初代星初代銀河研究会2025

高い窒素酸素比を持つ高赤方偏移銀河の元素の起源

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Watanabe et al. 2024 ApJ.962.50W

Watanabe et al. in prep

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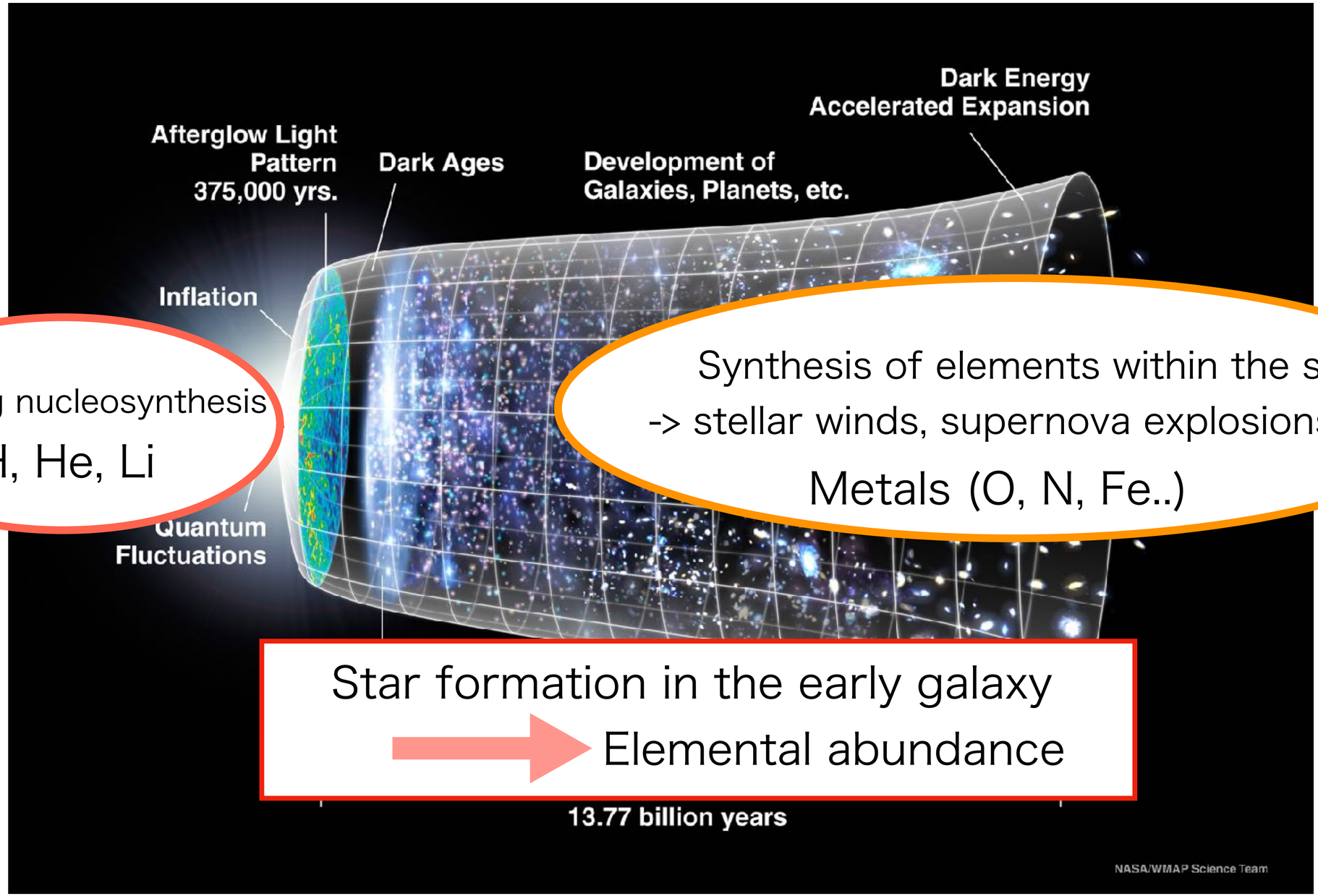
Cosmic History



Big bang nucleosynthesis

H, He, Li

Synthesis of elements within the star

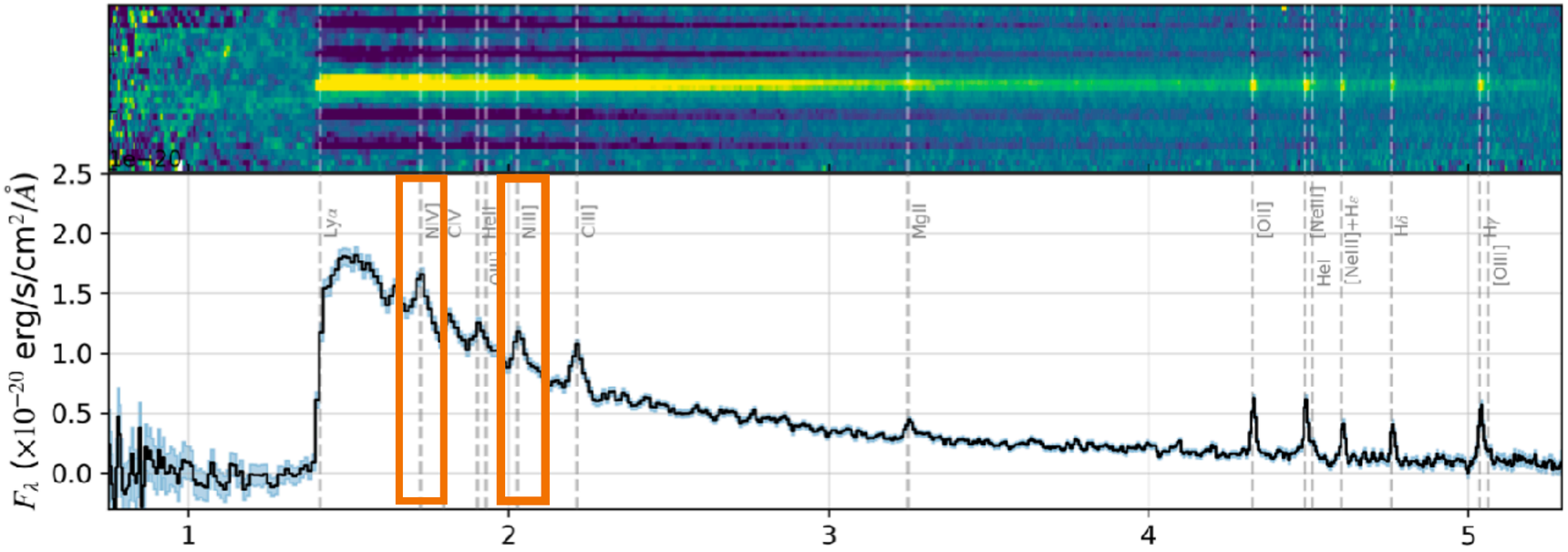
-> stellar winds, supernova explosions, etc.

Metals (O, N, Fe..)

