Shedding some light on the massive galaxy puzzle with nuMOIRCS

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Subaru Telescope

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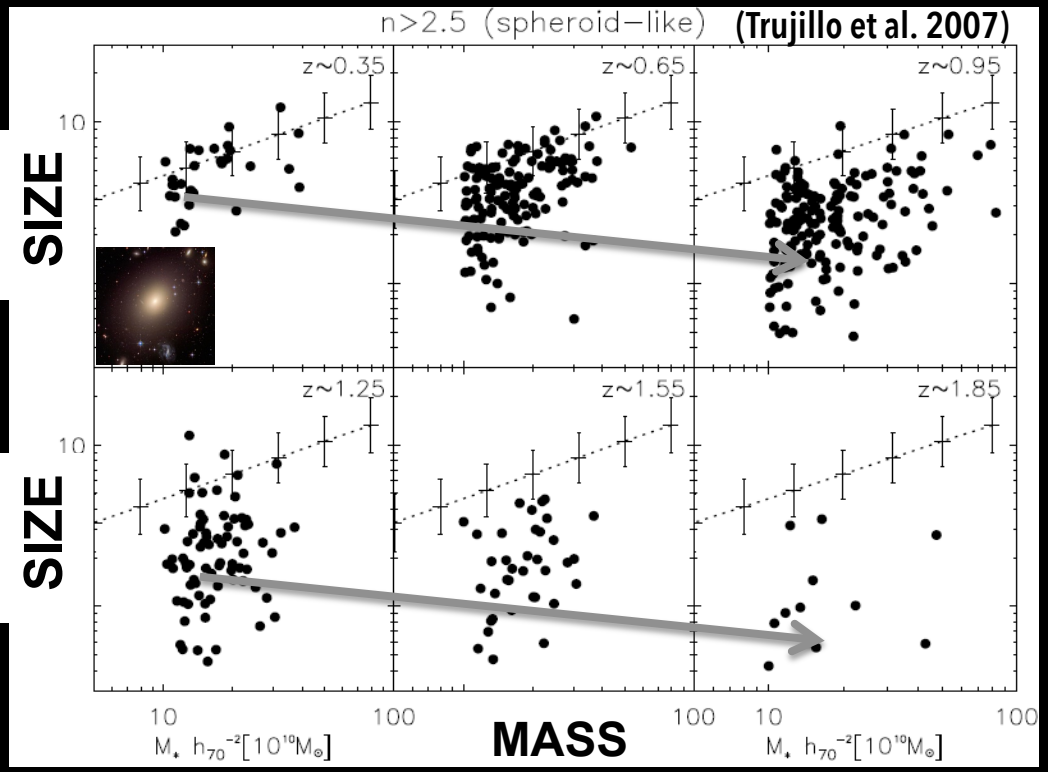
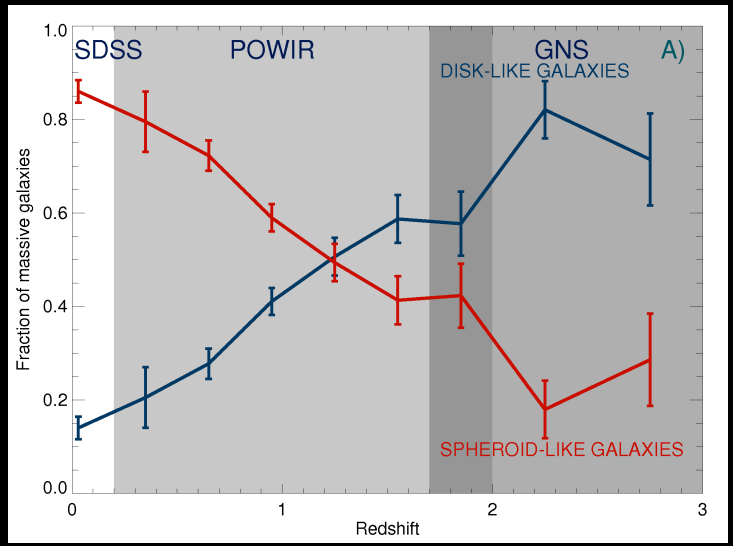
Subaru Users Meeting 2013, Wednesday 22nd January

1. The massive galaxy puzzle

Massive galaxies suffer a strong size and morphological evolution





(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)

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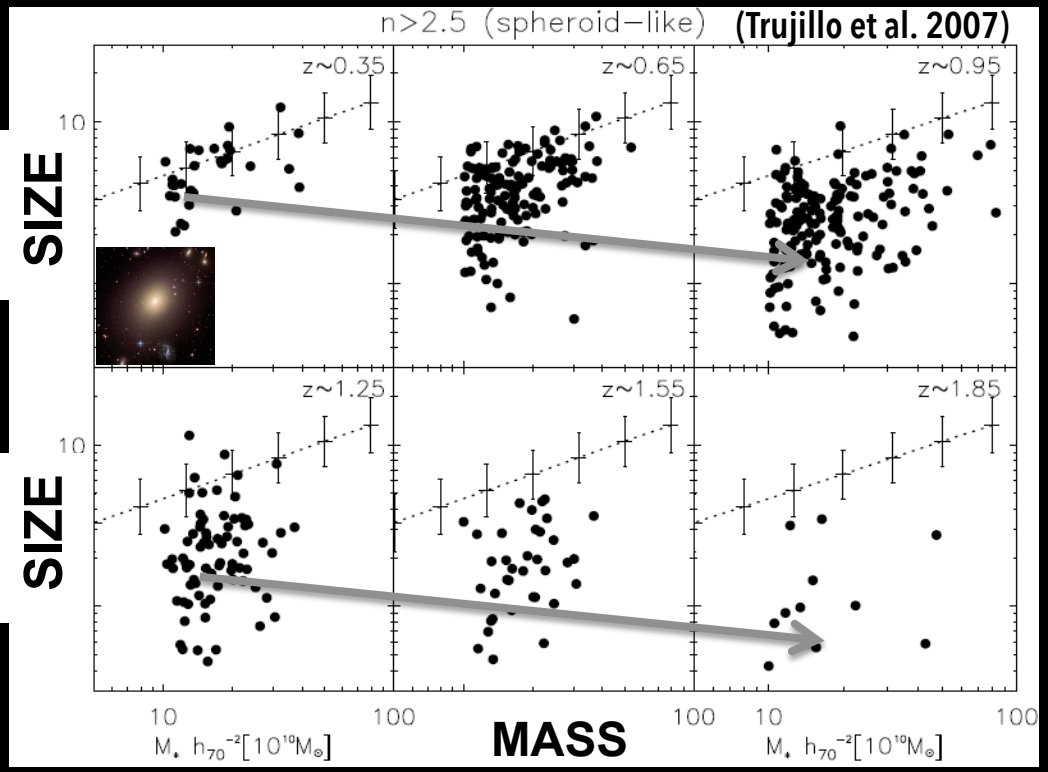

