HUNTING RELIC GALAXIES IN THE NEARBY UNIVERSE: PART I

BY

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AND

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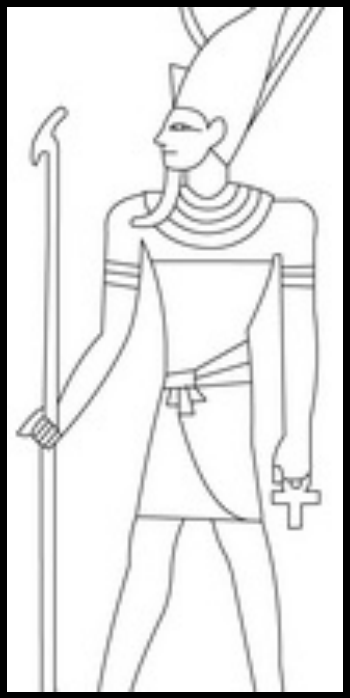
IPMU, Tuesday 3rd February 2015

What is a relic galaxy?

We consider a galaxy in the nearby Universe is a *relic* if…



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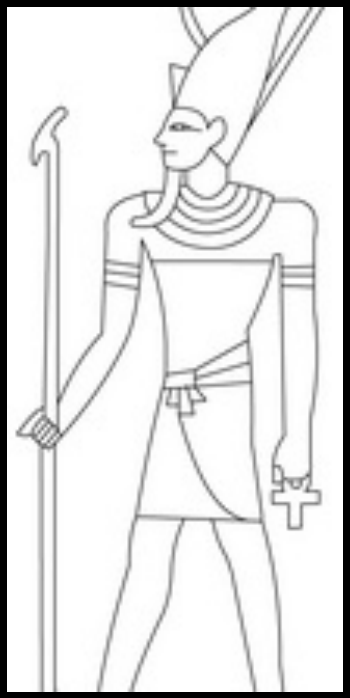

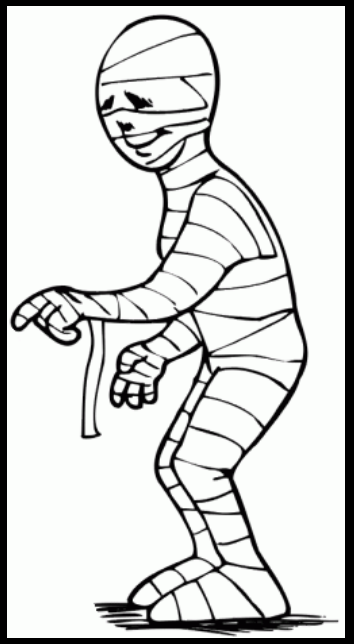

…has not been altered at ALL after its formation at high-z

= frozen over cosmic time

What is a relic galaxy?

SAME properties than those galaxies we see in the early Universe (z>2):

1. *Massive*:
$M^* > 10^{11}$ Msun

2. *Compact*:
$R_e < 2$ kpc

3. *Old at all radii*:
Age > 10 Gyr

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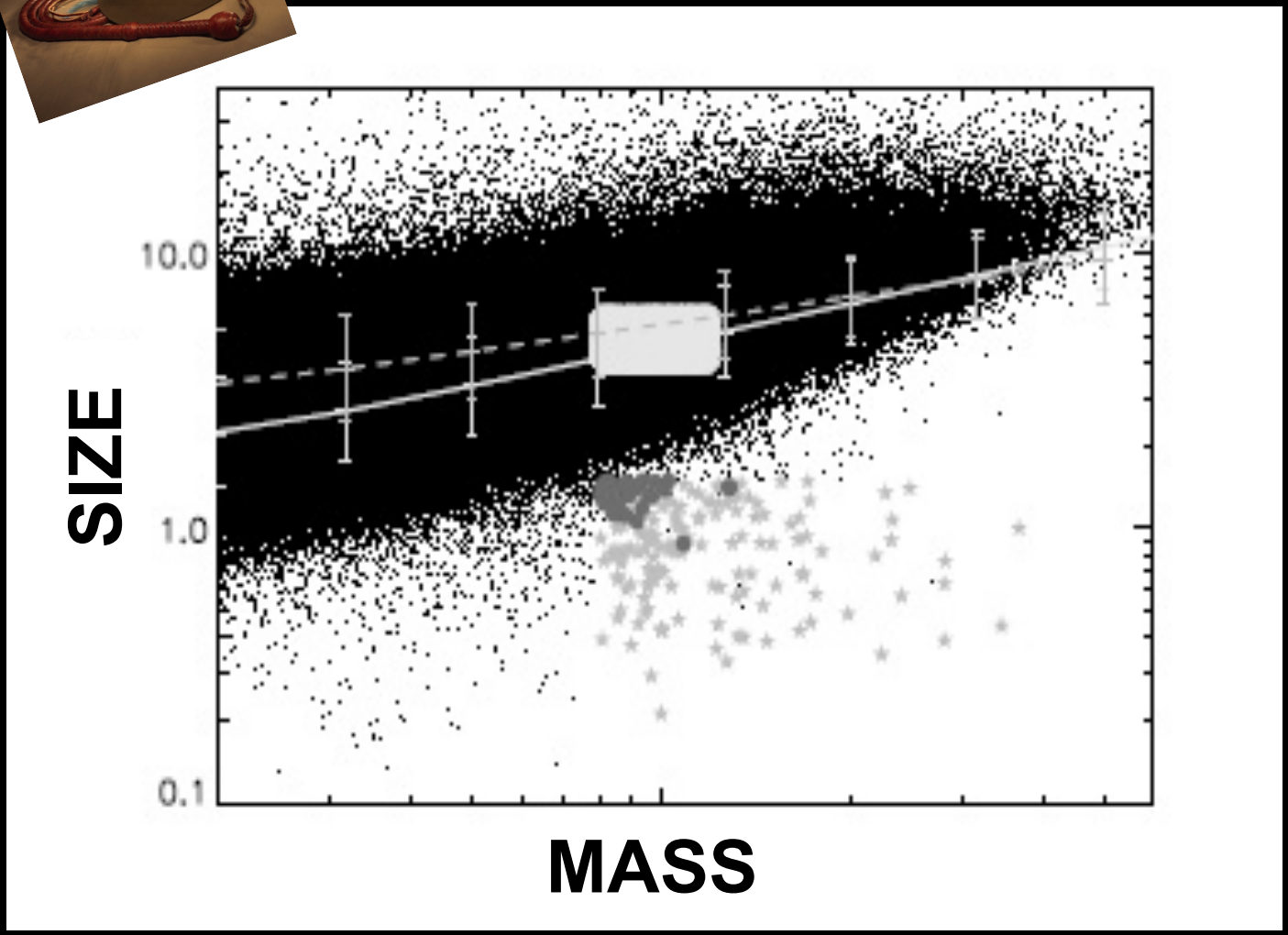
Don't miss

Hunting Relic Galaxies in the Nearby Universe: Part II

Trujillo's Talk

on Thursday 5th

Hunting relic galaxies in the nearby Universe...

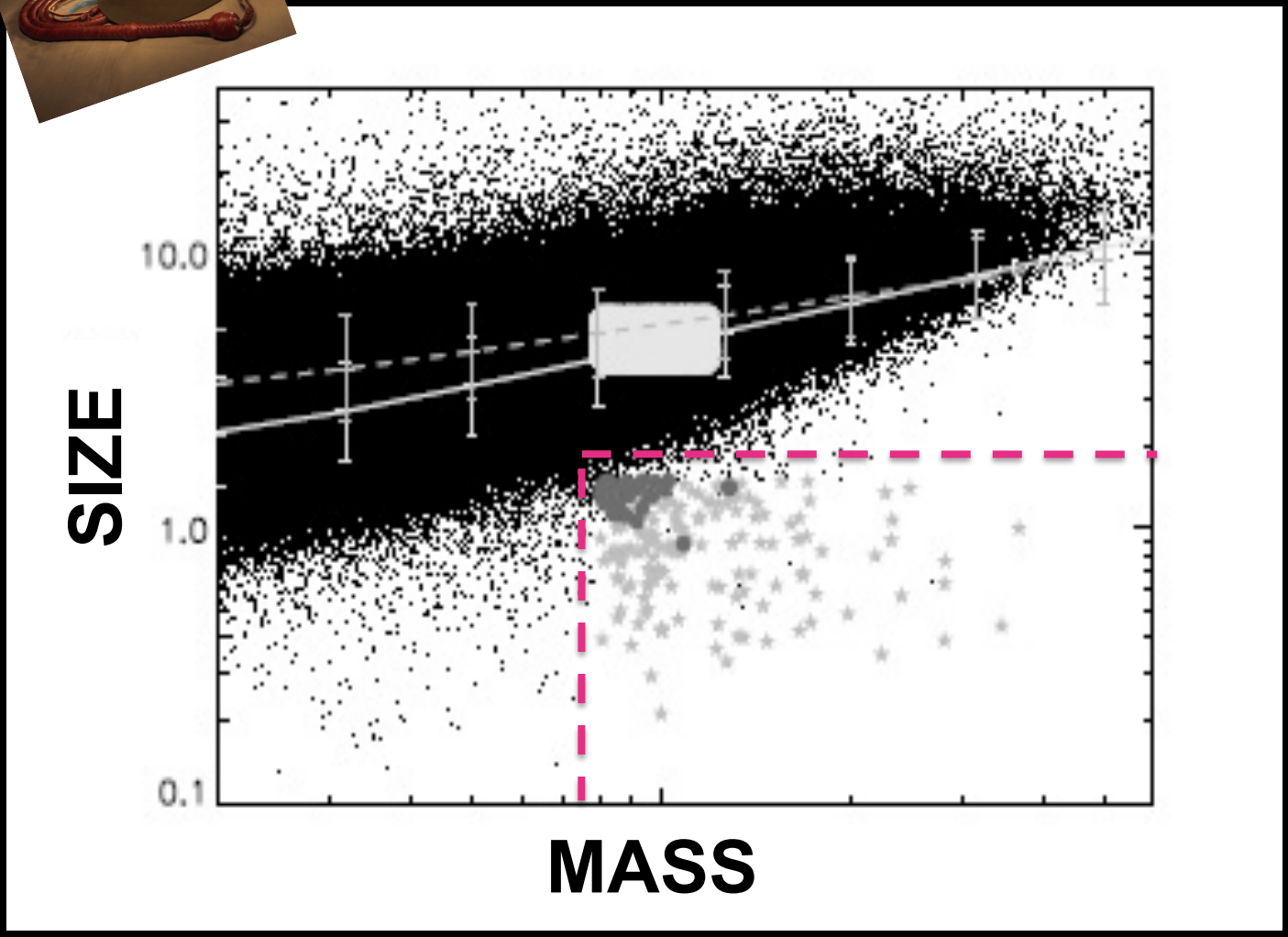


Galaxies in SDSS with:
(NYU Galaxy Catalog, Blanton et al. 2005)

$M^* > 8 \times 10^{10} M_\odot$
$R_e < 1.5$ kpc

Trujillo et al. (2009), Taylor et al. 2010, Valentinuzzi et al. 2010, Poggianti et al. 2013

Hunting relic galaxies in the nearby Universe...



