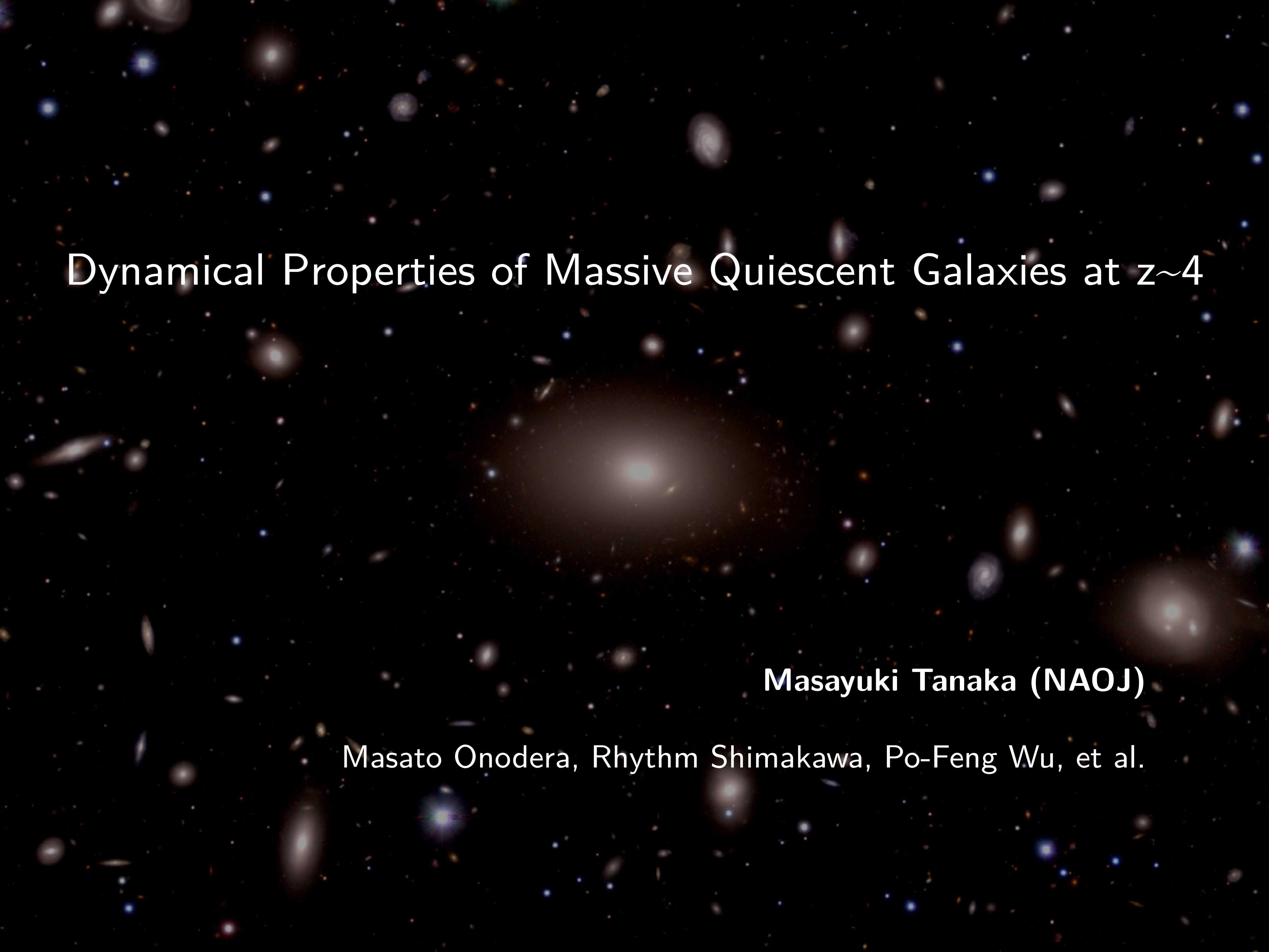


Dynamical Properties of Massive Quiescent Galaxies at z∼4

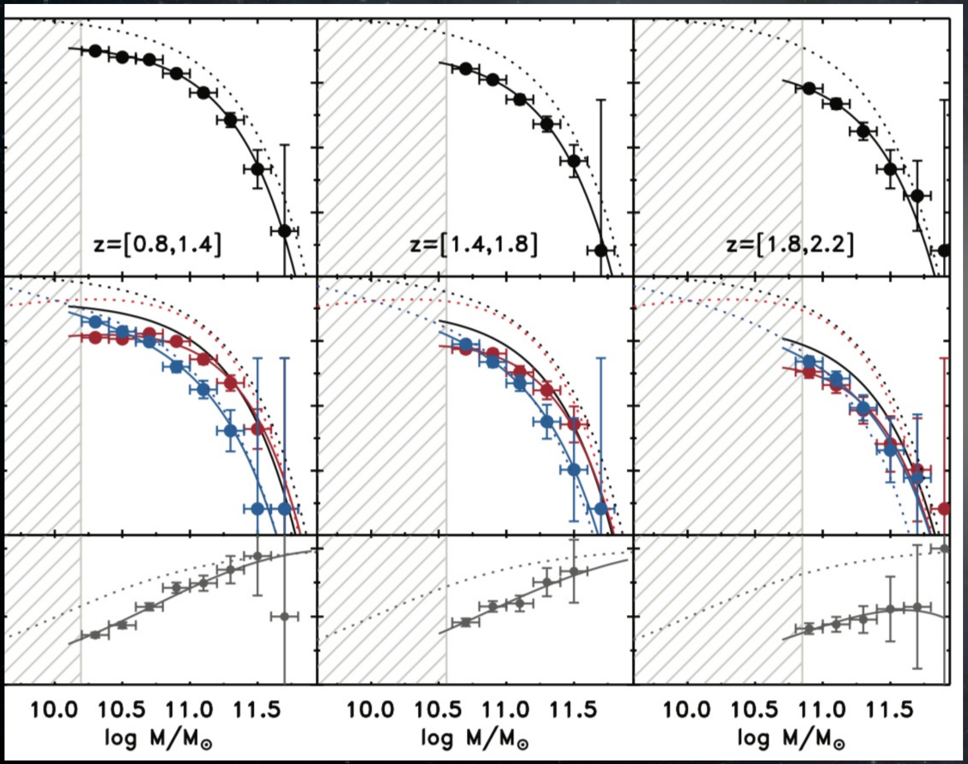
Masayuki Tanaka (NAOJ)

Masato Onodera, Rhythm Shimakawa, Po-Feng Wu, et al.

