The hunt for relic galaxies

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www.iac.es/project/traces

What are we looking for?

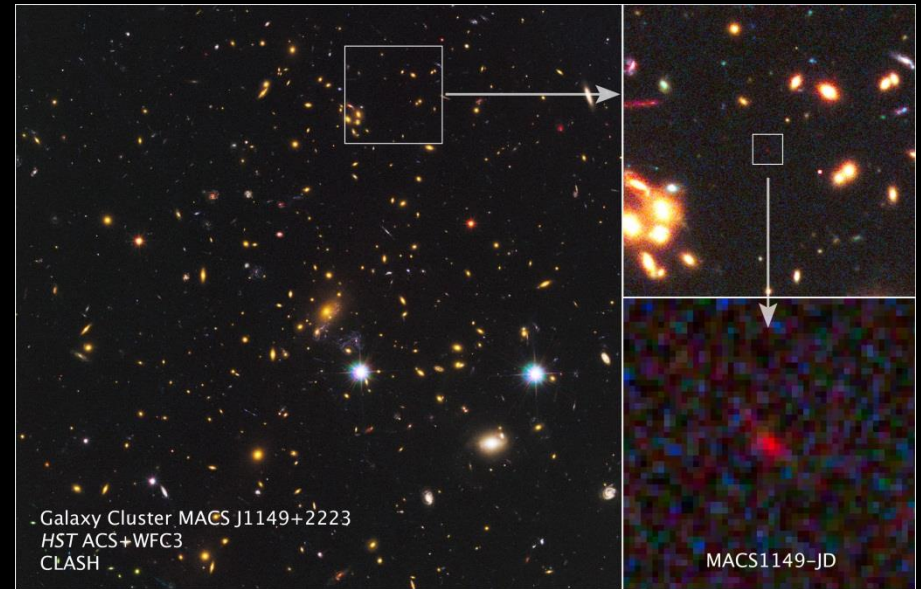We are trying to find objects unaltered since their formation in the early Universe

Why?

Relic galaxies are time capsules with unique information about the physical conditions of the primitive Universe

Direct exploration of the early Universe is very limited
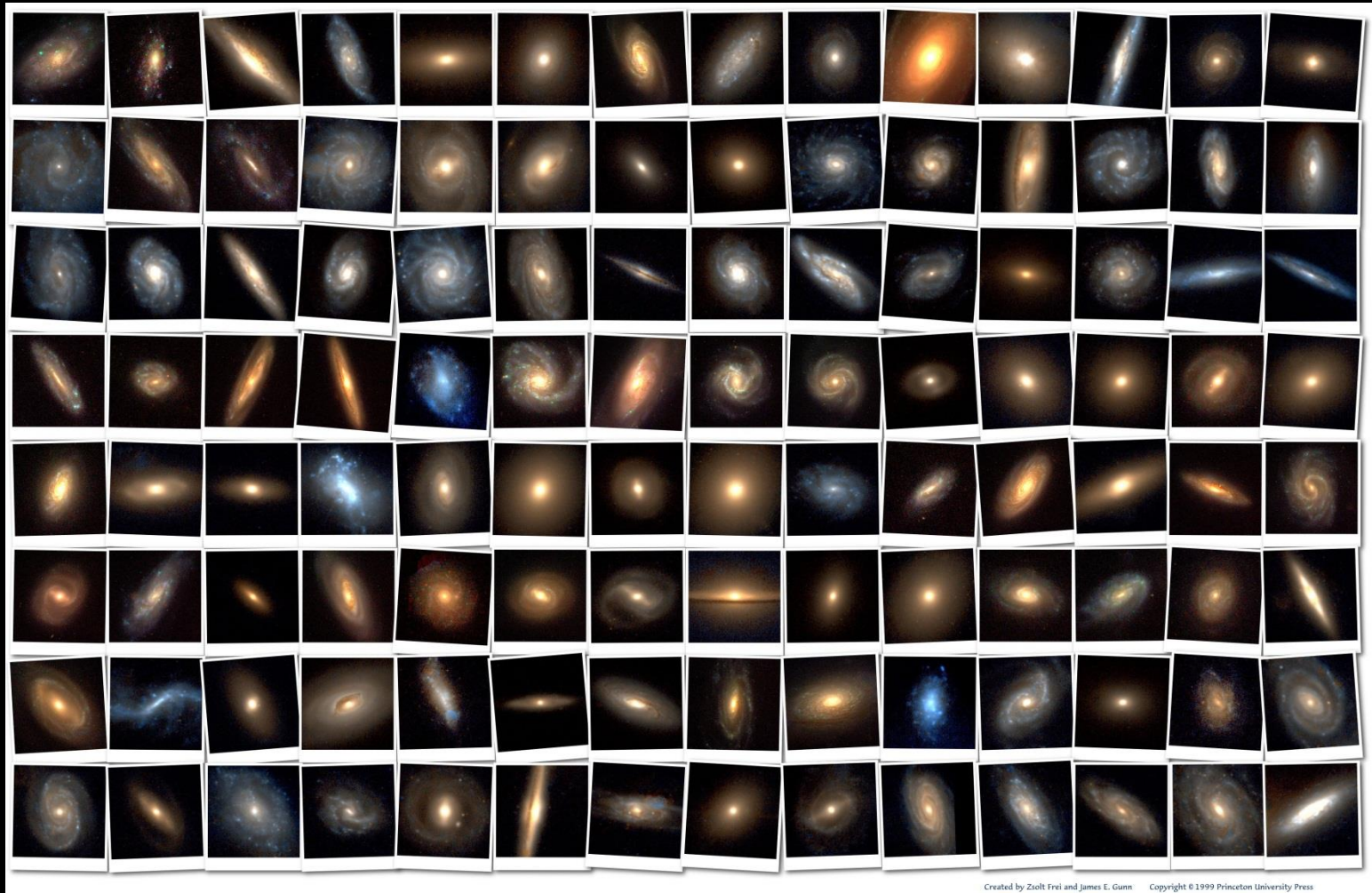
Nearby galaxy

Distant galaxy

Galaxy Cluster MACS J1149+2223
HST ACS+WFC3
CLASH

MACS1149-JD

We want to access to the early Universe (z>2) properties in full detail…

However, finding a relic galaxy is not easy…

The Universe is ruled by the gravity

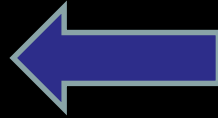# Which one of these is a relic galaxy?

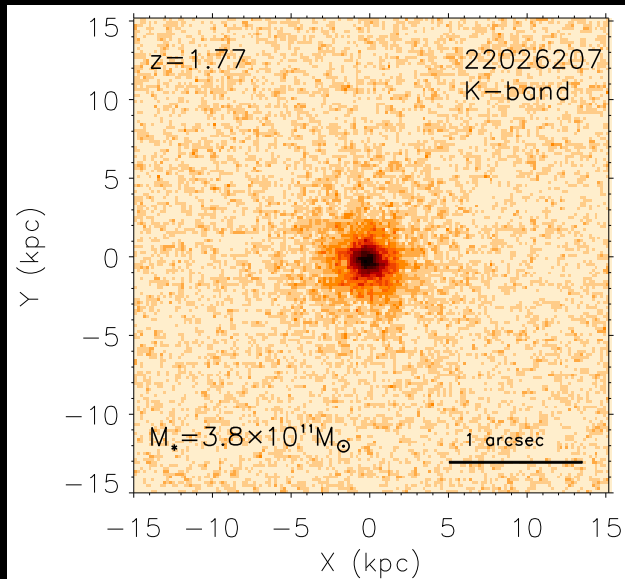Galaxy zoo in the nearby Universe

What are the properties that a relic galaxy should have?

We probe galaxies in the nearby Universe that have the same properties than those we have seen in the primitive Universe (z>2):

1. Massive: $M>10^{11}$ Msun
2. Compact: $R_e<1.5$ kpc
3. Old: Age > 10 Gyr
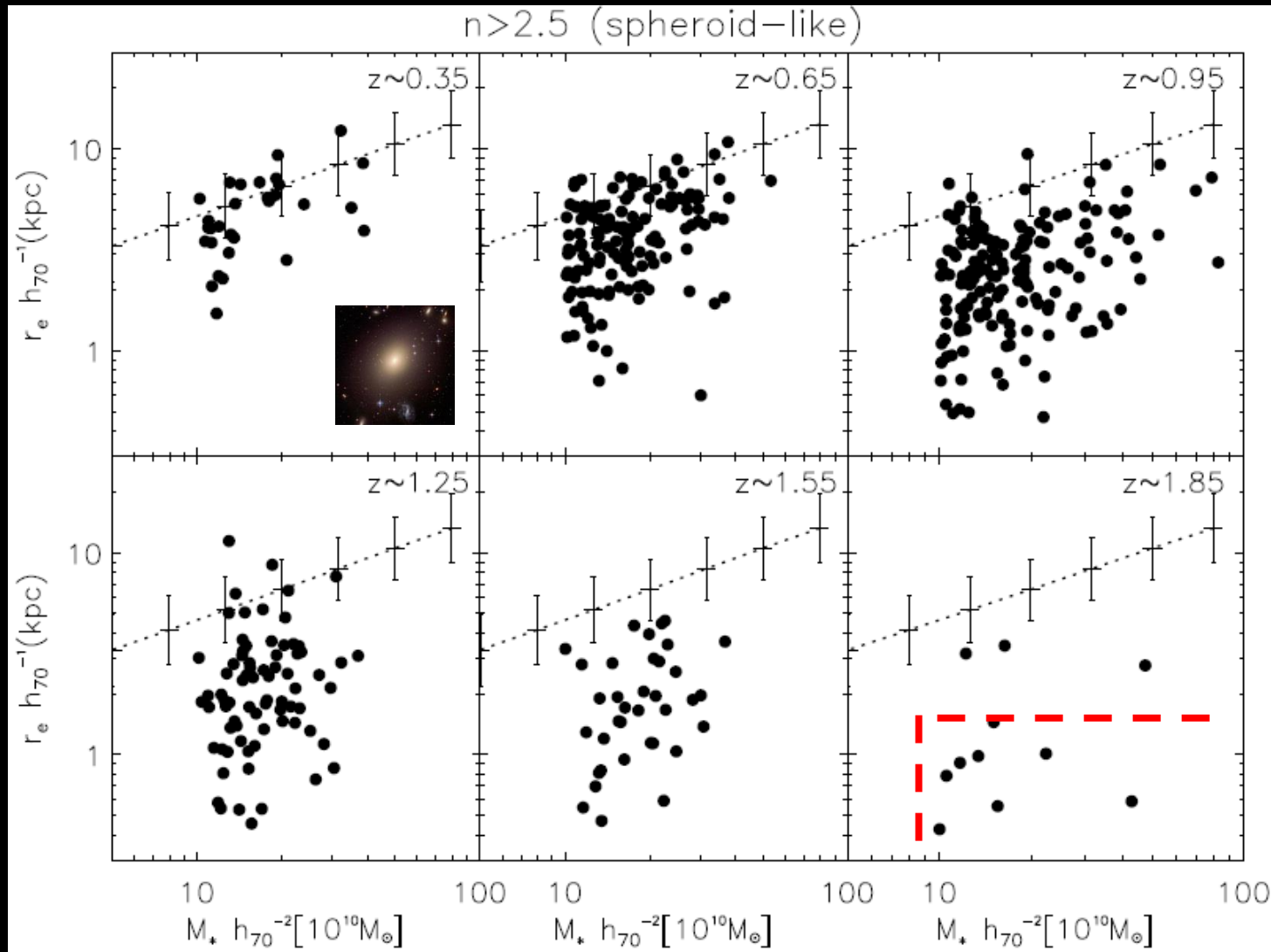
- These are the galaxies we can study with completeness up to z~3 with current telescope facilities

z=1.77   22026207
K−band

$M_* = 3.8 \times 10^{11} M_\odot$ 1 arcsec

Carrasco et al. (2010; Gemini AO)