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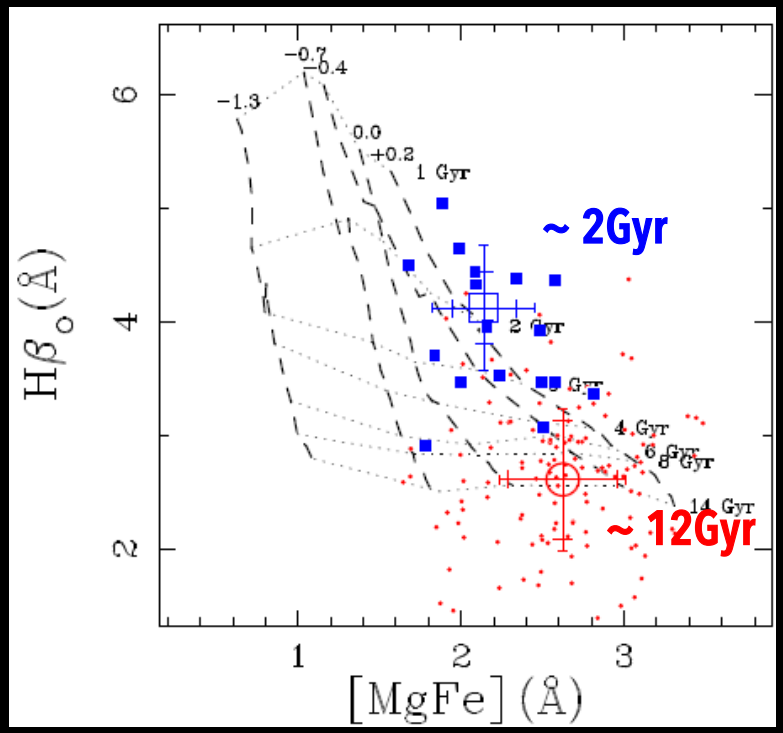
49 local compact massive galaxies < 0.03% !!

Trujillo et al. (2009), Taylor et al. 2010, Valentinuzzi et al. 2010, Poggianti et al. 2013

3) Old at all radii?

SDSS spectra 29 candidates

Trujillo et al. (2009)



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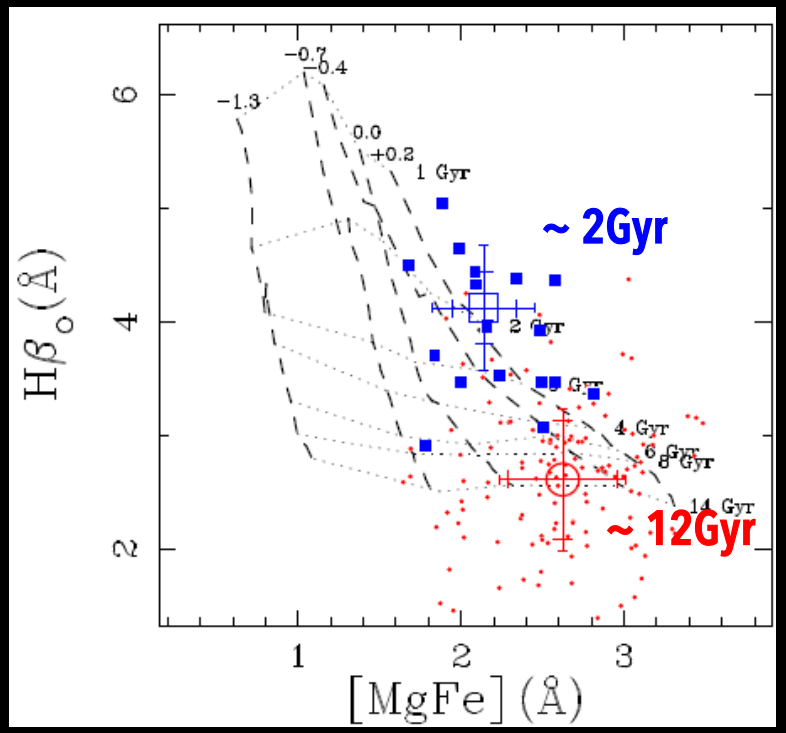
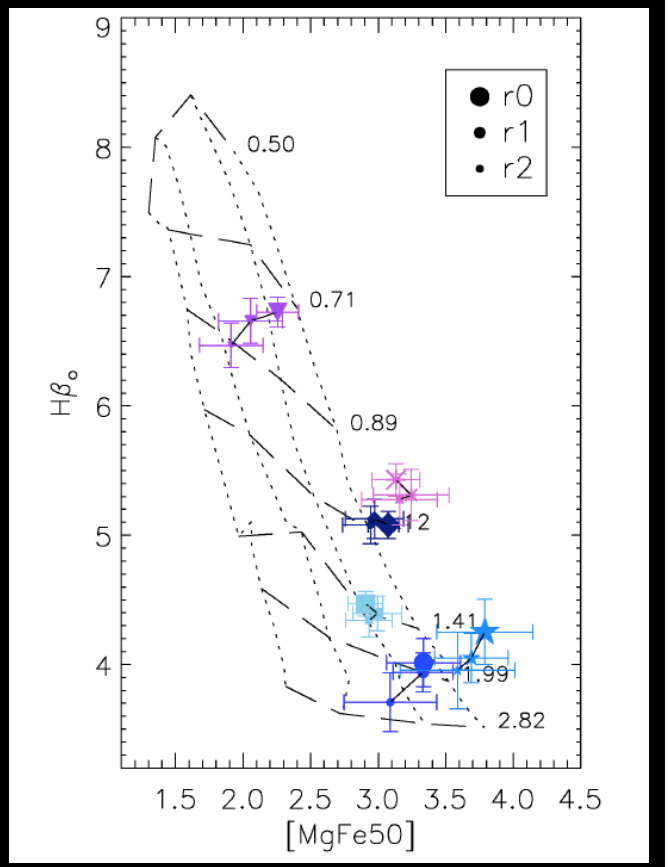


Long-slit spectra 7 candidates

with ISIS @ William Herschel Telescope

Ferré-Mateu et al. (2012)

- ✓ high S/N (~50)
- ✓ out to ~3 Re



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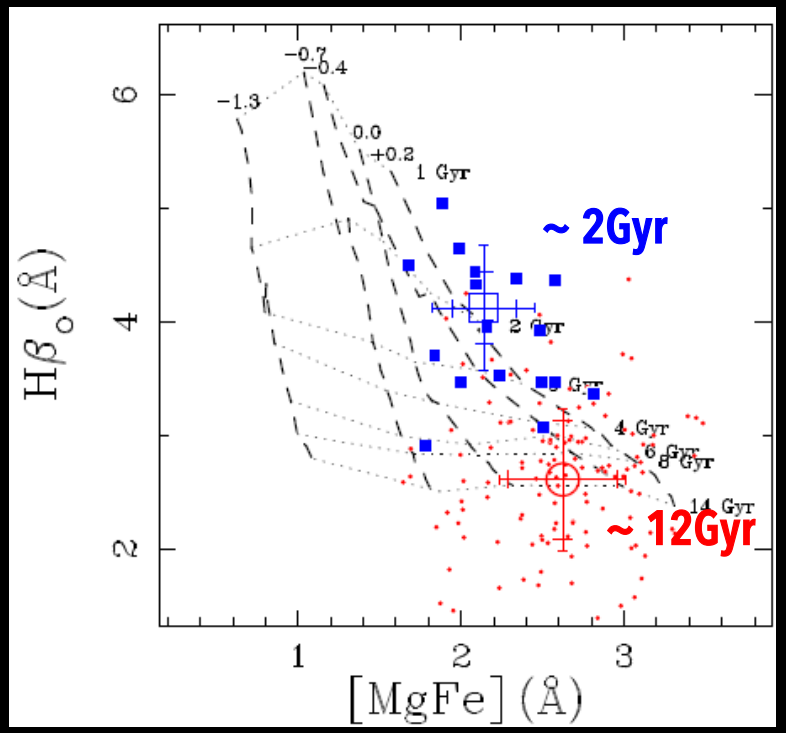

