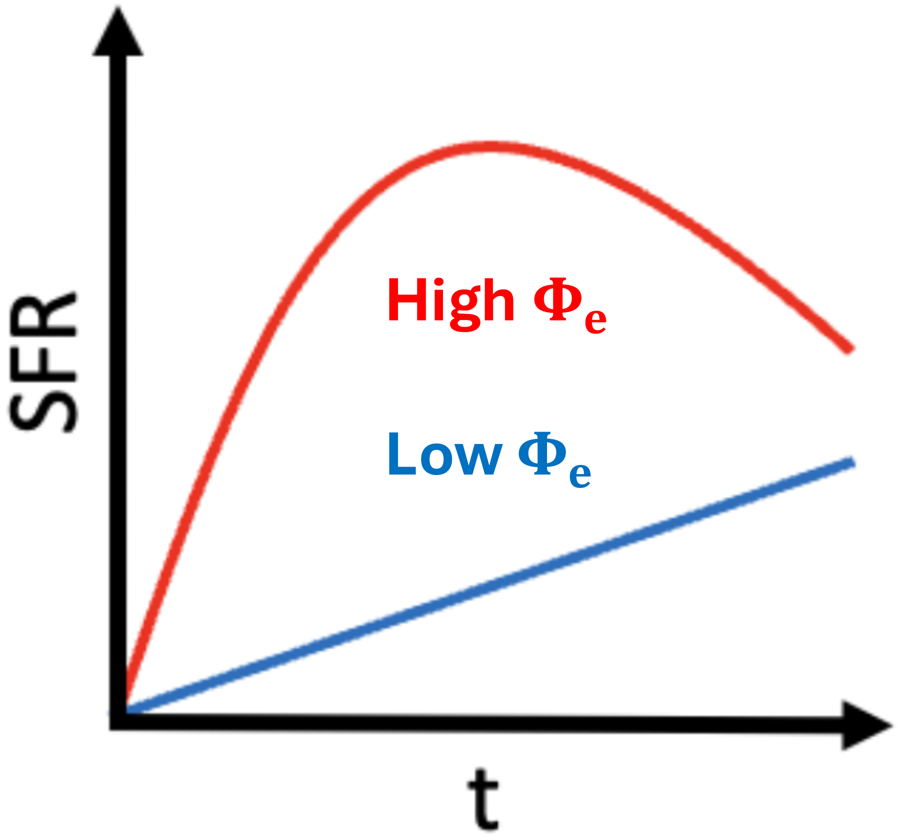
The competing effects of recent and long-term star-formation histories on galaxy chemical abundances

Nicholas Boardman, Vivienne Wild, Natalia Vale Asari, Francesco D’Eugenio

arXiv: 2505.07018

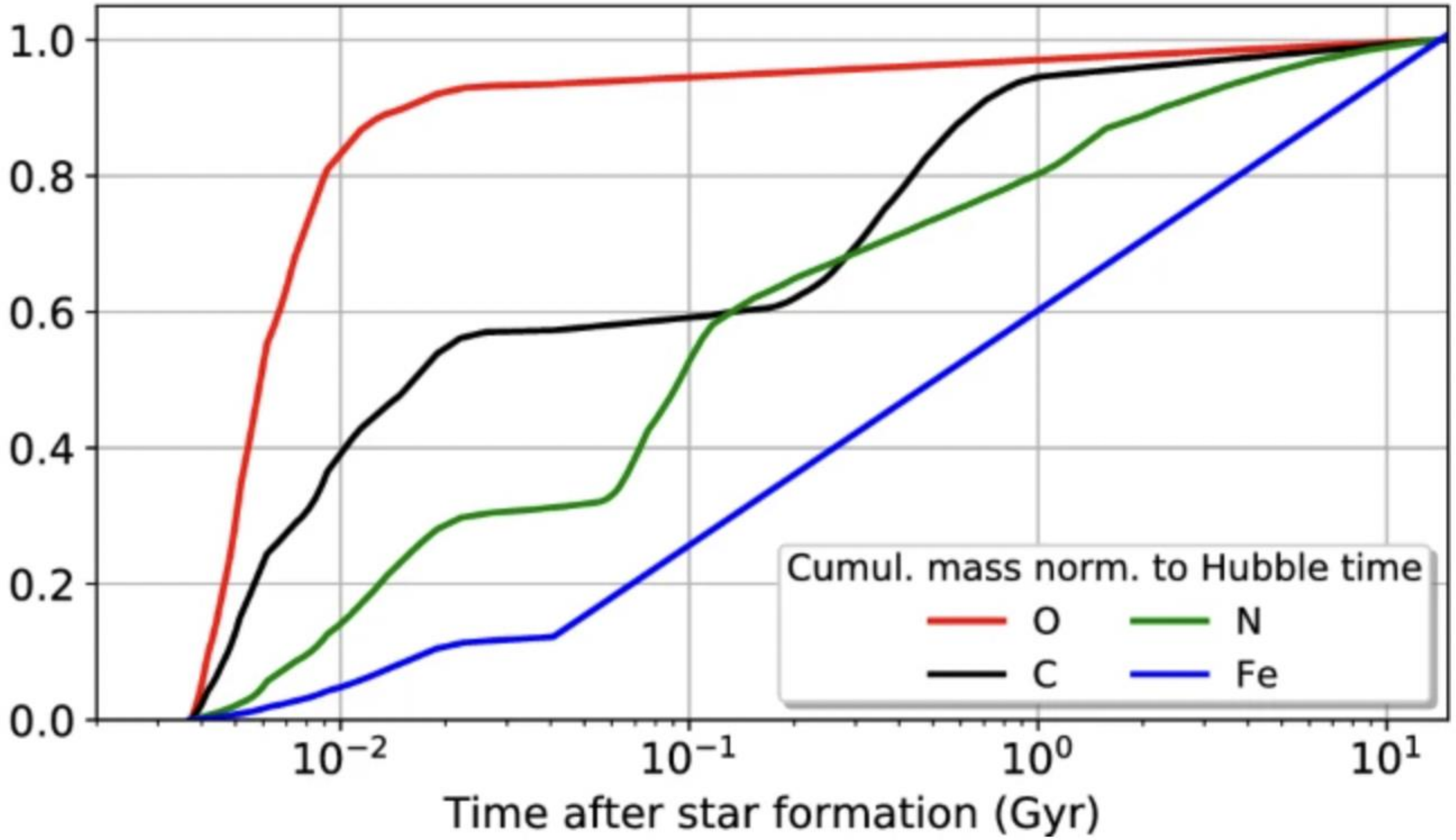
The key takeaway

- Stellar concentration (Φ_e = M*/R_e) is key to understanding gas-phase chemical abundances
- I will argue this to be due to Φ_e linking tightly with star-formation histories (SFHs)



