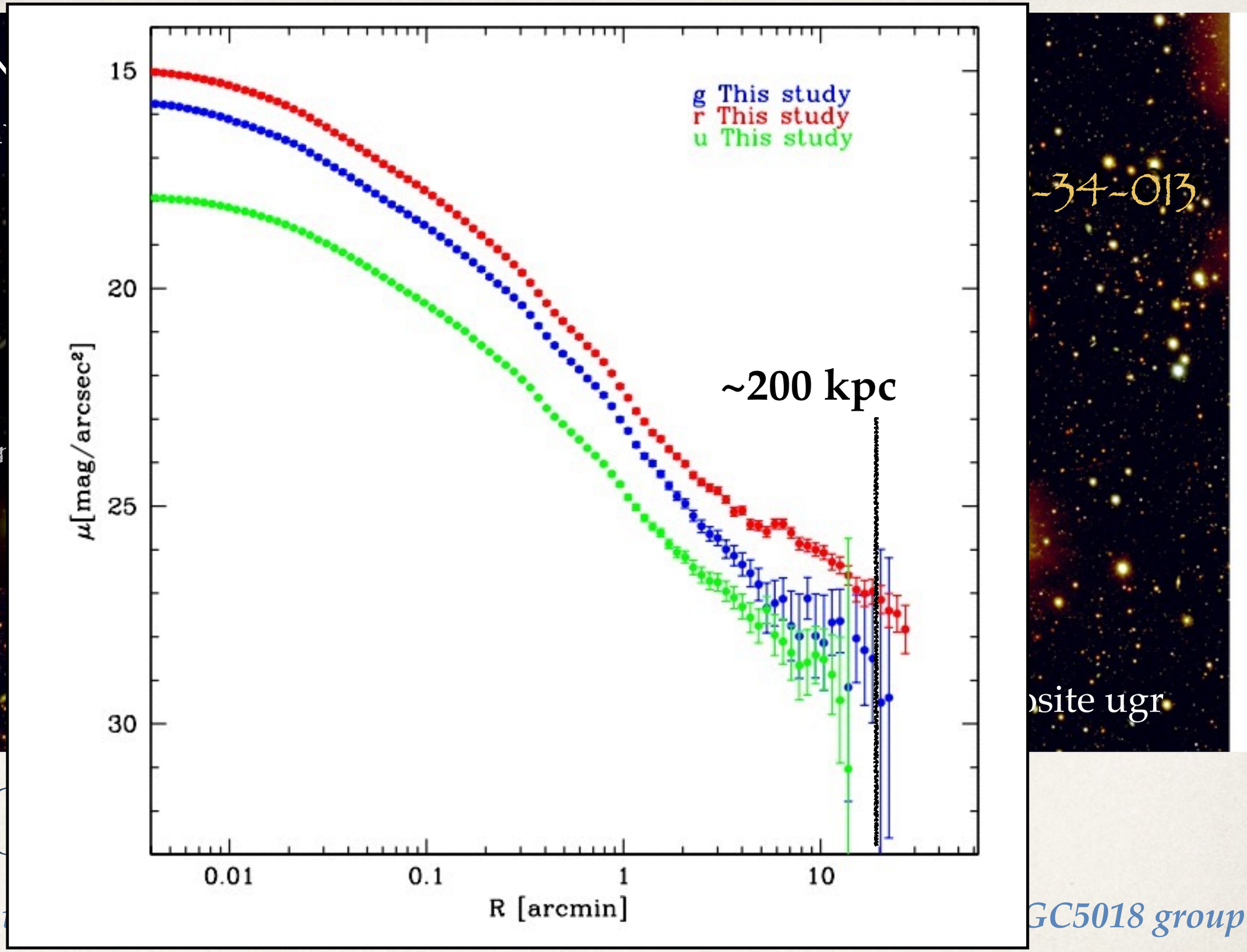

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Mapping *GC5018 group*

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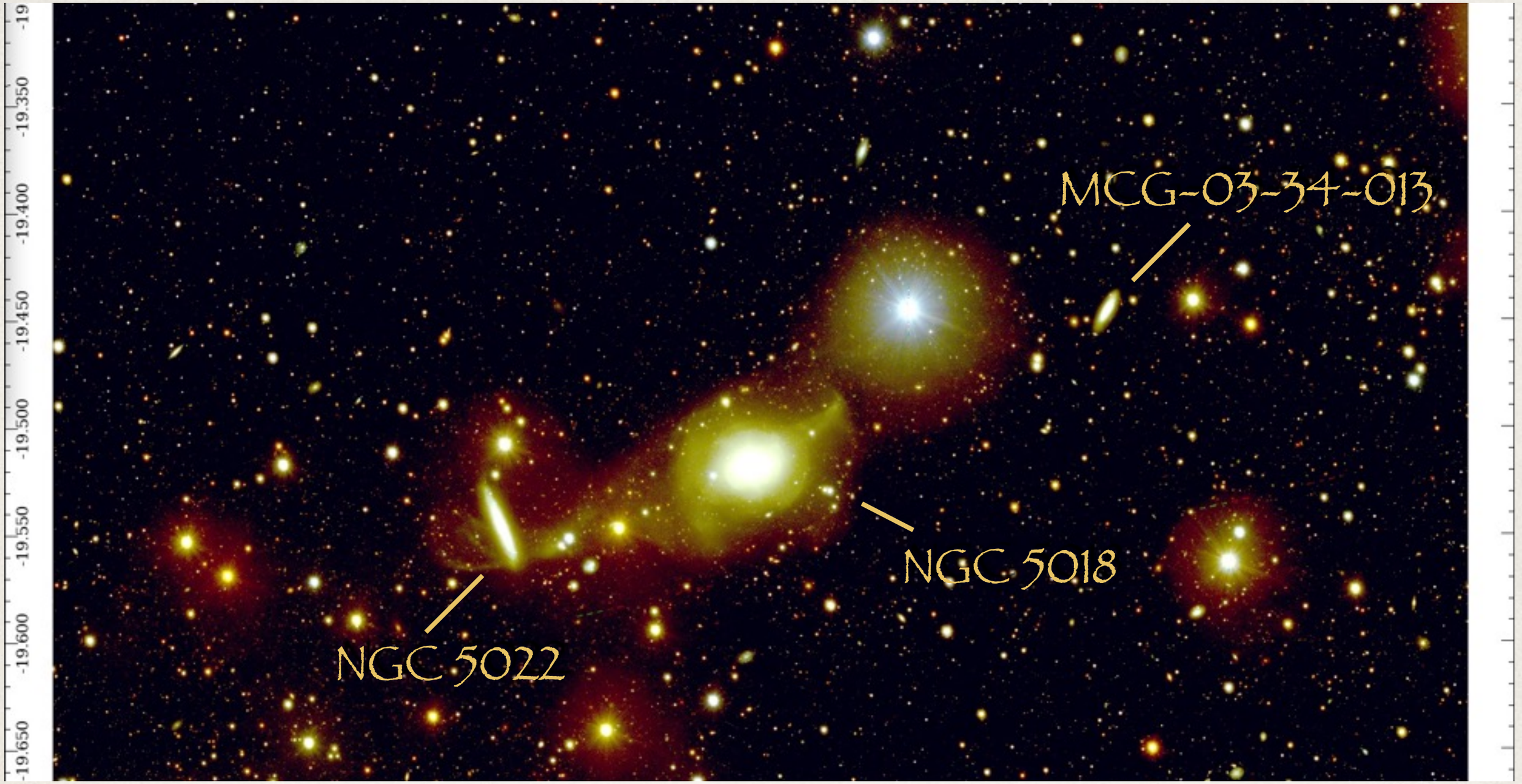

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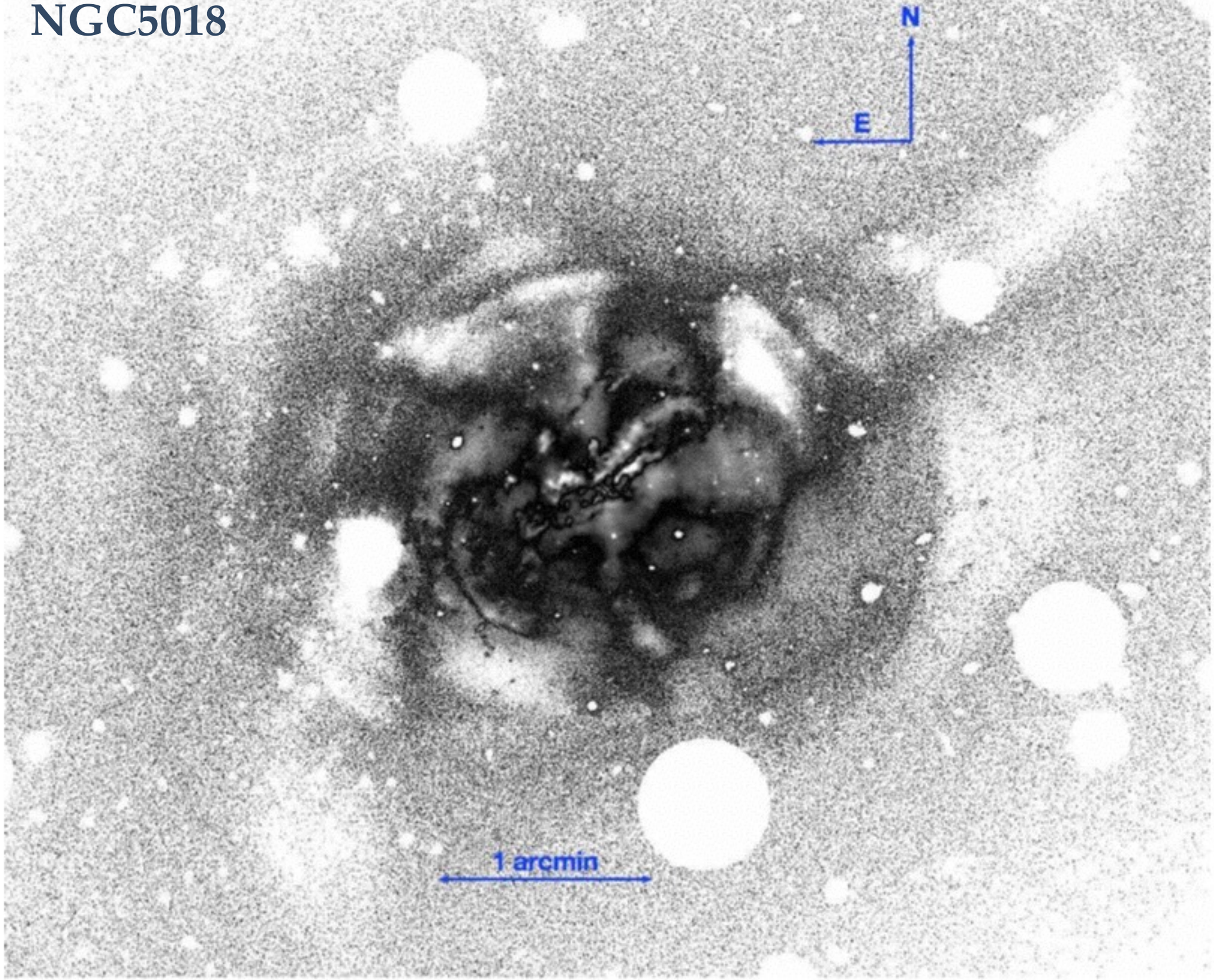
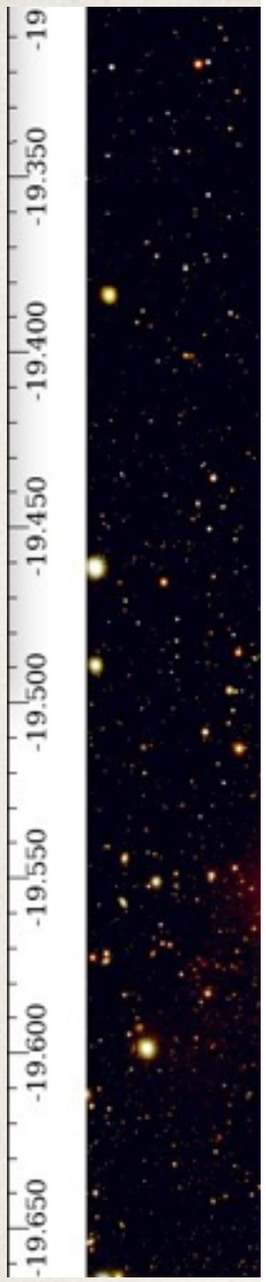
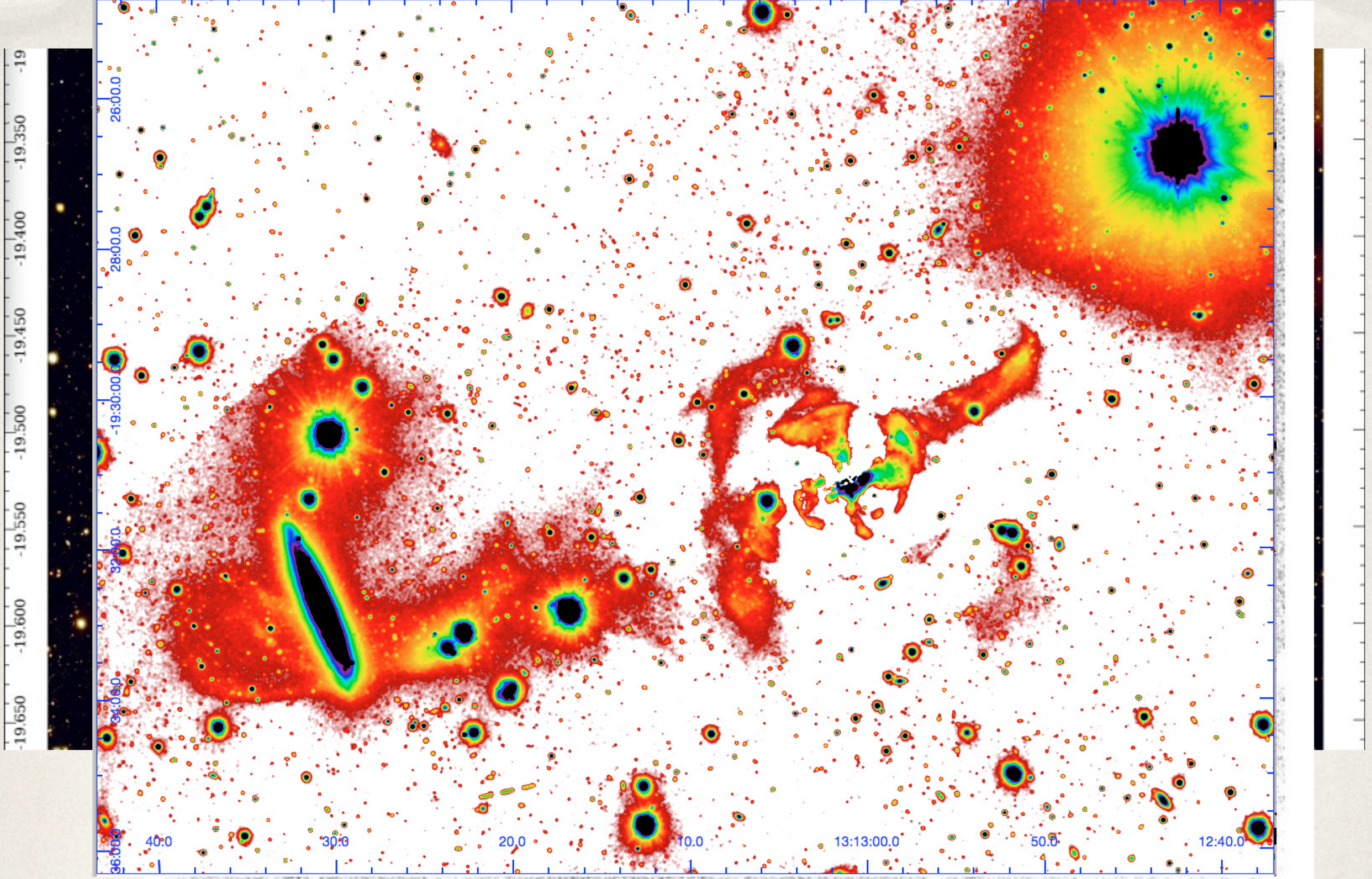
NGC5018





Mapping *p*

Spavone et al. 2018, ApJ, accepted



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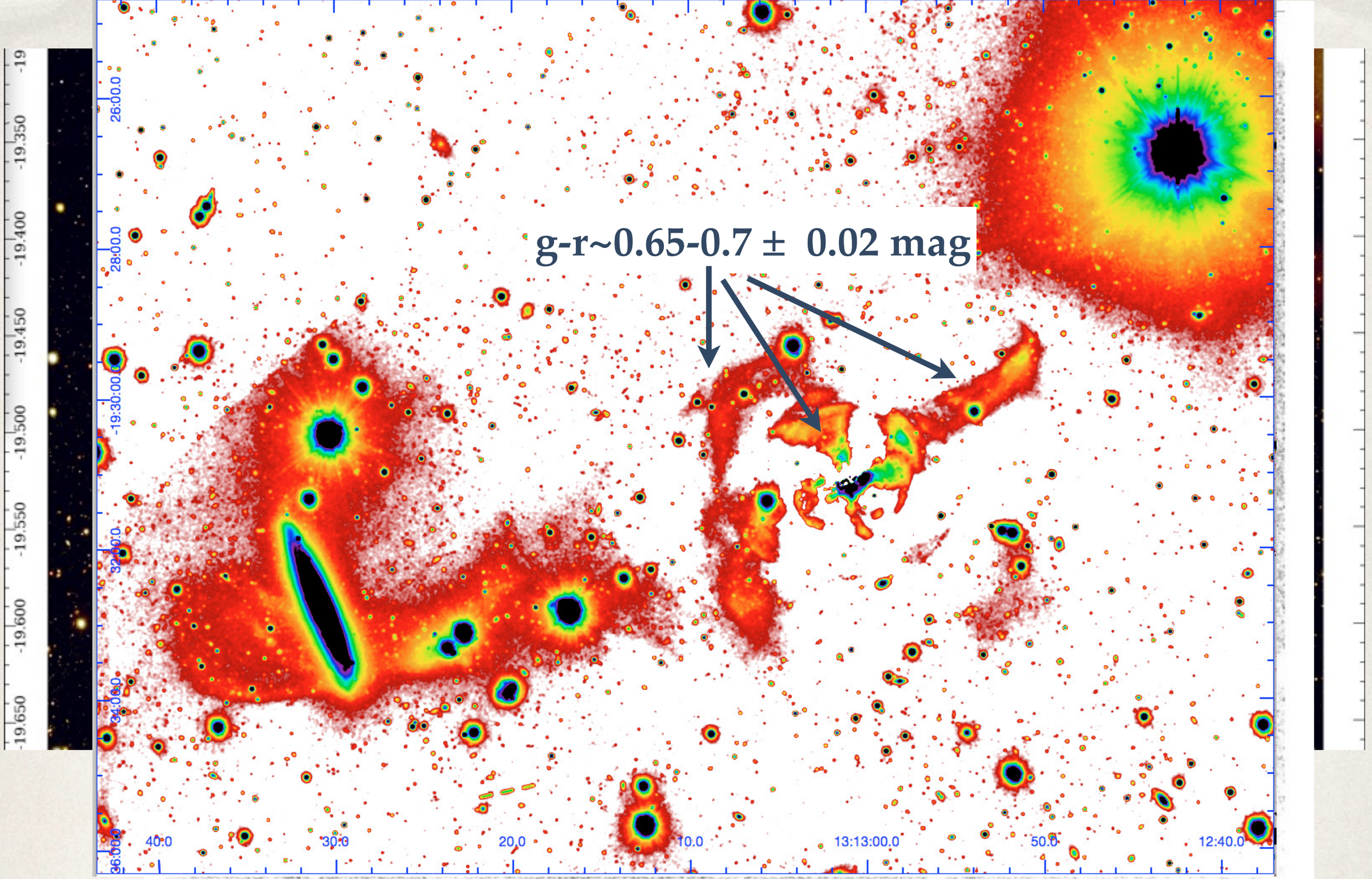

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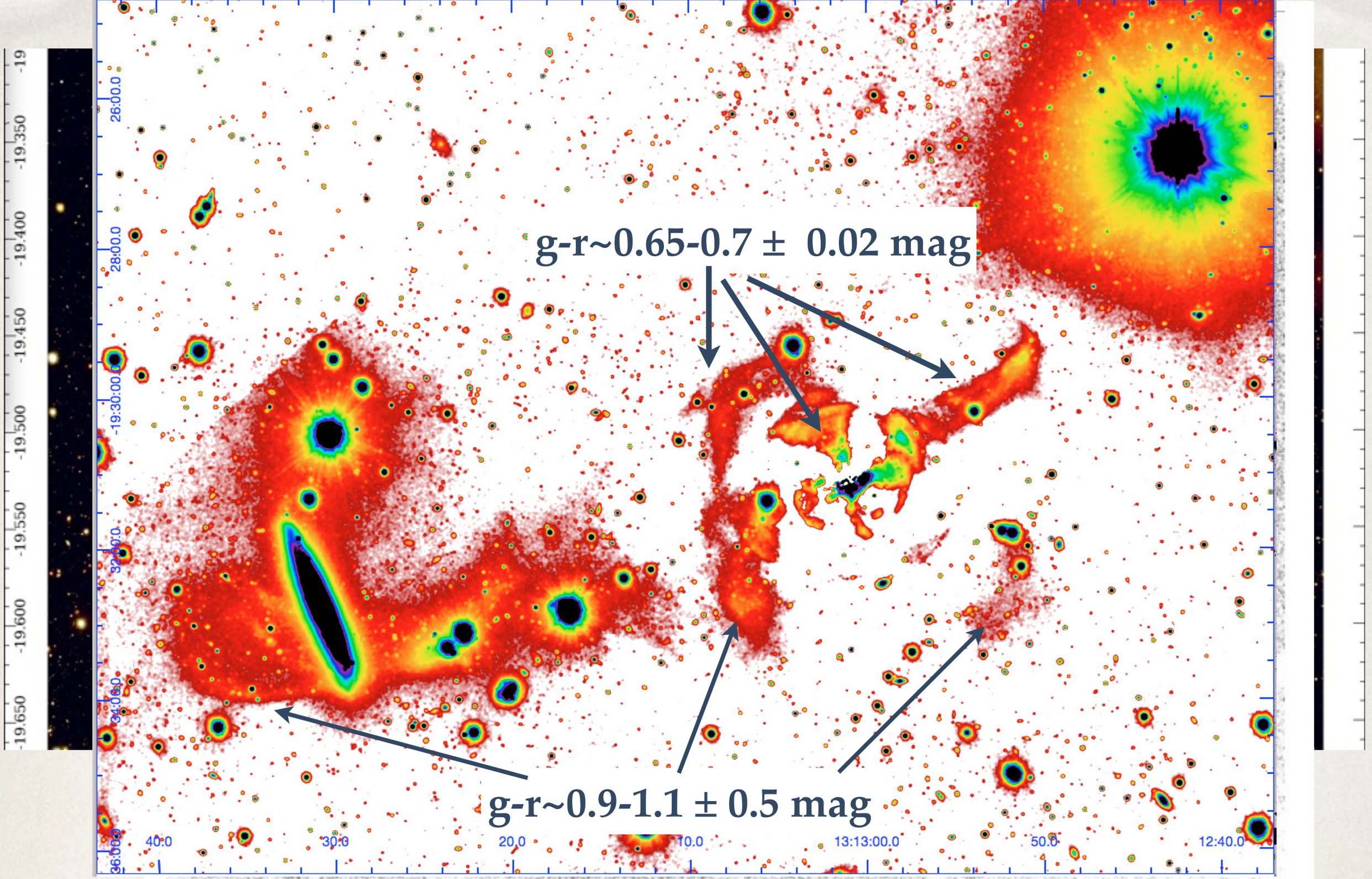

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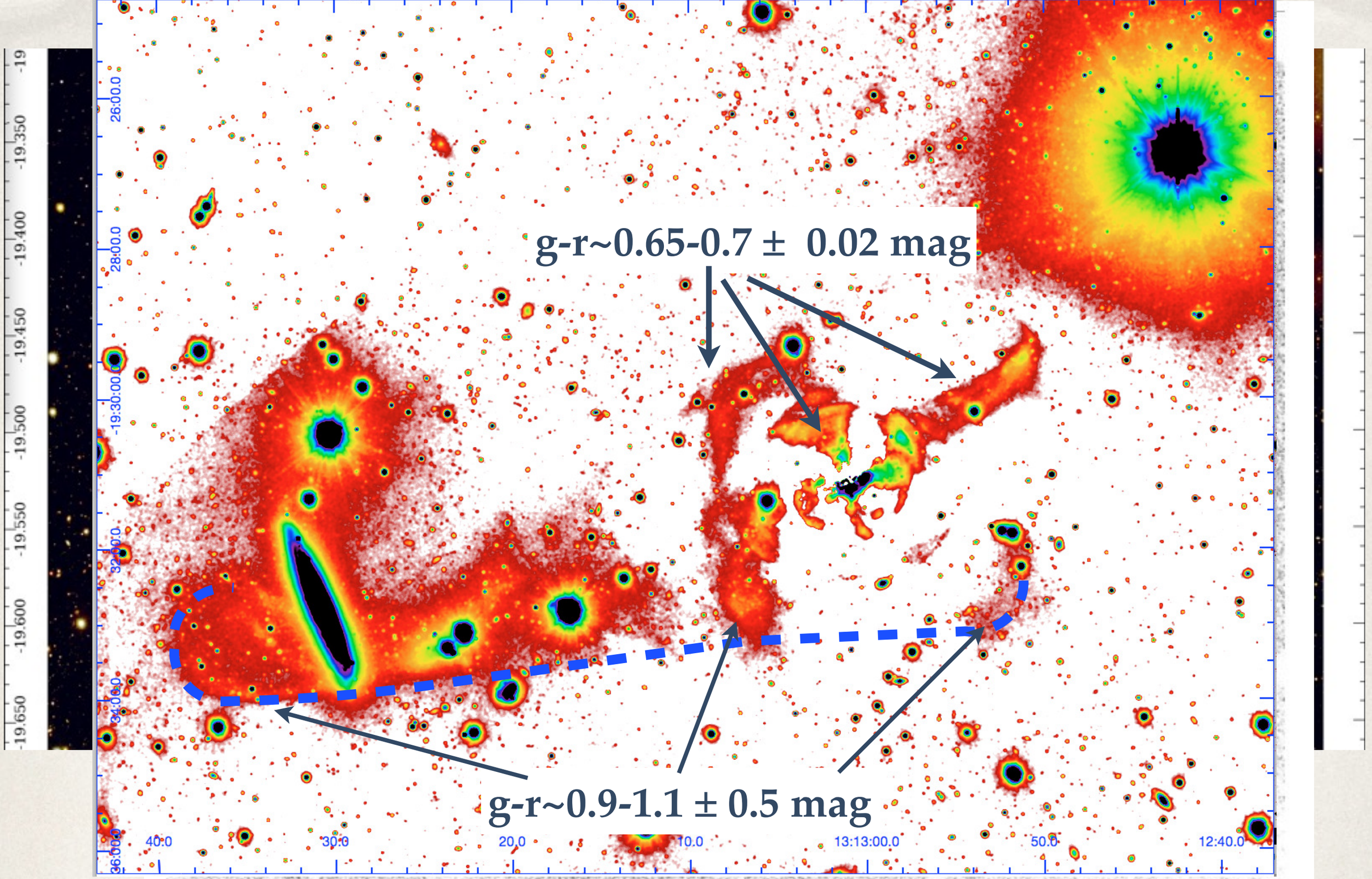

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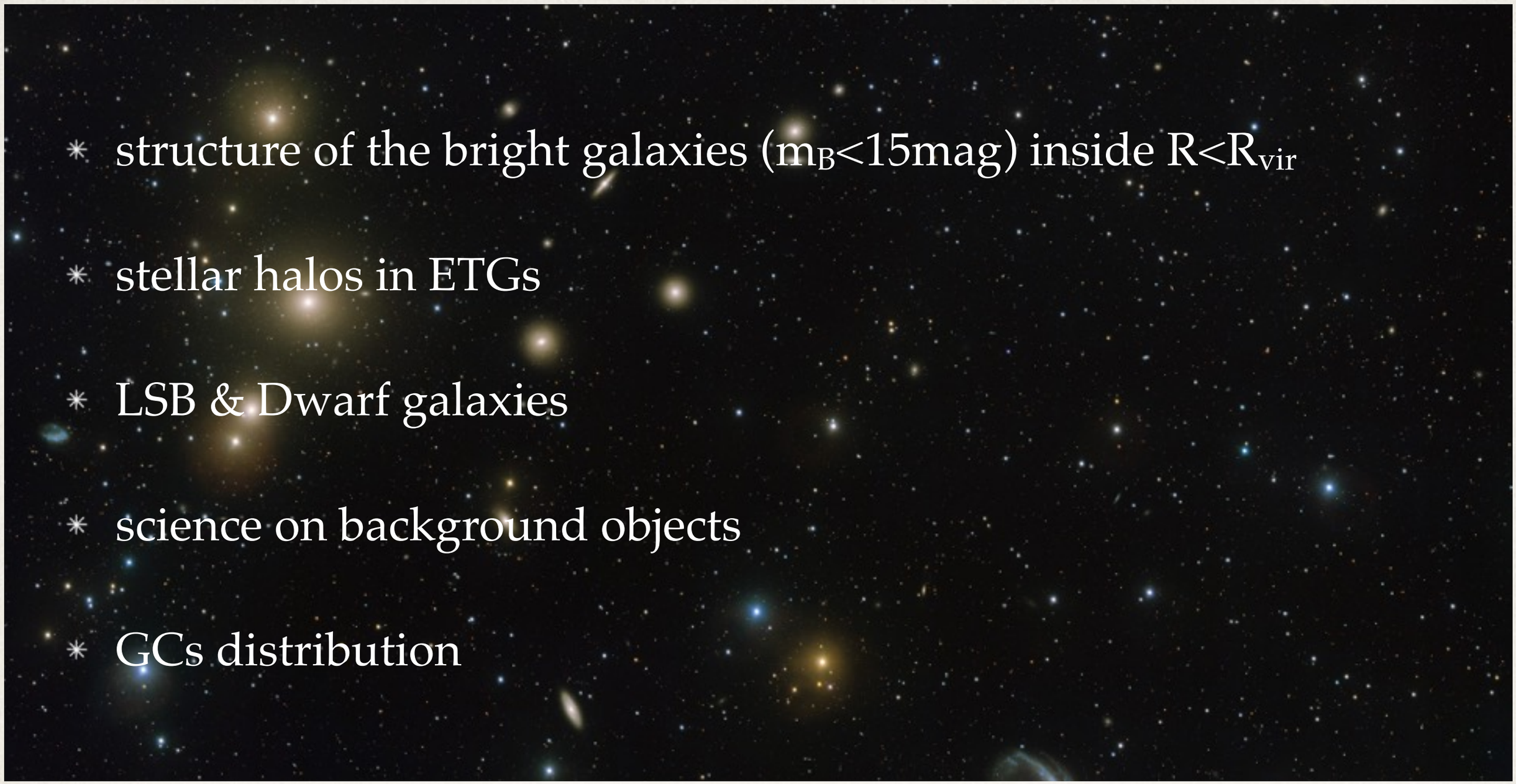
Fornax Deep Survey with VST

Results & ongoing works

P.I.: R. Peletier & E. Iodice



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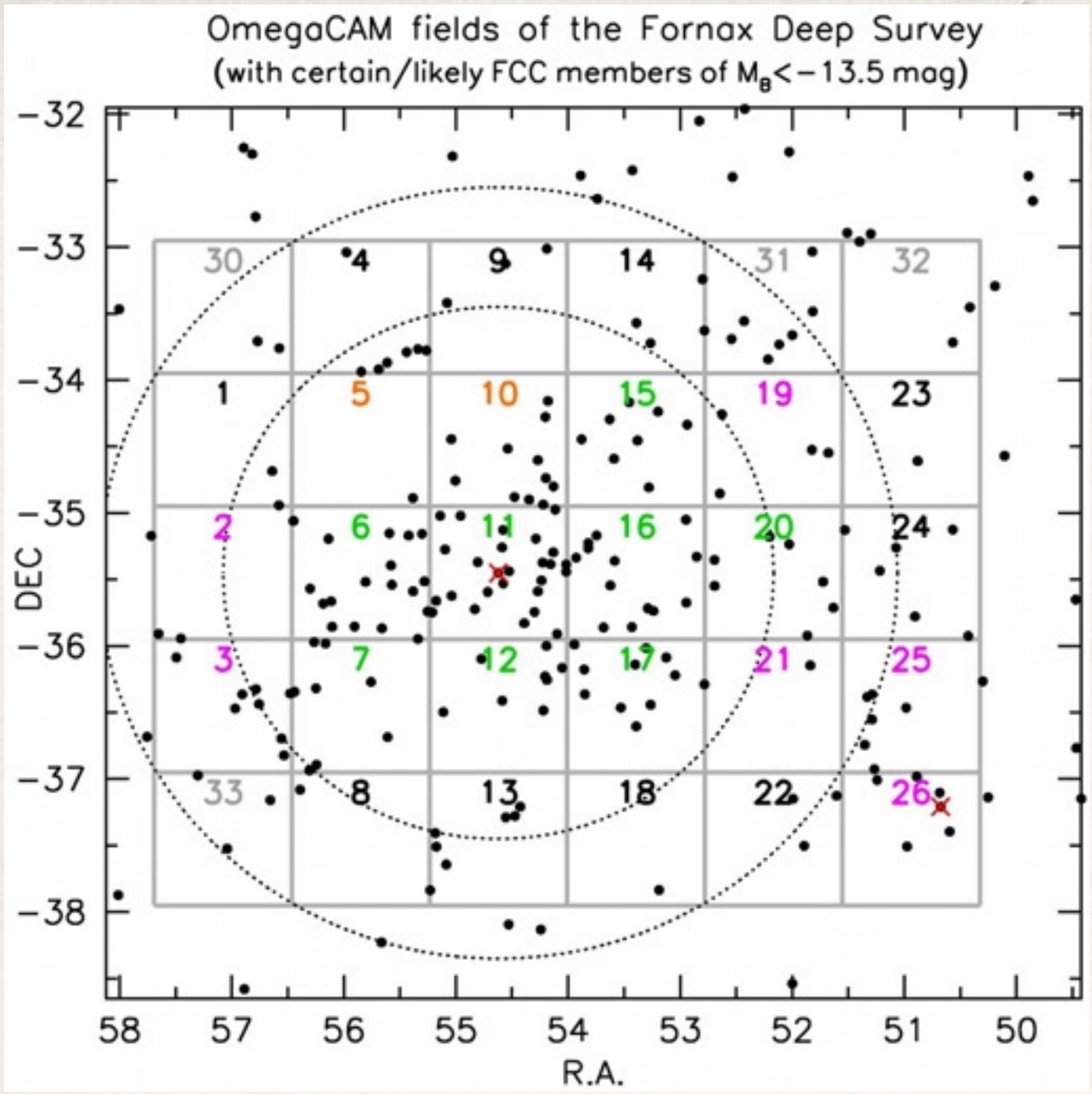


Tot int. time/field:

