

SMBH COEVOLUTION CHALLENGED BY NEARBY FOSSIL RED NUGGETS

BY

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AND

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Wednesday 23rd August 2017

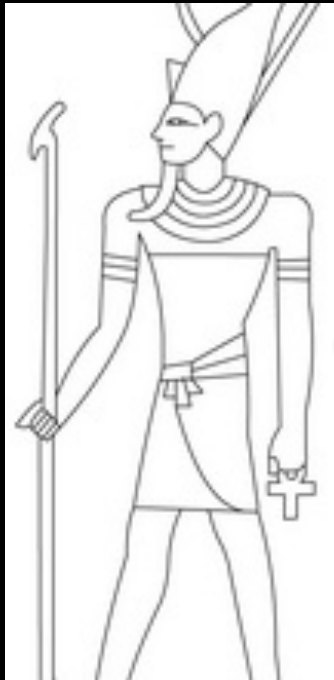
WHAT IS A FOSSIL/RELIC GALAXY?

We consider a galaxy in the nearby Universe is a **fossil/**
relic if...

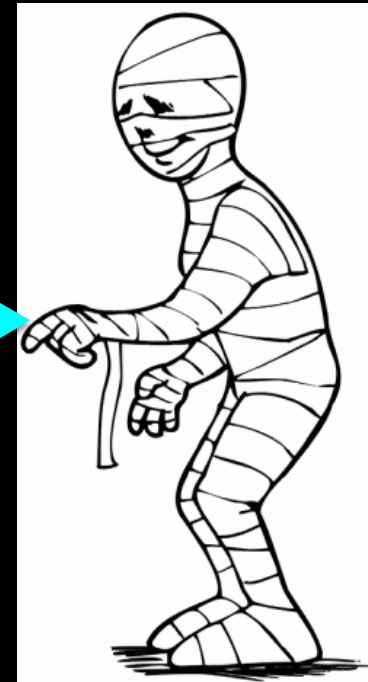
... has not been altered at ALL
after its formation at high- z
= **frozen over cosmic time**

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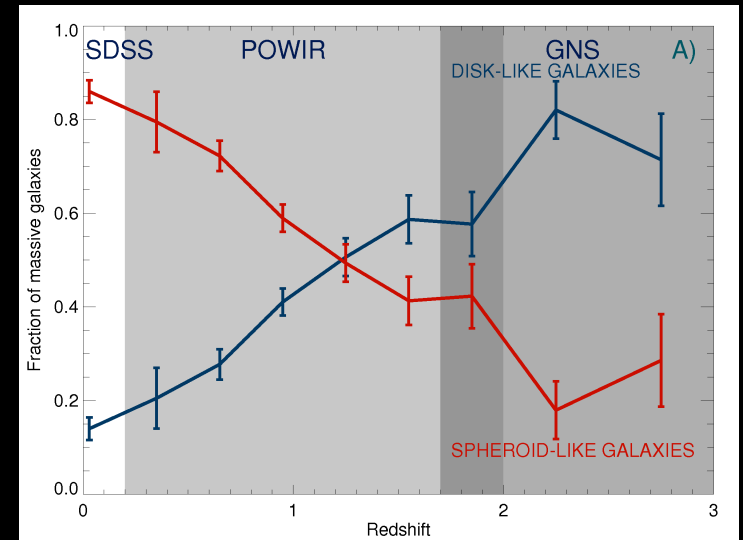
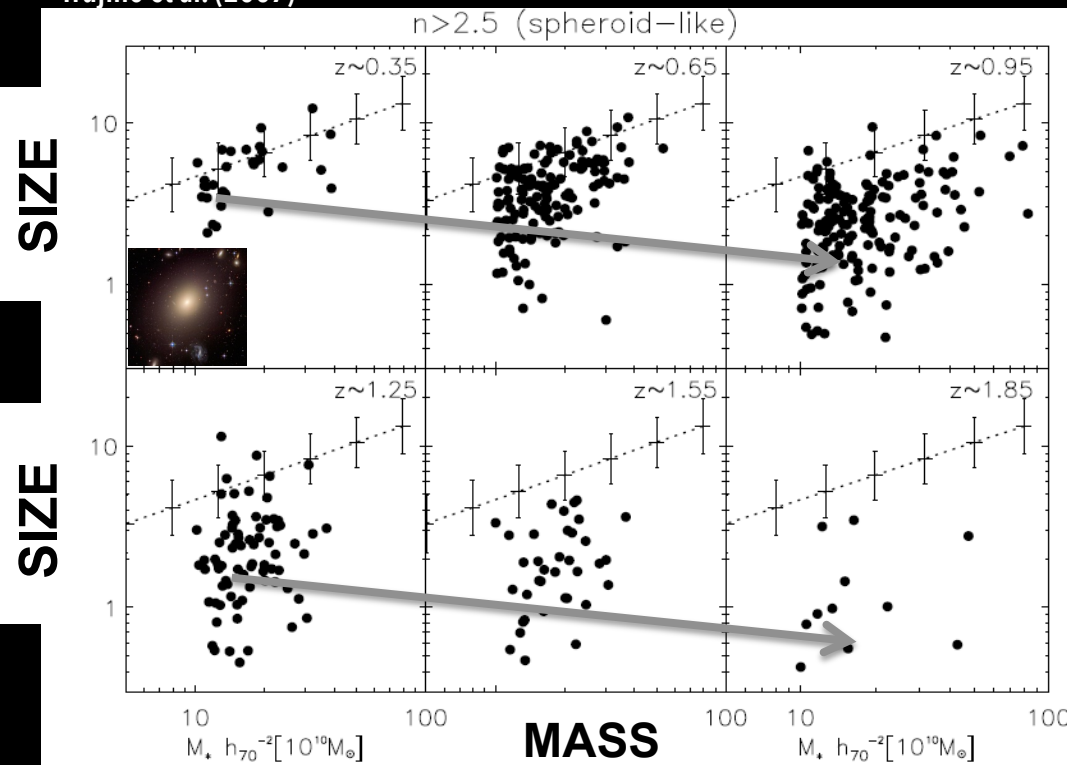
... has not been altered at ALL
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SAME properties than those
galaxies we see in the early
Universe

Massive galaxies suffer a **strong size and morphological evolution** since $z \sim 2-3$

Trujillo et al. (2007)



Buitrago et al. (2013)

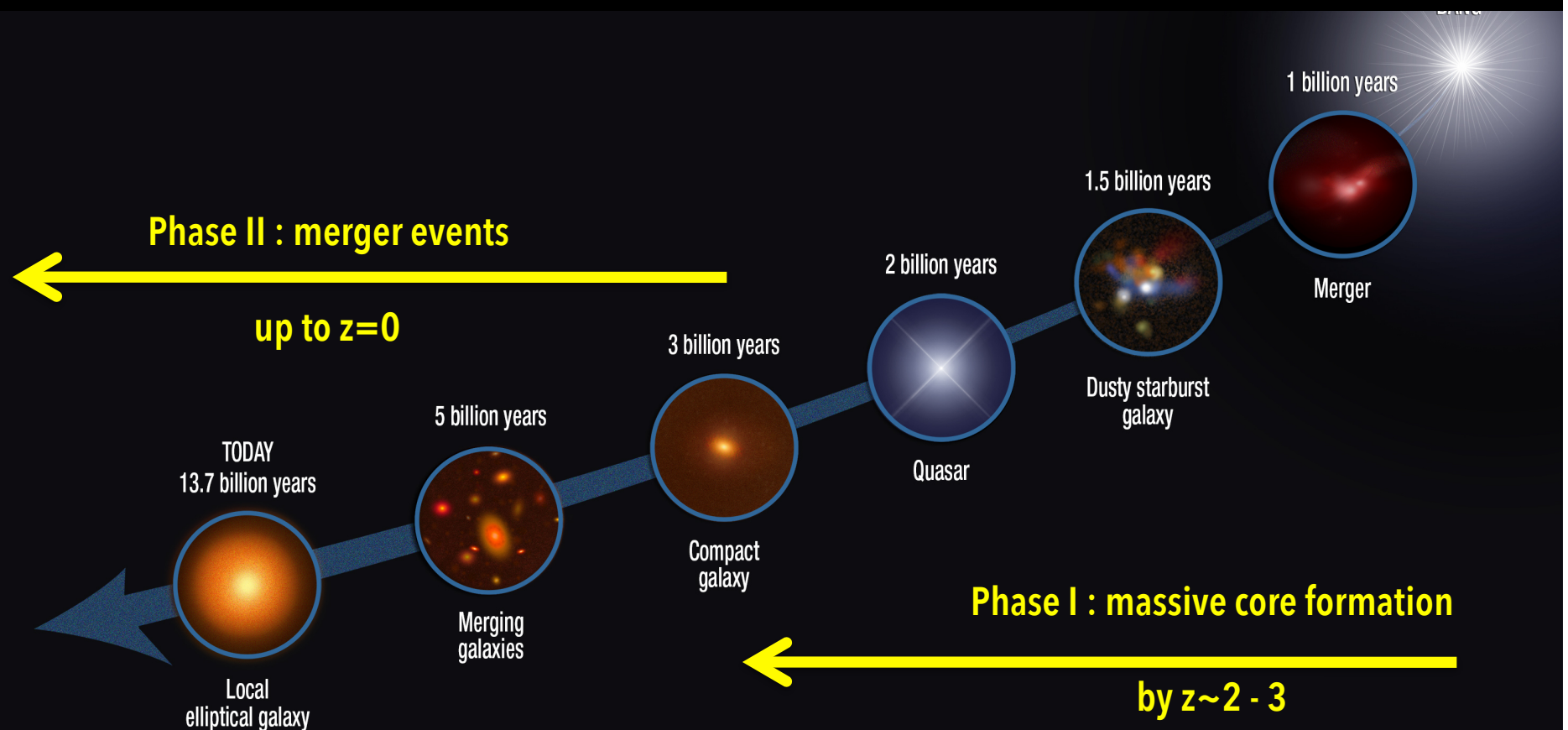
Daddi et al. 2005, Trujillo et al. 2006 & 2007, Longhetti et al. 2007, Zirm et al. 2007, Toft et al. 2007, Cimatti et al. 2008, van Dokkum et al. 2008, Buitrago et al. 2008, van der Wel et al. 2011, Law et al. 2012, Buitrago et al. 2013)

