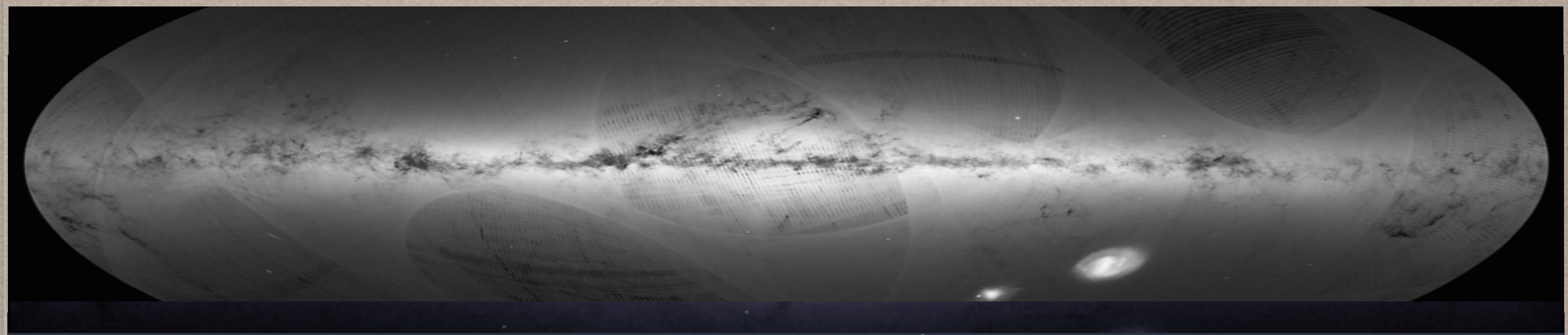
Low-alpha stars in the halo and the bulge from Gaia-ESO Survey data



A. Recio-Blanco

Collaborators: G. Kordopatis, A. Rojas-Arriagada & GES

Lab. Lagrange, Obs. Côte d'Azur

The Gaia-ESO Survey

VLT data

High-resolution spectroscopic survey

UVES (R~40000) 10^4 stars in the solar neighbourhood

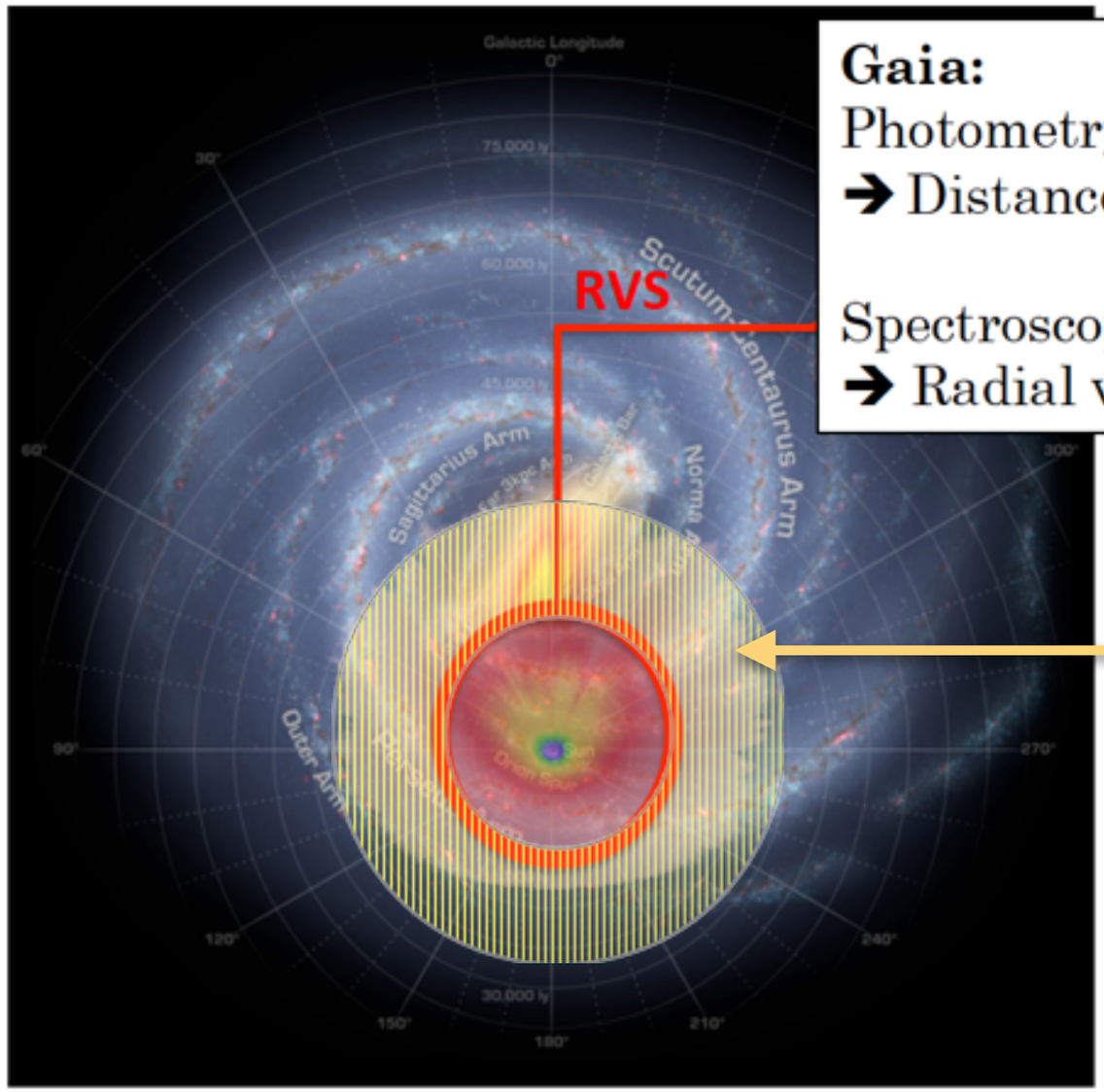
GIRAFFE (R~20000) 10^5 field and open cluster stars

Start: 2012, 5.5 years of observations

P.I.s G. Gilmore & S. Randich

The Gaia-ESO Survey

The Data Release 4



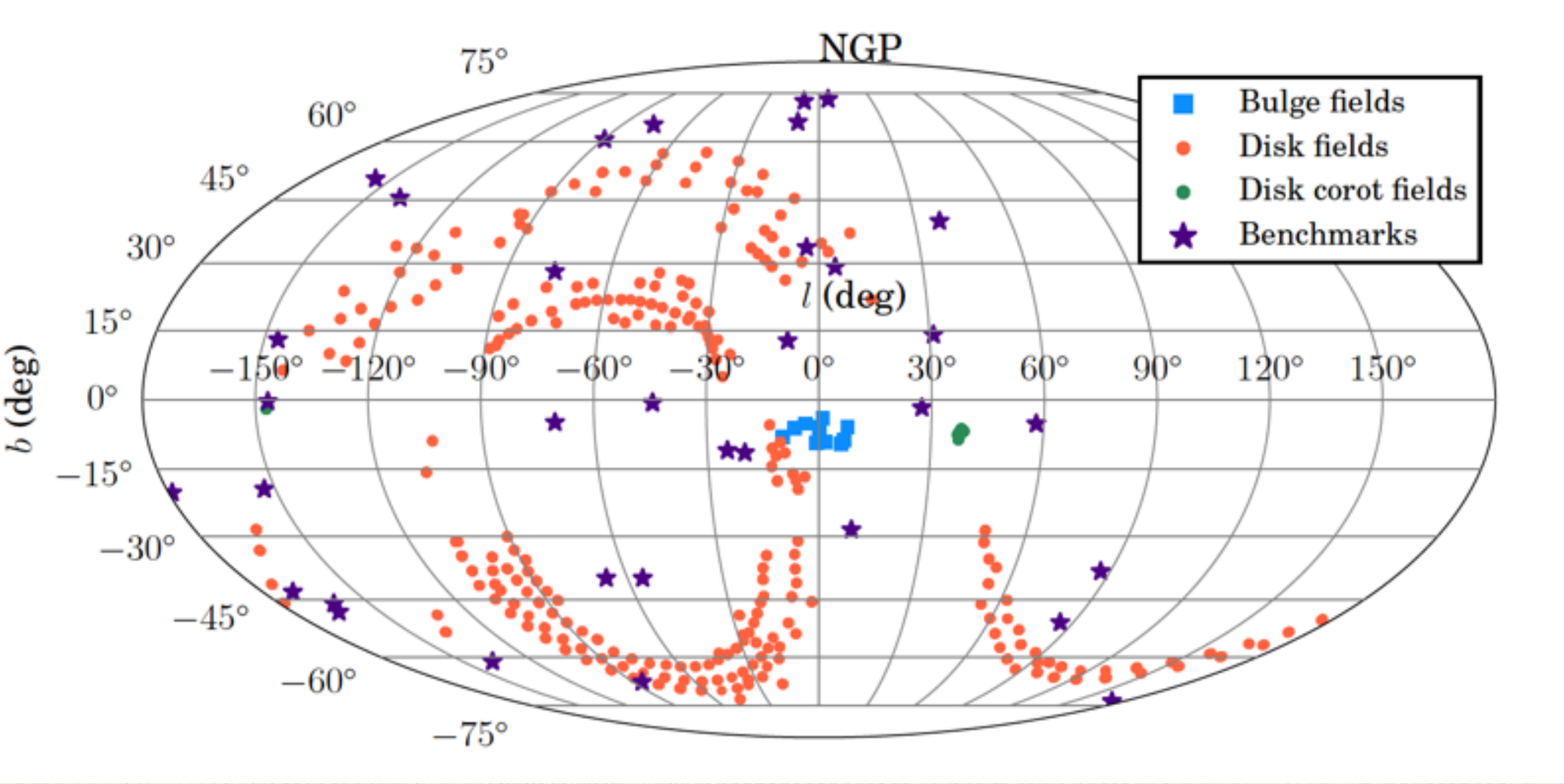
Gaia:
Photometry, astrometry: V<19
➔ Distances, proper motions