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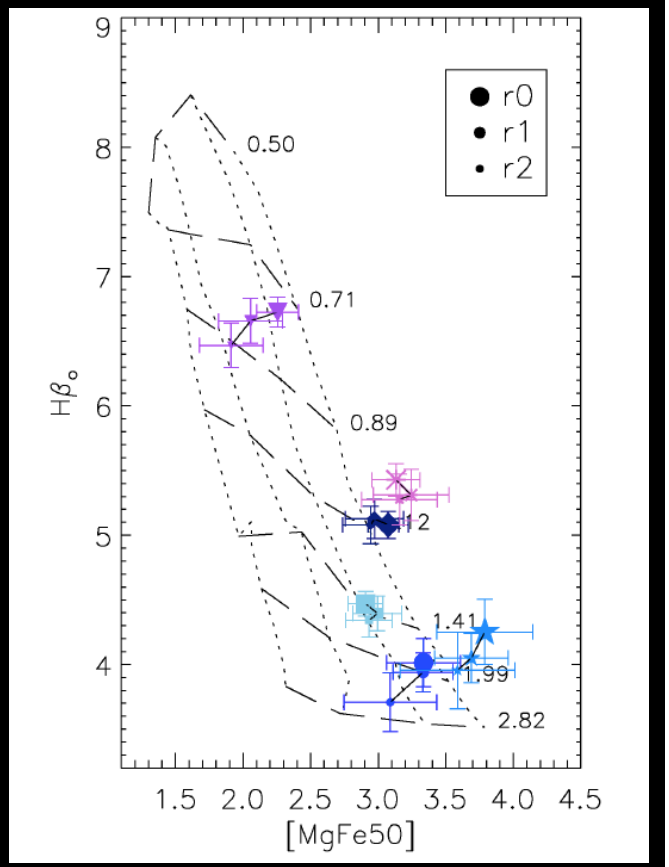
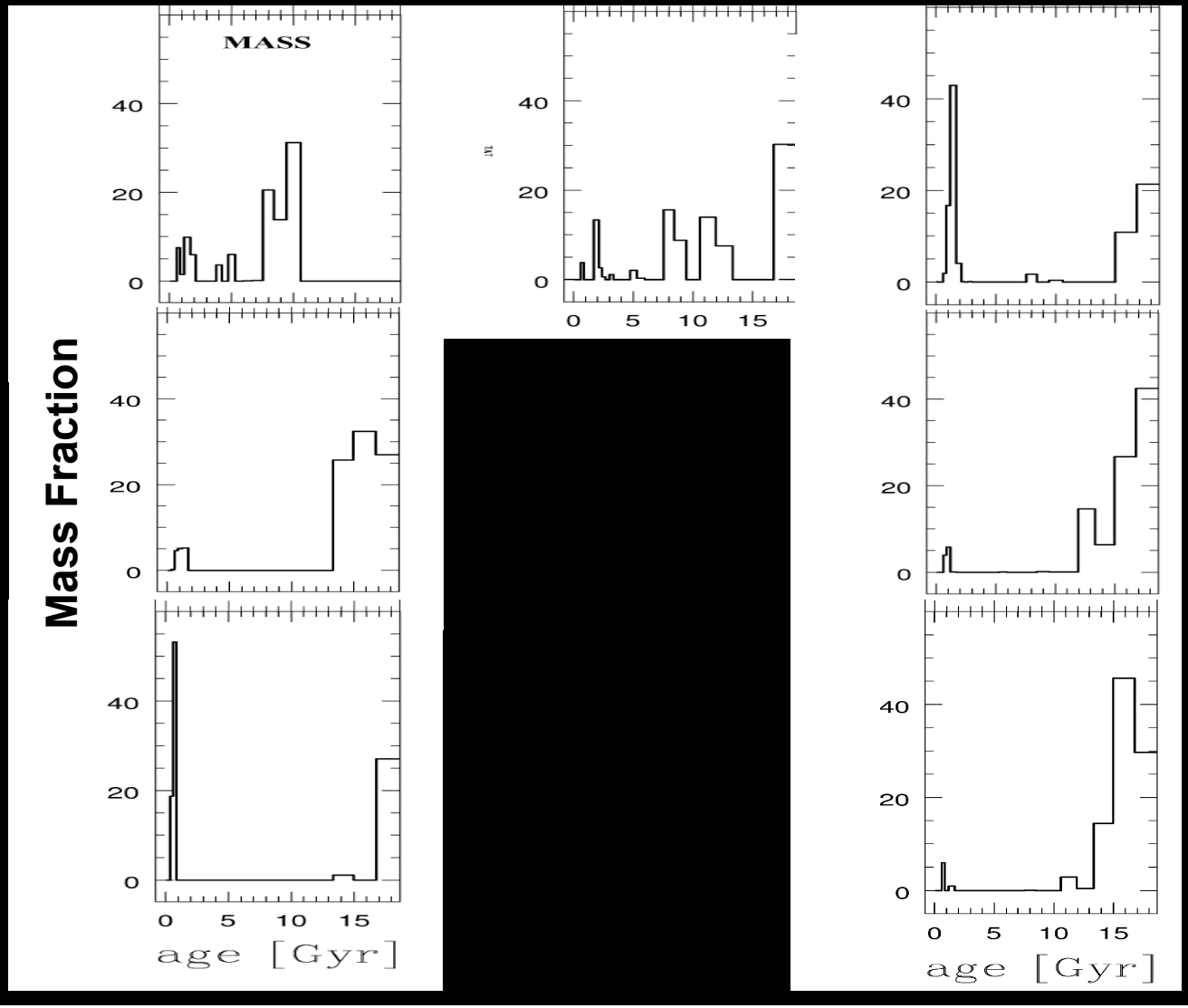


✗ Massive compact galaxies at z~0 are relatively young (~2 Gyr)

Line strength indices → Luminosity-weighted

3) Old at all radii?

Full-spectral-fitting → Luminosity & Mass-weighted



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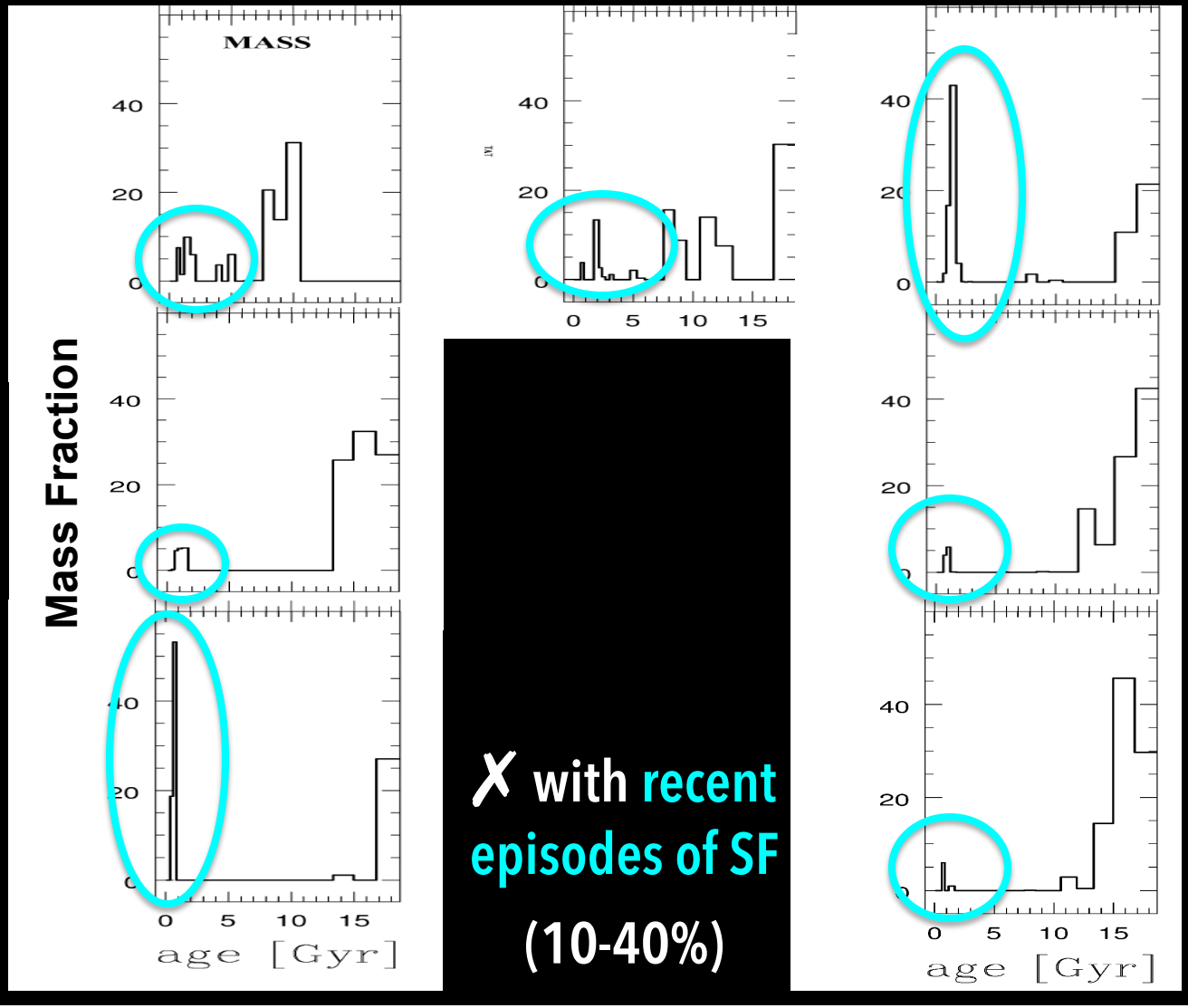

✗ with recent episodes of SF (10-40%)

They are NOT the relics from the early universe massive galaxies but their analogues!

… but how is it possible to form such amount of recent stellar mass?
Is it the same mechanism that forms massive galaxies at high-z?

(e.g. Keres et al. 2005, Oser et al. 2010, Ricciardelli et al. 2010, Wyuts et al. 2010)

They are NOT the relics from the early universe massive galaxies but their analogues!

Finding a relic galaxy is not easy…

van den Bosch et al. (2012)

1) Massive:
$M_* = 1.2 \times 10^{11} M_{sun}$

2) Compact:
$R_e = 1.2$ kpc

3) Old at all radii:
??

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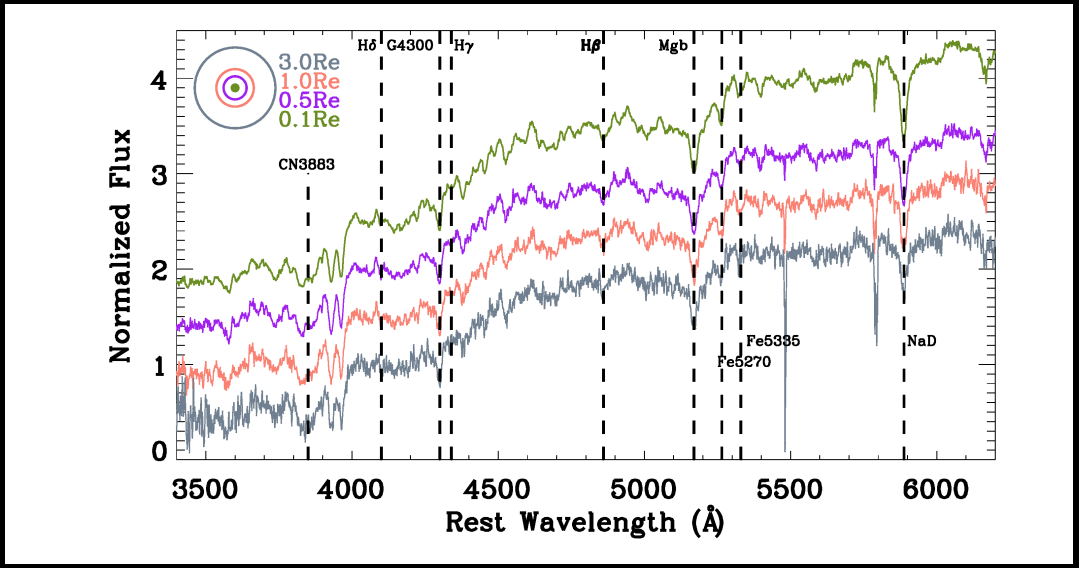
Long-slit spectroscopy