MASSIVE GALAXY FORMATION

TWO-PHASE MECHANISM:

Accretion of new material at the periphery of the central massive high- z galaxy

(e.g. Kochfar & Silk 2006, Naab et al. 2009, Hopkins 2009, Oser et al. 2010, Wyuts et al. 2010, Quilis & Trujillo 2012)



MASSIVE RELIC GALAXY FORMATION

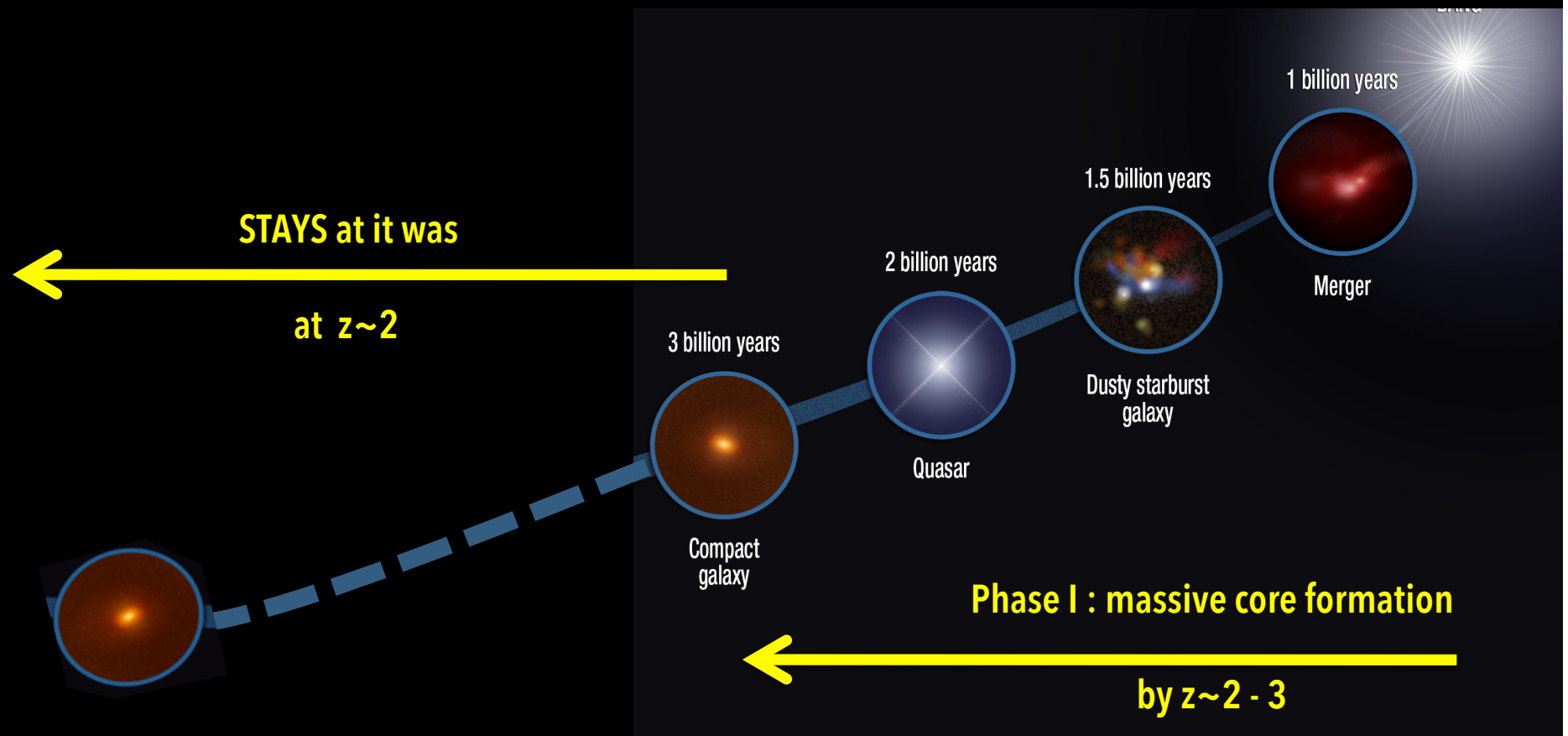
Stochastic event → some massive galaxies will avoid phase II

(Quilis & Trujillo 2012)

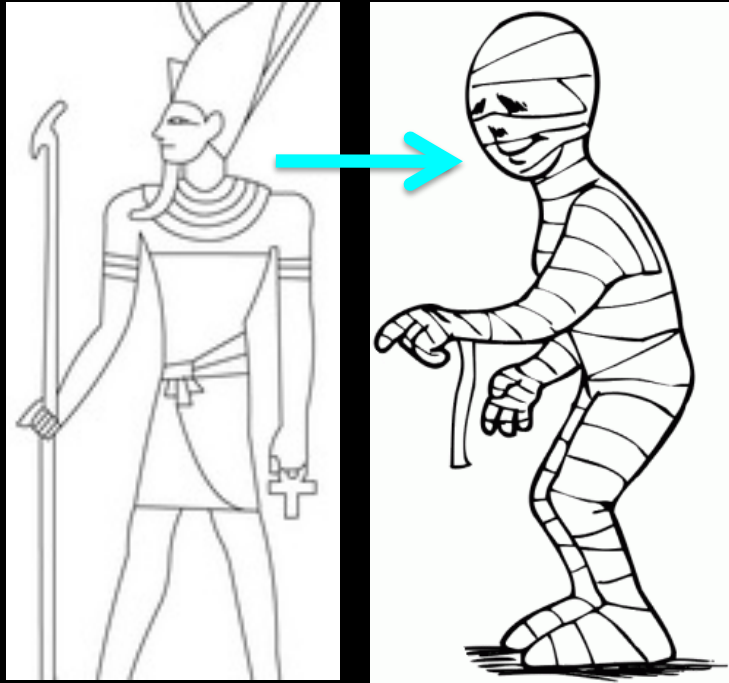
MASSIVE RELIC GALAXY FORMATION

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(Quilis & Trujillo 2012)



FOSSIL/RELIC RED NUGGETS



...has not been altered after
PHASE I

SAME properties to the red nuggets
we see at $z \sim 2-3$

1. Massive:

$$M^* > 10^{11} \text{ Msun}$$

2. Compact:

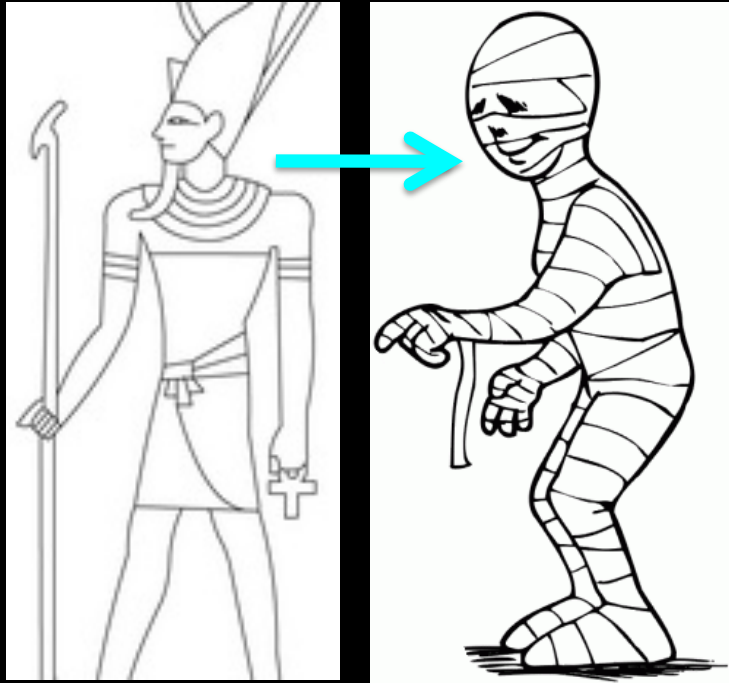
$$R_e < 2 \text{ kpc}$$

3. Old at all radii:

$$\text{Age} > 10 \text{ Gyr}$$



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Finding a relic galaxy hasn't been easy...

