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THE MOSDEF SURVEY: SULFUR EMISSION-LINE RATIOS PROVIDE NEW INSIGHTS INTO EVOLVING ISM CONDITIONS AT HIGH REDSHIFT[1]

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ABSTRACT

We present results on the emission-line properties of $1.3 \le z \le 2.7$ galaxies drawn from the complete MOSFIRE Deep Evolution Field (MOSDEF) survey. Specifically, we use observations of the emission-line diagnostic diagram of [OIII]λ5007/Hβ vs. [SII]λλ6717,6731/Hα, i.e., the "[SII] BPT diagram," to gain insight into the physical properties of high-redshift star-forming regions. High-redshift MOSDEF galaxies are offset towards lower [SII]λλ6717,6731/Hα at fixed [OIII]λ5007/Hβ, relative to local galaxies from the Sloan Digital Sky Survey (SDSS). Furthermore, at fixed [OIII]λ5007/Hβ, local SDSS galaxies follow a trend of decreasing [SII]λλ6717,6731/Hα as the surface density of star formation (Σ_{SFR}) increases. We explain this trend in terms of the decreasing fractional contribution from diffuse ionized gas (f_{DIG}) as Σ_{SFR} increases in galaxies, which causes galaxy-integrated line ratios to shift towards the locus of pure H II-region emission. The $z \sim 0$ relationship between f_{DIG} and Σ_{SFR} implies that high-redshift galaxies have lower f_{DIG} values than typical local systems, given their significantly higher typical Σ_{SFR}. When an appropriate low-redshift benchmark with zero or minimal f_{DIG} is used, high-redshift MOSDEF galaxies appear offset towards higher [SII]λλ6717,6731/Hα and/or [OIII]λ5007/Hβ. The joint shifts of high-redshift galaxies in the [SII] and [NII] BPT diagrams are best explained in terms of the harder spectra ionizing their star-forming regions at fixed nebular oxygen abundance (expected for chemically-young galaxies), as opposed to large variations in N/O ratios or higher ionization parameters. The evolving mixture of H II regions and DIG is an essential ingredient to our description of the ISM over cosmic time.

輝線比診断におけるDiffuse Ionized Gasの影響

- 銀河の輝線比診断はISMの物理を解く上で重要な手法。
- スリットやファイバーで測定されるHα fluxにはDiffuse Ionized Gas (DIG) の寄与が含まれている
  - DIGはHII領域の外側に存在し、観測されるHα fluxの30-60%を占める。
- DIGとHII領域では物理状態や電離状態が異なるが、[NII] BPT上ではその影響は見えない。
- DIGも合わせて理解しなければHII領域の物理を正しく知ることは出来ない。
- MOSDEFの完全なdatasetを使ってDIGの寄与(の変化)も含めて再評価する。

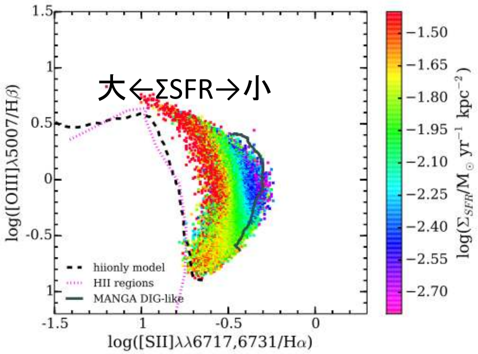


Figure 2. Median Σ_{SFR} for SDSS galaxies as a function of position in the [SII] BPT diagram. There is a strong trend for galaxies with higher values of Σ_{SFR} to be shifted towards lower values of [SII]λλ6717,3731/Hα at fixed [OIII]λ5007/Hβ (Masters et al. 2016). In addition, we indicate the running median for local H II regions (Pilyugin & Grebel 2016) with the dotted pink line. The running median line ratios are calculated in bins of H II-region electron temperature. The *hiionly* model from Sanders et al. (2017) is shown with the dashed black line, representing the ensemble average emission from H II regions in star-forming galaxies in the absence of DIG emission. Finally, the running median for "DIG"-like (i.e., low Hα surface brightness) spaxels from the SDSS/MaNGA DIG galaxy sample used in Sanders et al. (2017) is shown as the solid dark-grey curve. The running median line ratios for the "DIG"-like curve are calculated in bins of ([OIII]λ5007/Hβ)/([NII]λ6584/Hα), which correlates with nebular metallicity in local H II regions (Pettini & Pagel 2004).

Fig2. SDSS銀河の[SII] BPT

ΣSFRが大きいほど[SII]/Hαが小さくなる傾向。ΣSFRはHα fluxへのDIGの寄与 (f_{DIG})と逆相関するので、ΣSFR大→f_{DIG}小。

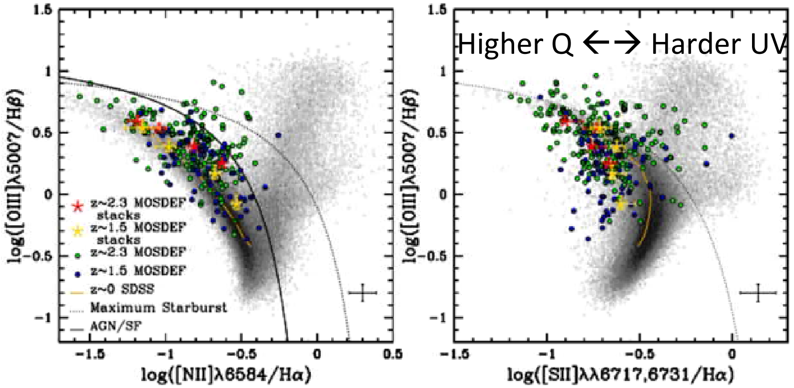
	SDSS	z~1.5	z~2.3
Log(ΣSFR)	-1.93	-0.46	-0.03
f_{DIG}	0.54	0.11	0.0