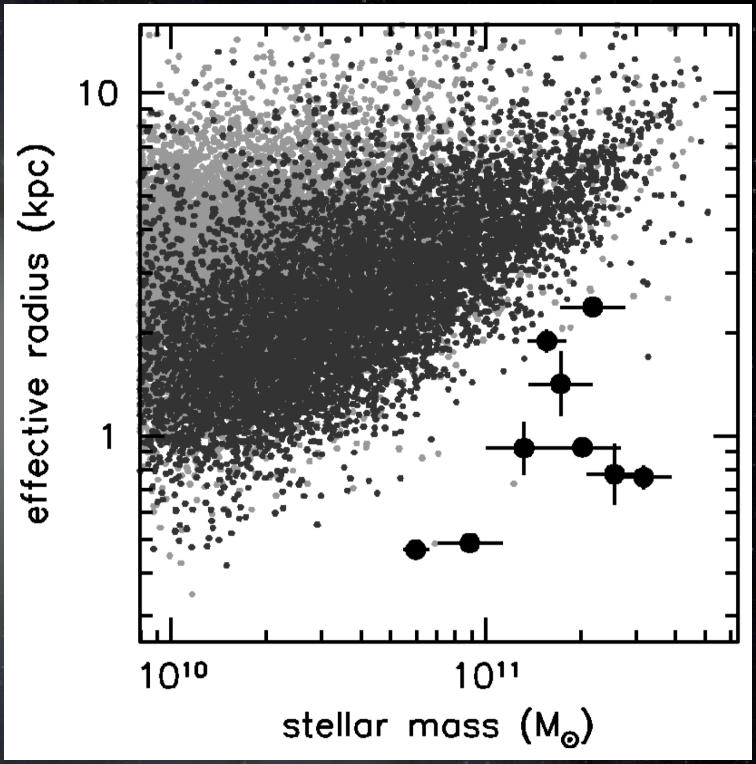
Massive early-type galaxies are dominated by old stellar populations and have not formed stars since an early epoch. What is the physical mechanism to form a massive galaxy in the early Universe and shut off their star formation?

Massive quiescent galaxies at high redshifts

Brammer+11

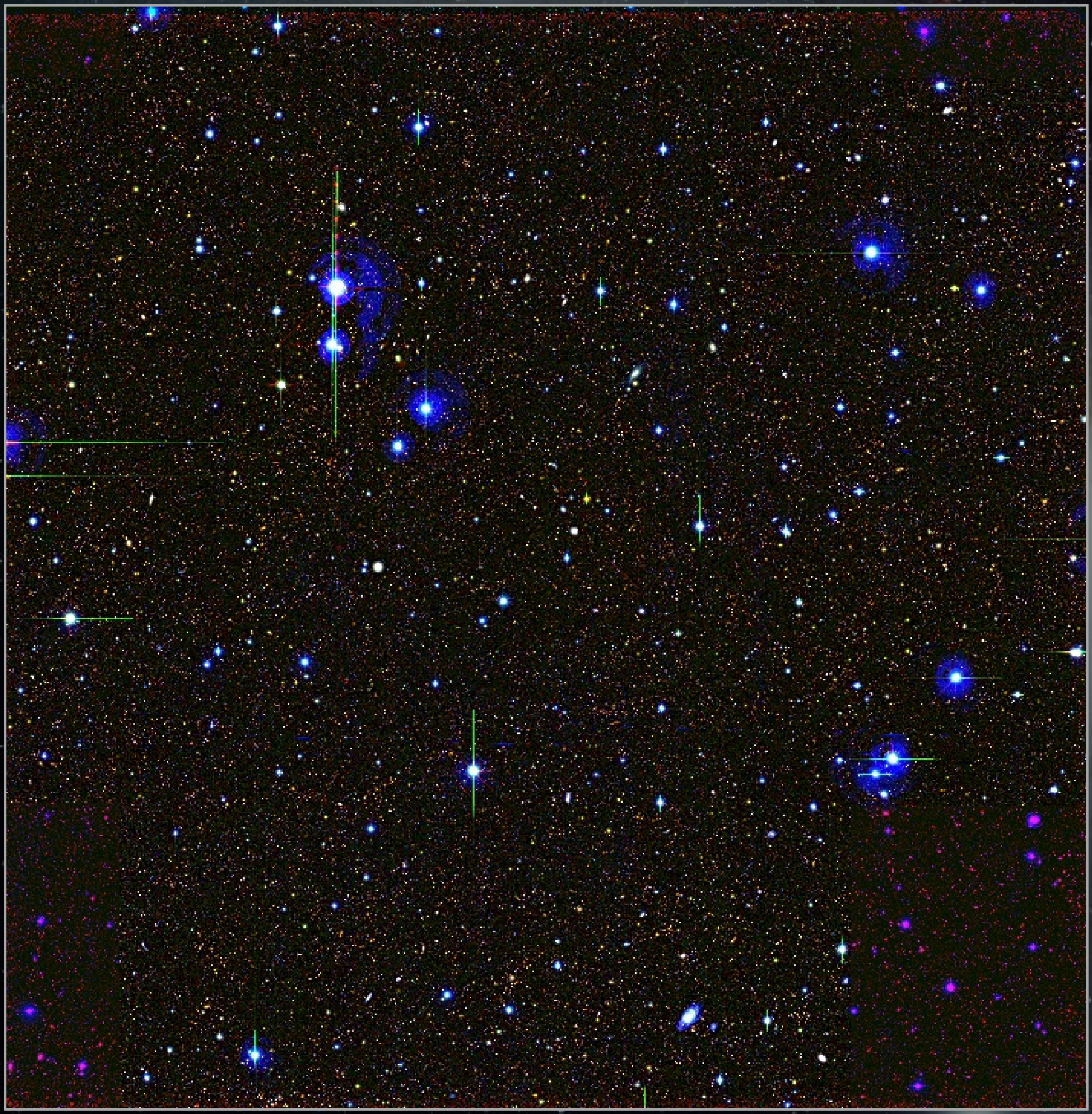


van Dokkum+09



~50% of the massive galaxies at z~2 are compact and quiescent.

Deep Multi-Wavelength Data in UDS

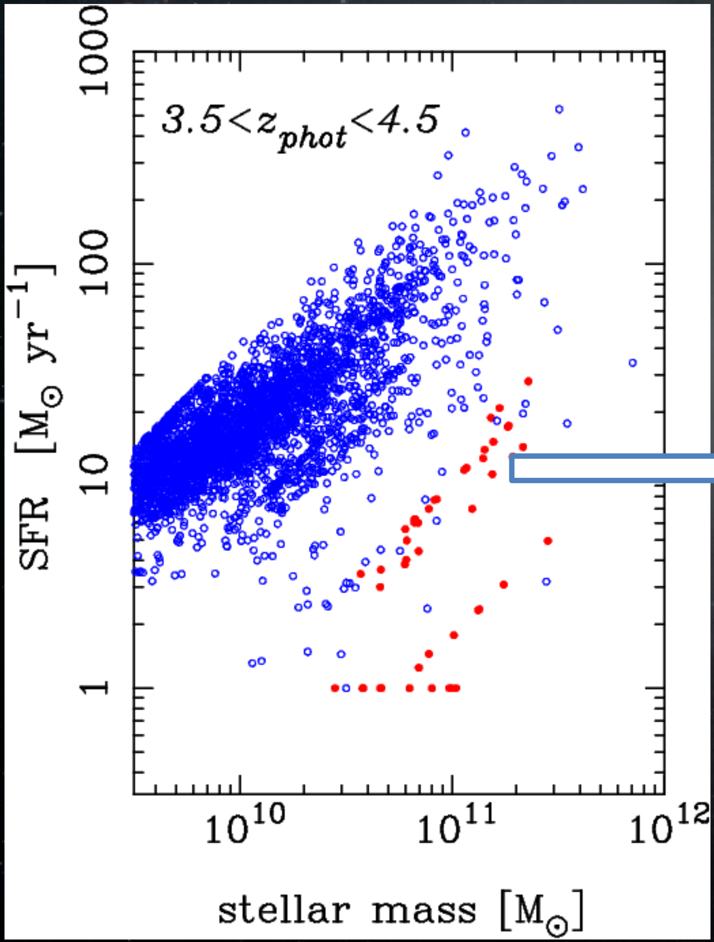


BzK composite

u:	26.8
B:	27.6
V:	27.3
R:	27.1
i:	27.0
z:	26.0
J:	25.2
H:	24.6
K:	25.0
[3.6]:	24.8
[4.5]:	24.3
[6.5]:	22.6
[8.0]:	22.5