Star formation in the early galaxy

→ Elemental abundance

Elemental Abundance Ratios in GN-z11



NASA, ESA, CSA, STScI, Brant Robertson (UC Santa Cruz), Ben Johnson (CfA), Sandro Tacchella (Cambridge), Marcia Rieke (University of Arizona), Daniel Eisenstein (CfA)

(Bunker et al. 2023)

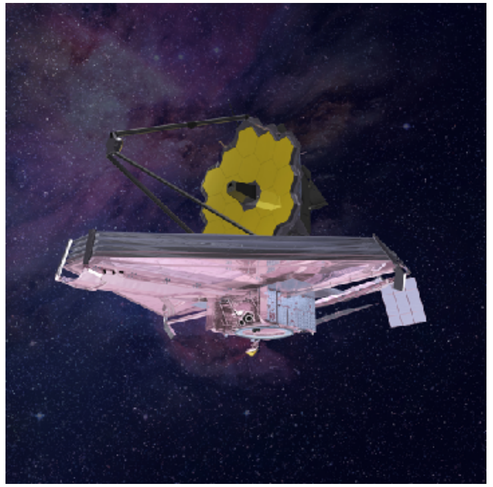
[C/O]= -0.55

[N/O]=0.60

4 times
the solar abundance

(Cameron et al. 2023)

$$[\mathrm{X/Y}] = \log\left(\frac{N_X/N_{X\odot}}{N_Y/N_{Y\odot}}\right)$$



What is the origin of rich nitrogen in the early universe?

High N/O Galaxies at High Redshift

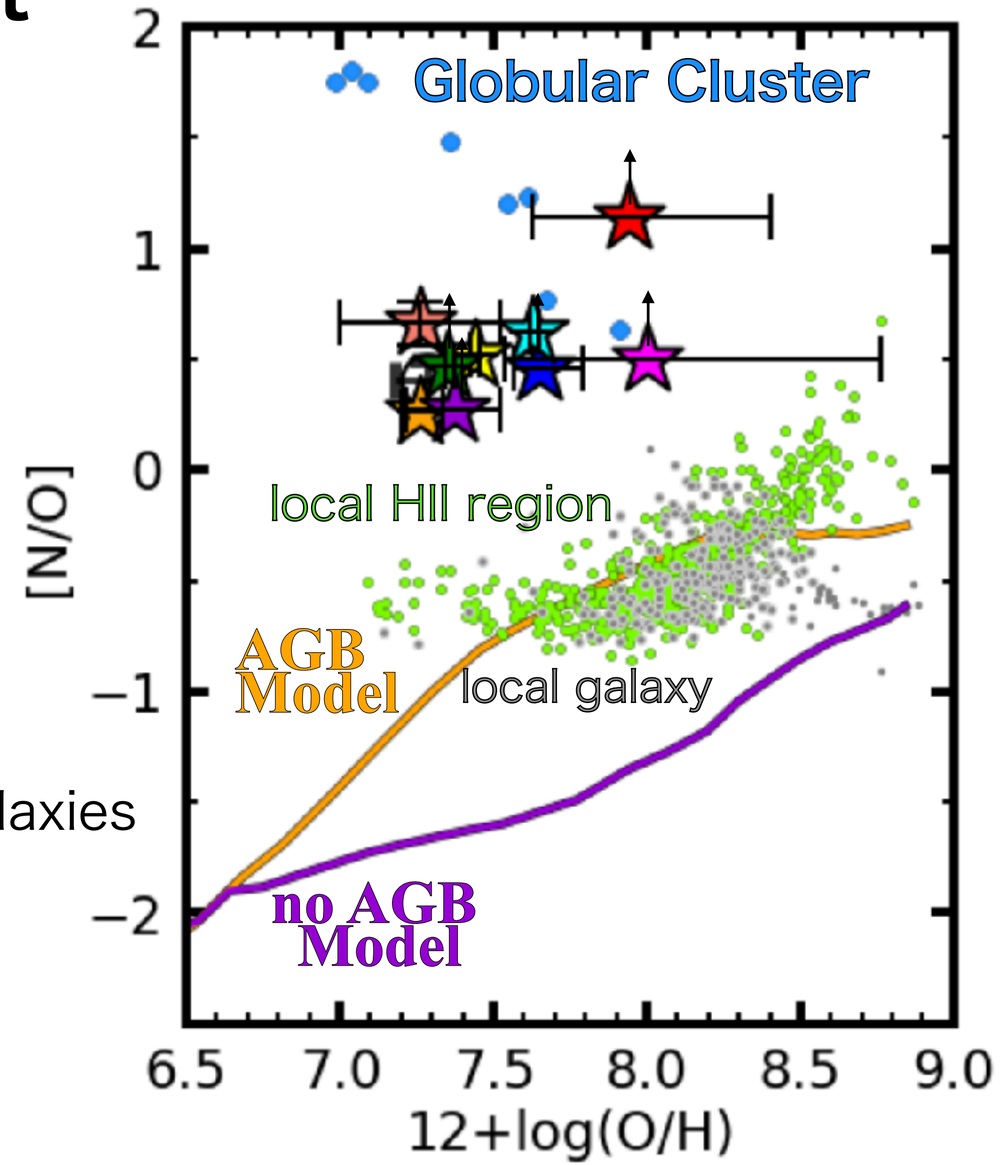
JWST observations reveal high N/O galaxies

→ Cannot be explained by AGB stars

Are unique event occurring?

Globular cluster have similar abundance with high N/O galaxies

→ Globular cluster origin at high redshift ?



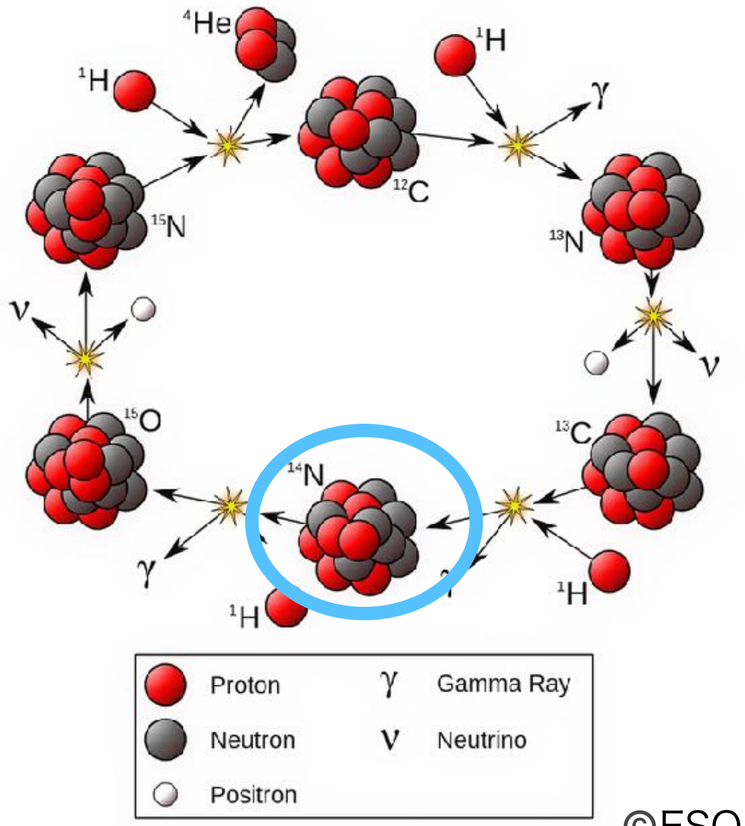
Identifying the origin of the high N/O galaxies

The C/N Values of High N/O Galaxies

The high N/O galaxies have low C/N ratios.

→ The equilibrium of the CNO cycle

The high N/O galaxies are enriched by CNO cycle?



