

IS SMBH COEVOLUTION CHALLENGED BY NEARBY RELIC GALAXIES?

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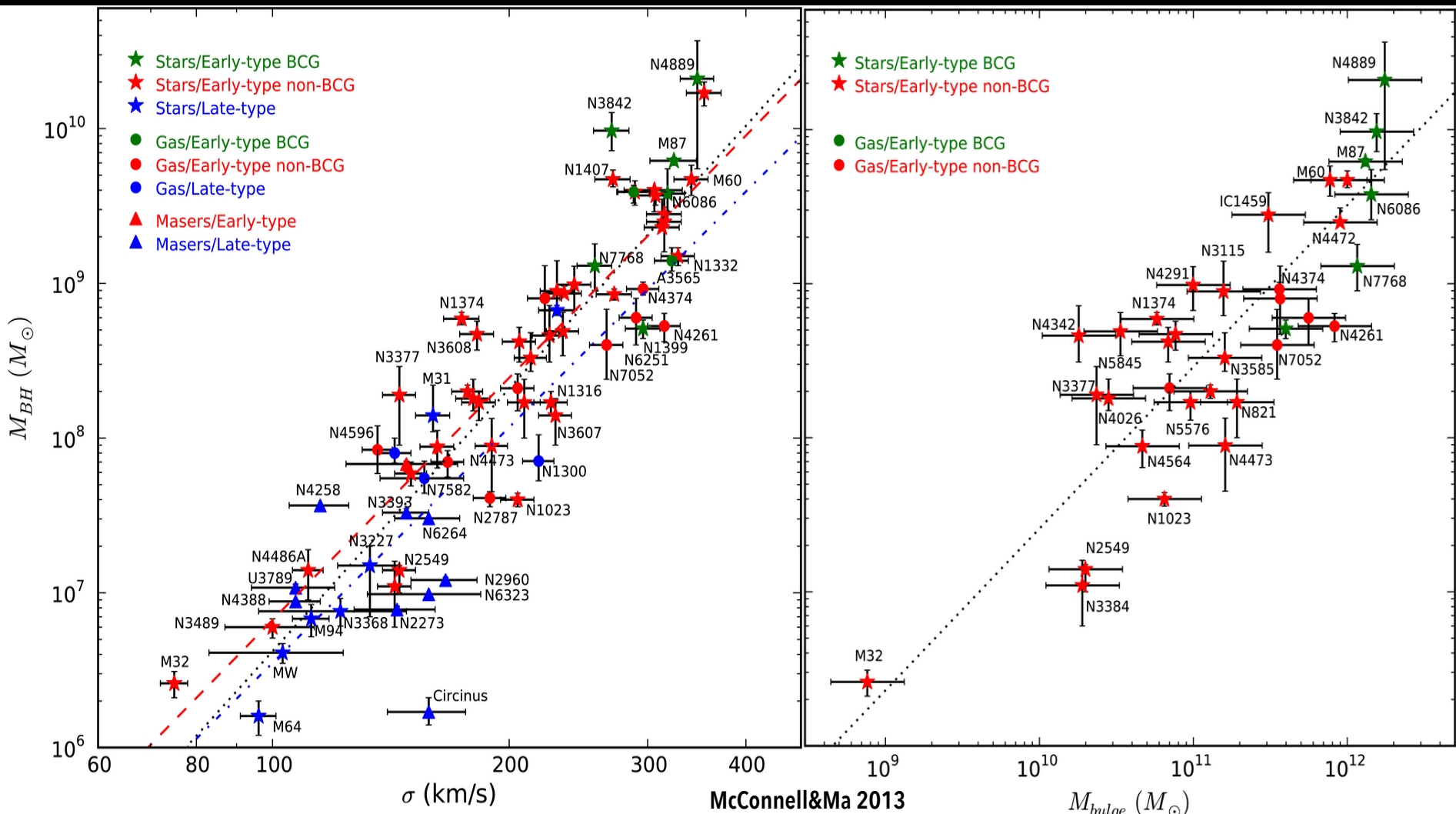


I. Trujillo (IAC), M. Mezcua (ICE-IEEC), A. Vazdekis (IAC), & R. van den Bosch (MPIA)

SMBH MASS – GALAXY SCALING RELATIONS

Tight scaling relations (sigma, stellar mass, bulge mass, luminosity, etc...)

e.g. Gebhardt +2000; Ferrarese&Merritt 2000; Gültekin +2009; Beifiori +2012; McConnell&Ma 2013; Kormendy&Ho 2013; Saglia +2016; Reines&Volonteri 2015; etc



