Sodium and aluminium: stellar evolution and Galactic chemical evolution with Gaia-ESO data

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Rainbows on the Southern Sky — ESO Garching, 4-9 October 2015

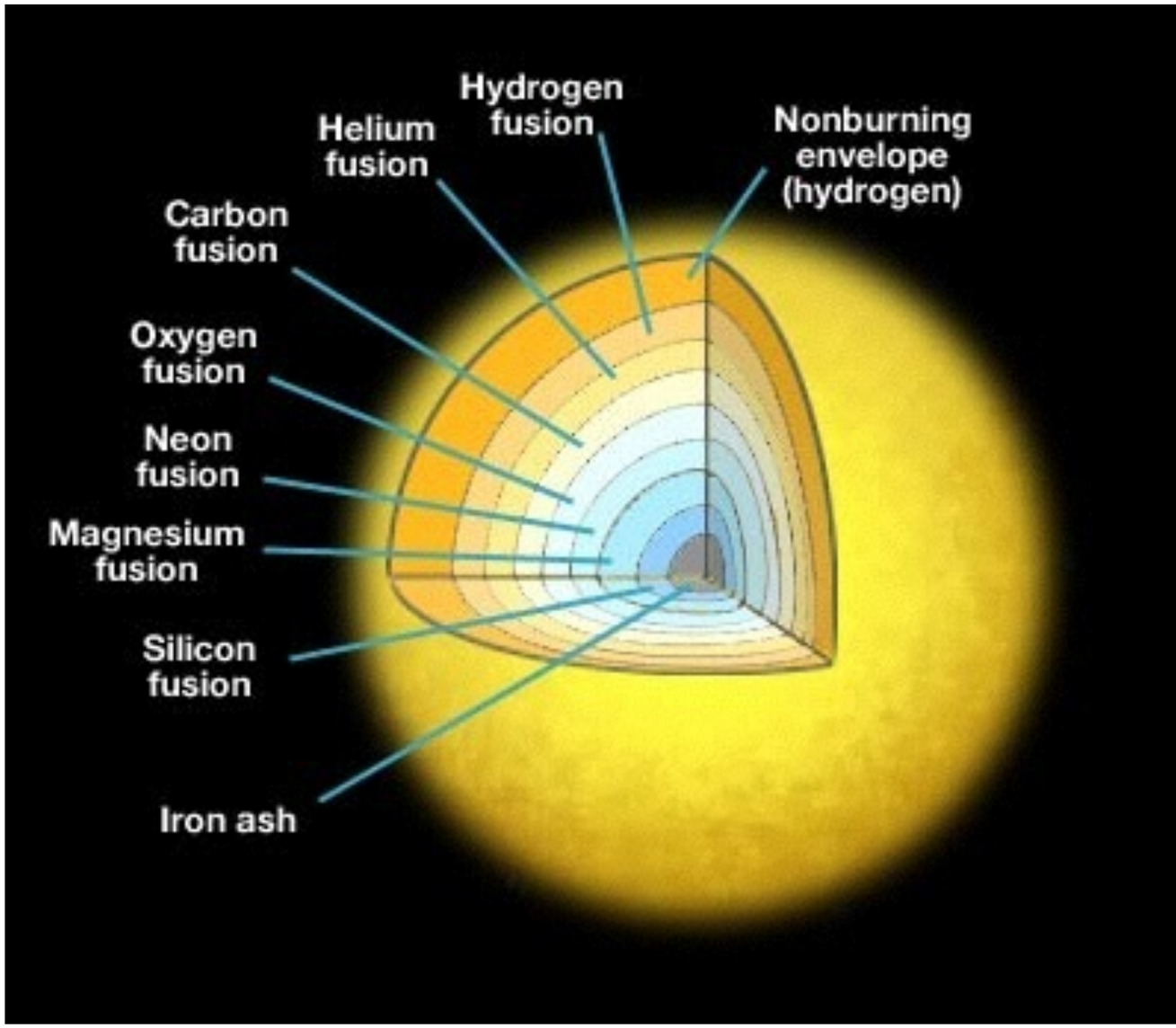
^{23}Na nucleosynthesis

- Hydrostatic carbon burning in massive stars:

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

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

- Affected by NeNa cycle in the H-burning envelope and by neutron capture on ^{22}Ne



credit: C. Palma, Penn State University

^{27}Al nucleosynthesis

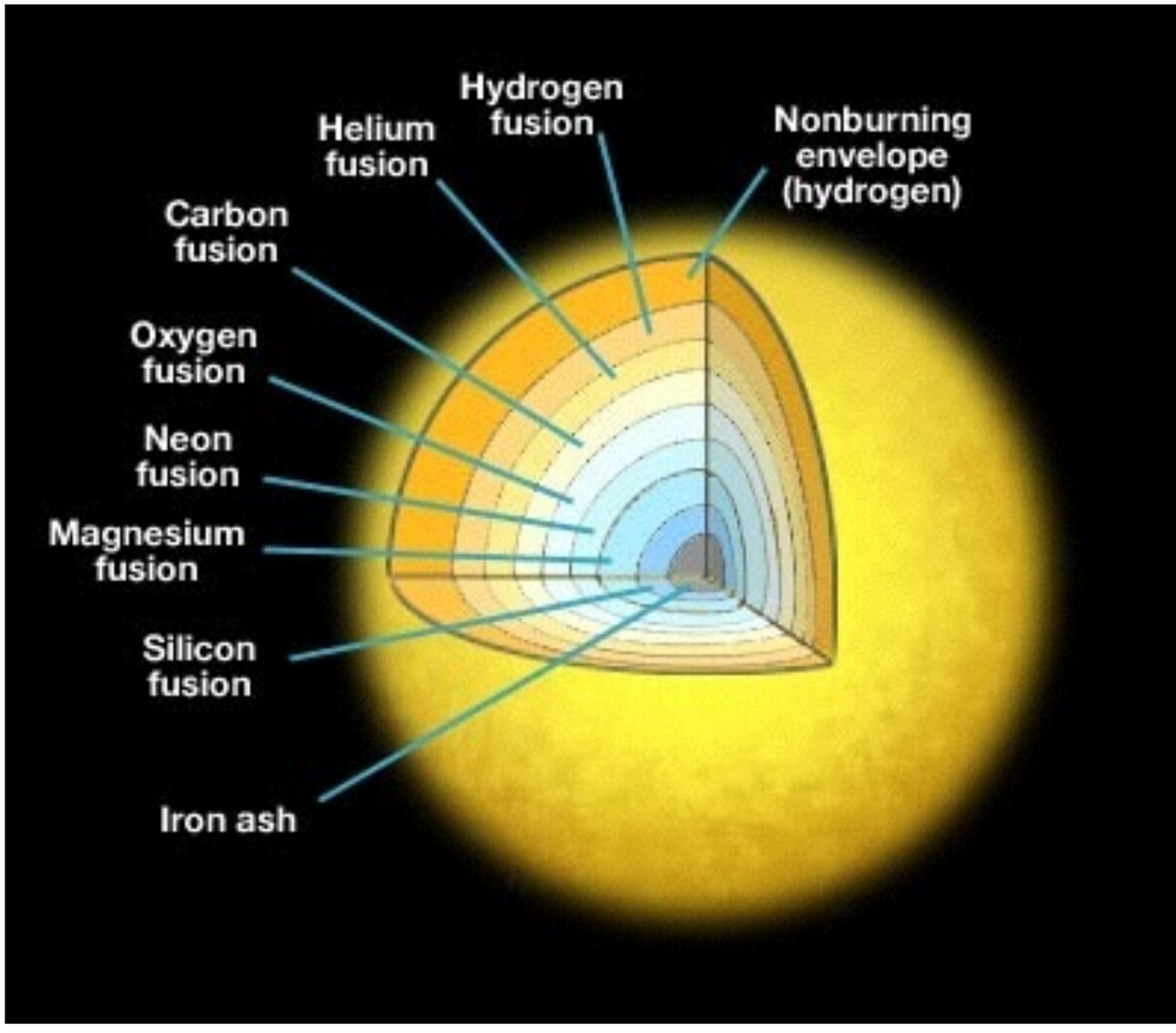
- Hydrostatic carbon and neon burning in massive stars:

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

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

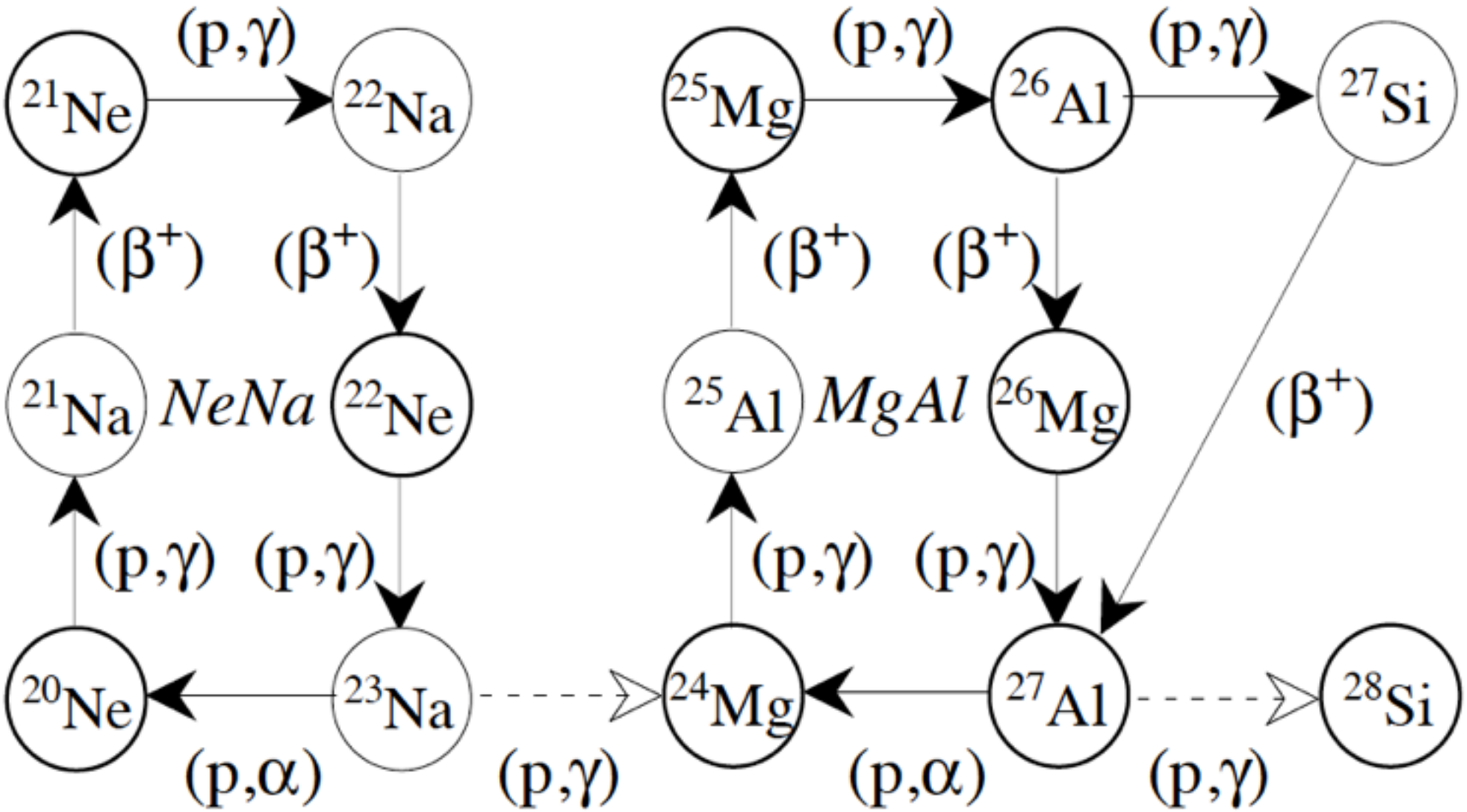
(…and others)