with ISIS@WHT up to ~3Re



Trujillo, Ferré-Mateu et al. 2014

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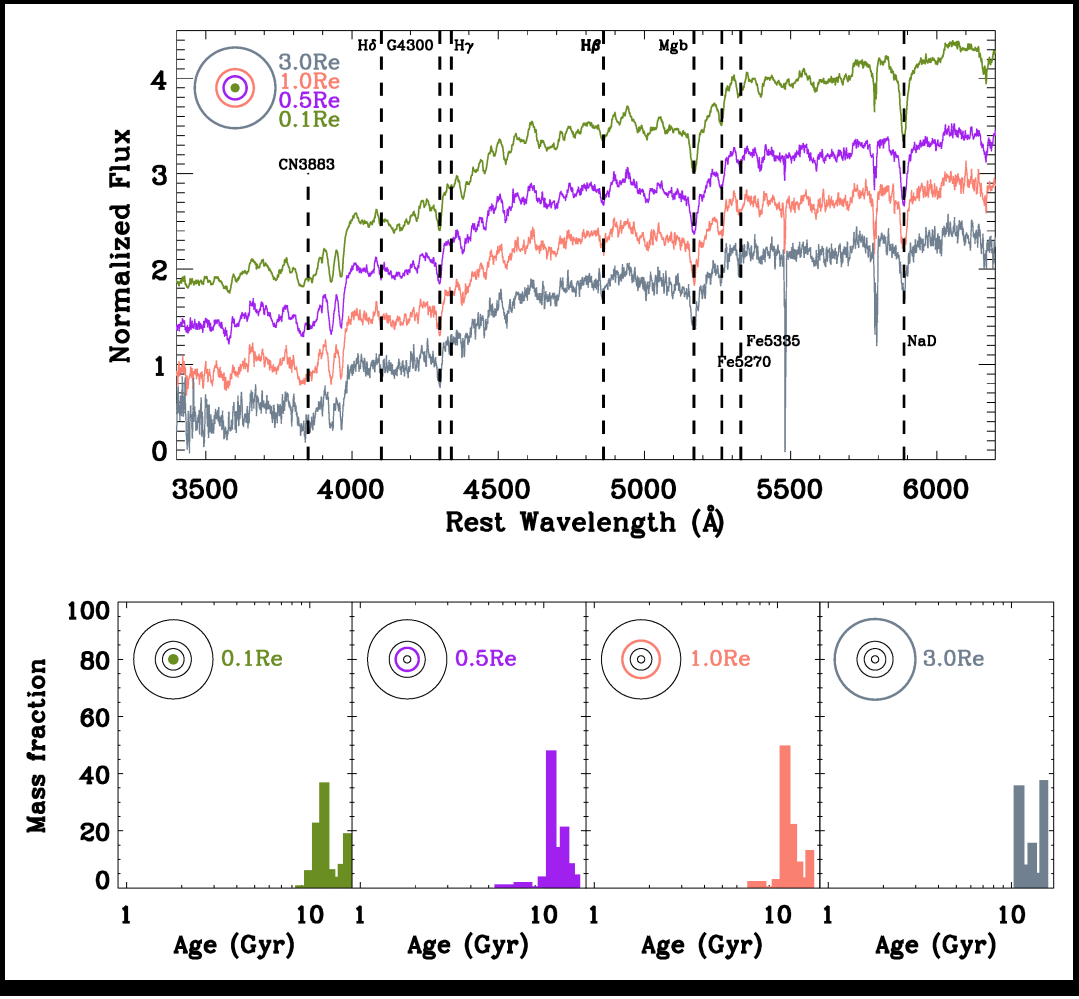

Age ~12 Gyr
all stars formed
> 10 Gyr

NGC1277 is the first confirmed relic galaxy studied in detail

because …

- Is massive ($M^* \sim 1.2 \times 10^{11} M_{sun}$)
- Is really compact (Re ~ 1.5 kpc)
- And ALL its stellar populations are OLD (> 10Gyr)

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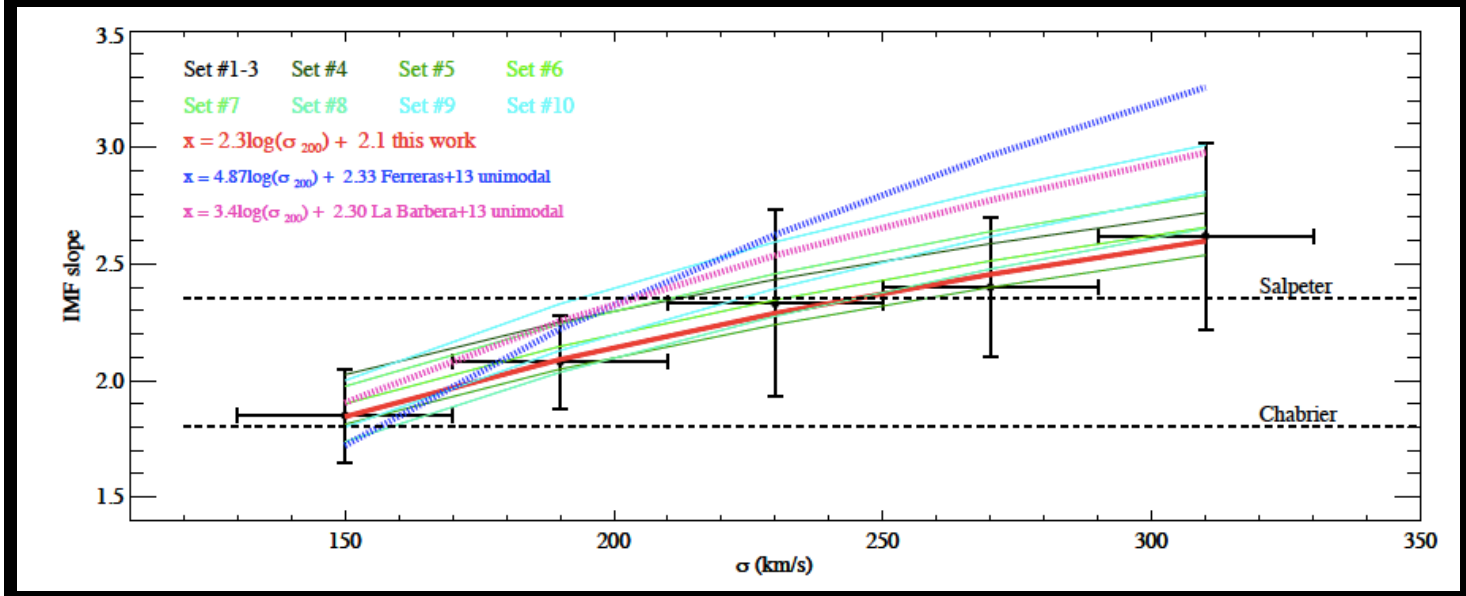
But are we biased with the assumption of a universal IMF?

(e.g. Ferré-Mateu et al. 2013)

IMF variations: dynamics vs stellar pops



IMF – σ relation: more massive galaxies demand steeper IMFs

(e.g. van Dokkum 2012, Cappellari 2012, Ferreras 2013, Spiniello 2013, La Barbera 2013)

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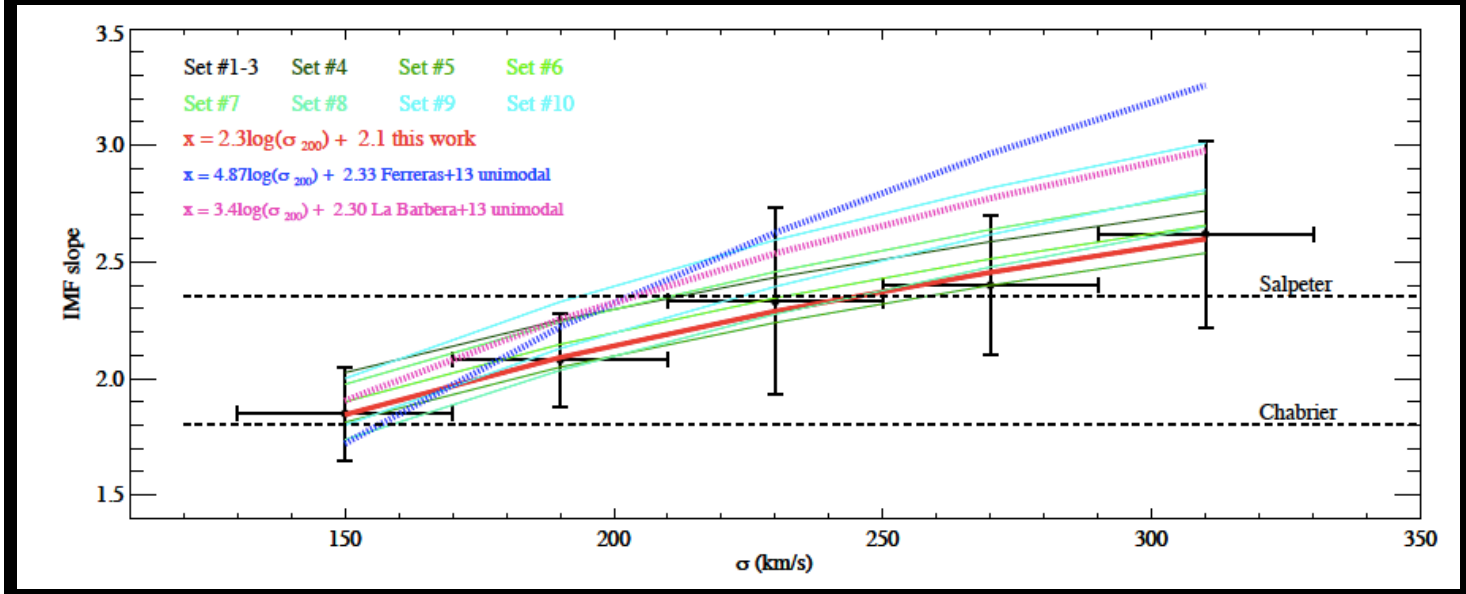

