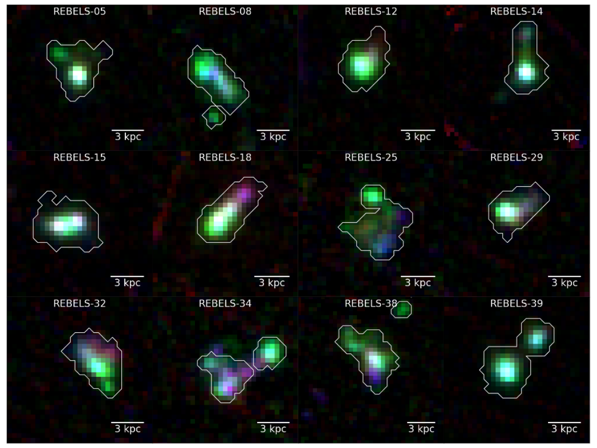
astro-ph seminar 2025.02.05 (Ryou Ohsawa)

REBELS-IFU: Dust attenuation curves of 12 massive galaxies at z≃7

Fisher et al, 2025, submitted to MNRAS (arXiv:2501.10541)

We present measurements of the dust attenuation curves of 12 massive ($9 < \log(M_\star/\mathrm{M}_\odot) < 10$) Lyman-break galaxies at $z = 6.5 - 7.7$ derived from *James Webb Space Telescope* (*JWST*) NIRSpec integral field unit (IFU) spectroscopy. The galaxies are drawn from the Atacama Large Millimeter/submillimeter Array (ALMA) Reionization Era Bright Emission Line Survey (REBELS) large program. The dust attenuation curves were obtained by fitting spectral energy distribution (SED) models with a flexible dust law to the full galaxy spectra over observed wavelengths $0.6 - 5.3\ \mu$m. These attenuation curves show a range of recovered slopes ($-0.39 \leq \delta \leq 0.08$) that are on average slightly flatter than seen in local sources of the same stellar masses, with none exhibiting very steep slopes. Three galaxies exhibit evidence for a 2175 Å dust bump ($> 4\sigma$) and we find SED fitting excluding the bump can overestimate derived stellar masses by up to 0.4 dex. Correcting for the dust attenuation with our best-fit attenuation curves we recover a range of intrinsic UV-slopes ($-2.5 \leq \beta_0 \leq -2.2$). The galaxies show moderate reddening ($A_V = 0.1 - 0.6$ mag) and the A_V to stellar mass relation is consistent with local sources. The attenuation law slope is found to correlate with A_V, while we see no strong correlation with stellar mass, M_{UV}, or gas-phase metallicity. Overall, our results show little evolution in dust properties in the REBELS sources compared to the local Universe. Comparing our recovered trends to empirical models suggests that the most important factor driving the variation in the attenuation curves in our sample is the dust-star geometry, not the properties of the dust grains themselves.

Key words: dust, extinction – galaxies: high-redshift



REVELS-IFU galaxies (Figure 1 of Rowland+, 2025)

