UNCOVER: Significant Reddening in Cosmic Noon Quiescent Galaxies

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Speaker: Bing Yan

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CONTENT

1. Introduction

Galaxies broadly fall into two classes: star forming and quiescent.
The processes that govern galaxy quenching remain poorly understood.
One explanation for the cessation of star formation is gas depletion
Quiescent galaxies are predominantly gas and dust poor in the local Universe.
Tracing the ISM content of quenched galaxies across cosmic time is therefore a critical probe of how and when galaxies cease star formation.

2. Observations

They consider JWST imaging and spectroscopy of cluster Abell 2744 from the UNCOVER and MegaScience programs.

The UNCOVER Treasury Program:
7 bands NIRCam; NIRSpec (0.6 -5.3 µm)
The Mega Science program:
13 bands

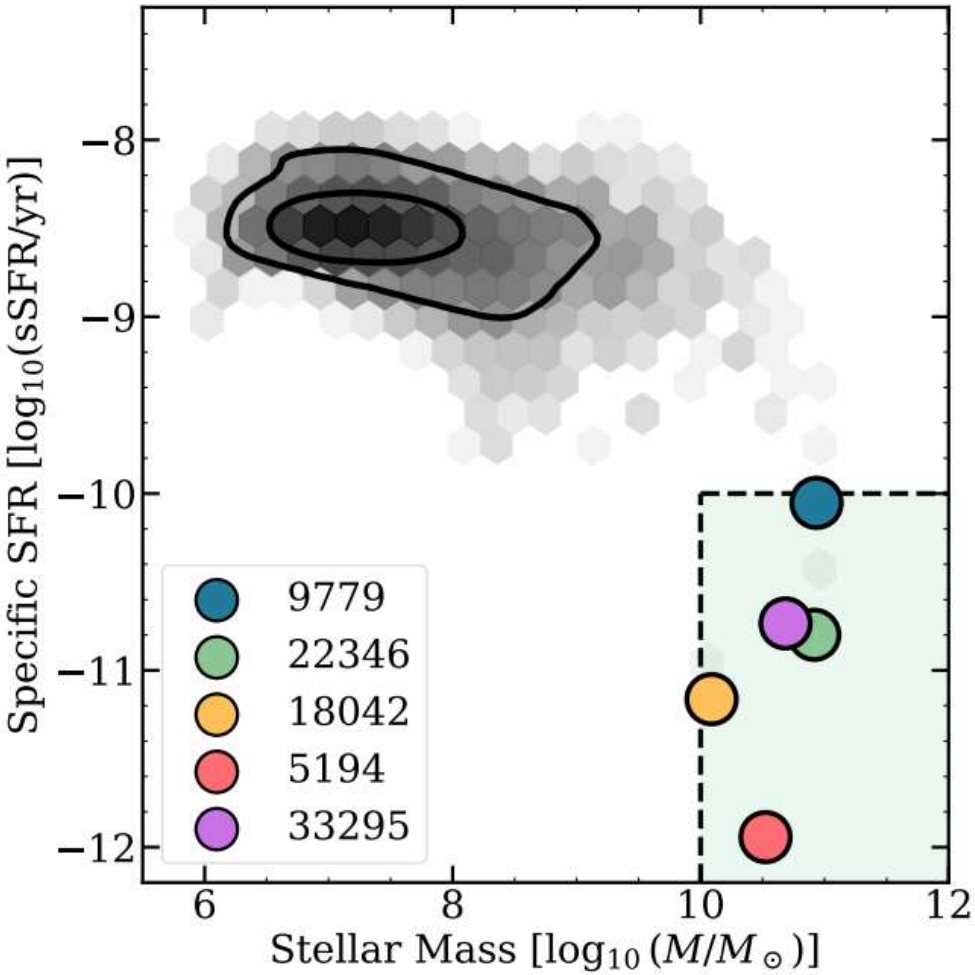
2.1 Sample selection

Part of the targeting strategy was selecting for quiescent galaxies.

