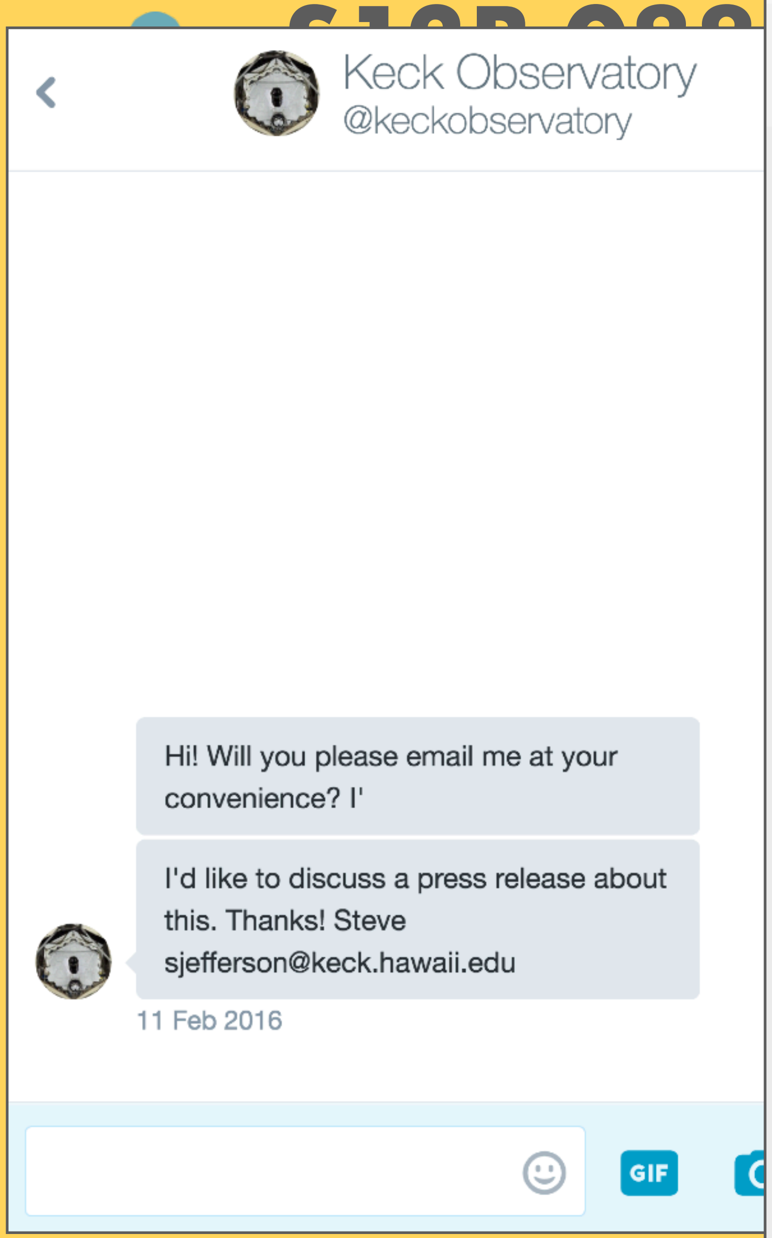
すばる-Keck連携で探る遠方楕円銀河

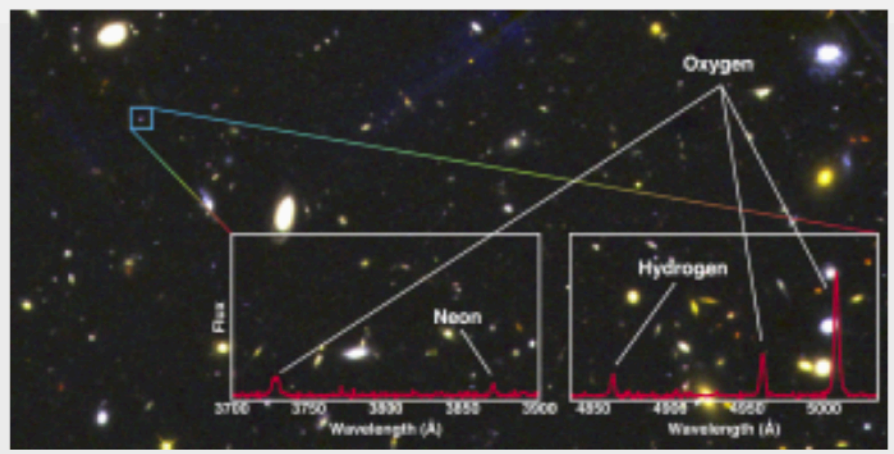
小野寺仁人
(国立天文台ハワイ観測所)

My recent use of Keck



Metal Content in Early Galaxies Challenges Star Forming Theory

MAY 10, 2016



CREDIT: 3D-HST / NASA / ESA / STSCI

A galaxy observed in this study (surrounded by a blue rectangle). The light we received from the galaxy in the distant Universe tells us - from hydrogen, oxygen, and neon emission lines - that they followed a different rule to produce the heavy elements.

MEDIA CONTACT

Steve Jefferson
W. M. Keck Observatory
sjefferson@keck.hawaii.edu

By Steve Jefferson

MAUNAKEA, Hawaii – An International team led by scientists at ETH Zurich in Switzerland used the W. M. Keck Observatory to study the role of star formation rates in metal contents of distant galaxies. What they discovered is the amount of metals are very similar, irrespective of galaxies' star formation activity, raising new questions about star-forming theory. Their findings were recently published in the Astrophysical Journal.

Using the MOSFIRE instrument installed on the Keck I telescope – one of the two world's largest optical telescopes at Keck Observatory – the scientists gathered data on 41 normal, star-forming galaxies that were 11 billion light years away.

Questions to be solved

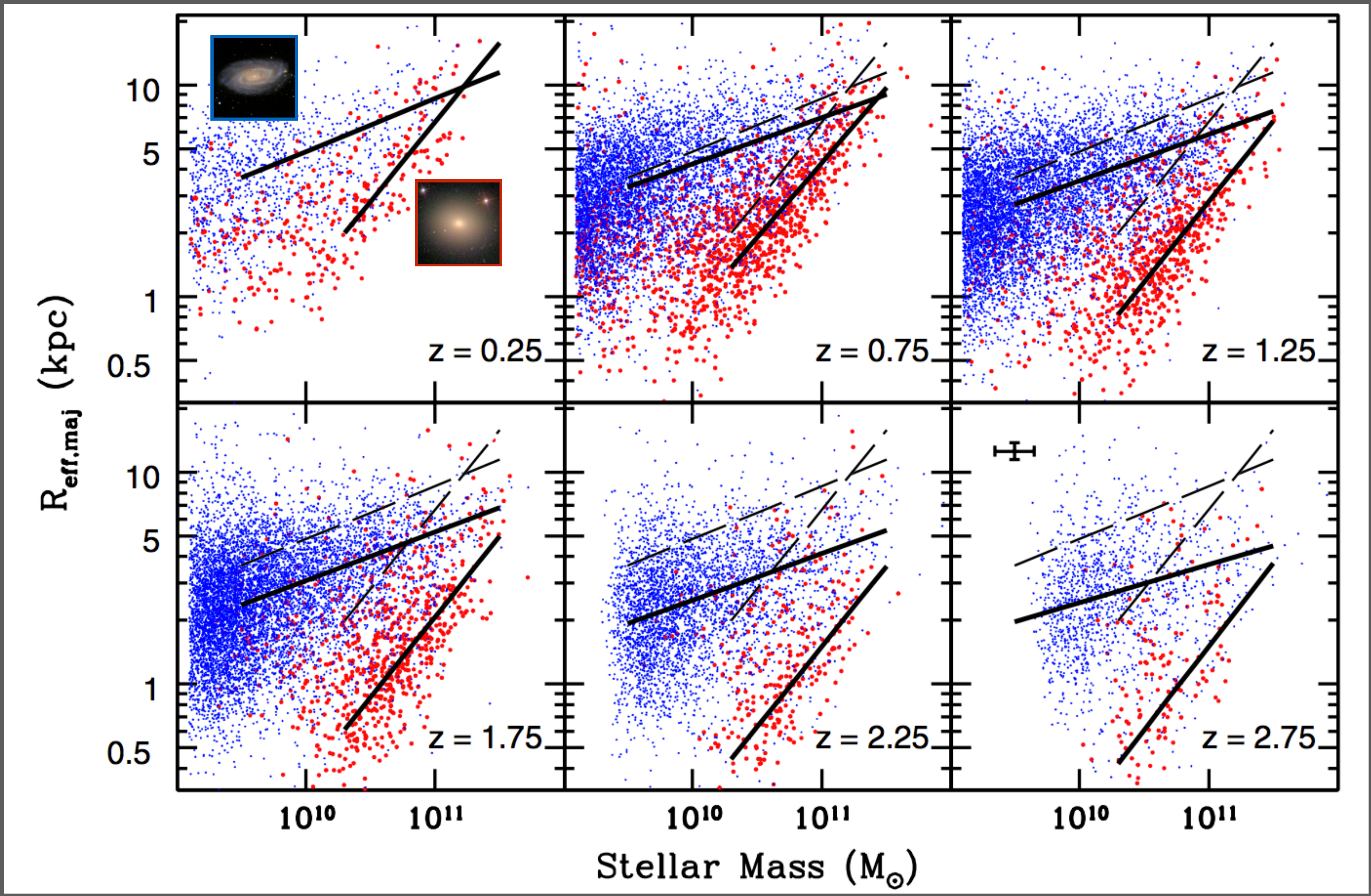
- How high-z passive galaxies evolved into local elliptical galaxies?
- What is the star formation history of passive galaxy population?
- What mechanism(s) is(are) responsible for quenching?