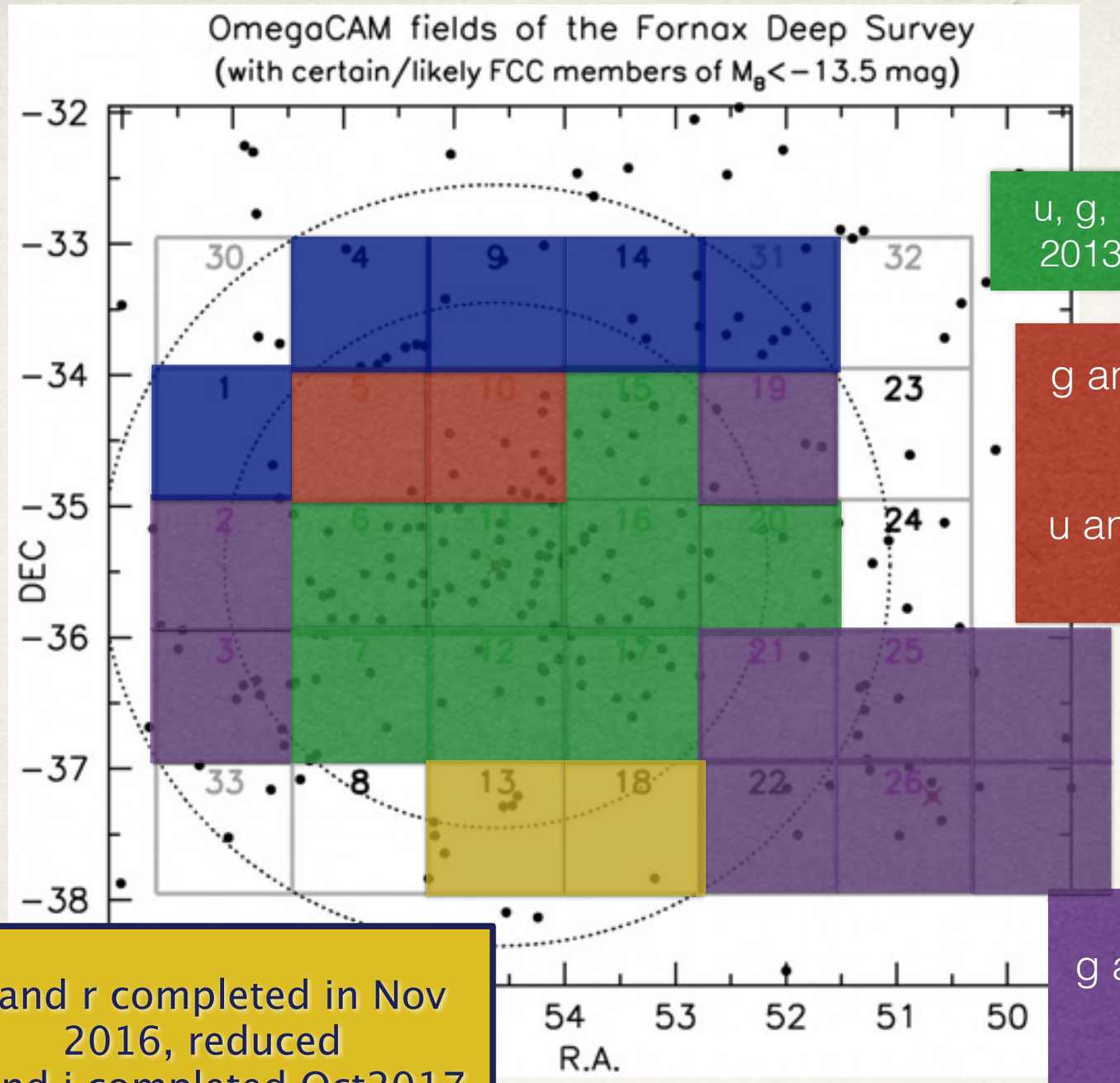
u: 3 hrs

g & *r*: 2.3 hrs

i: 1.8 hrs

Fornax Deep Survey with VST

observation were completed in Nov 2017 - reduced data will be released on April 2019



u, g, r and i: completed in 2013+2014 and reduced

g and i completed in 2014 and reduced

u and r completed in 2015 and reduced

g, r and i completed in Nov 2016, to be reduced

u completed in 2017

g and r completed in Nov 2016, reduced
u and i completed Oct2017

g and r completed in Nov 2015 and reduced

i completed in Nov2017

Tot int. time/field:

u: 3 hrs

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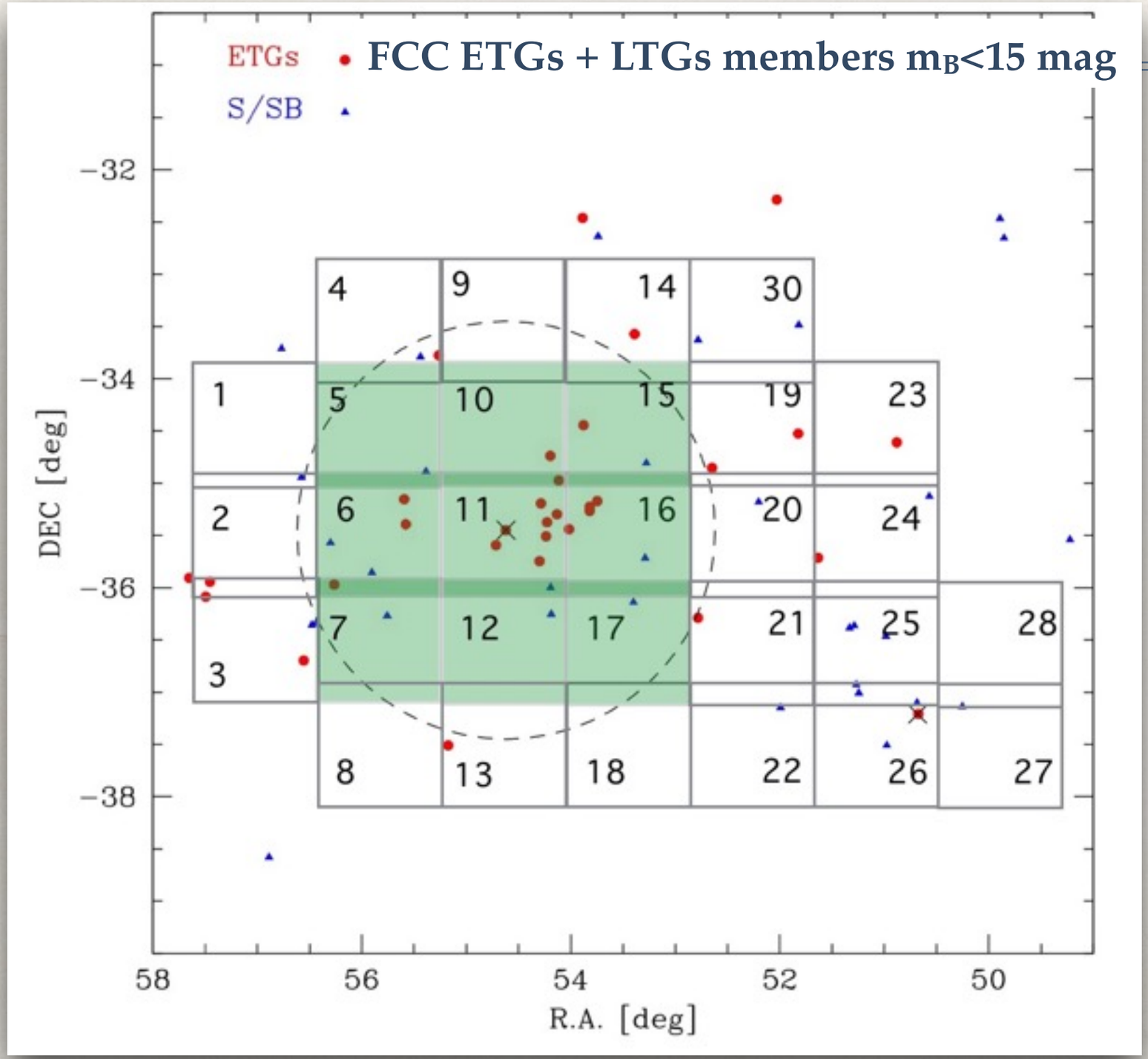
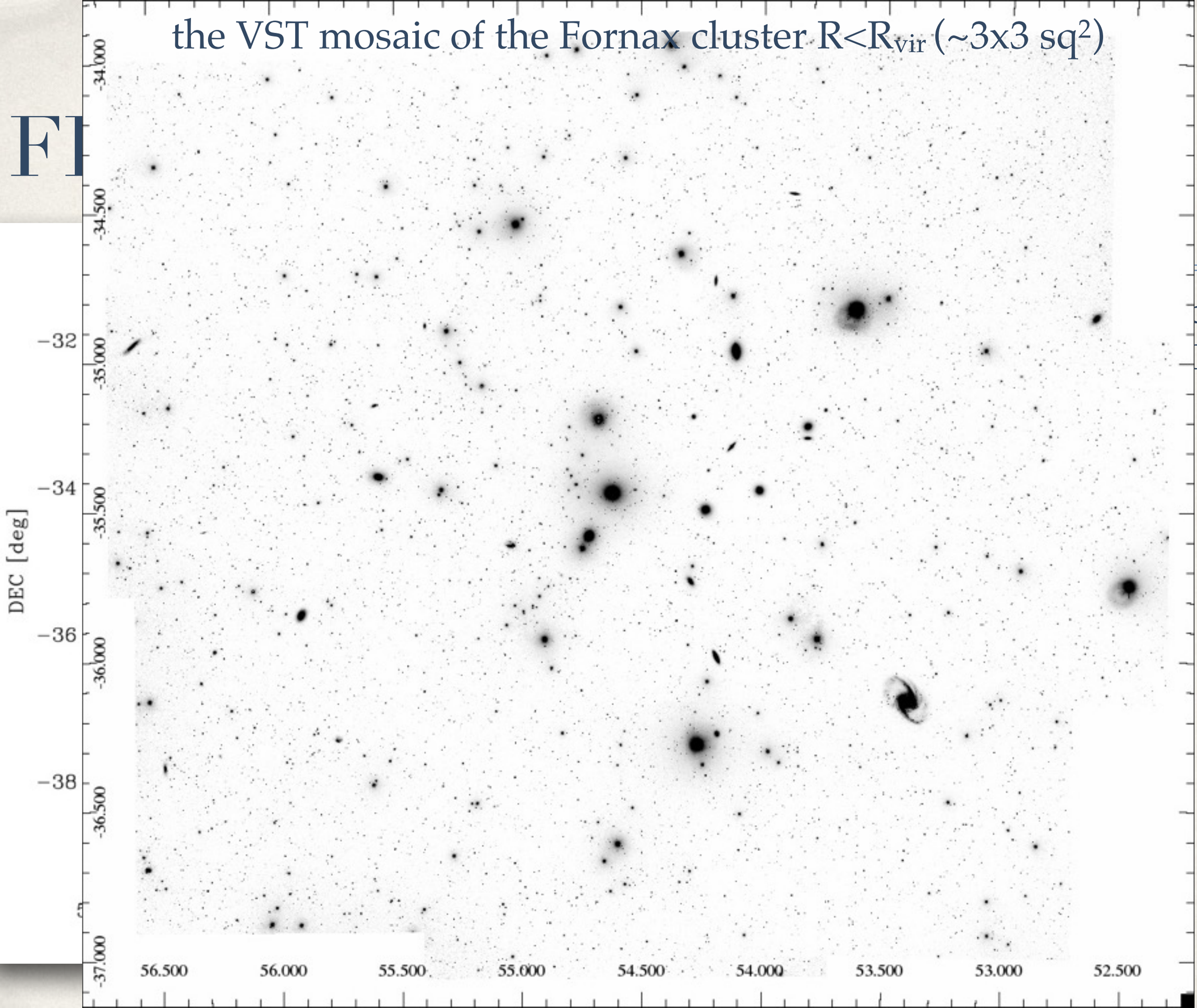
FDS: the ETGs inside R_{vir}



for $R<R_{vir}$ (~0.7 Mpc)
there are ~20 ETGs & ~10 LTGs

Fl

the VST mosaic of the Fornax cluster $R<R_{vir}$ (~3x3 sq^2)

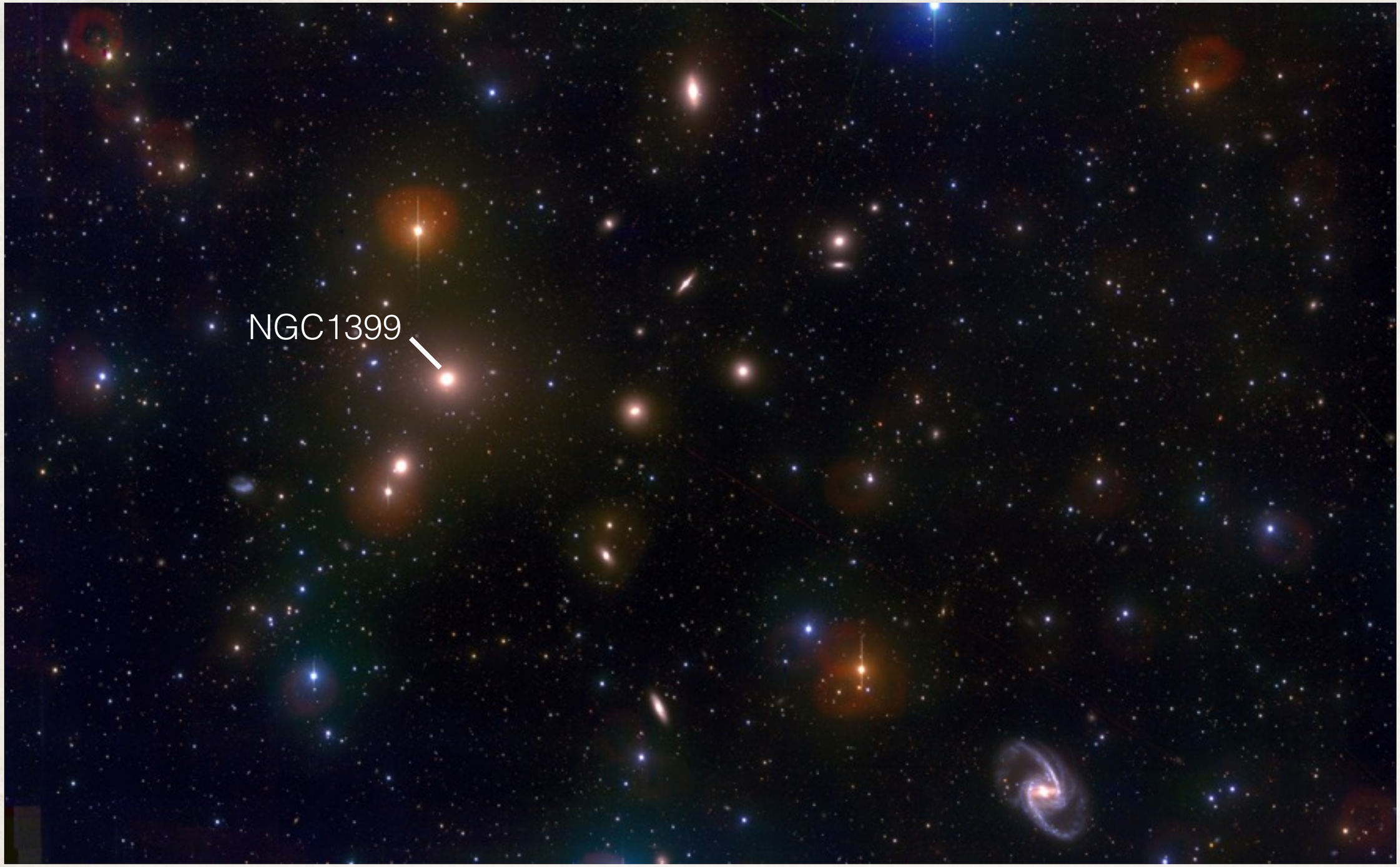


c)

) LTGs

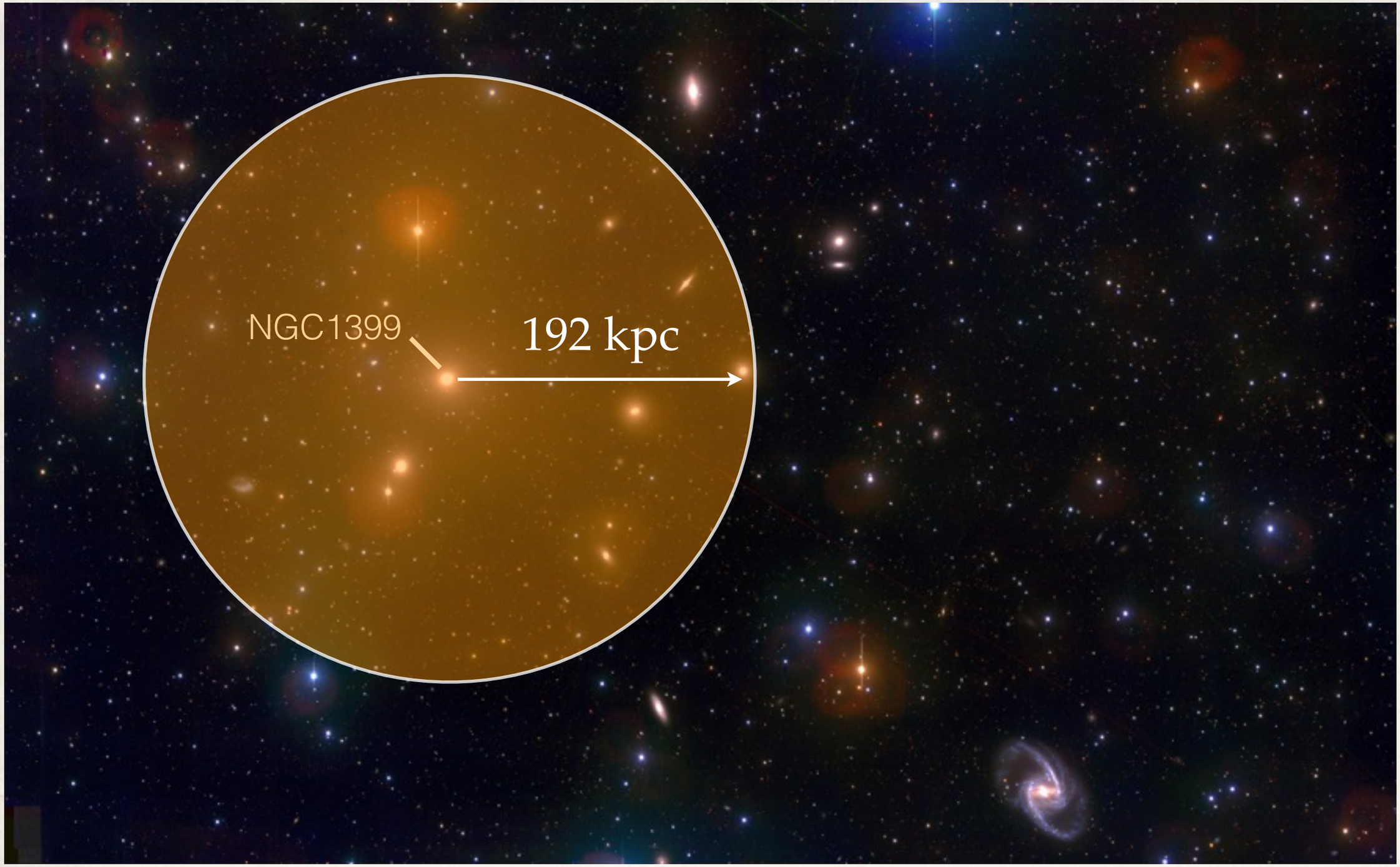
VST color composite image
https://www.eso.org/public/news/eso1612/

NGC1380
FCC143
NGC1374
NGC1380B
NGC1375
NGC1381
FCC182
NGC1399
NGC1379
NGC1404
NGC1387
NGC1427A
NGC1389
NGC1386
NGC1365
N
E



The extended stellar halo of NGC1399

Iodice et al. 2016, ApJ, 820, 42



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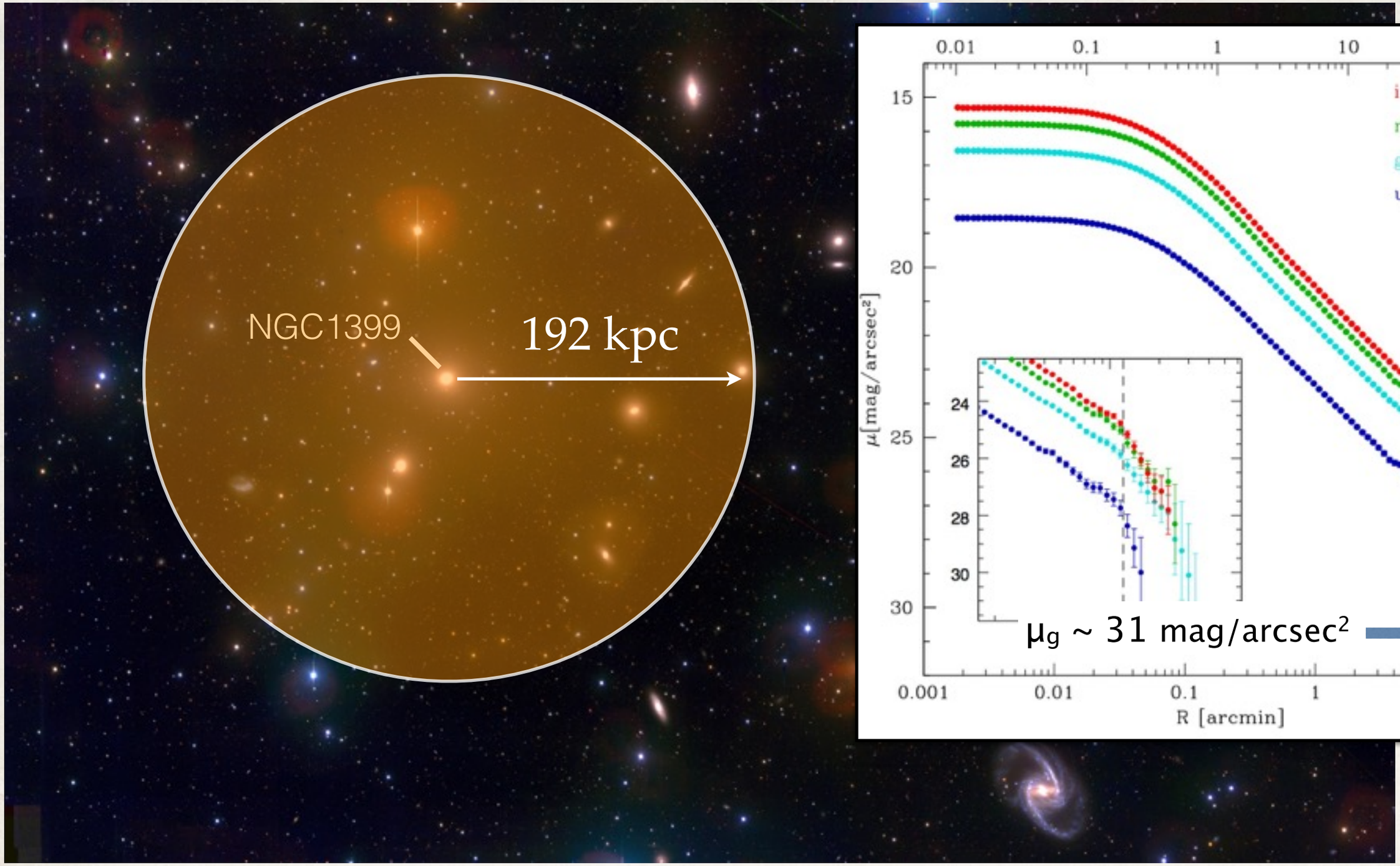

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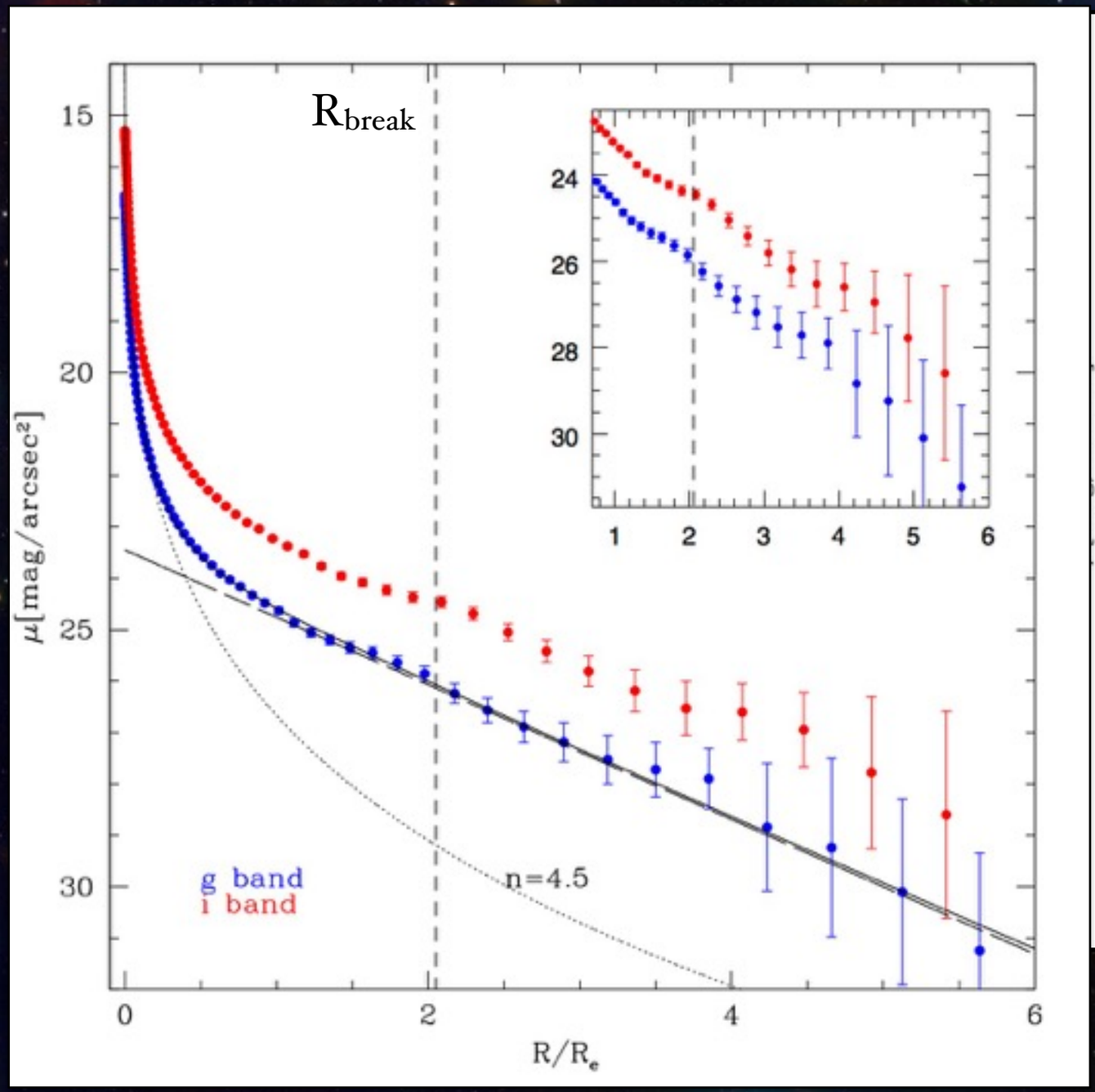

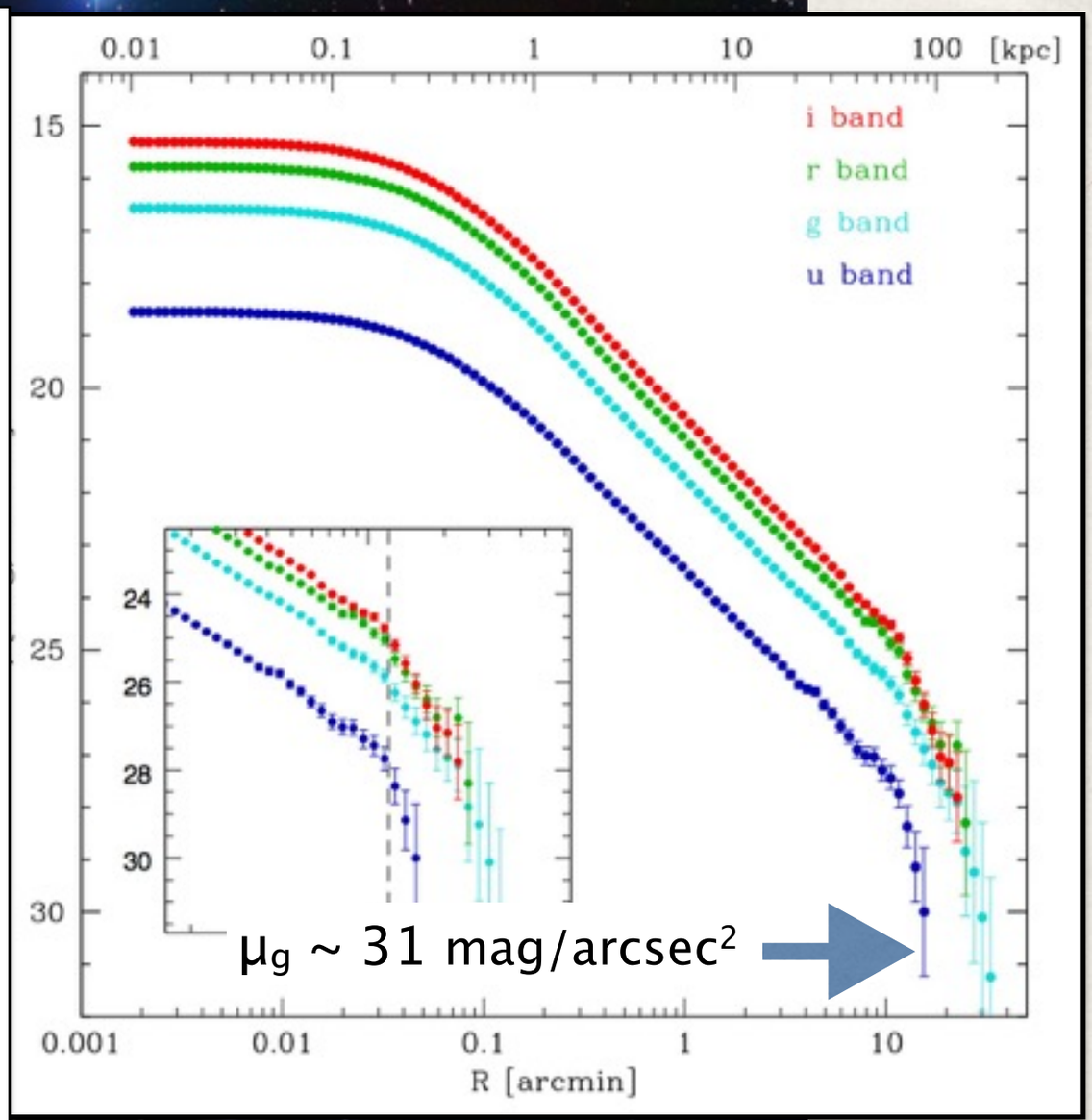

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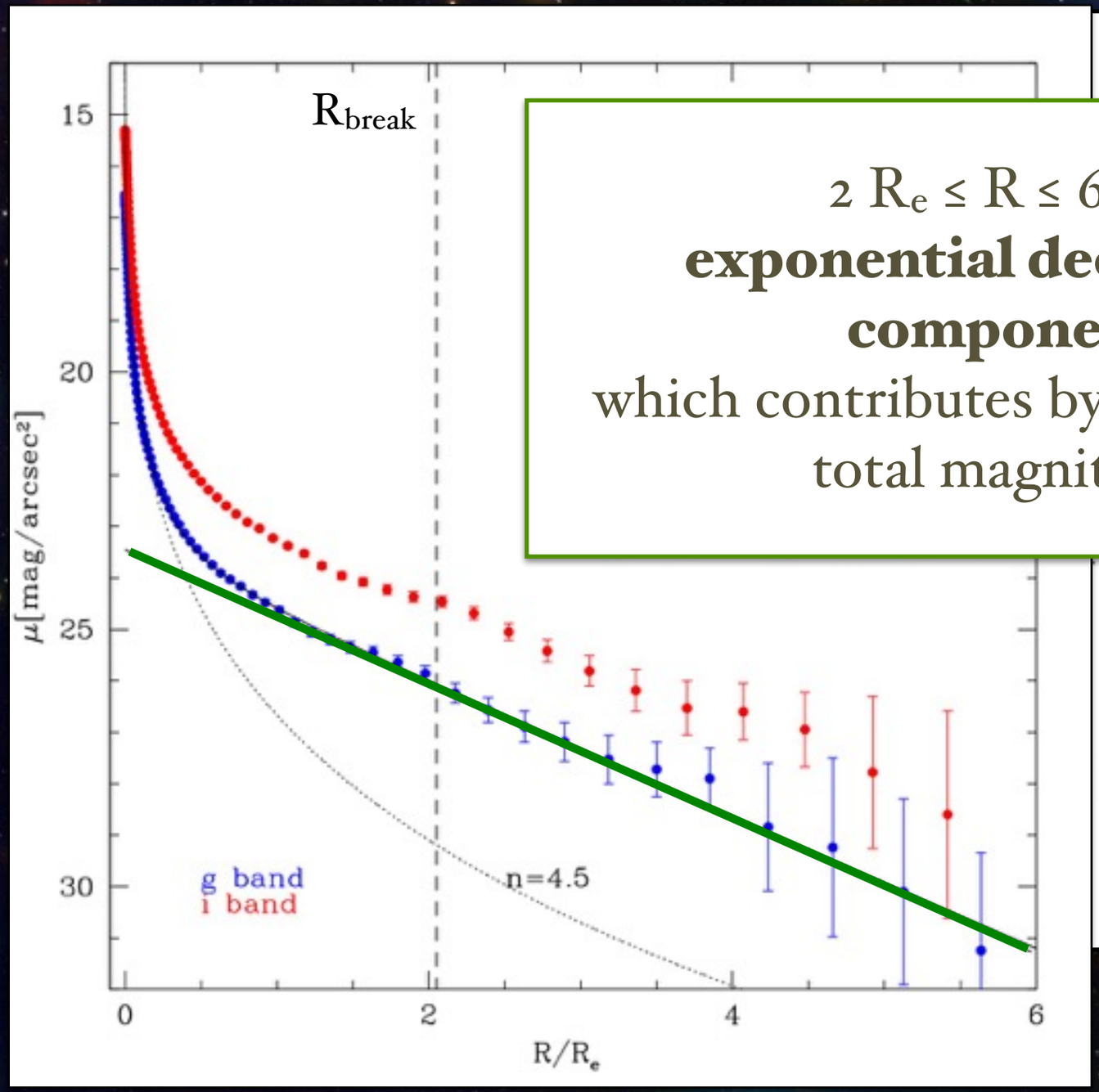
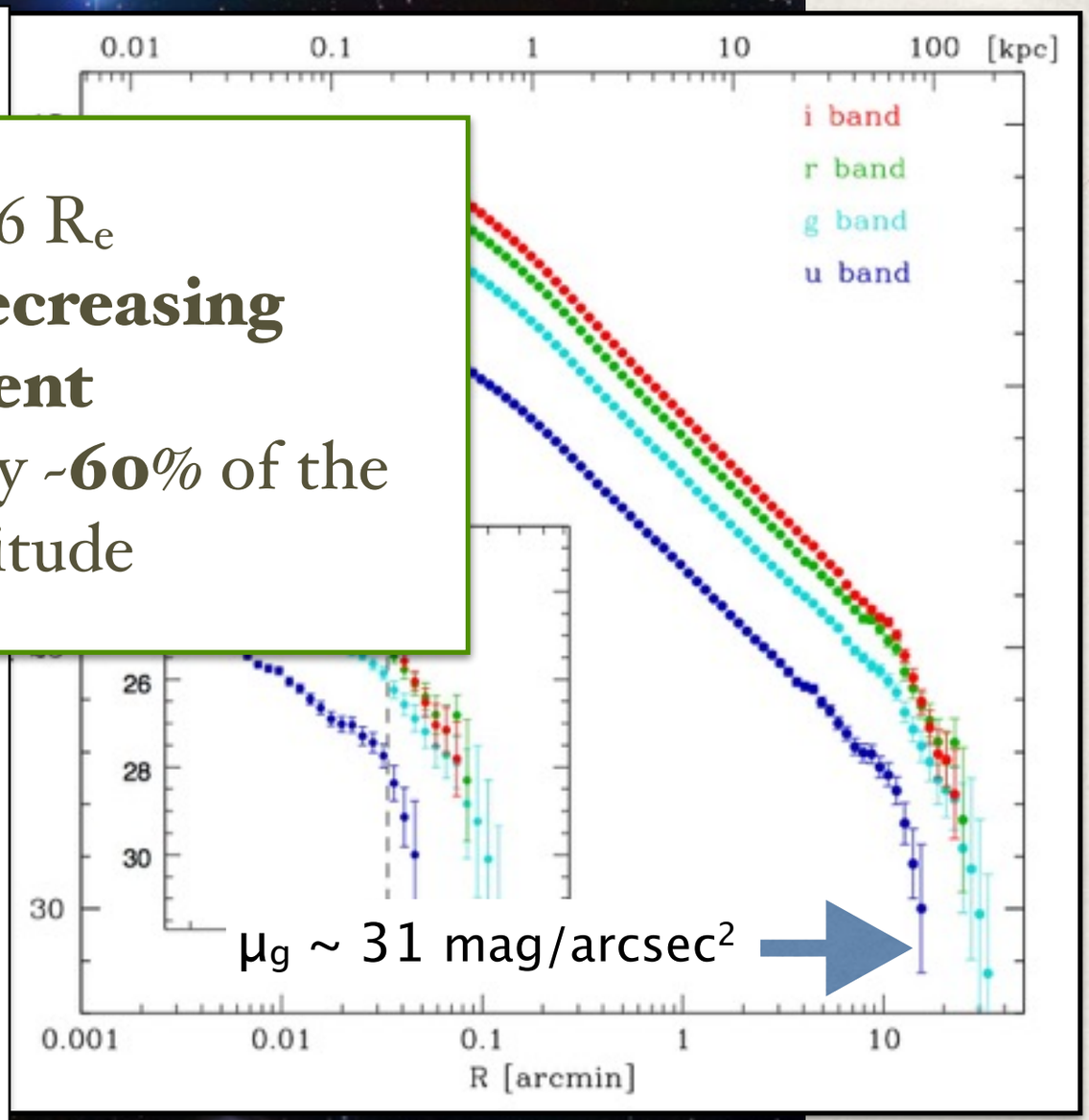