What are the properties that a relic galaxy should have?
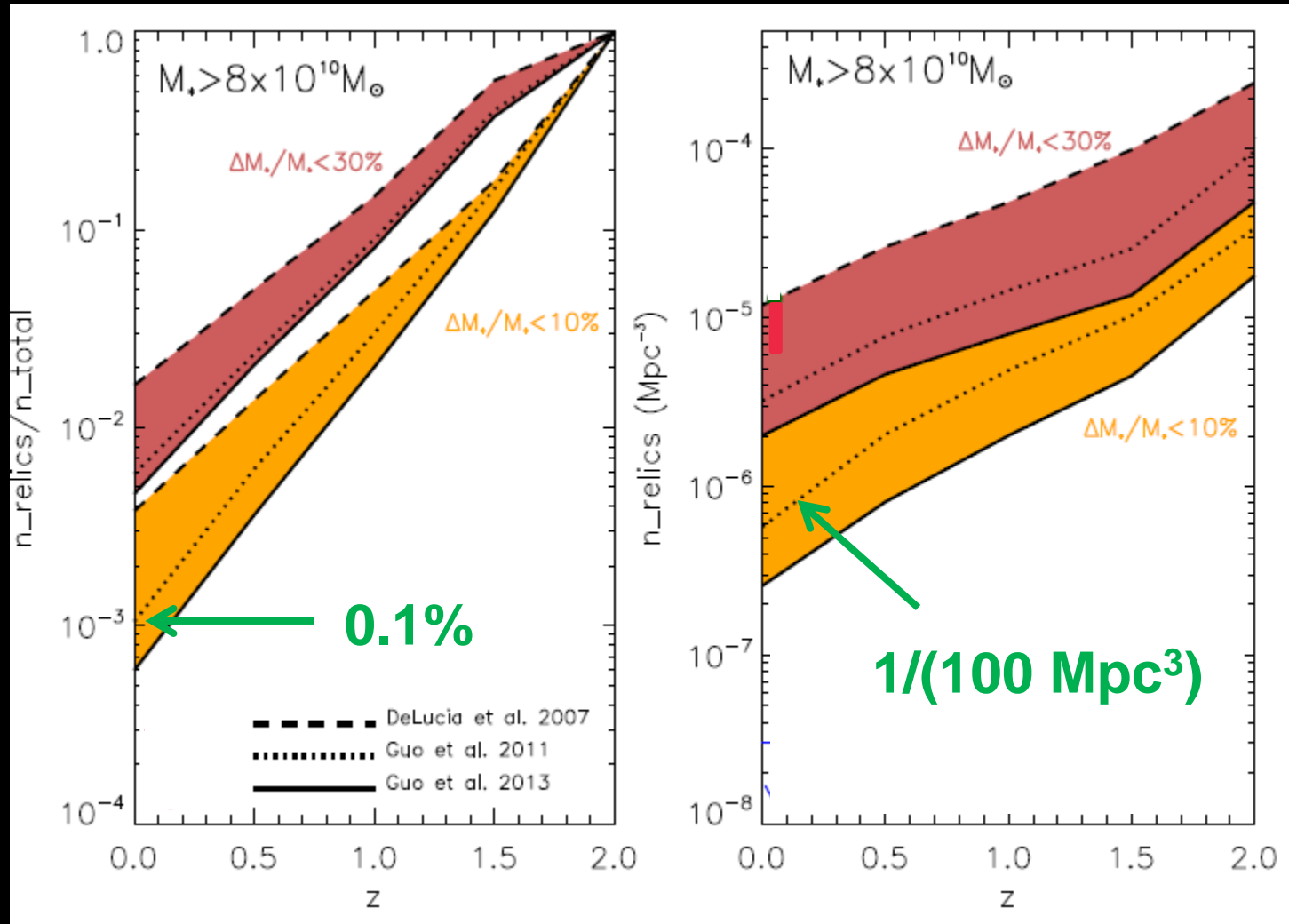

n>2.5 (spheroid-like)

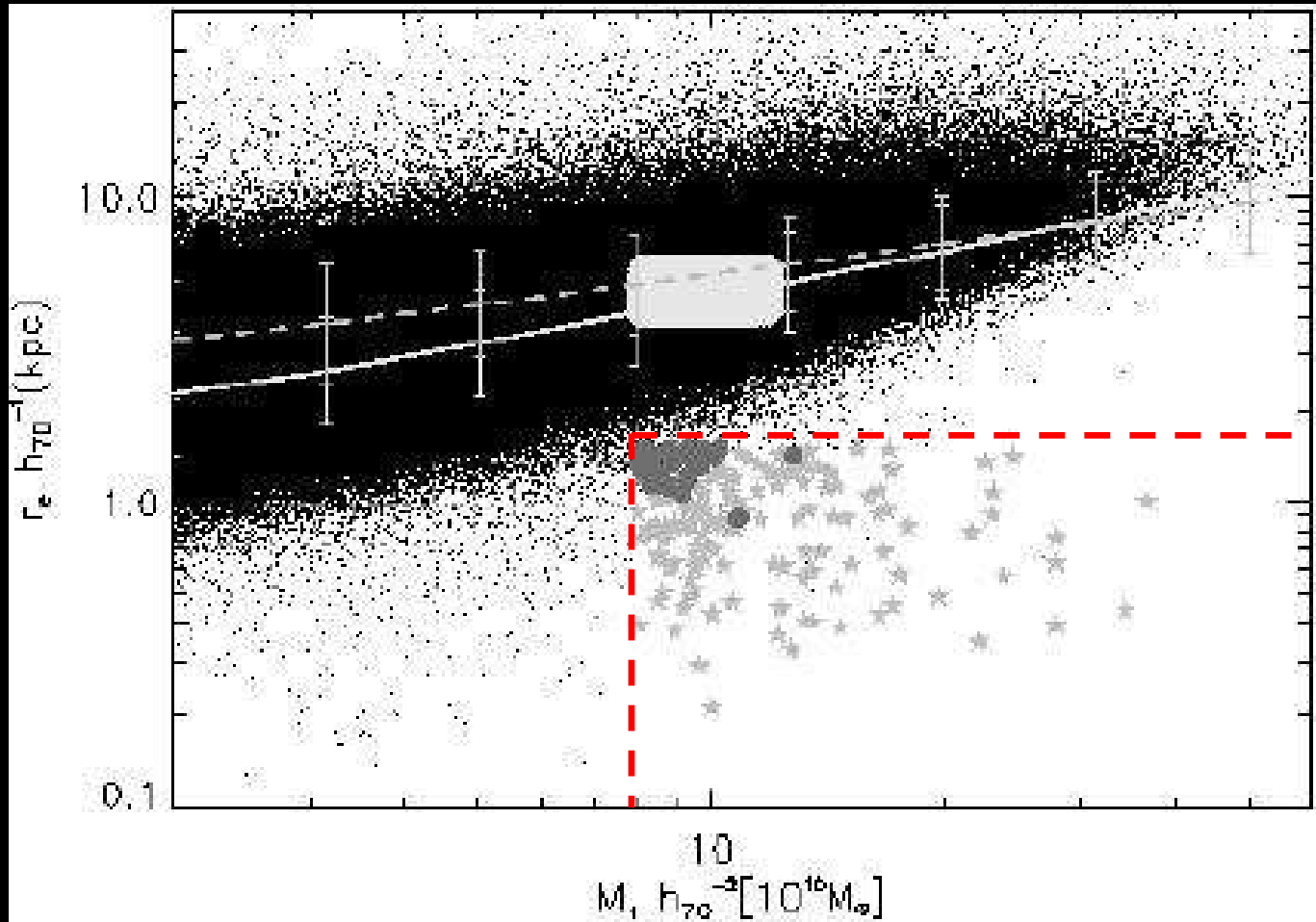Trujillo et al. (2007); Buitrago et al. (2008)

How many relic galaxies are in the nearby Universe?

The prediction from the ΛCDM cosmological model:
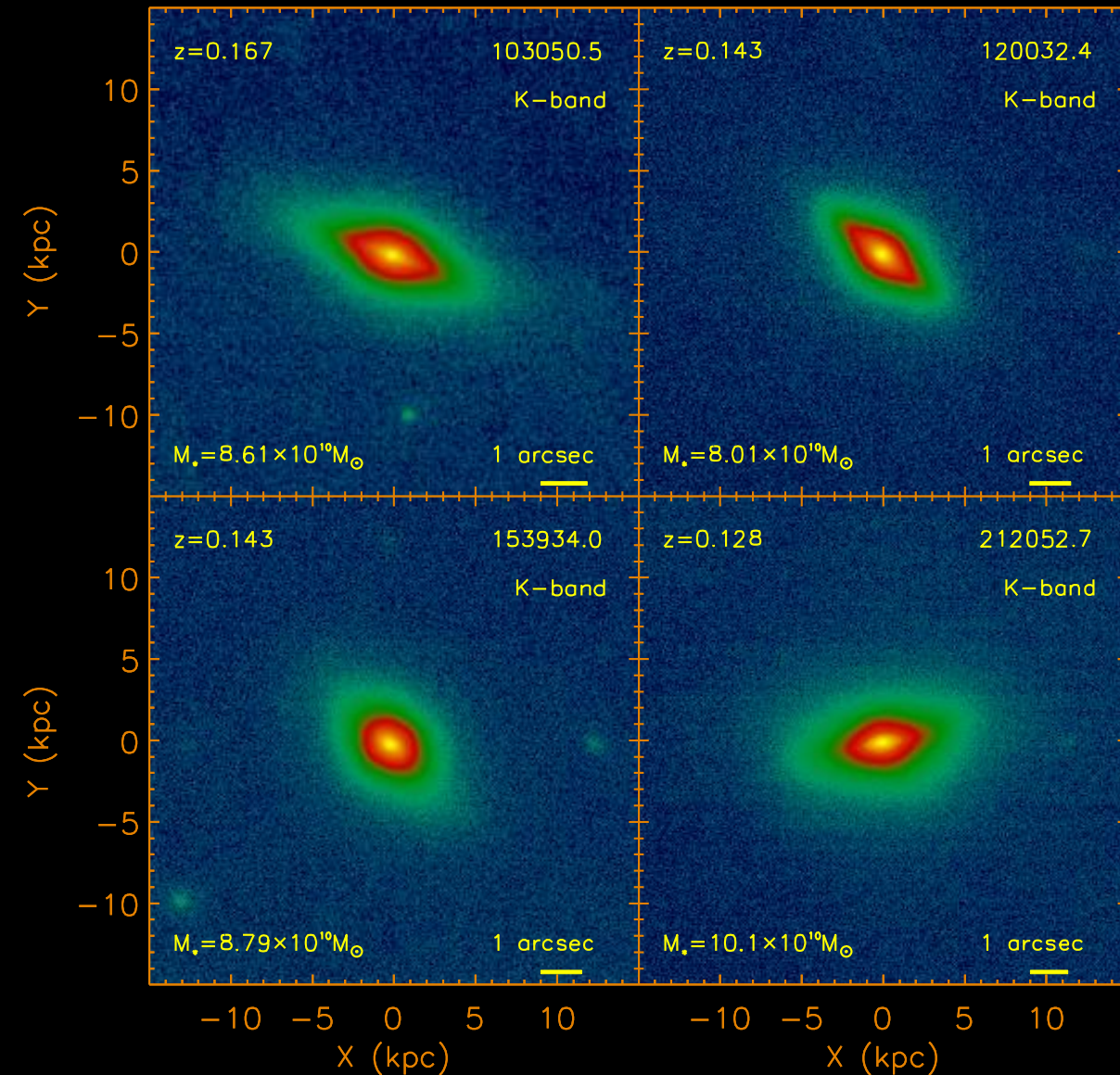