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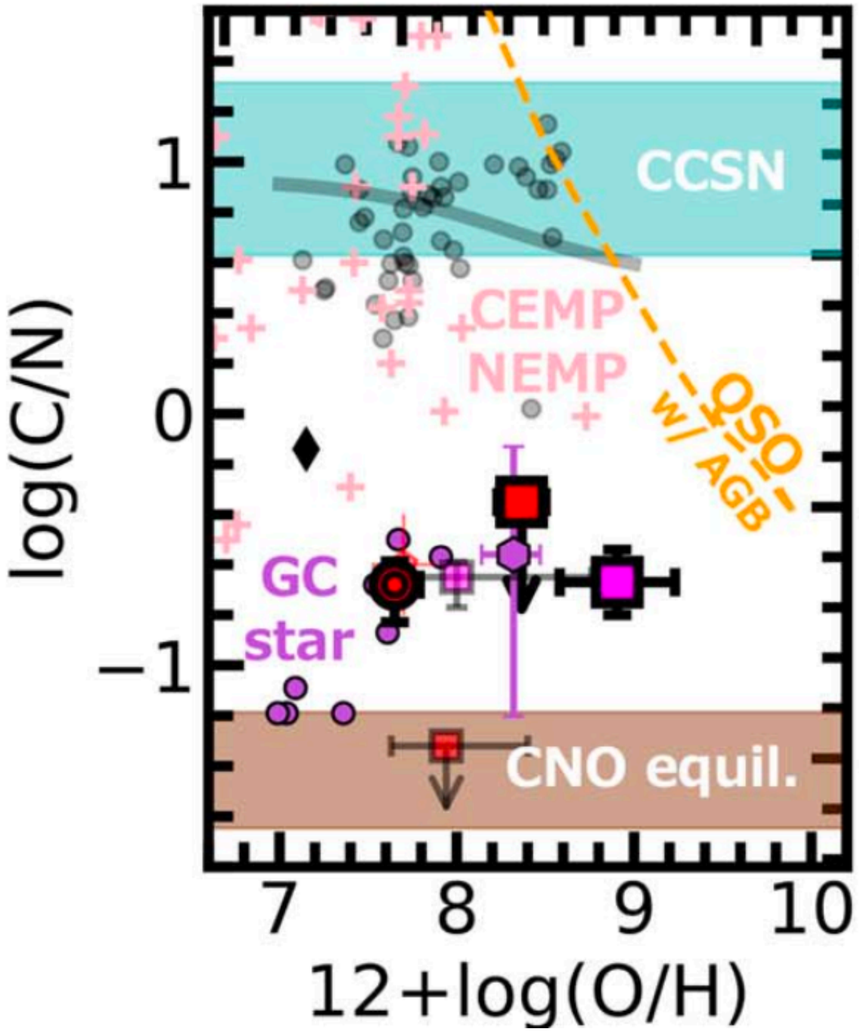

(Isobe,..,KW et al. 2023)

The Candidates of Nitrogen Origin

Three scenarios are suggested. (Senchyna+23, Charbonnel+23,Cameron+23)

In rotating stars, CNO cycle is active at the surface.

→Nitrogen increase at the stellar surface

- **Wolf-Rayet star (WR)**

  → ejected by stellar winds

- **Tidal disruption events (TDE)**

  → pulled apart by black hole

- **Supermassive star (SMS)** with $10^3 - 10^5\ M_\odot$

  The candidates of GC origin

  The inflowing gas triggers the CNO cycle in SMS.

  → ejected by stellar winds

No study has yet examined them collectively

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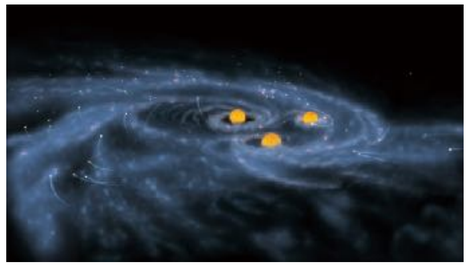

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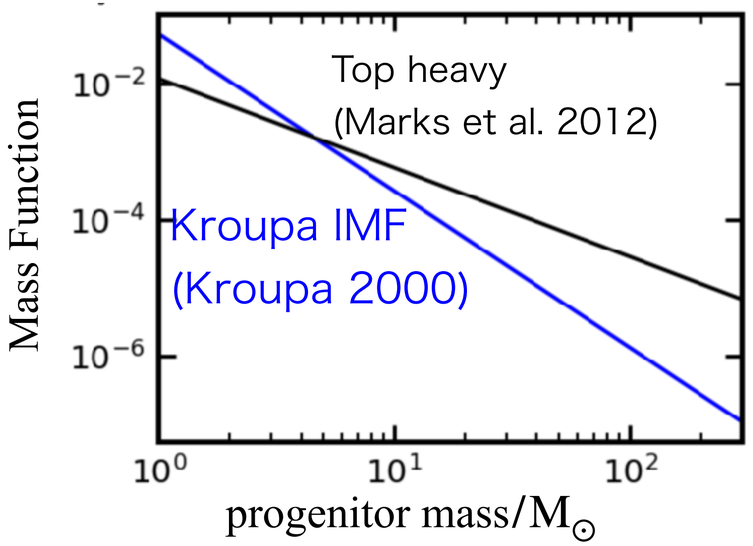
Developing the models for these 3 scenarios and Comparing with Observations

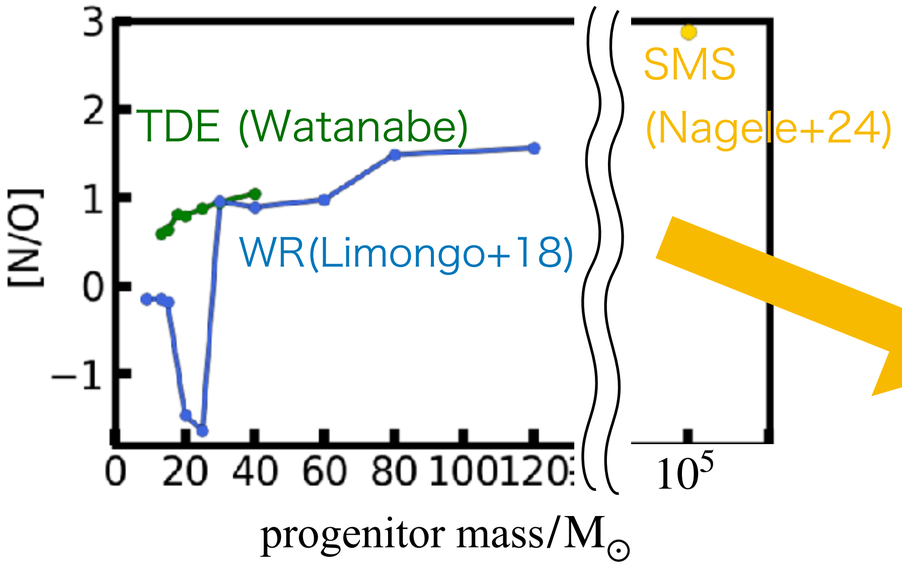
Developing One-box Chemical Evolution Models

