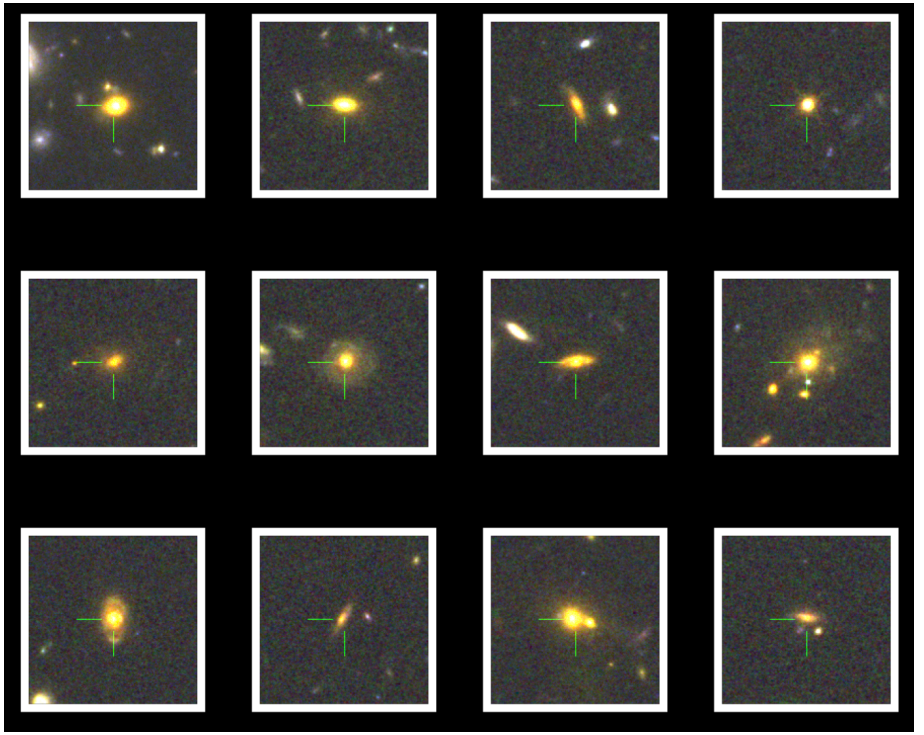
The study of mass-limited, high-redshift galaxy samples

Lee Spitler

ZFOURGE/COSMOS, log M > 11.1, z=1.3-1.75

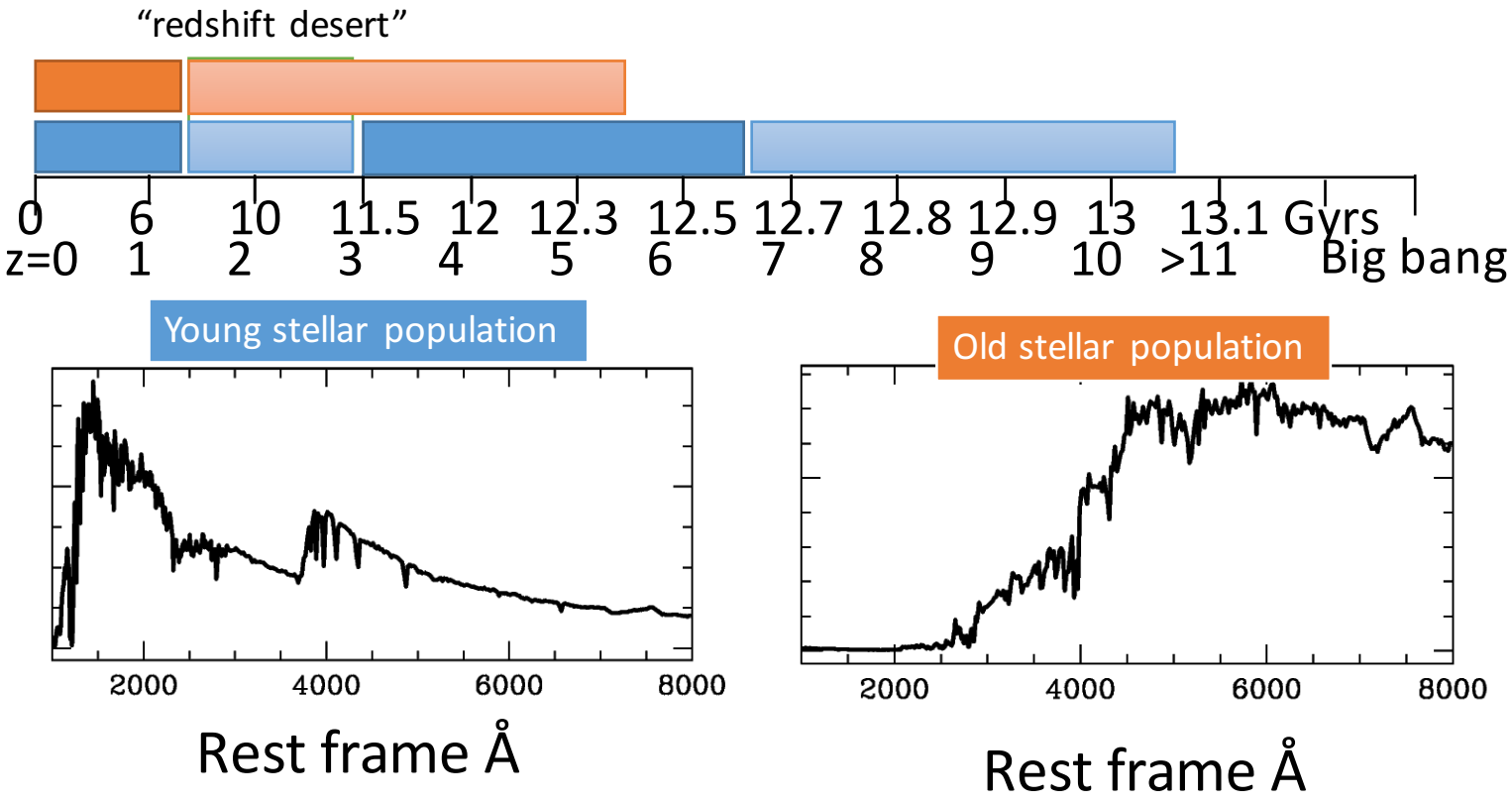


Australian Government
Department of Industry and Science

AAO

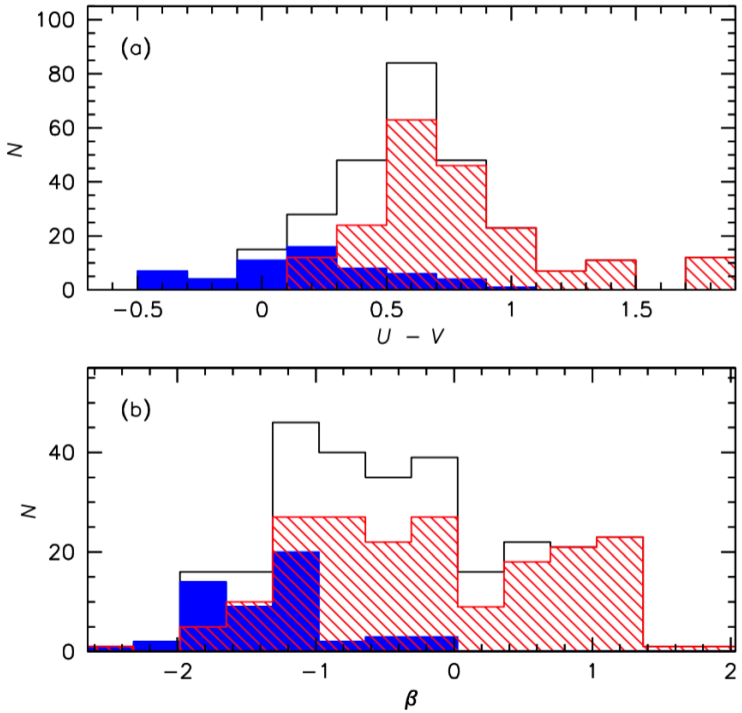
MACQUARIE University
SYDNEY·AUSTRALIA

The challenge of mass-limited samples



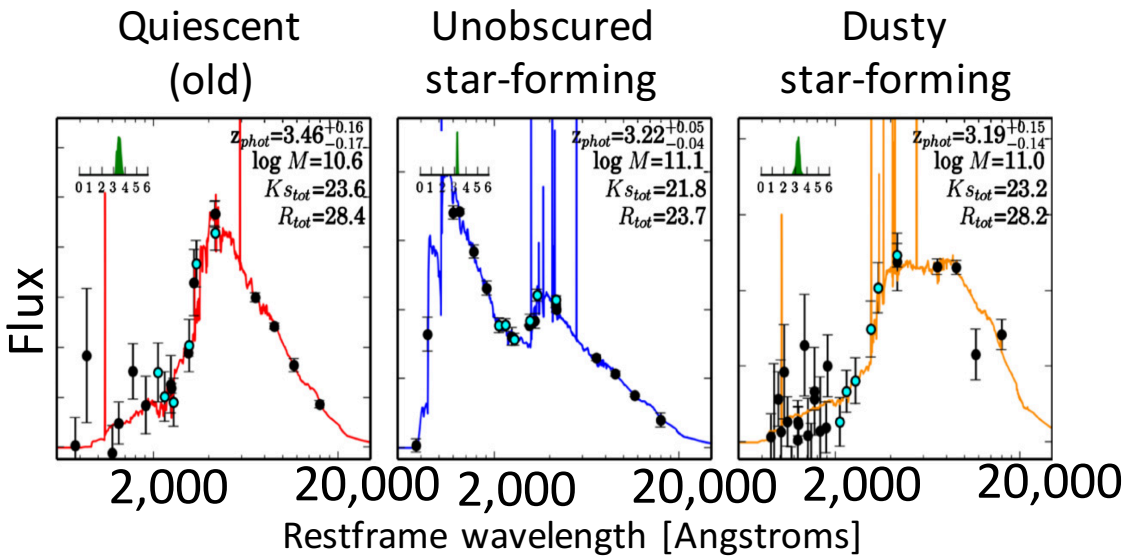
Introduction: mass-limited, high-redshift

Redshift z=2-3 diverse galaxy population



van Dokkum et al., 2006

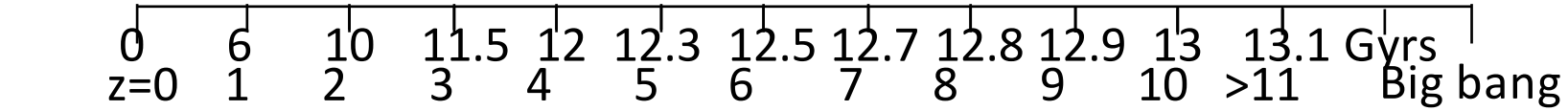
Redshift z=3-4 diverse galaxy population