Spectroscopy: V<16
➔ Radial velocity, abundances

GES spectroscopy

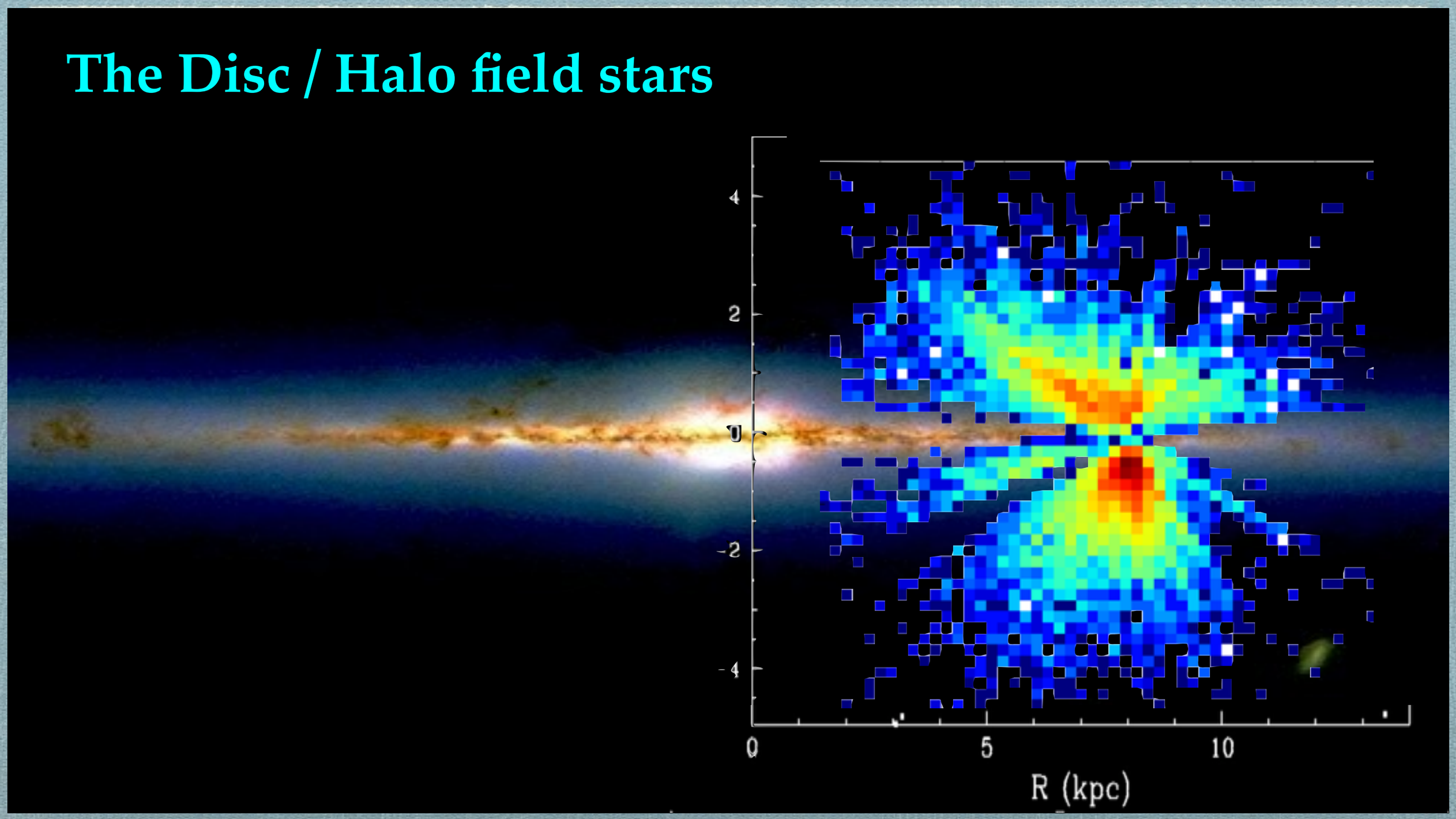
The Gaia-ESO Survey

The Data Release 4

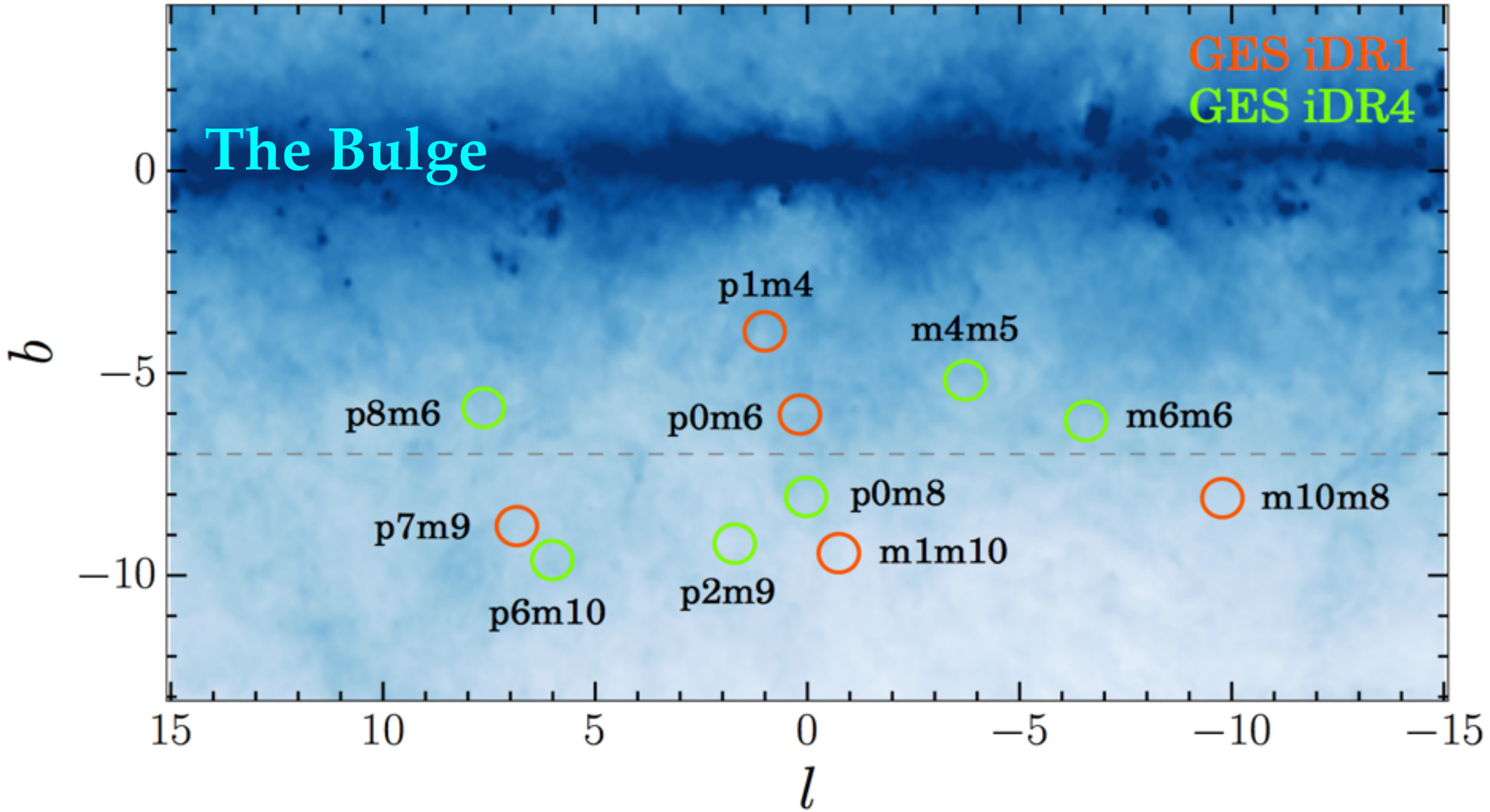


The Gaia-ESO Survey

The Disc / Halo field stars

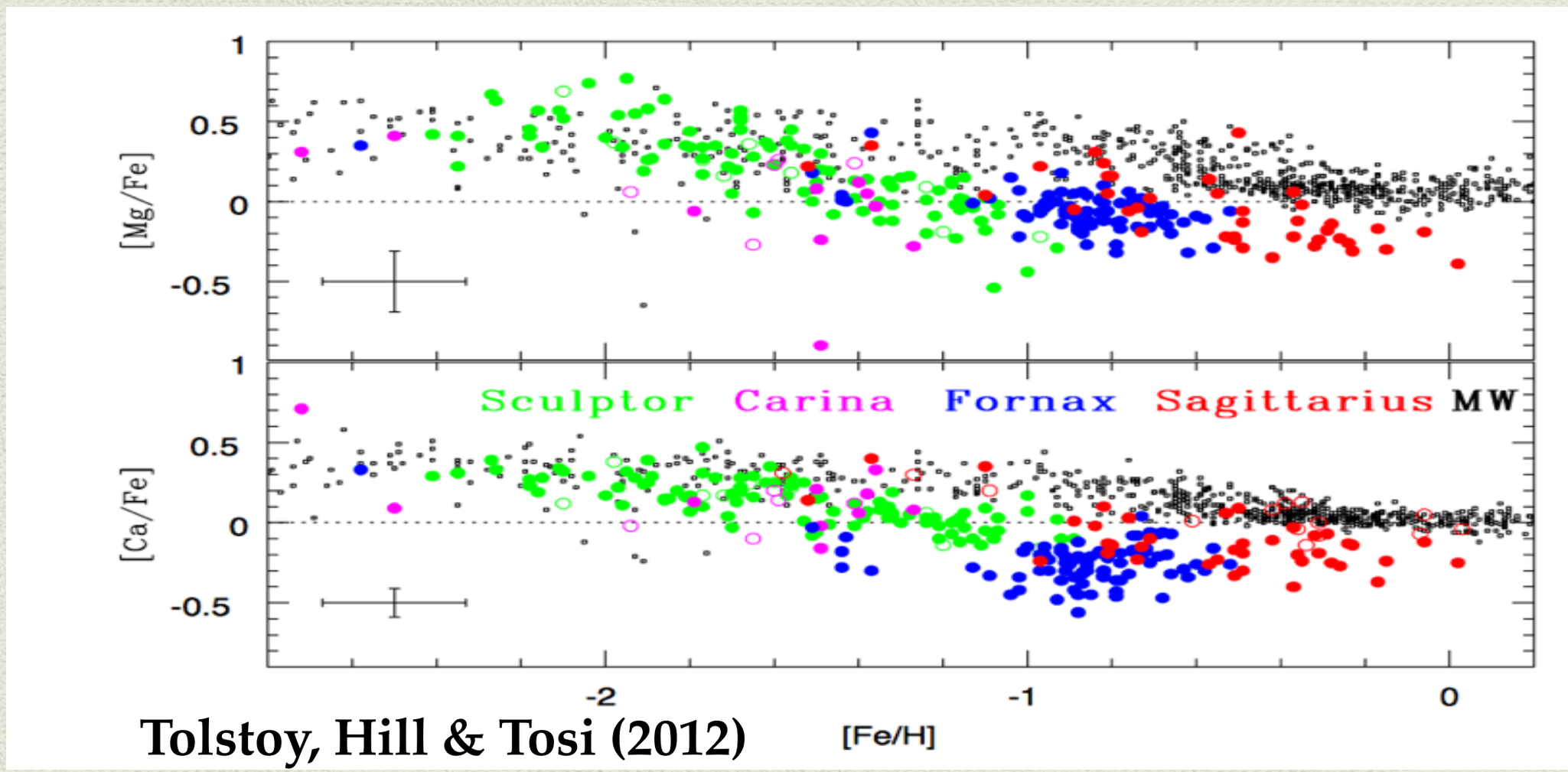


The Gaia-ESO Survey



Why « anomalous » low-α stars ?

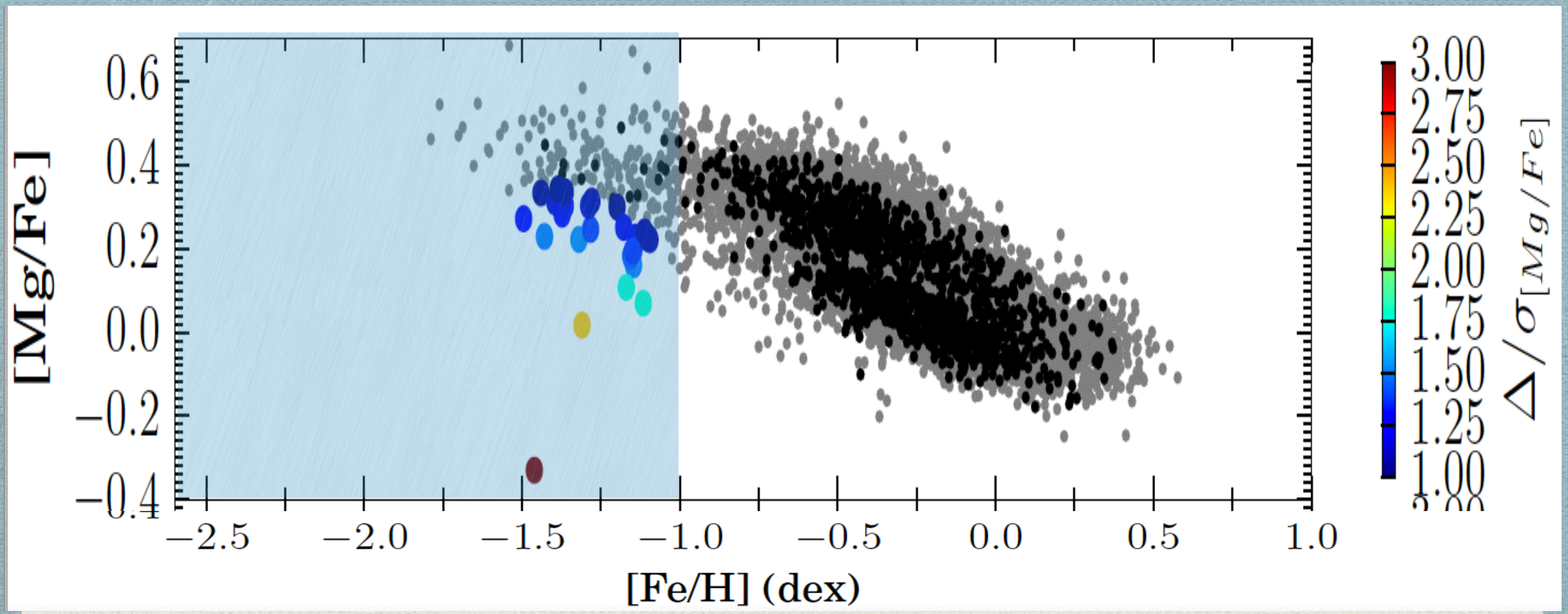
- Fingerprint of lower SFR environnements like dwarf galaxies
- Estimate the importance of accreted stars in the halo
- Analyse the substructure of a system



Tolstoy, Hill & Tosi (2012)

Why « anomalous » low-α stars ?

The halo



Typical [Mg/Fe] measurement dispersions (3 methods)= 0.04 dex

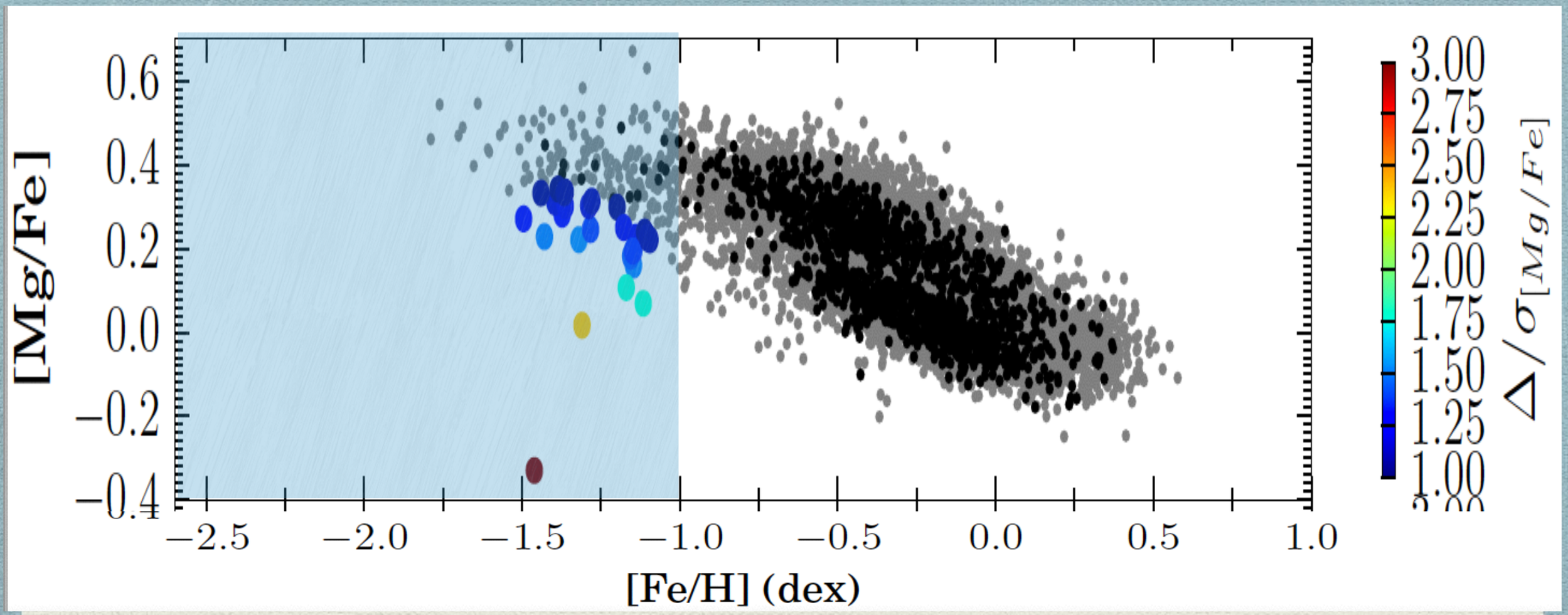
Median [Mg/Fe] value = 0.37 dex

Δ = [Mg/Fe]* - median_[Mg/Fe]

Spread for [Fe/H]<1 dex: 1σ=0.23 dex

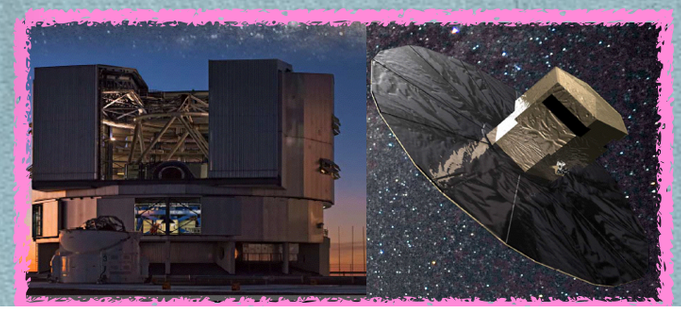
Why « anomalous » low-α stars ?

The halo

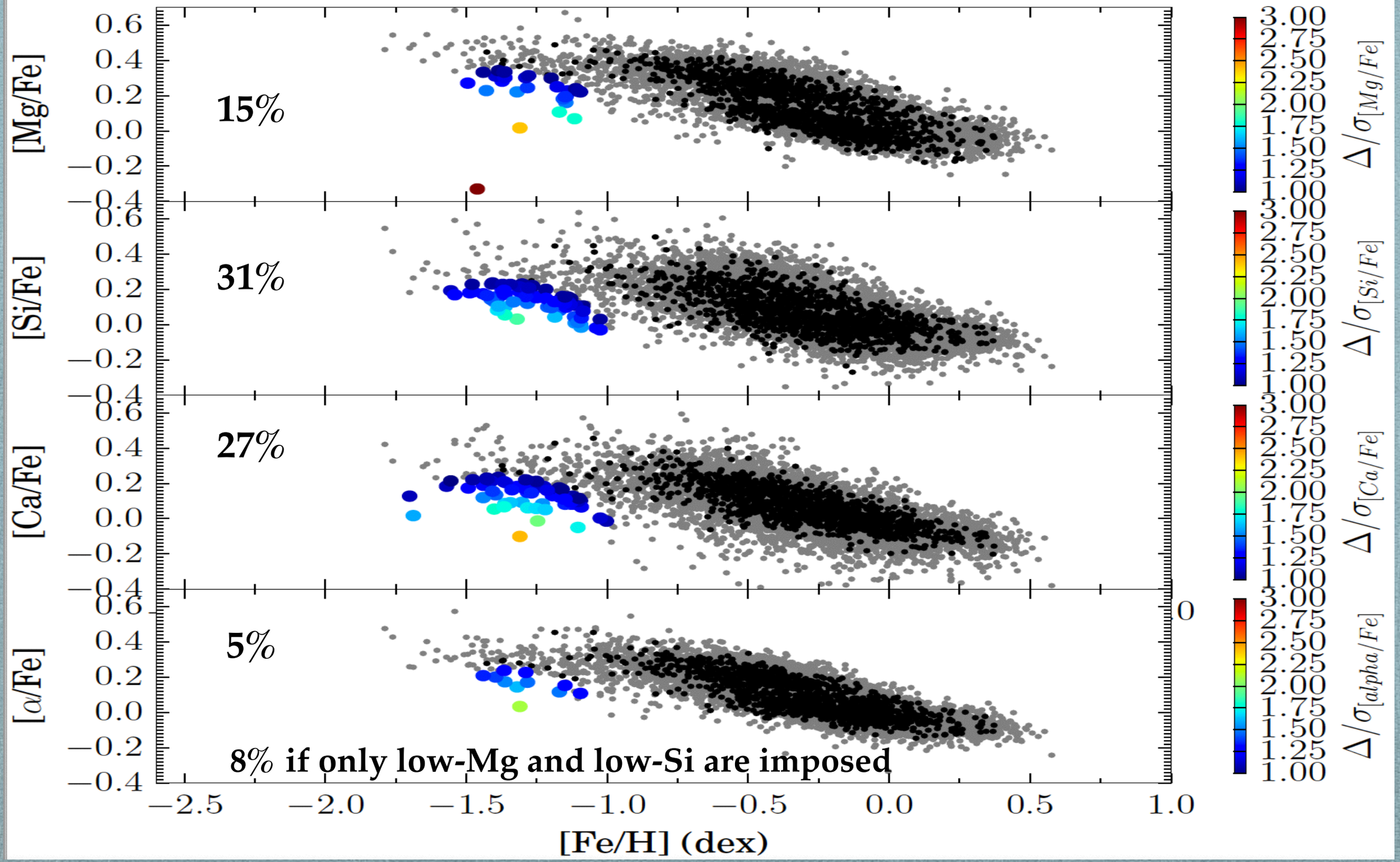


	[Mg/Fe]	[Si/Fe]	[Ca/Fe]
Measurement dispersions	0.04 dex	0.04	0.05
Median [Mg/Fe] value	0.37 dex	0.25	0.24
Spread for [Fe/H]<1 dex	0.23 dex	0.24	0.24

Why « anomalous » low-α stars ?