- Affected by MgAl cycle in H-burning layers at high temperatures



credit: C. Palma, Penn State University

NeNa and MgAl cycles

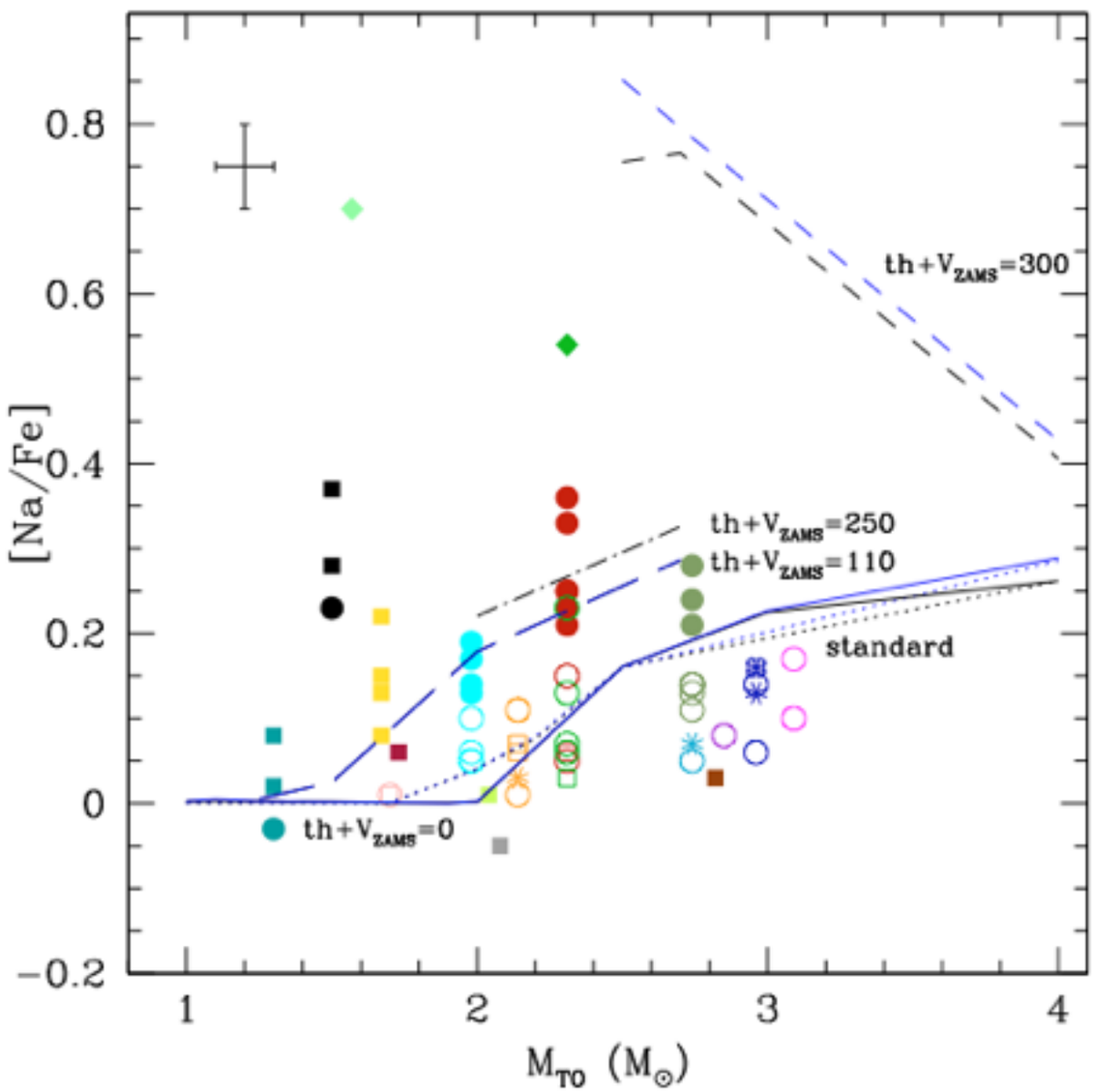


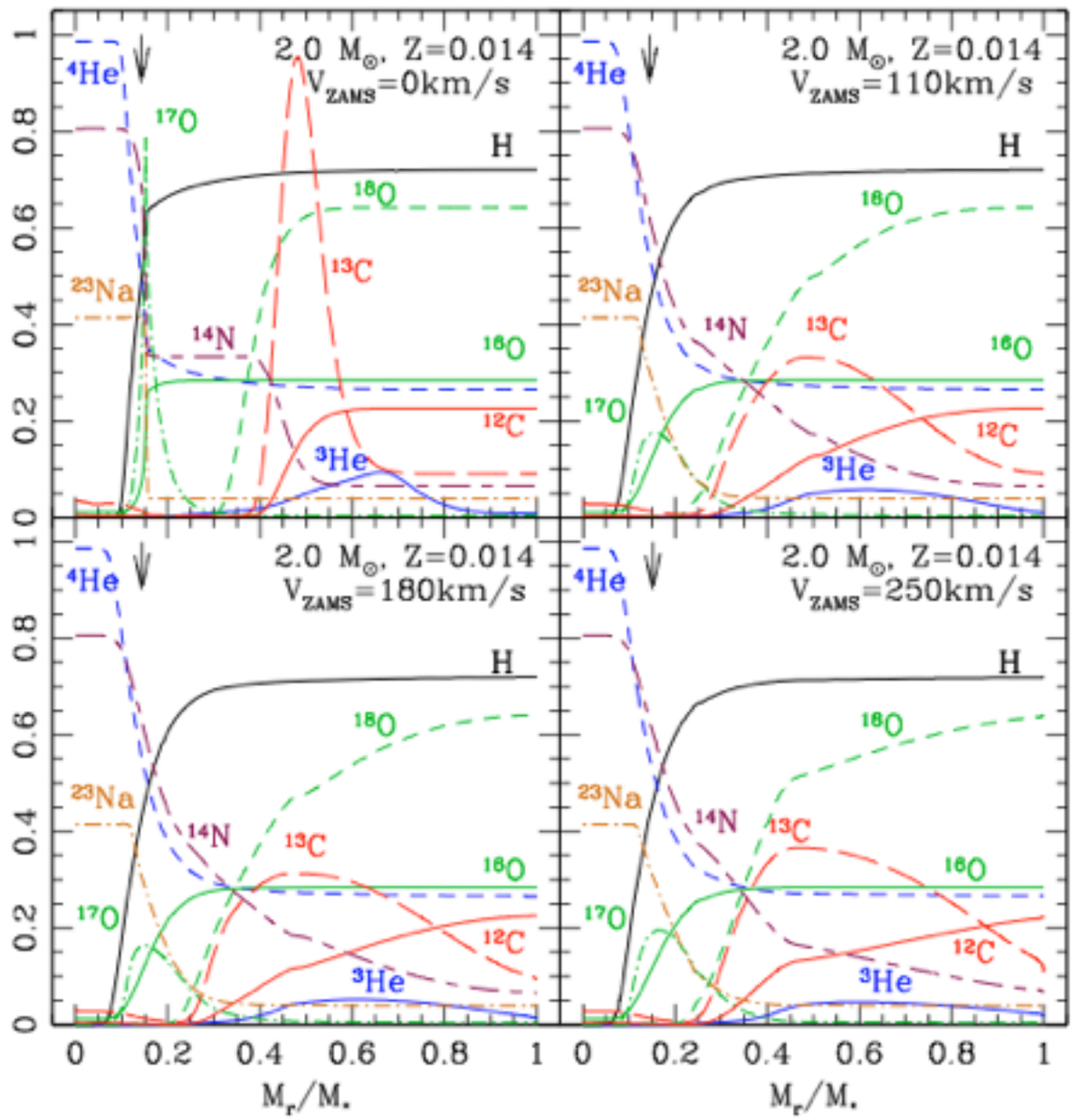
- NeNa is a cycle for $T_6 < 50$ K
- ^{27}Al accumulates for $T_6 > 70$ K

Arnould et al. (1999)