See e.g.

**Trujillo+09, Taylor+10, Valentinuzzi+10, Ferré-Mateu+12, Trujillo+12,
Damjanov+13, Poggianti+13, Damjanov+15,...**

But also at intermediate-redshift, see e.g.

Stockton+10, +13, Li-Yen+14, Damjanov+13, +15,...



Finding a relic galaxy hasn't been easy...



**NEVERTHELESS,
WE PERSISTED**



NGC1277

$M_* = 1.3 \times 10^{11} M_\odot$

$R_e = 1.2 \text{ kpc}$

$\sigma \sim 390 \text{ km/s}$

van den Bosch +12

Trujillo, Ferré-Mateu +14

Martín-Navarro, Ferré-Mateu +15



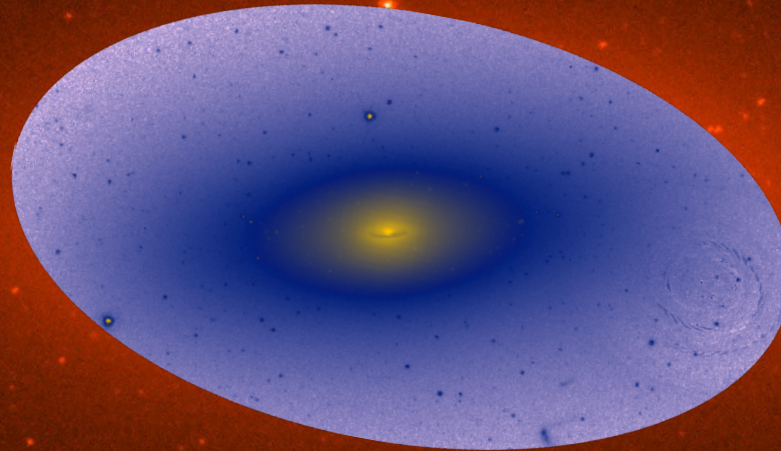


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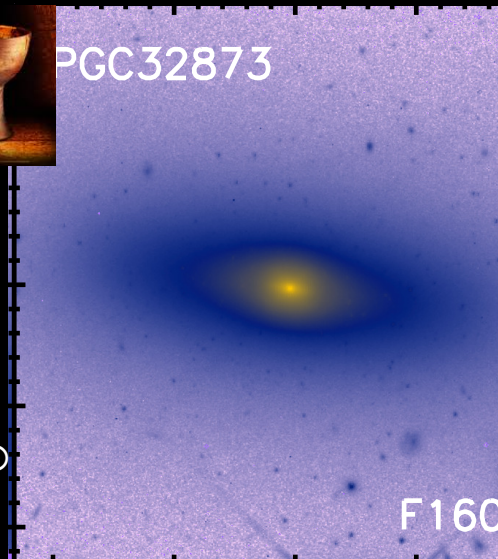
PGC32873

