# Alpha-element abundance patterns in star-forming regions of the Local Universe

## 1 Introduction

Oxygen:
- 3rd most abundant element in the Universe
- One of the $\alpha$-elements, even Z elements whose number of neutrons is Z

Production of $\alpha$-elements in stars:

**He—(triple-$\alpha$ process)→C→O, Ne→S, Ar⋯**

- Abundance ratio between $\alpha$-elements and oxygen ($\alpha$/O) is nearly constant, but **$\alpha$/O should have a weak dependency on metallicity** because of the production by type-Ia SN.
- This dependency is not so clear due to the lack of lines in stellar spectra (especially in Ar)
  ⇒**Assess with nebular abundance**
- Abundance of high-z SFGs can be measured with JWST. To properly analyze, high-quality abundance data of local object is important
  ⇒**Make reassessment of the analysis of Ne/O, S/O, and Ar/O among local objects**

## 2 Sample Selection

**Database:**
- DESIRED, DESIRED-E

**Criteria:**
- HII region or SFG
- Determined as Star-forming region with BPT diagram

## 3. Physical conditions and ionic abundances

### 3.1 Electron Density

**Density-sensitive line ratios:**
- [SII]6731/6716
- [OII]3726/3729
- [Cl III]5538/5518
- [FeIII]4658/4702
- [ArIV]4740/4711

**Adopted value:**
- $n_e([SII]) < 100 cm^{-3}$: $100 \pm 100 cm^{-3}$
- $100 < n_e([SIII]) < 1000$: average between $n_e([SII])$ and $n_e([OII])$
- $1000 < n_e([SIII])$: average of $n_e([SII])$, $n_e([OII]), n_e([Cl III]), n_e([FeIII]), n_e([ArIV])$

### 3.2 Electron Temperature

**Density-sensitive line ratios:**
- [OIII]4363/5007
- [NII]5755/6584
- [SIII]6312/9069

**Adopted value:**
- If S/N(auroral line)<2.5, $T_e$ determined with corresponding lines is discarded
- $T_e([SIII])$ is used only when $T_e([OIII])$ and $T_e([NII])$ are not available

### 3.3 Ionic Abundances

**Measurable ions:**
$O^+, O^{2+}, S^+, S^{2+}, Ne^{2+}, Ar^{2+}, Ar^{3+}$

**Electron temperatures for calculation:**
- $T_e([NII]): O^+, S^+, Ar^{2+}$
- $T_e([SIII]): S^{2+}$
- $T_e([OIII]): O^{2+}, Ne^{2+}, Ar^{3+}$

If corresponding $T_e$ is unavailable, it is estimated with the temperature relations of Garnett(1992)

### 3.4 Total abundances

**Oxygen:**

$$\frac{O}{H} = \frac{O^+ + O^{2+}}{H^+}$$

**Neon, Sulfur, Argon:**

Consider ICFs(Ionization correction factor):

$$\frac{Ne}{O} = ICF(Ne) \times \frac{Ne^{2+}}{O^{2+}}$$

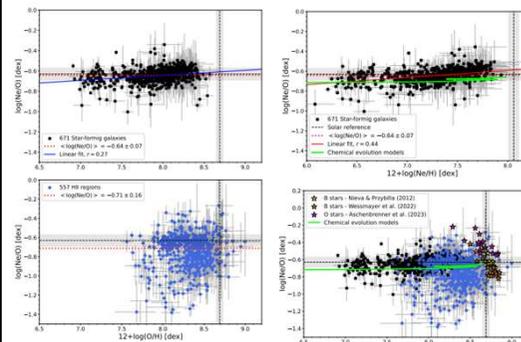$$\frac{S}{O} = ICF(S) \times \frac{S^+ + S^{2+}}{O}$$

$$\frac{Ar}{O} = ICF(Ar) \times \frac{Ar^{2+} + Ar^{3+}}{O^{2+}}$$

In this research, they adopted Izotov et al.(2006), considering its lower dependence on $O^{2+}/O$

## 4 Abundance ratio in the Local Universe

In this section, they discuss $\alpha$/O-metallicity, and $\alpha$/O- $\alpha$/H relation in HII region and SFGs.
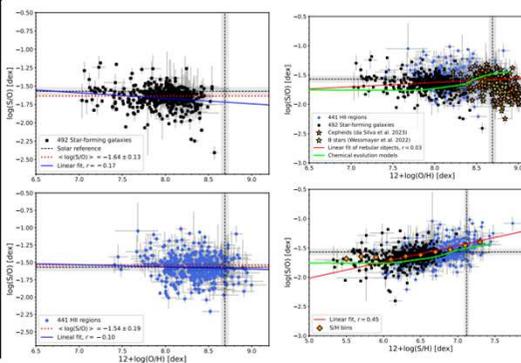
### 4.1 Ne/O



**HII region(Blue dots):**
- It shows so large dispersion of Ne/O
- It seems that ICF(Ne) cannot correct $Ne^+$

**SFG(Black dots):**
- Ne/O is positively correlated with Ne/H
- GCE model is consistent with metal-poor SFGs, but it's not with metal-rich ones
- Candidate of causes:
  1. O depletion
  2. Ne production efficiency
  3. Inaccurate ICF

### 4.2 S/O



- S/O is nearly constant with O/H in HII region and SFGs, but GCE models cannot reproduce this trend
- However, GCE models can reproduce S/O-S/H relation
- In this GCE model, about 30% of S is produced by type Ia SN

### 4.3 Ar/O
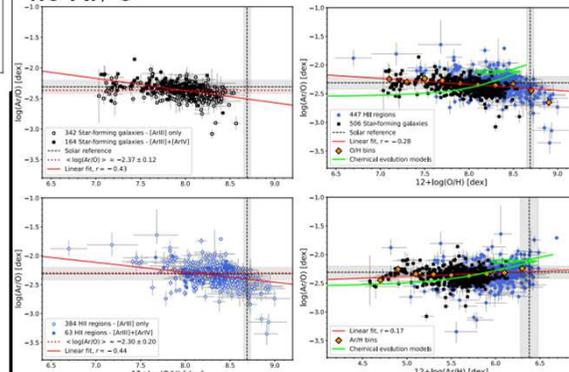


- Ar/O is negatively correlated with O/H, and it is positively correlated with Ar/H
- GCE model cannot reproduce both relation.
- Overestimation of contribution of type Ia SN in GCE model can be the cause of this in Ar/O-Ar/H relation

## 5 Conclusion

- Mean value of log($\alpha$/O) in HII regions and SFGs(These are consistent with solar value)

| | HII region | SFG |
|---|---|---|
| Ne/O | | -0.64 ± 0.07 |
| S/O | -1.54 ± 0.19 | -1.63 ± 0.13 |
| Ar/O | -2.30 ± 0.20 | -2.37 ± 0.12 |

- On average, metallicity of HII region is larger than that of SFG. This indicates that $\alpha$/O has dependency on metallicity, because of the production of type Ia SN.