Spitler et al., 2014

Motivation: high-redshift galaxy observations

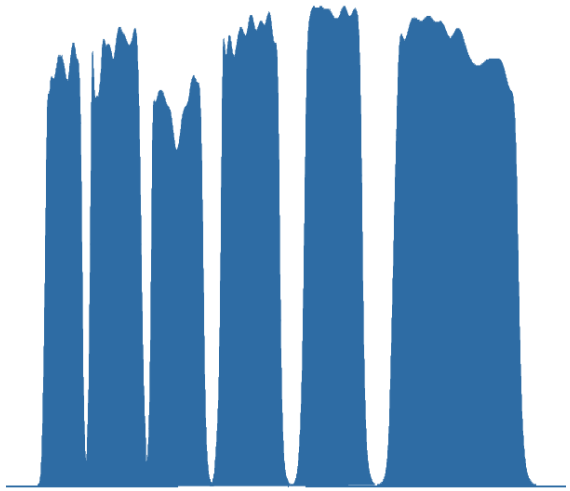
Current record redshift z = 11
~500Million years after Big bang



Current record for mass-limited sample of typical (L star) galaxies:
Redshifts z = 4
1.5 billion years after Big bang

The ZFOURGE Survey

The
FourStar Galaxy Evolution
Survey



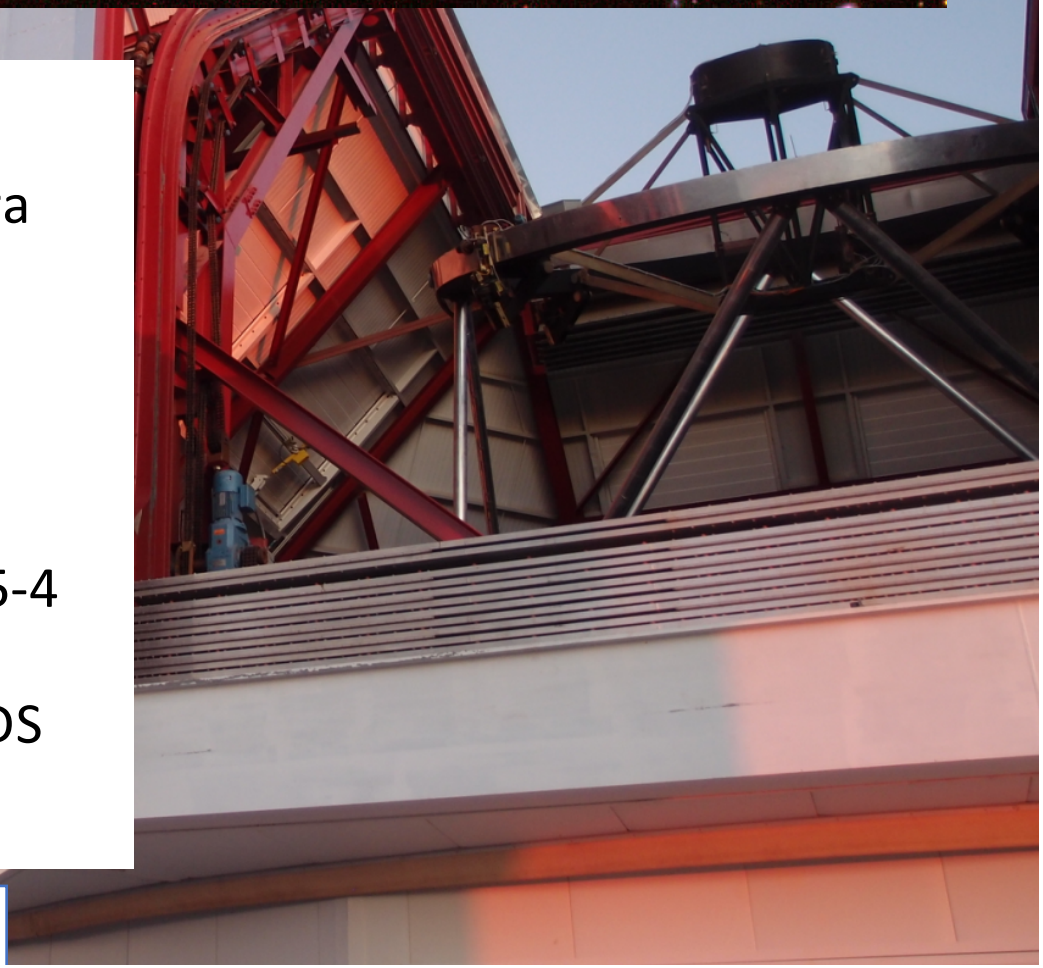
One of a few legacy, deep,
near-infared imaging surveys…

UltraVISTA

Ultra Deep Survey with the VISTA telescope

ZFOURGE

Fourstar Galaxy Evolution Survey



What:

~45 nights Magellan/ FourStar near-IR camera

Data:

5 medium-band filters

Ks broadband

Primary goal:

Accurate photometric redshifts: 1-2% @ z=1.5-4

3 legacy fields:

COSMOS, GOODS-S, UDS

11x11 arcmin^2 each

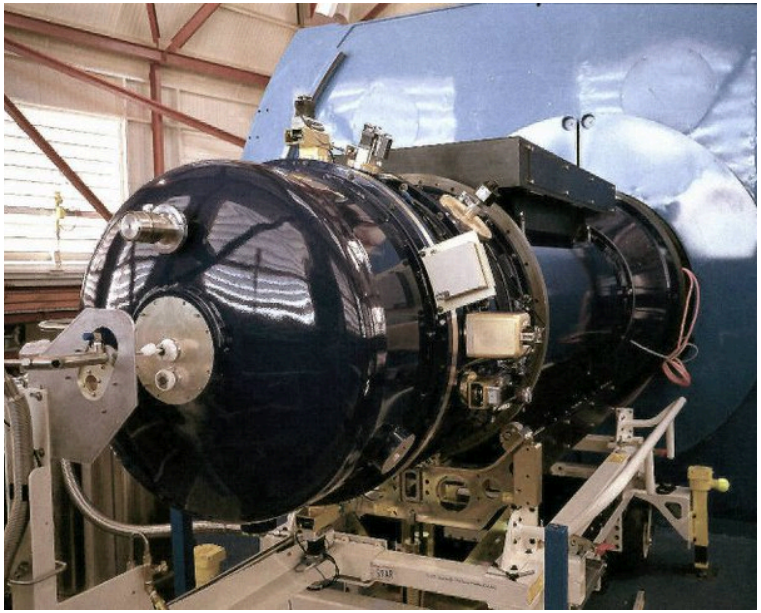
http://zfourge.tamu.edu/

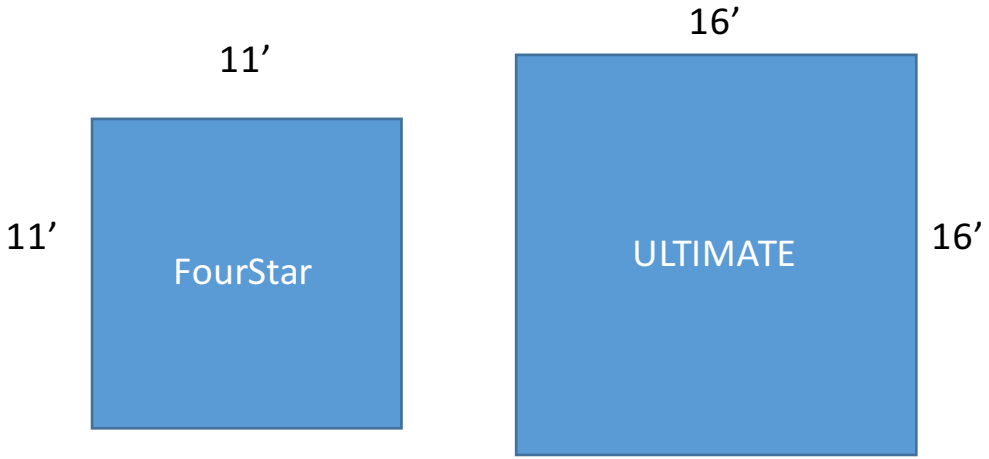
ZFOURGE
Fourstar Galaxy Evolution Survey

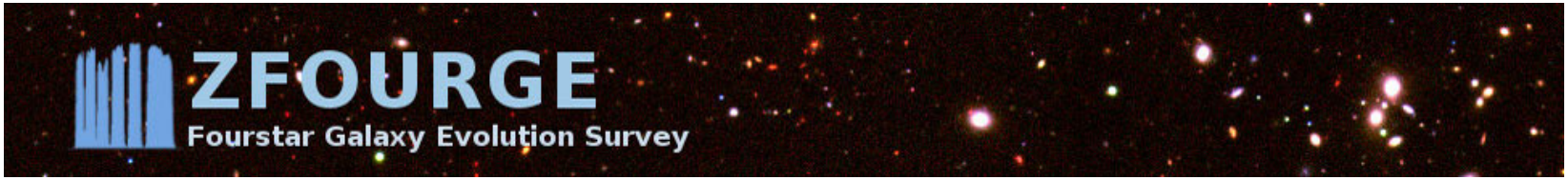
The FourStar camera

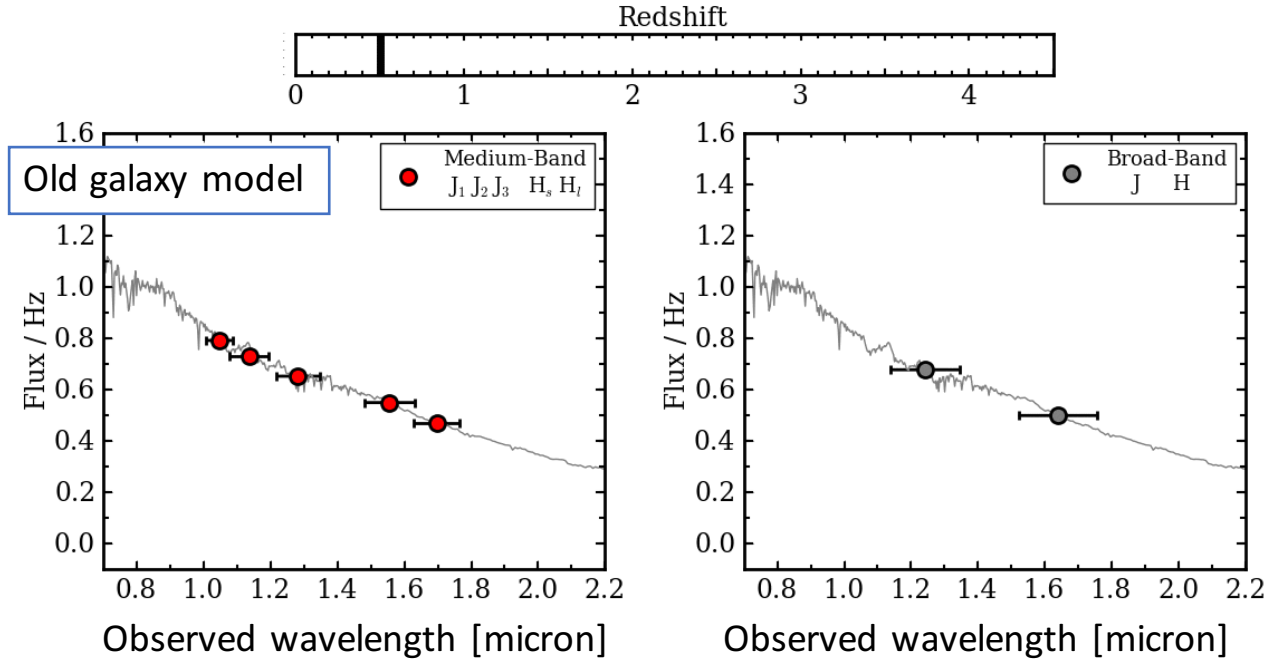
0.16” per pixel
11’x11’ FOV
4x2048x2048 Hawaii-2RGs

