Sodium and aluminium abundances in giants and dwarfs:

Implications for stellar and chemical evolution

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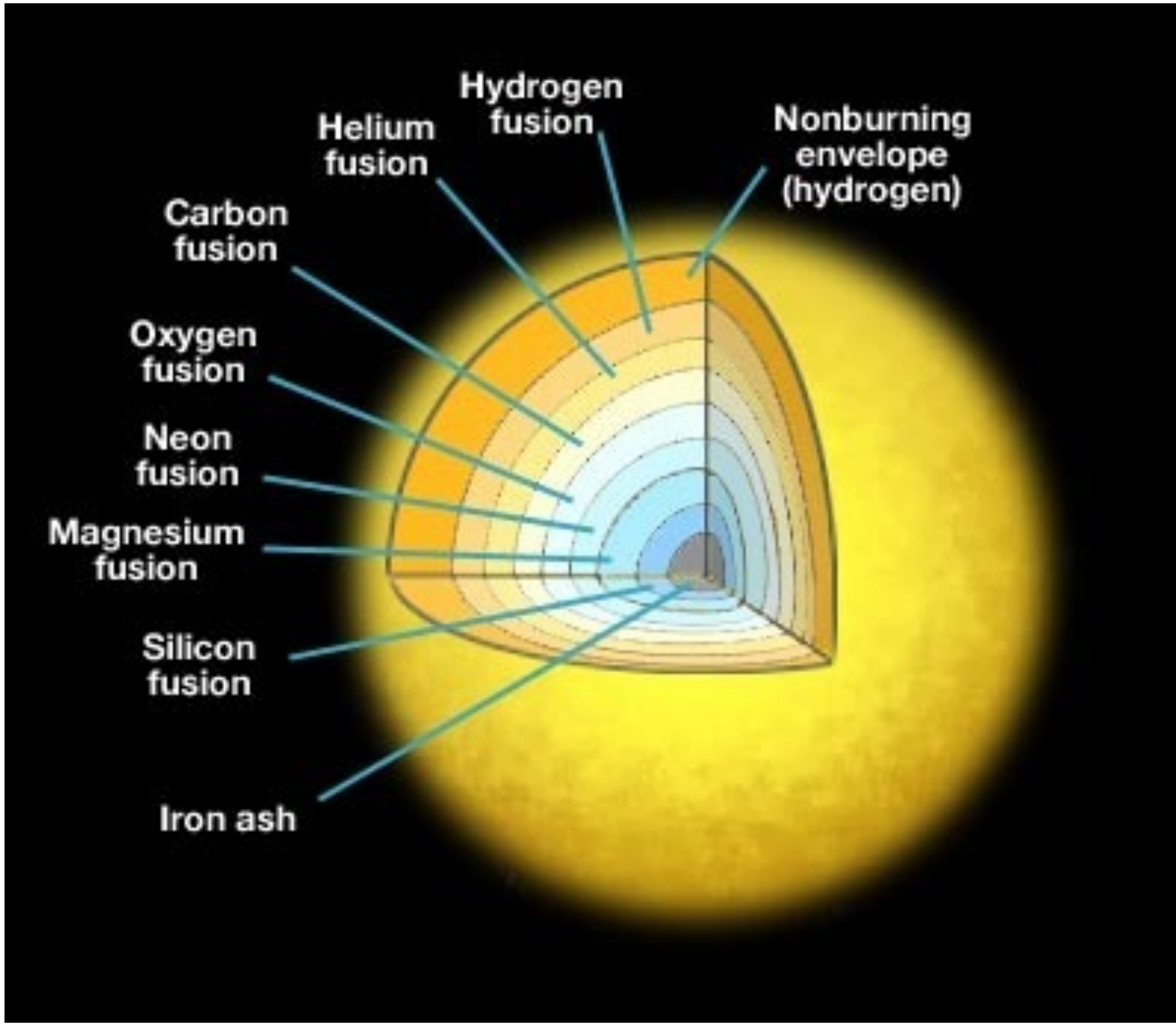
^{23}Na nucleosynthesis

- Hydrostatic carbon burning in massive stars:

$^{12}C(^{12}C,^{1}H)^{23}Na$

$^{23}Na(^{1}H,^{4}He)^{20}Ne$

- Primary element but:
- Affected by NeNa cycle in the H-burning envelope, neutron capture on ^{22}Ne



credit: C. Palma, Penn State University

^{27}Al nucleosynthesis

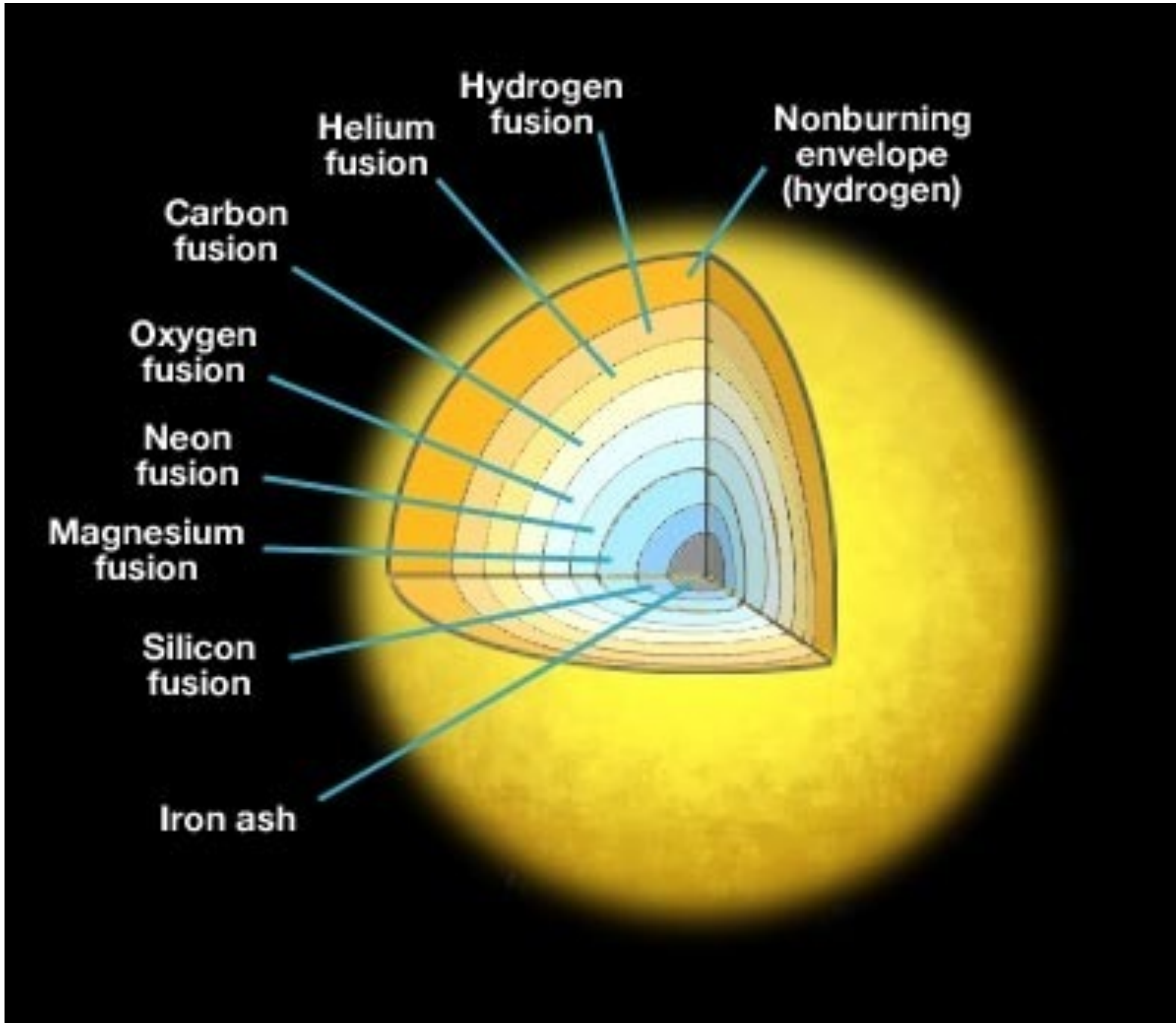
- Hydrostatic carbon and neon burning in massive stars:

$^{23}Na(^{4}He,^{1}H)^{26}Mg(^{1}H,\gamma)^{27}Al$

$^{22}Ne(^{4}He,n)^{25}Mg(n,\gamma)^{26}Mg(\beta^{-})^{27}Al$

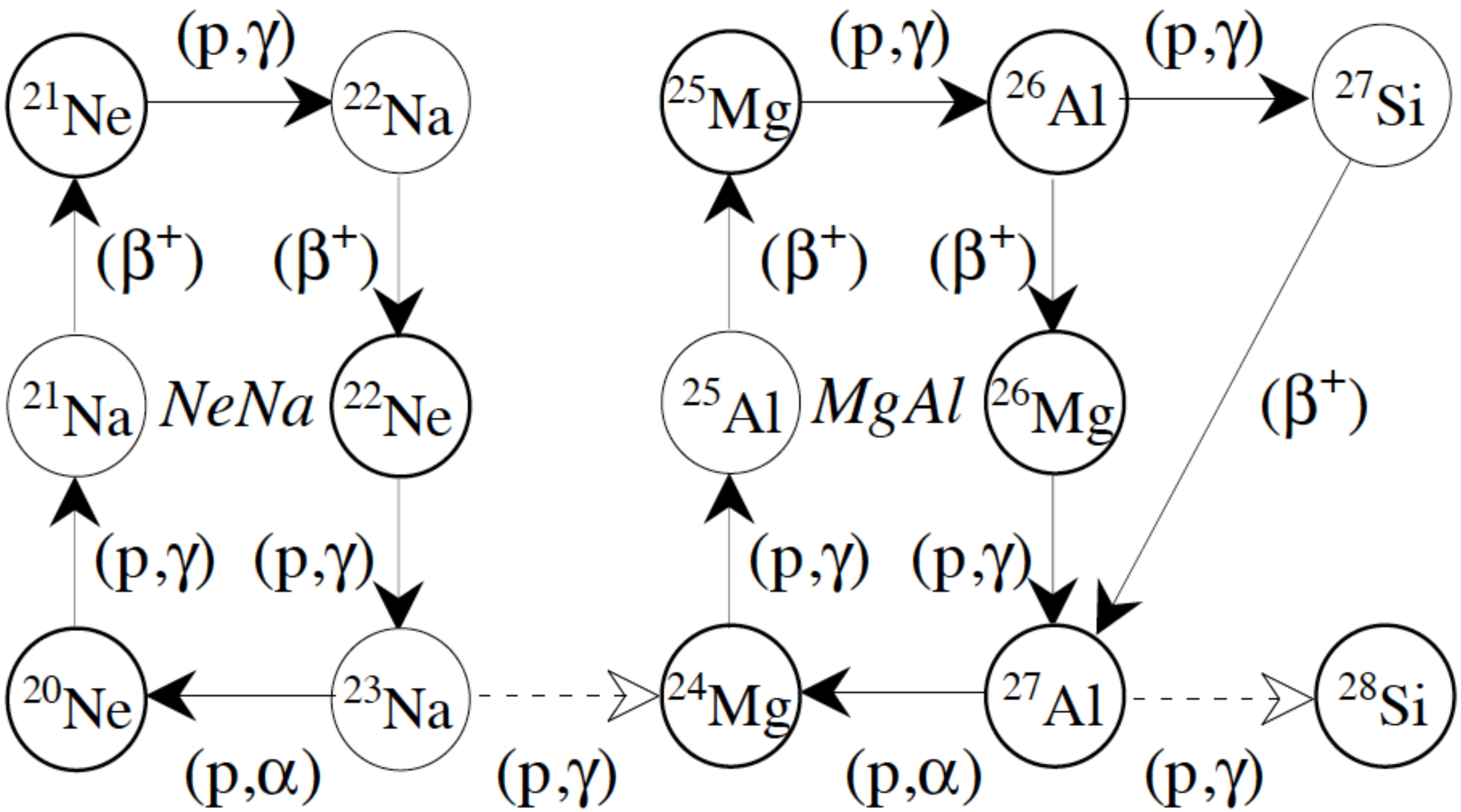
(…and others)