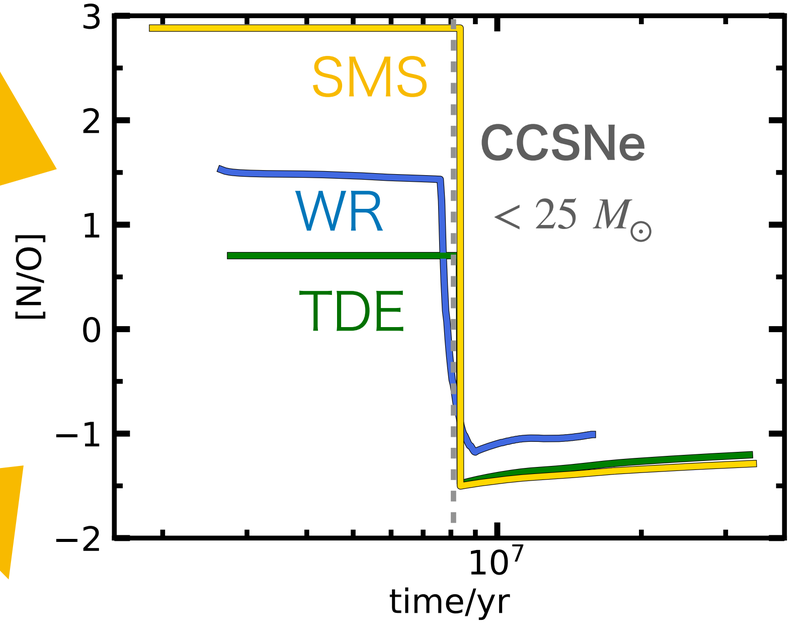
1. Star formation based on IMF



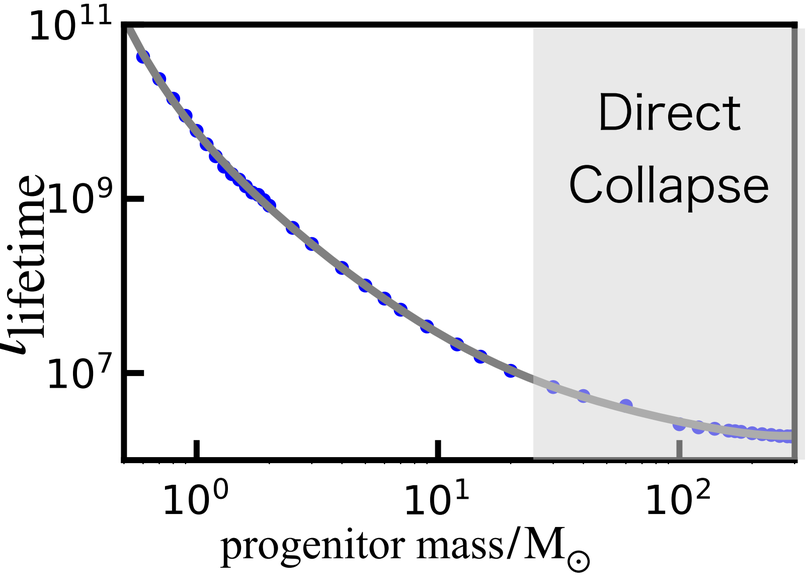
2. Nitrogen rich yields

(Suzuki & Maeda 2018)



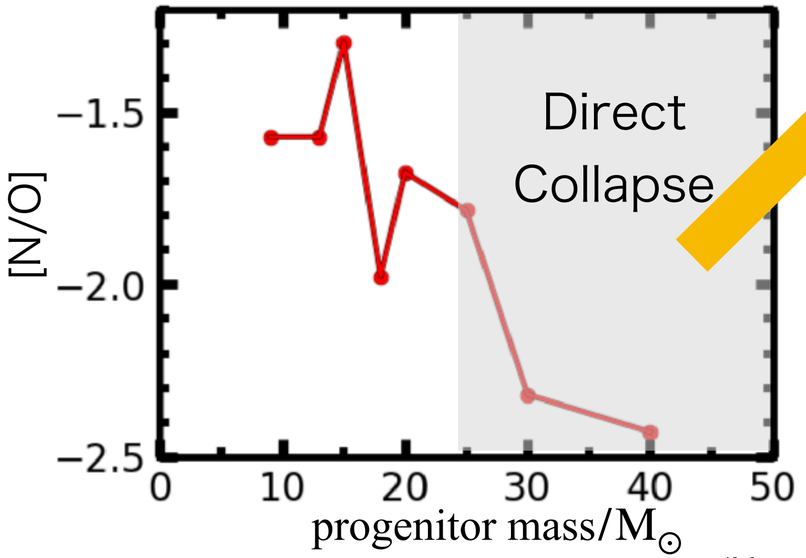


3. Life time of stars



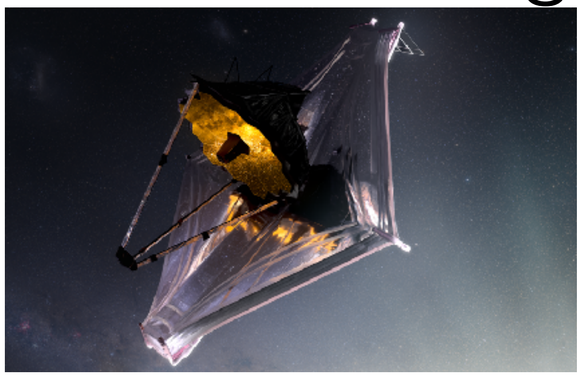
(Portinari et al. 1998, Takahashi et al. 2018)

4. Adding up CCSN ejecta from stars



(Nomoto et al. 2013)

Sample and Data



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Our sample: High N/O ([N/O]>0) galaxies already reported

・High-z galaxies

9 galaxies at $z > 6$

JWST/NIRSpec Multi-Object Spectroscopy (prism, grating)