In the UNCOVER DR4 catalog they select all massive quiescent galaxies between $2 < z < 3$.

Based on the UNCOVER DR3 photometric catalog, they require $\log_{10}[\frac{M}{M_\odot}] > 10$ $\log_{10}[\frac{\mathrm{sSFR}}{\mathrm{yr}}] < -10$

Five galaxies meet these criteria.



2.1 Sample selection

The redshifts and magnifications are adopted from the UNCOVER DR4 catalog.

$z \sim 2.5$

These galaxies do not appear to be undergoing interactions or to have any nearby (within 20 kpc projected distance) bright companions.

All five galaxies are lensed by Abell 2744

Table 1. Sample Summary.

Target	Ra	Dec	Redshift	Magnification	Half-light radius	Sersic index	Ellipticity
	J2000	J2000	z	μ	$[r_{\rm eff}/{\rm kpc}]$	n	b/a
9779	3.55653	−30.40865	2.54	1.47	$2.16^{+0.04}_{-0.04}$	$4.20^{+0.03}_{-0.03}$	$0.646^{+0.002}_{-0.002}$
22346	3.63103	−30.38324	2.50	1.34	$1.01^{+0.01}_{-0.01}$	$2.86^{+0.02}_{-0.02}$	$0.724^{+0.003}_{-0.003}$
18042	3.60158	−30.39149	2.44	2.12	$1.7^{+0.2}_{-0.2}$	$6.8^{+0.2}_{-0.2}$	$0.629^{+0.004}_{-0.005}$
5194	3.59226	−30.42074	2.58	2.26	$0.67^{+0.02}_{-0.02}$	$2.04^{+0.03}_{-0.03}$	$0.507^{+0.002}_{-0.002}$
33295	3.54429	−30.36806	2.40	5.86	$0.71^{+0.01}_{-0.01}$	$2.84^{+0.01}_{-0.01}$	$0.441^{+0.001}_{-0.001}$

NOTE—The structural parameters are from 2–dimensional Sérsic fits to each galaxy's F444W image. All masses and physical scales are lensing corrected.

