P05

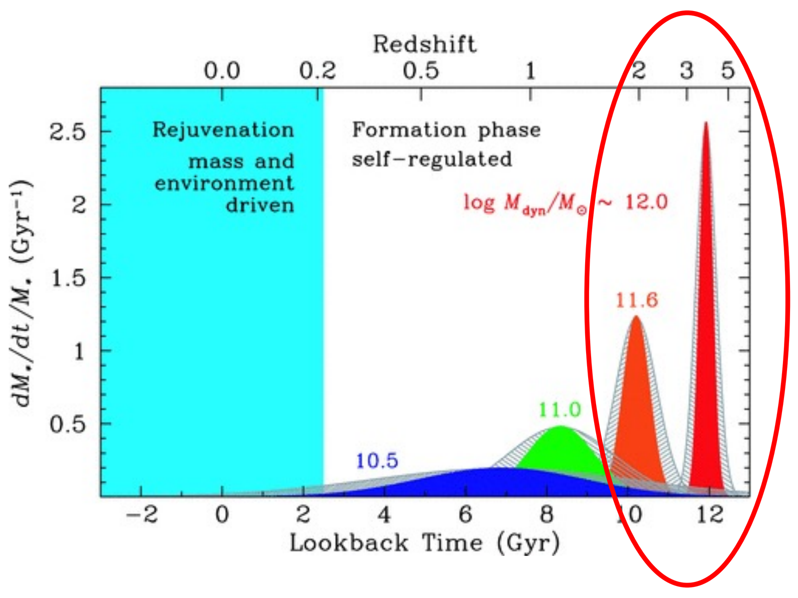
Spectroscopic observation of massive quenching galaxy at $z = 4.53$ and its properties.

Takumi Kakimoto (The Graduate University for Advanced Studies, SOKENDAI), Masayuki Tanaka, Masato Onodera, Rhythm Shimakawa (NAOJ)

Summary

We report a spectroscopic confirmation of a quenching galaxy at $z > 4$ in the COSMOS field with the K-band of Keck/MOSFIRE. The spectrum shows a weak [OII] emission and the Balmer break. We perform SED fitting using both photometry and spectrum to infer the physical properties of the galaxy. The obtained stellar mass is very high ($\log M_* > 10^{10.5} M_\odot$) and the current star formation rate is 1 or more dex below that of main-sequence galaxies at $z = 4.5$. These results show that this galaxy is massive quiescent (no significant ongoing star formation) and the most distant quiescent galaxy which is confirmed by spectroscopic observation.

1. Introduction: Star Formation History of local elliptical galaxies



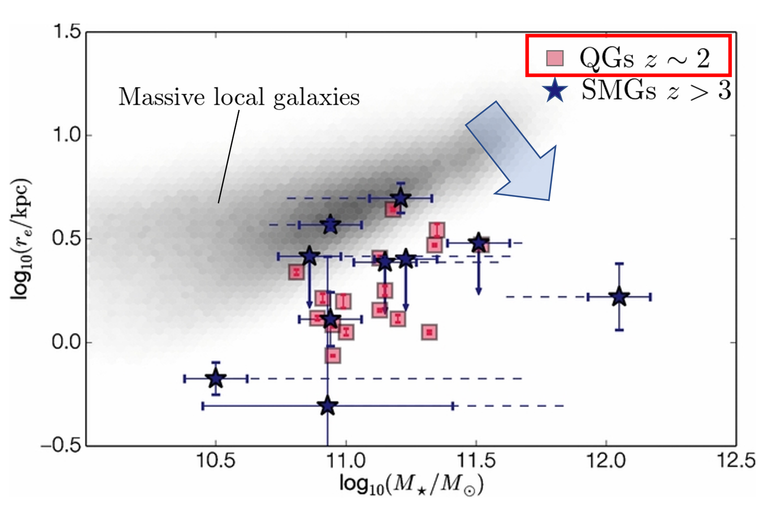
Massive elliptical galaxies experienced an intense burst of star formation in the early Universe. [1]

Open Questions

- What are the physical drivers of the starburst and subsequent quenching?
- Why did massive objects grow without star formation for a long time?

Many studies have been conducted to search for progenitors of the local ellipticals.

2. Target: Quiescent galaxies at high-z



Comparison of the stellar mass-size plane of high redshift SMGs, quiescent galaxies, and local galaxies. [2]

Typical characteristics

- Large stellar masses
- Compact size
- Little to no active formation of new stars

How they were formed is explored through their star formation history.

Motivation

- Observing deep rest-frame optical spectra of quiescent candidates at high redshift.
- To extend the investigation of the quiescent galaxies even further at $z > 4$.
- This is a formidable tool to test our galaxy formation models and simulations.

