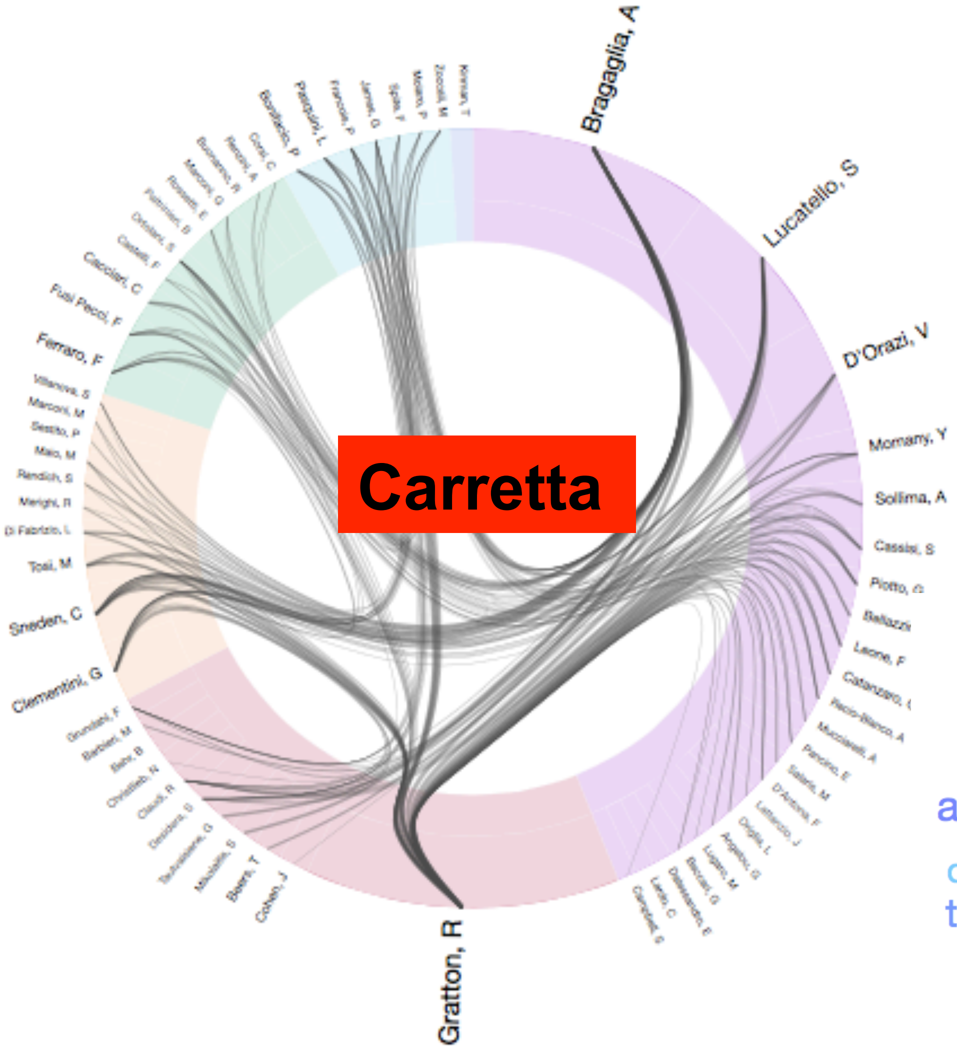
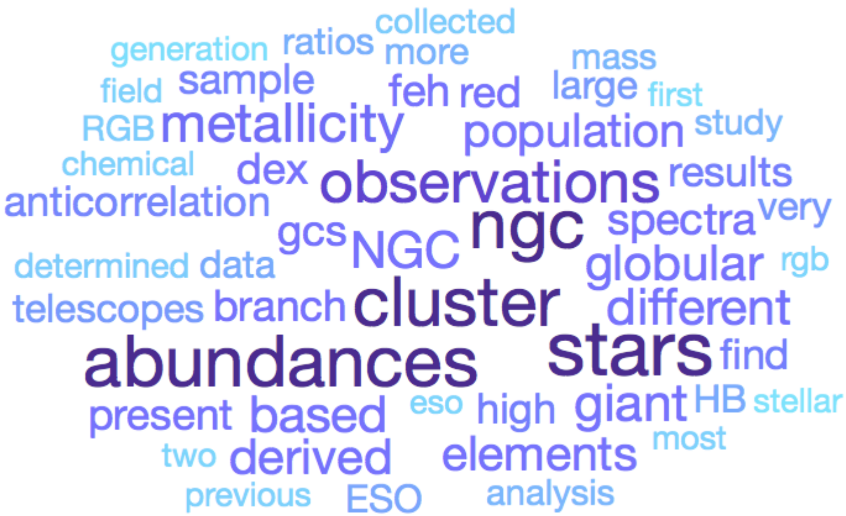
Eugenio Carretta – INAF Osservatorio Astronomico di Bologna



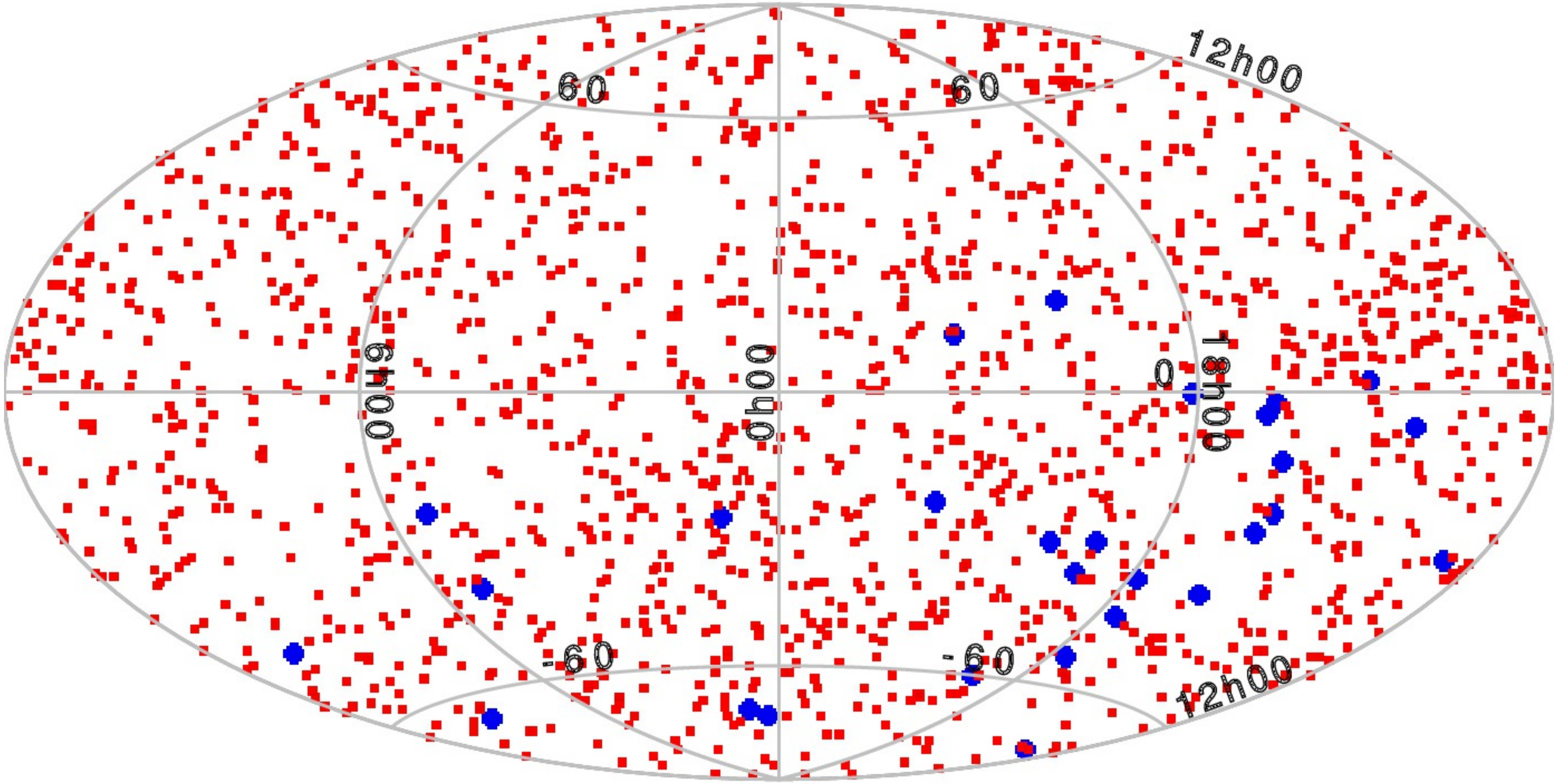
in a nutshell: collaborations and key words



Minisurveys:

Multiple populations in globular clusters

Accretion and dissipative components of the Milky Way's halo



past/present

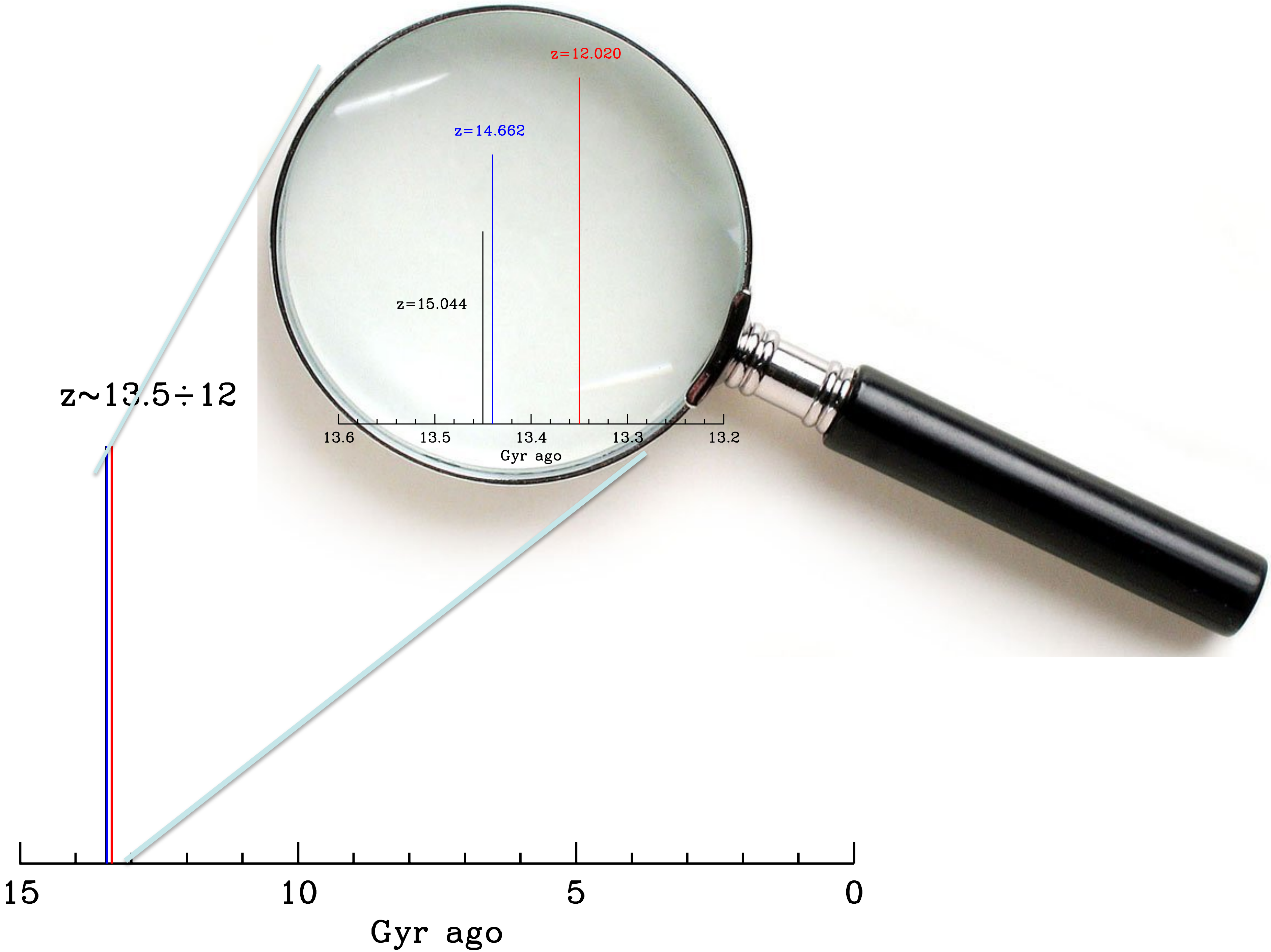
present/future

Na-O anticorrelation and HB

Core team: Carretta, Bragaglia, D'Orazi, Gratton, Lucatello, Sollima

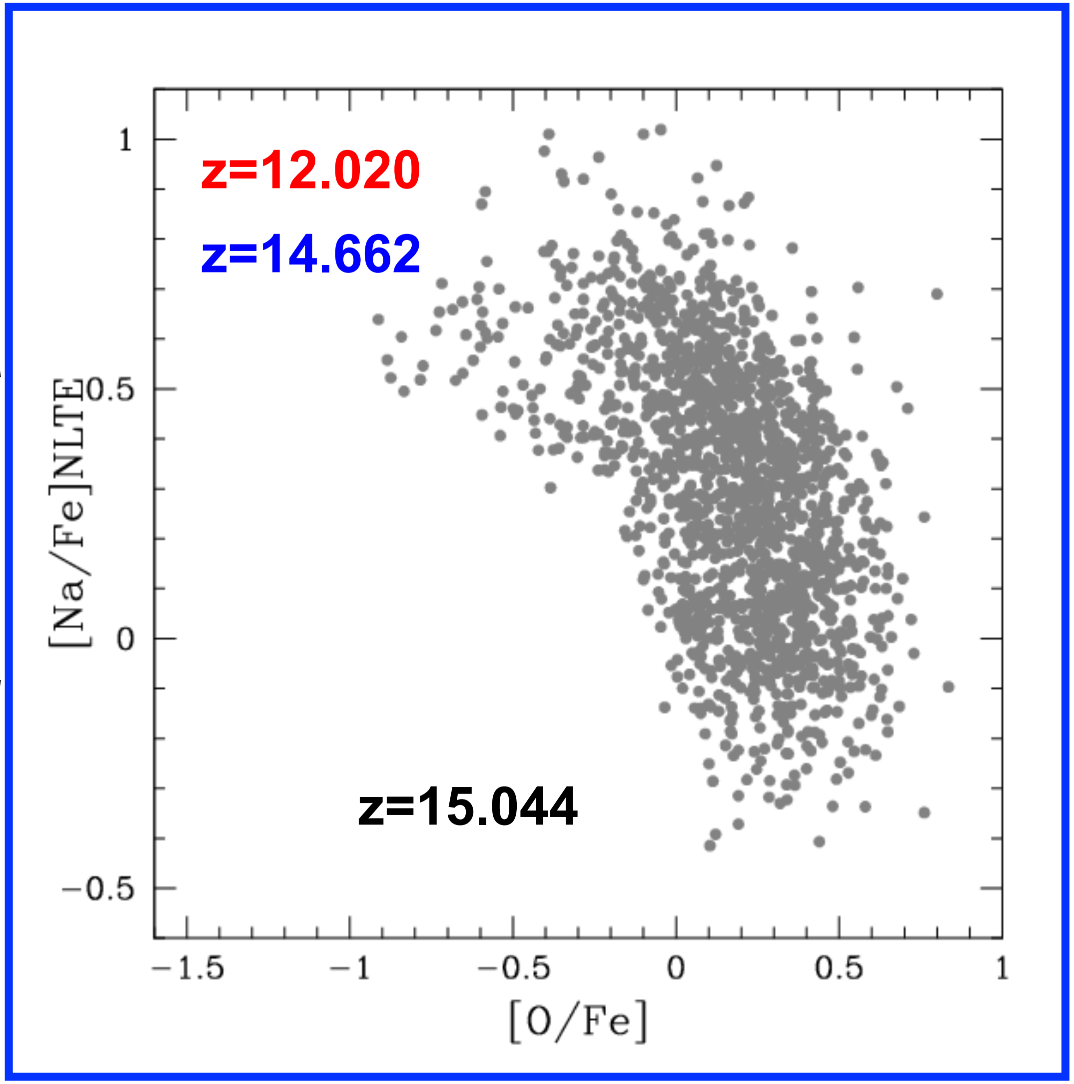
Main purposes of the survey

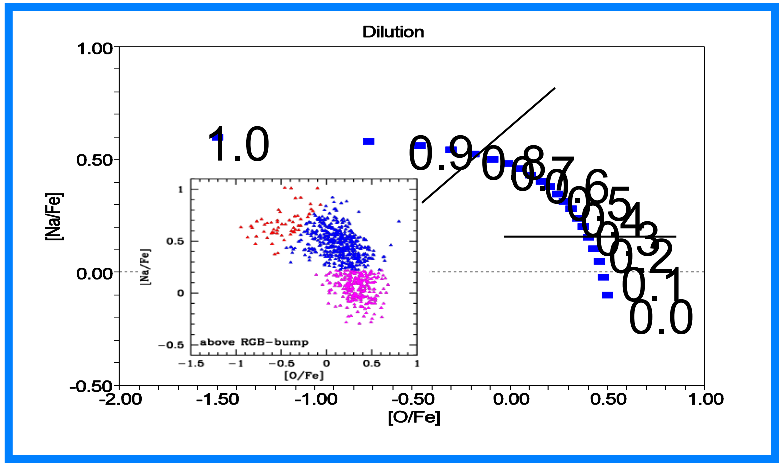
- How GCs formed (origin and early evolution)
- Link of multiple populations to global parameters
- Whether and how they contribute(d) to the Galactic halo



z=12.020
z=14.662
z=15.044
13.6
13.5
13.4
13.3
13.2
Gyr ago
z~13.5÷12
15
10
5
0
Gyr ago

Time span between stellar generations: few 10^6 – 10^7 yrs





second generation(s)

Na,O: proton-captures in H-burning ay high temperature

first generation

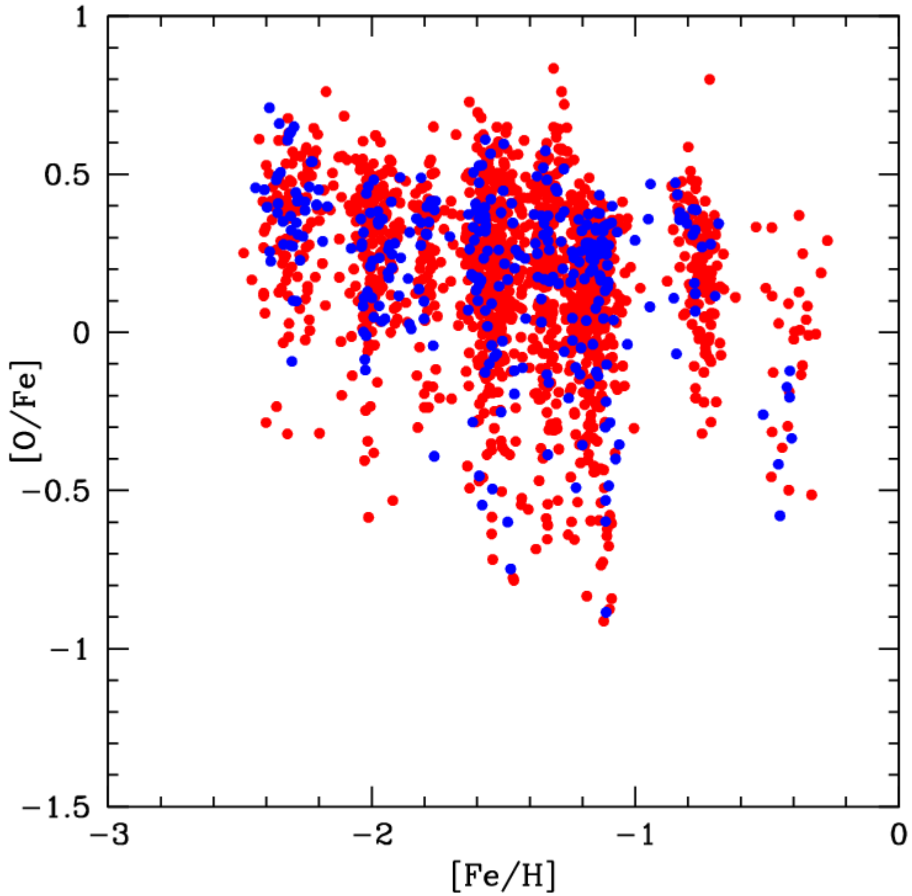
Na,O: hydrostatic burning + α-captures in massive stars

