AST 1420

Galactic Structure and Dynamics

Q&A

Presentations: *in three weeks!*

- Week 10 of Nov 23 - 27
- Each student presents on a topic for ~10 min.:
  - aim for 8 minute presentation (no more than 5 slides) + 2 minutes for questions
  - Will be evaluated on
    - Clarity of presentation
    - Material: do you cover the topic well
    - Understanding + connection to concepts in course
    - Response to questions
- Participation from other students: ask questions!
- **Please fill out the poll if you haven't already**

Final exam

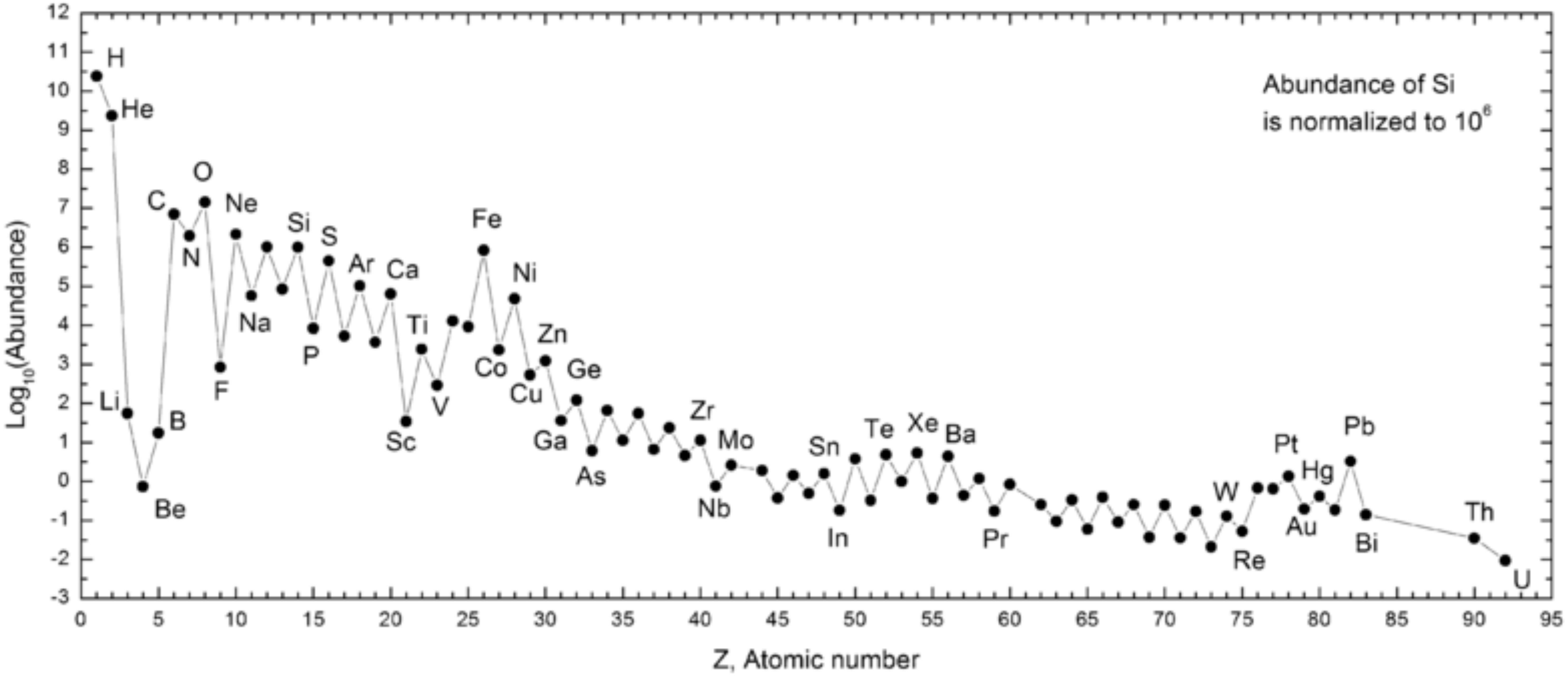
- Two parts:
  - Written: similar to assignments, will be posted by Dec. 7, due Dec. 17
  - Oral: ~20 min. with me, talk about final + follow-up questions —> Dec. 18 (will send poll to schedule)
  - No group work
- Qualifier part is independent of this following the new format. I do not know when/how this will happen…

