Stellar Nucleosynthesis and Galactic Chemical Evolution in the Era of Large Spectroscopic Surveys

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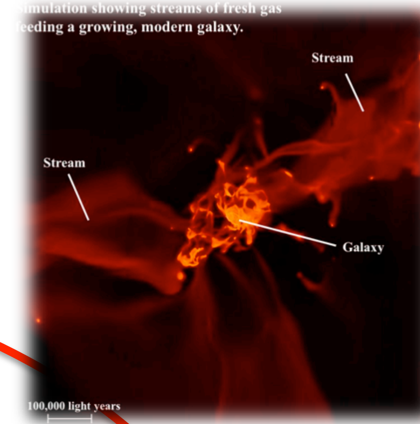
CHEMICAL EVOLUTION MODELS

(Tinsley 1980; Pagel 1997; Matteucci 2001)



GAS INFALL/ACCRETION

STAR FORMATION

OUTFLOWS

RECYCLING

STELLAR FEEDBACK (MASS, ENERGY)

CHEMICAL EVOLUTION MODELS

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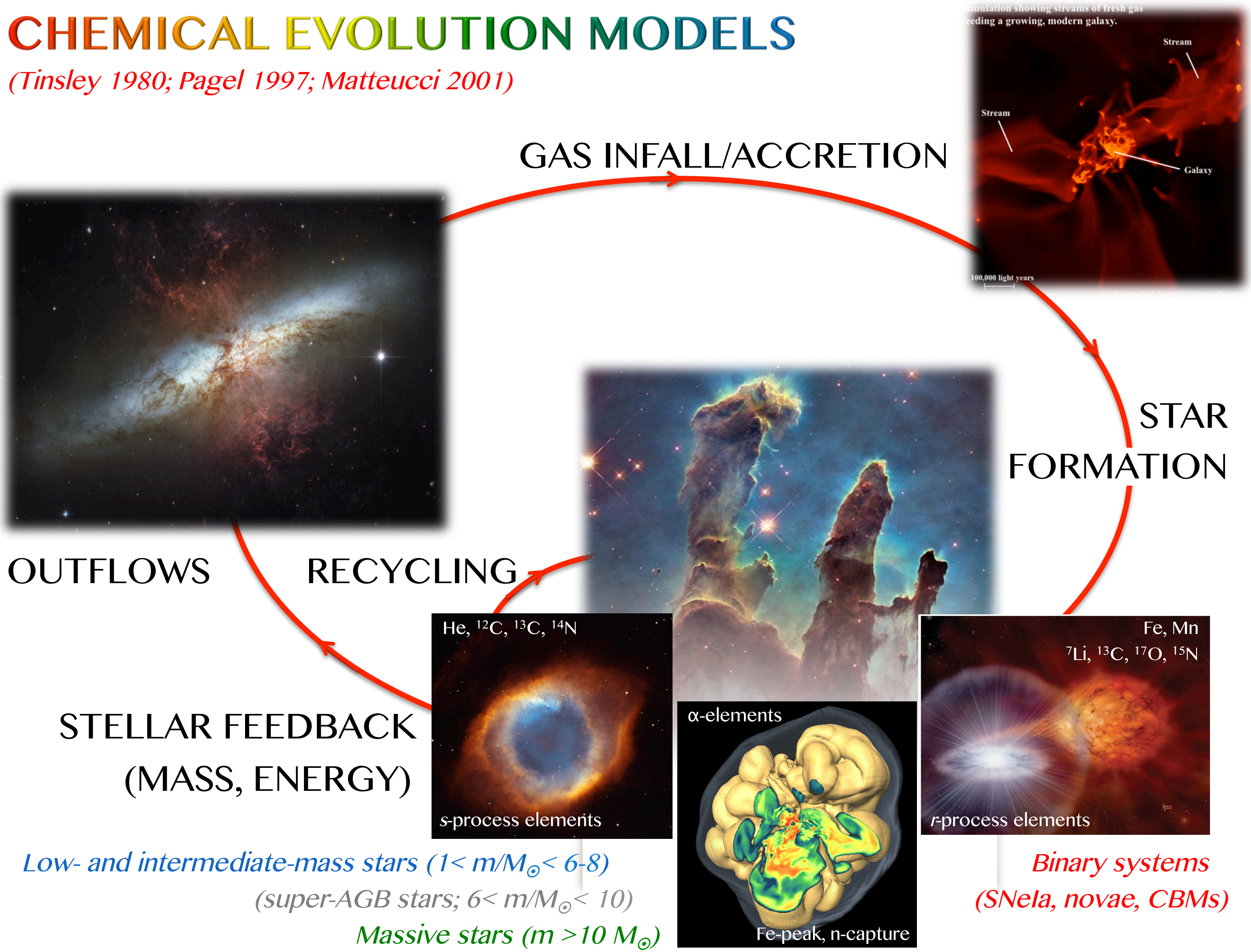
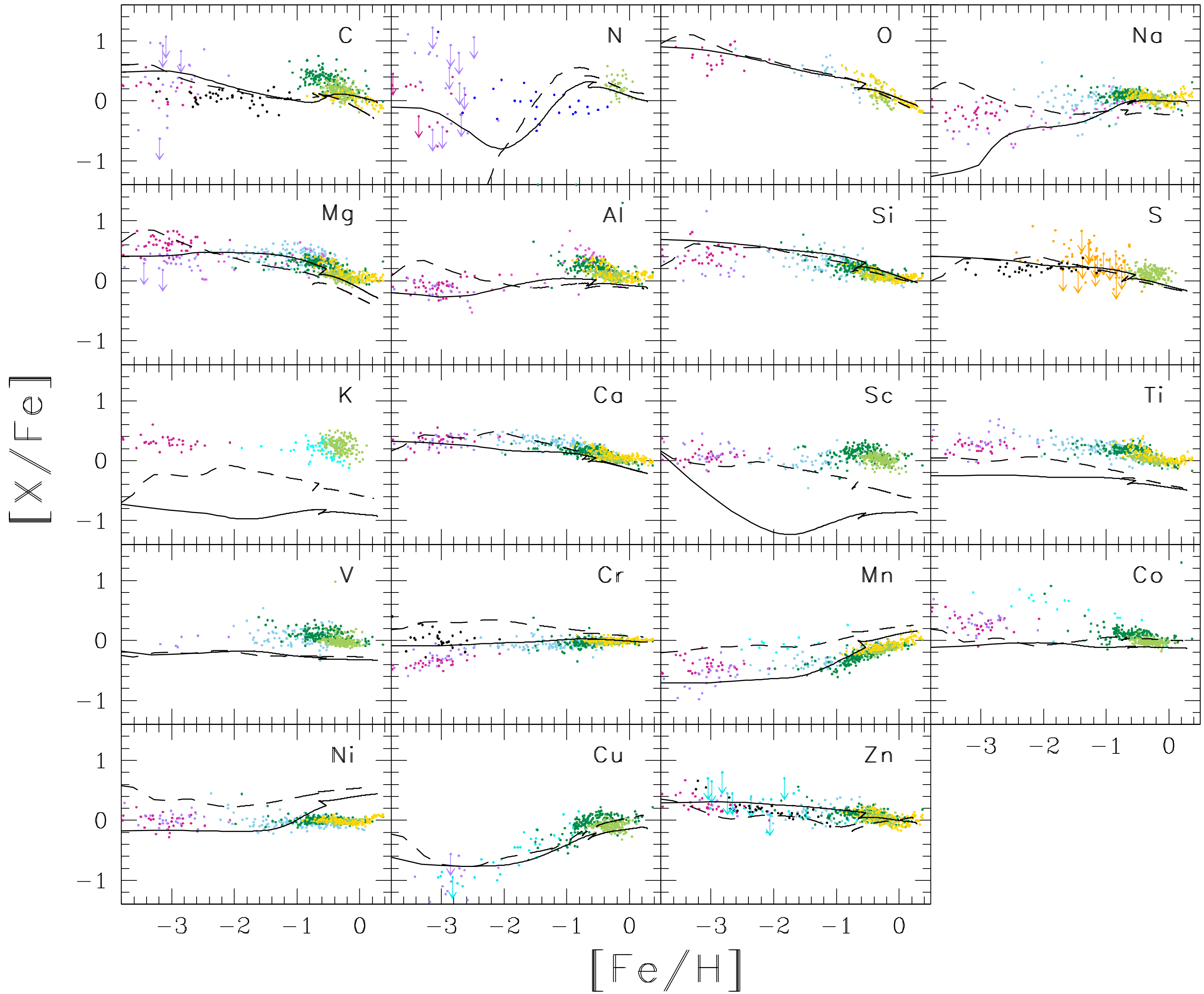
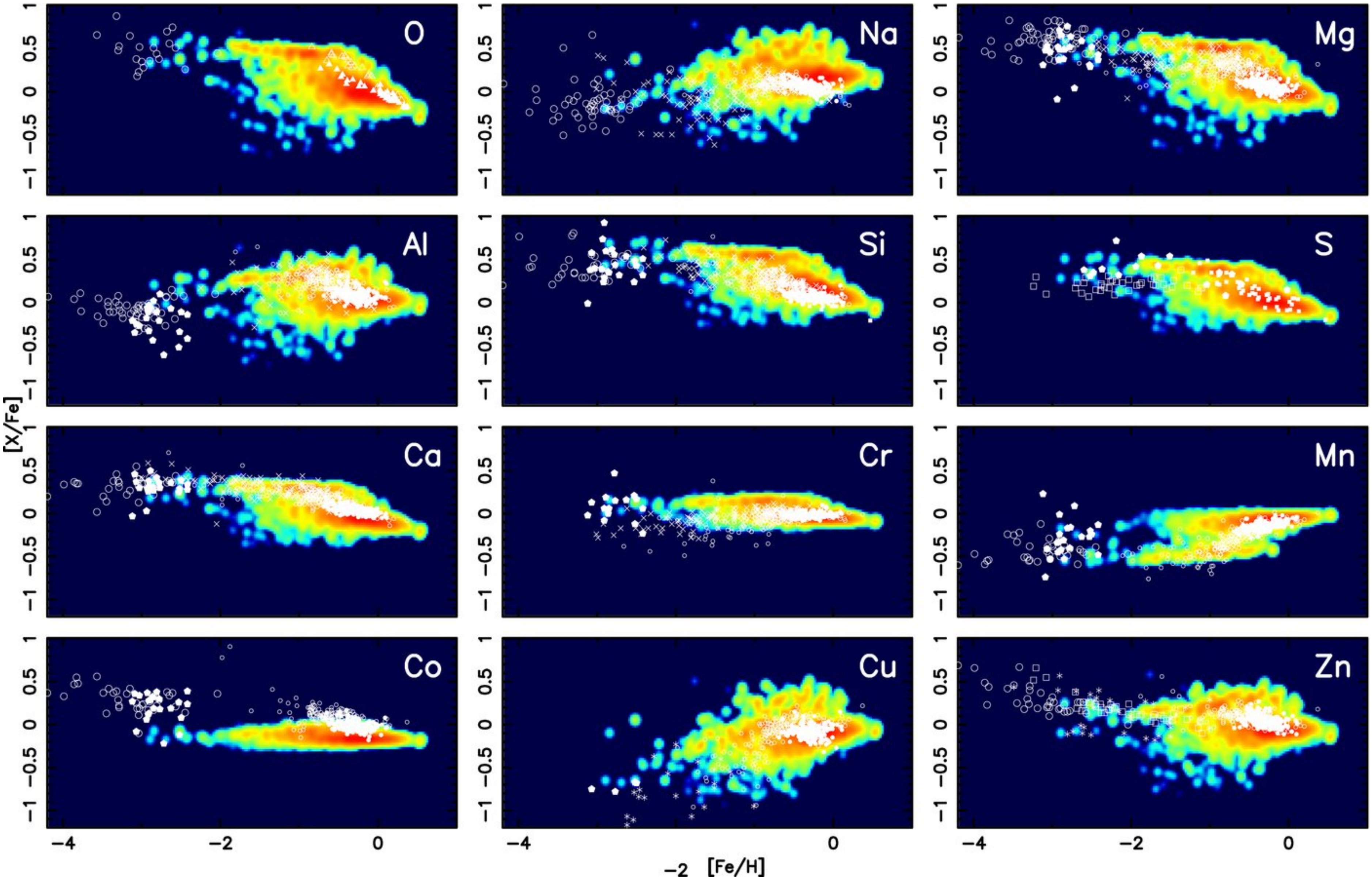