3. Target Selection & Spectroscopic follow-up

COSMOS field

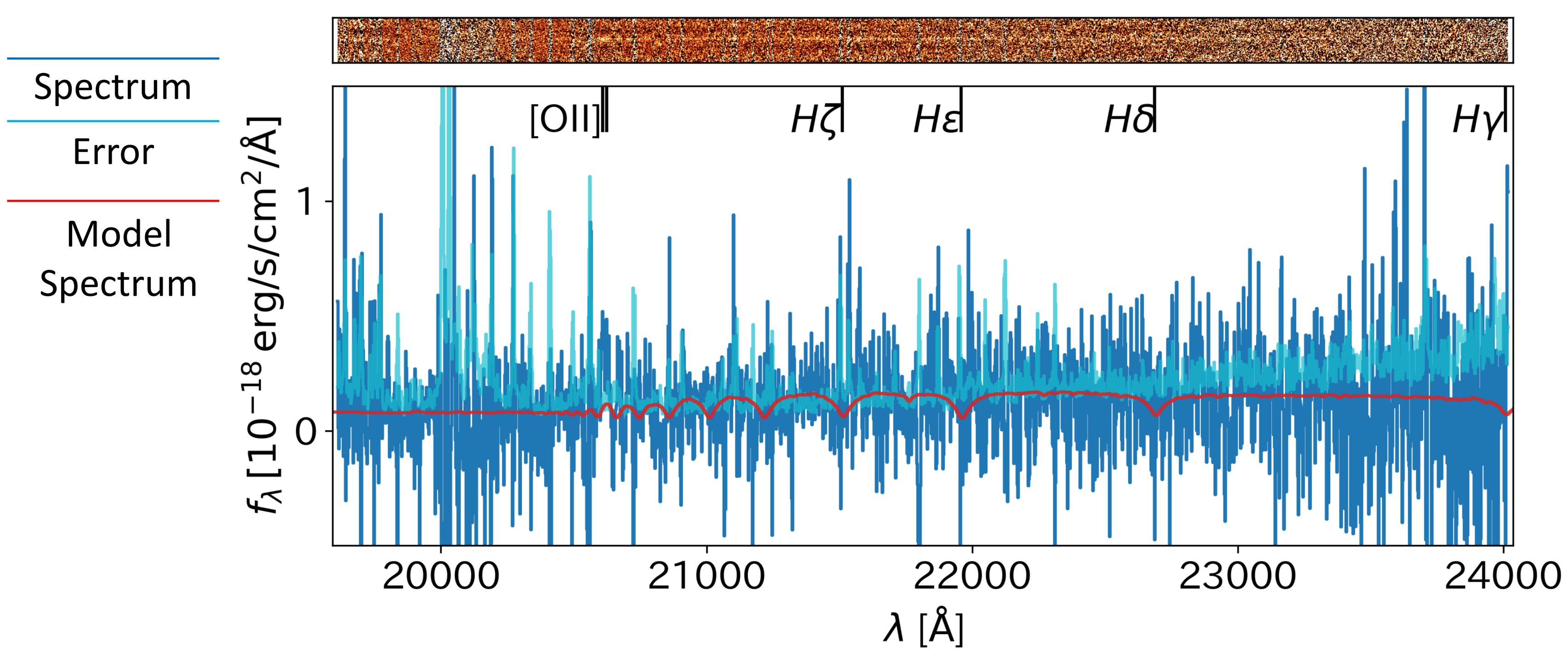
- The main data sets cover a wide area ($\approx$ 2 $\deg^2$).
- This field has been observed from the X-ray to the radio wavelength.
  → High-precision photometric redshifts can be obtained.

We confirmed a high redshift massive galaxy candidate with a strong Balmer break.

Keck 10-meter telescopes (Credit: W. M. Keck Observatory)

- ◆ We performed a spectroscopic follow-up using Keck/MOSFIRE spectrograph to confirm redshift and physical parameters.
- ◆ MOSFIRE spectrograph
  → NIR multi-object spectrograph
  We can observe Balmer break within the wavelength range.