Program: JADES, GLASS, CEERS, GO3073, GO2478

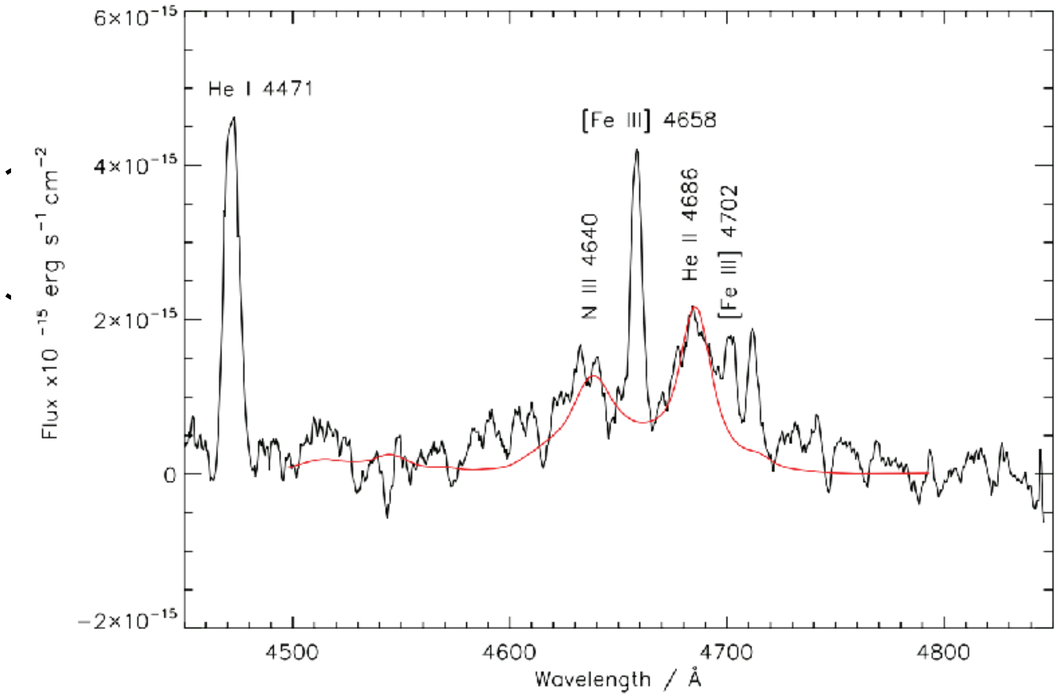
→ Data reduction and analysis

・Local galaxy

Mrk996 at $z = 0.00541$: WR galaxy

3.5 m Apache Point Observatory telescope

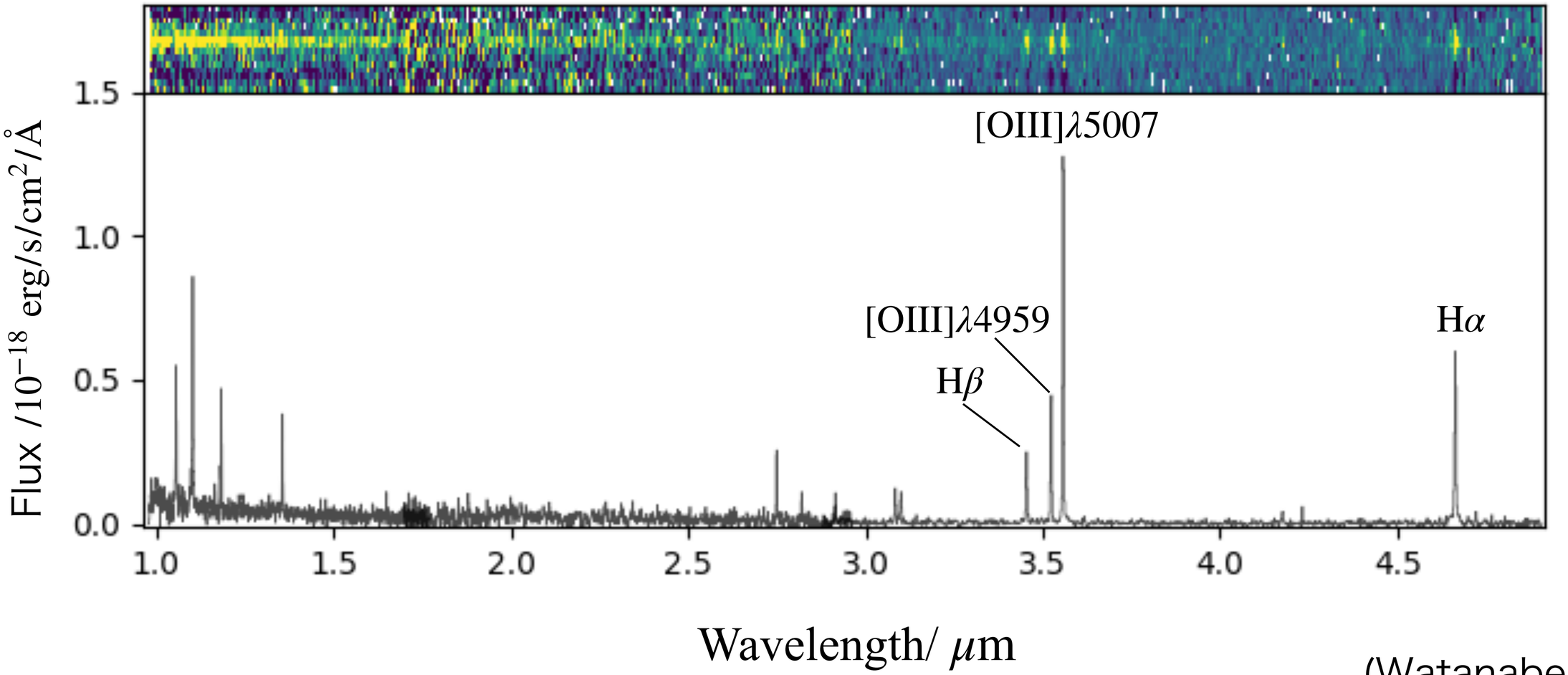
→ Using fluxes from Izotov et al. (2011)



(James et al. 2019)

Data Reduction & Analysis

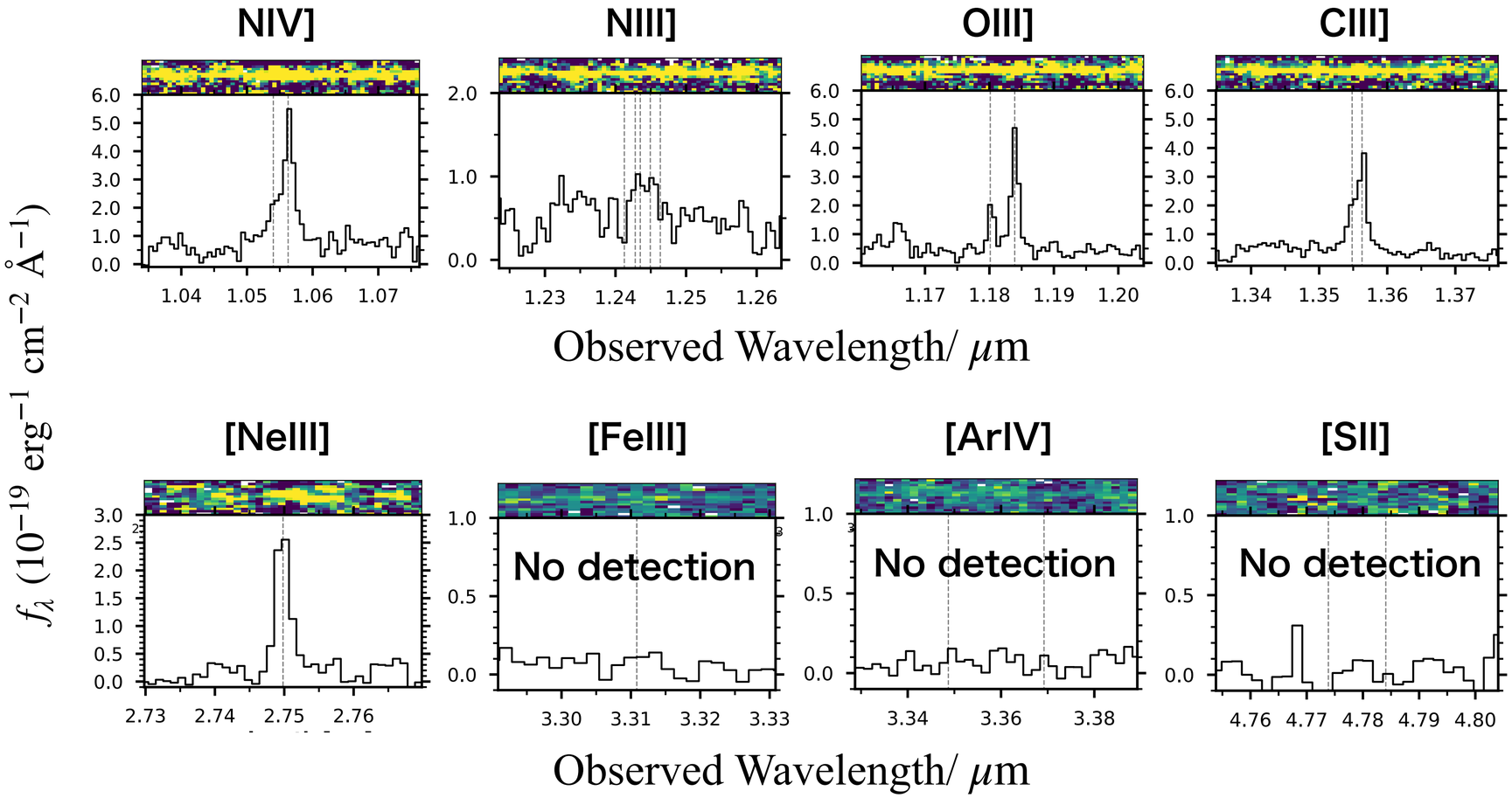
e.g.) RXCJ2248-ID



(Watanabe+ in prep)