- Affected by MgAl cycle in H-burning layers



credit: C. Palma, Penn State University

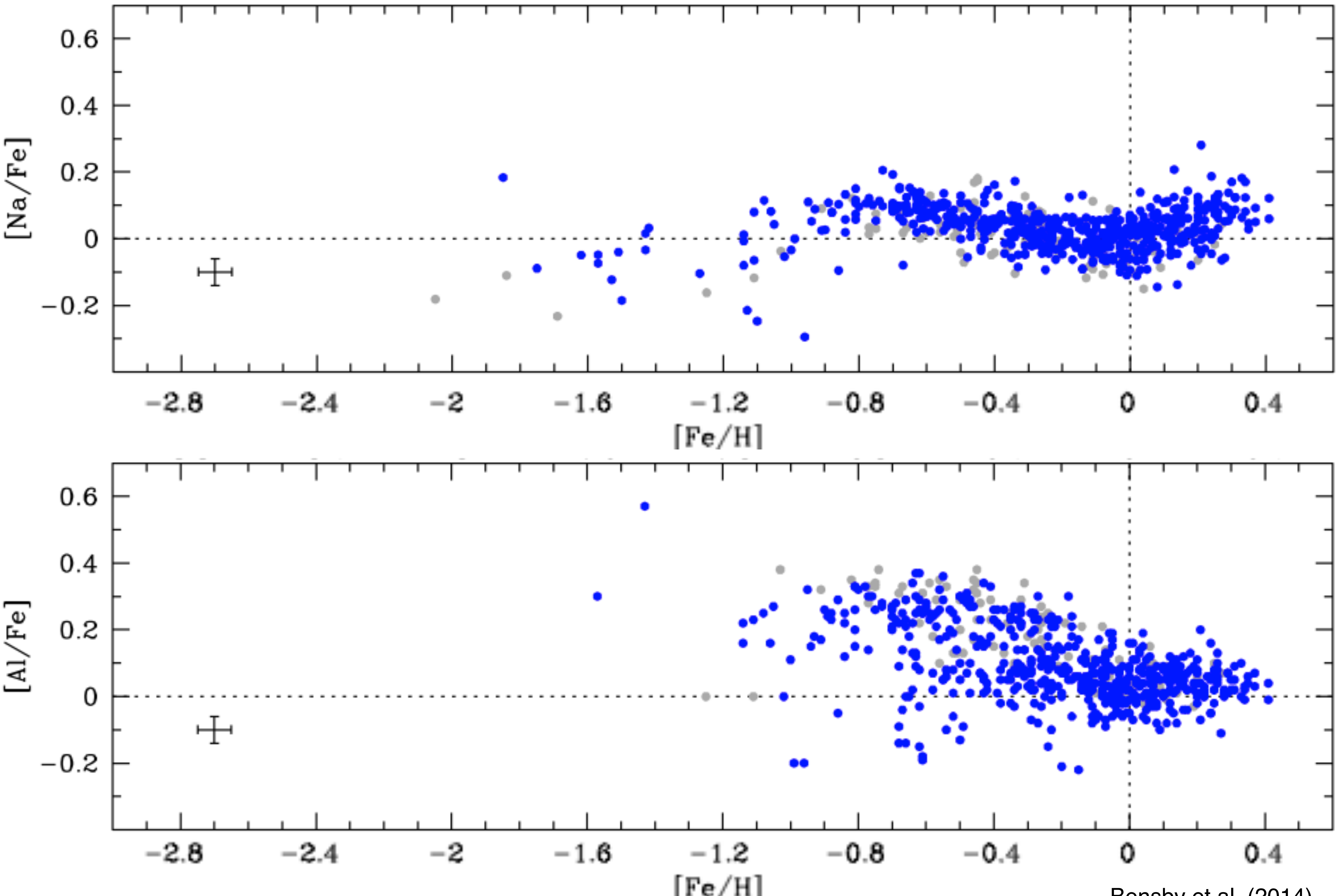
NeNa and MgAl cycles



- NeNa is a cycle for $T_6 < 50$
- ^{27}Al accumulates for $T_6 > 70$

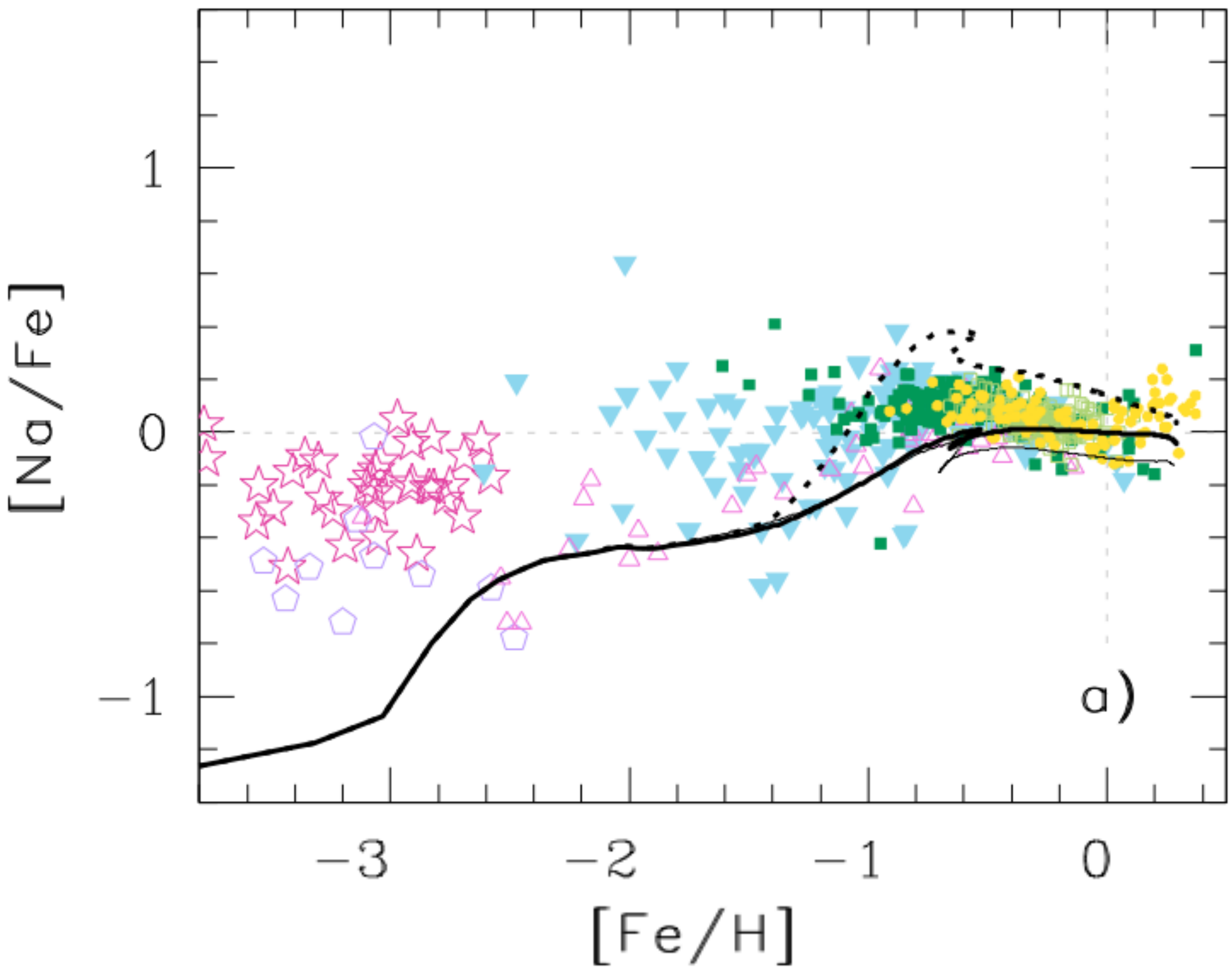
Arnould et al. (1999)

Chemical evolution



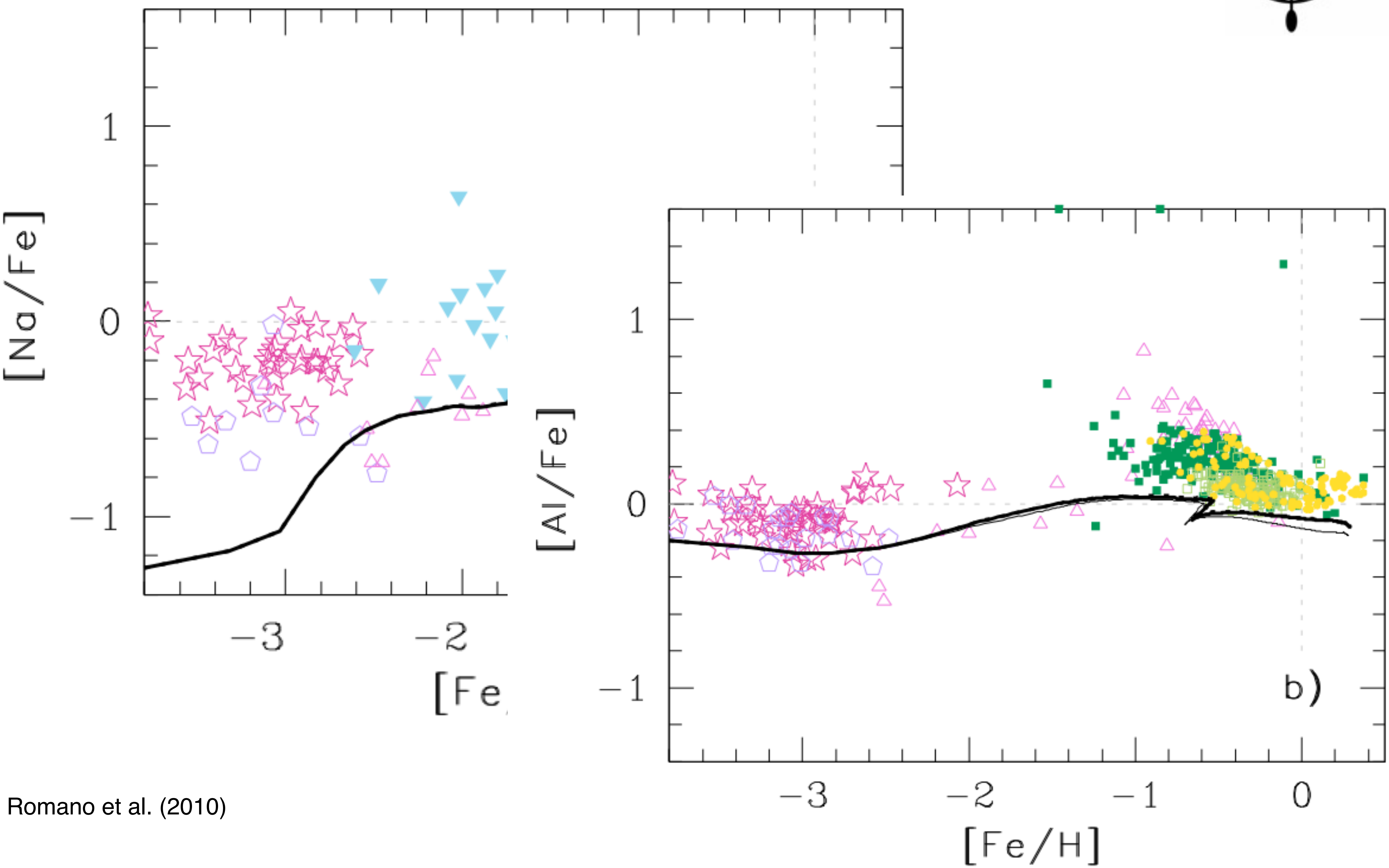
Bensby et al. (2014)