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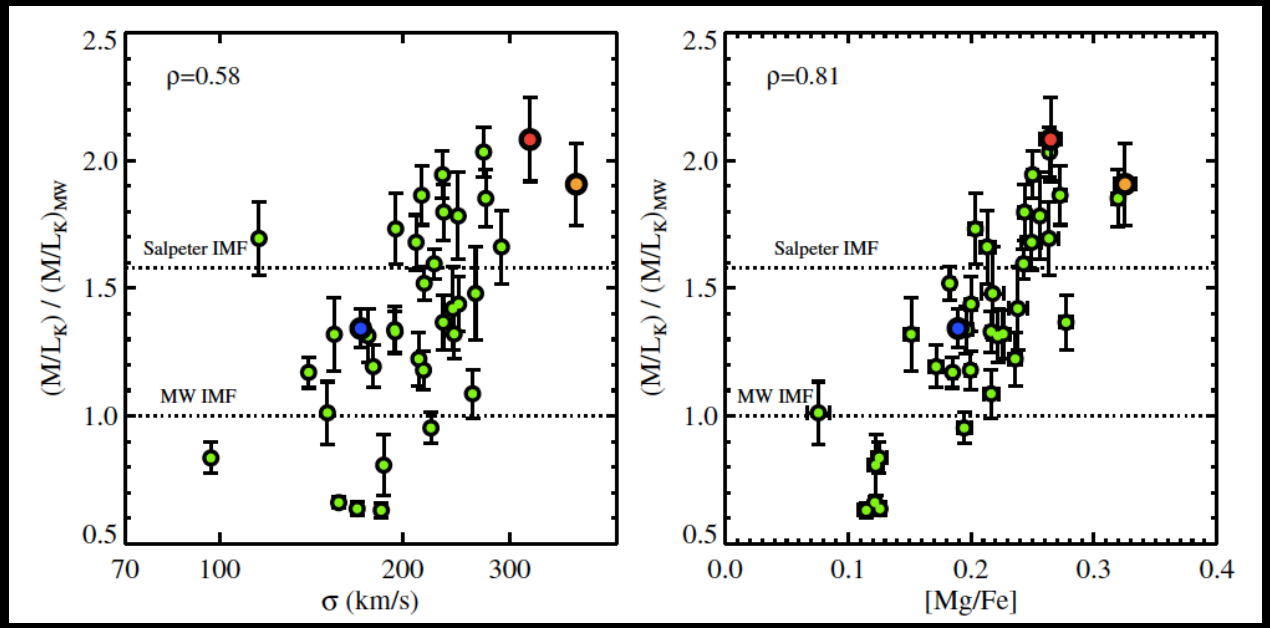
IMF – α/Fe relation: more α-enhanced galaxies demand steeper IMFs
(e.g. Conroy 2012)



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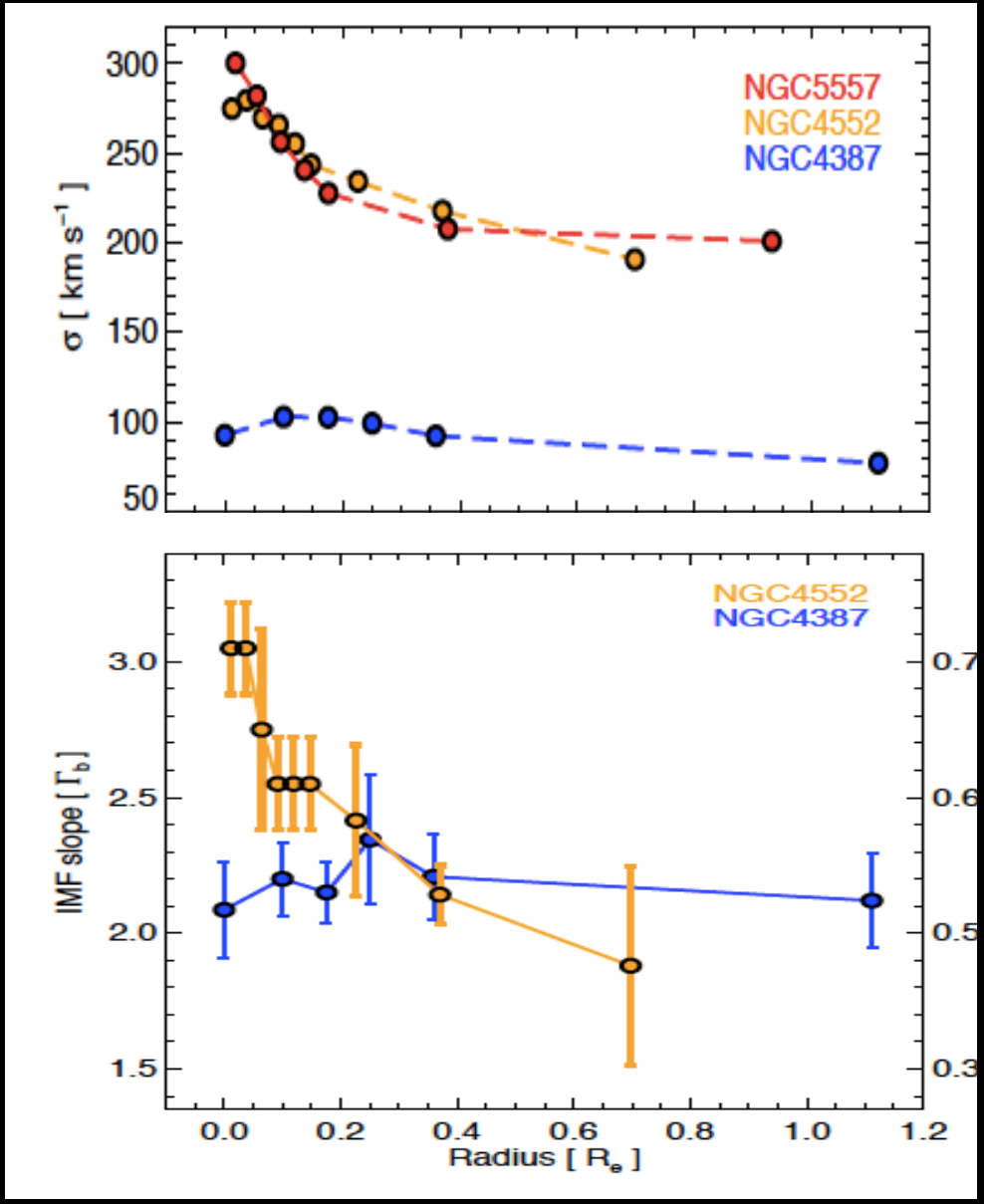
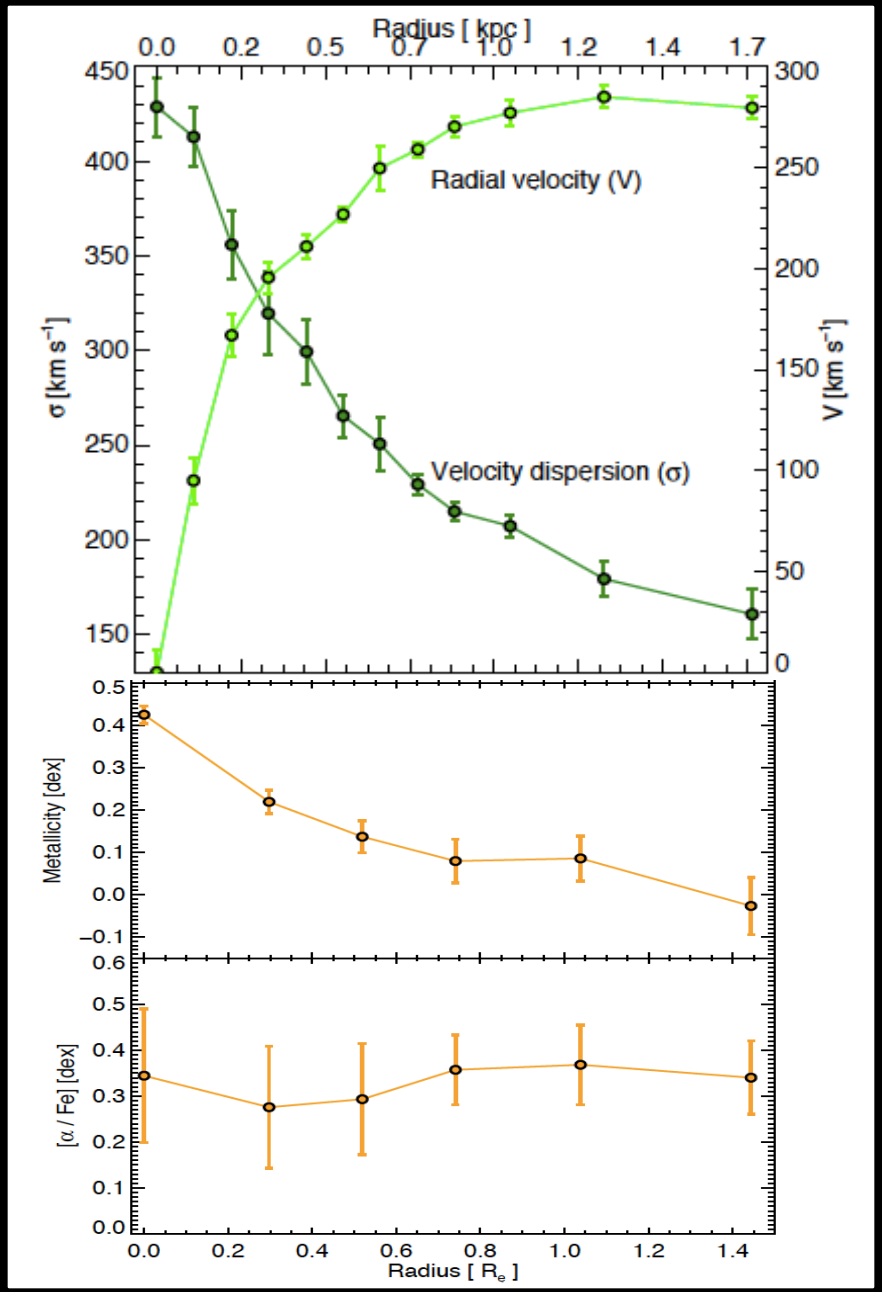