JWST Data Reduction & Analysis

e.g.) RXCJ2248-ID

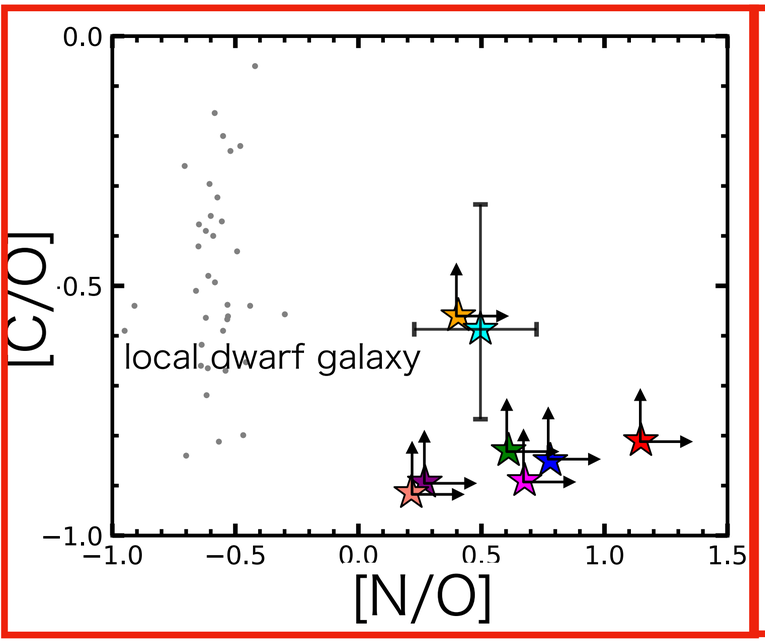


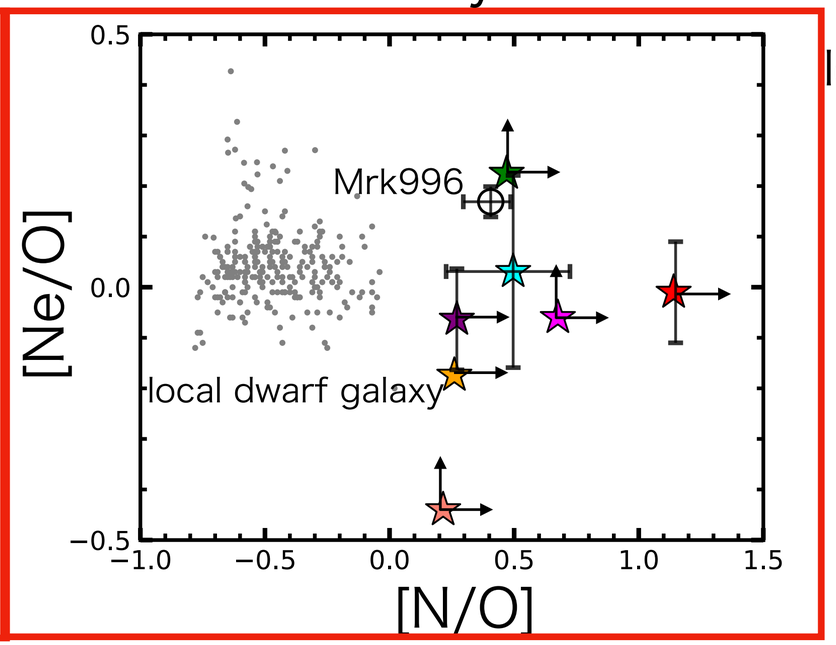
Fitting emission lines with a Gaussian profile convolved with the LSF of JWST/NIRSpec.

Deriving abundance ratios using Pyneb (Watanabe et al. 2024)

Observational Results

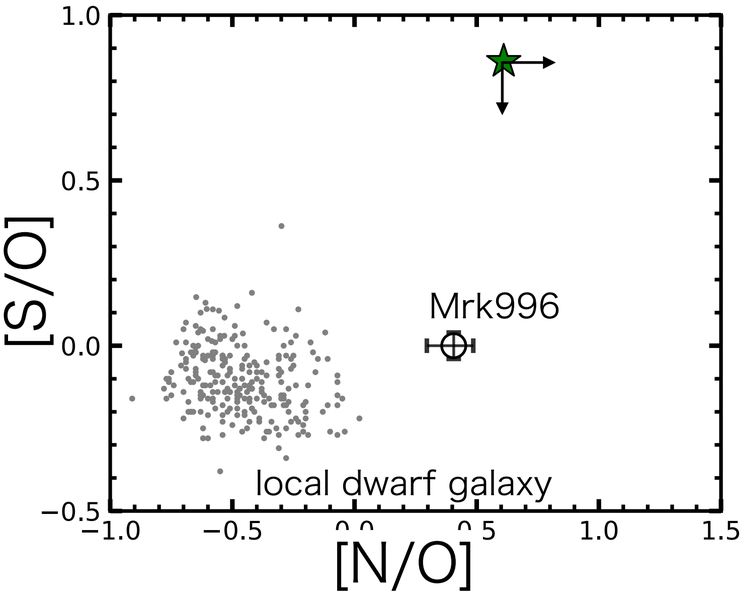
The number of abundance ratios is limited by observed wavelength range.

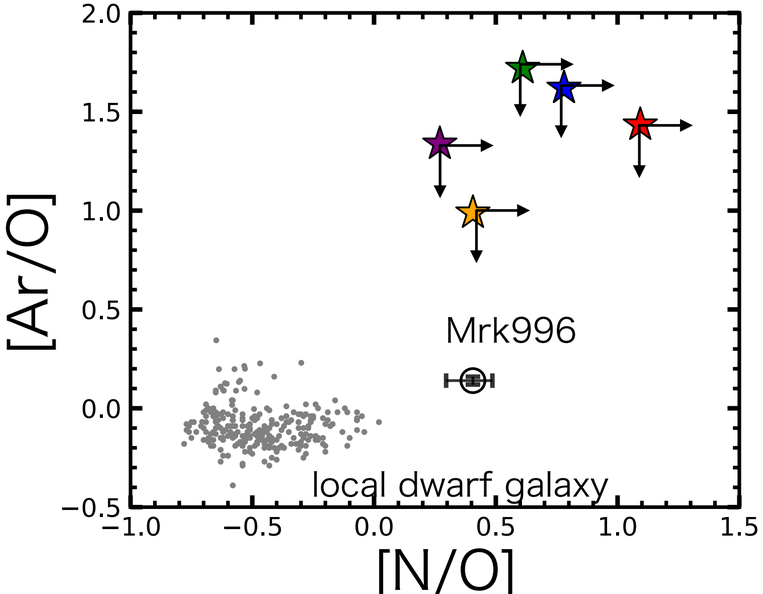


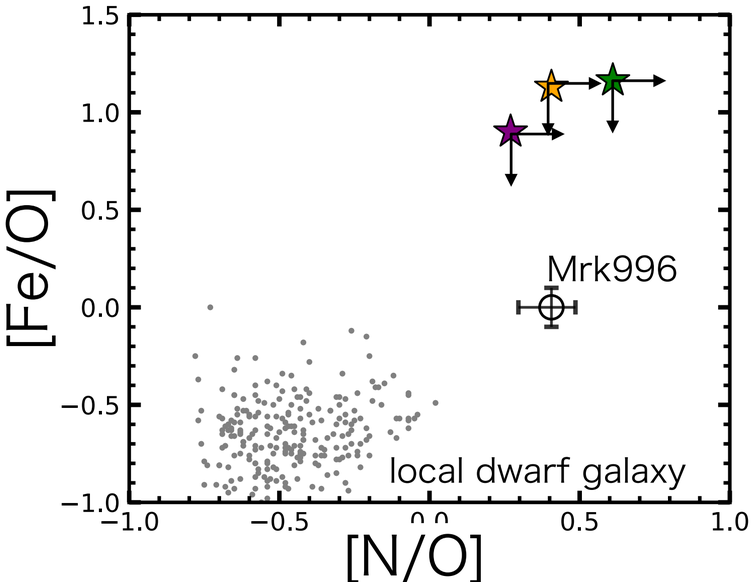


local dwarf galaxy(Izotov+06, Berg+19)