Quilis & Trujillo (2013)

The hunt for relic galaxies in the nearby Universe

Trujillo et al. (2009)

<0.03% of today massive (>$10^{11}M_{sun}$) galaxies are compact

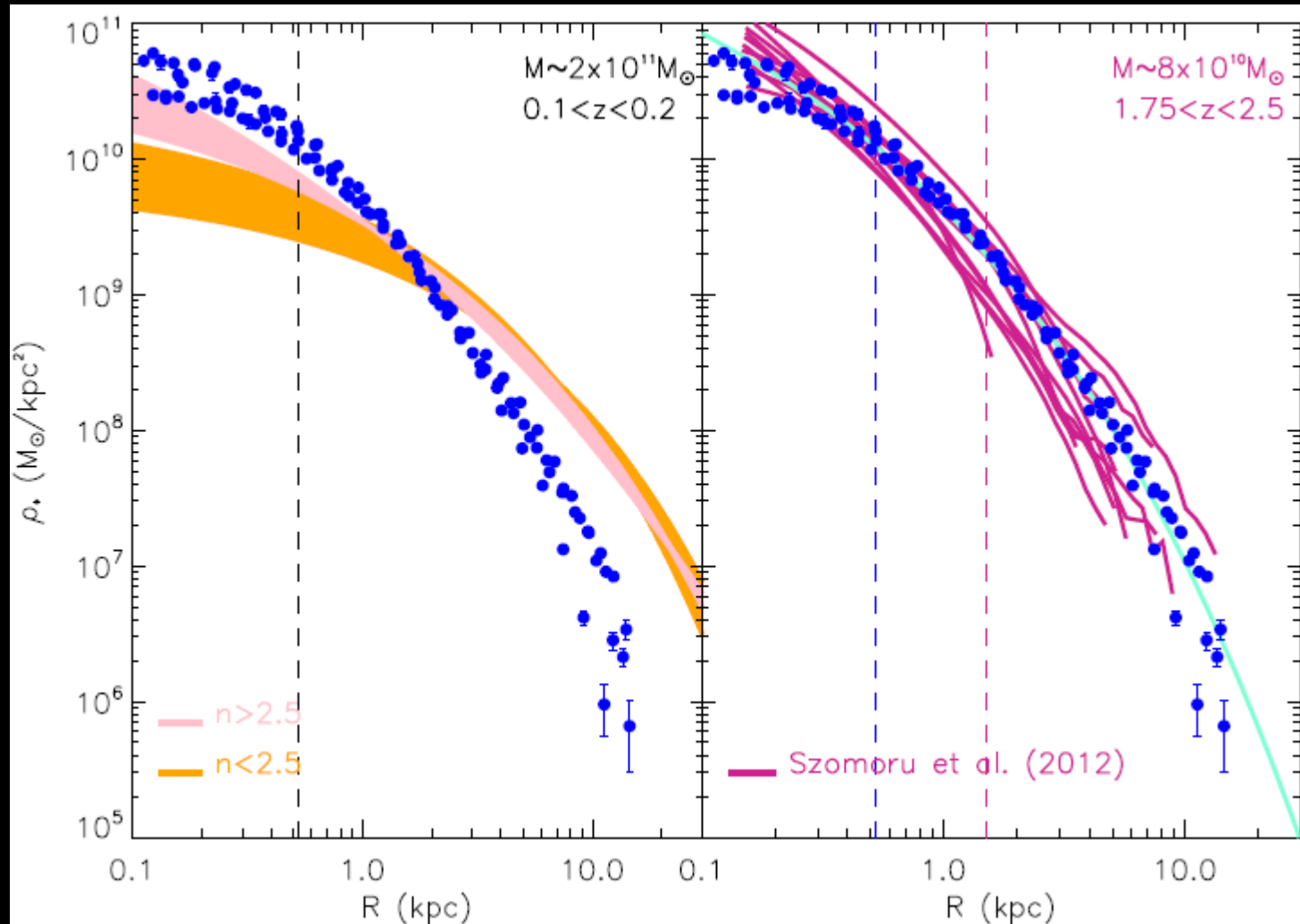# The hunt for relic galaxies in the nearby Universe

-K-band imaging at 0.15 arcsec resolution with Gemini AO

Trujillo, Carrasco et al. (2012)

See also:
Shih & Stockton (2011)

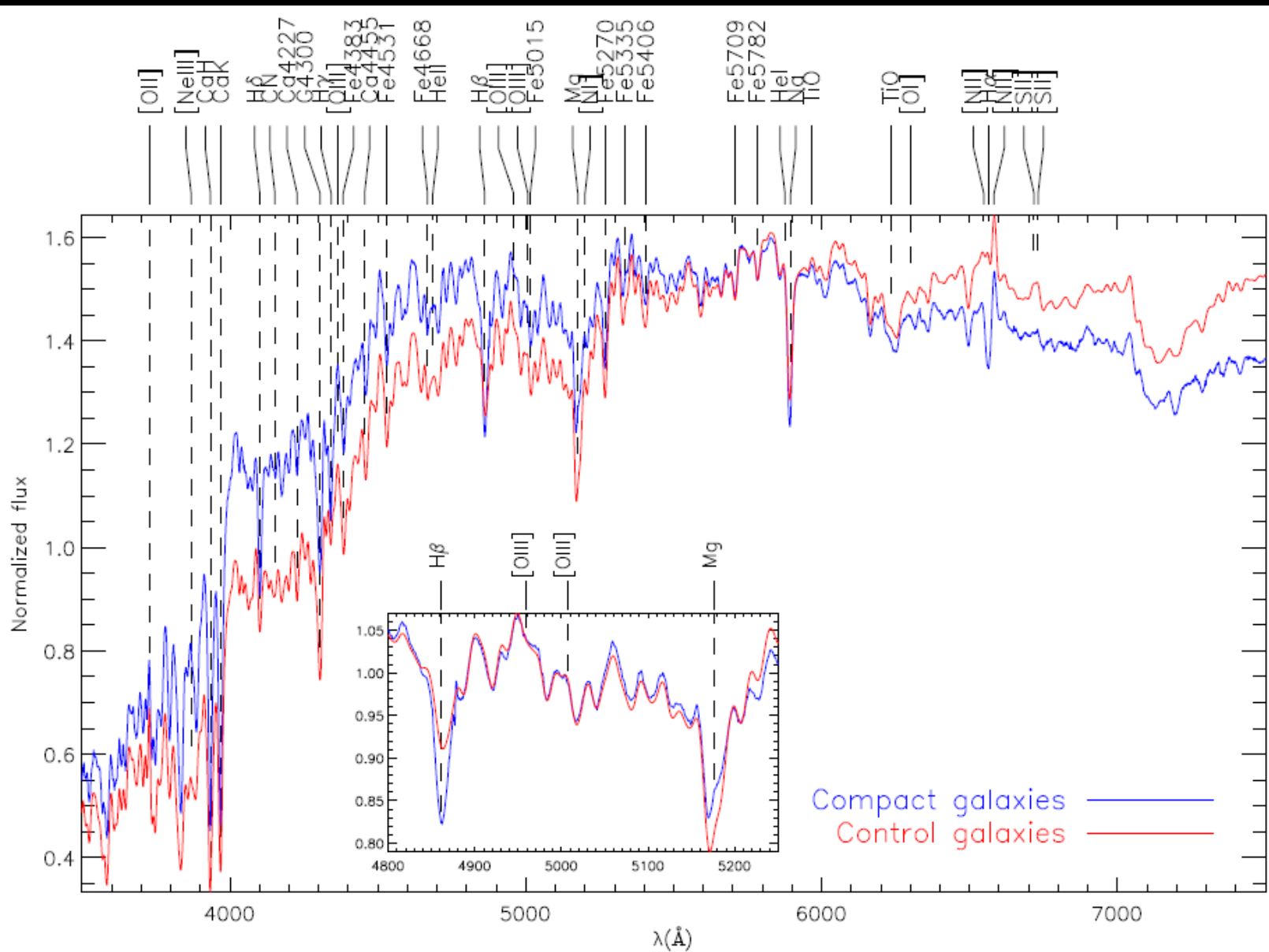# The hunt for relic galaxies in the nearby Universe