SMBH - galaxy CO-evolution 🍷👍

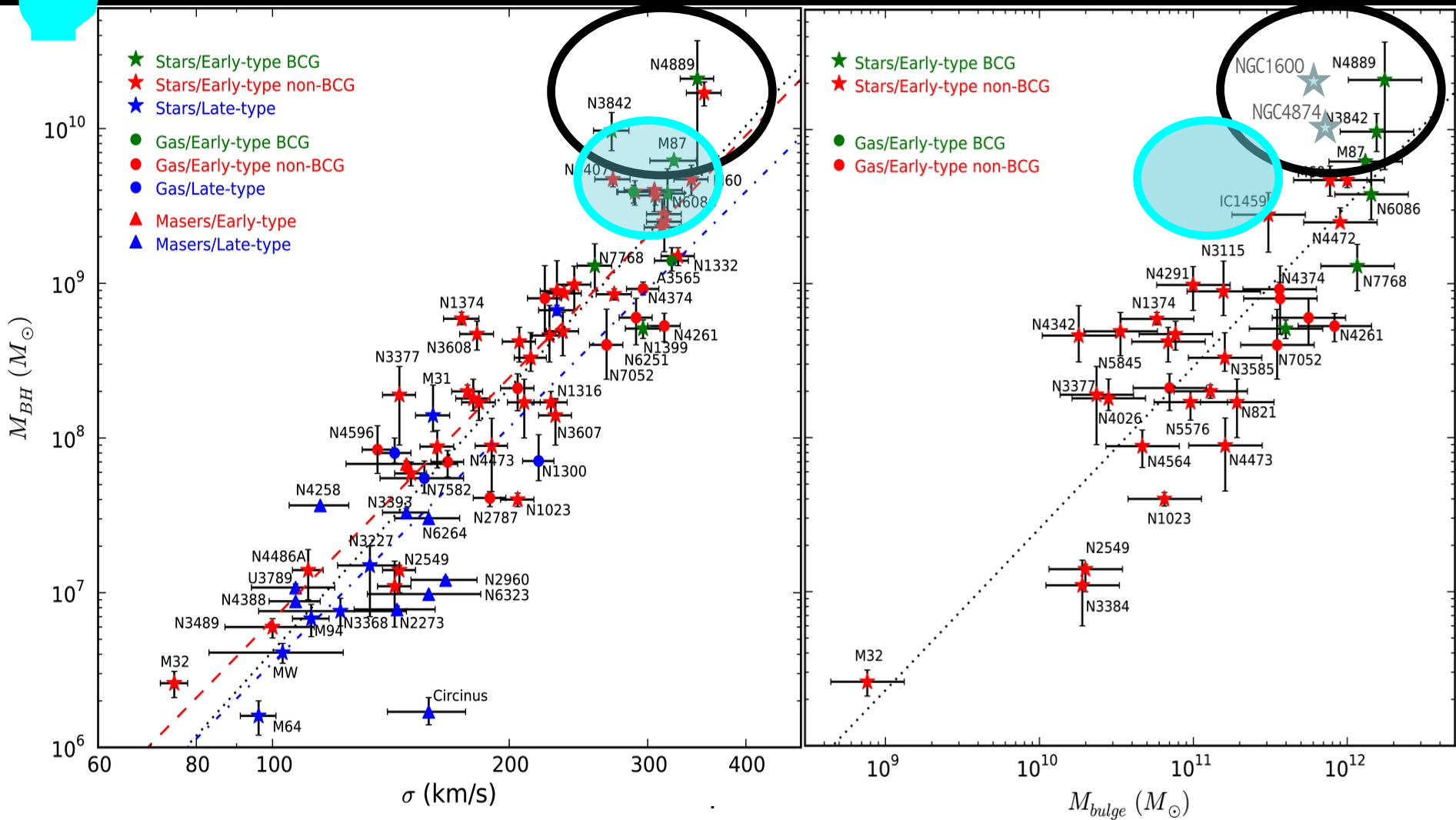


SMBH MASS – GALAXY SCALING RELATIONS

Outliers { At the massive end
For the M^* relation



e.g. van den Bosch +2012,
Walsh +2015; AFM+2015,+2017



What is wrong with these extreme SMBHs?

(Läsker+2013, Emsellem+2013, Yildirim+2015)

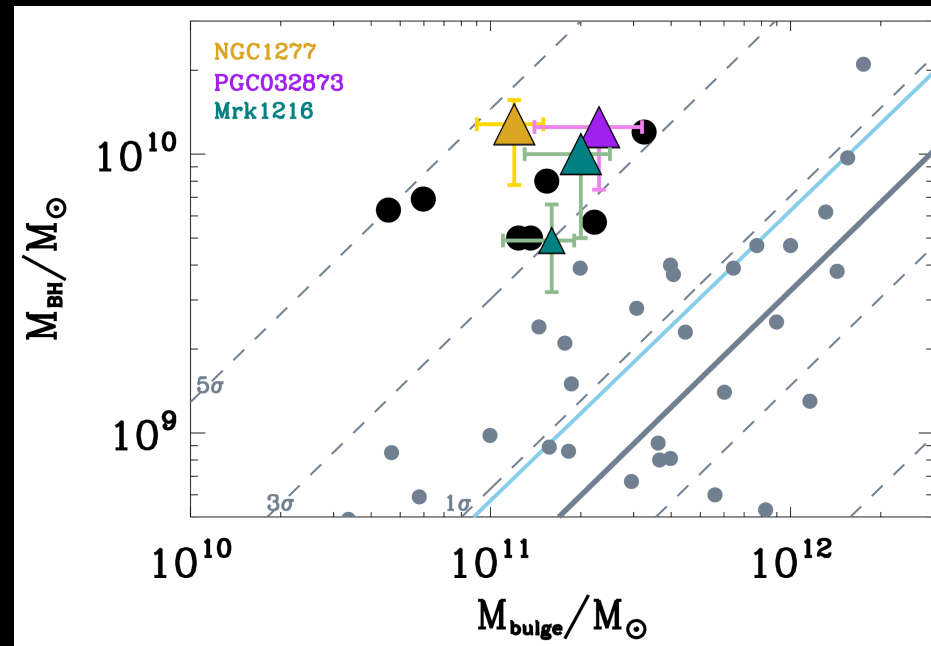


Ferré-Mateu+2017

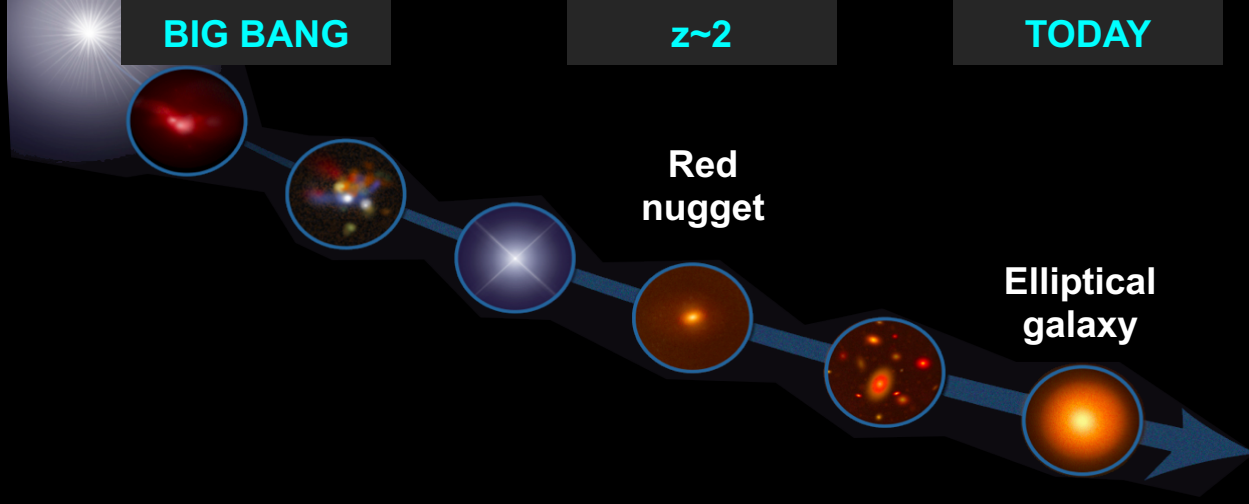
1) Effect of the **IMF** \rightarrow negligible
(Martin-Navarro+2015, Ferré-Mateu+2017)

2) **Upper limit** from the Virial \rightarrow
Lower SMBHs with dynamical models
(Yildirim+2015, Walsh+2016)

What are these galaxies?

