MAGNIFICENT CONSTRUCTIONS: HOW MASSIVE GALAXIES STOP FORMING STARS

KEVIN C. COOKE

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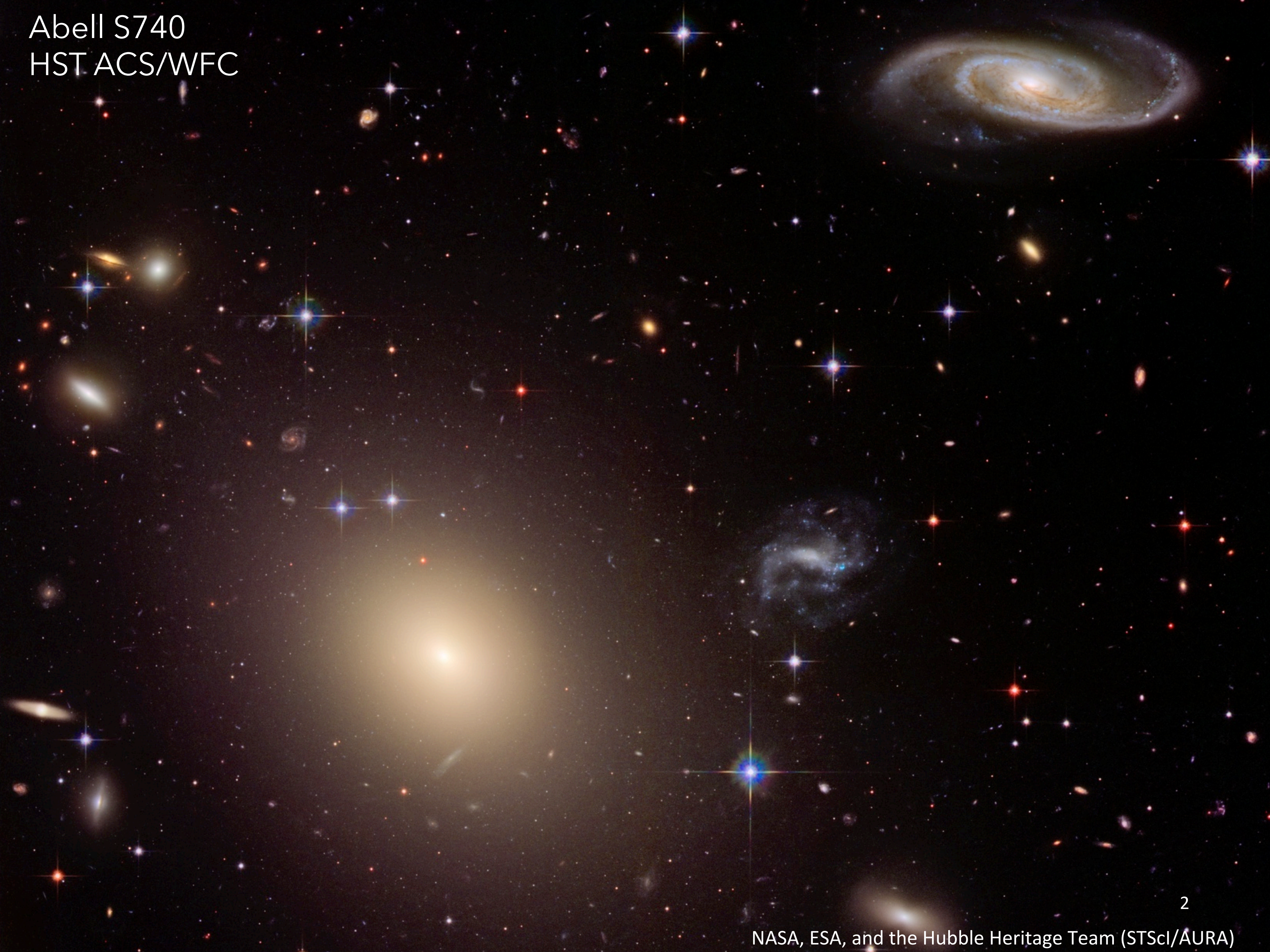
PHYSICS & ASTRONOMY

Understanding the Universe Starts Here

COSMOS

R·I·T

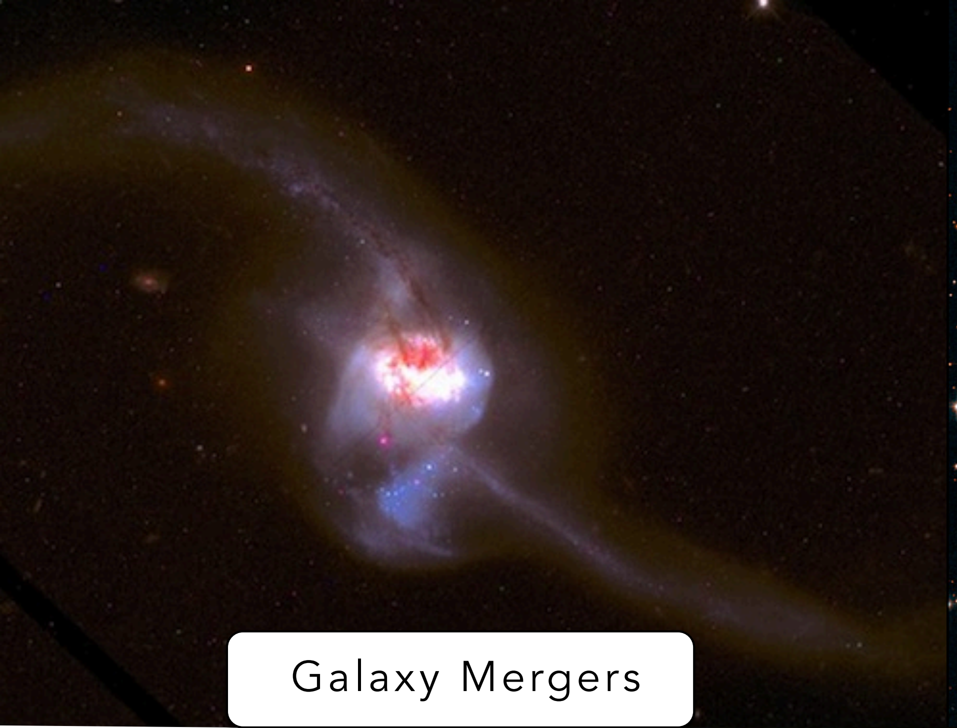
THE UNIVERSITY OF KANSAS

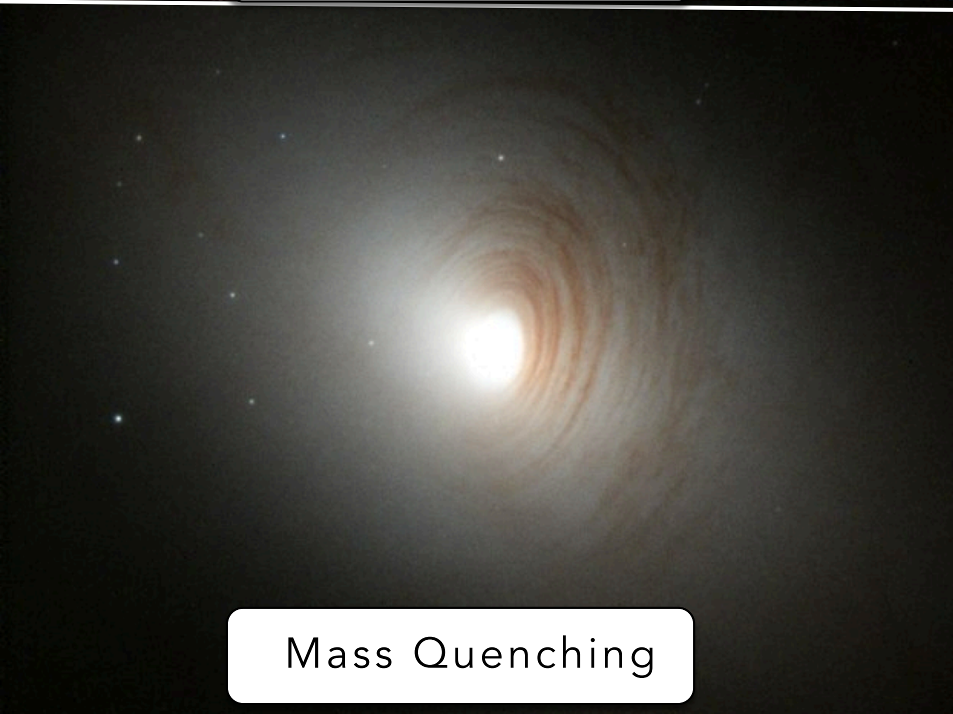


NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

OBJECTIVE:

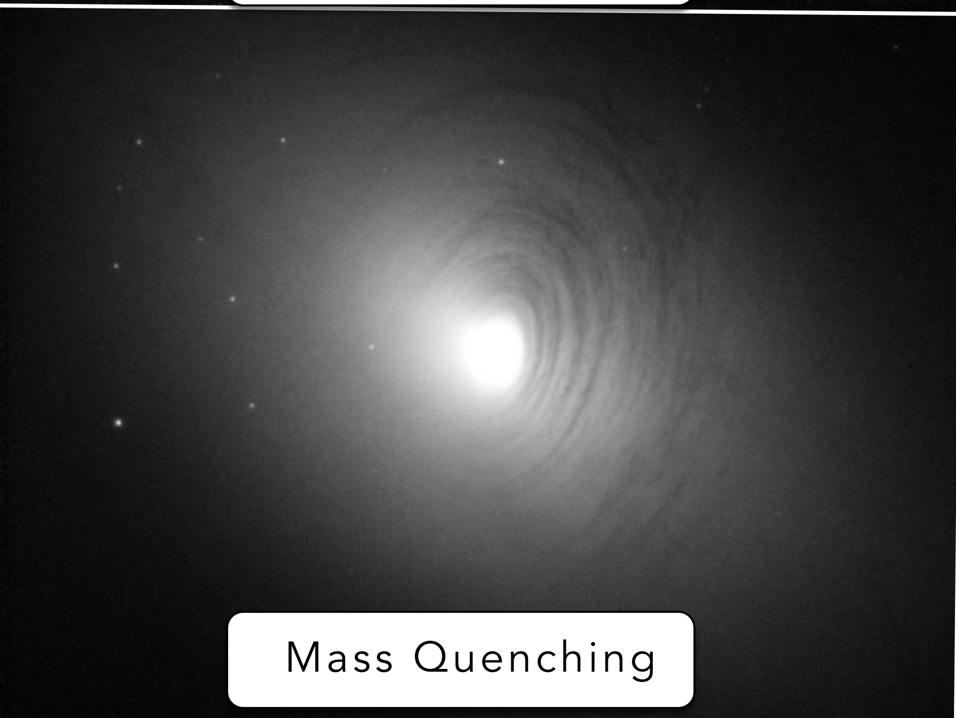
What factors moderate the growth of massive galaxies?