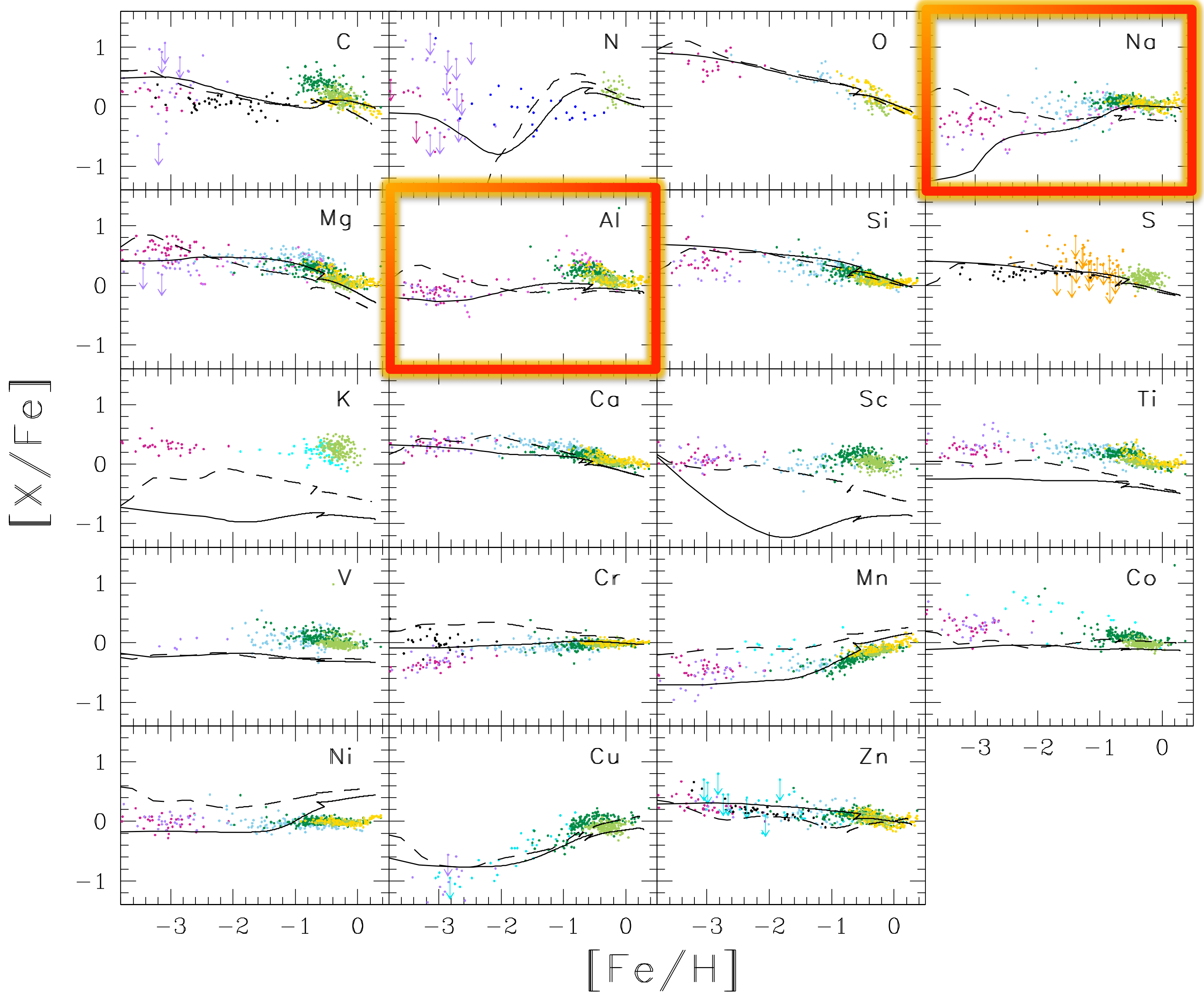
Solar neighbourhood data and models

Romano, Karakas, Tosi & Matteucci (2010 [A&A, 522, A32])



Solar neighbourhood data and models

Kobayashi & Nakasato (2011 [ApJ, 729, 16])



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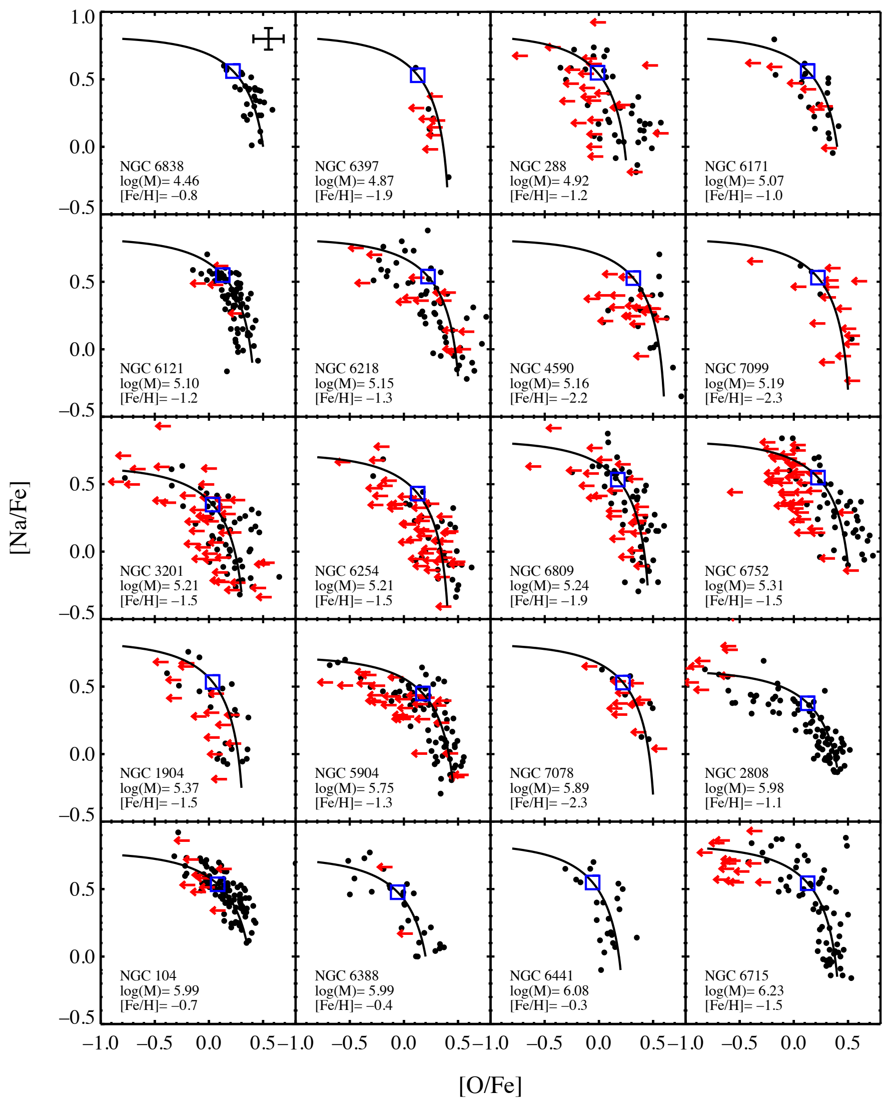
ANTI-CORRELATIONS IN GLOBULAR CLUSTERS