Key physical parameters

- **Structure** : size, Sersic index, ellipticity
- **Kinematics** : rotation vs random motion
- **Stellar population** : age, metallicity, element abundance

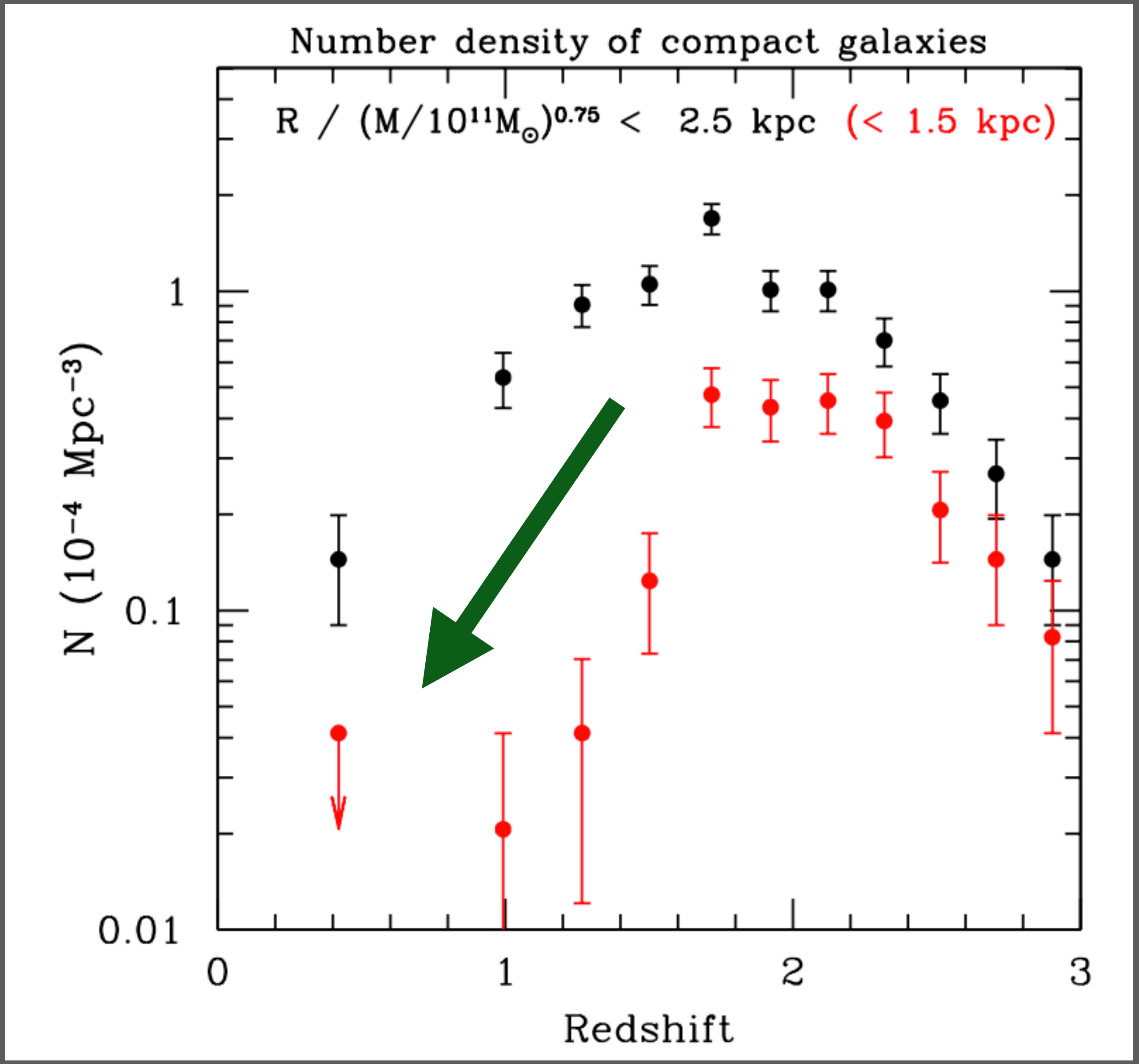
Structure

Strong evolution in mass-size relation

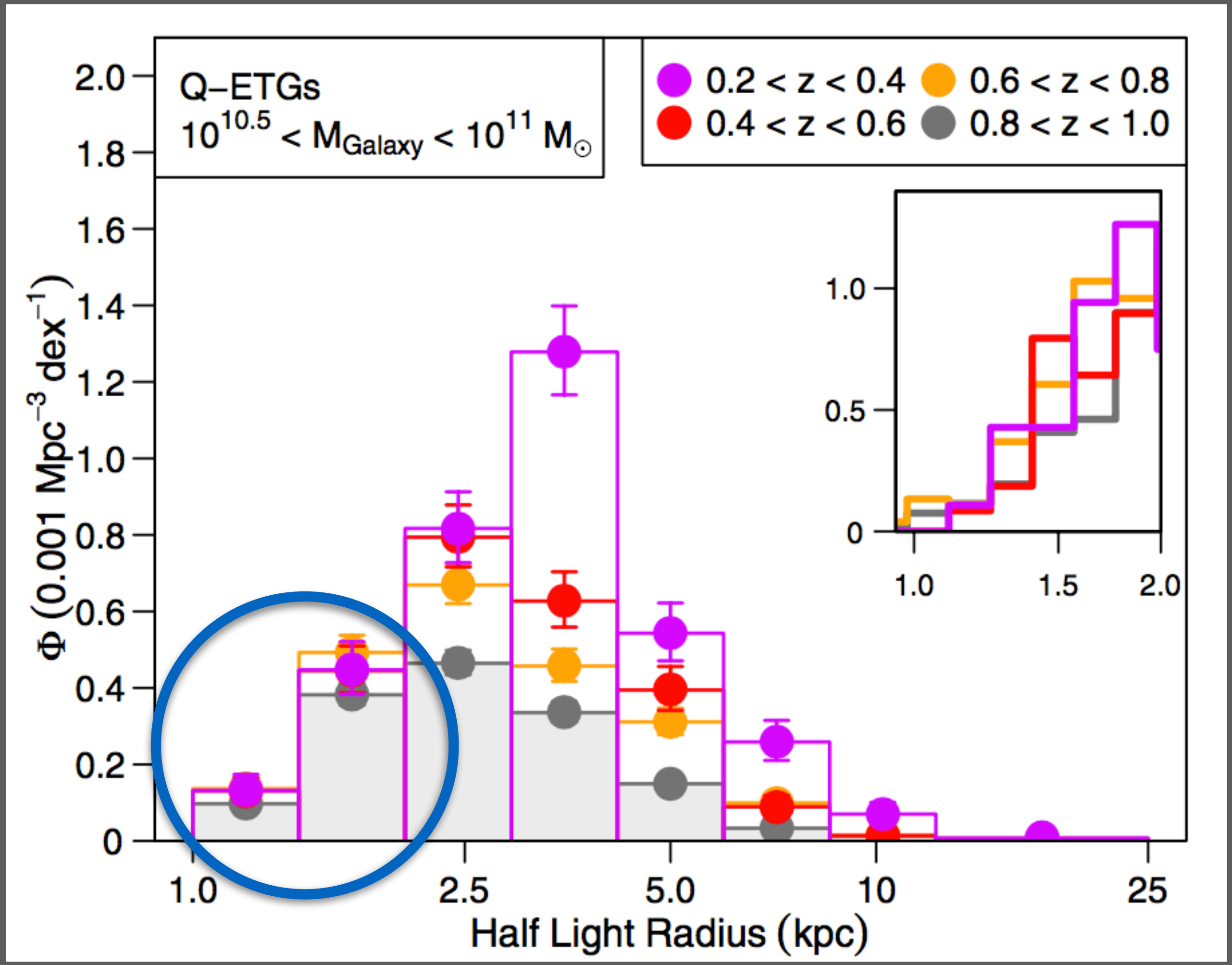


van der Wel+2014