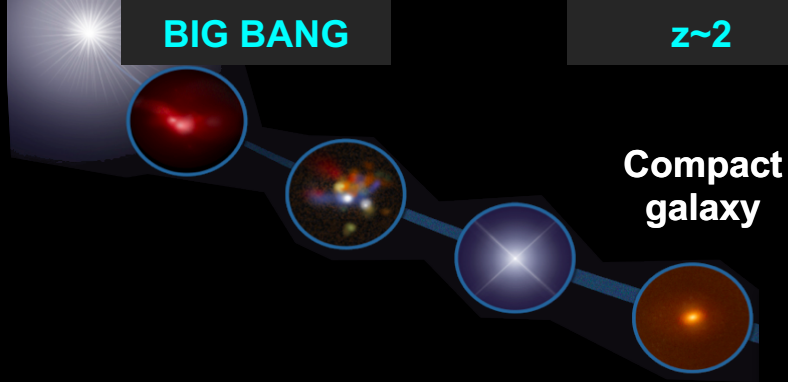


MASSIVE RELIC GALAXIES



**2-PHASE
FORMATION
SCENARIO**
(Oser+2010,
Hilz+2013,
Wellons+2015)

MASSIVE RELIC GALAXIES



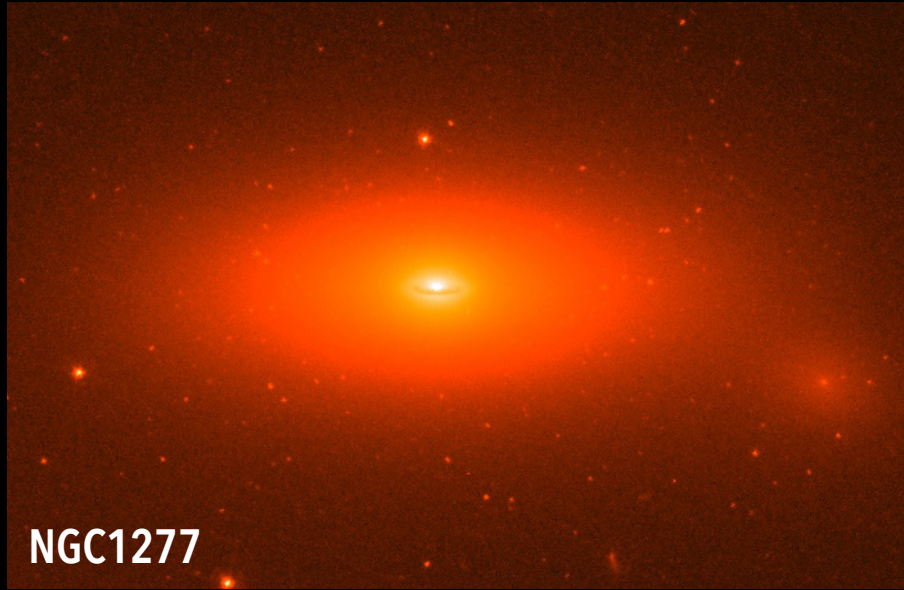
2-PHASE FORMATION SCENARIO
 (Oser+2010, Hilz+2013, Wellons+2015)

RELIC
 (fossil red-nugget)

Frozen over cosmic time:

SAME properties
 early Universe ($z > 2$)
 massive galaxies

(Damjanov +2009; Trujillo +2009,+2014; Ferré-Mateu +2015,+2017)



NGC1277

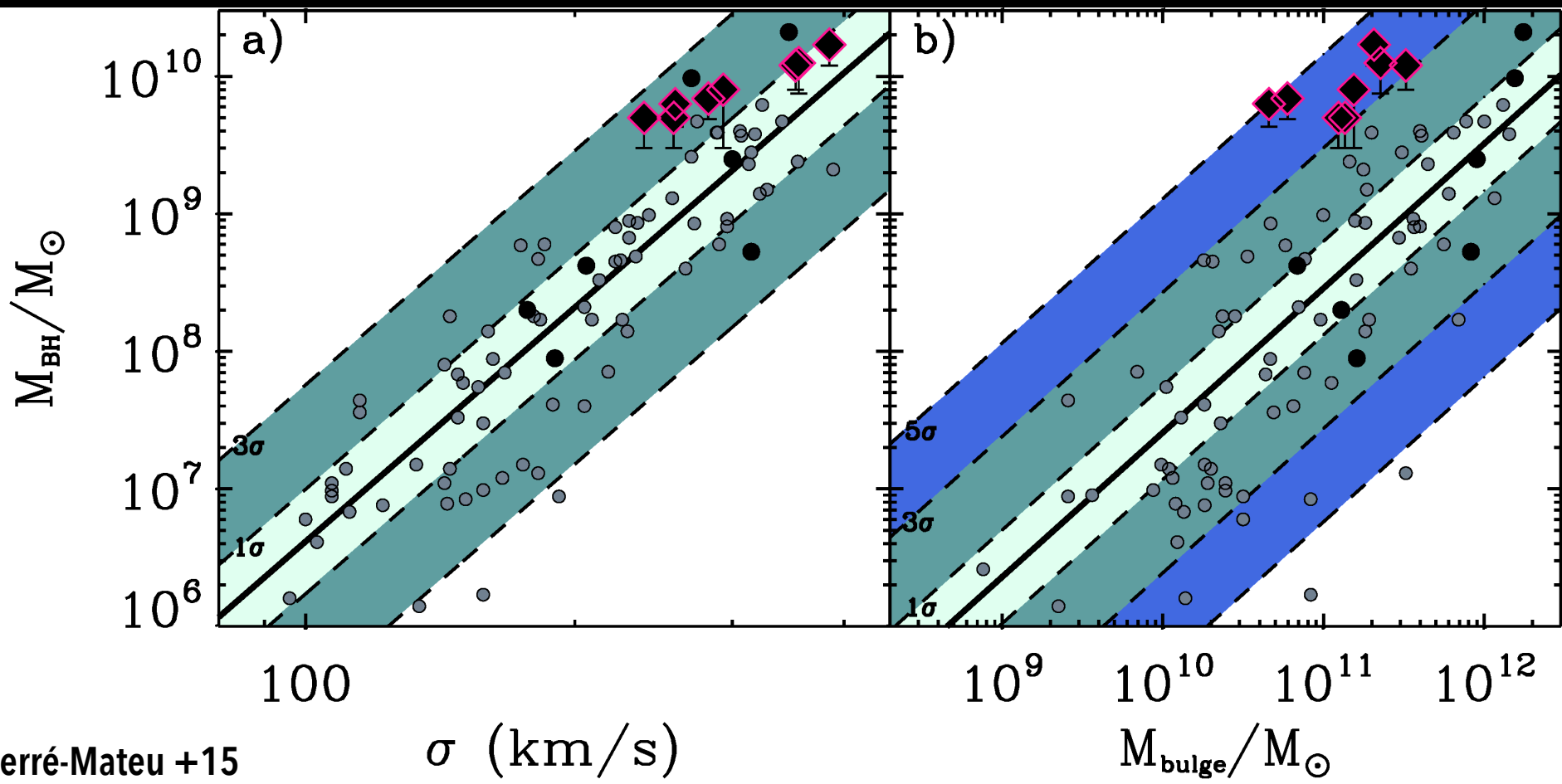
- 1. Massive:
 $M^* > 10^{11} M_{\text{sun}}$
- 2. Compact:
 $R_e < 2 \text{ kpc}$
- 3. Old at all radii:
 Age > 10 Gyr

ÜMBH AND MASSIVE RELIC GALAXIES

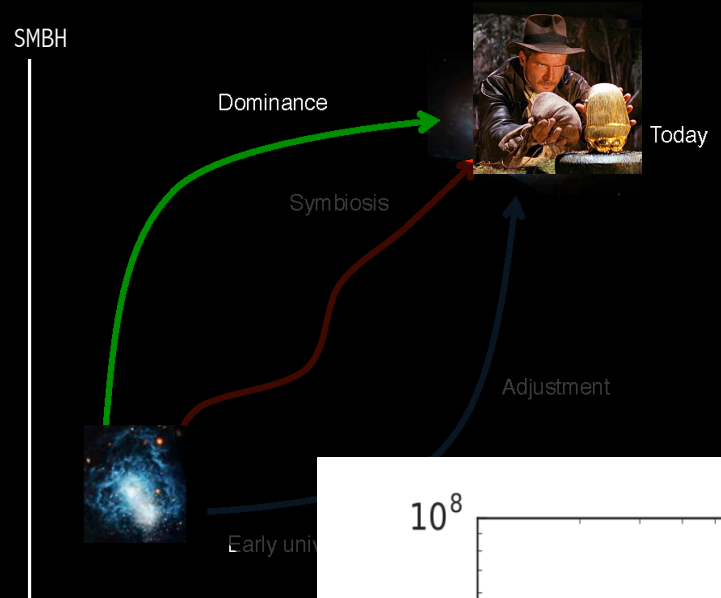
Clear outliers in the SMBH- M^* relation ($>3\sigma$)

but seem OK in the SMBH- σ one

Challenge for the SMBH-galaxy co-evolution?