Adapted from Boardman et al. 2025

The value of gaseous chemical abundances



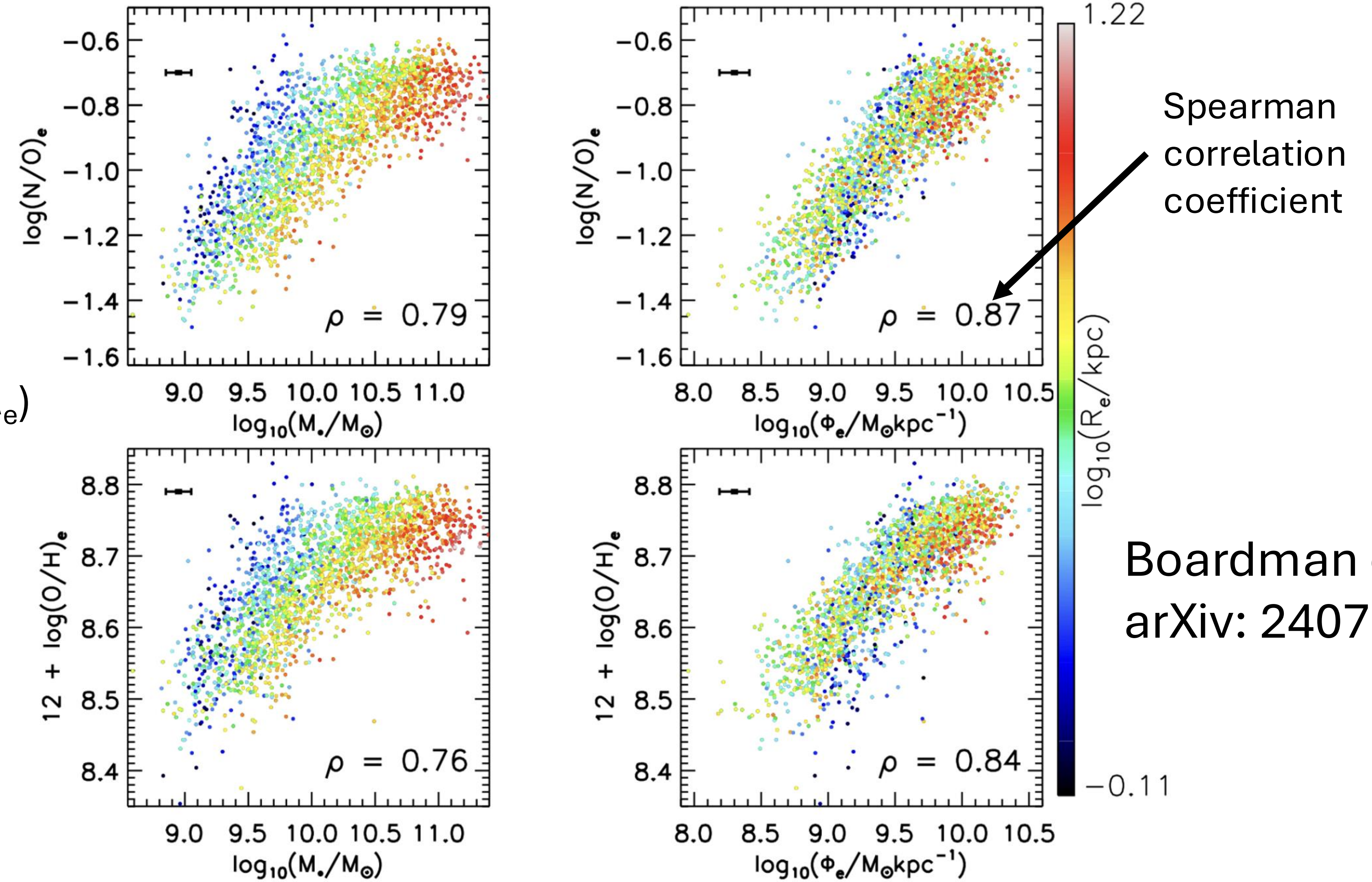
Maiolino & Mannucci 2019; attributed to model of Vincenzo et al. in prep.

- Gaseous chemical abundances are end-products of galaxy evolution
- O and N are both easy to measure in star-forming gas
- N enrichment proceeds over longer timescales at a metallicity-dependent rate
  - Though, still not well-understood, as certain JWST results can attest!

The Φ_e-N/O relation across galaxies

- **N/O correlates more strongly with Φ_e than with M*, as has previously been reported for metallicity[1]**
- **Interestingly, Φ_e appears to correlate more strongly with N/O then with metallicity**
  - **This suggests that Φ_e is indicative of star-formation histories**

(Remember: Φ_e=M*/R_e)

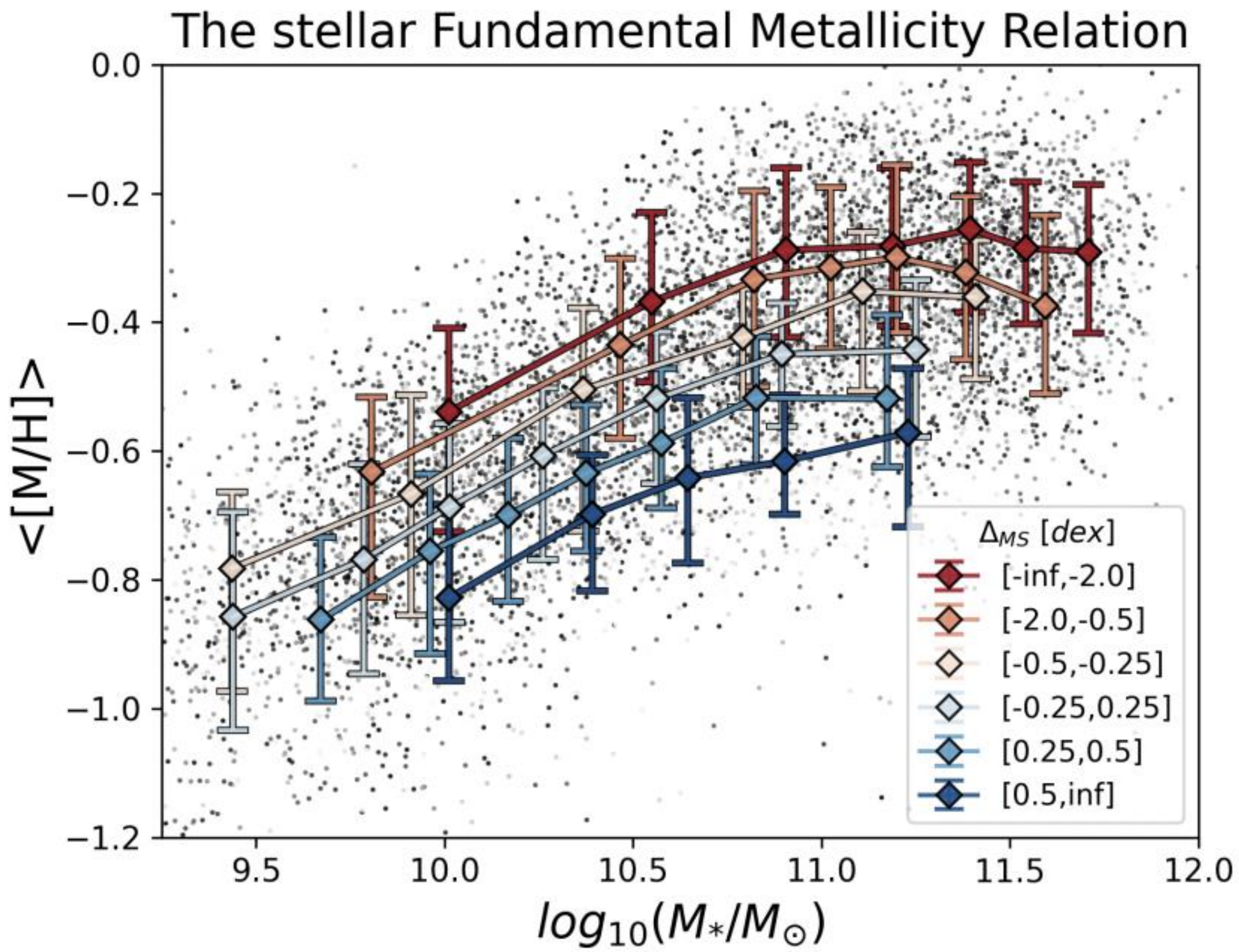


Boardman et al. 2024
arXiv: 2407.17945

[1]D'Eugenio et al. 2018

What about stellar metallicity?

- Stellar abundances represent the history of gaseous abundances
- Looser et al. 2024: stellar metallicity inversely correlates with SFR, at any given M* or Φ_e
- This mirrors the *fundamental metallicity relation* (FMR) for gas metallicities
- To understand this further, we can consider stellar metallicities alongside gas-phase N/O and O/H!



