The MOSDEF Survey: A Remarkable $z = 1.89$ Merger[1]

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ABSTRACT

We present a detailed study of a galaxy merger taking place at $z = 1.89$ in the GOODS-S field. Here we analyze Keck/MOSFIRE spectroscopic observations from the MOSFIRE Deep Evolution Field (MOSDEF) survey along with multi-wavelength photometry assembled by the 3D-HST survey. The combined dataset is modeled to infer the past star-formation histories (SFHs) of both merging galaxies. They are found to be massive, with $\log_{10}(M_*/M_\odot) > 11$, with a close mass ratio satisfying the typical major-merger definition. Additionally, in the context of delayed-τ models, GOODS-S 43114 and GOODS-S 43683 have similar SFHs and low star-formation rates ($\log_{10}(SFR(SED)/M_\odot/yr^{-1}) < 1.0$) compared to their past averages. The best-fit model SEDs show elevated $H\delta_A$ values for both galaxies, indicating that their stellar spectra are dominated by A-type stars, and that star formation peaked ~ $0.5 - 1$ Gyr ago and has recently declined. Additionally, based on SED fitting both merging galaxies turned on and shut off star formation within a few hundred Myr of each other, suggesting that their bursts of star formation may be linked. Combining the SFHs and $H\delta_A$ results with recent galaxy merger simulations, we infer that these galaxies have recently completed their first pericentric passage and are moving apart. Finally, the relatively low second velocity moment of GOODS-S 43114 given its stellar mass, suggests a disk-like structure. However, including the geometry of the galaxy in the modeling does not completely resolve the discrepancy between the dynamical and stellar masses. Future work is needed to resolve this inconsistency in mass.

Target Galaxies:

3D-HST: GOODS-S 43114/43683
ZFOURGE: CDFS-26715/27020

Both galaxies contain an X-ray AGN

MOSDEF slit

Image data

Science Target:

Using Keck/MOSFIRE spectra and emission-line corrected SED fitting to understand the galaxy SFHs, stellar population properties and the evolutionary stage of the merger
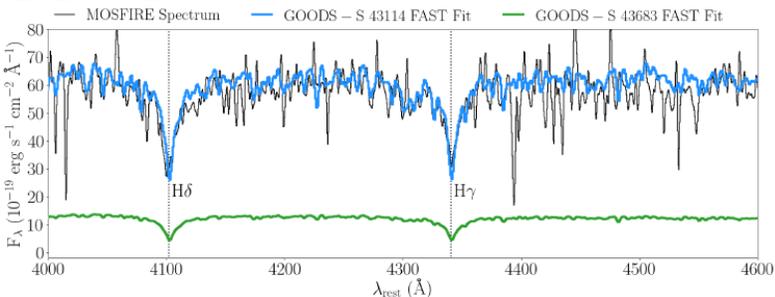
MOSDEF observation:

2hrs in *J, H, Ks*-band separately
z_{spec} = **1.8869**, consistent with the photometric redshift in the 3D-HST catalog (1.9135)
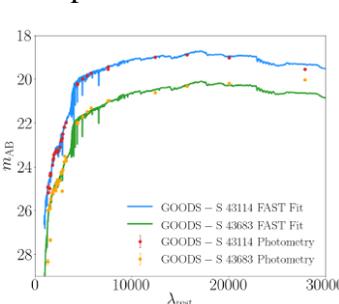At this redshift, nebular emission lines such as [O II], Hβ, [O III], Hα, [NII] fall outside of the *J, H,* and *Ks*-bands. But observed the Hγ and Hδ Balmer absorption lines in the *J* band

SED fitting:

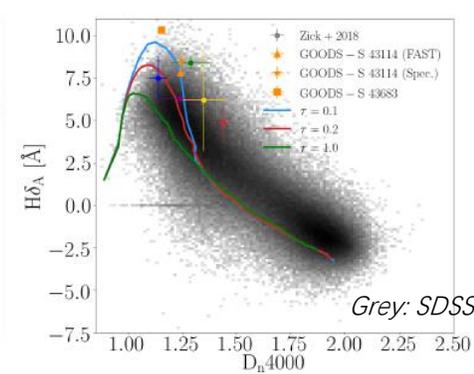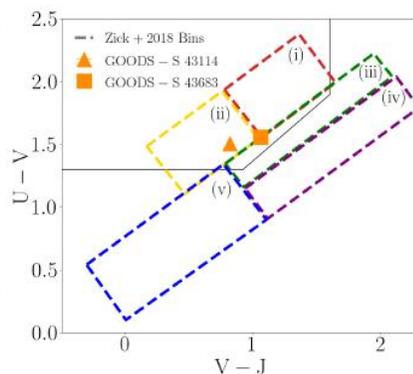FAST (FSPS + Chabrier03 + Calzetti00 + delay-τ)
Prospector