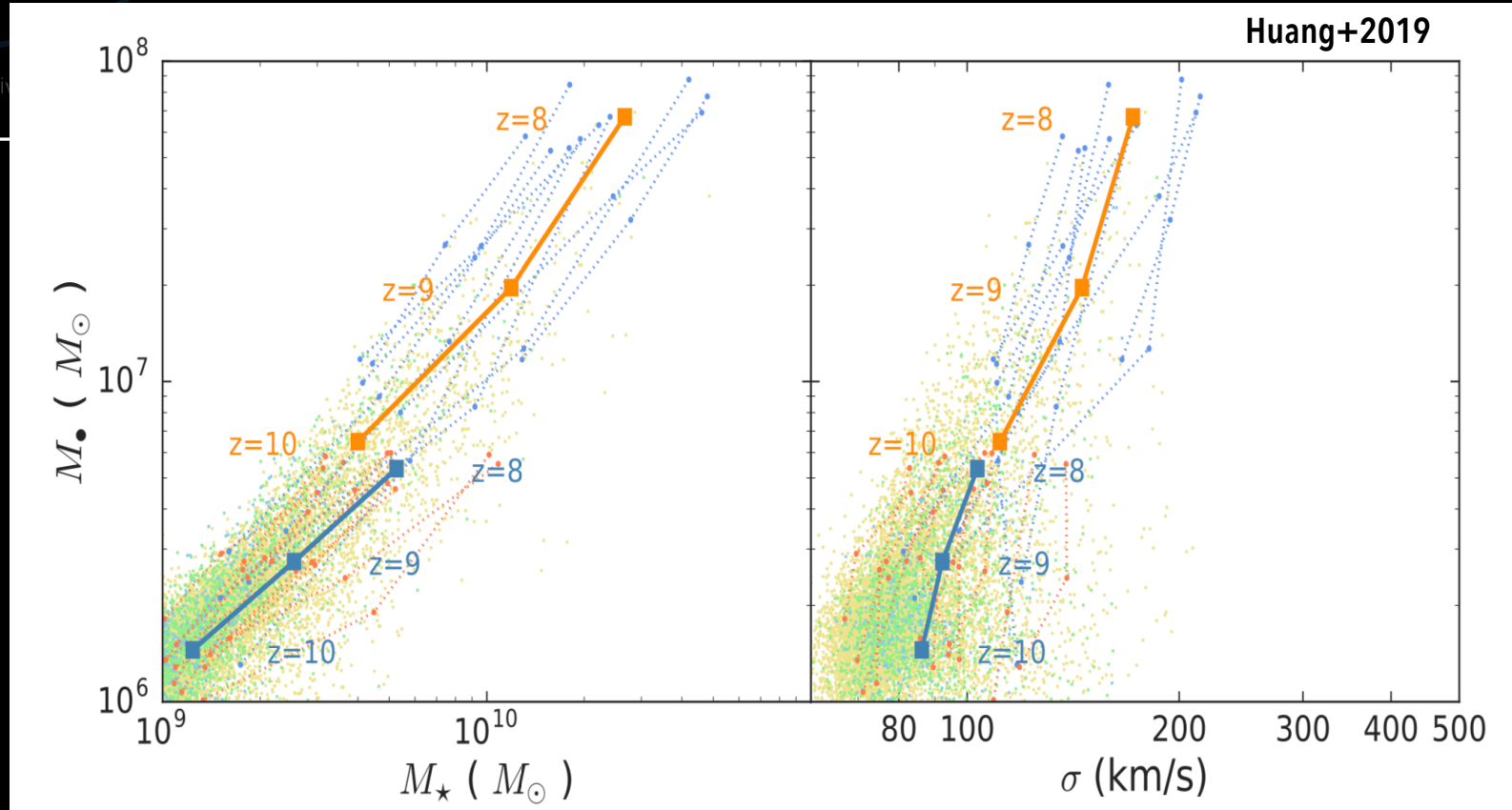
CO-EVOLUTION?



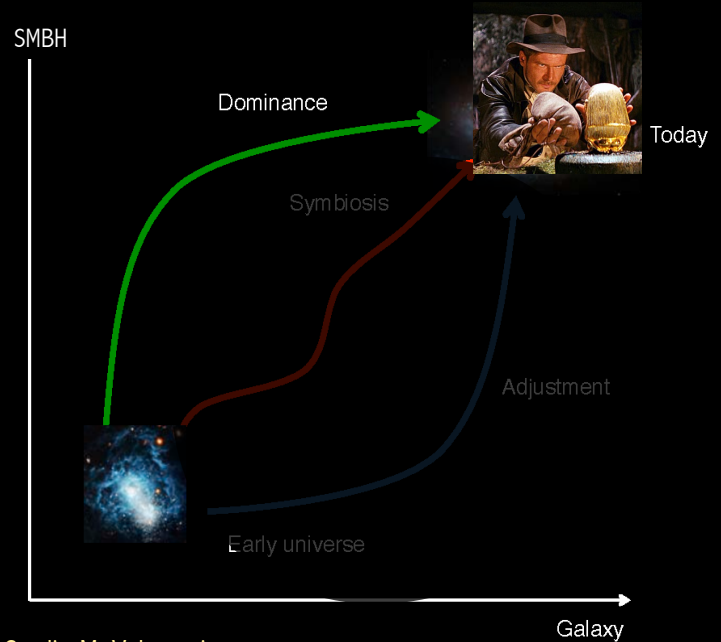
SIMULATIONS seem to favor a an early and steep BH growth

e.g. BLUETIDES (Tenneti+2018, Huang+2018,+2019);
EAGLE (Barber +2016, van Son +2019)