Ferré-Mateu et al.
2017a

$M_* = 2.3 \times 10^{11} M_\odot$

$R_e = 1.8 \text{ kpc}$

$\sigma \sim 360 \text{ km/s}$

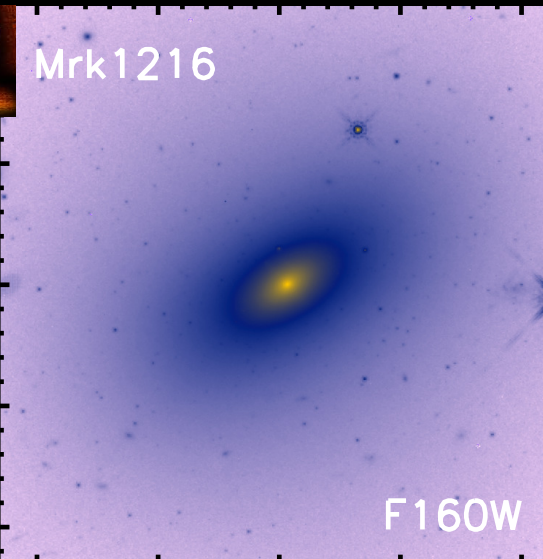


Mrk1216

$M_* = 2.0 \times 10^{11} M_\odot$

$R_e = 2.1 \text{ kpc}$

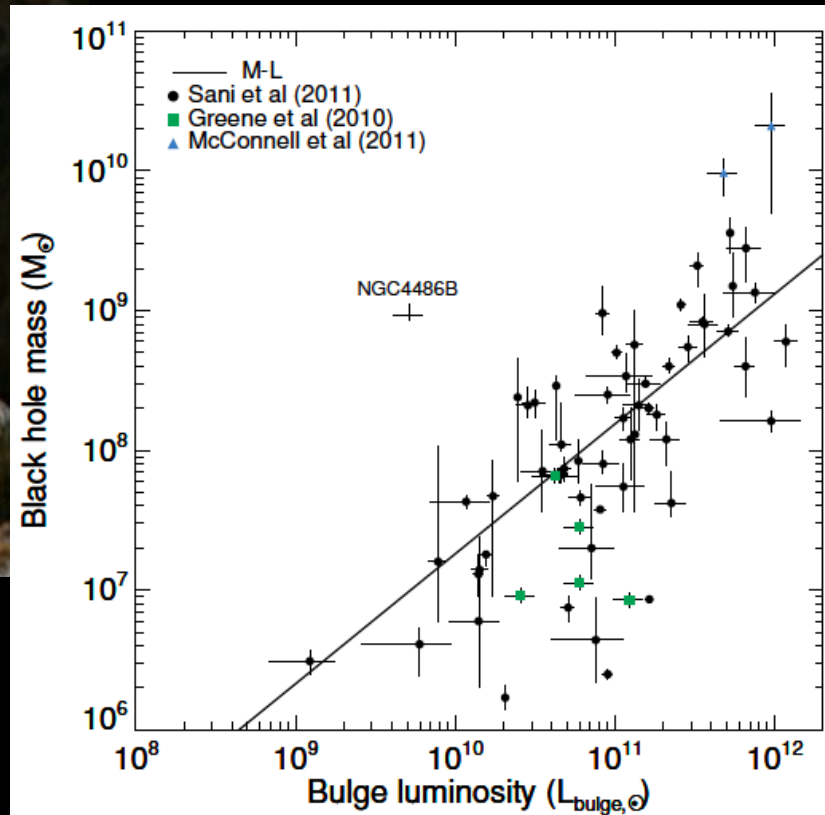
$\sigma \sim 370 \text{ km/s}$

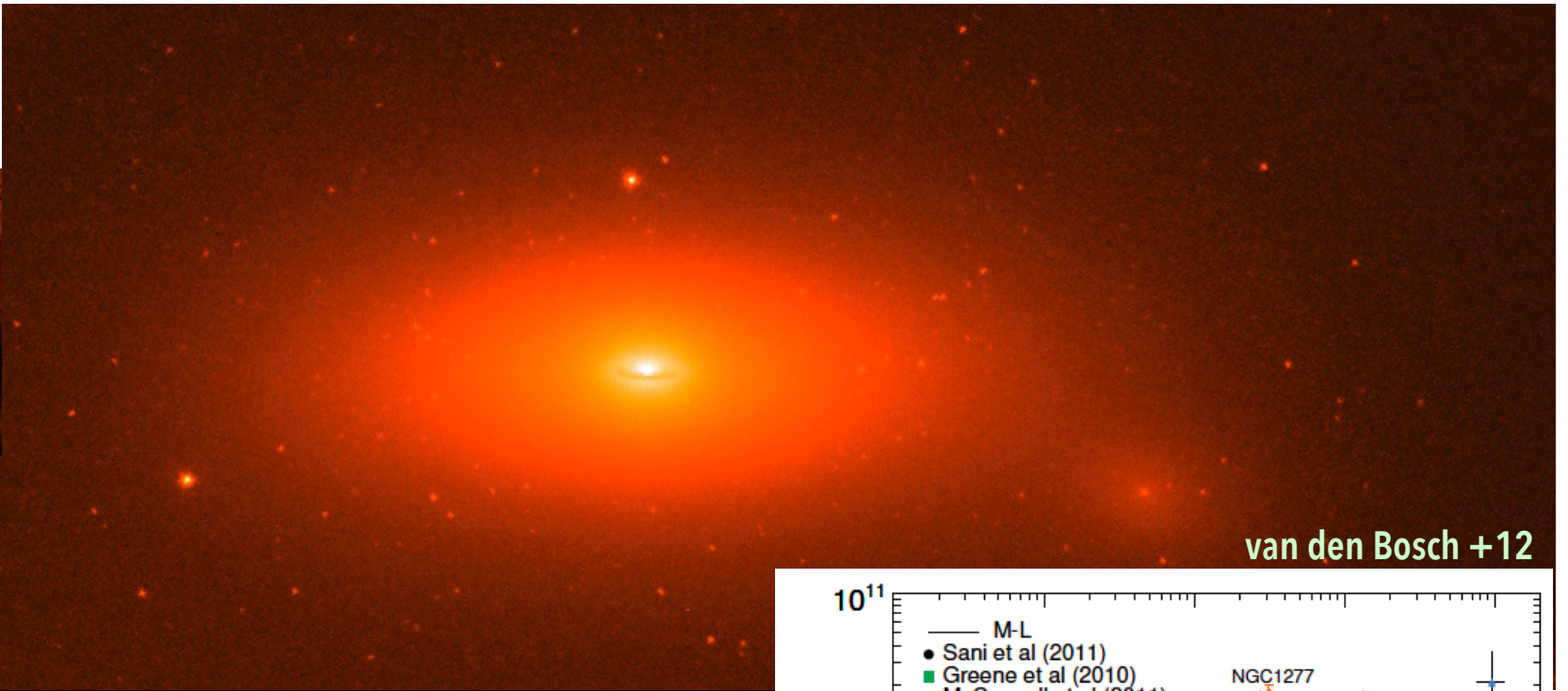


SMBH-GALAXY CO-EVOLUTION

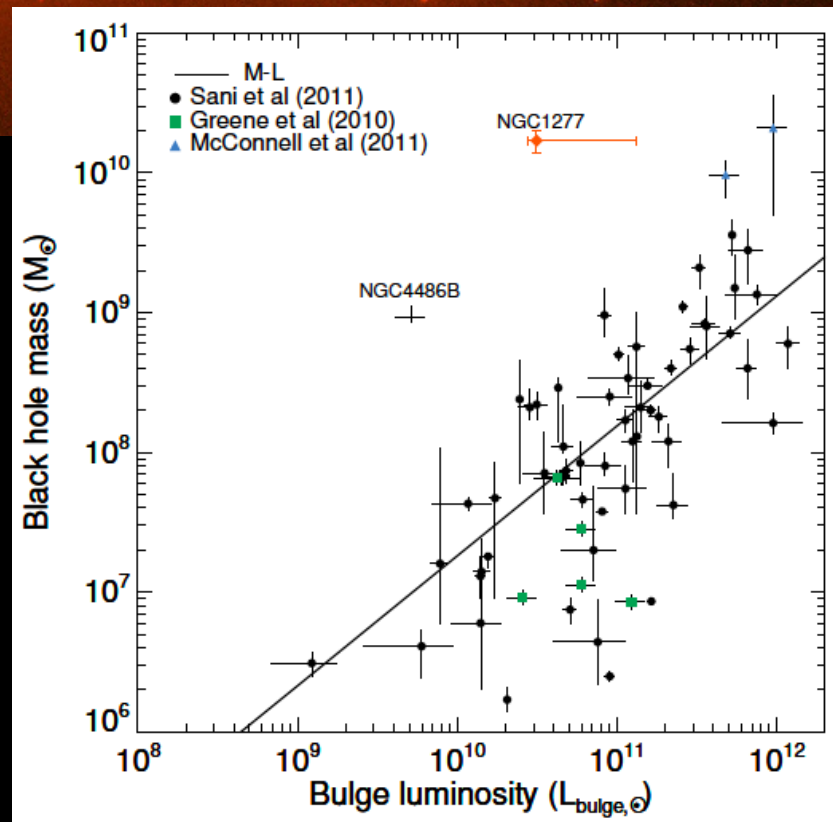


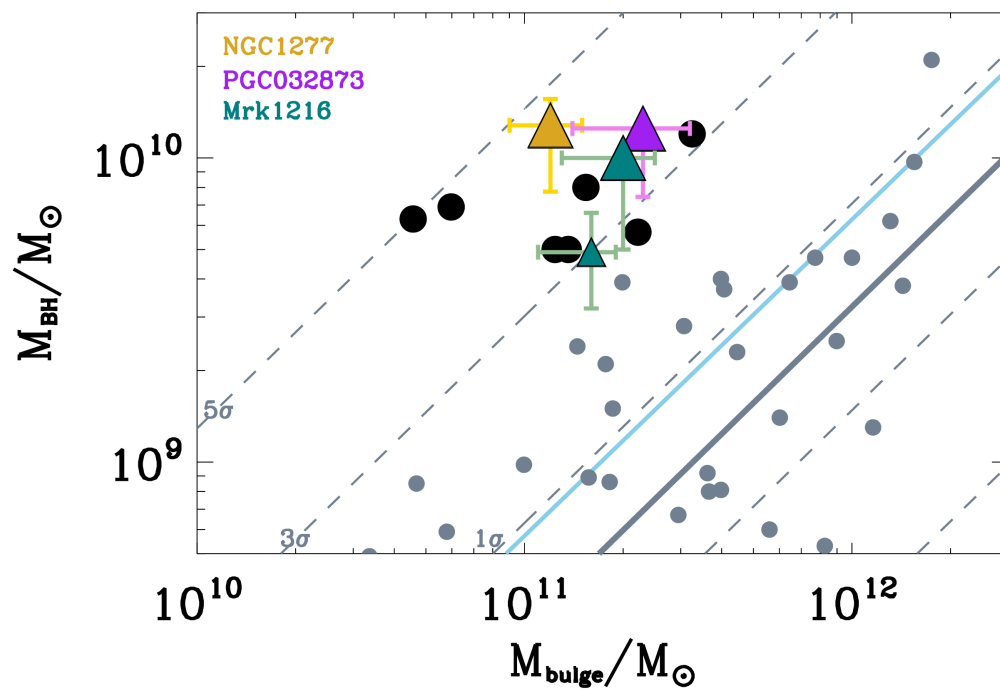
$M_{\text{BH}}-\sigma$, $M_{\text{BH}}-M_{\text{bulge}}$, $M_{\text{bh}}-L$
(Magorrian+1998, Ferrarese&Merritt 2000,
Gültekin+2009, Beifiori+2012,
McConnel&Ma 2012, Kormendy&Ho 2013,
and many others)



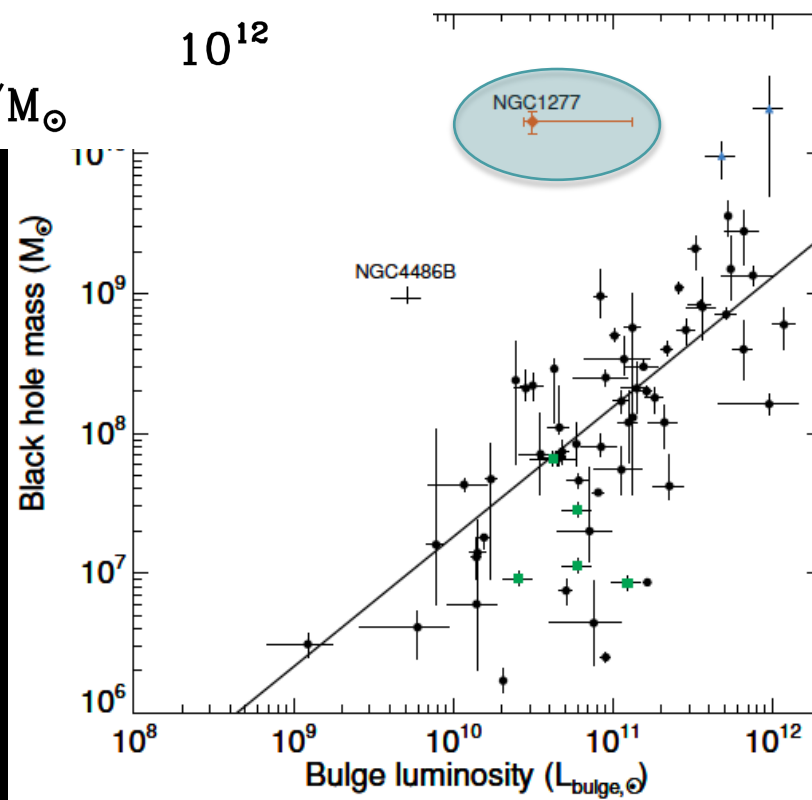


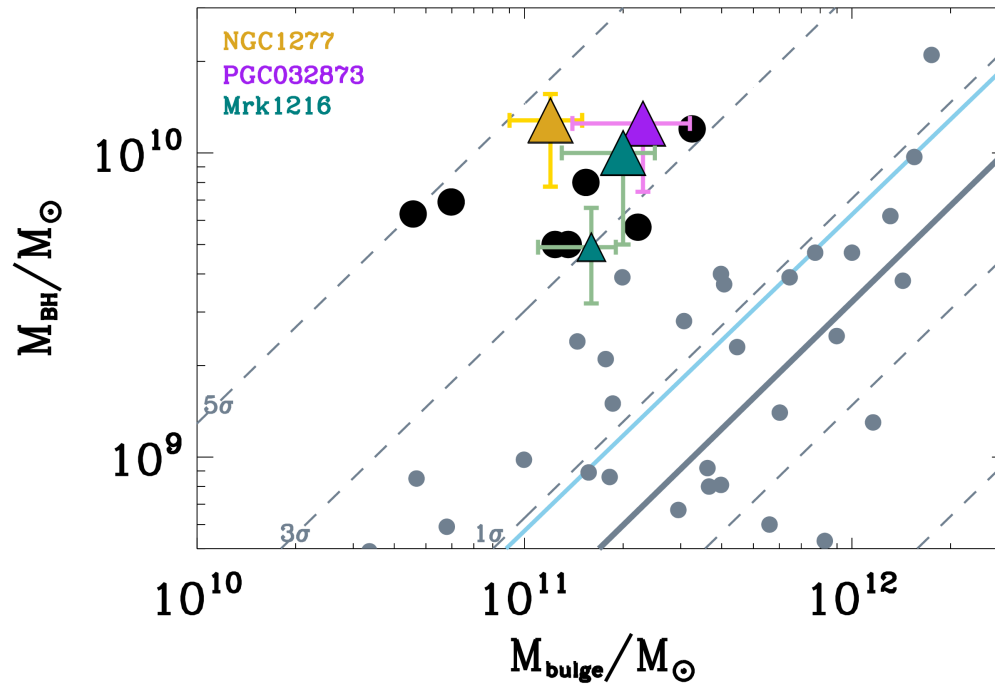
van den Bosch +12





Ferré-Mateu + 17a





Ferré-Mateu +17a

What is wrong with these extreme SMBHs?