Individual growth vs progenitor bias

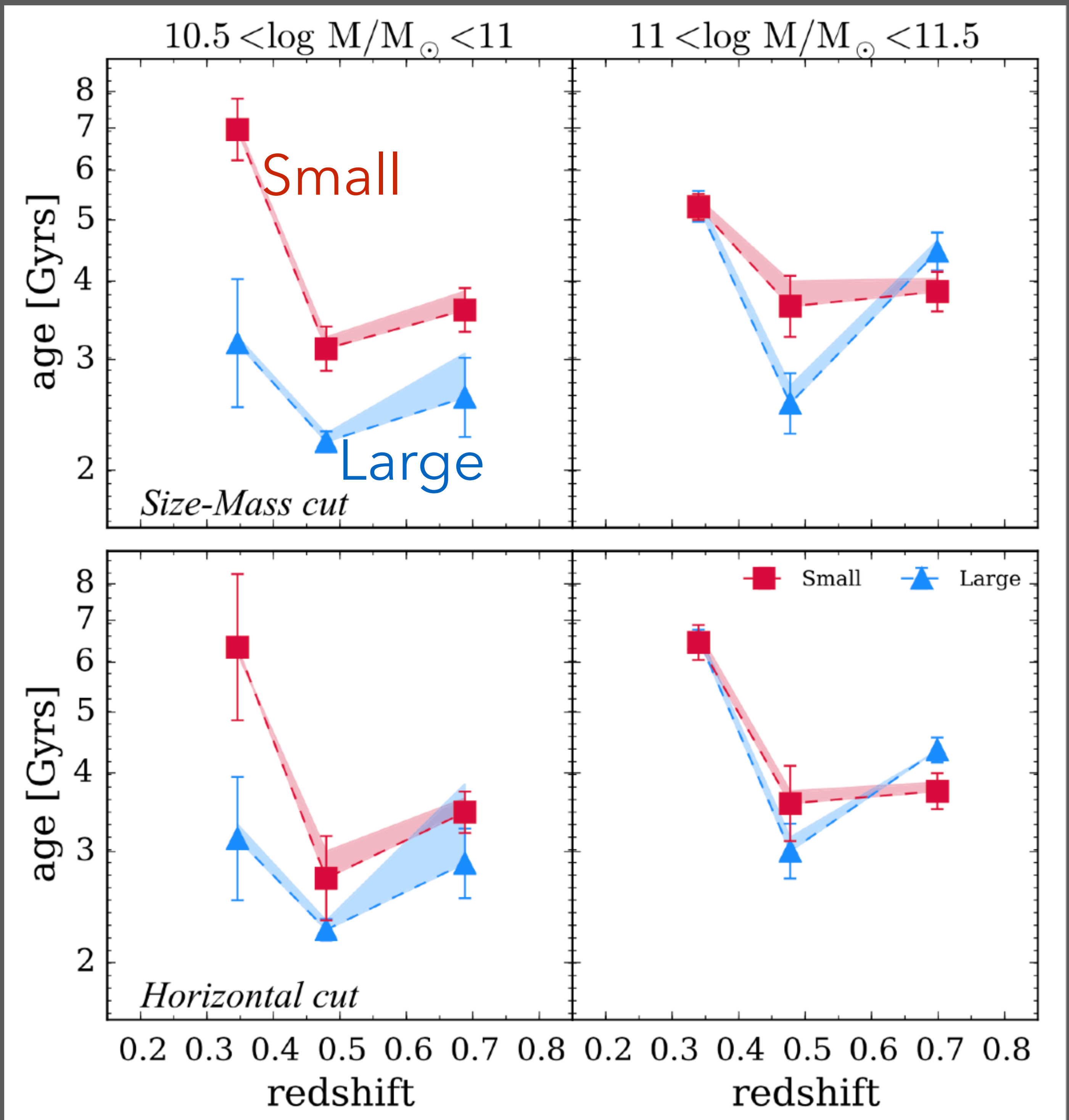


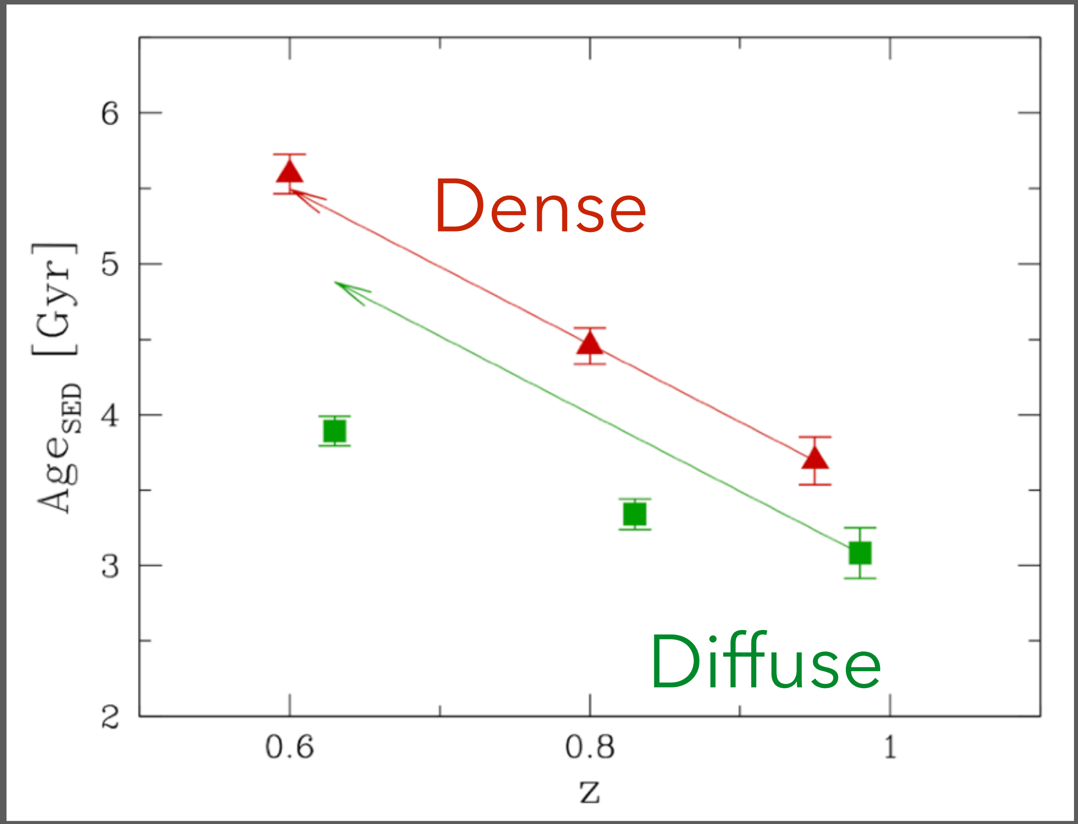
van der Wel+2014



Carollo+2013

Importance of progenitor bias at z<1

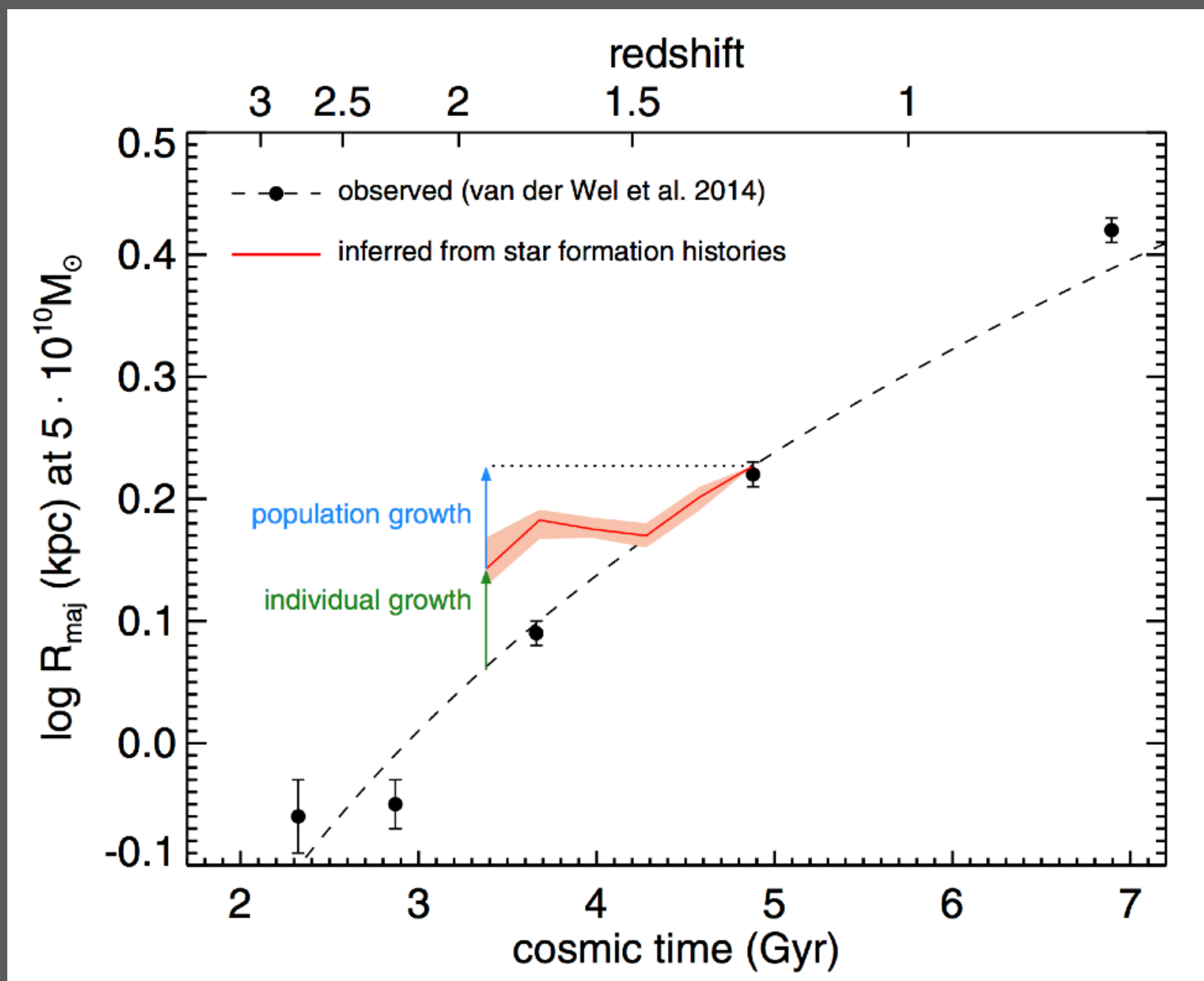


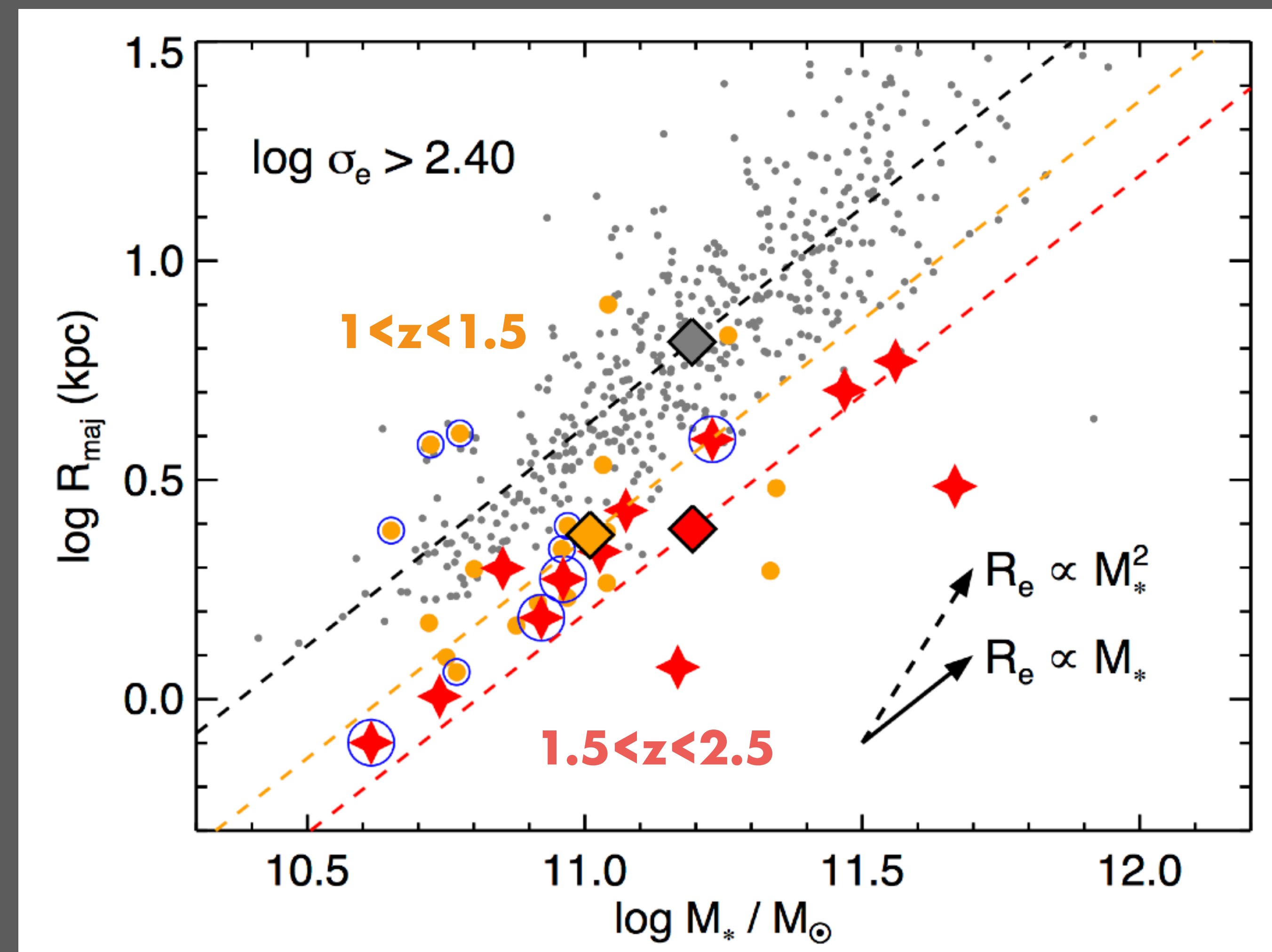


Compact passives are consistent with pure passive evolution, while large ones remain younger