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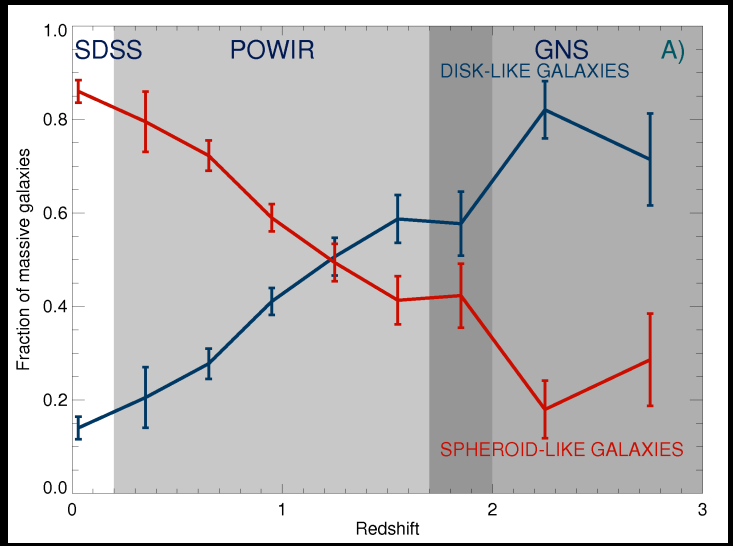

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Which is the main mechanism to explain this evolution?

MINOR MERGERS seem to be the main mechanism:

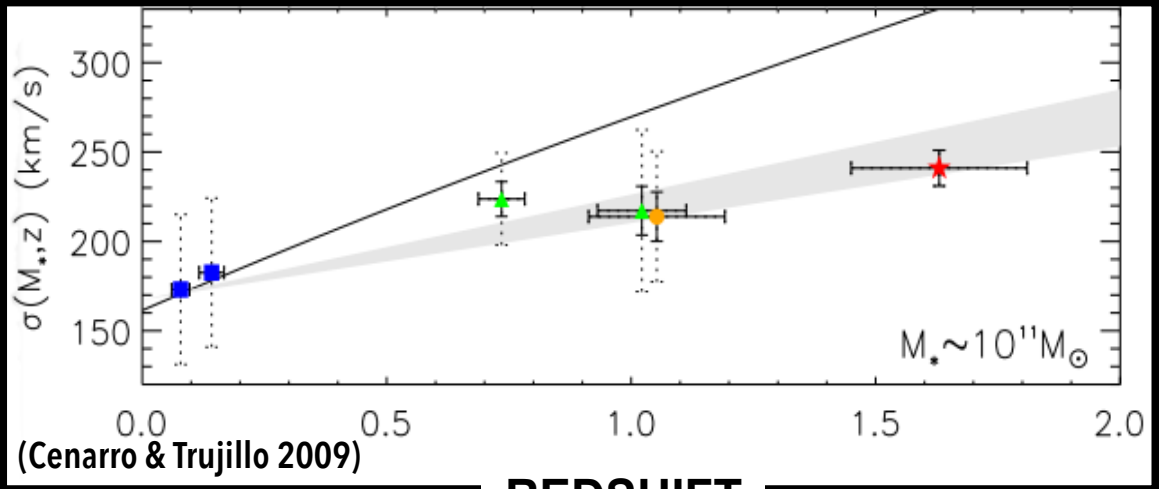
Accretion of new material at the periphery of the central massive high-z galaxy

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

1) Continous increase in size by the build up of external parts → untouched cores
(e.g. Bezanson et al. 2009, Hopkins et al. 2009, van Dokkum & Conroy 2010)

2) Size growth not related with the age of the galaxy (e.g. Trujillo et al. 2011, Saraco et al. 2011)

3) Mild velocity dispersion evolution (e.g. Cappellari et al. 2009, Cenarro & Trujillo 2009, Hopkins et al. 2009, van de Sande et al. 2011)



(Cenarro & Trujillo 2009)

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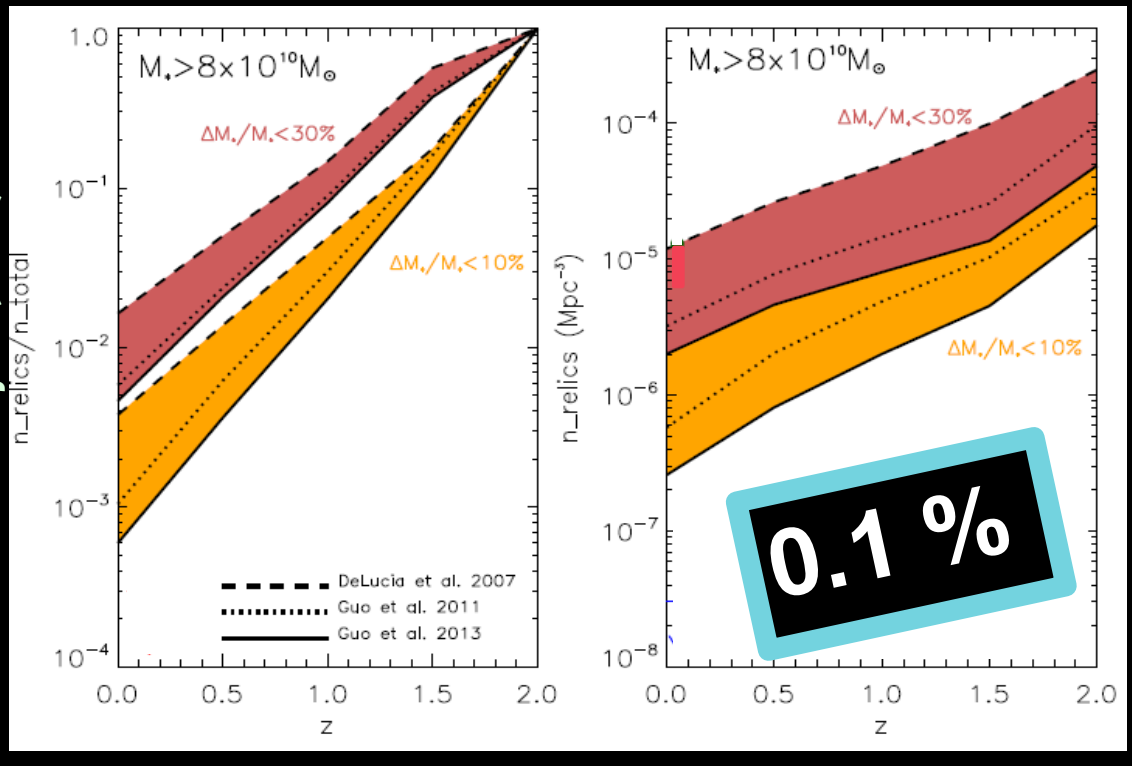
4) Number of satellites surrounding the massive galaxy at different redshifts (e.g. Kaviraj et al. 2009, Jackson wt al. 2010, Man et al 2012, Newman et al. 2012, Mármol-Queraltó et al. 2012, Quilis & Trujillo 2012)

