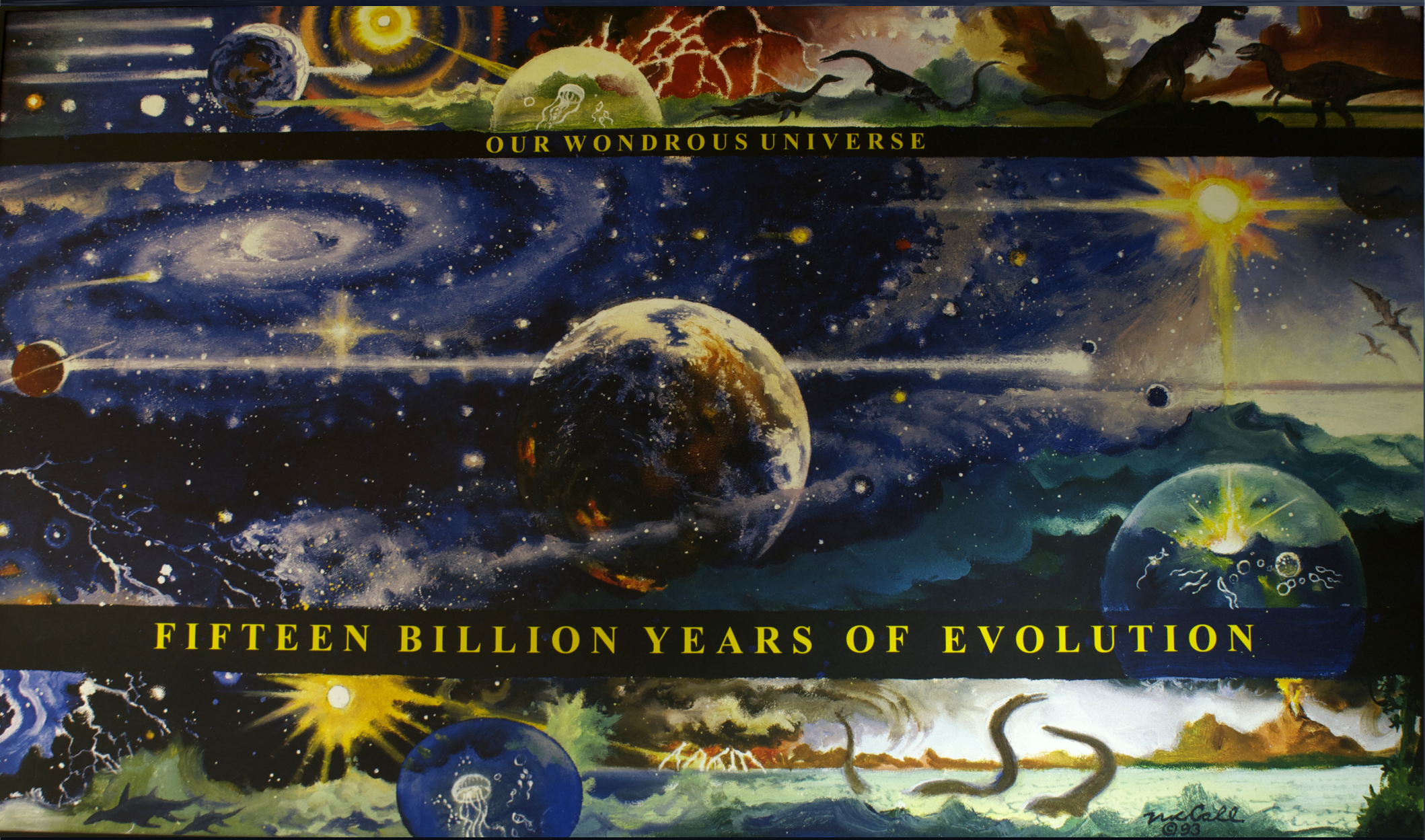
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