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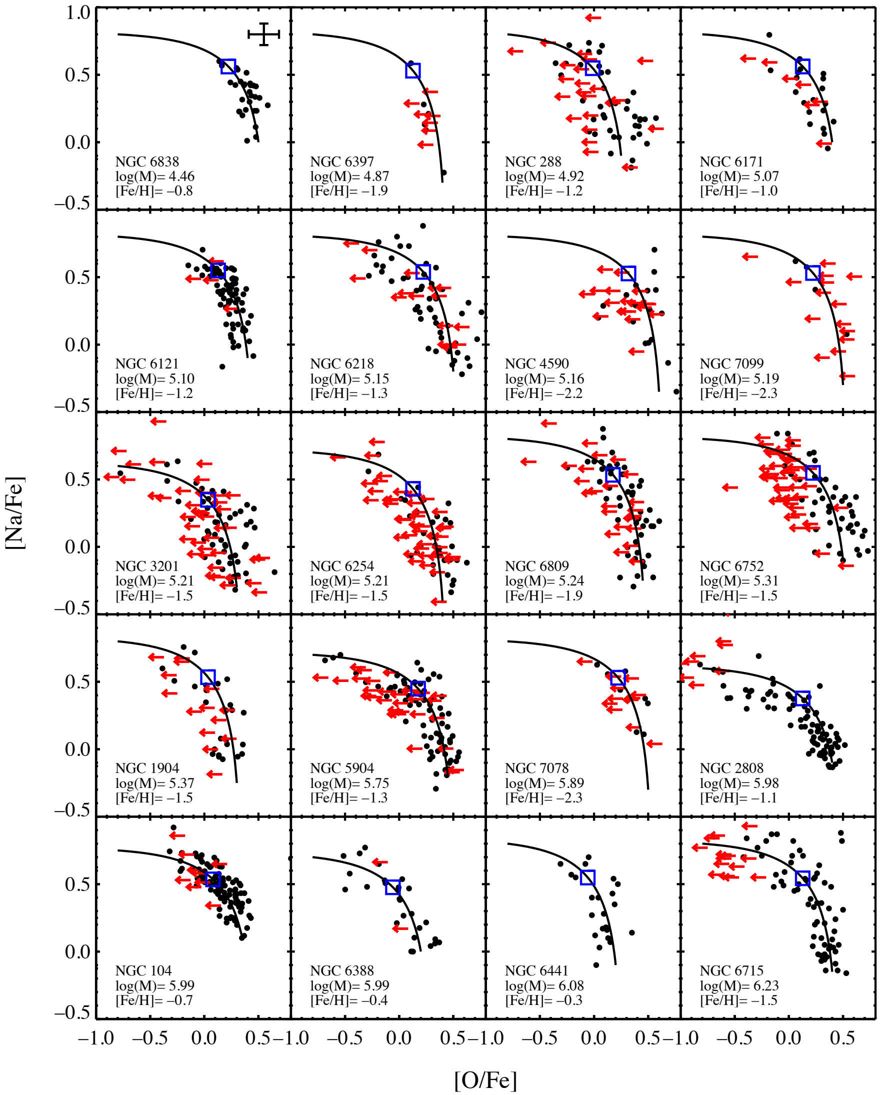
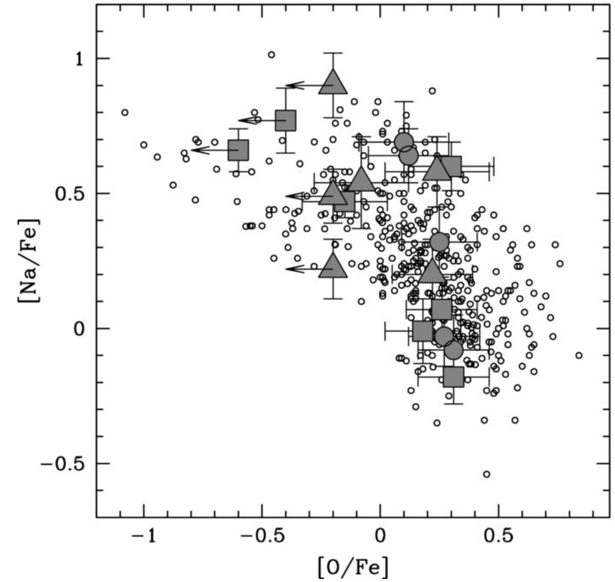
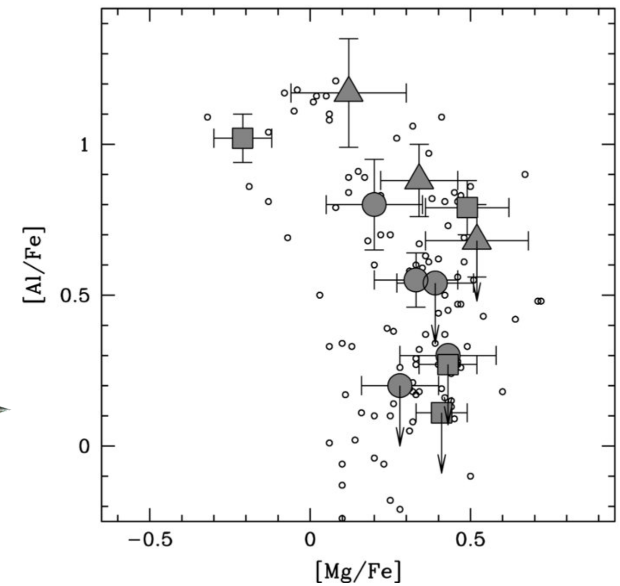


MW

Ubiquitous in old GCs!

LMC





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Mucciarelli et al. (2009 [ApJ, 695, L134])