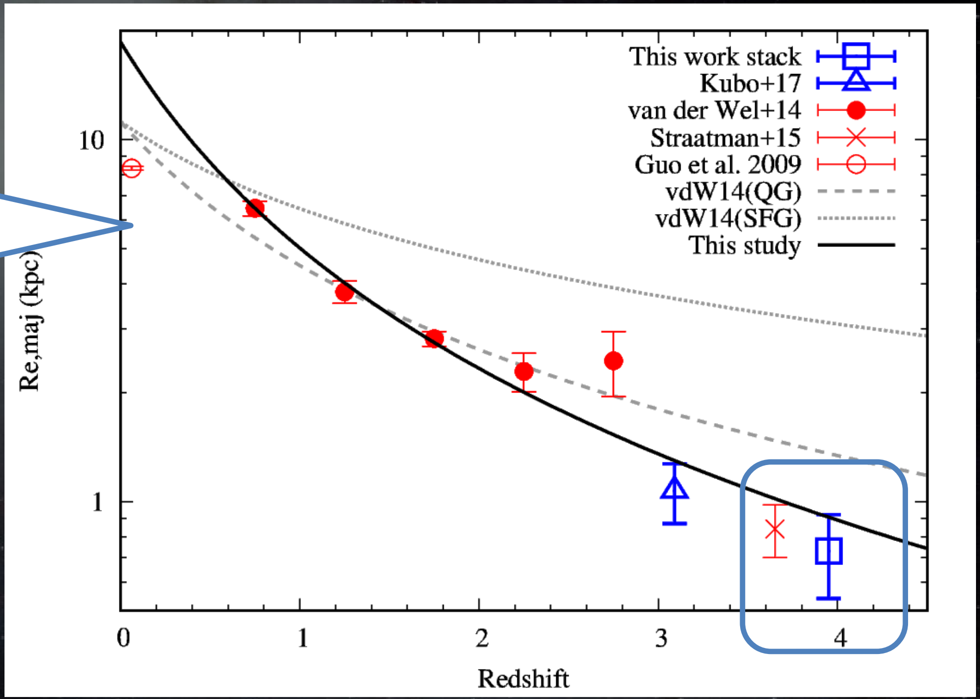
5sigma in 2” aperture

Massive quiescent galaxies at z~4



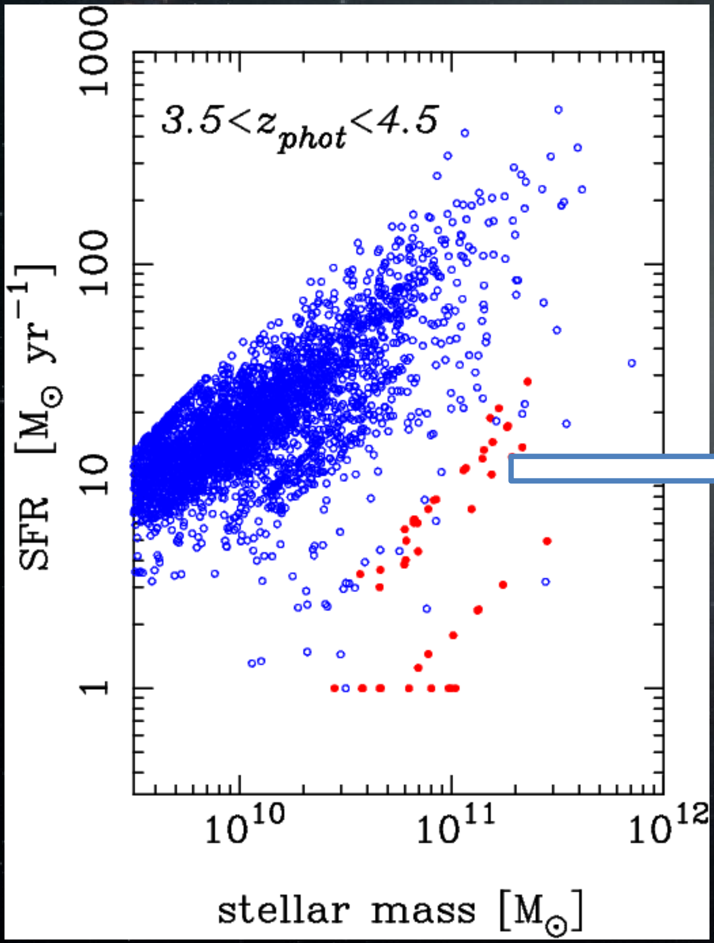
Quiescent: sSFR<10^-9.5 yr^-1

Extremely compact sizes from the AO-assisted K-band imaging!