Fig4. MOSDEF銀河の[SII] BPT

(Fig1と異なるのは、比較する近傍データのΣSFRをMOSDEFと揃えた点。)

近傍銀河よりも[SII]/Hαが右に来る([NII]/Hαも同様)。

→ high-zではharder ionizing spectrum
(電離パラメタの違い説を棄却)



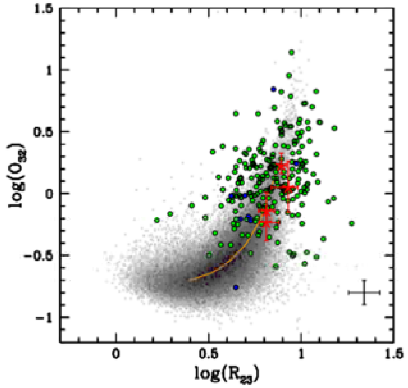
[NII] BPT↗

High-z銀河はlocal銀河より右上にオフセットしている。

原因：高い電離パラメタ、固い電離スペクトル、高電子密度、N/Oガス比の違い、AGN等。

↑[SII] BPT

近傍と大きくは変わらないか、やや左寄り。



←R_{23} vs. O_{32}

近傍と大きくは変わらない。

Figure 1. **Top left:** [NII] BPT diagram for $1.4 \le z \le 2.7$ MOSDEF galaxies. Green [blue] points indicate $z \sim 2.3$ [$z \sim 1.5$] MOSDEF galaxies with $\ge 3\sigma$ detections of all 4 BPT emission lines. Median MOSDEF errorbars are indicated in the lower-right-hand corner of each panel. The grayscale histogram and orange curve correspond, respectively, to the distribution and running median of local SDSS galaxies. The running median line ratios are calculated in closely-spaced bins of stellar mass. Large red [gold] stars indicate measurements from composite spectra, binned by stellar mass, of all MOSDEF $z \sim 2.3$ [$z \sim 1.5$] galaxies with coverage of the relevant emission lines and $\ge 3\sigma$ Hα detections. Stacks of increasing stellar mass have lower [OIII]λ5007/Hβ. The black dotted curve is the "maximum starburst" line from Kewley et al. (2001), while the black solid curve is an empirical AGN/star-formation threshold from Kauffmann et al. (2003). Although plotted here for completeness, SDSS galaxies falling above the Kauffmann et al. (2003) curve are not included in our analysis. **Top right:** [SII] BPT diagram. Symbols are the same as in the left-hand panel. **Bottom:** O_{32} vs. R_{23} diagram, corrected for dust. Stacked points are not shown for the $z \sim 1.5$ sample in this panel, given the small size of the sample with [OII]λλ3726,3729 coverage.

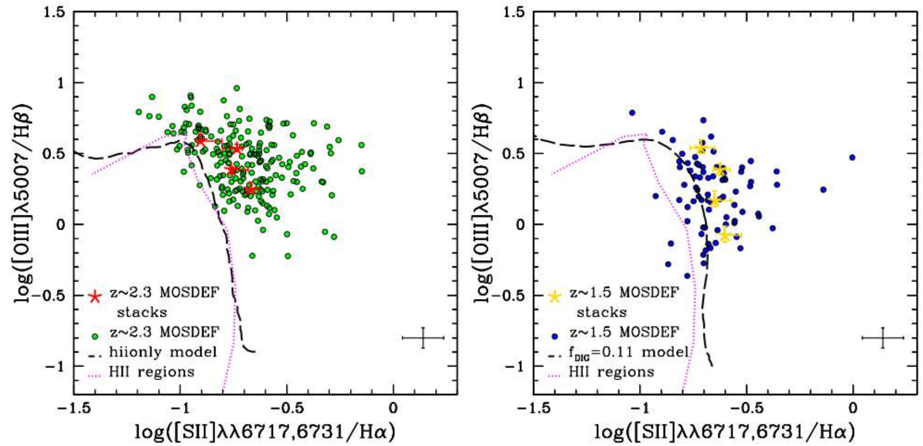


Figure 4. Comparison in the [SII] BPT diagram beween MOSDEF galaxies, HII regions, and models with low DIG emission fraction. **Left:** [SII] BPT diagram for $z \sim 2.3$ MOSDEF galaxies and stacks (green points, red stars), median sequence of local H II regions (magenta dotted line), and *hiionly* model from Sanders et al. (2017) (black dashed line). $z \sim 2.3$ MOSDEF galaxies are clearly offset towards larger [OIII]λ5007/Hβ and/or larger [SII]λλ6717,6731/Hα relative to local H II regions and the *hiionly* model. **Right:** The same plot, but for $z \sim 1.5$ MOSDEF galaxies and stacks (blue points, gold stars), local H II regions (magenta dotted line), and a model from Sanders et al. (2017) representing the ensemble average emission from H II regions in star-forming galaxies plus a DIG fractional contribution to the Hα emission of $f_{DIG} = 0.11$. The offset between $z \sim 1.5$ MOSDEF galaxies and the comparison curves is smaller than for the $z \sim 2.3$ MOSDEF sample.