Fagioli, MO+2016; Gargiulo+2016; VLT/VIMOS

Importance of (minor) mergers at z>1



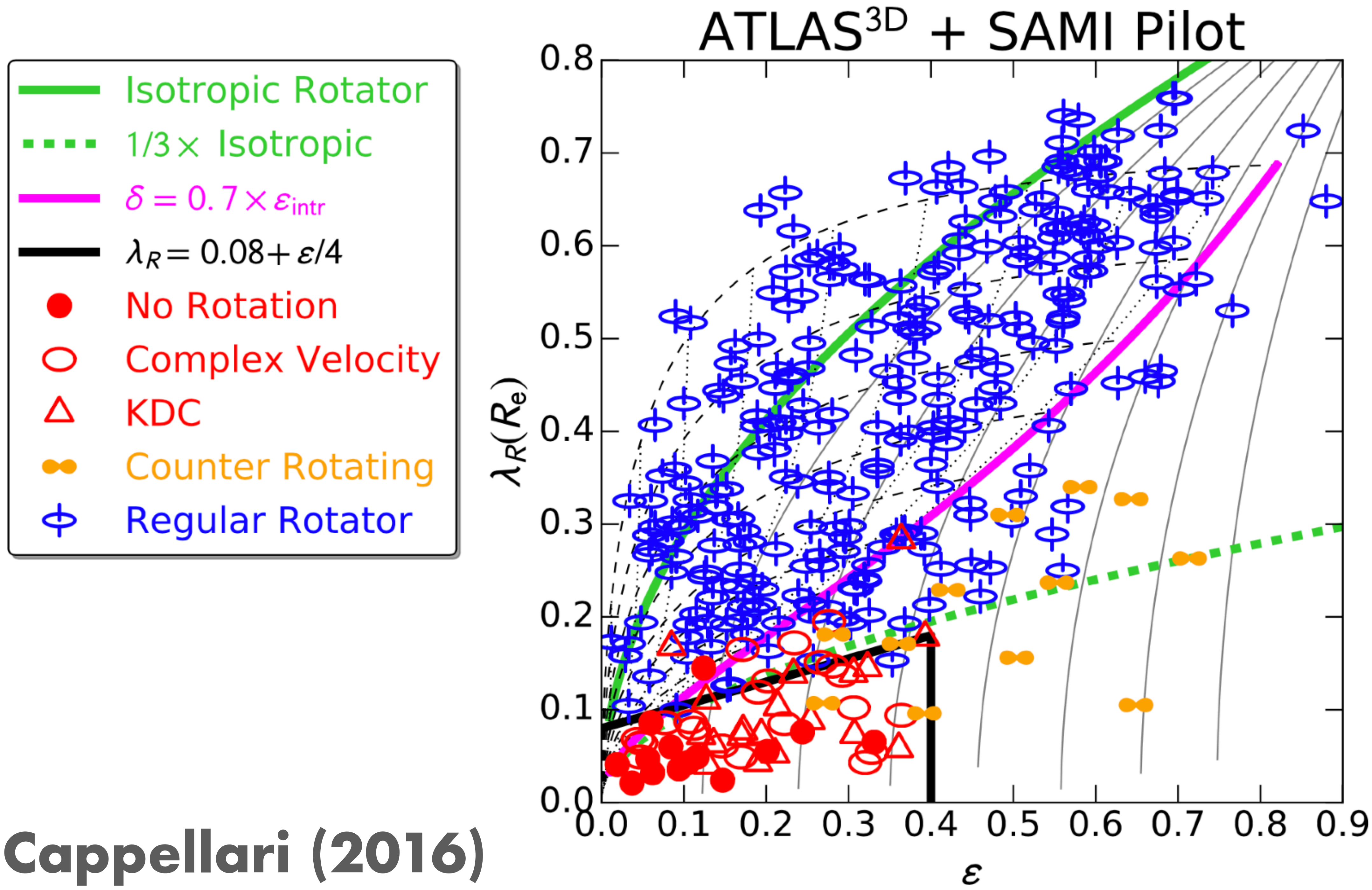


- **At higher redshift, (minor, dry) mergers appear to play an important role in increasing the size**

Belli+2015, 2017; Keck/LRIS,MOSFIRE

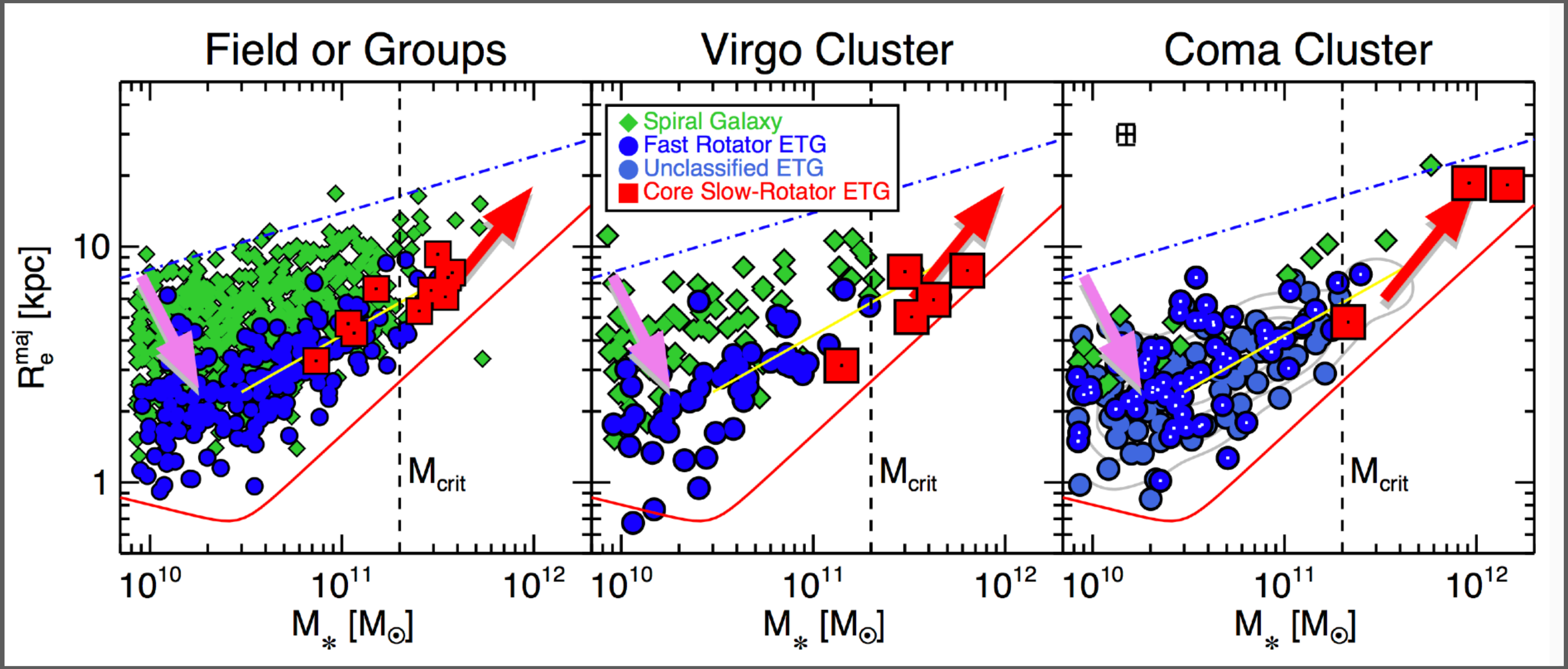
Kinematics

Kinematics of local early-types



Cappellari (2016)

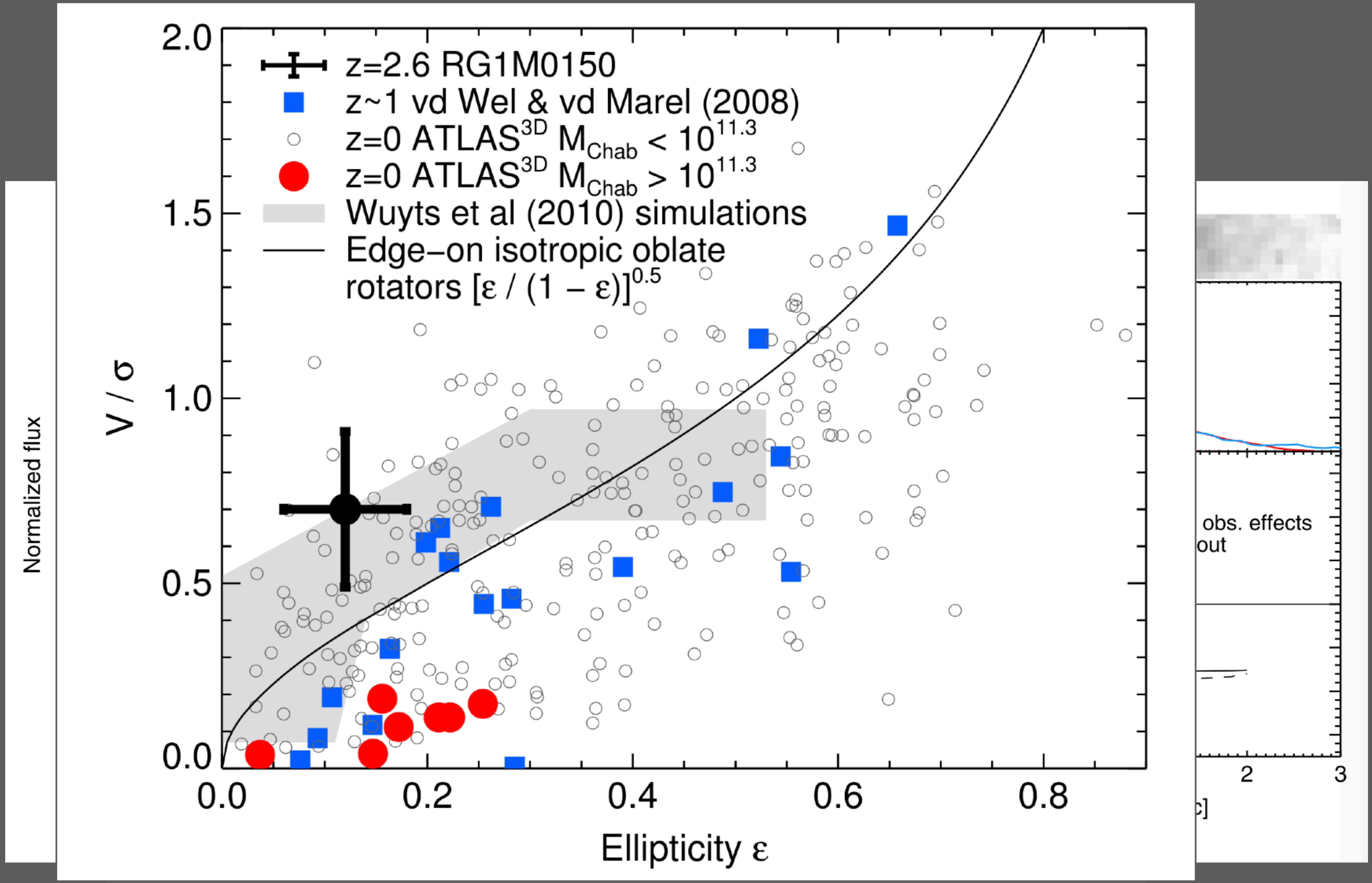
Fast/slow rotators in the mass-size plane