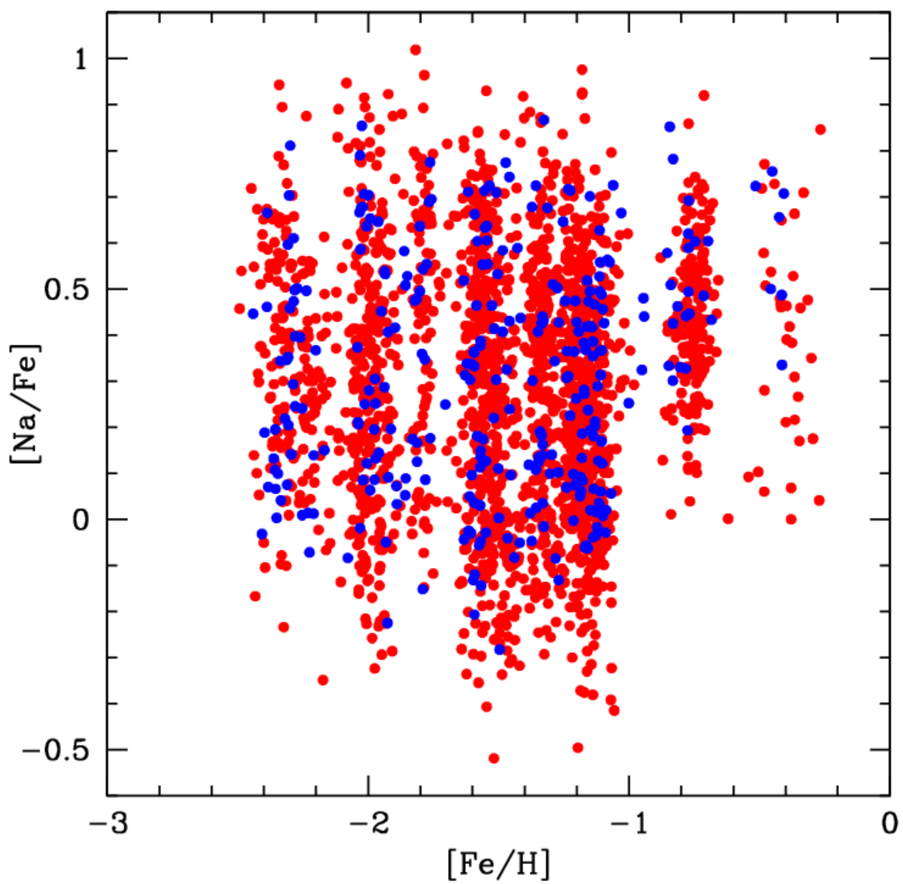
Immediate aim:

✓ homogeneous Fe, O, Na abundances for ~100 red giants in each of many GCs with different HB morphology

~ 2600 stars analyzed in 25 GCs

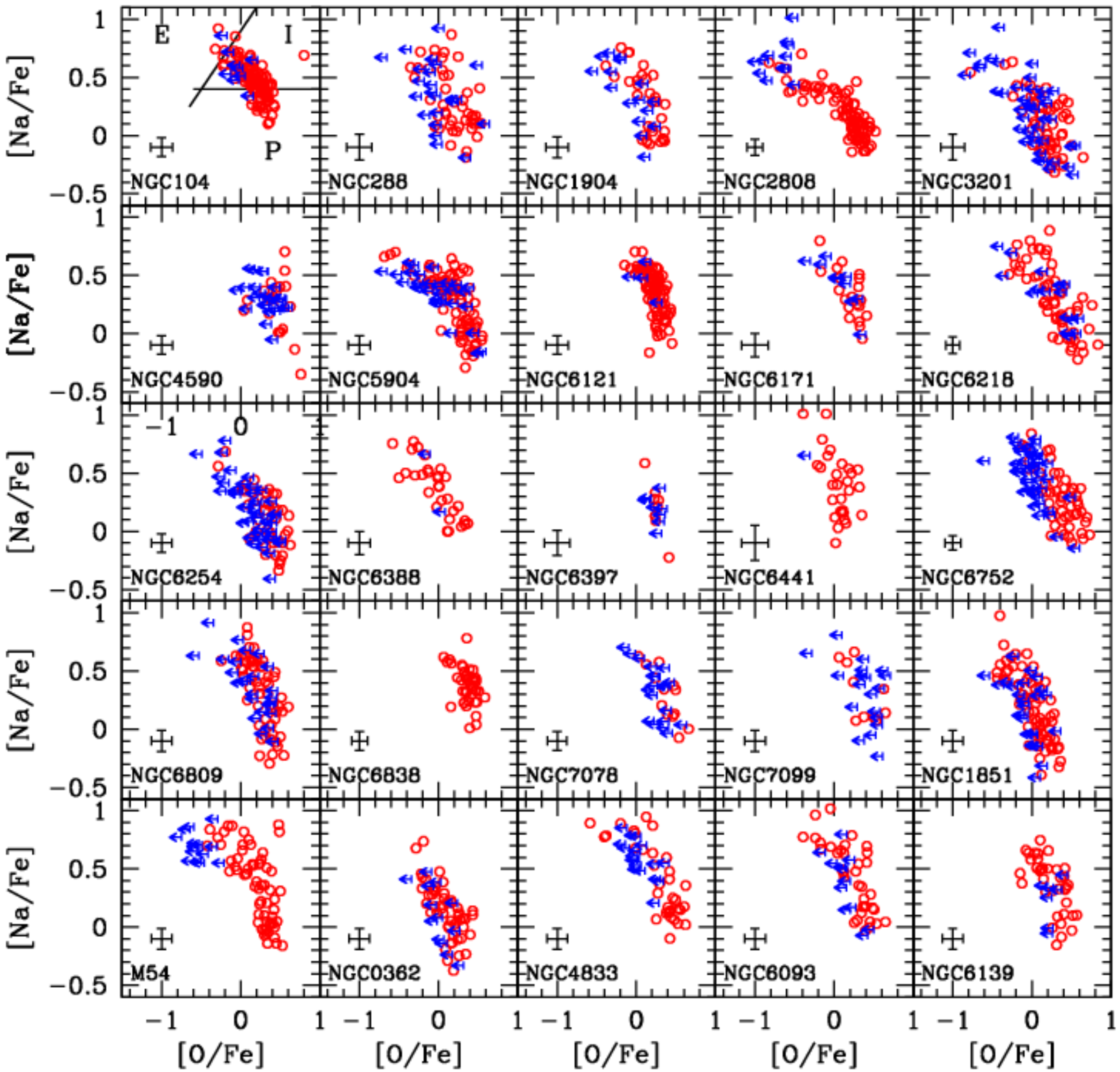
by-product: new high-resolution metallicity scale (Carretta et al. 2009)





DNA of Galactic globular clusters:

✓ Na-O anticorrelations → multiple stellar generations → intrinsic feature of bona fide GCs