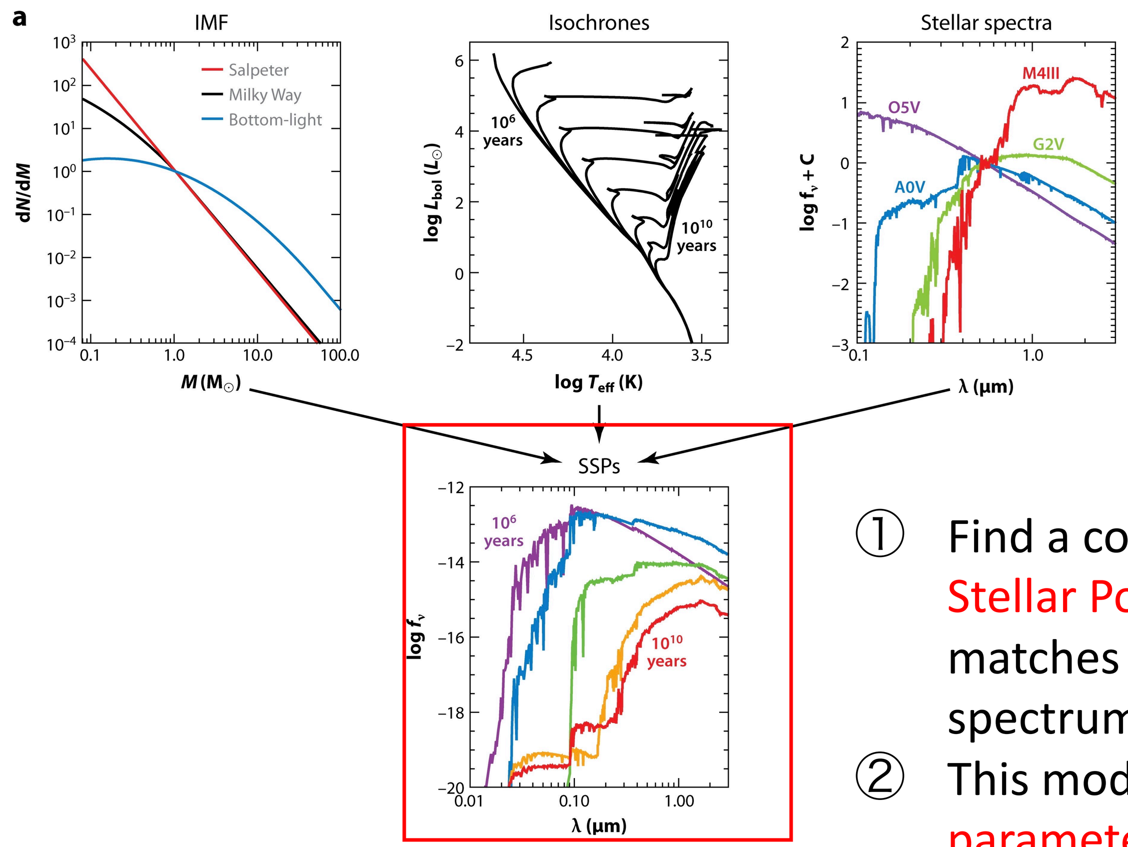
➢ Result: Object's Spectrum & Redshift



◆ The presence of weak [OII] emission lines allowed us to estimate the detailed redshift of the source. $z = 4.531 \pm 0.001$

4. SED fitting

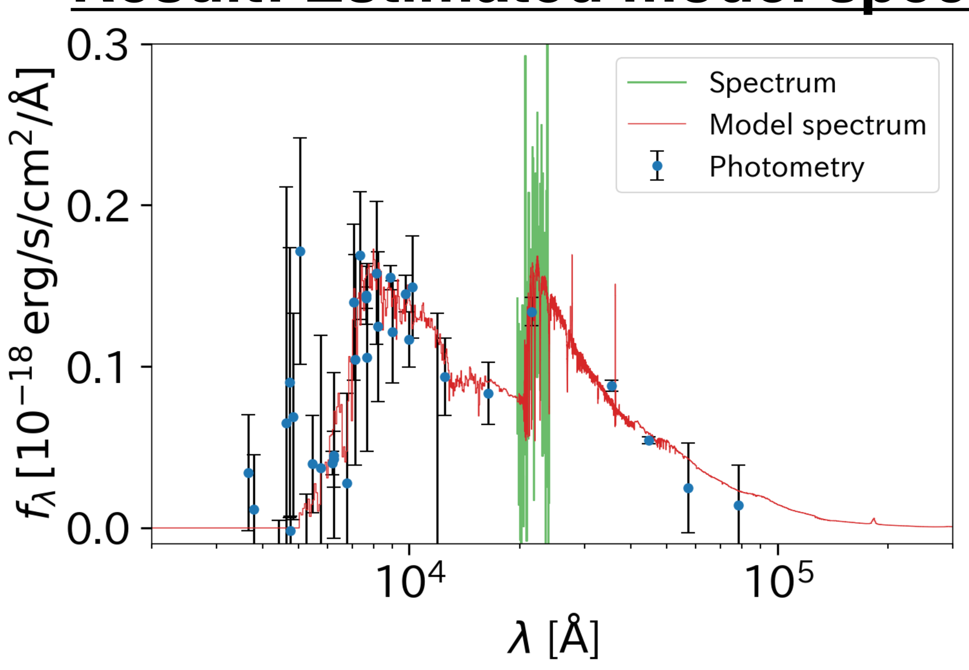
➢ The stellar population synthesis model



Overview of the stellar population synthesis technique. [3]

① Find a combination (model) of Simple Stellar Populations (SSPs) that matches the observed SED and spectrum.
② This model will estimate the physical parameters (SFR, z) and star formation history.