5) Number of massive & compact galaxies in the nearby Universe (e.g. Trujillo et al. 2009, Taylor et al. 2010, Valentinuzzi et al. 2010, Poggianti et al. 2013)

Quilis & Trujillo (2013)



MINOR MERGERS seem to be the main mechanism

BUT…

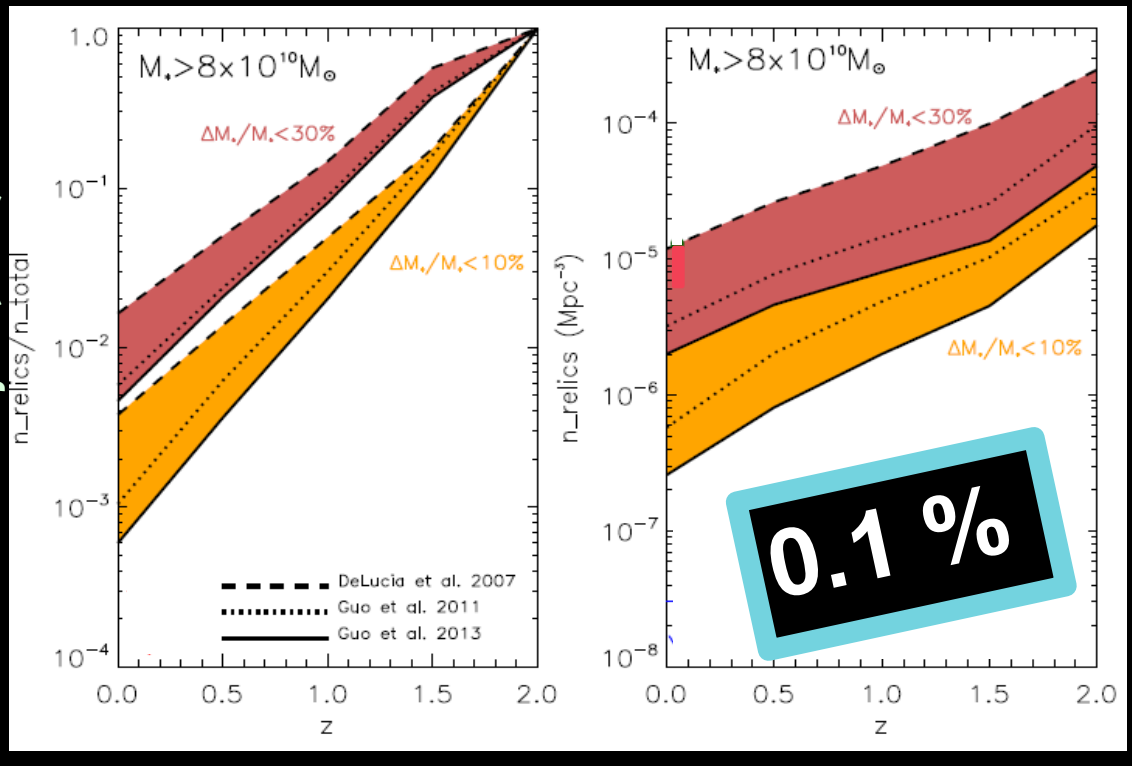
4) Number of satellites surrounding the massive galaxy at different redshifts (e.g. Kaviraj et al. 2009, Jackson wt al. 2010, Man et al 2012, Newman et al. 2012, Mármol-Queraltó et al. 2012, Quilis & Trujillo 2012)

→ Missing by a factor ≈ 2

5) Number of massive & compact galaxies in the nearby Universe (e.g. Trujillo et al. 2009, Taylor et al. 2010, Valentinuzzi et al. 2010, Poggianti et al. 2013)

→ Extremely low fraction → are they the relics of the early Universe massive galaxies?

Quilis & Trujillo (2013)



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

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

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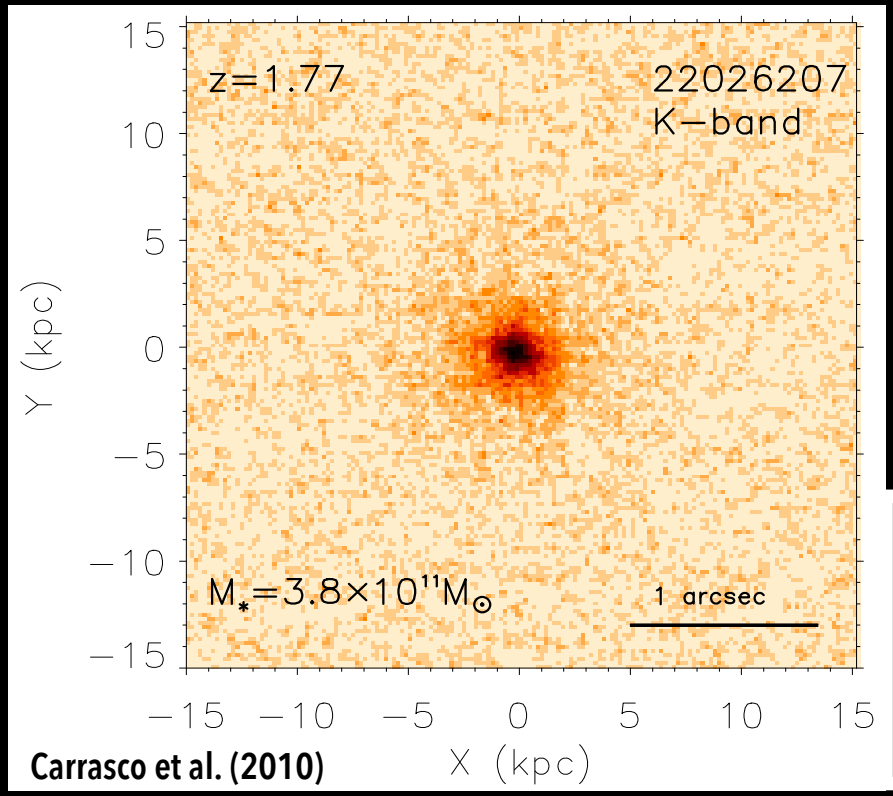