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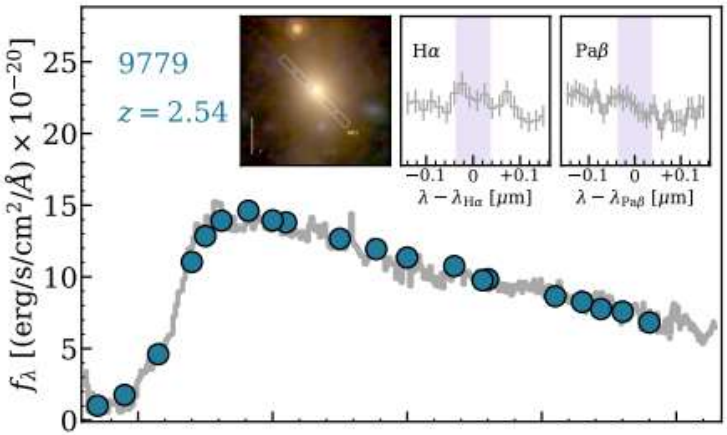
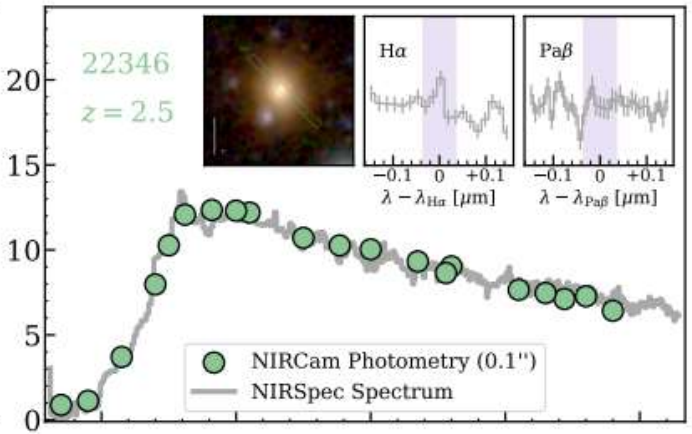
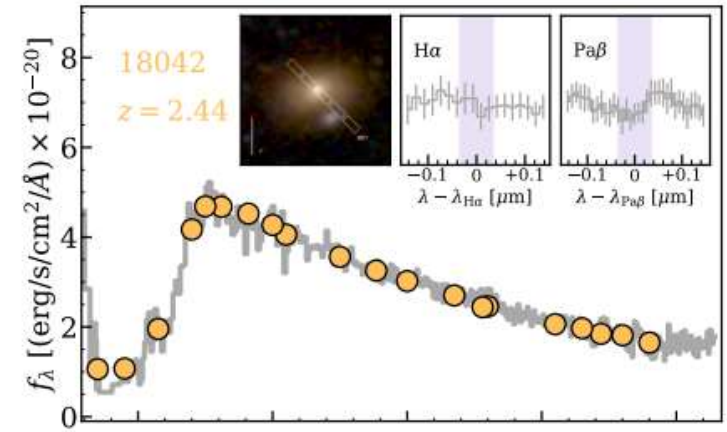
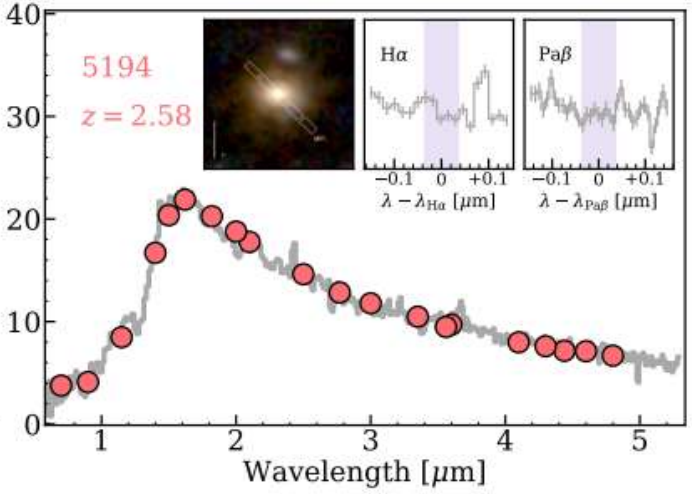
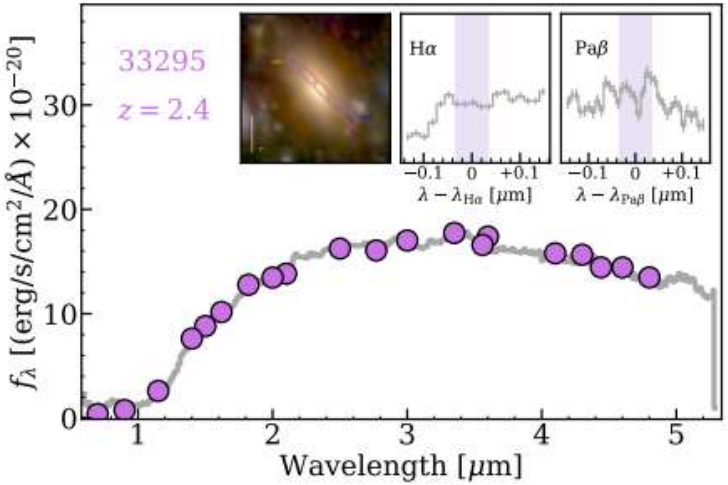










3. Spatially resolved Characterization

To fully leverage the dense wavelength coverage and JWST's high angular resolution, they perform spatially resolved stellar population synthesis modeling.

3.1. Annular Photometry

First, they model each target's F444W image as a single component 2–dimensional S´ersic profile with pysersic
They next extract spatially resolved SEDs from mosaic images that have been PSF matched to the lowest resolution images (F444W) using elliptical annuli.
To avoid low SNR, annuli are limited to radii less than three half-light radii r_{eff}.