Chemical evolution



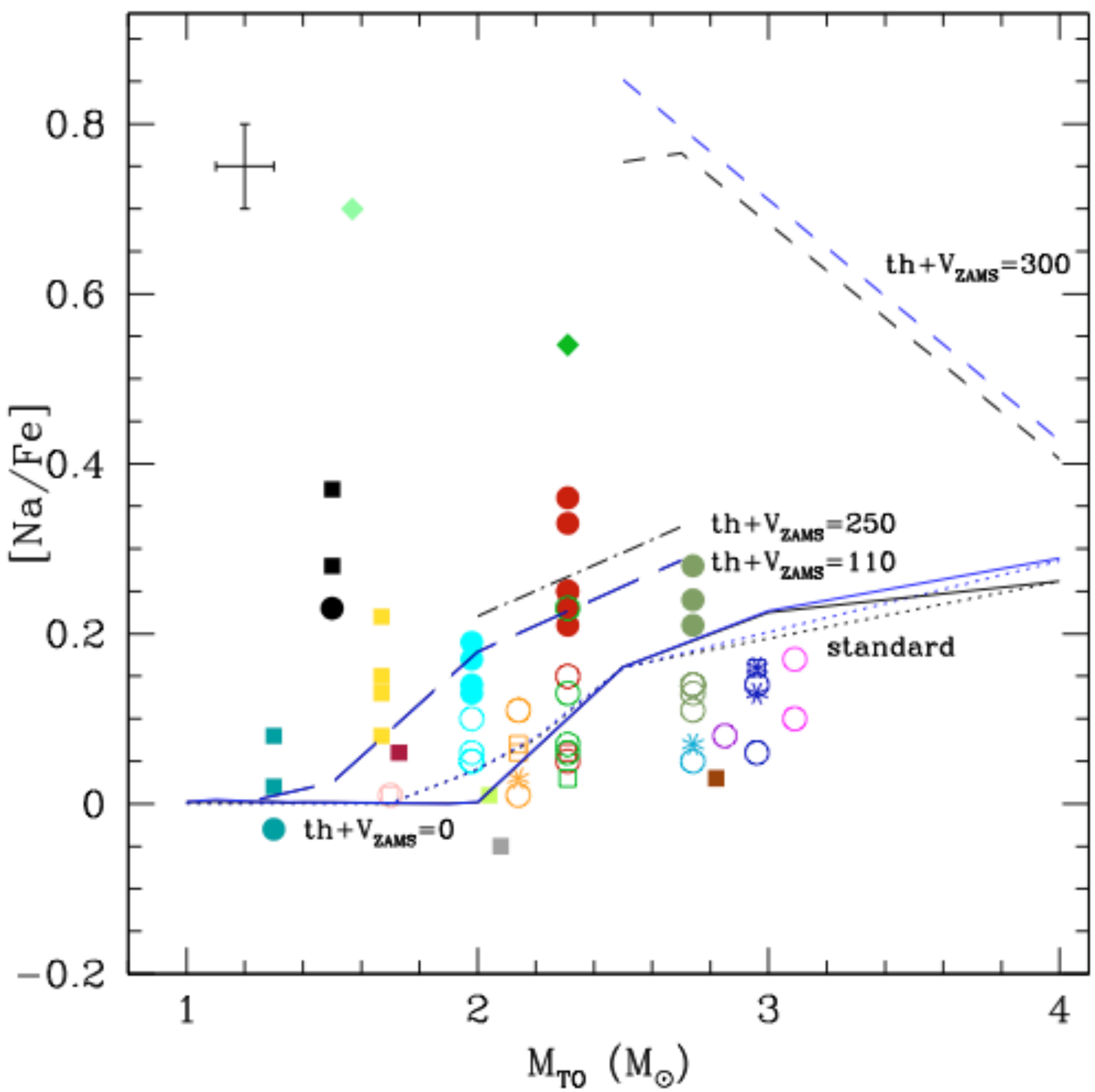
Romano et al. (2010)

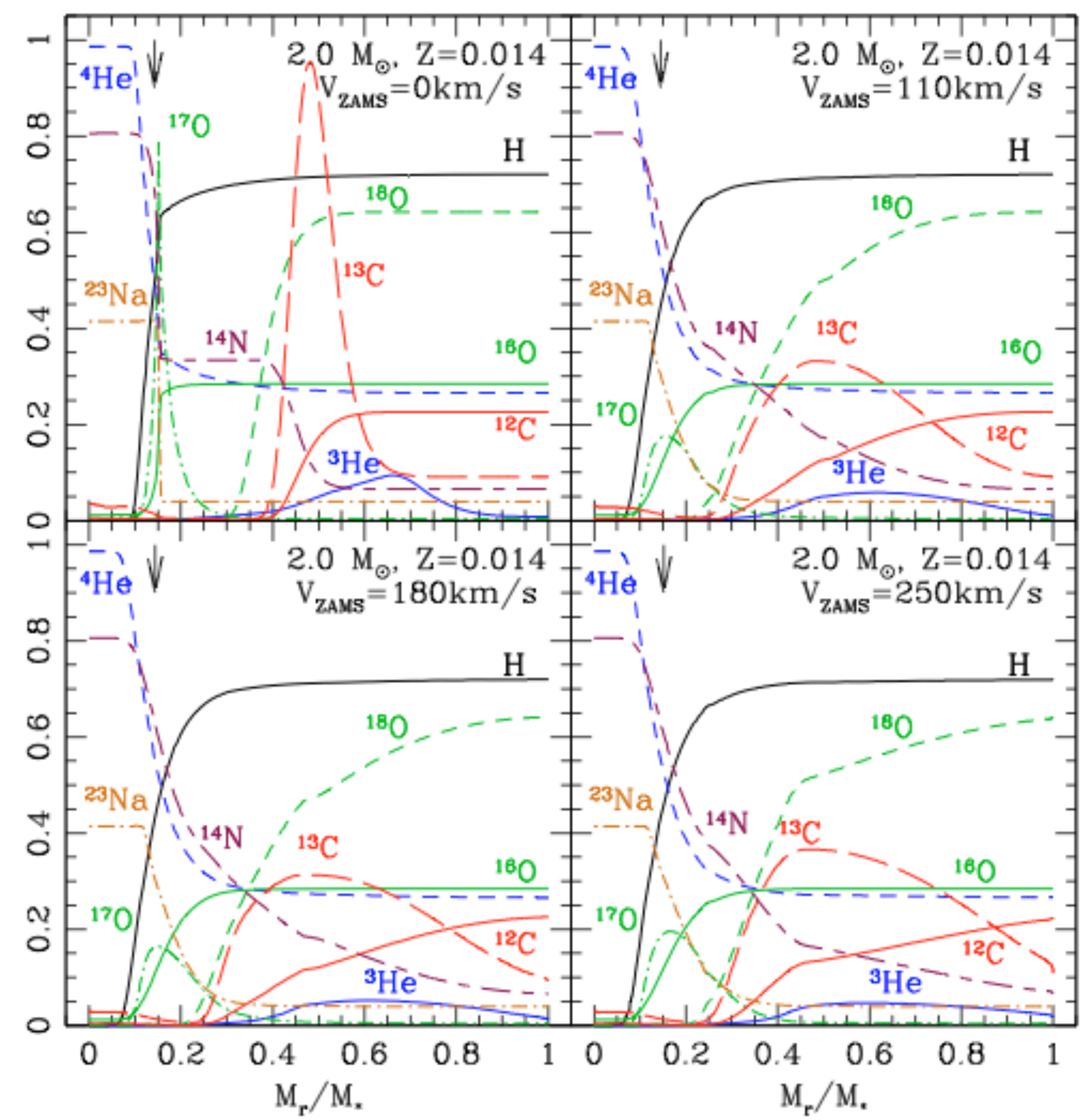
Chemical evolution



Romano et al. (2010)