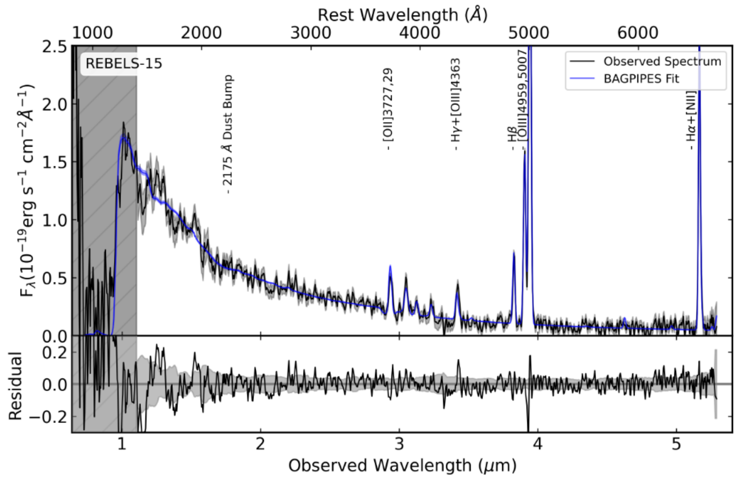
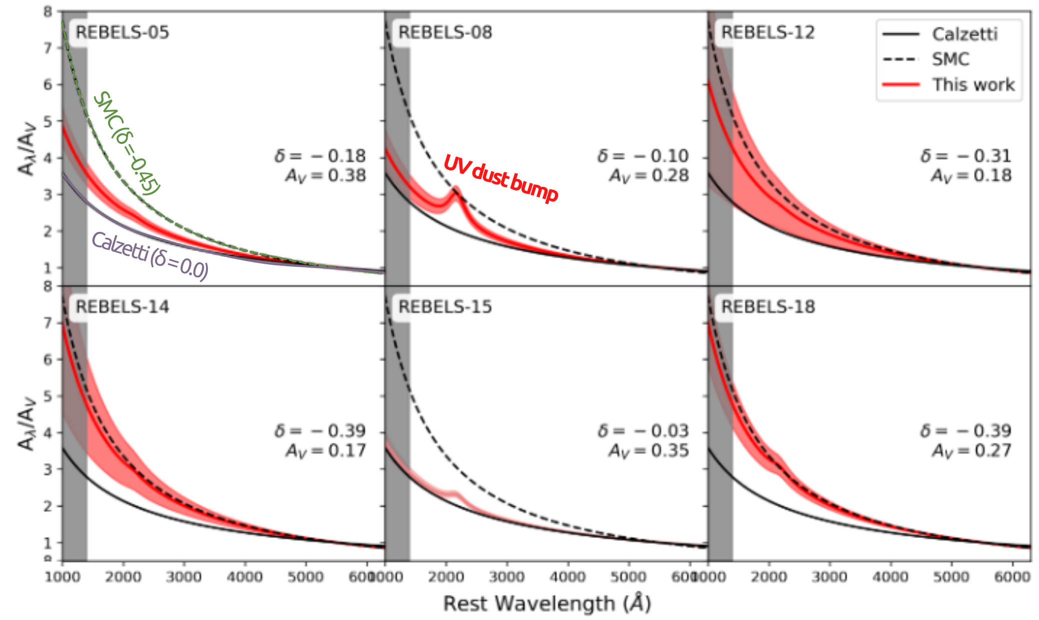


Figure 1 (Example of a spectrum and fitting result)

Table 1 (Overview of samples and fitting results)