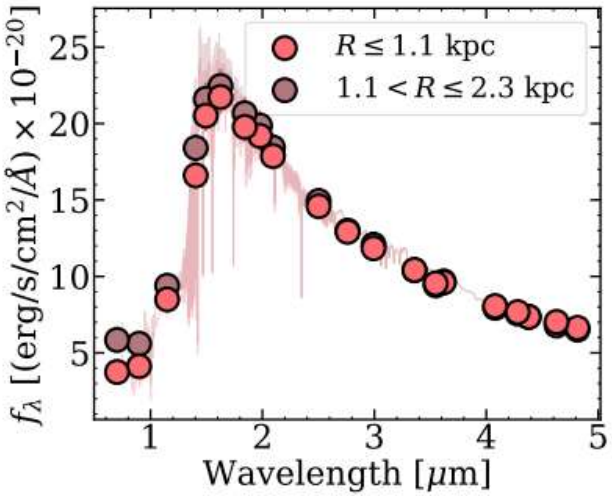
3.2 Stellar population synthesis

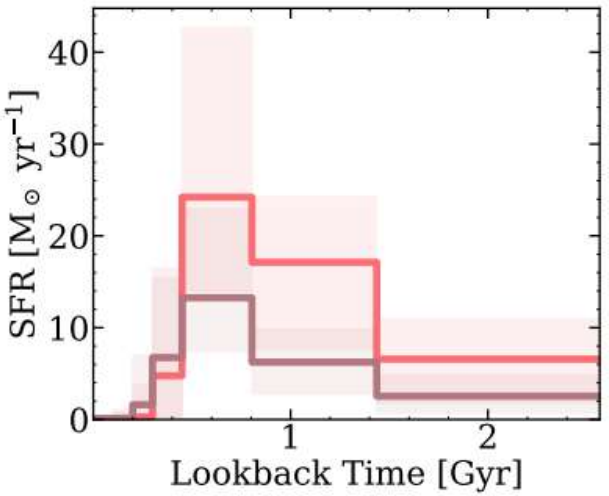
To map the SEDs to stellar populations, they employ Prospector, a toolkit for Bayesian population synthesis
As inputs, they adopt

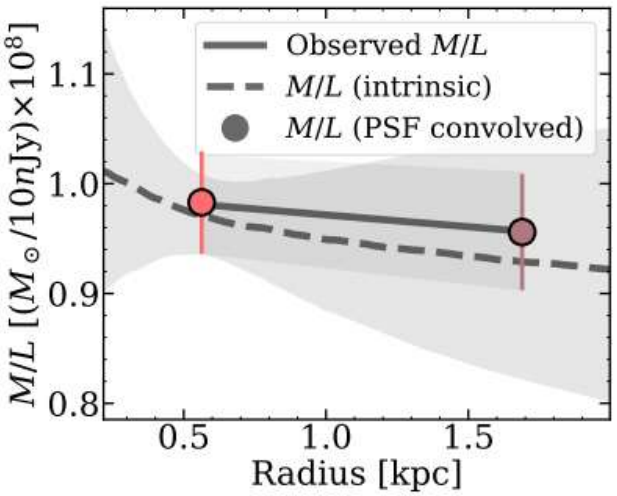
- FSPS models
- MILES spectral library
- MESA Isochrones and Stellar Tracks
- the Chabrier (2003) initial mass function
- Dust attenuation follows Kriek & Conroy (2013) with amplitude $A_V \in (0, 2.5)$ and power-law index $\delta \in (-1, 0.4)$
- metallicity as a free-parameter: $Z/Z_\odot \in (0.01, 1.5)$