Stellar evolution





Charbonnel & Lagarde (2010)

A number of open questions

1. Chemical evolution:

- The behaviour of [Na-Al/Fe] vs. [Fe/H] not well understood
- Increase in [Na/Fe] for [Fe/H] > 0.0 is a mystery
- High [Al/Fe] at disk metallicities also not reproduced

2. Stellar evolution:

- High [Na-Al/Fe] in giants, present or not?
- If yes, how does it depend on the stellar mass?
- And: Fully consistent models that explain stellar and chemical evolution?

Our GES project

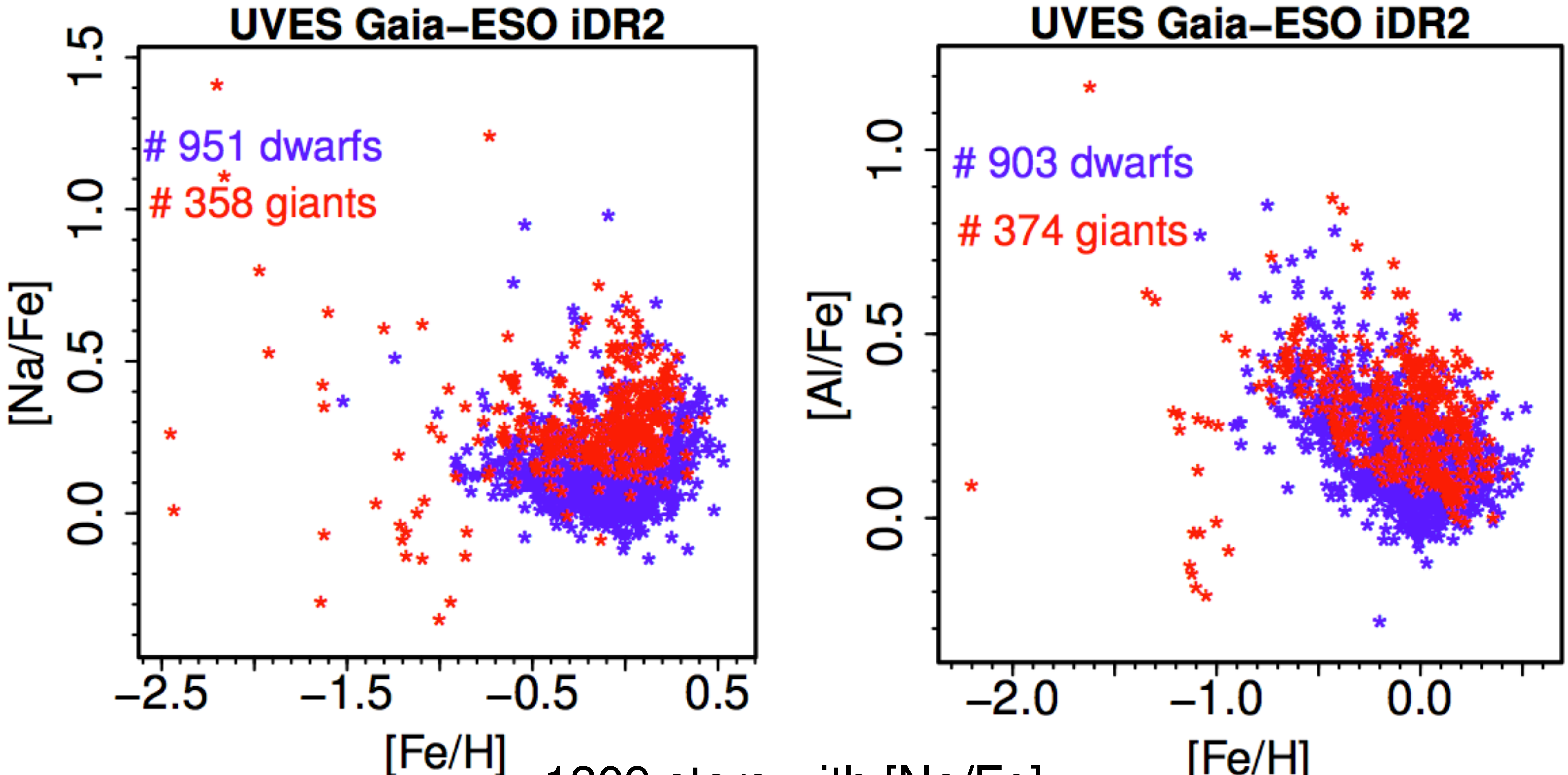
Study both issues together

- Use the same models to fit stellar evolution behaviour and predict yields for the chemical evolution models
- GES: Na and Al abundances for dwarfs and giants
- GES: Homogeneous abundances for cluster vs. cluster comparison

Still missing:

- New models being computed
- NLTE corrections for Na and Al
- Ages for field stars