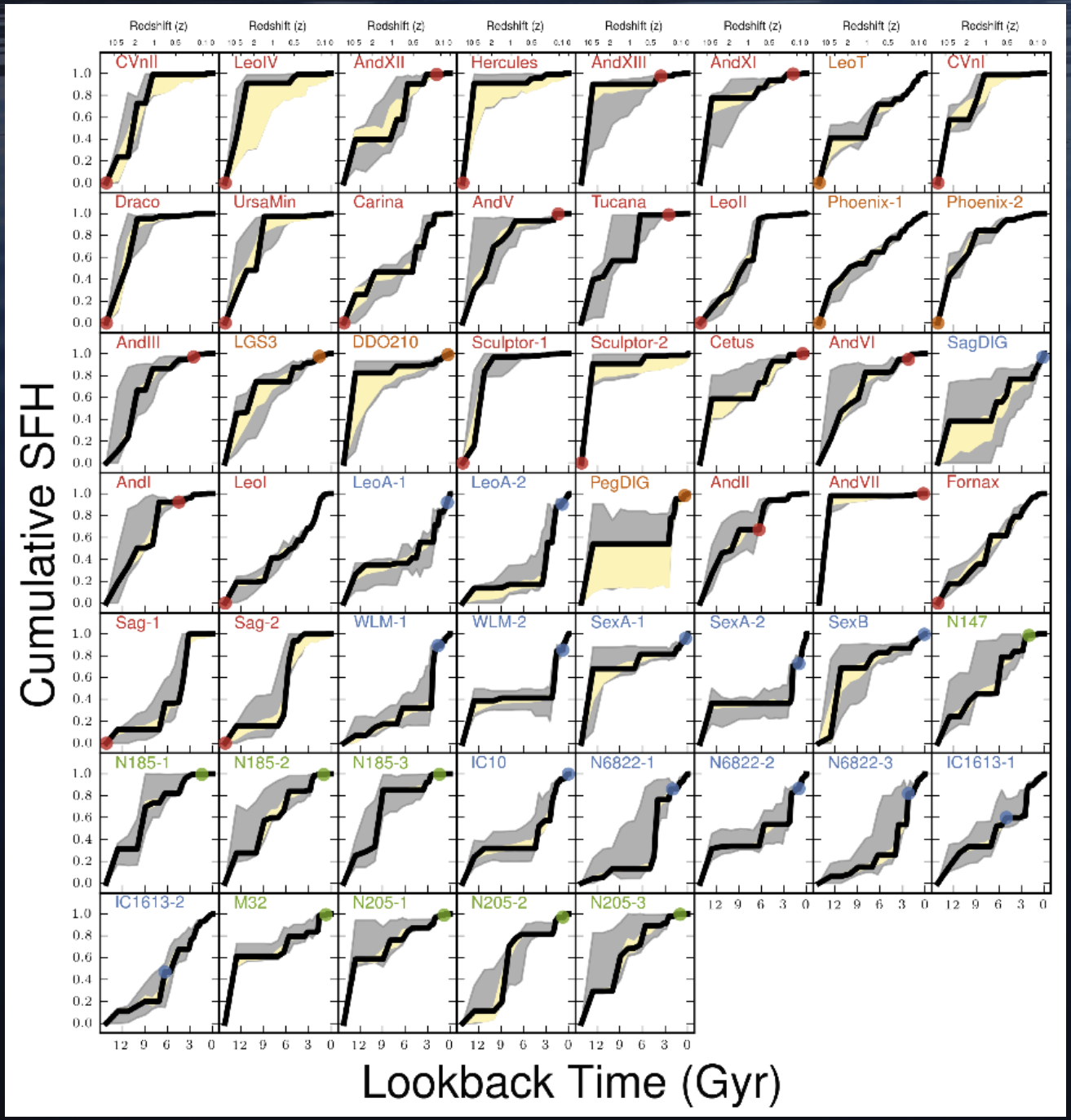
Insights from the Outskirts:

Reading the chemical evolutionary signatures of the Fornax dSph

Ben Hendricks - Landessternwarte Heidelberg
and A. Koch, C. Boeche, G. Lanfranchi, M. Walker, J. Penarrubia, C. I. Johnson, G. Gilmore

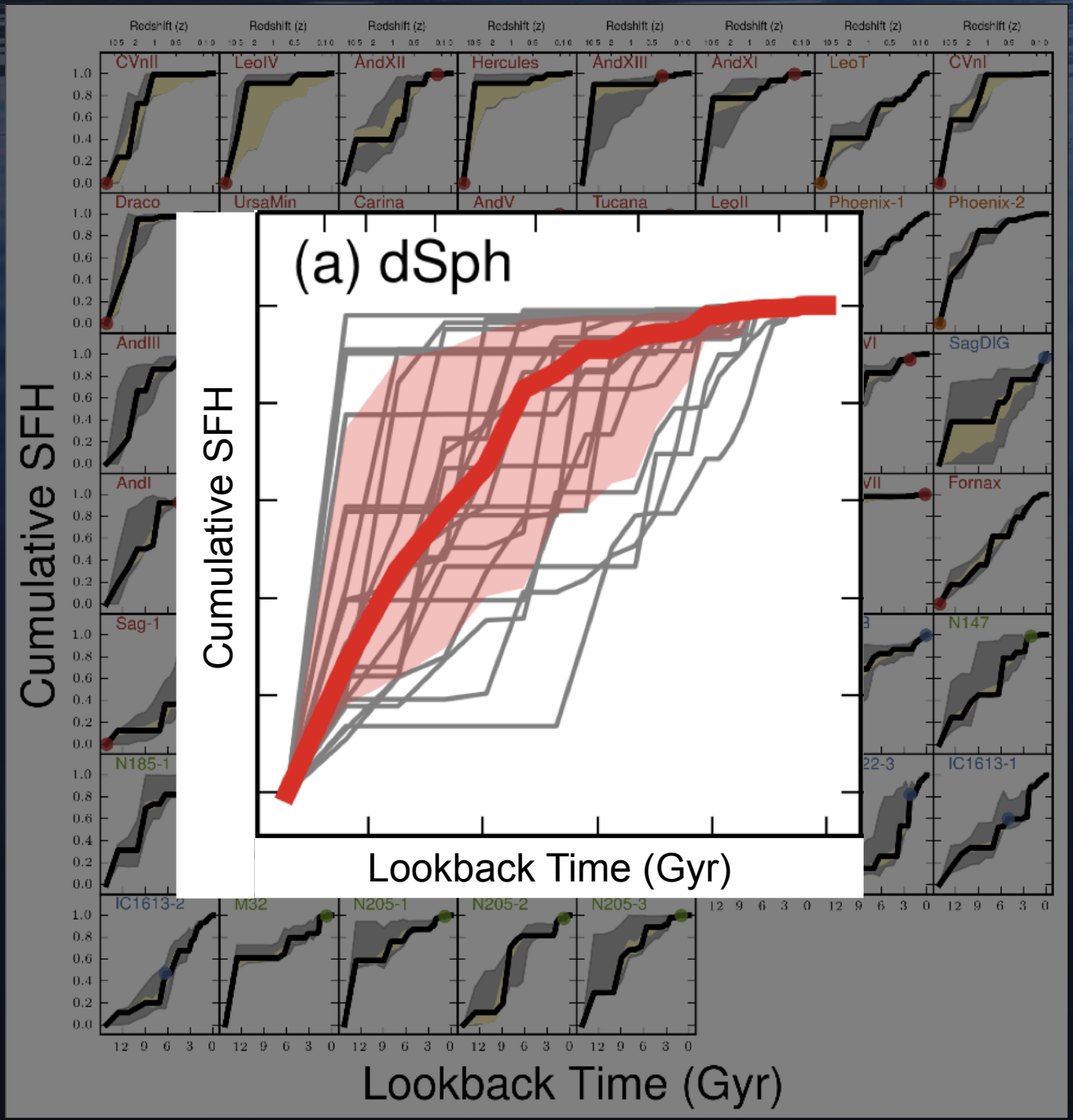
ESO workshop "*Resolved And unresolved Stellar PopUlaTIoNs*", Garching, 2014/10/17



Variety *amongst* dSphs

- remains, even when luminosity or distance to MW is taken into account!
- but: old population is common feature; SF started at same epoch
- environmental impact important: (reionization, ram-pressure stripping, tidal stirring, mergers?)