Galaxy Mergers

Environmental Quenching

Mass Quenching

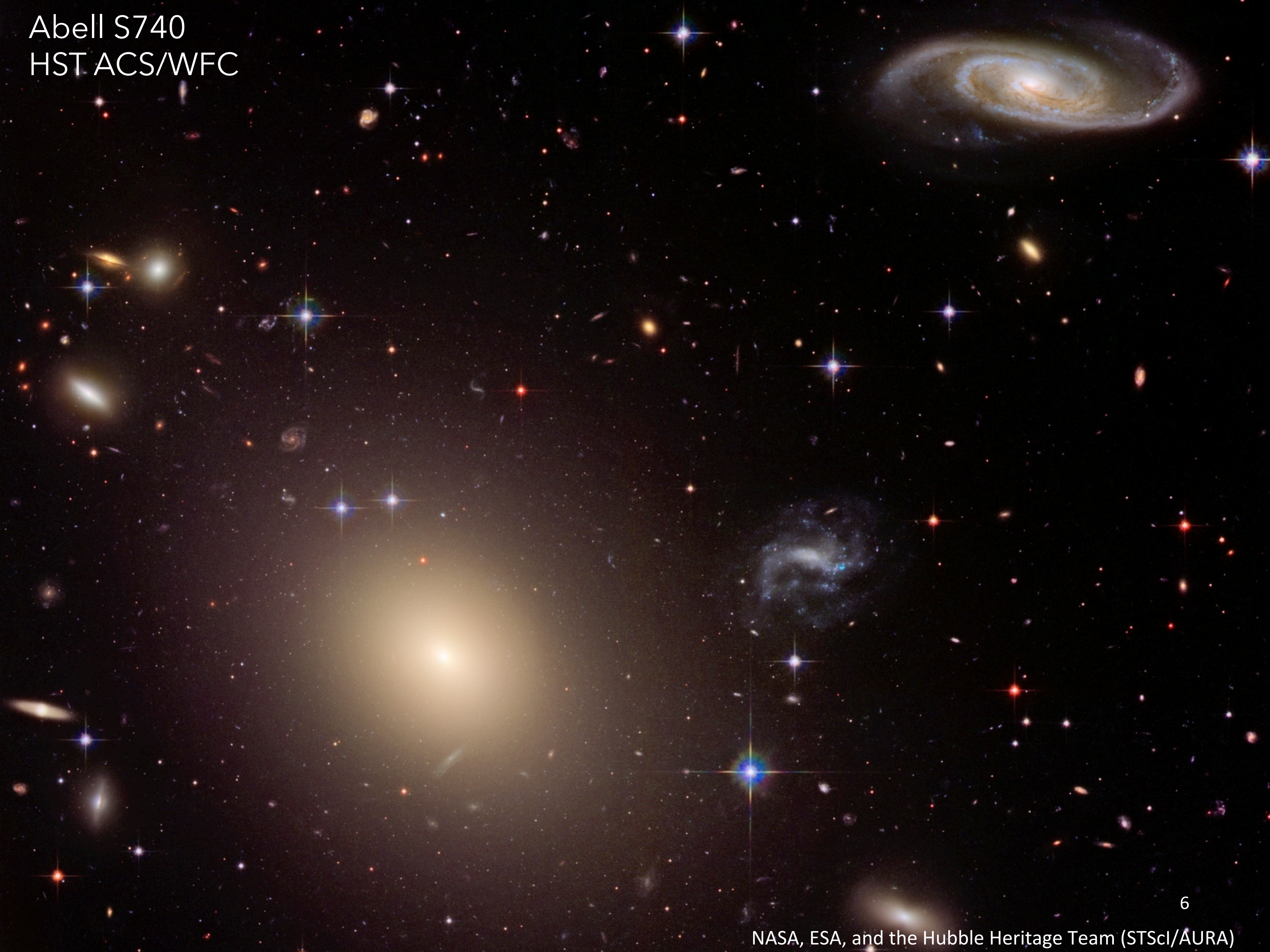
AGN Feedback


Galaxy Mergers

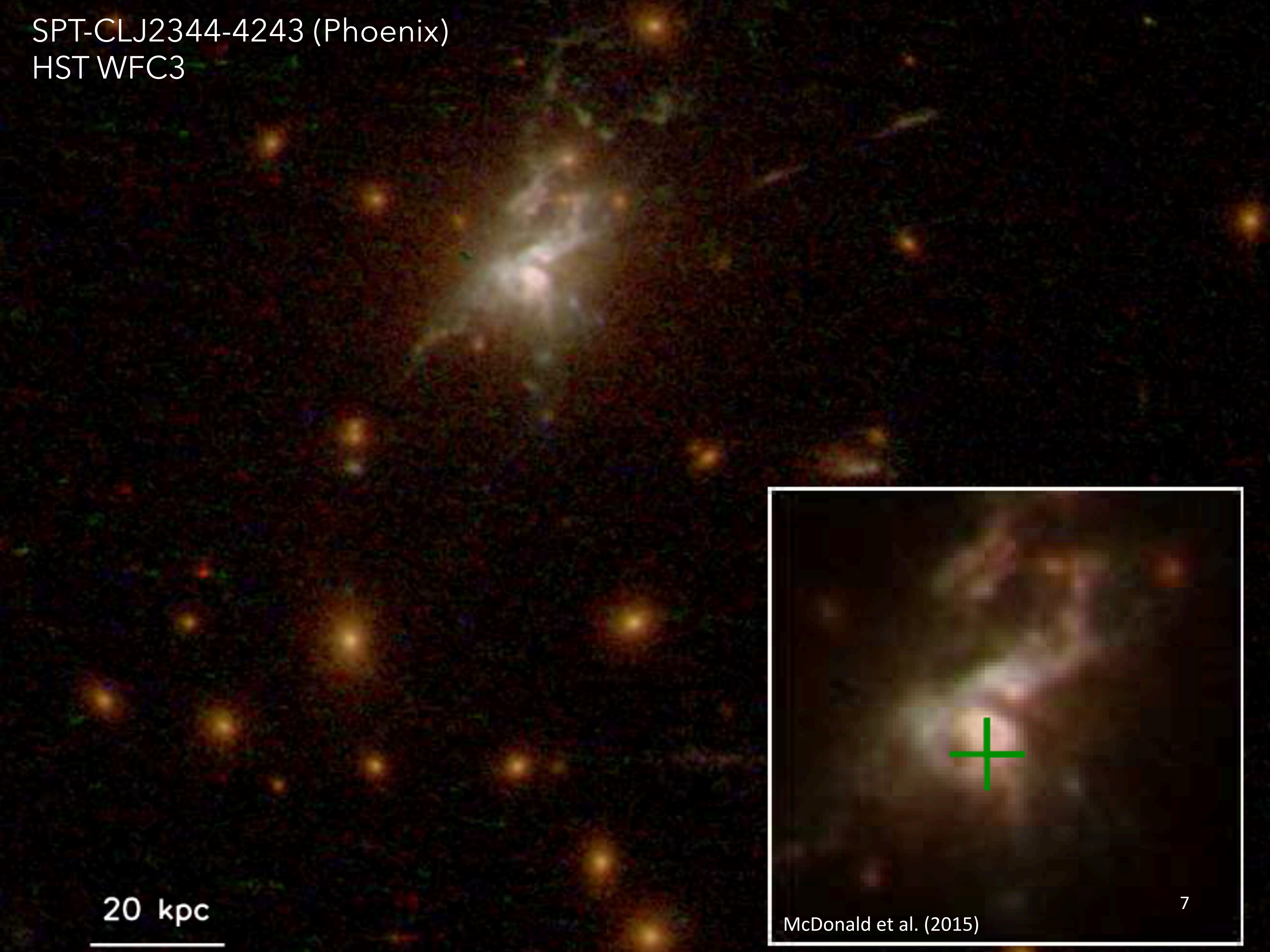
Environmental Quenching

Mass Quenching

AGN Feedback

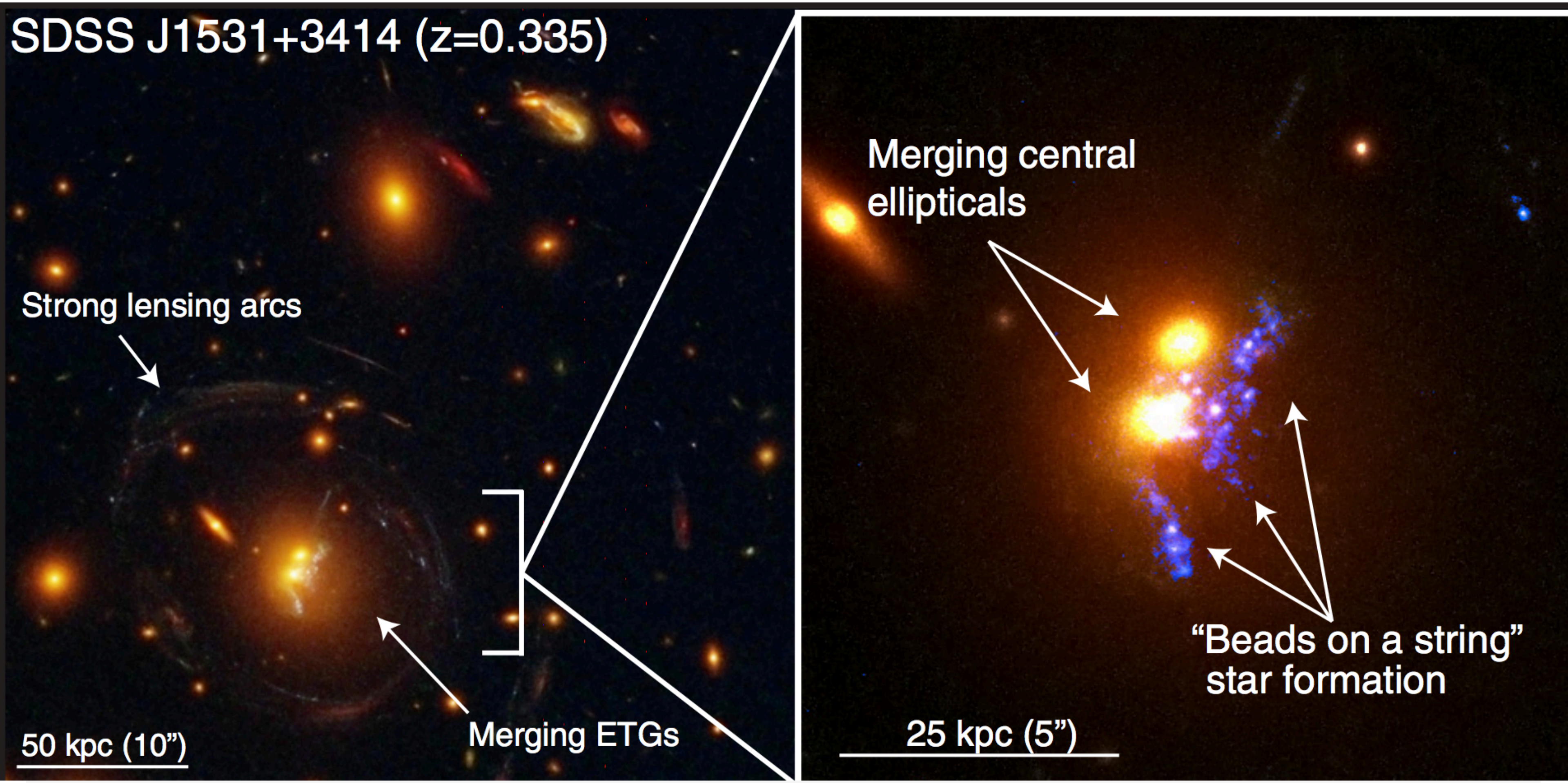
Abell S740
HST ACS/WFC



NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

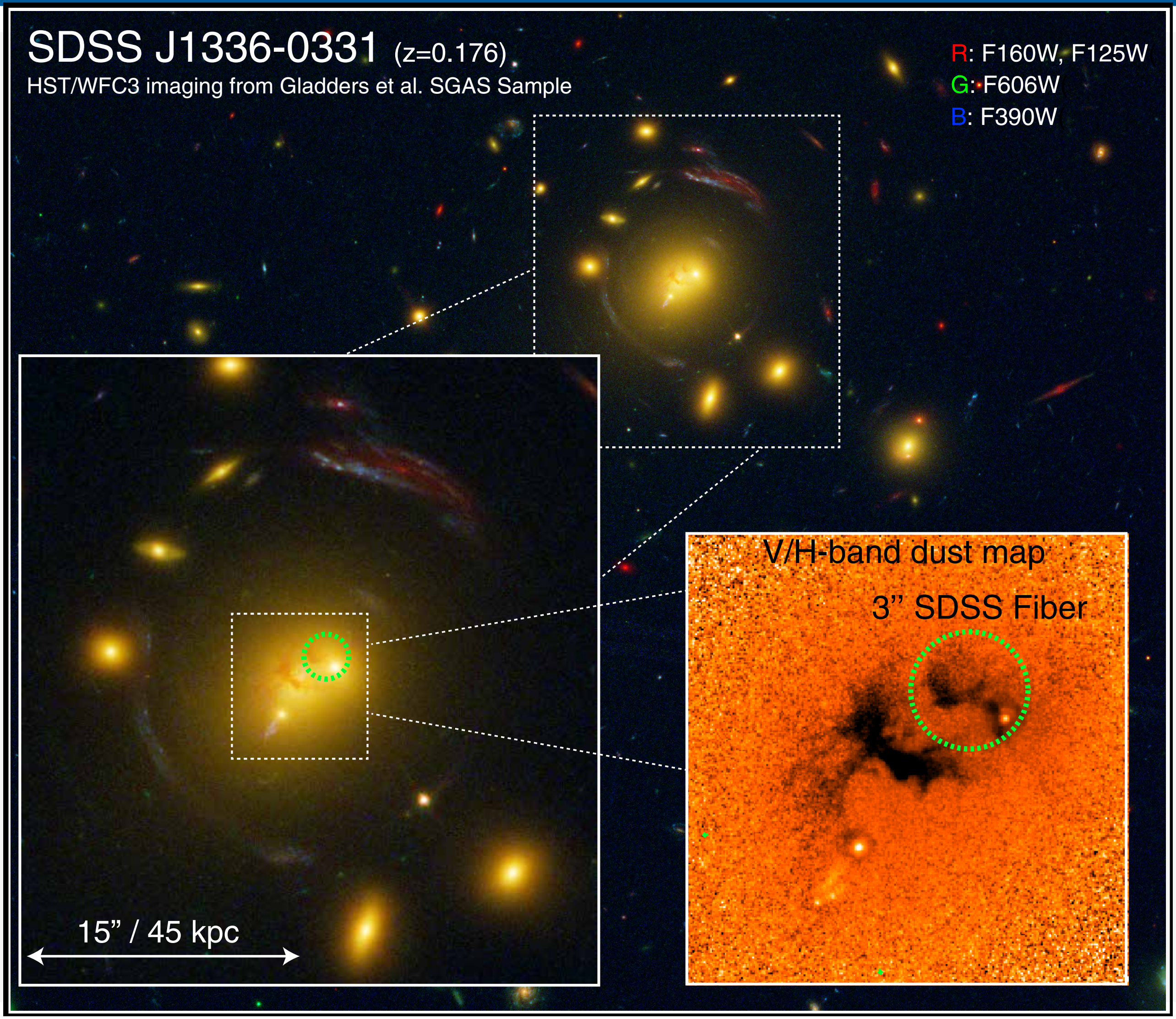

SPT-CLJ2344-4243 (Phoenix)
HST WFC3
20 kpc
McDonald et al. (2015)

MERGER INDUCED STAR FORMATION



Tremblay et al. (2014)

MERGER INDUCED STAR FORMATION



Cooke et al. (2016)

WHAT ABOUT HIGH REDSHIFT?

- There already exists a population of quenched early-type galaxies beyond $z > 1$ (e.g., Glazebrook et al. 2004).
- High redshift candidates have ½ - ¼ the effective radius when comparing $z = 1.4$ galaxies to present day (e.g., Daddi et al. 2005).
- Yet we still observe some unique systems forming stars near present day.

BCG PROGENITOR INVESTIGATION

- Need to identify high redshift progenitors and determine when star formation is no longer sufficient to sustain further growth.

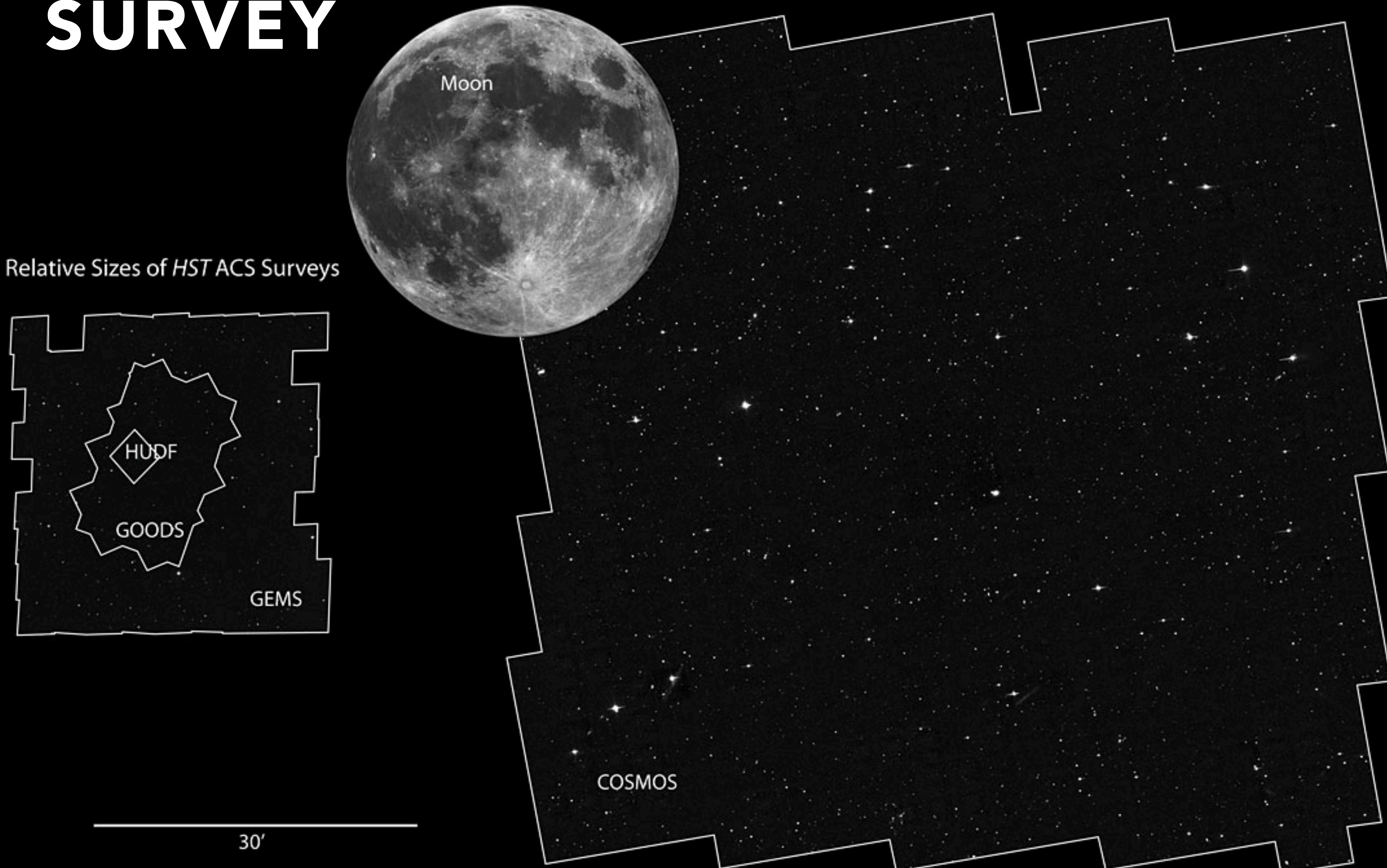
- Consider local environment to identify precursors to today's dense environments.