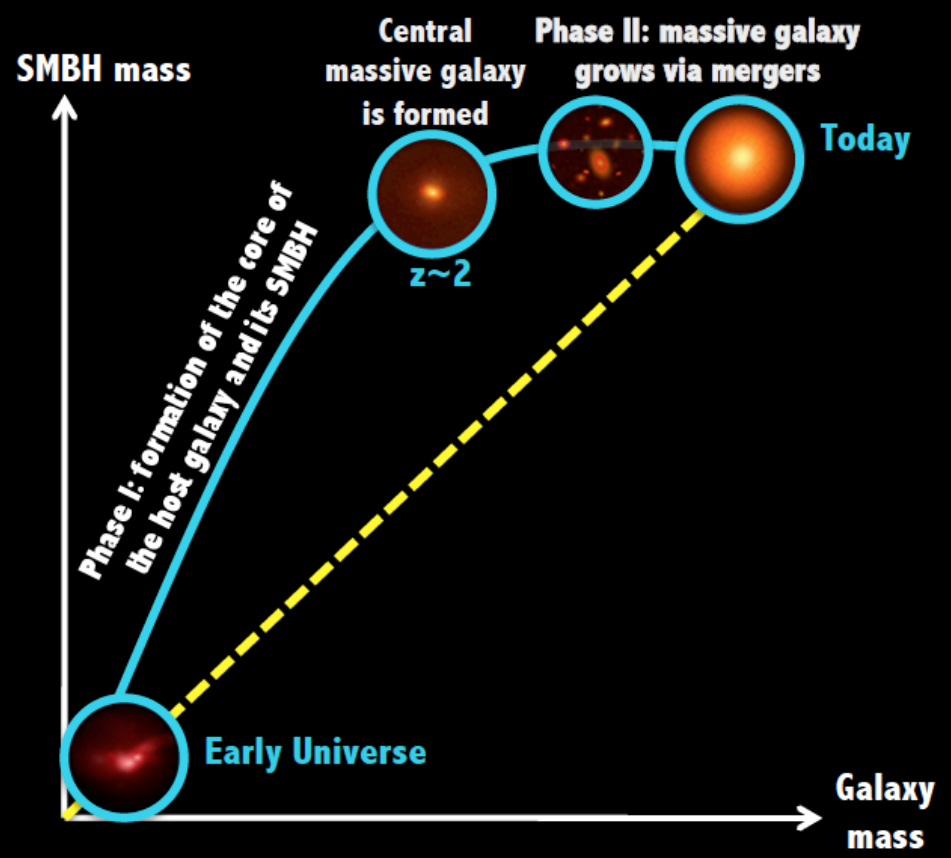
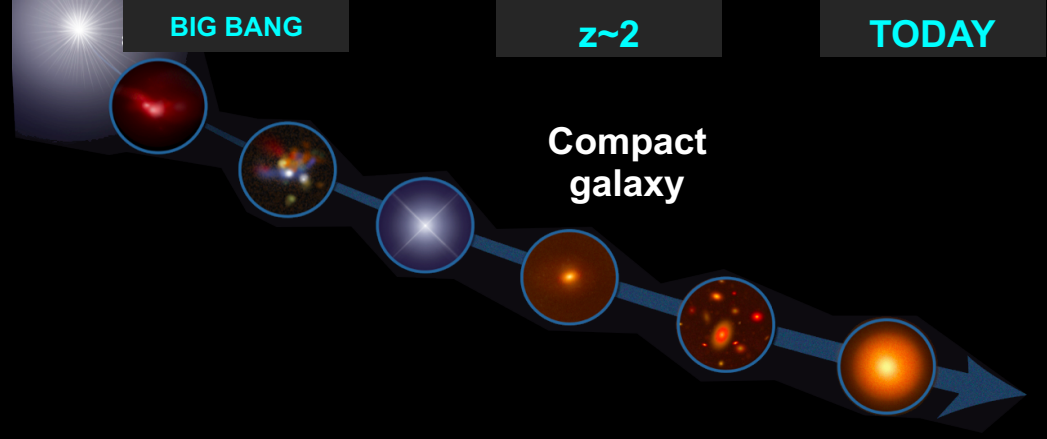
Credit: M. Volonteri



CO-EVOLUTION?

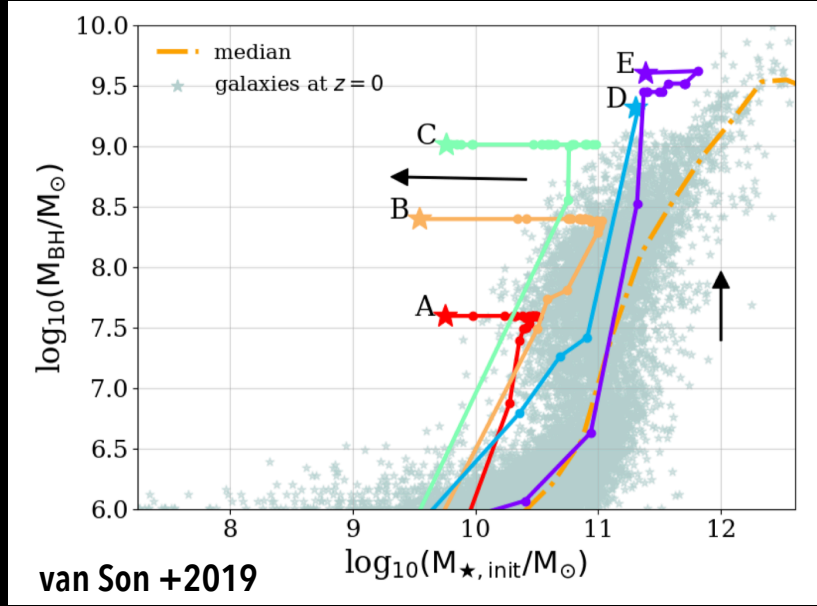
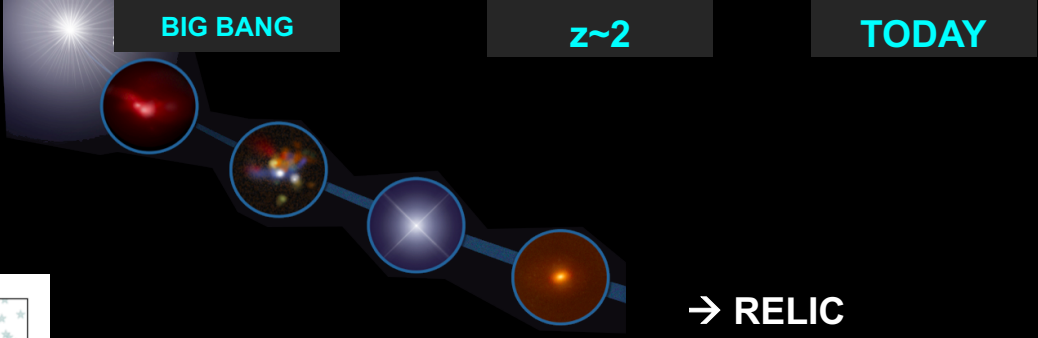