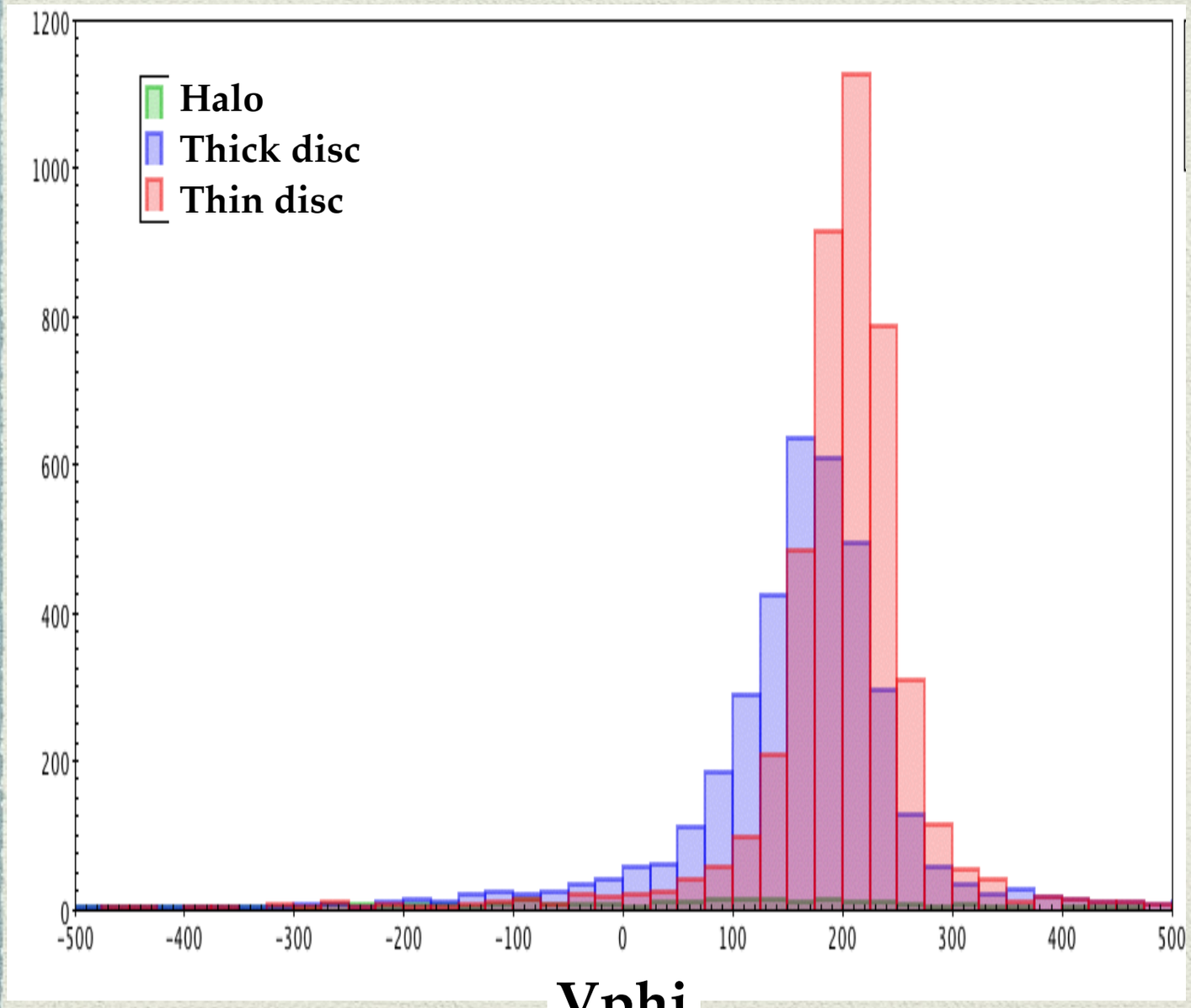
The halo

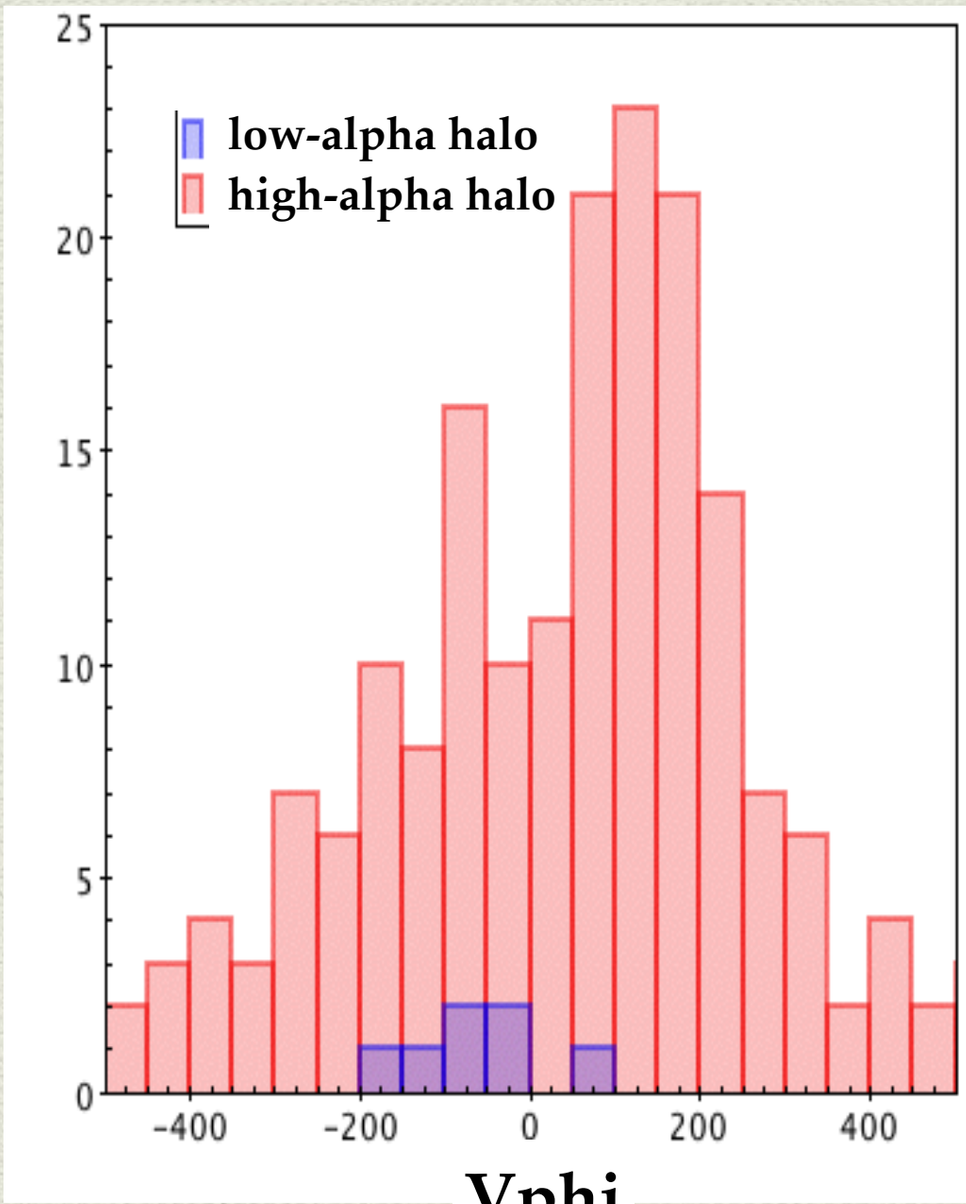


Why « anomalous » low-α stars ?

The halo

Kinematics: low-alpha stars have a halo Vphi distribution



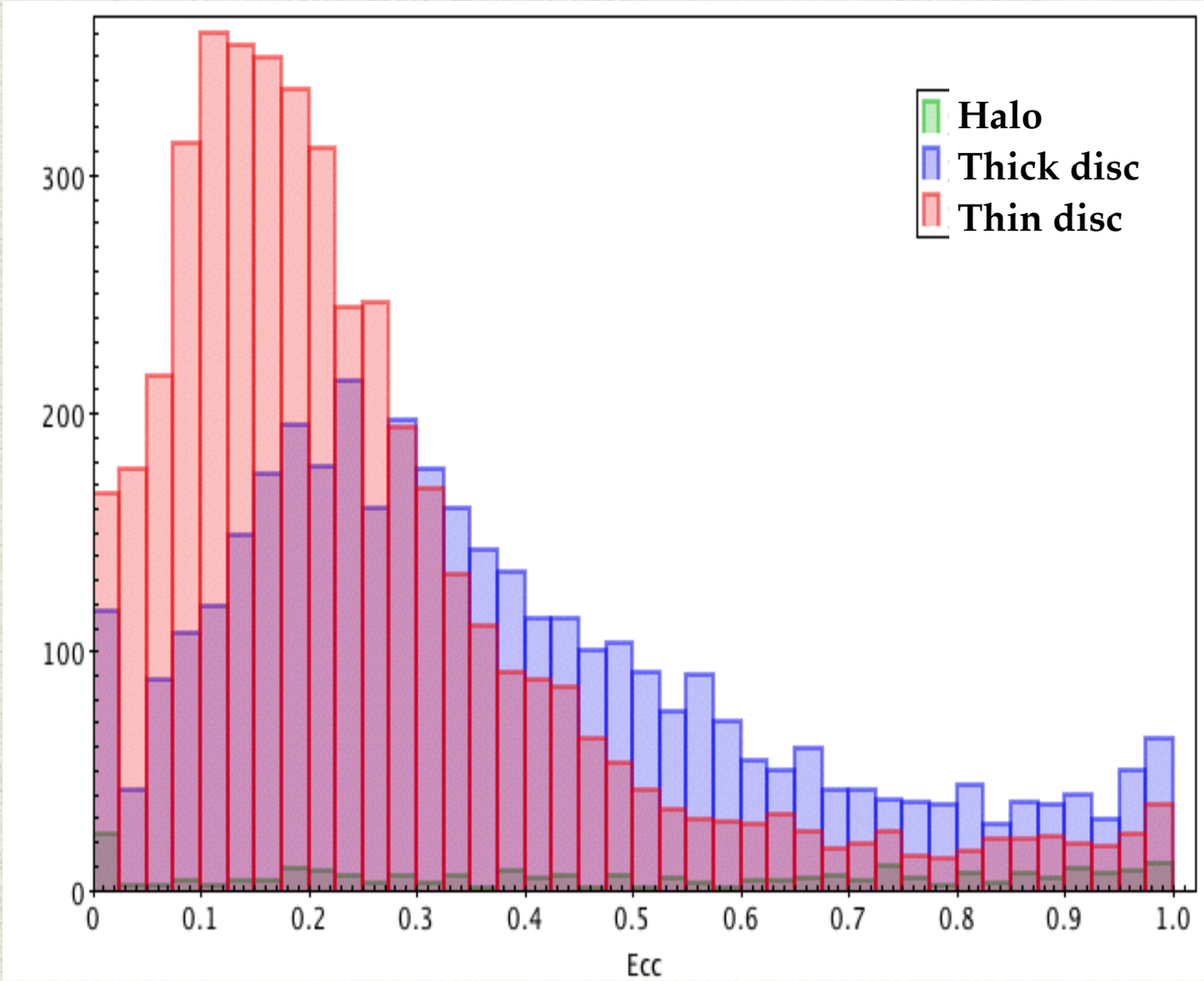


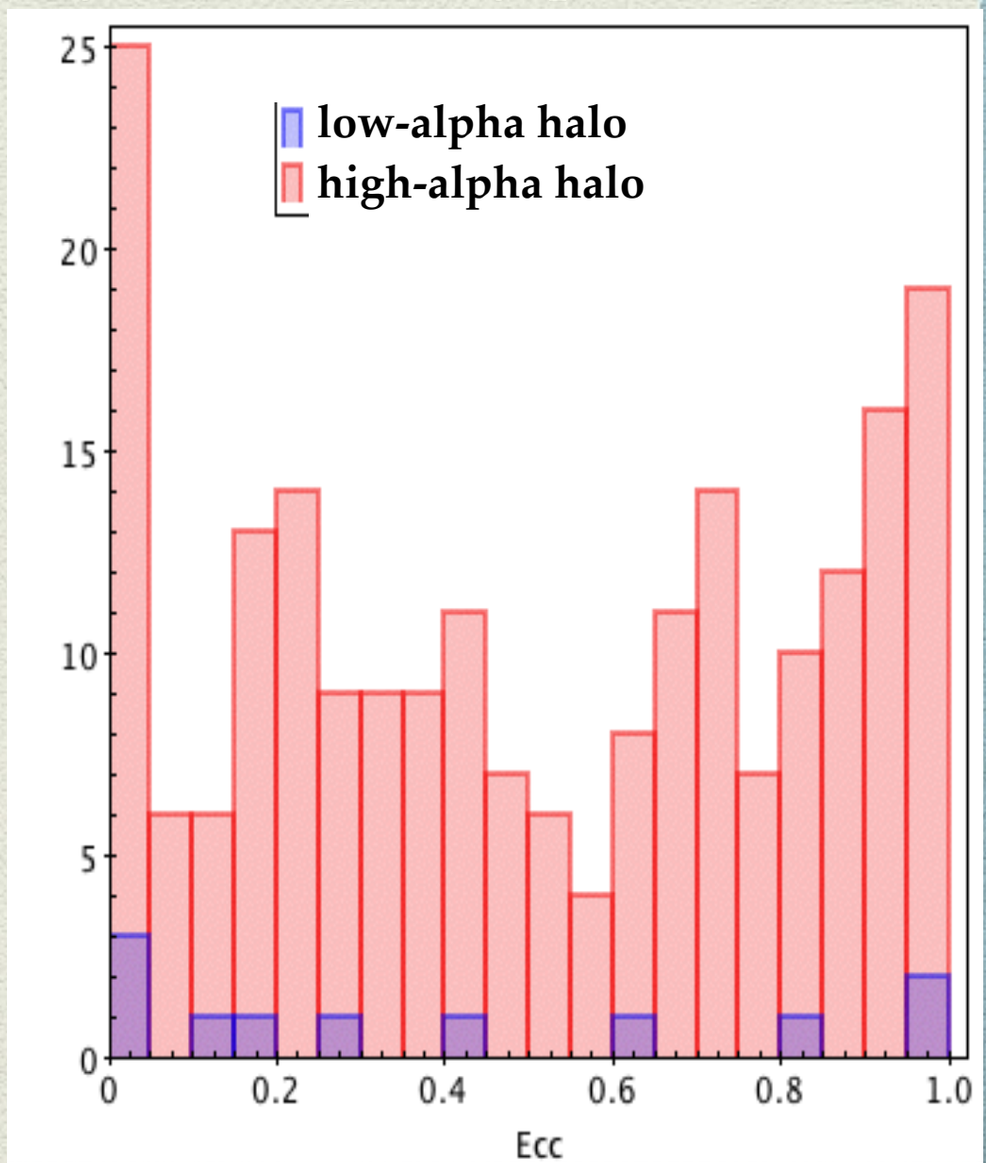
Why « anomalous » low-α stars ?