- COSMOS is complete above $10^{10.1}$ $M_{\odot}$ to z ~ 3 (Laigle et al. 2016).

- Several methods are in use to identify galaxy progenitors.
  - Mass Selection
  - Constant co-moving number density
  - Evolving co-moving number density

e.g., van Dokkum et al. (2010), Torrey et al. (2017)

COSMOS SURVEY

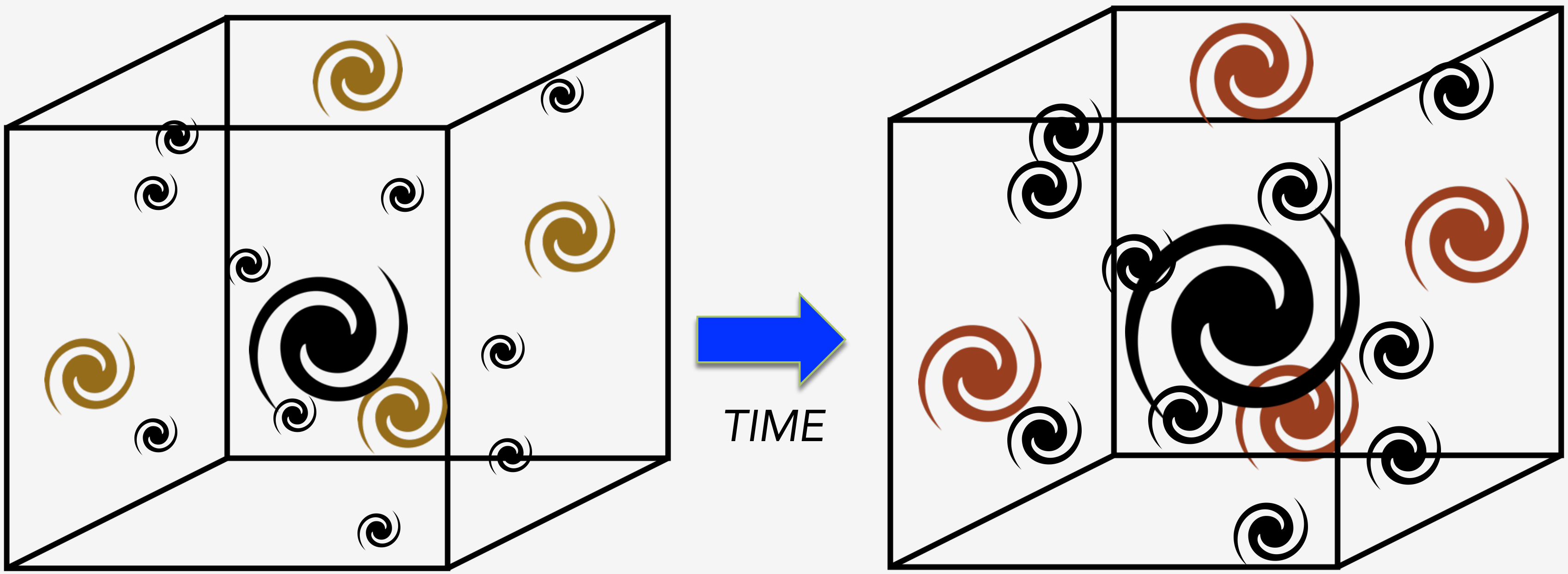


NASA, ESA

cosmos.astro.caltech.edu

CONSTANT CO-MOVING NUMBER DENSITY METHOD

- As star formation is correlated to galaxy stellar mass, a population of a given mass will grow in a similar manner. The density of that population remains unchanged.



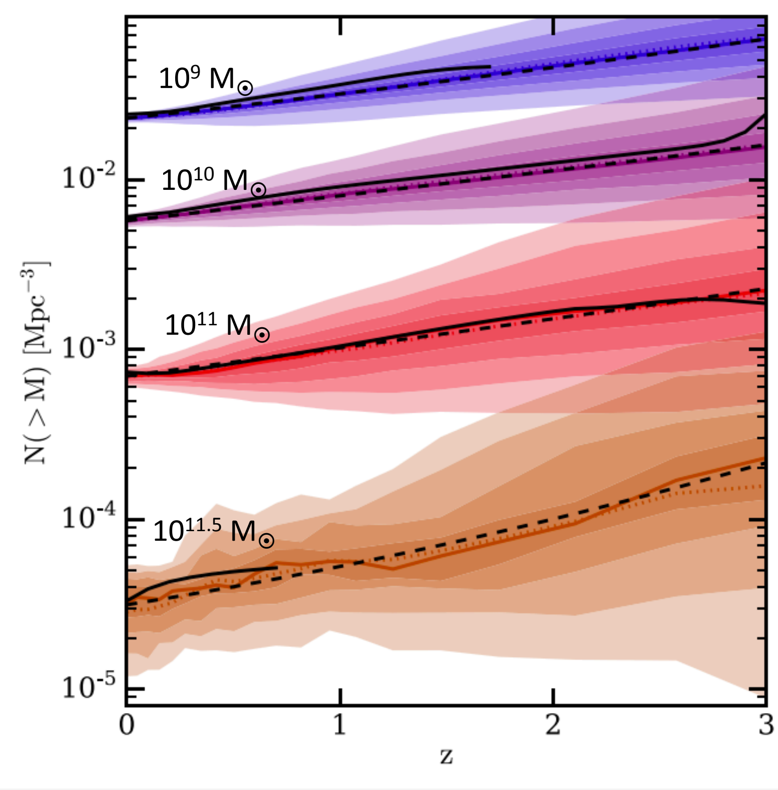
Cooke et al. (2019)

M_{*early} corresponds to the same N_{gal} as $M_{*,\ late}$.

EVOLVING CO-MOVING NUMBER DENSITY METHOD

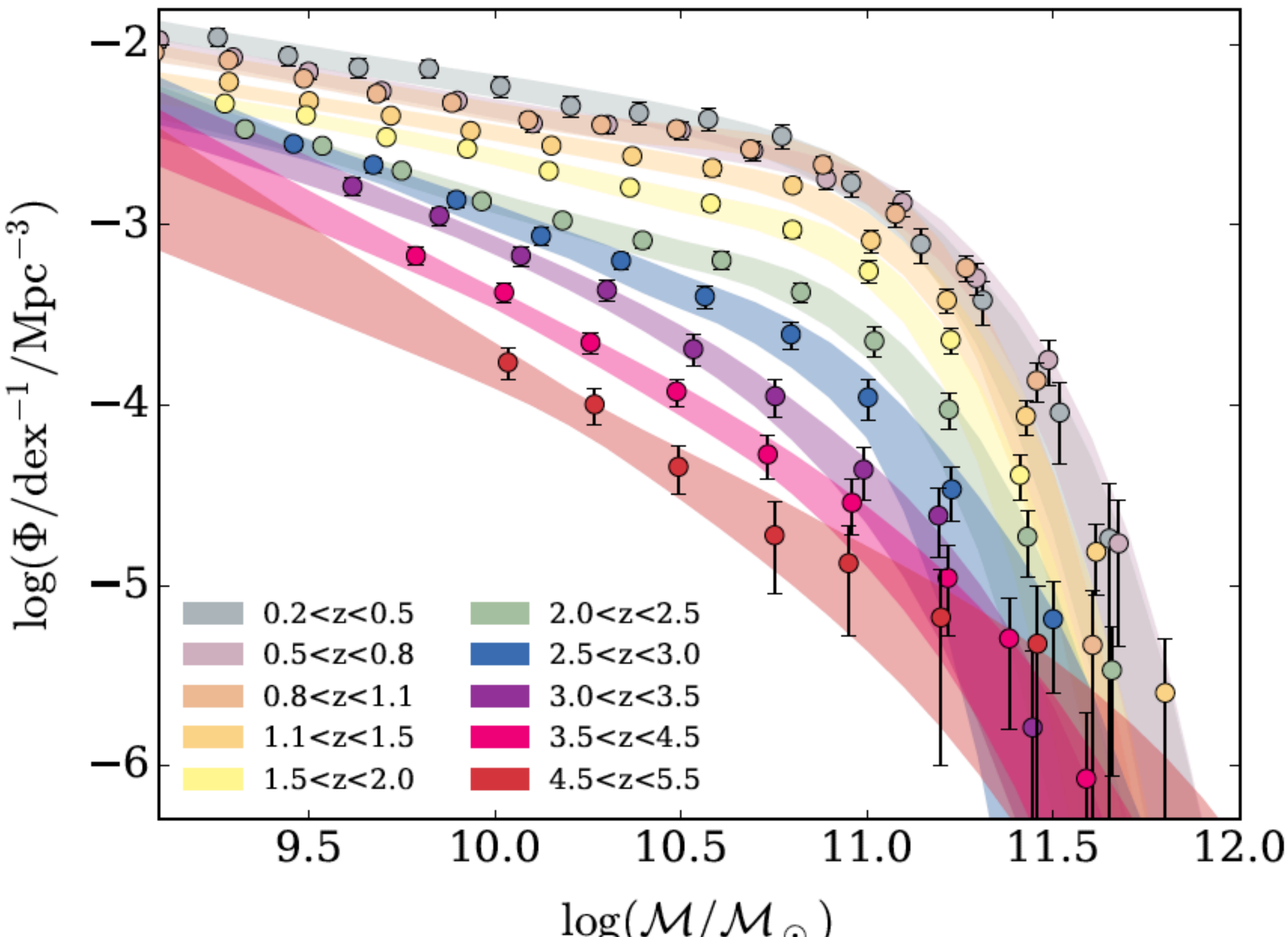
- Mergers complicate this picture. While major mergers at this extreme mass range are rare, they will happen over time and especially in proto-cluster environments.

- To correct for mergers, the selection density increases with increasing redshift as more merger partners are selected.



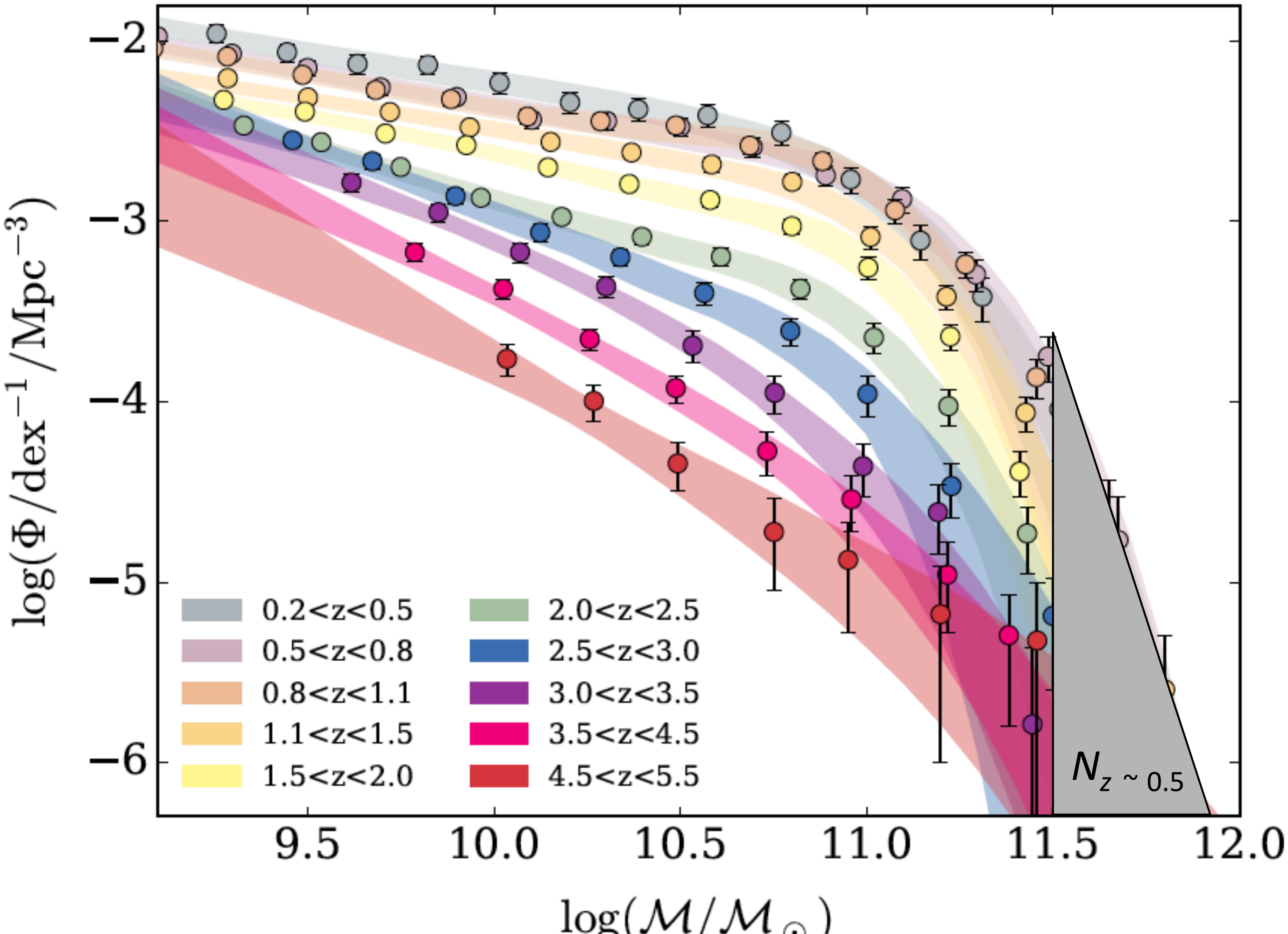
Rodriguez-Gomez et al. (2015), Torrey et al. (2017, & private comm.)