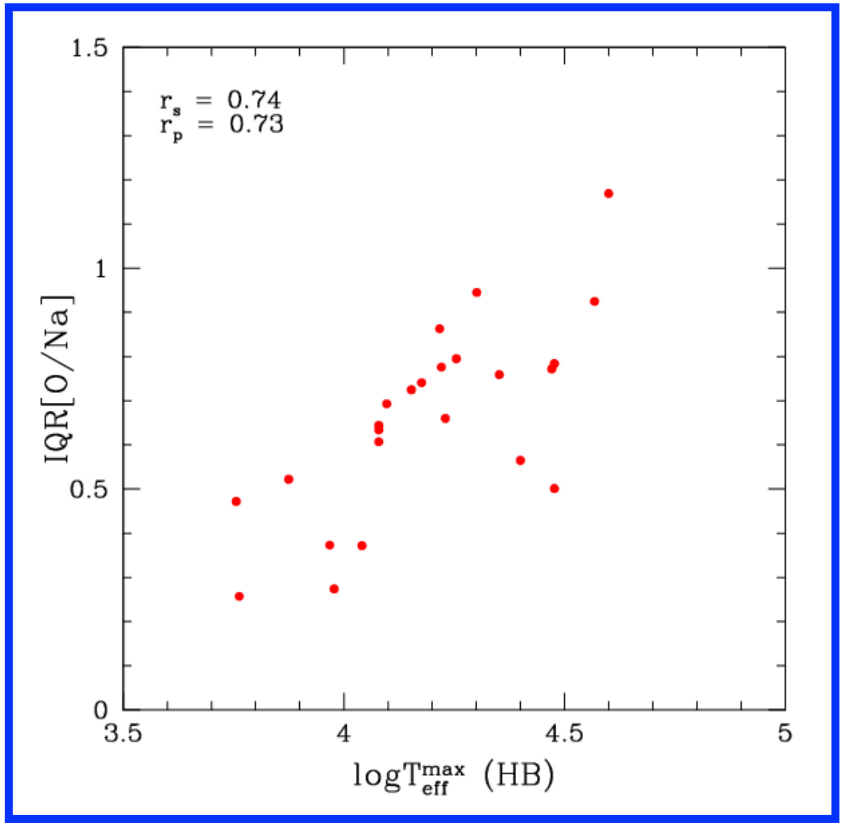


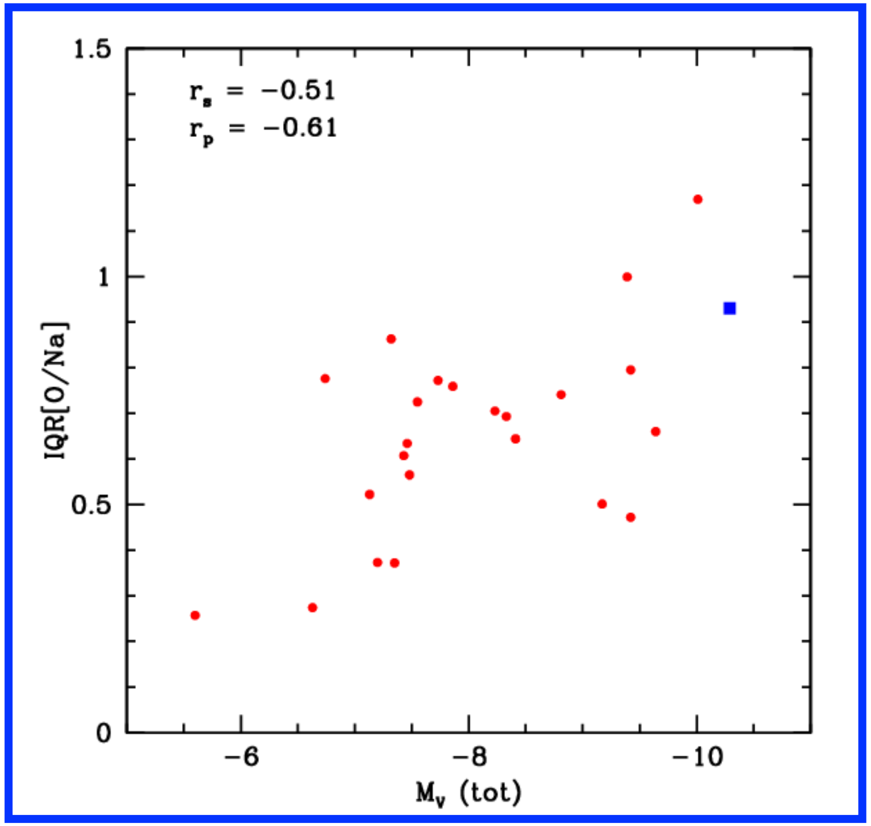
Carretta et al. 2006
Carretta et al. 2007a,b,c
Gratton et al. 2006
Gratton et al. 2007
Carretta et al. 2009a,b,c
Carretta et al. 2010a,b,c,d,e
Carretta et al. 2011
Carretta et al. 2012a,b,c
Carretta et al. 2013a,b
Carretta 2013
Carretta et al. 2014a,b,c
Carretta 2014
Carretta et al. 2015
Bragaglia et al. 2015
Carretta 2015

Link with global properties:

- ✓ **Link with horizontal branch morphology**
- ✓ **Total mass (proxy: absolute magnitude M_V): driving parameter**

IQR[O/Na] = interquartile range of the [O/Na] ratio = extension of the Na-O anticorrelation

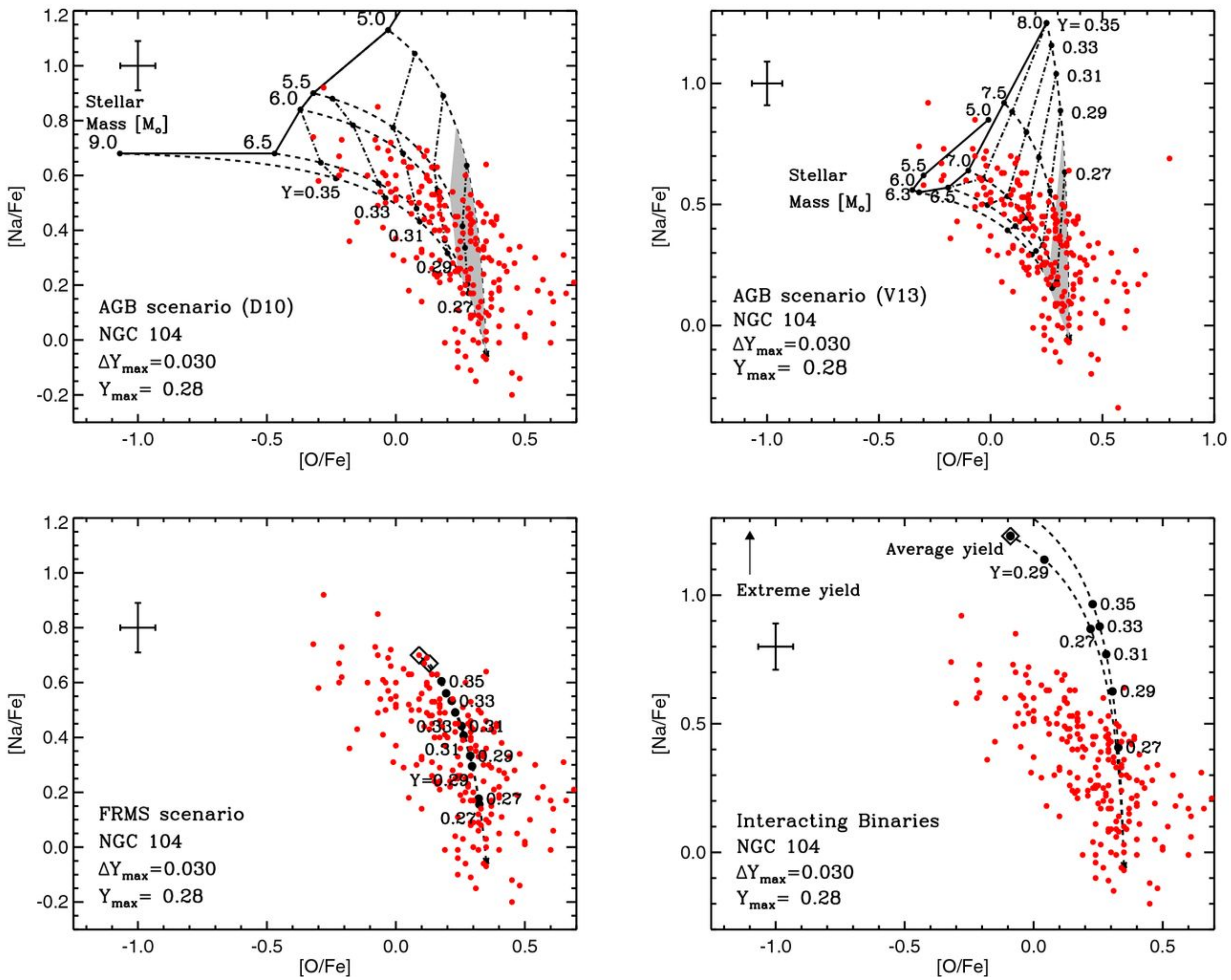




■ **ω Centauri (Johnson & Pilachowski 2009)**

Origin of globular clusters:

- No one still knows for sure



Bastian et al. 2015

Fast rotating massive stars (Decressin et al. 2007)

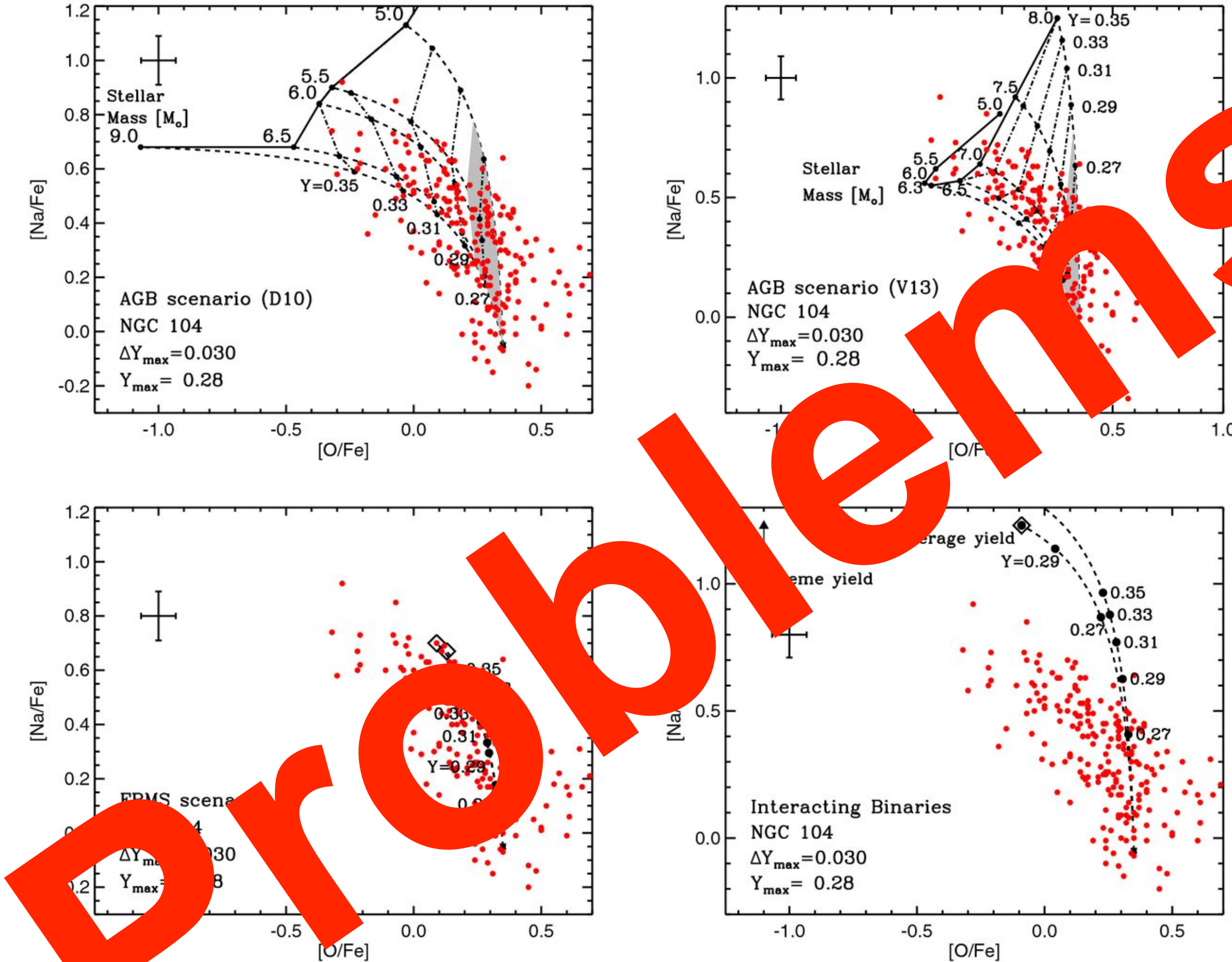
Intermediate-mass AGB stars (Ventura et al. 2001)

Intermediate-mass binaries (de Mink et al. 2009)

Very massive stars (Denissenkov & Hartwick 2014)

Origin of globular clusters:

- No one still knows for sure

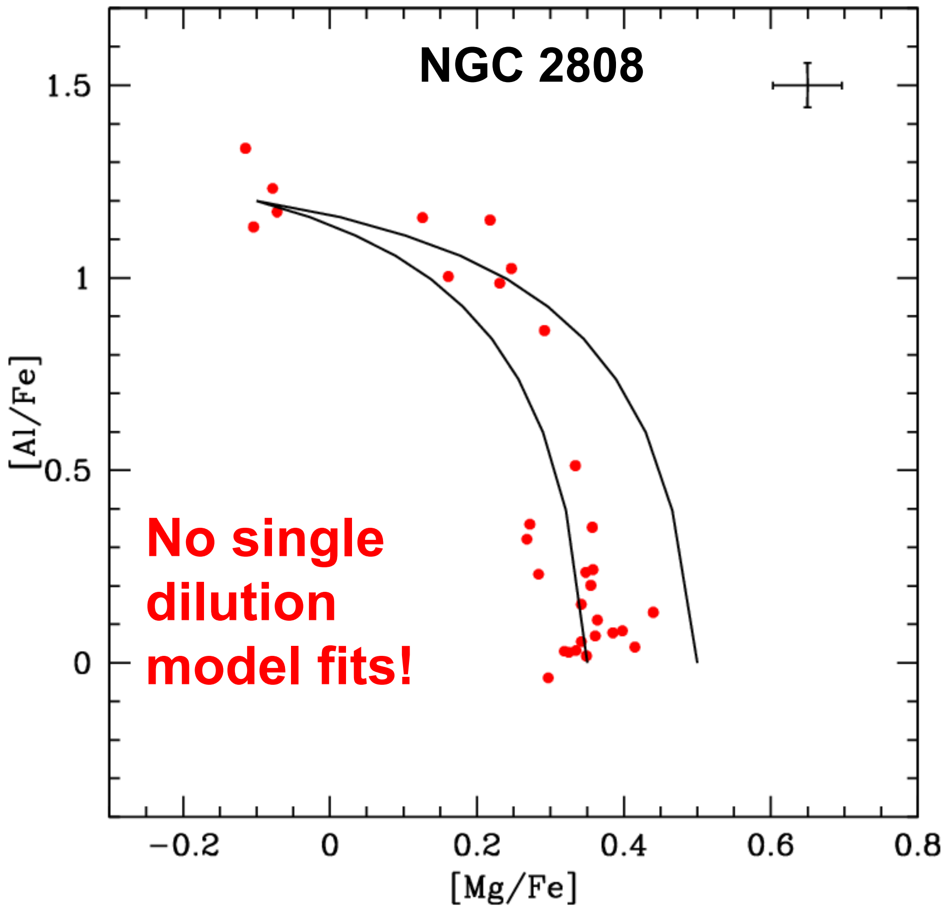


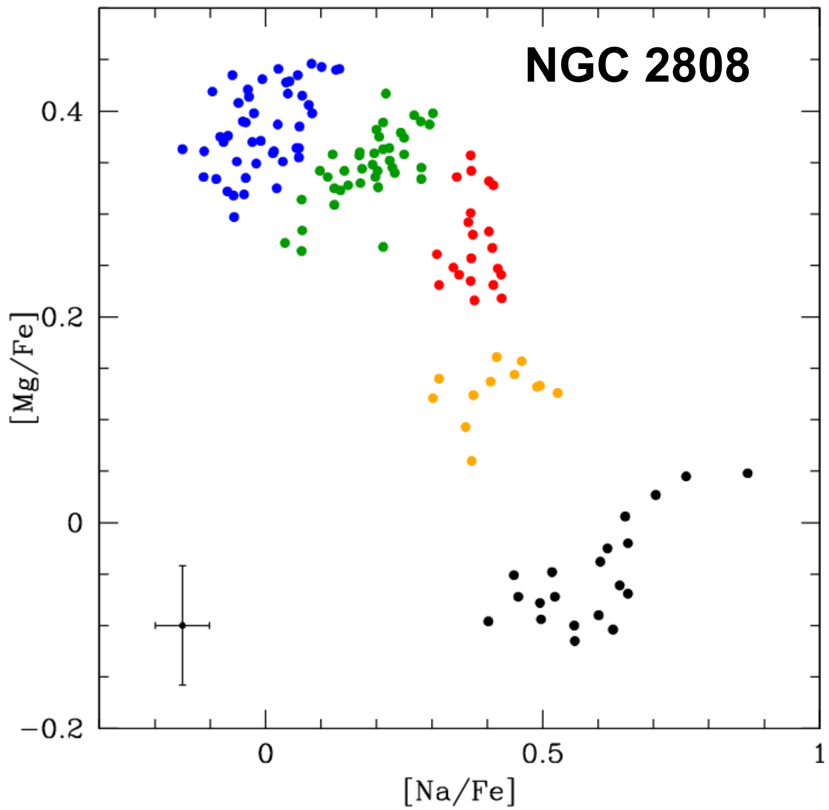
Bastian et al. 2015

Problems…

Fast rotating massive stars (Decressin et al. 2007)
Intermediate-mass AGB stars (Ventura et al. 2001)
Intermediate-mass binaries (de Mink et al. 2009)
Very massive stars (Denissenkov & Hartwick 2014)

Discrete groups: further complexity in multiple populations

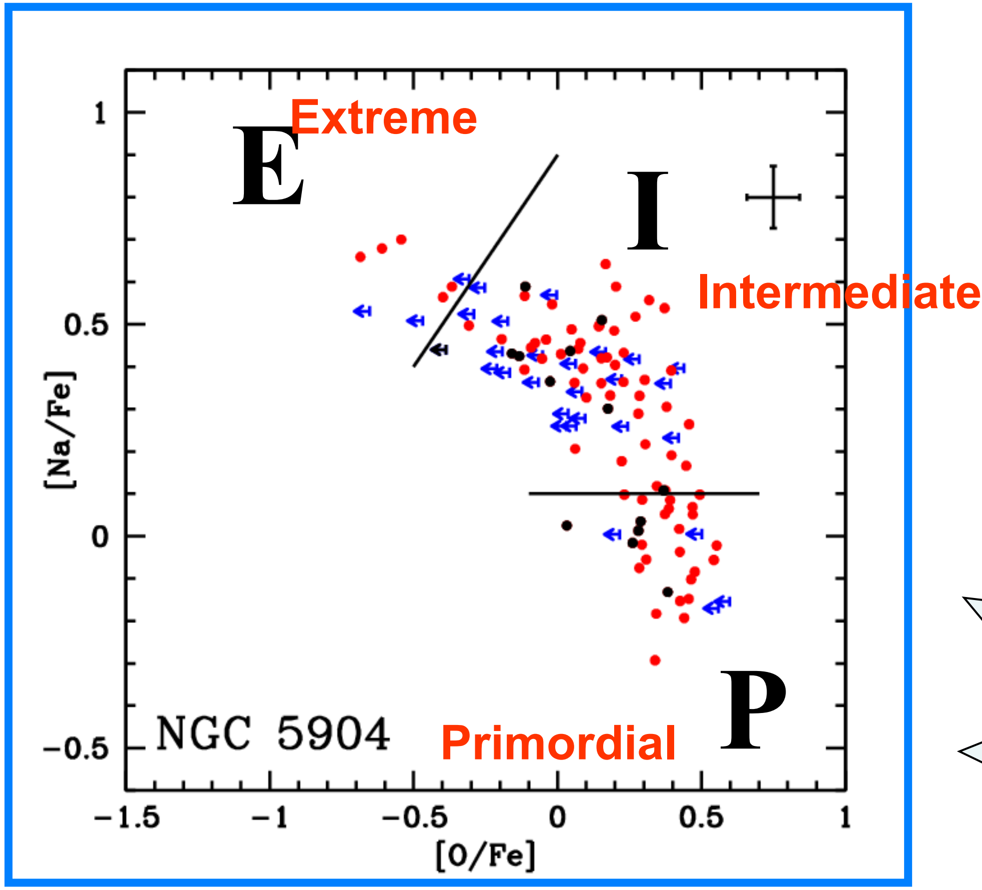




spectroscopy: NGC 6752 (Carretta et al. 2012)
NGC 2808 (Carretta 2015)

photometry: NGC 2808 (Milone et al. 2015)
and other GCs

Constraints on GC mass P ≅ 33% I ≅ 50-70%



The most massive P stars contribute to form second generation stars (I,E), currently 2/3 of GC stars

Mass budget problem

- precursor of GCs were 10-20 times more massive than present end products (Bekki et al. 2007 and many others) and
- proto-GC lost ~90% of their stars → possibly main contribution to halo

First attempt: SG stars in halo

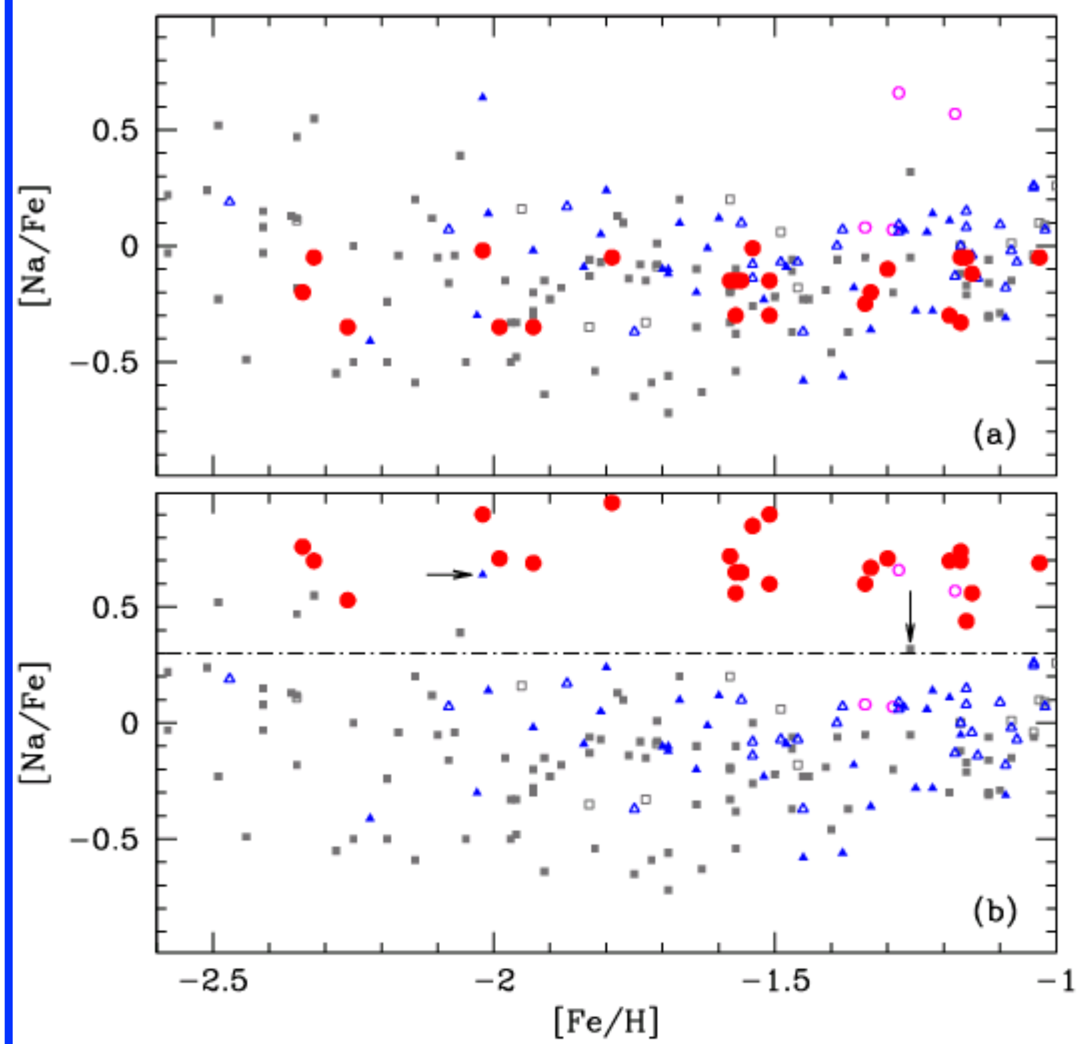
Na min GC
(Primordial)
SN nucleosy.