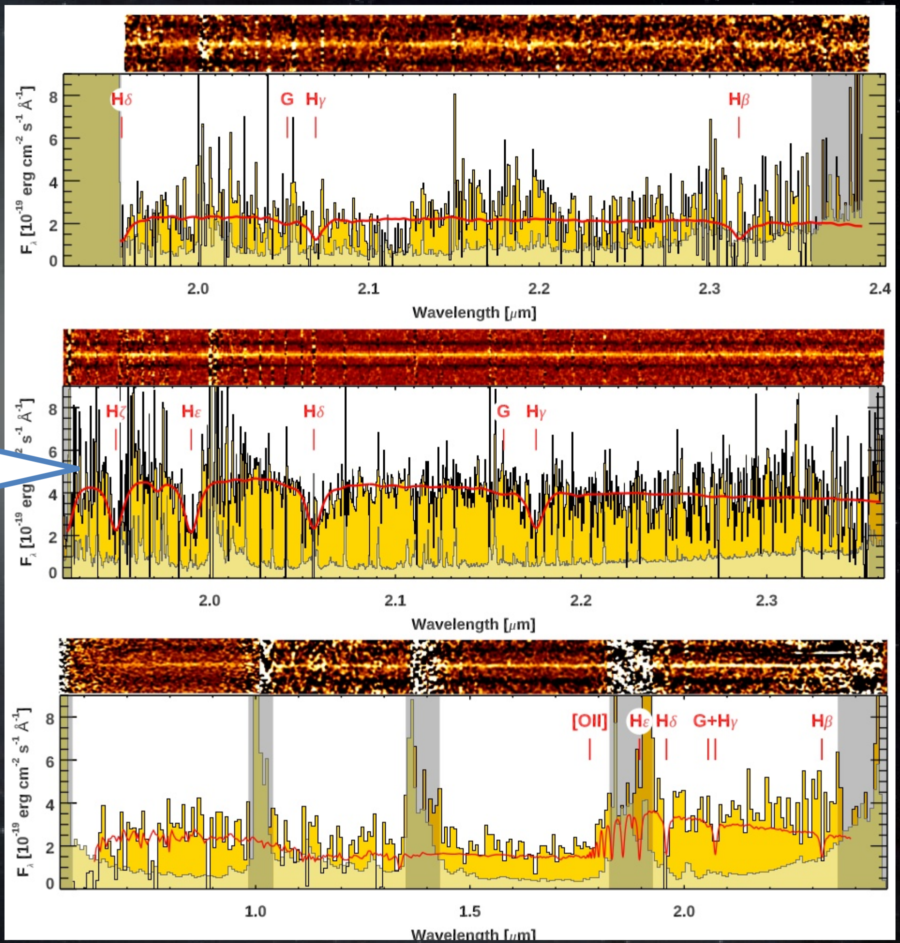


Kubo, MT, et al. 2018

Massive quiescent galaxies at z∼4



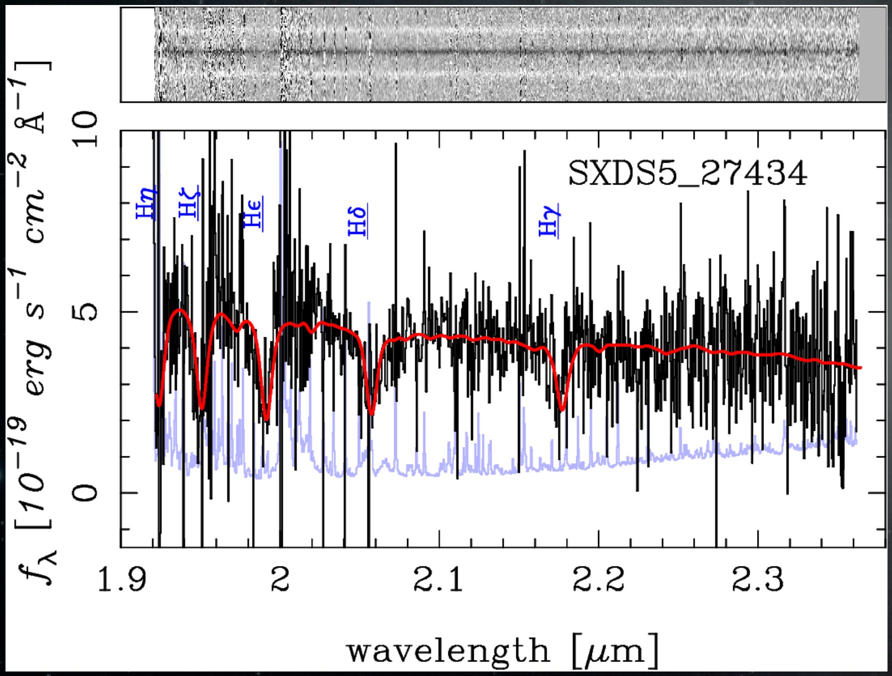
Quiescent: sSFR<10^-9.5 yr^-1



Valentino, MT, et al. 2020 ApJ

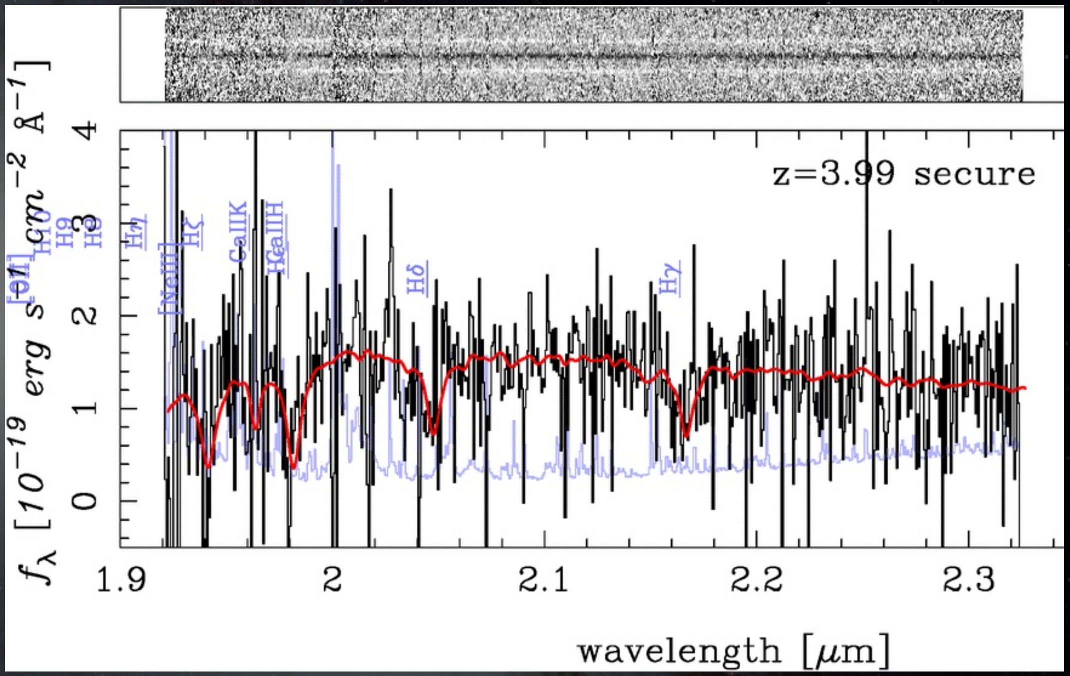
MOSFIRE spectra

z=4.01



~7 hours integration with MOSFIRE
(Tanaka+ 2019, ApJ,885, L34)