EVOLVING CO-MOVING NUMBER DENSITY METHOD



Davidzon et al. (2017)

EVOLVING CO-MOVING NUMBER DENSITY METHOD



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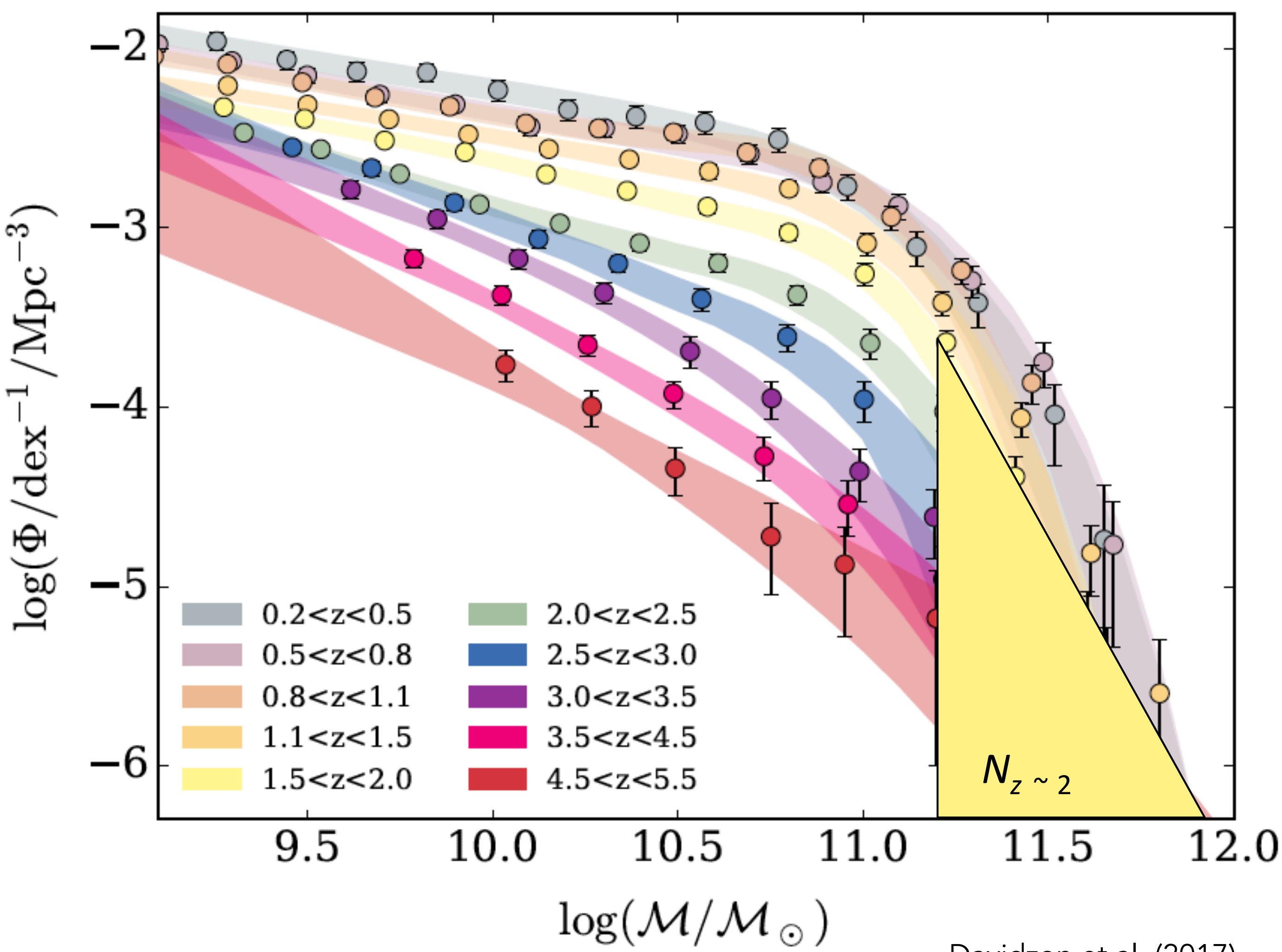
EVOLVING CO-MOVING NUMBER DENSITY METHOD



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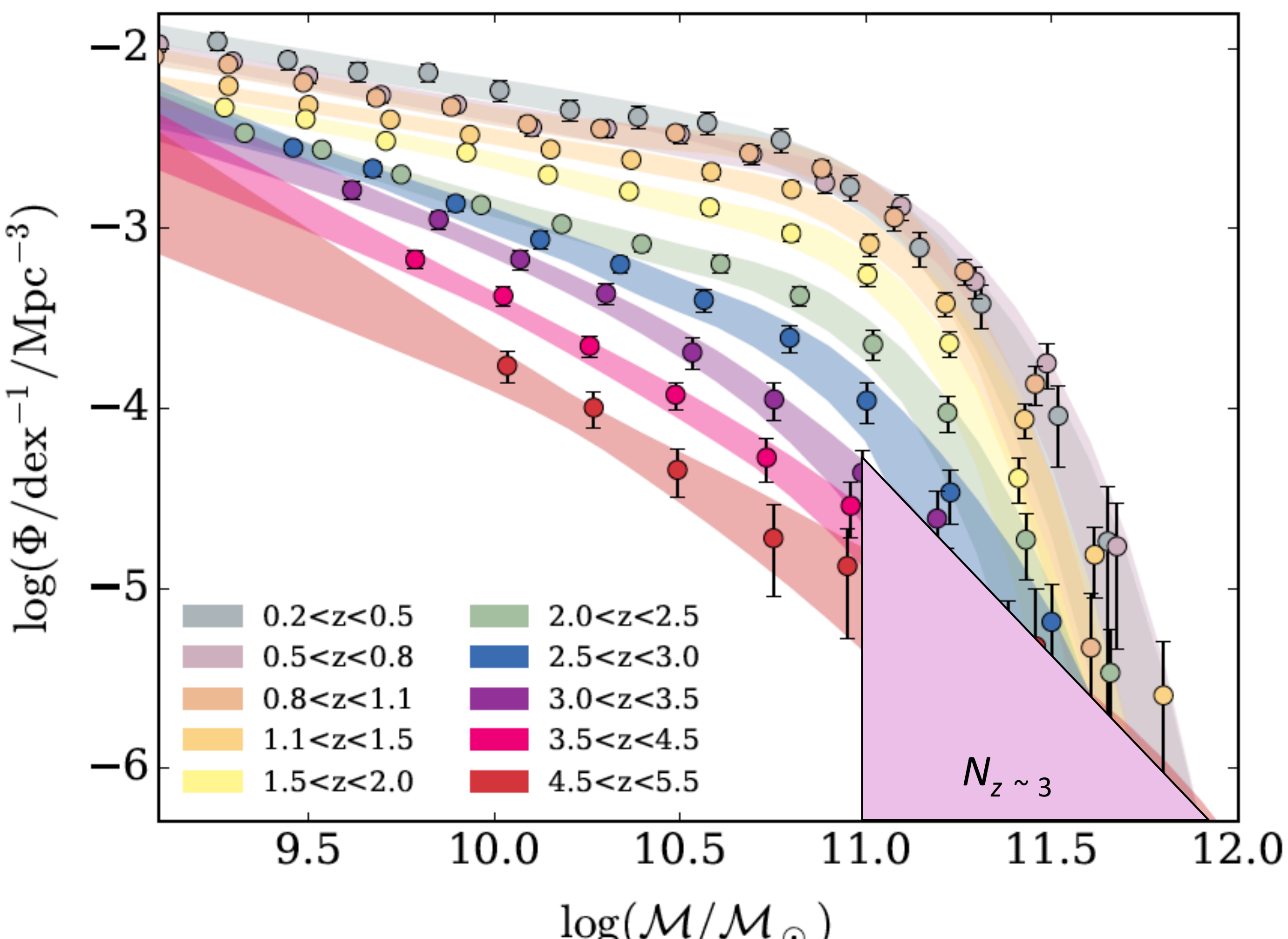
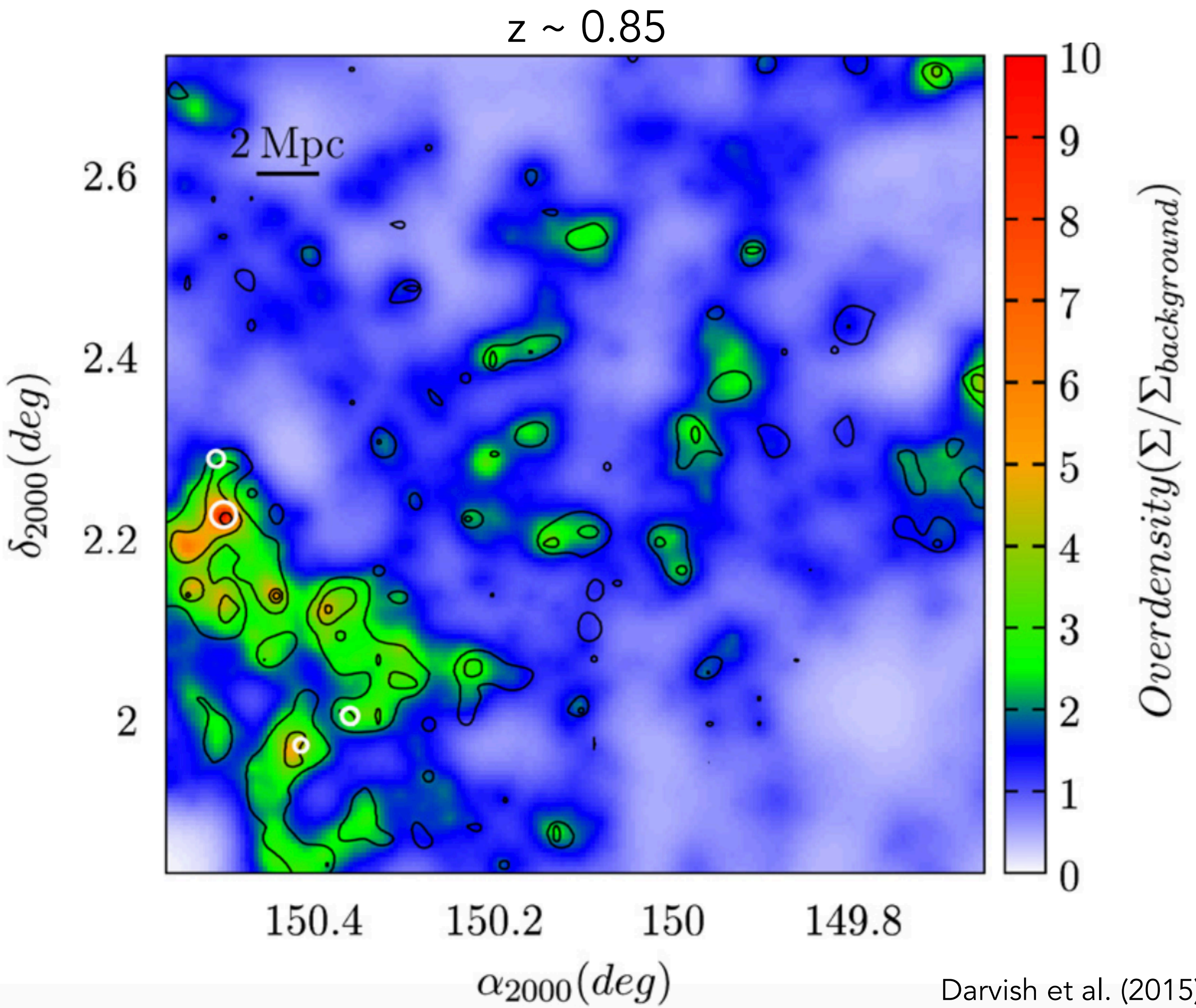
EVOLVING CO-MOVING NUMBER DENSITY METHOD



Davidzon et al. (2017)

COSMOS DENSITY MAPS



Darvish et al. (2015)

Dense

$> 2\ \Sigma_{Background}$

Intergroup

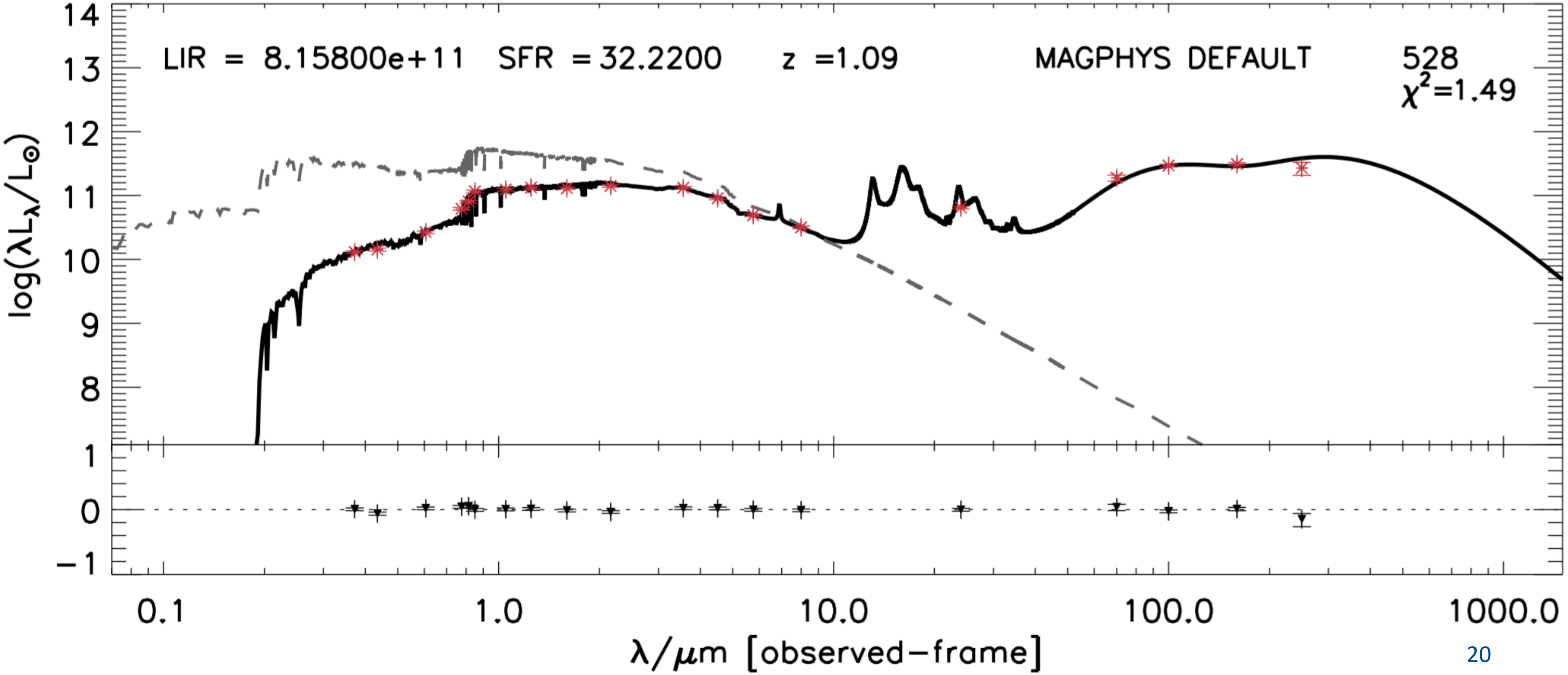
$1 < \Sigma/\Sigma_{Background} < 2$

Field

$< \Sigma_{Background}$

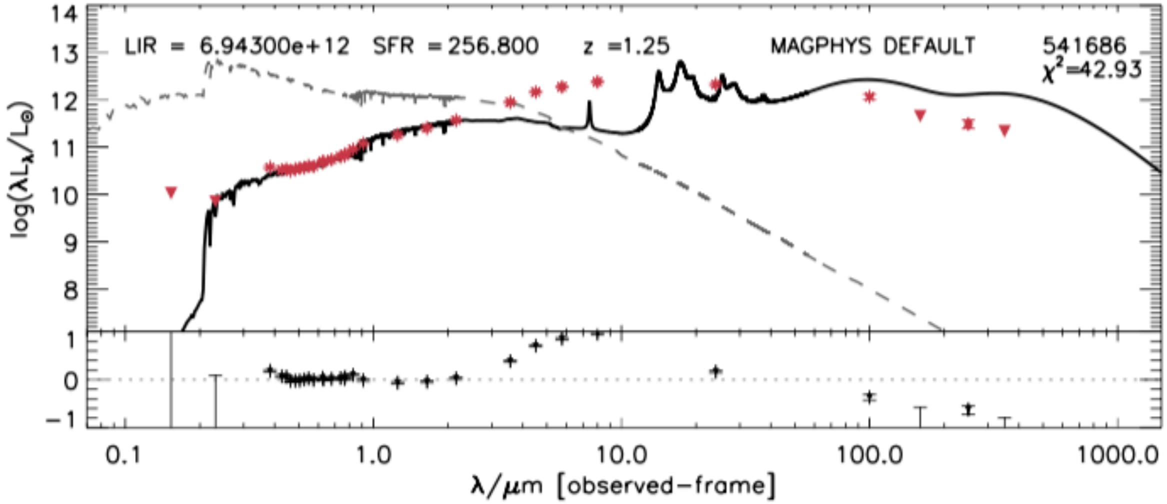
PROGENITOR CHARACTERIZATION

- MAGPHYS:
  - **Total**
  - Stellar (no attenuation)