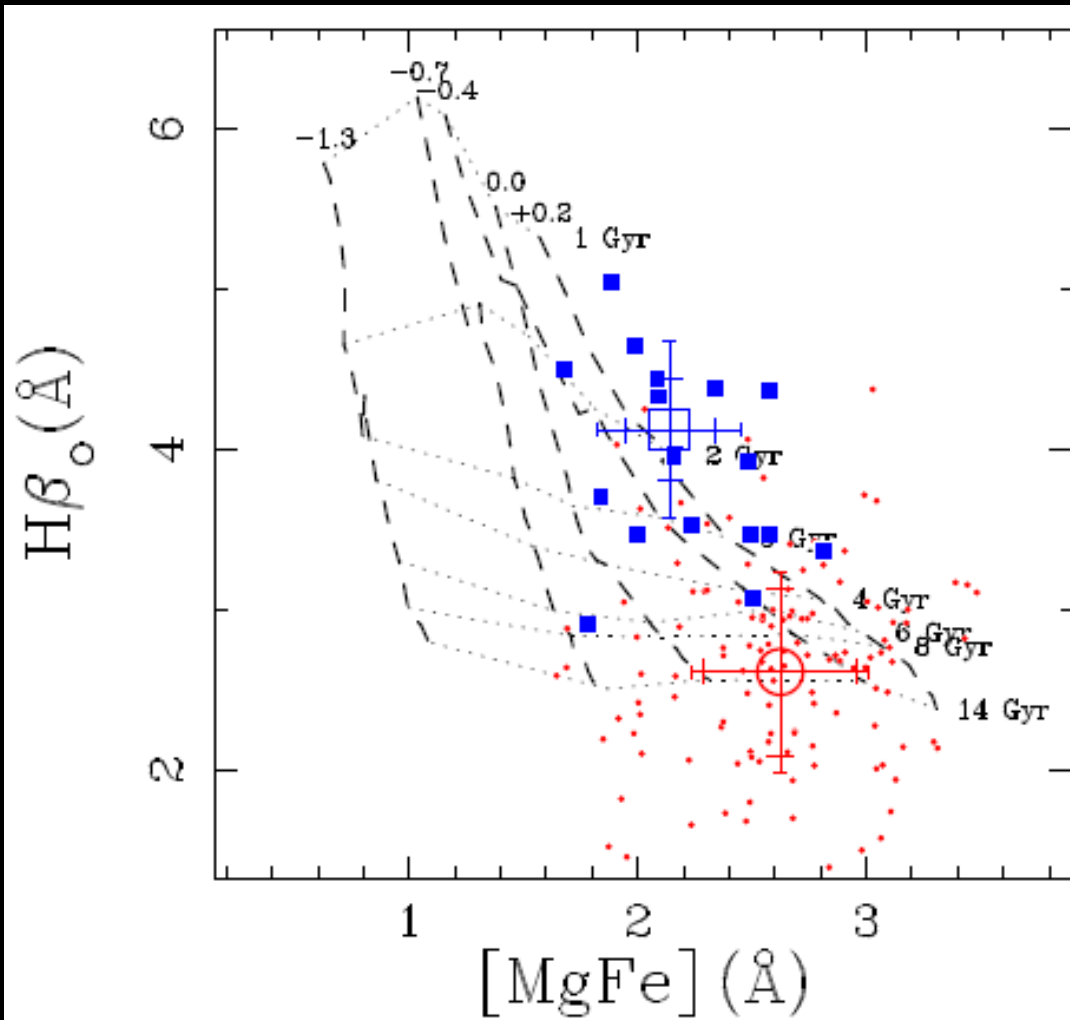-K-band imaging at 0.15 arcsec resolution with Gemini AO

Trujillo, Carrasco et al. (2012)

The hunt for relic galaxies in the nearby Universe

Trujillo et al. (2009)

The hunt for relic galaxies in the nearby Universe

-Massive compact galaxies at z~0.15 are relatively young (~2 Gyr)

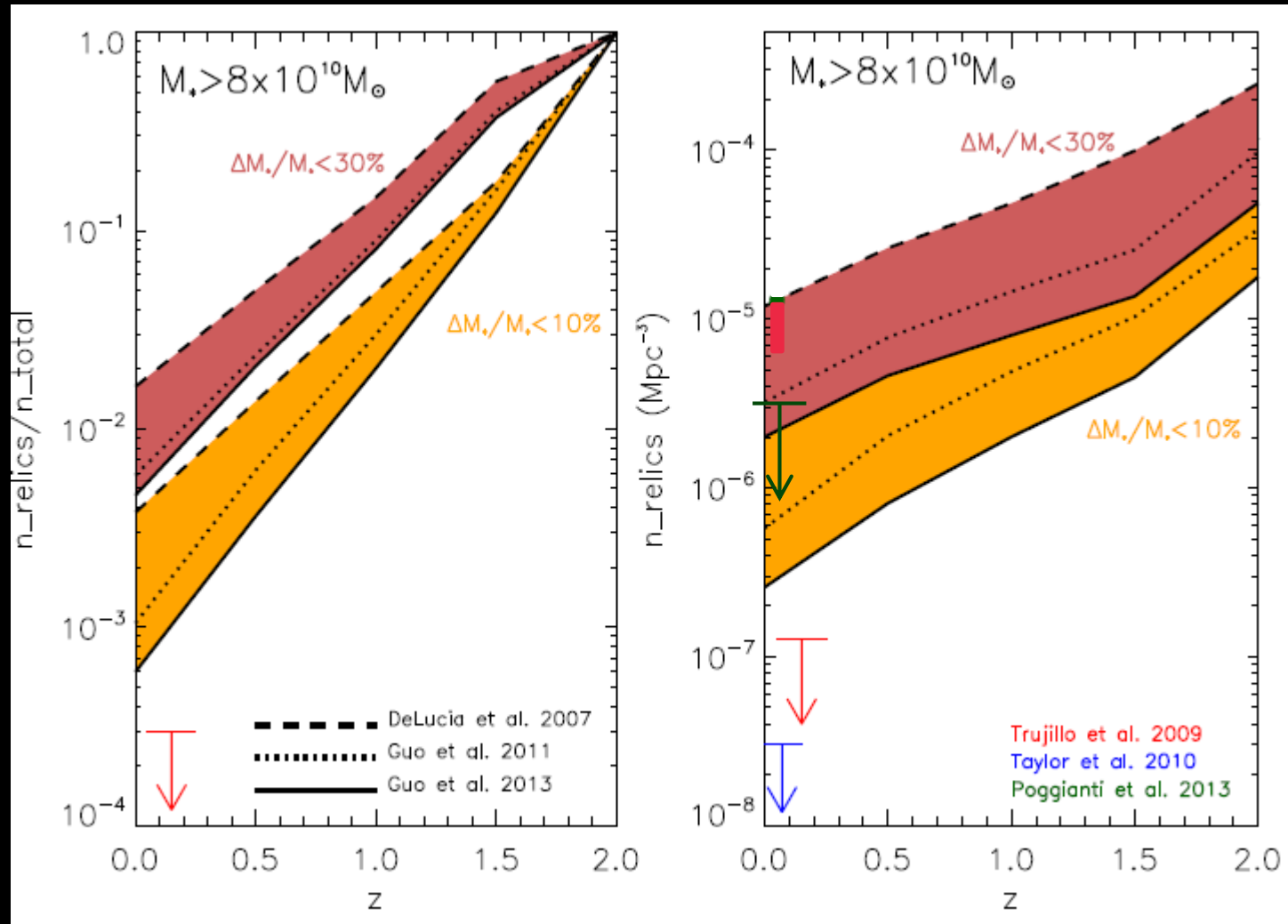-There are not compact massive relics today from the early universe

BIG SURPRISE!!!

Trujillo et al. (2009); Ferré-Mateu et al. (2012)

The hunt for relic galaxies in the nearby Universe

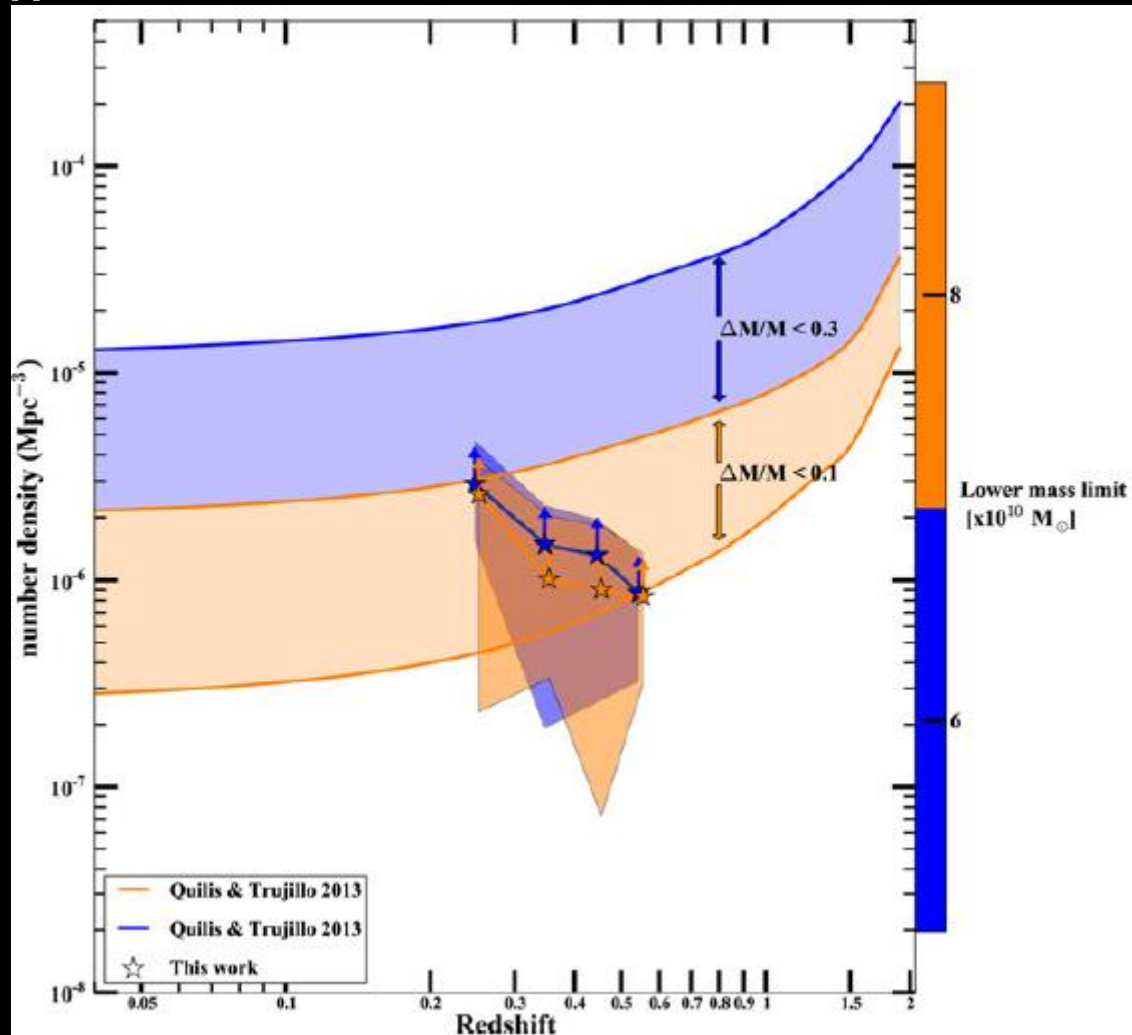Nearby Universe data compared with the theoretical predictions…

Quilis & Trujillo (2013)

The hunt for relic galaxies in the nearby Universe

Intermediate redshift data compared with the theoretical predictions…

Damjanov et al. (2014)

The hunt for relic galaxies in the nearby Universe

Intermediate redshift data agrees with the theoretical expectations…

Where are the relic galaxies today then?