SODIUM AND ALUMINIUM SYNTHESIS IN STARS

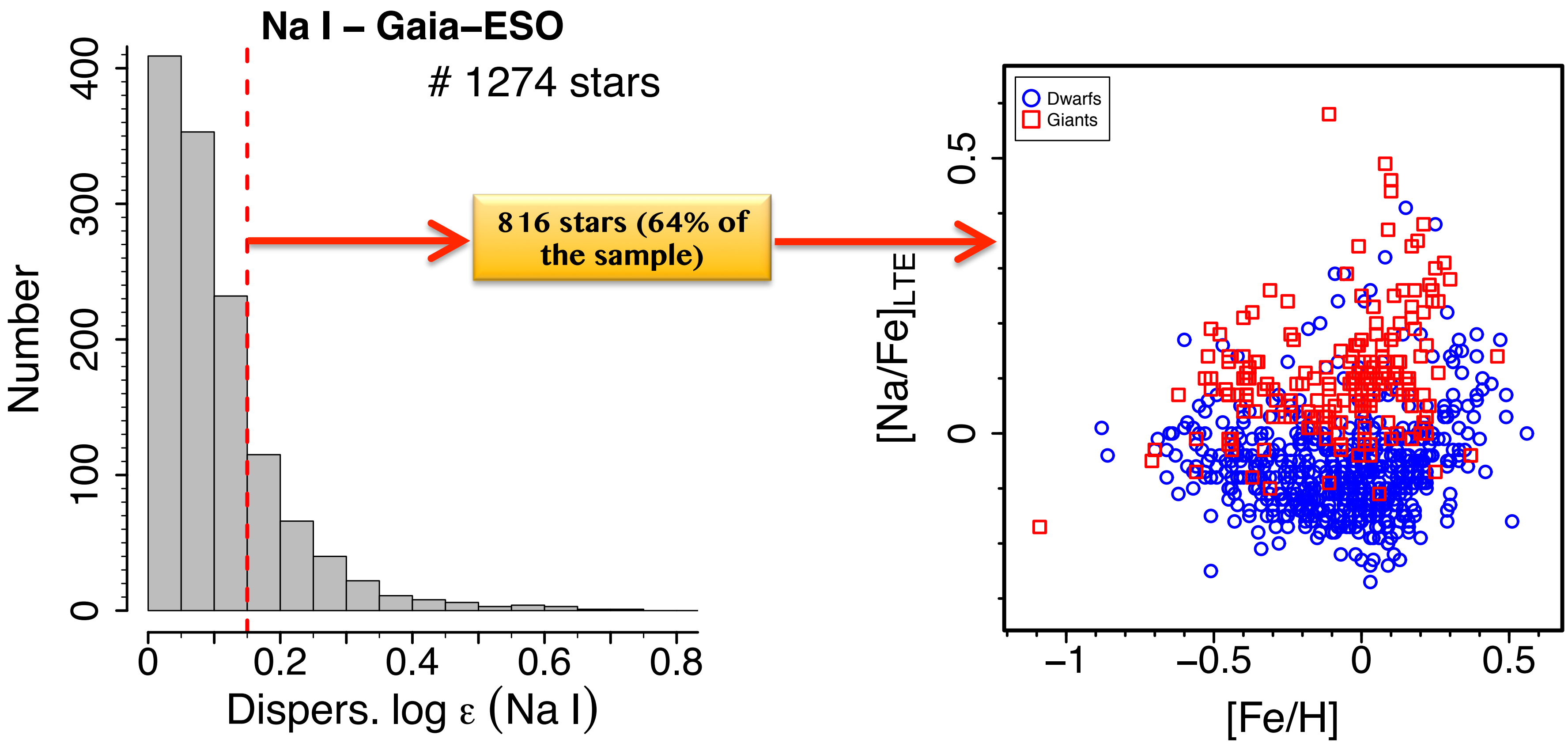
- Odd-Z element with single stable isotope (^{23}Na).
- On a Galactic scale, mainly synthesized during hydrostatic carbon burning in massive stars (Salpeter 1952 [ApJ, 115, 326]; Cameron 1959 [ApJ, 130, 429]). Final abundance sensitive to the neutron excess (Woosley & Weaver 1995 [ApJS, 101, 181]).
- Also produced in high-temperature H-burning regions through the NeNa cycle (Salpeter 1955 [Phys. Rev., 97, 1237]; Denisenkov & Denisenkova 1990 [Sov. Astr. Letters, 16, 275]). In low- and intermediate-mass stars, Na produced by the NeNa cycle can be mixed to the stellar surface, either during the first dredge-up or later during the asymptotic giant branch (AGB) phase (El Eid & Champagne 1995 [ApJ, 451, 298]; Mowlavi 1999 [A&A, 350, 73]; Karakas 2010 [MNRAS, 403, 1413]).

- Odd-Z element with single stable isotope (^{27}Al).
- Mainly synthesized during carbon and neon burning in massive stars (e.g. Arnett & Thielemann 1985 [ApJ, 295, 589]).
- Also produced through the MgAl cycle in the internal convective regions of AGB stars of initial mass above ~5 $M_\odot$ undergoing hot bottom burning (Ventura et al. 2013 [MNRAS, 431, 3642]; Doherty et al. 2014 [MNRAS, 437, 195]).

SODIUM MEASUREMENTS IN FIELD STARS

Gaia-ESO Public Survey data — *Smiljanic, Romano, Bragaglia & GES Consortium (2016 [A&A, submitted])*

(Overview talk by S. Randich)



See Smiljanic et al. (2014 [A&A, 570, A122]) for details about the analysis of UVES spectra in GES

ALUMINIUM MEASUREMENTS IN FIELD STARS

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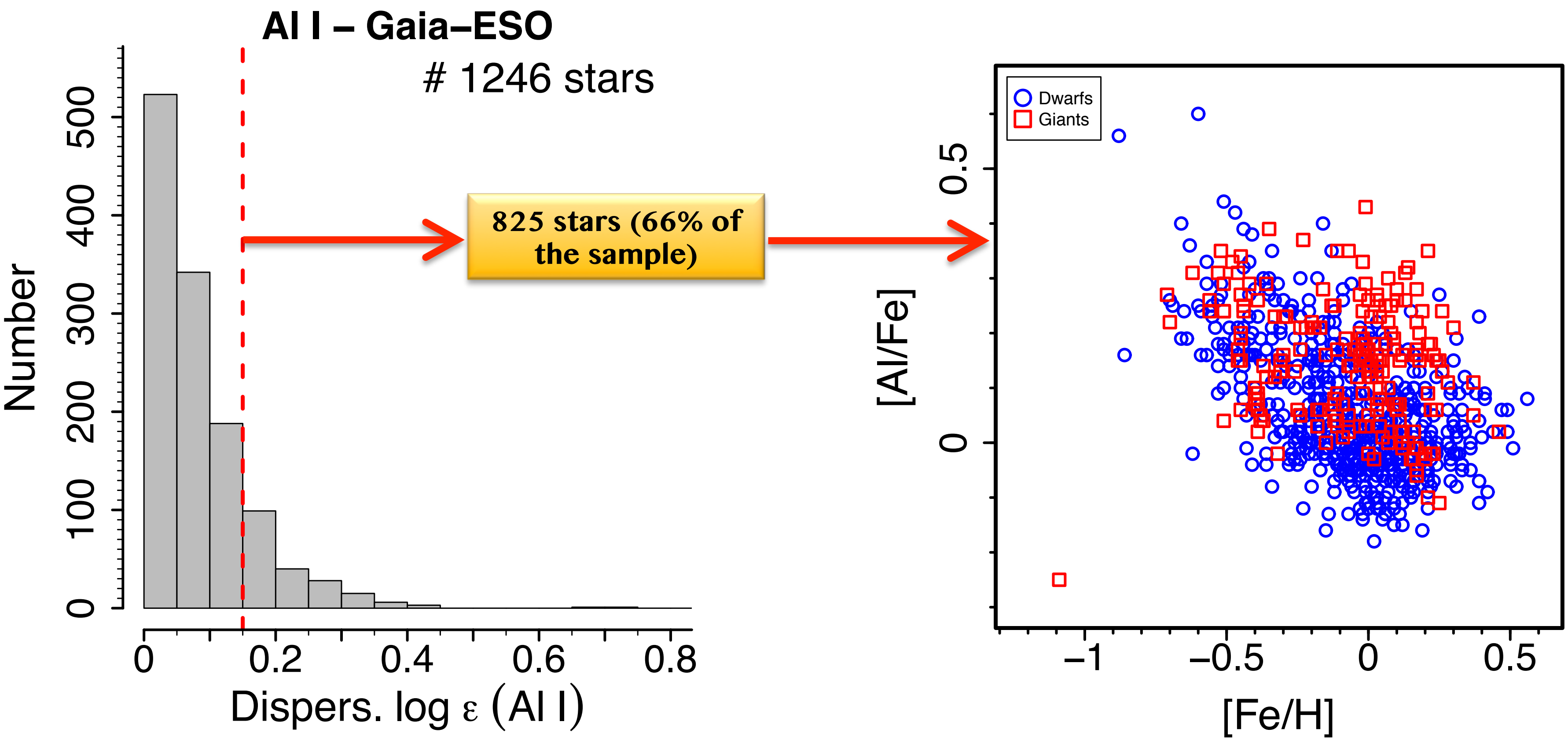