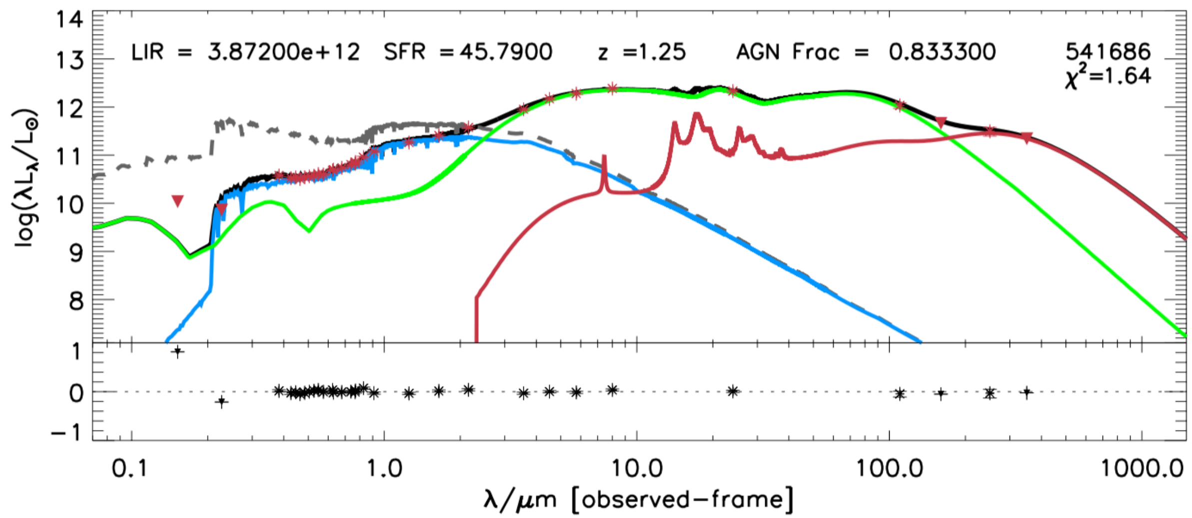


PROGENITOR CHARACTERIZATION

- Obj:541686
- MAGPHYS:
  - **Total**
  - Stellar (no attenuation)

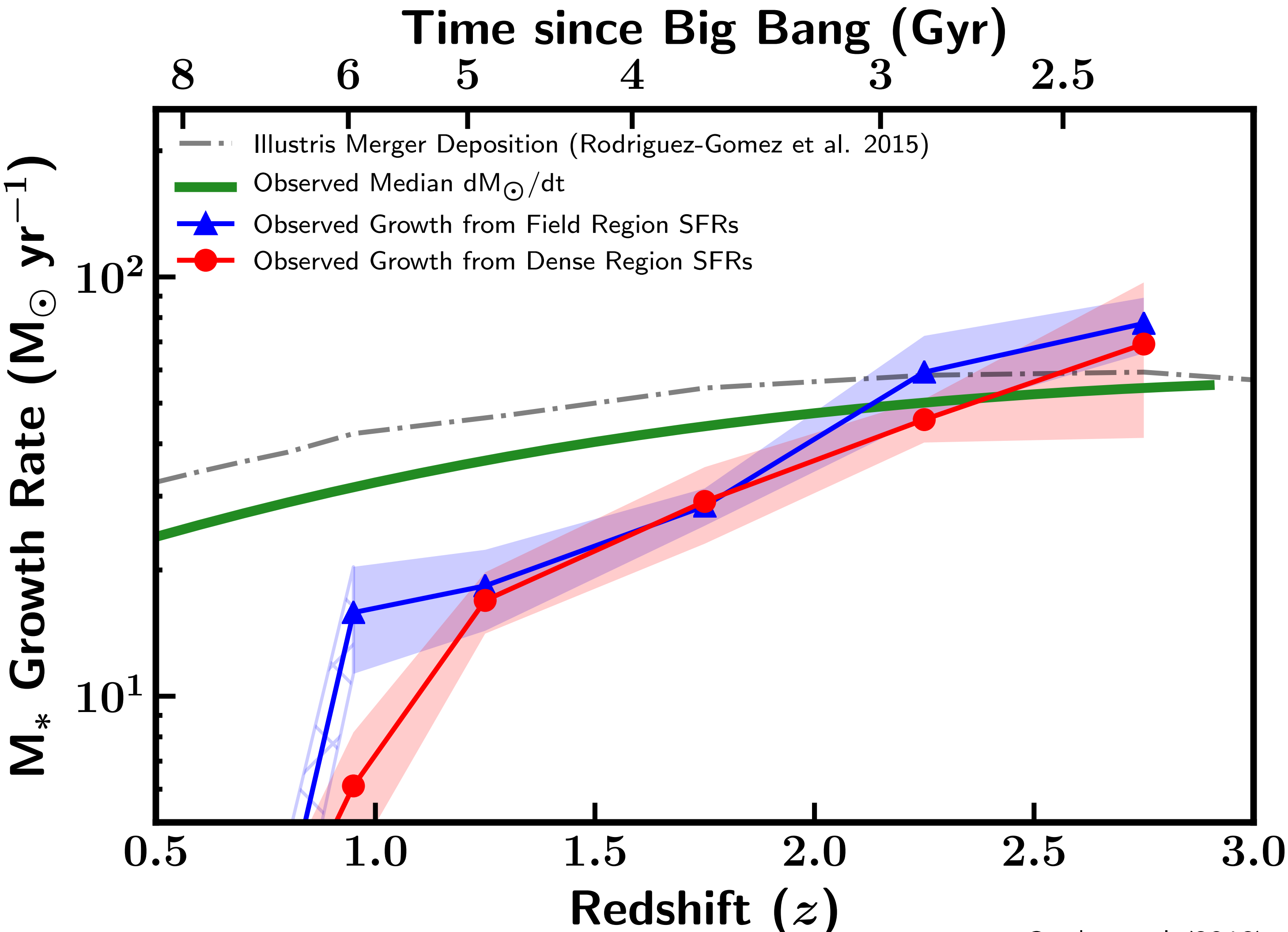


- SED3FIT:
  - **Total**
  - Pure Stellar
  - Att. Stellar
  - Dust
  - AGN



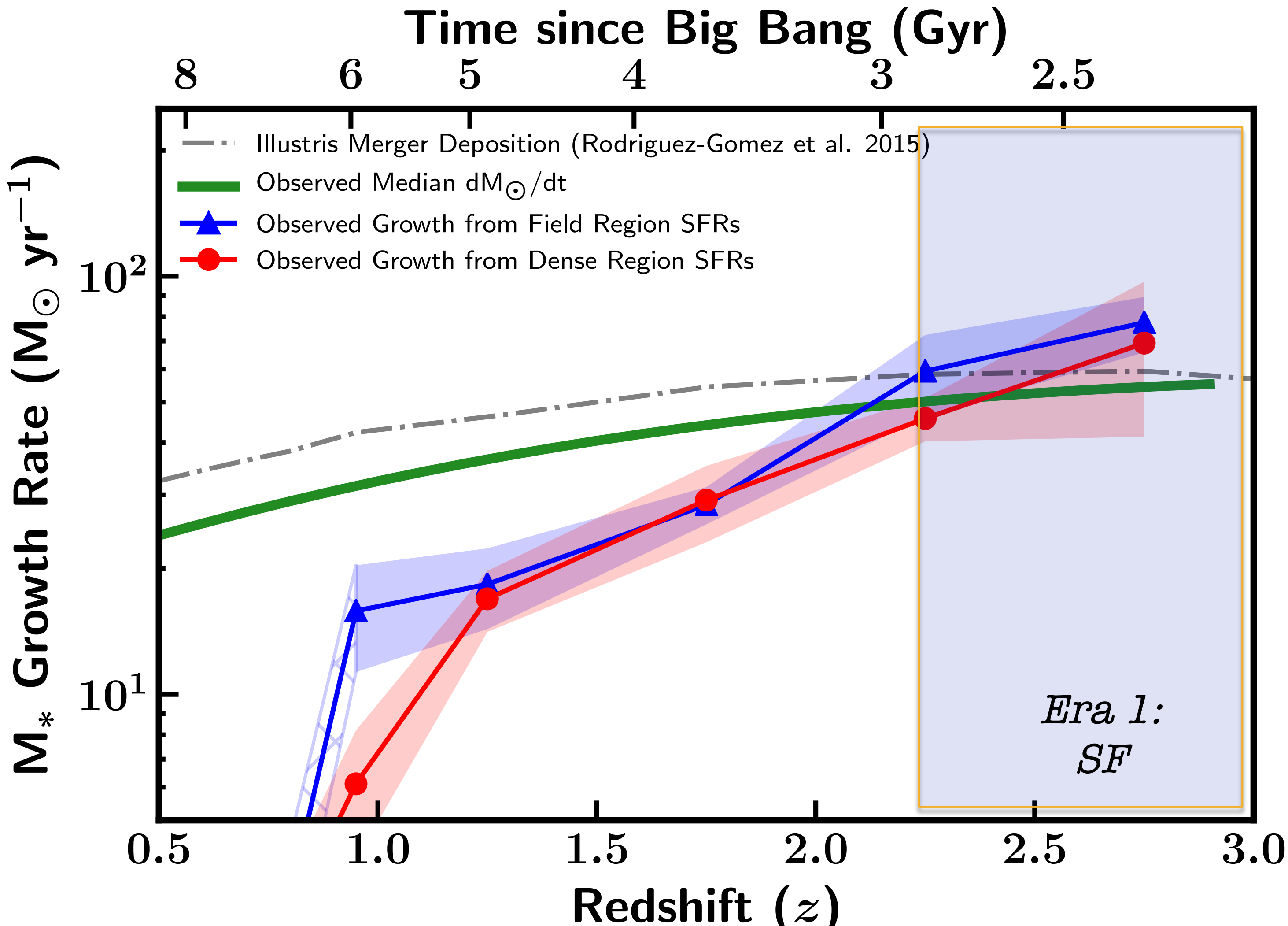
da Cunha et al. (2008), Berta et al. (2013)

PROGENITOR GROWTH RESULTS



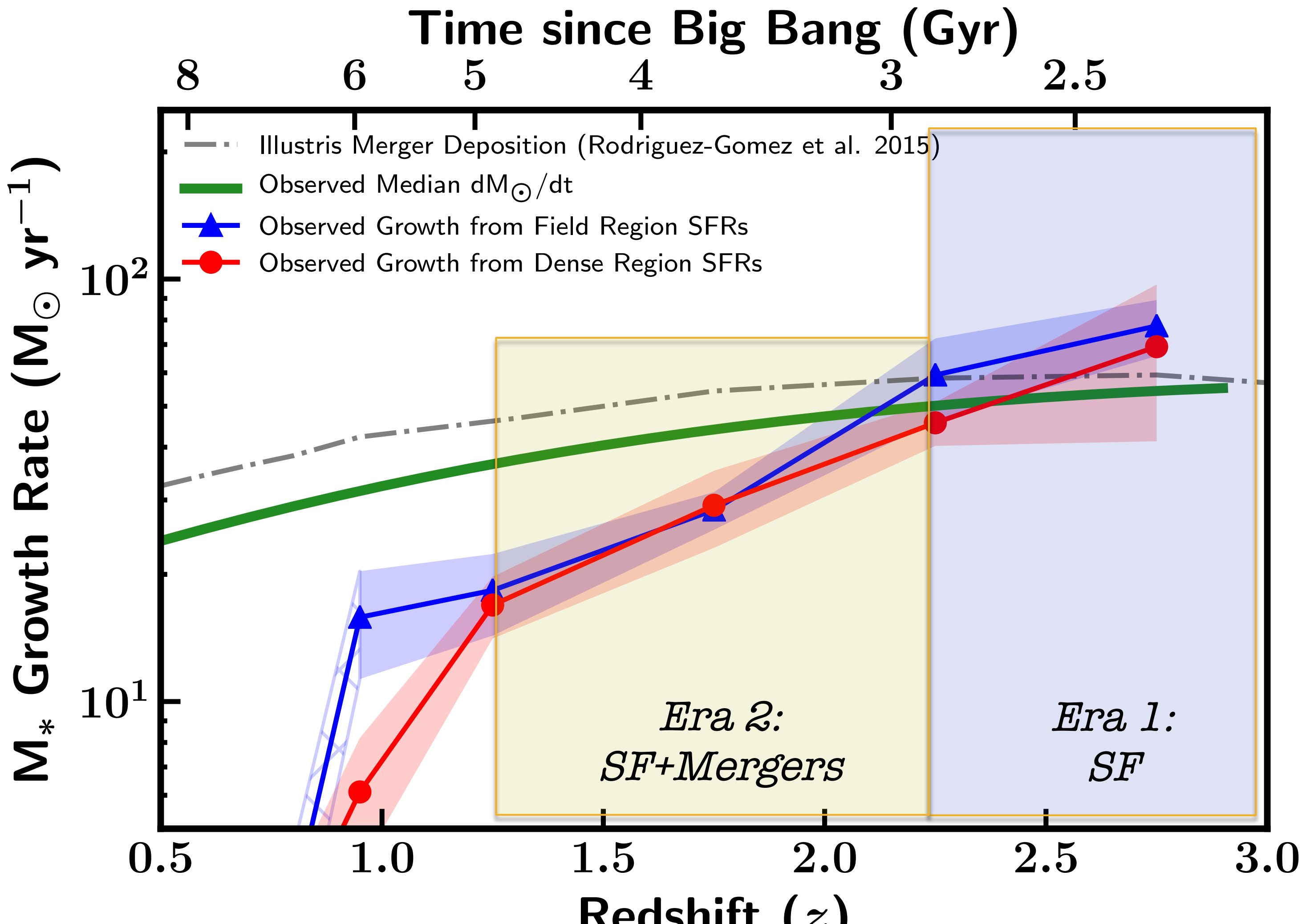
Cooke et al. (2019)