$2\ R_e \leq R \leq 6\ R_e$

exponential decreasing component

which contributes by ~**60**% of the total magnitude



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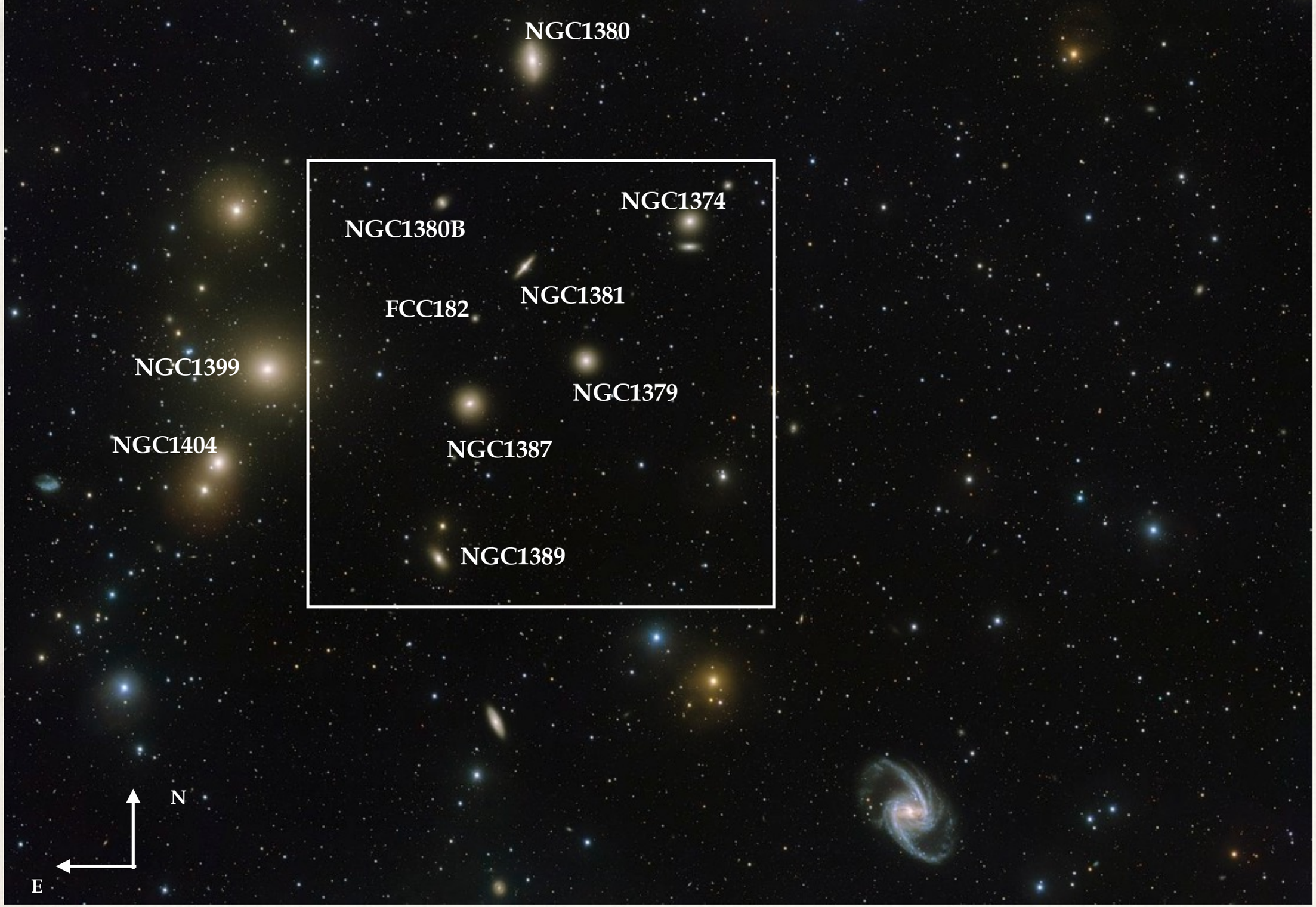
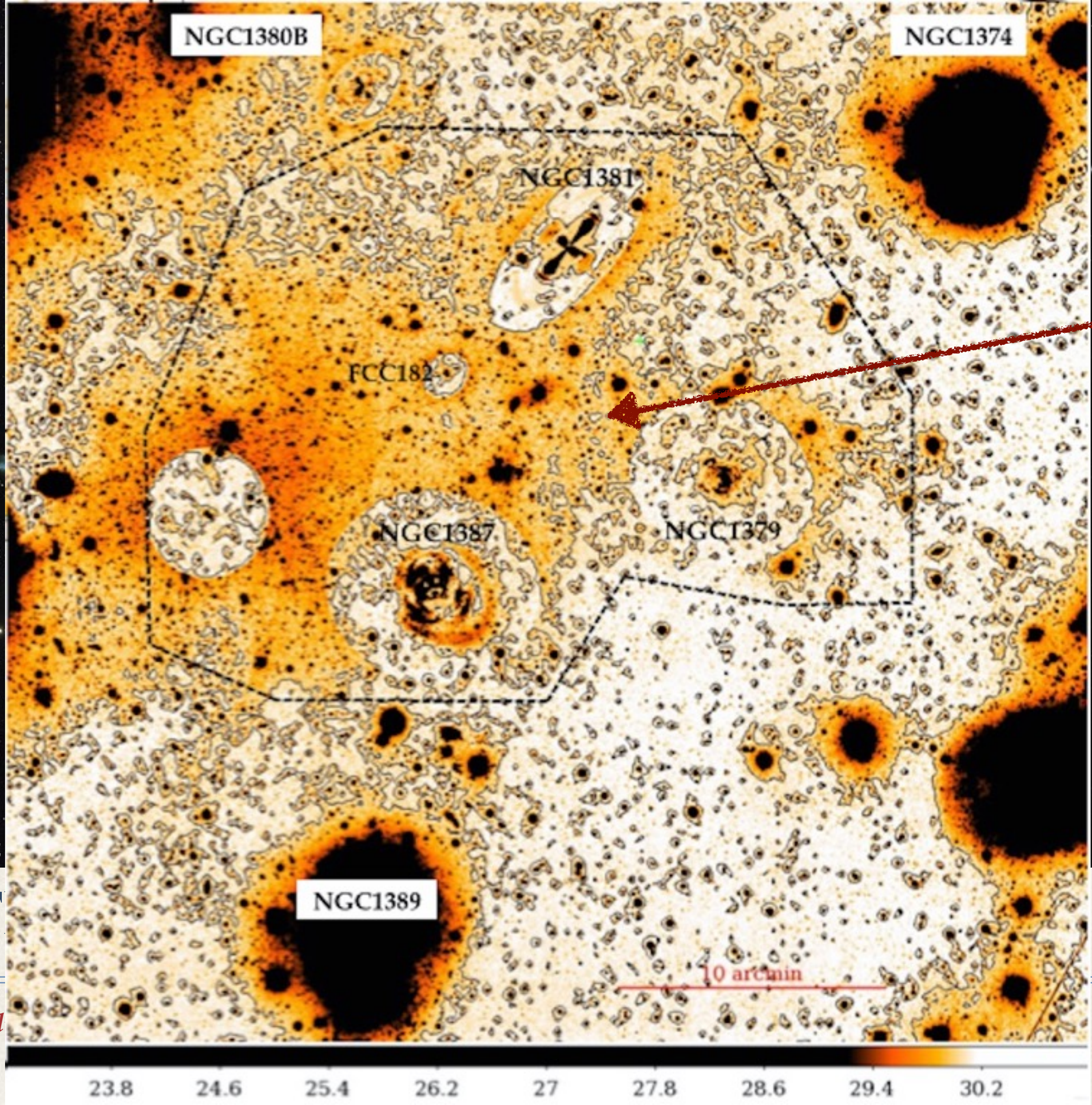


The intracluster regions: the ICL

Iodice et al. 2017, ApJ, 851, 75


NGC1380B
NGC1374
NGC1381
FCC182
NGC1387
NGC1379
NGC1389
10 arcmin
23.8
24.6
25.4
26.2
27
27.8
28.6
29.4
30.2

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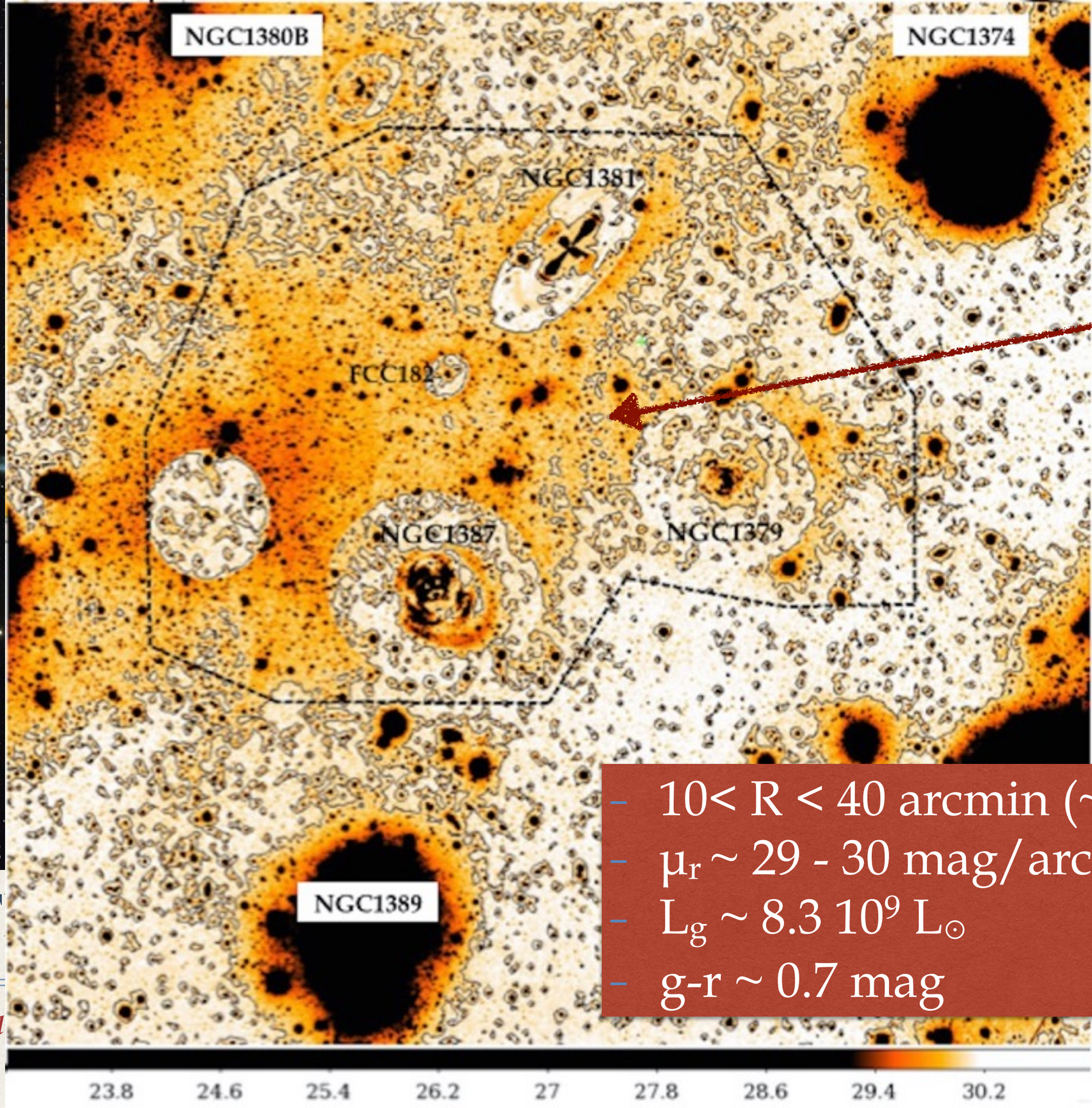

ICL

- $10 < R < 40$ arcmin (~ 58-230 kpc)
- $\mu_r \sim 29 - 30$ mag/arcsec^2
- $L_g \sim 8.3\ 10^9\ L_\odot$
- g-r ~ 0.7 mag

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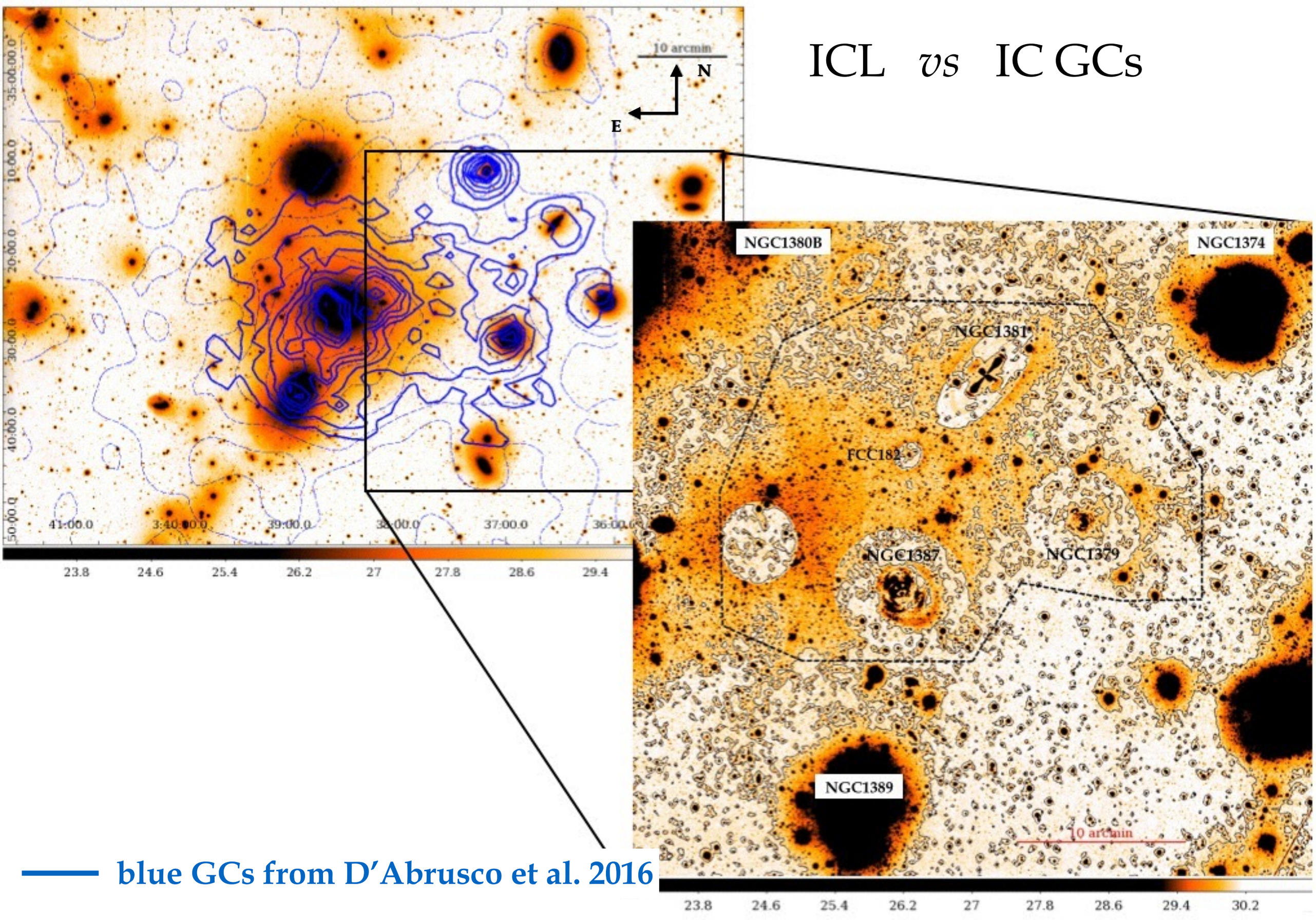
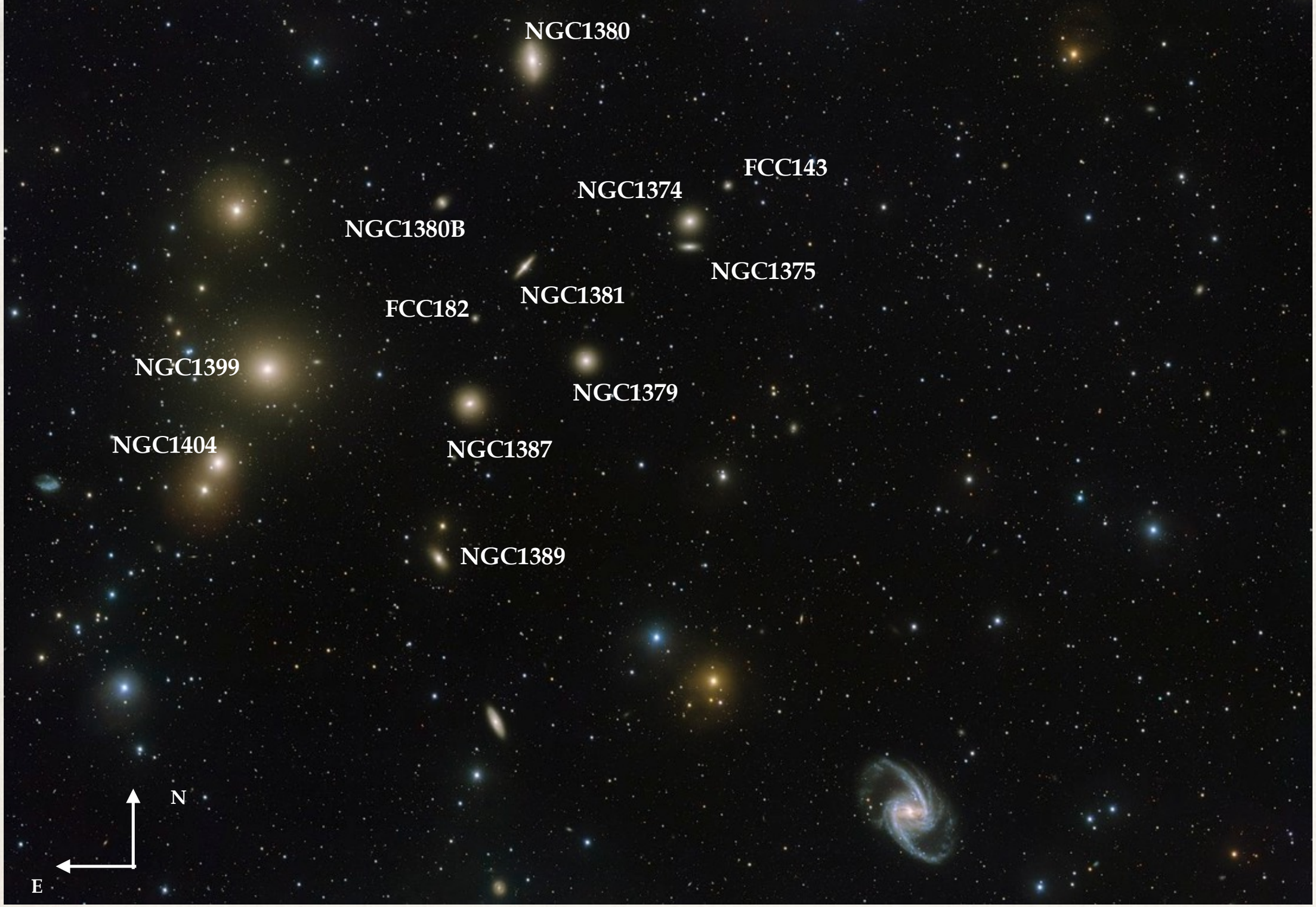
ICL *vs* IC GCs



blue GCs from D'Abrusco et al. 2016

blue GCs from Cantiello et al. 2017



The bright ETGs in the R_{vir} of the cluster

Iodice et al. 2018, A&A, submitted

Table 2. Early-type galaxies inside the virial radius ($R_{vir} \sim 0.7$ Mpc) of the Fornax cluster, brighter than $m_B < 15$ mag.

object	α h:m:s	δ d:m:s	Morph Type	radial velocity km/s	m_B mag	FDS field	Names
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FCC083	03 30 35.1	-34 51 14	E5	1543	12.3	F15-F19	NGC1351, ESO0358-G21
FCC090	03 31 08.1	-36 17 19	E4 pec	1916	15.0	F16-F17	
FCC143	03 34 59.1	-35 10 10	E3	1376	14.3	F16	NGC1373, ESO358-G21
FCC147	03 35 16.8	-35 13 34	E0	1386	11.9	F16	NGC1374, ESO358-G23
FCC148	03 35 16.8	-35 15 56	S0	730	13.6	F16	NGC1375, ESO358-G24
FCC153	03 35 30.9	-34 26 45	S0	1639	13.0	F10-F15	IC1963, ESO358-G26
FCC161	03 36 04.0	-35 26 30	E0	1405	11.7	F11-F16	NGC1379, ESO358-G37
FCC167	03 36 27.5	-34 58 31	S0/a	1827	11.3	F10-F11	NGC1380, ESO358-G28
FCC170	03 36 31.6	-35 17 43	S0	1793	13.0	F11	NGC1381, ESO358-G29
FCC177	03 36 47.4	-34 44 17	S0	1495	13.2	F10	NGC1380A, ESO358-G33
FCC182	03 36 54.3	-35 22 23	SB0 pec	1823	14.9	F11	
FCC184	03 36 56.9	-35 30 24	SB0	1337	12.3	F11	NGC1387, ESO358-G36
FCC190	03 37 08.9	-35 11 37	SB0	1784	13.5	F11	NGC1380B, ESO358-G37
FCC193	03 37 11.7	-35 44 40	SB0	999	12.8	F11	NGC1389, ESO358-G38
FCC213	03 38 29.2	-35 27 02	E0	1430	10.6	F11	NGC1399, ESO358-G45
FCC219	03 38 52.1	-35 35 38	E2	1944	10.9	F11	NGC1404, ESO358-G46
FCC276	03 42 19.2	-35 23 36	E4	1454	11.8	F6	NGC1427, ESO358-G52
FCC277	03 42 22.6	-35 09 10	E5	1620	13.8	F6	NGC1428, ESO358-G53
FCC301	03 45 03.5	-35 58 17	E4	1020	14.2	F7	ESO358-G59
FCC310	03 46 13.7	-36 41 43	SB0	1352	13.5	F3-F7	NGC1460, ESO358-G62

Notes. *Col.1* - Fornax cluster members from Ferguson (1989). *Col.2 and Col.3* - Right ascension and declination. *Col.4, Col.5 and Col.6* - Morphological type, Heliocentric radial velocity and total magnitude in the B band given by Ferguson (1989). *Col.7* - Location in the FDS field (see Fig.1). *Col.8* - Other catalogue name.

The bright ETGs in the R_{vir} of the cluster

Iodice et al. 2018, A&A, submitted

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FCC090	03 31 08.1	-36 17 19					
FCC143	03 34 59.1	-35 10 10					
FCC147	03 35 16.8	-35 13 34					
FCC148	03 35 16.8	-35 15 56					
FCC153	03 35 30.9	-34 26 45					
FCC161	03 36 04.0	-35 26 30					
FCC167	03 36 27.5	-34 58 31					
FCC170	03 36 31.6	-35 17 43					
FCC177	03 36 47.4	-34 44 17					
FCC182	03 36 54.3	-35 22 23					
FCC184	03 36 56.9	-35 30 24					
FCC190	03 37 08.9	-35 11 37					
FCC193	03 37 11.7	-35 44 40					
FCC213	03 38 29.2	-35 27 02					
FCC219	03 38 52.1	-35 35 38					
FCC276	03 42 19.2	-35 23 36					
FCC277	03 42 22.6	-35 09 10					
FCC301	03 45 03.5	-35 58 17					
FCC310	03 46 13.7	-36 41 43					

Notes. *Col.1* - Fornax cluster members from [illegible] Morphological type, Heliocentric radial velocity and total magnitude in the B band given by Ferguson (1989). *Col.7* - Location in the FDS field (see Fig.1). *Col.8* - Other catalogue name.

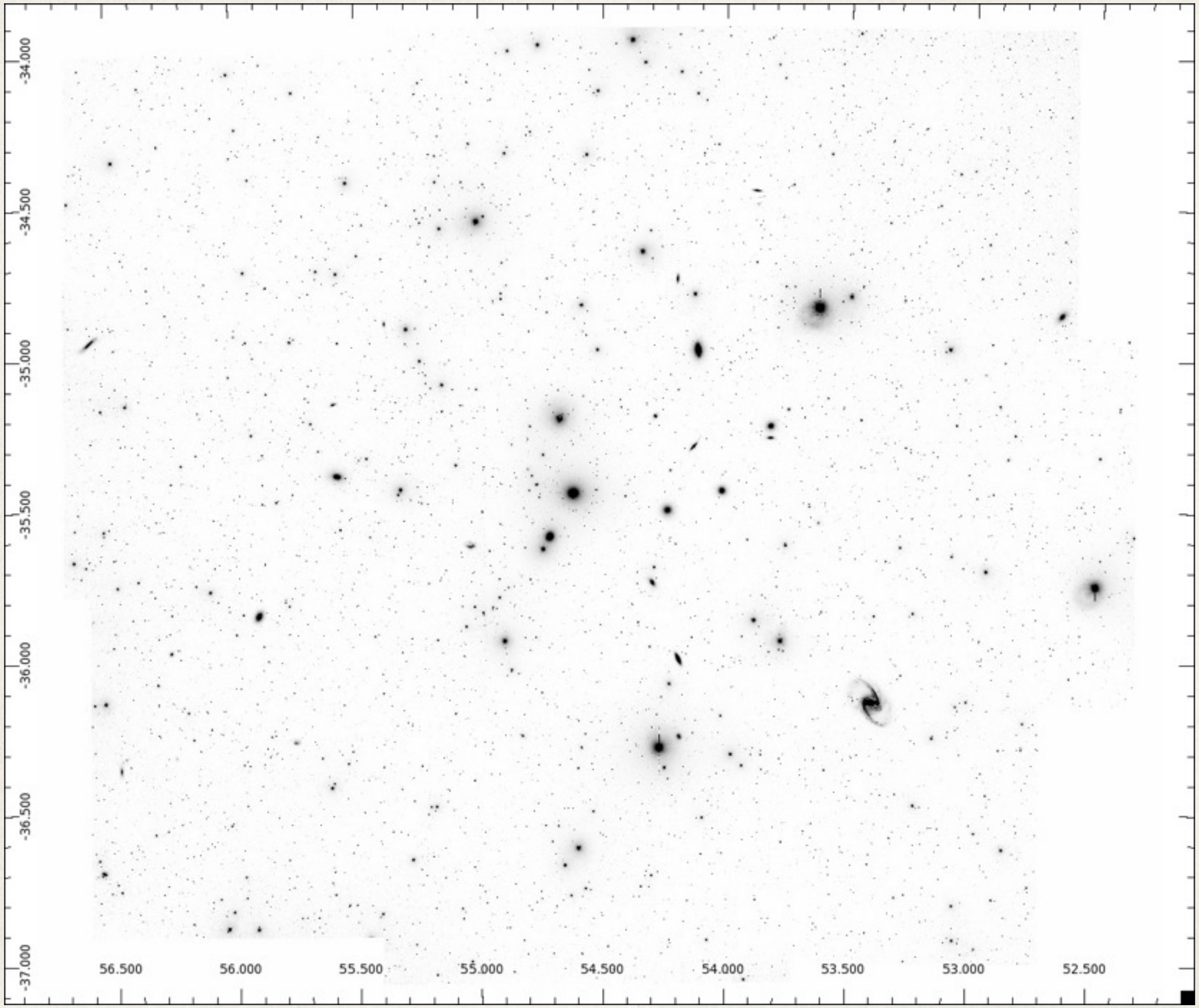
Surface photometry:

- deep images & isophotal analysis
- total magnitudes & R_e in *ugri*
- *g-r* & *g-i* integrated colors, color profiles & 2D colormaps
- stellar M/L
- overview of the galaxy structure (including stellar halos) *vs* environment

The bright ETGs in the R_{vir} of the cluster

Iodice et al. 2018, A&A, submitted

The bright ETGs in the R_{vir} of the cluster: RESULTS



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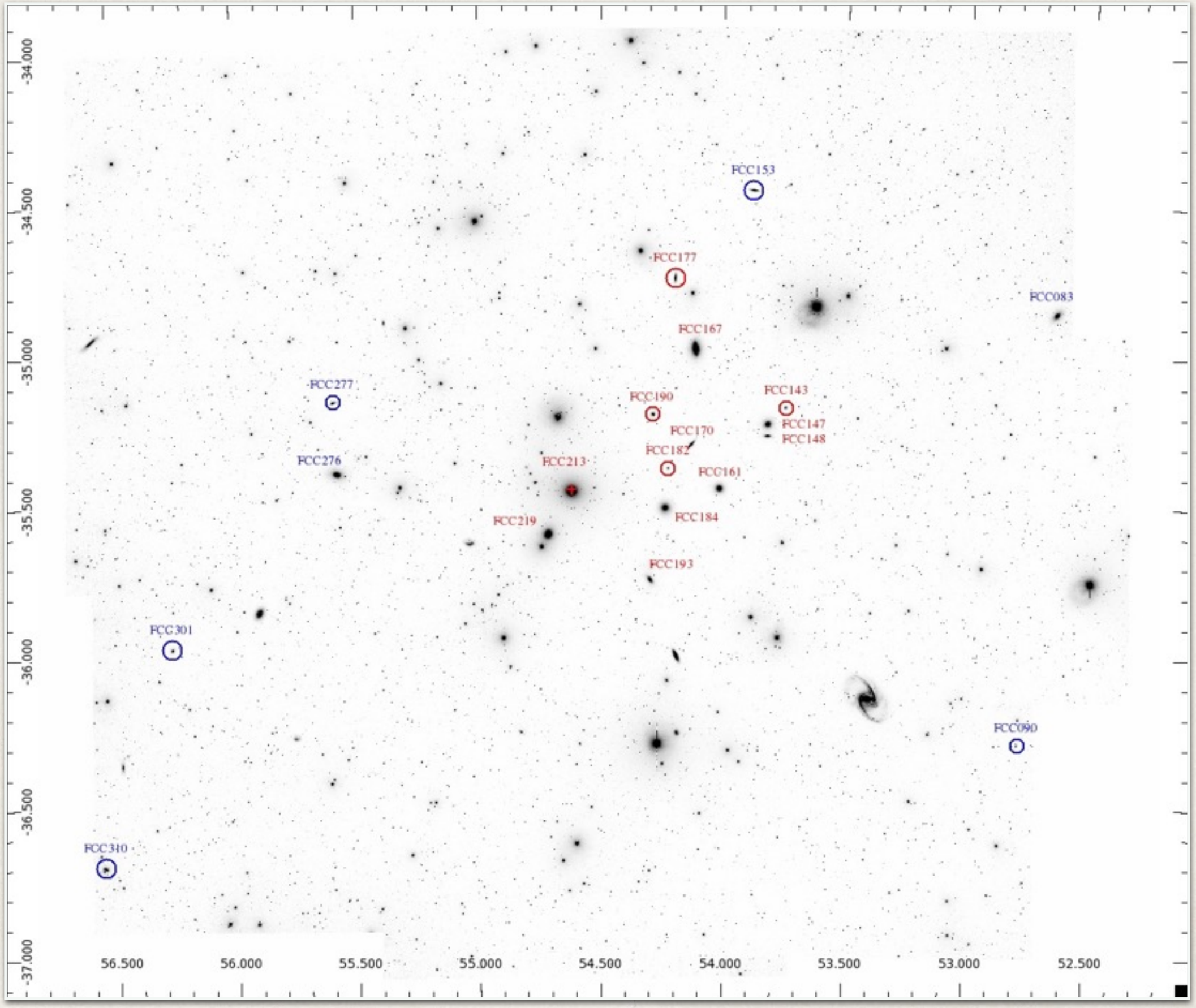
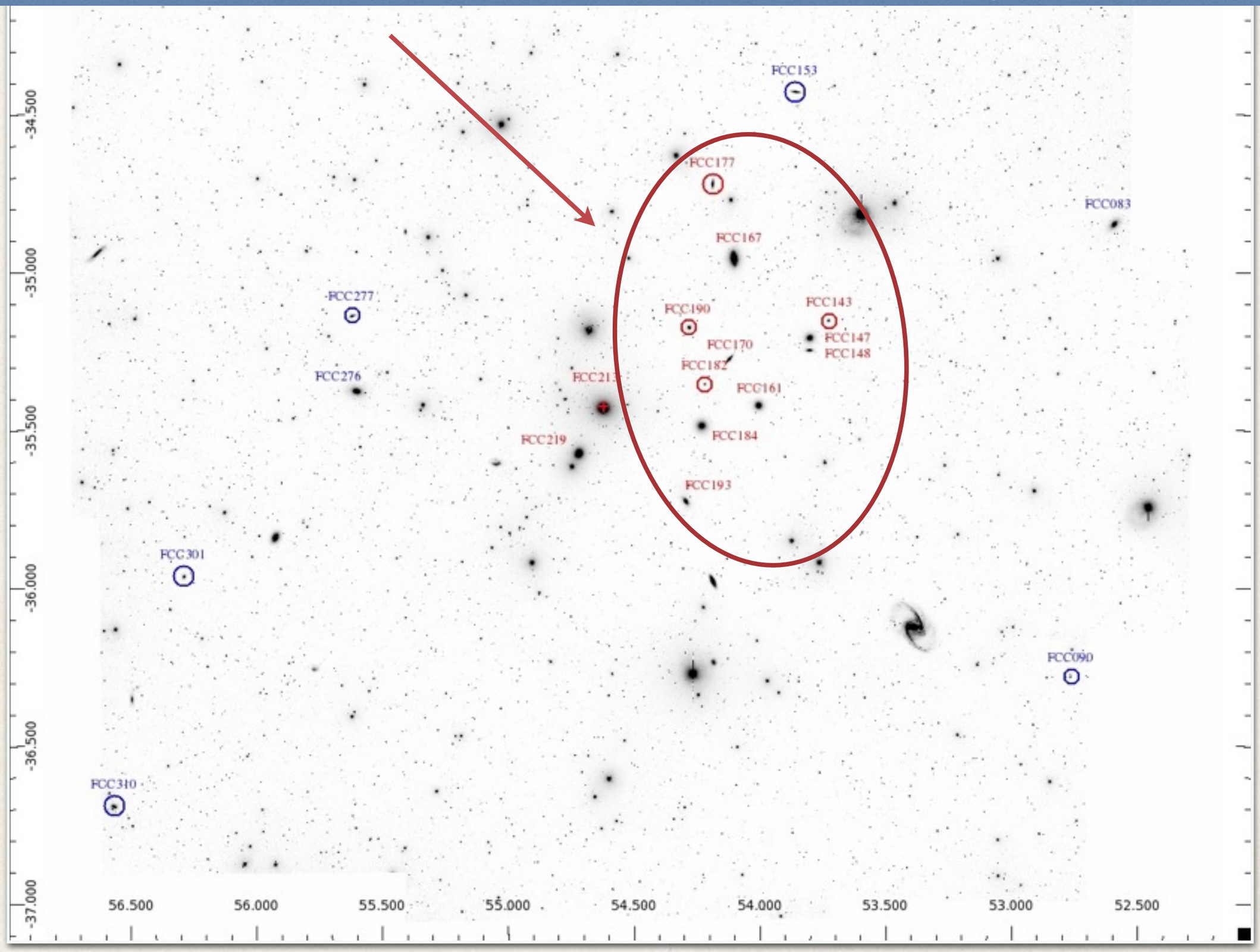


the bulk of the gravitational interactions between galaxies should have happened on the W-NW side of the cluster, where most of the bright ETGs are located and where the intra-cluster baryons are found