Credit: M. Volonteri



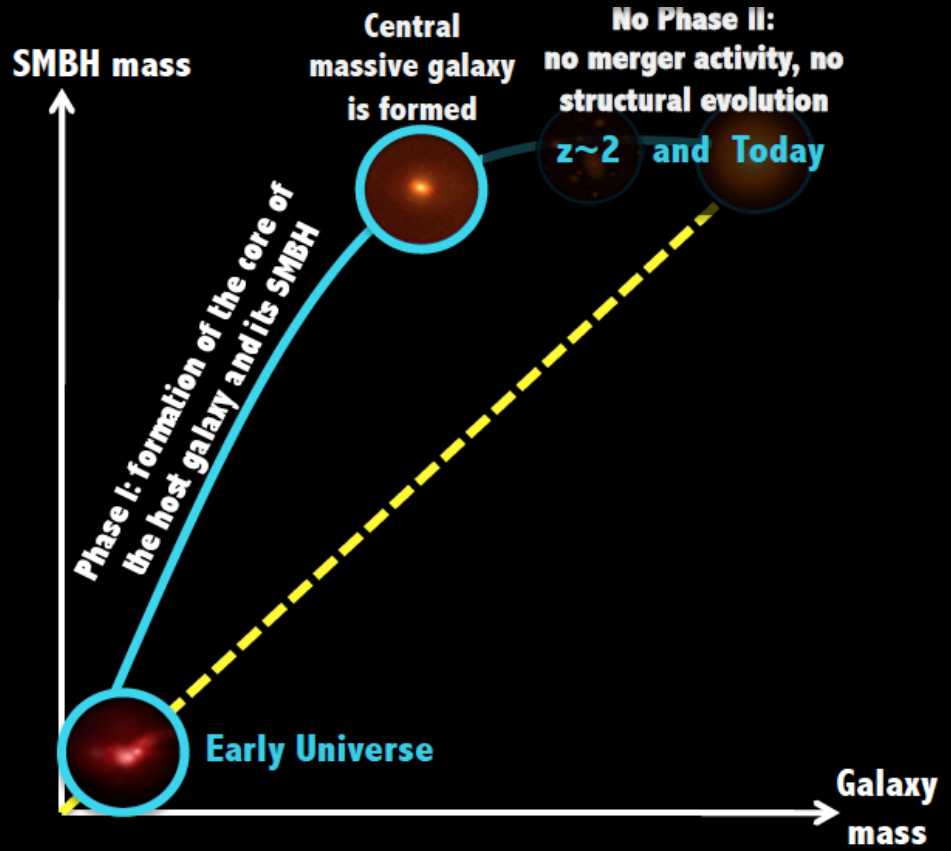
Massive galaxy evolutionary track

CO-EVOLUTION?



Relic galaxies are natural outliers because their different evolutionary path

Ferré-Mateu et al. 2015



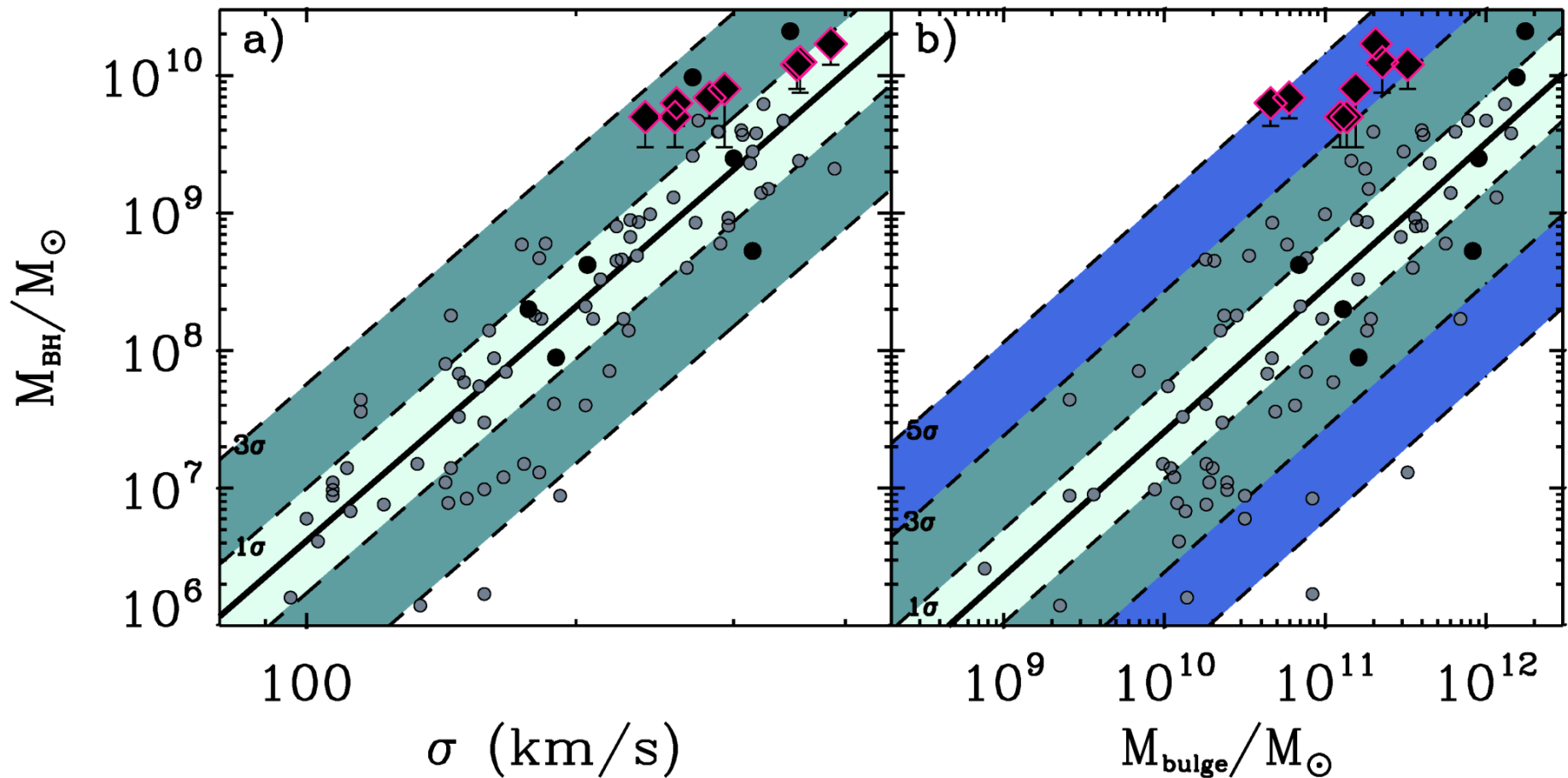
Relic galaxy evolutionary track

Force the relic to suffer the accretion phase

Size **x 7**

Velocity dispersion **x1.1** (Oogi&Habe+2013, Wellons+2015, Tapia+2015)

Stellar masses **x5** (Oser+2010+2012, Trujillo+2011, Hilz+2012)