Looser et al. 2024

Sample & Data

- We obtained emission line maps from MaNGA survey data
- From these maps, we determined N/O and O/H values at 1 R_e
- M_* and R_e obtained from NASA-Sloan-Atlas catalog (Blanton et al. 2011)
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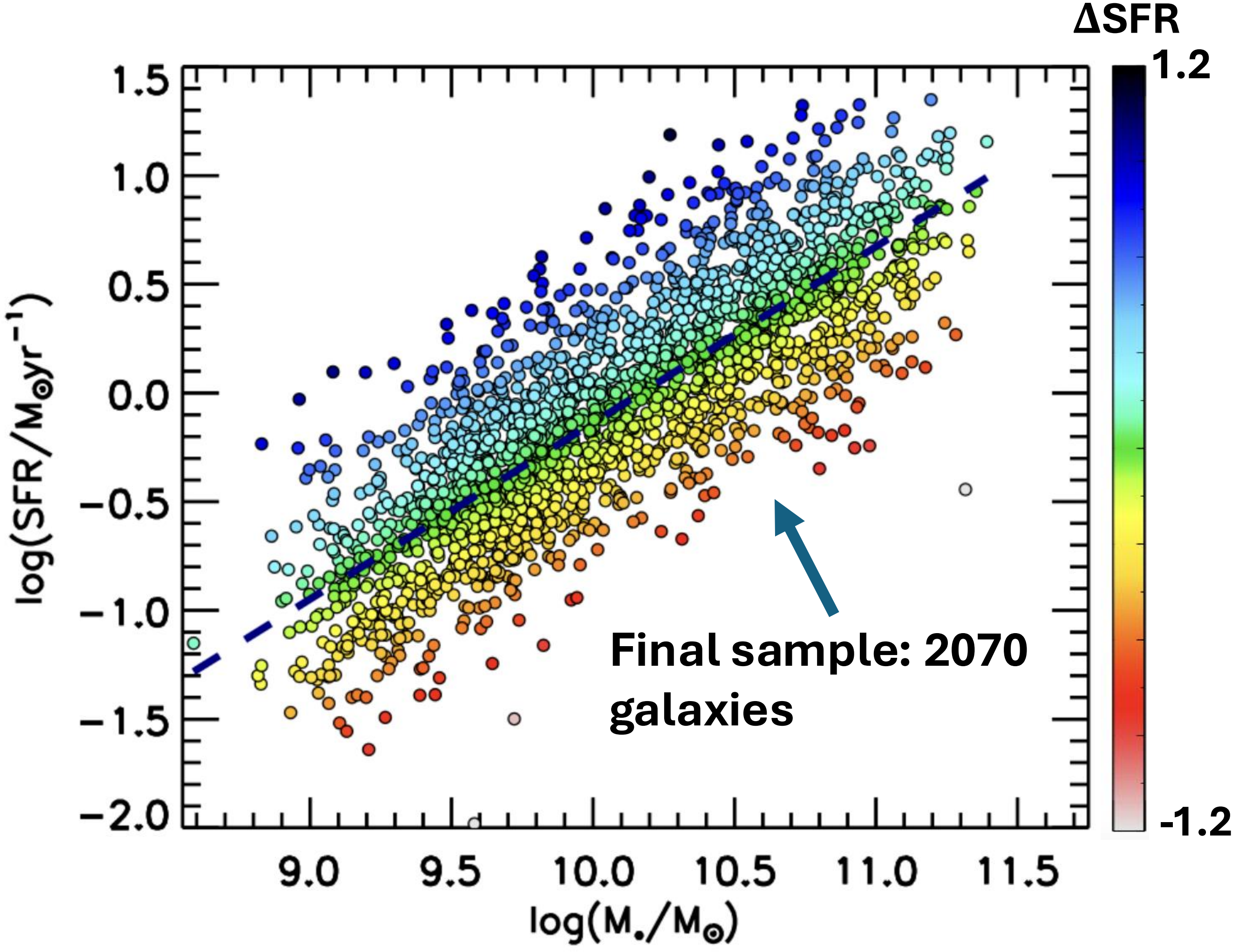

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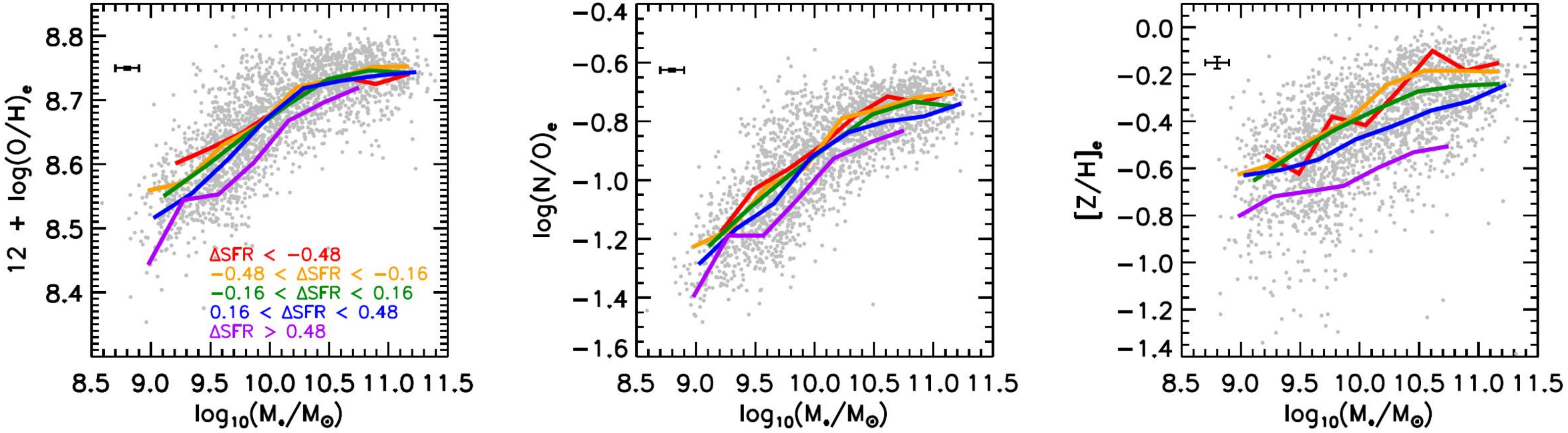
Boardman et al. 2025

How informative are different ‘fundamental’ relations?



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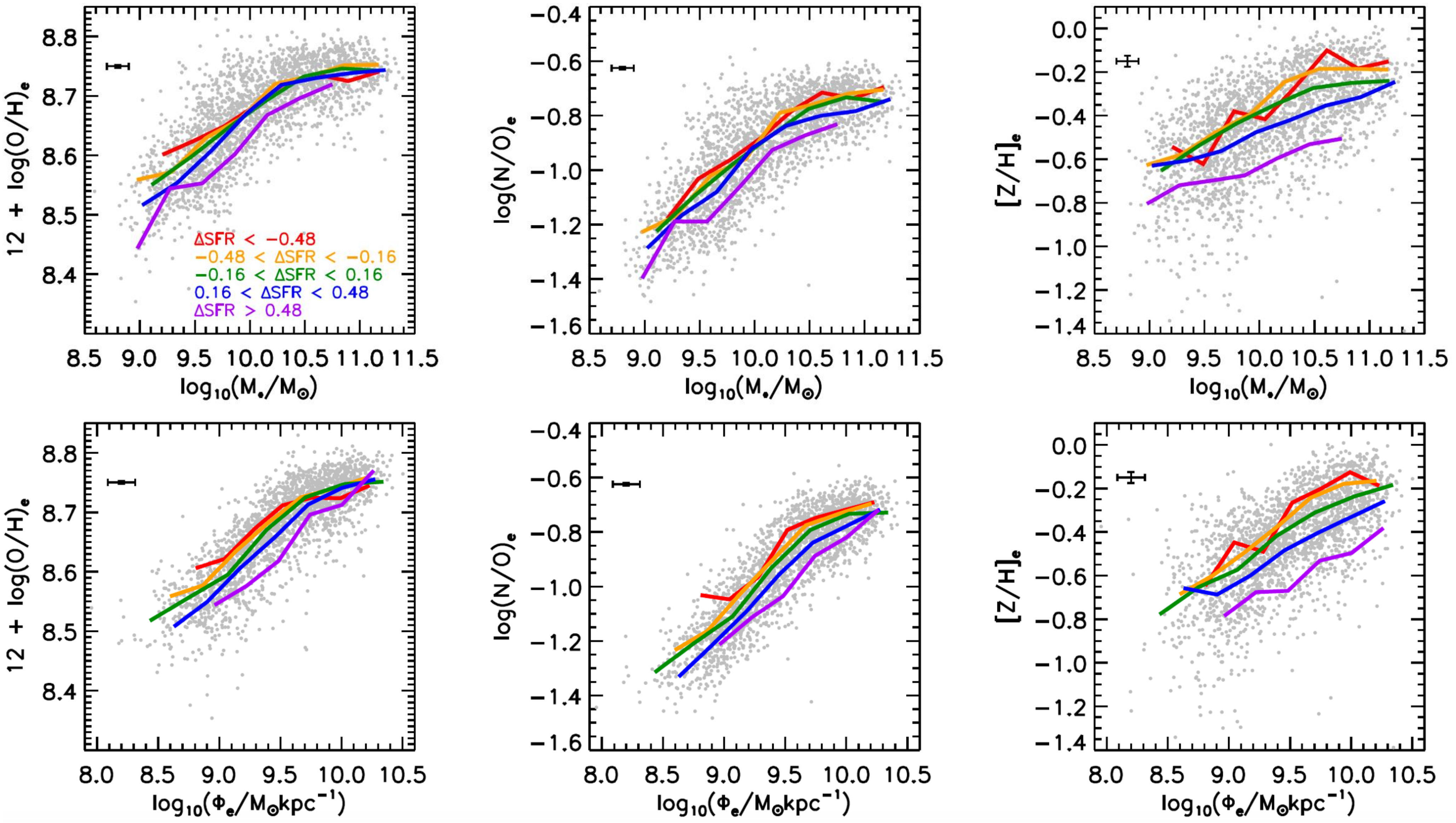