3.3 Mass-weighted structure

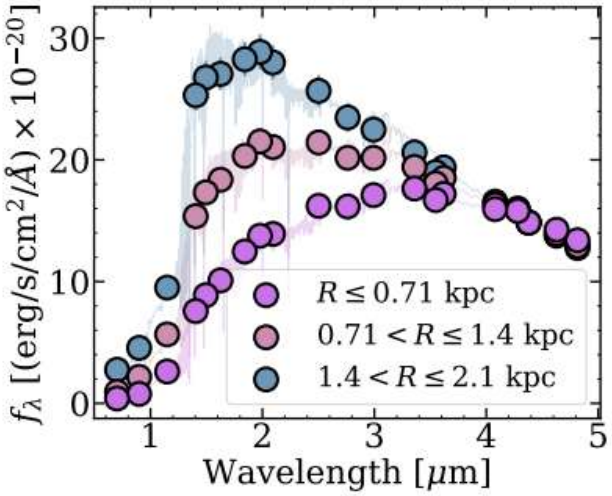
UNCOVER 5194 (flat color gradient)

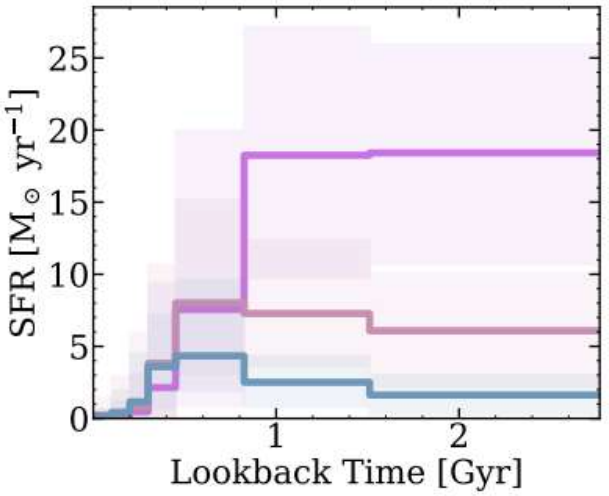


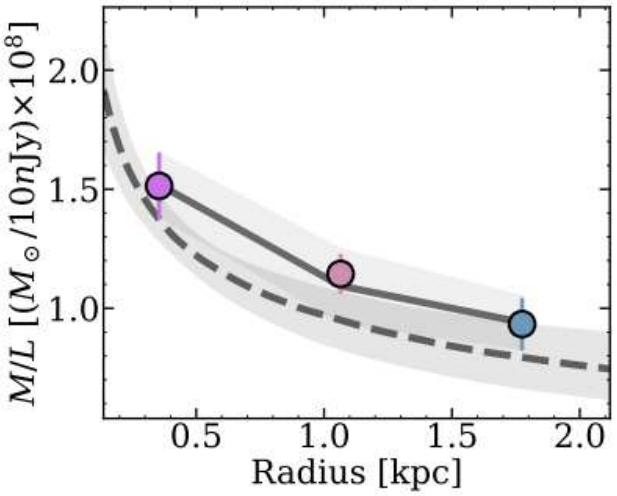




UNCOVER 33295 (negative color gradient)