Weisz et al. 2014



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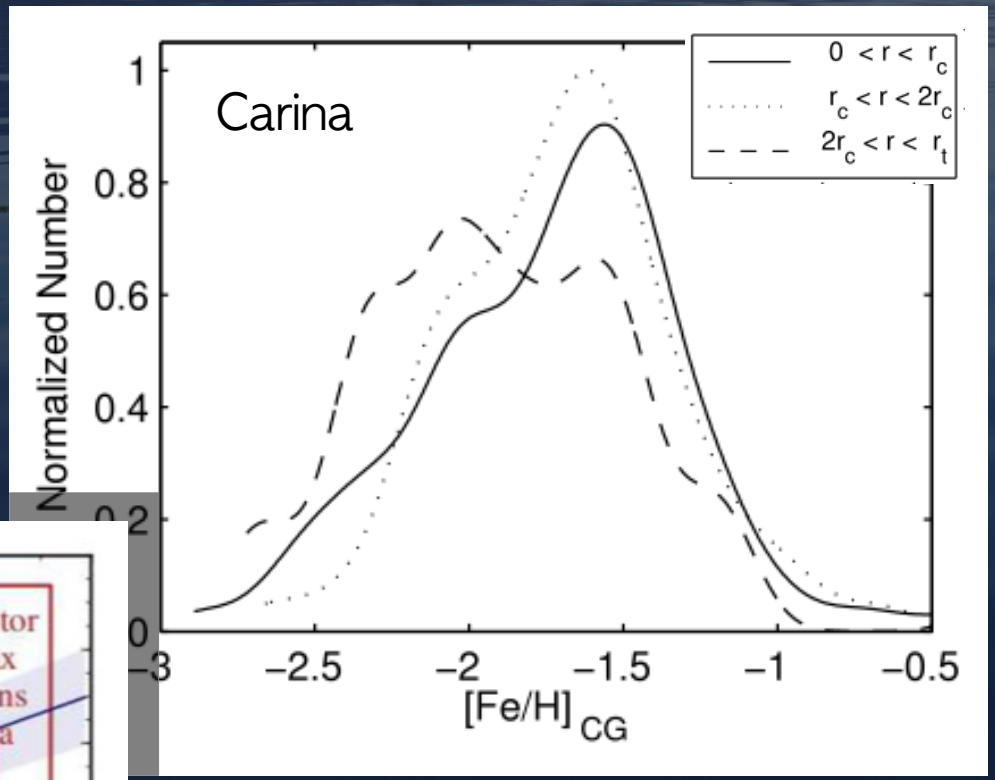
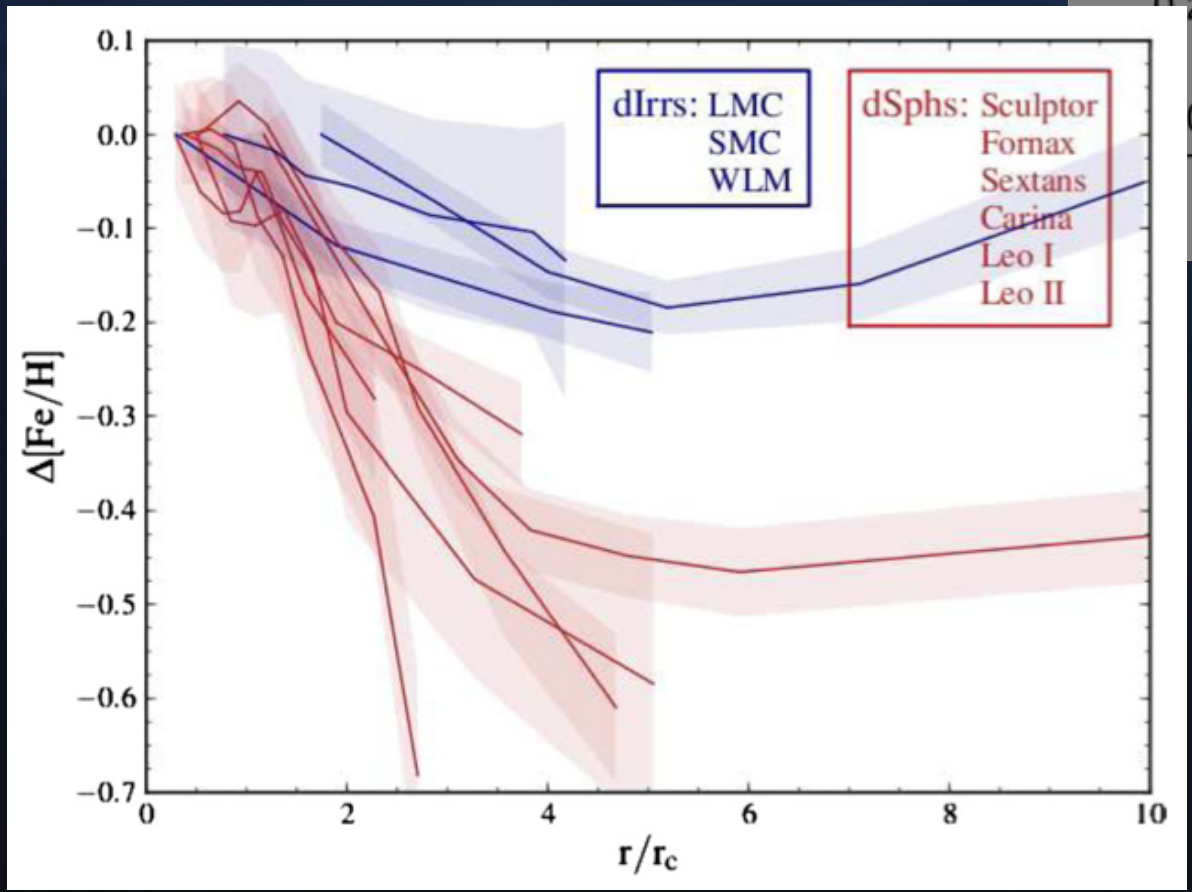
Variety *within* dSphs

- shells, substructures, radial metallicity gradients

- every *local* sample is biased!





