Chemical Evolution of Pop-III Galaxies

IGM-theory group
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How to detect first stars?

Direct detection is not yet reported - they are very short lived and far away

Big difference between pop-II and pop-III is in **initial mass function (IMF)**
→ **enrichment history and abundance pattern** may be different

Q. Can this be used for indirect indicator?
Is there a noticable difference in chemistry?

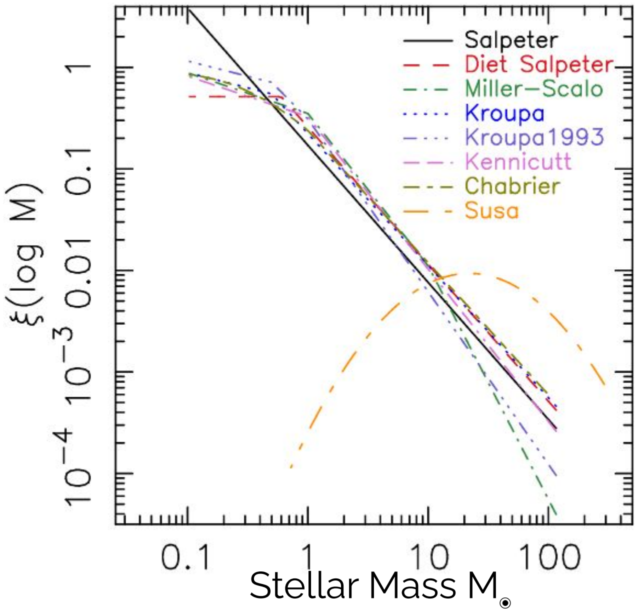
We tried to answer these questions with a basic model calculation

Stellar Initial Mass Function (IMF)

metal is a great coolant

inefficient cloud fragmentation due to low metal
→ formation of massive stars is enabled

in Z=0 environment, **stars up to 300M☉ can be formed**



Saitoh 2017

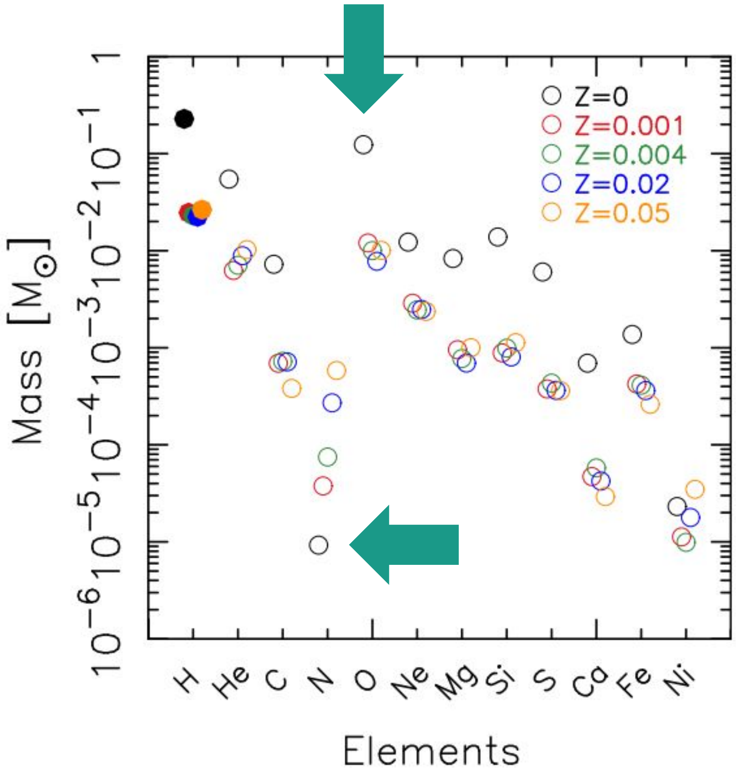
Pop-III/pop-II chemistry

Especially, the **N/O ratio would be different**

But 300M$_\odot$ stars start to explode as early as ~2 Myr, polluting ambient gas

Then pop-II quickly comes in, and their most massive 100M$_\odot$ stars explode in ~3 Myr

How long can we see its “smoking gun”?