Radial variations in the IMF

Martín-Navarro et al. 2014



Back to NGC1277 and its radial variations…

Strong velocity dispersion profile

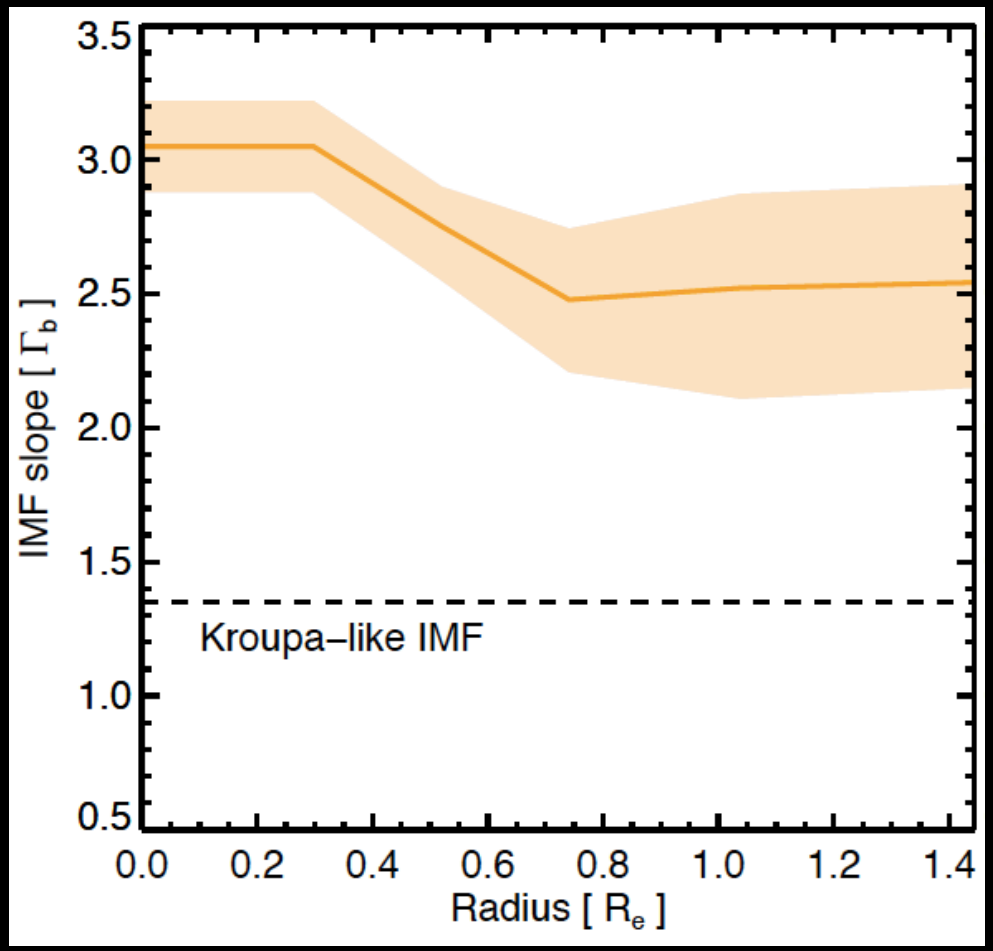
Mild metallicity gradient

No age or α /Fe gradient

van den Bosch et al. 2012, Trujillo et al. 2014, Martín-Navarro et al. 15

Long-slit spectroscopy
with ISIS@WHT +OSIRIS@GTC

Martín-Navarro et al. 2015



- Steep IMF at all galactocentric distances → **local σ is not the main driver** of the observed IMF variations

- Is **the pristine IMF** of the "monolithic-like" phase of massive galaxies at high-z, will become universal-like by mergers

- Even using a steep IMF, the criteria **of all old still holds**

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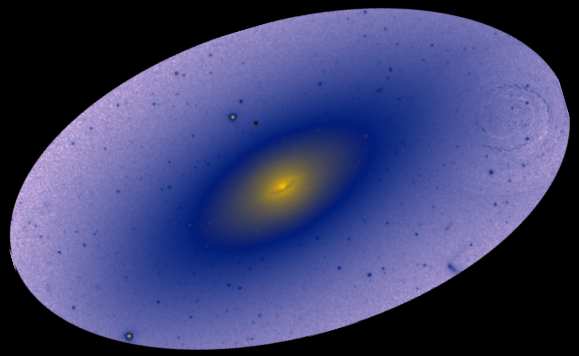
which opens the possibility to study in full detail the properties of the early Universe



But we still need to understand …

- Is it a unique galaxy?
- What really drives the IMF variations?
- The galaxy dynamics → new dynamical models
- Does it really host a Super Massive Black Hole?

(e.g. van den Bosch et al. 2012, Lasker et al. 2013, Emsellem et al. 2013)

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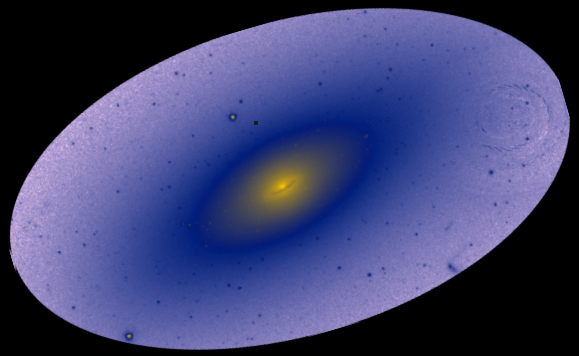

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STAY TUNED!

Relic galaxies and their SMBHs:
coevolution or not?

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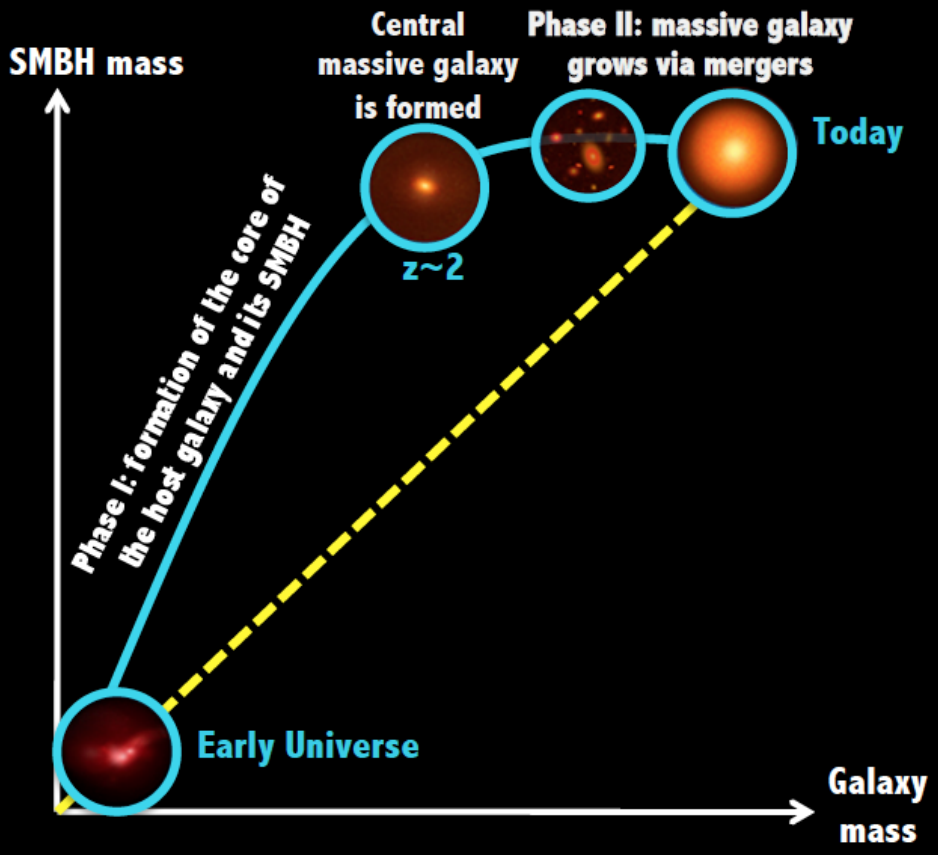
Relic galaxies are outliers in the SMBH scaling relations due to a different evolutionary path

Ferré-Mateu et al. 2015



Massive galaxy evolutionary track

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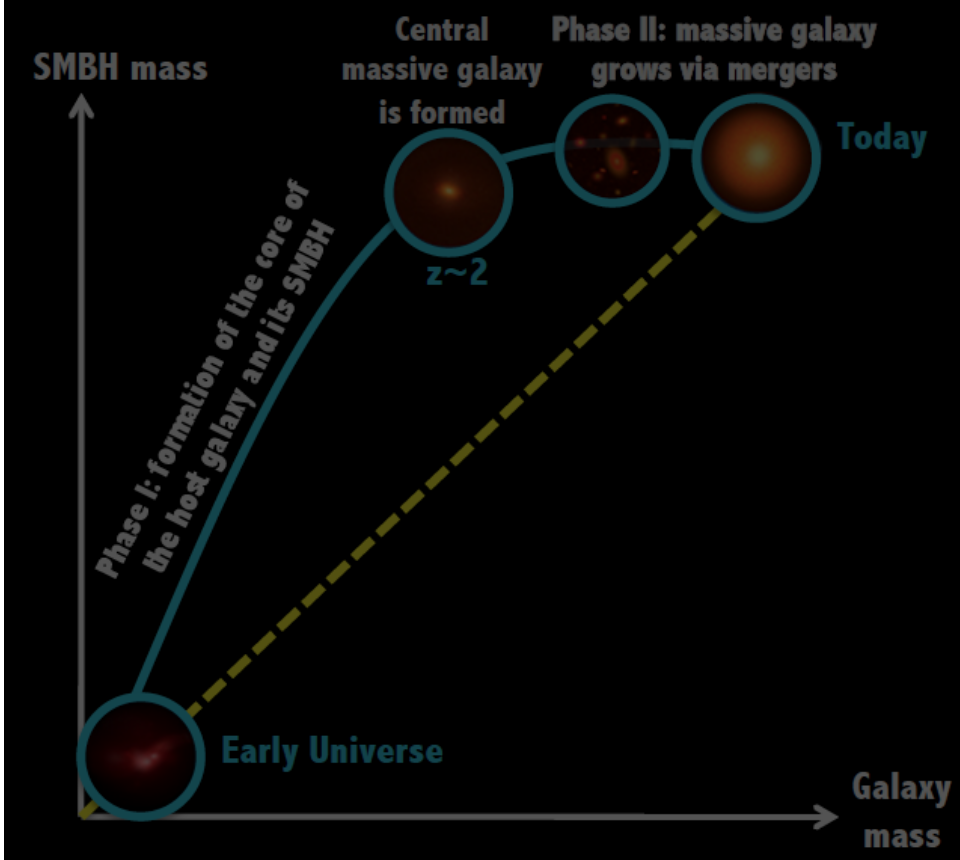