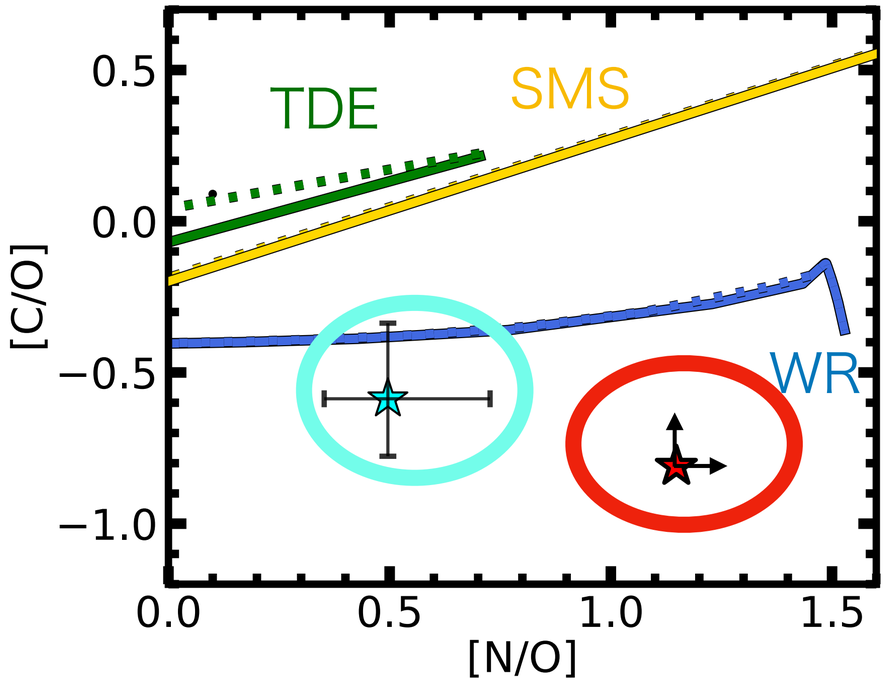
(Watanabe+ in prep)





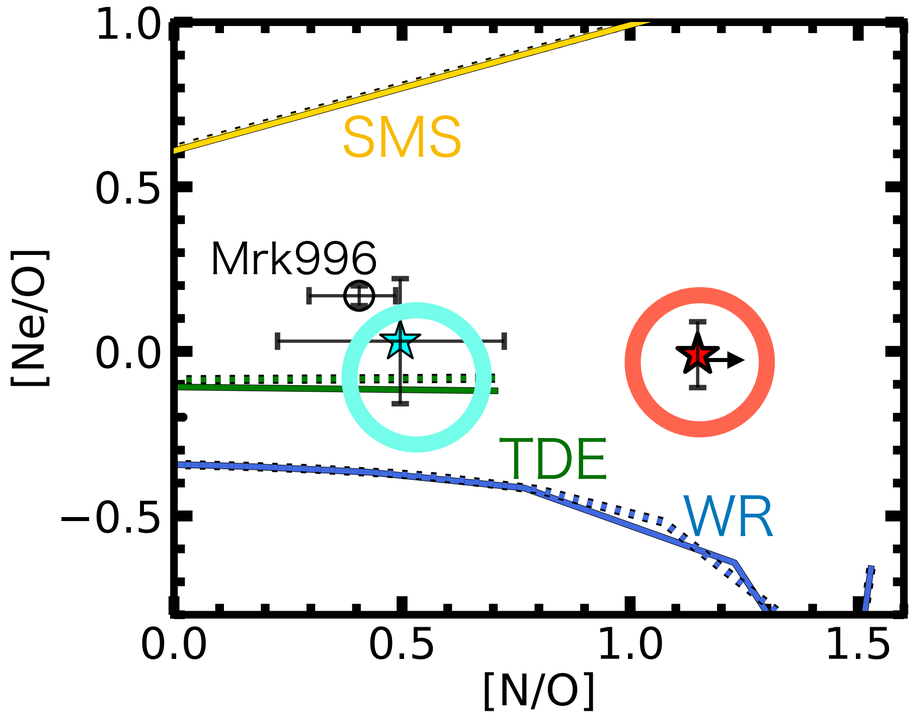


Results: C/O, Ne/O and N/O



Kroupa IMF & low metallicity

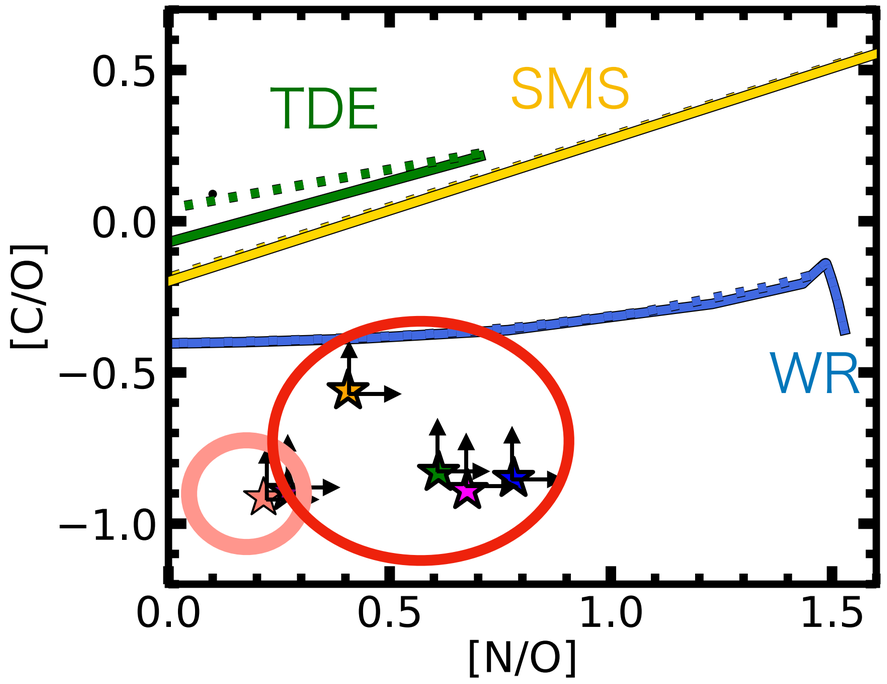
Top-heavy IMF & low metallicity



Galaxy	Comparison with Models	Possible Origin
GHZ9 ☆	[C/O] is consistent with WR models, but [Ne/O] is incosistent	Not three scenarios
CEERS_01019 ★	[N/O]>1.0 , [Ne/O]~0 are inconsistent with all models	Not three scenarios
Mrk996 ○	[Ne/O] is consistent with TDE models	**TDE**