(Läsker+13, Emsellem+13, Yildirim+15)

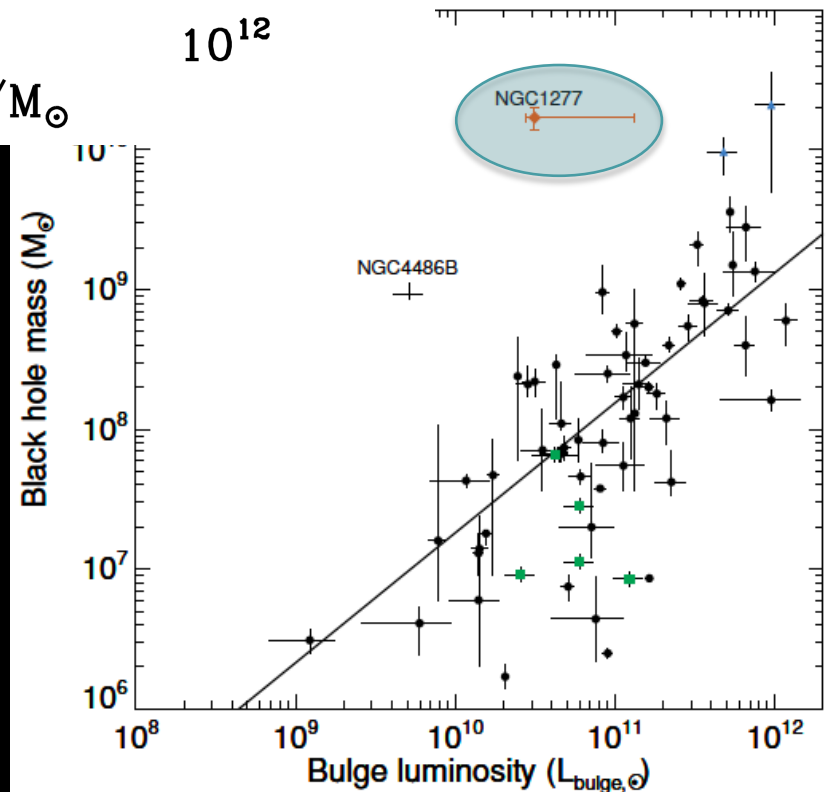
1) Effect of the **IMF** → negligible

(Martin-Navarro+15, Ferré-Mateu+17a)

2) **Upper limit** from the Virial →

Lower SMBHs with dynamical models

(Yildirim+15, Walsh+16)

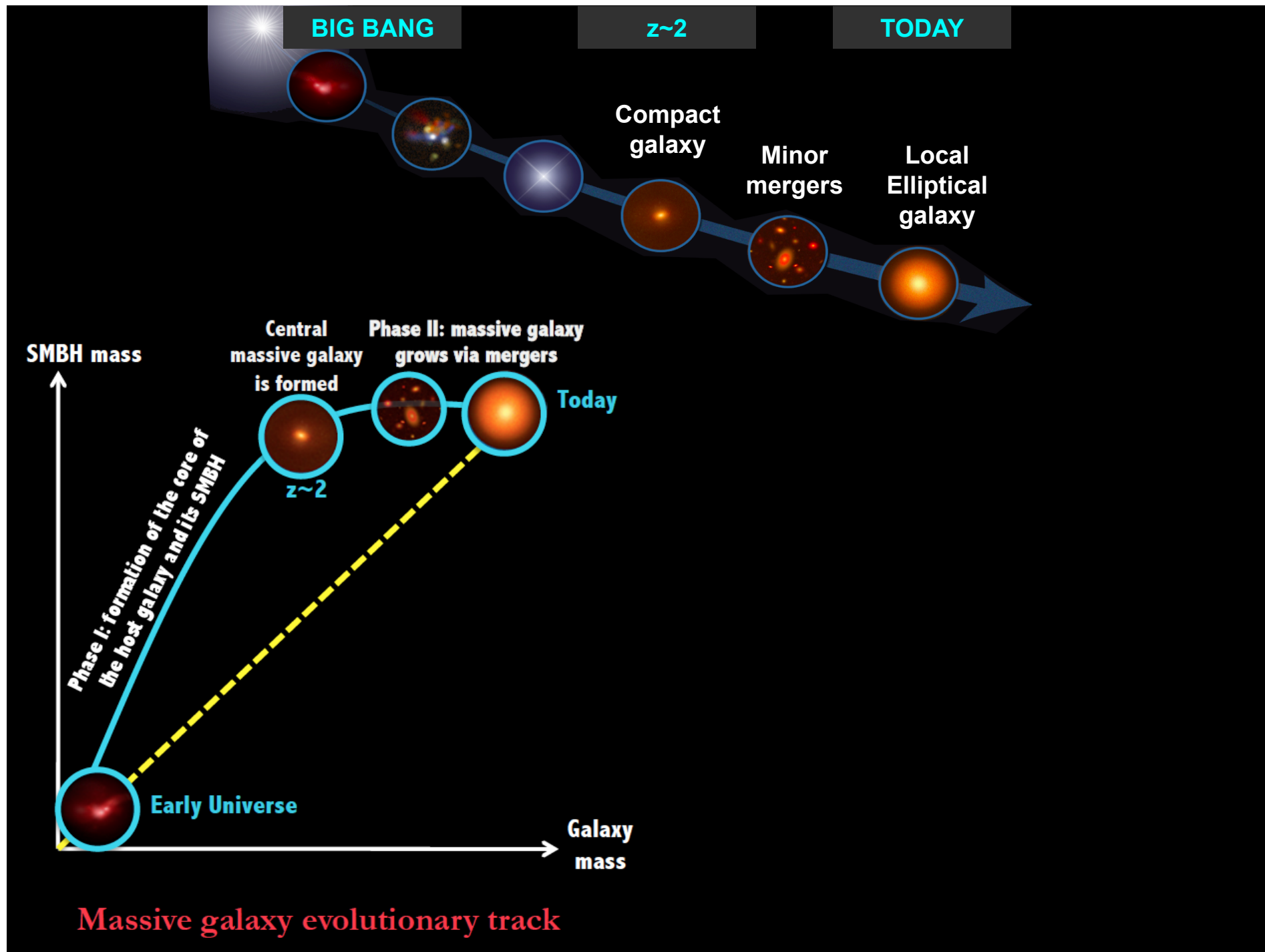


RELIC GALAXIES AND SMBH:

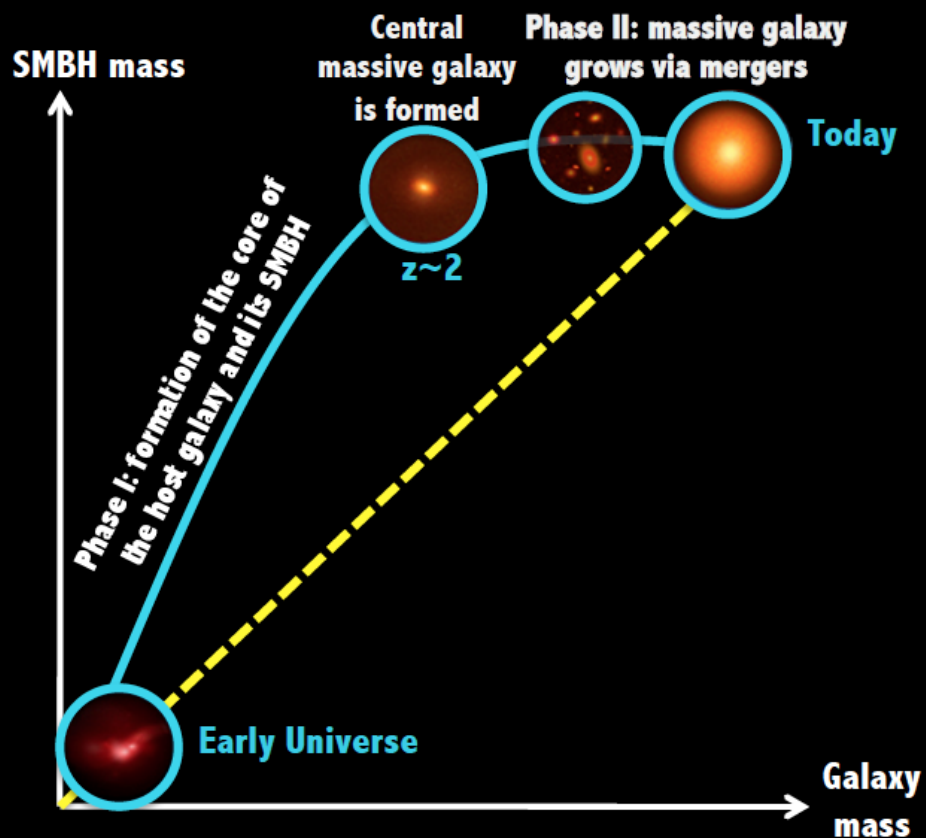


Massive relic galaxies are natural outliers in the SMBH scaling relations because they follow a **different evolutionary path**