PROGENITOR GROWTH RESULTS



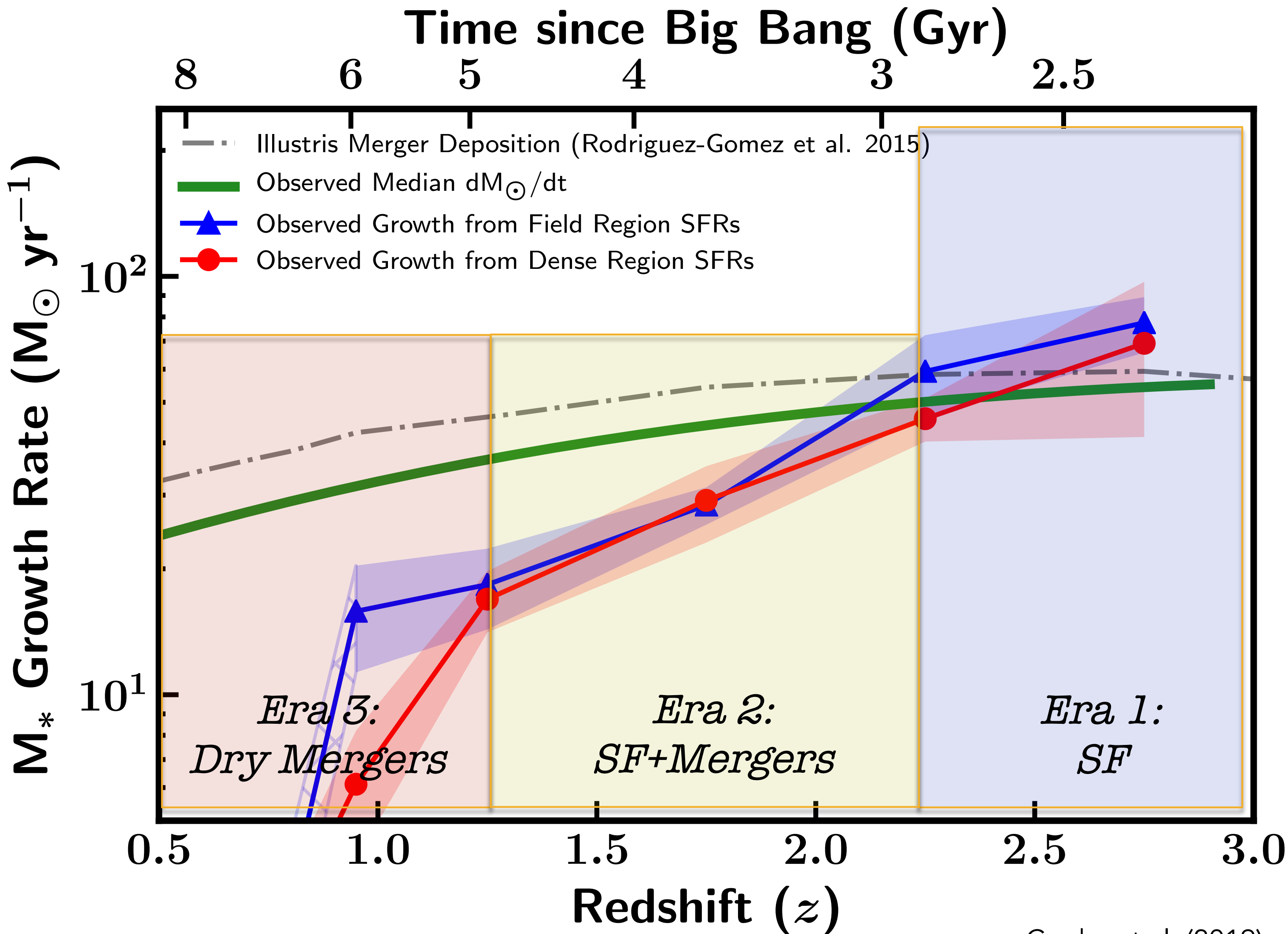
Cooke et al. (2019)

PROGENITOR GROWTH RESULTS



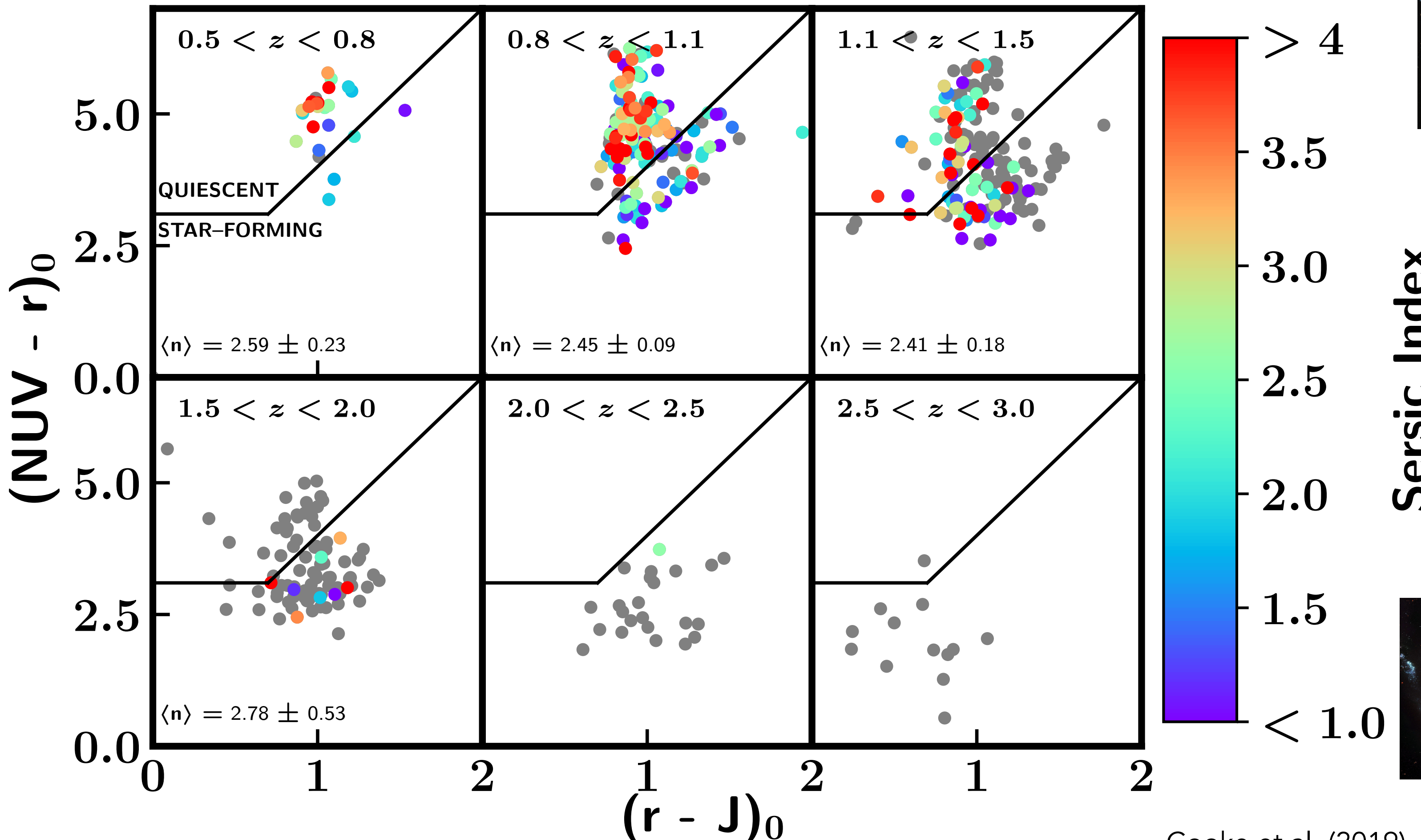
Cooke et al. (2019)

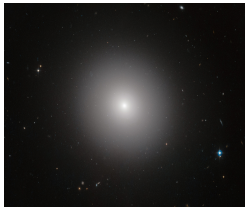
PROGENITOR GROWTH RESULTS



Cooke et al. (2019)

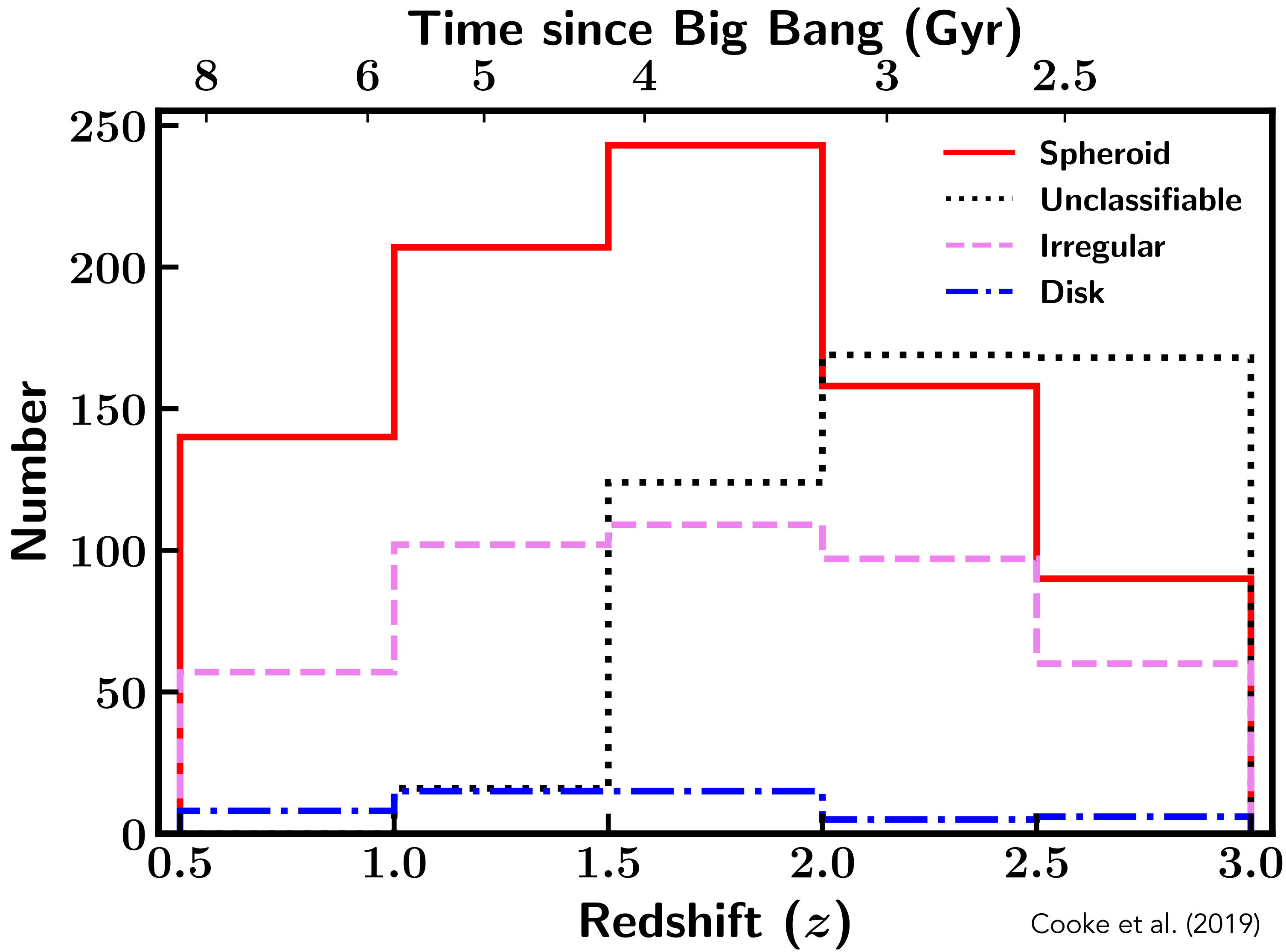
LIGHT PROFILE EVOLUTION





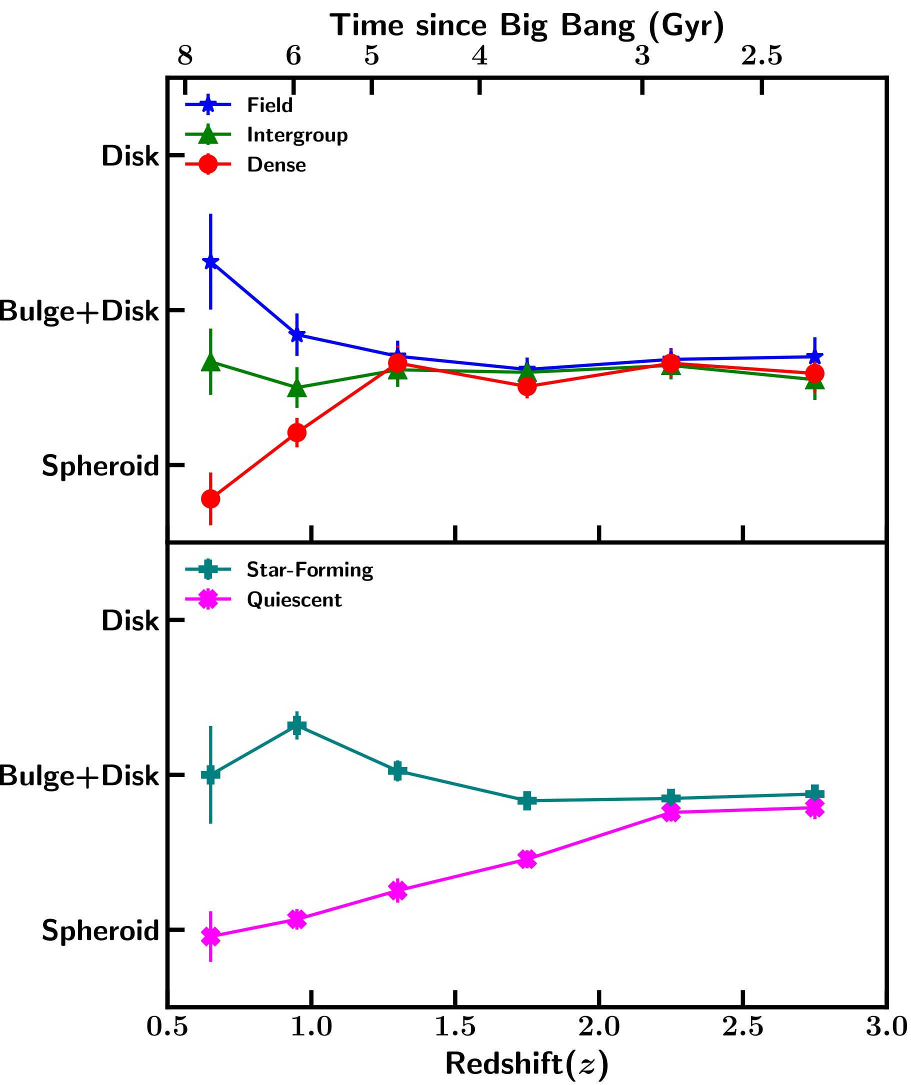
Cooke et al. (2019)

PROGENITOR MORPHOLOGY



Cooke et al. (2019)

EVOLUTION OF MORPHOLOGY



- We find that BCG progenitor morphologies are indistinguishable between different environments above z ~ 1.
- Quiescent progenitors become more spheroidal over time, while star-forming progenitors maintain a composite structure.