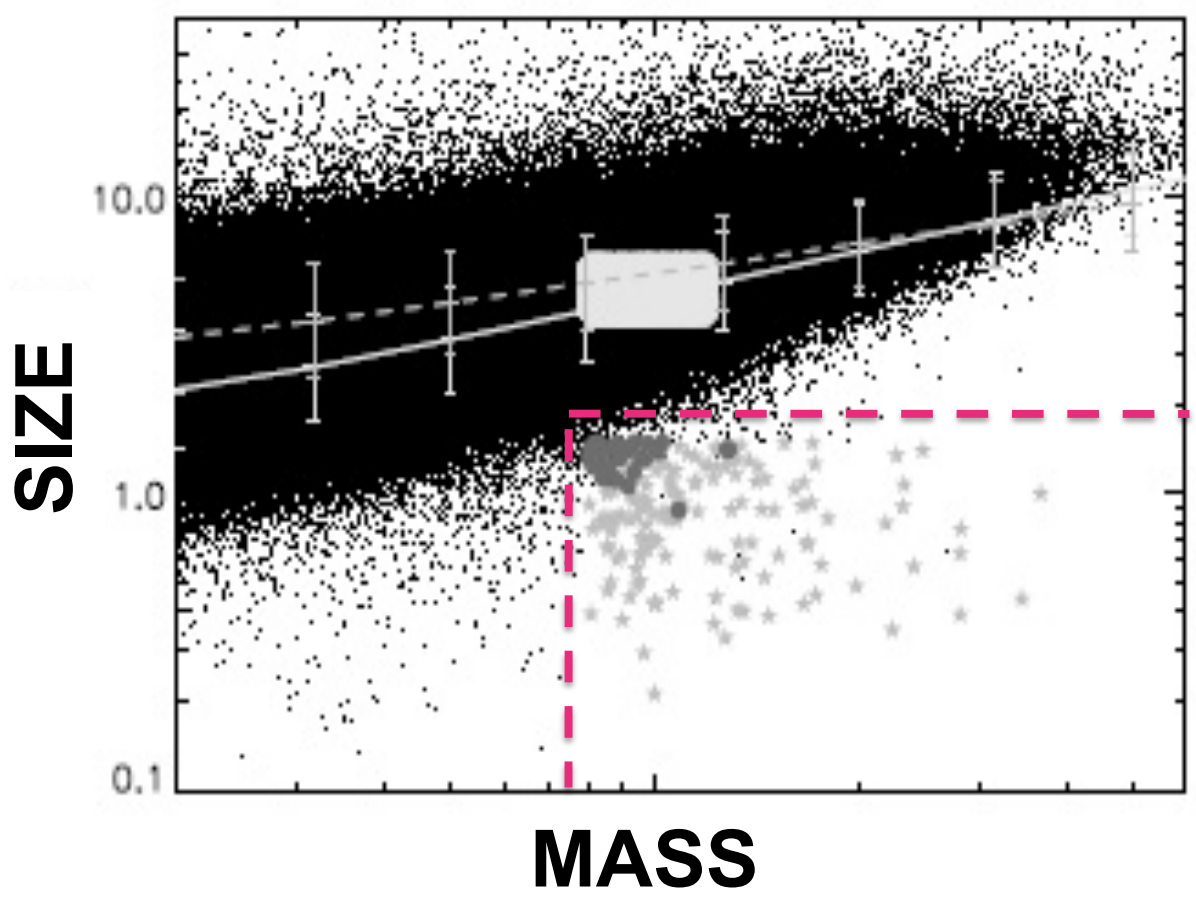
Carrasco et al. (2010)

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***: Age > 10 Gyr

2. Local compact massive galaxies...

... are they the relics of the high-z Universe?



49 local compact massive galaxies in SDSS:
(NYU Galaxy Catalog, Blanton et al. 2005)
$M^* > 10^{11} M_\odot$
$R_e < 1.5$ kpc

Trujillo et al. (2009),
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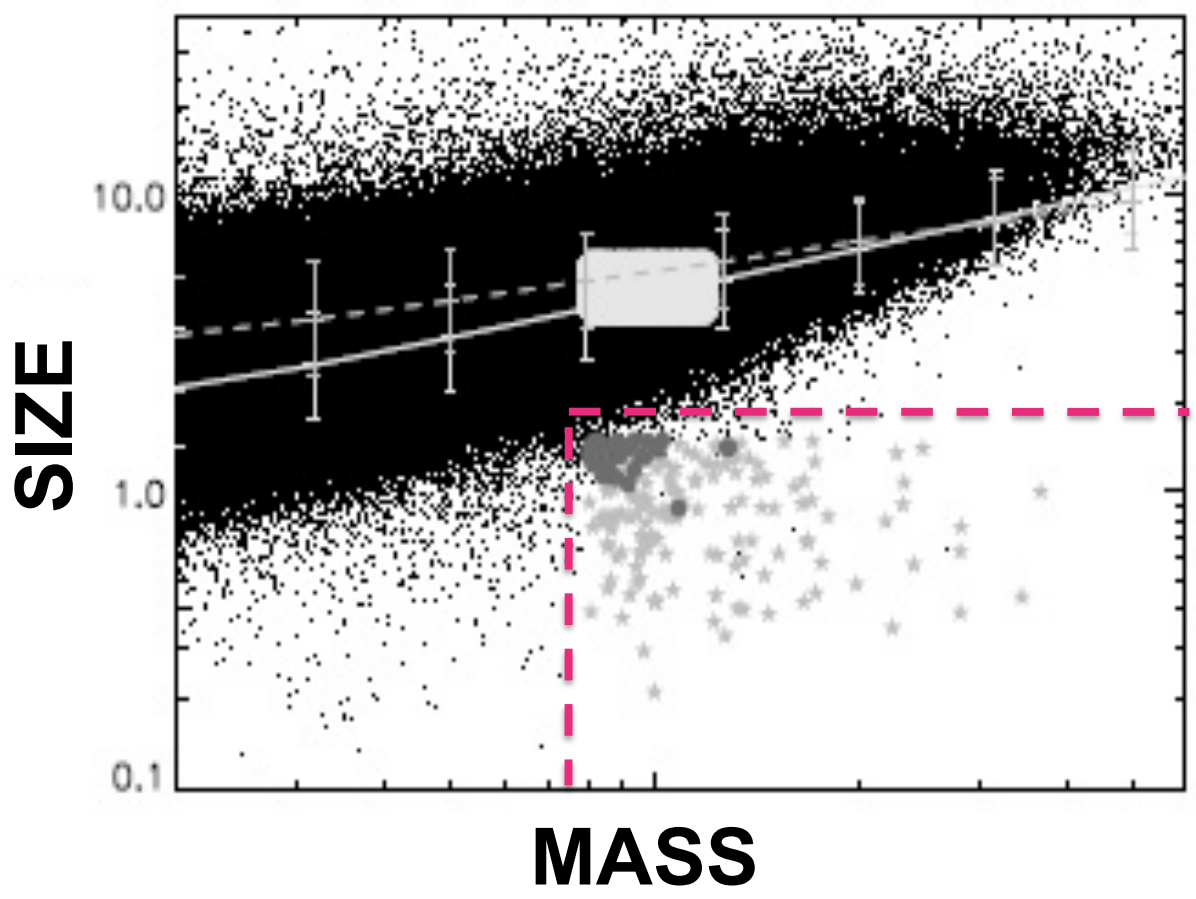

