Dissecting the SFR-M* relation at z ~ 2
Implications for SFR diagnostics at high redshift

Irene Shivaei[1,2], Naveen Reddy[1], Mariska Kriek, Alice Shapley, Bahram Mobasher, Brian Siana, Alison Coil, William Freeman, Ryan Sanders, Sedona Price, Mojegan Azadi

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[1] University of California at Riverside, [2] NSF Graduate Research Fellow

Introduction

Star formation rate (SFR) is one of the most fundamental quantities for constraining the physics of galaxy formation and evolution. The past decade has seen a multitude of studies that trace SFRs out to high redshift and examined their correlation with other galaxy properties, such as stellar masses (M*). The correlation between SFR and M* suggests that galaxies assemble their stellar mass in a relatively steady process, as opposed to a rapid starburst mode.

At redshift z~2, universe was at its peak of star-formation activity and galaxies were at the process of assembling most of their stellar mass. Therefore, studying the SFR-M* relation at that epoch is crucial for better understanding the galaxy evolution processes. Previous efforts to constrain the SFR-M* relation at z~2 have inconsistent results regarding the slope, normalization, and scatter of the relation. These studies can not be easily compared with each other as they adopt different samples and different SFR indicators.

In the MOSDEF survey, we have access to multiple SFR diagnostics for a large and comprehensive sample of galaxies at z~2 that can be used to resolve some of the discrepancies between the previously derived SFR-M* properties. These SFR diagnostics include:

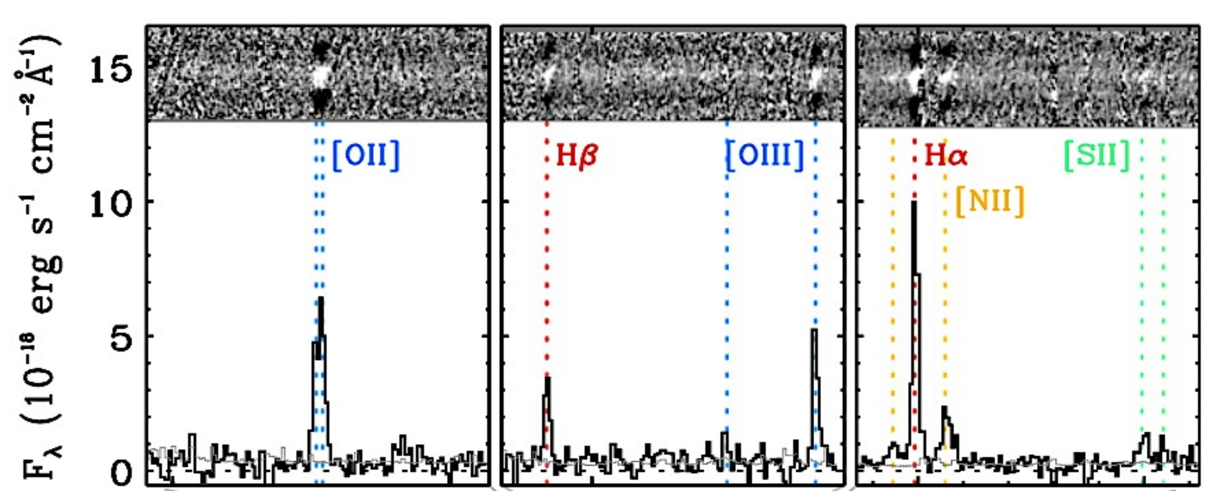
- Robust dust-corrected SFR(Hα, Hβ) from near-IR spectroscopy
- Obscured SFR(IR) from *Spitzer* and *Herschel* mid- and far-IR photometry
- Unobscured SFR(UV) as well as SFRs derived from SED fitting, from UV to near-IR photometry

The MOSDEF Survey*

The MOSFIRE Deep Evolution Field (MOSDEF) survey is a large program with MOSFIRE near-IR spectrometer on the Keck I telescope, to observe the stellar, gaseous, metal, dust, and black hole content of ~1500 galaxies at 1.37≤ z ≤ 3.80.

The MOSDEF sample is selected based on rest-optical (H-band) magnitudes and is observed in five CANDELS fields: AEGIS, COSMOS, GOODS-N, GOODS-S, and UDS.