ID	z	UV slope β	M_{UV} /mag	Z /$Z_\odot$	A_V /mag	extinction slope δ	bump strength B	$\log_{10}(M_\star/\mathrm{M}_\odot)$	intrinsic UV slope β_0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
REBELS-05	6.496	-1.42 ± 0.05	-21.49 ± 0.07	0.66 ± 0.25	$0.38^{+0.10}_{-0.09}$	$-0.18^{+0.06}_{-0.07}$	$0.18^{+0.17}_{-0.12}$	$9.60^{+0.11}_{-0.10}$	-2.31 ± 0.06
REBELS-08	6.749	-1.92 ± 0.05	-21.88 ± 0.03	0.34 ± 0.16	$0.28^{+0.07}_{-0.07}$	$-0.10^{+0.06}_{-0.08}$	$3.00^{+0.48}_{-0.40}$	$9.30^{+0.11}_{-0.10}$	-2.41 ± 0.05
REBELS-12	7.346	-1.68 ± 0.03	-22.39 ± 0.03	0.35 ± 0.11	$0.18^{+0.08}_{-0.09}$	$-0.31^{+0.20}_{-0.29}$	$0.15^{+0.22}_{-0.10}$	$9.80^{+0.09}_{-0.10}$	-2.37 ± 0.04
REBELS-14	7.084	-1.74 ± 0.03	-22.30 ± 0.04	0.16 ± 0.05	$0.17^{+0.07}_{-0.06}$	$-0.39^{+0.14}_{-0.23}$	$0.24^{+0.27}_{-0.15}$	$9.54^{+0.12}_{-0.14}$	-2.44 ± 0.05
REBELS-15	6.875	-2.01 ± 0.03	-22.40 ± 0.03	0.12 ± 0.09	$0.35^{+0.08}_{-0.07}$	$-0.03^{+0.04}_{-0.04}$	$0.99^{+0.15}_{-0.14}$	$9.40^{+0.03}_{-0.03}$	-2.45 ± 0.03
REBELS-18	7.675	-1.56 ± 0.03	-22.11 ± 0.02	0.64 ± 0.19	$0.27^{+0.04}_{-0.05}$	$-0.39^{+0.07}_{-0.12}$	$0.56^{+0.18}_{-0.16}$	$9.98^{+0.04}_{-0.04}$	-2.39 ± 0.03
REBELS-25	7.307	-1.61 ± 0.09	-21.46 ± 0.05	0.85 ± 0.33	$0.25^{+0.09}_{-0.06}$	$-0.35^{+0.13}_{-0.15}$	$2.72^{+0.65}_{-0.67}$	$9.07^{+0.10}_{-0.08}$	-2.22 ± 0.12
REBELS-29	6.685	-1.89 ± 0.05	-22.00 ± 0.04	1.11 ± 0.40	$0.33^{+0.08}_{-0.07}$	$-0.09^{+0.07}_{-0.08}$	$0.71^{+0.30}_{-0.27}$	$9.94^{+0.06}_{-0.08}$	-2.38 ± 0.06
REBELS-32	6.729	-1.34 ± 0.07	-21.16 ± 0.08	0.61 ± 0.19	$0.46^{+0.14}_{-0.13}$	$-0.08^{+0.07}_{-0.09}$	$0.53^{+0.29}_{-0.29}$	$9.75^{+0.11}_{-0.12}$	-2.38 ± 0.07
REBELS-34	6.634	-2.23 ± 0.03	-22.25 ± 0.02	0.44 ± 0.32	$0.10^{+0.05}_{-0.04}$	$-0.14^{+0.13}_{-0.19}$	$1.03^{+0.52}_{-0.51}$	$9.59^{+0.09}_{-0.07}$	-2.31 ± 0.04
REBELS-38	6.577	-1.63 ± 0.06	-21.99 ± 0.05	0.39 ± 0.17	$0.58^{+0.11}_{-0.14}$	$0.08^{+0.05}_{-0.05}$	$0.12^{+0.13}_{-0.08}$	$9.93^{+0.08}_{-0.09}$	-2.47 ± 0.06
REBELS-39	6.845	-2.07 ± 0.04	-22.39 ± 0.04	0.21 ± 0.16	$0.16^{+0.06}_{-0.04}$	$-0.23^{+0.08}_{-0.10}$	$0.94^{+0.39}_{-0.35}$	$9.56^{+0.11}_{-0.09}$	-2.37 ± 0.04



Part of Figure 2 (Estimated attenuation curve)

Context

High-z galaxies (z > 4) sometimes show strong dust emission. Dust properties at high-z and the formation process are to be revealed.

Previous photometric studies revealed redded UV slopes of high-z galaxies, suggesting the presence of dust.

The UV slope is essential to constrain the SFH, but the measured UV slopes are subject to dust reddening. The dust attenuation law at high-z is to be investigated.

Key Findings

They revealed the dust attenuation curves for distant galaxies at z≃7 based on NIR IFU spectroscopy.

25 % of the high-z galaxies show significant UV bump absorption, suggesting small carbonaceous dust grains.

The distribution of dust clumps in galaxies may determine the appearance of the attenuation curve, rather than the properties of dust grains.

Targets

They picked up samples from the REVELS project, that observes high-z galaxies with ALMA for the [C II]$_{158\,\mu\mathrm{m}}$ line and dust continuum.

12 galaxies were selected for JWST/NIRSpec observation. They are the [C II] brightest objects in REVEALS.

Observation

The targets were observed with the JWST/NIRSpec IFU mode. The spectral resolution is R ~ 100. The observed wavelengths ranges 0.7–5.2 μm, corresponding to 1000–6600 Å. The spectra were extracted from the apereture defined in Figure 1 (Rowland+, 2025).