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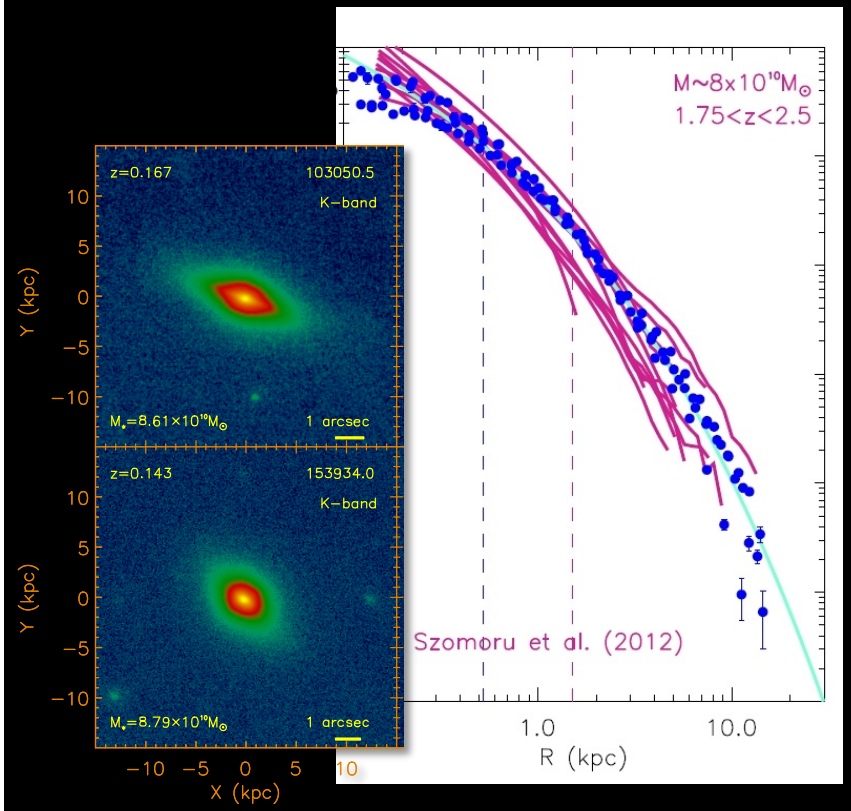
<0.03% of today massive galaxies are compact

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

Are local compact massive galaxies the relics?

1) Deep K-band imaging

Trujillo, Carrasco & Ferré-Mateu (2012)



✓ Massive compact galaxies at z~0 present same morphologies and profiles as high-z massive galaxies

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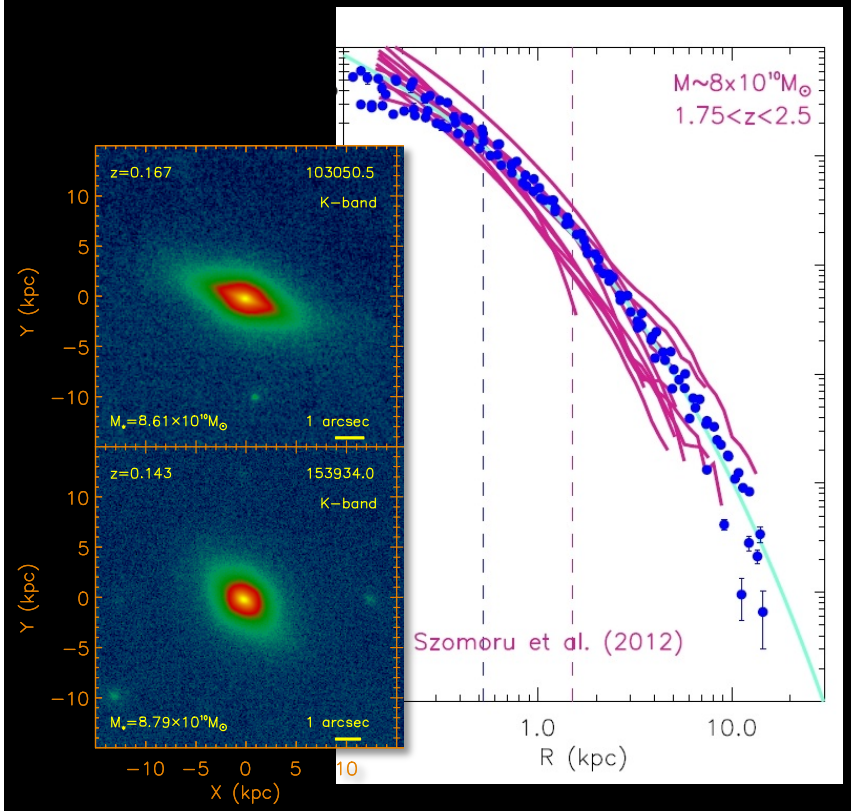

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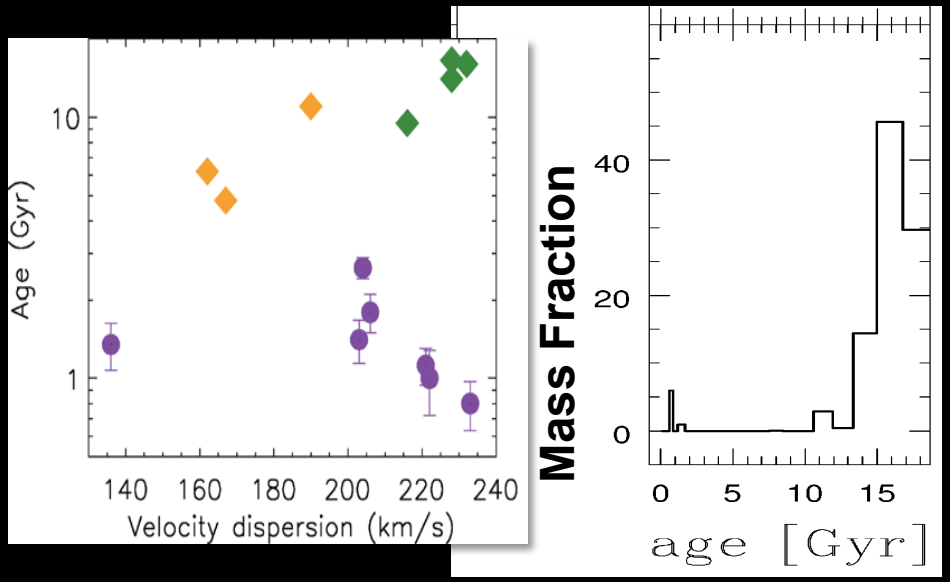
2) Deep long-slit spectroscopy