Yield of each element per 1 M$_\odot$ SSP particle
Saitoh 2017

Calculate Metallicity Evolution

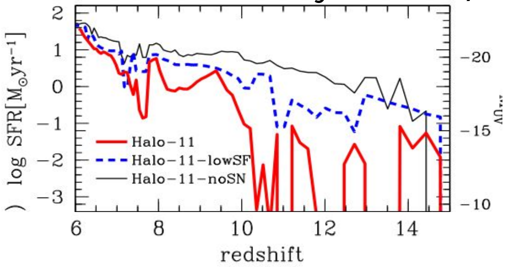
trace evolution of a massive dark matter halo ($M_{star}=10^9\ M_\odot$, $M_{halo}\sim10^{11}\ M_\odot$ at z=11)
... similar to GN-z11 (Oesch+2016)

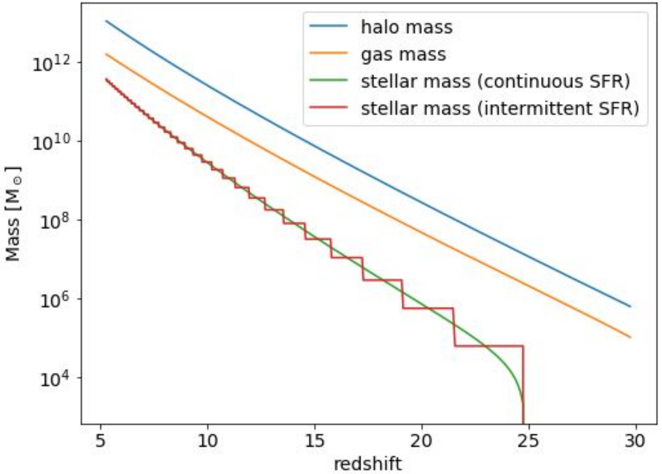
gas inflow rate = Ω_b/Ω_m * DM halo growth rate (Behroozi+2013)

star formation is proportional to M_{gas}
... continuous case / intermittent case (30 Myr)

For chemical evolution,
we used **CELib** (Saitoh 2017)

Yajima+2017



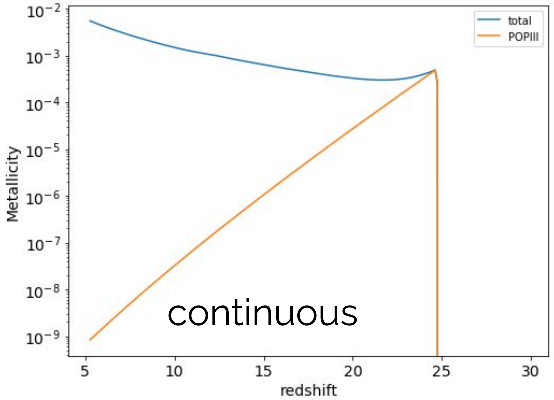


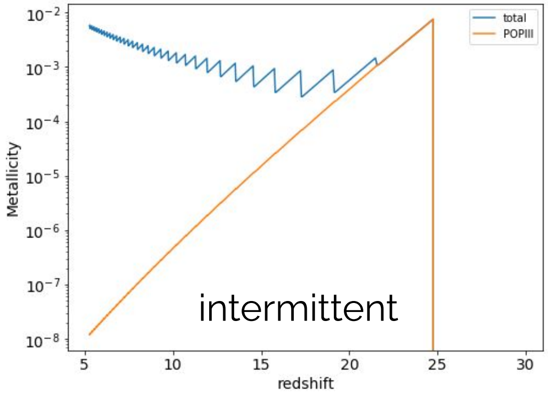
Results 1: Metallicity Evolution

Metal enrichment by first stars at z ~ 25

Metallicity evolution show similar trend between continuous case and intermittent case