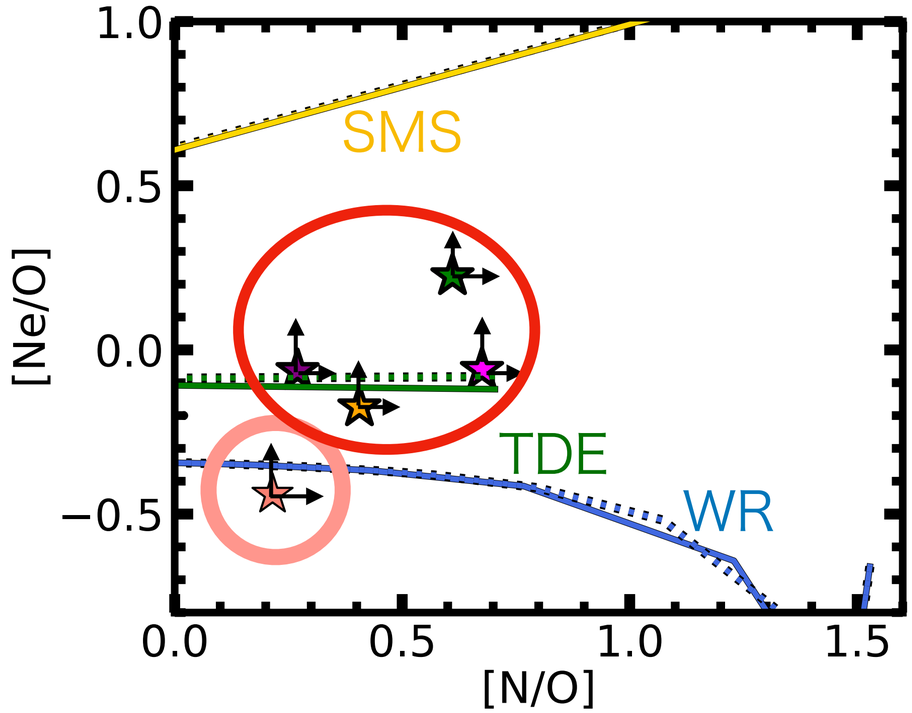
[N/O]>0.5 and [Ne/O] $\gtrsim 0$ → Requires **Ne and N** enhancement without increasing **O**.

Results: C/O, Ne/O and N/O



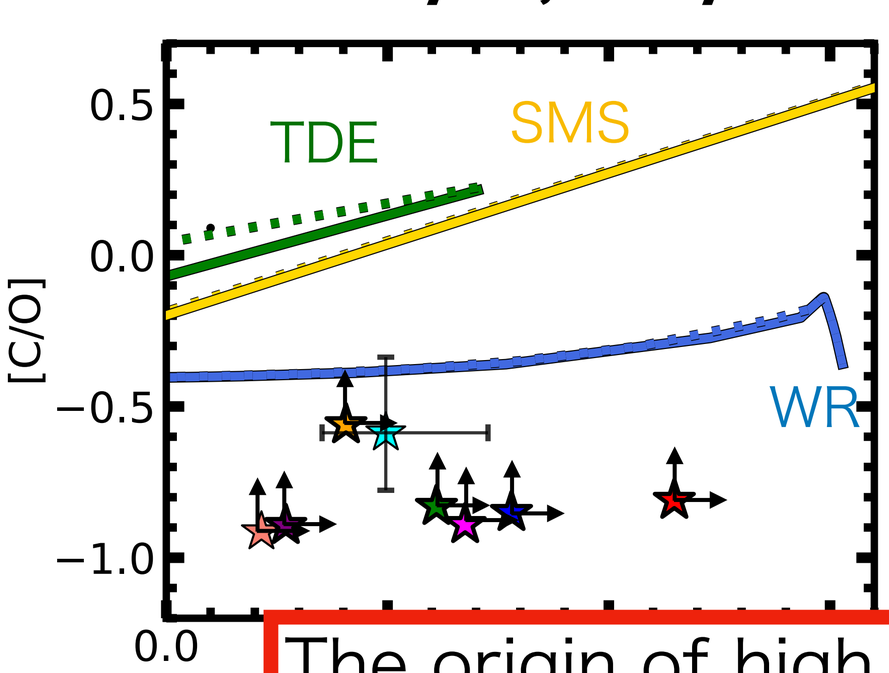
Kroupa IMF & low metallicity

Top-heavy IMF & low metallicity



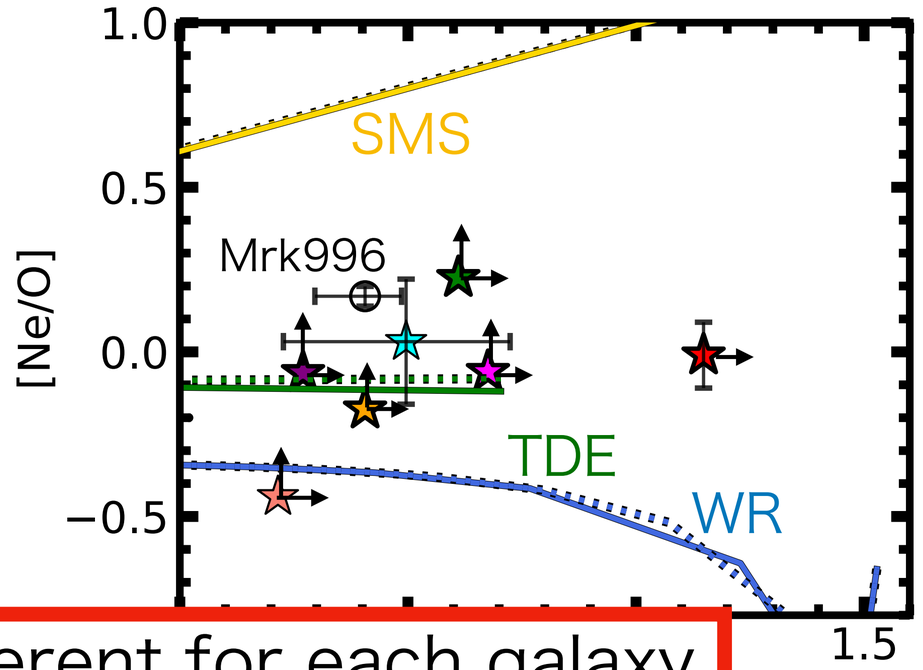
Galaxy	Comparison with Models	Possible Origin
GHZ2 ★	[N/O] , [C/O], and [Ne/O] are consistent with all models	All three scenarios
Other high-z galaxies	[Ne/O] is consistent with SMS and TDE models	SMS or TDE

Results: C/O, Ne/O and N/O



Kroupa IMF & low metallicity

Top-heavy IMF & low metallicity



The origin of high N/O galaxies is different for each galaxy.

Galaxy	Comparison with Models	Possible Origin
GHZ9 ★	[C/O] is consistent with WR models, but [Ne/O] is incosistent	Not three scenarios
CEERS_01019 ★	[N/O]>1.0 , [Ne/O]~0 are inconsistent with all models	Not three scenarios
GHZ2 ★	[N/O] , [C/O], and [Ne/O] are consistent with all models	All three scenarios
Other high-z galaxies	[Ne/O] is consistent with SMS and TDE models	SMS or TDE
Mrk996 ○	[Ne/O] is consistent with TDE models	TDE

Summary

-Investigate the origin of nitrogen in galaxies with high N/O

→ Sample: 9 galaxies at $z > 6$ observed with JWST/NIRSpec + Mrk996

-Deriving elemental abundance ratios other than N/O

→ [C/O] and [Ne/O] measured in 8 galaxies

-[C/O] and [Ne/O] ratios reveal varying model consistency for different high-z galaxies.

→ Requires **Ne** enhancement without increasing **O and C**.

- Mrk 996 is a WR galaxy, but the origin of elements does not come from WR stars.