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



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

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

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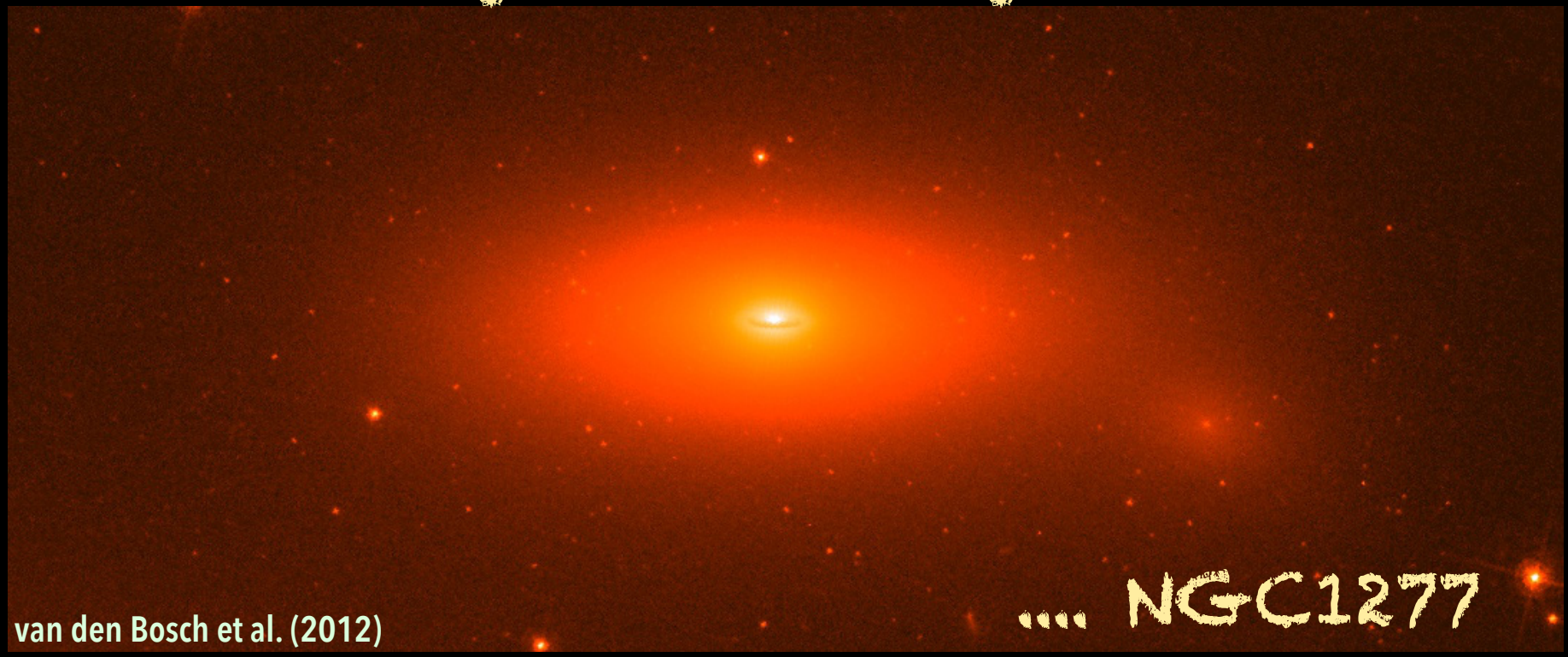
So, is there any relic around?
Is then the minor merger scenario correct?
Are we observationally missing some objects?

3. The study case galaxy...



van den Bosch et al. (2012)

Properties:

SMBH:

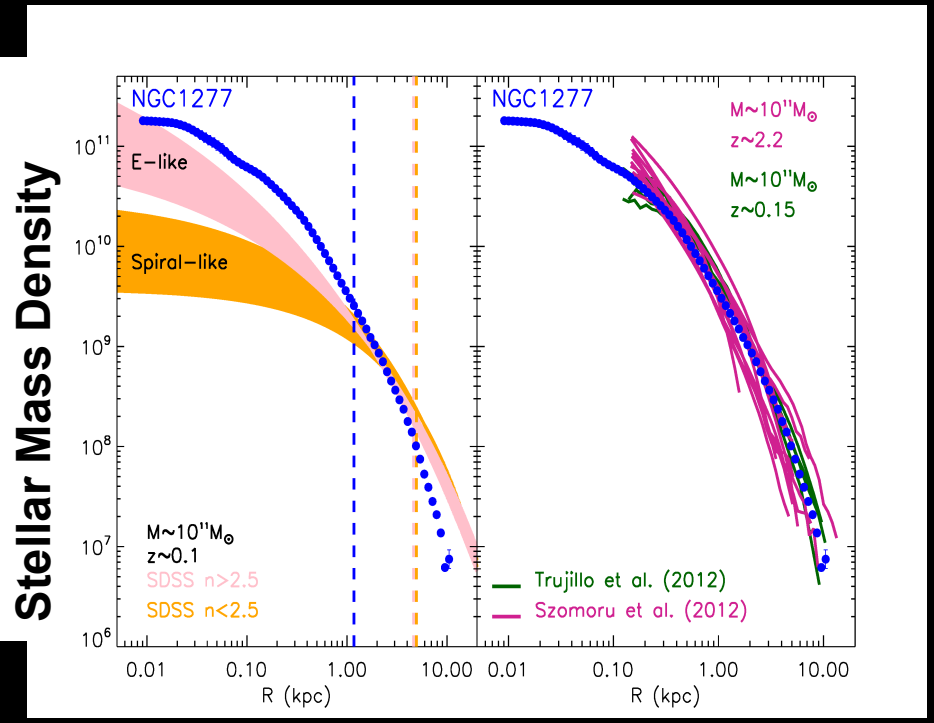
$M\bullet = 2 \times 10^9$ Msun → $M\bullet/M^* \sim 0.02$ → 4 times more than expected!

Galaxy:

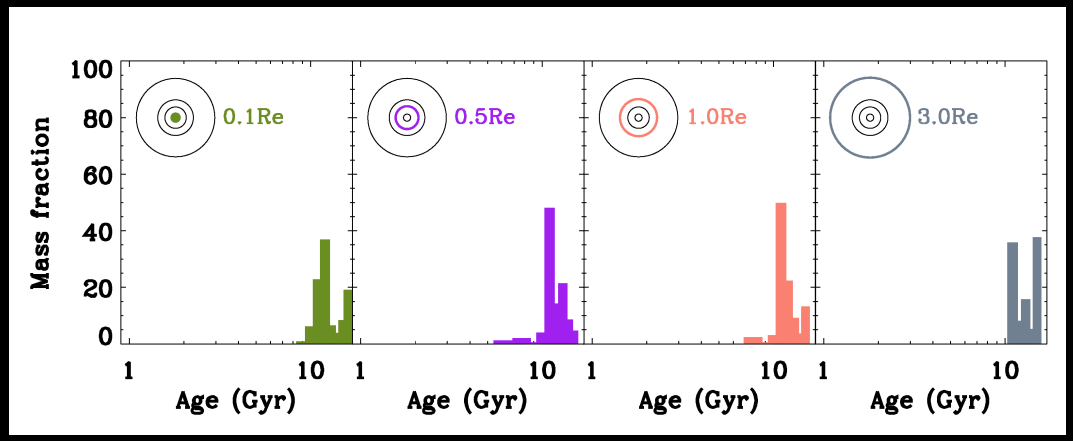
$M_* = 1.2 \times 10^{11} M_{sun}$ $R_e = 1.2$ kpc $\sigma > 330$ km/s $V_{rot} > 300$ km/s

New deep long-slit spectroscopy with ISIS@WHT up to ~3Re

Trujillo, Ferré-Mateu et al. 2014



✓ as high-z massive galaxies!