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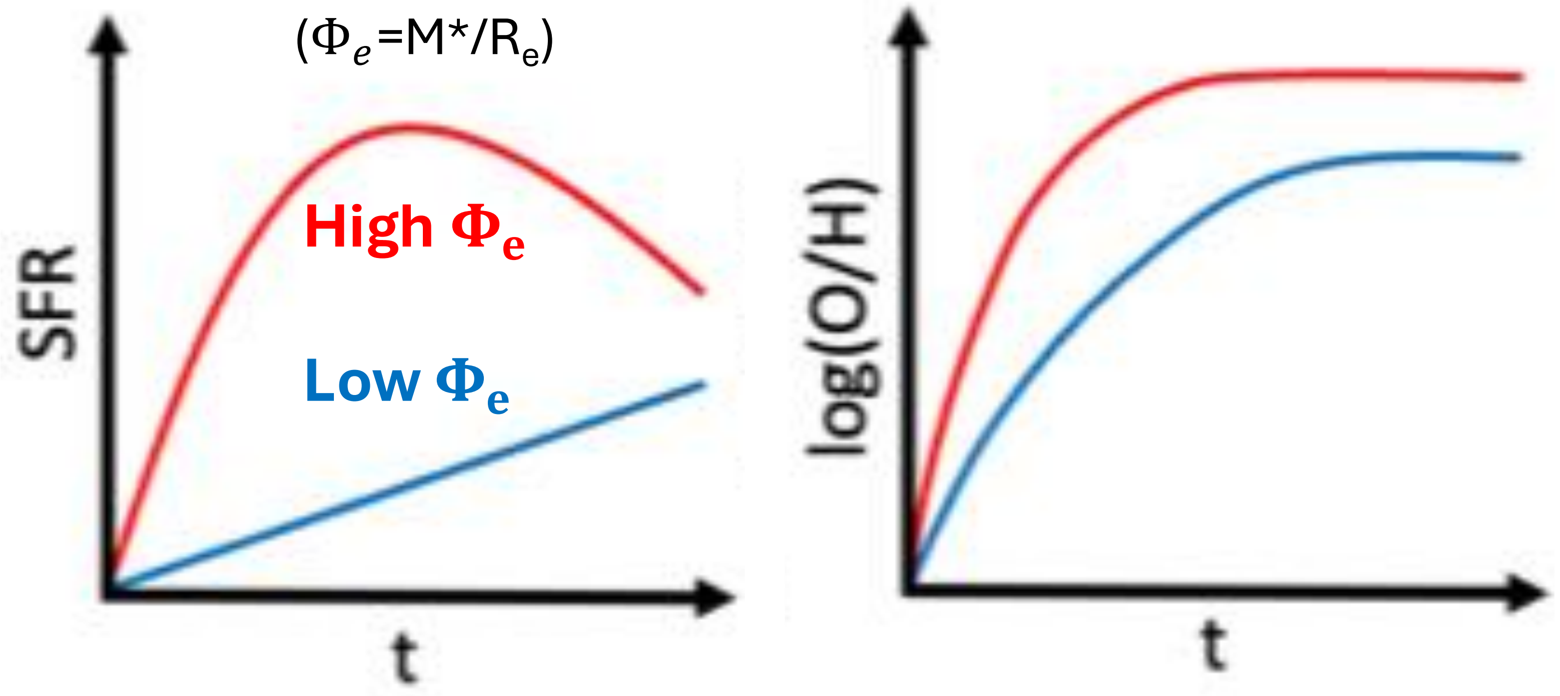
Why is Φ_e so predictive of chemical abundances?



Low Φ_e → **Late SFH** → **Lower O/H**

High Φ_e → **Early SFH** → **Higher O/H**

Boardman et al. 2025

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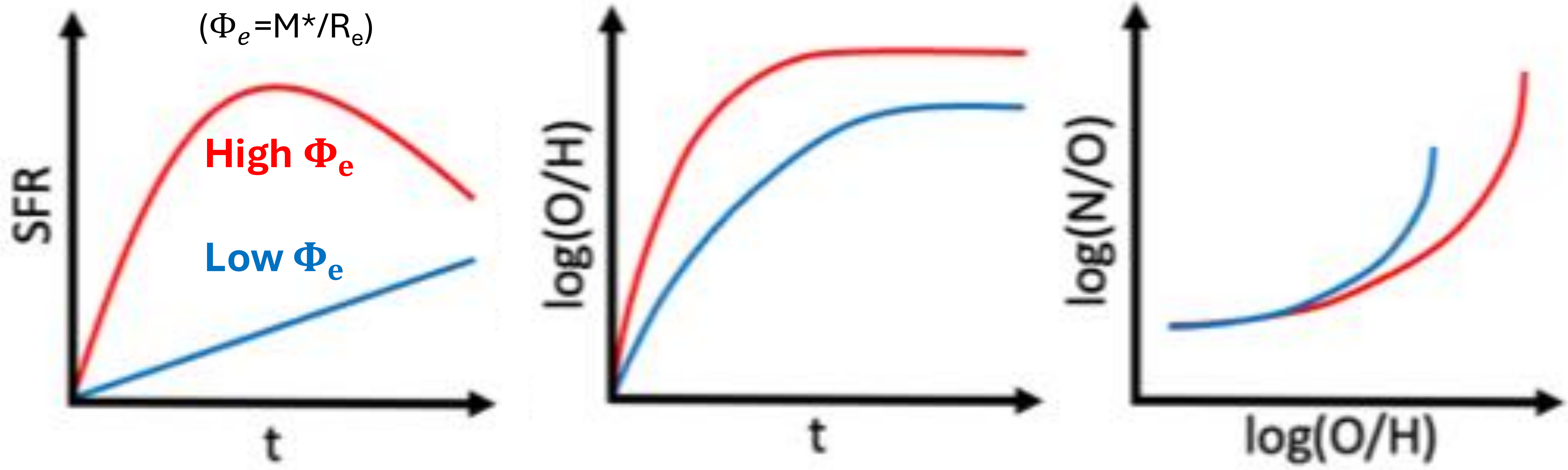

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Boardman et al. 2025

A unified interpretation of ‘fundamental’ relations

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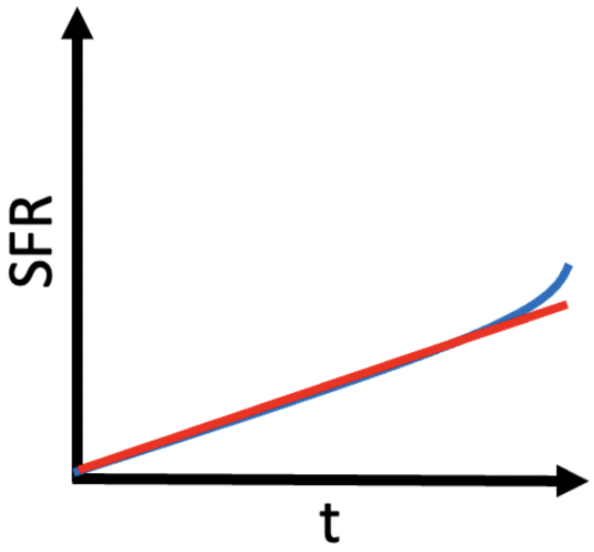

Late-time gas inflow variations

SFR variations

Boardman et al. 2025

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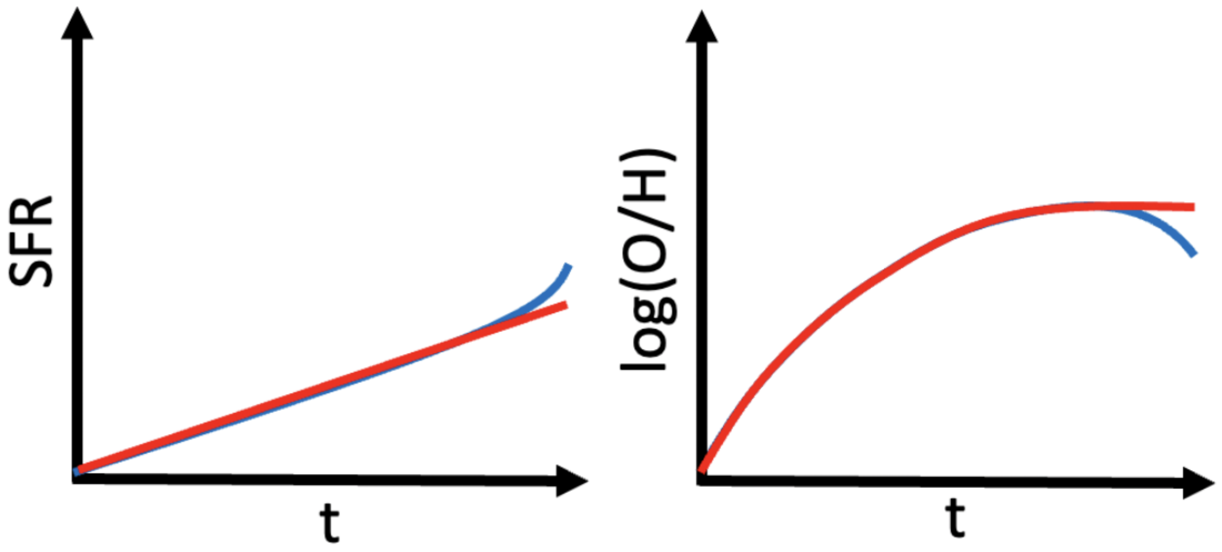