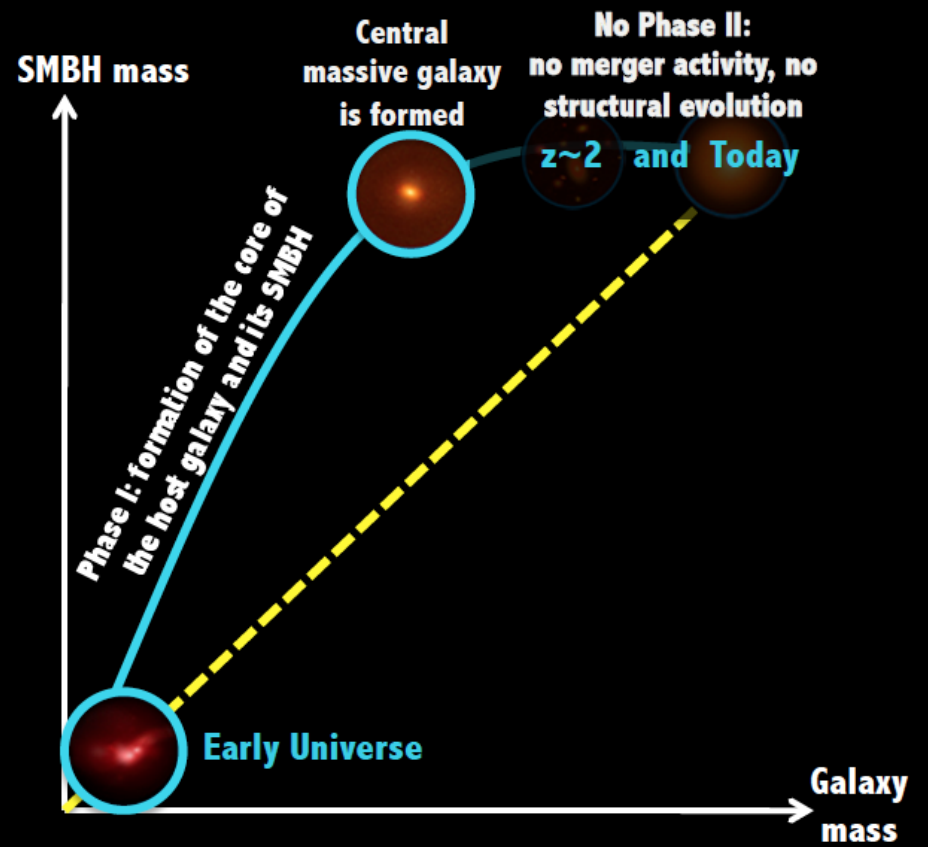
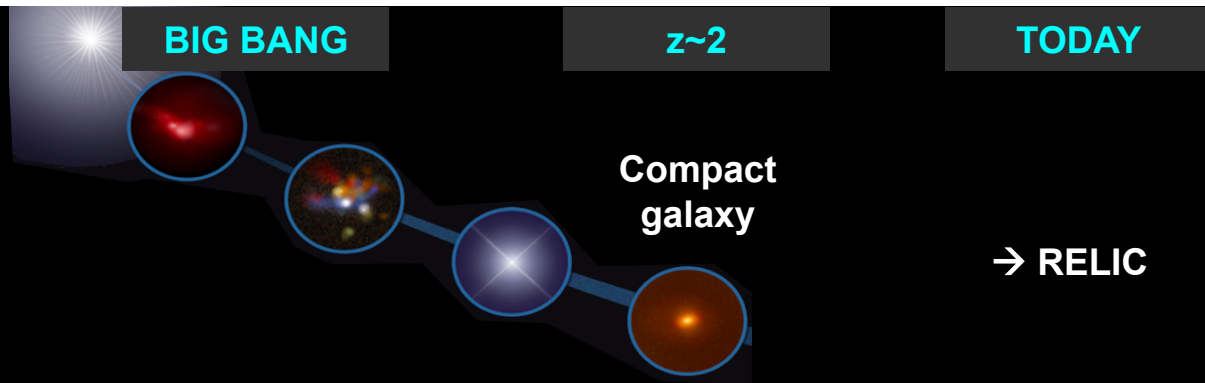
Ferré-Mateu et al. 2015, 2017a



Remember
Drouart talk!



Massive galaxy evolutionary track



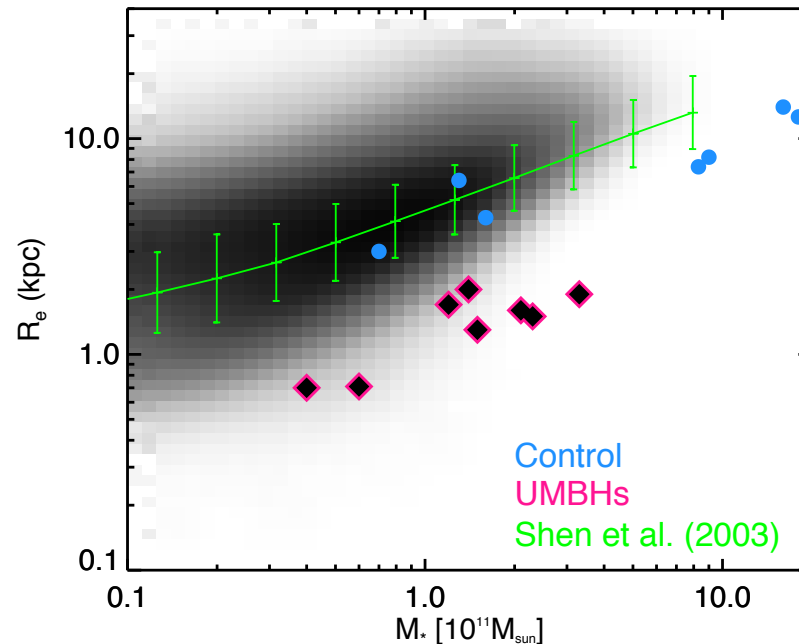
Relic galaxy evolutionary track

THE SAMPLE

Galaxies from the HETMG Survey (van den Bosch+15) that are
good candidates to host a SMBH:

- To have $M_{\text{vir}} > 4 \times 10^9 M_{\text{sun}}$
 - To be nearby enough to resolve the BH
 - To lay far beyond the 3σ deviation
 - To have SDSS spectra
- 174 galaxies ($R_e \sim 4 \text{ kpc}$)
→ 30 galaxies ($R_e \sim 2 \text{ kpc}$)
→ 8 ÜMBH candidates