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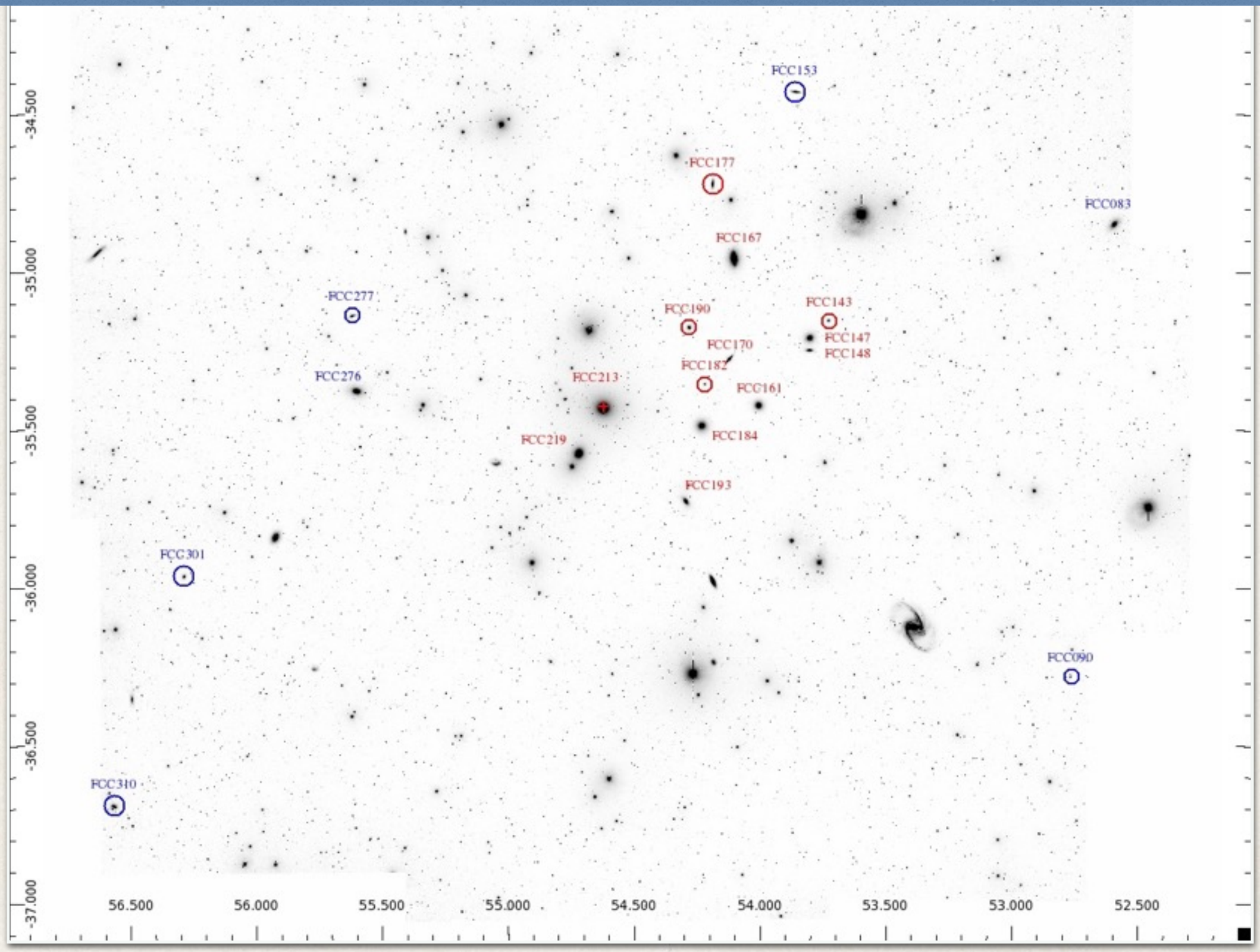

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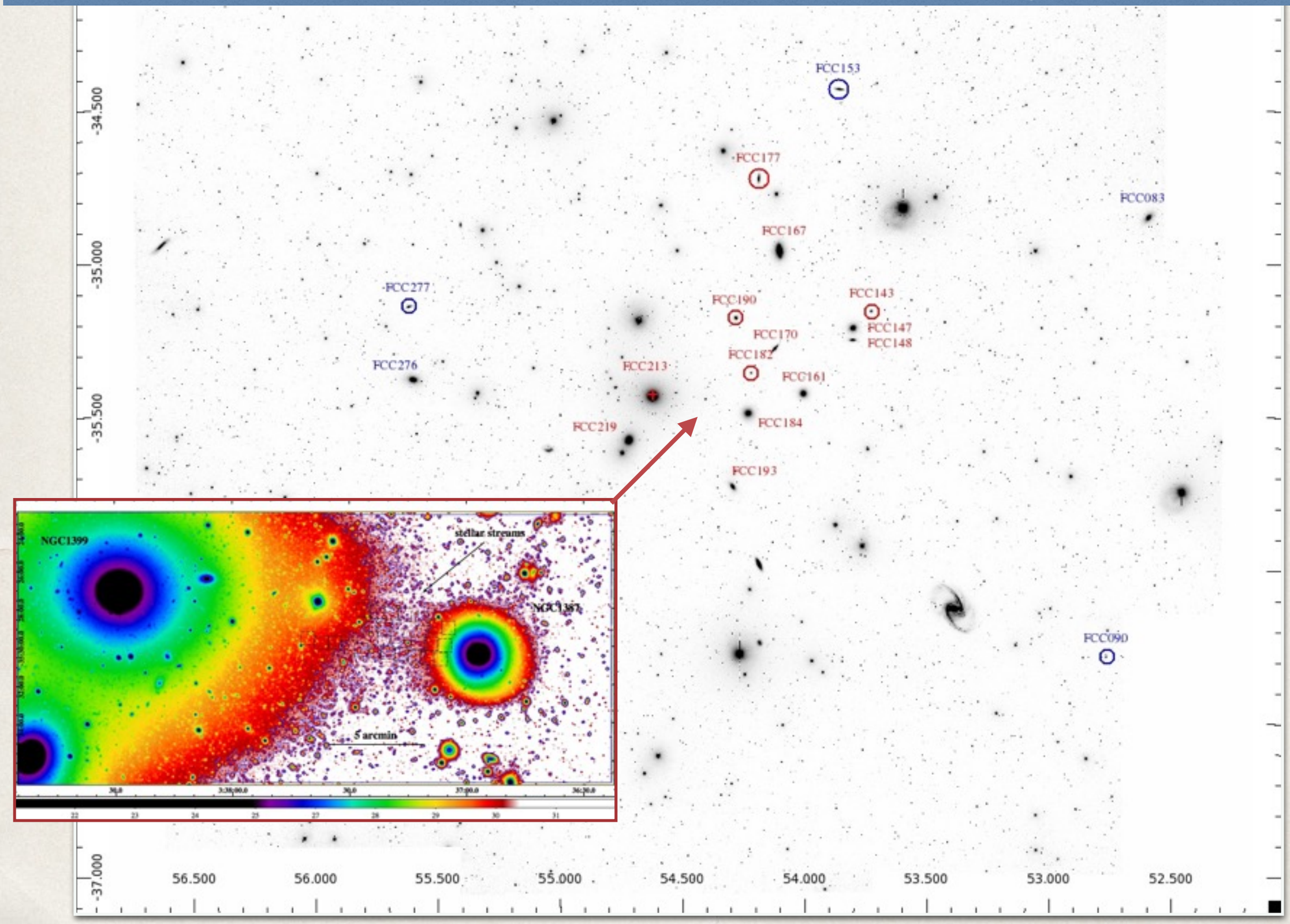

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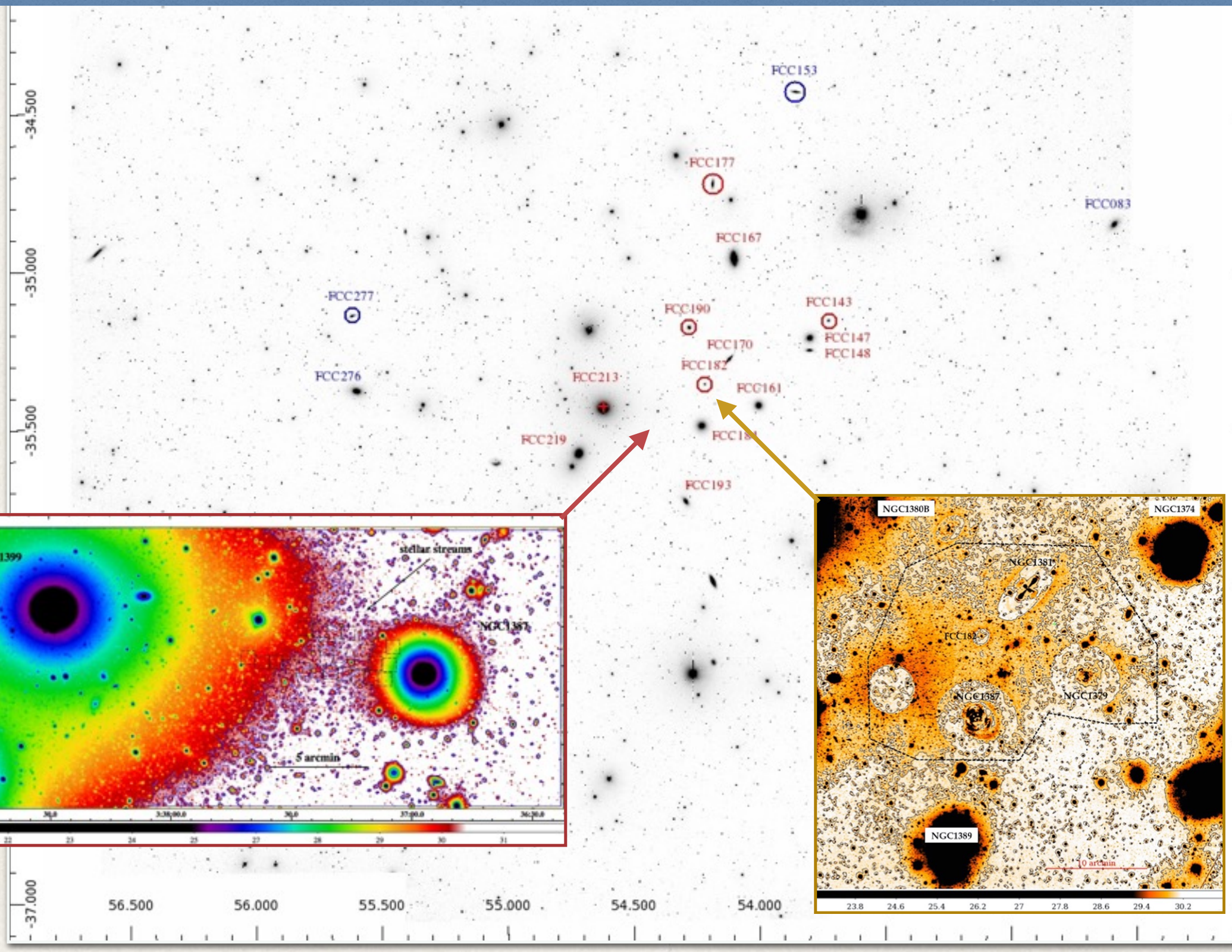

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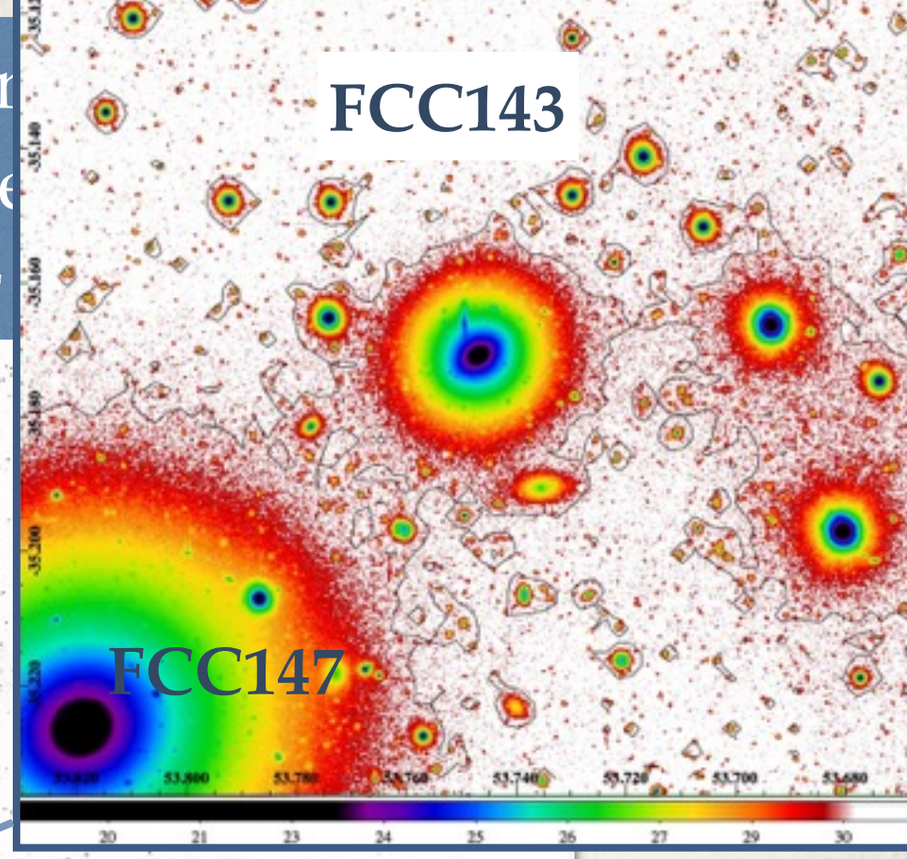

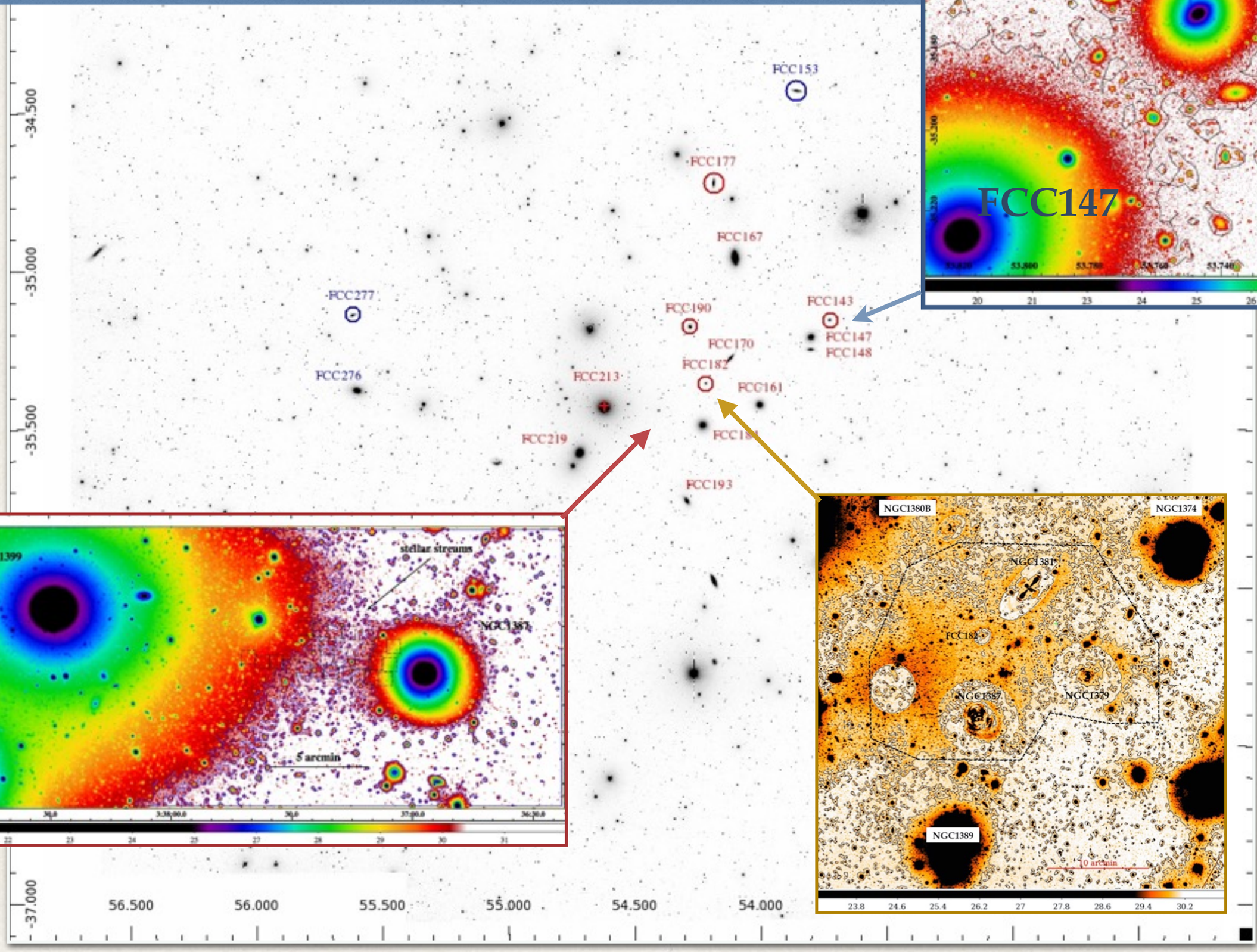

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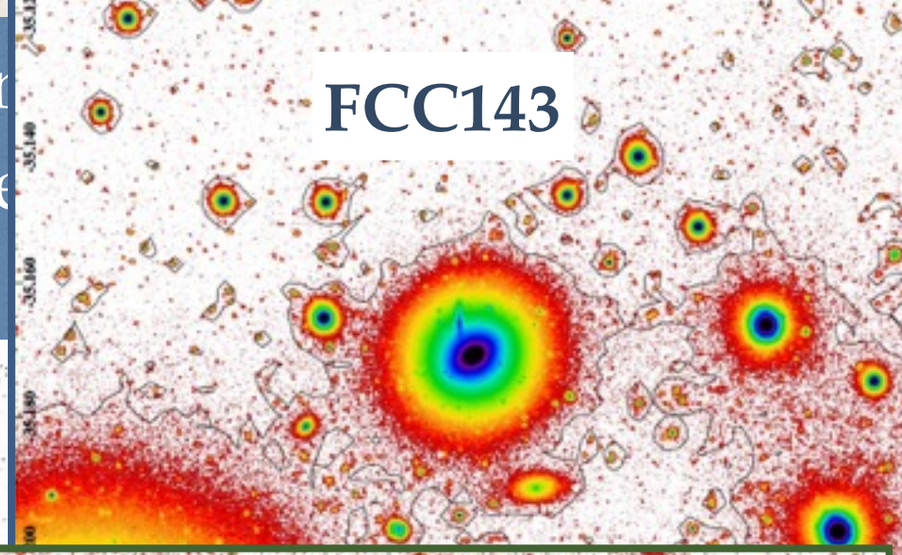
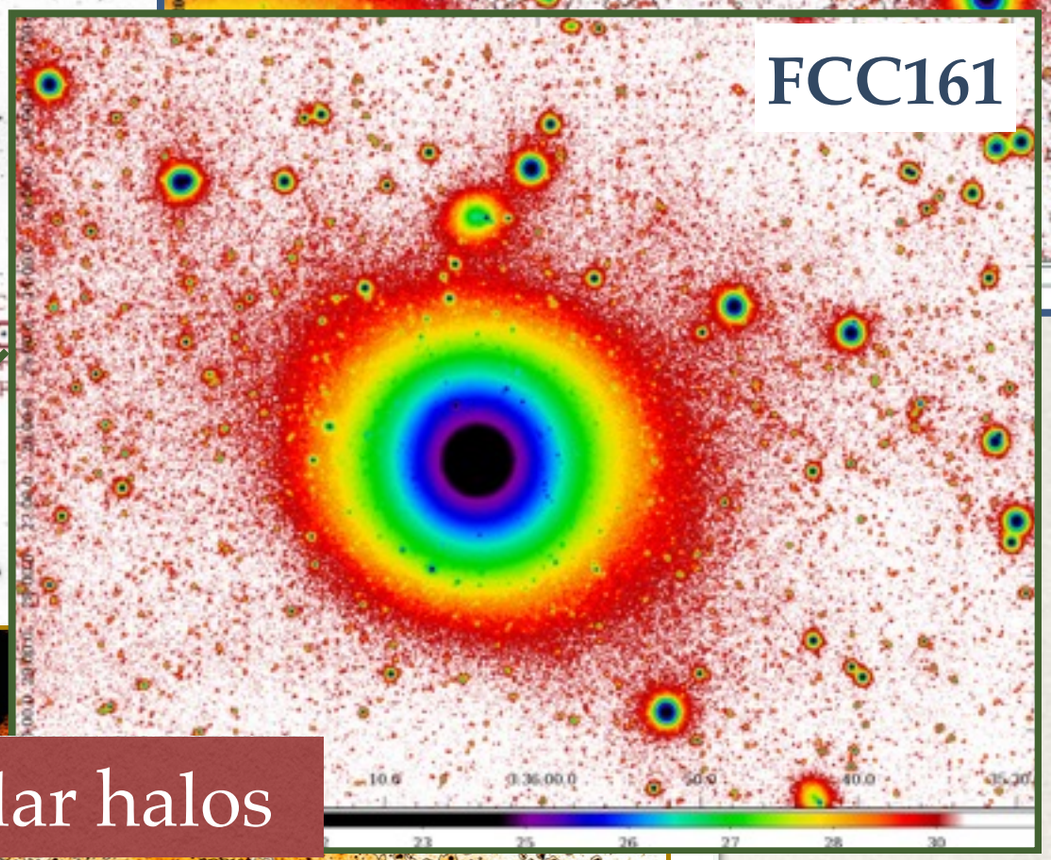
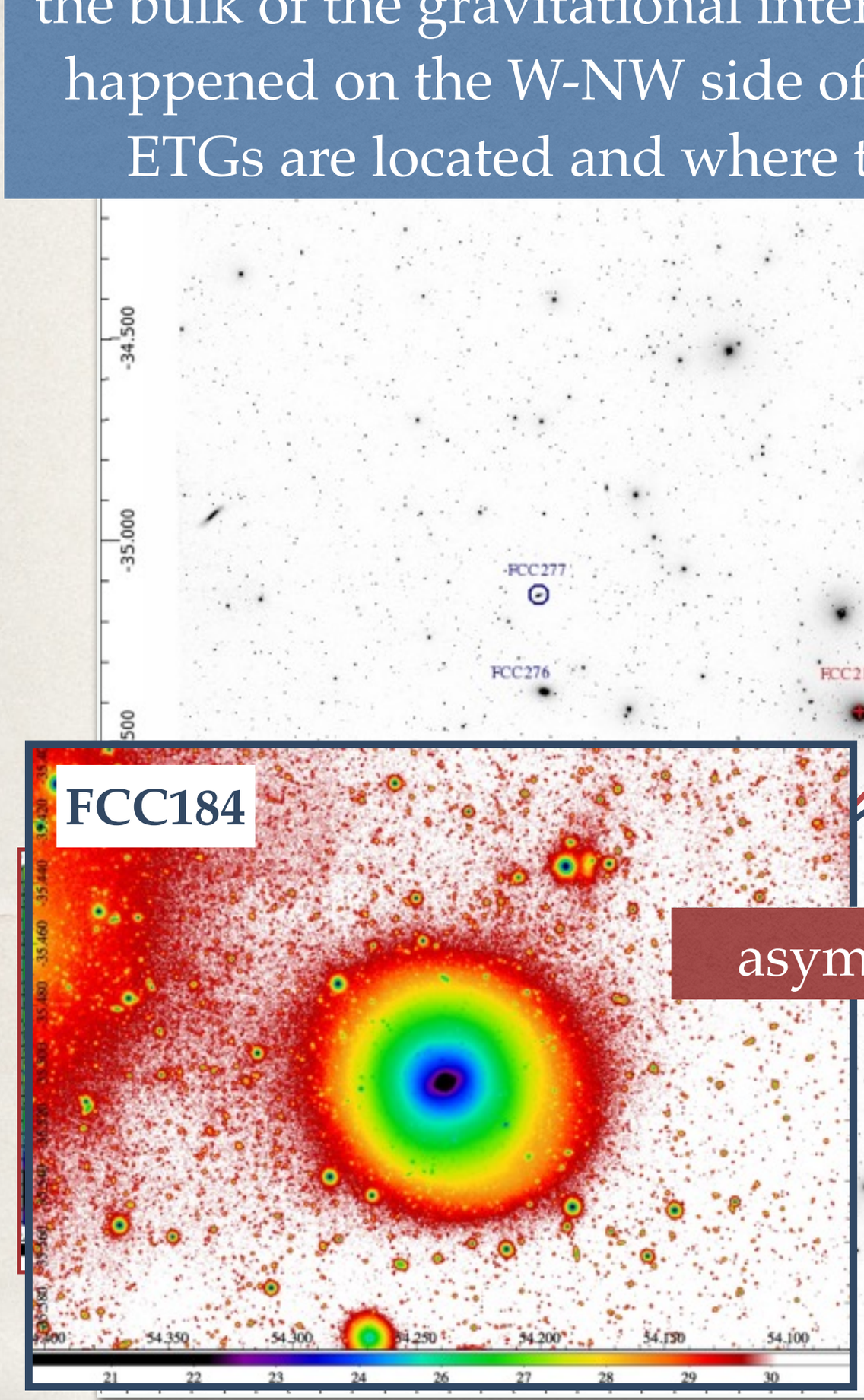
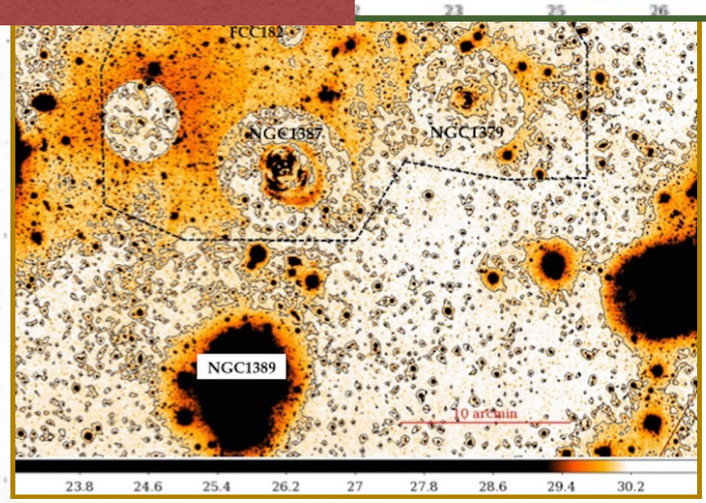


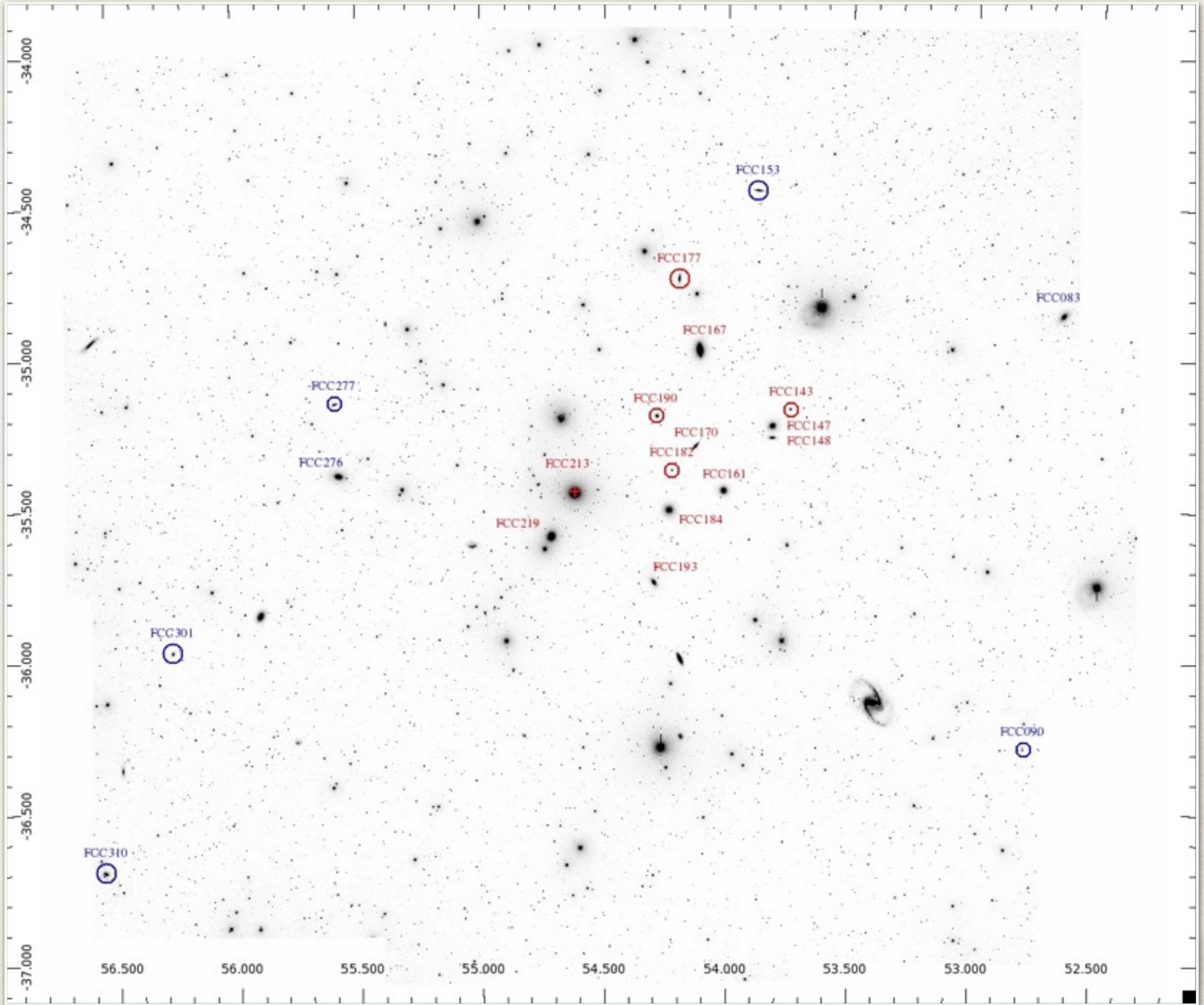




asymmetric stellar halos



The bright ETGs in the R_{vir} of the cluster: RESULTS



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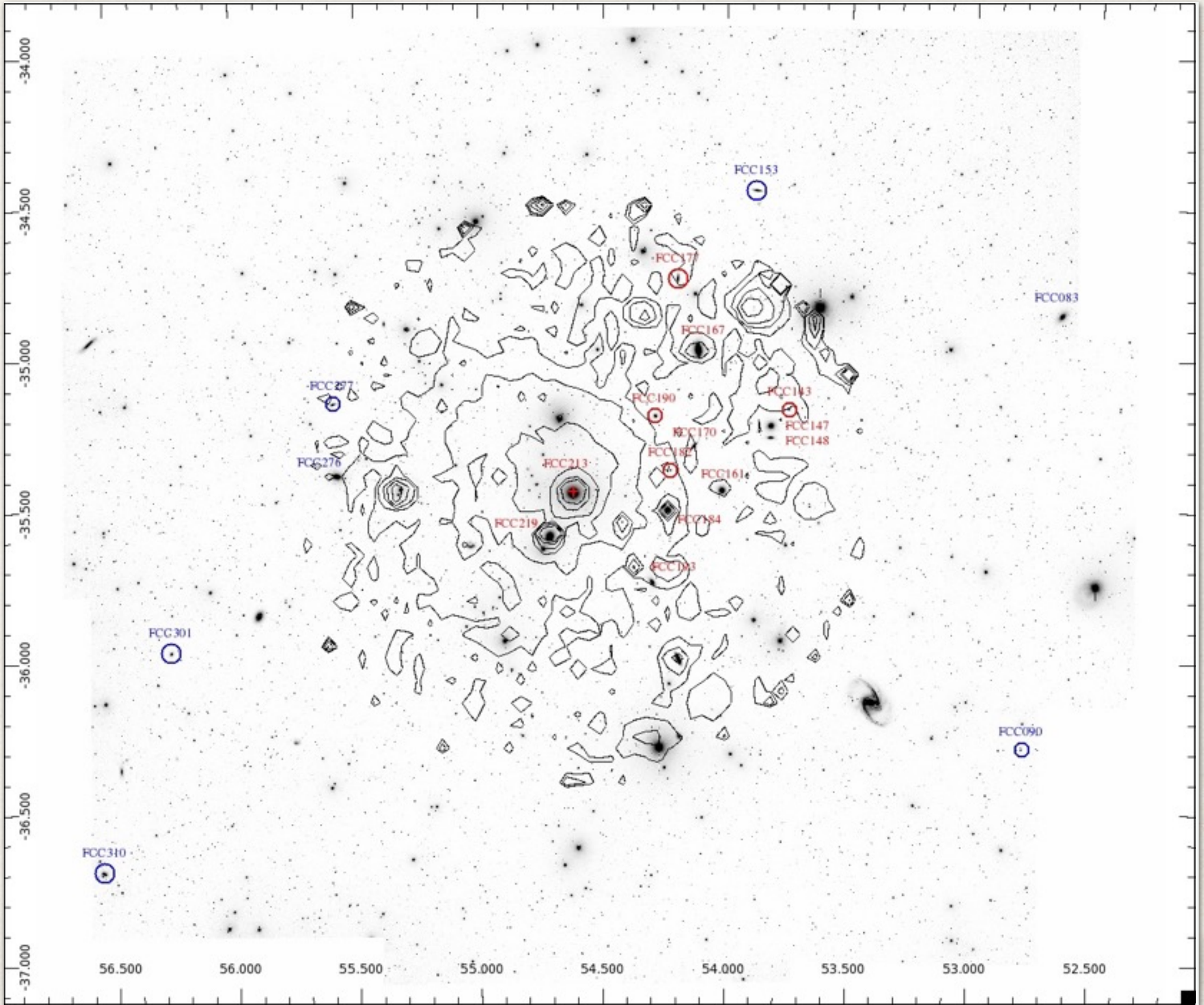