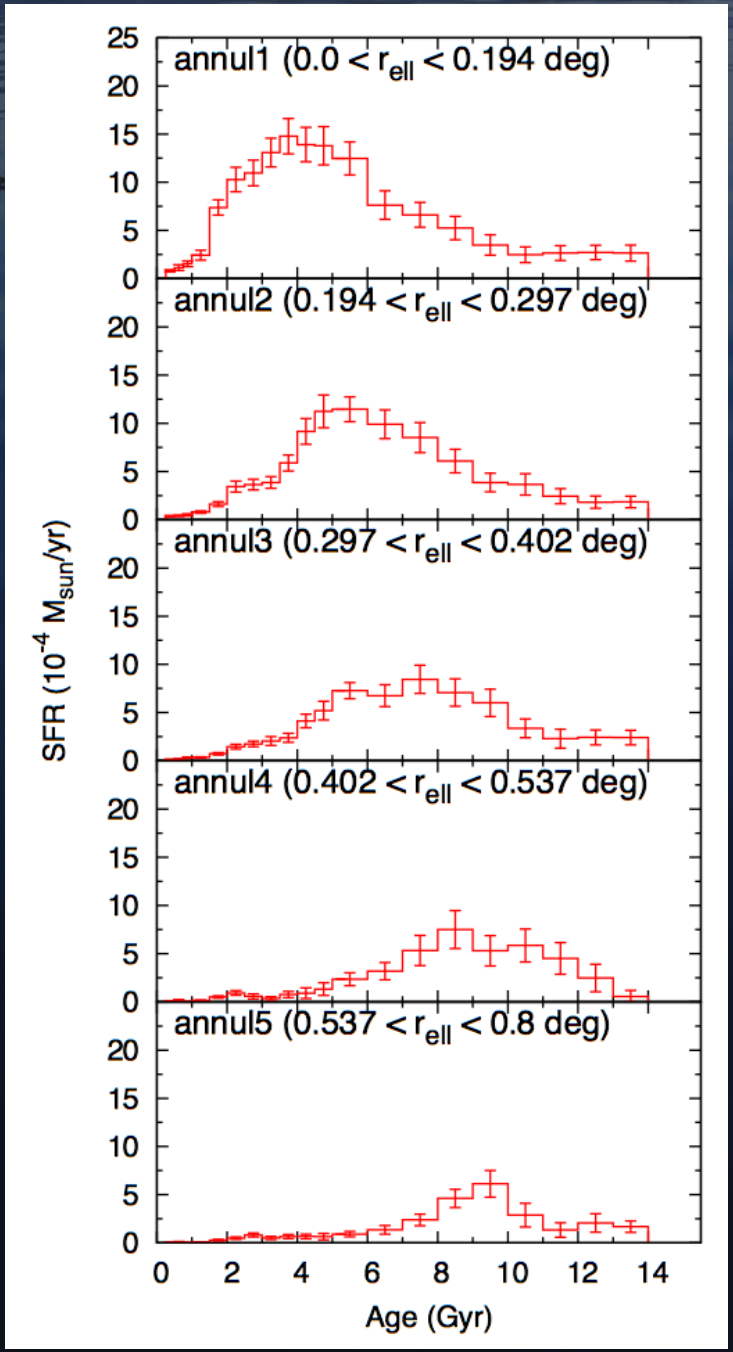
top: Koch et al. 2006
left: Leaman et al. 2013