Age ~12 Gyr

✓ all stars formed > 10 Gyr

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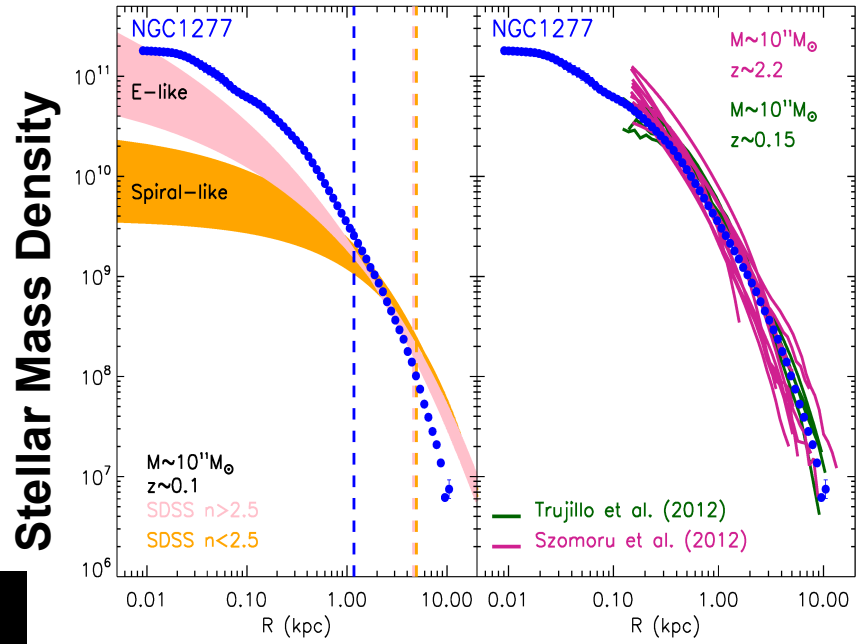
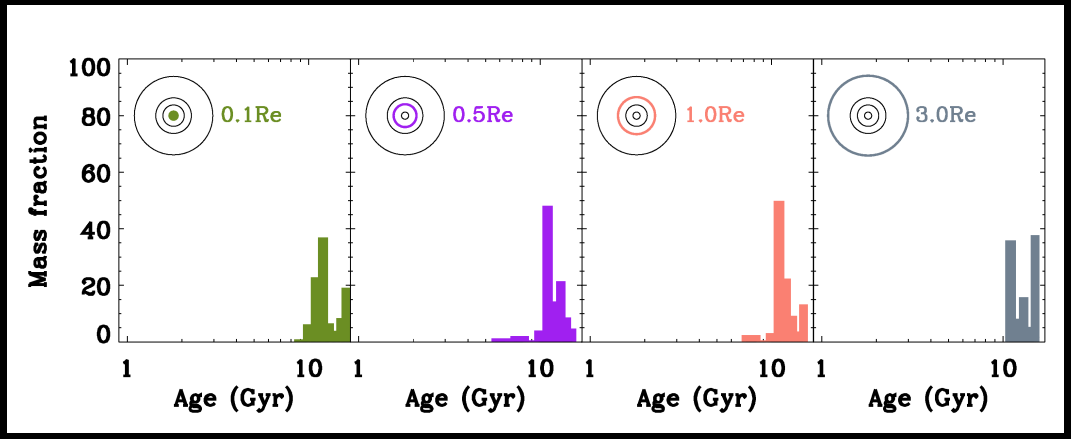


✓ as high-z massive galaxies!

NGC1277 is a serious candidate to be a relic

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



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4. new upgrade for the Multi-Object InfraRed Camera and Spectrograph

MOIRCS

- second generation instrument on the Cassegrain focus

- wide FOV (4′x7′ imaging; 4′x6′ spectroscopy)

- near-IR → 0.8 – 2.5 μm

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- Integral-Field Unit (IFU) instead of multi-slit

COMING SOON!

2D perspective on galaxy formation and evolution: single spectrum with different apertures *vs* spatially resolved distribution

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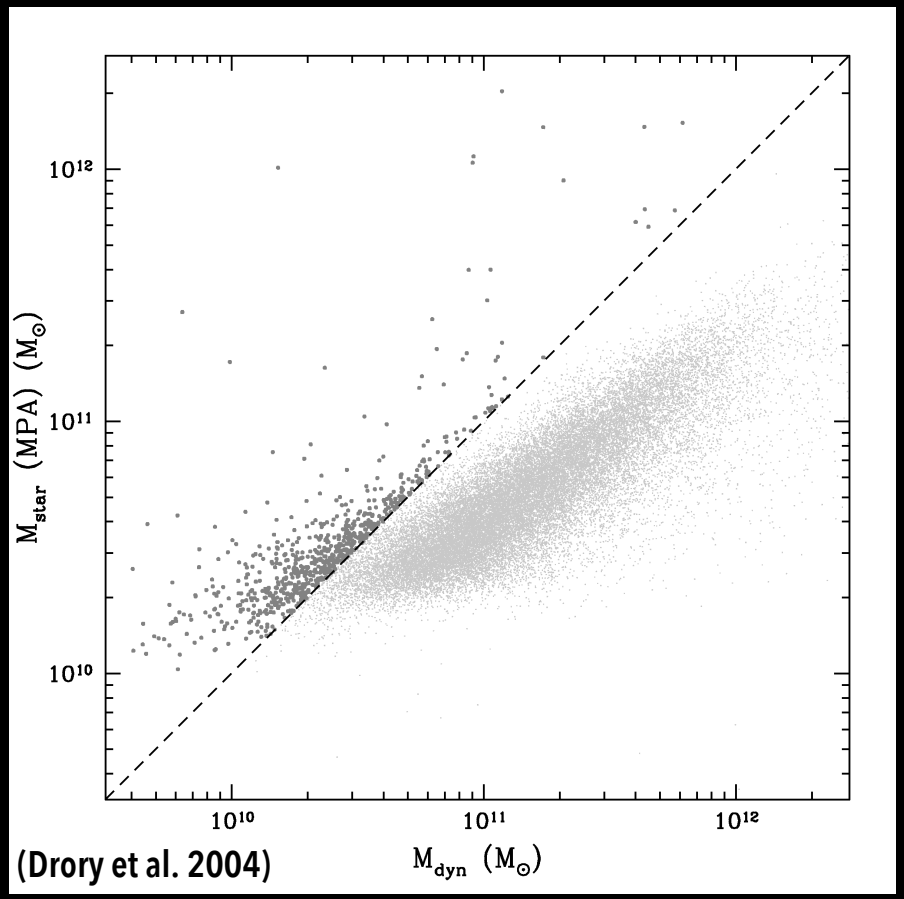
Good instrument to follow-up IFU surveys (e.g. SAURON, ATLAS3D, CALIFA, PINGS, MANGA, SINS, GLACE, IMAGES,…)

5. Massive galaxies with nuMOIRCS:

Compact Massive galaxies

Discrepancy where $M_{dyn} < M^*$

(e.g. Drory et al. 2004, Stockton & Shih 2010, Martínez-Manso et al. 2011, Ferré-Mateu et al. 2012)