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BUT: little impact on measured [Z/H]

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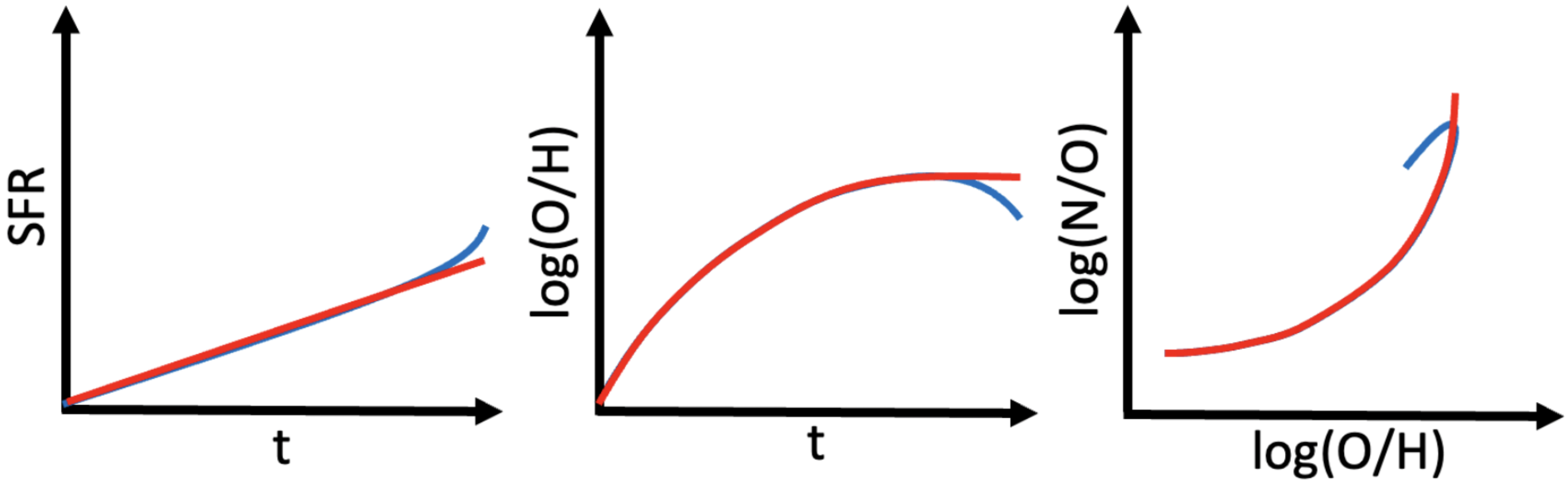

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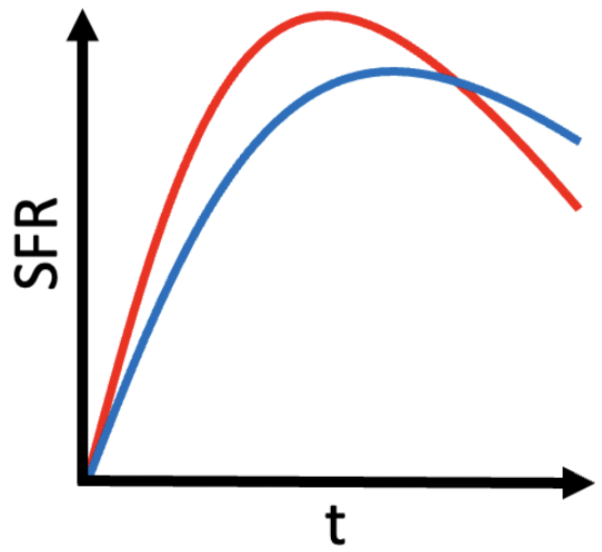

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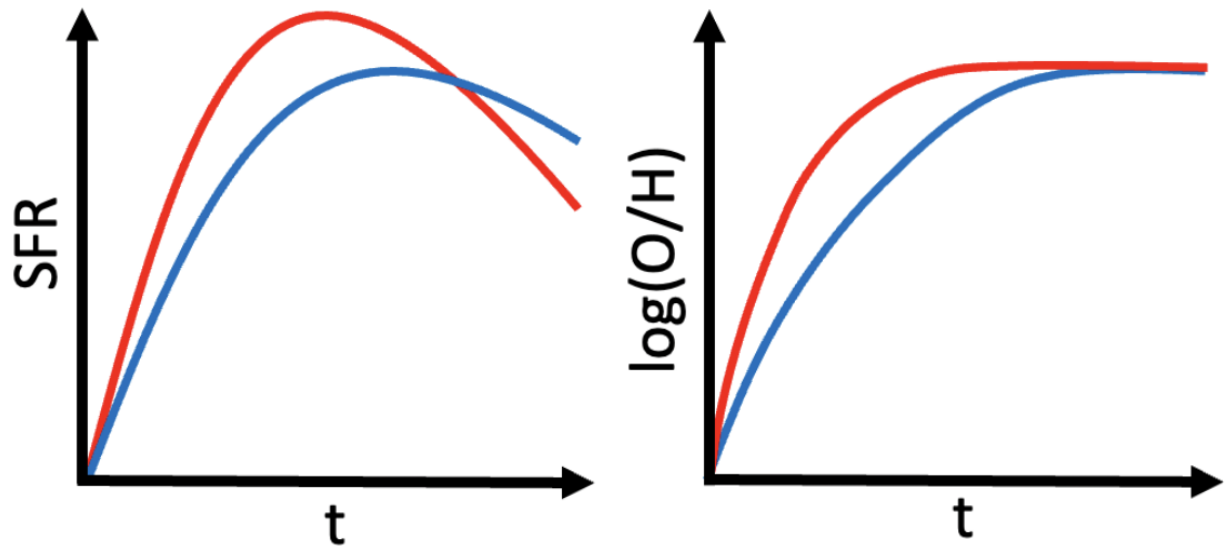

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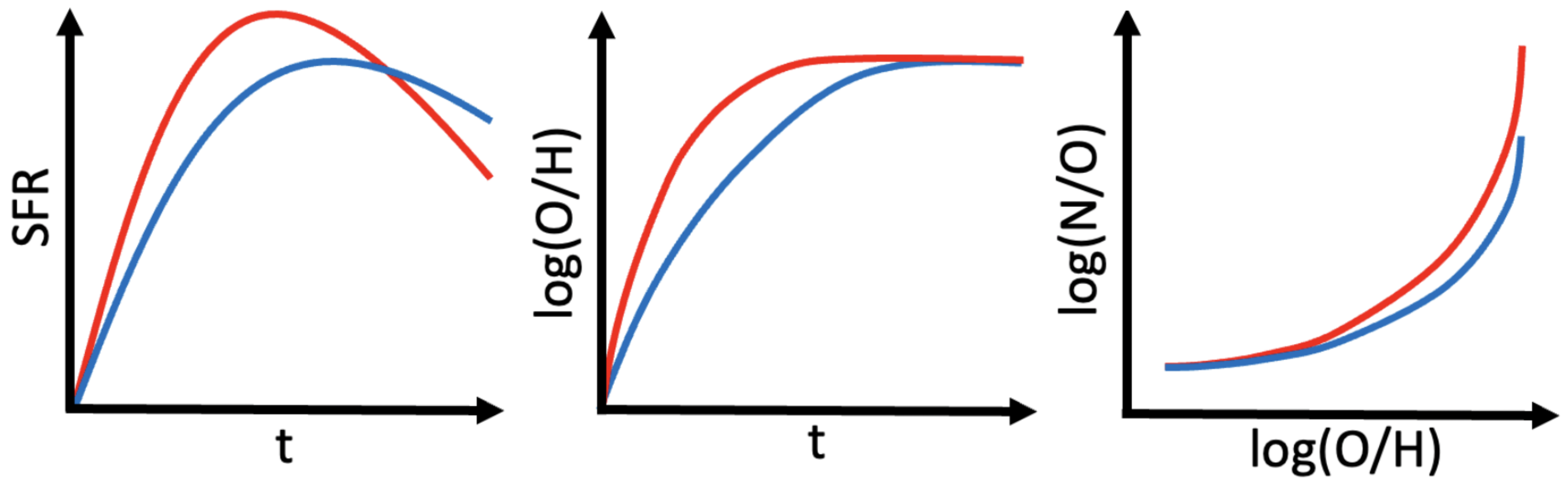