Na & Al
Stellar evolution

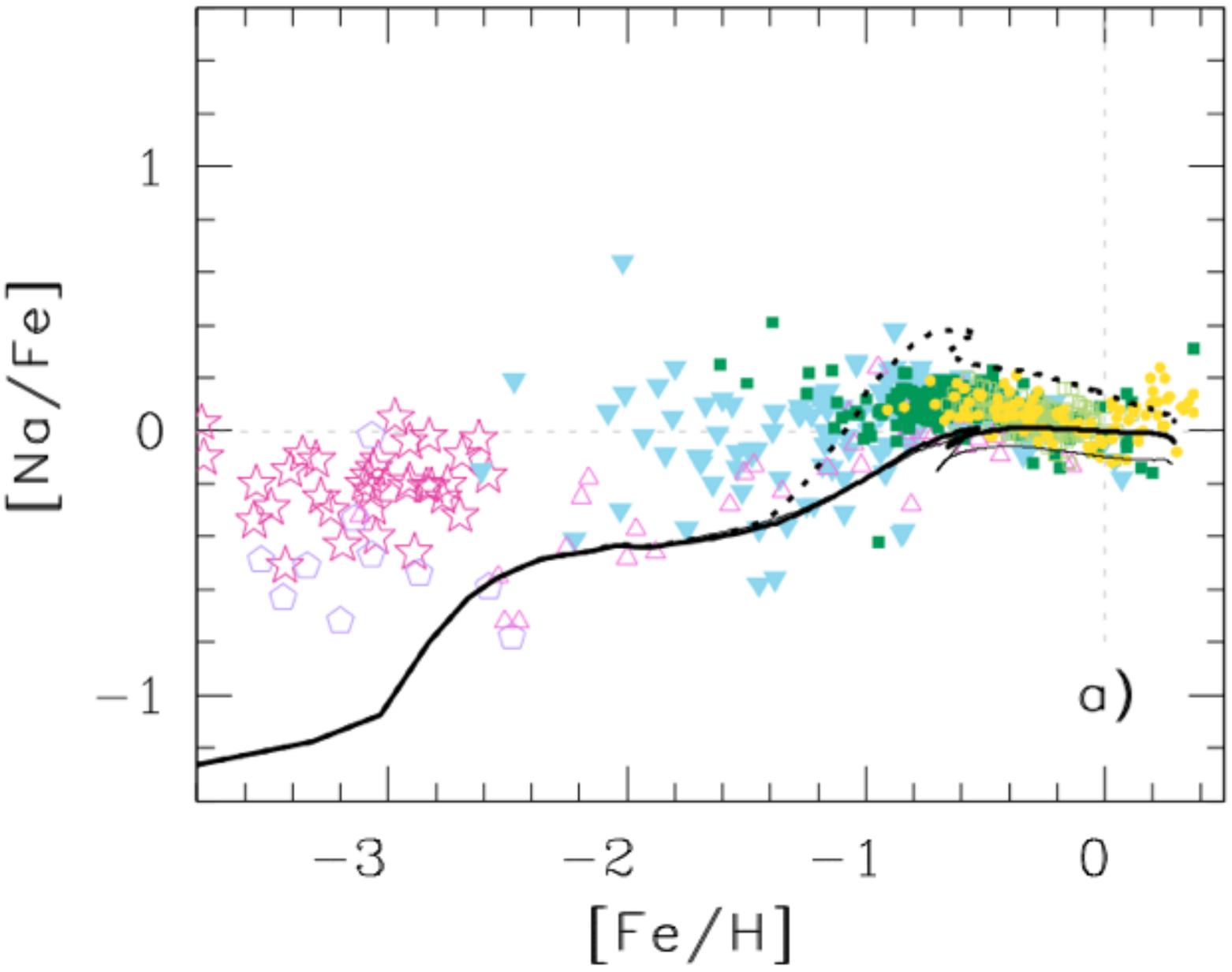
1.0-4.0 Msun giants - after the 1st dredge-up





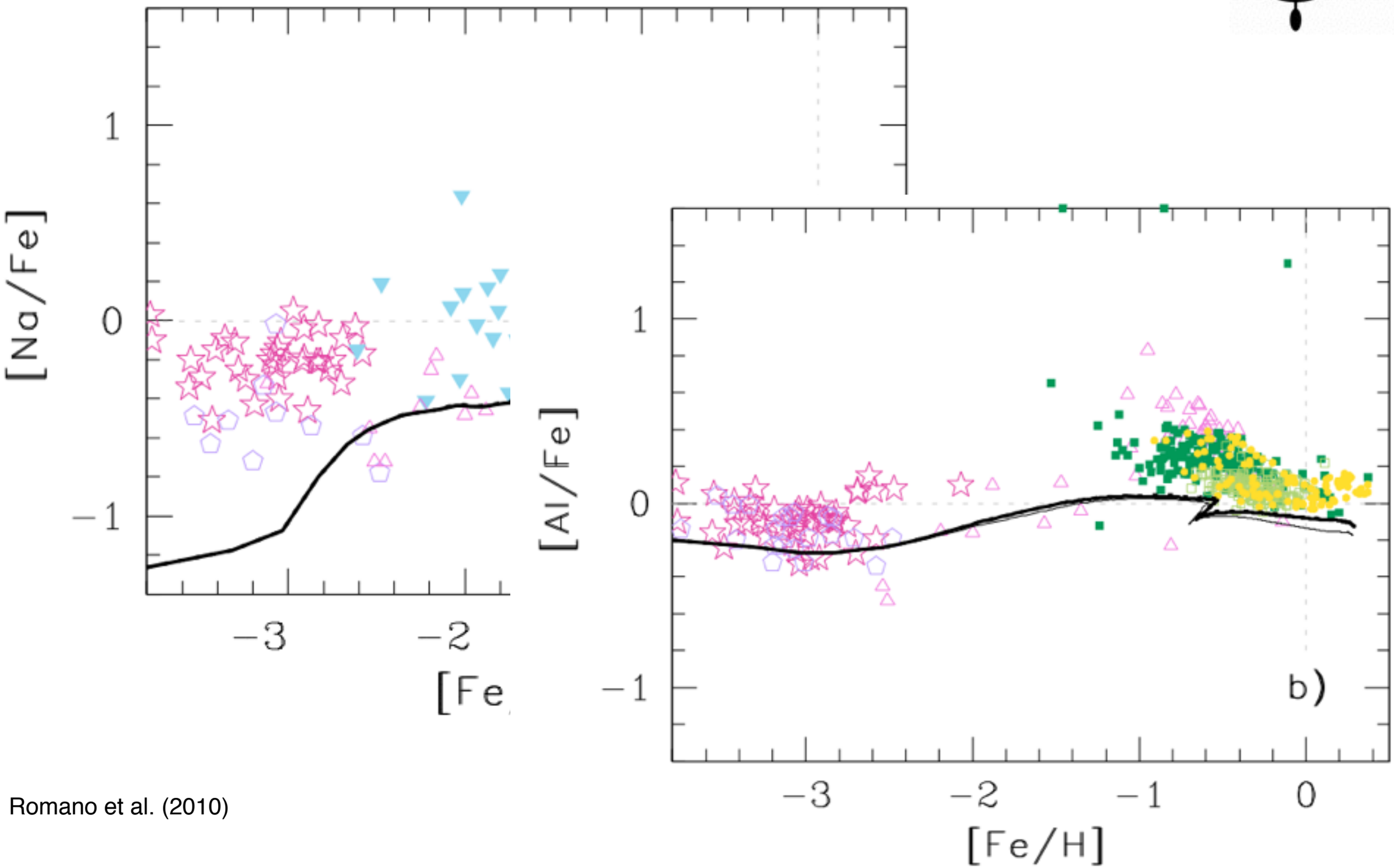
Charbonnel & Lagarde (2010)

Na & Al
Chemical evolution



Romano et al. (2010)

Na & Al
Chemical evolution



Romano et al. (2010)

This project

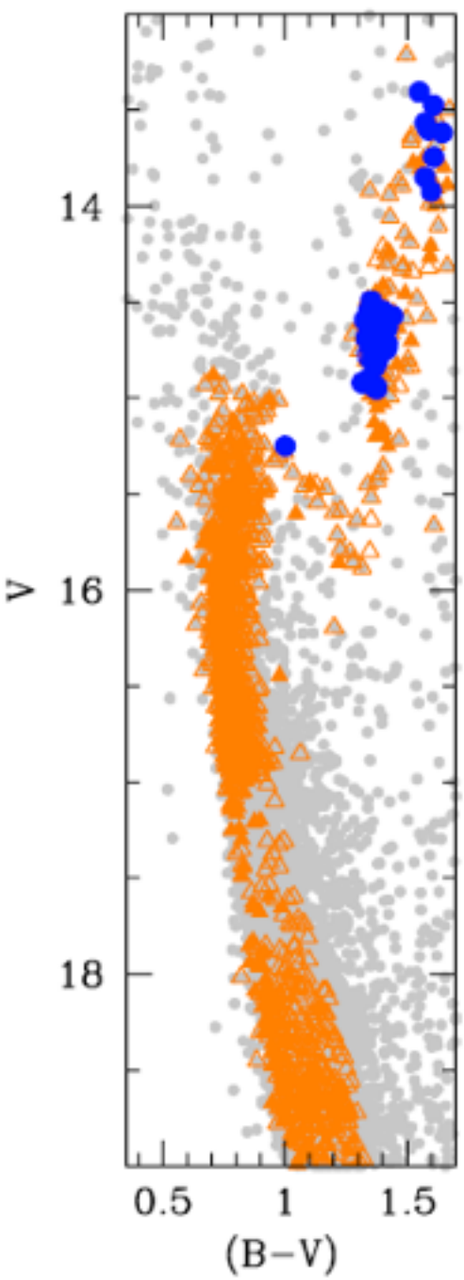
Readdress both issues using Gaia-ESO data