PI: Eric Persson (Carnegie)





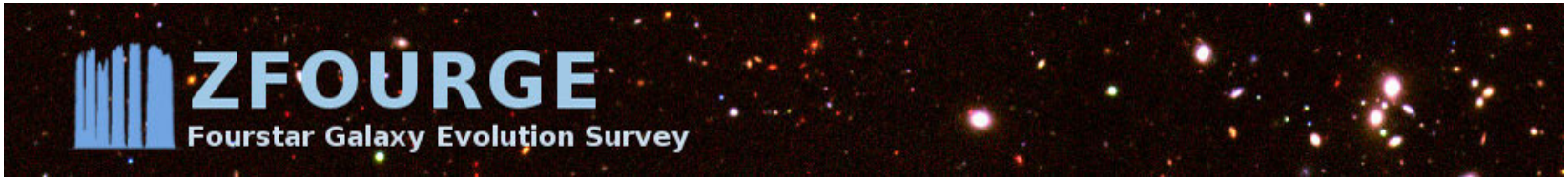




ZFOURGE filters

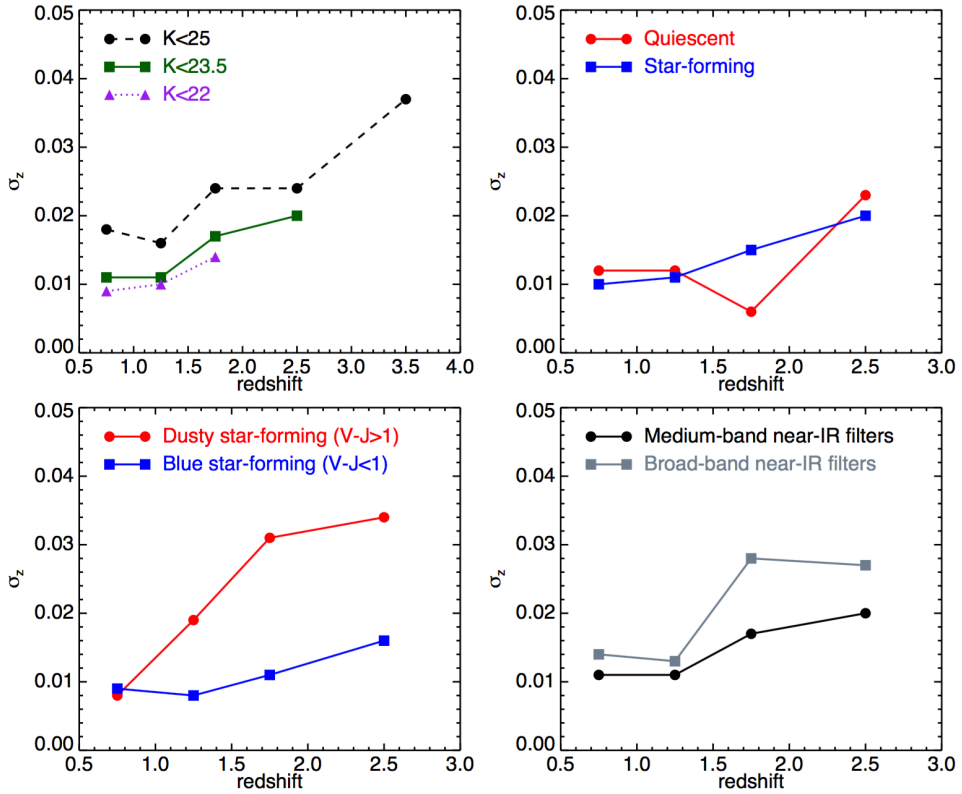
Traditional filters

Animation credit: Adam Tomczak

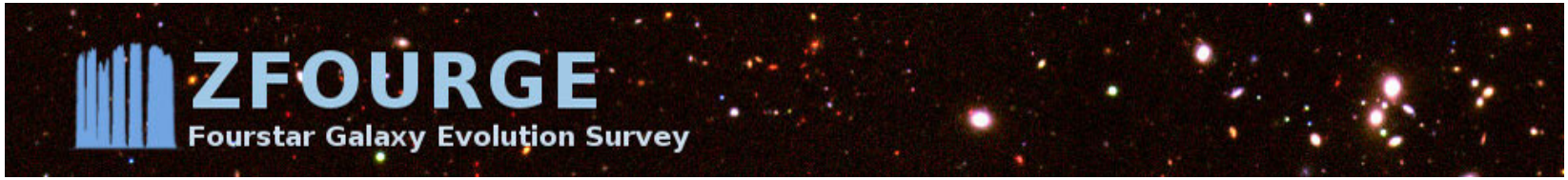


Scatter in
Delta z / (1 + z)

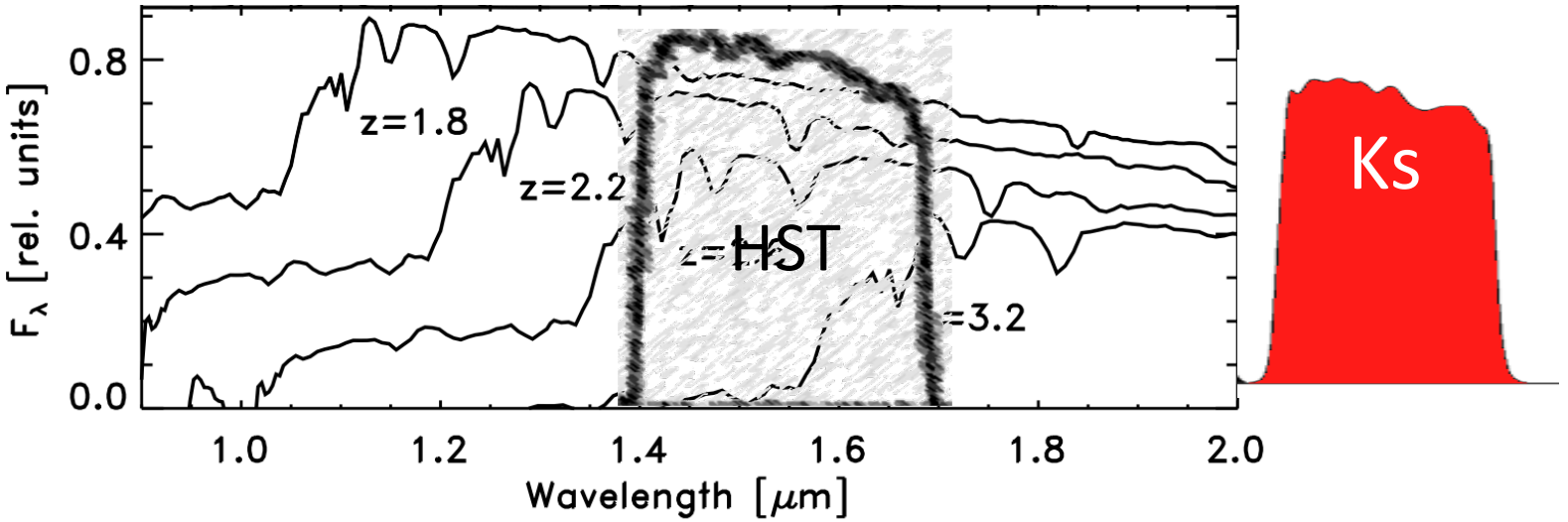
Derived using galaxy pairs



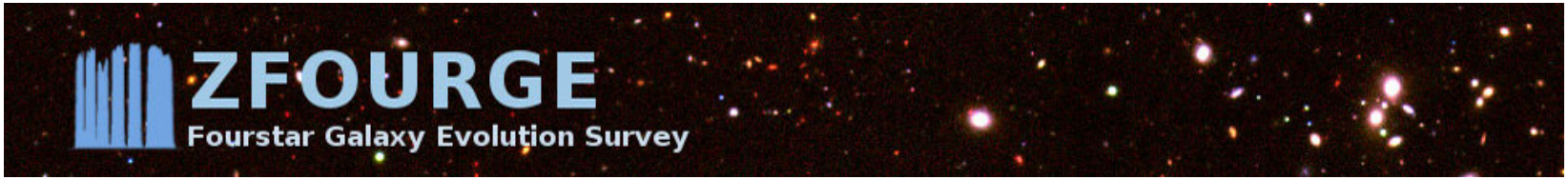
Straatman, Spitler, et al. 2016

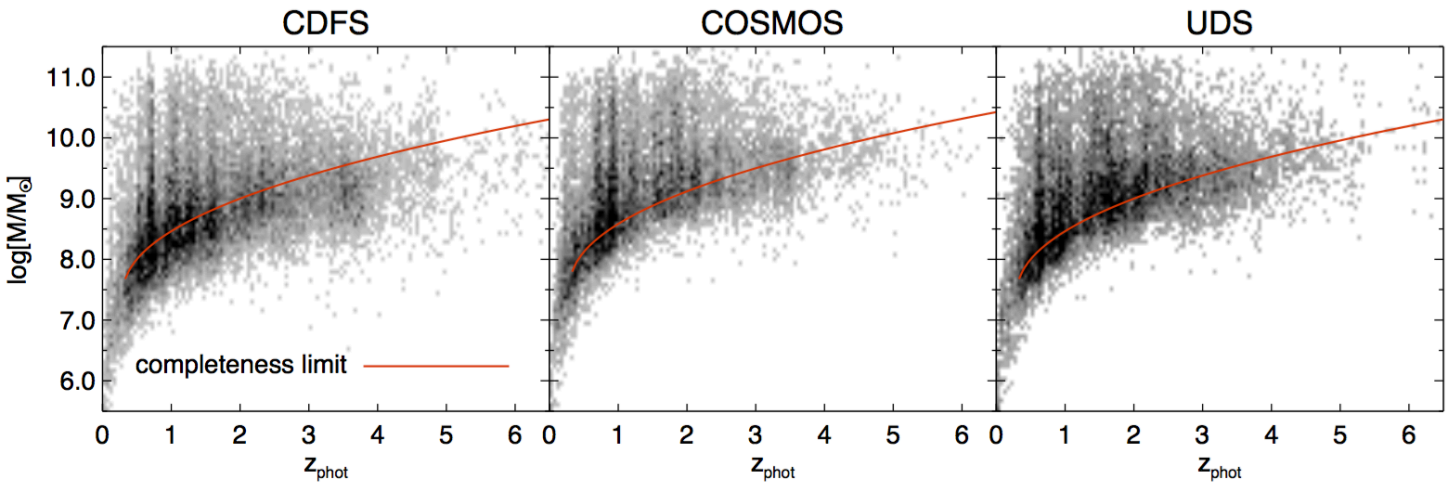


- Identify/select galaxies using evolved star light
  - Stellar mass-limited
    select galaxies with Ks-band: access older stars