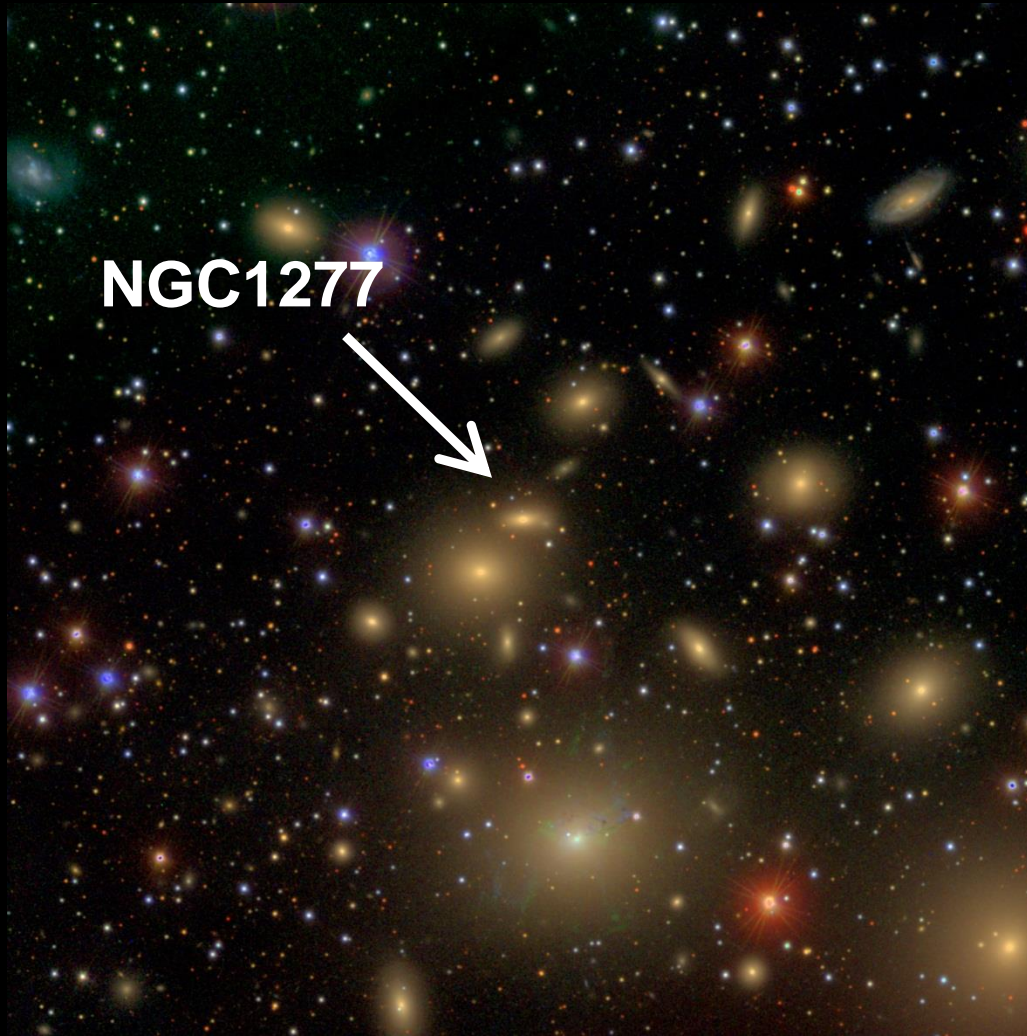Is the galaxy formation model correct?

Are we missing observationally present-day relic objects?

The hunt for relic galaxies in the nearby Universe

The Perseus Galaxy cluster

The hunt for relic galaxies in the nearby Universe

The Perseus galaxy cluster

NGC1277: our first relic galaxy candidate

HST ACS F625W

Global properties (van den Bosch et al. 2012):

$M_* = 1.2 \times 10^{11}\ M_{sun}$ $R_e = 1.2$ kpc $\sigma > 330$ km/s
$V_{rot} > 300$ km/s

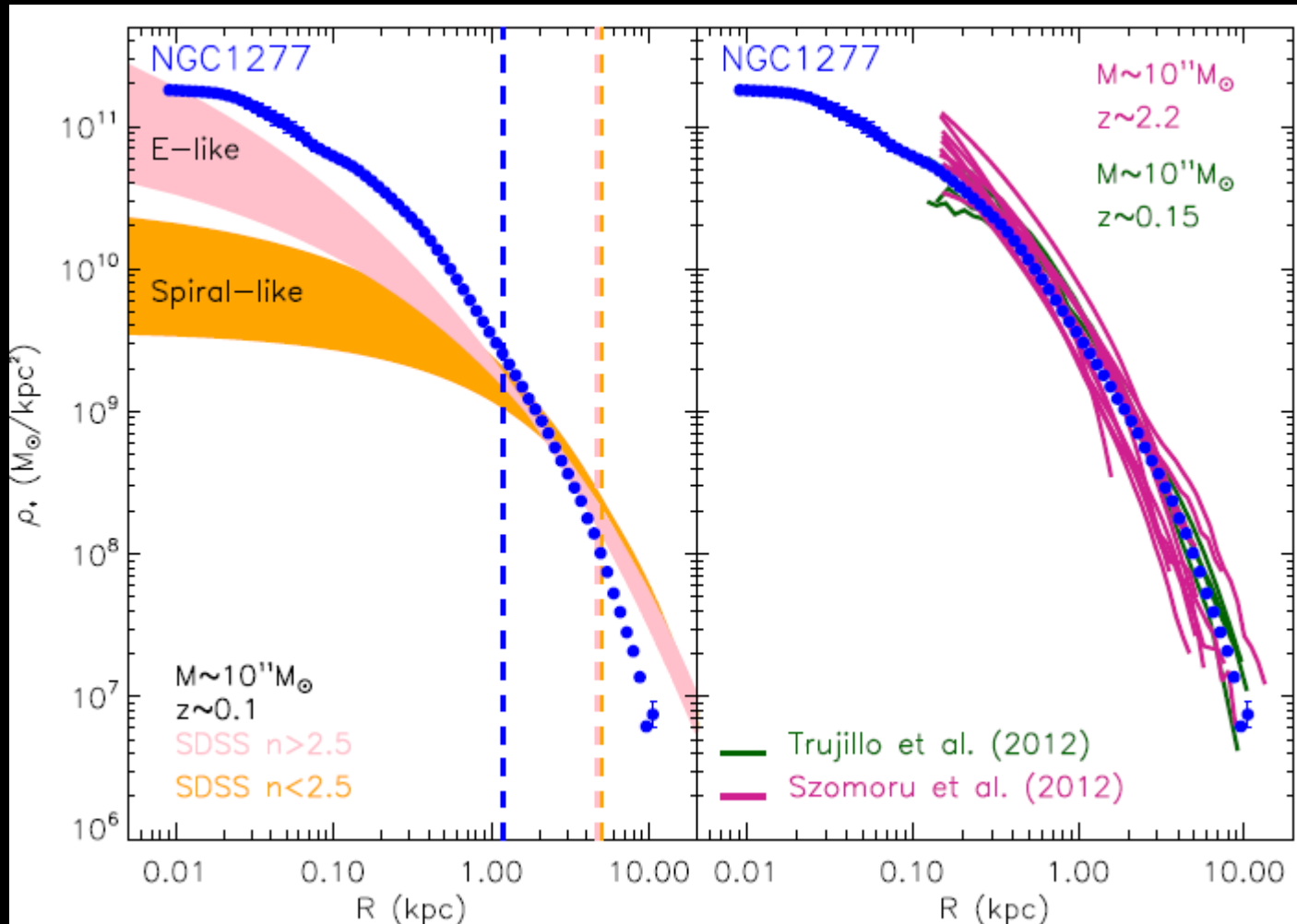# NGC1277: our first relic galaxy candidate
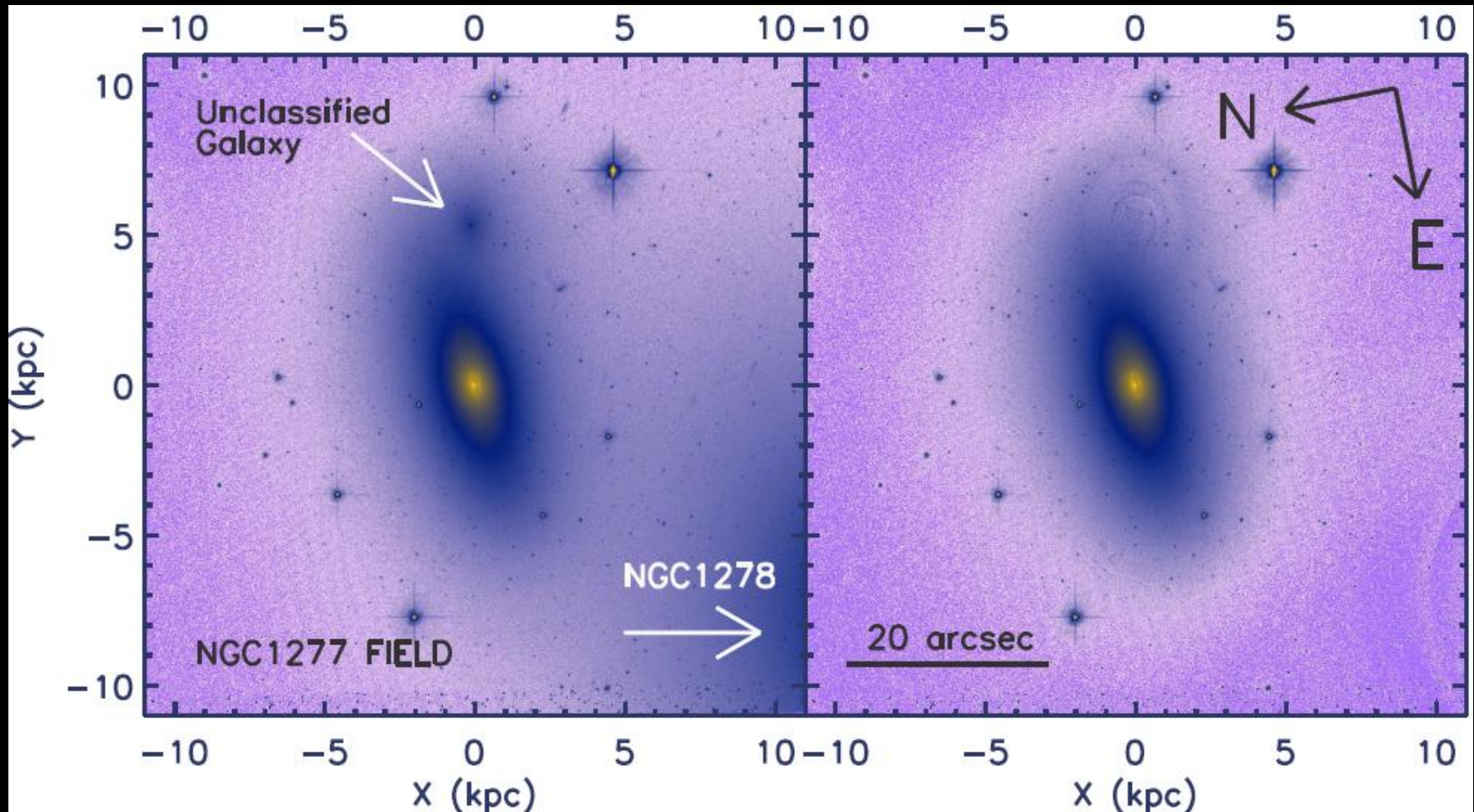
Trujillo et al. (2014)

