

# “Chemical abundances in high-redshift galaxies: A powerful new emission line diagnostic”

Dopita et al., (2016) <http://arxiv.org/abs/1601.01337> (Ap & SS, accepted)

## Abstract

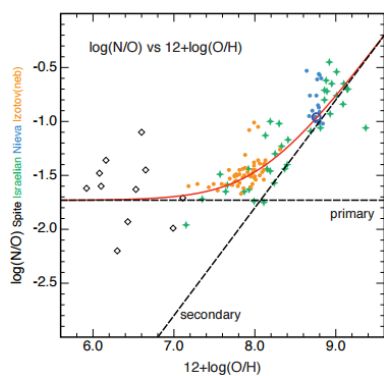
This Letter presents a new, remarkably simple diagnostic specifically designed to derive chemical abundances for high redshift galaxies. It uses only the H $\alpha$ , [N II] and [S II] emission lines, which can usually be observed in a single gating setting, and is almost linear up to an abundance of  $12 + \log(O/H) = 9.05$ . It can be used over the full abundance range encountered in high redshift galaxies. By its use of emission lines located close together in wavelength, it is also independent of reddening. Our diagnostic depends critically on the calibration of the N/O ratio. However, by using realistic stellar atmospheres combined with the N/O vs. O/H abundance calibration derived locally from stars and H II regions, and allowing for the fact that high-redshift H II regions have both high ionisation parameters and high gas pressures, we find that the observations of high-redshift galaxies can be simply explained by the models without having to invoke arbitrary changes in N/O ratio, or the presence of unusual quantities of Wolf-Rayet stars in these galaxies.

- (1) 遠方銀河の金属量を求める新しい calibration を提案.
- (2) それを用いた遠方銀河のISMの物理状態の考察.

遠方 (z~2) で金属量 (gas-phase metallicity) を精度よく見積もるのはまだ難しい  
→ 適用範囲が広く、観測も簡単な輝線で求められるか？

## モデリング手法

- HII領域の光電離モデル → Mappings5.0 (Sutherland in prep)
- EUVスペクトル形状 → Starbursts99 (Leitherer 1999)



(新しい点)  
先行研究では無視されていた, ionized gas pressure (log P/k) をパラメータとして組み込み, 結果に与える影響を初めて調べた.

(弱点?)  
N/O vs. O/H の較正の精度に大きく影響を受ける. 今回は系統的な観測データと現実的な恒星大気モデルを入れて高精度の較正を実現.

Fig. 1.— The calibration of N/O vs. O/H used in this paper. The data points are derived from the following papers: Izotov et al. (1999); Israelian et al. (2004); Spite et al. (2005) and Nieva & Przybilla (2012)

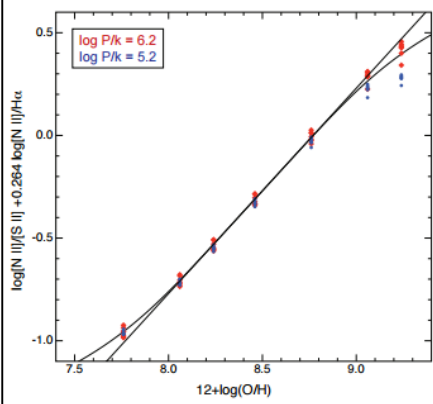


Fig. 3.— Calibration of the [N II]/[S II] and [N II]/H $\alpha$  emission line ratio combination against  $12 + \log(O/H)$ . The red group of points represent the models having  $\log P/k = 6.2 \text{ cm}^{-3} \text{ K}$ , while the blue points are for  $\log P/k = 5.2 \text{ cm}^{-3} \text{ K}$ . The lines shown are the best linear fits and 5th. order fits as described in the text.