Ks-band limits for galaxies @ 5-sigma are ~25 AB mag





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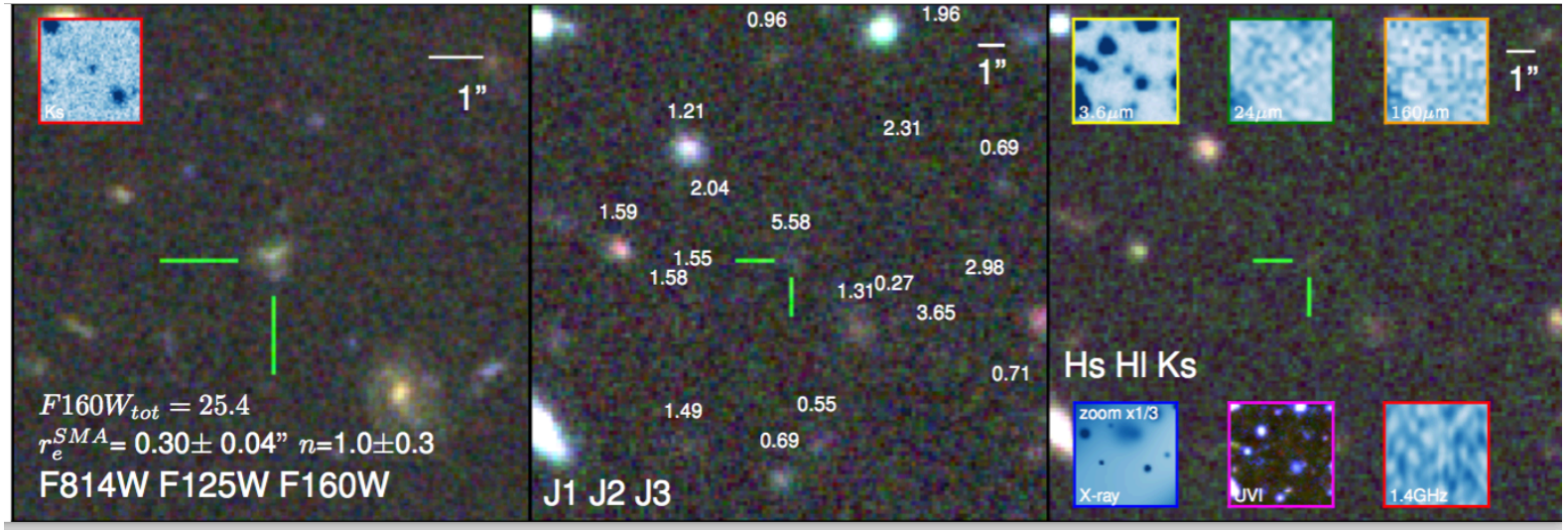
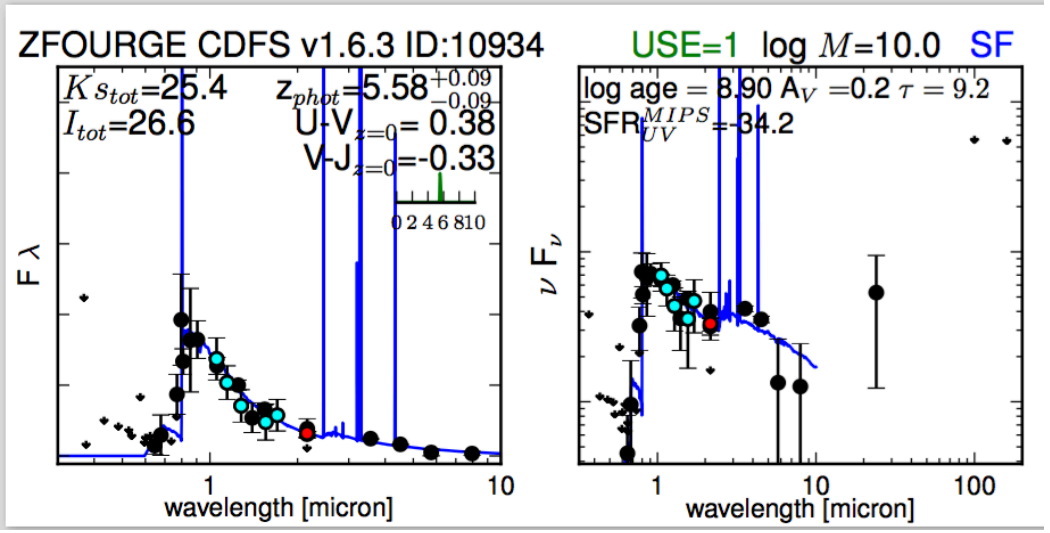


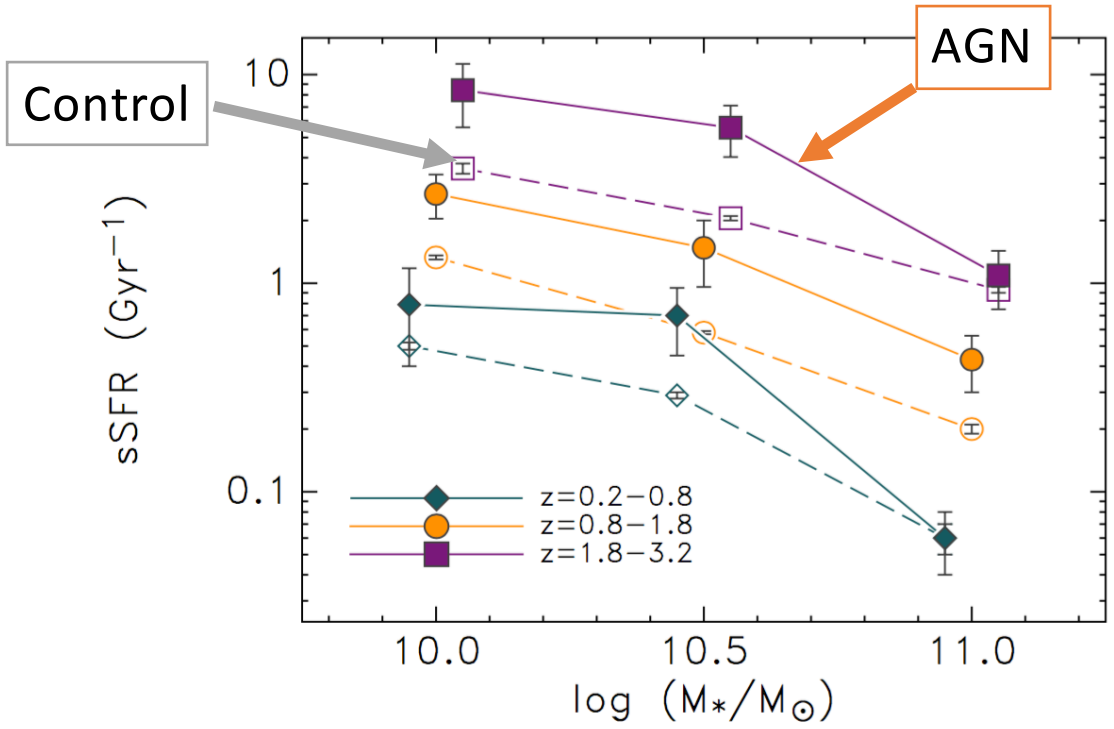
- EAZY photometric redshifts
- FAST stellar populations
- SFRs from UV + MIPS + PACS

Bonus catalogs

- Xray, radio, IR selected AGN
- HST sizes
- 3DHST cross-matched
- Spectroscopic redshifts



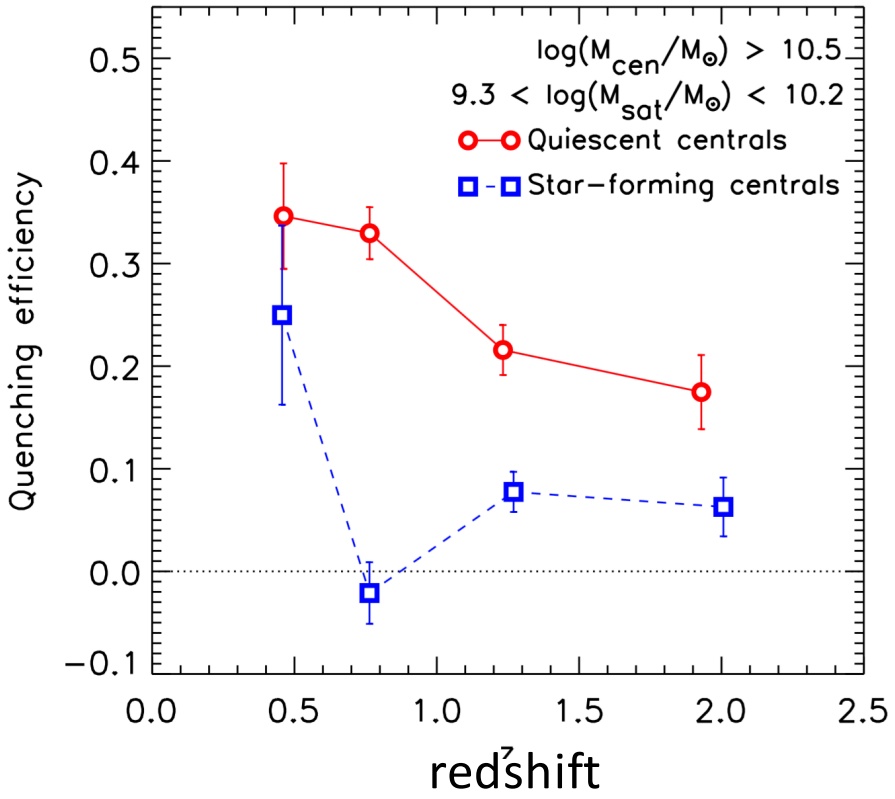
AGN vs non-AGN mass-matched hosts



Cowley, Spitler et al., 2016

Environmental trends: quiescent central galaxies tend to have quiescent satellites

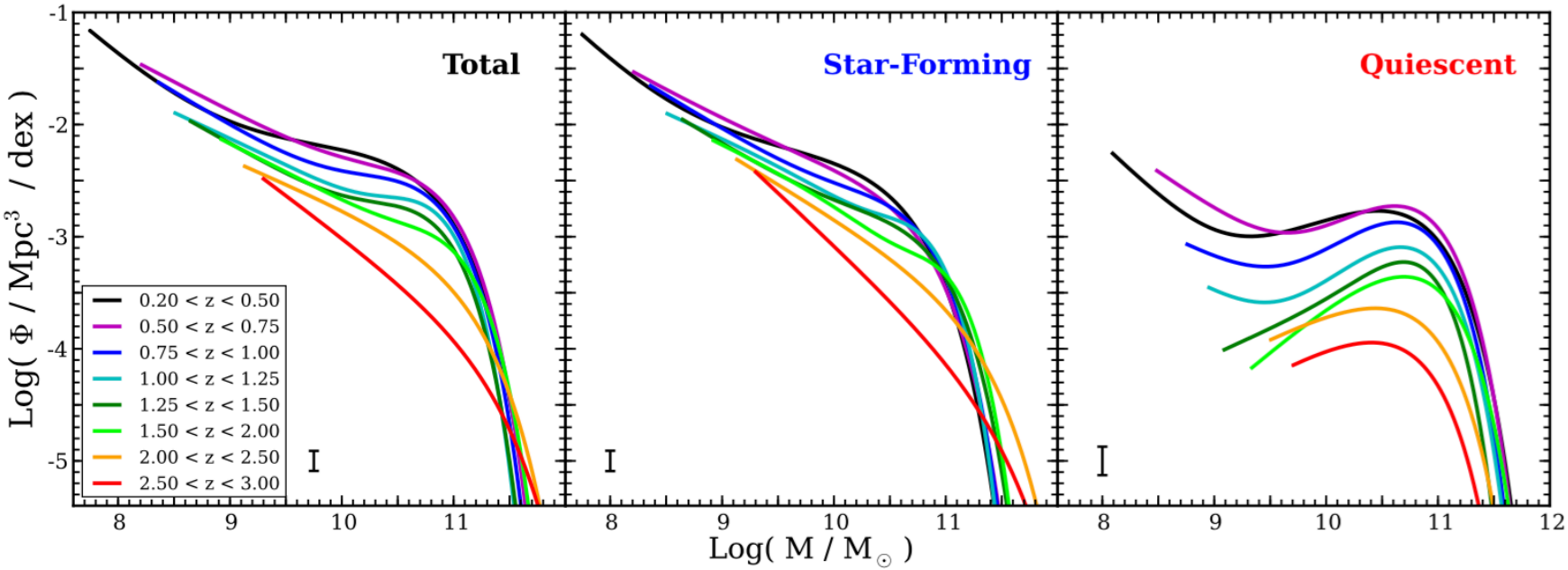
Fraction of quiescent galaxies above background level