Reminders

- Assignment 2 due now!
- Assignment 3 posted…
- **No classes (lectures/Q&A) next week (reading week)**

Yields

Abundances in the Sun



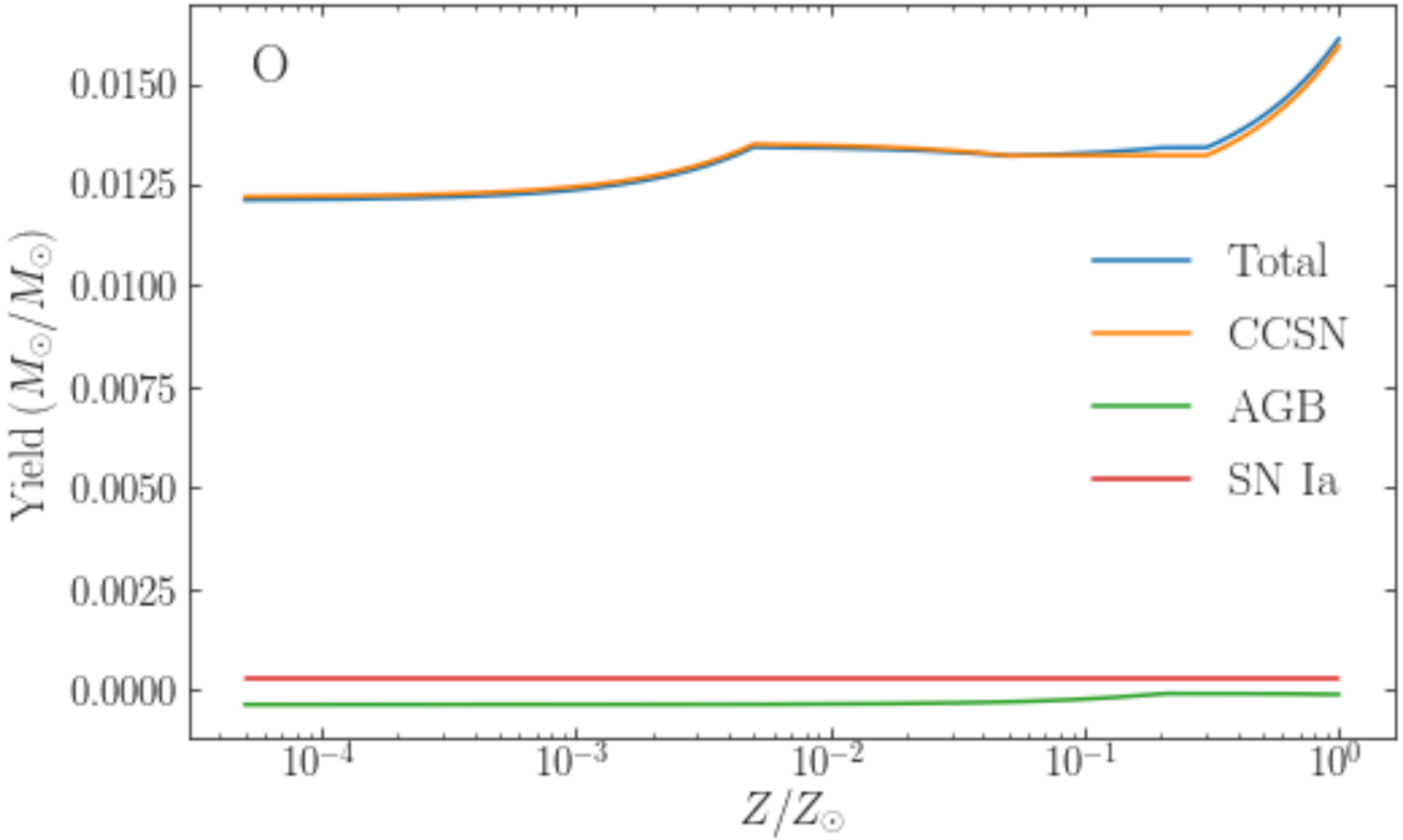
$${}^{12}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{16}_{8}\mathrm{O} + \gamma \qquad E = 7.16\ \mathrm{MeV}$$
$${}^{16}_{8}\mathrm{O} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{20}_{10}\mathrm{Ne} + \gamma \qquad E = 4.73\ \mathrm{MeV}$$
$${}^{20}_{10}\mathrm{Ne} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{24}_{12}\mathrm{Mg} + \gamma \qquad E = 9.32\ \mathrm{MeV}$$
$${}^{24}_{12}\mathrm{Mg} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{28}_{14}\mathrm{Si} + \gamma \qquad E = 9.98\ \mathrm{MeV}$$
$${}^{28}_{14}\mathrm{Si} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{32}_{16}\mathrm{S} + \gamma \qquad E = 6.95\ \mathrm{MeV}$$
$${}^{32}_{16}\mathrm{S} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{36}_{18}\mathrm{Ar} + \gamma \qquad E = 6.64\ \mathrm{MeV}$$
$${}^{36}_{18}\mathrm{Ar} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{40}_{20}\mathrm{Ca} + \gamma \qquad E = 7.04\ \mathrm{MeV}$$
$${}^{40}_{20}\mathrm{Ca} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{44}_{22}\mathrm{Ti} + \gamma \qquad E = 5.13\ \mathrm{MeV}$$
$${}^{44}_{22}\mathrm{Ti} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{48}_{24}\mathrm{Cr} + \gamma \qquad E = 7.70\ \mathrm{MeV}$$
$${}^{48}_{24}\mathrm{Cr} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{52}_{26}\mathrm{Fe} + \gamma \qquad E = 7.94\ \mathrm{MeV}$$
$${}^{52}_{26}\mathrm{Fe} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{56}_{28}\mathrm{Ni} + \gamma \qquad E = 8.00\ \mathrm{MeV}$$