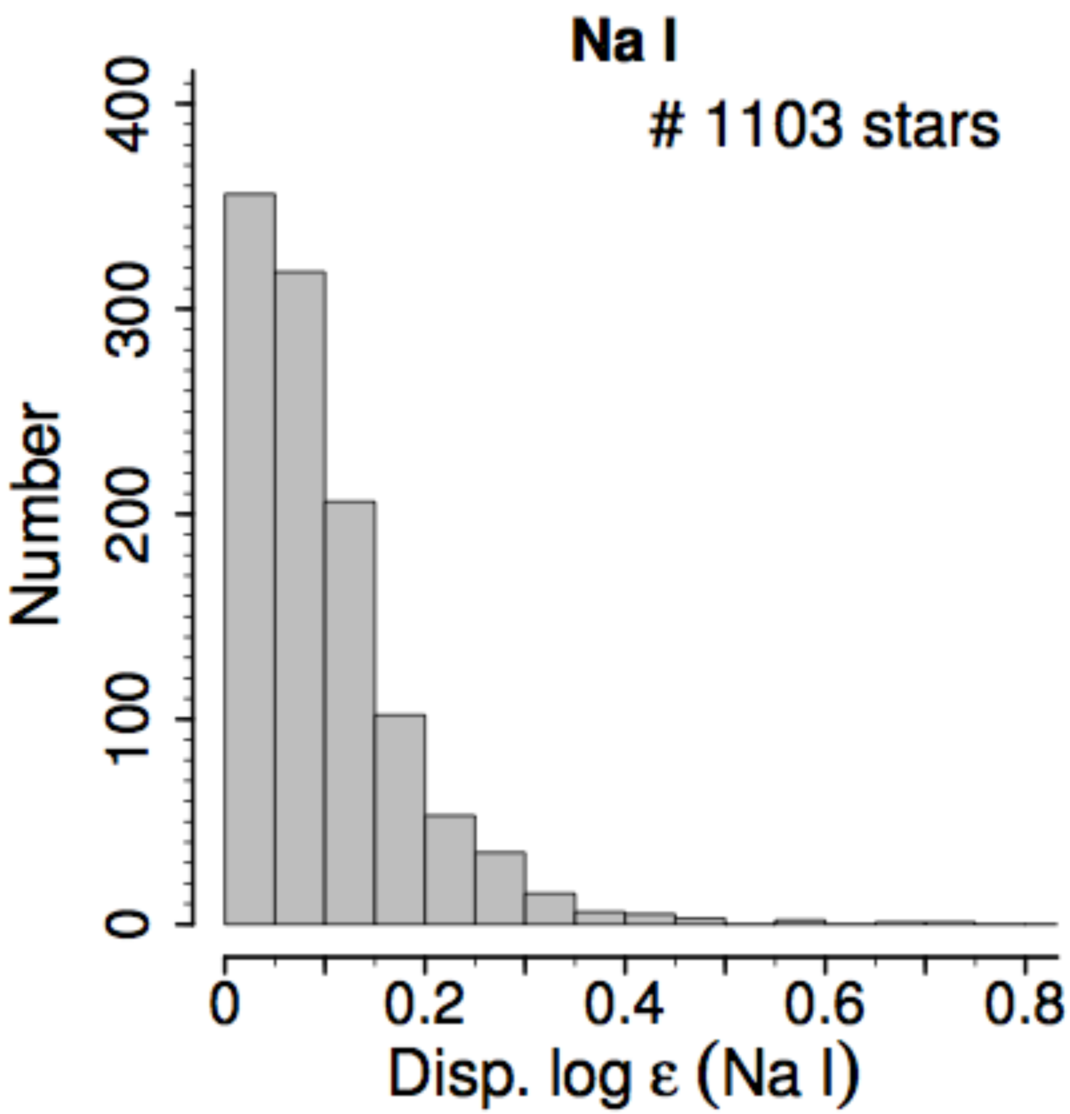
GES iDR2

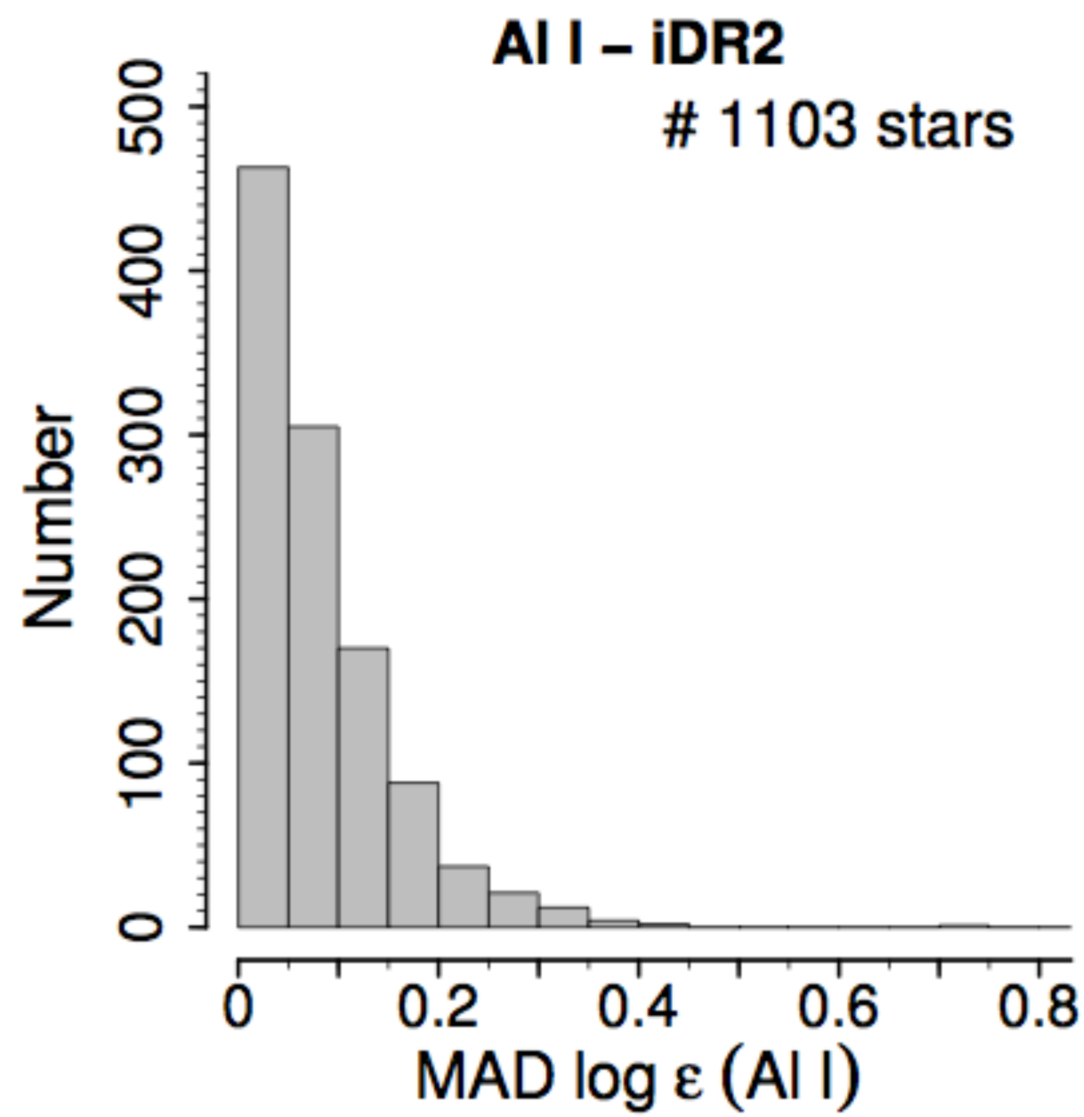


1309 stars with [Na/Fe]
1277 stars with [Al/Fe]
1240 stars with both abundances
1103 stars (excluding GCs)

Smiljanic et al. (2014)