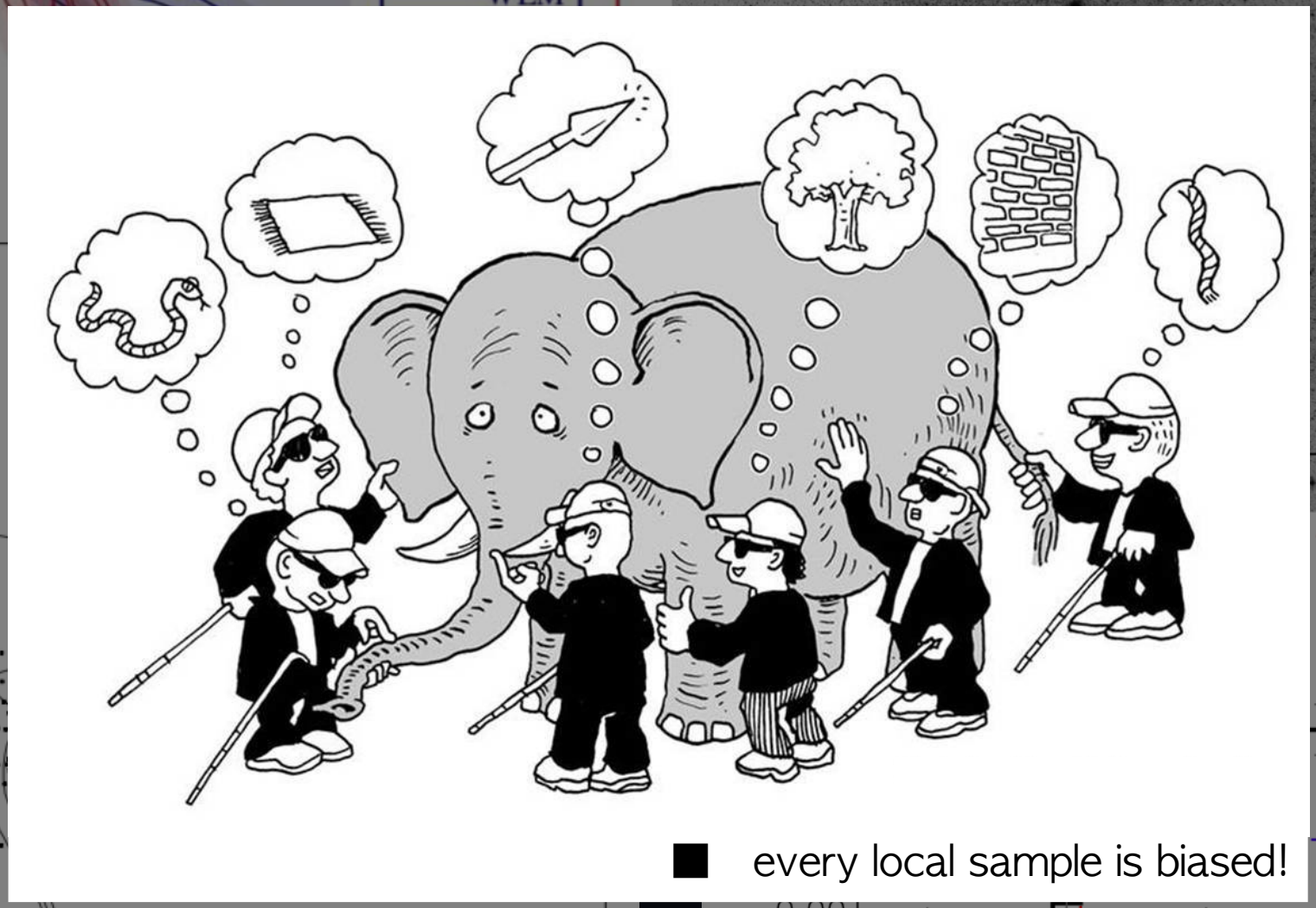
Variety *within* dSphs

- shells, substructures, radial metallicity gradients, radial SFH gradients, …
- every *local* sample is biased!

Understanding the chemodynamical differences *within* dSphs may be the key to understand the variations *amongst* them.

e.g. Fornax:
de Boer et al. 2012b





■ every local sample is biased!