* Survey website: http://mosdef.astro.berkeley.edu



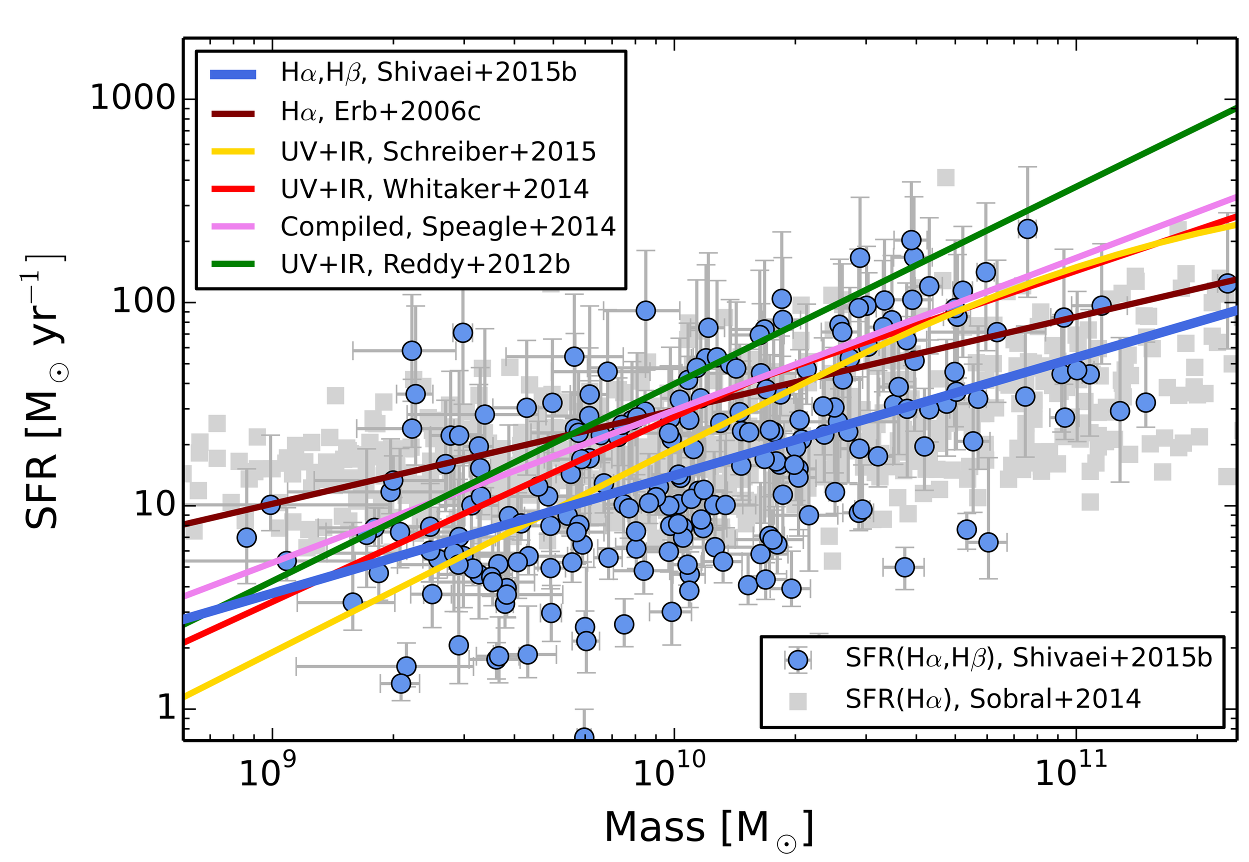
Kriek et al. (2015)

(*Above*:) an example of a MOSDEF near-IR spectrum of a galaxy at z ~ 2. The bright rest-frame optical emission lines are visible in the 2D spectra (above) and the 1D extraction (below).

SFR-M* in MOSDEF and other studies

In Shivaei et al. (2015b), we explored the relationship between dust-corrected SFR derived from Hα, Hβ and stellar mass derived from SED fitting for 216 galaxies at z ~ 2 (right figure). We measured a log(SFR)-log(M*) slope of 0.6 ± 0.1.