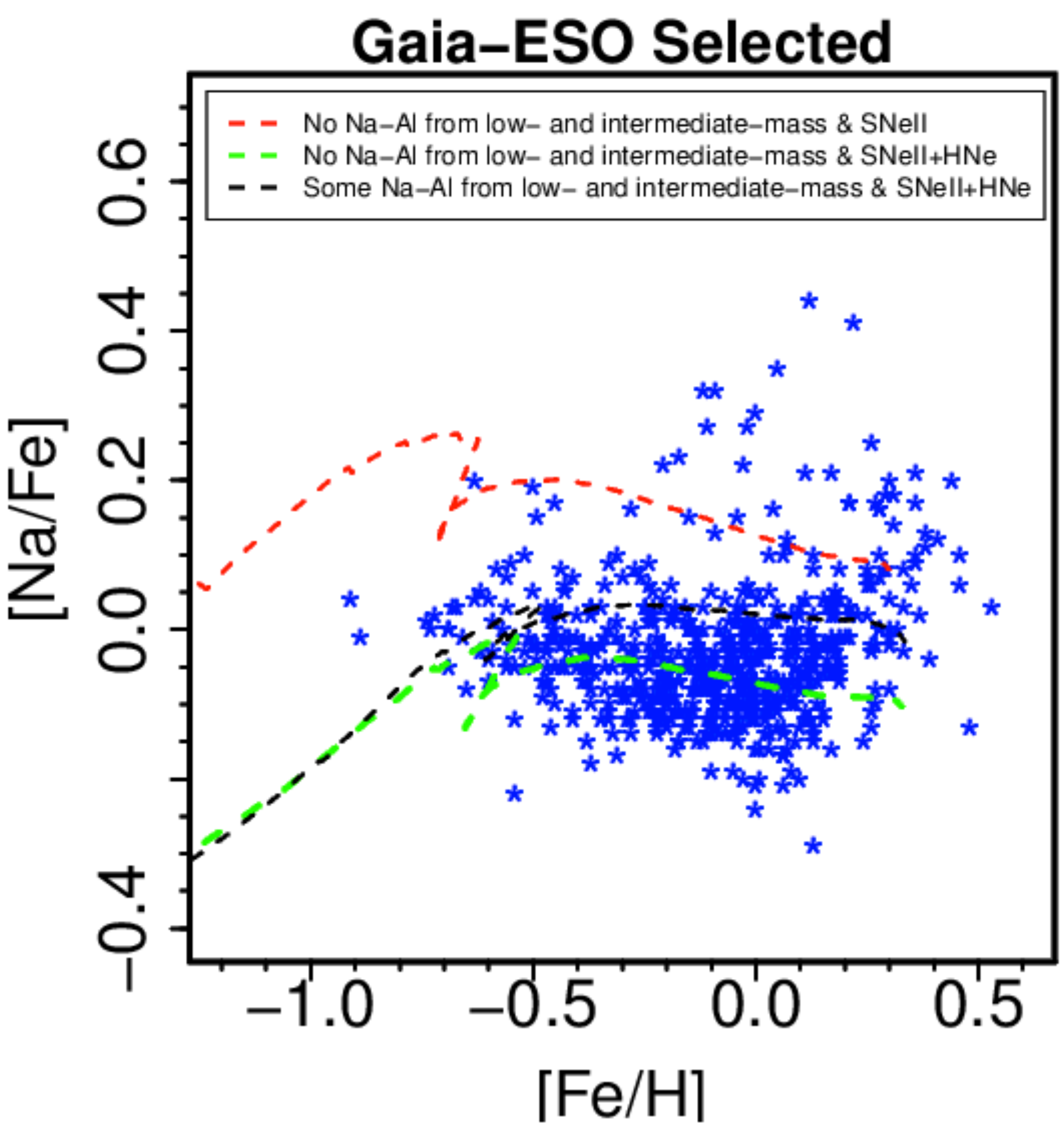
Do not forget the uncertainties

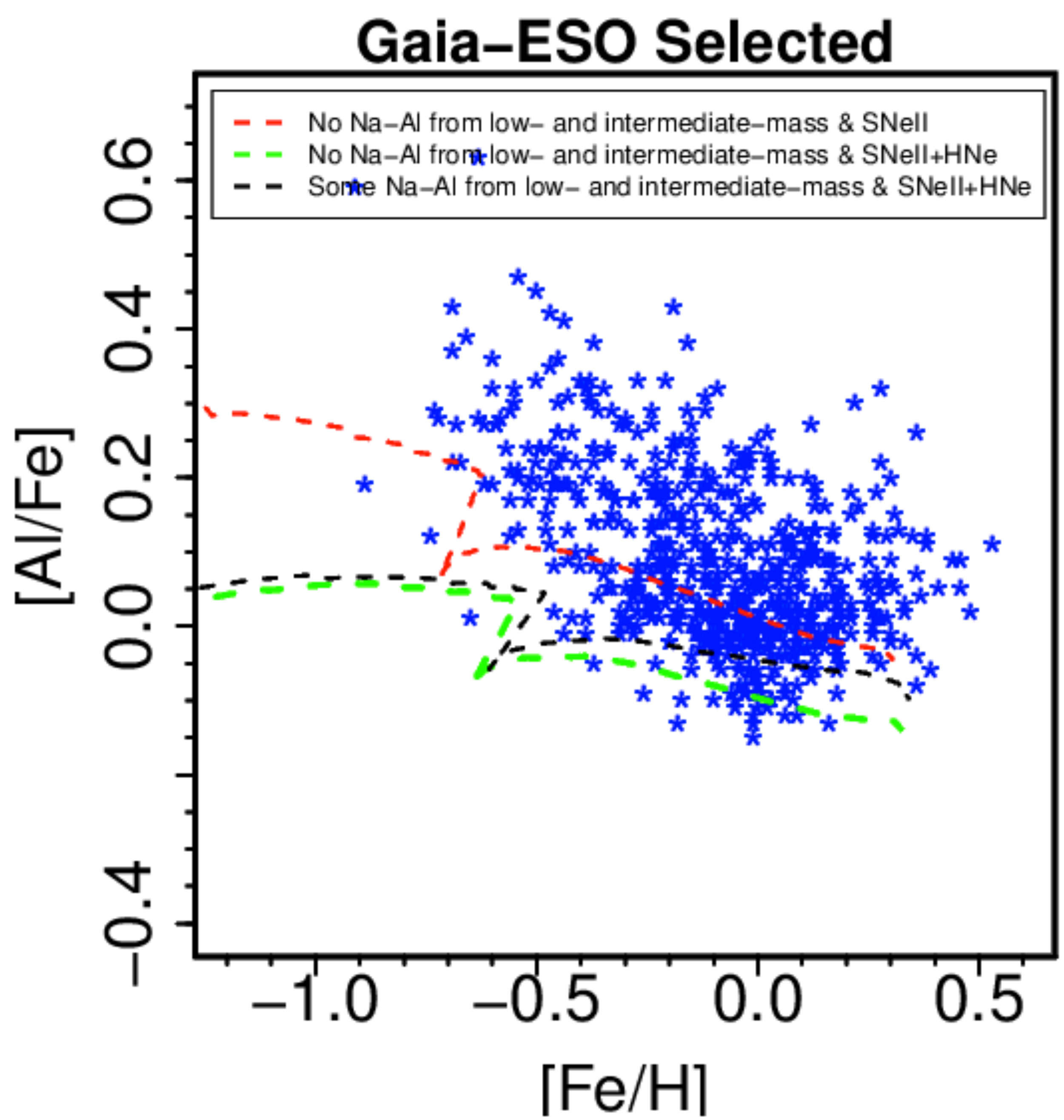




Cut at σ = 0.15 dex (Na & Al)
(preliminary - test ongoing)
761 (574+187) stars with both Na and Al

GES vs. models





Models: Romano et al. (2010)