Kawinwanichakij et al. 2016

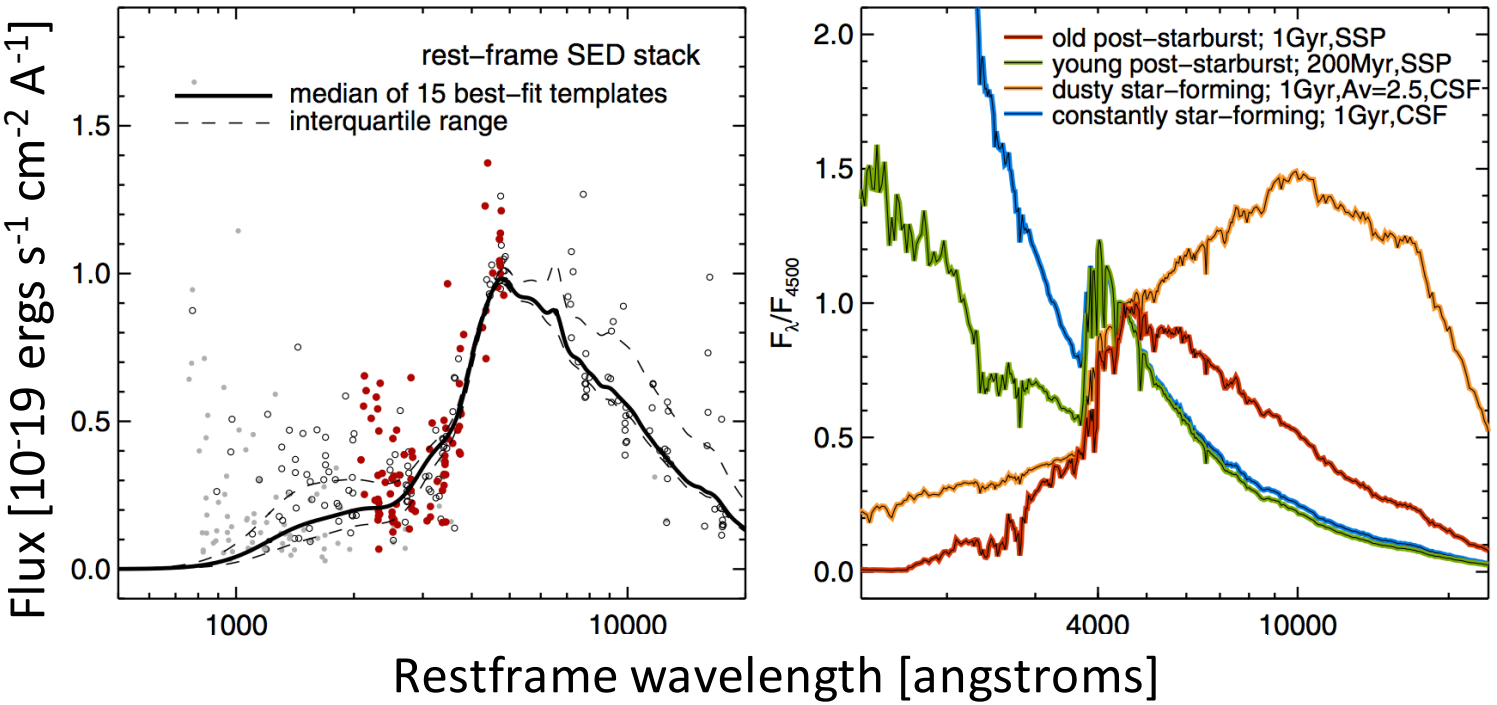
Galaxy mass functions

Need deep Ks-band selection and K123 redshifts



Tomczak et al., 2014

Discovery of z=4 quiescent galaxies



Straatman et al. 2014

Mass-limited survey with ULTIMATE-WFC

Comparison to other deep near-IR imagers

WFIRST

- **~0.5x0.5 deg.**
- Z,y,J,H,H+
- 0.11”/pixel

ULTIMATE / WFC

- 0.26x0.26 deg.
- Y,J,H,**Ks**
  - **Also medium and narrow-bands**
- 0.1”/pixel
- **200 night survey?**

EUCLID

- **0.763×0.722 deg.**
- Y, J and H
- 0.3”/pixels

JWST

- 0.037x0.037 deg.
- Y, J, H, Ks, **2.7um, 3.6um, 4.4um**
- **0.03-0.06”/pixel**

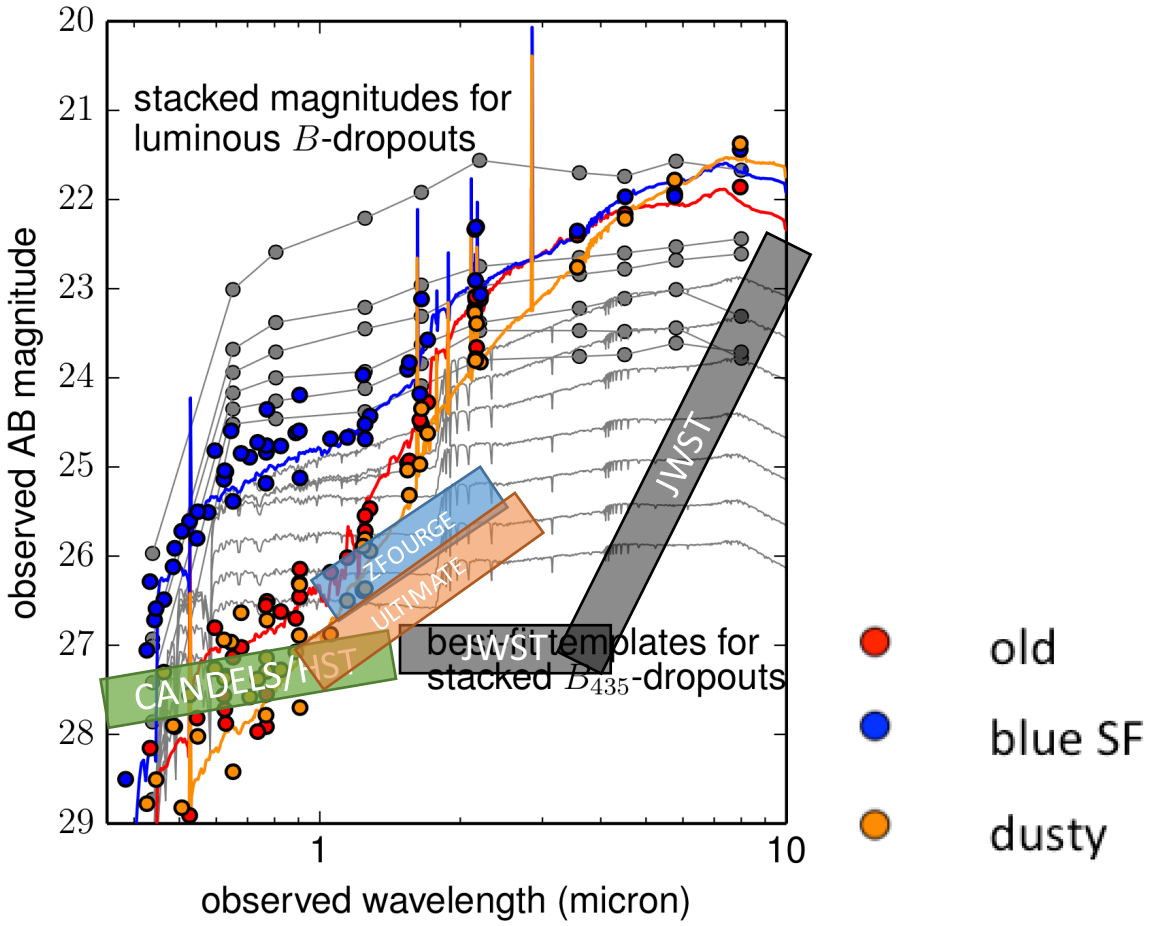
http://www.euclid-ec.org/?page_id=2490

http://www.stsci.edu/wfirst/obsoverview

Advantages of ULTIMATE WFC

- Rarer, massive galaxies
  - JWST deep good for numerous, low mass galaxies
  - Or very rare low mass galaxies – the first quiescent satellites to quench?
- Fill in JWST bands – complete, comprehensive catalog
- Emission-line survey, spanning all redshifts

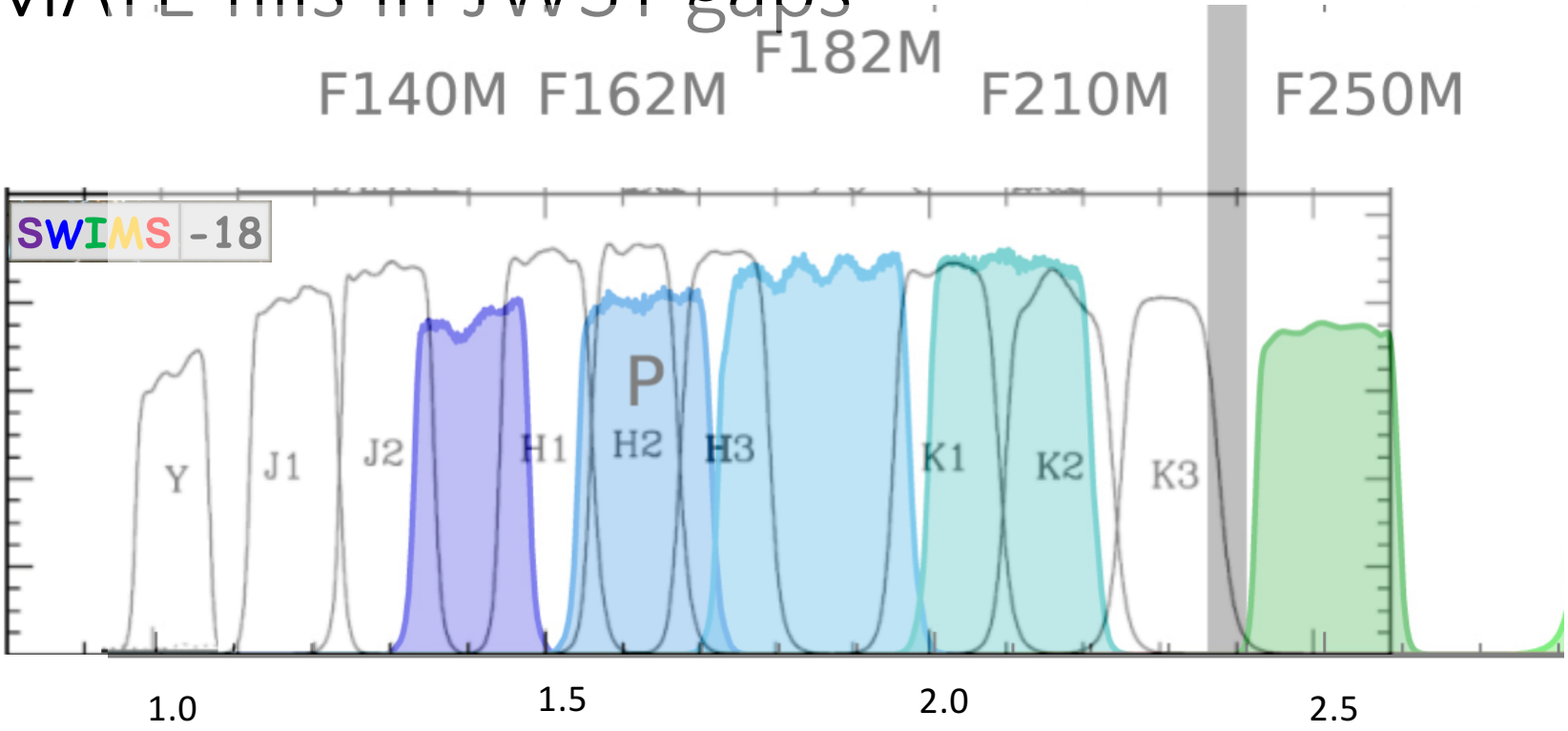
How bright are z=3-4 massive galaxies?