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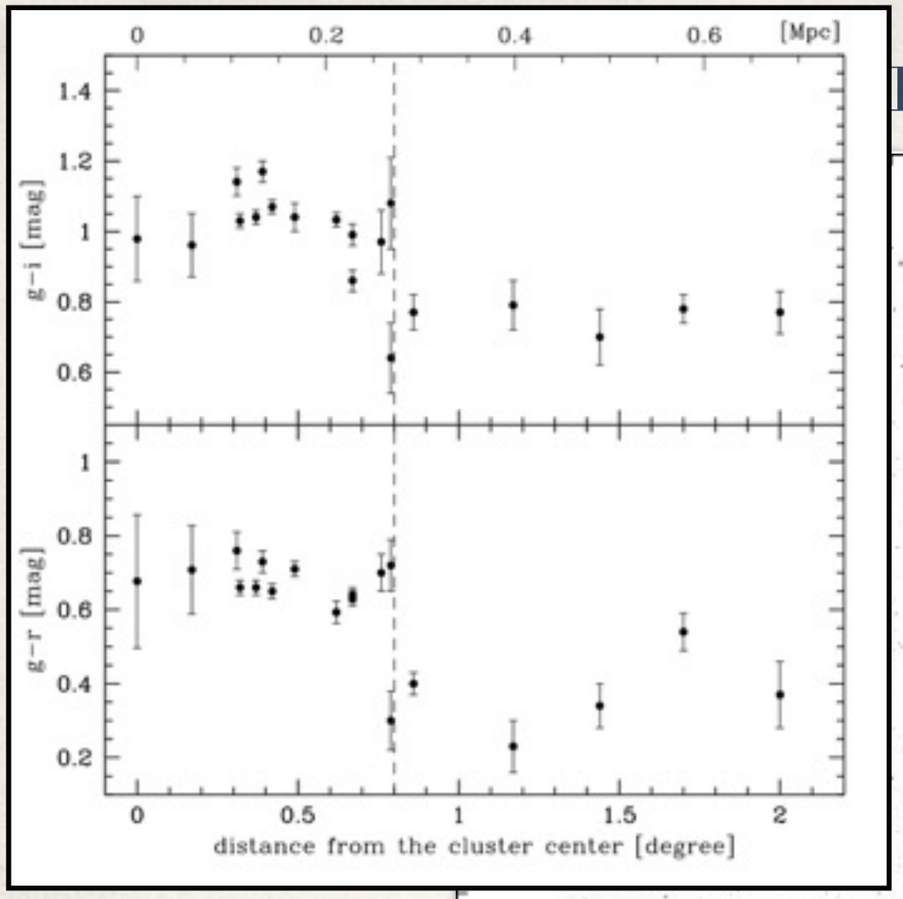

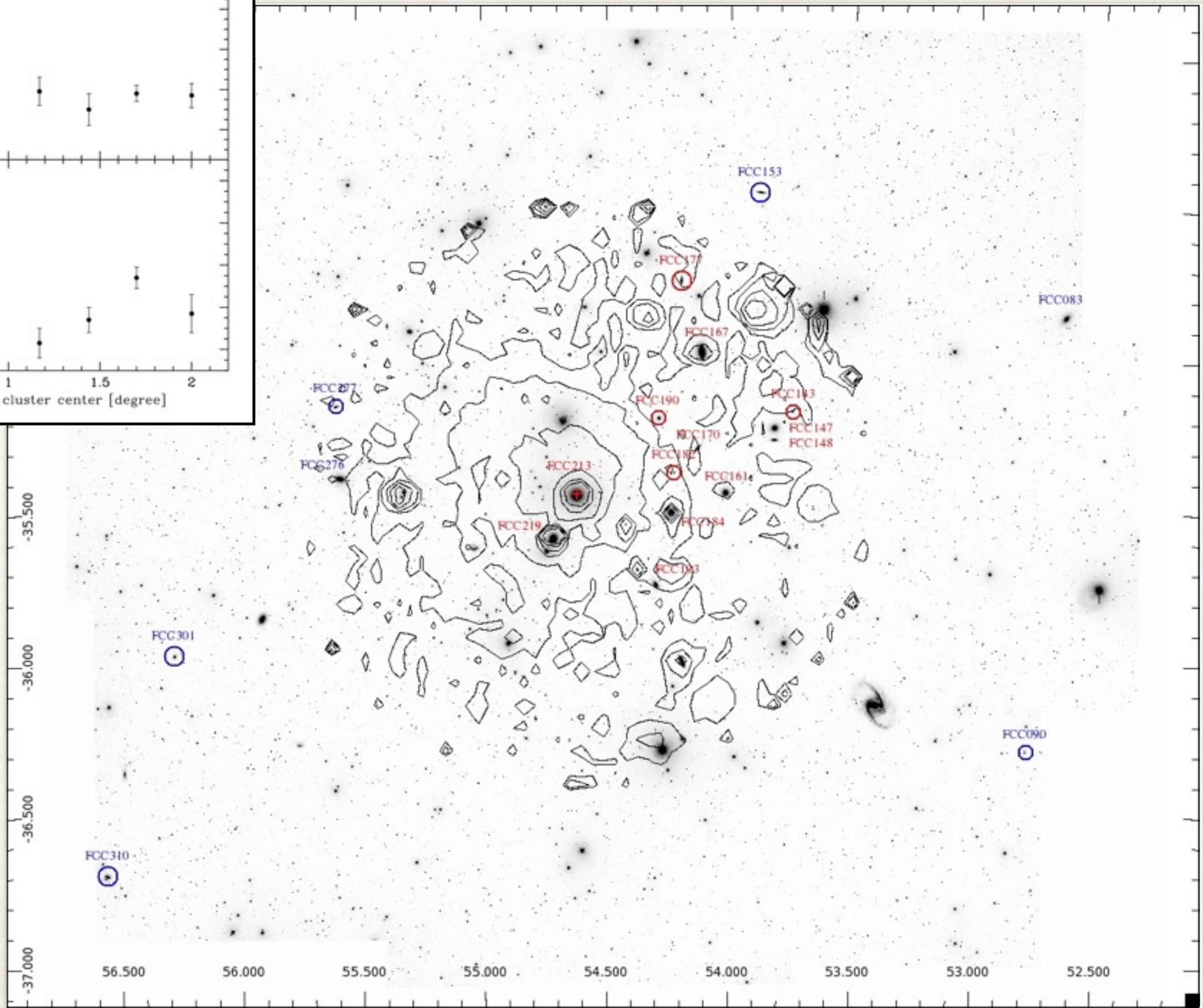

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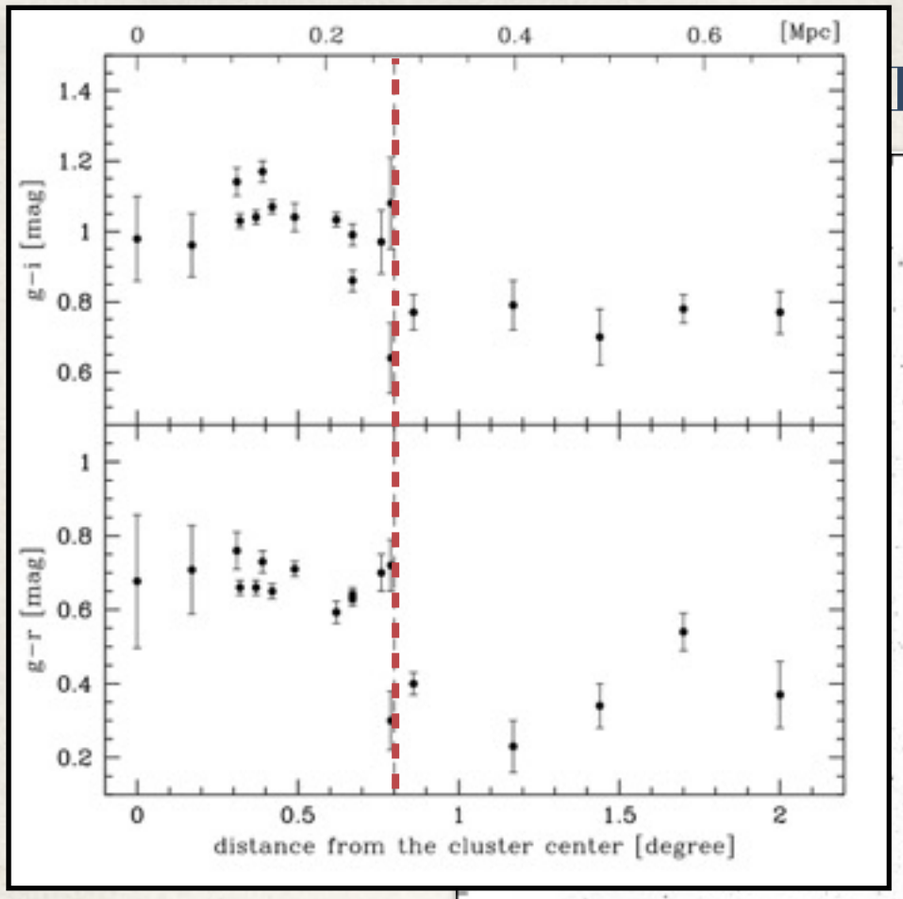

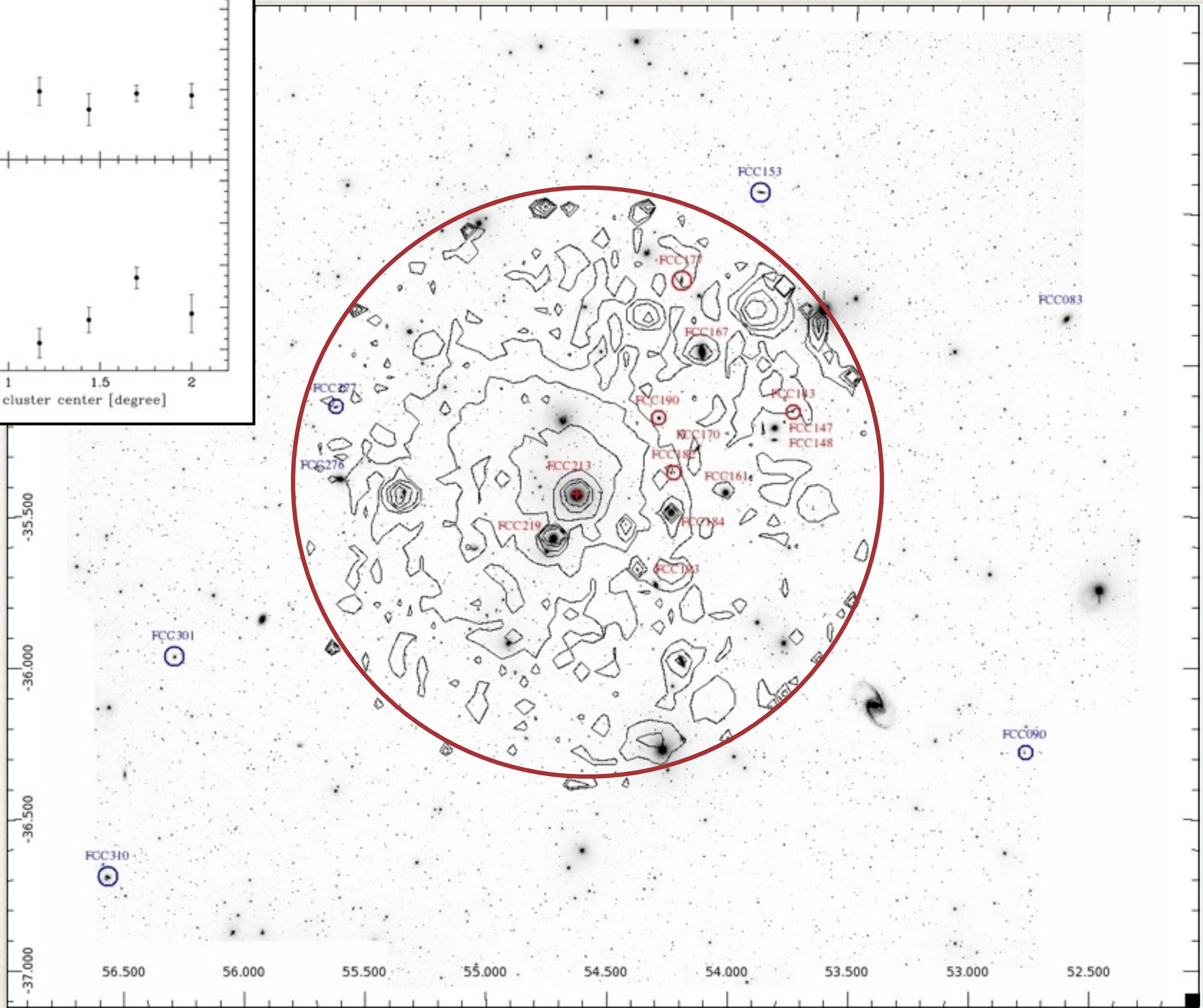

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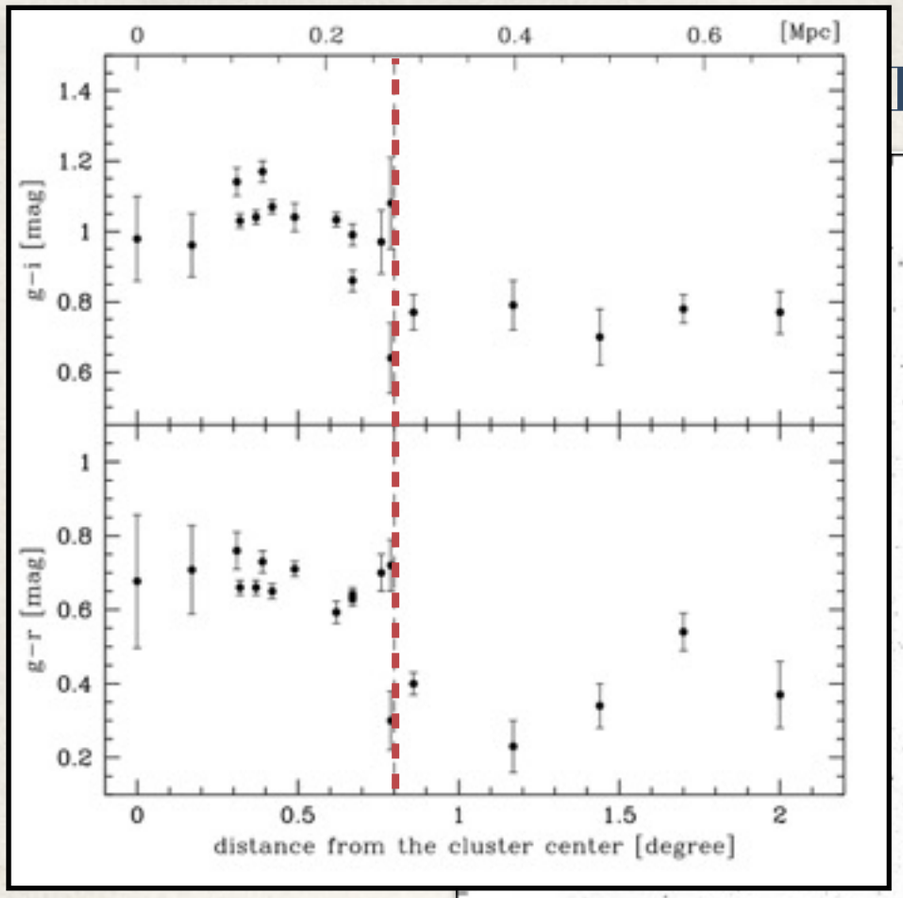

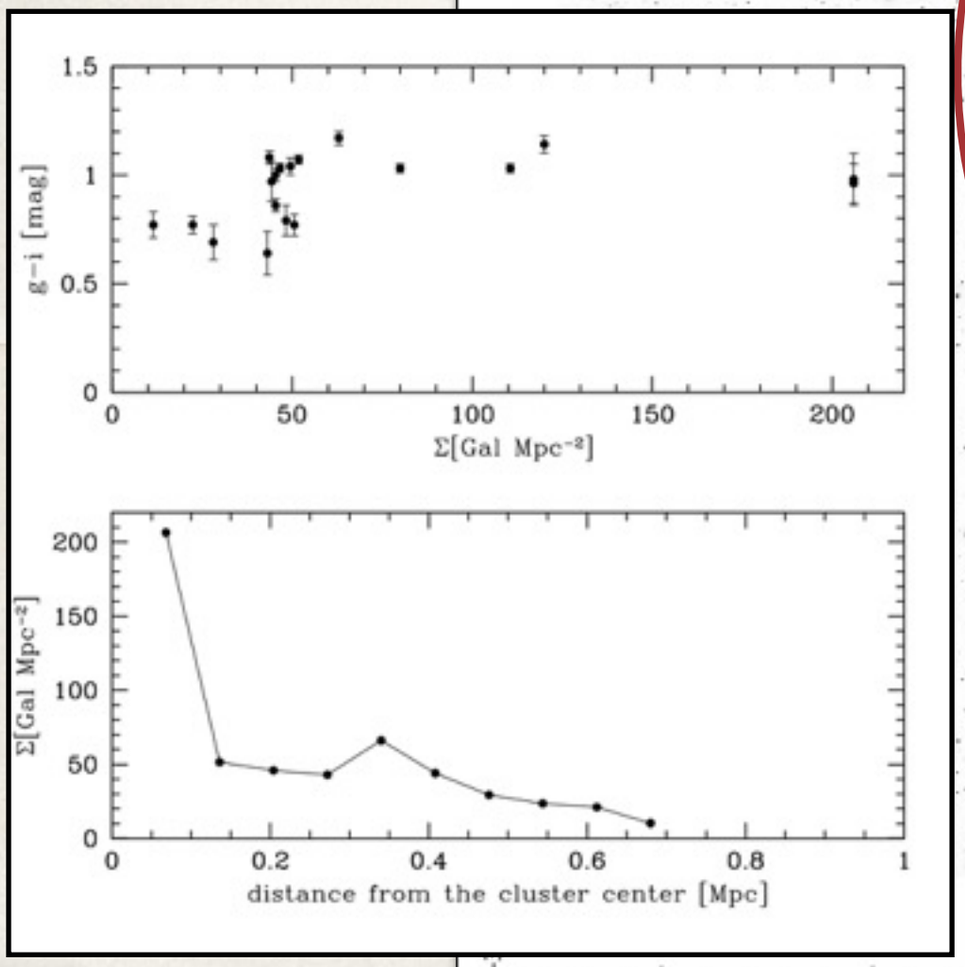

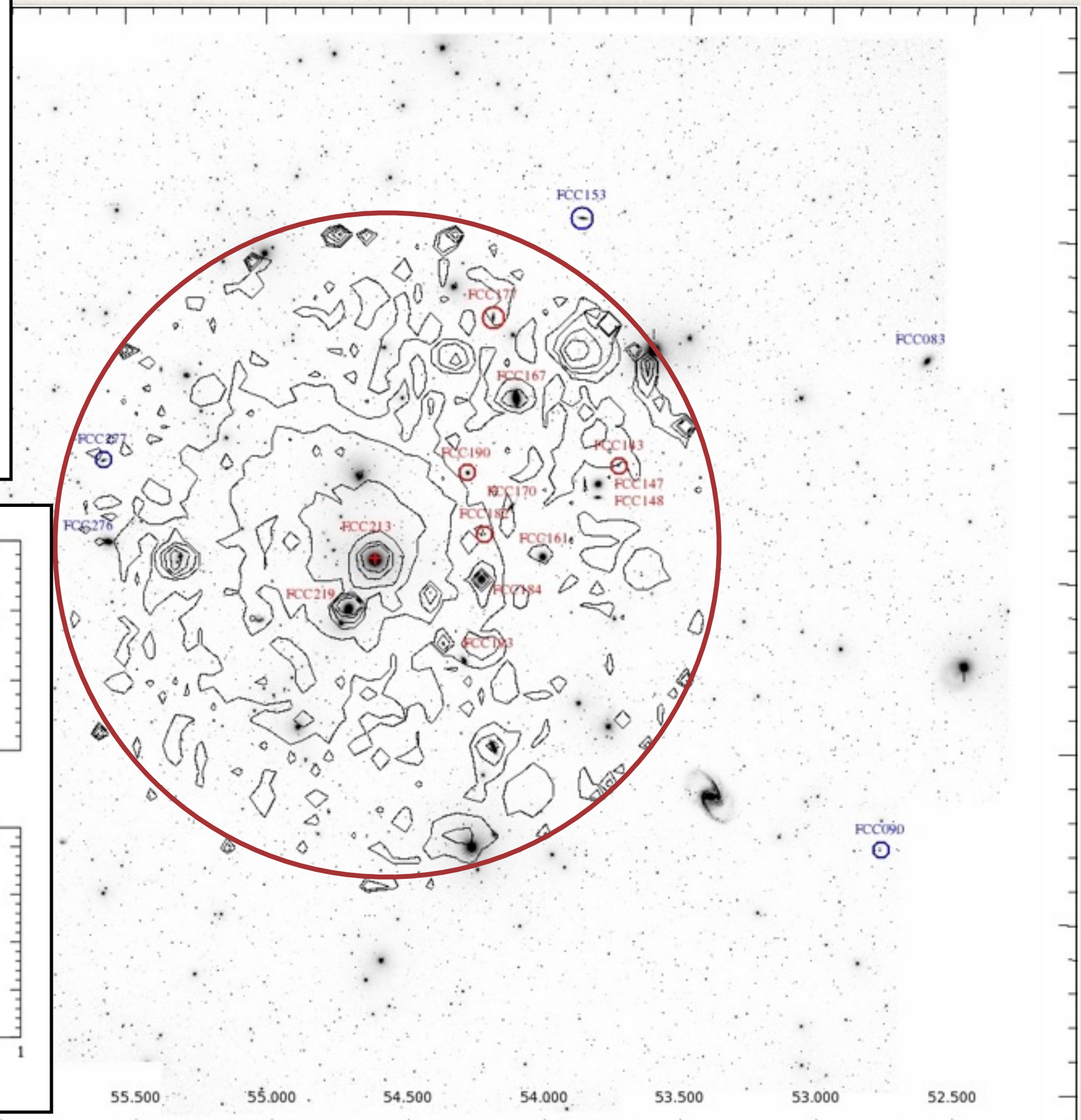

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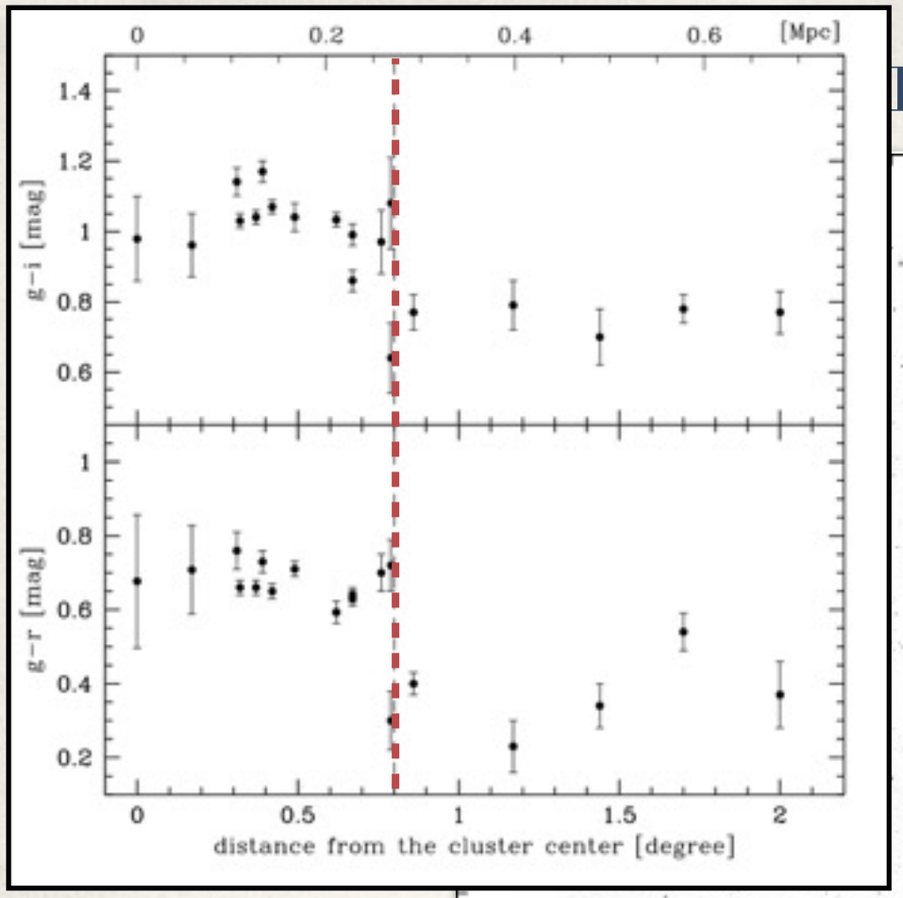

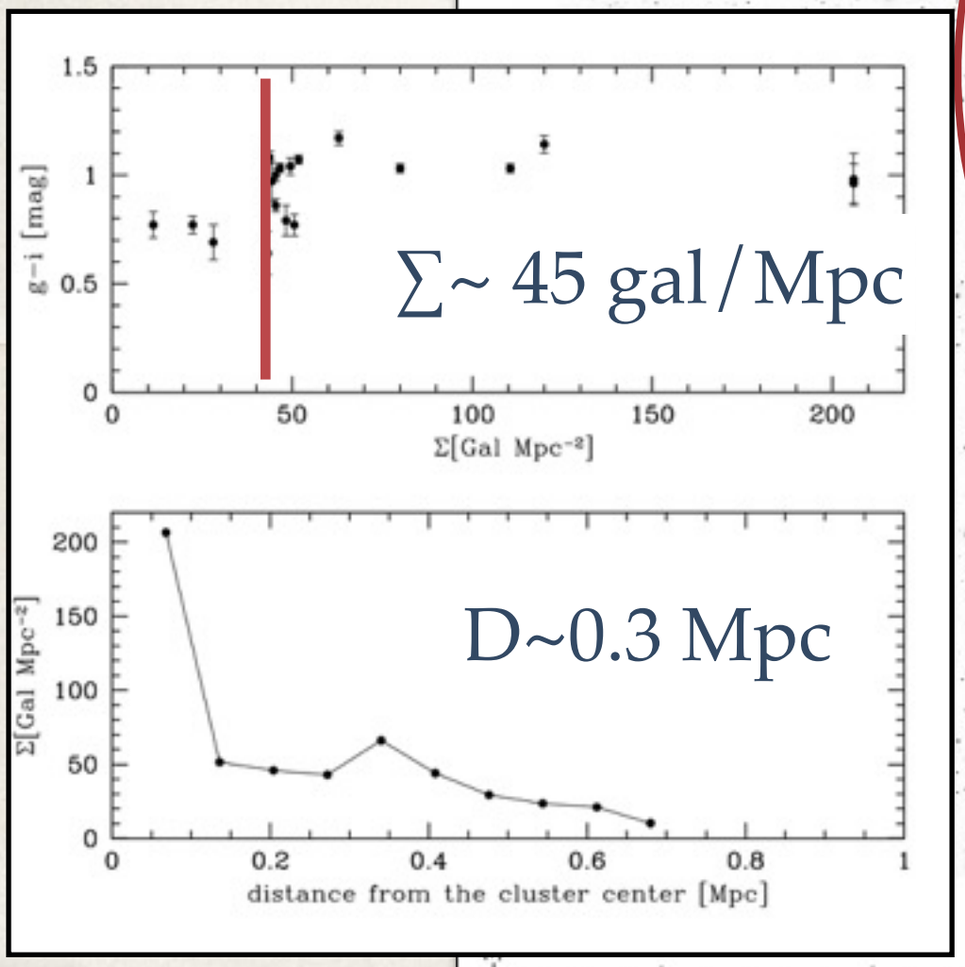

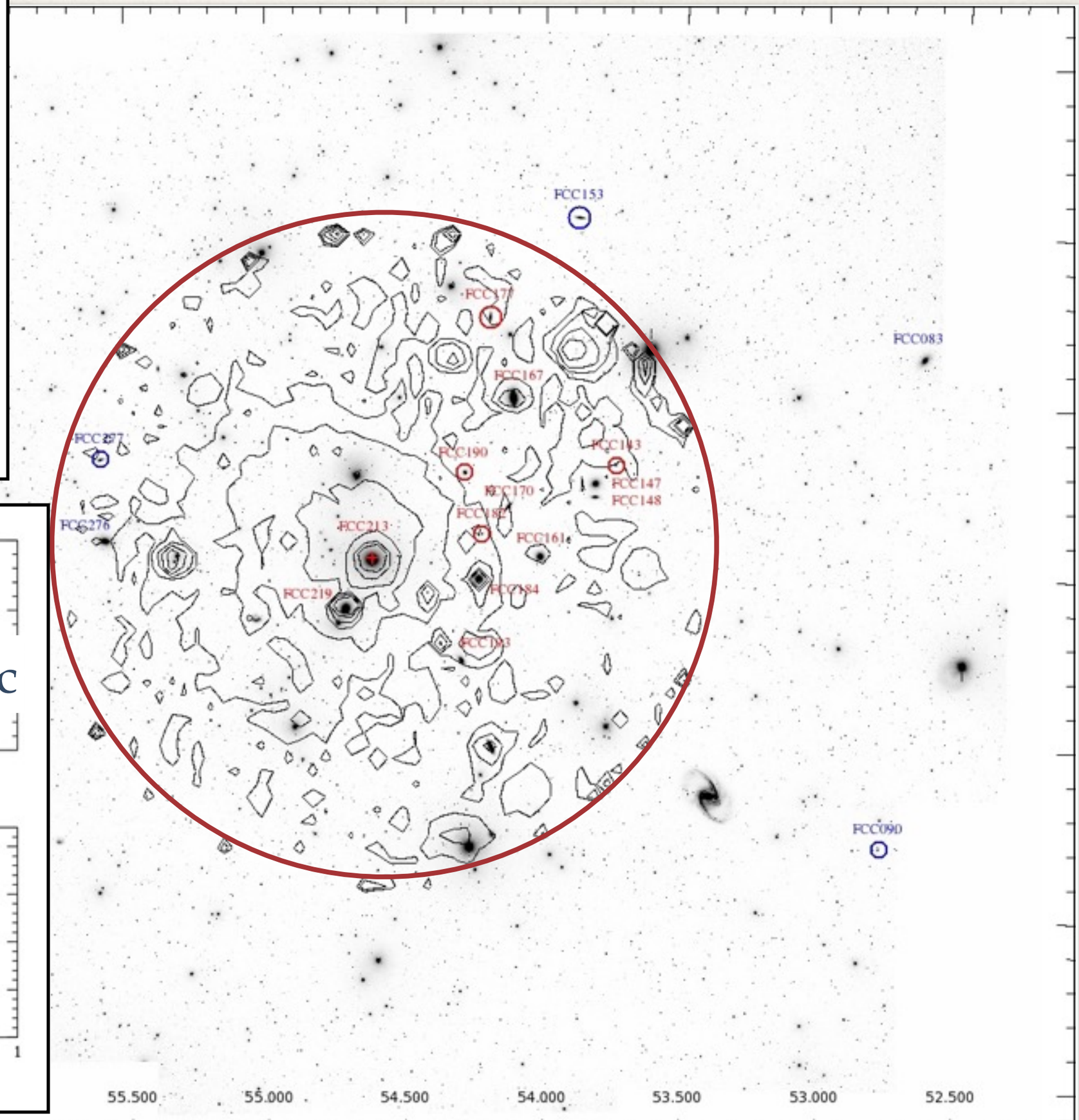

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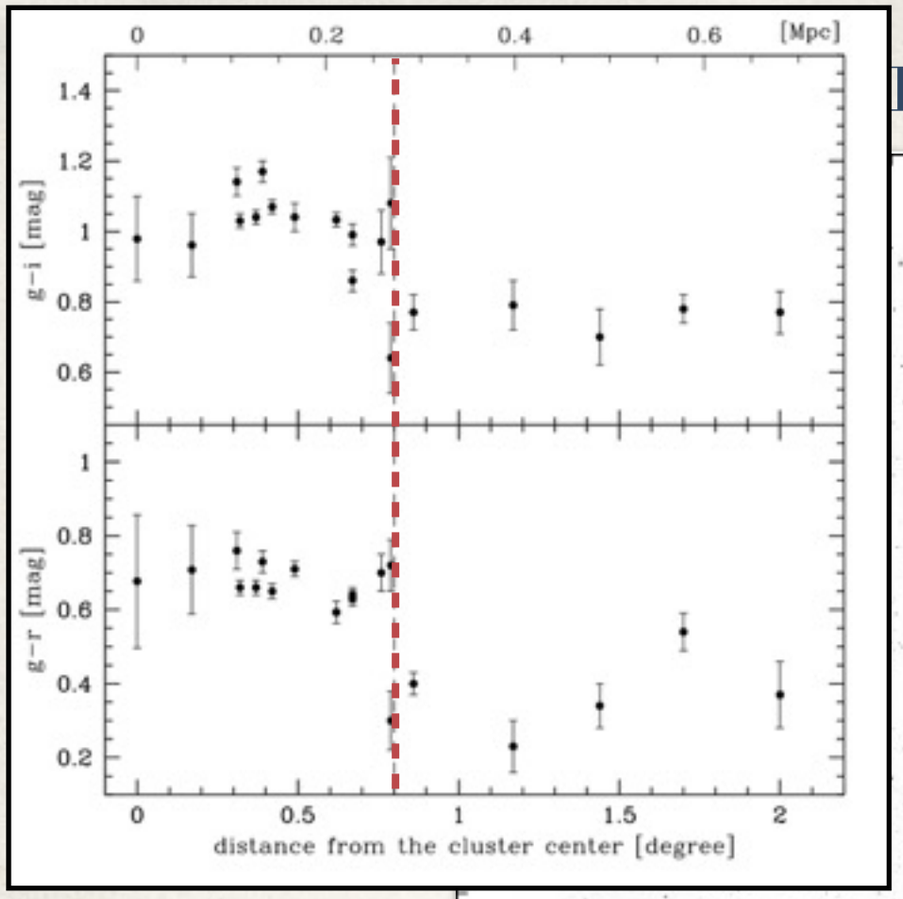
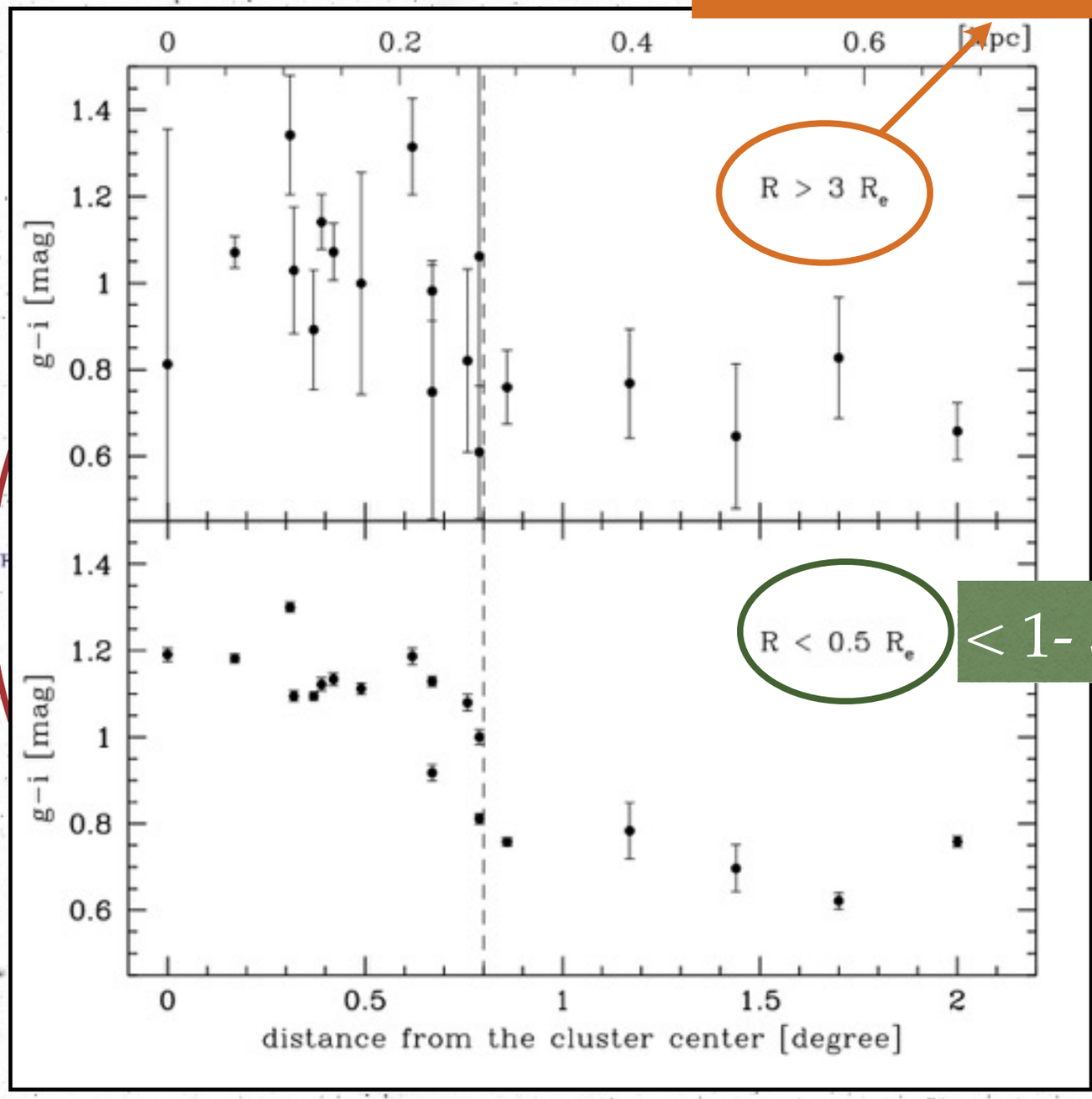
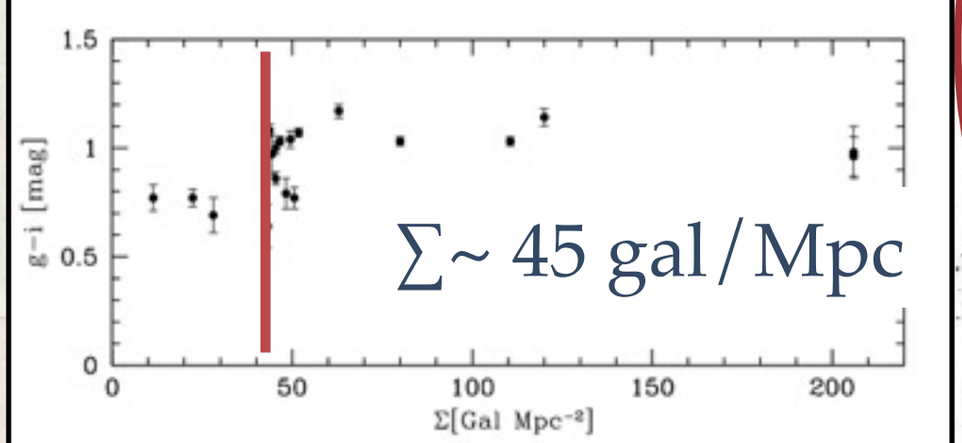