Four old open clusters

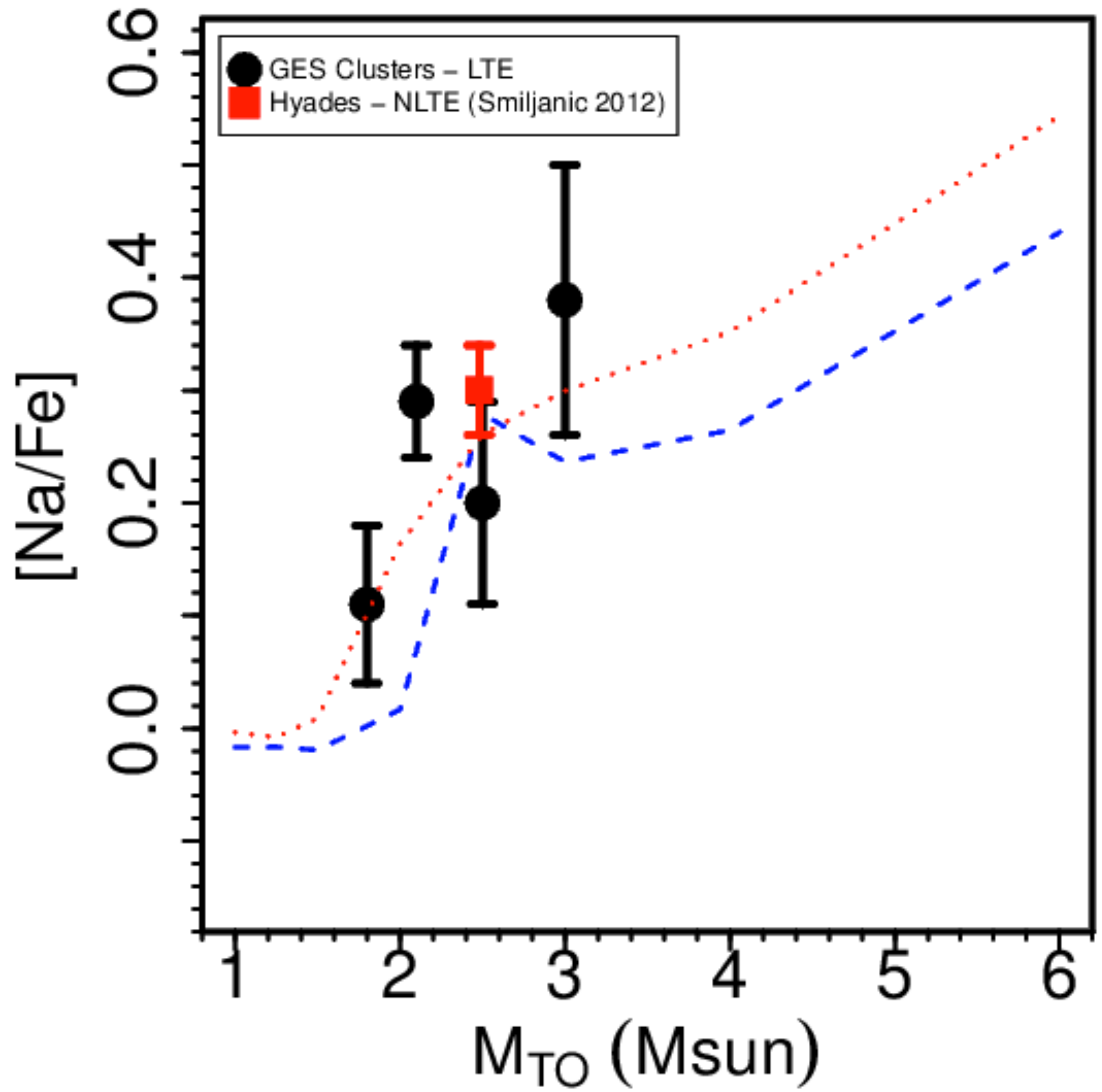
- NGC 6705 (M 11): [Fe/H] = +0.10, Age = 250-316 Myr, M_{TO} = 3.2-3.5 M_{sun} (Cantat-Gaudin et al. 2014)

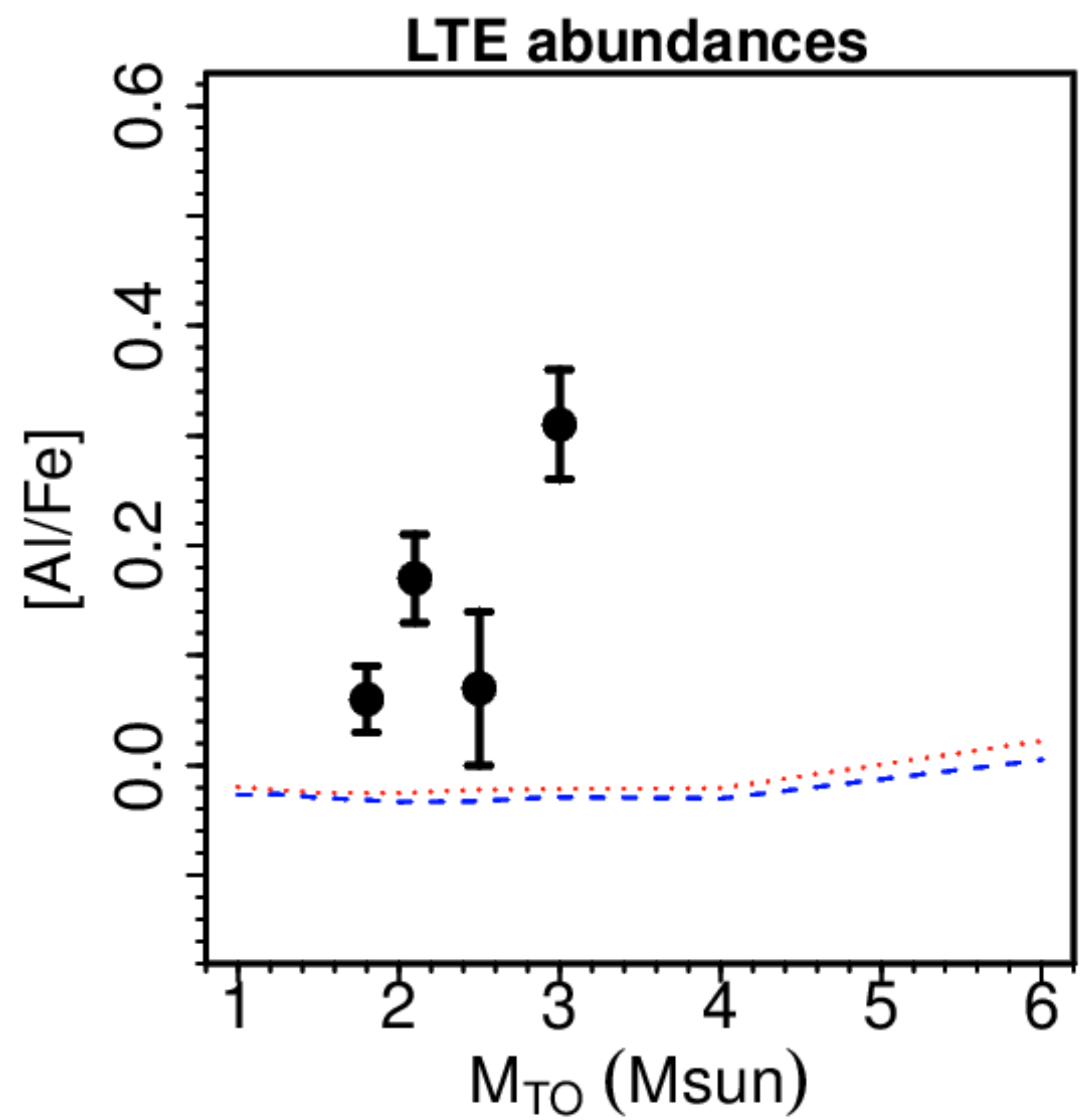
- NGC 4815: [Fe/H] = = +0.03, Age = 500-630 Myr, M_{TO} = 2.5-2.7 M_{sun} (Friel et al. 2014)

- Trumpler 20: [Fe/H] = = +0.17, Age = 1.35-1.66 Gyr, M_{TO} = 1.8-1.9 M_{sun} (Donati et al. 2014a)

- Berkeley 81: [Fe/H] = = +0.21 (Magrini et al., in prep.), Age = 0.75-1.0 Gyr, M_{TO} = 2.1-2.2 M_{sun} (Donati et al. 2014b)

[Na-Al/Fe] vs. stellar mass





Models: Lagarde et al. (2012)

Summary

- Sample: 1103 (761) stars to investigate [Na-Al/Fe] vs. [Fe/H] ([Fe/H] > -1.00)

  4 old open clusters to investigate [Na-Al/Fe] vs. Mass

- Chemical evolution: GES abundances similar to previous literature results

- Stellar evolution: [Na/Fe] seems to agree with stellar evolution models, [Al/Fe] does not

- To be done: New chemical evolution models to be computed

  New stellar evolution models to be computed

  NLTE corrections pending

- Results are preliminary but look promising

References

- Arnould et al. 1999 (A&A, 347, 572)
- Bensby et al. 2014 (A&A, 562, A71)
- Cantat Gaudin et al. 2014 (A&A, 569, A17)
- Charbonnel & Lagarde 2010 (A&A, 522, A10)
- Donati et al. 2014a (A&A, 561, A94)
- Donati et al. 2014b (MNRAS, 437, 1241)
- Friel et al. 2014 (A&A, 563, A117)
- Lagarde et al. 2012 (A&A, 543, A108)
- Romano et al. 2010 (A&A, 522, A32)
- Smiljanic et al. 2014 (A&A, 570, A122)