z=3.99

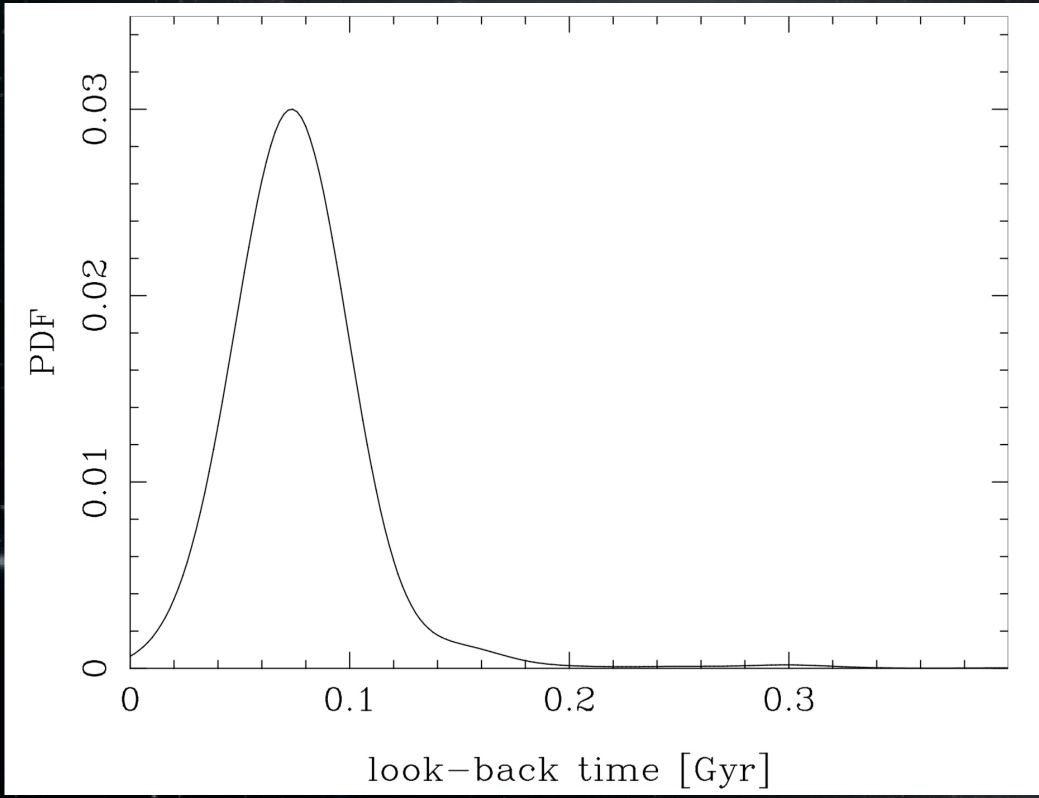


~15 hours integration with MOSFIRE
(Tanaka+ in prep)

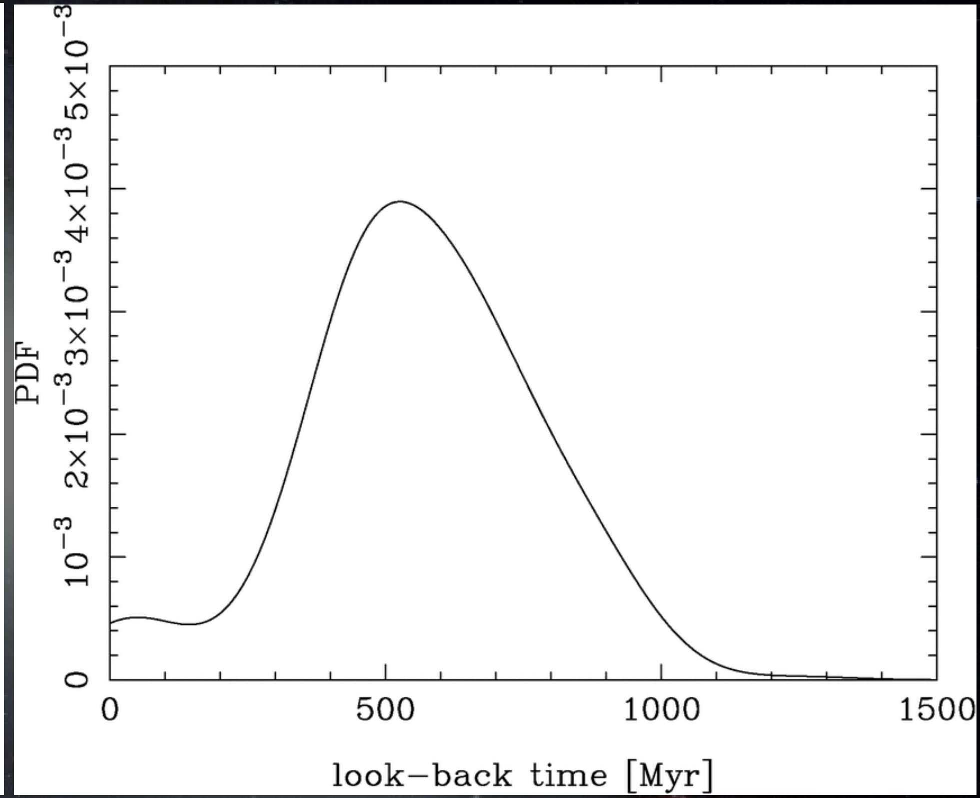
Highest redshift quiescent galaxies known to date!

Star formation histories

z=4.01

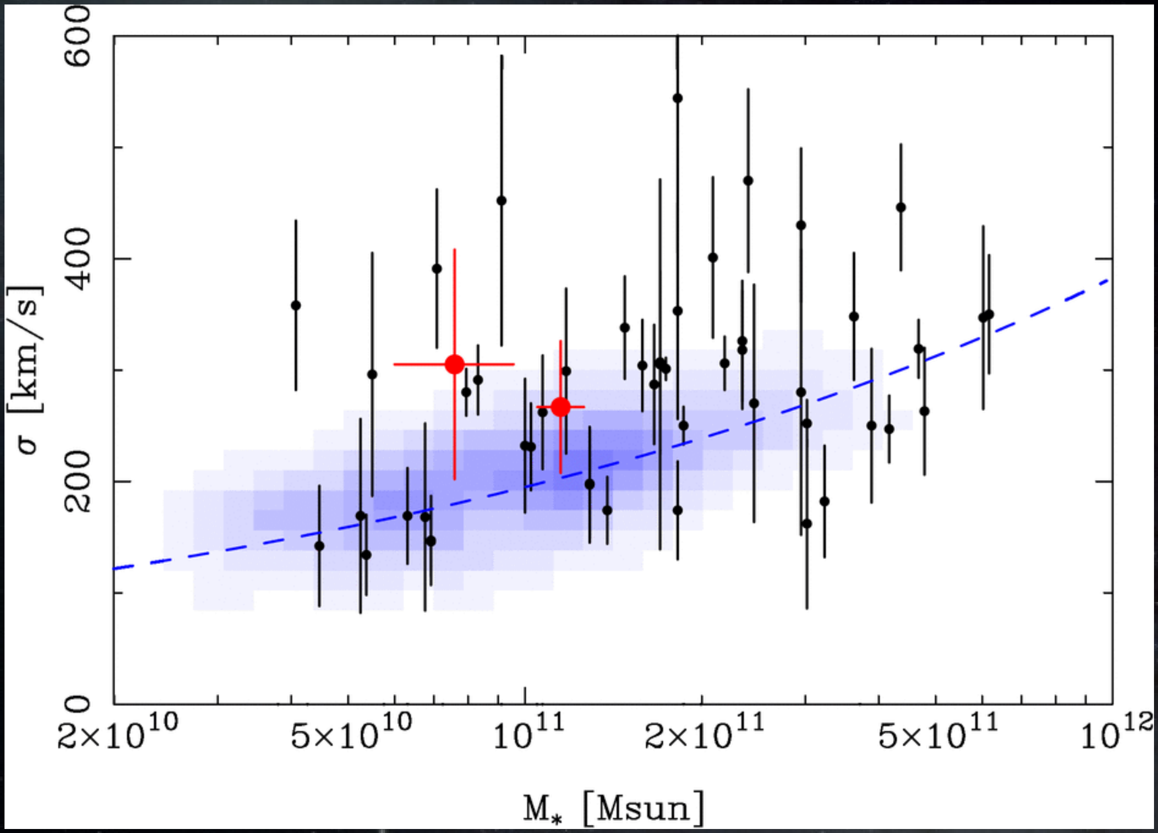


z=3.99



SFH from pPXF (age distribution of the SSP templates contributed to the best-fit spectrum). The z=4.01 is a young poststarburst, while the z=3.99 is a more typical poststarburst. The latter object has z_form~6.

