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Broad-band selection, spectroscopic identification, and physical properties of a population of extreme emission line galaxies at 3<z<3.7

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ABSTRACT

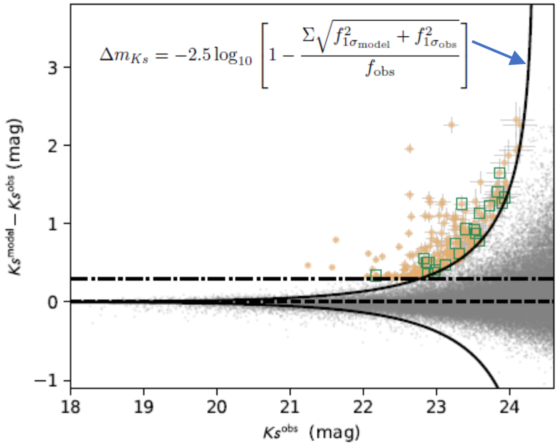
We present the selection, spectroscopic identification, and physical properties of extreme emission line galaxies (EELGs) at $3 < z < 3.7$ aiming at studying physical properties of an analog population of star-forming galaxies (SFGs) at the epoch of reionization. The sample is selected based on the excess in the observed Ks broad band flux relative to the best-fit stellar continuum model flux. By applying a 0.3 mag excess as a primary criterion, we select 240 EELG candidates with intense emission lines and estimated observed-frame equivalent width (EW) of $\gtrsim 1000$ Å over the UltraVISTA-DR2 ultra-deep stripe in the COSMOS field. We then carried out a HK band follow-up spectroscopy for 23 of the candidates with Subaru/MOIRCS, and find that 19 and two of them are at $z > 3$ with intense [O III] emission, and Hα emitters at $z \simeq 2$, respectively. These spectroscopically identified EELGs at $z \simeq 3.3$ show, on average, higher specific star formation rates (sSFR) than the star-forming main sequence, low dust attenuation of $E(B-V) \lesssim 0.1$ mag, and high [O III]/[O II] ratios of $\gtrsim 3$. We also find that our EELGs at $z \simeq 3.3$ have higher hydrogen ionizing photon production efficiencies ($\xi_{\rm ion}$) than the canonical value ($\simeq 10^{25.2}\,{\rm erg^{-1}\,Hz}$), indicating that they are efficient in ionizing their surrounding interstellar medium. These physical properties suggest that they are low metallicity galaxies with higher ionization parameters and harder UV spectra than normal SFGs, which is similar to galaxies with Lyman continuum (LyC) leakage. Among our EELGs, those with the largest [O III]/[O II] and EW([O III]) values would be the most promising candidates to search for LyC leakage.

Sample selection:

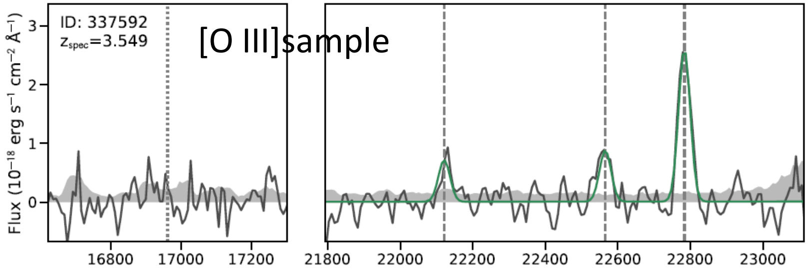
The COSMOS2015 catalog SED fitting → Continuum (stellar-only model) Ks^{model}

$$\Delta m_{K_s} = Ks^{model} - Ks^{obs}$$

$$\Delta m_{Ks} = -2.5 \log \frac{\mathrm{FWHM}_{Ks}}{\mathrm{EW_{obs}([O\,III] + H\beta) + FWHM}_{Ks}},$$



23 EELG candidates: 21 of them have detected emission lines and the origin of K-band excesses are confirmed as [O III] (19) and Hα (2) at z ~ 3.3 and z ~ 2.2. (Main part of this article are the 19 [O III] emitters here)



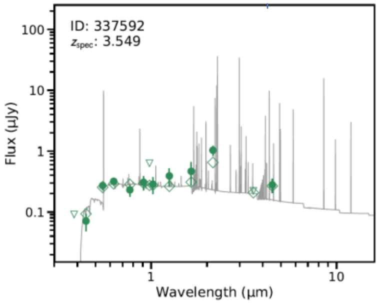
ID	$z_{\rm moircs}$	F([O II]λ3727)	F(Hβ)	F([O III]λ5007)	F(Hα)	F([N II]λ6583)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
[O III] emitters[a]						
337592	3.5492	< 1.65	2.84 ± 0.48	10.41 ± 0.42	···	···
Composite of [O III] emitters						
Low-mass composite	···	1.70 ± 0.13	1.22 ± 0.06	9.01 ± 0.08	···	···
High-mass composite	···	3.16 ± 0.17	1.46 ± 0.09	9.79 ± 0.11	···	···