Properties:
No sign of interactions with other nearby galaxies…

NGC1277: our first relic galaxy candidate

Trujillo et al. (2014)

Properties:
Stellar mass density profile equivalent to those in high-z massive galaxies…

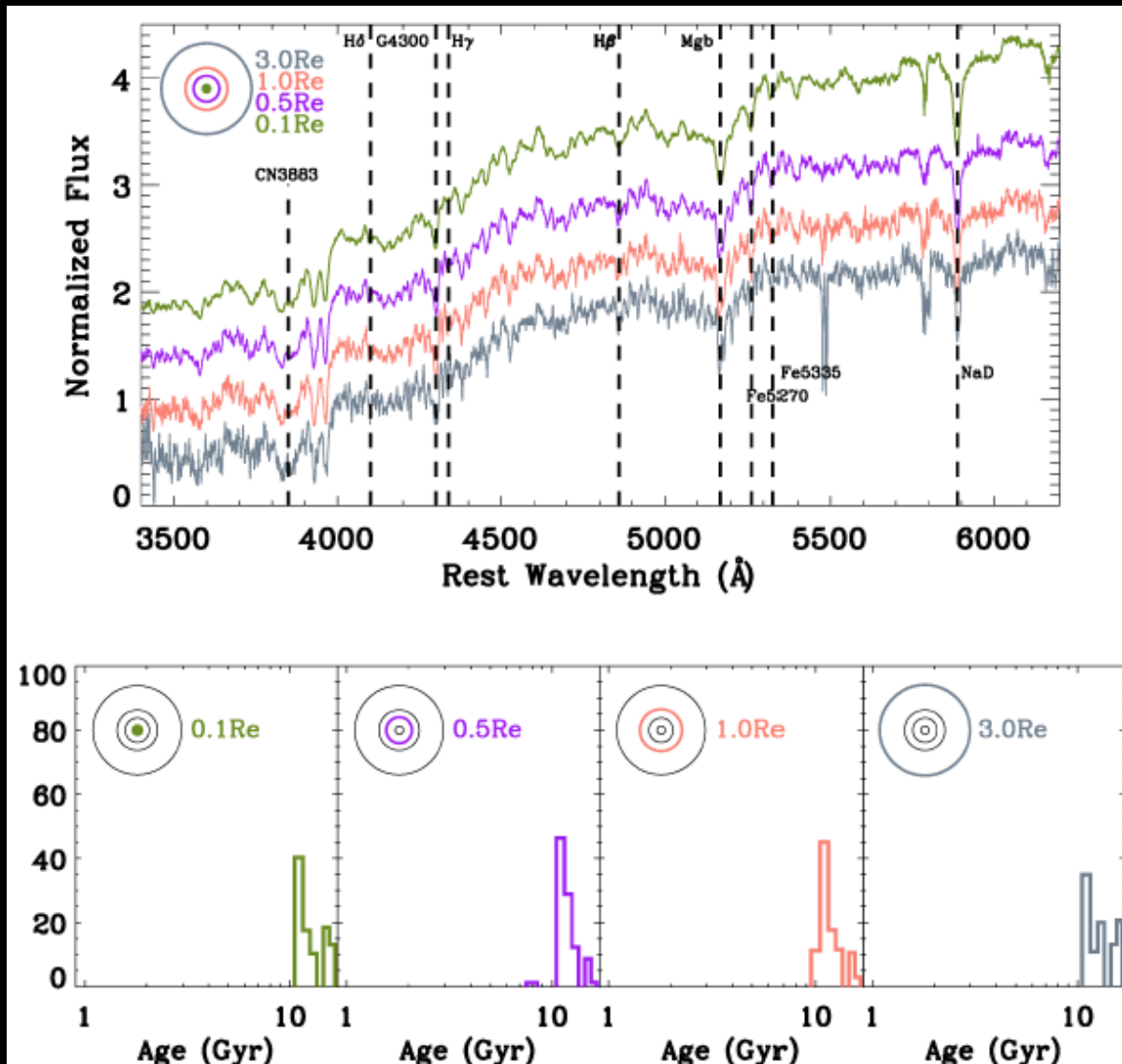# NGC1277: our first relic galaxy candidate

HST ACS F625W

How are the stellar population properties of NGC1277?

We have conducted very deep spectroscopy with the WHT and GTC (S/N>150)
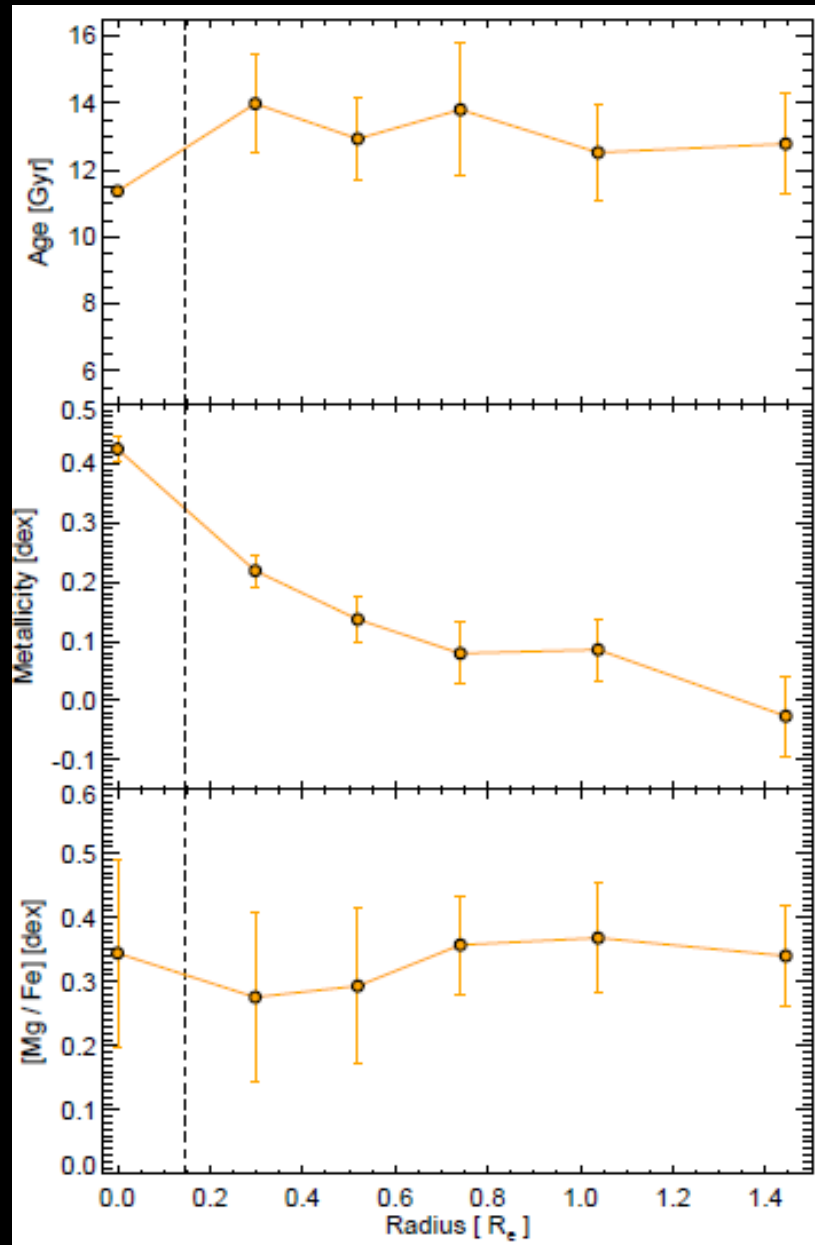
NGC1277: our first relic galaxy candidate

Trujillo et al. (2014)

Properties:

At all radii, Star Formation Histories compatible with no new star formation in the last 10 Gyr…

NGC1277: our first relic galaxy candidate

Martin-Navarro et al. (2015)

Properties:

Age, metallicity and α/Fe radial profiles are pretty homogenous…

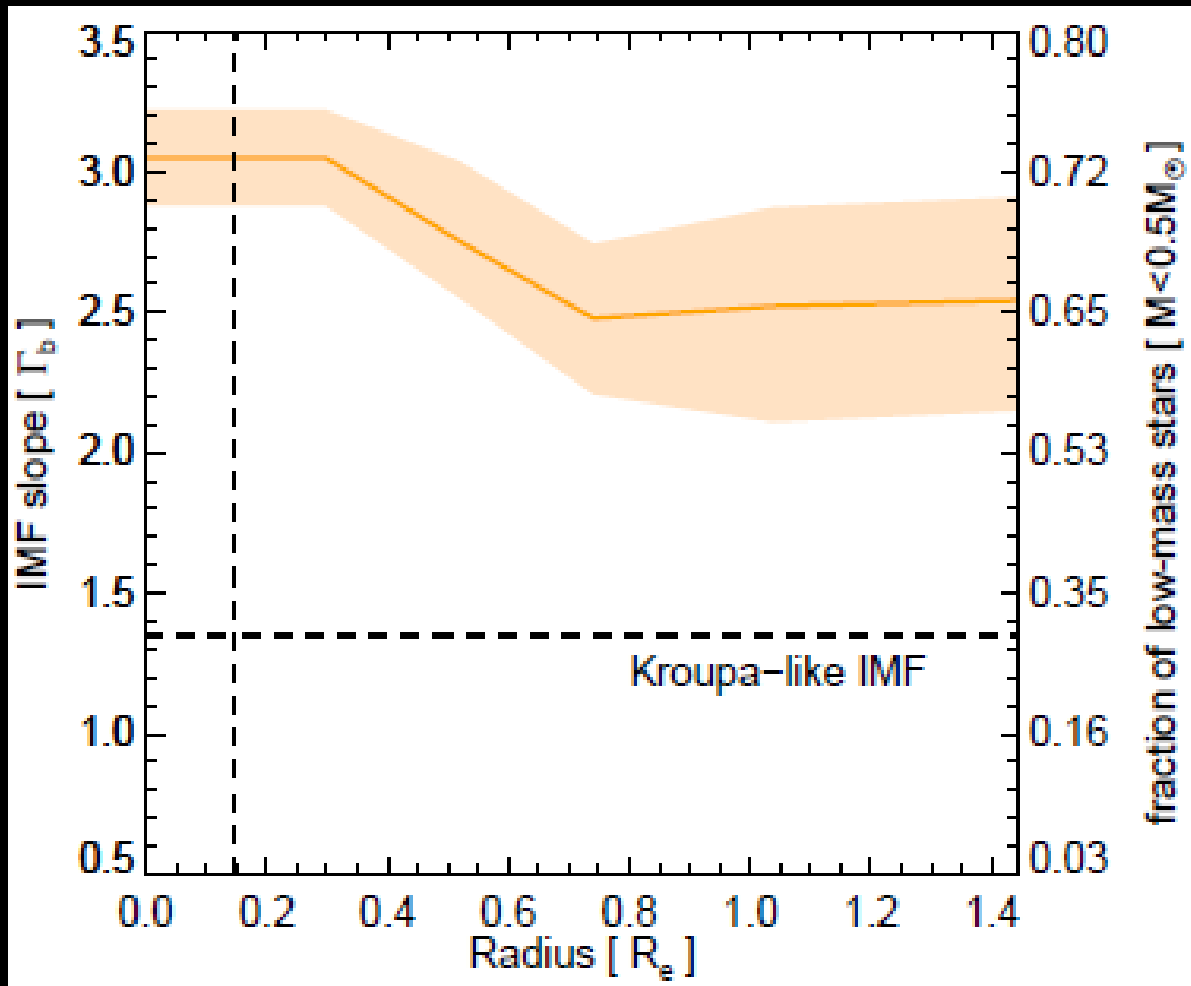# NGC1277: our first relic galaxy candidate