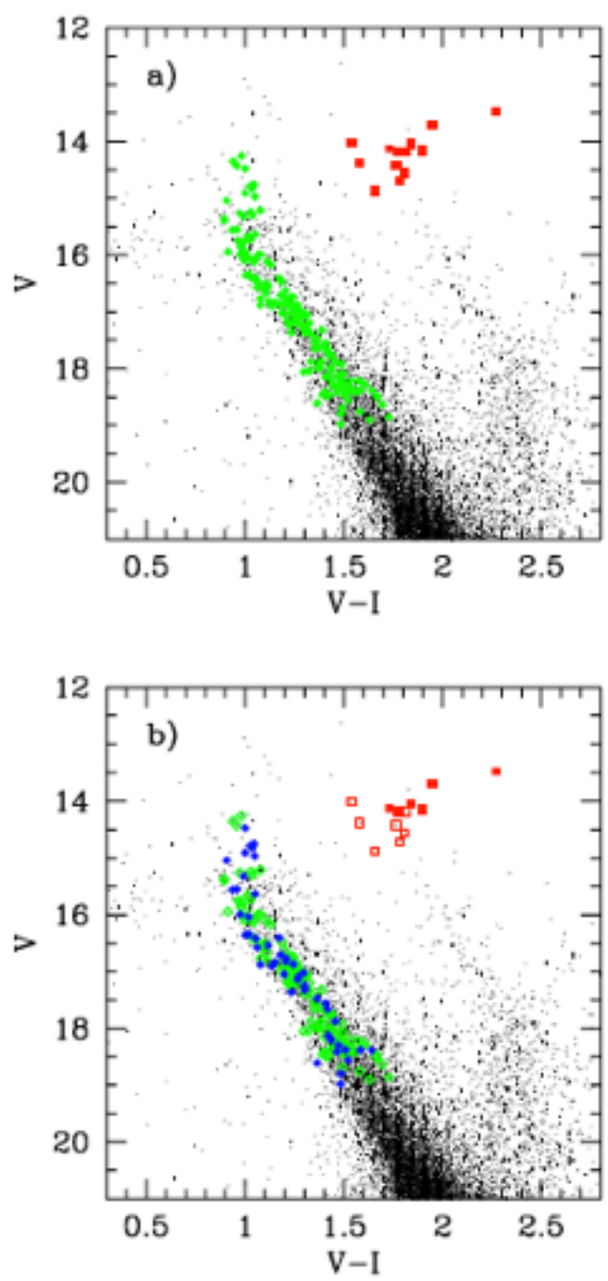
- Homogeneous Na and Al abundances for dwarfs and giants from UVES spectra
- Selected stars with high-quality abundances; Teff > 4000; no PMS; no GCs, no field giants
- ~650 dwarfs in the solar neighbourhood (~380 with ages)
- ~150 giants in 7 open clusters (stellar masses 1.1 to 3.2 Msun)

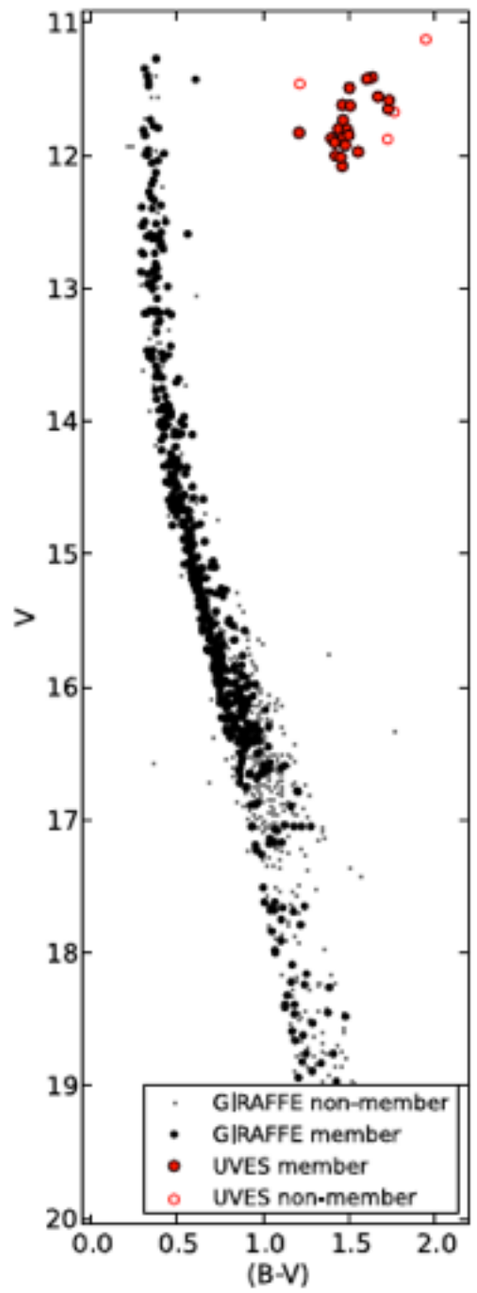
Compared to model predictions

- Chemical evolution models with updated yields
- Stellar evolution models with and without extra-mixing
- Improve the observational constraints on the behaviour of Na and Al