In the right plot, relations from other studies are shown with colored lines. Clearly, there is a discrepancy between the slope of the SFR-M* relation derived from different studies. The comparison suggests that studies that use Hα SFRs measure systematically shallower slopes compared to those that adopt IR inferred SFRs.

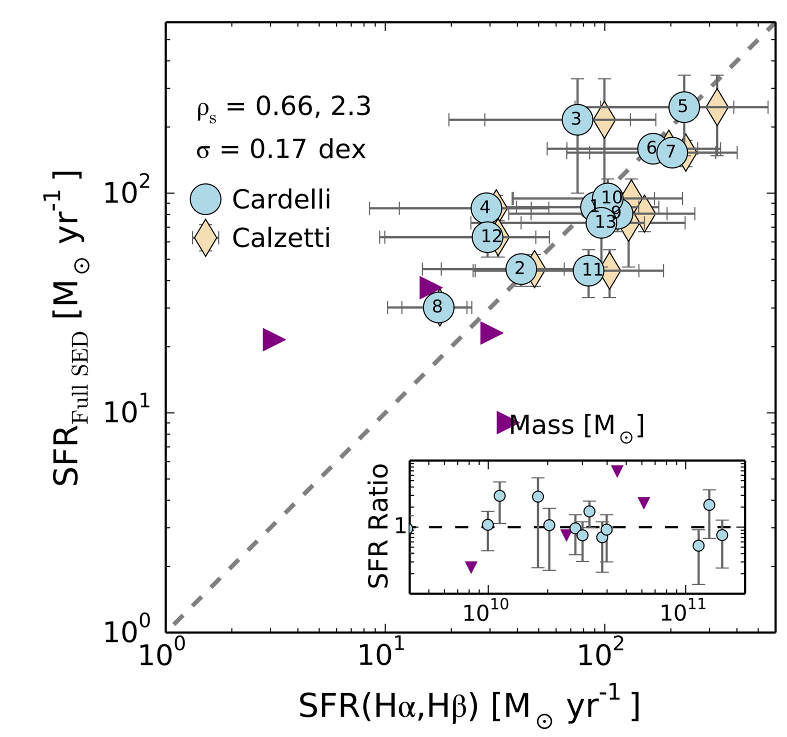


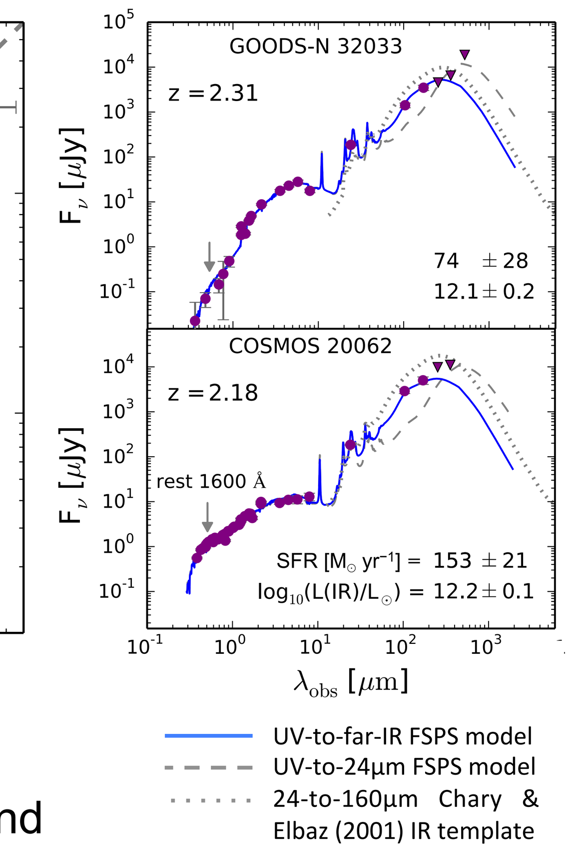
Questions: How does choosing different SFR diagnostics affect the slope of the SFR-M* relation? What conditions must be met for various SFR diagnostics to be valid?