- Abundances of elements like C, O, Ne, Is, S are high because they are involved in alpha processes to burn He. Many of these are going on in the onion layer model of a star just before it explodes
- Elements with an odd number of protons are not involved in these. They need to be produced through other processes during the explosion of the star itself, when energy is abundant

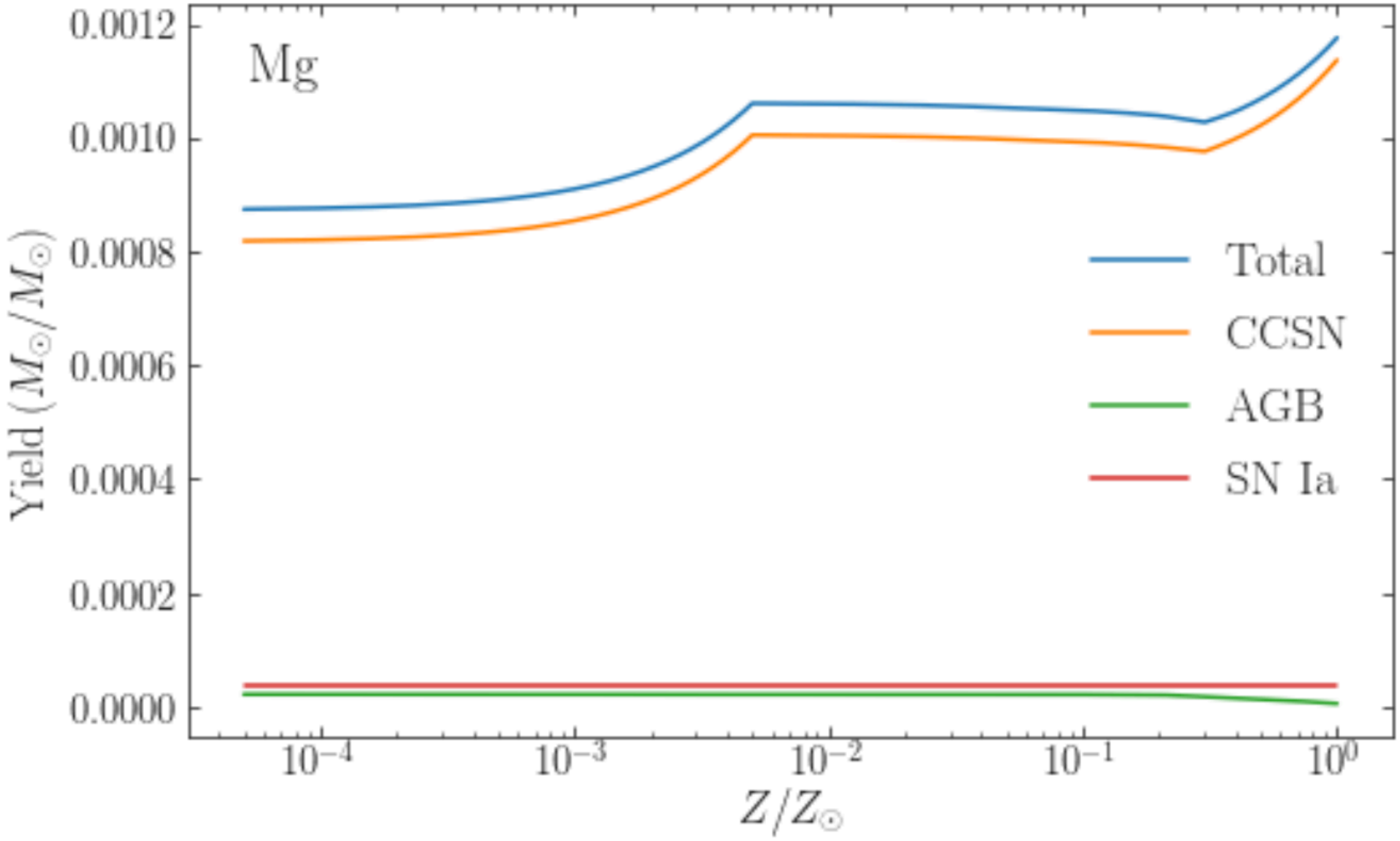
Population level yields

- Supernovae are rare, but
  - All stars with $M > 8$ Msun explode as core-collapse supernovae
  - Type Ia supernova (SNIa) progenitors have $2 < M/M_{sun} < 8$ —> more abundant
  - For every 1000 Msun of stars formed, 2 SNIa happen
- While supernovae are rare, each explosion creates a *lot of metals*
  - For example, a 35 Msun star creates 5 Msun of oxygen and 1 Msun of carbon
  - A 60 Msun star creates 8.5 Msun of oxygen and 3.5 Msun of carbon
  - A type Ia supernova creates 0.77 Msun of iron
- Elements do not generally get destroyed more than are taken from the ISM
- Integration over total stellar population takes rarity into account