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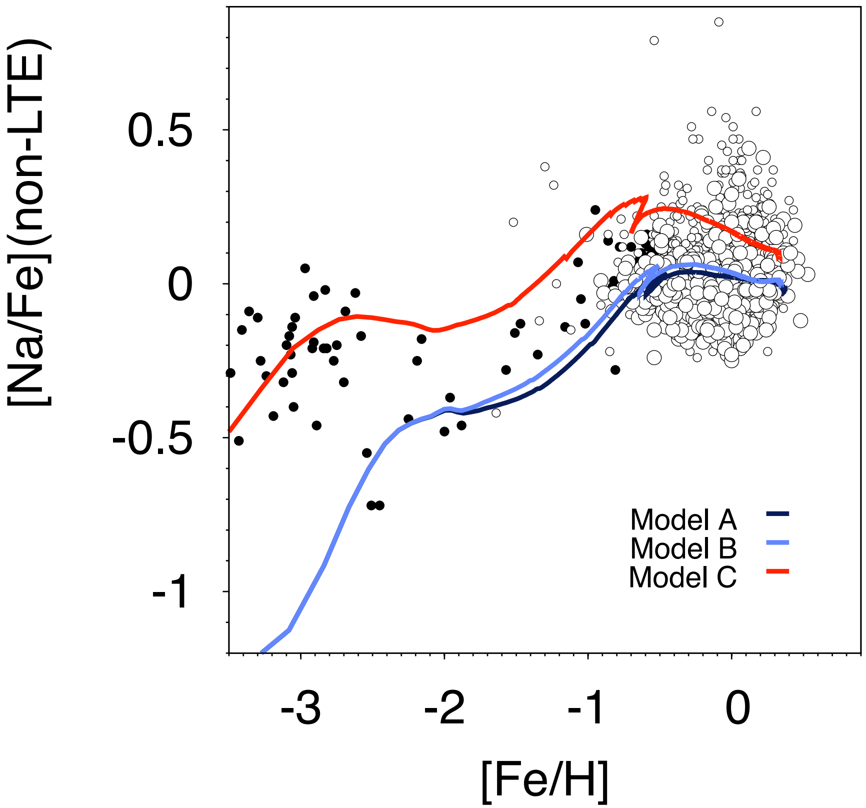
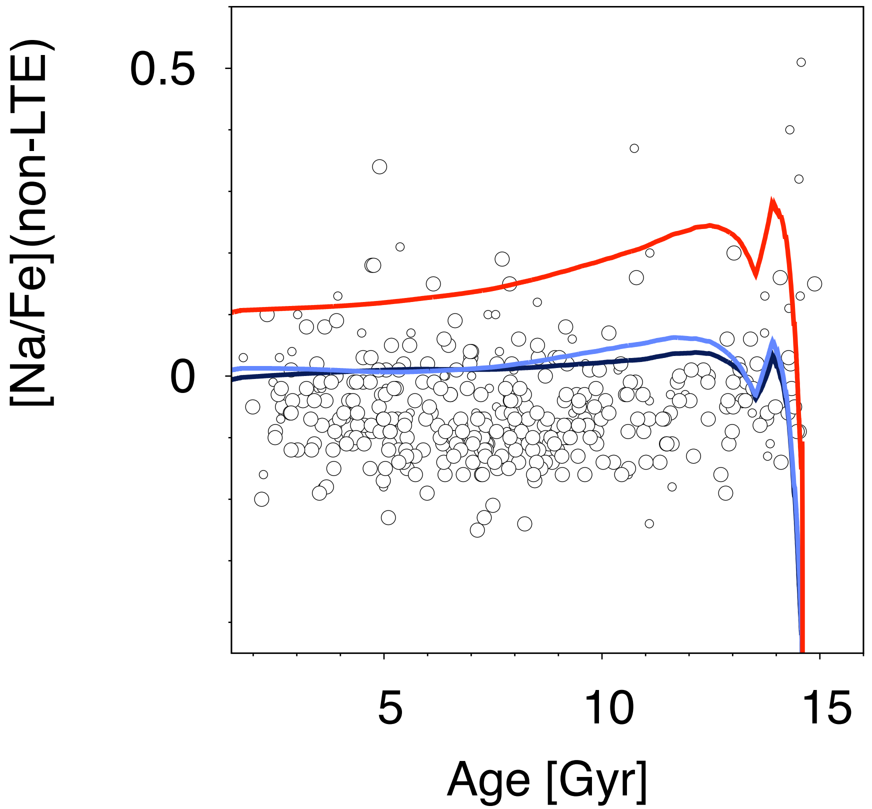
OBSERVATIONS VS GCE MODEL PREDICTIONS





- Non-LTE corrections on a line-by-line basis using grids from Lind et al. (2011 [A&A, 528, A103])
- Ages for field dwarfs computed following Bergemann et al. (2014 [A&A, 656, A89])

Smiljanic, Romano, Bragaglia & GES Consortium (2016 [A&A, submitted])

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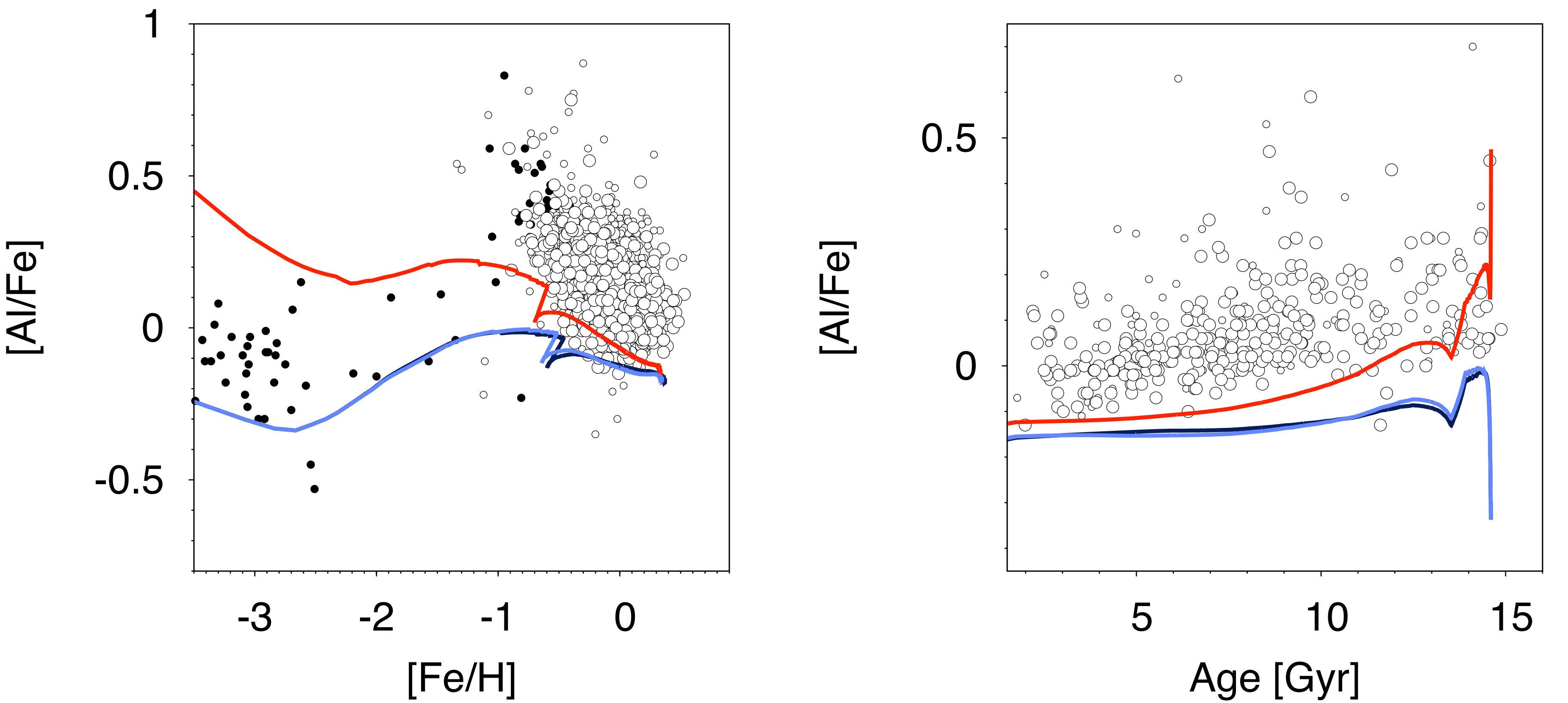
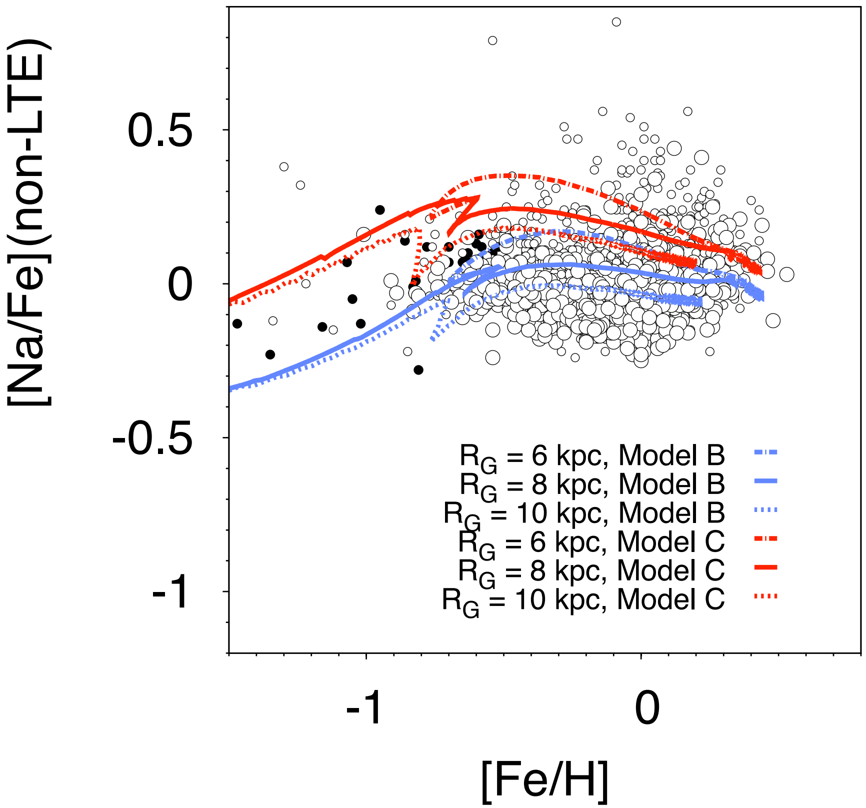