- Local massive (>2x10^{11}Ms) galaxies are essentially slow rotators

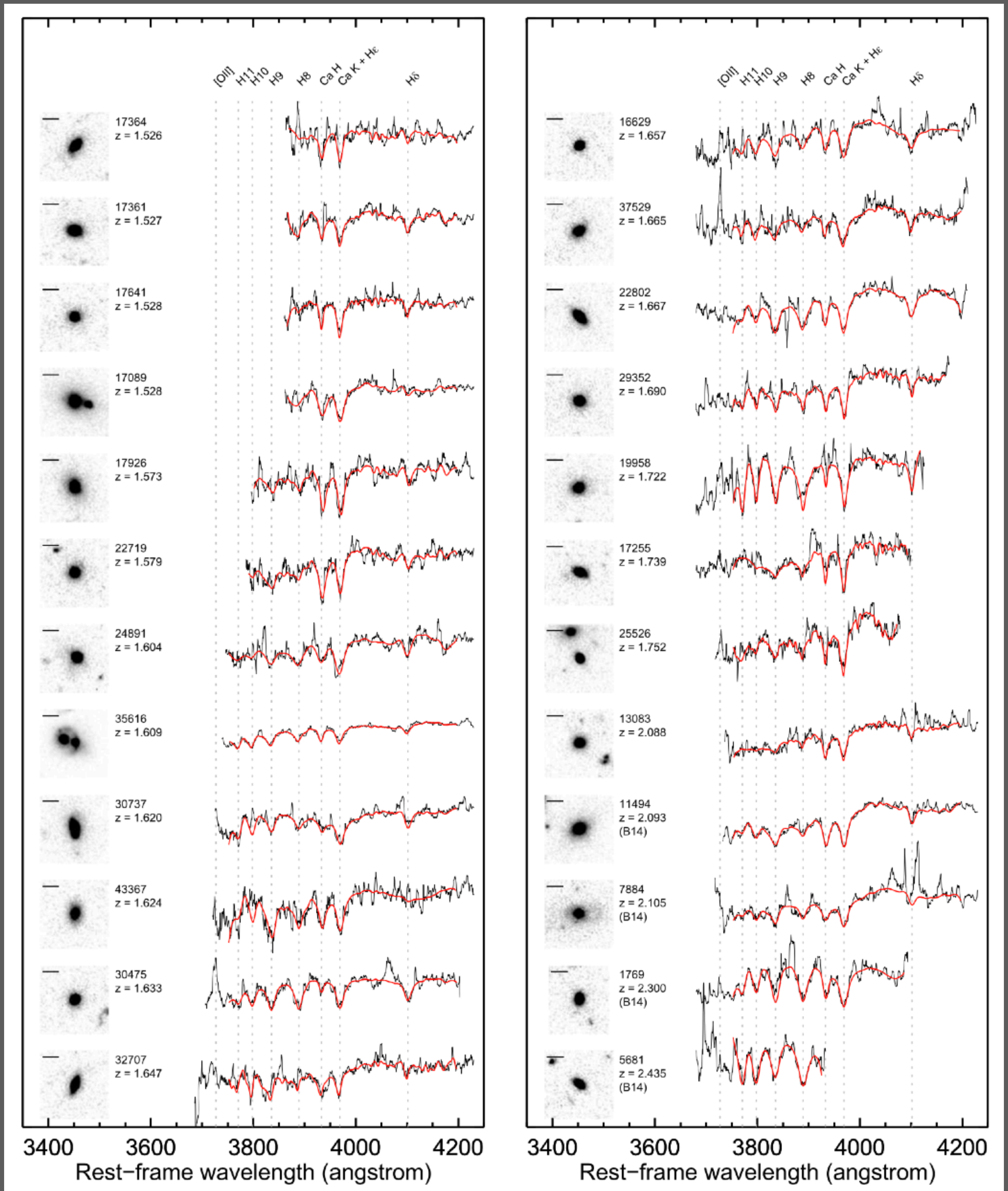
Cappellari (2016)

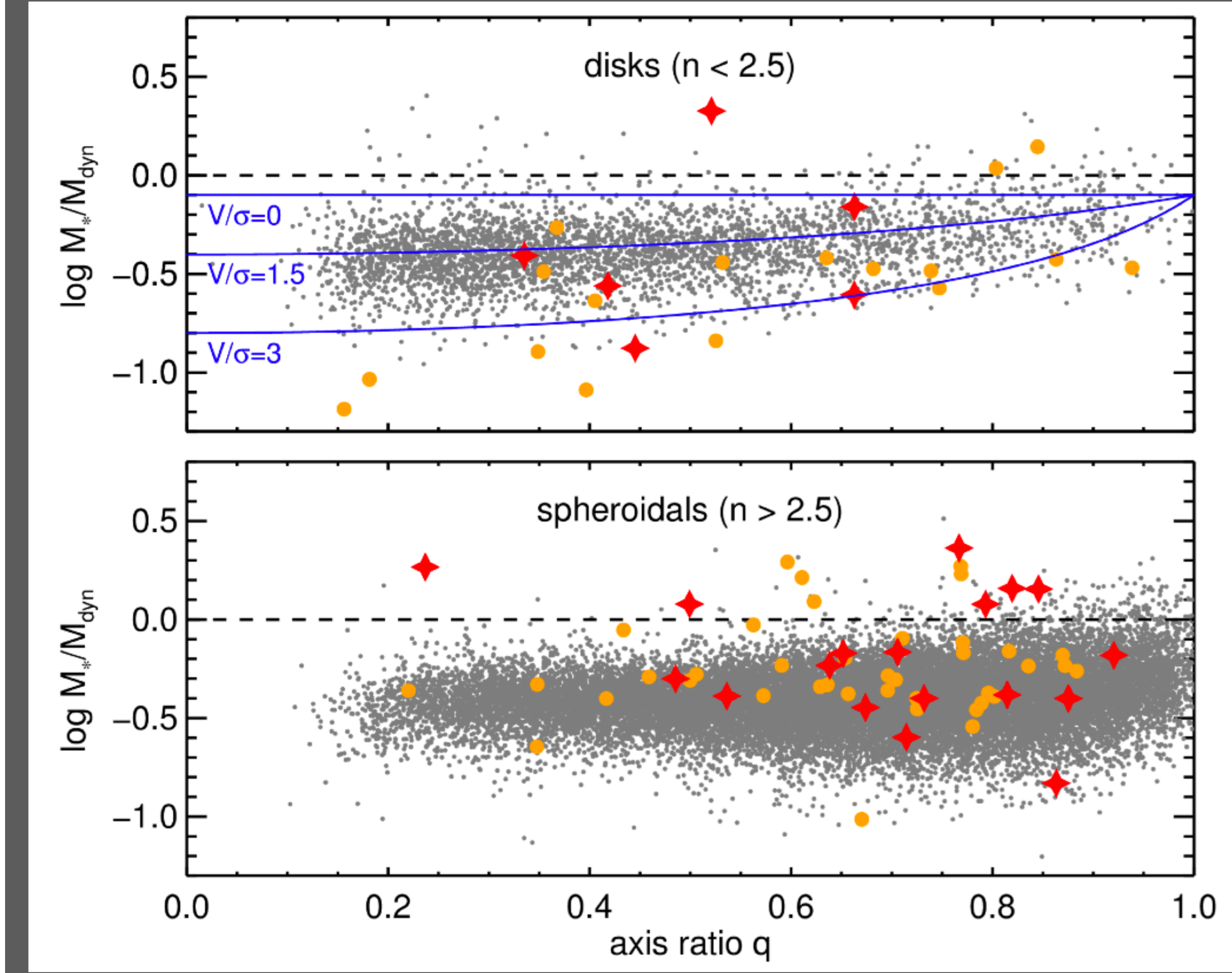
Rotating massive passive galaxies at high-z