Cooke et al. (2019)

COOKE ET AL. (2019) CONCLUSIONS

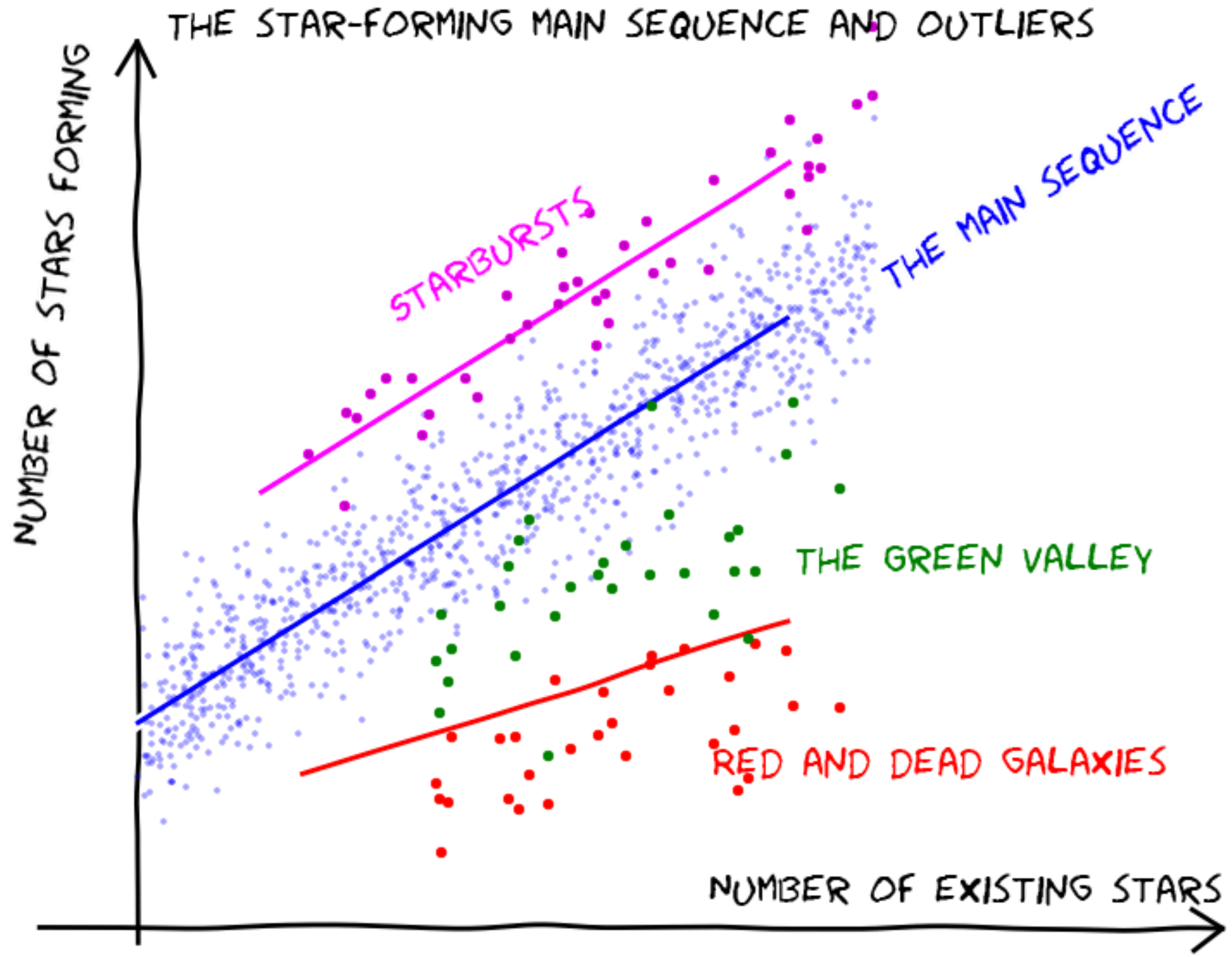
- Result: BCG progenitors grow through 3 phases consistent with observed merger rates, ***but independent of environment until low redshift (z ~ 1.1)***.

- The majority of BCG progenitors transition to a red, quiescent state after z ~ 1.1. However there is no detectable evolution in Sérsic index.

- Progenitors become more spheroidal with decreasing redshift in dense environments, while those in the field become diskier.

- How does this compare to the general population?

STAR FORMATION MAIN SEQUENCE



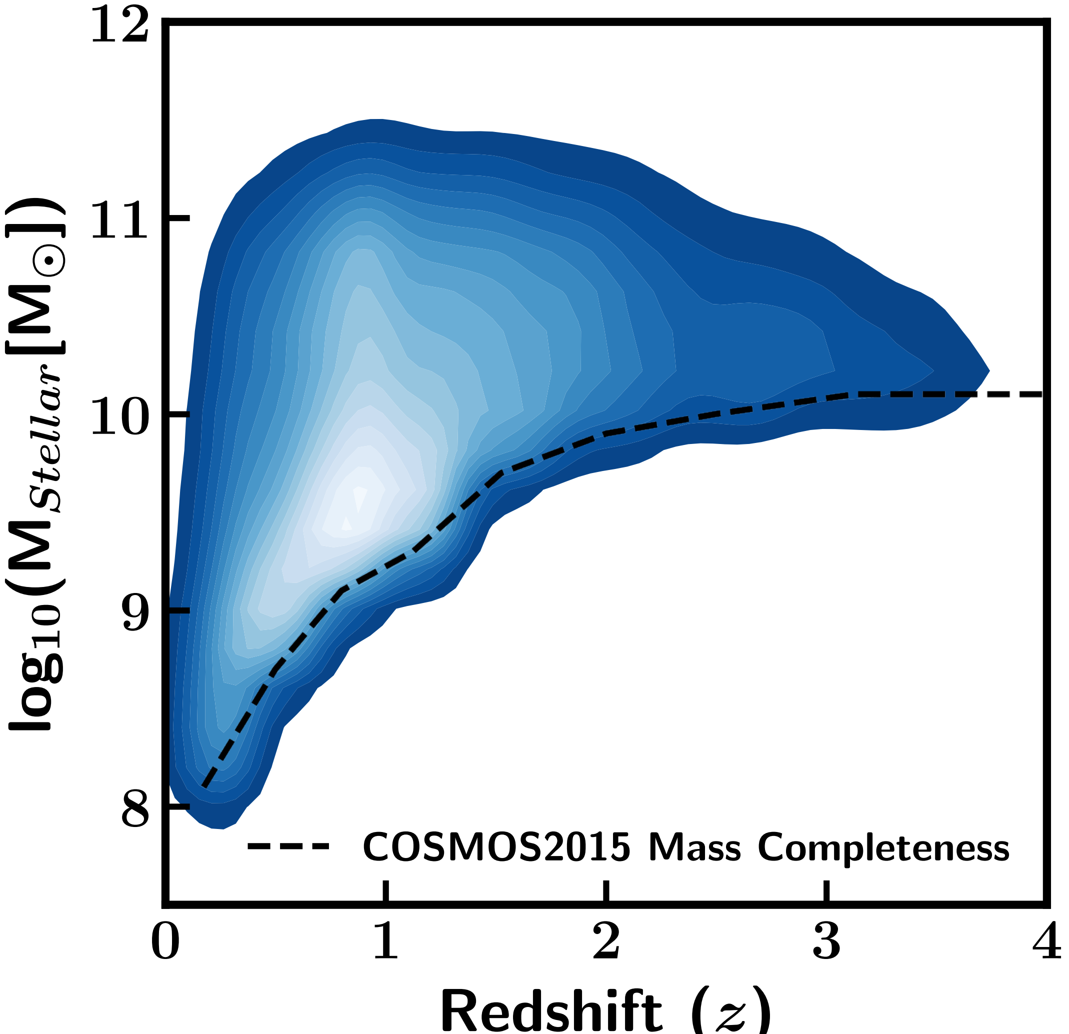
Harry Ferguson
http://candels-collaboration.blogspot.com/2013/02/star-formation-in-mountains.html

STATE OF THE STAR FORMATION MAIN SEQUENCE (SFMS)

- Shape of the SFMS has been observed out to z ~ 2.5 (Whitaker et al. 2012, Lee et al. 2015).
- Environmental effects on star formation have been observed out to z~1 (e.g., Darvish et al. 2018), but it is debatable at higher redshifts (Elbaz et al. 2007, Erfanianfar et al. 2015).
- Goal: Identify what redshifts and stellar mass bins any environmental dependence manifests.
- Build off previous COSMOS results, to higher redshifts and with sensitivity to environment.

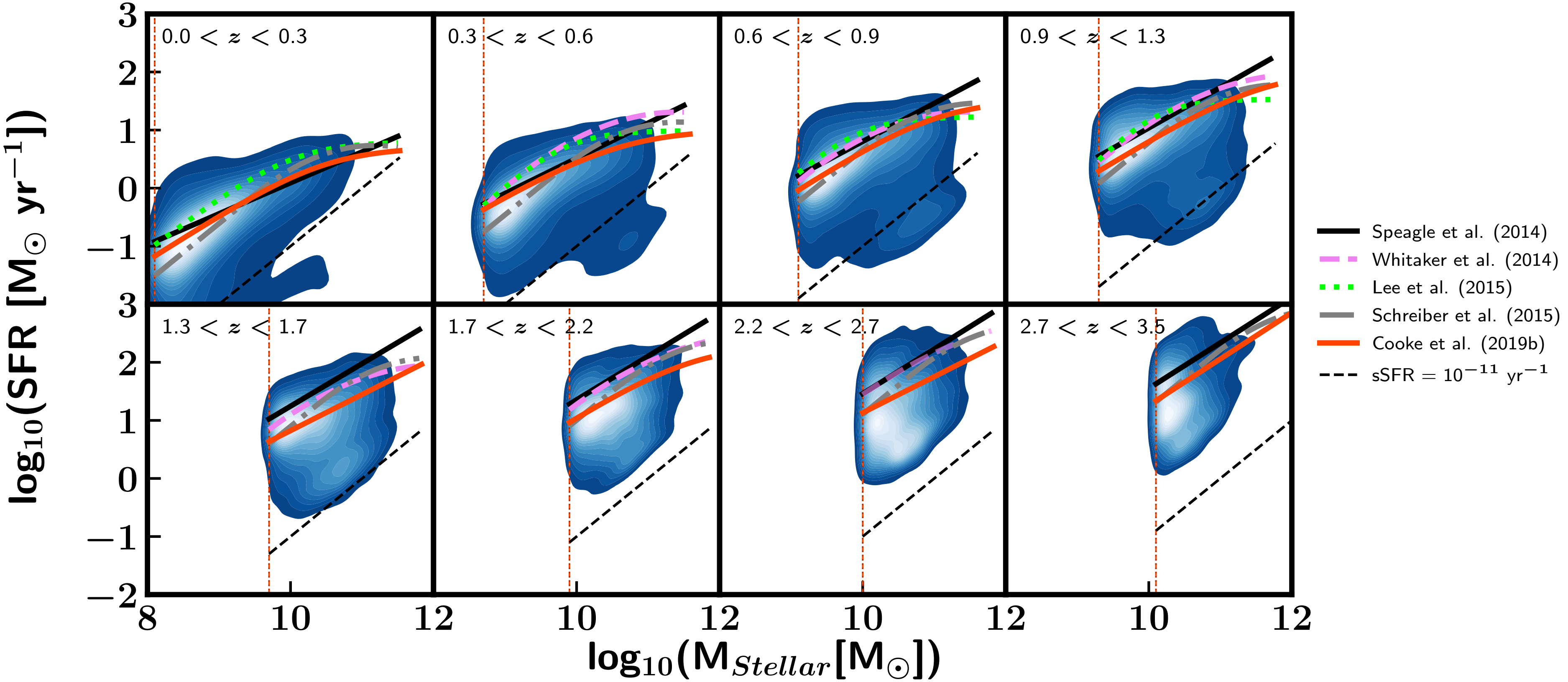
eg. van Dokkum et al. (2010), Torrey et al. (2017)

COSMOS MASS-COMPLETE SAMPLE



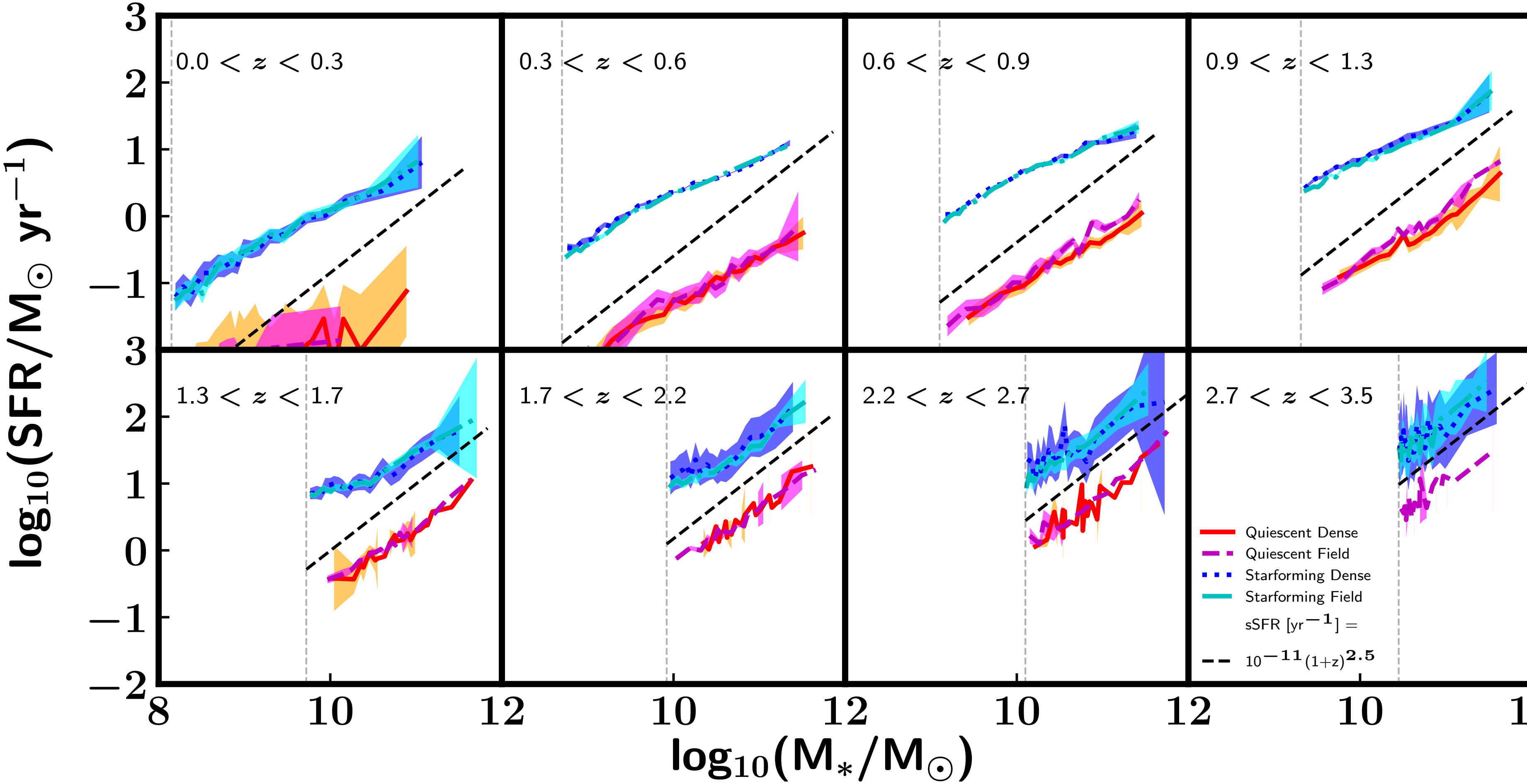
Cooke et al. (2020 in prep)

SFMS EVOLUTION WITH REDSHIFT



Cooke et al. (2020 in prep)

SFMS EVOLUTION SELECTED BY NUVrJ COLOR-COLOR



Cooke et al. (2020 in prep)

COSMOS SFMS CONCLUSIONS

- Result: We do not see evidence for a dependence with environment at z > 1. We also see no difference in the quiescent population as well.

- Next Steps: We are reducing the publically available WFC3/IR data from the MAST archive to expand the available Bulge-to-Total luminosity ratios to limit ourselves to only disk-dominated systems.

- As of now, the local environment is observed to play little part in affecting the median SFR behavior of galaxies at a given mass.

SF SHUTDOWN DUE TO AGN

- The radiant energy from an actively accreting SMBH can heat and unbind the cold gas component of the host galaxy (e.g. Hopkins et al. 2006).
  - However some targets remain star-forming while X-ray bright (e.g. (Salome et al. 2015; Mahoro et al. 2017, Perna et al. 2018).
- Goal: Understand how AGN shut down star-formation
  - Find the rare objects where the cold gas remains while an AGN is active.
- Kirkpatrick et al. (2020) identified such a population using the Stripe 82X survey. (LaMassa et al. 2016)

Nature

COLD QUASARS

- Cold quasars are a population of unobscured, IR-detected quasar.
  - $Lx > 10^{44}$ ergs/s
  - $S_{250} > 30$ mJy
  - Combination of X-ray and IR detection selects for the narrow timeframe where the AGN has not cleared the gas.