Massive quiescent galaxies at z=4



z=4

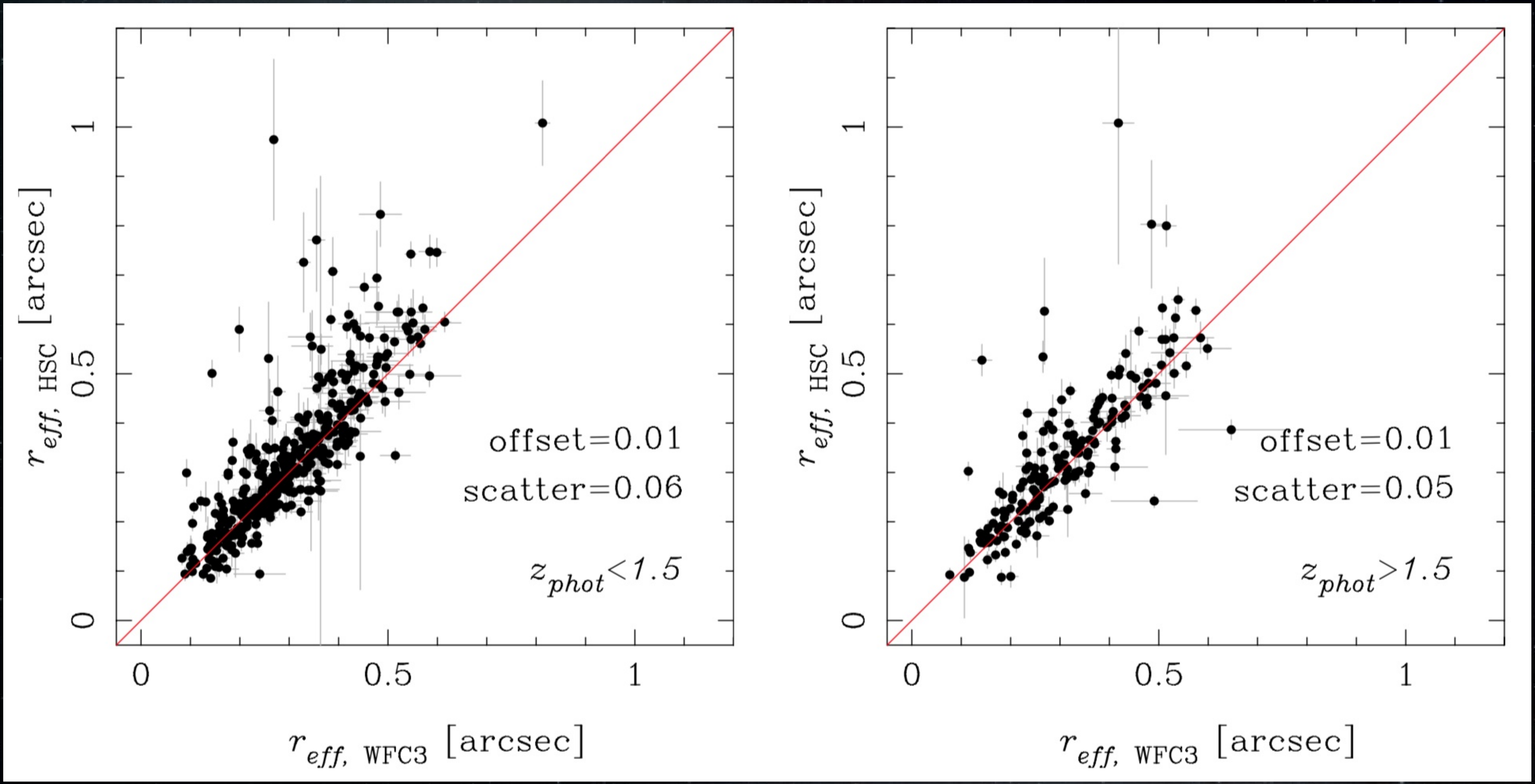
z~2

z~0.7 (LEGA-C)