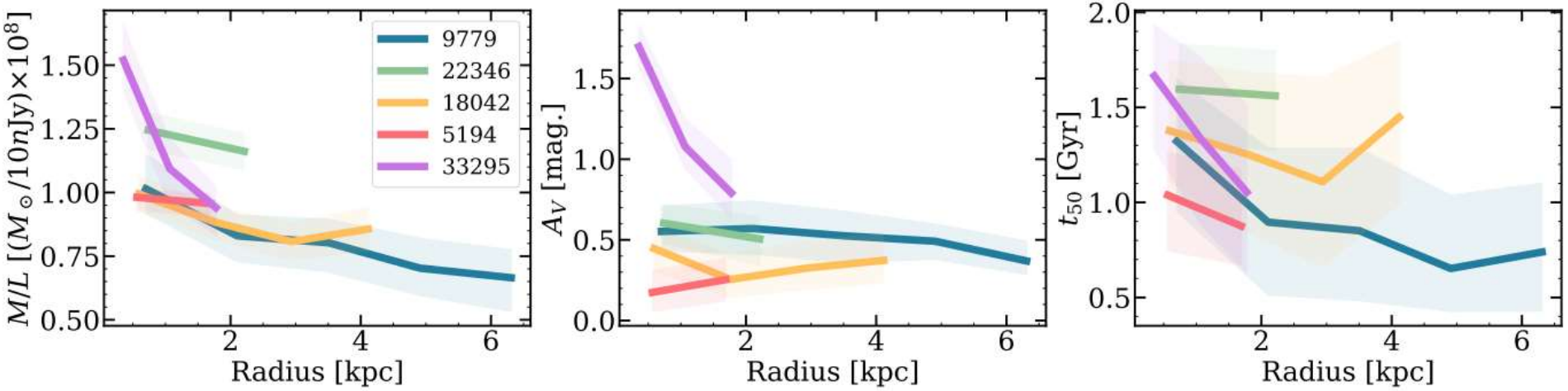






4. Results

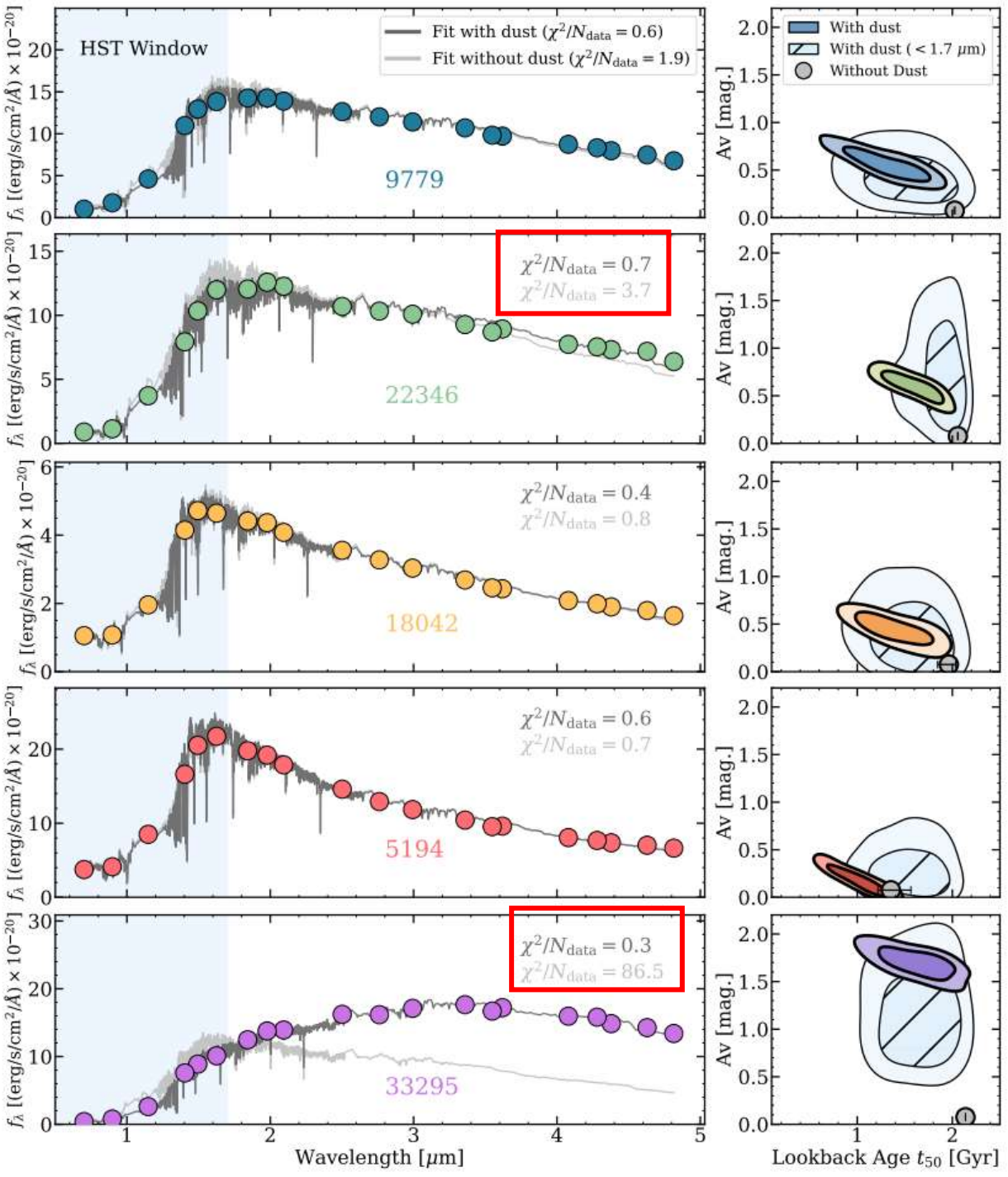
The galaxies predominantly display negative color gradients.
For each galaxy, they report mass-to-light ratio (M/L), dust attenuation (AV), and age (t50, the lookback time by which half the stellar mass had been formed) as a function of radius.
The inferred stellar populations formed ~ 1 Gyr ago in lookback time (corresponding to a formation redshift of z ~ 4), with quenching times of t90 ~ 0.5 Gyr.