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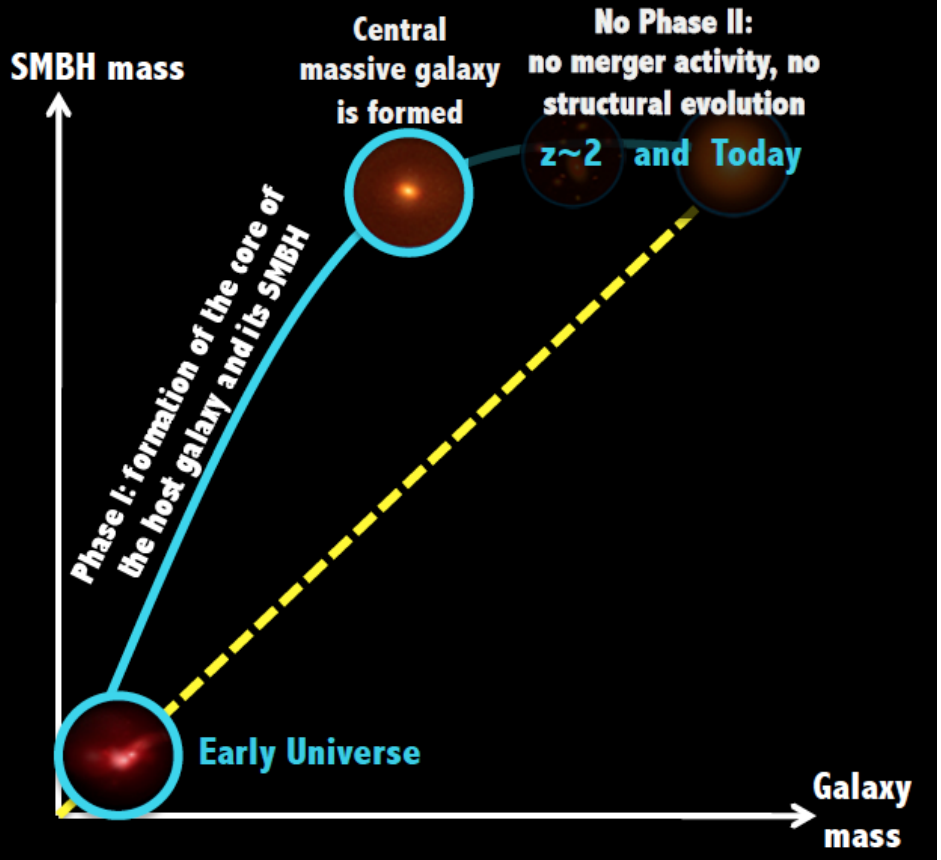
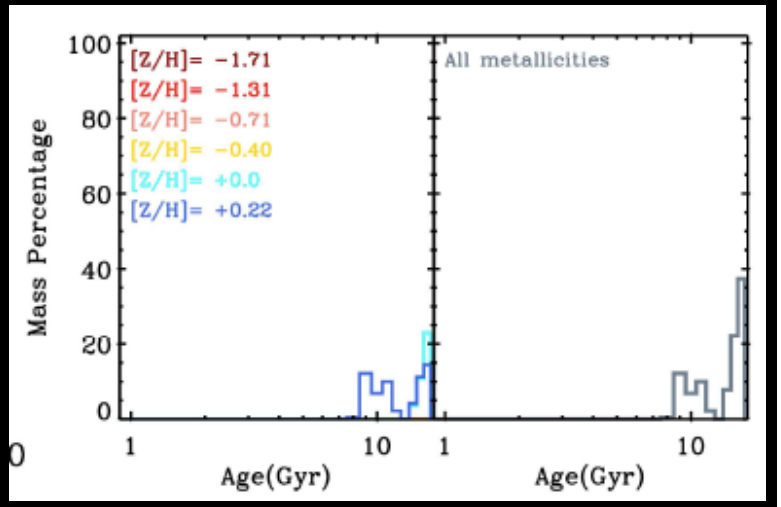


Relic galaxy evolutionary track

Relic galaxies and their SMBHs: coevolution or not?

- 7 compact & massive galaxies from HETMG Survey (van den Bosch, in prep)
- SFH → compatible with being relic galaxies
- Lower limit of SMBH formation at ~ 10 Gyr



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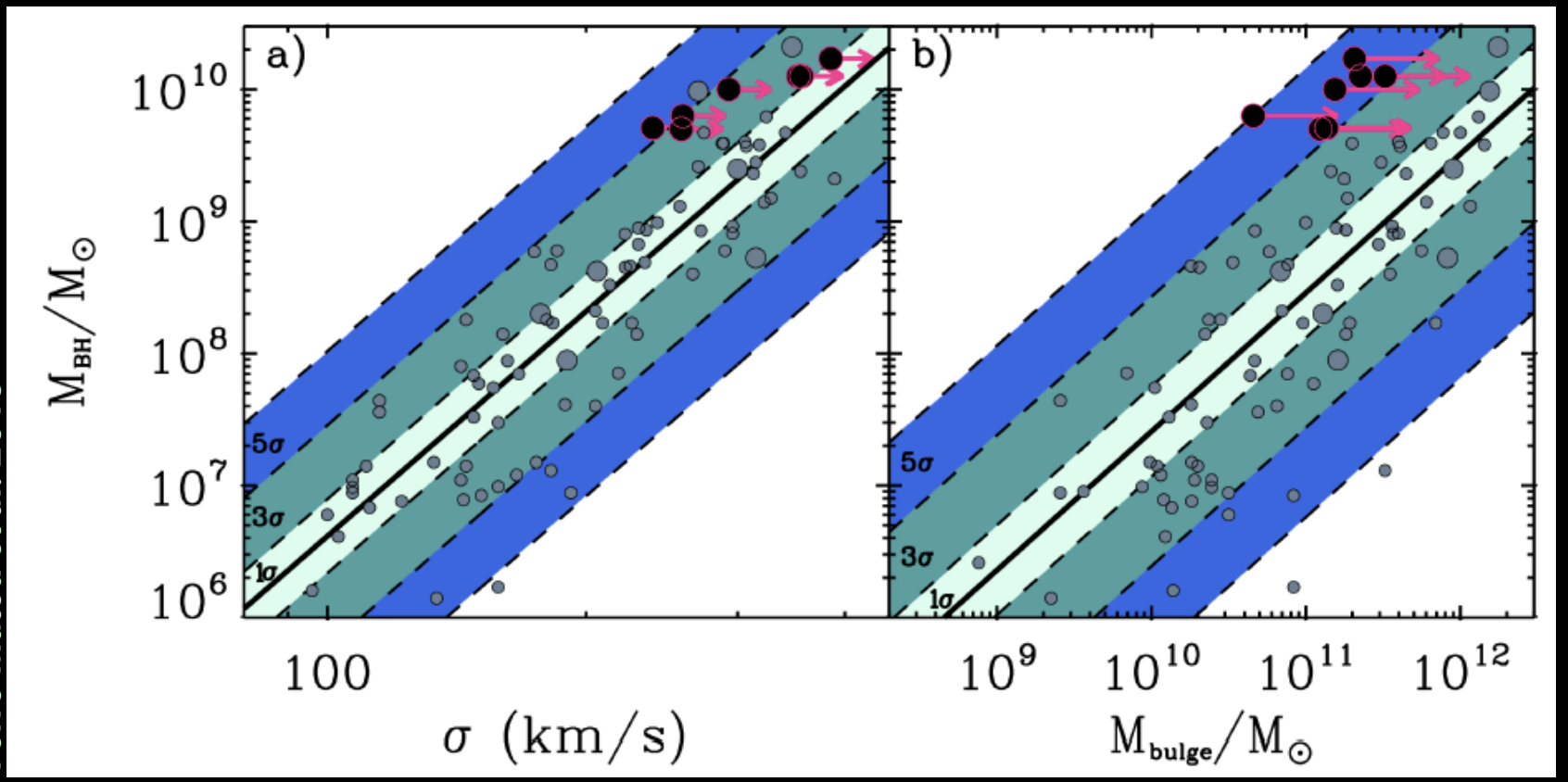

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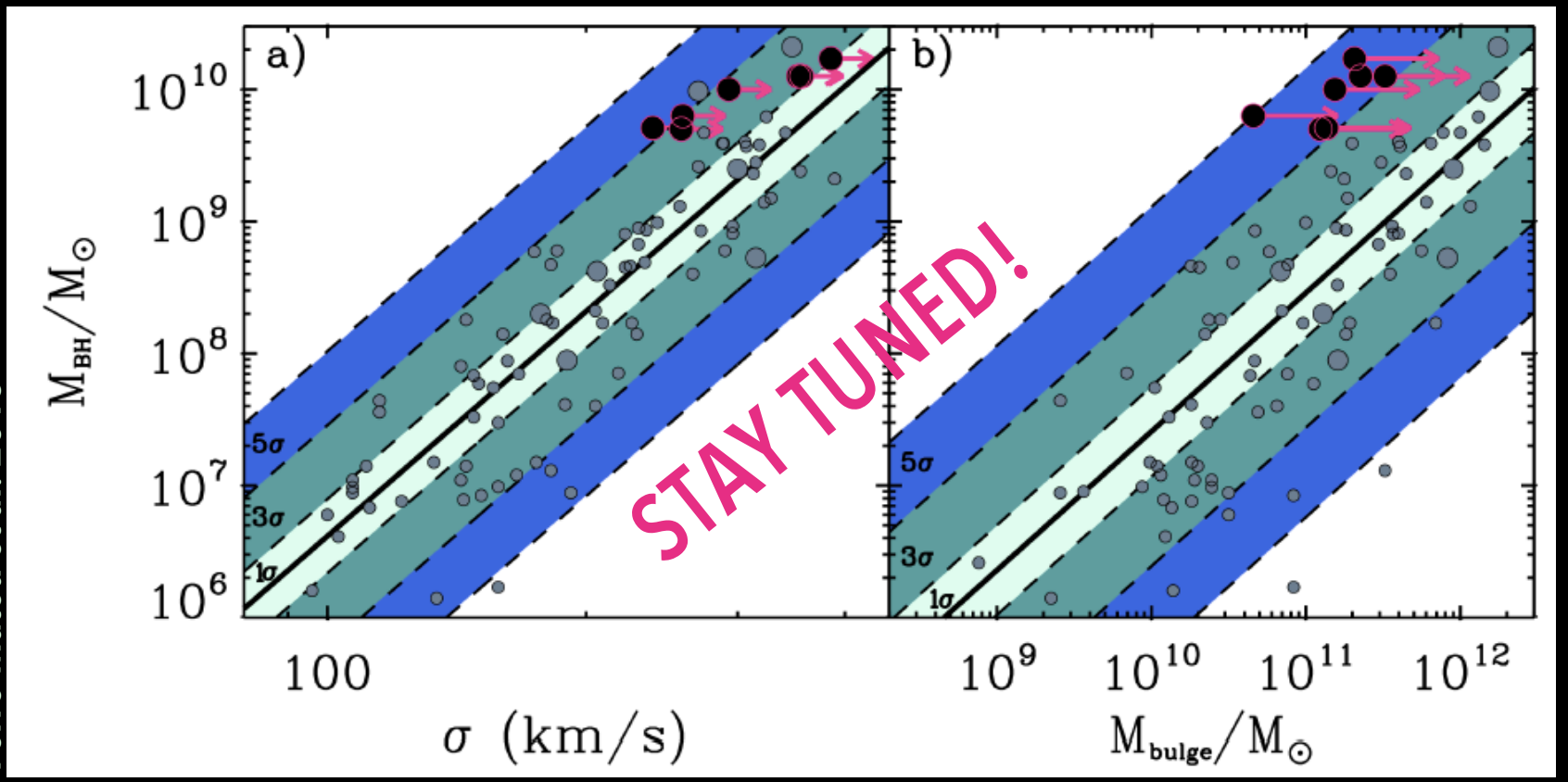


