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The first census of precise metallicity radial gradients at cosmic noon from HST

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The chemo-structural evolution of galaxies at the peak epoch of star formation (i.e., $z\sim2$, a.k.a. cosmic noon) is a key issue in galaxy evolution physics that we do not yet fully understand. A key diagnostic of this process is the spatial distribution of gas-phase oxygen abundance (i.e.metallicity). There have been numerous attempts to investigate the evolution of metallicity radial gradients using ground-based data, yet these data are often acquired under natural seeing, whose median resolution is around $\sim0.''6$ at best. Multiple papers have shown that intrinsically steep radial gradients can only be recovered by imaging spectroscopy with sub-kpc spatial resolution; seeing-limited observations will result in spuriously flat, ergo systematically biased, radial gradients. This beam-smearing problem is even more aggravating at higher z, due to intrinsically smaller galaxy sizes. One solution to this problem is relying on the technique of adaptive optics. Though effective, this method is highly costly due to a number of reasons: the relatively low Strehl ratio in H/K-band necessary to probe cosmic noon sources, the constraining proximity between targets and bright tip/tilt reference stars, etc. As a consequence, the progress of obtaining unbiased (i.e.*precise*) metallicity radial gradients at sub-kpc resolution in cosmic noon galaxies has been slow, yielding only $\sim$20 measurements before our work.

We, on the other hand, take a different route. In a series of works (Jones *et al.* 2015; Wang *et al.* 2017, 2018, in prep.), we invented and improved a much more effective method to measure *precise* metallicity gradients in cosmic noon galaxies. By combining the deep Hubble Space Telescope near-infrared grism data and a novel Bayesian method inferring metallicity directly from emission line fluxes, we obtained over 80 unbiased metallicity maps at $z\sim1.2$-2.3. *This improves the sample size by one order of magnitude!* Our maps reveal diverse galaxy morphologies, indicative of various effects such as efficient radial mixing from tidal torques, rapid accretion of low-metallicity gas, and other physical processes which can effectively affect the gas and metallicity distributions in individual galaxies. In particular, we found two dwarf galaxies at $z\sim2$ displaying greatly positive (i.e.inverted) gradients, strongly suggesting that powerful galactic winds triggered by central star bursts carry the bulk of stellar nucleosynthesis yields to the outskirts (Wang *et al.* 2018). We also observe an intriguing correlation between stellar mass and metallicity gradient, consistent with the "downsizing" galaxy formation picture that more massive galaxies are more evolved into a later phase of disk growth, where they experience more coherent mass assembly at all radii and thus show shallower metallicity gradients. Furthermore, 10% of the gradients measured in our sample are inverted, which are hard to explain by currently existing hydrodynamic simulations and analytical chemical evolution models. Our data analysis techniques can also be applied to data from future space missions employing grism instruments, i.e., JWST, WFIRST, Euclid, etc.

References

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