The lesson from the stellar population analysis…

The extraordinary large $\alpha/Fe>0.3$ implies extremely short formation time-scale: ~100 Myr

Star Formation Rate: ~1000 M_{sun}/yr

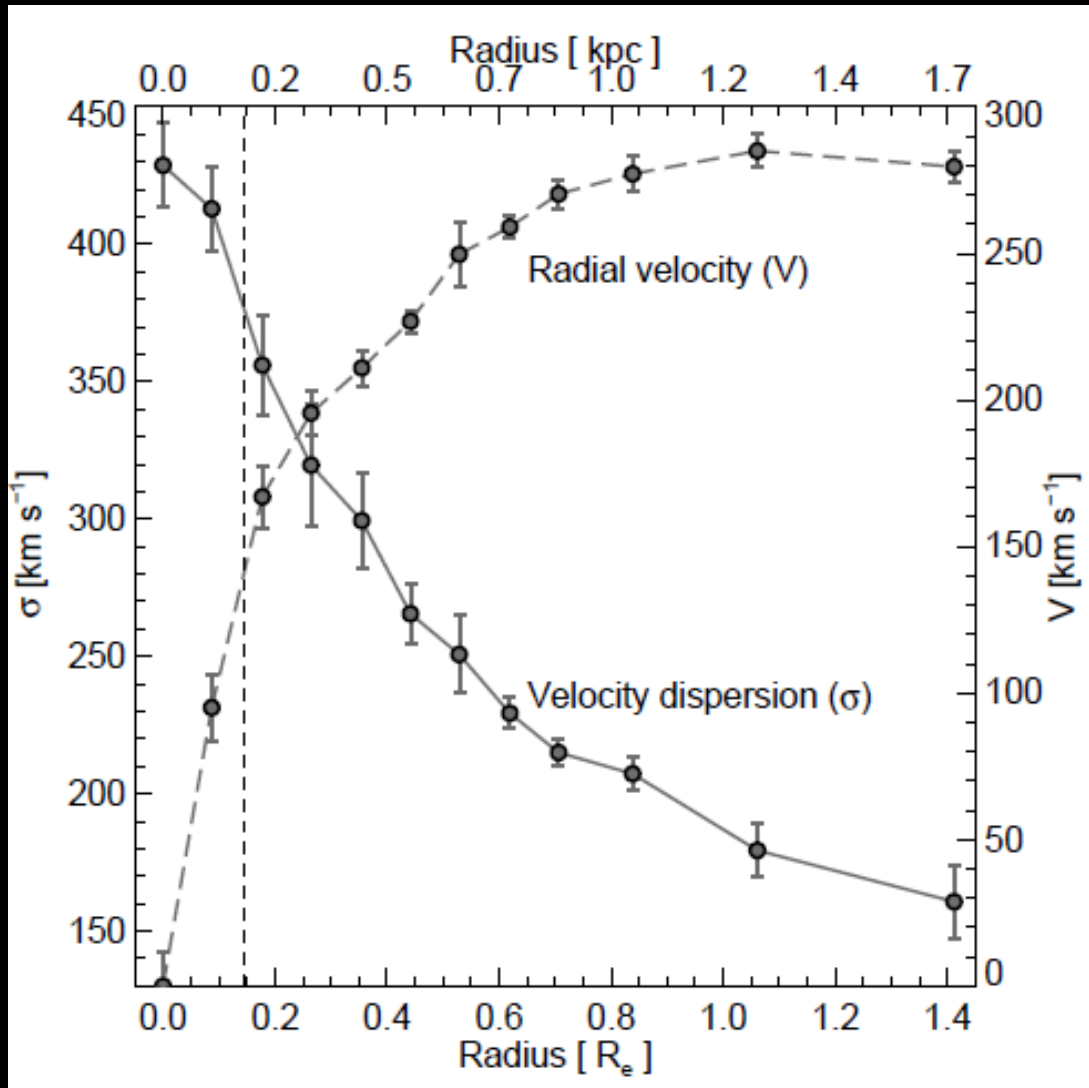# NGC1277: our first relic galaxy candidate

Martín-Navarro et al. (2015)

The primordial IMF of the massive galaxies:

The IMF was significantly more bottom-heavy than now

NGC1277: our first relic galaxy candidate

Martín-Navarro et al. (2015)

Other Properties
(van den Bosch et al. 2012;
Emsellem et al. 2013):

It has a large supermassive blackhole compared to the galaxy:
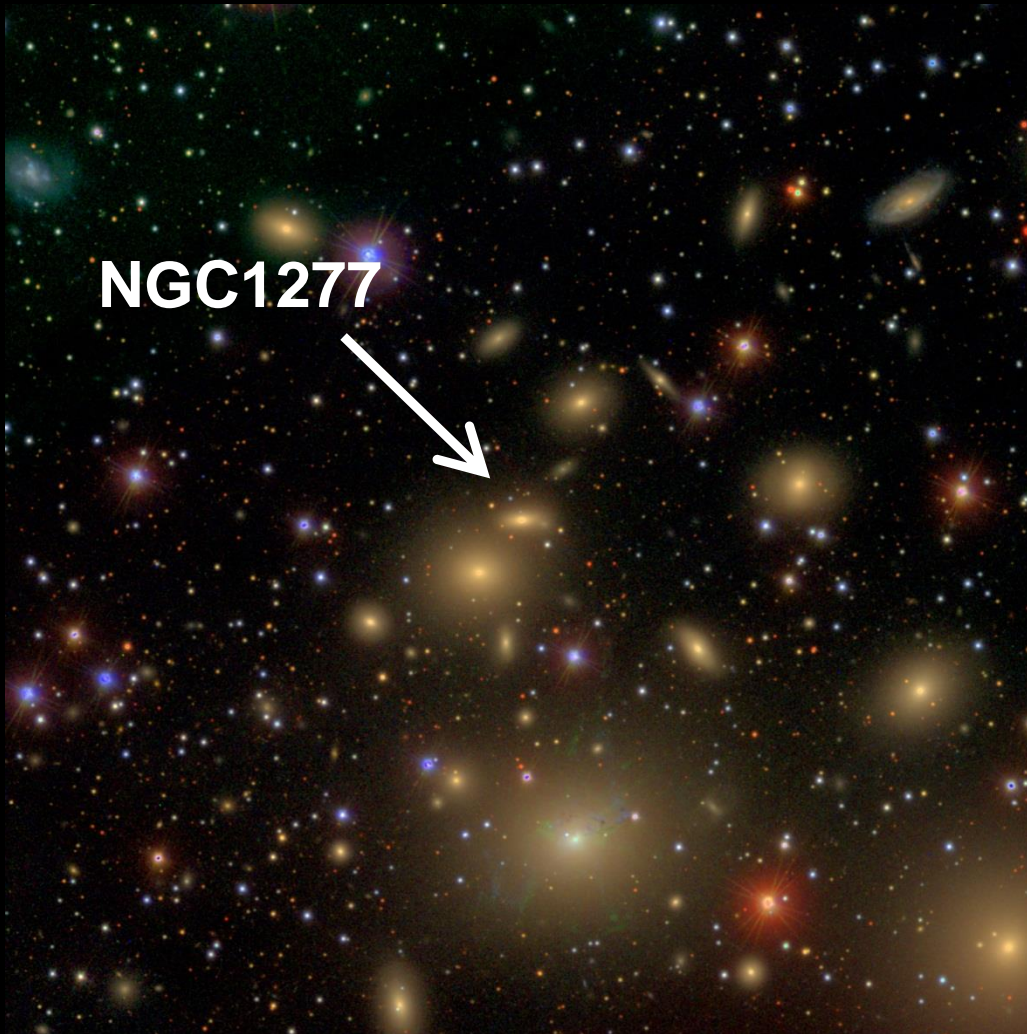
$M_{\bullet}$=2x10^9 M$_{sun}$ -> $M_{\bullet}/M_*$~0.02 -> 4 times more than expected!

Where are the relic galaxies hidden?

Are the galaxy clusters particularly favorable to host relic galaxies?