Metal enrichment by pop-III stars is overwritten by pop-II stars after next SF

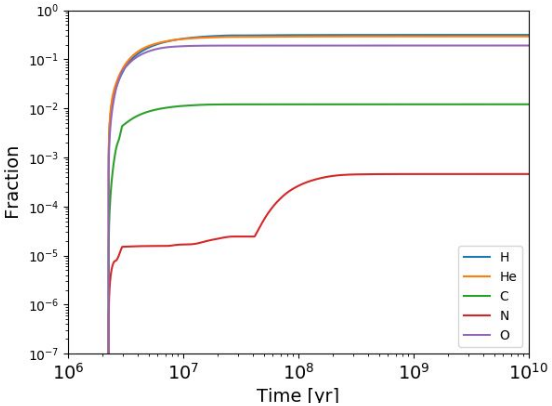




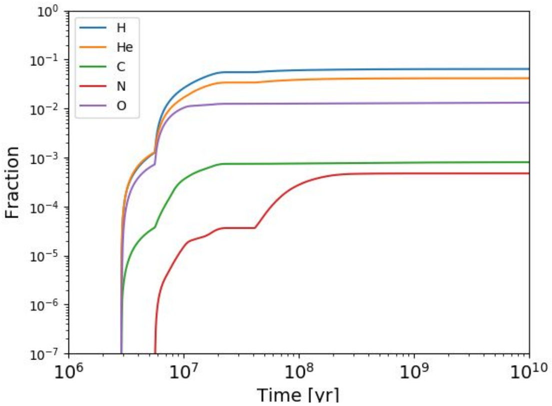
Evolution of Returned Mass Fraction

Pop-III eject a large amount of O while little N by SNeII

In pop-II, O yield becomes lower while N becomes higher



pop III (Susa IMF)
$Z<=10^{-7}$



pop II (Chabrier IMF)
$Z=10^{-6}$

Cumulative return mass fractions as a function of SSP particle age

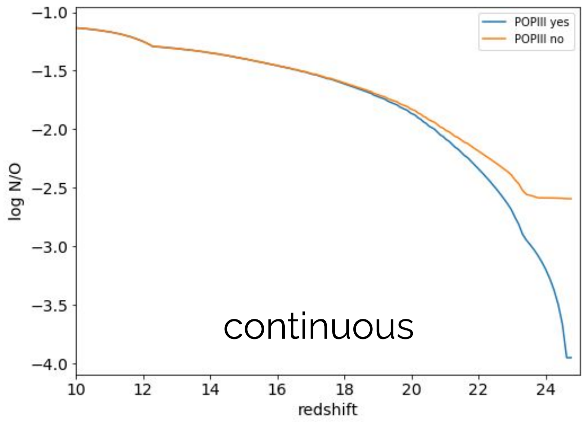
Results 2: N/O Evolution

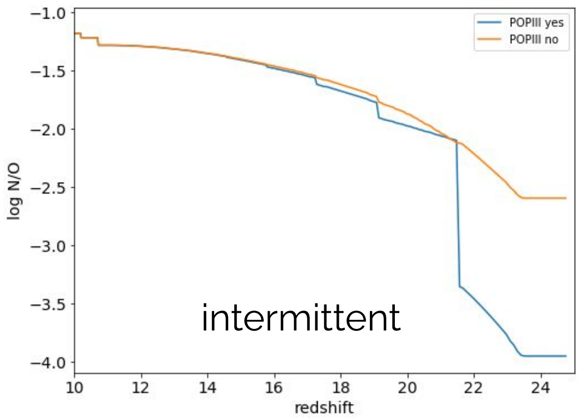
Difference in early phase in both cases

In continuous SFR case,
log N/O stays distinctively low (< -3.0) for 20 Myr

In intermittent case,
log N/O stays low for a longer time

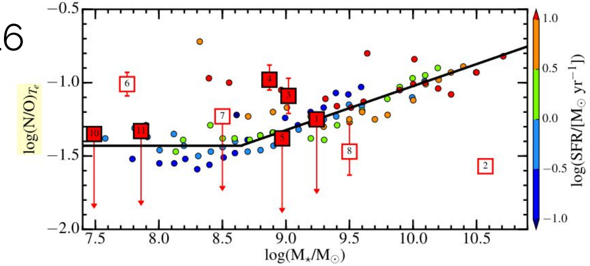
log N/O increases as metallicity increases