➢ Result: Estimated model spectrum

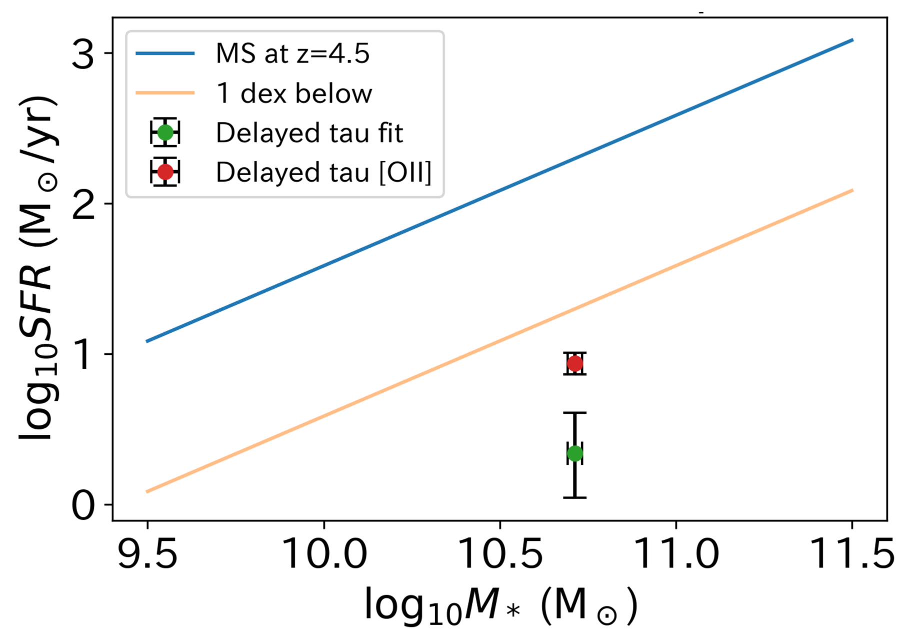


Rest-frame UV to FIR SED & model spectrum from prospector[4].

Fitting code: Prospector[4]
Assumption:
① Chabrier IMF[5]
② Solar metallicity
③ Delayed-tau SFH

- ◆ Strong Balmer break
  → Post-starburst phase
- ◆ The rest-frame UV light is still present.
  → Star formation may be continuing.

➢ Estimated Physical Properties



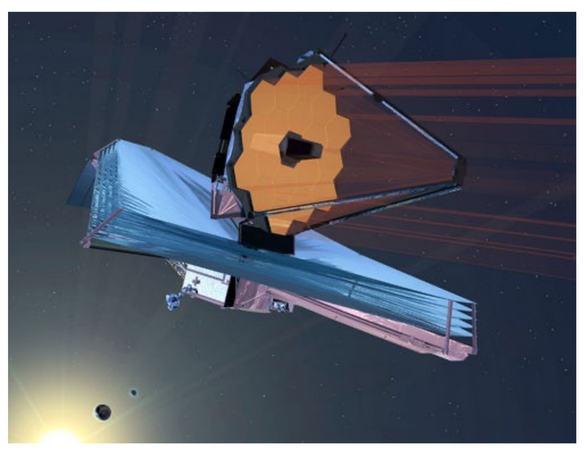
Estimated SFR is >1 dex below the main sequence of galaxies at z=4.5 (Blue line[6]).

Target galaxy's features (Preliminary)

① Large stellar mass
② Very short star formation timescale
③ Younger stellar age
④ The very low star formation rate $SFR < 10\,M_\odot/\mathrm{yr}$

Massive Quiescent

5. Future Prospects



James Webb Space Telescope (Credit: NASA)

- ◆ Estimating star formation history
- ◆ Comparing to the cosmological simulation results.
  → Search for possible progenitors to study how to evolve this object.
- ◆ Follow-up observation by JWST or ALMA.
  → We can understand the surrounding environment which may play an important role to quench.

- **Reference**

[1] Thomas et al. 2010, MNRAS, 404, 1775
[2] Toft et al. 2014, ApJ, 782, 68
[3] Conroy C. 2013, ARA&A, 51, 393
[4] Johnson et al. 2021, ApJ, 254, 22
[5] Chabrier G. 2003, PASP, 115,763
[6] Schreiber et al. 2015, A&A, 575, A74