The Perseus galaxy cluster

NGC1277
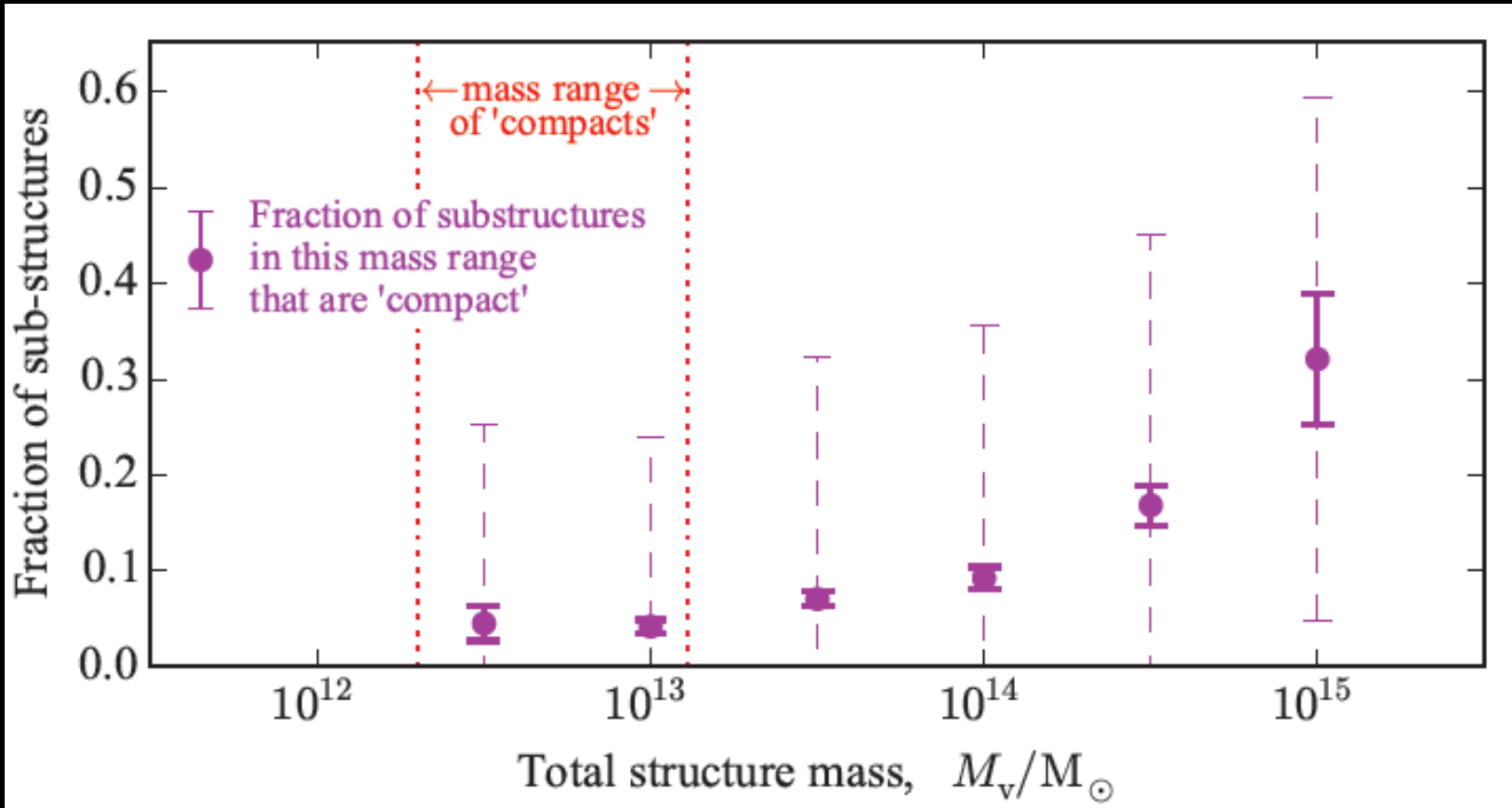
Properties:

a) The brightest cluster in the sky when observed in the X-ray band -> gas accretion unlikely

b) Large velocity dispersion $\sigma \sim 1300$ km/s -> galaxy collision unlikely

Very rich galaxy clusters: the place to find relic galaxies?

Where are the relic galaxies hidden?
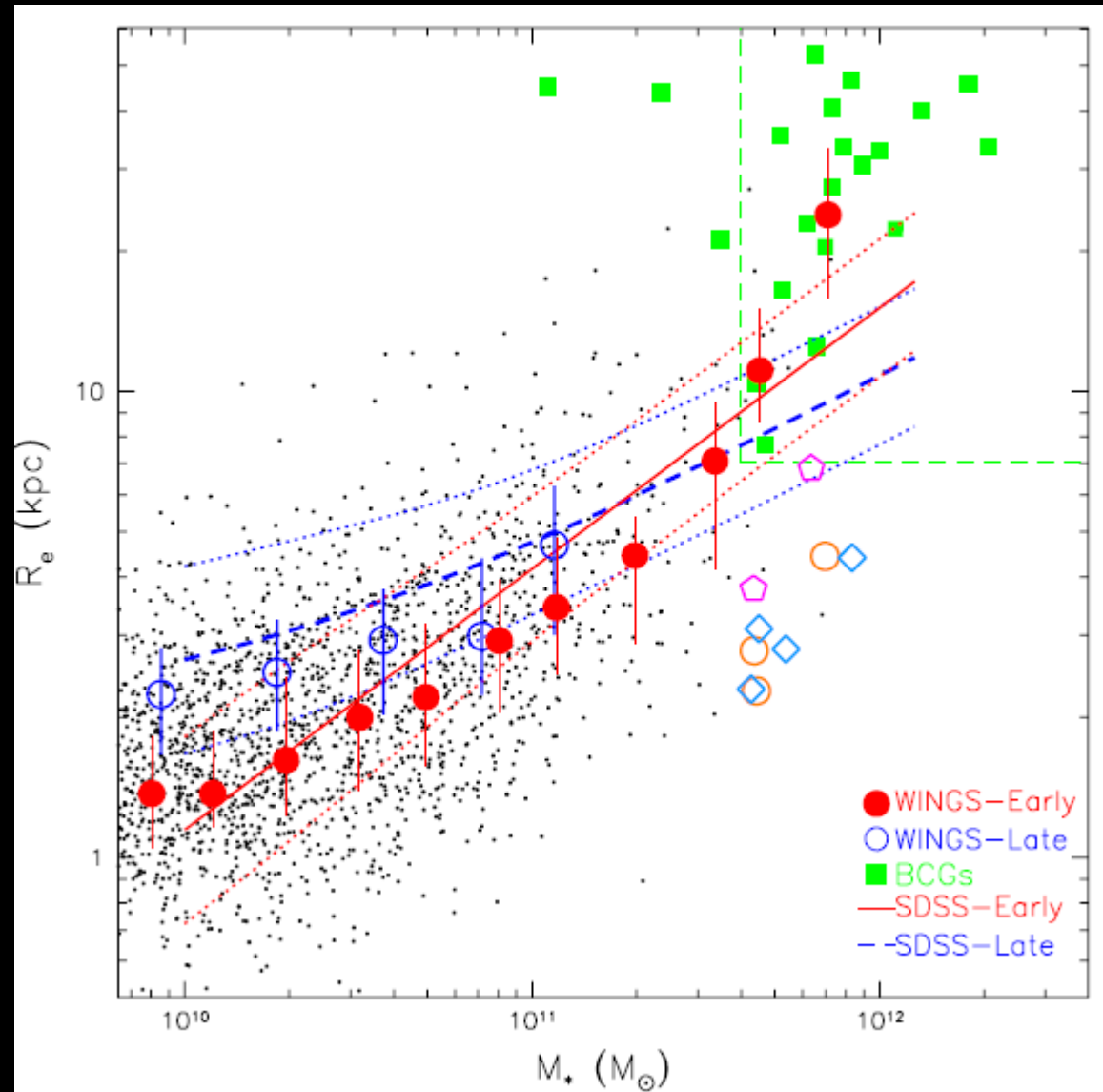
What should we expect theoretically?

Stringer et al. (2015)

Where are the relic galaxies located?

Further hints from the observational point of view…

Valentinuzzi et al (2010)

Summary

Finding a relic galaxy in the nearby Universe opens the study in full detail of the properties of the early Universe, BUT:

1. They are less than theoretically expected… unclear whether is a problem of the model or the observations…

2. We have found a relic candidate in the Perseus Cluster: NGC1277

3. The relic galaxy has dynamical and stellar population properties different than today massive objects

What is next?

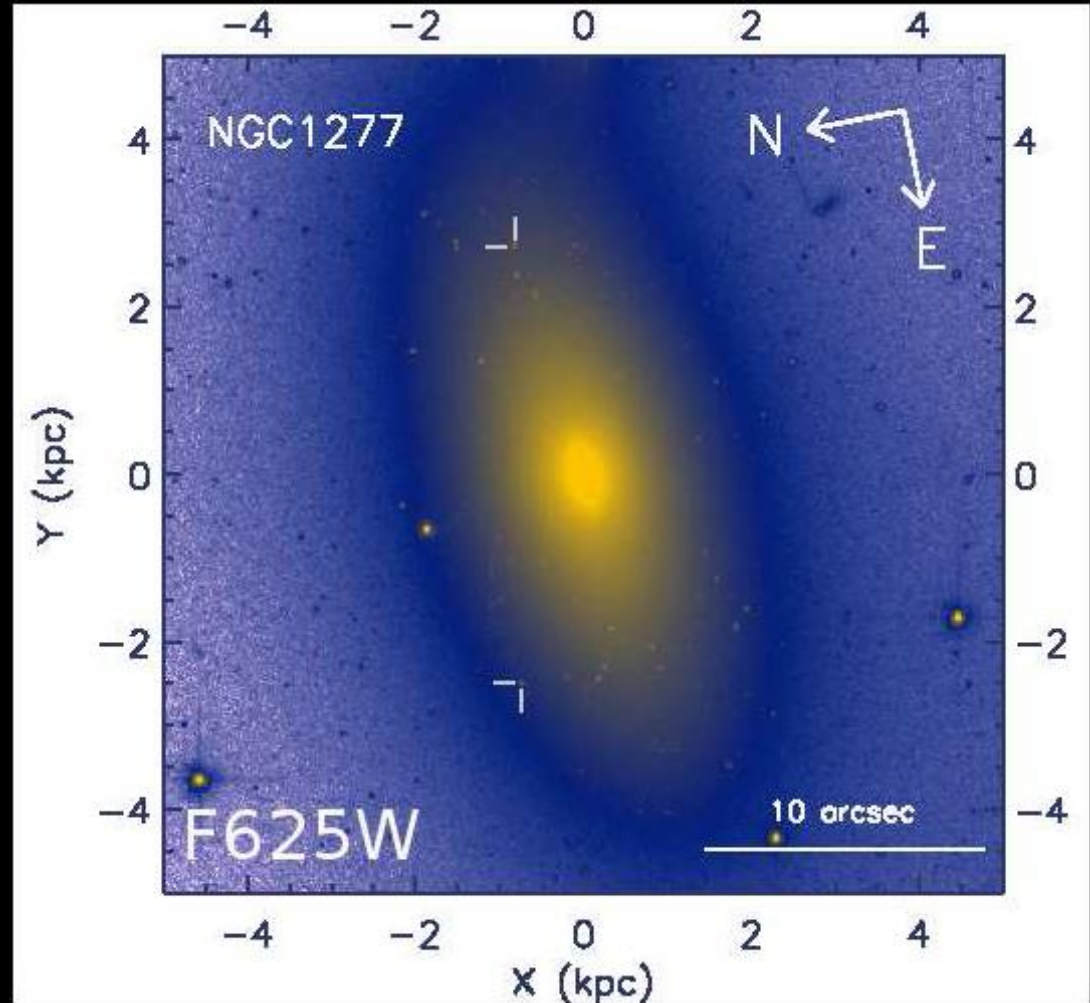1. What is the distribution of dark matter in the primordial galaxies?

Which type of dark matter halos these relic galaxies inhabit?

- Very deep 3D spectroscopy with PMAS/PPAK IFU

- High resolution K-band NIRI ALTAIR/LGS AO with GEMINI

What is next?

2. What was the primordial population of globular clusters?

(High resolution r-band imaging with HST)

What all this tell us from the initial conditions of the Universe?… stay tuned…