- Ages for field dwarfs computed following Bergemann et al. (2014 [A&A, 656, A89])
- (381 dwarfs retained, with fractional age error < 30%)

Smiljanic, Romano, Bragaglia & GES Consortium (2016 [A&A, submitted])

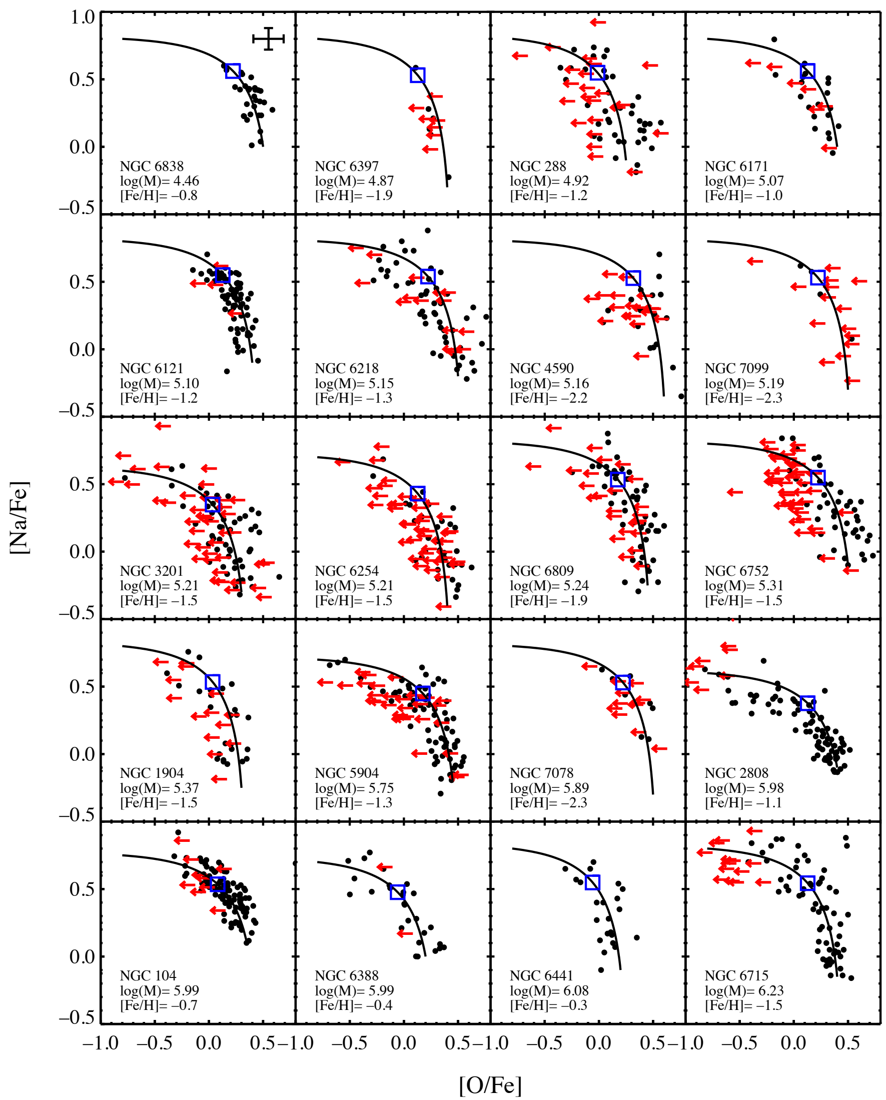
OBSERVATIONS VS GCE MODEL PREDICTIONS



- Part of the spread could be due to radial migration of stars born at different Galactocentric radii
  ($\nu_{SF}(R_{GC})$ as in Spitoni, Romano, Matteucci & Ciotti 2015)
- Do the models lack some site of Na production at late stages?

Smiljanic, Romano, Bragaglia & GES Consortium (2016 [A&A, submitted])

NA-O ANTI-CORRELATION IN GLOBULAR CLUSTERS



From observations to theory …

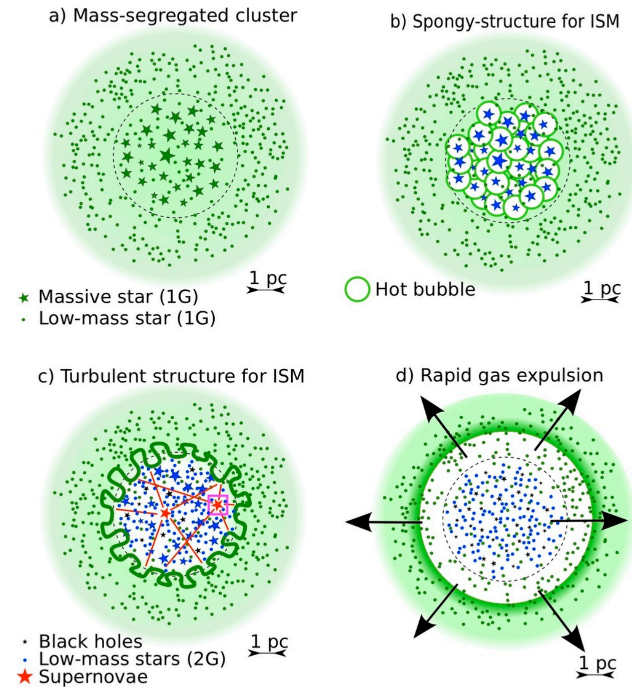


Figure from Krause et al. (2013 [A&A, 552, A121])

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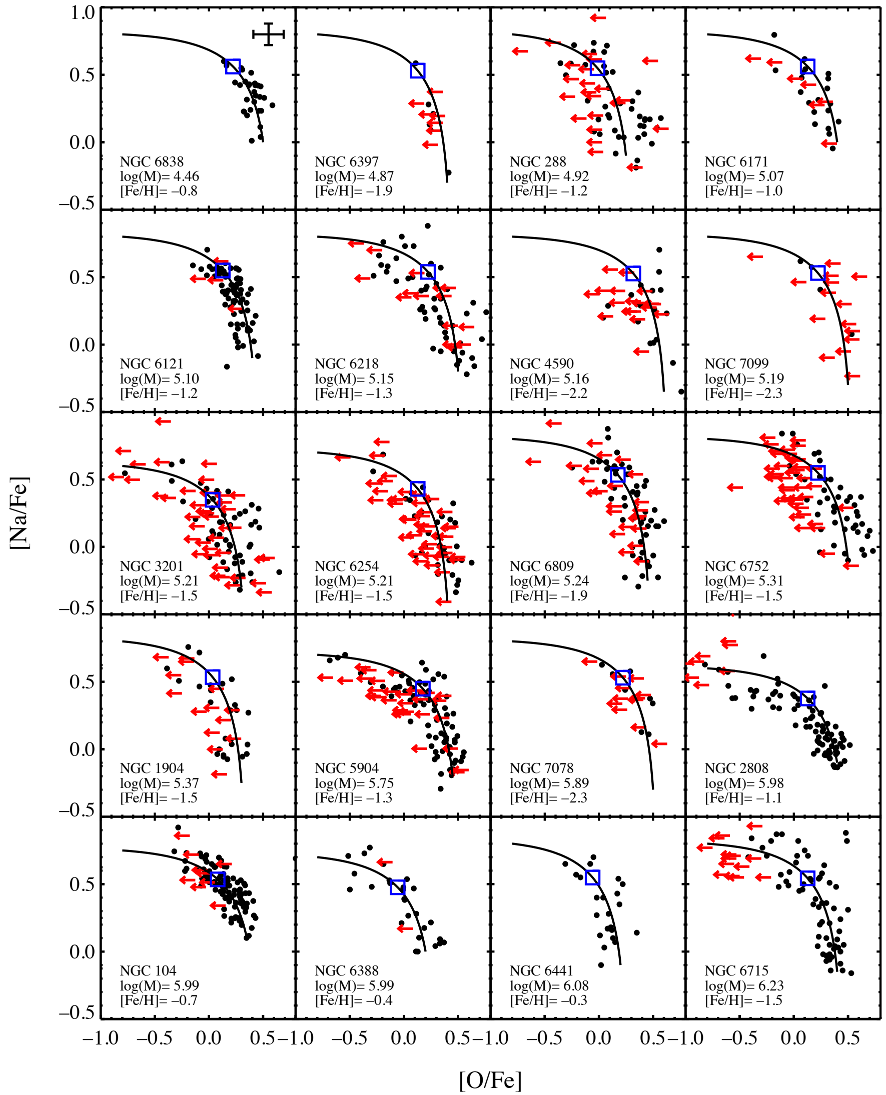

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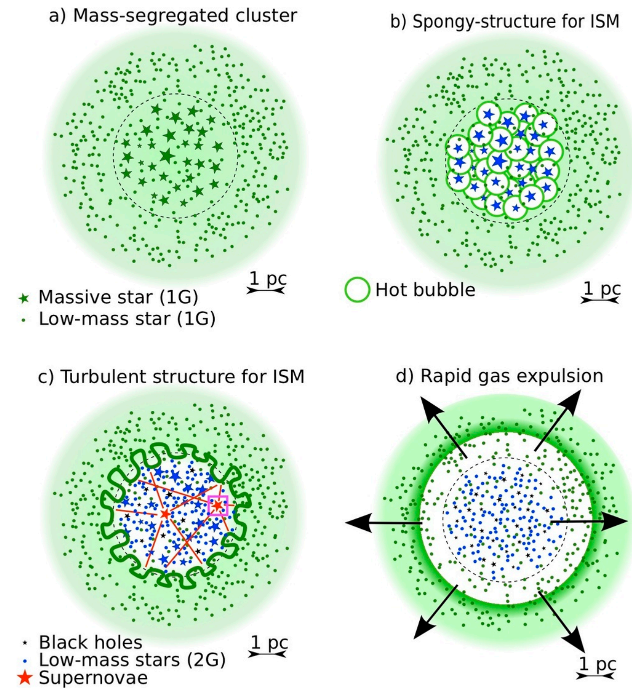

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WHO ARE THE POLLUTERS?