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Boardman et al. 2025

Implications for high-redshift observations

- The traditional FMR is the weakest tested relation
  - Thus, it's not very useful for understanding galaxy chemical evolution
- Replacing M* with Φ_e significantly tightens gas abundance trends…**but *significant* redshift evolution is expected**
  - Mass-size and mass-metallicity relations evolve with redshift (e.g. Maiolino et al. 2008 van der Wel et al. 2014)
- Galaxy structures, SFHs and chemical abundances are intimately linked…

Structure

Chemical abundance

SFH

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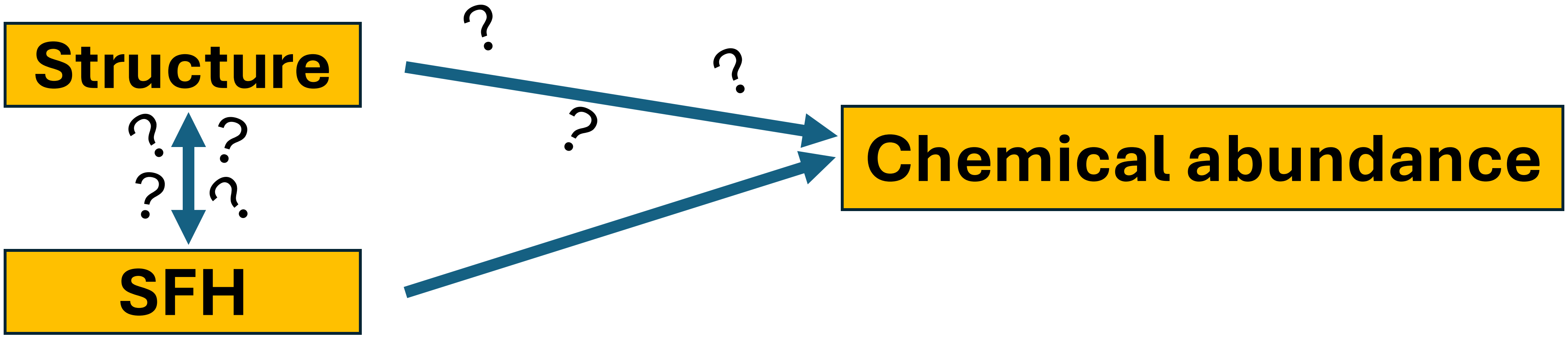
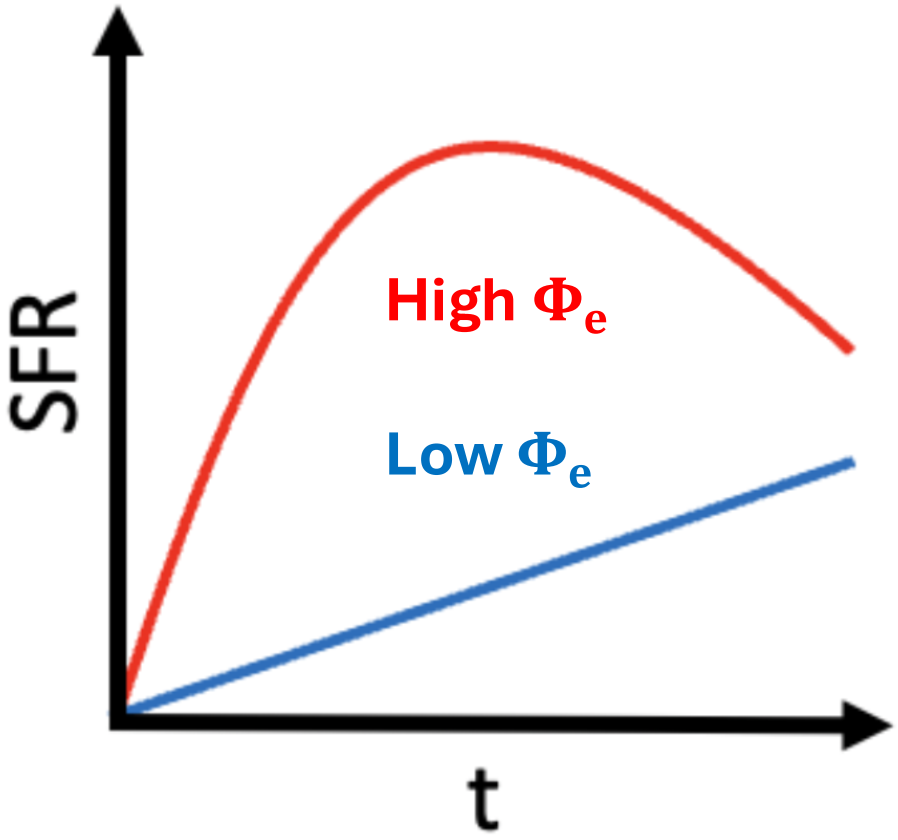
- Galaxy structures, SFHs and chemical abundances are intimately linked… but role of structure remains unclear



Summary

- Stellar concentration (Φ_e = M*/R$_e$) is key to understanding gas-phase chemical abundances
- I argued this to be due to Φ_e linking tightly with star-formation histories (SFHs)
- Φ_e-based relations should evolve strongly with redshift
- The traditional FMR is the weakest tested relation; Φ_e-based relations are much more informative.



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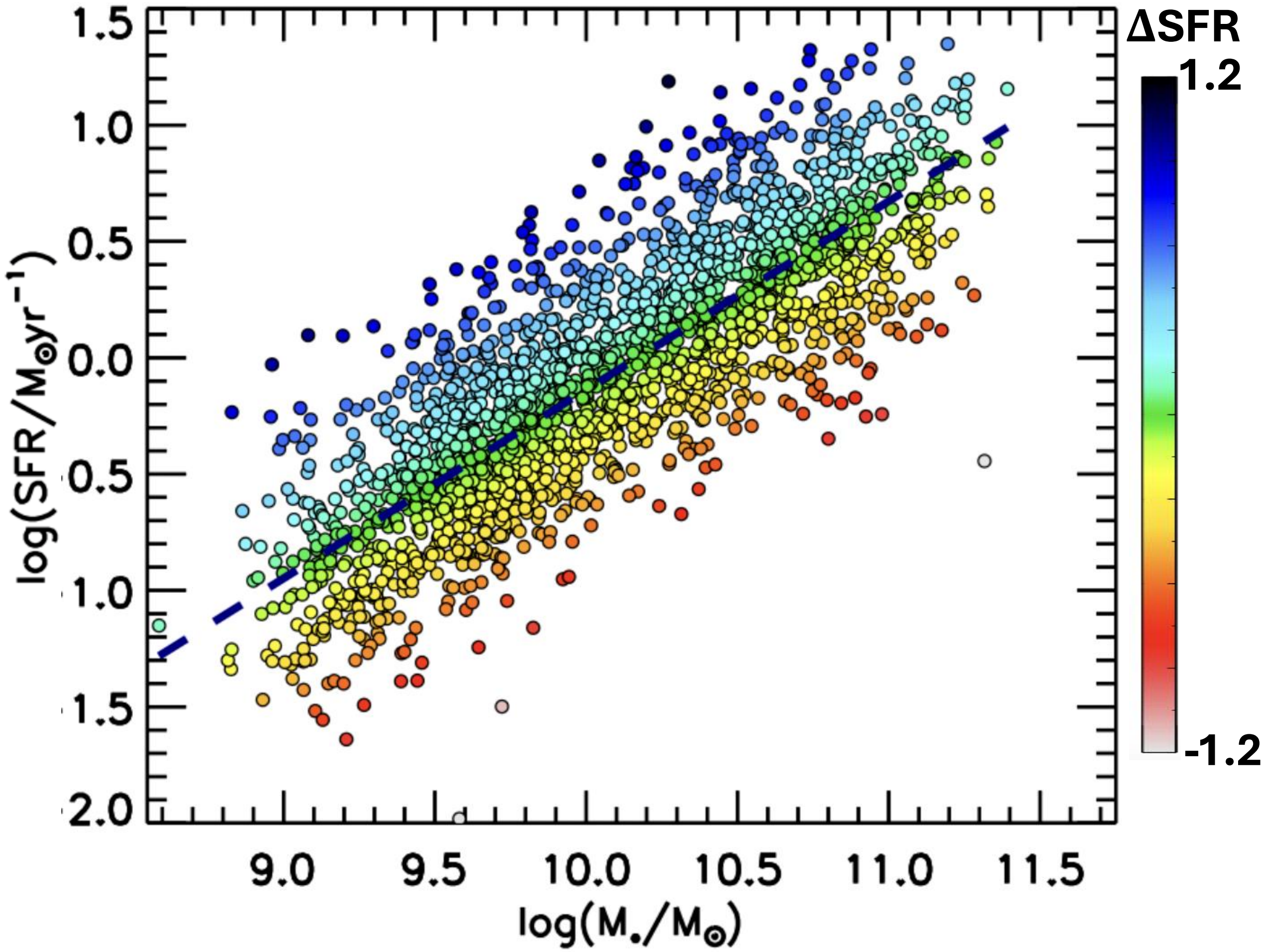