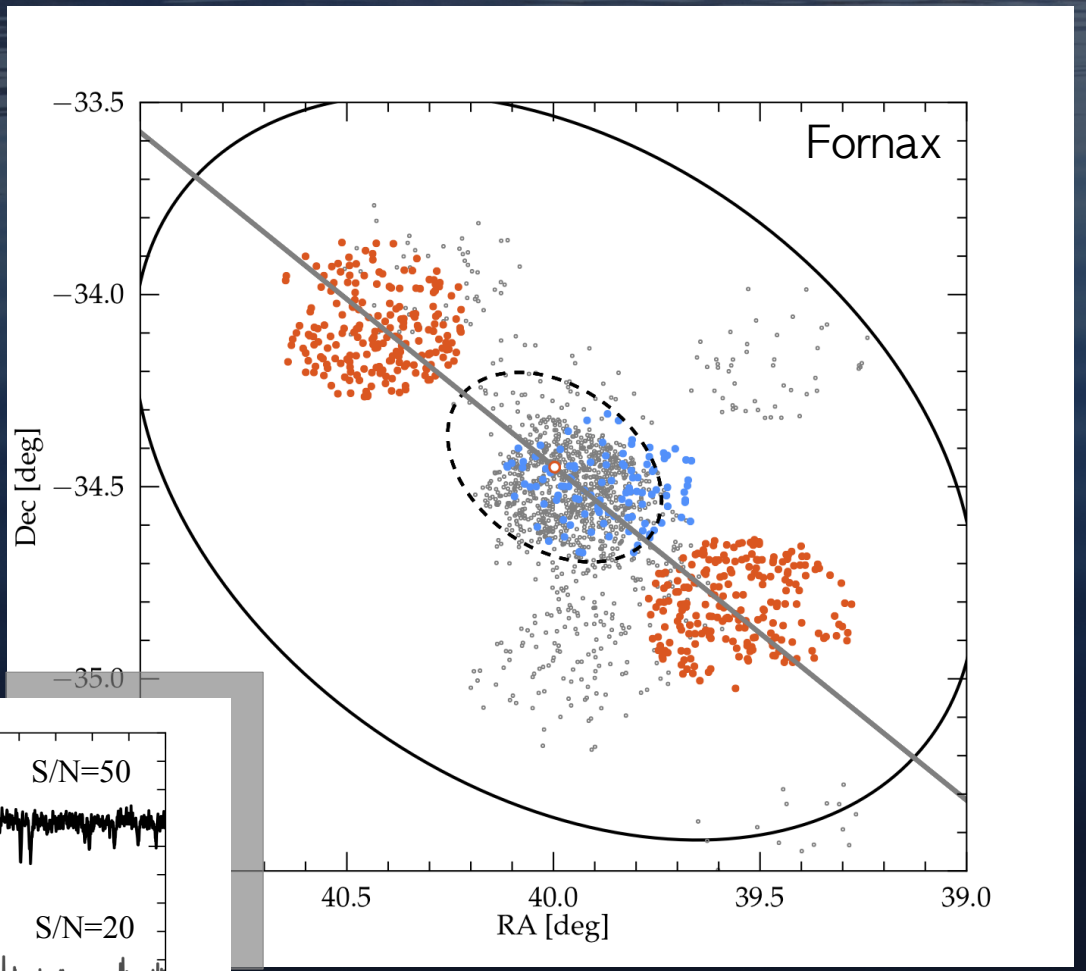
Our Dataset: Fornax' Outskirts

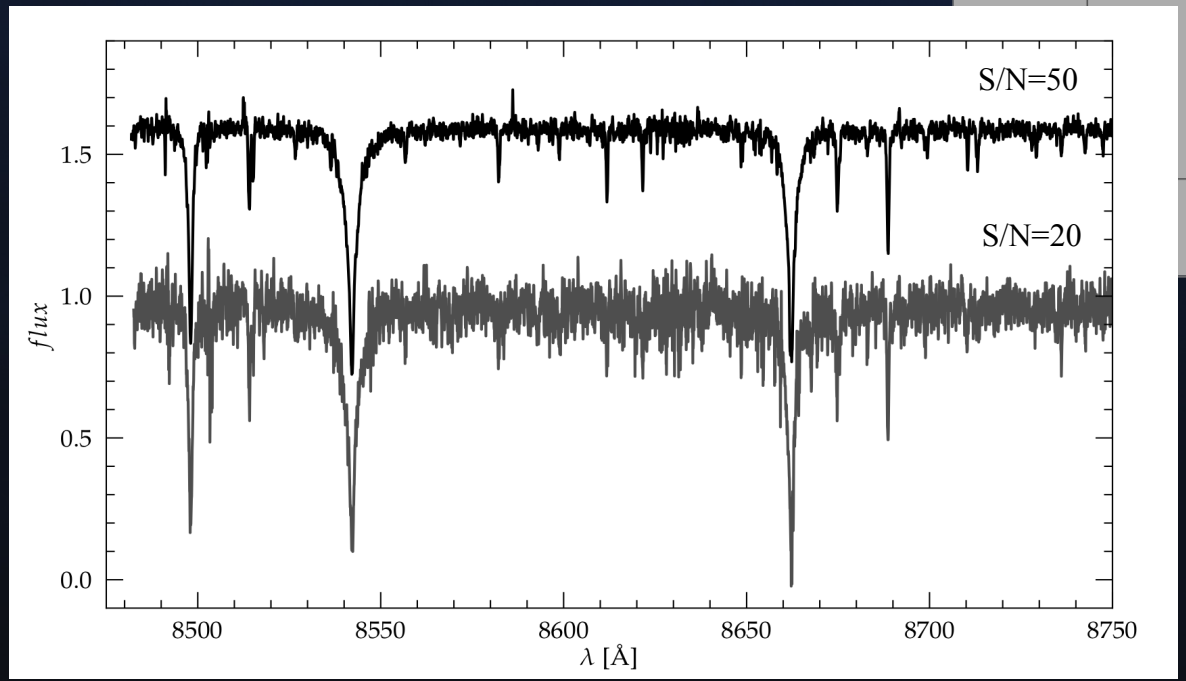
R~16,000 S/N ~ 30

■ [Fe/H] (CaT), RV for **340 field stars** + **13 individual GC stars** (H2, H5)