median $M_{1700} = -18.05 \pm 0.42$

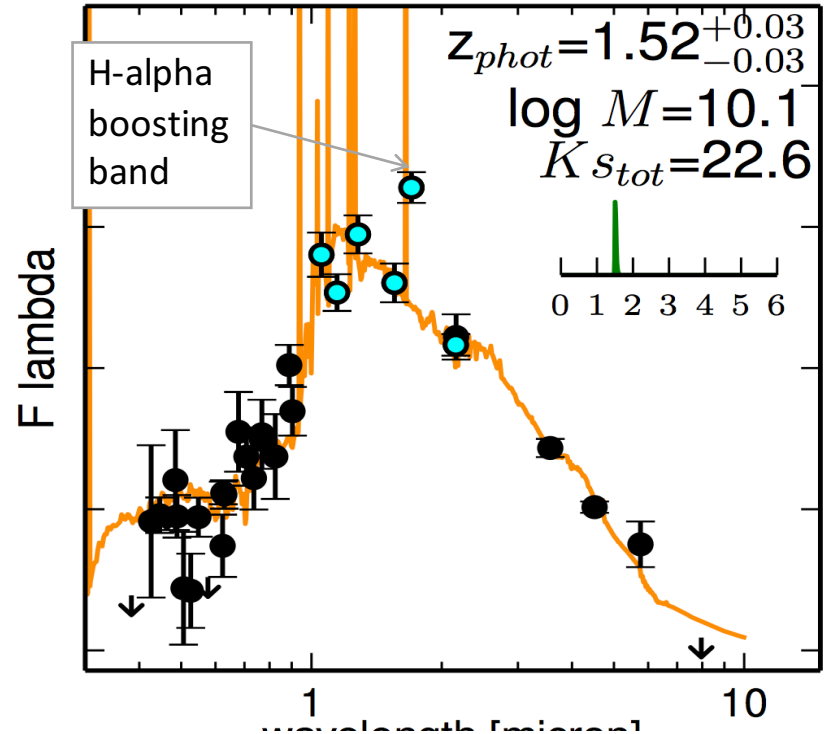
Spitler et al. 2014

JWST fills in the opaque windows
ULTIMATE fills in JWST gaps



Possible ULTIMATE filterset = black outline, JWST/NIRCam = color filters

Capture emission-lines with medium-band filters

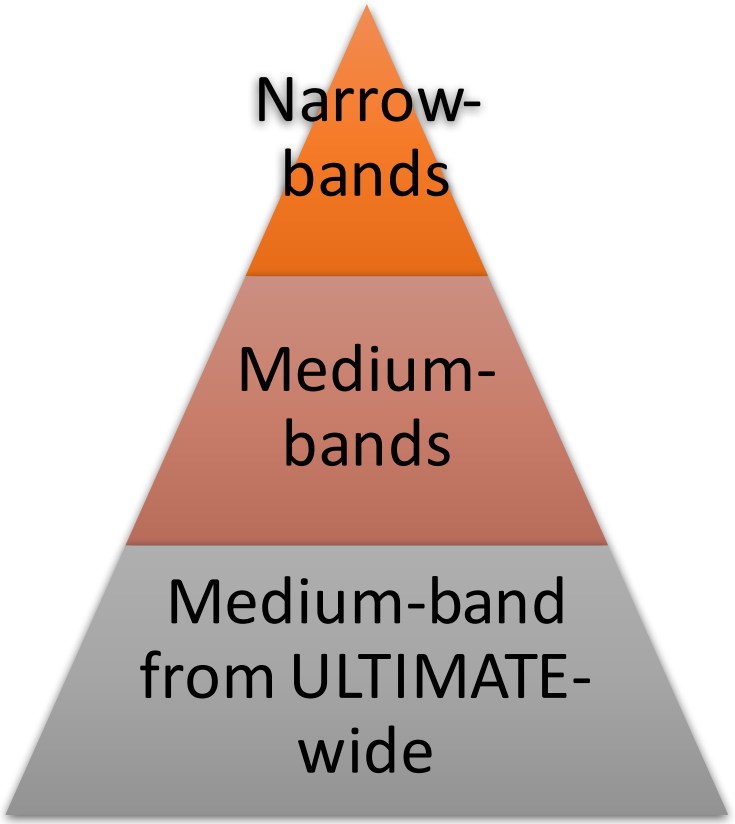


EAZY photo-z best-fit template

Cyan: ZFOURGE observations
Black: other observations

Use medium-bands as strong/moderate emission-line mapper

- Comprehensive large field of view emission-line map
- Sensitive to:
  - Really rare, high-SFRs (medium-bands, from *ULTIMATE-wide*),
  - moderate-SFRs (medium-bands),
  - Abundant, low-SFRs (narrow-bands)



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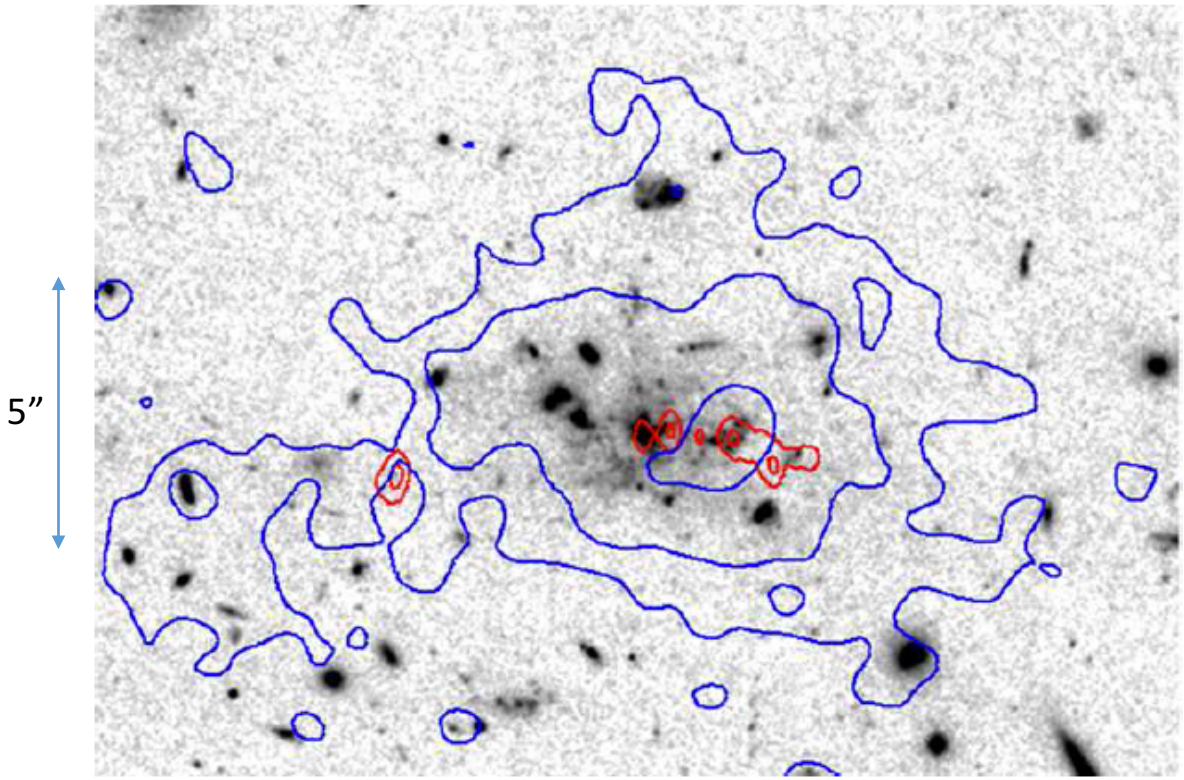
Mass-limited survey with ULTIMATE-MOS

- A key advantage compared to other near-infrared MOS (e.g. MOSFIRE) and even TMT (few targets) is the large number of nights to use it