- Found 4% of X-ray and optically selected quasars, loosely constraining their stage to last ~10^6 yrs.

- SFR ~ 200-1000 M/yr

- $\log_{10}(M_*/M_{sol}) \sim 10.5\text{-}11.2$

CQ 507, z = 1.6
DECam grz
Kirkpatrick et al. (2020)

COLD QUASAR FOLLOW UP

- Kirkpatrick et al. followed up on a sample of lower X-ray luminosity targets.
  - 0.5x the original X-ray cutoff

- SOFIA HAWC+ Band C (89 microns) total intensity observations.

- Met with technical difficulties at first....

NASA

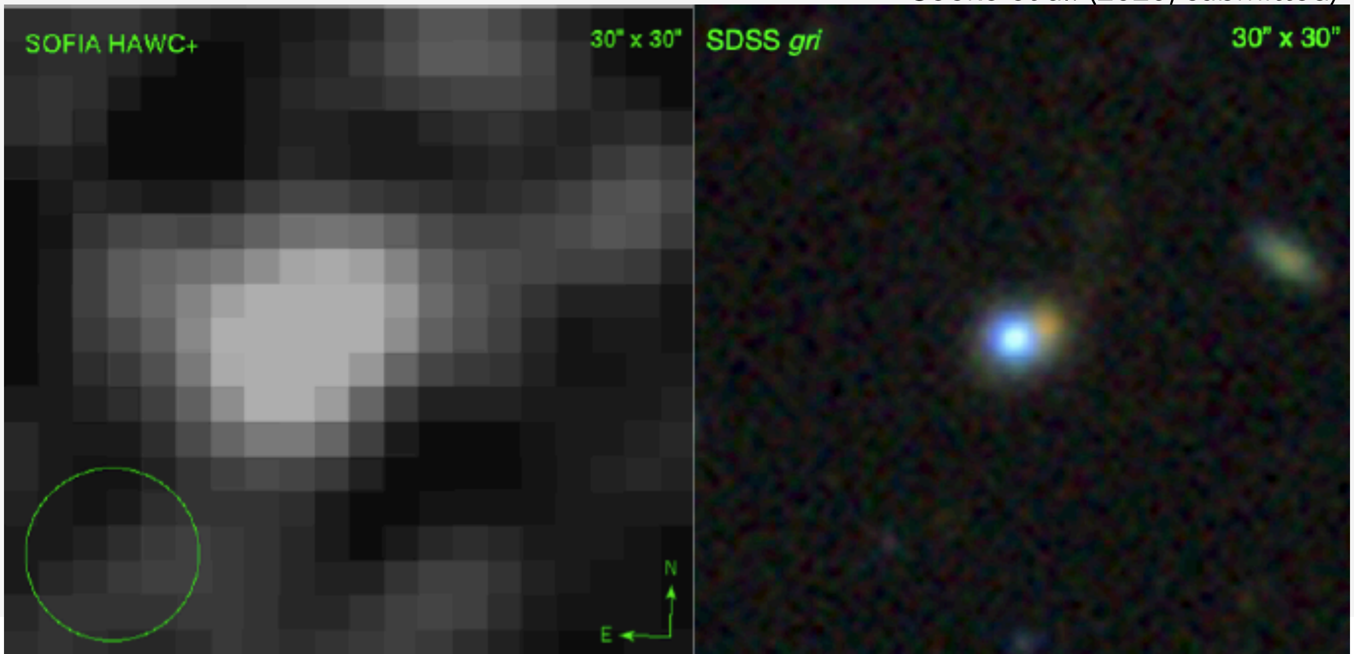
COLD QUASAR FOLLOW UP

- Kirkpatrick et al. followed up on a sample of lower X-ray luminosity targets with SOFIA HAWC+ Band C (89 microns) total intensity observations.

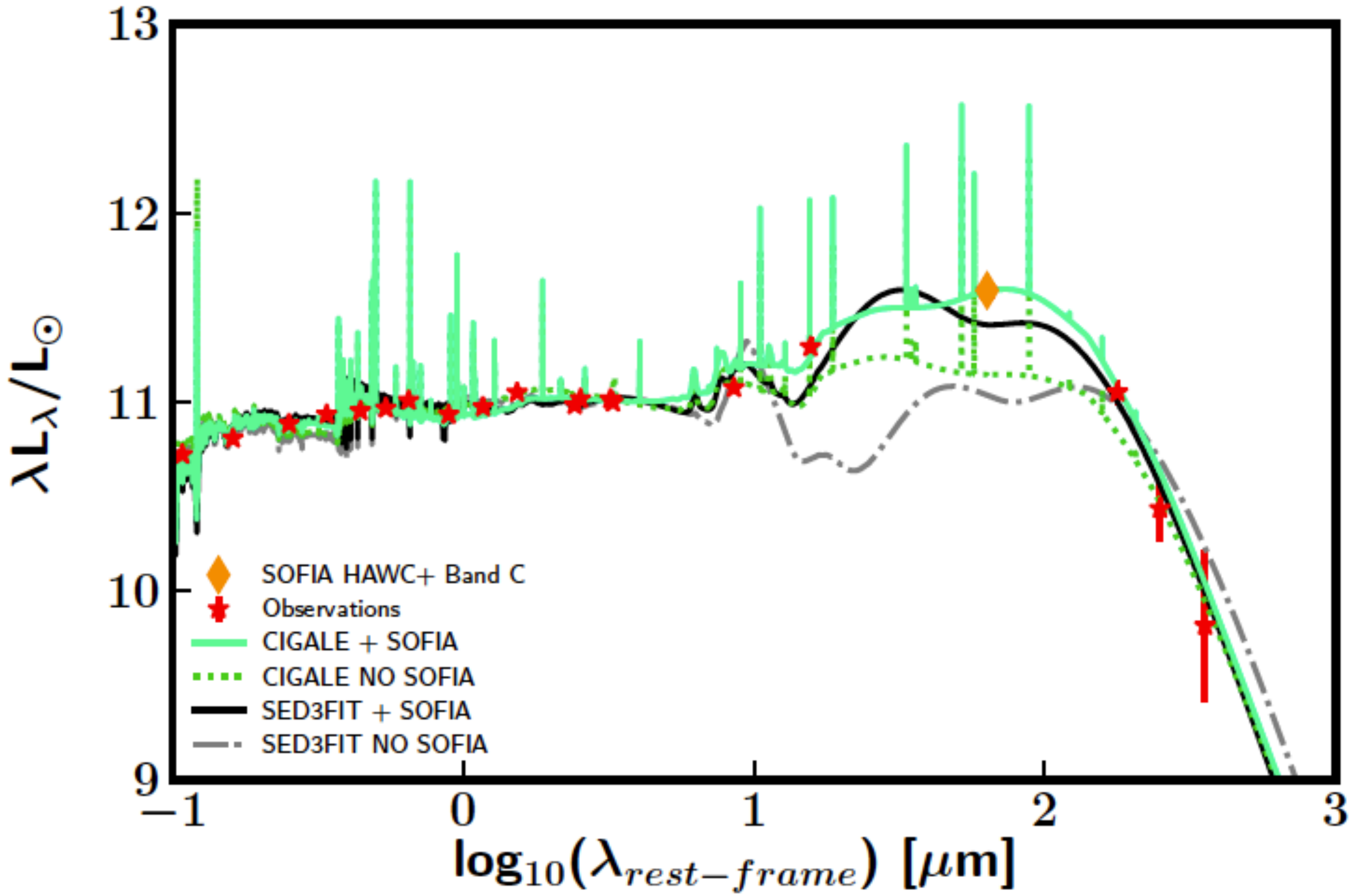
- Detection! 75.42 +/-14.2 mJy at (SNR = 5.31) at z = 0.405!

CQ4479

Cooke et al. (2020, submitted)



WHY SOFIA?



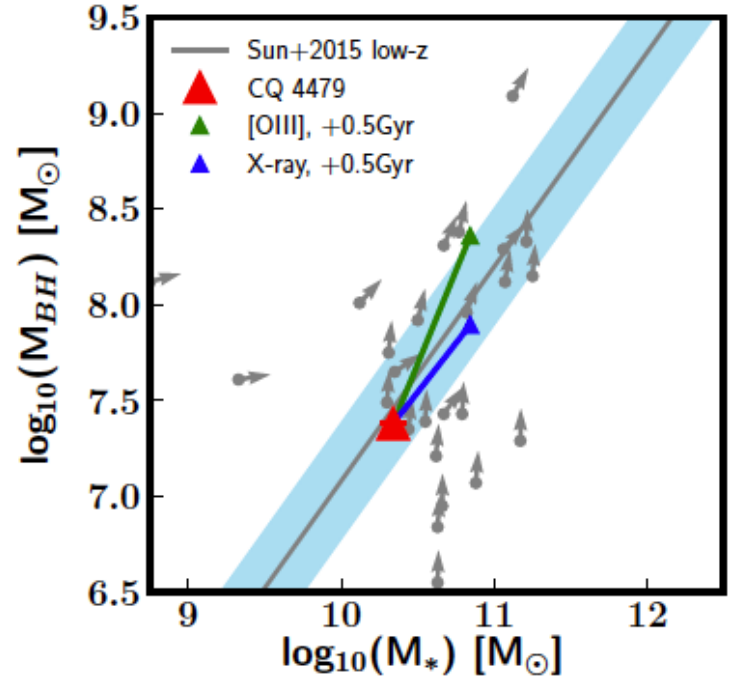
Cooke et al. (2020, submitted)

COOKE ET AL. (2020, SUB) RESULTS

- We find that cold quasars behave similarly to previously observed samples of Herschel-detected broad-line AGN (Sun+2015)
  - We use SDSS optical spectra and Stripe 82X X-ray to find SMBH accretion rates.

- SMBH and stellar component are growing in lock-step, indicating this is truly an early stage where SFR is not shutting down.

- Future Work: Delve deeper into comparing cold quasars with red quasars (Urrutia et al. 2012, Glikman et al. 2017) and hotDOGs (Ricci et al. 2017).



Cooke et al. (2020, submitted)

REVIEW AND THE FUTURE

- We find that BCGs at $z < 1$ can exhibit rare episodes of star formation triggered by major gas rich mergers.

- Progenitors at $z > 1$ are a diverse population of ellipticals and irregulars which are often star-forming at $z > 2$.
  - Examined environmental dependences at higher redshifts than previously studied.

- Cold quasars represent AGN hosts at the transition point between star-forming and quiescent
  - Provide new information on the co-temporal growth of the SF and AGN.

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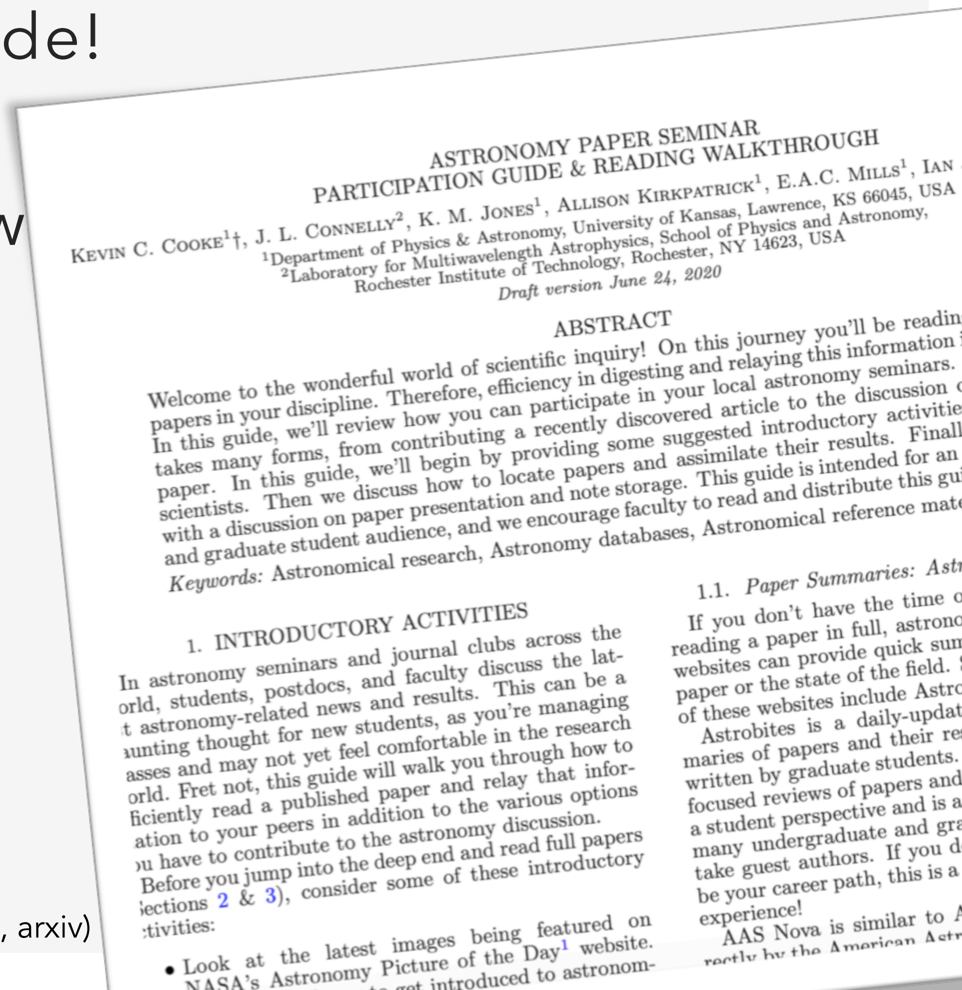

ASTRONOMY PAPER SEMINAR
PARTICIPATION GUIDE & READING WALKTHROUGH

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Draft version June 24, 2020

ABSTRACT

Welcome to the wonderful world of scientific inquiry! On this journey you'll be readin papers in your discipline. Therefore, efficiency in digesting and relaying this information i In this guide, we'll review how you can participate in your local astronomy seminars. takes many forms, from contributing a recently discovered article to the discussion c paper. In this guide, we'll begin by providing some suggested introductory activitie scientists. Then we discuss how to locate papers and assimilate their results. Finall with a discussion on paper presentation and note storage. This guide is intended for an and graduate student audience, and we encourage faculty to read and distribute this gui

Keywords: Astronomical research, Astronomy databases, Astronomical reference mate

1. INTRODUCTORY ACTIVITIES

In astronomy seminars and journal clubs across the orld, students, postdocs, and faculty discuss the lat-t astronomy-related news and results. This can be a aunting thought for new students, as you're managing asses and may not yet feel comfortable in the research orld. Fret not, this guide will walk you through how to ficiently read a published paper and relay that infor-ation to your peers in addition to the various options u have to contribute to the astronomy discussion. Before you jump into the deep end and read full papers ections 2 & 3), consider some of these introductory tivities:

- Look at the latest images being featured on NASA's Astronomy Picture of the Day[1] website.

1.1. *Paper Summaries: Astr*

If you don't have the time o reading a paper in full, astrono websites can provide quick sum paper or the state of the field. of these websites include Astro Astrobites is a daily-updat maries of papers and their re written by graduate students. focused reviews of papers and a student perspective and is a many undergraduate and gra take guest authors. If you d be your career path, this is a experience!
AAS Nova is similar to A

Cooke et al. (2020, arxiv)