4. Results

All five galaxies favor dusty stellar populations.
They next consider whether the galaxies are consistent with dust-free stellar populations.

AV = 0



5. Discussion

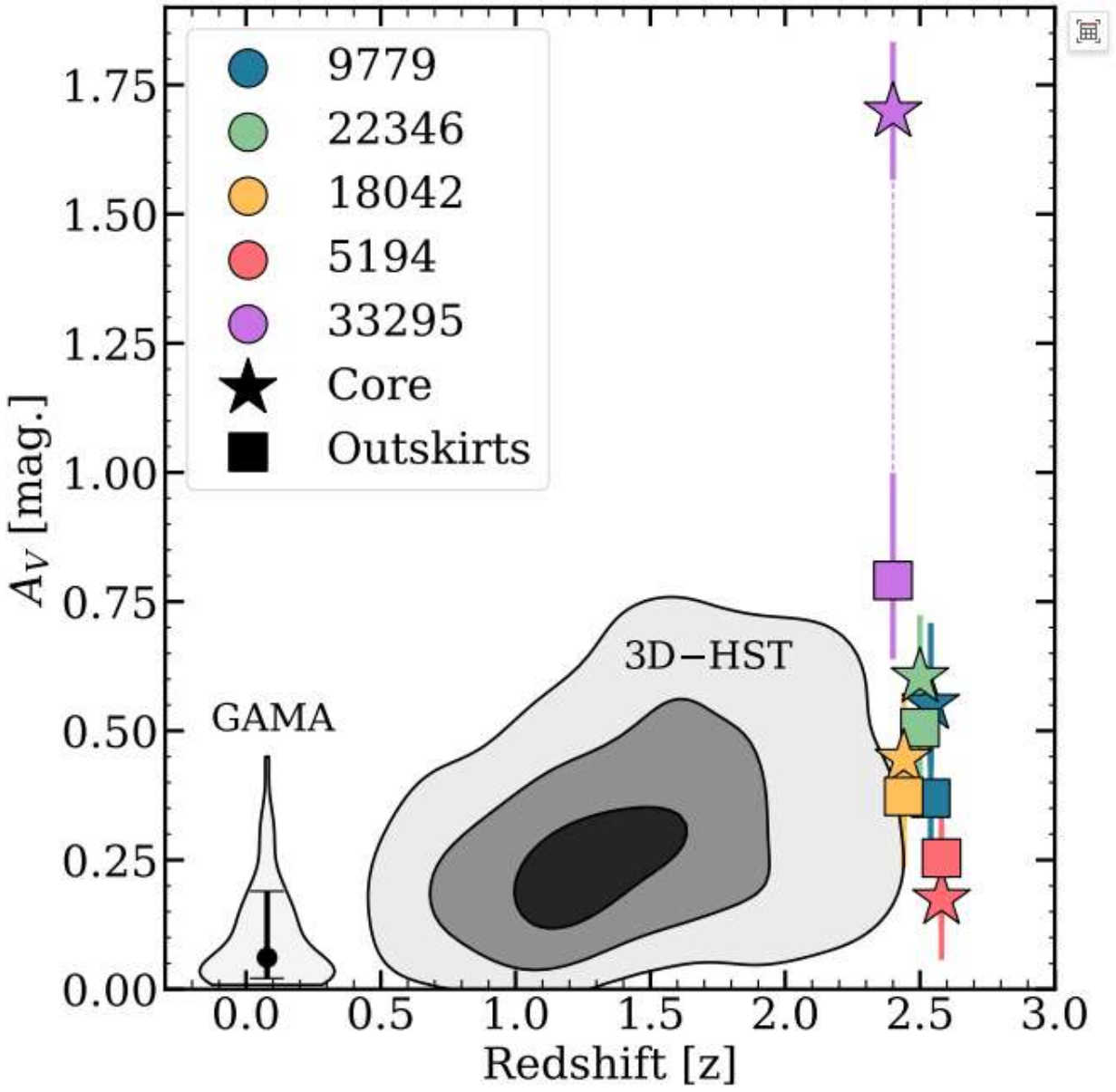
(i) the galaxies are indeed quiescent, with all five satisfying $\log_{10}[\frac{\mathrm{sSFR}}{\mathrm{yr}}] \lesssim -10$ via numerous tracers of the star formation rate;