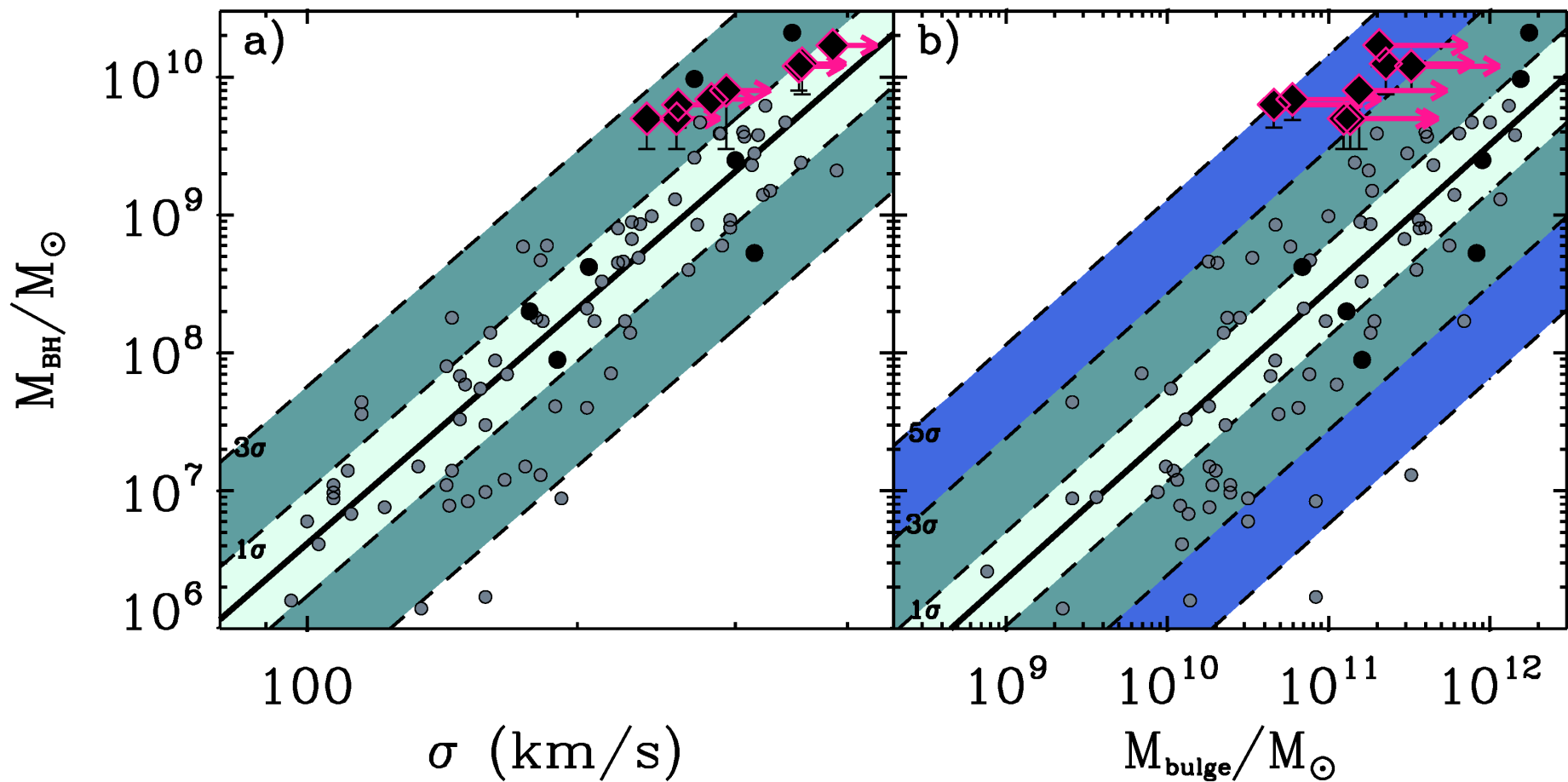


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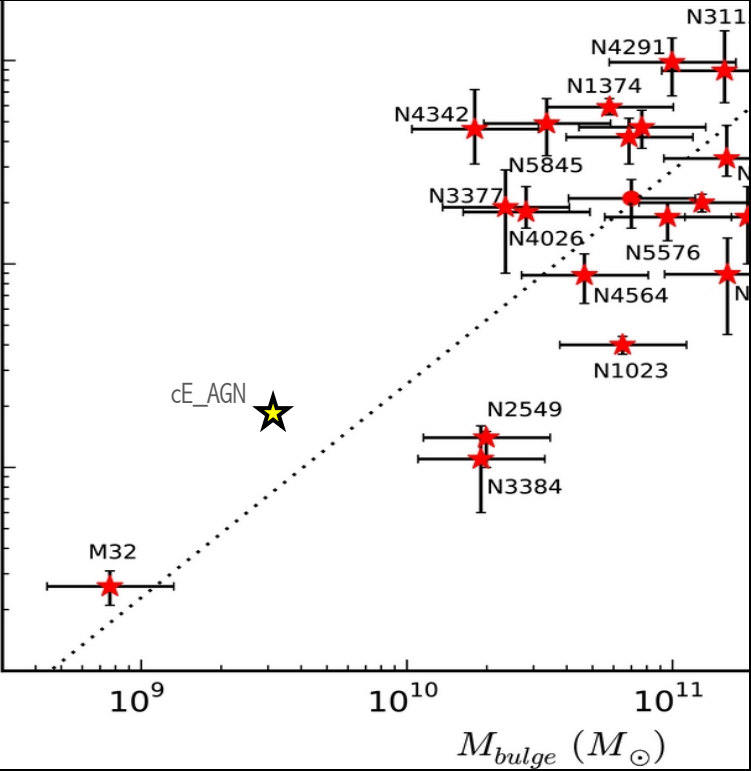
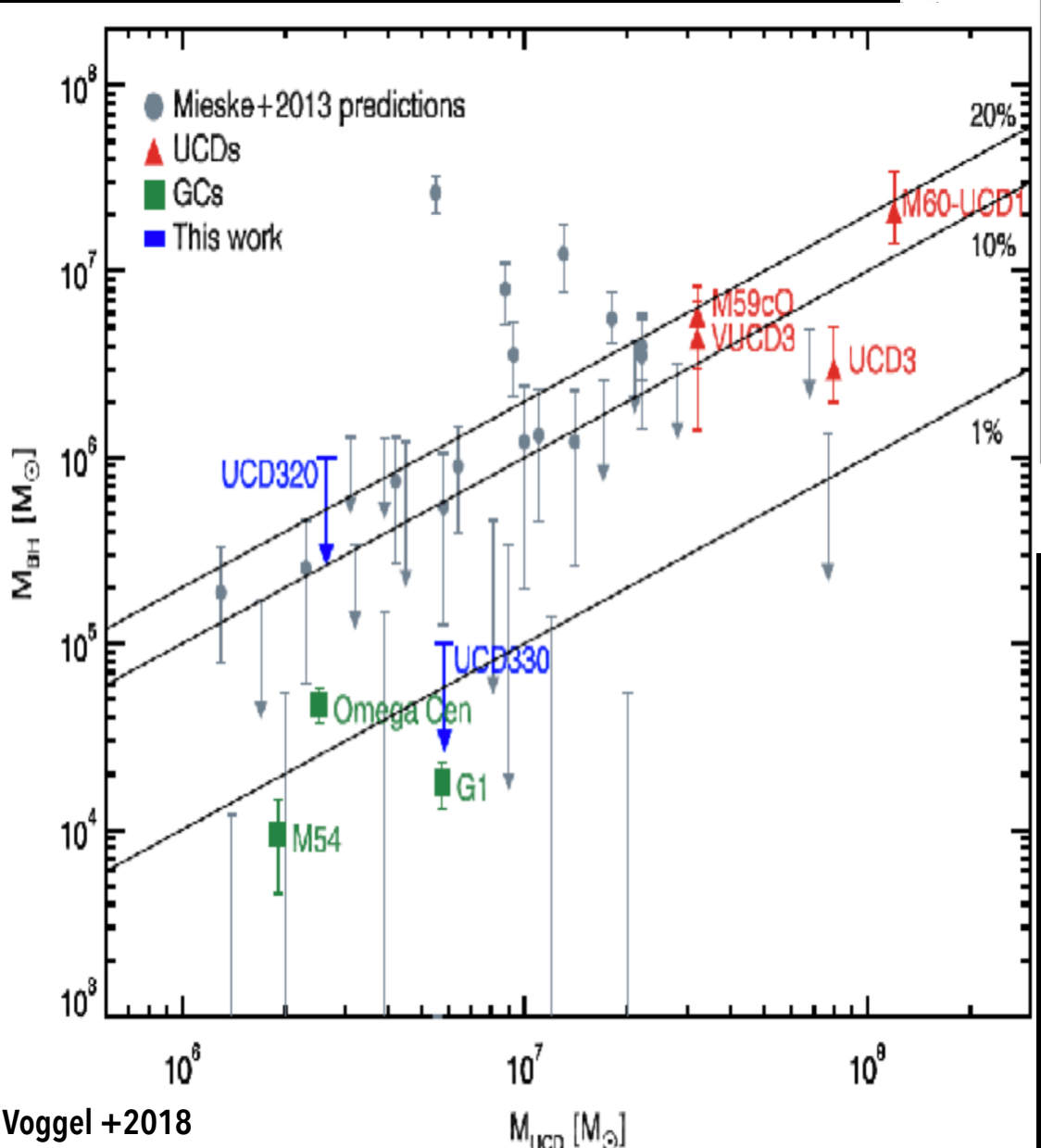