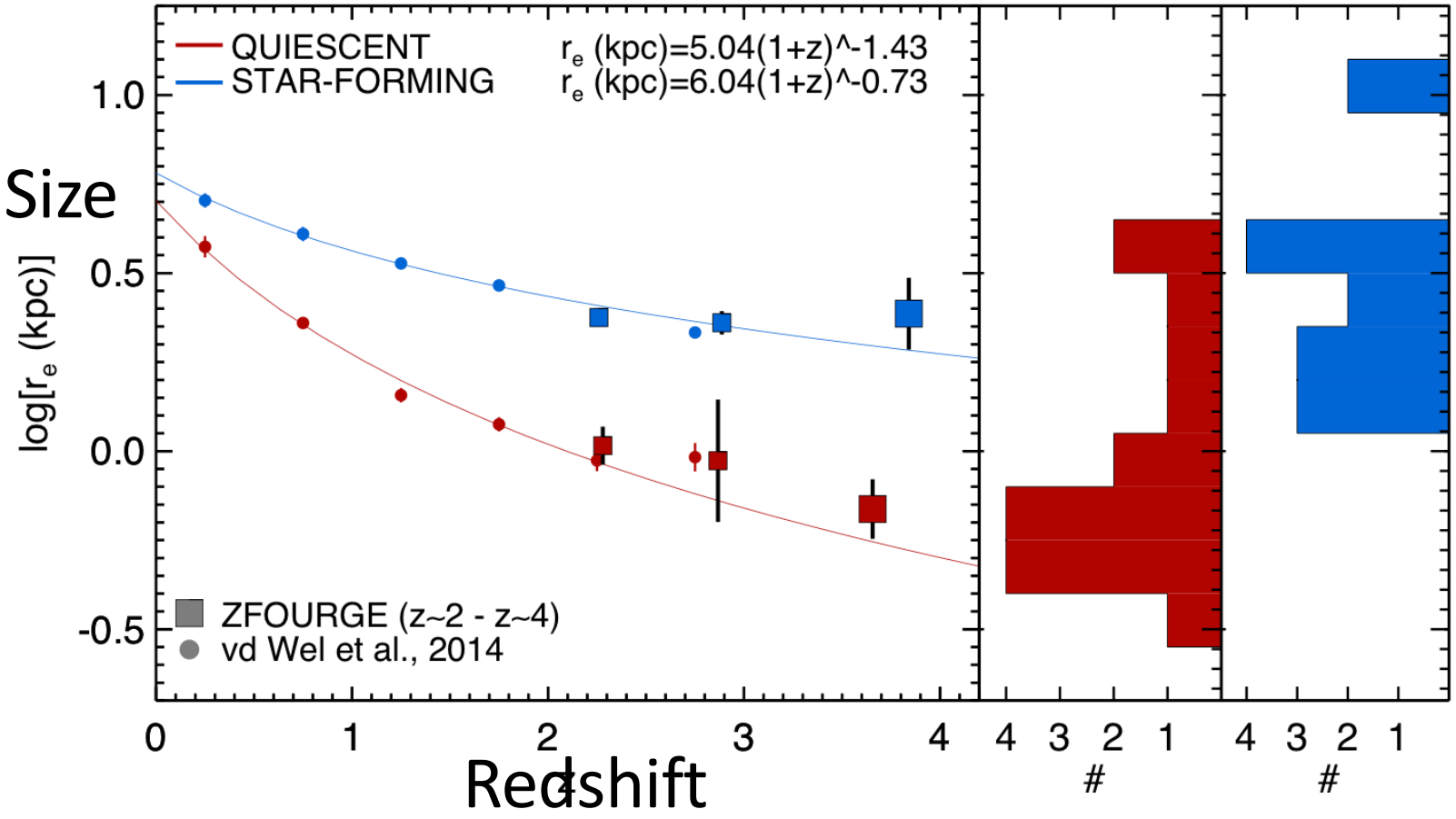
Mass-limited survey with ULTIMATE-IFU

“MUSE-like” IFU maps of massive galaxies



Spiderweb galaxy; Lyα (blue, resolution ~1")
Miley, George et al. Astron.Astrophys.Rev. 15 (2008)

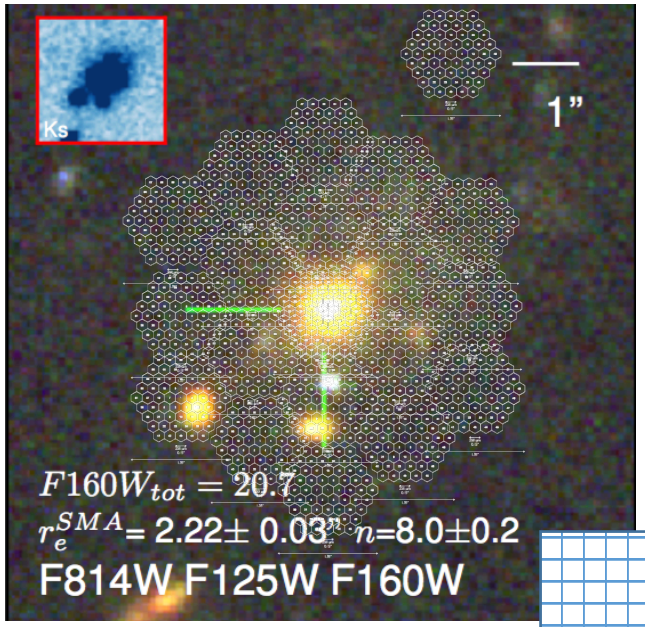
Size evolution of log M > 10.5 galaxies



Pin-down the size-growth of massive galaxies

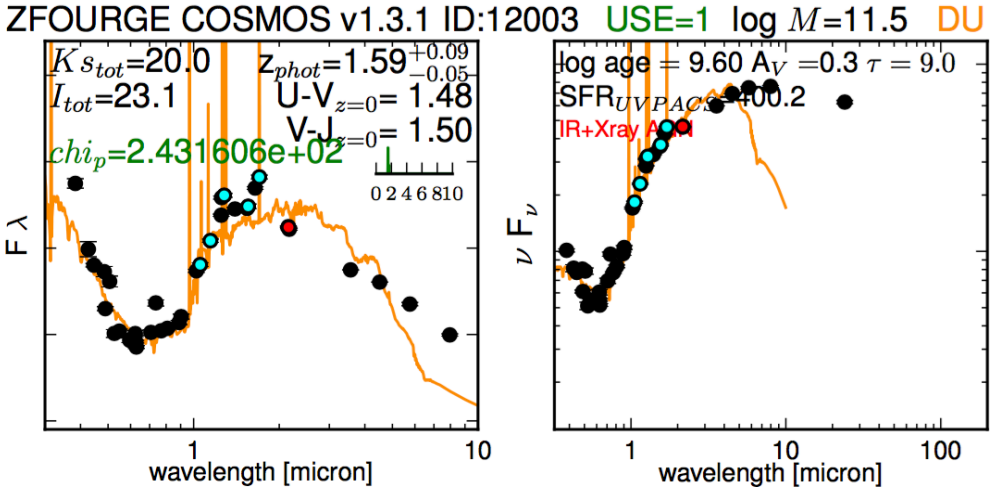
- Known evolution in size from z~4 to z~0
- Merging
  - Big stuff nearby
- Minor merging
  - Many small things
- IFU maps can help?

“MUSE-like” IFU maps of massive galaxies

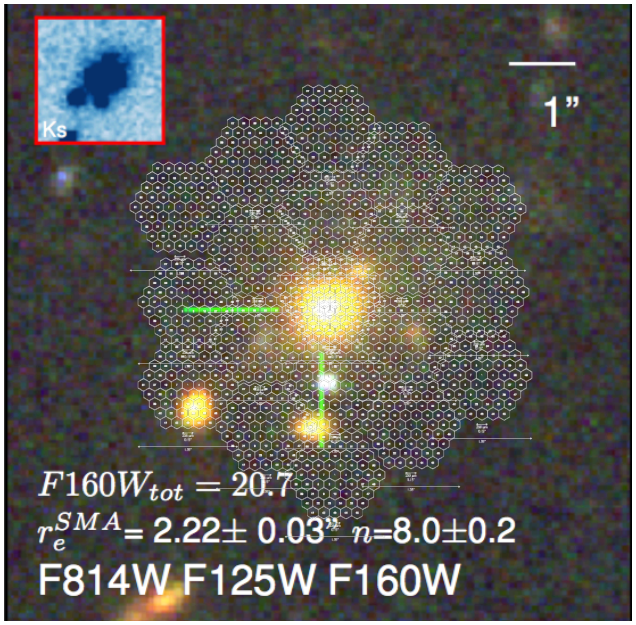


VLT/KMOS

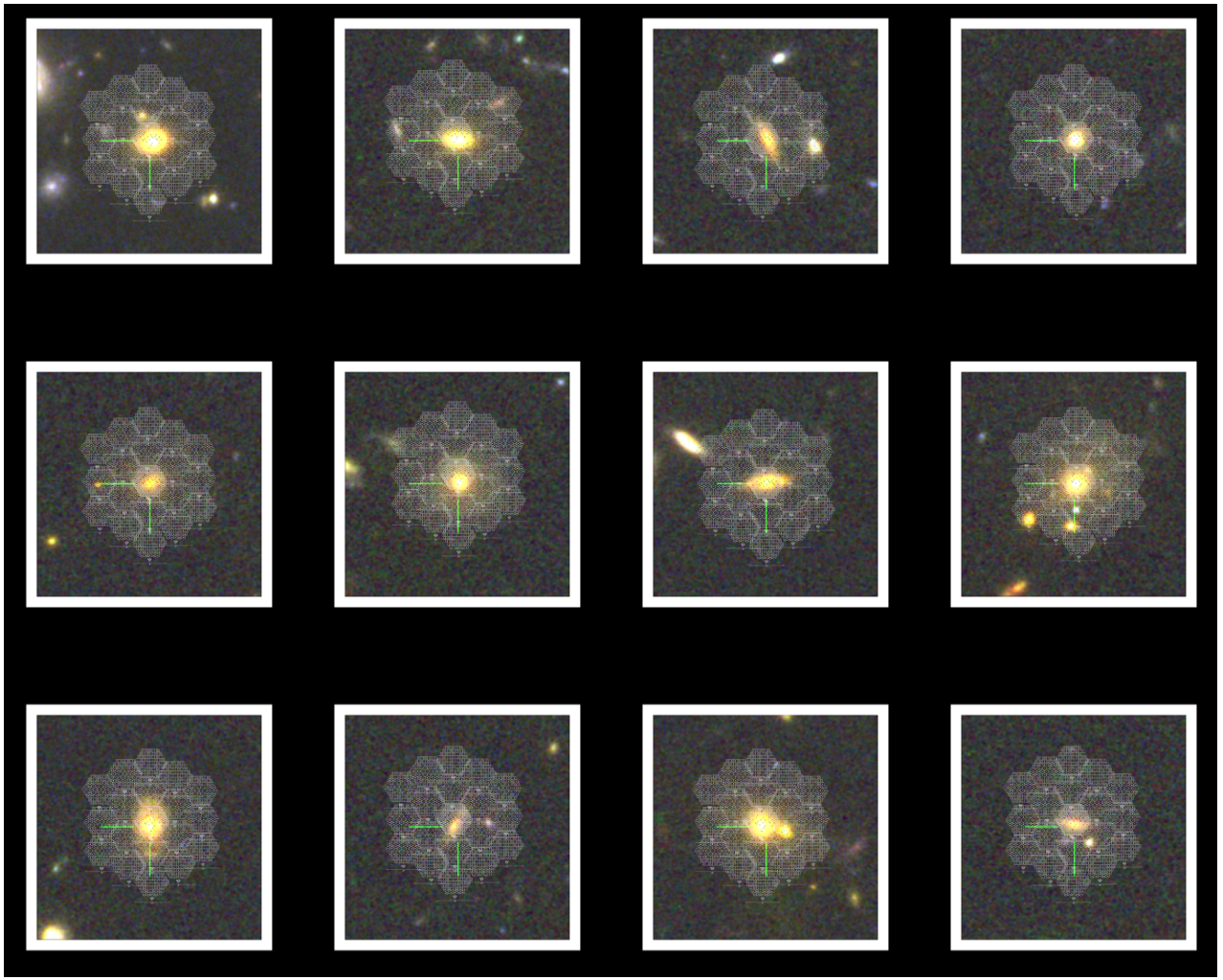
- 7 pointings
  - 4”x4”
- +12 pointings
  - 7”x7”