z=0

Stellar velocity dispersion does not significantly evolve over the last 12 Gyr

Rest-frame UV sizes from HSC-SSP

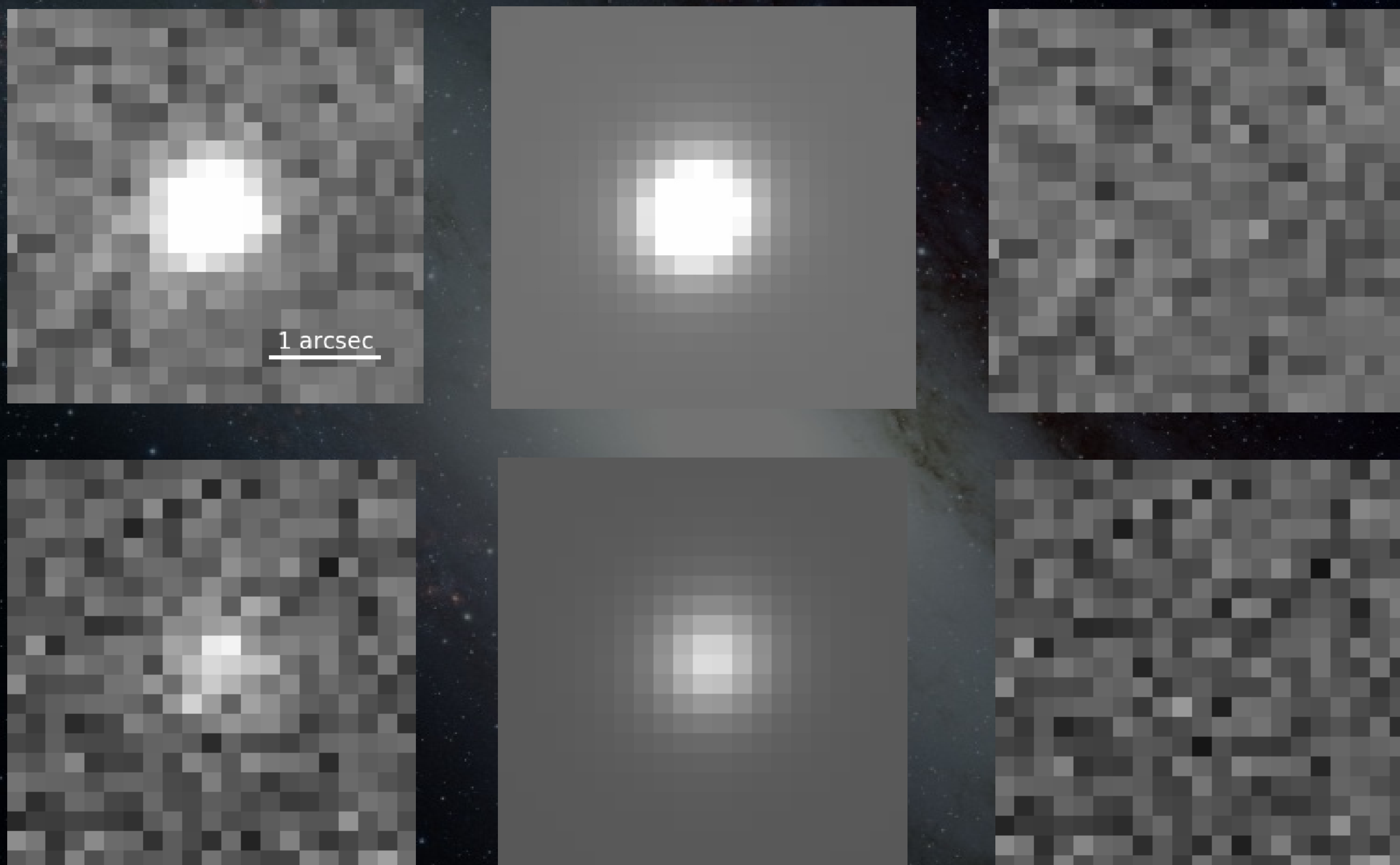


HSC-SSP is pretty good for constraining sizes.

Rest-frame UV sizes from HSC-SSP

z=4.01

z=3.99

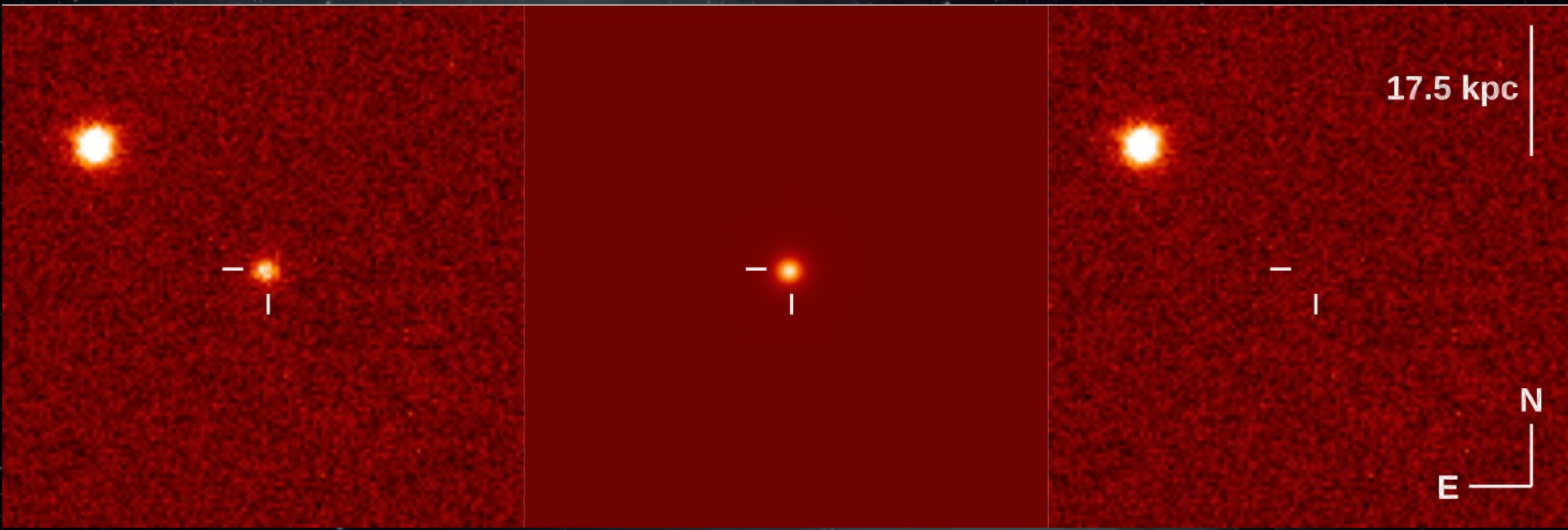


Original image   Best-fit model   Residual

z=4.01: r_{eff} = 0.76 +/- 0.20 kpc

z=3.99: r_{eff} = 1.0 +/- 0.50 kpc

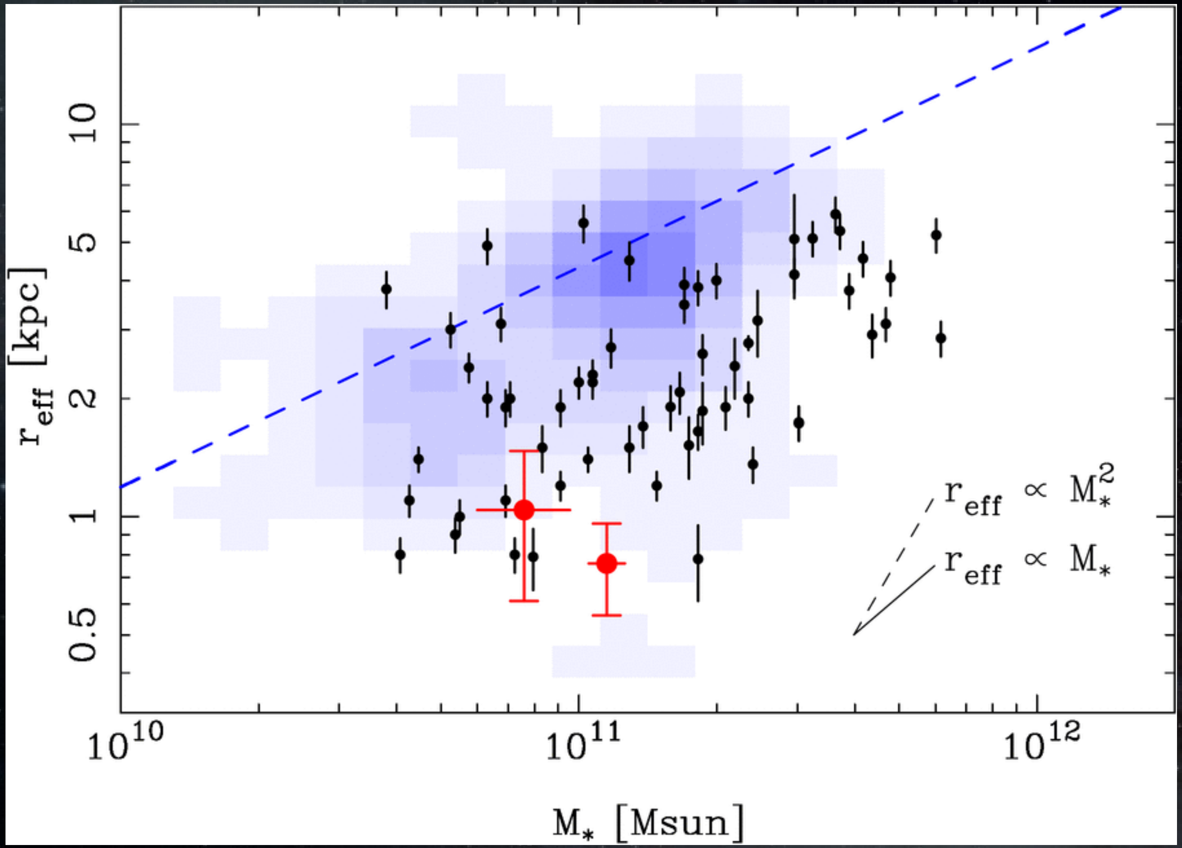
Rest-frame optical sizes from HAWK-I + GLAAL