The halo

Orbital parameters: low-alpha stars have a halo Ecc distribution

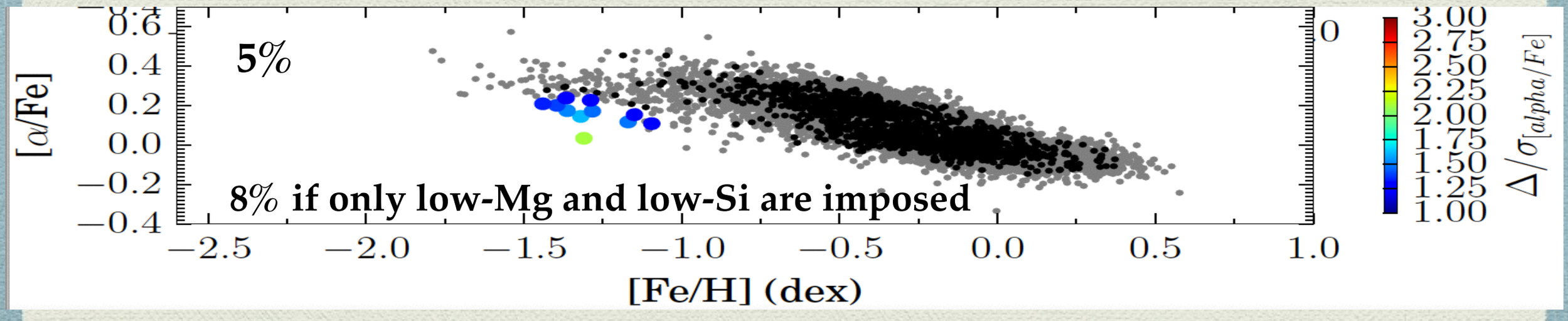
Binney (2012) program with Dehnen & Binney (2002) galaxy potential





Why « anomalous » low-α stars ?

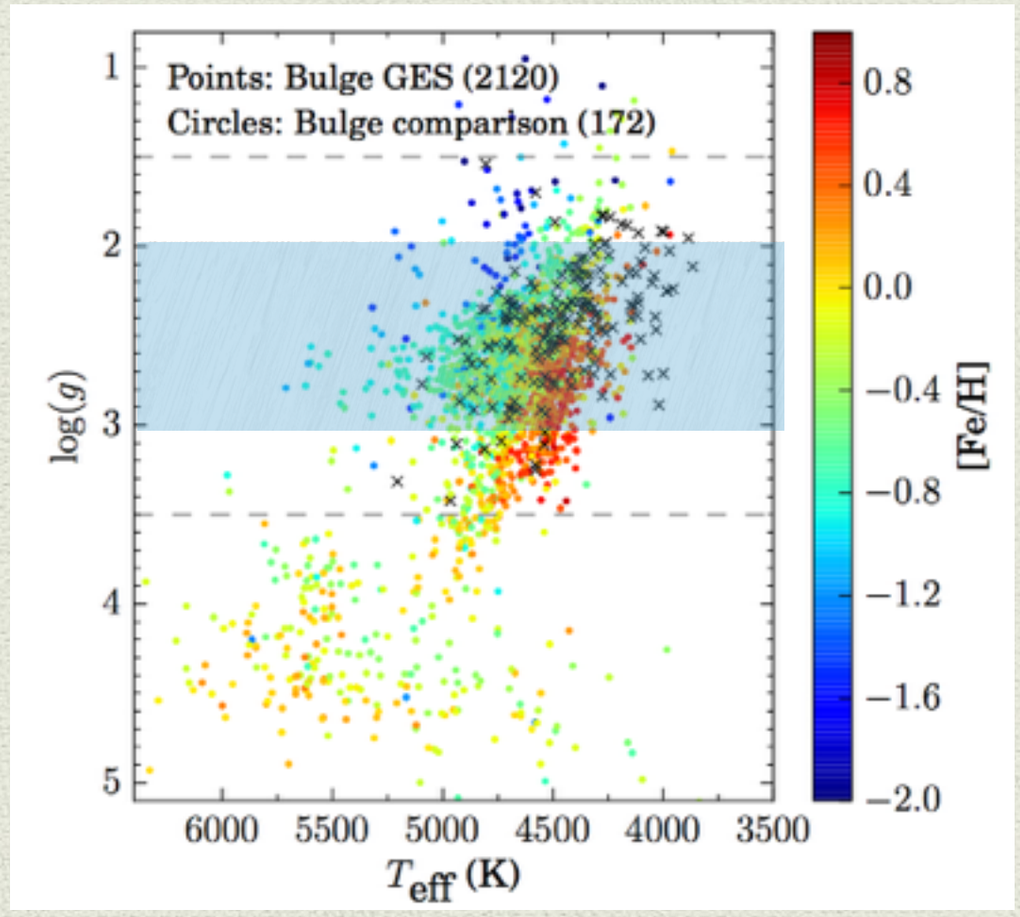
The halo: SUMMARY

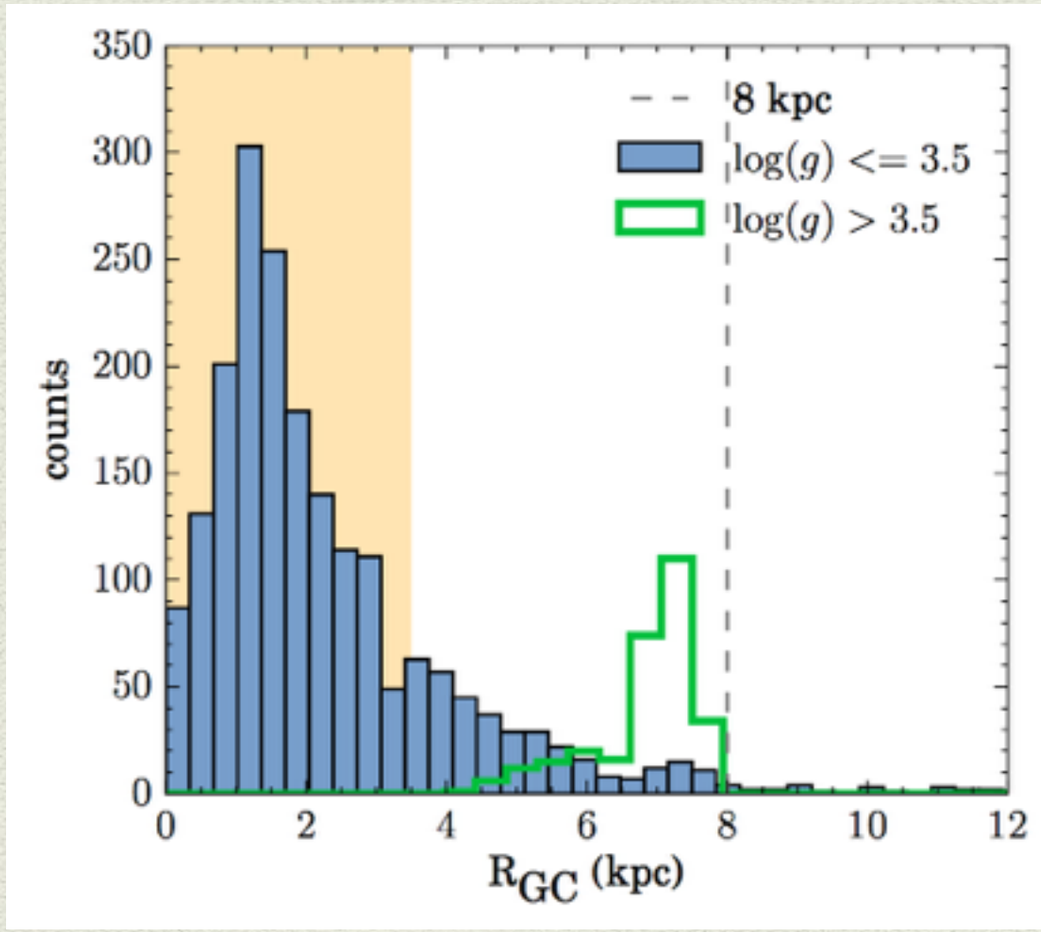


- **(Very) small contribution of dwarf galaxies** to inner halo formation < 10%
- Previous estimation (Jackson-Jones et al. 2015) using global [α/Fe] of DR1 ~28%, compatible with our estimation using one element only
- In agreement with estimations using RR-lyrae photometry Fiorentino et al. (2015)

Why « anomalous » low-α stars ?

The bulge

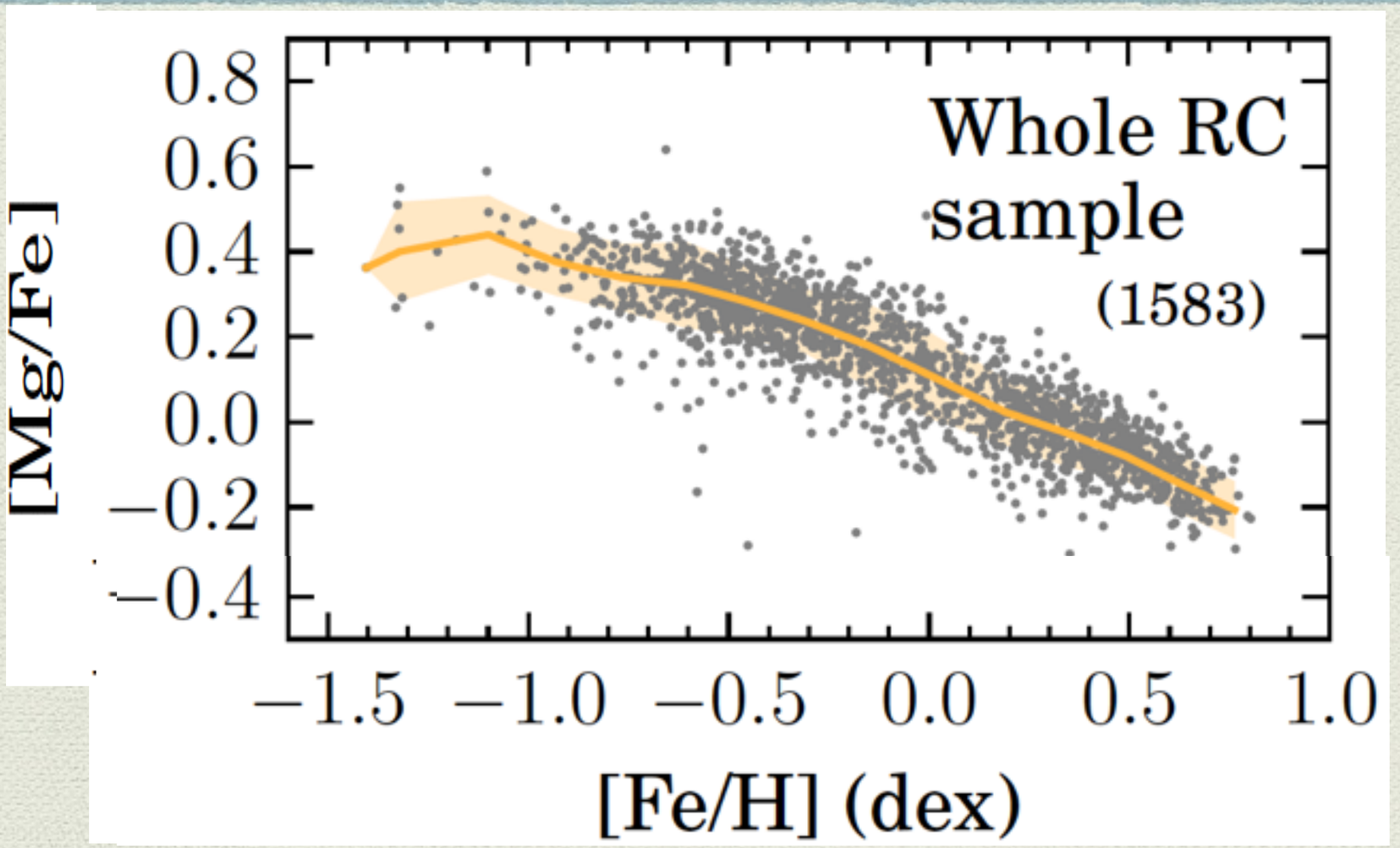




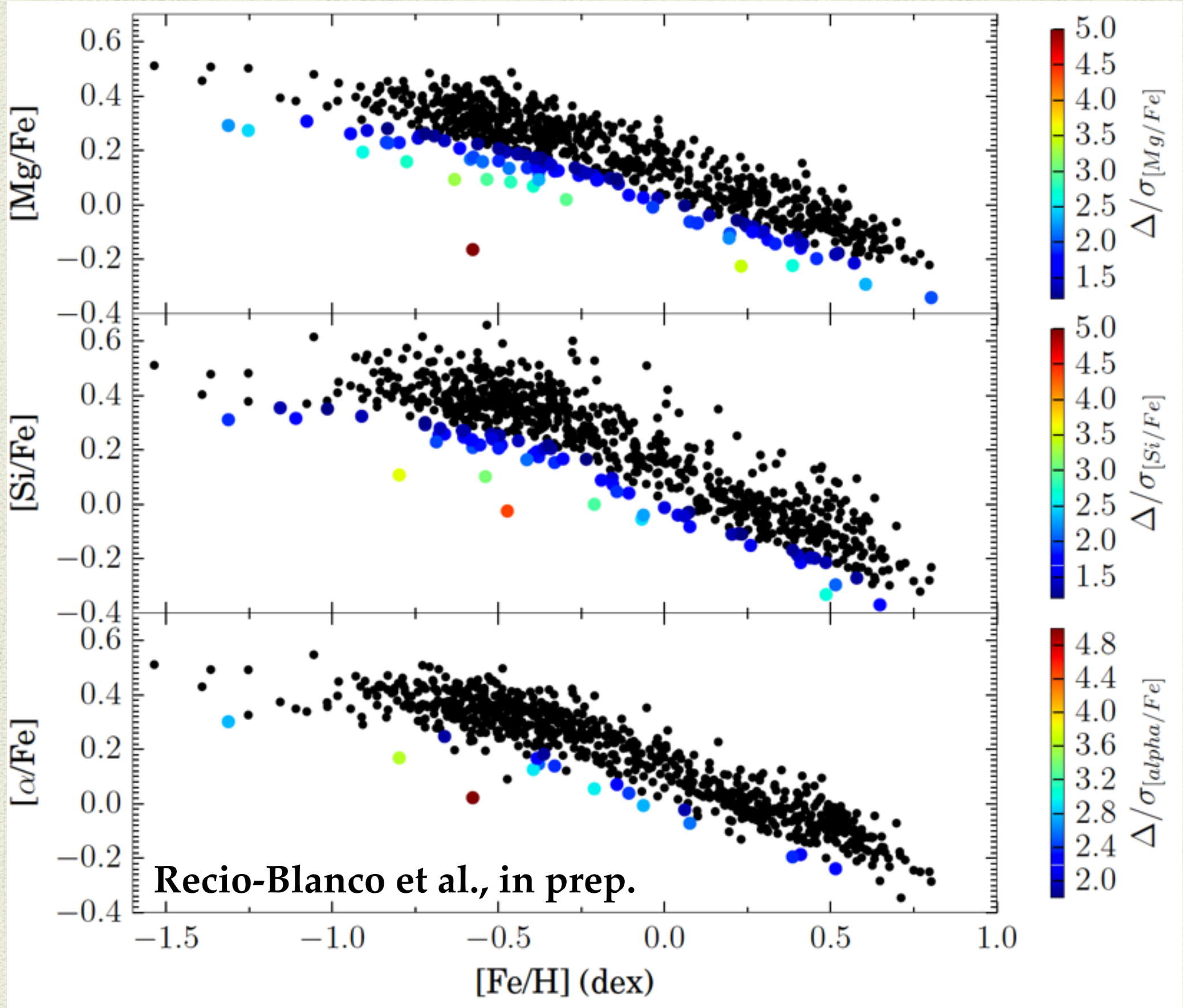
Rojas-Arriagada et al. (2016, submitted)

Why « anomalous » low-α stars ?