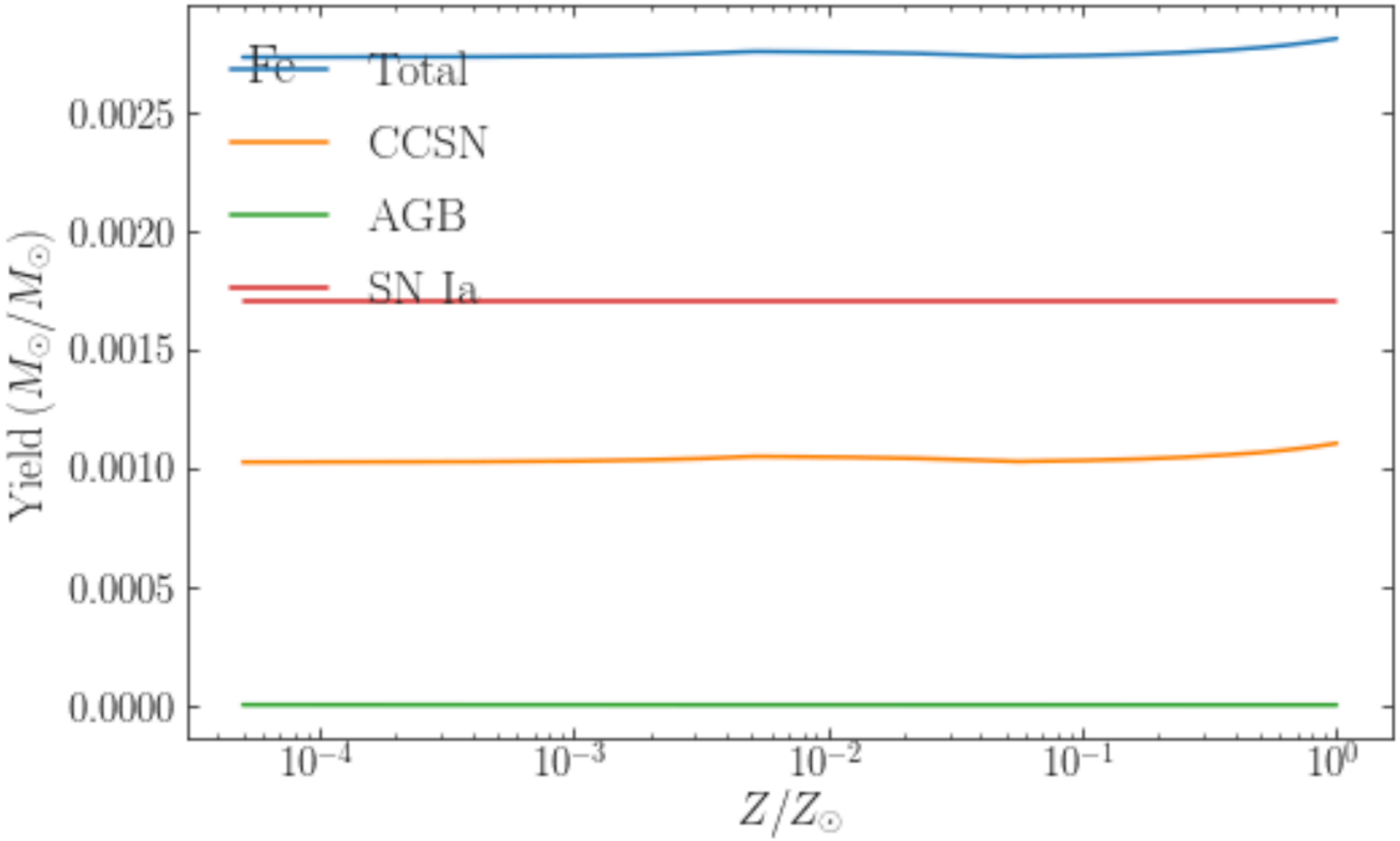
Population level yields



Population level yields



Population level yields



The accreting box model

The accreting box model

- We argued in the lecture (and showed in the notes) that an equilibrium state Z=p is achieved when gas is accreted at the rate at which it is consumed by star formation
    - True equilibrium requires t —> infinity and M —> infinity
    - But you get to equilibrium exponential fast