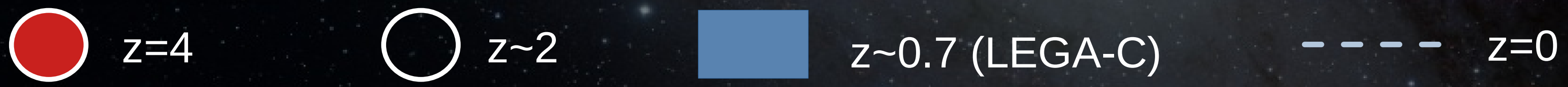


Original image | Best-fit model | Residual

The z=4.01 galaxy has $r_{eff} = 0.74 + 0.17\ /\ \text{-}0.08$ kpc

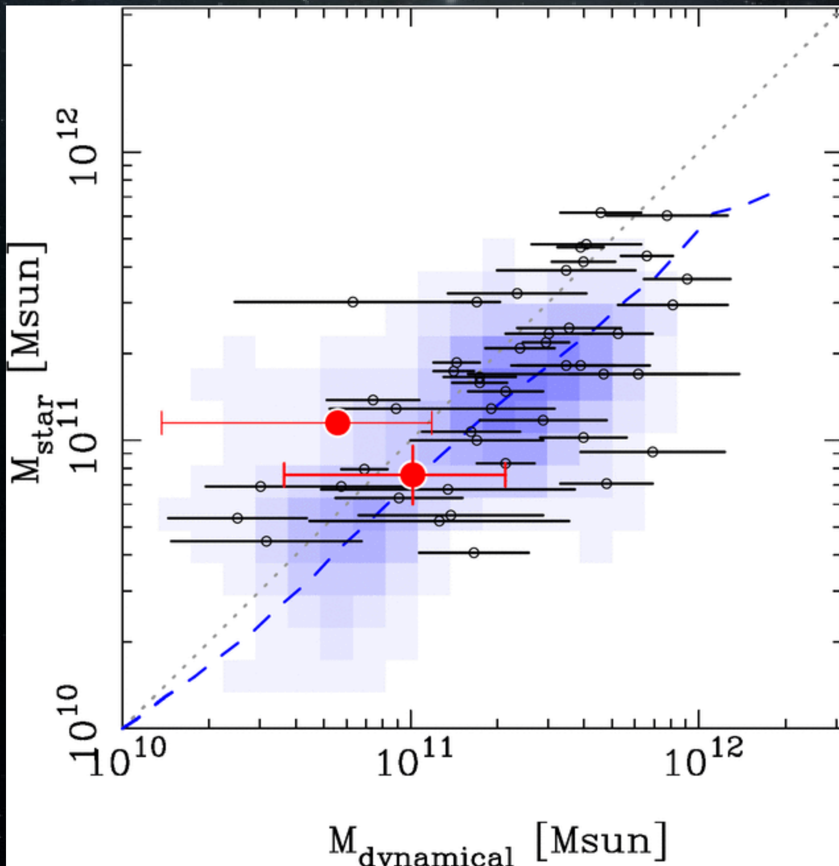
Size-Stellar Mass relation

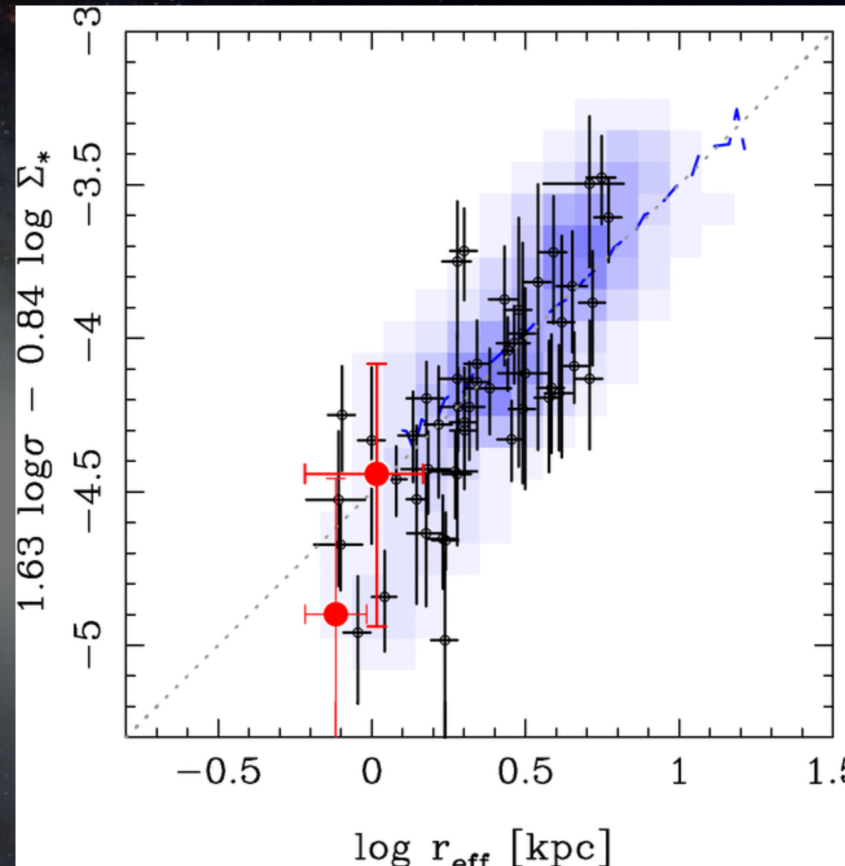




The z=4 objects are very compact for their mass. Their sizes are Consistent with the typical size of z~4 galaxies from Kubo+ 2018.

First Dynamical Analysis at z=4





z=4 z~2 z~0.7 (LEGA-C) z=0

- The dynamical mass is consistent with the stellar mass from photometry.
- The z=4 object is on the mass fundamental plane.

Discussion and Summary

- We have confirmed the highest redshift quiescent galaxies at z=4.
- We made the first measurement of stellar velocity dispersion at such a high redshift.

- Stellar velocity dispersion does not significantly evolve over the last 12 Gyr.
- But, we know that sizes and masses increase with time.
- This suggests that the mass growth does not occur equally at all radii; mass growth mostly occurs in the outer parts. That also drives the size evolution.
- This is consistent with the 2-phase formation scenario.
- But, this galaxy may be rotating!
- Step forward to a larger sample and also to JWST.