The bulge



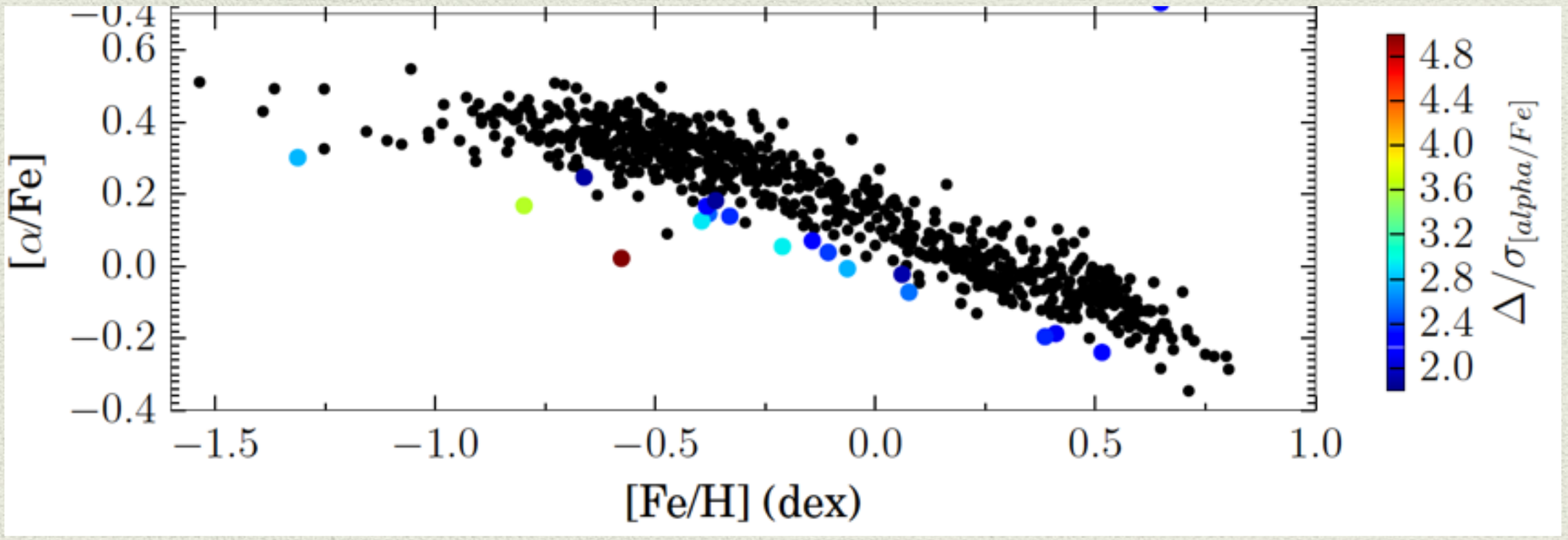
How homogeneous is this sequence?
Is there any substructure?
Is there a single evolutionary path or more?


[Mg/Fe]
[Si/Fe]
[α/Fe]
[Fe/H] (dex)
Δ/σ[Mg/Fe]
Δ/σ[Si/Fe]
Δ/σ[alpha/Fe]
Recio-Blanco et al., in prep.

Why « anomalous » low-α stars ?

The bulge

2% of stars with [alpha/Fe] lower than the standard values with underabundances > 2 sigma



Why « anomalous » low-α stars ?

The bulge

2% of stars with [alpha/Fe] lower than the standard values with underabundances > 2 sigma

cname	T_{eff}	log g	[Fe/H]	[Mg/Fe]	[Si/Fe]	[Al/Fe]	$\Delta/\sigma[\alpha/Fe]$	setup configuration
18034317-3006349	4819 ± 95	2.65 ± 0.35	-0.38 ± 0.02	0.12 ± 0.06	0.17 ± 0.05	0.23 ± 0.06	2.5	HR10,HR21
18032412-3003001	4674 ± 36	2.39 ± 0.14	-0.66 ± 0.03	0.24 ± 0.02	0.26 ± 0.02	0.26 ± 0.08	2.0	HR10,HR21
17534571-4105165	4354 ± 37	2.06 ± 0.24	-0.39 ± 0.02	0.07 ± 0.06	0.18 ± 0.02	0.49 ± 0.04	2.9	HR21
17553025-4106299	4606 ± 168	2.70 ± 0.26	-0.58 ± 0.02	-0.16 ± 0.08	0.21 ± 0.08	0.34 ± 0.02	5.3	HR21
17562638-4129329	4561 ± 53	2.45 ± 0.42	-0.33 ± 0.05	0.12 ± 0.08	0.15 ± 0.07	0.13 ± 0.09	2.4	HR21
17571064-4145311	4959 ± 87	2.74 ± 0.50	-0.38 ± 0.08	0.14 ± 0.02	0.19 ± 0.07	0.22 ± 0.05	2.2	HR21
17571166-4128521	4553 ± 49	2.55 ± 0.28	-0.06 ± 0.05	0.02 ± 0.09	-0.04 ± 0.06	0.12 ± 0.02	2.8	HR21
17573538-4136125	4809 ± 72	2.48 ± 0.24	-0.80 ± 0.02	0.23 ± 0.02	0.11 ± 0.09	0.16 ± 0.03	3.6	HR21
17582234-3449464	4560 ± 150	2.51 ± 0.59	0.07 ± 0.04	-0.06 ± 0.08	-0.08 ± 0.02	0.22 ± 0.14	2.6	HR21
18030869-2956389	4607 ± 105	2.78 ± 0.45	-0.11 ± 0.07	0.03 ± 0.09	0.04 ± 0.03	0.27 ± 0.04	2.4	HR21
18033088-3003563	4551 ± 43	2.71 ± 0.08	0.41 ± 0.02	-0.16 ± 0.05	-0.21 ± 0.02	0.00 ± 0.03	2.1	HR21
18035188-3005558	4574 ± 65	2.86 ± 0.28	-0.21 ± 0.08	0.11 ± 0.02	0.00 ± 0.09	0.21 ± 0.03	3.0	HR21
18233838-3413015	4625 ± 64	2.98 ± 0.29	0.38 ± 0.07	-0.22 ± 0.03	-0.17 ± 0.02	-0.08 ± 0.04	2.4	HR21
18244002-2449329	5000 ± 216	2.83 ± 0.52	-1.31 ± 0.08	0.29 ± 0.03	0.31 ± 0.02	—	2.8	HR21
18250175-2514127	4463 ± 91	2.79 ± 0.08	0.51 ± 0.02	-0.18 ± 0.08	-0.29 ± 0.04	0.02 ± 0.02	2.3	HR21
18251816-2529497	4663 ± 45	2.78 ± 0.37	-0.36 ± 0.07	0.16 ± 0.04	0.20 ± 0.03	—	2.0	HR21
18352178-2659169	4636 ± 57	2.85 ± 0.33	0.06 ± 0.03	0.00 ± 0.02	-0.04 ± 0.04	0.17 ± 0.06	2.0	HR21
18360308-2716364	4664 ± 36	2.43 ± 0.28	-0.14 ± 0.06	0.09 ± 0.03	0.04 ± 0.08	0.25 ± 0.07	2.2	HR21

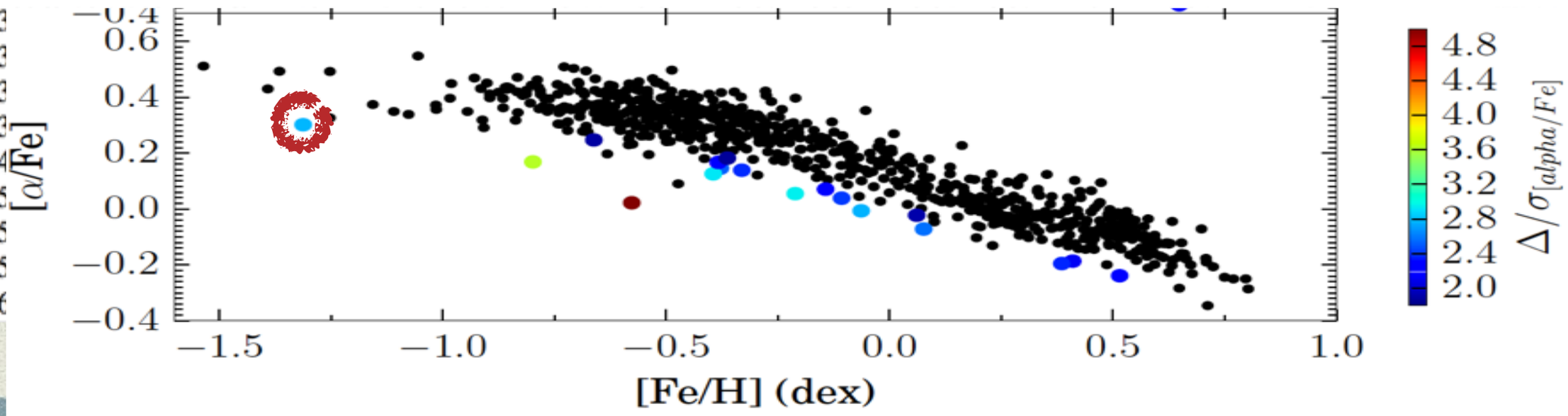
Why « anomalous » low-α stars ?

The bulge

2% of stars with [alpha/Fe] lower than the standard values with underabundances > 2 sigma

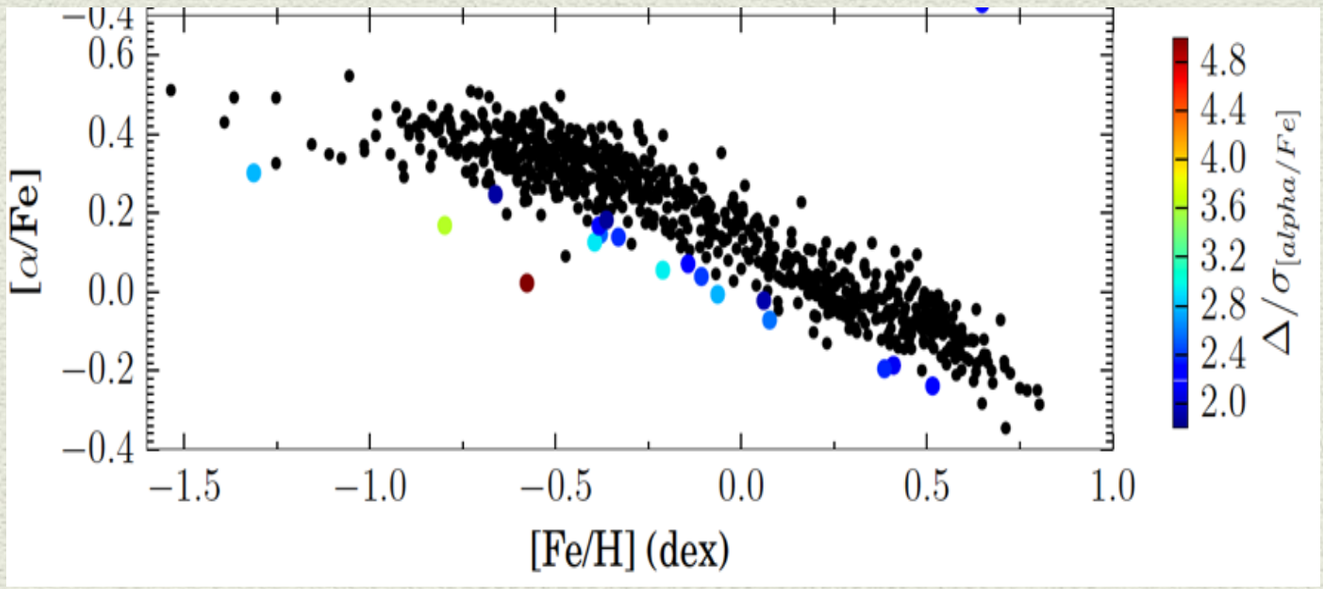
cname	T_{eff}	log g	[Fe/H]	[Mg/Fe]	[Si/Fe]	[Al/Fe]	$\Delta/\sigma[\alpha/Fe]$	setup configuration
18034317-3006349	4819 ± 95	2.65 ± 0.35	-0.38 ± 0.02	0.12 ± 0.06	0.17 ± 0.05	0.23 ± 0.06	2.5	HR10,HR21
18032412-3003001	4674 ± 36	2.39 ± 0.14	-0.66 ± 0.03	0.24 ± 0.02	0.26 ± 0.02	0.26 ± 0.08	2.0	HR10,HR21
17534571-4105165	4354 ± 37	2.06 ± 0.24	-0.39 ± 0.02	0.07 ± 0.06	0.18 ± 0.02	0.49 ± 0.04	2.9	HR21
17553025-4106299	4606 ± 168	2.70 ± 0.26	-0.58 ± 0.02	-0.16 ± 0.08	0.21 ± 0.08	0.34 ± 0.02	5.3	HR21
17562								
17571								
17571								
17573								
17582								
1803								
1803								
1803								
1823								
1824								
1825								
1825								
1835								
1836								

Two stars in Baade's Window: agreement with [Mg/Fe] estimations of Hill et al. (2011)

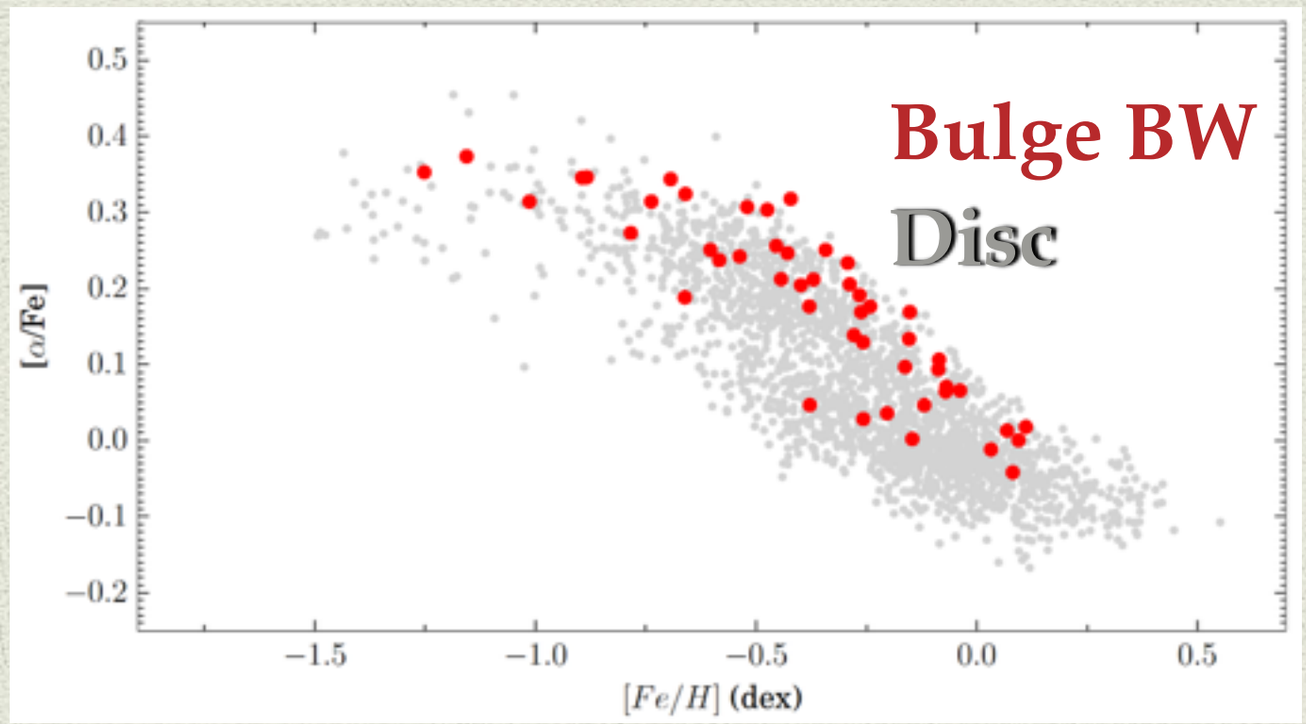


Why « anomalous » low-α stars ?