Spectral Analysis

The NIR spectra were fitted with BAGPIPES, where non-parametric SFH, the BC03 stellar population model (Bruzual & Charlot, 2003), Kroupa (2001) IMF, and nebular line grid by CLOUDY were used.

The dust attenuation curve is parameterized as

$$\frac{A_\lambda}{A_V} = \left(\frac{\lambda}{5500\ \text{Å}}\right)^{-n} + \frac{D_\lambda(B)}{R_V}$$

Parmaeter	Limits	Prior
z	–	Fixed
$\log_{10}(M_\star/\mathrm{M}_\odot)$	(7, 12)	Uniform
$Z\,/\,Z_\odot$	(1e-06, 10)	Logarithmic
$\log U$	(-3, 0)	Uniform
A_V / mag	(0, 5)	Uniform
η	(1, 3)	Uniform
δ	(-2, 0.75)	Uniform
B	(0, 4)	Uniform

Table 2 (Fitting parameters)

Non-parametric SFH (6 bins) are also optimized in the SED fitting.

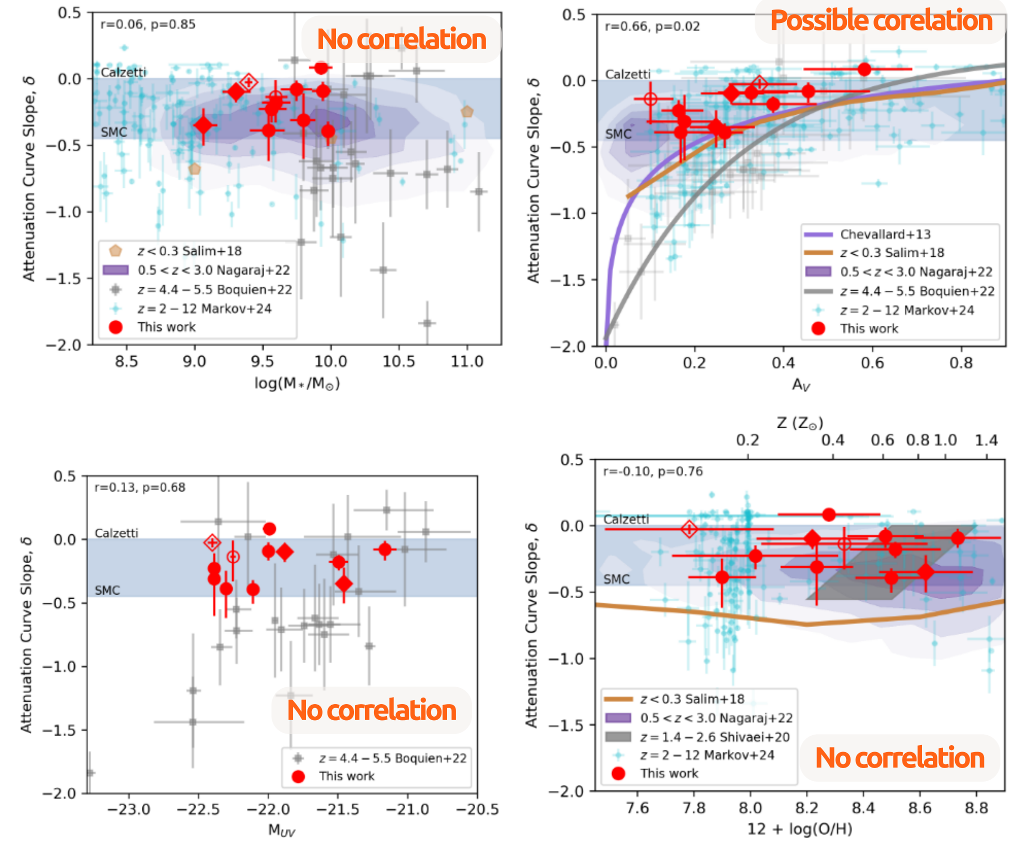


Figure 3 (Correlations with the UV slope)