GOODS-S 43114 & GOODS-S 43683 Physical Properties

Physical Property (1)	GOODS-S 43114 (2)	GOODS-S 43683 (3)
H_{AB}	19.843 ± 0.003	21.479 ± 0.011
$\log_{10}(M_*/M_\odot)$	$11.64^{+0.00}_{-0.00}$	$11.04^{+0.00}_{-0.00}$
$\log_{10}(t/\tau)$	$0.96^{+0.00}_{-0.00}$	$0.88^{+0.01}_{-0.00}$
$\log_{10}(\tau/yr)$	$8.00^{+0.00}_{-0.00}$	$7.80^{+0.00}_{-0.00}$
$\log_{10}(SFR(SED))$ ($M_\odot yr^{-1}$)	$0.81^{+0.00}_{-0.00}$	$0.97^{+0.01}_{-0.06}$
$\log_{10}(sSFR(SED))$ (yr^{-1})	$-10.83^{+0.00}_{-0.00}$	$-10.07^{+0.00}_{-0.06}$
A_V	$0.46^{+0.00}_{-0.00}$	$1.24^{+0.01}_{-0.02}$
U–V	$1.50^{+0.00}_{-0.00}$	$1.56^{+0.005}_{-0.005}$
V–J	$0.82^{+0.00}_{-0.0001}$	$1.06^{+0.007}_{-0.007}$
D_n4000	$1.23^{+0.00}_{-0.00}$	$1.16^{+0.004}_{-0.001}$
Hδ_A (Å)	$7.81^{+0.00}_{-0.00}$	$10.17^{+0.06}_{-0.01}$
σ_e (km s^{-1})	166 ± 21	N/A
$\log_{10}(M_{dyn}/M_\odot)$	11.16 ± 0.11	N/A
R_e (arcseconds)	0.366 ± 0.002	N/A
Sésic Index	5.26 ± 0.06	N/A
Axis Ratio	0.865 ± 0.004	N/A

major merger

Other parameters:

4000Å break (Dn4000:
$F_{4050-4250}/F_{3750-3950}$),

The velocity dispersion,
The dynamical mass
(M_{dyn}),
…

Results & Discussion:

Galaxy Stellar Populations

Grey: SDSS

quiescent (red), post-starburst (yellow), dusty galaxies with lower sSFRs (green), dust star-forming (purple), and non-dusty star-forming (blue)

The elevated $H_{\delta A}$ in both galaxies
→ The spectra are dominated by A-type stars
→ Star formation shut down in a time frame where the O- and B-type stars no longer exist but the A-type stars still remain.
Confirmed by SED fitting

State of the Merger

FIRE-2 model, three key stages in a merger:
1. the first pericentric passage,
2. the second pericentric passage,
3. coalescence

the first passage occurred ~0.5-1 Gyr ago
2-2.5 Gyr (This merger)
< 0.5 Gyr

FIRE-2 use local galaxies ~10^{10} $M_\odot$, hard to compare quantitively
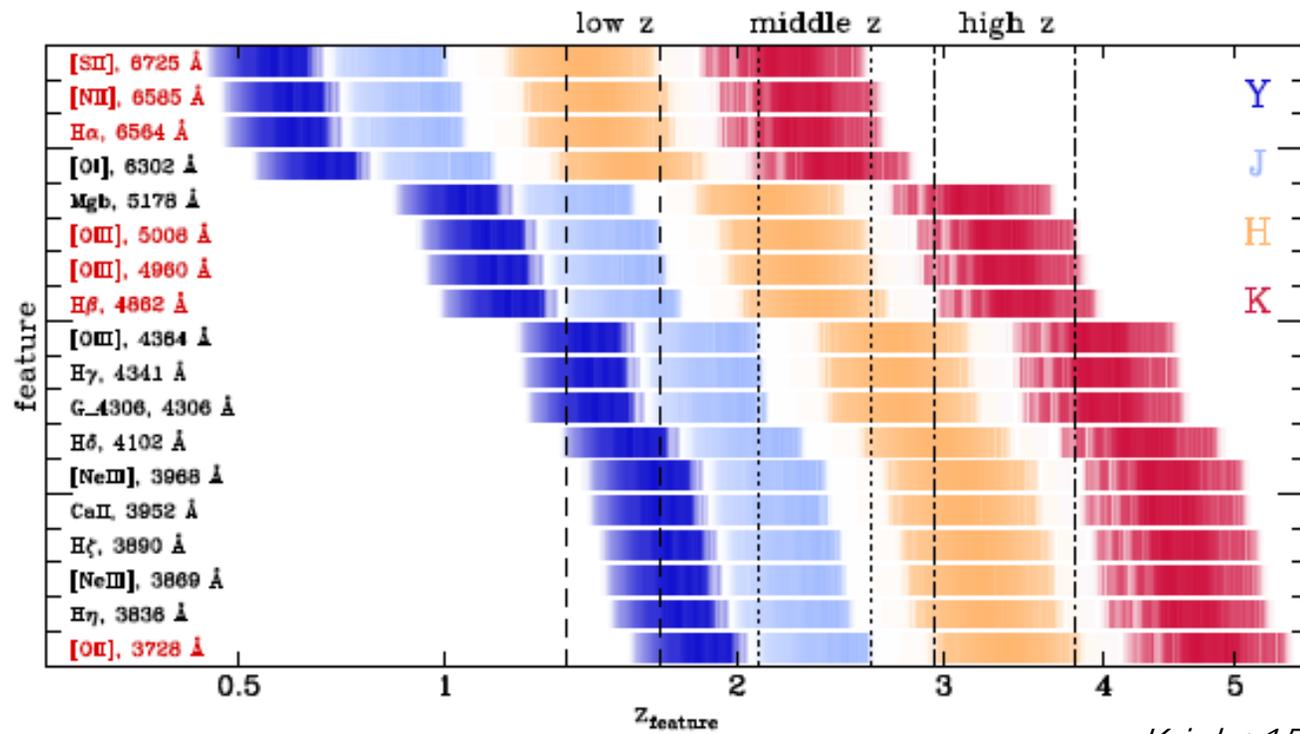
Implications of M_* and M_{dyn}

$M_{dyn} < M_*$ → M_* is robust (39 datapoints and double check by SED)
→ M_{dyn} is underestimated + Axis ratio ~0.865
→ roughly face-on disk
New model (consider the effect of inclination) to calculate the dynamical mass → $M_{dyn} = 11.44 < M_*$ still → the unknown internal dynamics

MOSDEF

Kriek+15

SFH