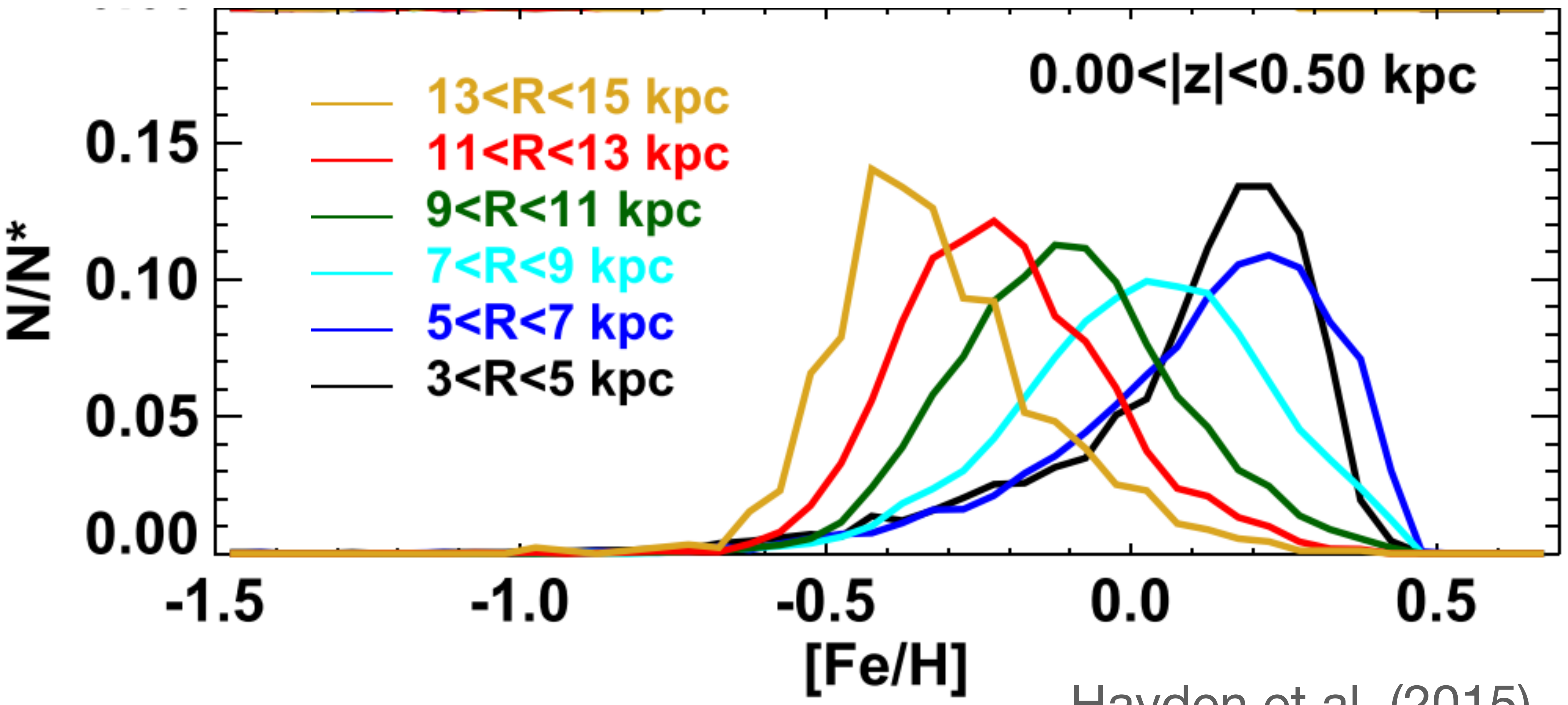
$$Z = p\left[1 - \exp\left(1 - \frac{M}{M_g}\right)\right] .$$

- Intuitive argument: accreting box turns a chunk of gas with abundance Z into a chunk with abundance p
    - Think of it like this:
        - Star formation removes a chunk of gas of mass M with abundance Z
        - Inflow balances this with a chunk of gas with abundance zero with mass M-M_{yield}
        - Enrichment adds metals of mass M_{yield} (so the total mass in the ISM is balanced)
        - At the end the abundance of this chunk of gas is M_{yield} / (M-M_{yield}+ M_{yield}) = M_{yield} / M = p
    - So the overall abundance keep increasing (because p > Z) until Z=p and a steady state is reached

Multi-zone models for galaxies

Multi-zone models for galaxies

- We discussed chemical evolution in terms of a single box, but the existence of abundance gradients and differences in the metallicity distribution at different radii shows that galaxies are not just a box!
- In the absence of significant radial flows, can think of a galaxy as a combination of one-zone models in rings
  - Assume that gas within the ring is mixed (through shear), but no mixing between rings
  - Existence of abundance gradients show that this must be approximately the case, at least at late times
- Early in the history of a galaxy like the Milky Way, turbulence driven by feedback from supernovae might mix the entire disk and create a single closed box