## 金属量の較正式

- (利点) - H $\alpha$ , [NII], [SII] のみ使用 (いずれも abundance sensitive)
- 1バンドで全ての輝線が取得できる. 減光補正も不要.
- 遠方で観測されている金属量の範囲をカバー

$$y = \log [NII]/[SII] + 0.264 \log [NII]/H\alpha, \quad (1)$$

$$12 + \log(O/H) = 8.77 + y \quad (2)$$

観測効率が高く, 不定性の少ない calibration になっている

## 本モデルが与える新しい解釈

- 遠方 (z~2) のISMの物理状態を調べる研究が増えてきた (MOSFIRE, FMOS etc...)
- ↓
- ・ [NII]/H $\alpha$ を固定した場合に, 近傍より [OIII]/H $\beta$  の上昇
- ・ [SII]/H $\alpha$  に対して, [NII]/H $\alpha$  は高めのオフセットをもつが報告されている (e.g. Masters2014, Shapley2015)
- ↓
- 遠方銀河のISMの物理状態が近傍と異なるのはわかってきたが, どのパラメータがどう効いているのかはまだ議論の最中.

## 先行研究の解釈

- ・ 遠方銀河に, T<sub>e</sub> ~ 80000 K のWolf-Rayet 星がたくさんいれば説明できる. (i.e. 高温環境による[OIII]の上昇, 質量放出によるISMへのN供給)

## 本研究の解釈

- ・ gas pressure が電離パラメータ(U)と同様の効果を与える
- 遠方銀河のISMは “高Uかつ高P” が実現しているとすれば説明できる (つまり, N/O比を手で調整したり, 高温WR星が多数という特異な状況は必要ない)

高Pは以下の効果をもたらす  
(i) 高N<sub>e</sub> → FIR微細構造線によるcoolingを抑制 → 高温環境 → [OIII]/H $\alpha$  ↑  
(ii) [SII] doubletの衝突脱励起 → [SII]/H $\alpha$  ↓

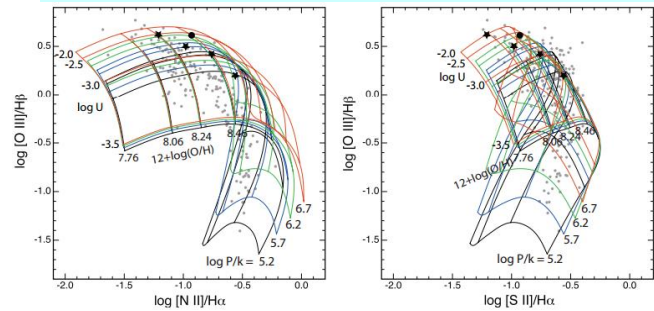


Fig.4

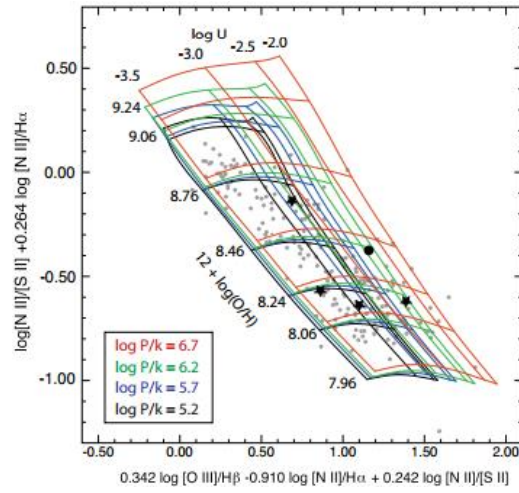


Fig. 2.— The 3D projection of the  $[\text{N II}]\lambda 6484/\text{H}\alpha$  the  $[\text{N II}]\lambda 6484/[\text{S II}]\lambda\lambda 6717, 31$  and the  $[\text{O III}]\lambda 5007/\text{H}\beta$  line ratios which cleanly separates the abundance ( $y$ -axis) from the effects of pressure and ionisation pressure ( $x$ -axis). For comparison with the theoretical grid, the observations of van Zee et al. (1998) of individual H II regions in local spiral galaxies are shown as grey circles, and for high-redshift galaxies we plot the  $z \sim 2$  MOSDEF stacks from Shapley et al. (2015) (stars), and the  $z \sim 2$  composite spectrum from the Magellan FIRE survey from Masters et al. (2014) (filled black circle). These data points are generally consistent with sub-solar metallicity, high pressure, and high ionisation parameter.