The bulge



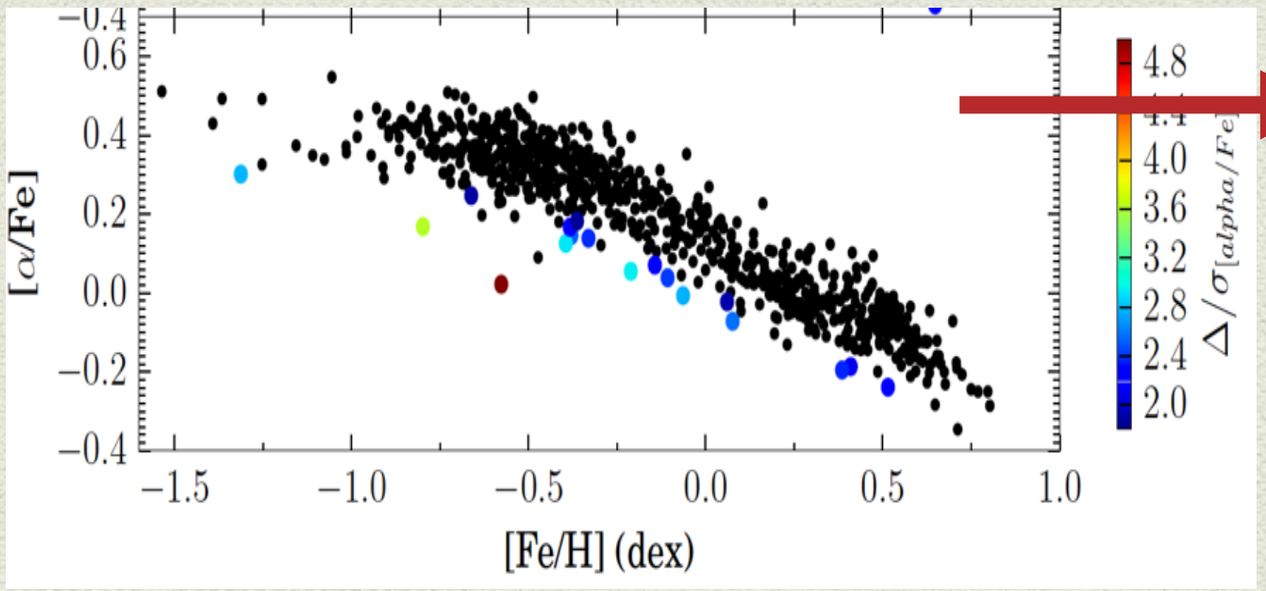
General bulge sample in HR21 (only Mg and Si)

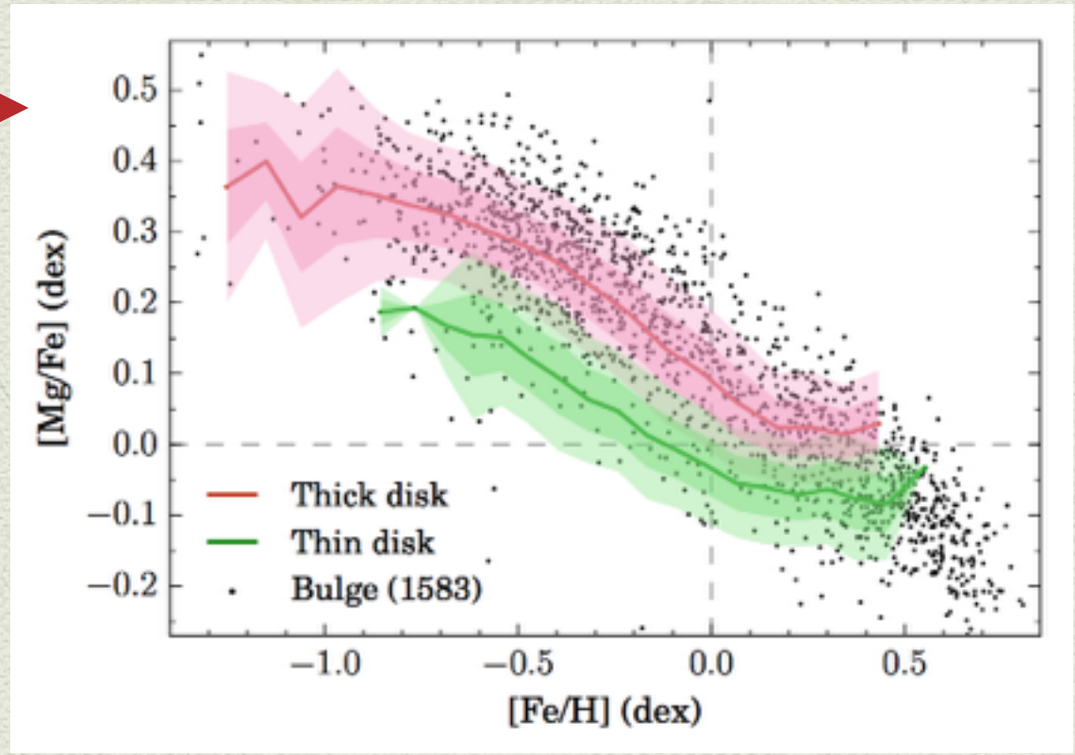


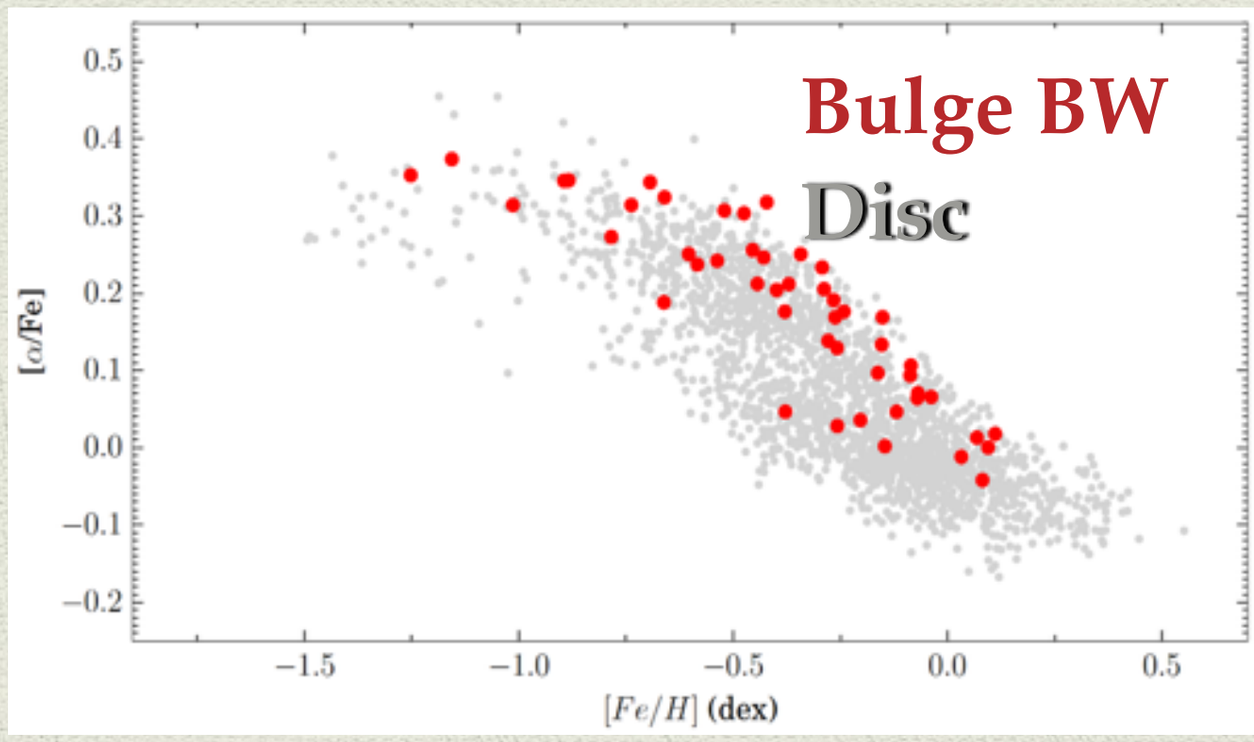
Baade's Window sample in HR21+HR10
~40 stars with three alpha-elements (Mg, Si and Ca)

Why « anomalous » low-α stars ?

The bulge







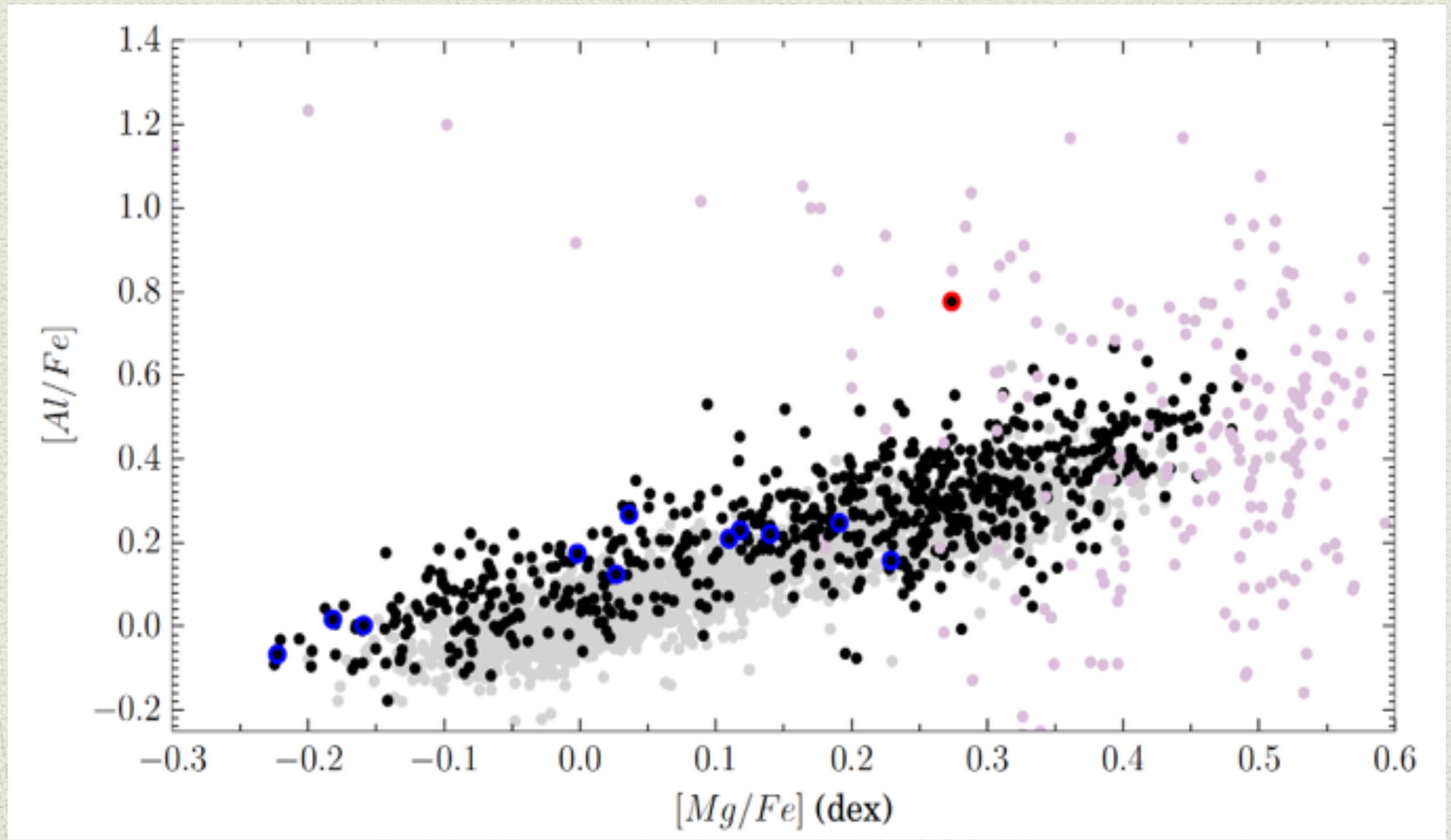
Not a single [α/Fe]-sequence?

What about globular clusters contribution?

Why « anomalous » low-α stars ?

The bulge

Looking for Al-Mg anticorrelation signature of Globular Cluster *escapées* stars … one star!

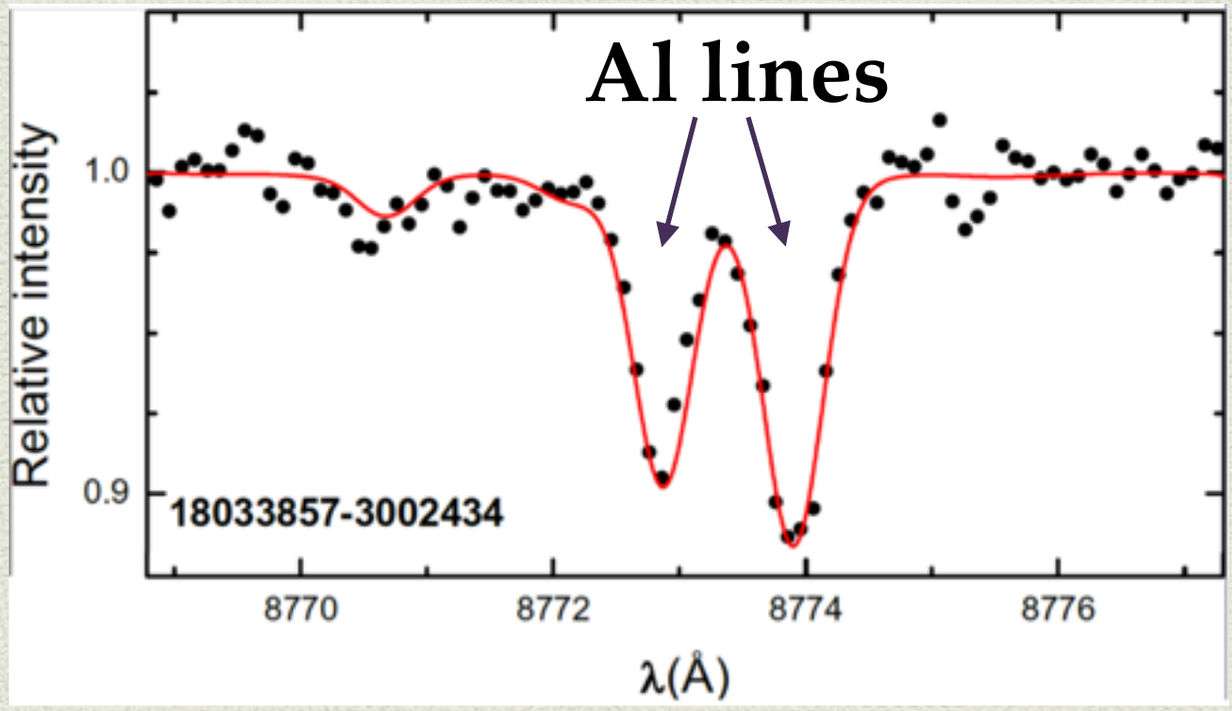


Most low-α stars have typical disc [Al/Mg] ratios

Why « anomalous » low-α stars ?