- AGB stars (D'Ercole et al. 2008 [MNRAS, 391, 825])
- FRMSs (Decressin et al. 2007 [A&A, 475, 859])
- Pop III stars (Choi and Yi 2007 [MNRAS, 375, L1])
- Massive binaries (de Mink et al. 2009 [A&A, 507, L1])

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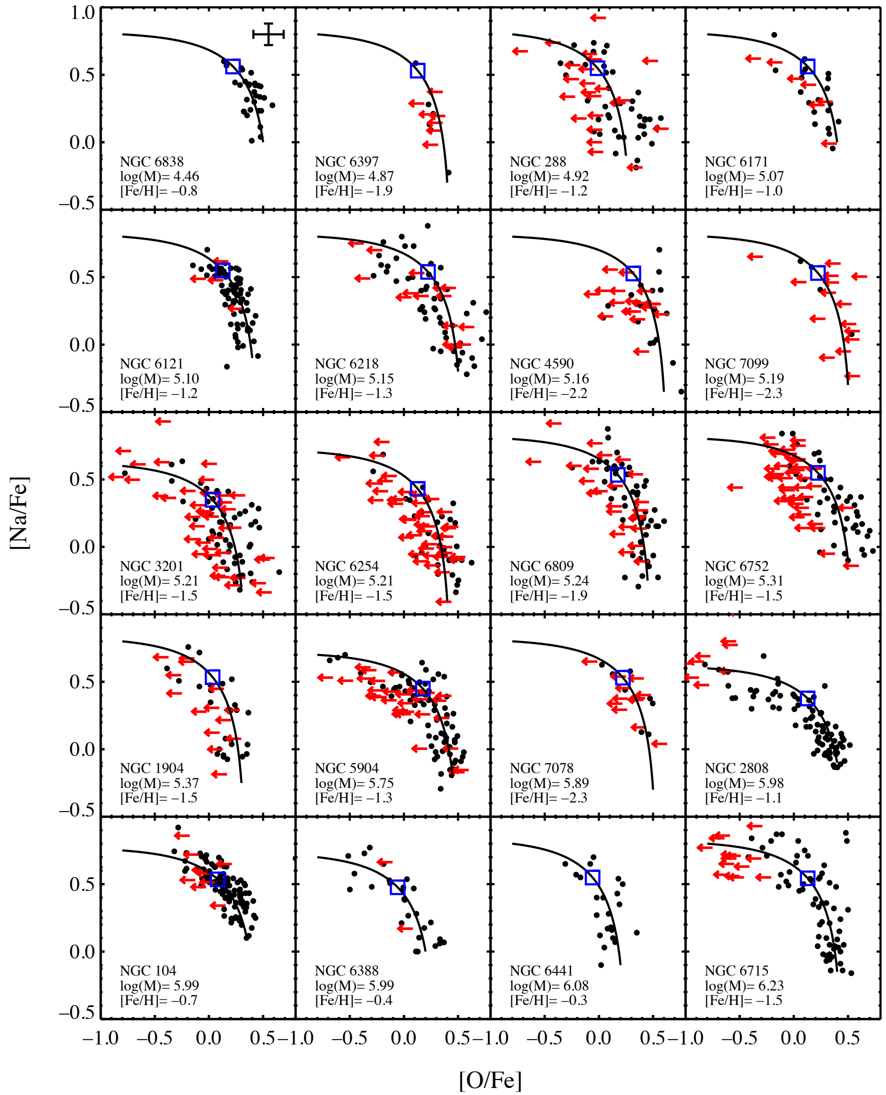

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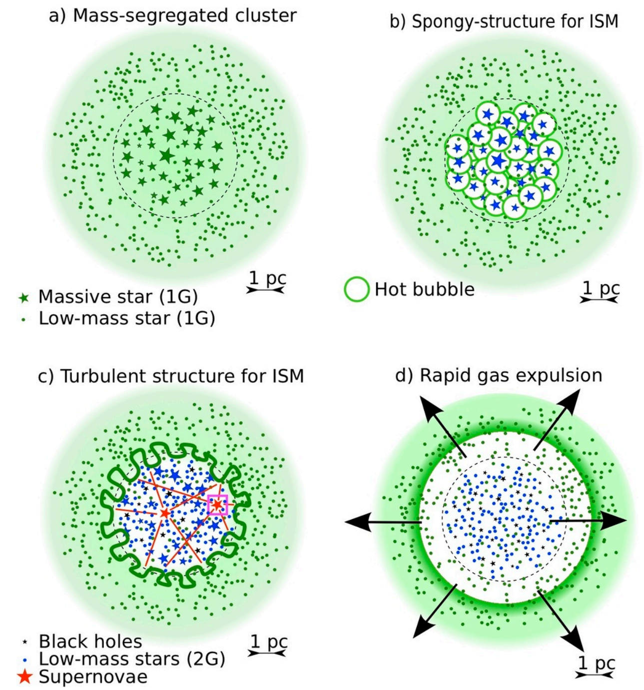

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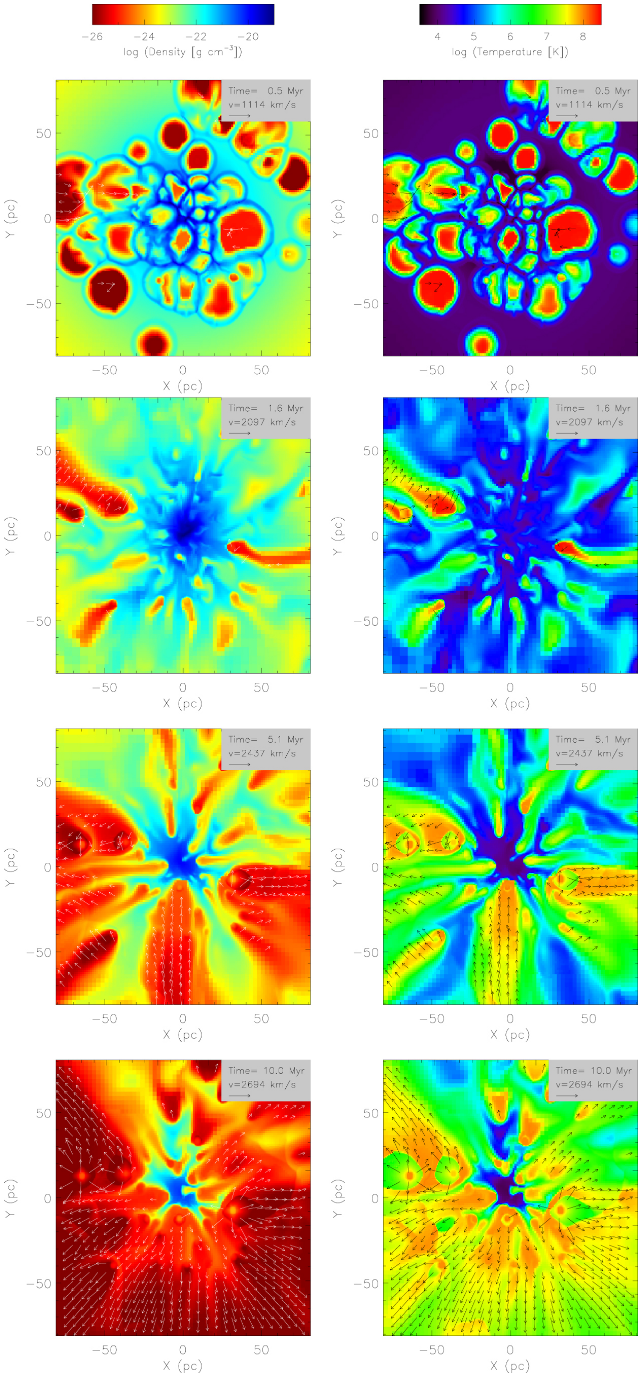
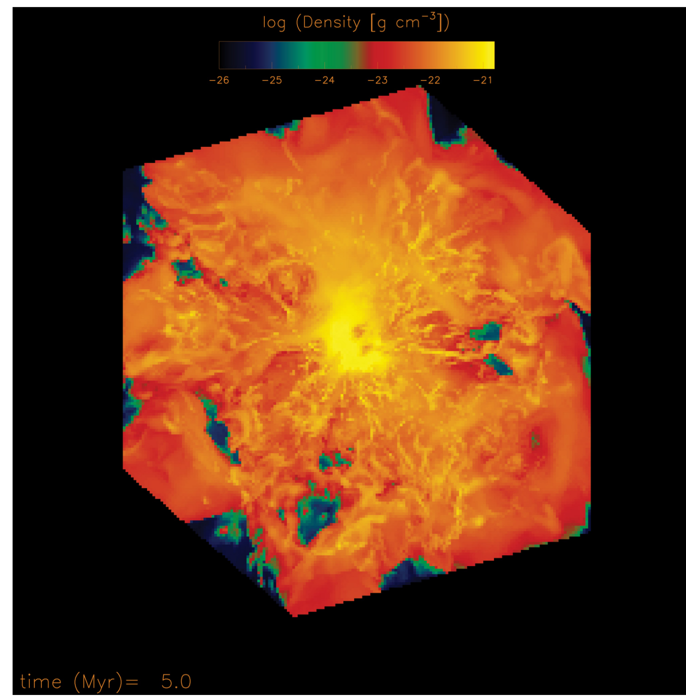
… BUT ARE THE YIELDS RELIABLE?