NGC1270
NGC1271
NGC1277
NGC1281
NGC2767
PGC012557
PGC012562
PGC032873



Ferré-Mateu +15

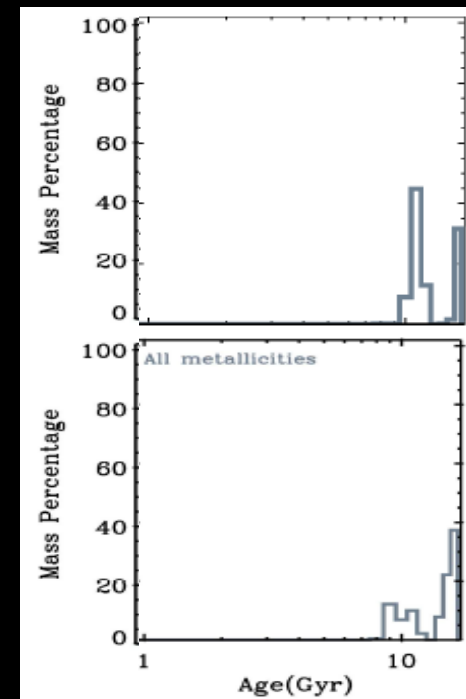
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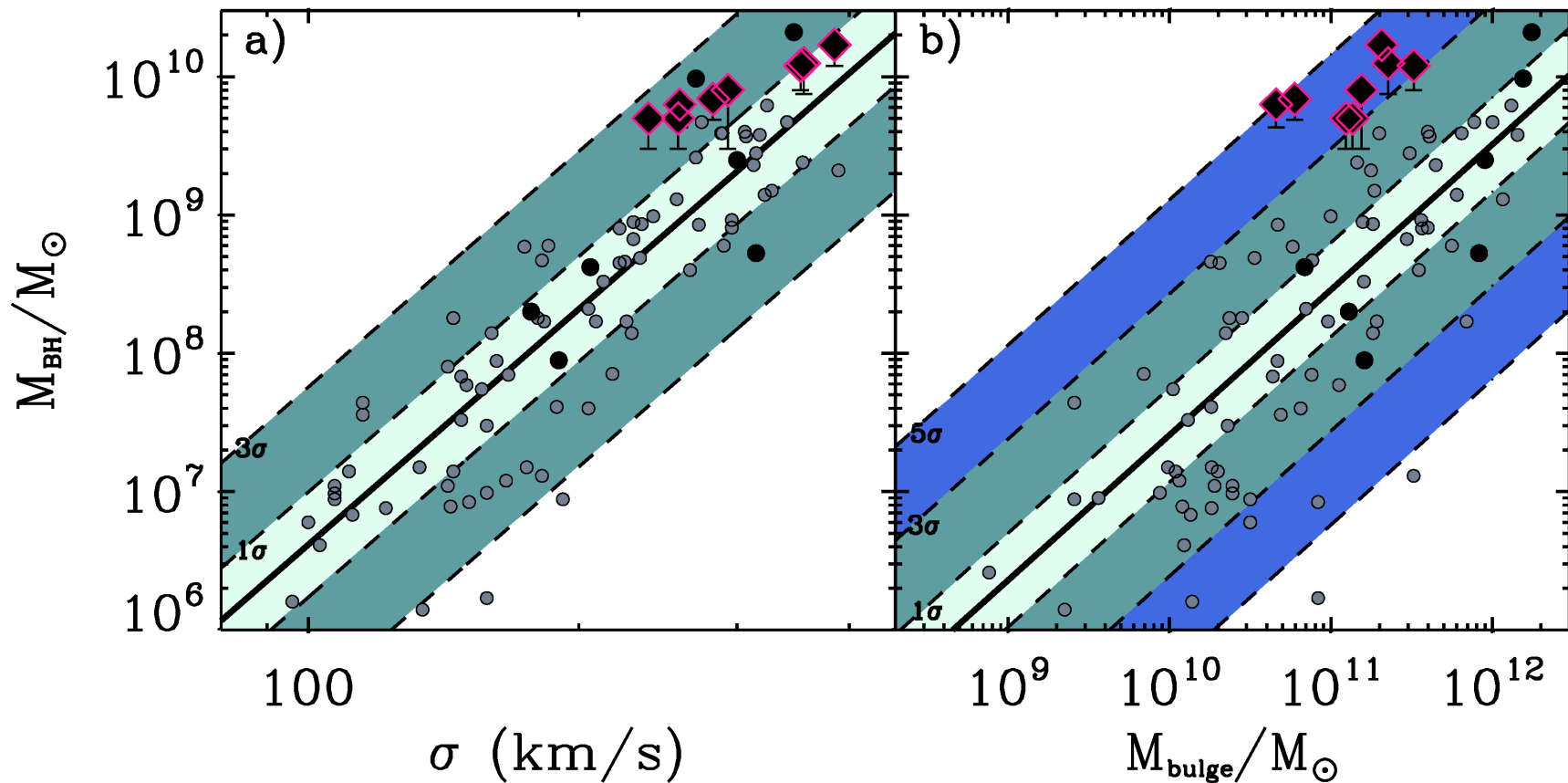
✓ SFH → compatible with being **relic galaxies**

✓ Lower limit of SMBH formation at $\sim 10 \text{ Gyr}$
→ **SMBH is already in place by $z \sim 2$**



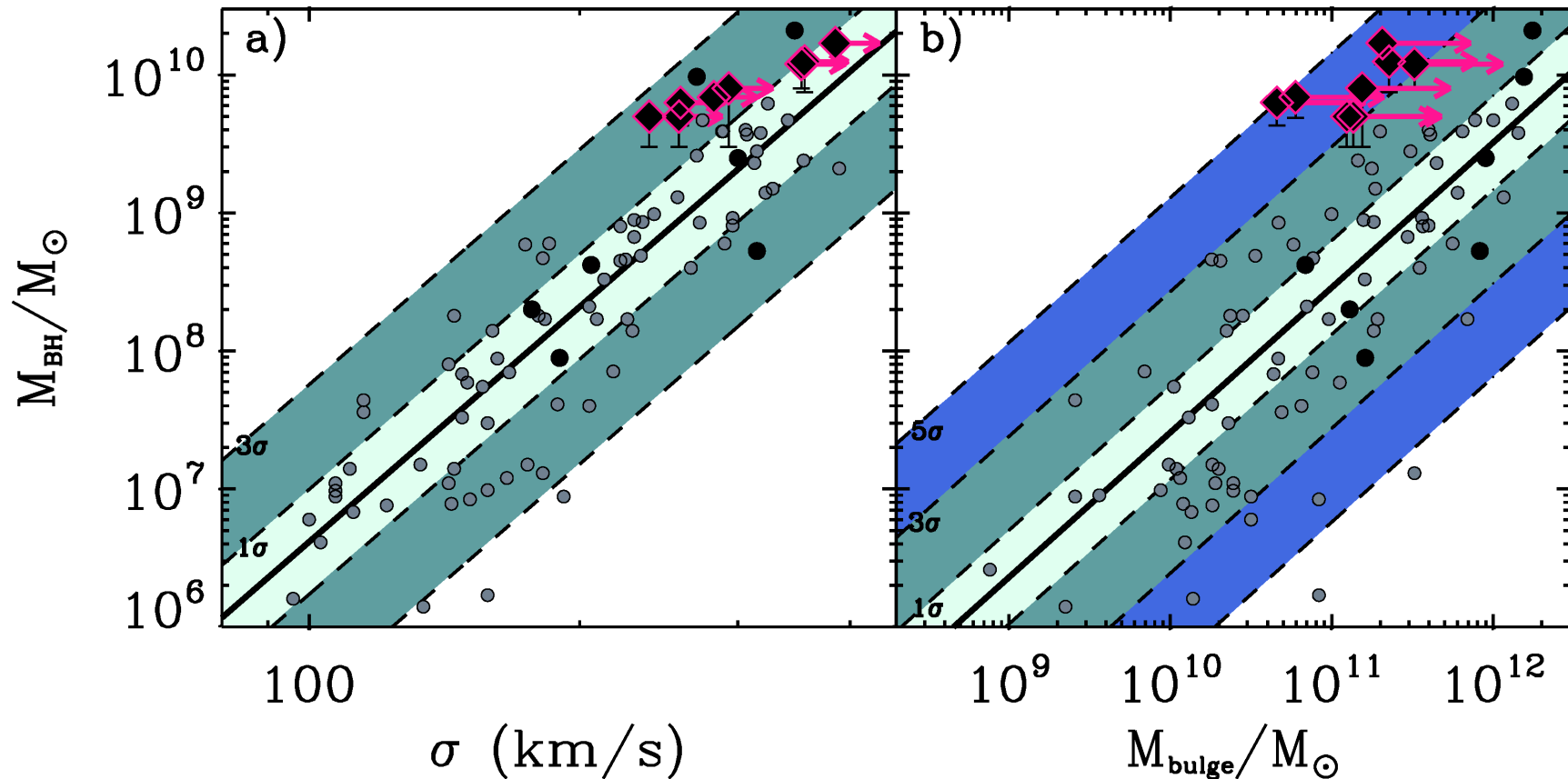
Relic galaxies are outliers in the SMBH scaling relations because they follow a **different evolutionary path**

Ferré-Mateu et al. 2015



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Ferré-Mateu et al. 2015



Size x 7

Velocity dispersion x1.1 (Oogi&Habe+13, Wellons+15, Tapia+15)

Stellar masses x5 (Oser+10+12, Trujillo+11, Hilz+12)

SUMMARY



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~~1) SMBH coevolution challenged by fossil red nuggets~~

- 1) The SMBH and the host galaxy are slightly **de-coupled**
- 2) Massive relic galaxies are outliers in the SMBHs scaling relations because they follow **another evolutionary path** than large massive ellipticals
- 3) Limit for SMBH formation at **~ 10 Gyr**
- 4) Possible way to **detect** the elusive relic galaxies