Relic galaxies are **natural outliers** in the SMBH scaling relations because they follow a **different evolutionary path**



ALL massive relic galaxies are outliers.... but not ALL outliers are massive relics!

LOW-MASS OUTLIERS

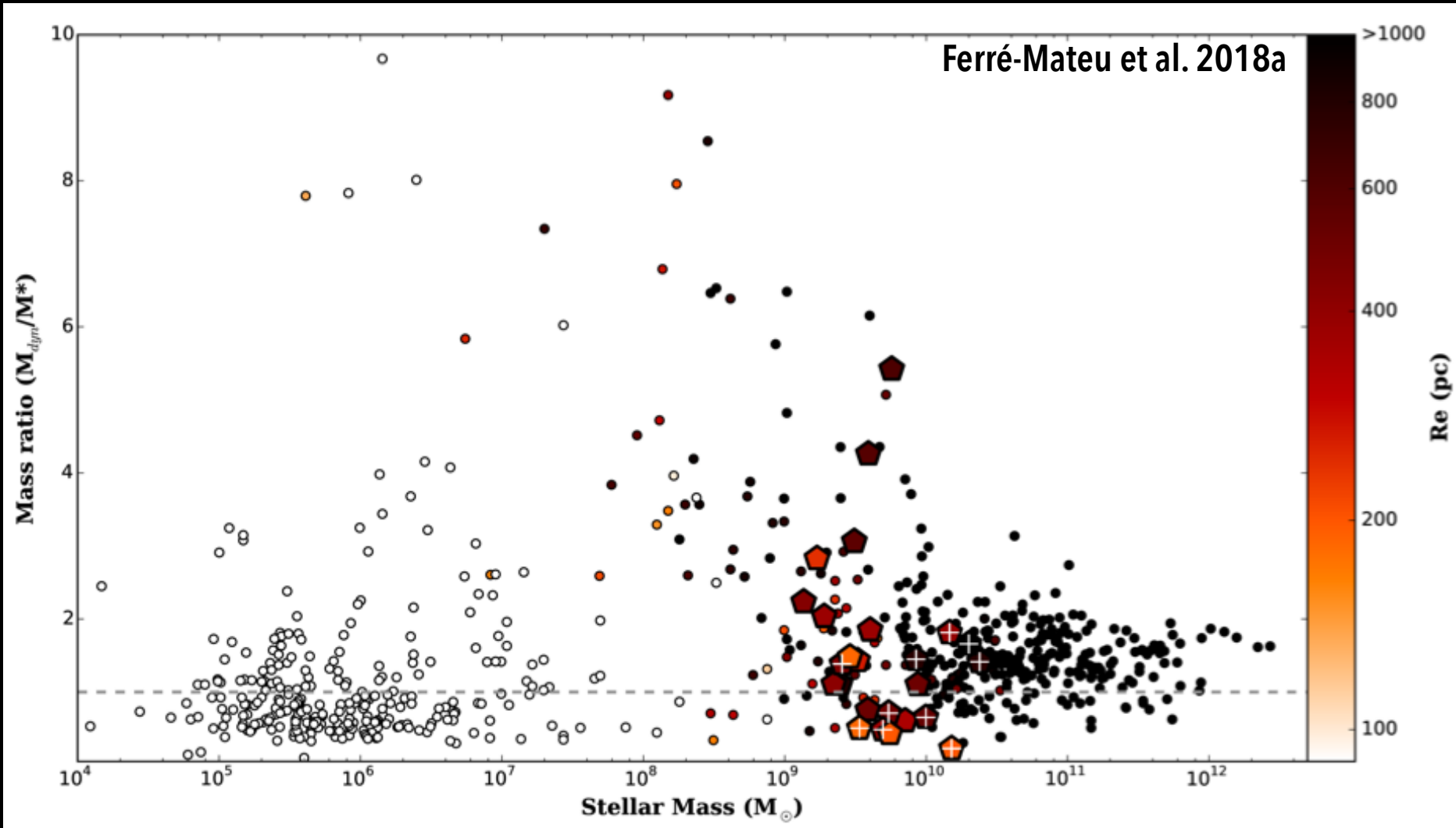


OUTLIERS also exist at the low mass end

Typically compact objects
(UCDs and cEs)
 remnants of stripped dEs and E/S
 → some should **host SMBHs**

(e.g. Mieske+2013; Seth+2014; Voggel+2018, Krajinovic+2018, Pechetti+2017)

COMPACT (LOW-MASS) OUTLIERS



Enhanced M_{dyn}/M^* (and high [Mg/Fe], mass-metallicity outliers, ...)
→ indicative of SMBHs in low-mass, compact systems

X-RAY SIGNATURES IN cEs

Work in progress with M. Mezcua (ICE) and our student C. Soriano



From 400 cEs → 10% with Chandra X-ray detection

SDSS Optical information: photometry, stellar masses, stellar populations, fluxes → BPT diagrams

→ SMBH estimation from broad lines

→ Populate the lower-mass end of compact systems

outliers are cool!

SUMMARY

1) Massive relic galaxies are **natural outliers** in the SMBHs scaling relations because they follow another evolutionary path

2) Limit for **SMBH formation at $\sim 10\text{Gyr}$** 

3) **Co-evolution?** either the SMBH starts earlier or it develops faster, compatible with simulations

4) SMBHs are a powerful tool to indicate the nature of galaxies:

4.1) Possible way to **detect the elusive relic galaxies**: all relics must be outliers (but not all outliers have to be relics)

4.2) indicate the **nature of other compact systems** (cEs and UCDs)