Na max GC
p-capture

Venn et al. (2004)

Fulbright
(2006)

Gratton et al.
(2003)



Carretta et al. (2010)

6 Na-rich stars

Escluding binaries:

CS22898027

CS22947187

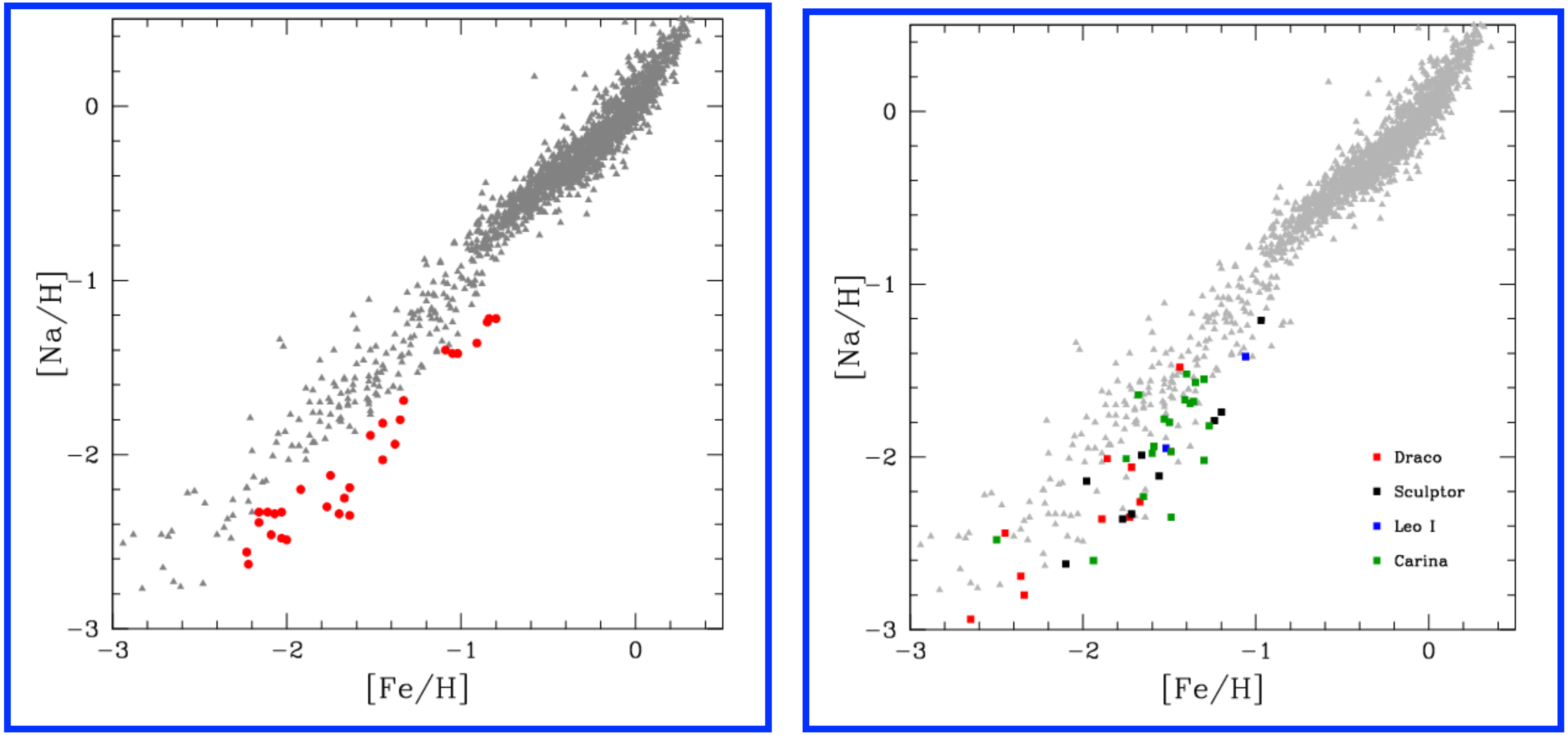
G246-38

HD178443

2/144=1.4% stars with Na of SG stars in GCs

~2.8% metal-poor component of MW

stars of accretion component/low-α/retrograde orbits



Draco: Cohen & Huang 2009, Shetrone et al. 2001

Sculptor: Kirby & Cohen 2012, Shetrone et al. 2003, Geisler et al. 2005

Carina: Shetrone et al. 2003, Venn et al. 2012, Koch et al. 2008

Leo I: Shetrone et al. 2003

INFERENCE 1:

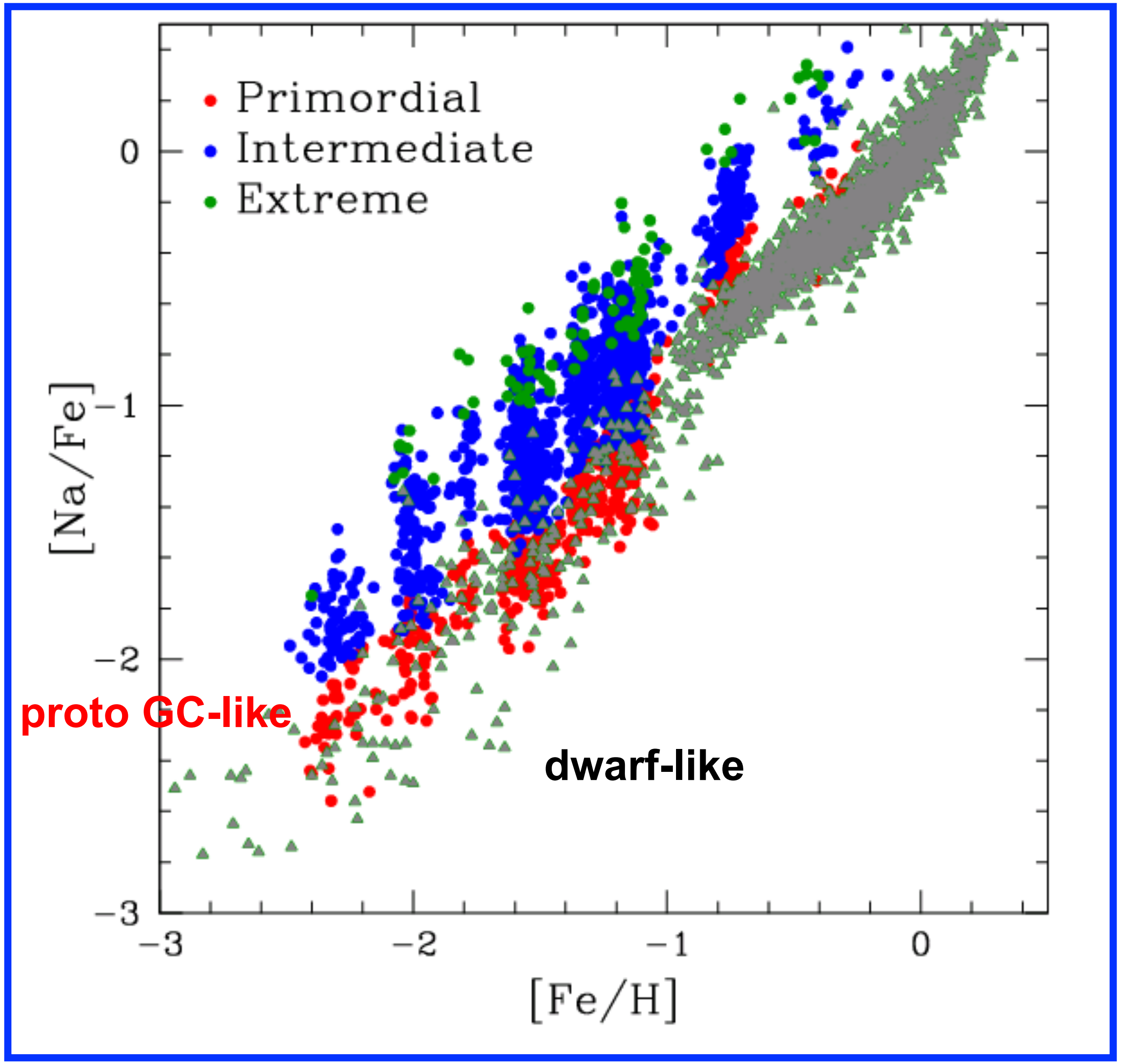
2 classes of contributors to the halo

Minority: dwarf-like composition (~10%)

Bulk: proto GC-like composition (P component in GCs) ~90%

INFERENCE 2:

Masses proto-GC >> masses present-day dSphs



AGV

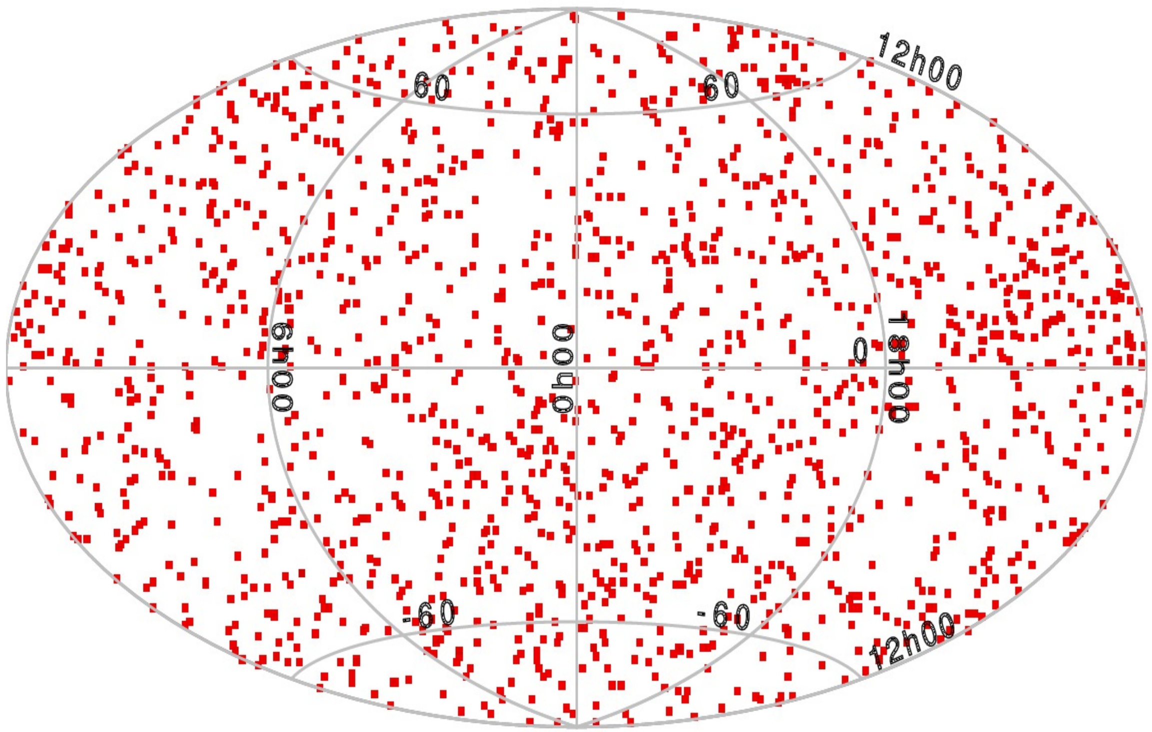
Aspettando Gaia al Varco
Awaiting for Gaia Venture

Eugenio Carretta

Angela Bragaglia

Donatella Romano

OABo



Raffaele Gratton

Sara Lucatello

Valentina D'Orazi

OAPd

Monika Adamów

UTexas,Austin

Chris Sneden

project AGV

1466 Galactic field stars (accretion +dissipative components) selected from Hipparcos catalogue

UVES

HARPS

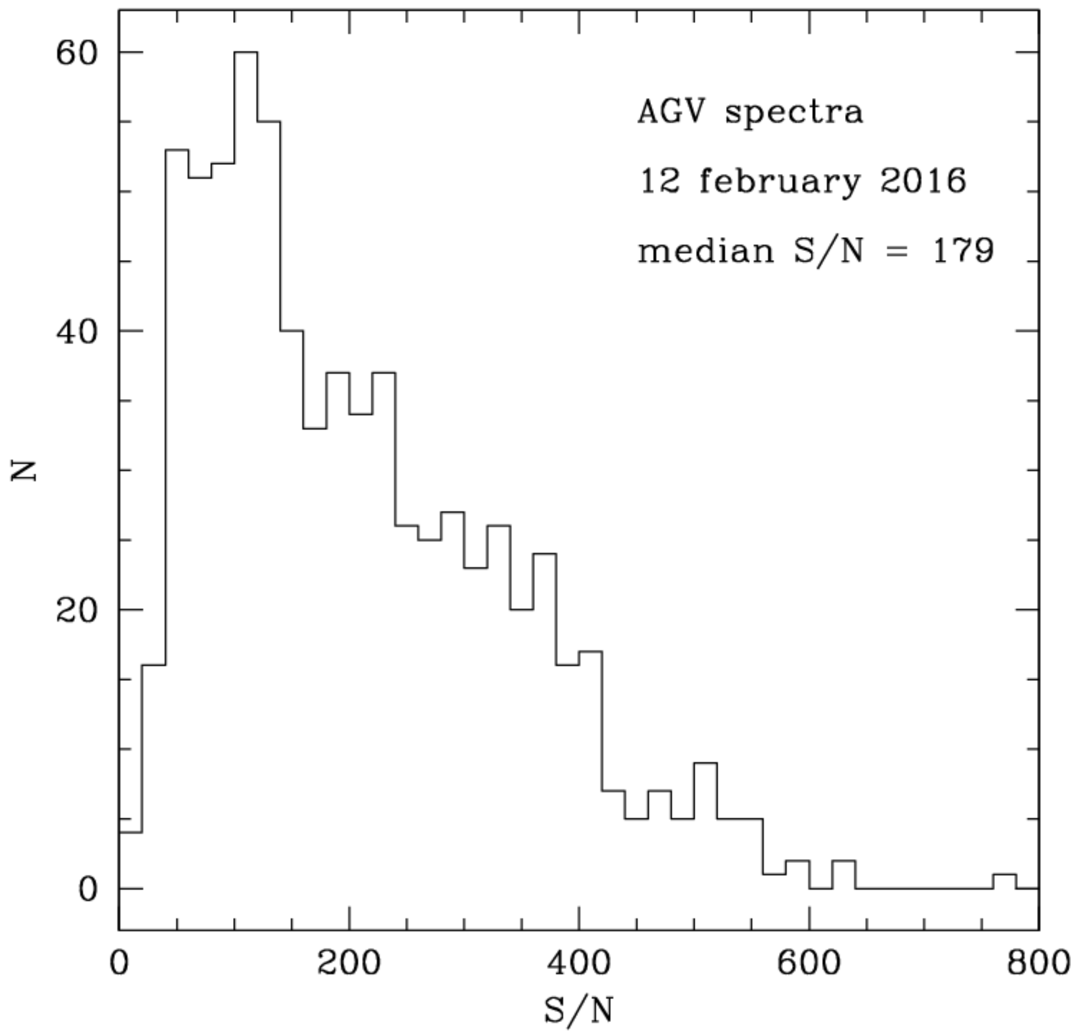
FEROS

HIRES

FIES

McDonald

SOPHIE



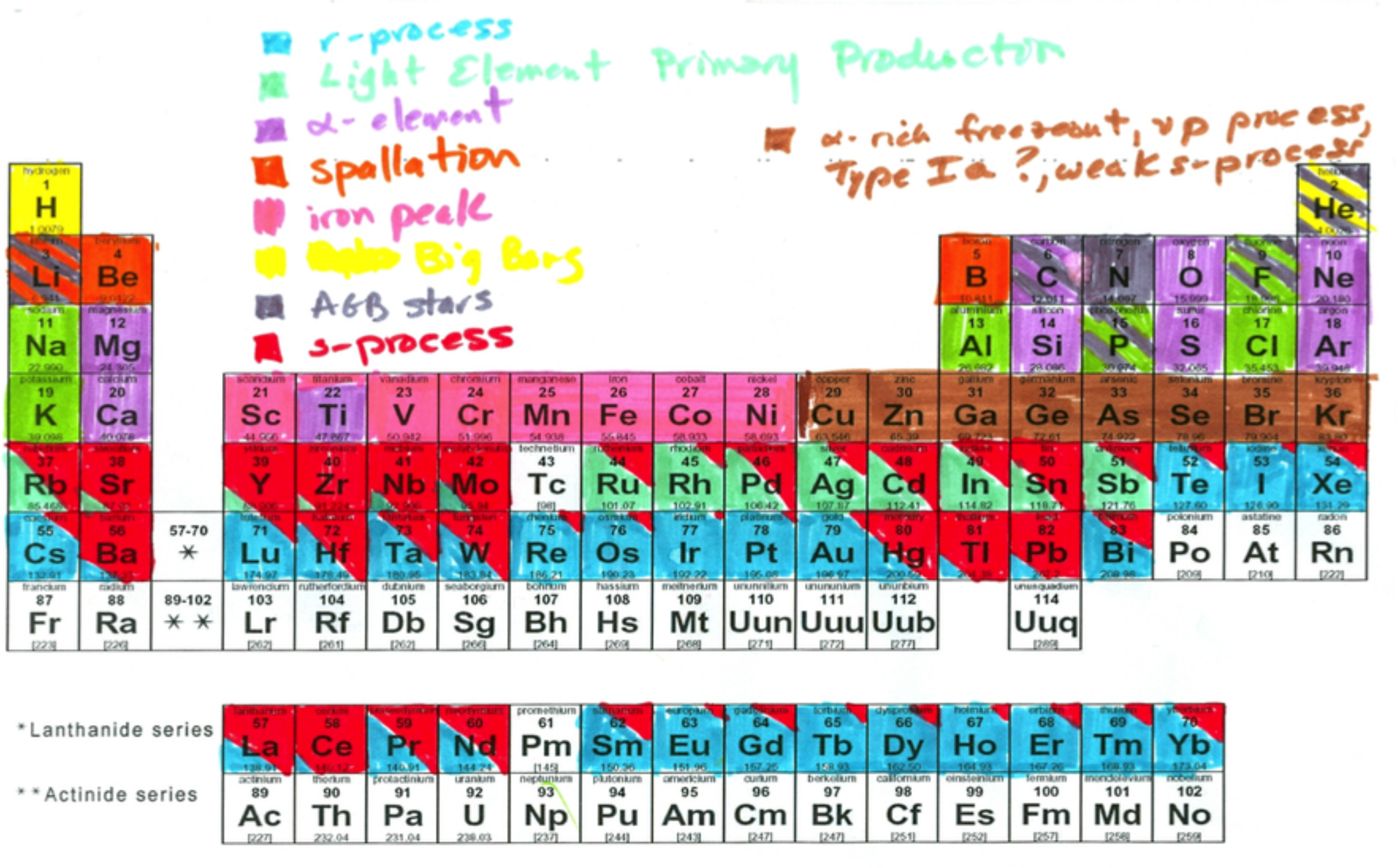
errors

~1 mÅ (giants)