Discussion

Kojima+2016



Galaxies with extremely low logN/O(<-3) would be dominated by pop-III

Observations of z~2 SFG: log(N/O) ~ -1.5 (e.g., Kojima+2016)

But trace of pop-III disappear really quickly (< 20 Myr)!
(still, it can probe longer period than other indicators such as strong HeII lines)

If SF is shut off for a while after the first burst, low log(N/O) can be observed for a longer time, too

Summary & Future Works

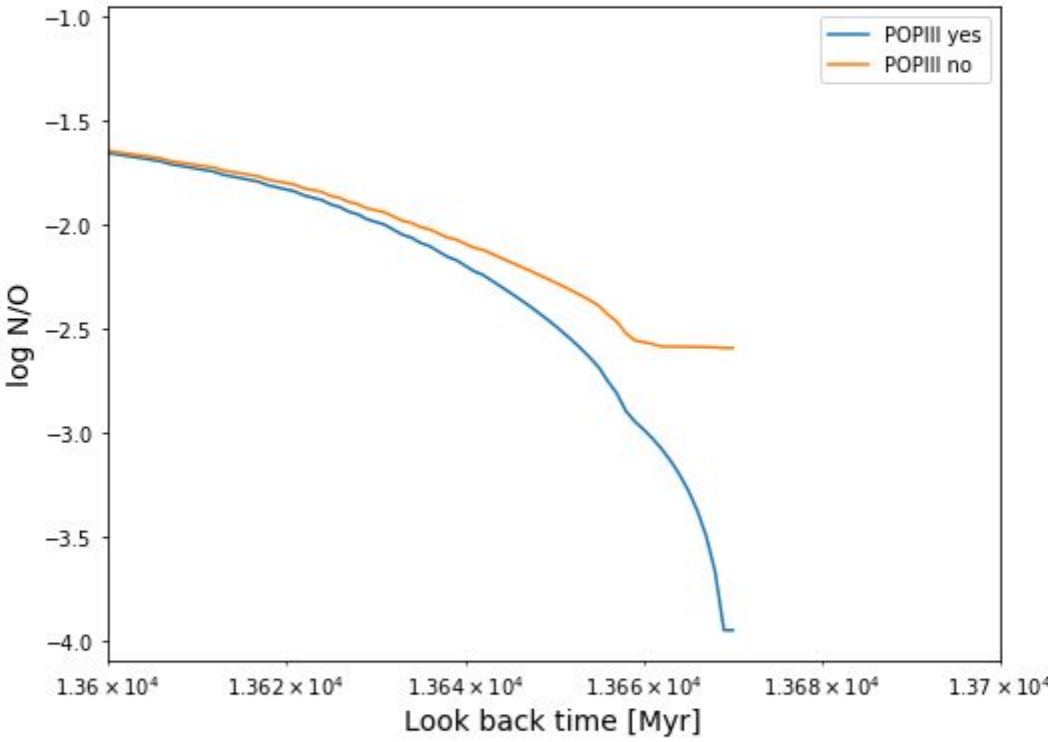
We calculate metallicity and N/O evolution of first galaxies with CELib

In continuous SF case, N/O stays distinctively low (<log(N/O)<-3) for ~ 20 Myr

For a single burst, low N/O might be sustained for a longer time

New N/O measurement technique for high-z is required
(strong line / T_e method unavailable) - can be invented using e.g., CLOUDY?

N/O Evolution (continuous SFR)



N/O Evolution (longer intermittent, interval = 100Myr)