(i) the galaxies' mass-weighted structures are consistent with the larger population of z ∼ 2.5 quiescent galaxies;

(ii) the galaxies are notably reddened: all five favor dust attenuation levels of AV ≳ 0.2, one favor AV ≳ 0.4;

(iii) most of the galaxies (4/5) display weak negative color gradients (the exception is UNCOVER 33295, which has strong M/L and AV gradients).

5.1 Dustv quiescent galaxies



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5.2 Dust masses

They consider an additional probe of the galaxies' dust content: FIR emission.

All five galaxies are undetected in the ALMA 1.2 mm continuum from the DUALZ survey. They are therefore limited to placing upper bounds on the galaxies' dust masses.

All five galaxies are constrained to $\log_{10}(M_{\rm dust}/M_\odot) \lesssim 7.5$ corresponding to dust fractions of $M_{\rm dust}/M_\star \lesssim 10^{-3}$.

5.3 Color gradients: UNCOVER 33295

UNCOVER 33295 presents strong radial gradients:
mass-to-light ratio declines by nearly 50% from the core to the outskirts
the radial gradient is non-zero at the 3σ level.

$$\frac{d}{dR}(M/L) = -0.4^{+0.1}_{-0.1} \times 10^8 \ [(M_\odot/10n\mathrm{Jy/kpc})]$$

The M/L gradient results from high central dust attenuation (AV ~ 1.5 in the core and ~ 1 in the outskirts)
the dust attenuation gradient is non-zero at the 3σ level

$$\frac{d}{dR}(A_V) = -0.7^{+0.2}_{-0.2} \ [\mathrm{mag./kpc}]$$

while the age gradient is consistent with zero.

$$\frac{d}{dR}(t_{50}) = -0.4^{+0.4}_{-0.4} \ [\mathrm{Gyr/kpc}]$$

5.3 Color gradients: UNCOVER 33295

UNCOVER 33295 is triply-imaged, with $\mu \gtrsim 6$ for all three images.

For the photometric and spectroscopic analysis, they consider the least distorted image— i.e., near equal radial and tangential shear ($\mu = 5.9$).

They repeat the annular photometry extraction and modeling procedure with the annuli sizes scaled to mimic an intrinsic magnification of $\mu = 1.5$, rather than the observed value of $\mu = 5.9$.

the “demagnified” UNCOVER 33295 still presents detectable radial dependence.

6. Conclusions

They studied five massive quiescent galaxies at $z \sim 2.5$.
Multiple tracers confirm the galaxies are indeed quiescent, including a lack of Hα, Paschen–β, and FIR emission.
They concluded:
the galaxies are predominately dusty;
the majority favor $AV \gtrsim 0.4$ and are incompatible with dust free stellar populations.