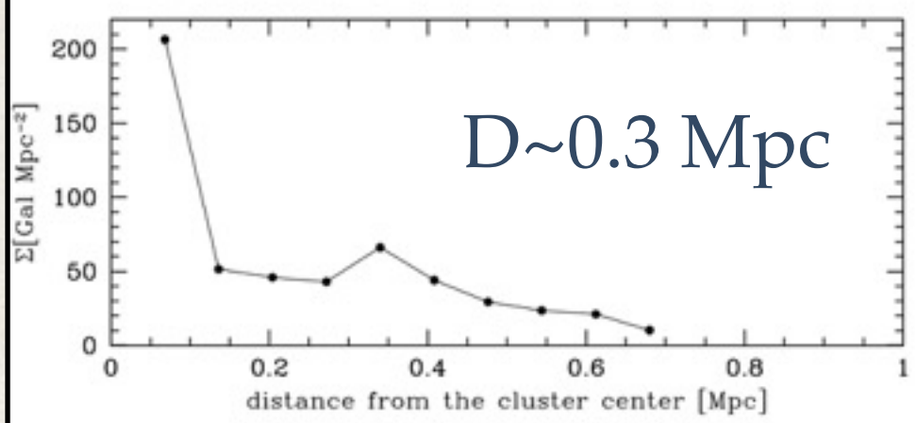
outskirts > 10 -30 kpc



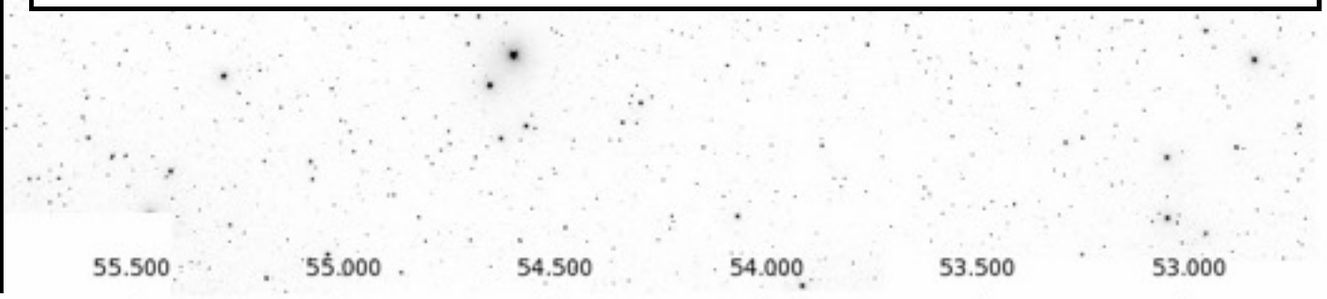
< 1- 3 kpc



Σ~ 45 gal/Mpc



D~0.3 Mpc



n the R_{vir} of the cluster: RESULTS

stellar halos made by the accretion
of rather massive, metal-rich satellite galaxies

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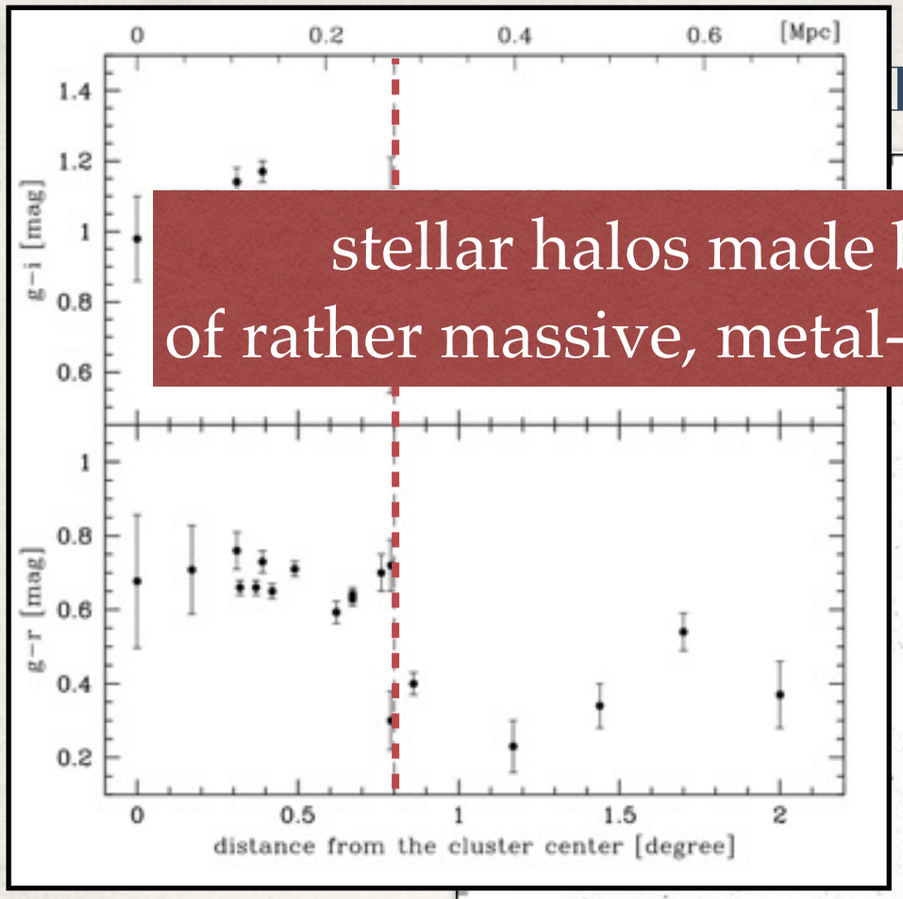
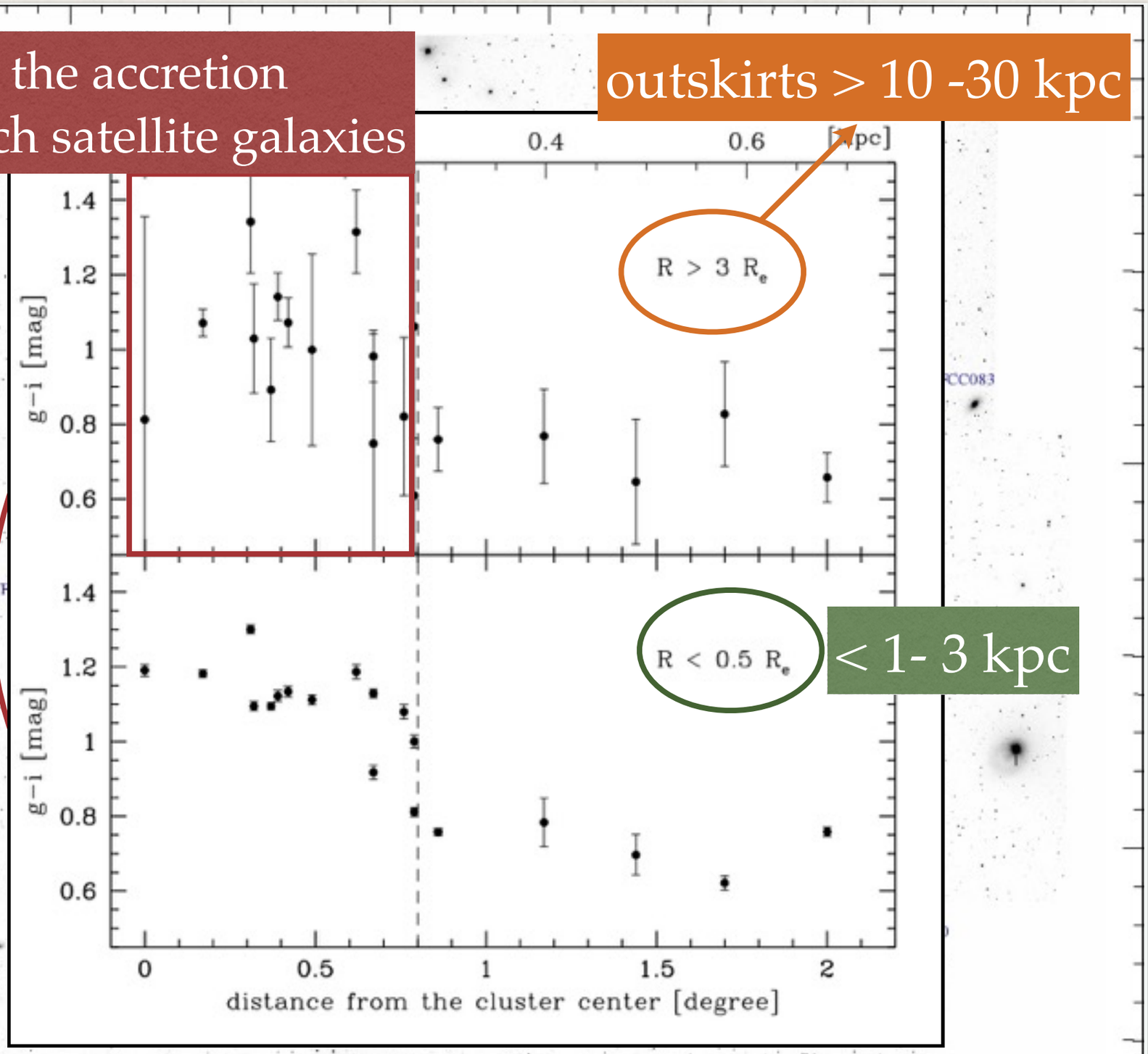
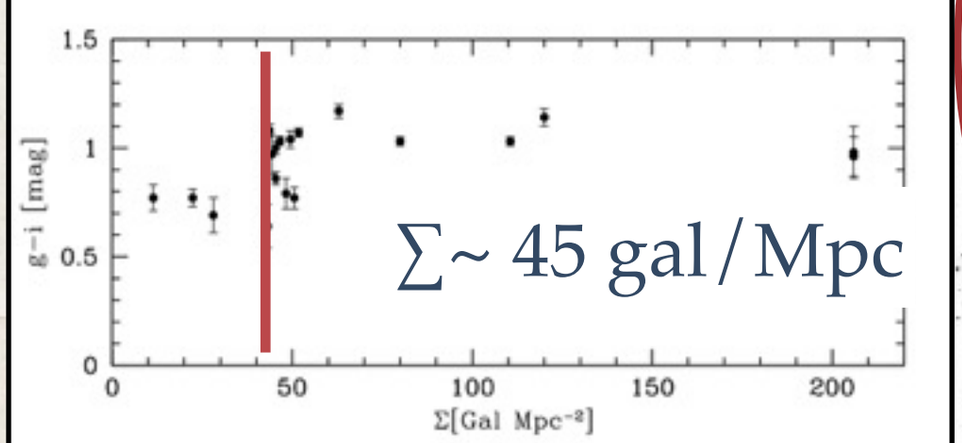




< 1- 3 kpc



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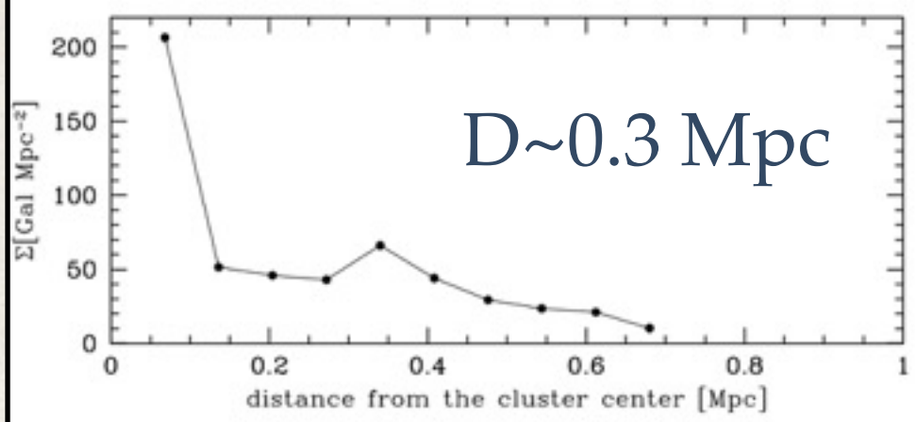

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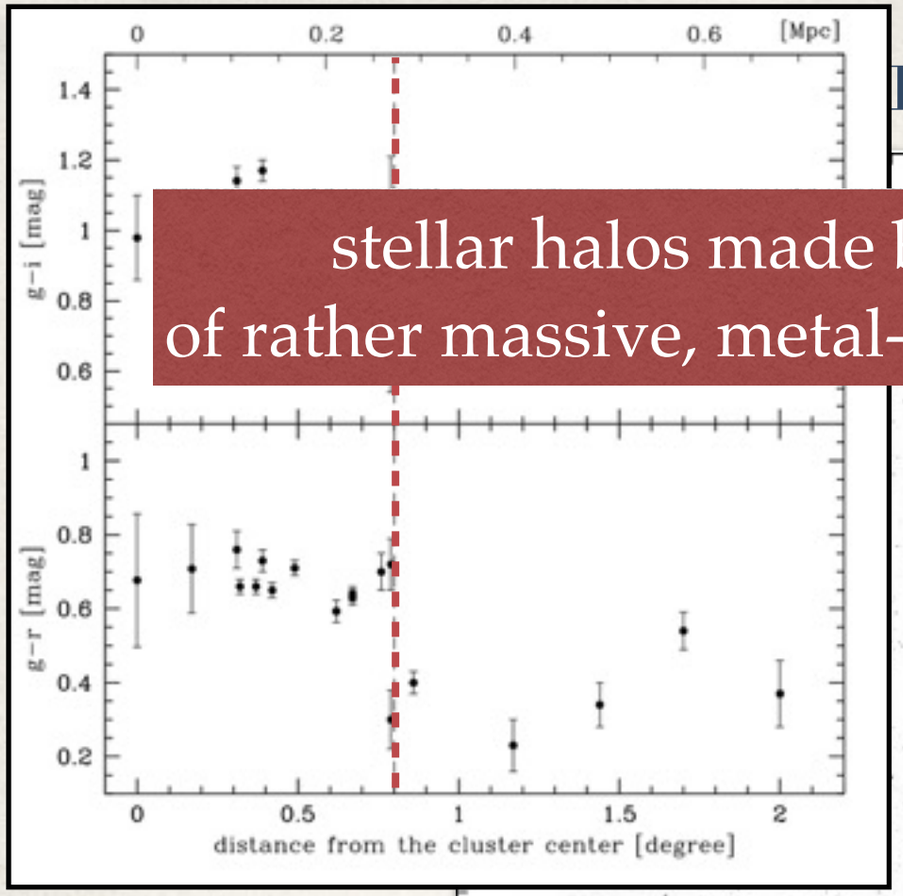
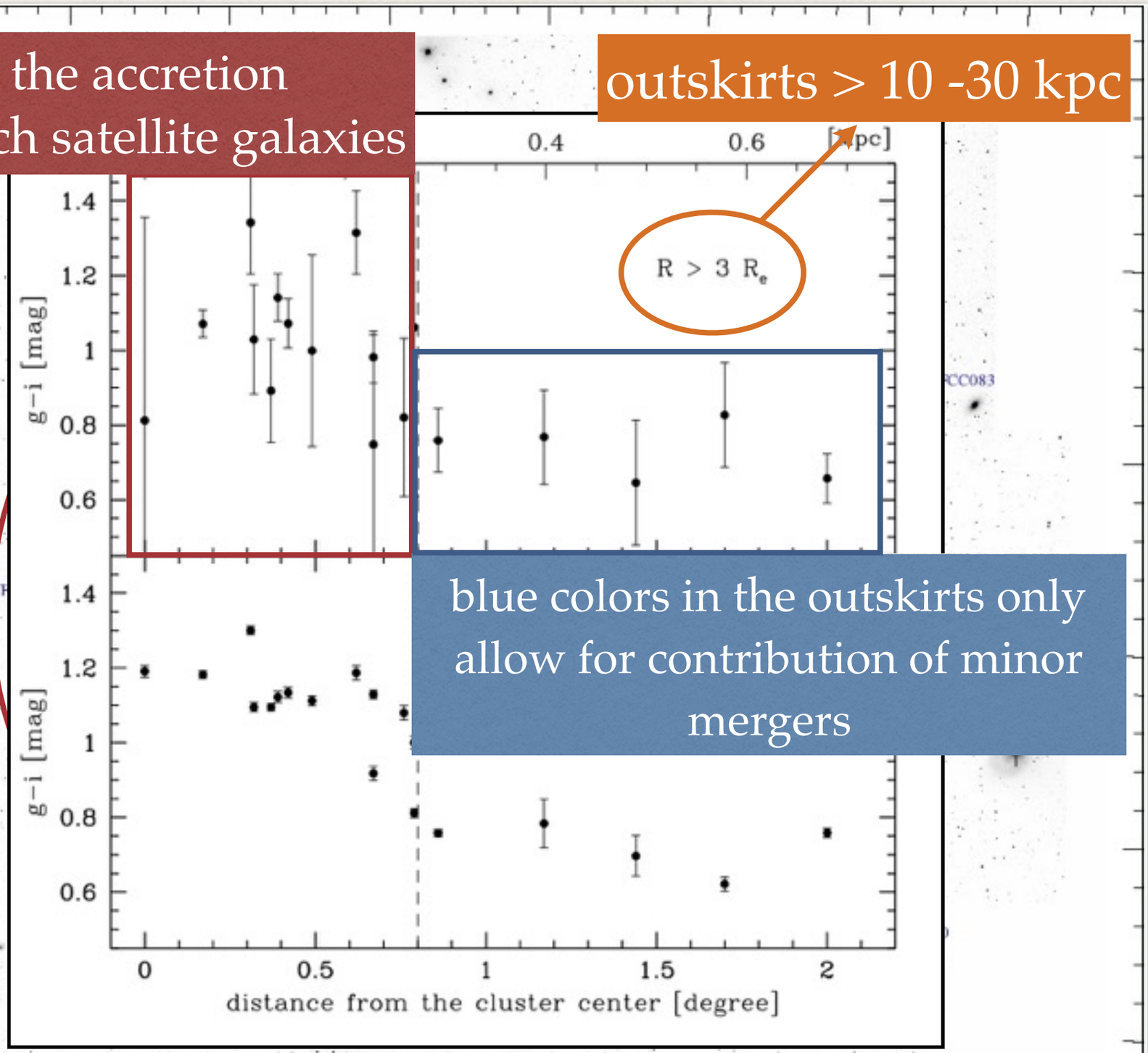
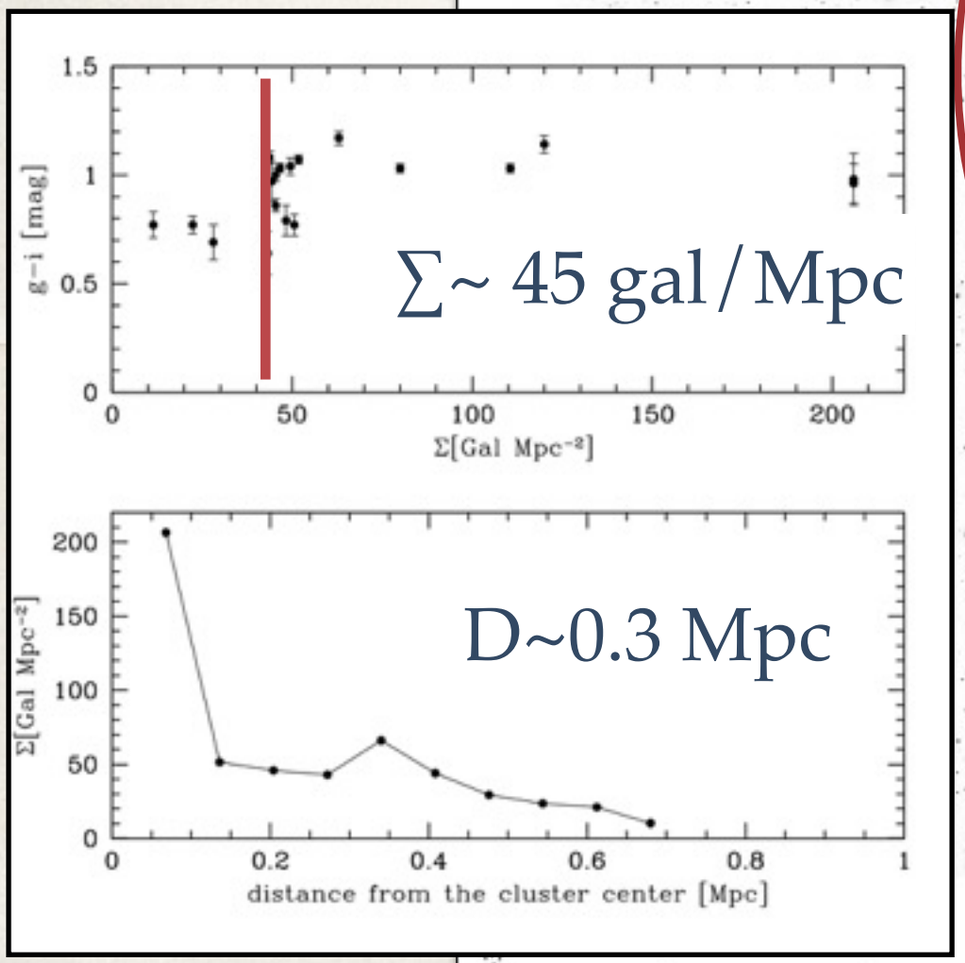
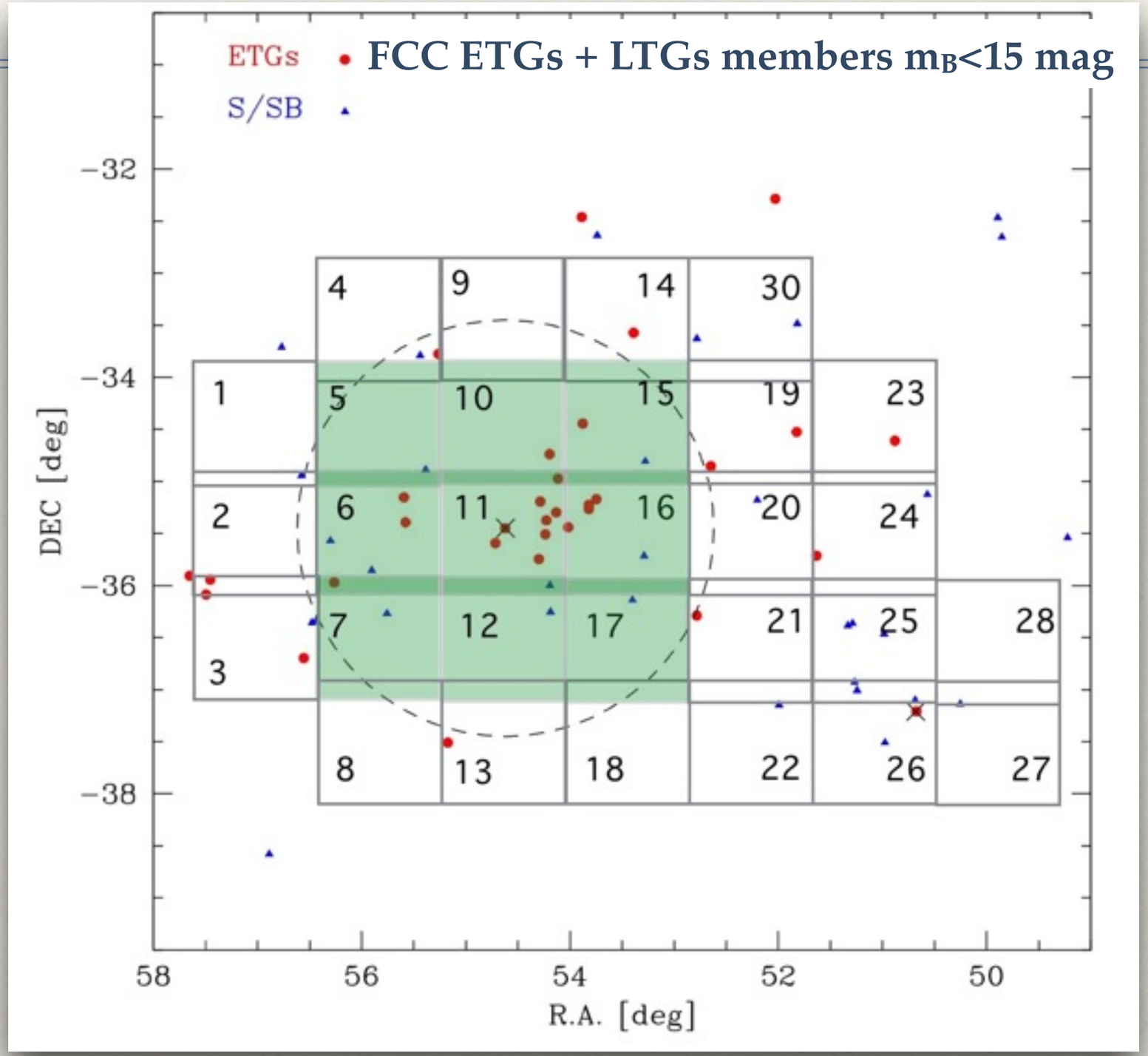




blue colors in the outskirts only allow for contribution of minor mergers



FDS: the SW group



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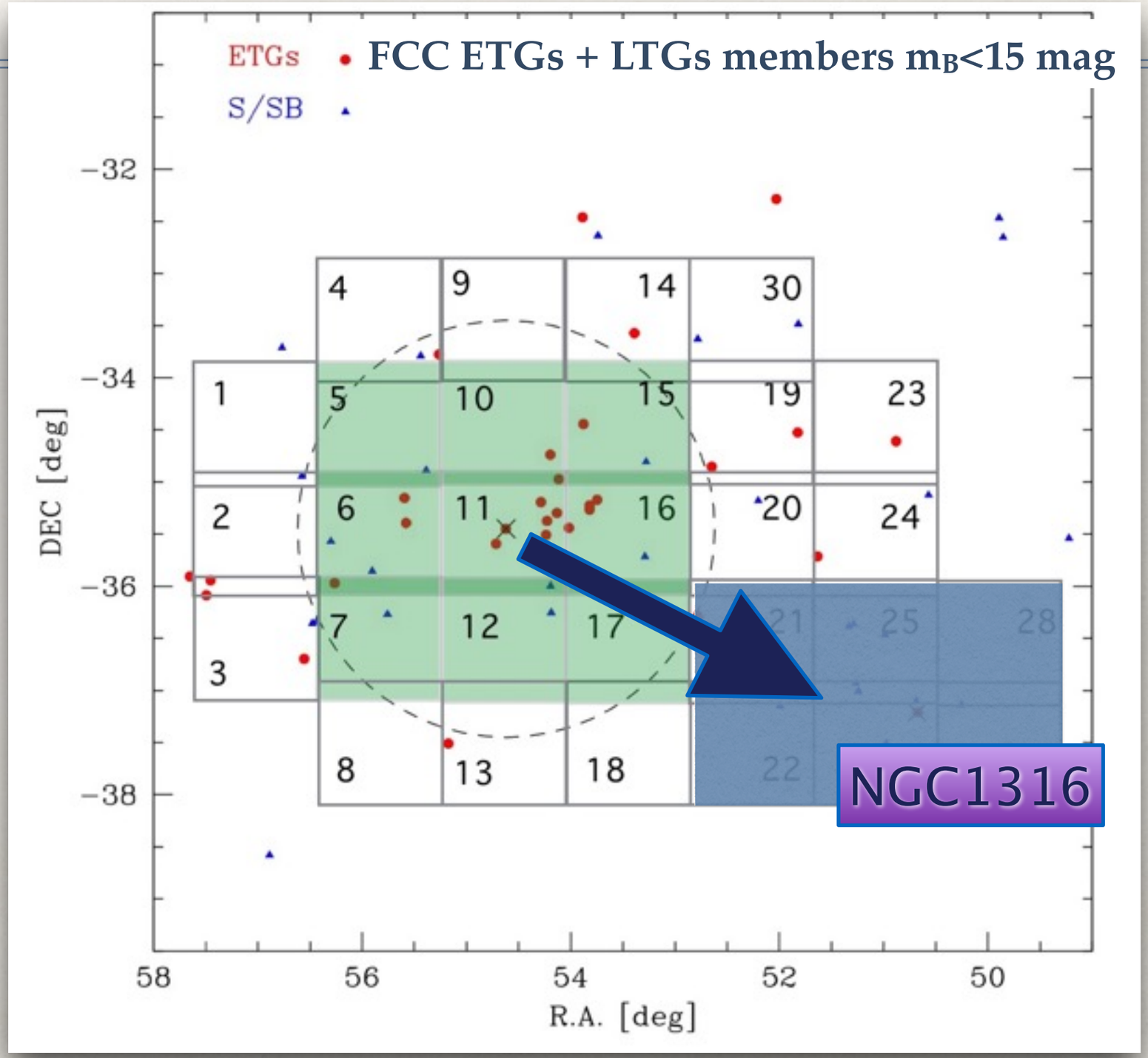
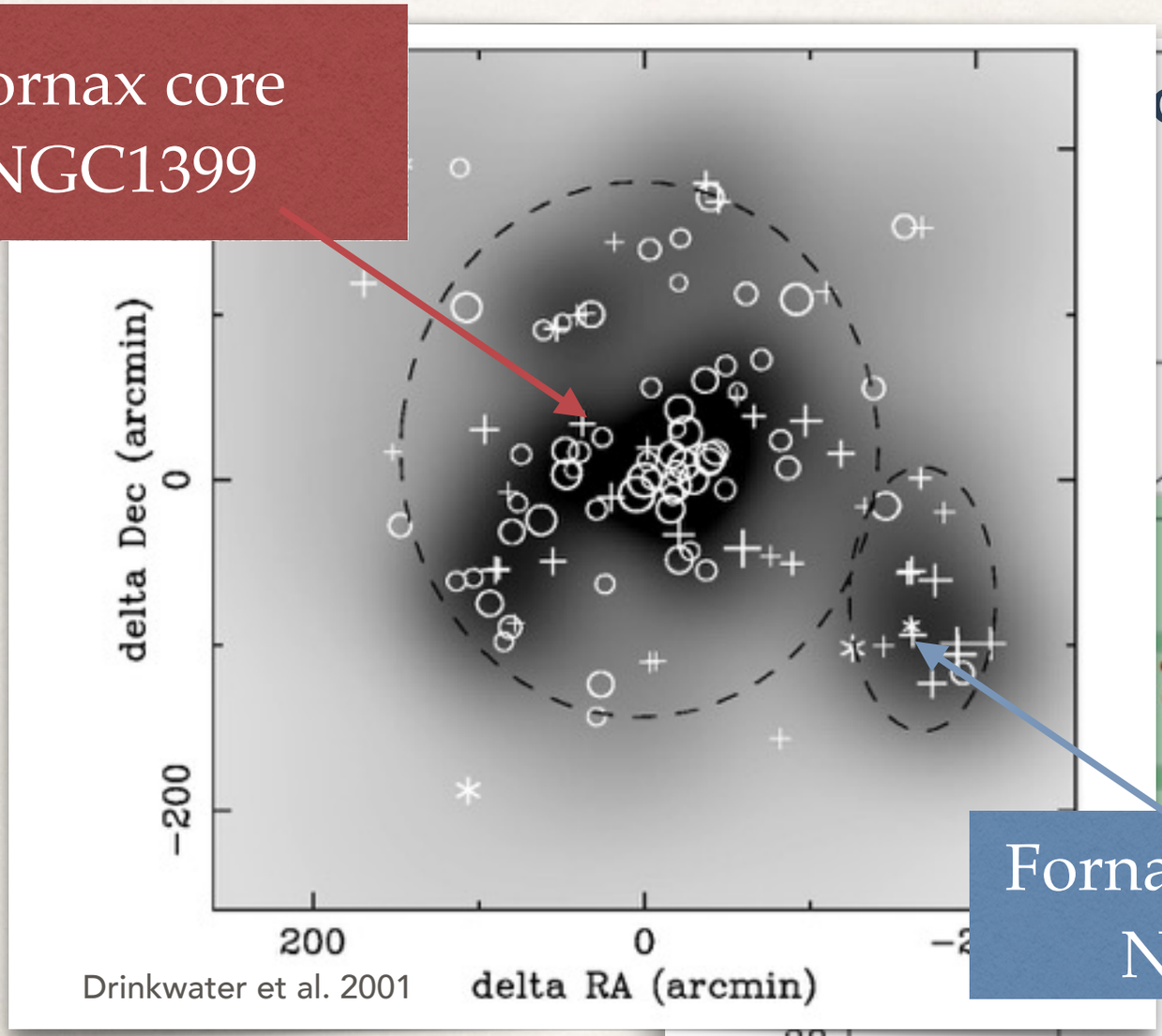
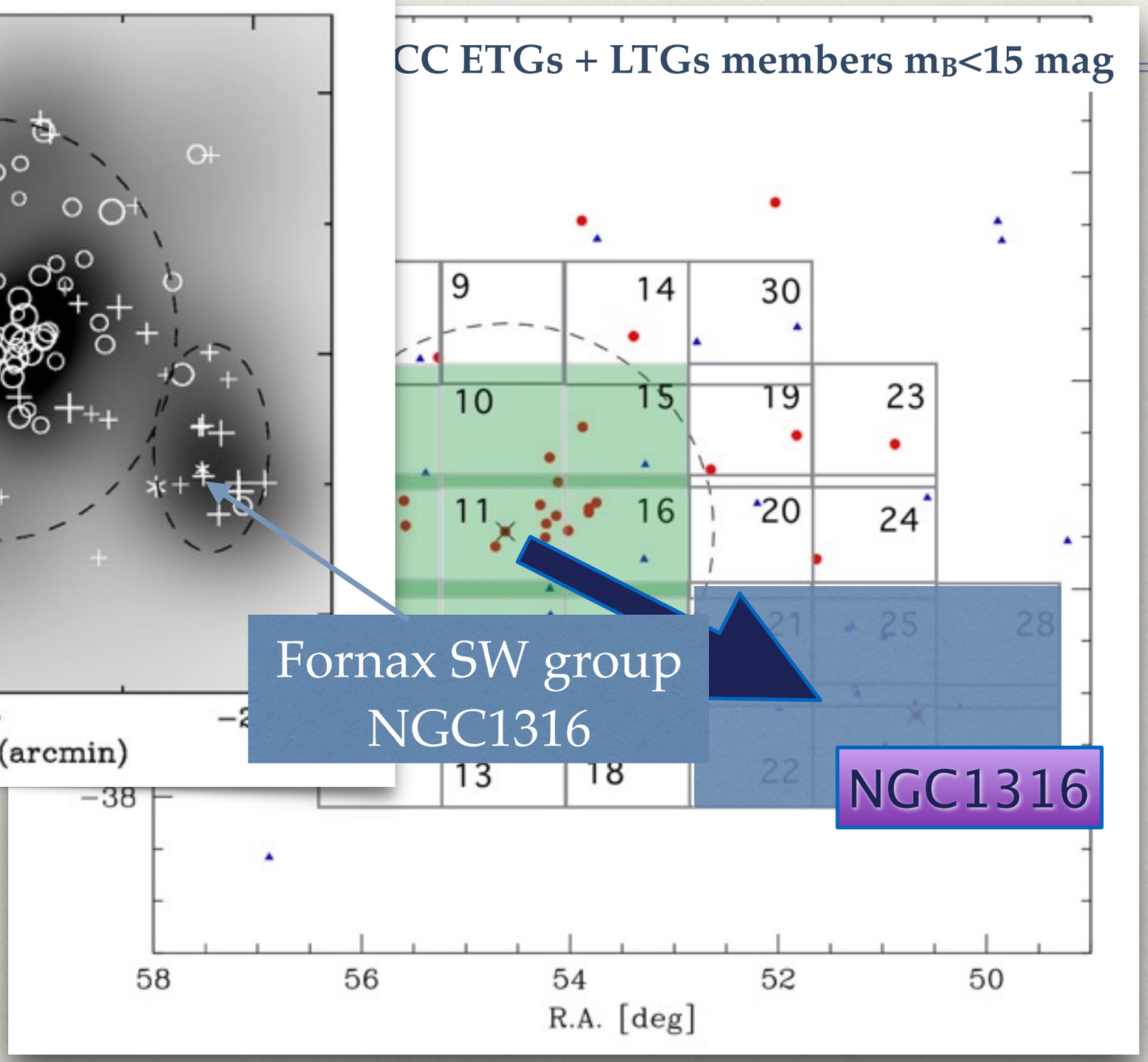