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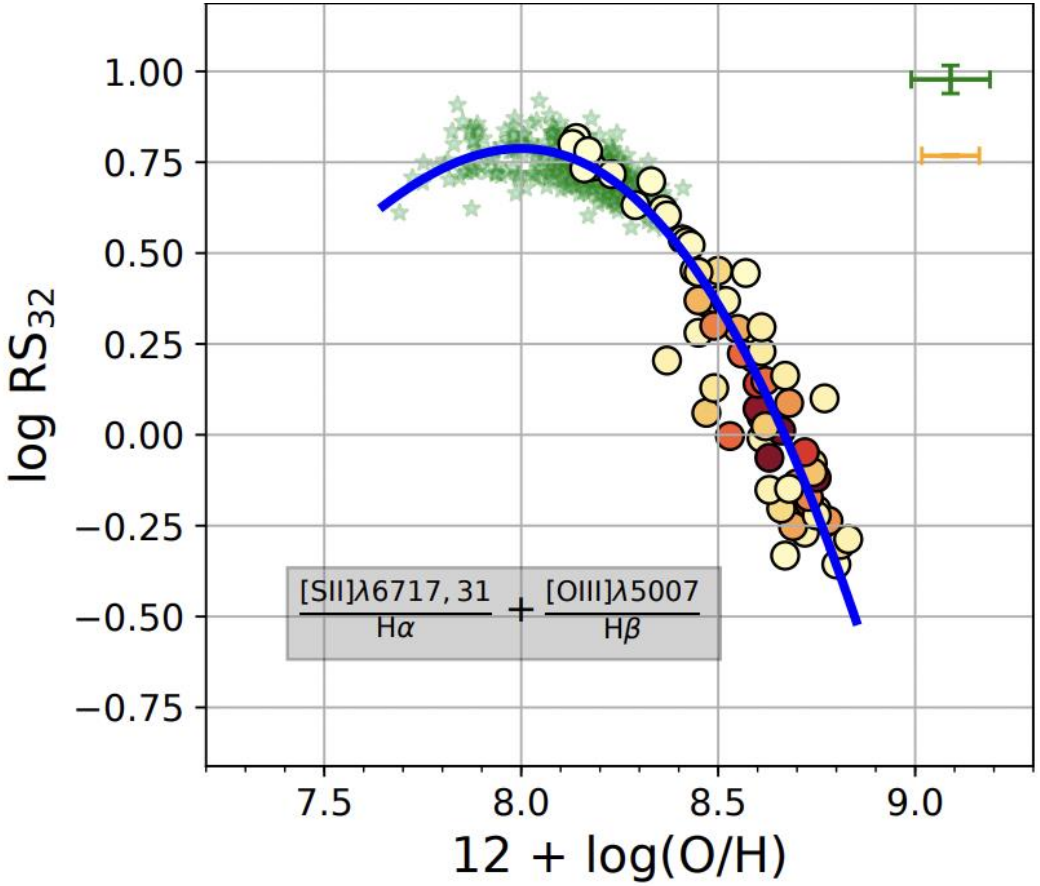
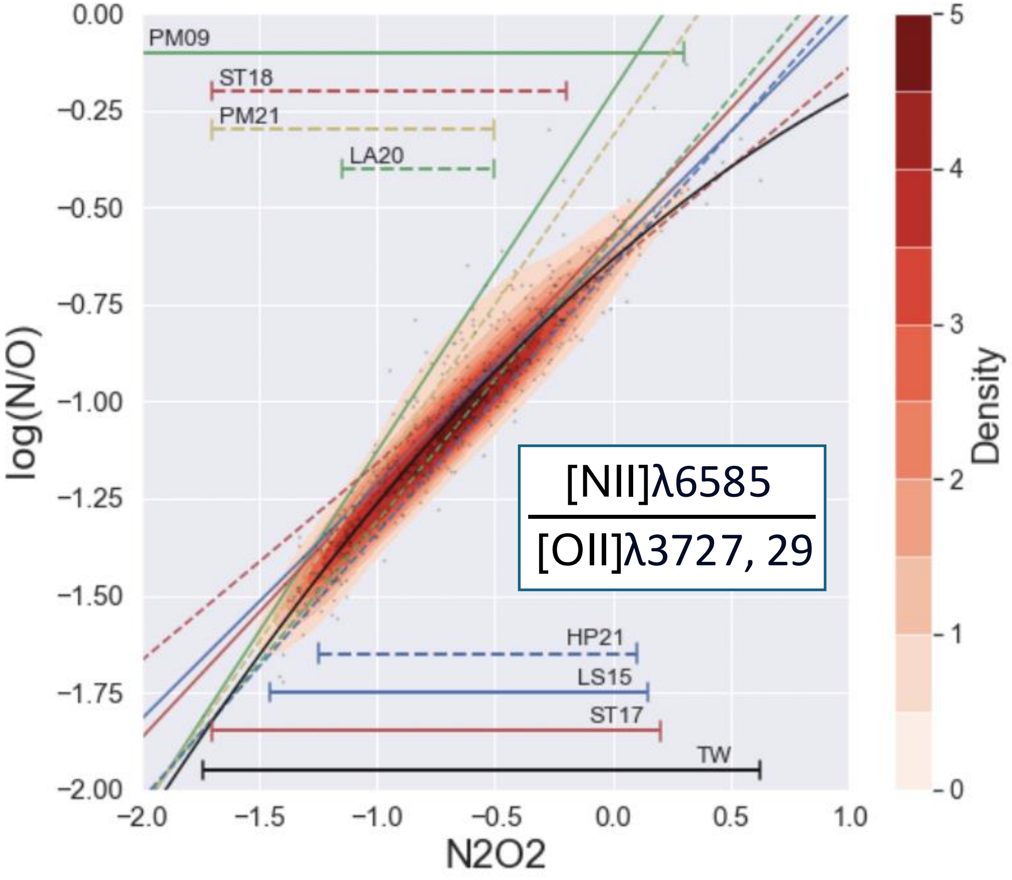
Boardman et al. accepted