Gaia-ESO Open Clusters





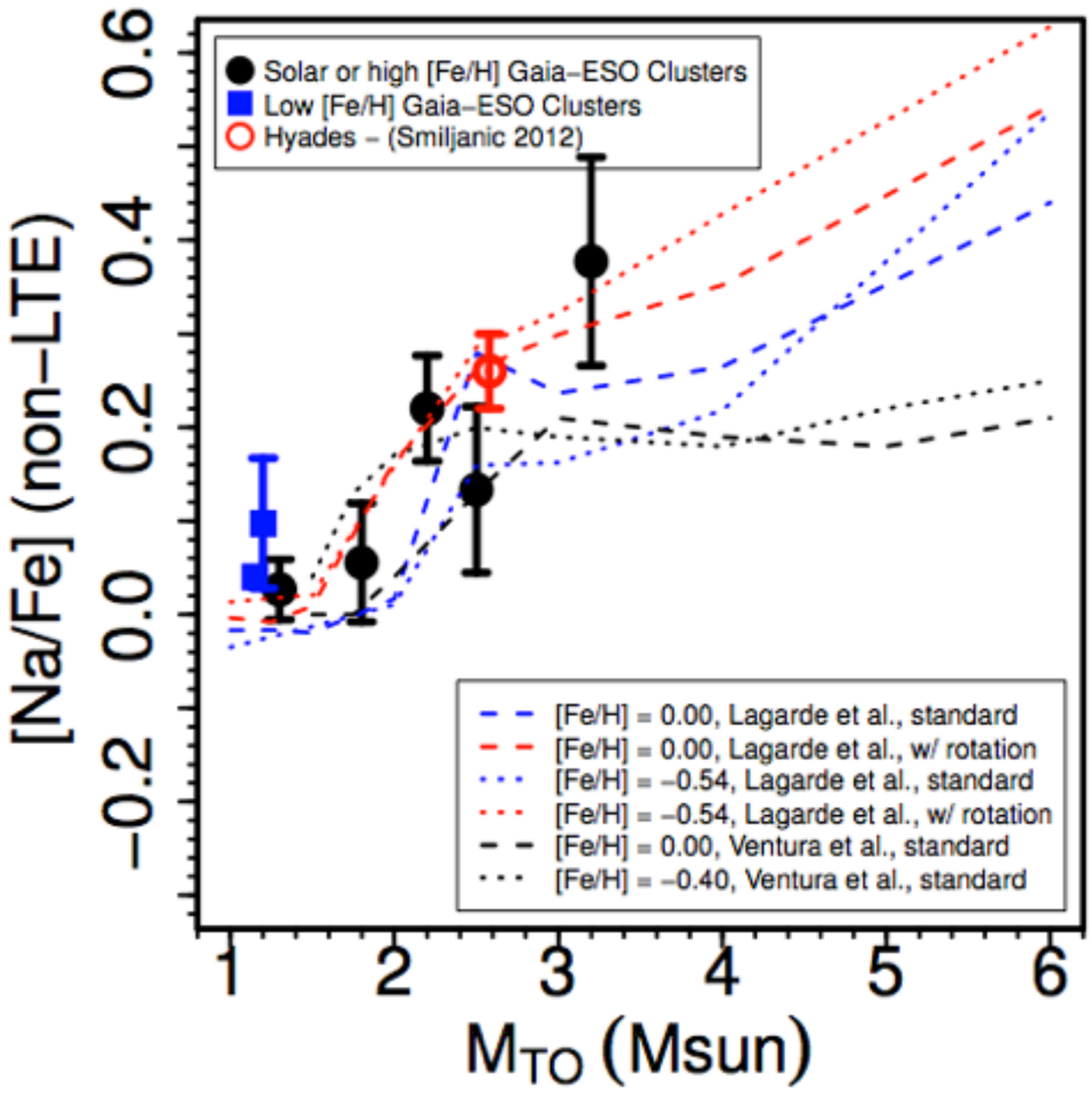


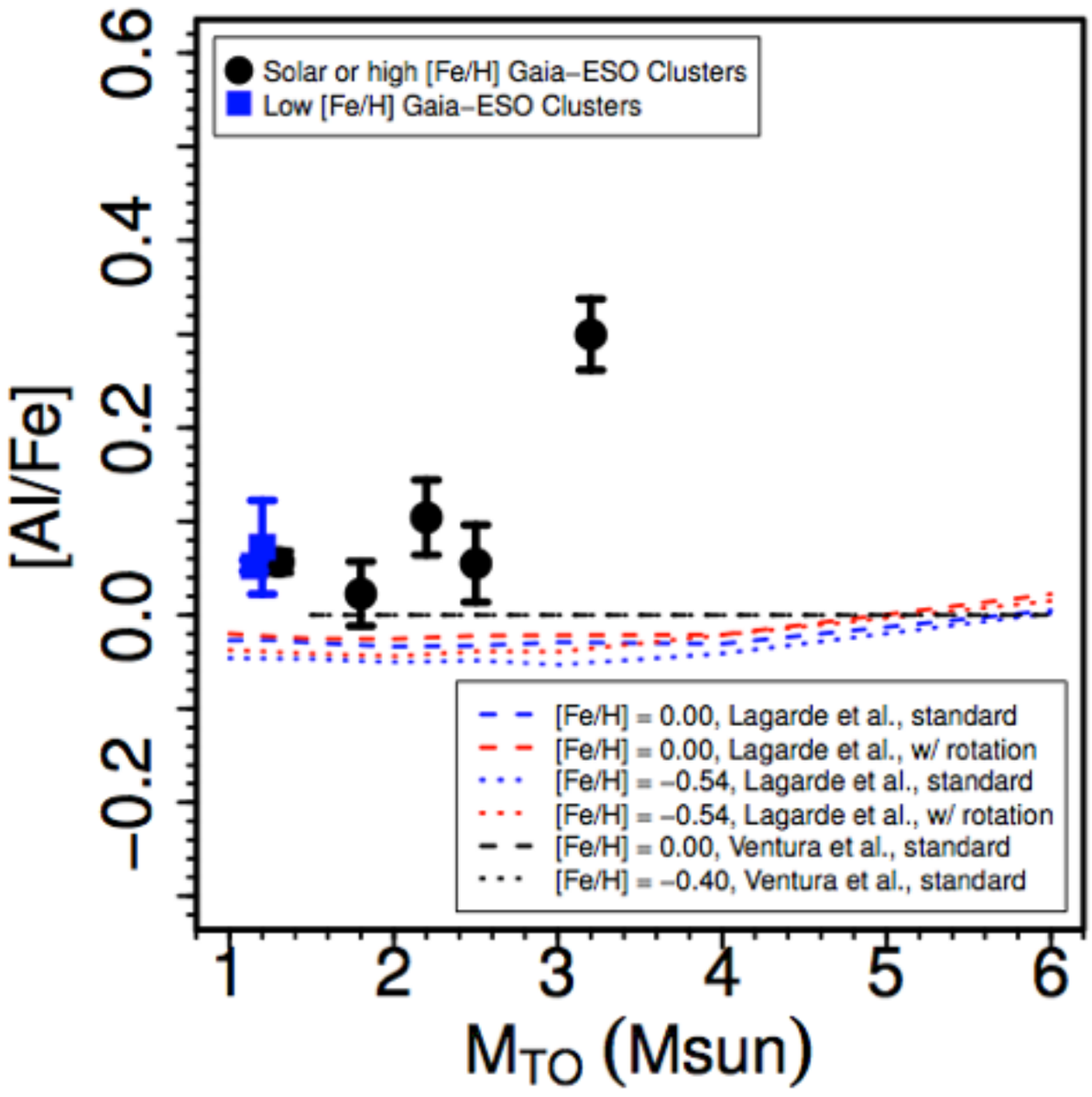
Gaia-ESO revised cluster parameters

Homogeneous age (stellar mass) and metallicity scales

Trumpler 20: Donati et al. (2014)
NGC 4815: Friel et al. (2014)
NGC 6705: Cantat Gaudin et al. (2014)

[Na-Al/Fe] vs. stellar mass

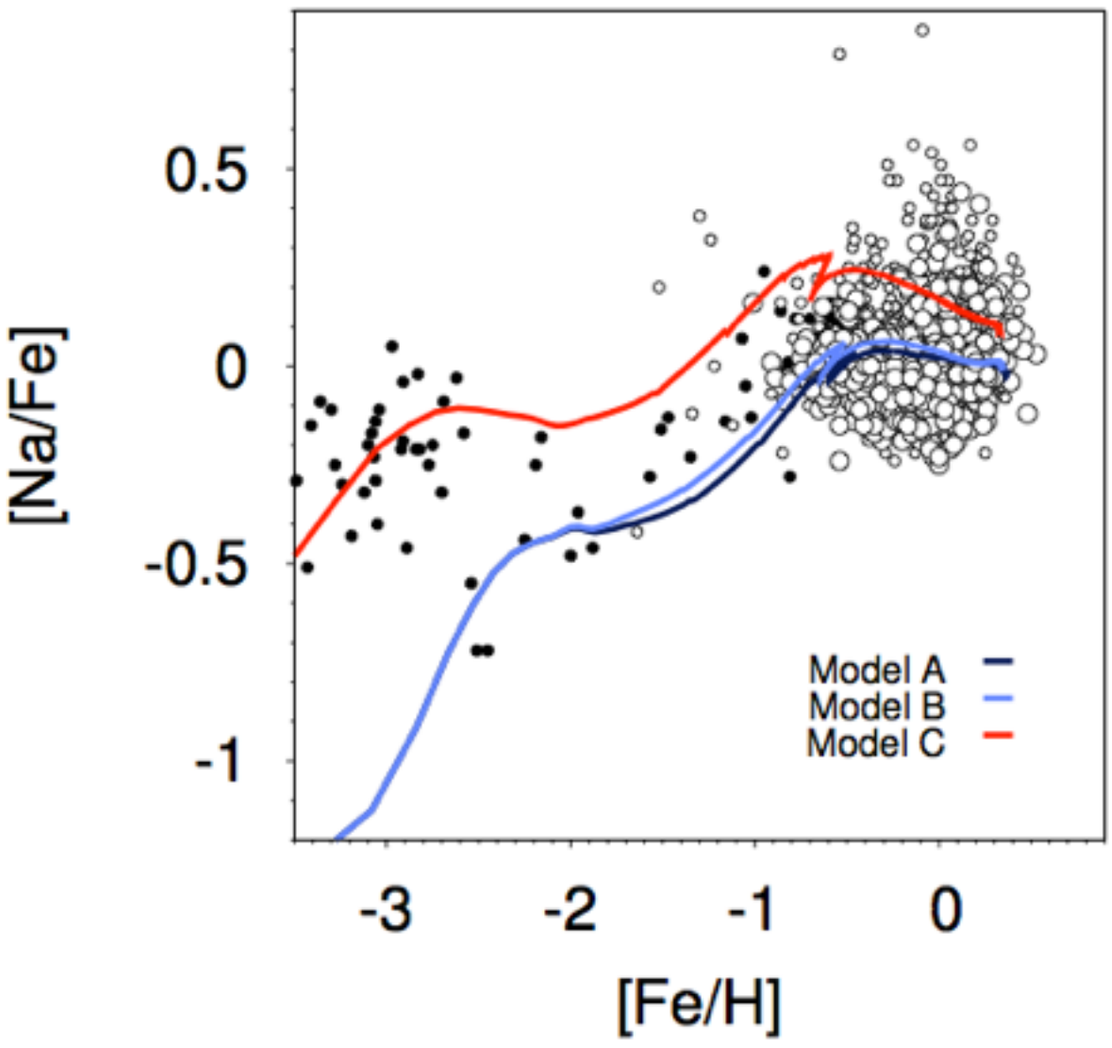


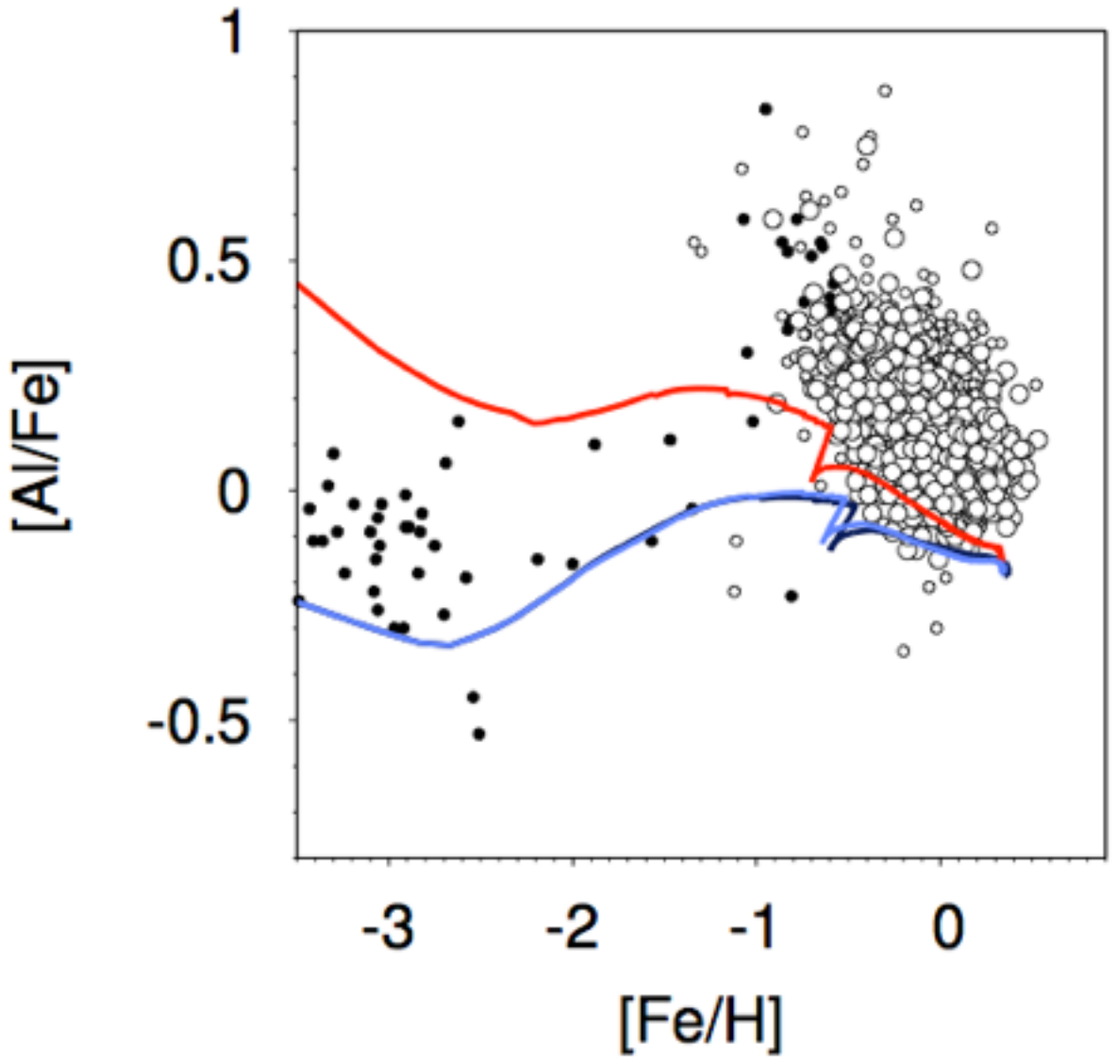


Models: Lagarde et al. (2012) & Ventura et al. (2013)

[Na-Al/Fe] trends with [Fe/H]