NOTE— (1) Object ID; (2) spectroscopic redshift measured from MOIRCS spectra; (3) [O II]λ3727 ([O II]λ3726 + [O II]λ3729) flux; (4) Hβ flux; (5) [O III]λ5007 flux; (6) Hα flux; and (7) [N II]λ6583 flux. All fluxes are in units of 10^{-17} erg s^{-1} cm^{-2}, not corrected for dust extinction and stellar absorption. Quoted upper limits are the 3σ upper limit.

ID	EW([O III]λ5007)	O_{32}	R_{23}	$\log \xi_{\rm ion,0}$
	(Å)			(erg^{-1} Hz)
337592	2051 ± 82	> 7.2	4.8 ± 3.1	25.86 ± 0.15

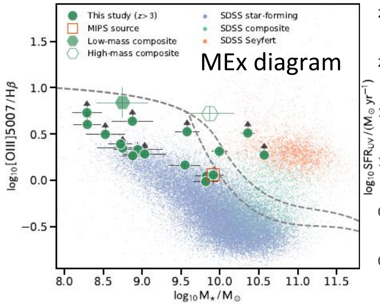
Physics properties:

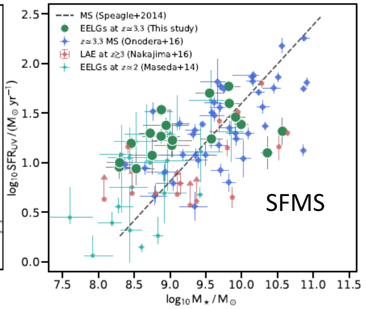
1. Broad-band SED fitting (CIGALE)
   Delayed-τ models (representative for EELGs)
   Inclusion of emission lines (log U = - 2.5)
   Result: Only use the stellar mass from the SED
2. UV-based dust attenuation and star formation rate
   $$\beta_{\rm UV} = -2.616 + 11.259\, E(B-V)_{\rm star}.$$
   $$\log {\rm SFR}/(M_\odot\,{\rm yr^{-1}}) = \log \nu L_\nu(1500\,{\rm Å})/({\rm erg\,s^{-1}}) - 43.46.$$
3. Equivalent width of the [O III] 5007 emission line
4. R23 and O32 line ratios
   Dust extinction, SMC curve
   $E(B-V)_{neb} = 3.06\ (B-V)_{star}$
   [O III]λ5007/[O III]λ4959 = 3
5. Ionizing photon production efficiency
   $$\xi_{\rm ion} = \frac{N({\rm H^0})}{L_{\rm UV,corr}}\ [{\rm s^{-1}/(erg\,s^{-1}\,Hz^{-1})}].$$
   $$L({\rm H\alpha})/L({\rm H\beta}) = 2.86$$



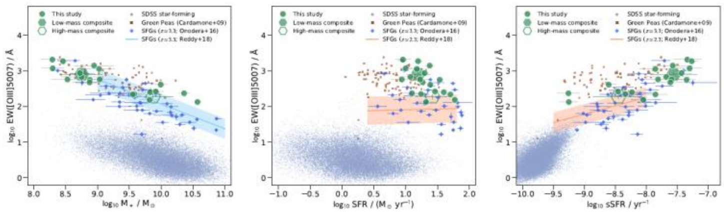
Results and discussion:

1. AGN contamination
   $\mathrm{FWHM} \simeq 400\text{–}500\ \mathrm{km\ s^{-1}}$ No broad Lines
2. About SFMS (Same trend in Hα emitters of ZF)



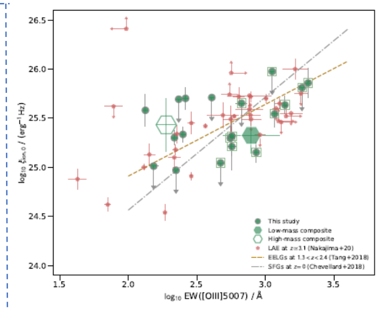


3. [O III]EW and physical parameters



Left: Strong EW([O III])–M* relation
Right: The galaxies on upper right may be younger and more metal-poor than normal galaxies on the MS (Similar to Sanders et al. 2020b with [O III]4363)

4. Ionization properties: (EELG are among normal SFGs and LAEs)
Higher ionization parameters
Higher ξ_{ion} (25.54) (No $\xi_{ion} - \beta_{UV}$ relationship)



EELGs are efficient hydrogen ionizing photon producers