O/H and N/O calibrators

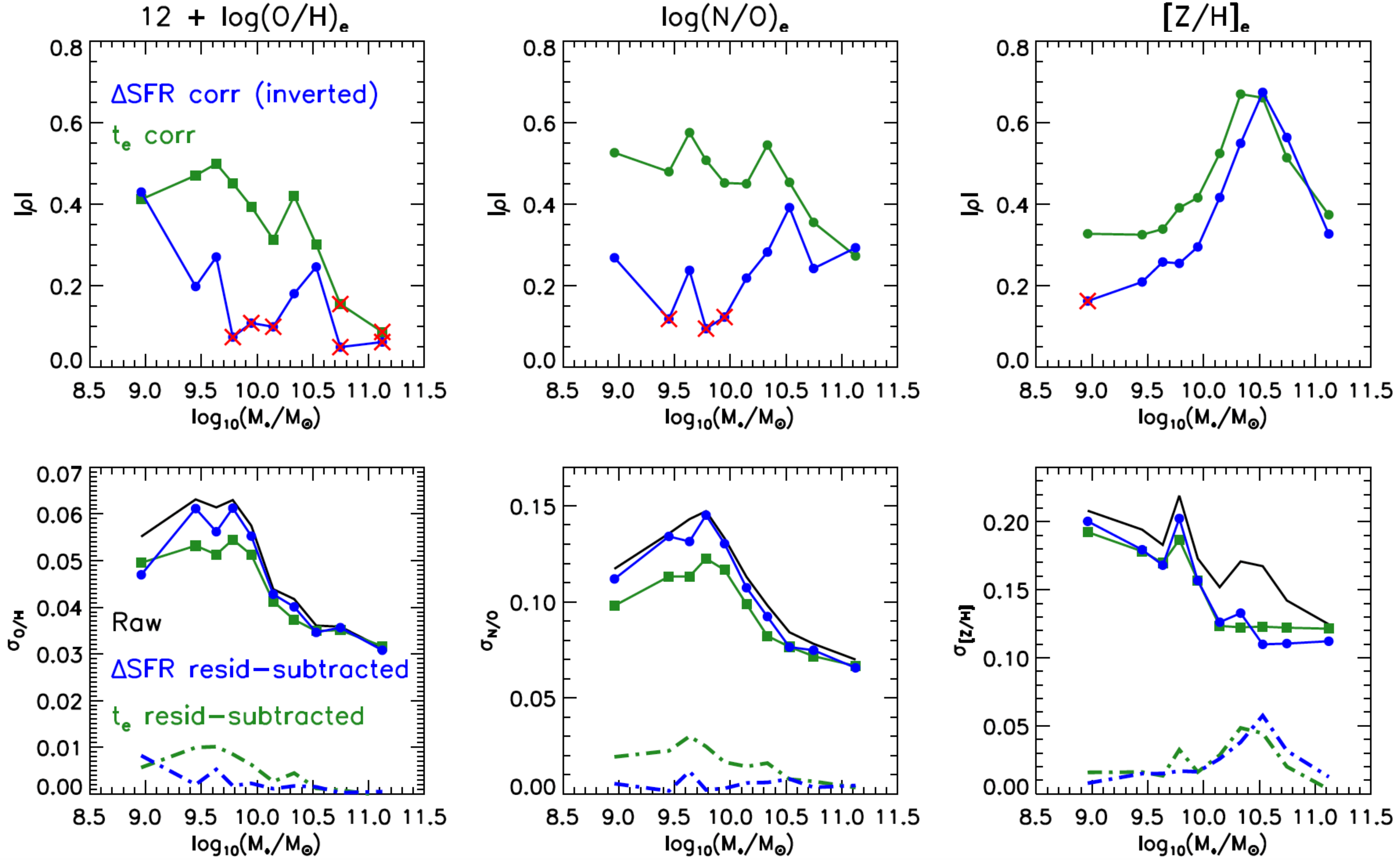


Curti et al. 2020



Florido et al. 2022

- O/H and N/O calculated via direct method strong line calibrators
- Calibrators chosen for their independence: RS_{32} for O/H, N2O2 for N/O



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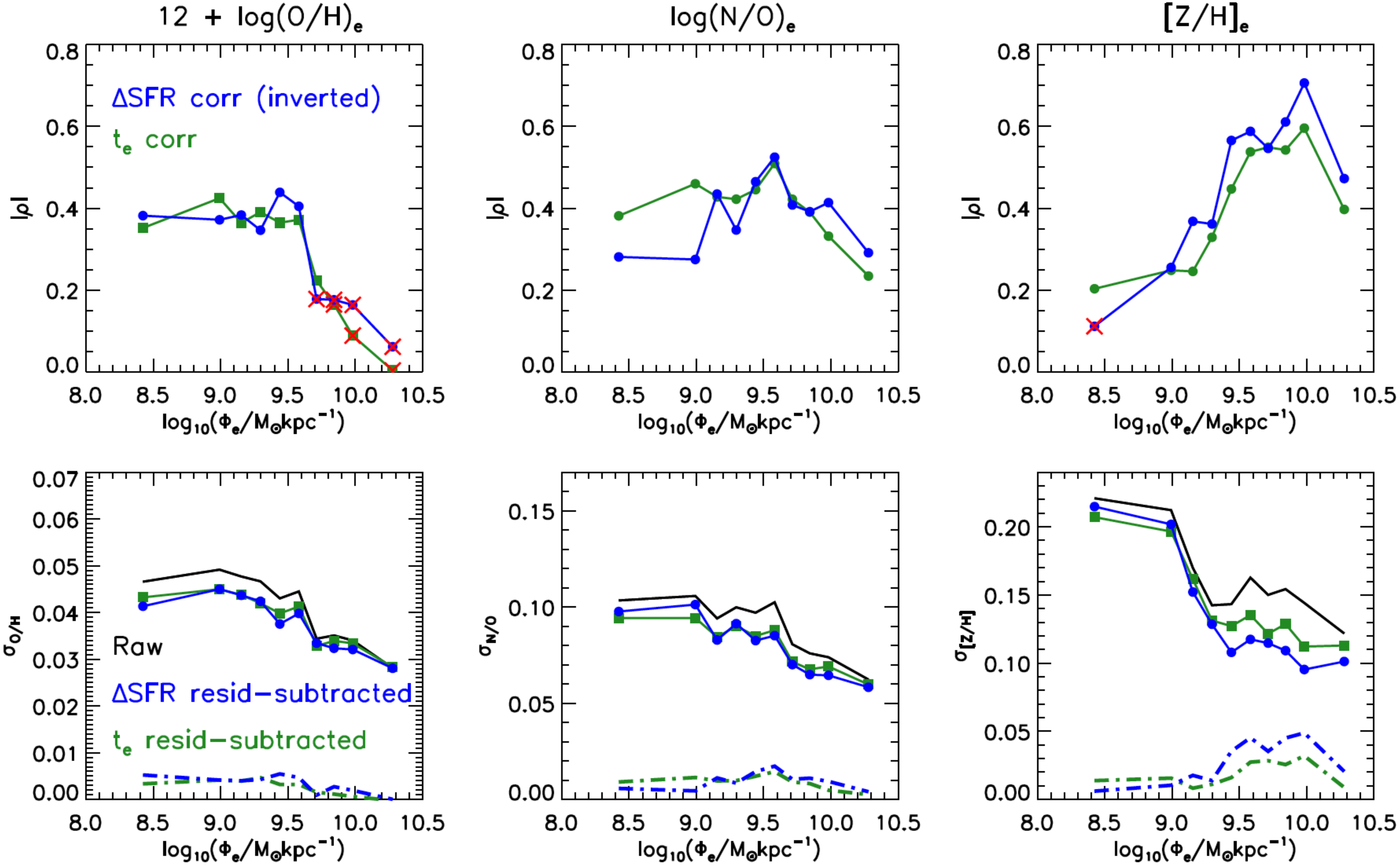

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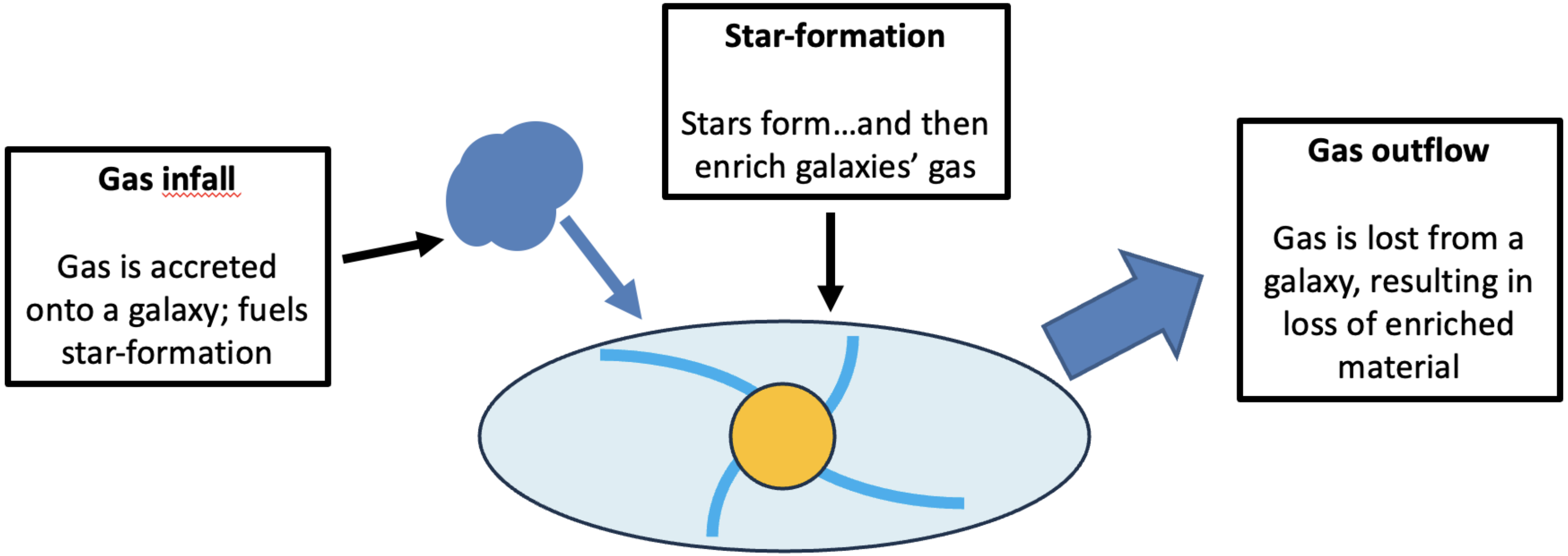
Boardman et al. accepted

Chemical evolution in galaxies

- **Chemical abundances are key to understanding galaxy formation and evolution**
- Chemical evolution in galaxies involves three key processes:



- **Gaseous abundances** represent the end-results of these processes
- **Stellar abundances** represent the properties of gas when stars formed