Gaia-ESO solar neighbourhood ([Fe/H] > -1.0) + selected halo data



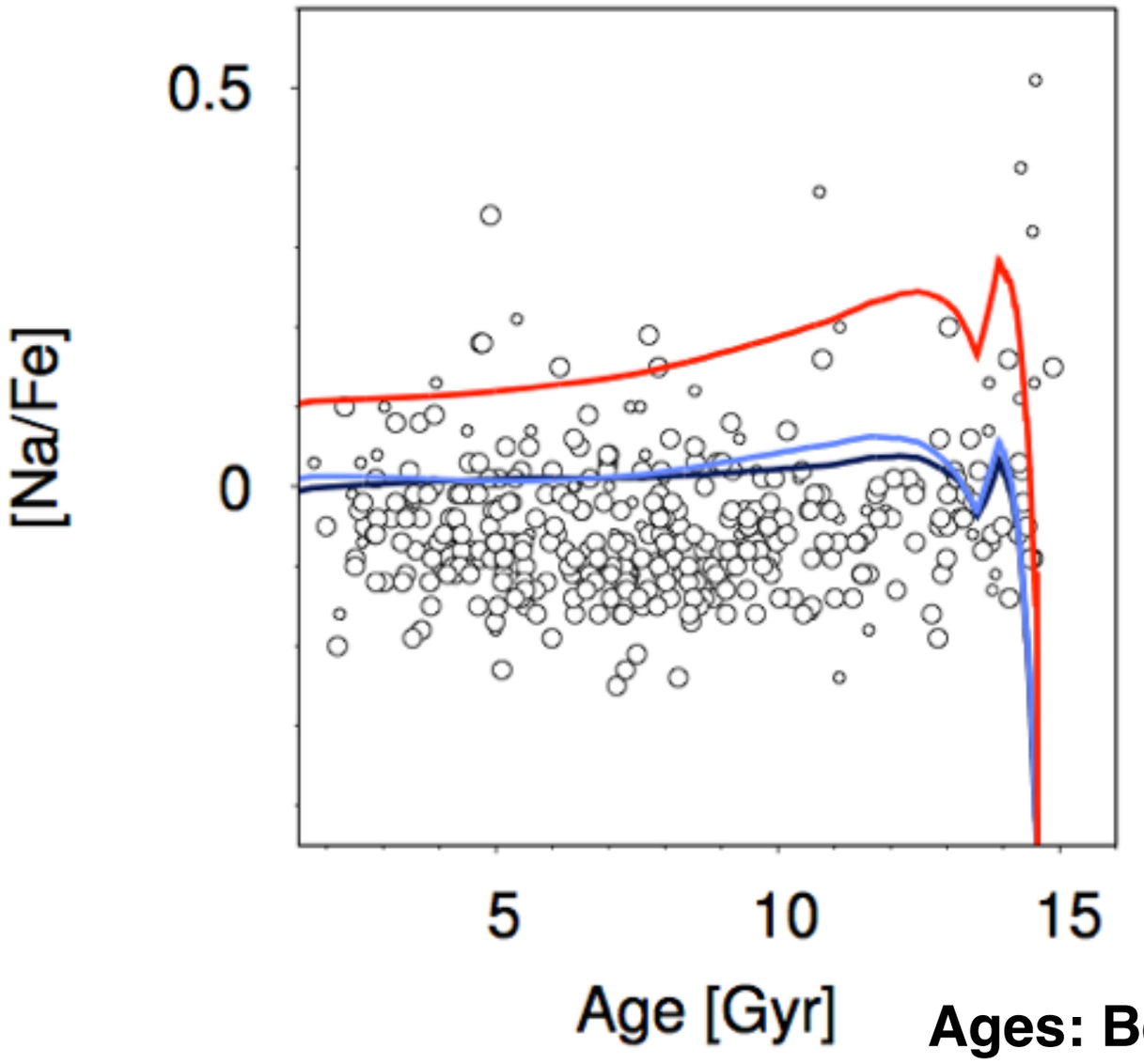


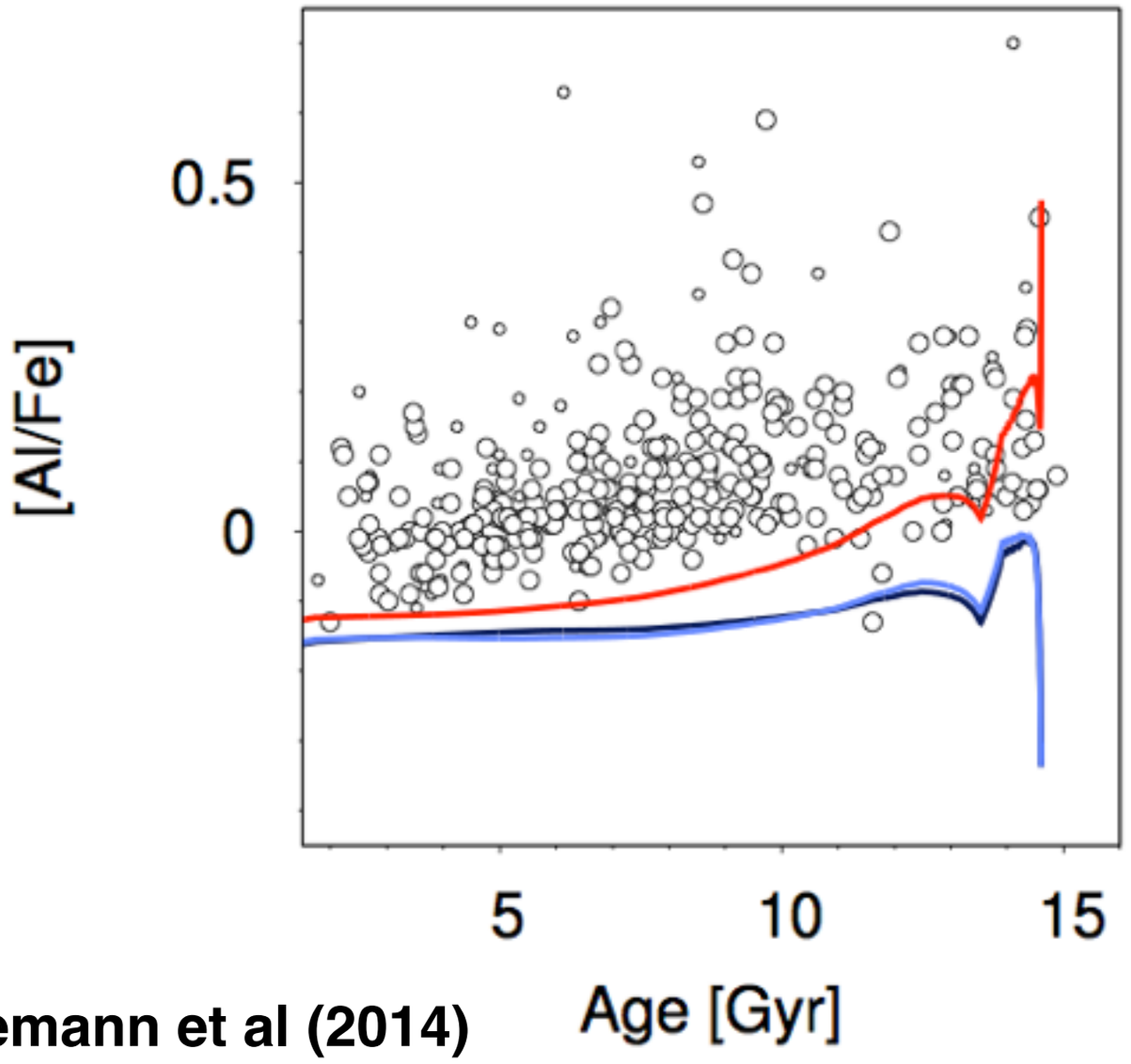
Model A: Karakas (2010) + Kobayashi et al. (2006) stars >20 Msun as HNe

Model B: Ventura et al. (2013) + Kobayashi et al. (2006) stars >20 Msun as HNe

Model C: Ventura et al. (2013) + Kobayashi et al. (2006) all stars as SNII

[Na-Al/Fe] trends with Age





Ages: Bergemann et al (2014)