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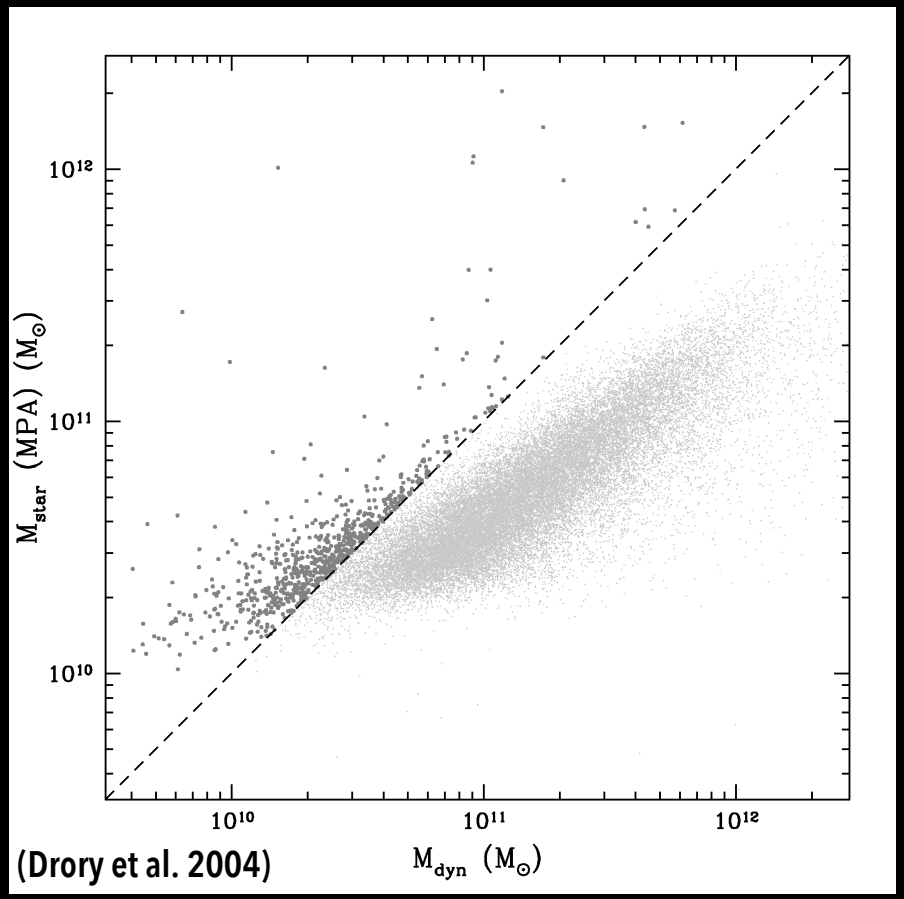

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Virial Formula is a bad calibrator for such small objects, both under the homology and non-homology assumption

(e.g. Cappellari et al. 2013, Peralta-de Arriba et al. 2014)

$$M_{vir} = [K(n)\,\sigma^2\,R_e]/G$$

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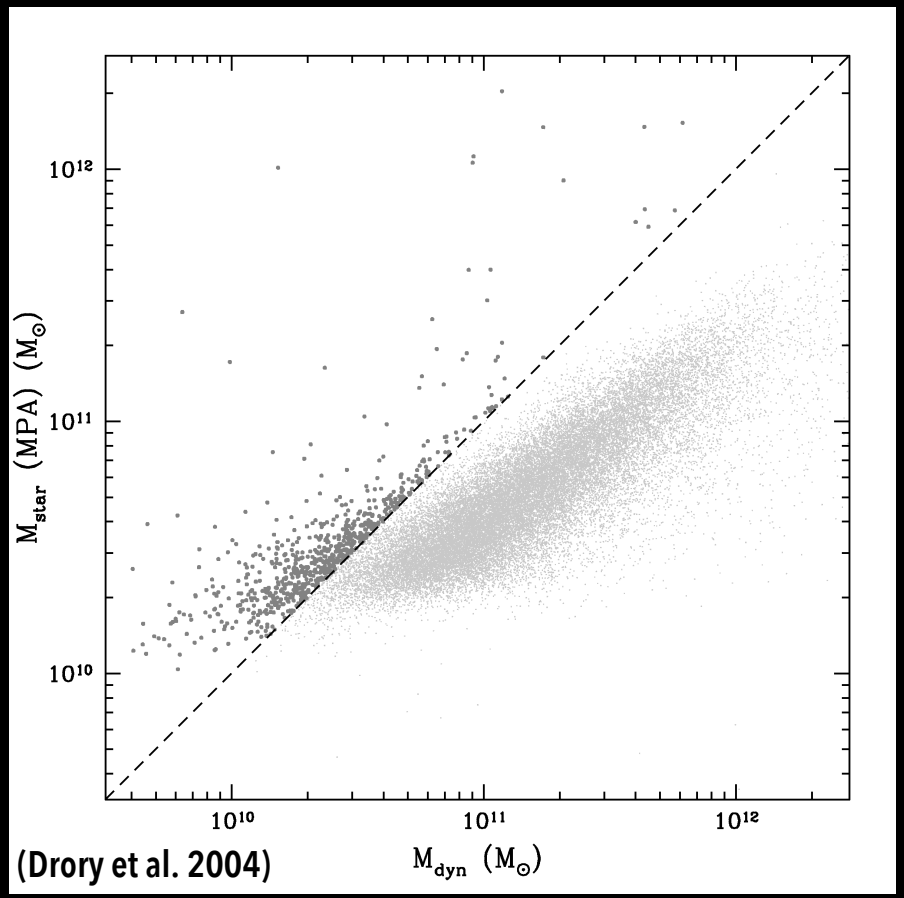

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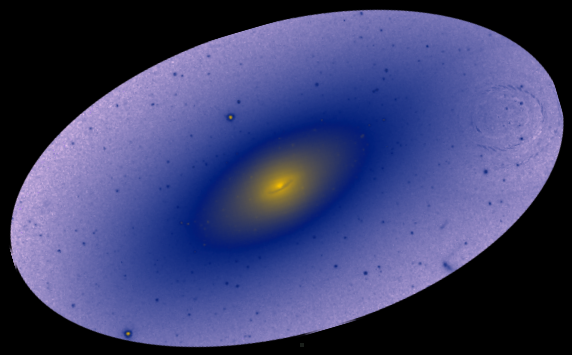
DYNAMICAL MODELS

5. Massive galaxies with nuMOIRCS:
NGC1277



- Accurate 2D dynamical models
-Radial effect with non-universal IMFs
- stellar populations of globular clusters
- dust effect and nuclear activity

…and this is just one galaxy!

Other scientific goals:

- Study the inside-out growth of ETGs under the minor merger scenario
- Radial variations on the IMF inside ETGs
- Study the star formation on disk galaxies to understand the stellar migration
- Study the distribution of the ionized gas to understand its nature in different galaxy regions
- Study the galaxy kinematics with enough resolution to do chemodynamics
- Create accurate dynamical models to study the total mass distribution
- Study the relation between the growth of SMBHs and their massive hosts
- Clusters at high-z: study the environmental dependence of galaxy properties
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