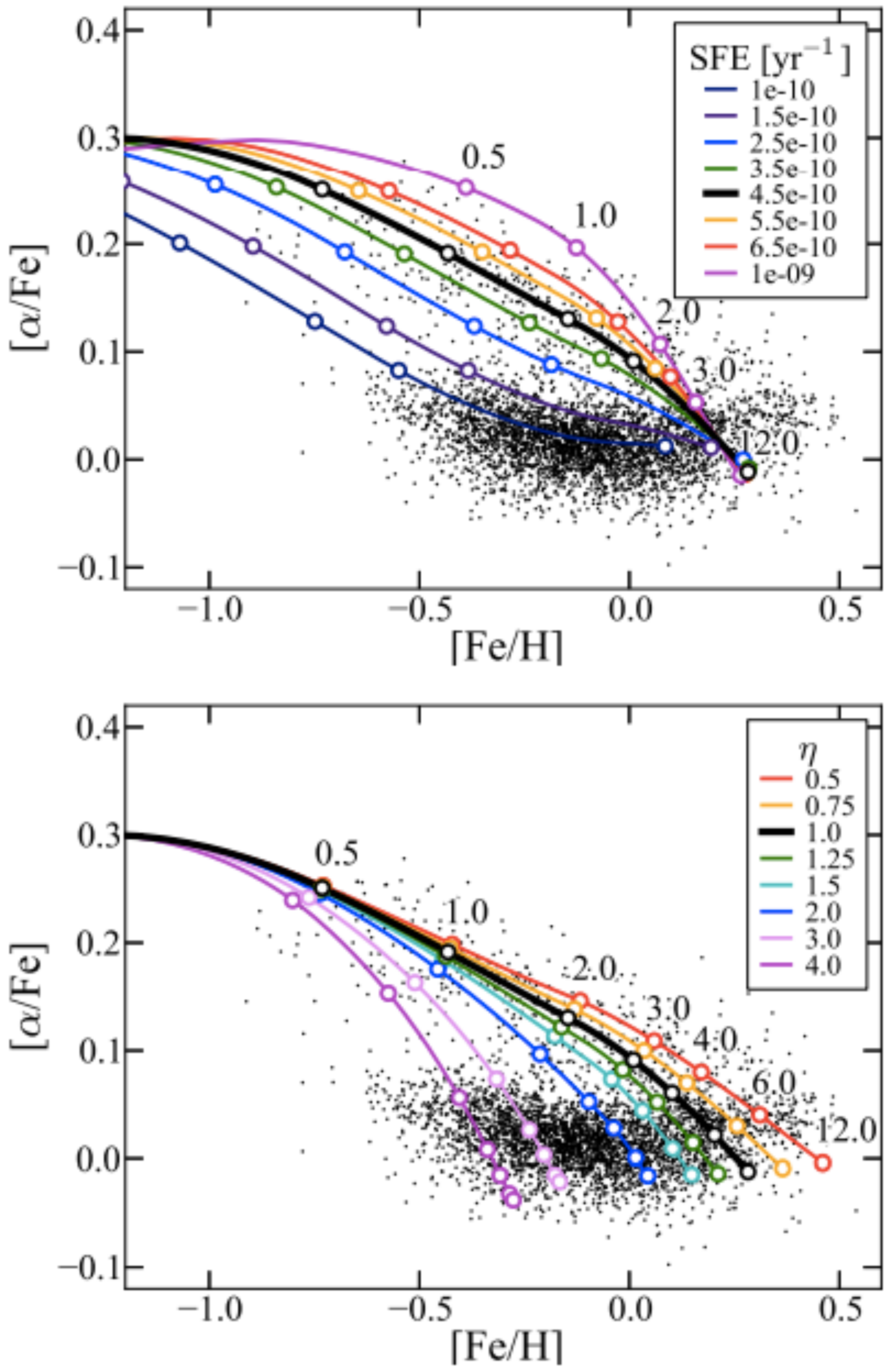


Hayden et al. (2015)