SUMMARY

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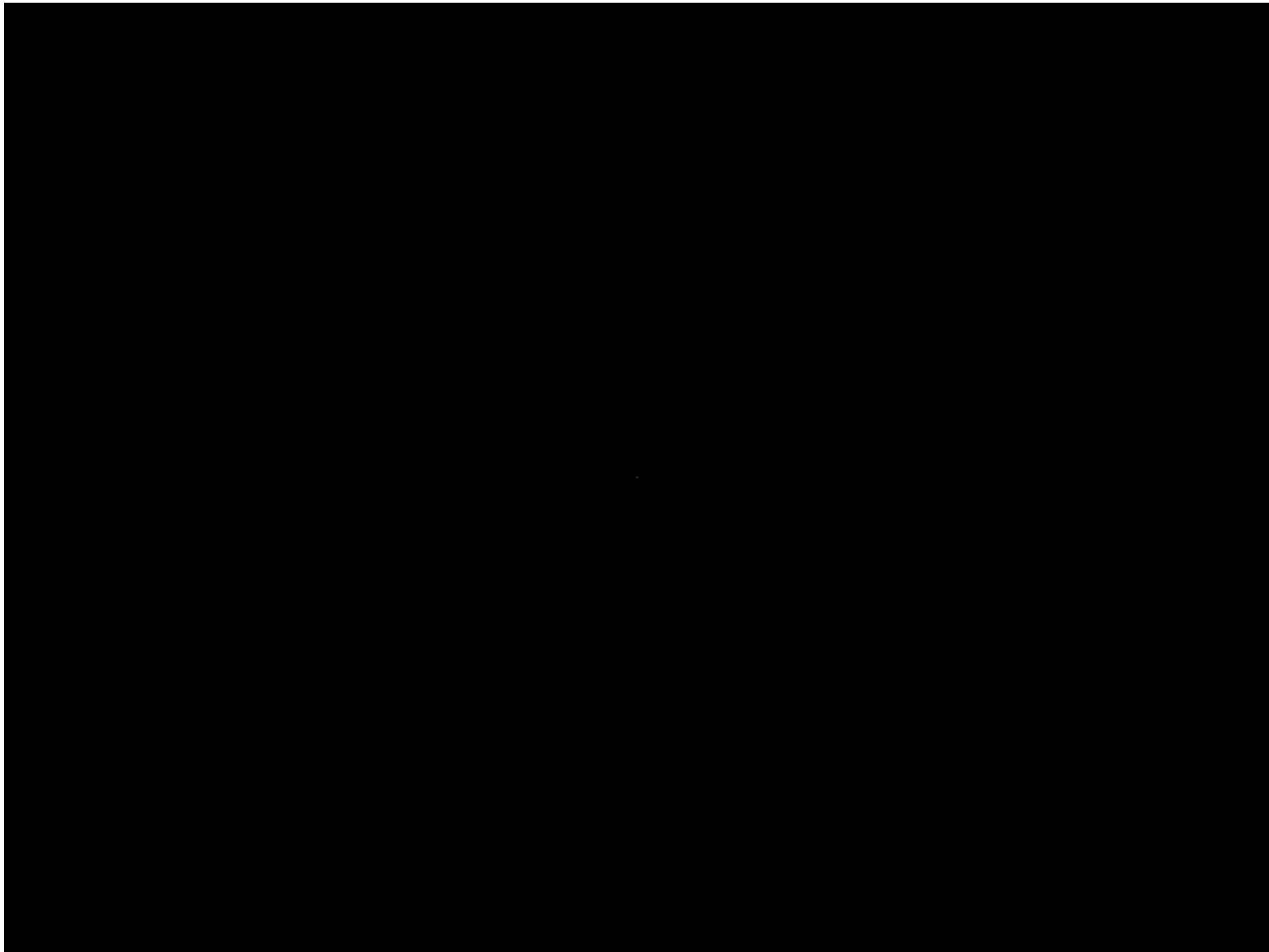
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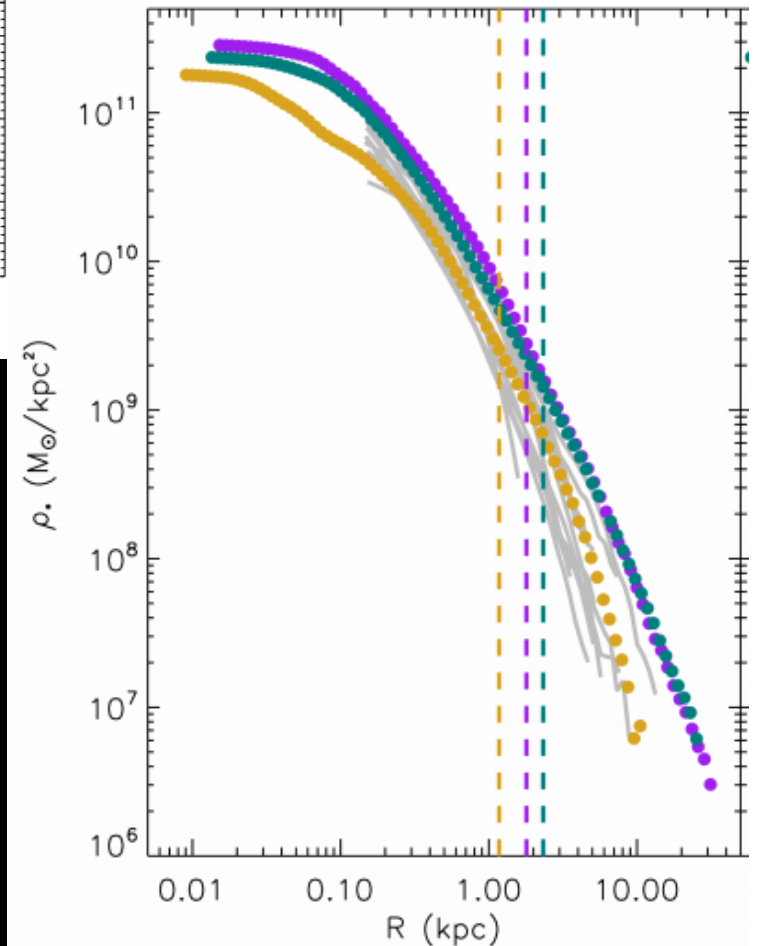
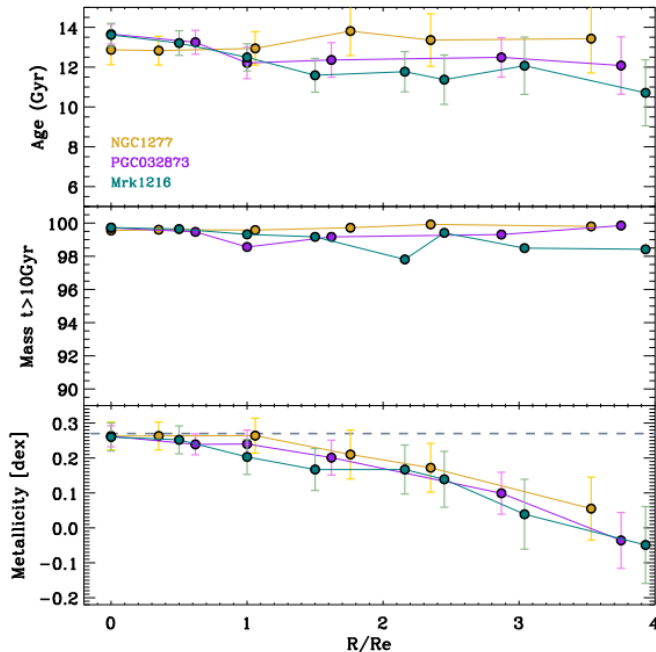
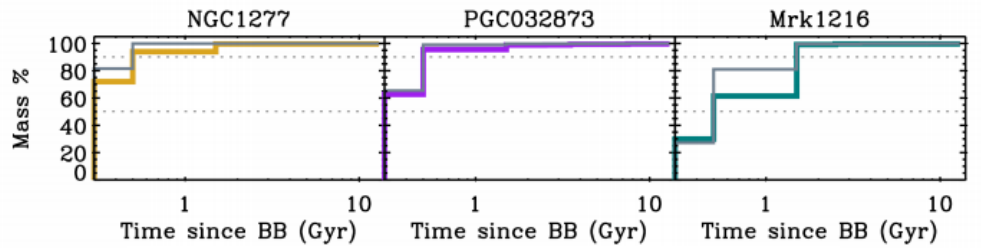
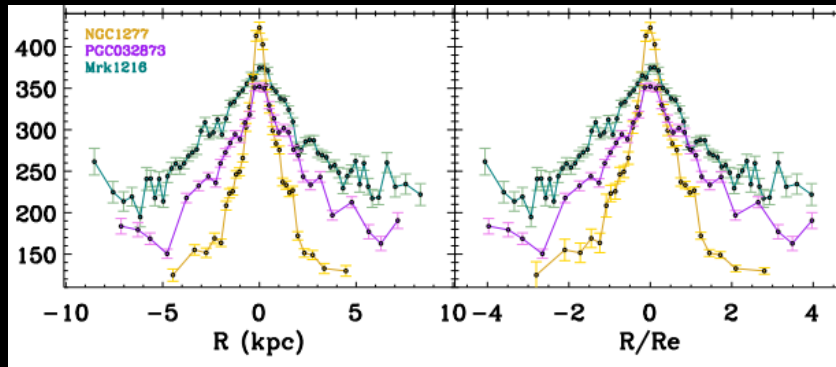
5) What happens at lower stellar masses?
UCDs, cEs, ... \rightarrow **new low-mass relic** found

(Ferré-Mateu et al. 17b, submitted!)





Same morphologies, kinematics and density profiles to $z \sim 2$ red nuggets



Ferré-Mateu et al. 2017a

Consistently old through all radii
Even if steeper IMFs are considered
(Ferré-Mateu+13, Martín-Navarro+15)

DIFFERENT LEVELS OF BEING A RELIC

Different **degrees on the massive relic properties:**

- most pristine relics, extreme cases of star formation, sizes, etc... → CLUSTER
- less extreme, larger compact sizes, slightly extended star formation histories, etc... → FIELD

(Both observationally and with numerical/cosmological simulations:
e.g. Cebrian+14, Poggianti+13, Peralta-Darriba+15, Stringer+15 ,...)



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ENVIRONMENTAL DEPENDENCE

Ferré-Mateu et al. 2017a