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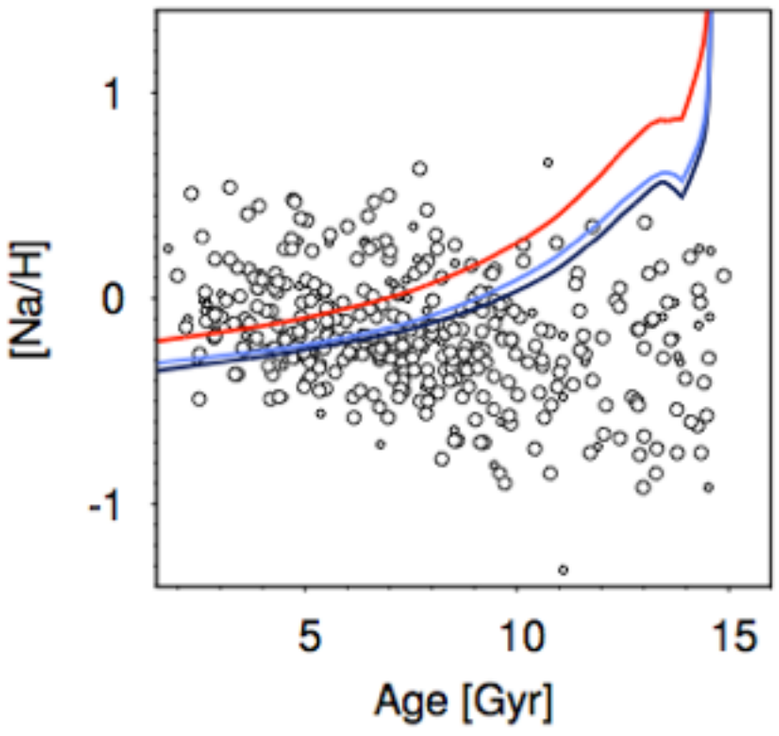
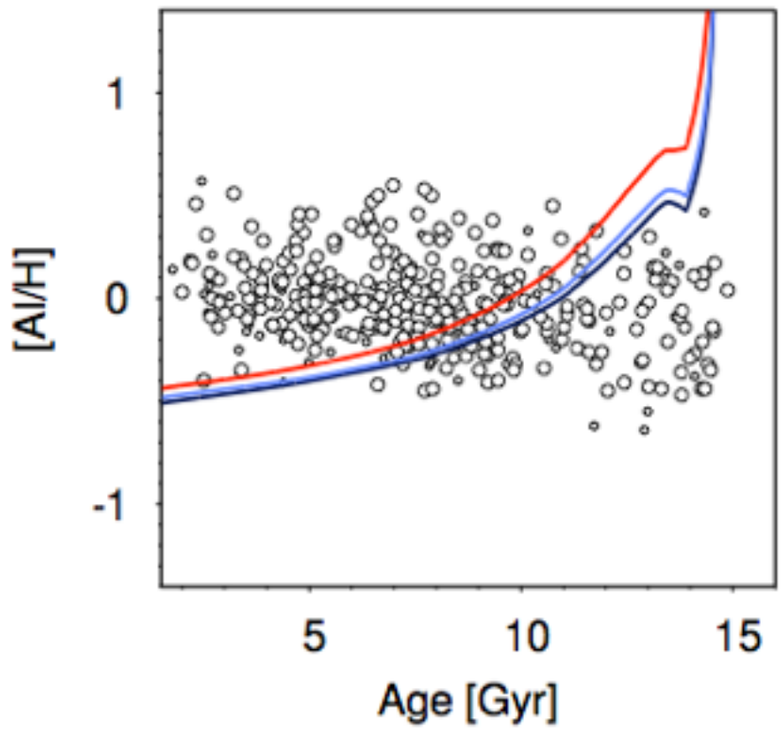
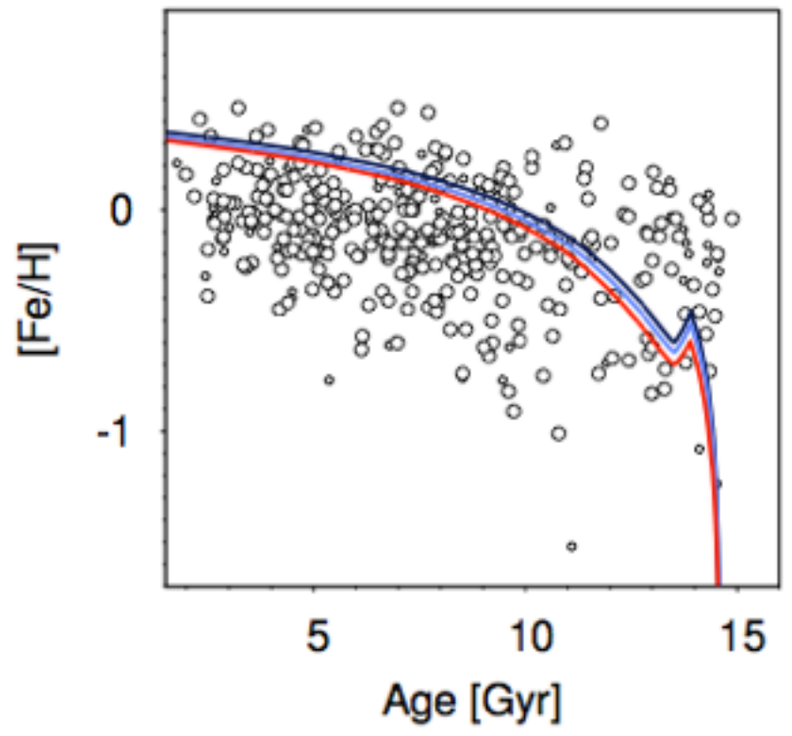


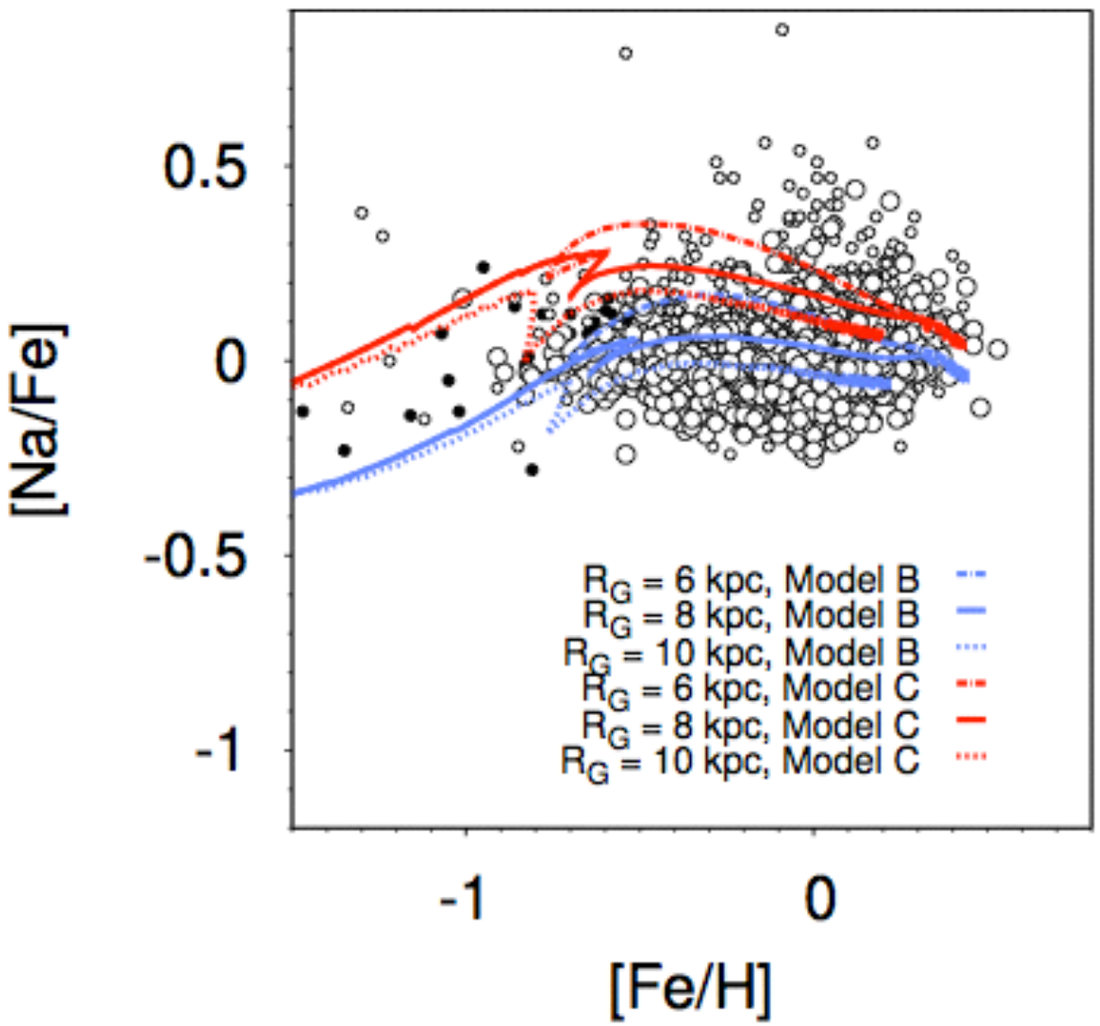


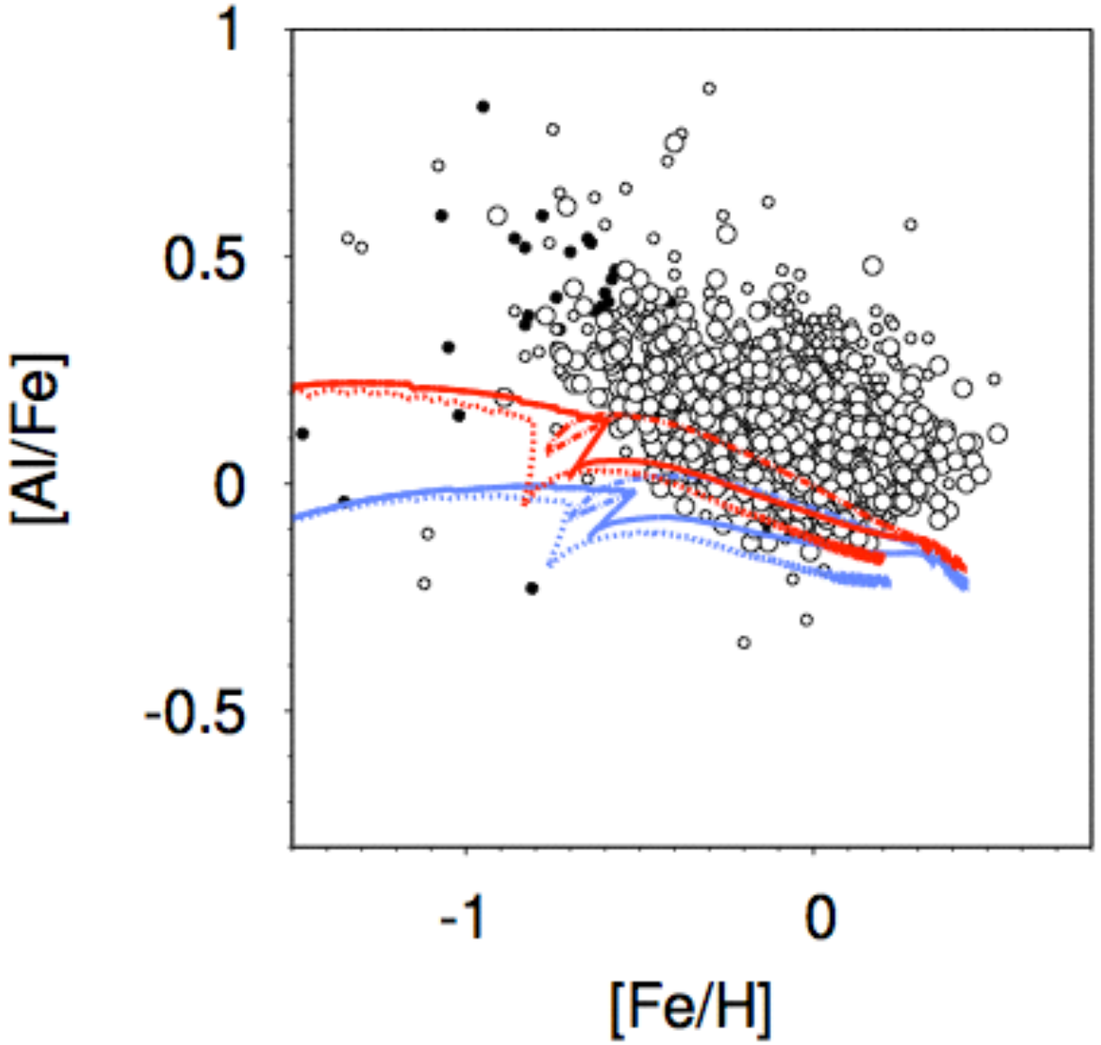


Ages: Bergemann et al (2014)

- Fe slightly overproduced, but:
- Na and Al overproduced at early stages in the disk
- Na and Al underproduced at young ages in the disk
- Yields uncertain or missing production site? Explosive H-burning? Novae as for Lithium? (Izzo et al. 2015)

[Na-Al/Fe] trends with Rgc





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Summary

- This is a pilot study:

  1. Spectrum analysis being improved (better abundances)

  2. Sample will increase (~60-80 OCs; ~4000 solar neighbourhood dwarfs)

  3. Non-LTE for Al needed

  4. Improved yields for massive stars (+stellar rotation) to become available

  5. Incorporate other elements in the discussion (e.g. Mg and Li)

- Chemical evolution: Models still have difficulties. Clues that we are maybe missing a late production site of Na and Al?