FDS: the SW group

Fornax core
NGC1399



Drinkwater et al. 2001



VST color composite image
https://www.eso.org/public/images/eso1734a/

VST color composite image
https://www.eso.org/public/images/eso1734a/

NGC1316

VST color composite image
https://www.eso.org/public/images/eso1734a/

NGC1326A
NGC1326B
NGC1326
NGC1316C
NGC1341
NGC1317
NGC1310
FCC028
NGC1316

VST color composite image
https://www.eso.org/public/images/eso1734a/

NGC1326A
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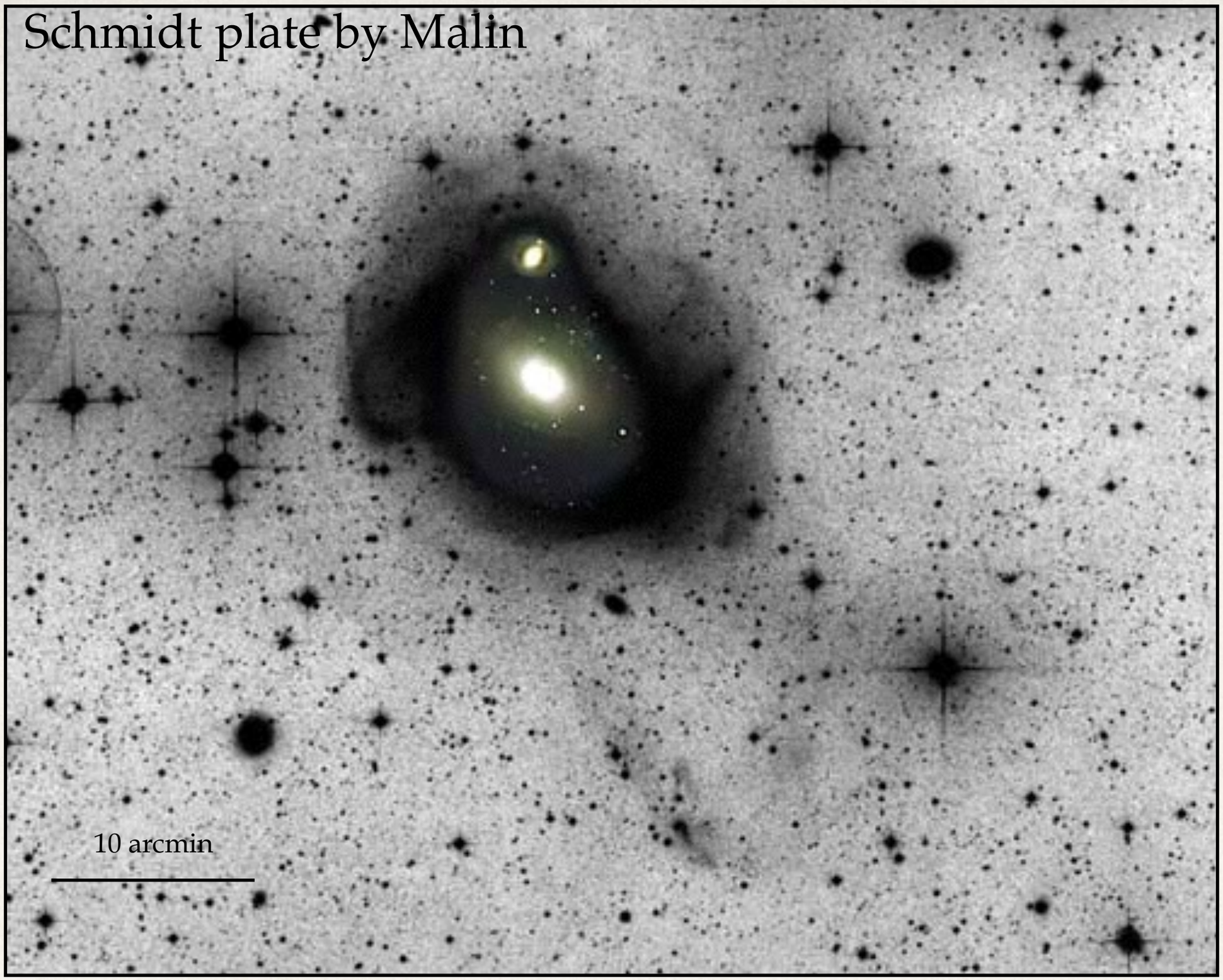
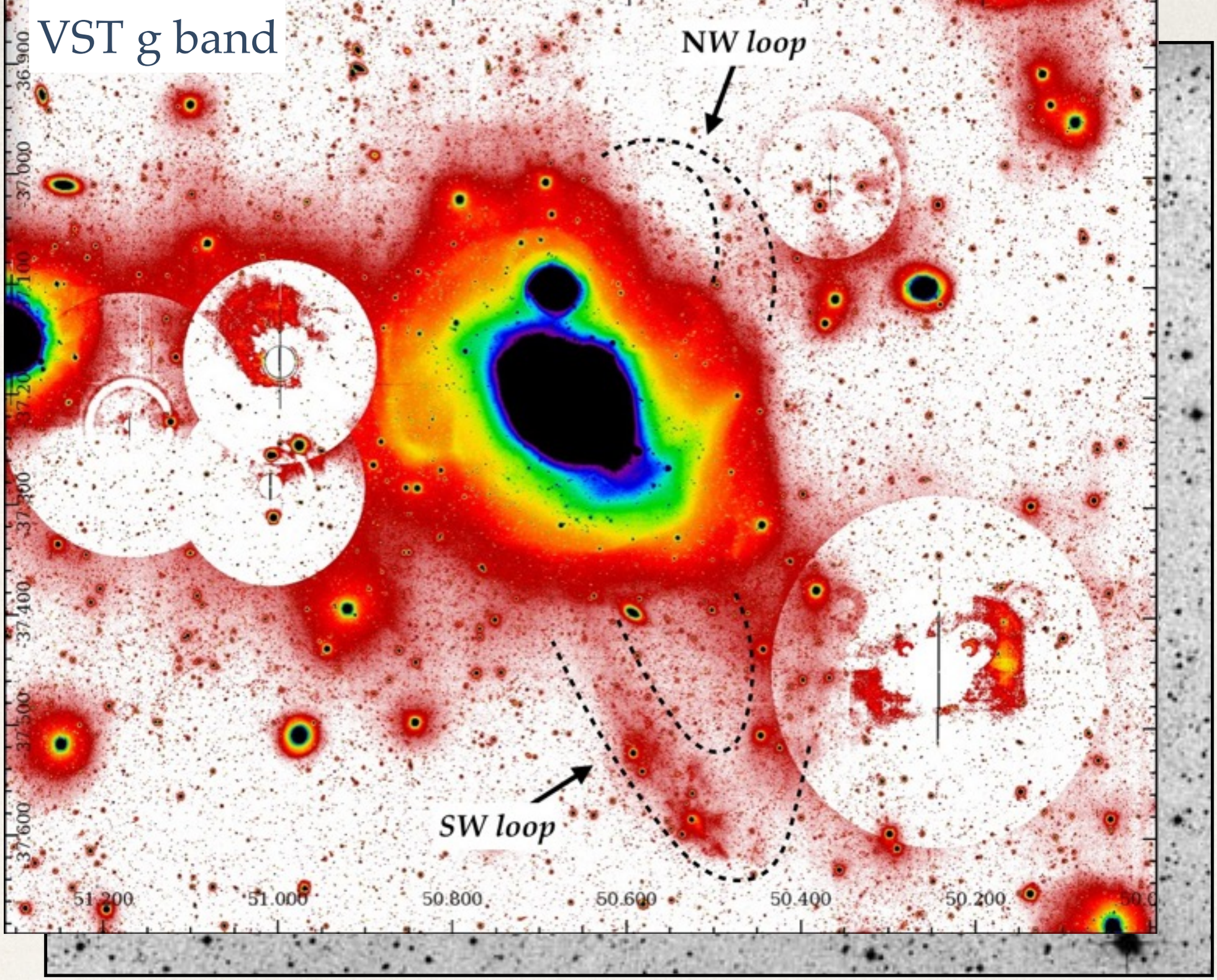


Fornax A: a two-phase assembly caught in act

Iodice et al. 2017, ApJ, 839, 21



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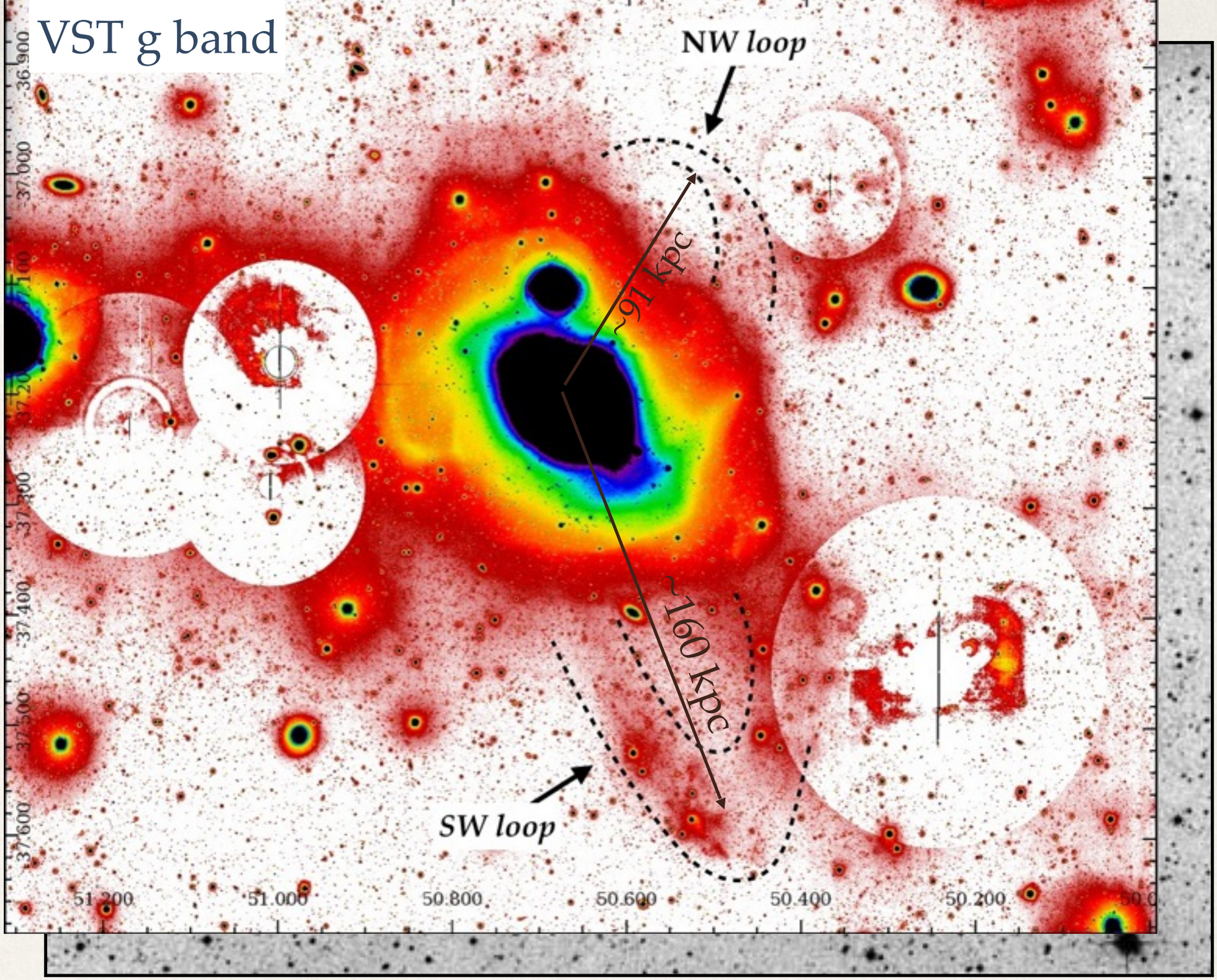
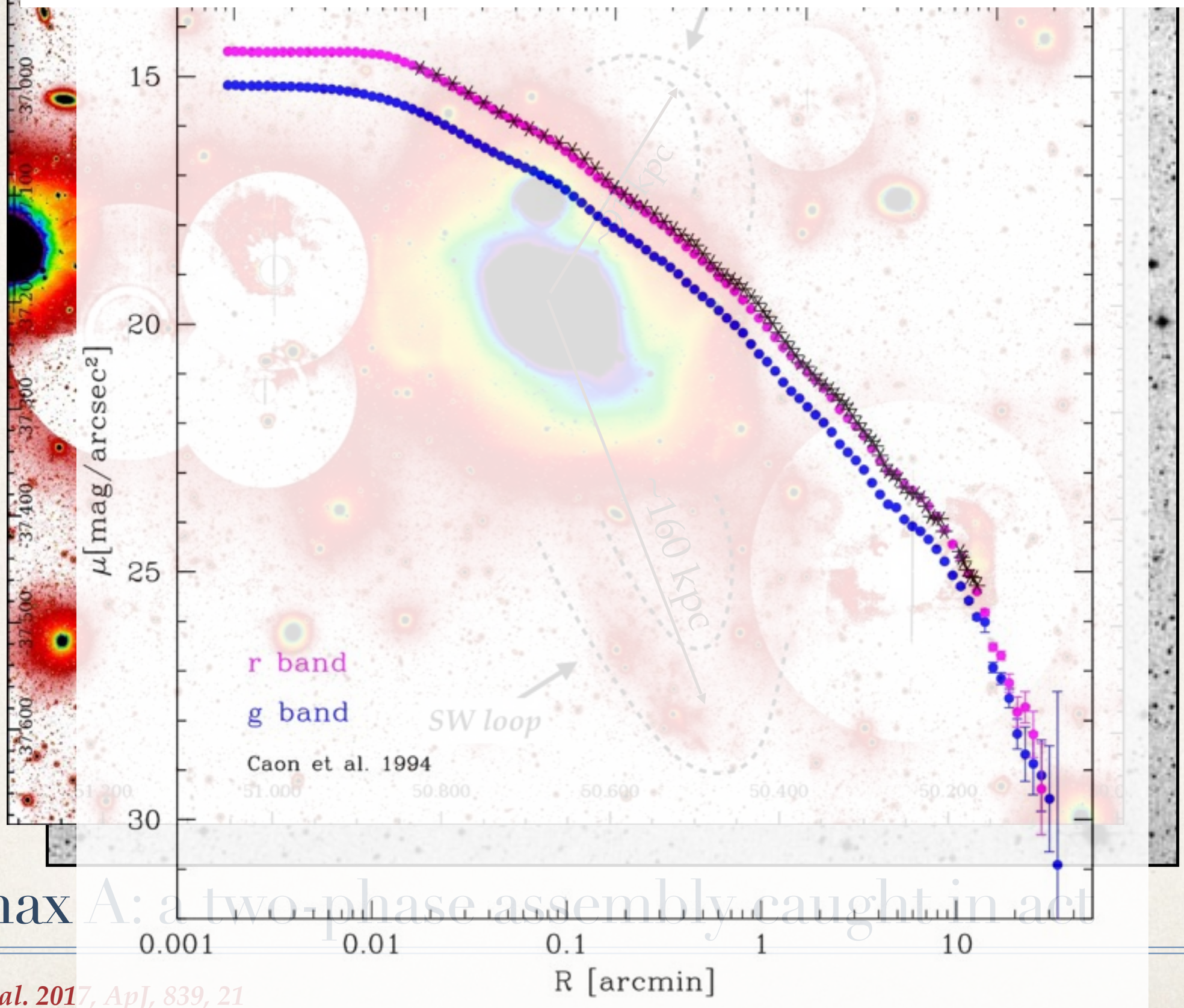


Fornax A: a two-phase assembly caught in act

Iodice et al. 2017, ApJ, 839, 21

surface photometry out to 33 arcmin (~200 kpc ~15R_e)



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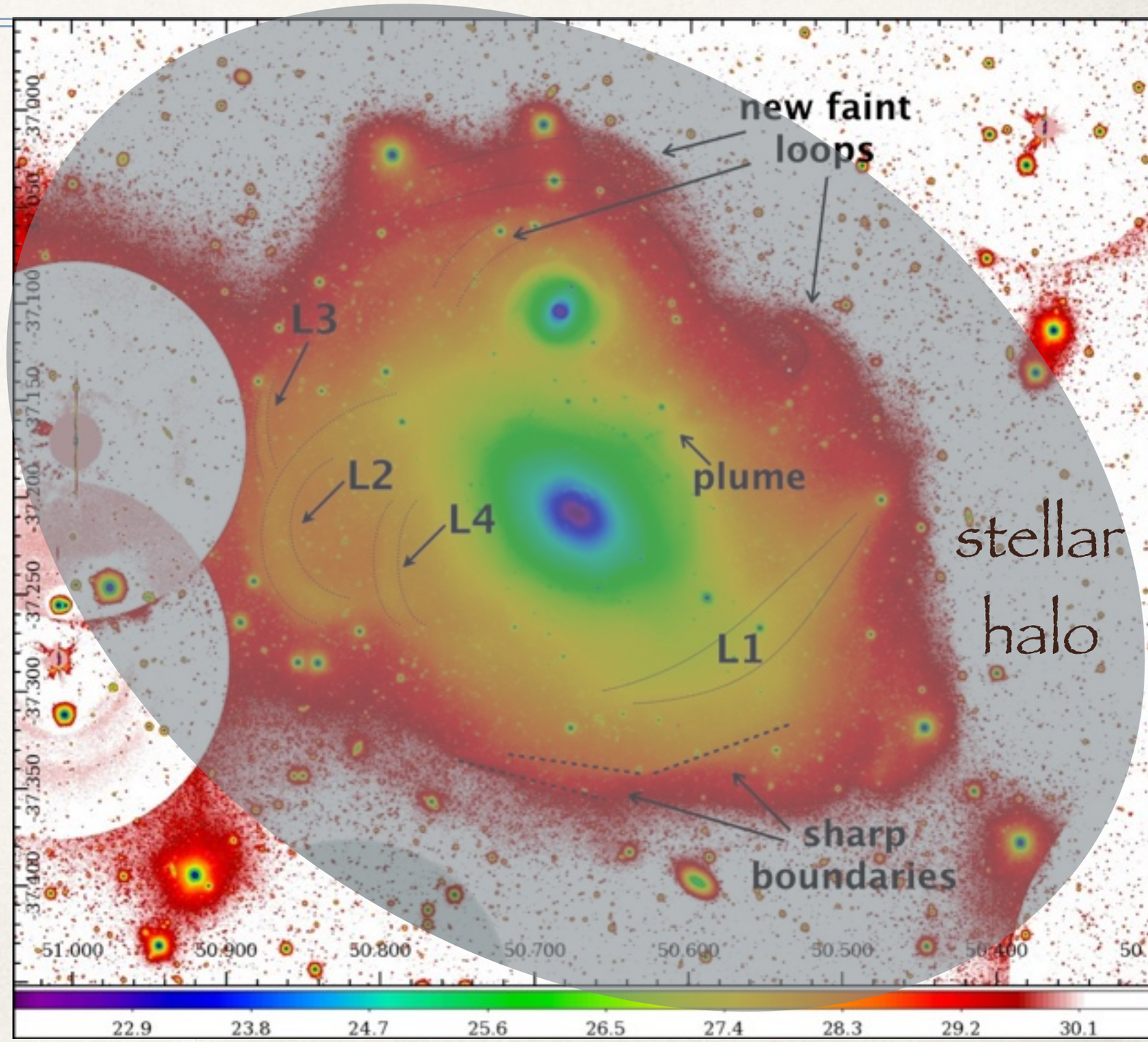
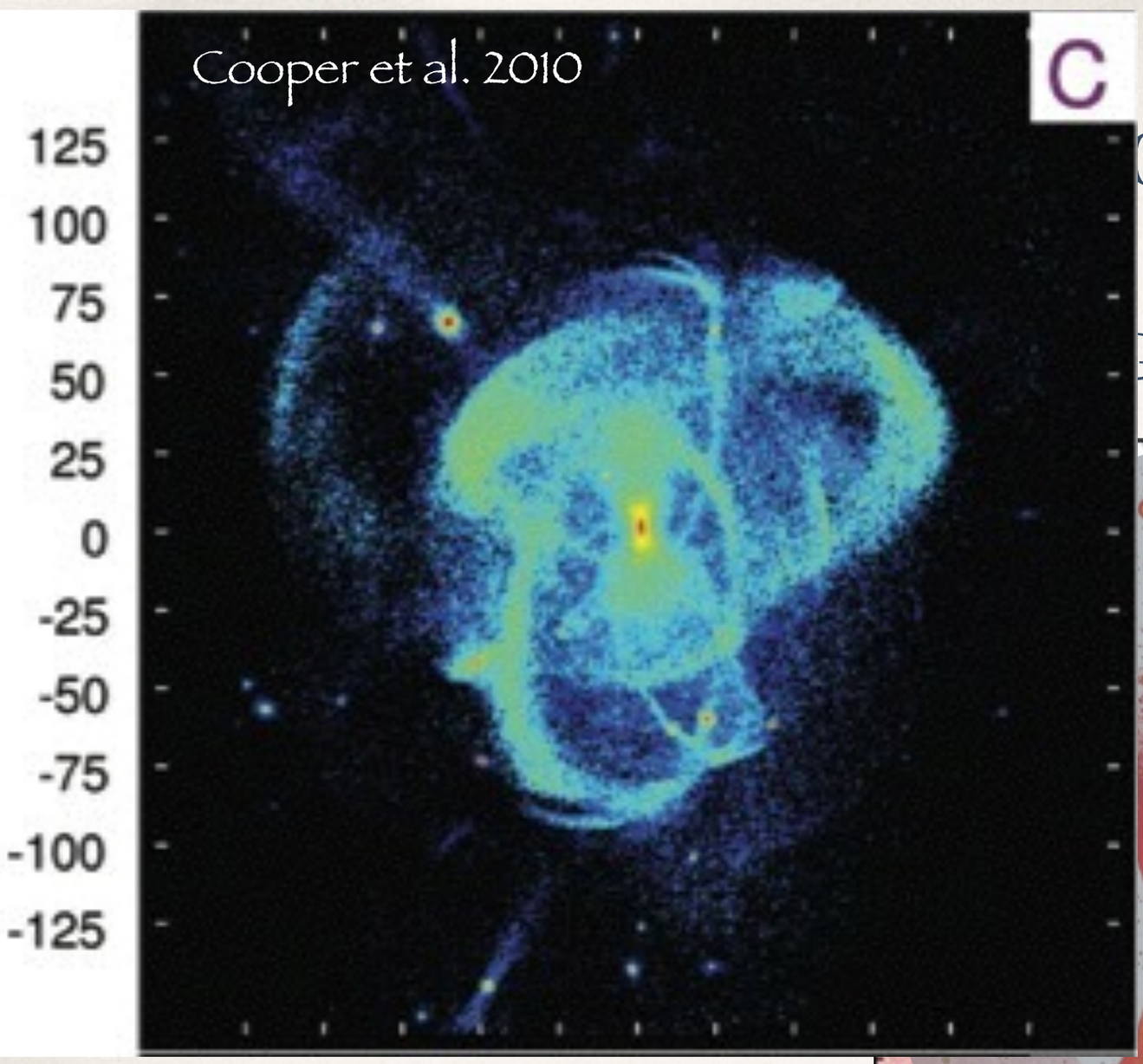
Observations *vs* theoretical predictions

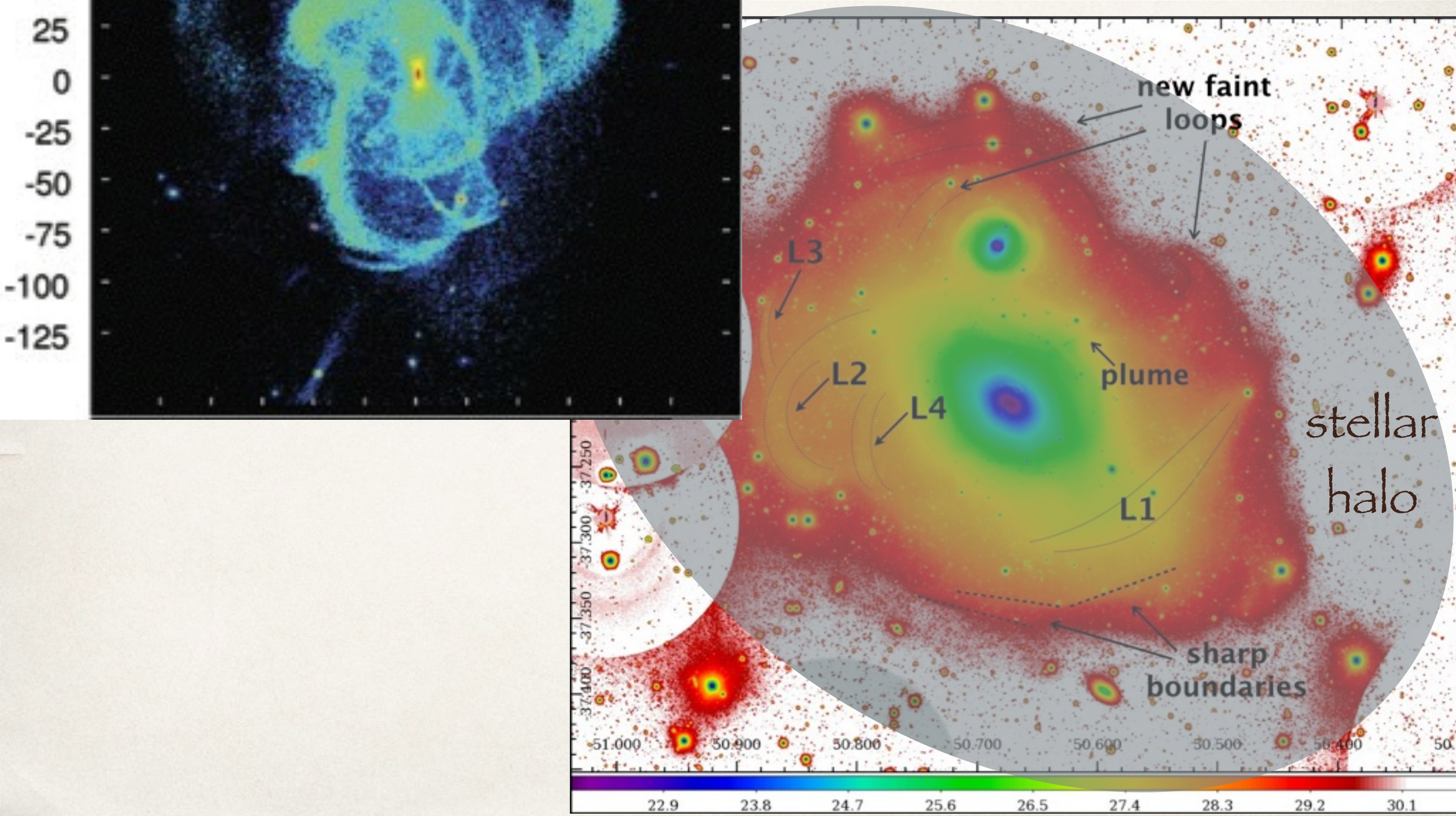
the build up of the stellar halo in NGC1316

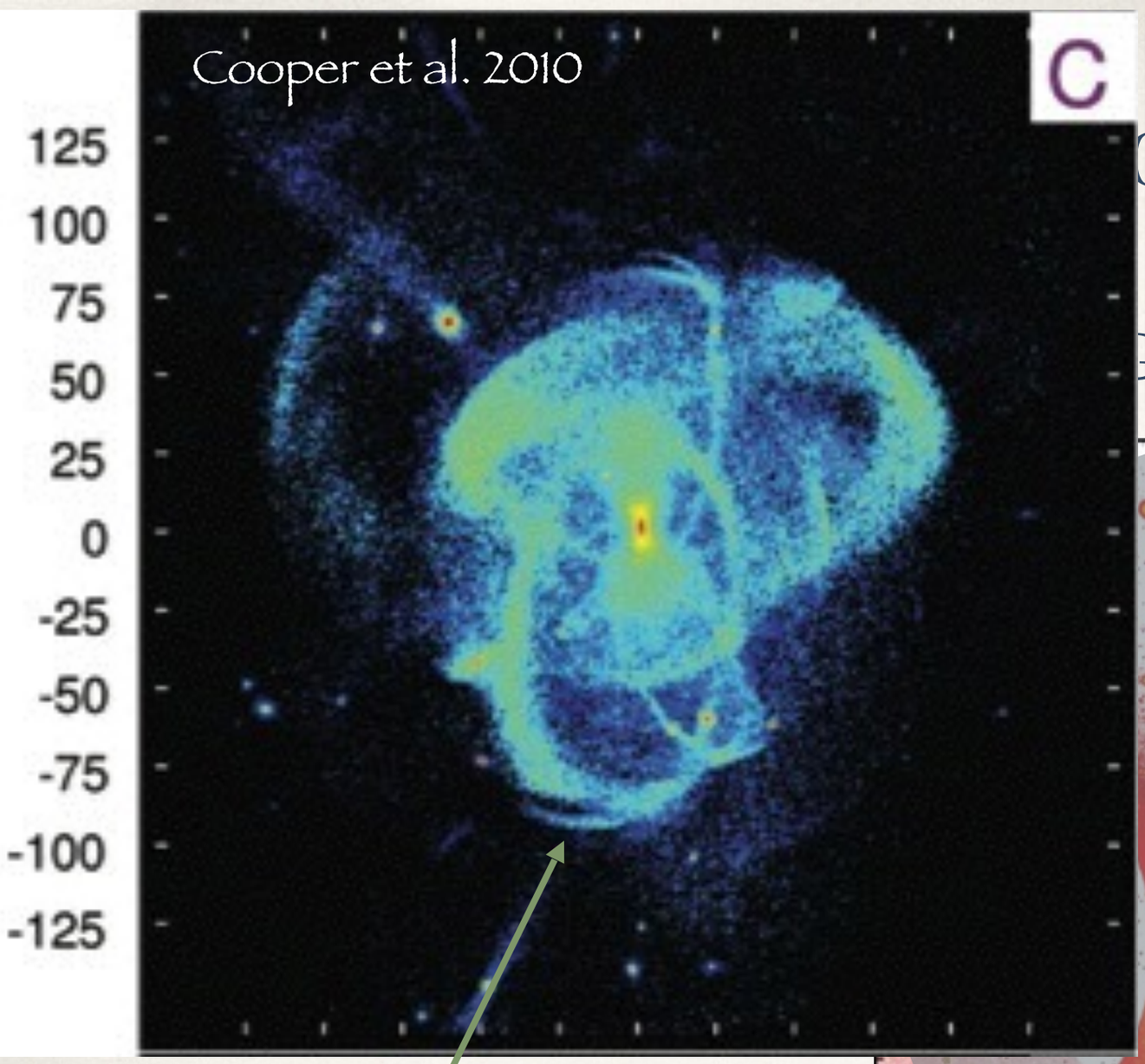




stellar halo in NGC1316 formed by gradual accretion of several progenitors:

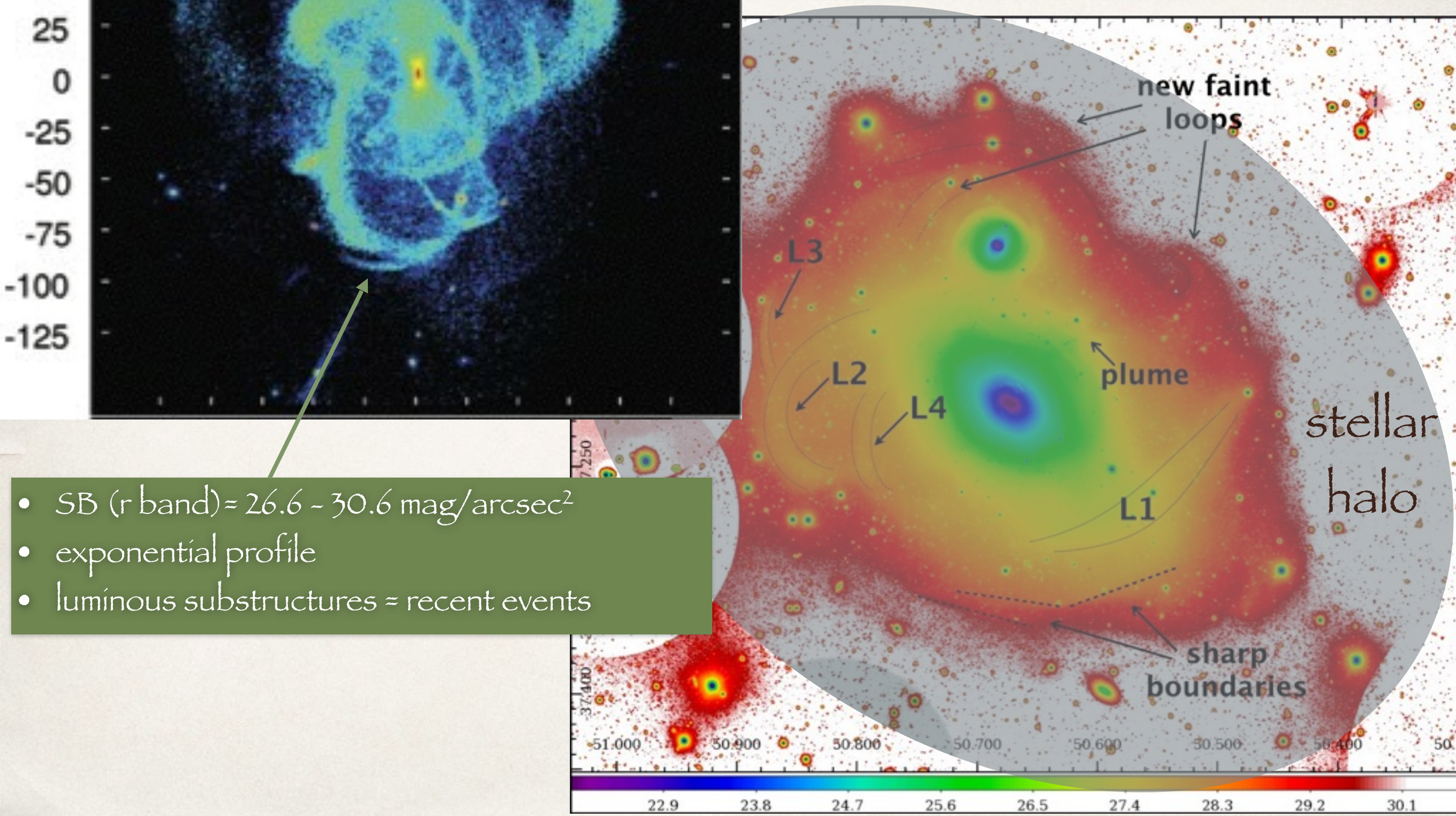
similar morphology + total extension



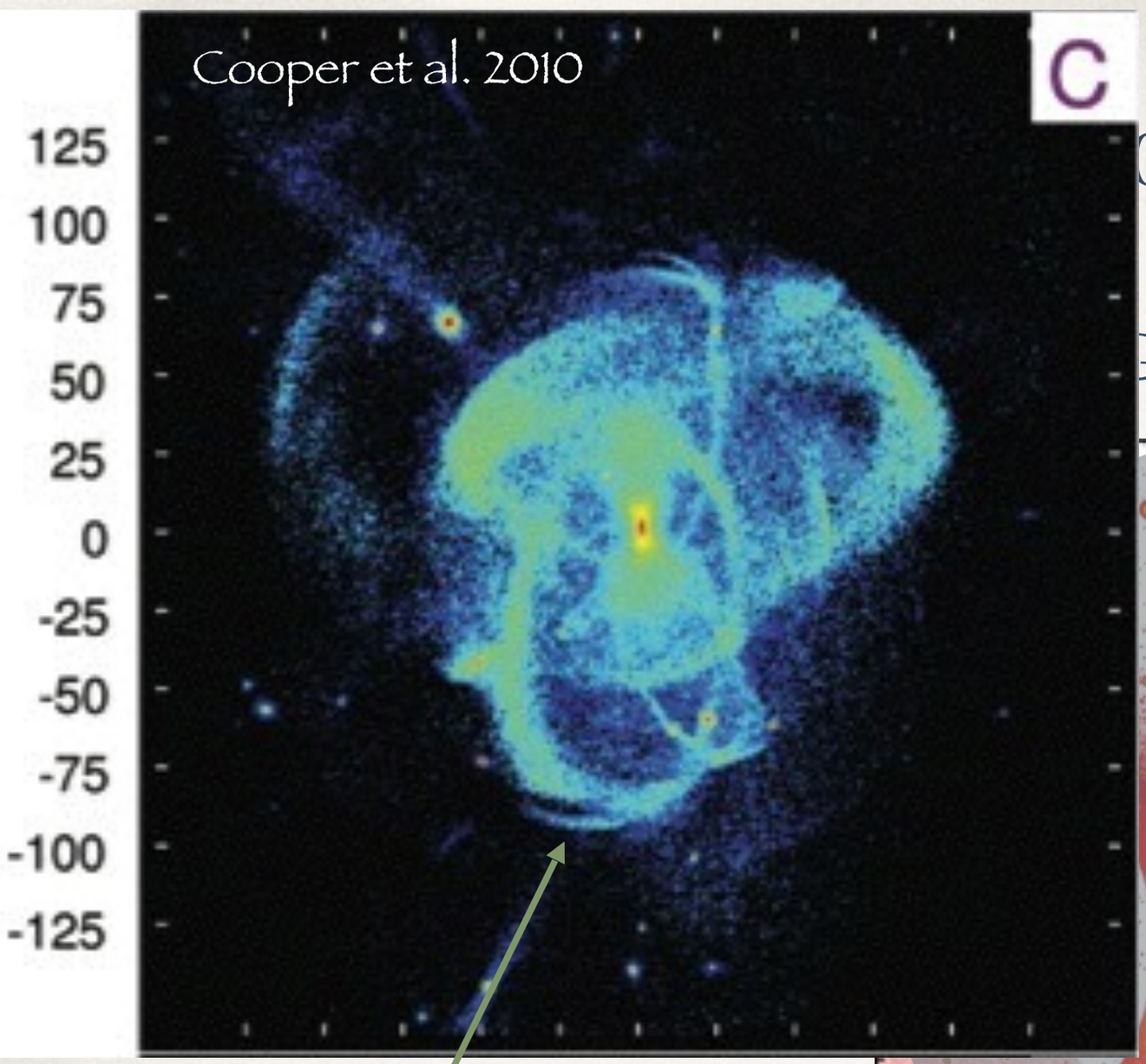


stellar halo in NGC1316 formed by gradual accretion of several progenitors:

similar morphology + total extension



- SB (r band) = 26.6 - 30.6 mag/arcsec^2
- exponential profile
- luminous substructures = recent events



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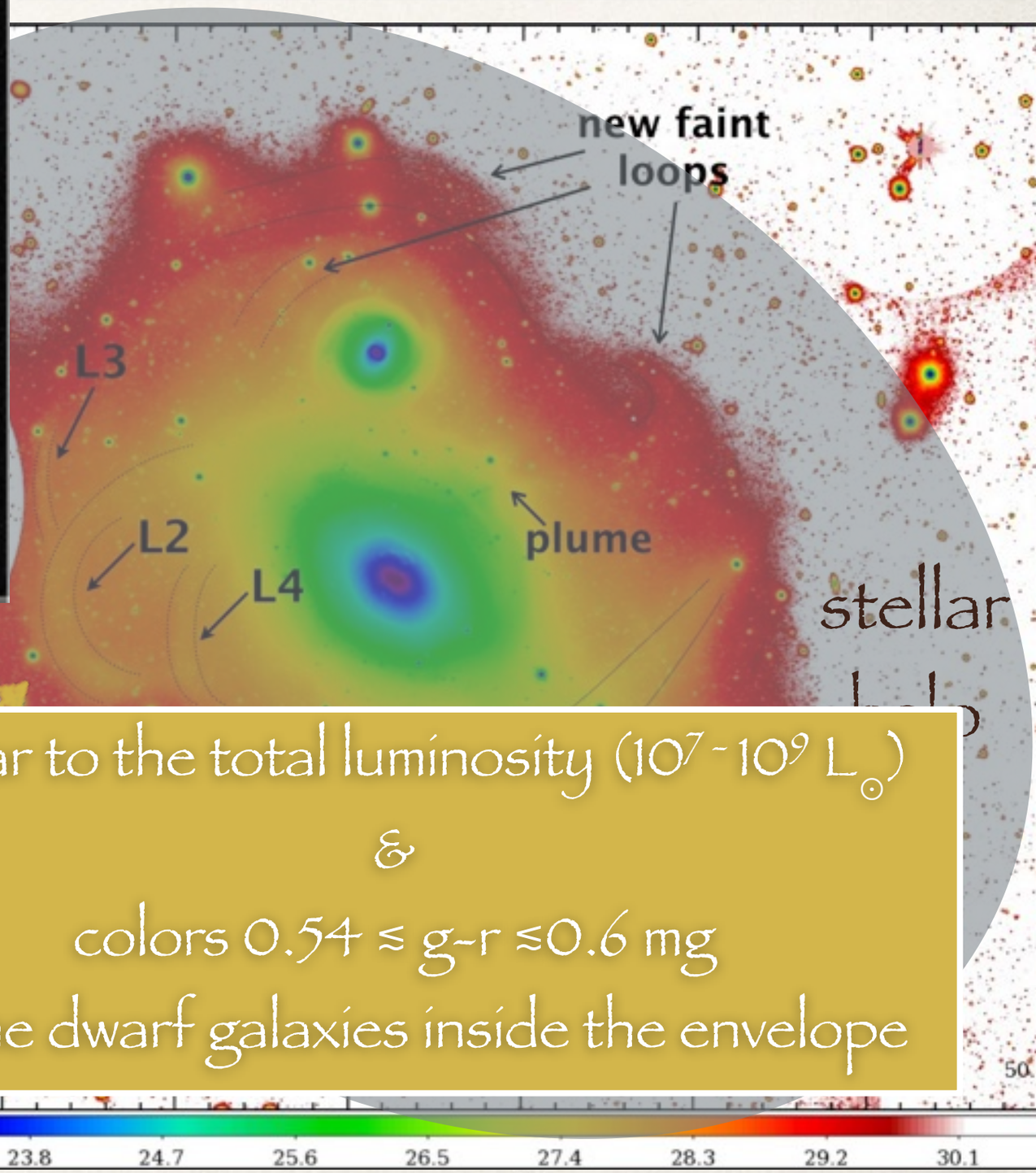

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$L_{(L2+L3)} = 7\,10^9\ L_\odot$

g-r =0.54 mag

similar to the total luminosity (10^7 - 10^9 $L_\odot$)

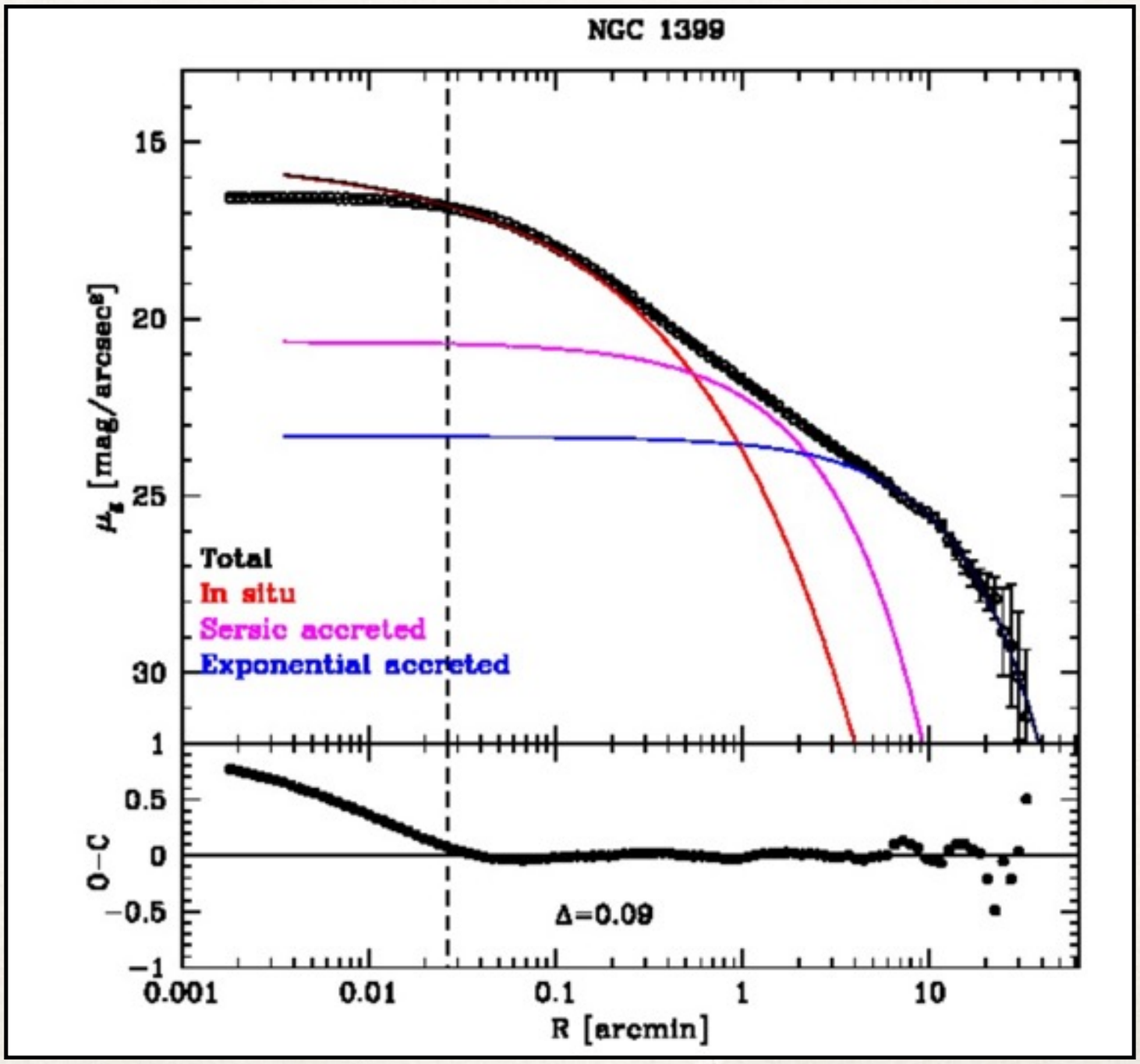
&

colors 0.54 ≤ g-r ≤0.6 mg

of the dwarf galaxies inside the envelope

Observations *vs* theoretical predictions

Fit of the SB profiles
to identify the main components dominating the galaxy light



Spavone et al. 2017, A&A, 603, 38

Observations *vs* theoretical predictions

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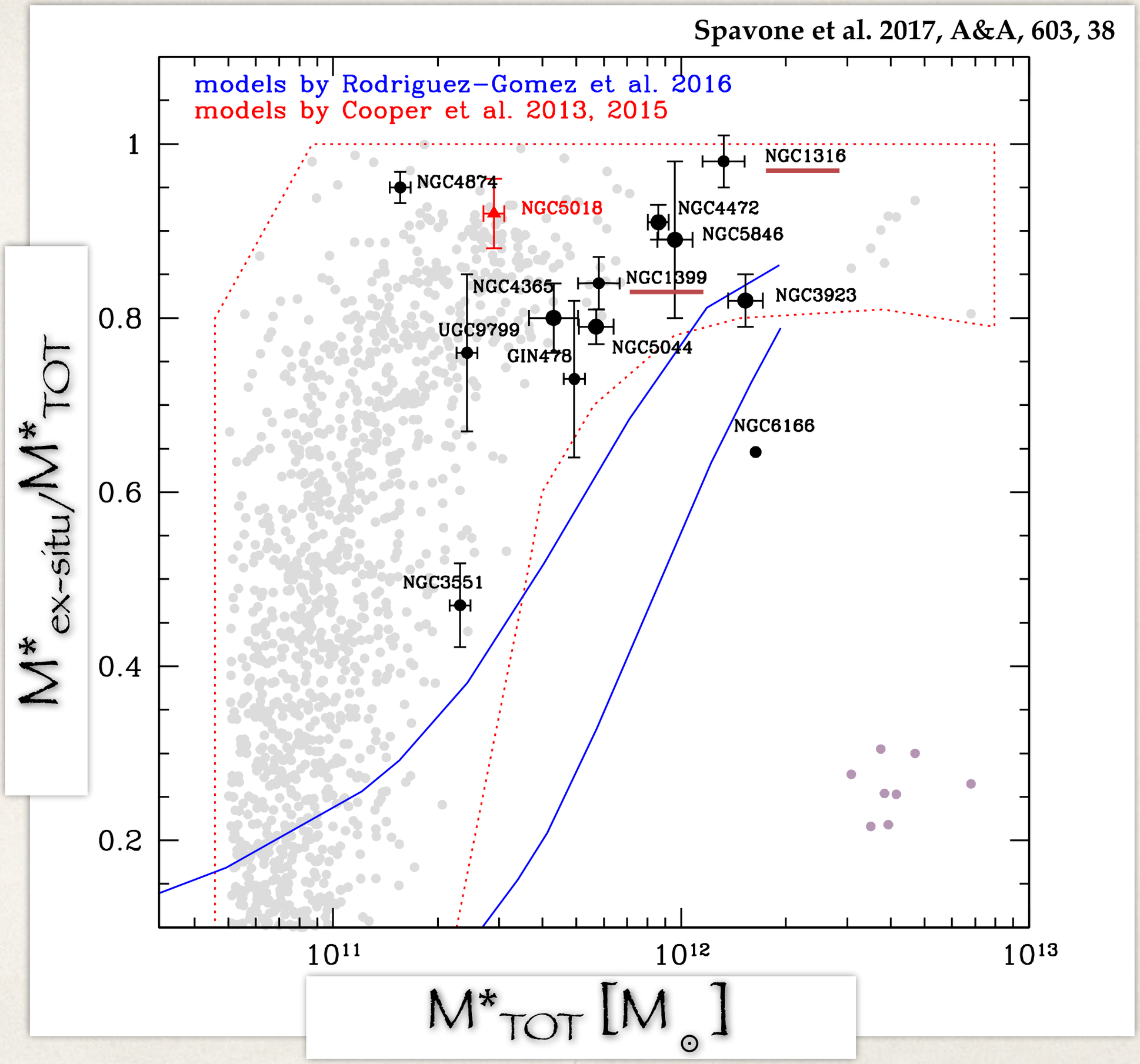

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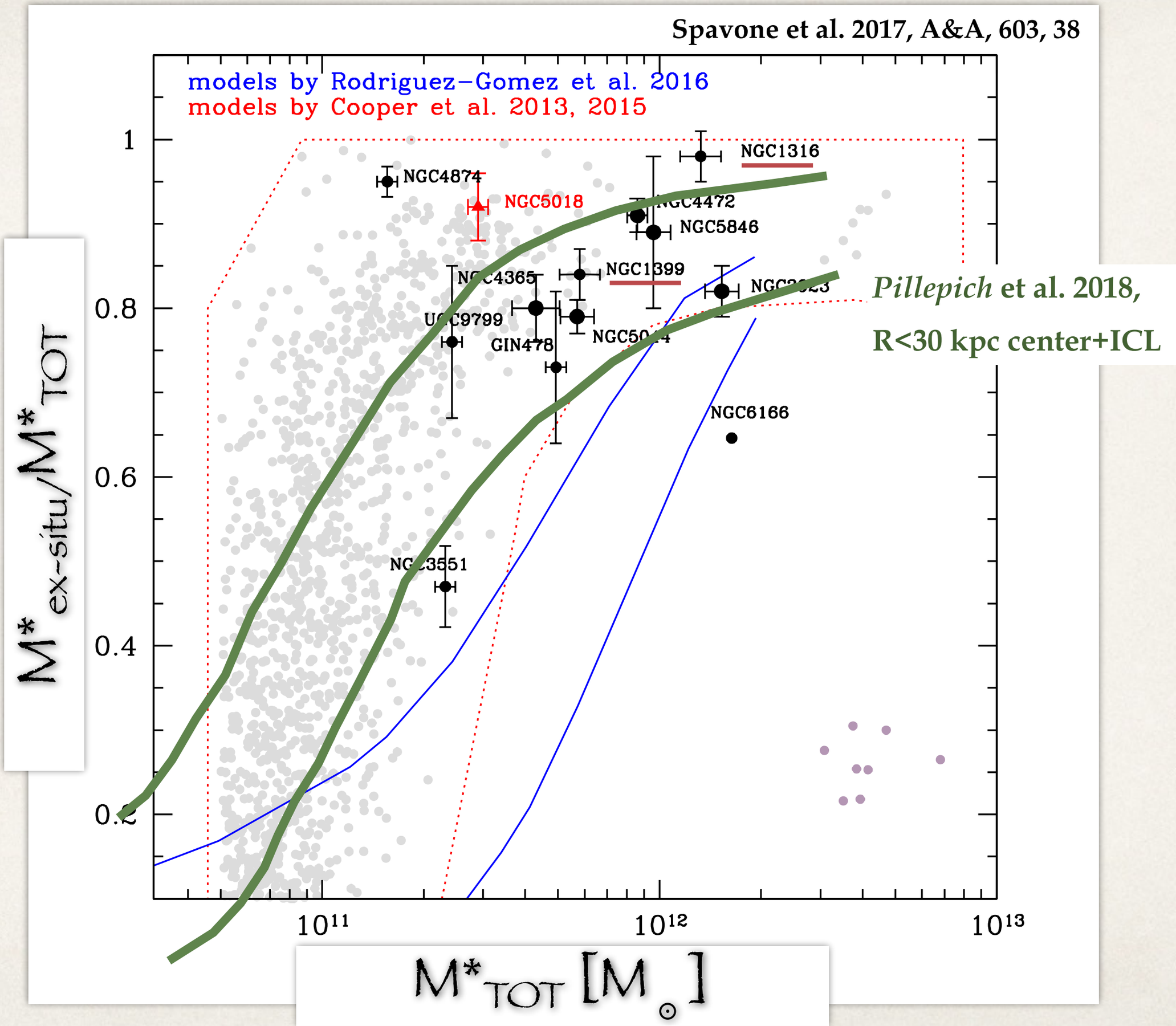

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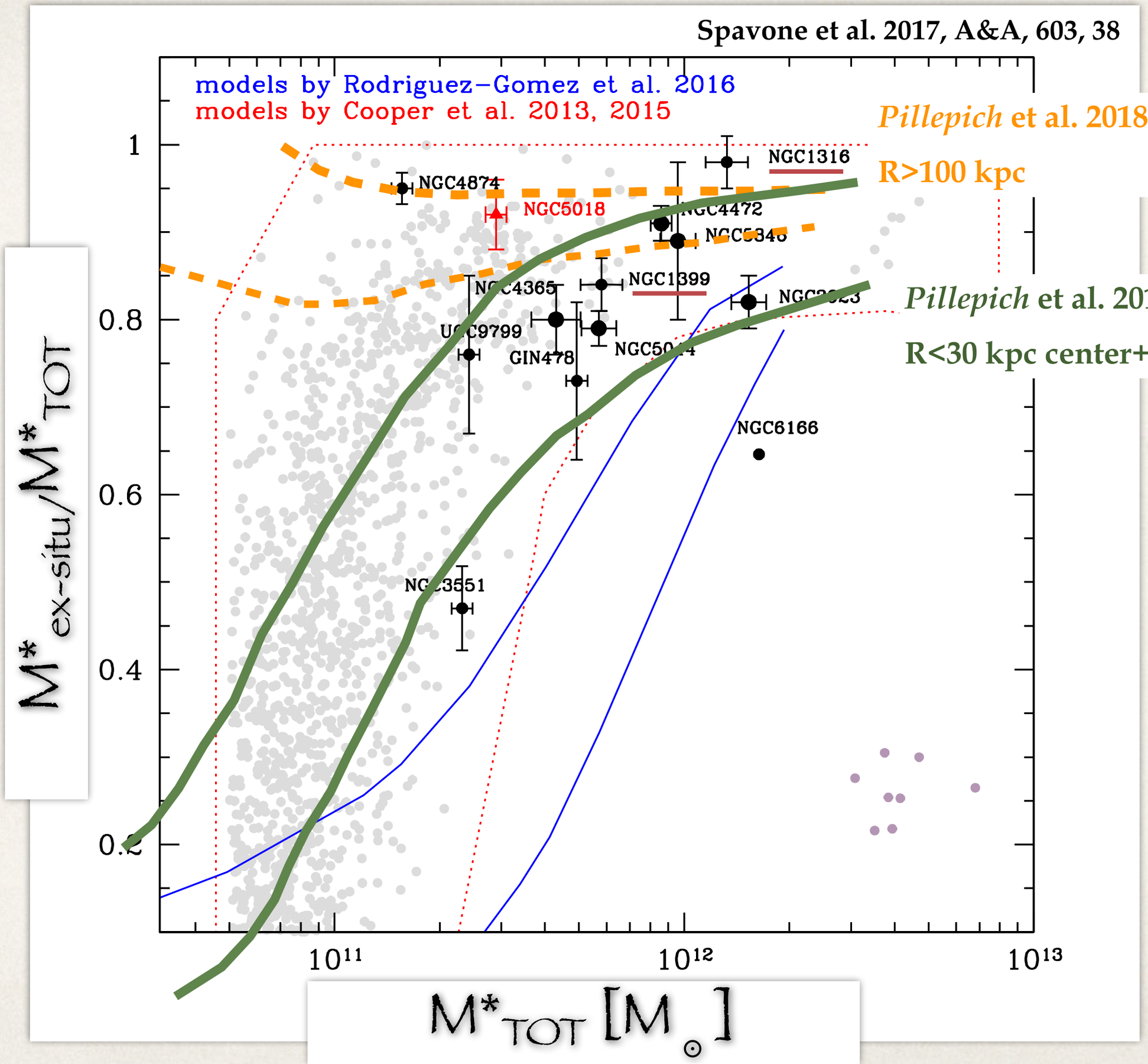
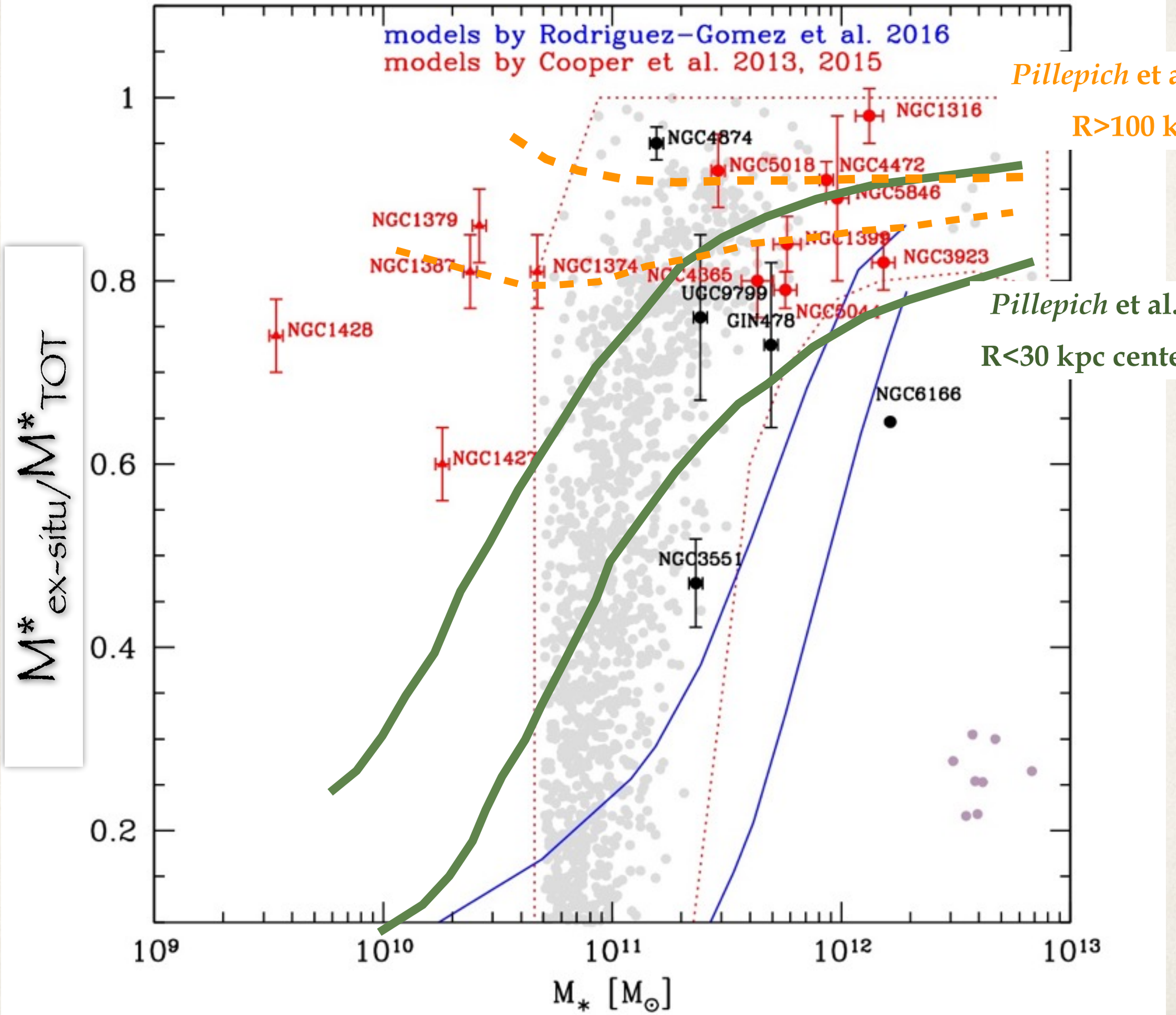




Pillepich et al. 2018,

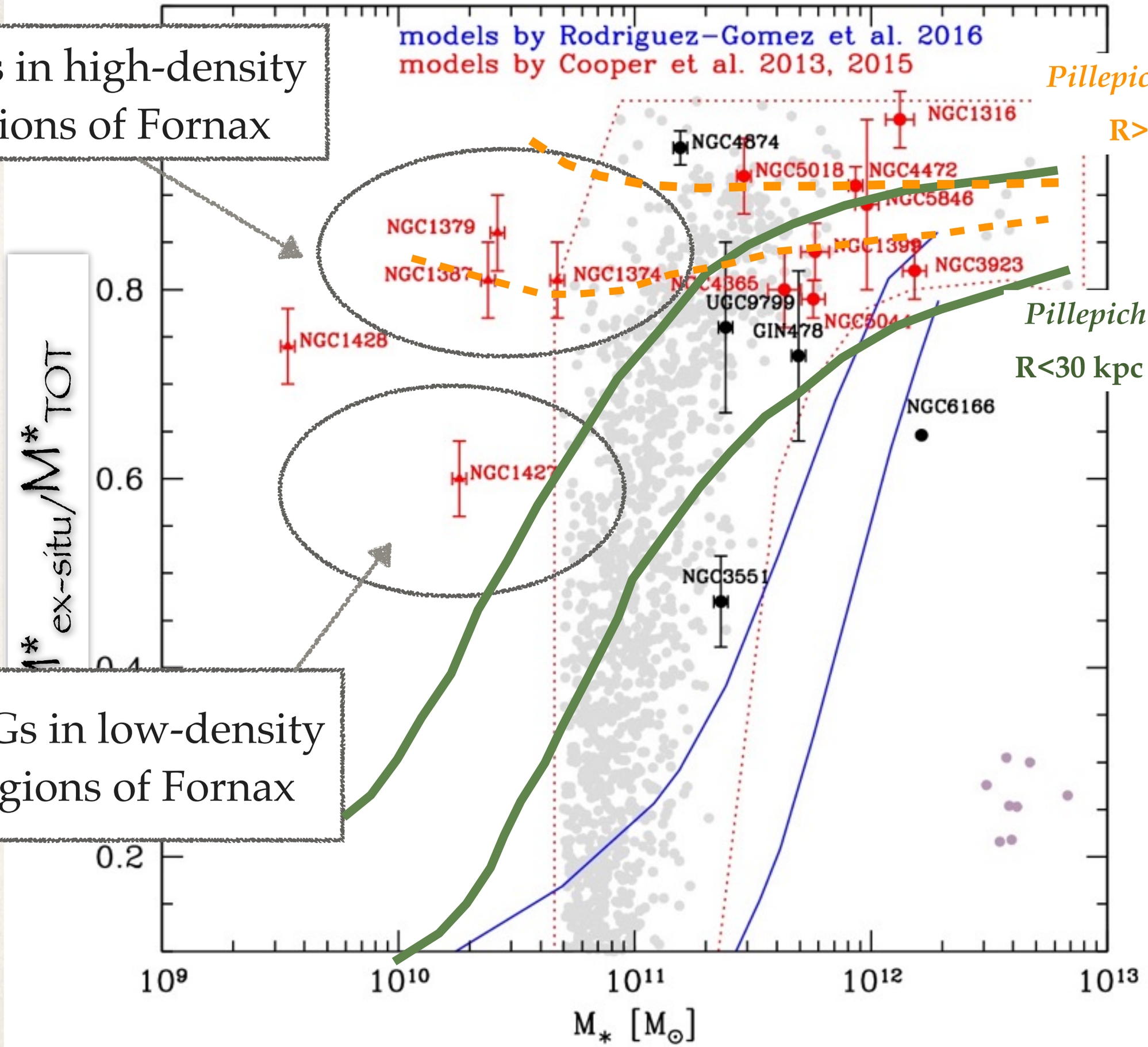
R>100 kpc

Pillepich et al. 2018,

R<30 kpc center+ICL

ETGs in high-density regions of Fornax

ETGs in low-density regions of Fornax



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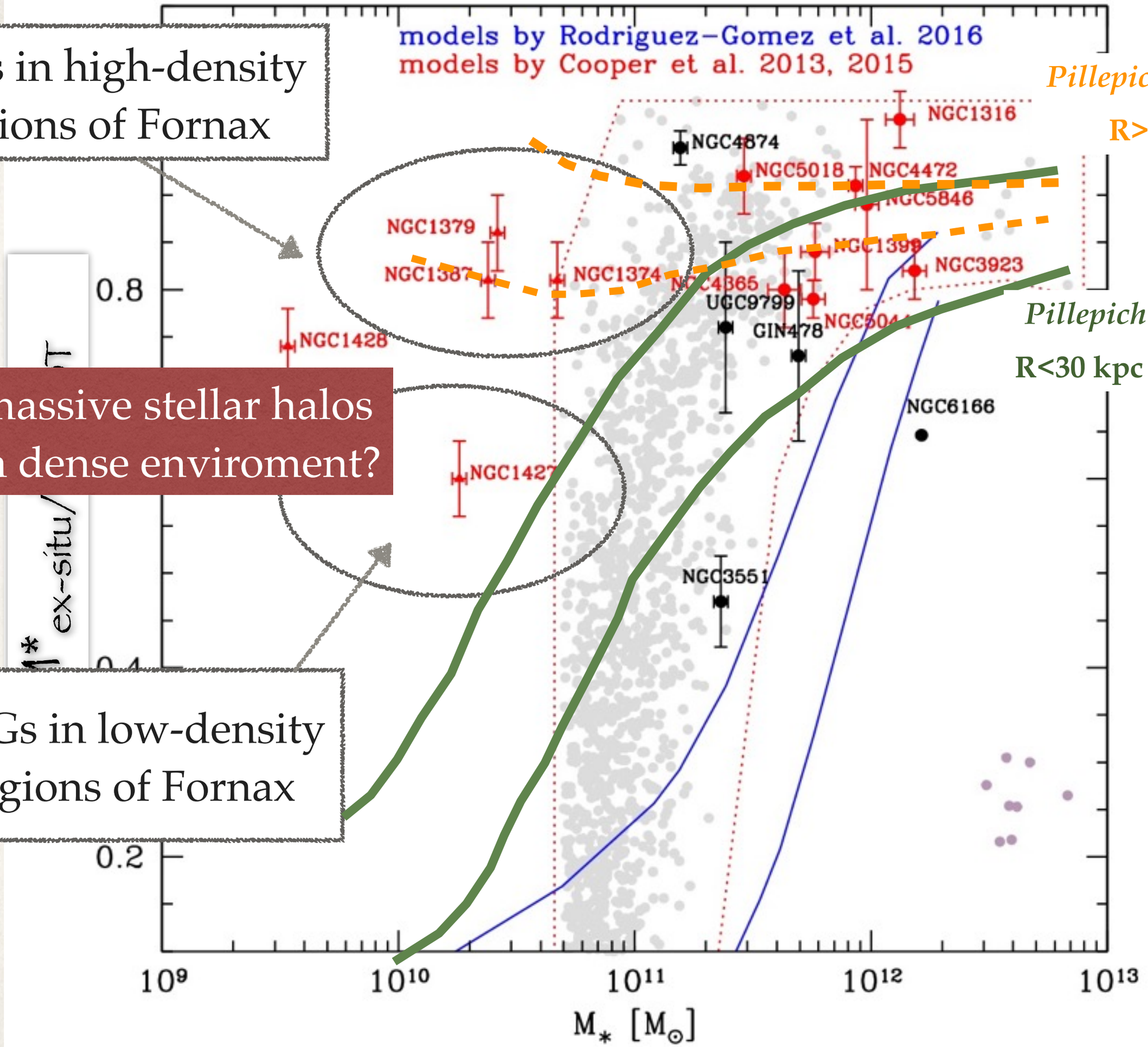
ETGs in high-density regions of Fornax

massive stellar halos in dense enviroment?

ETGs in low-density regions of Fornax



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Concluding remarks

- The large mosaic obtained with the 1 deg^2 FoV of OmegaCam@VST

+

- the arcsec-level angular resolution of 0.21 arcsec/pixel

+

- the large integration time

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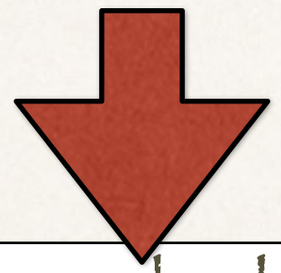

- the galaxy structure from the brightest inner regions to the faint outskirts, out to the intracluster regions
- stellar halos properties (structure, colors, mass fraction) as function of the enviroment
- provides observables to be compared with simulations