The bulge

Looking for Al-Mg anticorrelation signature of Globular Cluster *escapées* stars … one star!



- Clean normalisation & sky substraction

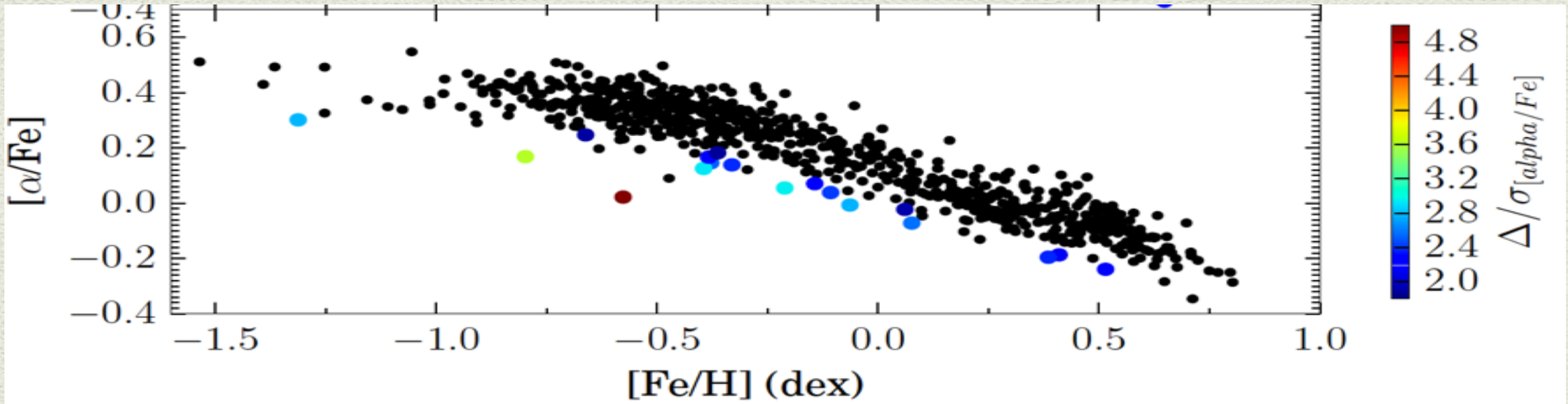
- **Al-rich and Mg-poor (but not Si-poor or Ca-poor)**

cname	T_{eff}	log *g*	[Fe/H]	[Mg/Fe]	[Si/Fe]	[Al/Fe]	$\Delta/\sigma[\alpha/Fe]$	setup configuration
18033857-3002434	4869 ± 130	2.66 ± 0.38	-1.25 ± 0.03	0.27 ± 0.03	0.38 ± 0.07	0.78 ± 0.03	2.0	HR10,HR21

Why « anomalous » low-α stars ?

The bulge: SUMMARY

Recio-Blanco et al., in prep.



- **Evidence of low-α stars in the bulge**
- **Evidence of possible globular clusters contribution** (in agreement with Schiavon et al. (2016)
- **Reinforces the picture of a composite nature of the Bulge**

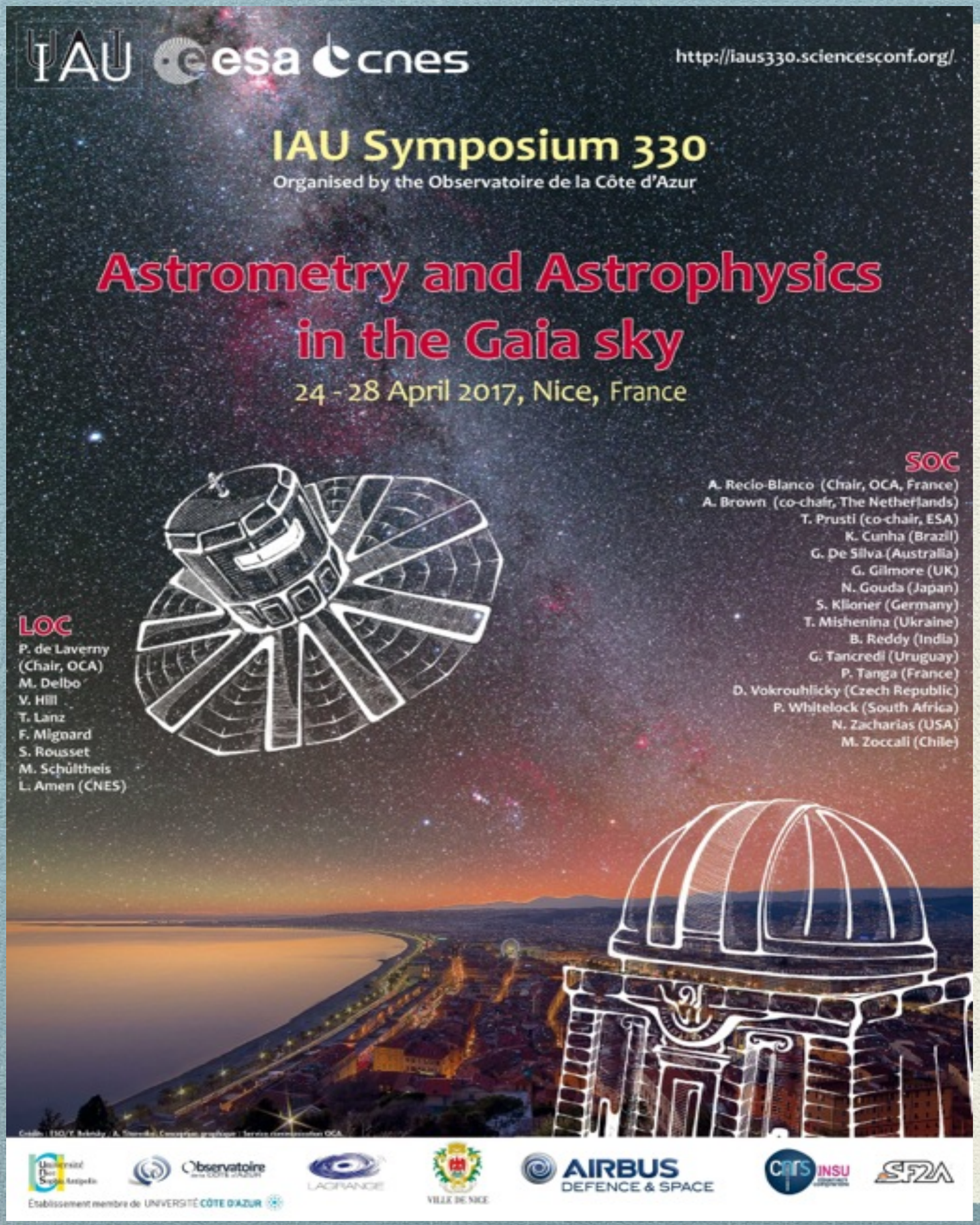
Why « anomalous » low-α stars ?

General considerations on data

- **Individual abundances measurements have several (complex!) sources of errors**

- **To look for outliers and substructure it is important:**

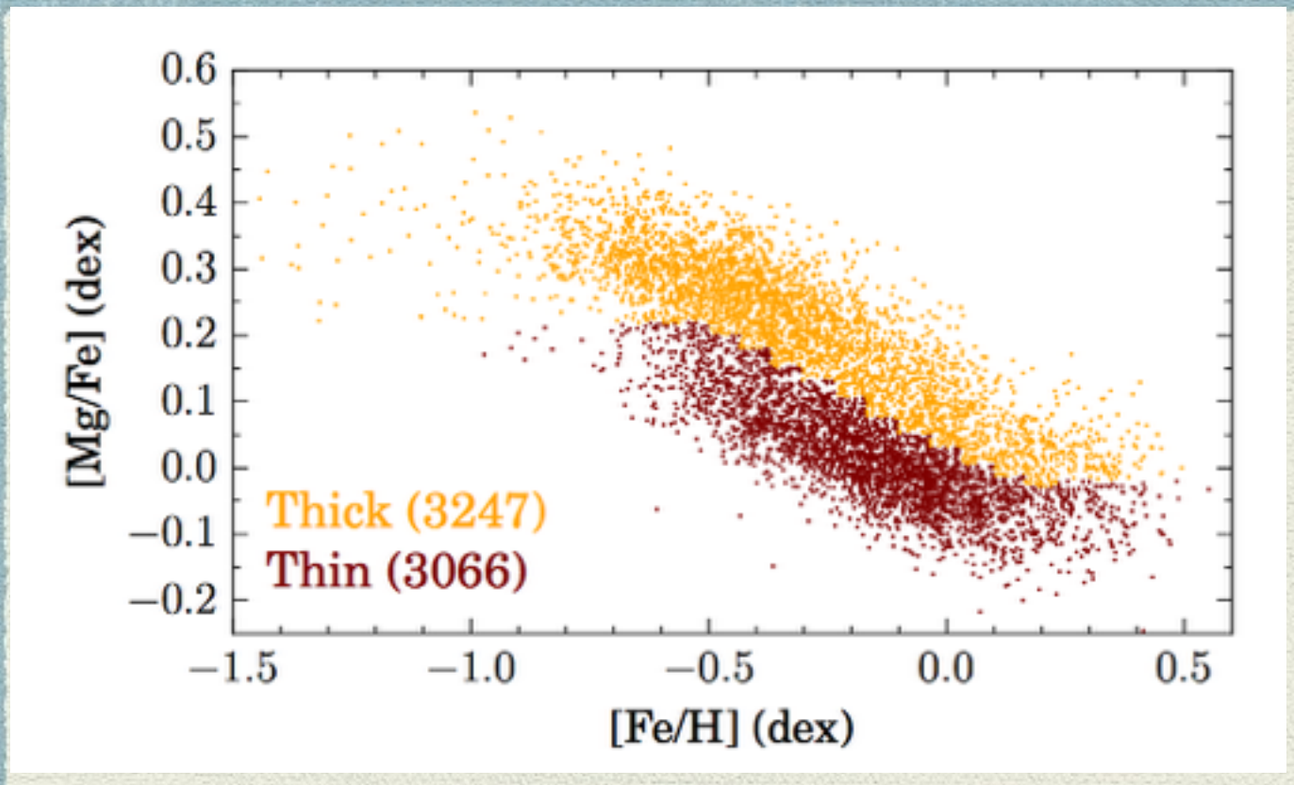
  1. **to combine / crosscheck several measurements**
  2. **to consider several elements of the same « family »**
  3. **no to rely on data-driven methods (that work in a closed environnement of knowledge)**