3D HYDRODYNAMICAL SIMULATIONS@CINECA, BOLOGNA

Calura, Few, Romano, & D'Ercole (2015 [ApJ Letters, 414, 3231])
Calura et al. (2016 [in prep.])

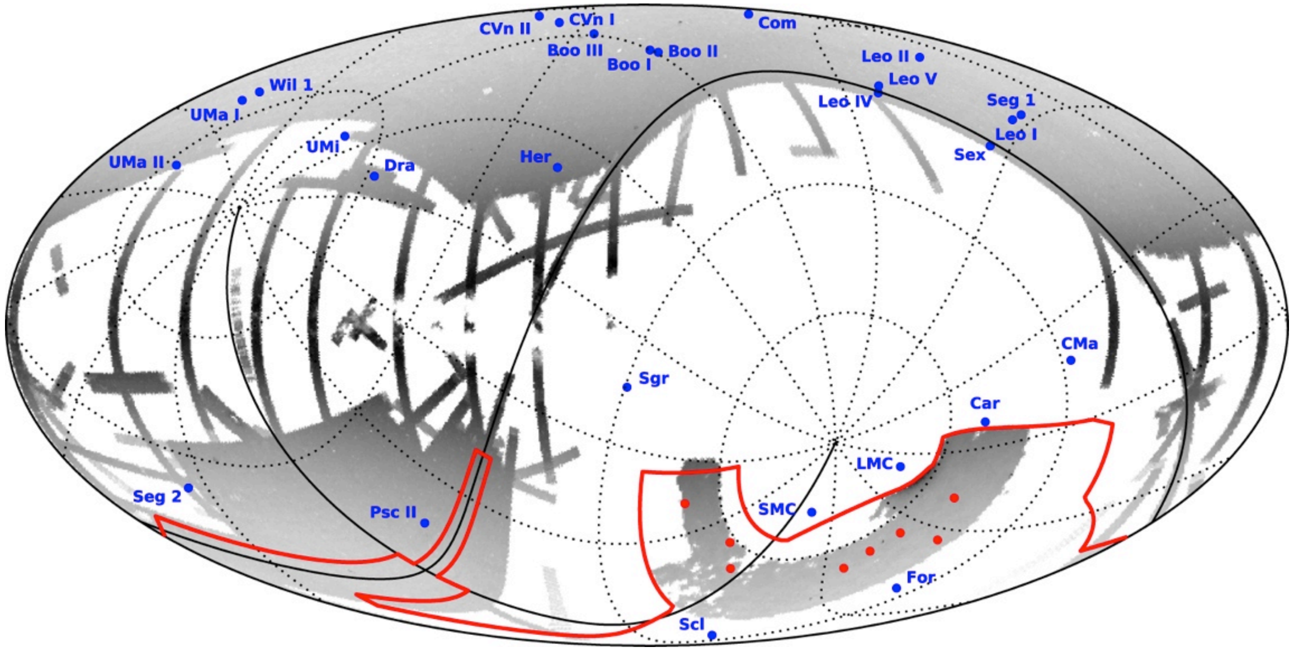


- Using Adaptive Mesh Refinement code RAMSES (Teyssier 2002 [A&A, 385, 624])
- Gas-rich GC precursor ($M_{proto\text{-}GC}$~10^7 $M_\odot$; M_{stars}~3×10^6 $M_\odot$)
- Initial mass distribution: Plummer (1911), a = 27 pc
- Self gravity: YES
- Dark matter: NO
- Computational box: (162 pc)^3
- Max res=0.6 pc



NO DETAILED CHEMISTRY INCLUDED YET

SDSS and other ongoing wide-field, deep photometric surveys are changing our view of the Milky Way's satellite population···



First-year DES data: eight new satellite systems (Bechtol et al. 2015 [ApJ, 807, 50])

Ultra-Faint Dwarfs:

- Least luminous, $L_{tot} = 3 \times 10^2$–$10^5\ L_\odot$
- Most dark matter dominated, $M/L = 10^2$–$10^3\ M_\odot/L_{\odot,V}$
- Least chemically enriched, [Fe/H] ∼−2.5 dex

IS THERE A LINK BETWEEN GCs AND UFDs?

Romano, Calura et al. (2016 [in prep.])

SIMULATING THE BOOTES I ULTRA-FAINT DWARF:

$M_{tot} \sim 6 \times 10^7$ $M_\odot$

$M_{stars} \sim 6 \times 10^4$ $M_\odot$

$r_{eff} = 250$ pc

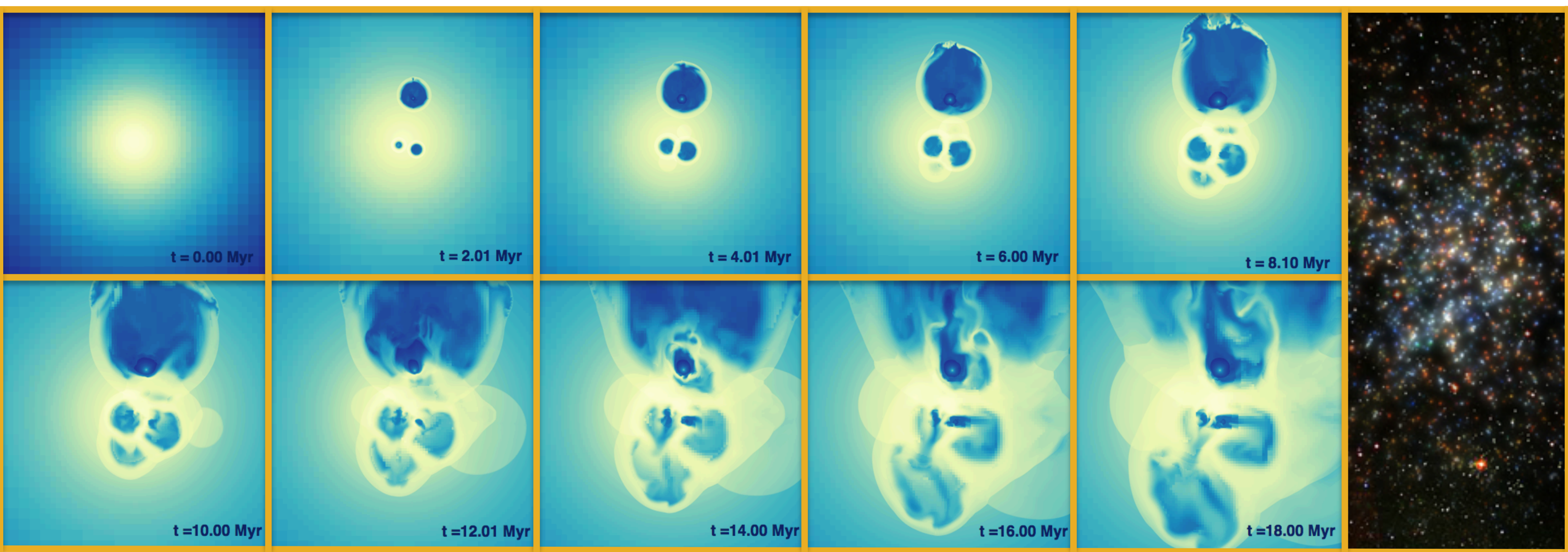
Self gravity: NO

Dark matter: YES

Computational box: $(2\ \mathrm{kpc})^3$

Max res< 1 pc

NO DETAILED CHEMISTRY (YET)



SUMMARY AND FUTURE WORK

- Except for a handful of elements, whose nucleosynthesis in stars is well understood by now, large uncertainties still affect chemical evolution model predictions.
- This is especially true for Na and Al. These elements define characteristic anti-correlations in globular cluster stars, that are not seen in the Galactic field.
- Next steps:
  - Test updated yields, by means of pure chemical evolution models for the Milky Way
  - Implement the detailed chemistry in 3D hydrodynamical simulations and study the formation and evolution of the smallest Milky Way companions
- Eventually get a comprehensive view of the Galactic halo formation

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