Newman+2015; Keck/MOSFIRE, Magellan/FIRE

Indirect measurement of rotation at z~2



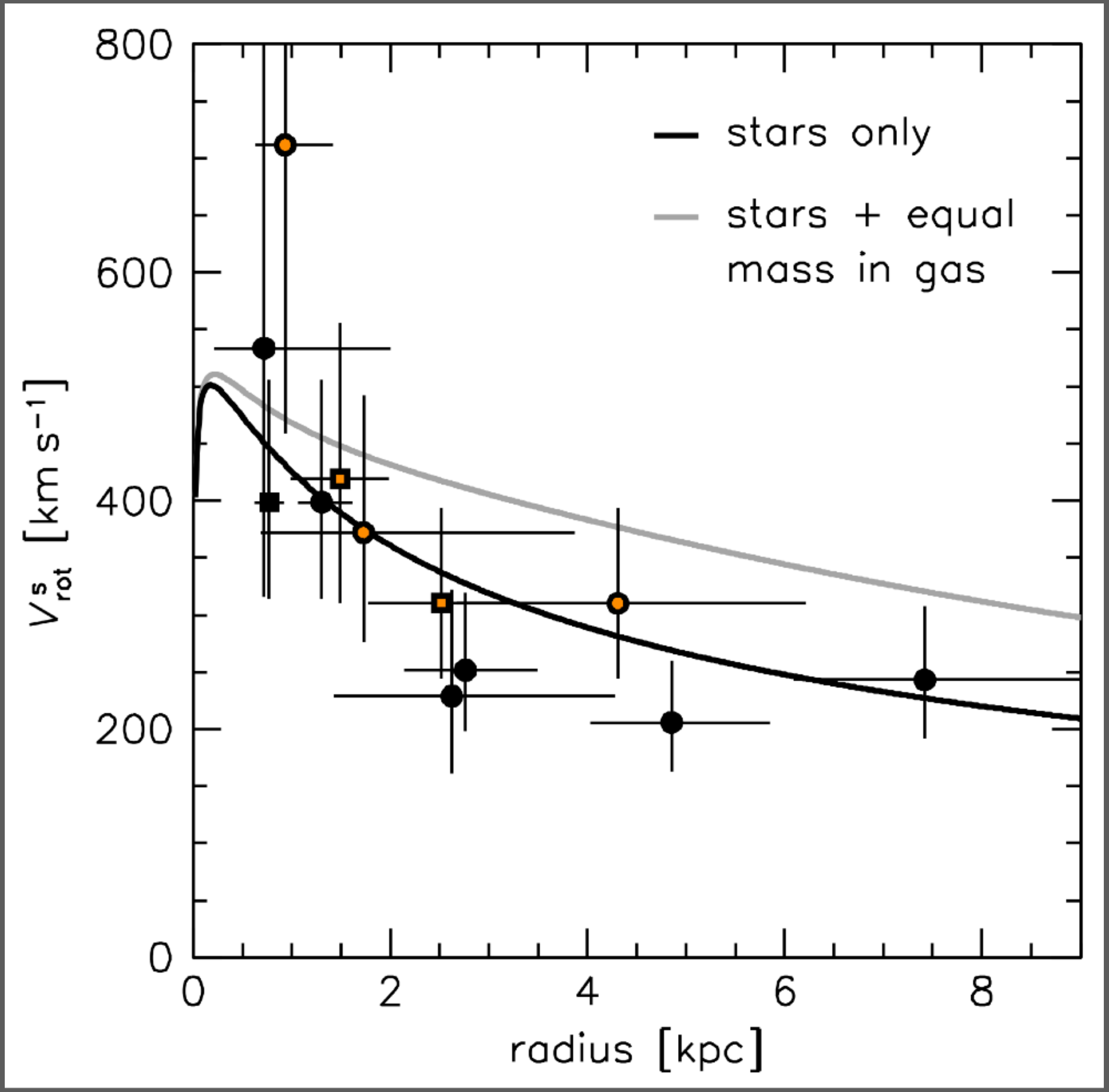


Larger V/σ is indicated for low-n passive galaxies at z~2 than at z=0

Belli+2017; Keck/MOSFIRE

Rotating compact SFGs at 2<z<2.5

Compact "star-forming" galaxies at 2<z<2.5 are found to be rotating gas component with Vrot up to 500km/s at the center

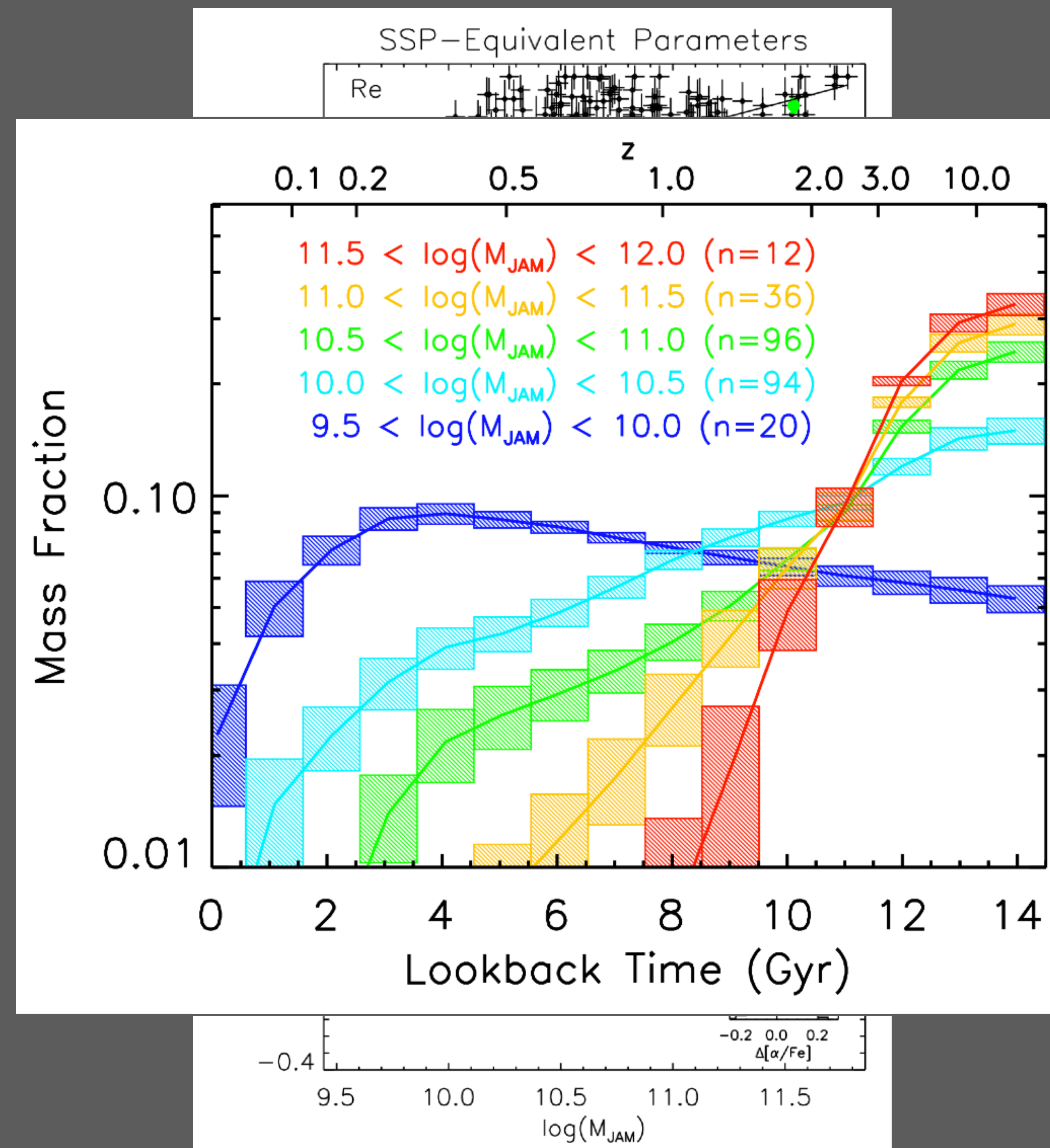


van Dokkum+2015; Keck/NIRSPEC, MOSFIRE

Stellar populations

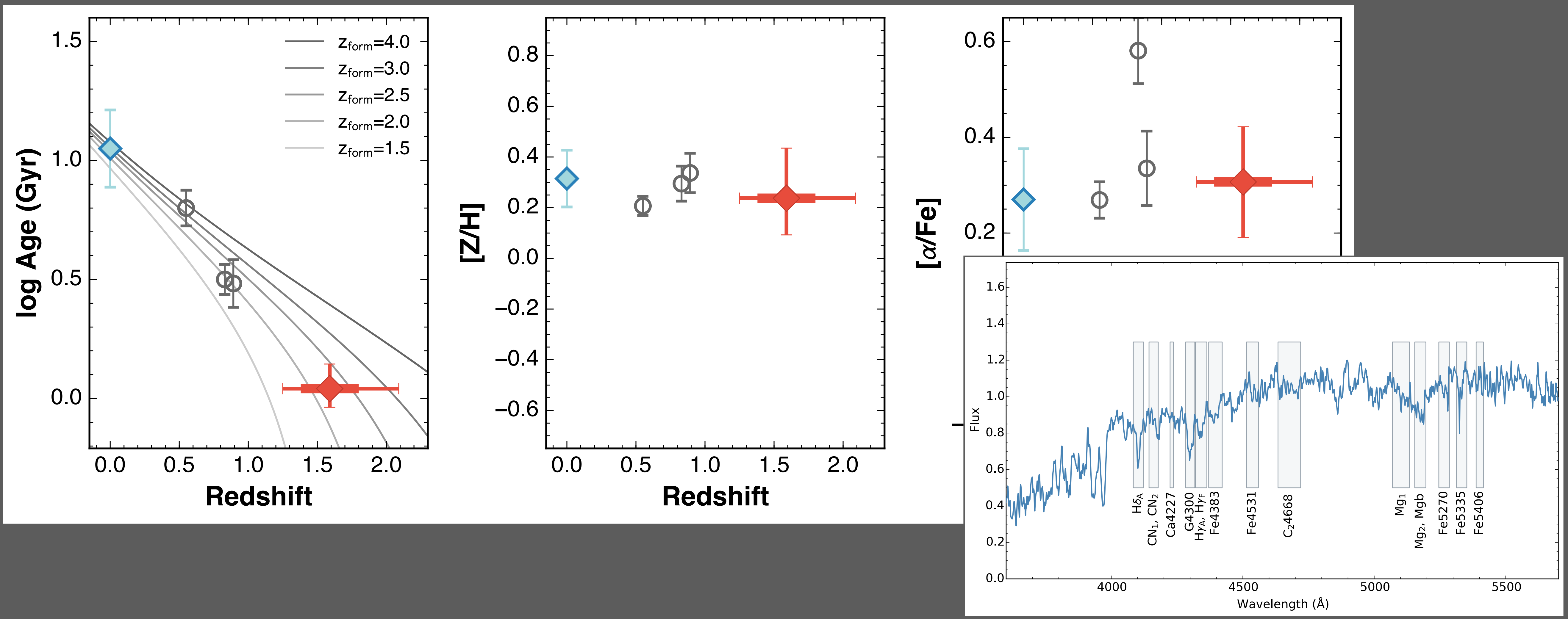
Stellar population of local early-types

- More massive early-types are older, more metal-rich, and more α-enhanced
- More massive galaxies are formed at higher redshift with more intense and shorter SF activity