- Stellar evolution: [Na/Fe] vs. stellar mass agrees with stellar evolution models, [Al/Fe] vs. stellar mass, to be decided

References

- Arnould et al. 1999 (A&A, 347, 572)
- Bensby et al. 2014 (A&A, 562, A71)
- Bergemann et al. 2014 (A&A, 565, A89)
- 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)
- Izzo et al. 2015 (ApJ, 808, L14)
- Karakas 2010 (MNRAS, 403, 1413)
- Kobayashi et al. 2006 (ApJ, 653, 1145)
- Lagarde et al. 2012 (A&A, 543, A108)
- Lagarde et al. 2015 (A&A, 580, A141)
- Morel et al. 2014 (A&A, 564, A119)
- MacLean et al. 2015 (MNRAS, 446, 3556)
- Romano et al. 2010 (A&A, 522, A32)
- Smiljanic et al. 2014 (A&A, 570, A122)
- Ventura et al. 2013 (MNRAS, 431, 3642)

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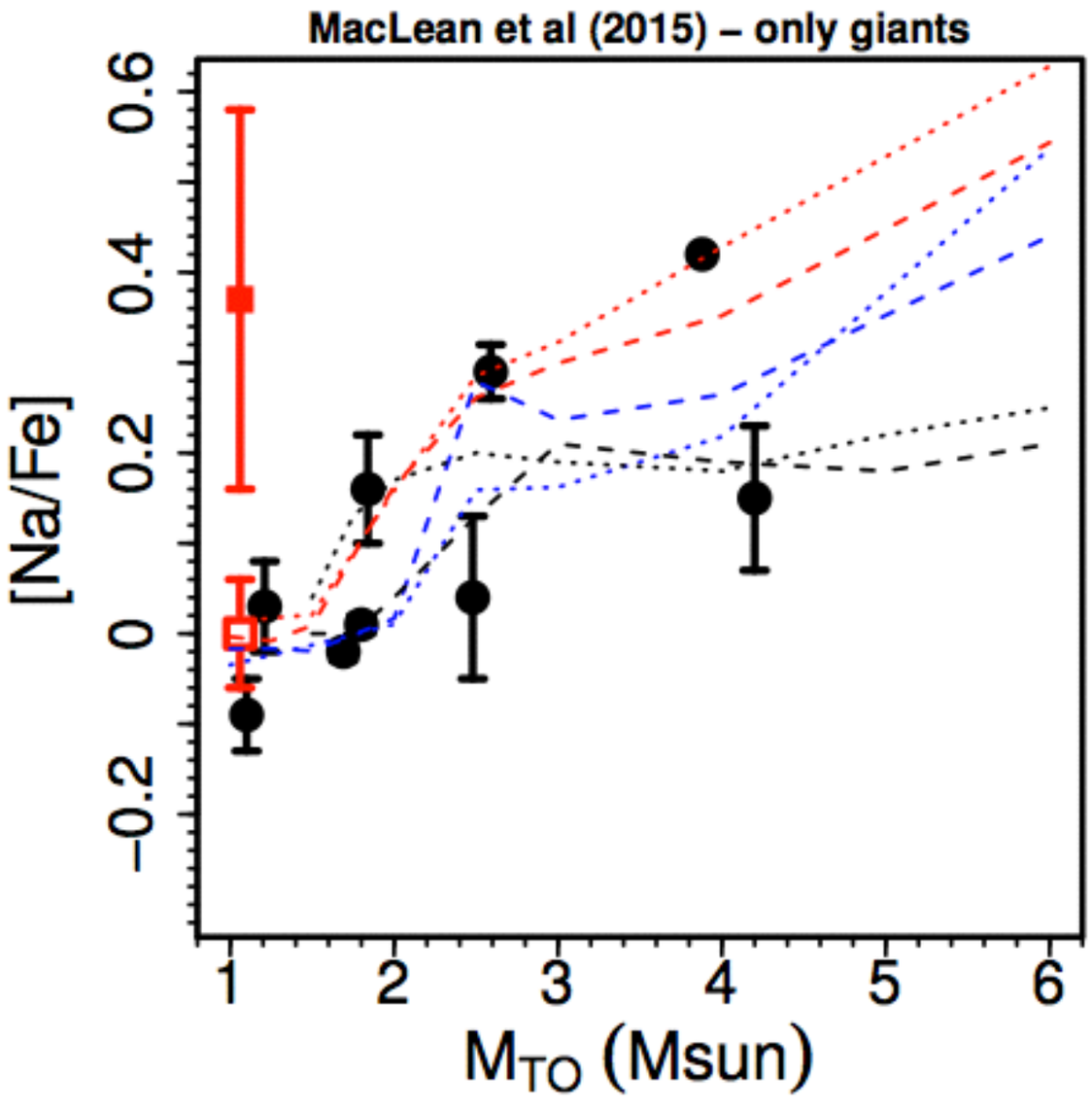
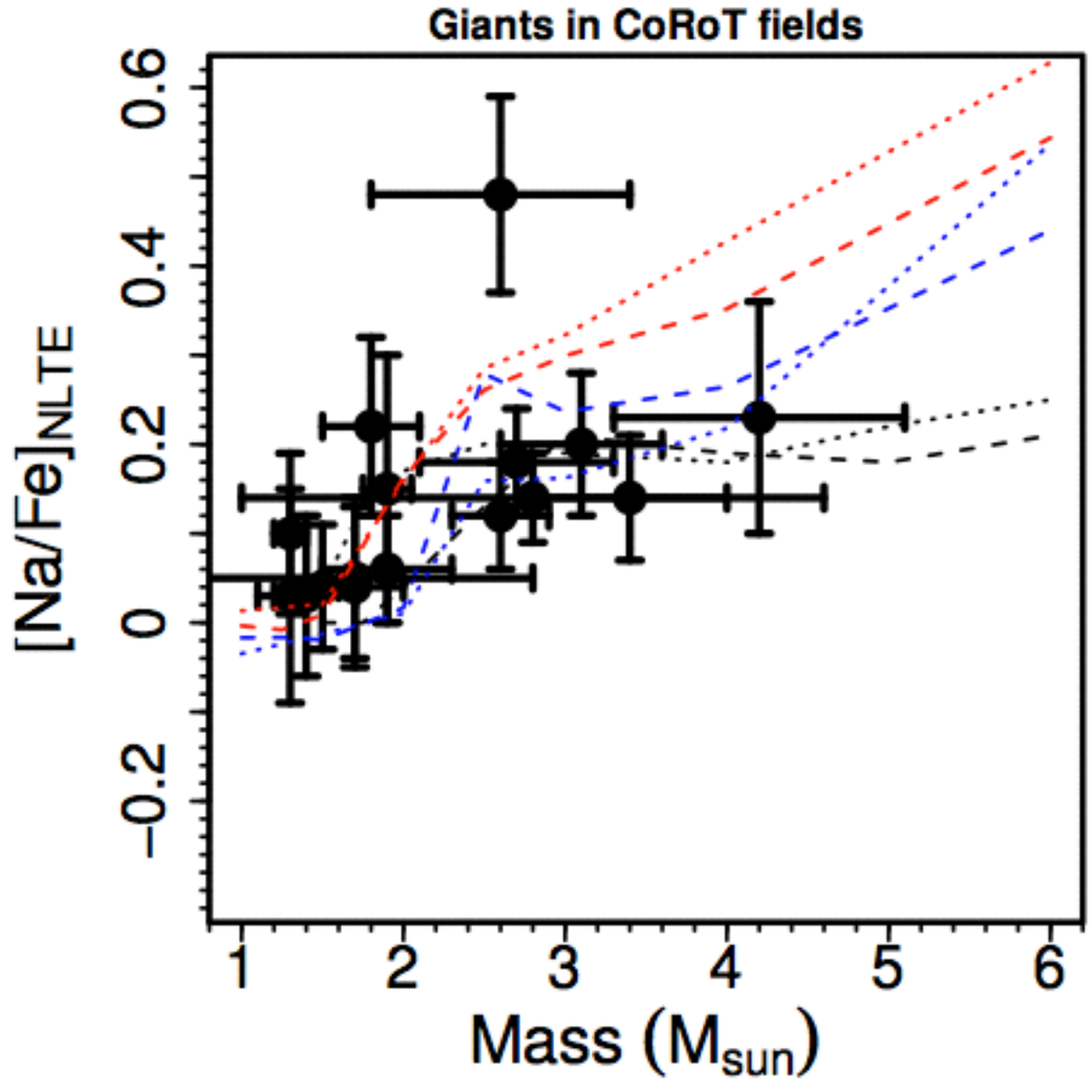
[Na-Al/Fe] vs. stellar mass (well selected literature)





CoRoT giants: Na from Morel et al. (2014) and masses from Lagarde et al. (2015)