Comparison of SFR diagnostics:

1. How accurate does Hα trace SFR at z ~ 2?

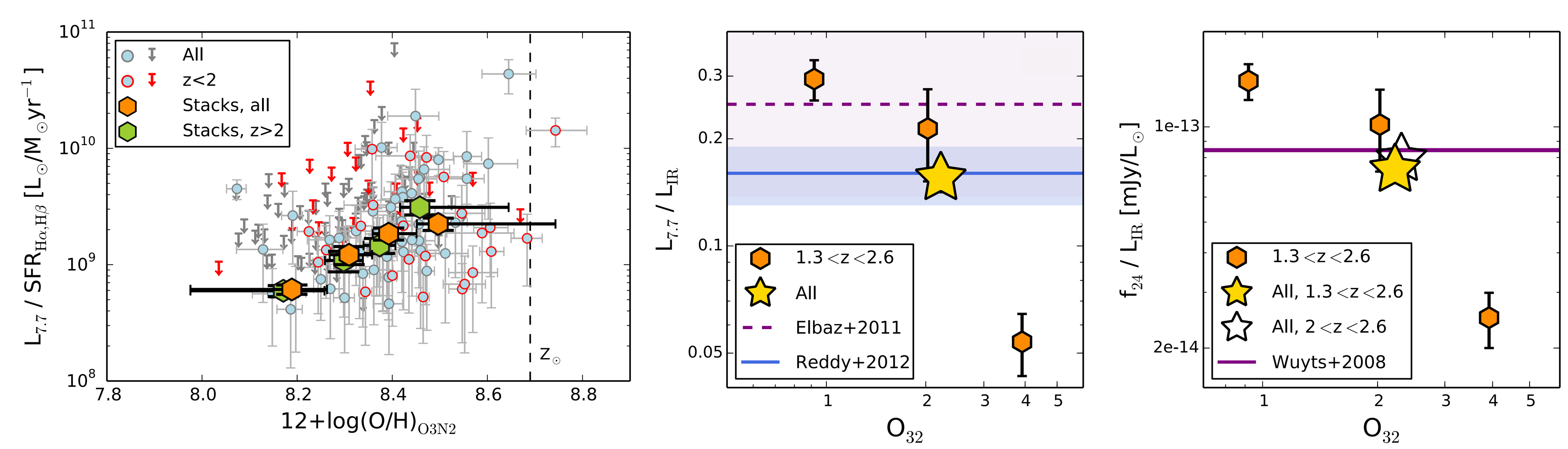
As galaxies at z ~ 2 were more star-forming compared to now, it has been argued that Balmer lines may miss optically thick star-forming regions at these high redshifts. In order to investigate this possible bias, we compared the MOSDEF SFR(Hα,Hβ) with independently measured UV-to-far-IR SFRs derived from panchromatic SED fitting (right two models).





Result: In Shivaei et al. (2016), we showed that Hα luminosity, once corrected for dust attenuation using the Balmer decrement, does not underestimate the SFR even for the most dusty and star-forming galaxies in our sample (SFRs ~ 250 M$_\odot$yr^{-1}).

2. How accurate does 24μm trace SFR at z ~ 2?



Spitzer/MIPS 24μm is commonly used as an indicator of total IR luminosity (L_{IR}) and SFR at high redshift, as it traces 7.7μm PAH emission at z~2. To explore the robustness of this SFR diagnostic at different ISM environments, we investigated the relative strength of 7.7μm luminosity, traced by MIPS 24μm, to SFR(Hα,Hβ) as well as to IR luminosity, derived from *Herschel*/PACS 100 and 160μm bands, as a function of metallicity (left plot) and ionization state (middle and right plots). There is a clear trend between 7.7μm intensity and metallicity, ionization state, and as a consequence the stellar mass. This result implies that PAH molecules are effectively destroyed by harder radiation fields in low metallicity environments.

Result: The commonly-used conversions of $L_{8\mu m}$ to L_{IR} (horizontal lines in the plots above) are only consistent with more massive and metal-rich galaxies.

Right figure demonstrates that using a single conversion from rest 7.7μm to L_{IR} (diamonds) underestimates SFRs at low masses, and hence, results in a steeper slope of the SFR-M* relation. In contrast, blue stars that are calculated from our mass-dependent conversion of $L_{7.7\mu m}$ to L_{IR} (Shivaei et al. 2016, in prep), are in a very good agreement with SFR(Hα,Hβ) (red circles) and with a shallower slope of the SFR-M* relation.