McDermid+2015; ATLAS3D

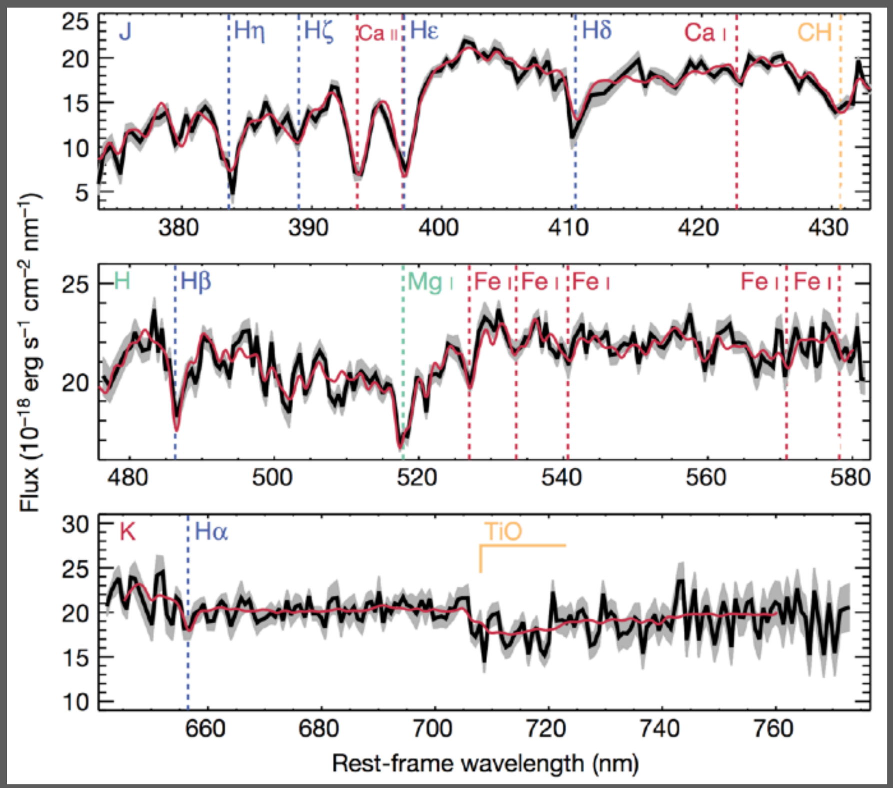
Passive evolution at z<1.6



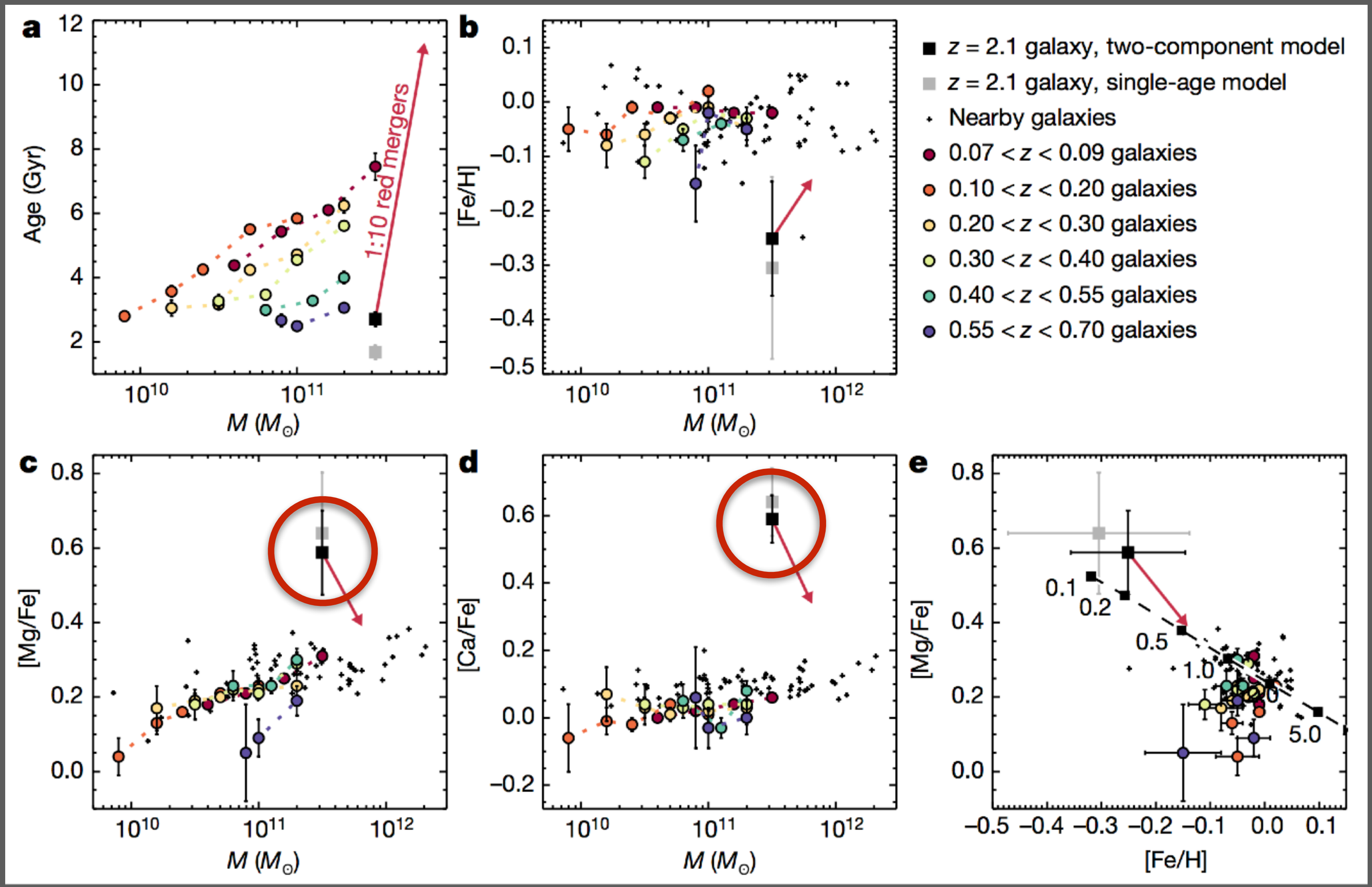
- **Average stellar population parameters are consistent with passive evolution with z_f~2.3**

Onodera+2015; Subaru/MOIRCS

Extreme α-abundance at z=2.1



Kriek+2016
Keck/MOSFIRE



- A z=2.1 showing highly enhanced α-abundance is discovered
- Prefer minor mergers to settle on the lower-z relations

Proposed observations

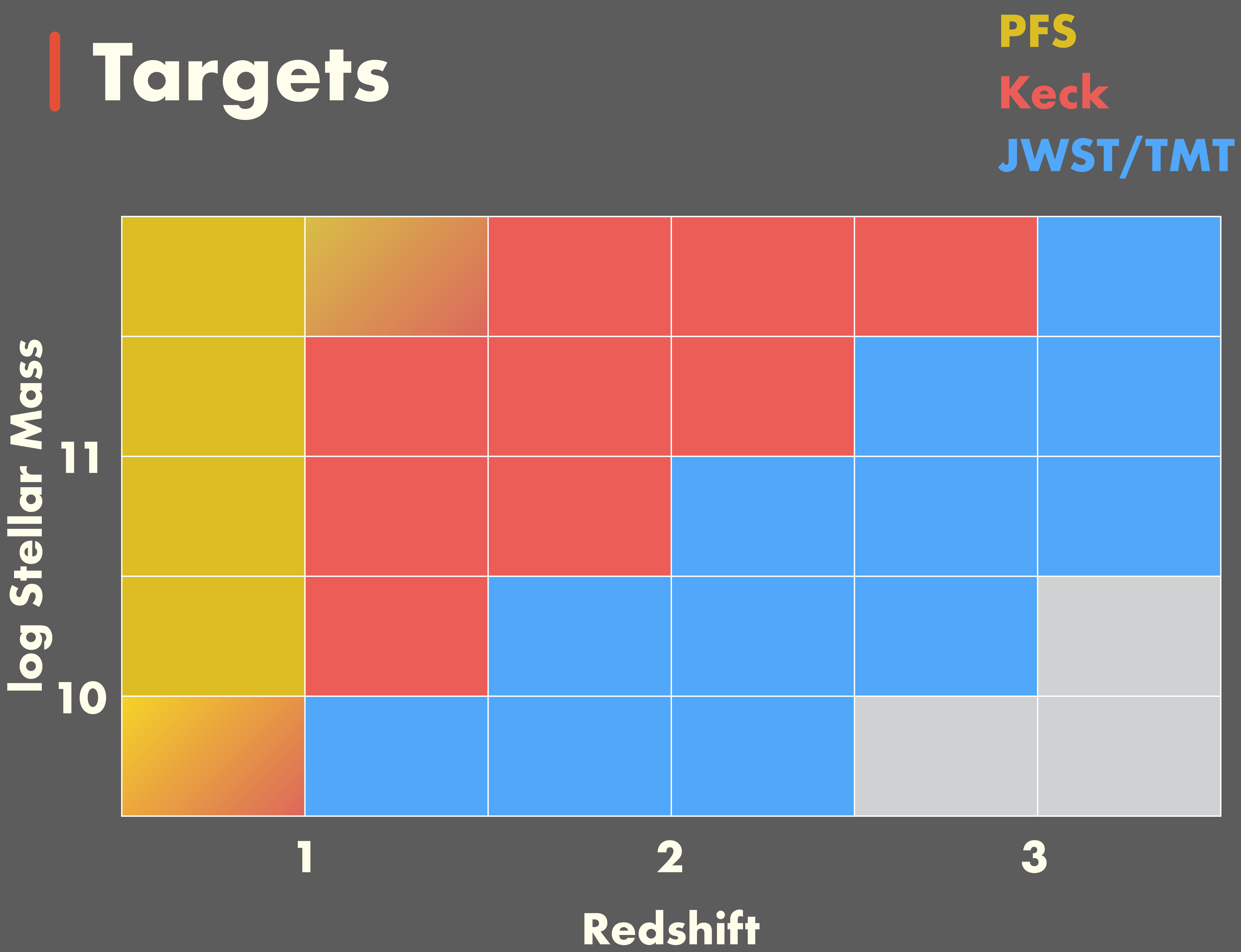
Issues in current studies

- Small number of objects
  - Average or outlier?
  - Scatter?
- Need to understand dispersions/diversity as well as the average behaviours