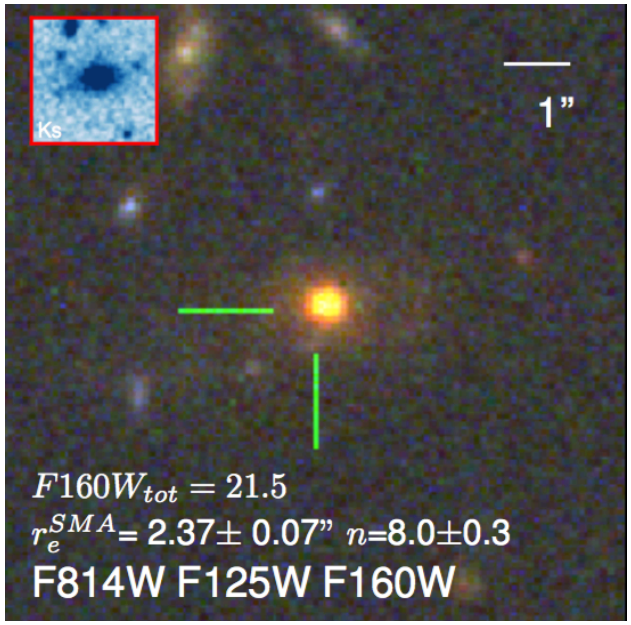
ZFOURGE/COSMOS, log M > 11.1, z=1.3-1.75



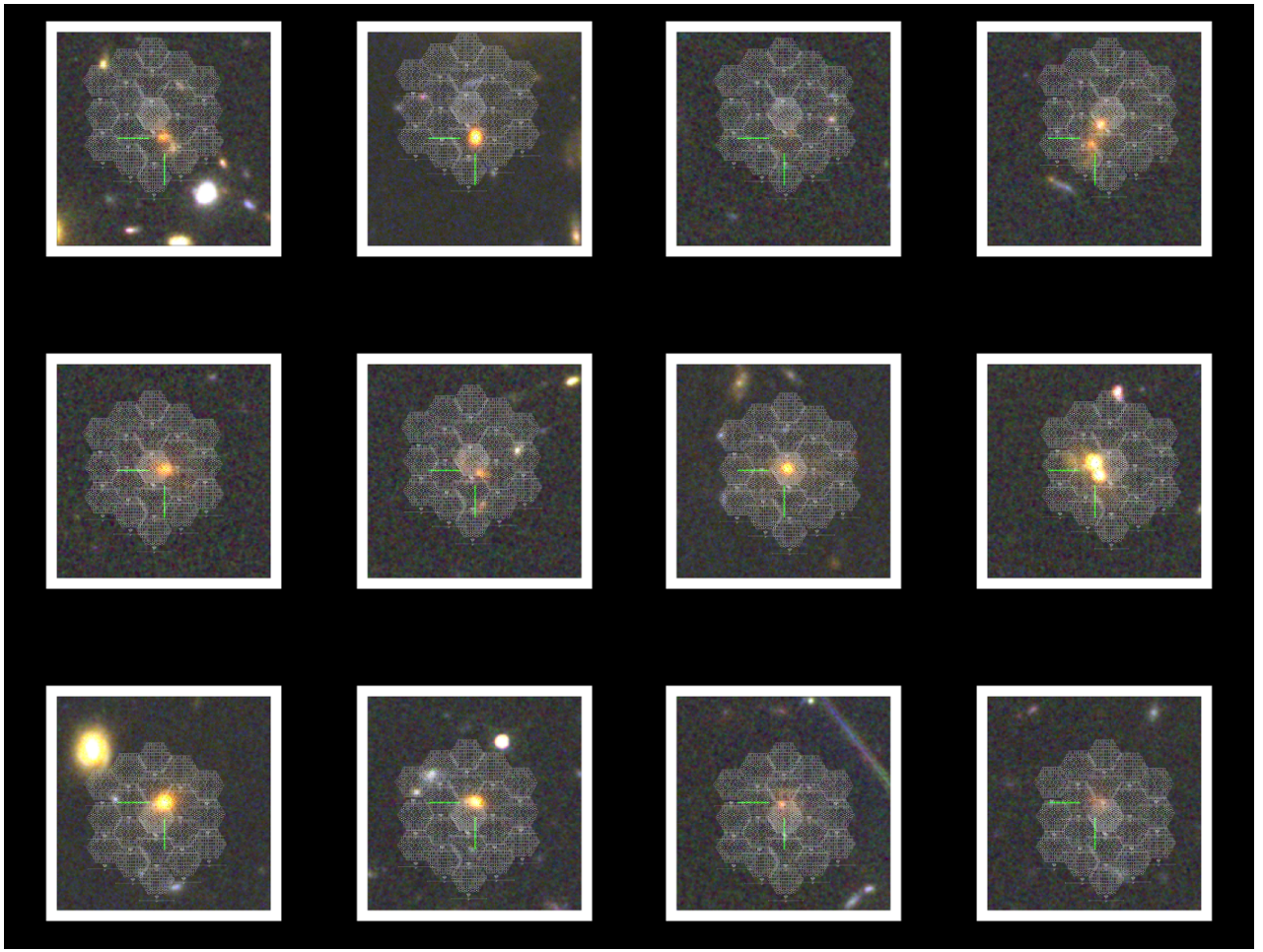
60% are star-forming



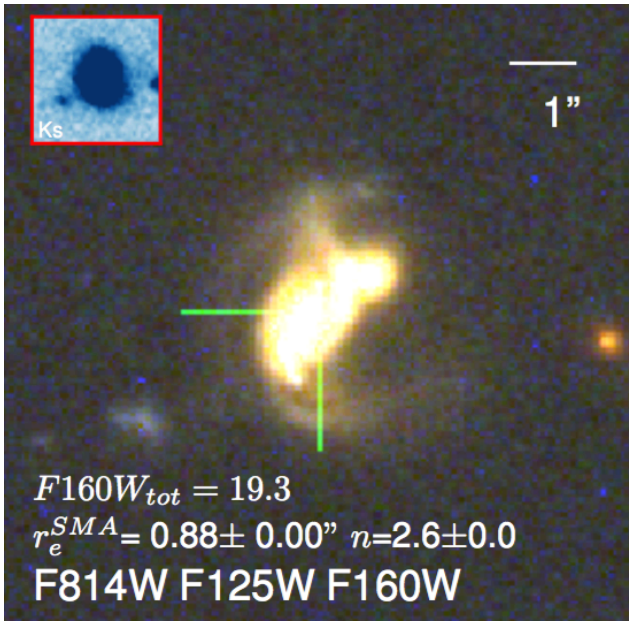
ZFOURGE/COSMOS, log M > 11.1, z=2.0-2.6

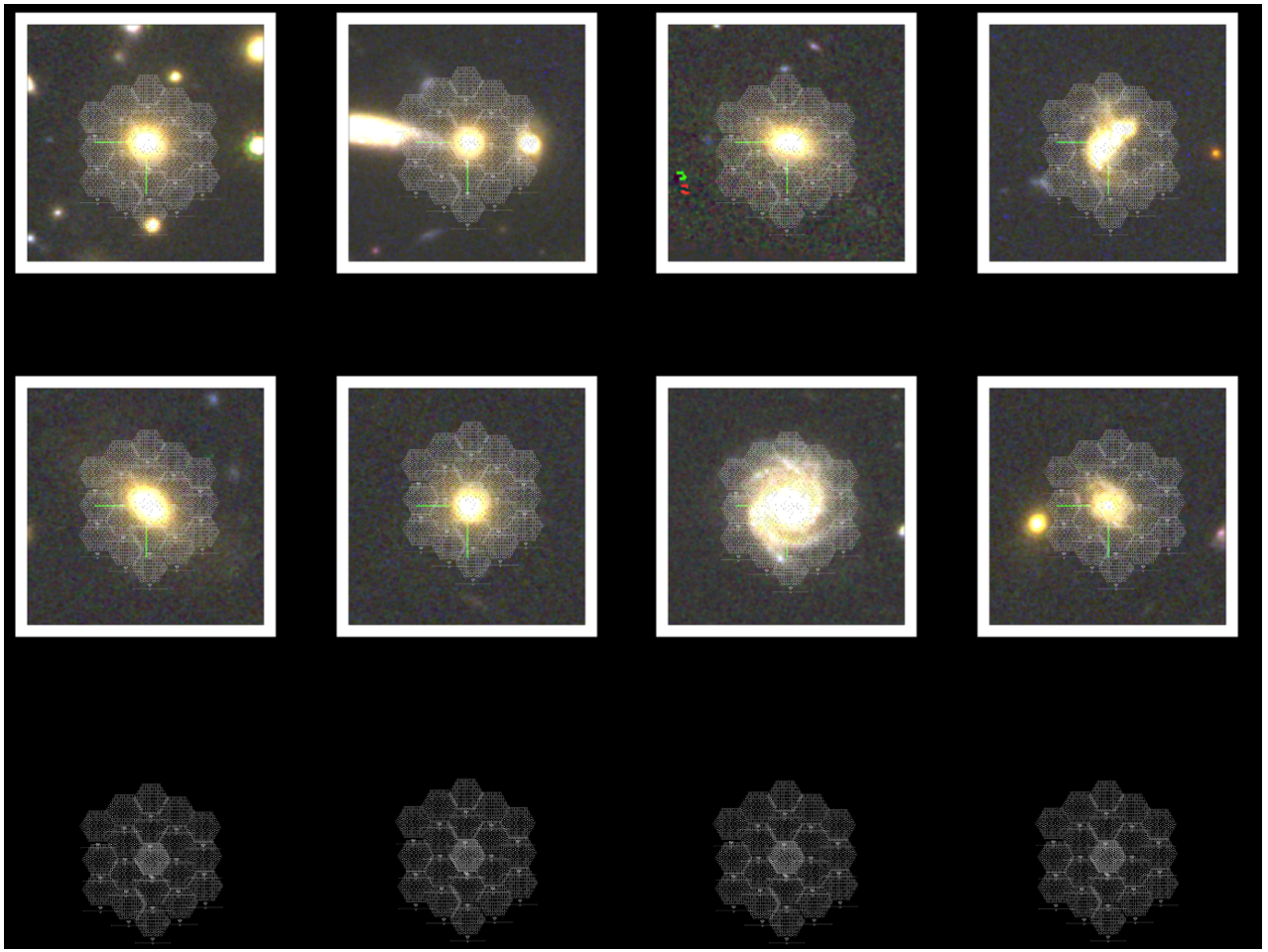


80% are star-forming



ZFOURGE/COSMOS, log M > 11.1, z=0.5-1.1





50% are star-forming

Questions

- Q1: What do you think is the "KEY" science/observations for ULTIMATE in your research field? We hope to establish the very best science cases which are unique enough even in mid-late 2020s (i.e. post-JWST or WFIRST era!).
  - Massive galaxy formation – rare, z=3-6, dusty or old galaxies – follow-up with TMT
- Q2: Which instrument (WFC/MOS/IFU) do you think is 1st priority for ULTIMATE? We currently consider the wide-field imager (WFC) is 1st priority, but we want to have your opinion.
  - IFU high-redshift survey is unique
  - WFC will become a workhorse K-band survey imager
  - MOSFIRE is doing near-IR MOS very well right now, but not a 200 night survey!
- Q3: Our current plan is to (1) build GLAO first, and then to (2) build new NIR instrument(s). This means that we will start our ULTIMATE science with GLAO +MOIRCS at the first stage. Do you have good science cases to be done with GLAO+MOIRCS during the period of ~2020-2023?
  - Mass-limited surveys require deep, moderately wide FOV imaging. GLAO will help with the depth, but by how much?
- Q4: Which survey design sounds best for you (see survey_design.pdf)? Your comments/suggestions on the ULTIMATE survey design are very welcome.
  - C (deep, wide K-band) with select subset of medium-bands to complement JWST