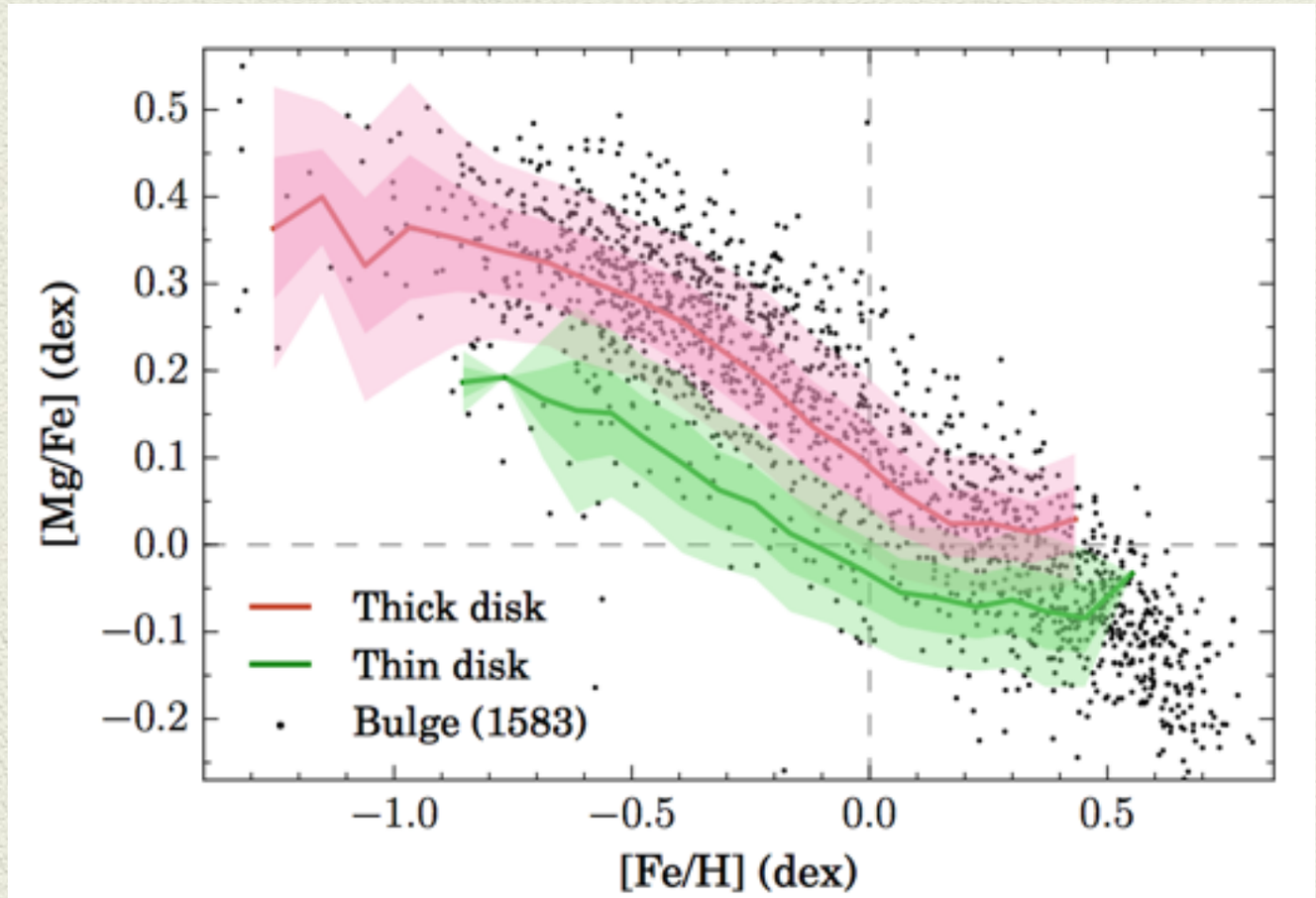


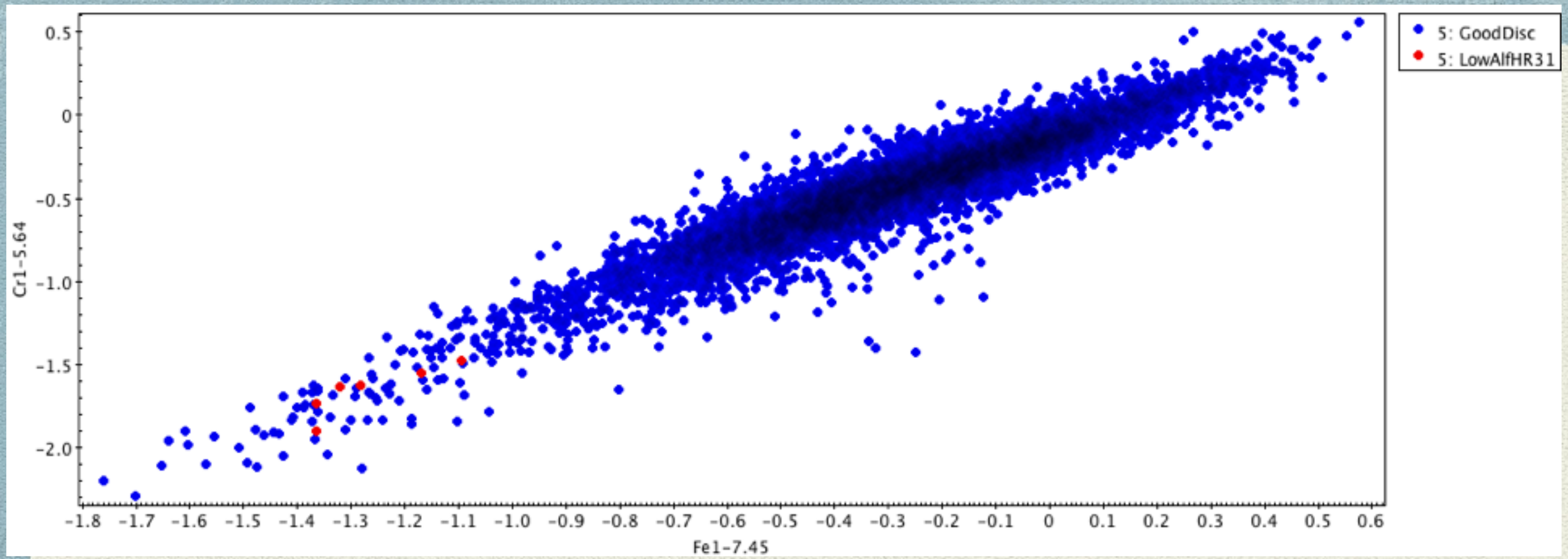
First IAU Symposium of the Gaia era

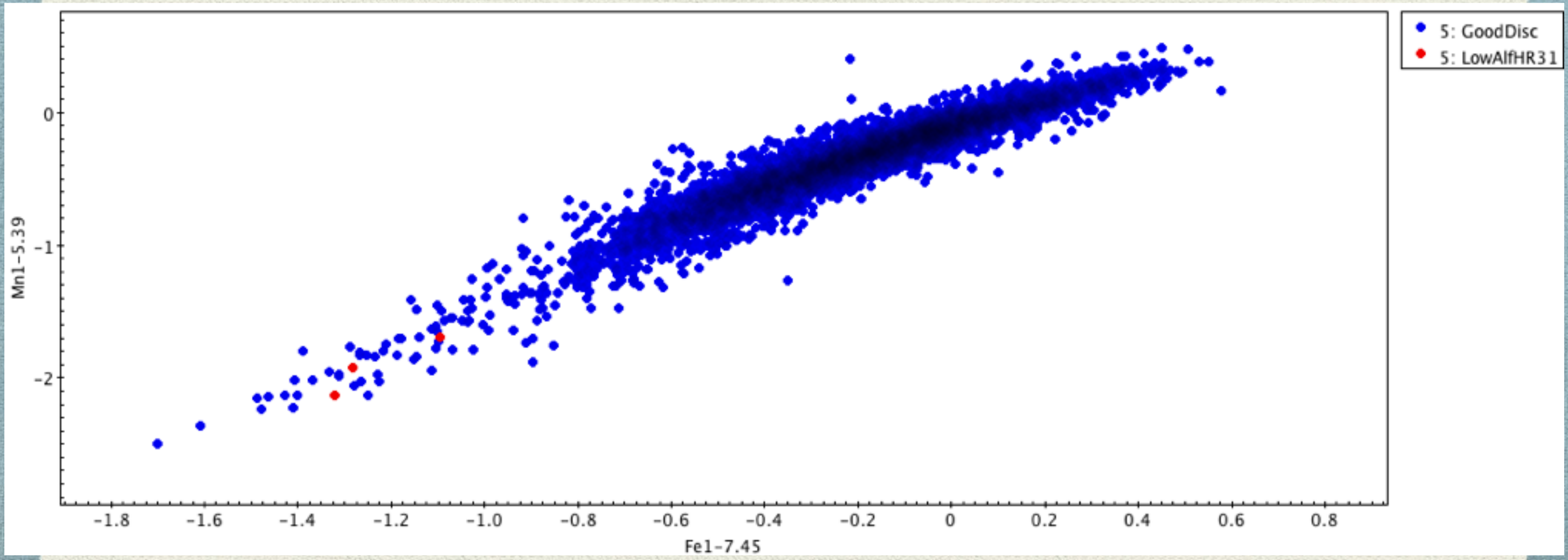
- IAU grants deadline: 1st Nov.
- Abstracts deadline: 4th Dec.

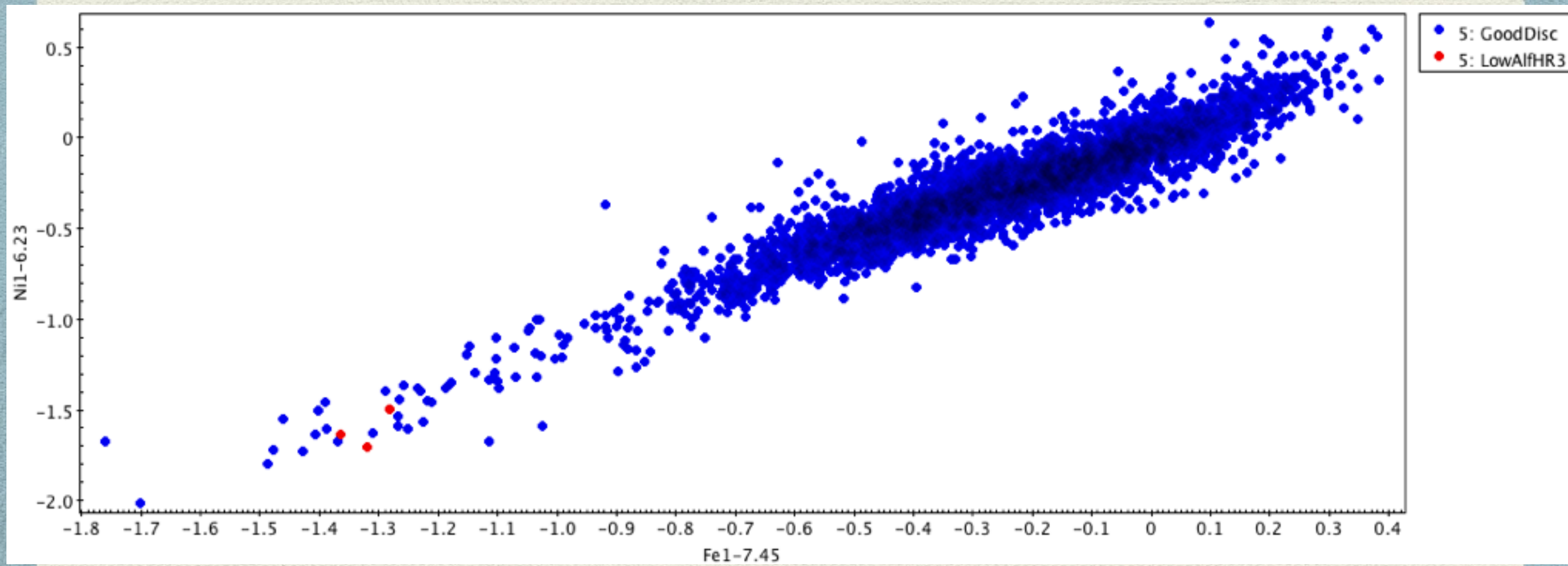
Rendez-vous in the French Côte d'Azur next spring !!

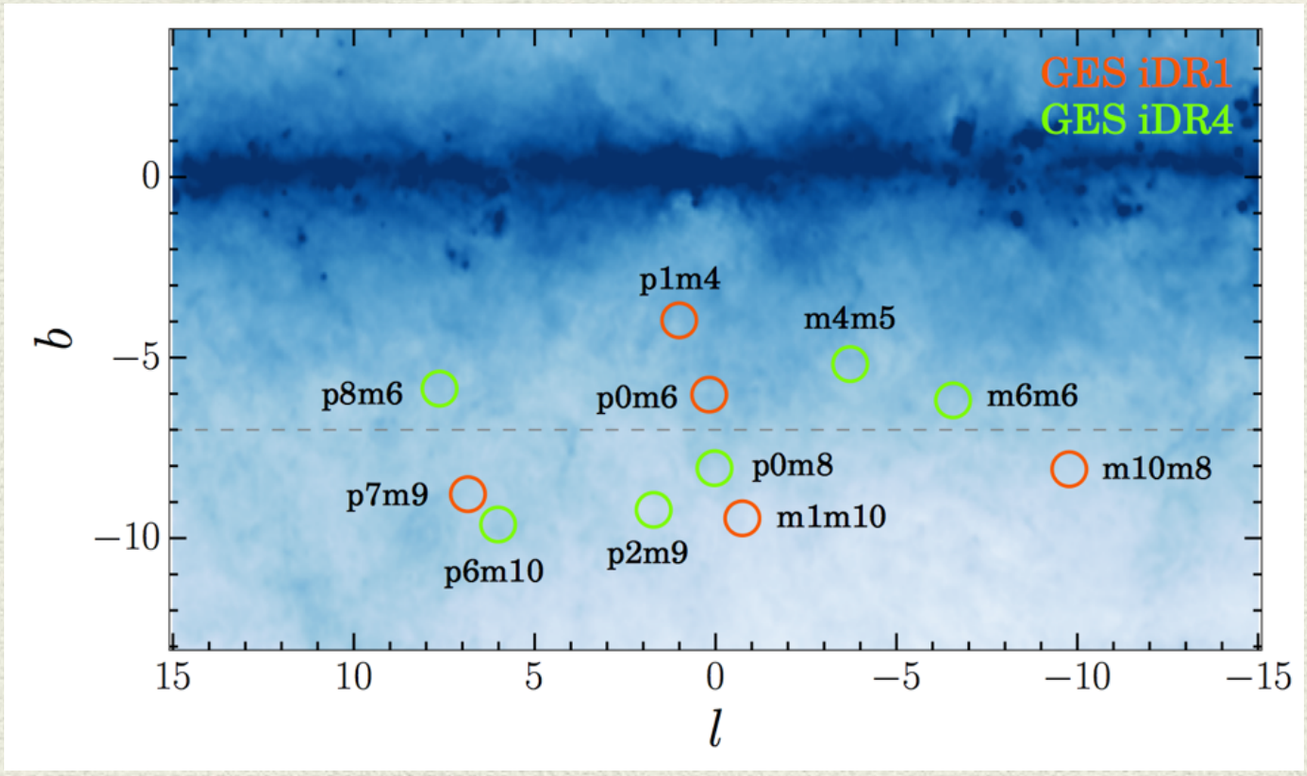

0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
[Mg/Fe] (dex)
Thick (3247)
Thin (3066)
−1.5
−1.0
−0.5
0.0
0.5
[Fe/H] (dex)

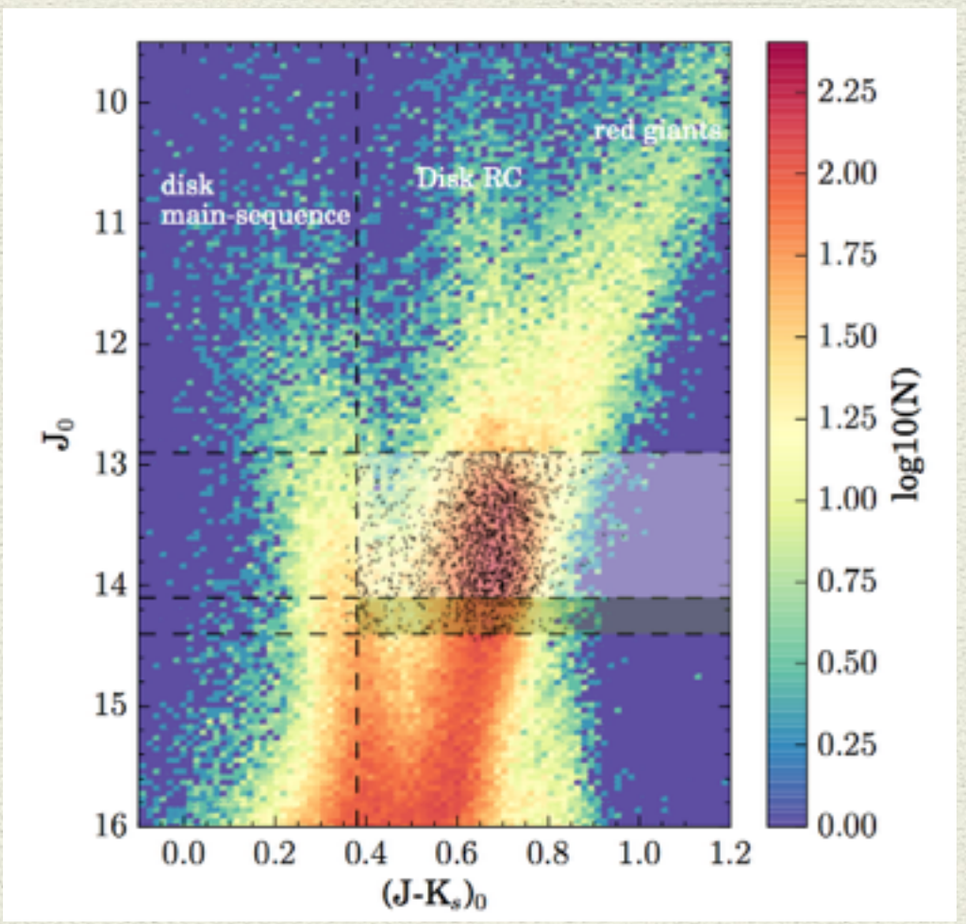

0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
[Mg/Fe] (dex)
Thick disk
Thin disk
Bulge (1583)
−1.0
−0.5
0.0
0.5
[Fe/H] (dex)


5: GoodDisc
5: LowAlfHR31
Cr1-5.64
Fe1-7.45
0.5
0
-0.5
-1.0
-1.5
-2.0
-1.8 -1.7 -1.6 -1.5 -1.4 -1.3 -1.2 -1.1 -1.0 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6


5: GoodDisc
5: LowAlfHR31
Mn1-5.39
Fe1-7.45
0
-1
-2
-1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8


5: GoodDisc
5: LowAlfHR3
Ni1-6.23
Fe1-7.45
0.5
0
-0.5
-1.0
-1.5
-2.0
-1.8
-1.7
-1.6
-1.5
-1.4
-1.3
-1.2
-1.1
-1.0
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4


GES iDR1
GES iDR4
p1m4
m4m5
p8m6
p0m6
m6m6
p0m8
m10m8
p7m9
m1m10
p6m10
p2m9
b
l
0
−5
−10
15
10
5
0
−5
−10
−15


disk
main-sequence
Disk RC
red giants
J_0
$(J-K_s)_0$
log10(N)
10
11
12
13
14
15
16
0.0
0.2
0.4
0.6
0.8
1.0
1.2
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00