Interactive activity

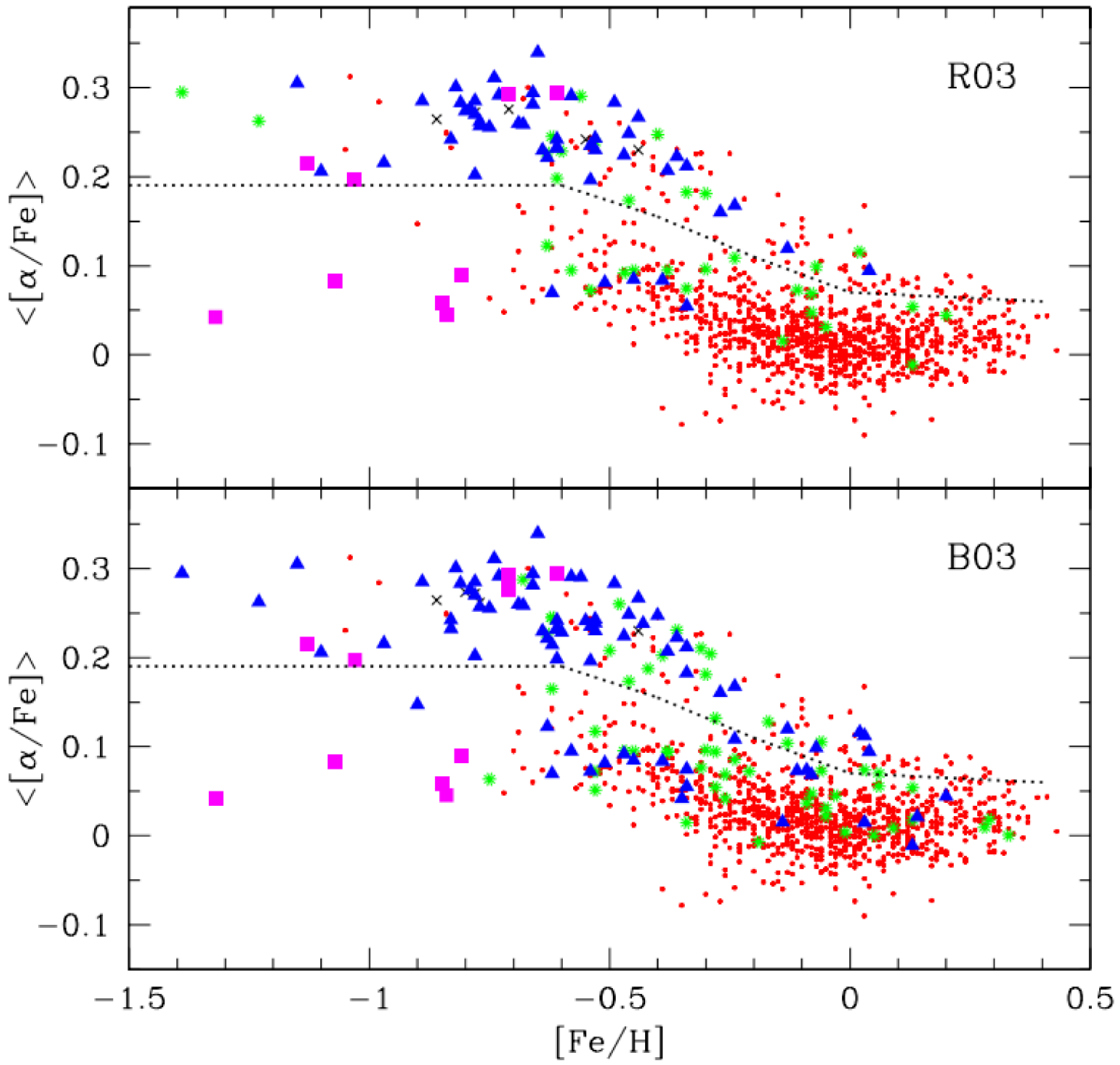
Chemical evolution in the solar neighborhood

- Understanding the evolution of abundance ratios requires us to take into account the delay between star formation and enrichment by type Ia supernovae
- Have to assume a star formation efficiency
  - SFE = SFR/Mgas, tau_{SFE} = 1/SFE
- Can either specify inflow rate or the star formation history (SFH)
  - In example, we'll set the SFH to be e^-t/tau (inflow is then set to match this)
- Outflows parametrized by eta
  - eta = outflow-rate / SFR



Chemical evolution in the solar neighborhood

- We’ll look at the distribution of solar neighborhood stars in [Mg/Fe] vs. [Fe/H]
- Mg is an almost pure CCSN element, Fe gets contributions from CCSN and SNIa
- Abundance distribution has two tracks:
    - “High alpha”: older stars (age > 8 Gyr)
    - “Low alpha”: younger stars (age < 8 Gyr)
- By trying to match the location of the data by varying the SFE, SFH, and outflow eta see what you can learn about the physical conditions under which these different stars were born
- Questions to ask:
    - How does the model change when you change the parameters, what is the physical reason for this?
    - Can you match the location in [Mg/Fe] vs. [Fe/H]?
    - Can you also match the distribution of [Fe/H]?
    - What might be missing from the model?



Adibekyan et al. (2011)

https://bit.ly/3oTSjfo