Subaru-Keck synergy

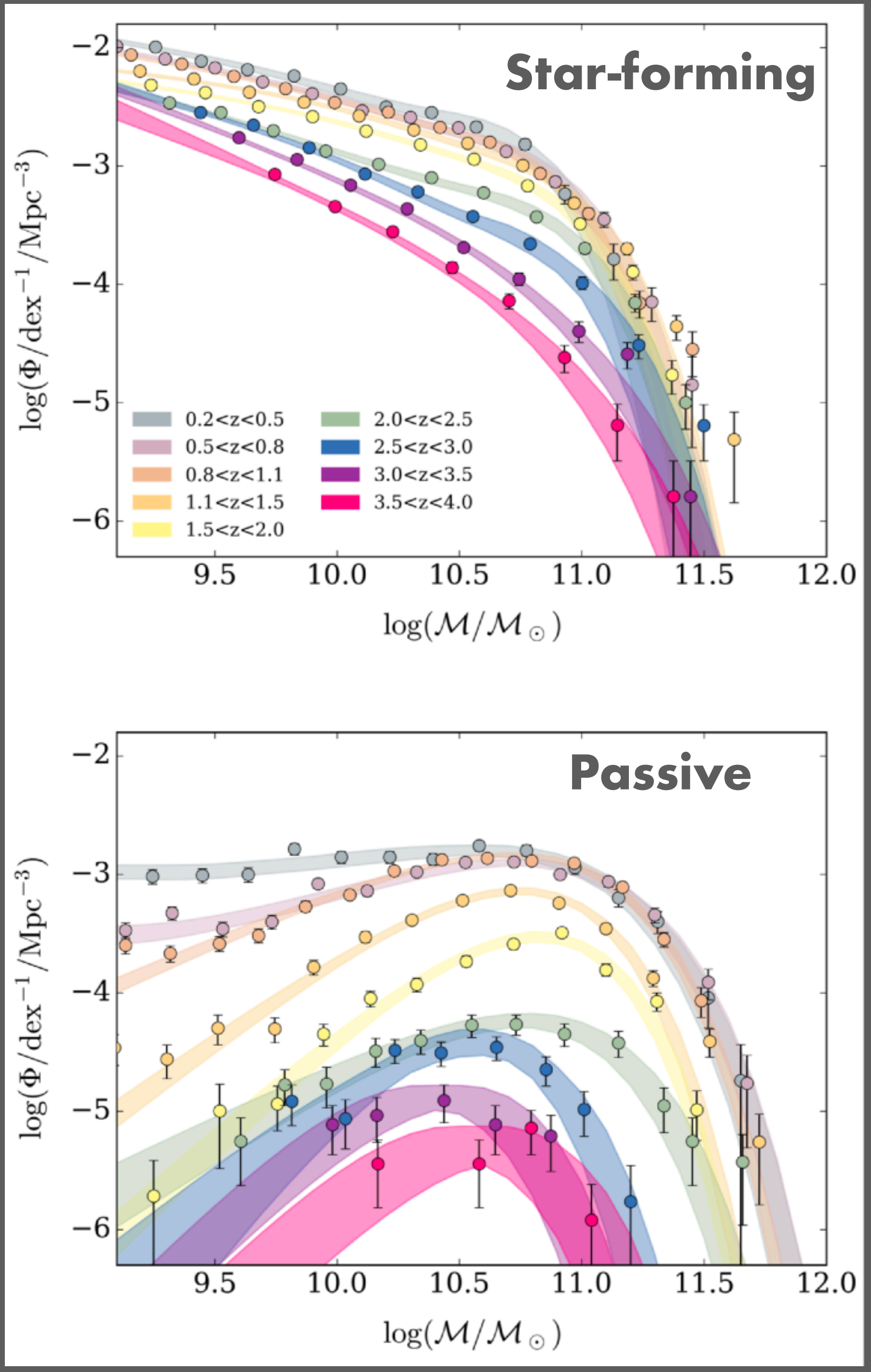
- Rare objects : HSC Deep/Ultra-deep (like) observations
  - Massive passive galaxies
  - Lensed passive galaxies
- Need to detect faint continuum with high S/N : Sensitive spectrograph on Keck (mostly MOSFIRE, LRIS/DEIMOS depending on the redshift of targets)
  - Typically 5-10 hours/object even with MOSFIRE (cf. 30 min to detect emission lines at z>3 in Onodera+2016)
  - Need more nights than typical allocation of the time exchange program to construct a (relatively) large sample

Targets



Sample size

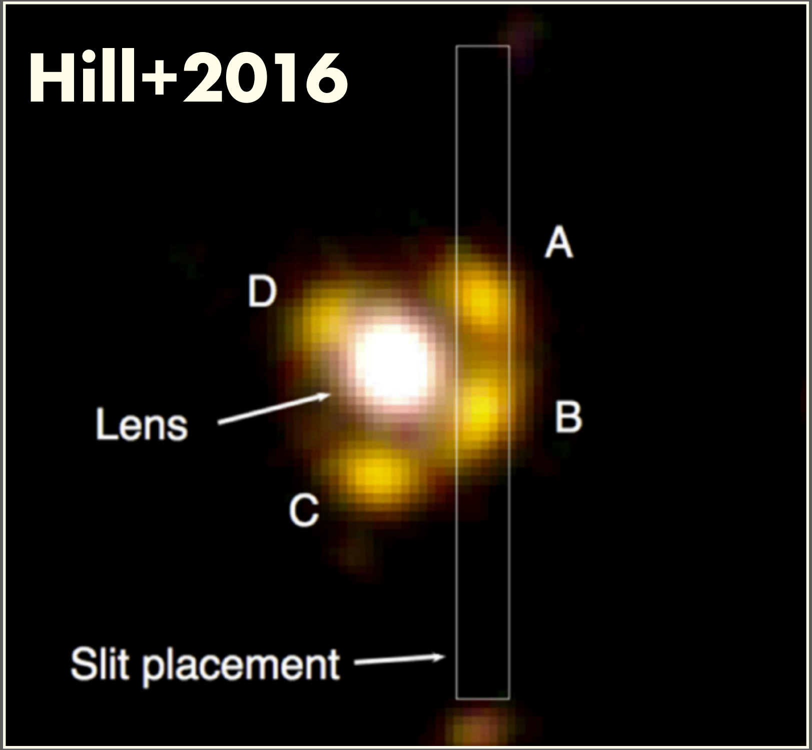
- Based on the mass function of passive galaxies at 1.5<z<2.5, ~50 objects/sq.deg with logM>11 are expected; ~5 objects/sq.deg with logM>11.5
- Overdensity is expected (e.g., Onodera+2012)
- Use, e.g., HSC-Deep/Ultra-Deep data for the best target selection

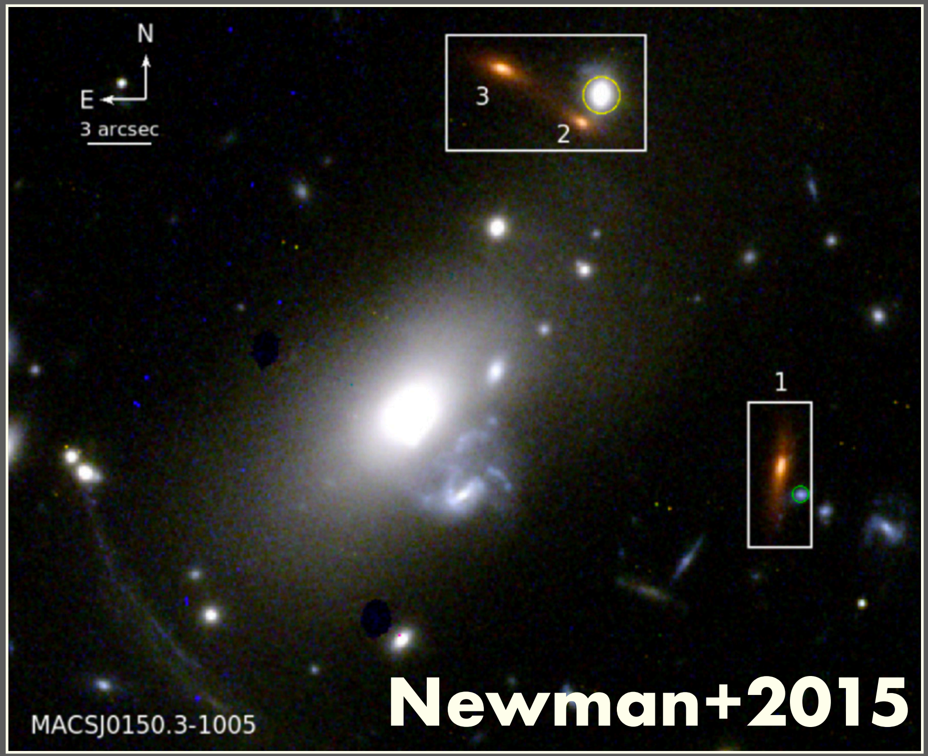


Davidzon+2017

Potential serendipity

- Lensed high-z passive galaxies
  - Spatially resolved kinematics/stellar populations by (AO-assisted) IFU data (e.g., OSIRIS)
- Unexpected interesting objects?





Further follow-ups

- Environment
  - Passive/star-forming galaxies around primary targets (basically w/o additional observing time)
- JWST/TMT
  - Systematic observation of stellar population and kinematics in a spatially resolved way (not necessarily lensed)

Missing piece : structural measurement

- Large part of HSC SSP fields does not have HST-resolution imaging to carry out structural measurements
- Follow-up HST, ground-based AO, Euclid, and/or WFIRST data will be needed
- Target objects are very bright, so shallow imaging would be sufficient

Summary

- Deep wide-field imaging Subaru/HSC + sensitive spectroscopy at Keck is probably the best way to competitively exploit passive galaxy evolution at z~2
- Need more nights than typically allocated for time exchange scheme
- Systematic study of kinematics and stellar populations combined with structures will provide an important clue to understand diversity of passive galaxies