~3 mÅ (dwarfs)

< 0.05 dex

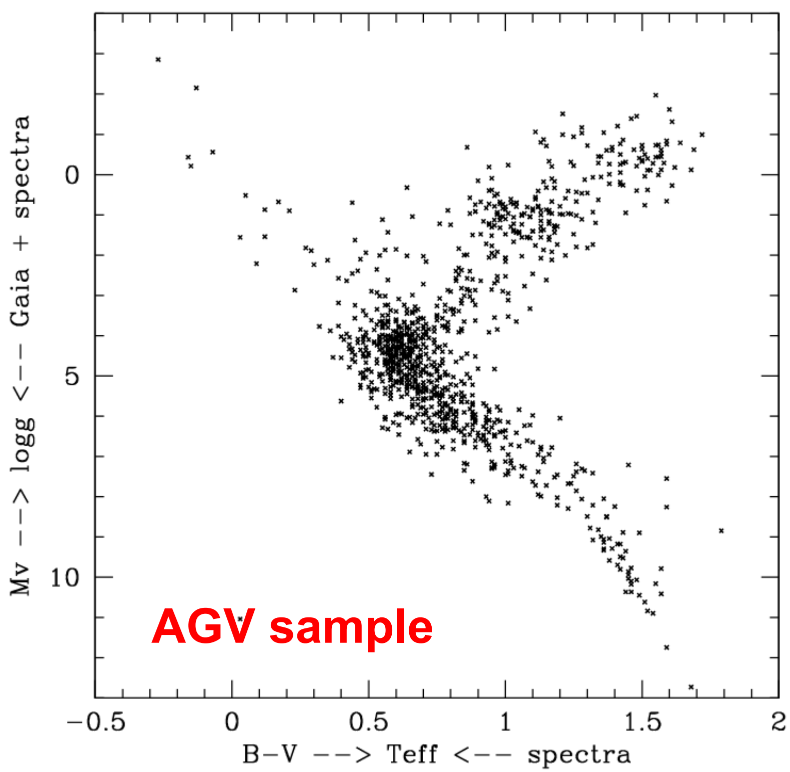
Large spectral coverage, high resolution, high S/N → **accurate abundances**

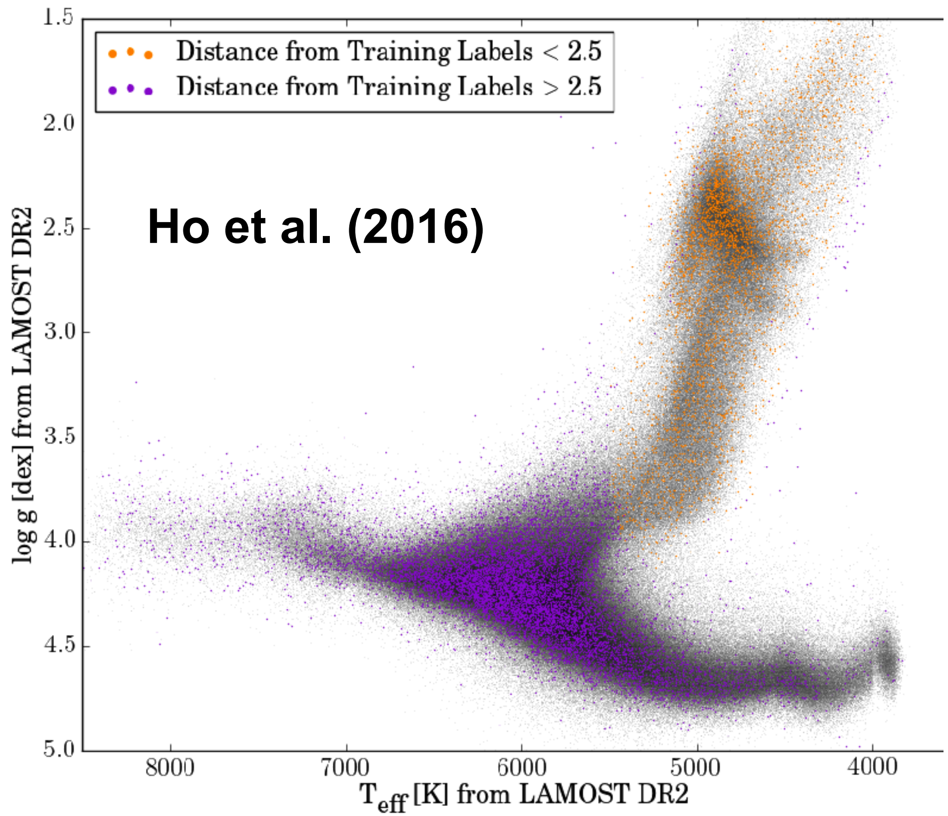


(colouring by Jennifer Johnson and Inese Ivans)

Accurate distances (and space velocities) from Gaia + precise abundances

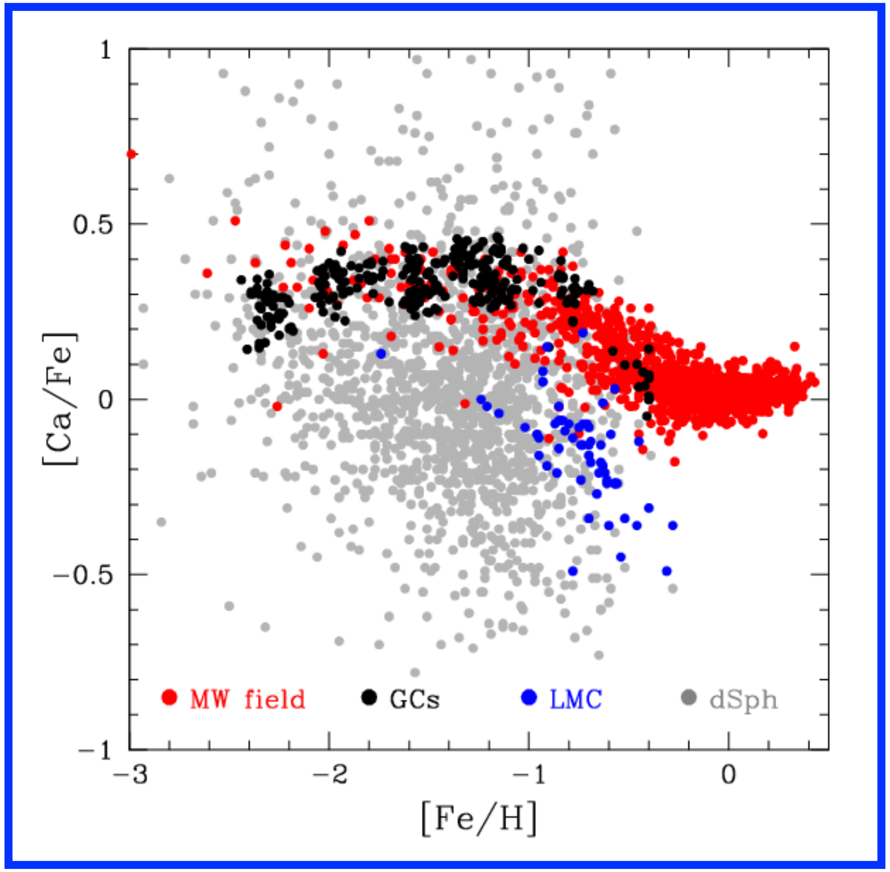
AGV: reference sample for calibrating other, lower resolution, spectroscopic surveys and GCE models

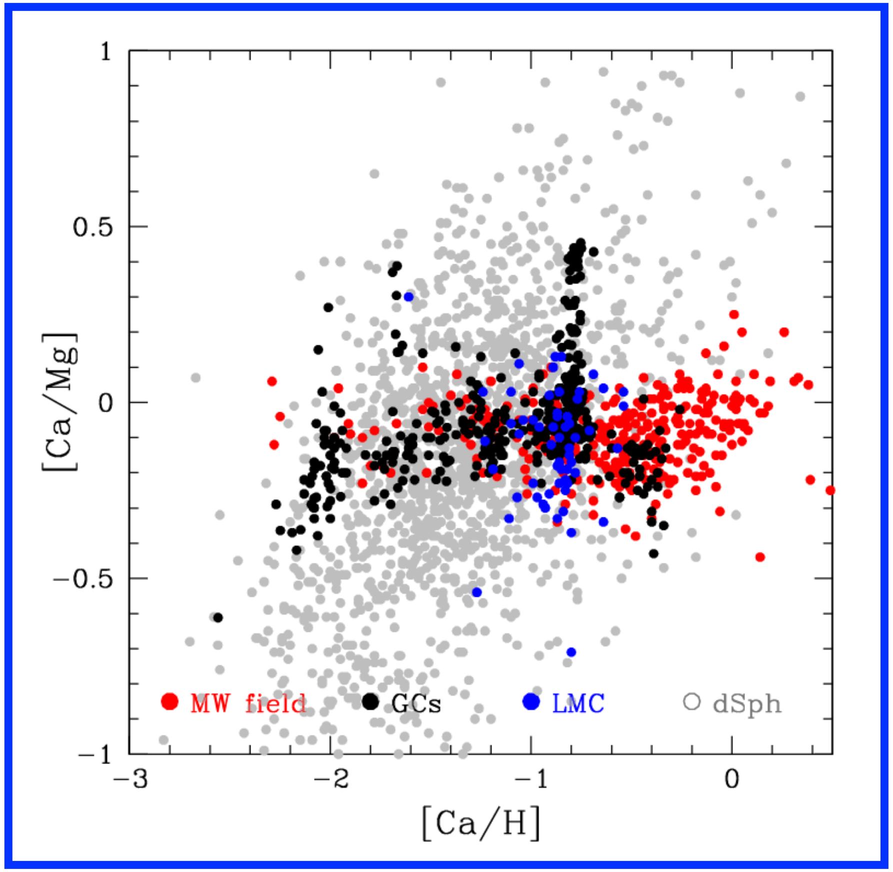




[Ca/Fe] may resolve GC stars from dSph stars, not from field halo MW stars

[Ca/Mg] may resolve extreme second generation GC stars from field halo MW stars





Adibekyan et al. (2012), Chen (2000), Gratton et al. (2003), Jonsell et al. (2005), Pompeia et al. (2008), Carretta et al. (2010), Kirby et al. (2011)