Ferré-Mateu et al. 2015

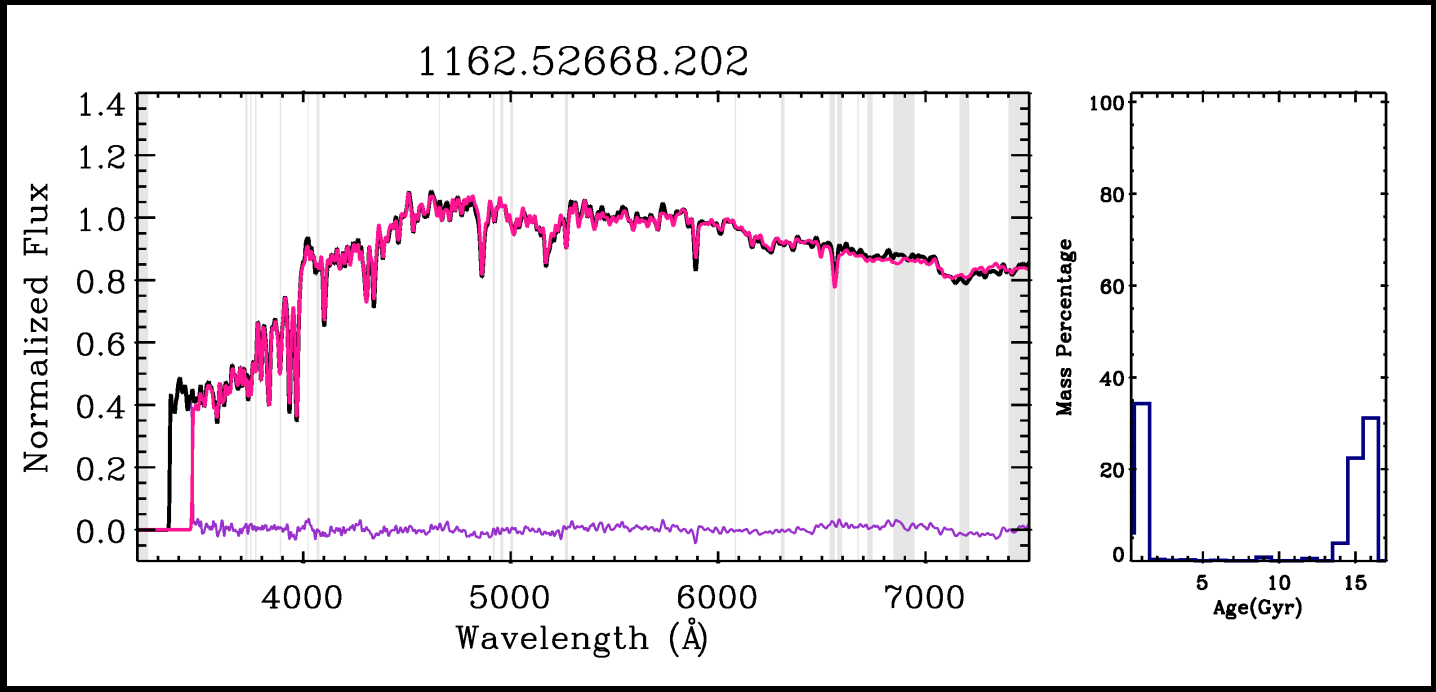
Summary with open questions

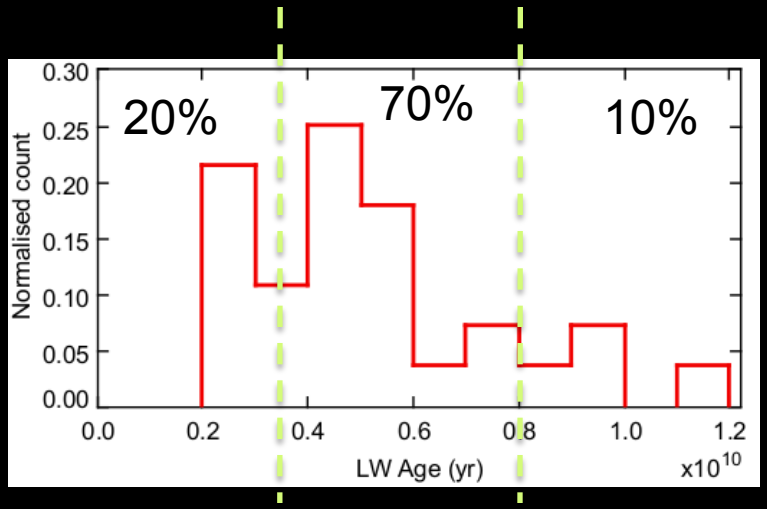
1) Sample of nearby compact massive galaxies that are the analogues of those in the early Universe; *but how did they form all that recent SF?*

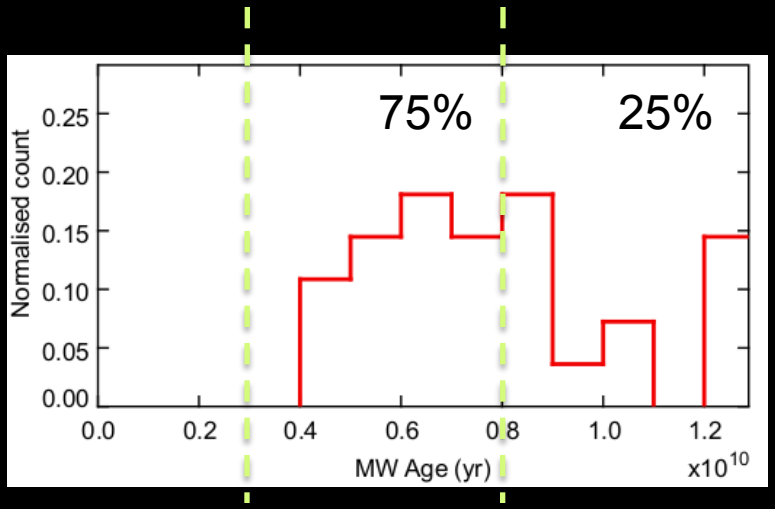
2) NGC1277 is the first confirmed relic galaxy; *but is this galaxy a "weirdo"?*

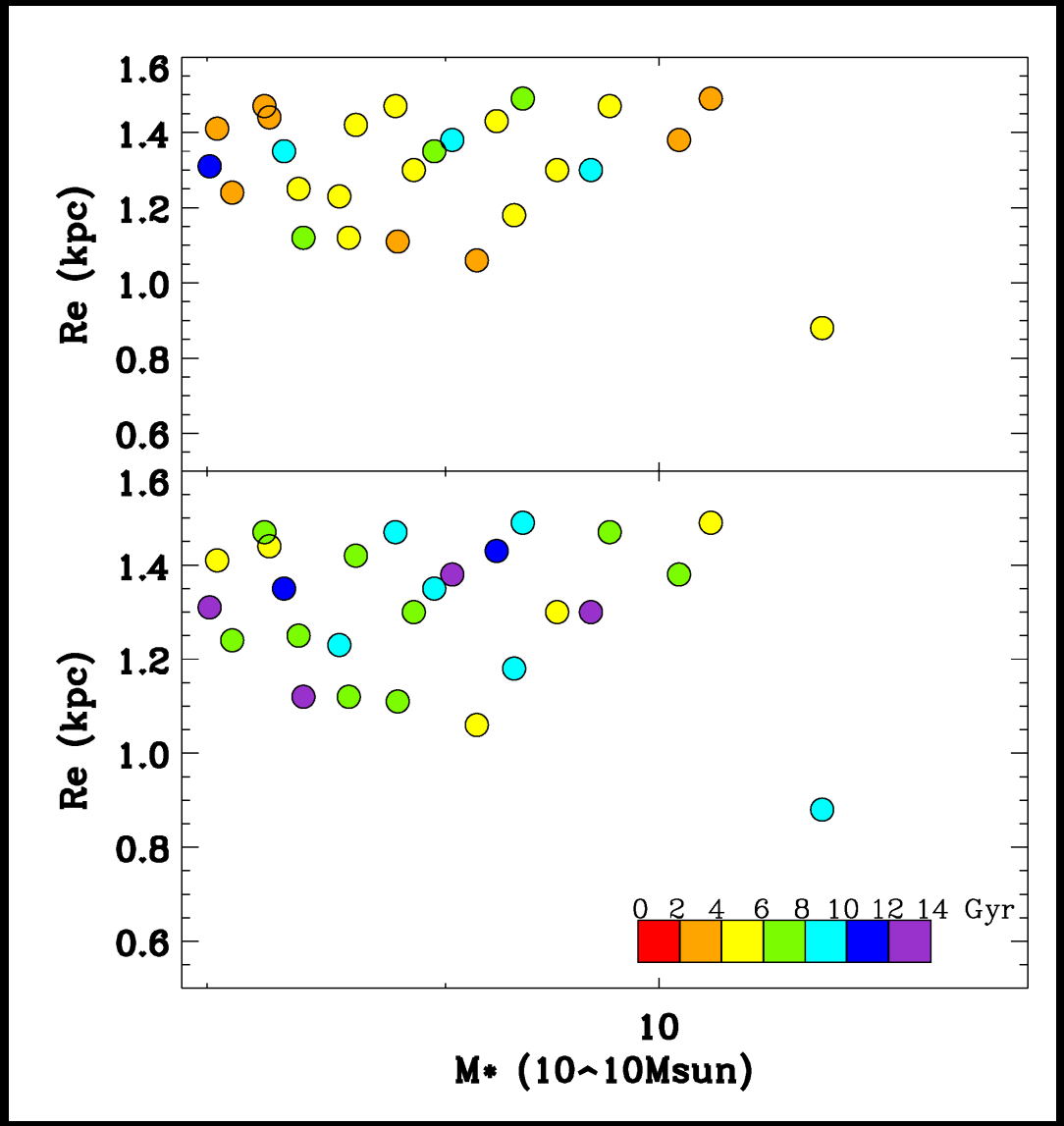
3) The relic galaxies are extreme outliers in the SMBHs scaling relations because they follow another evolutionary track than large massive ellipticals; *how to explain other outliers than are not relics (compact or not)?*

With the T09 sample of 29 local compact massive galaxies….









But NO age-size dependency!