■ **alpha-elements for ~100 stars** with high S/N: [Fe/H], [Mg/H], [Si/H], [Ti/H]

catalog online available soon





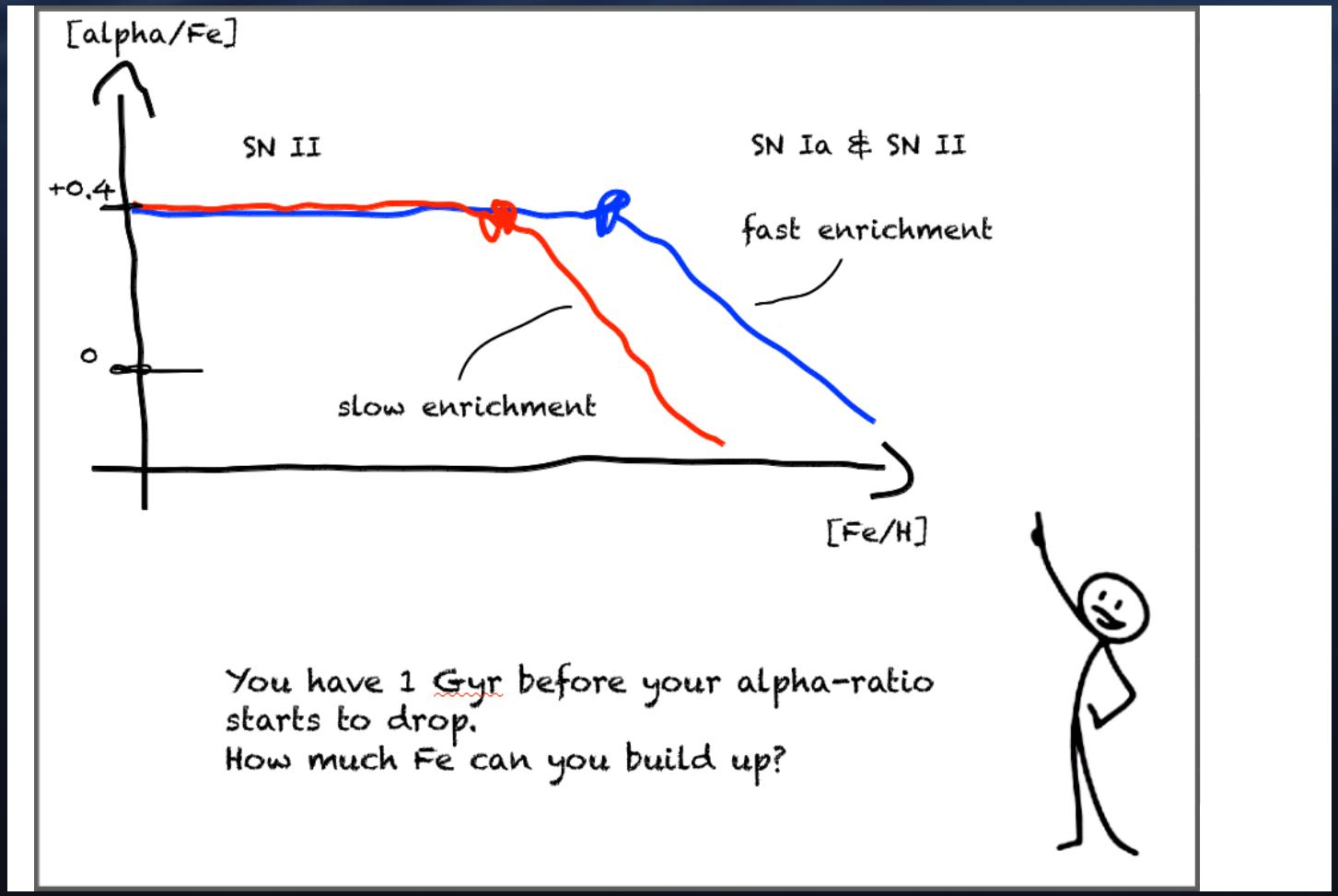
high-res:

- Hendricks et al. 2014a, 2014b
- Letarte et al. 2010

low-res:

- Pont et al. 2004, Battaglia et al. 2006, Kirby et al. 2008

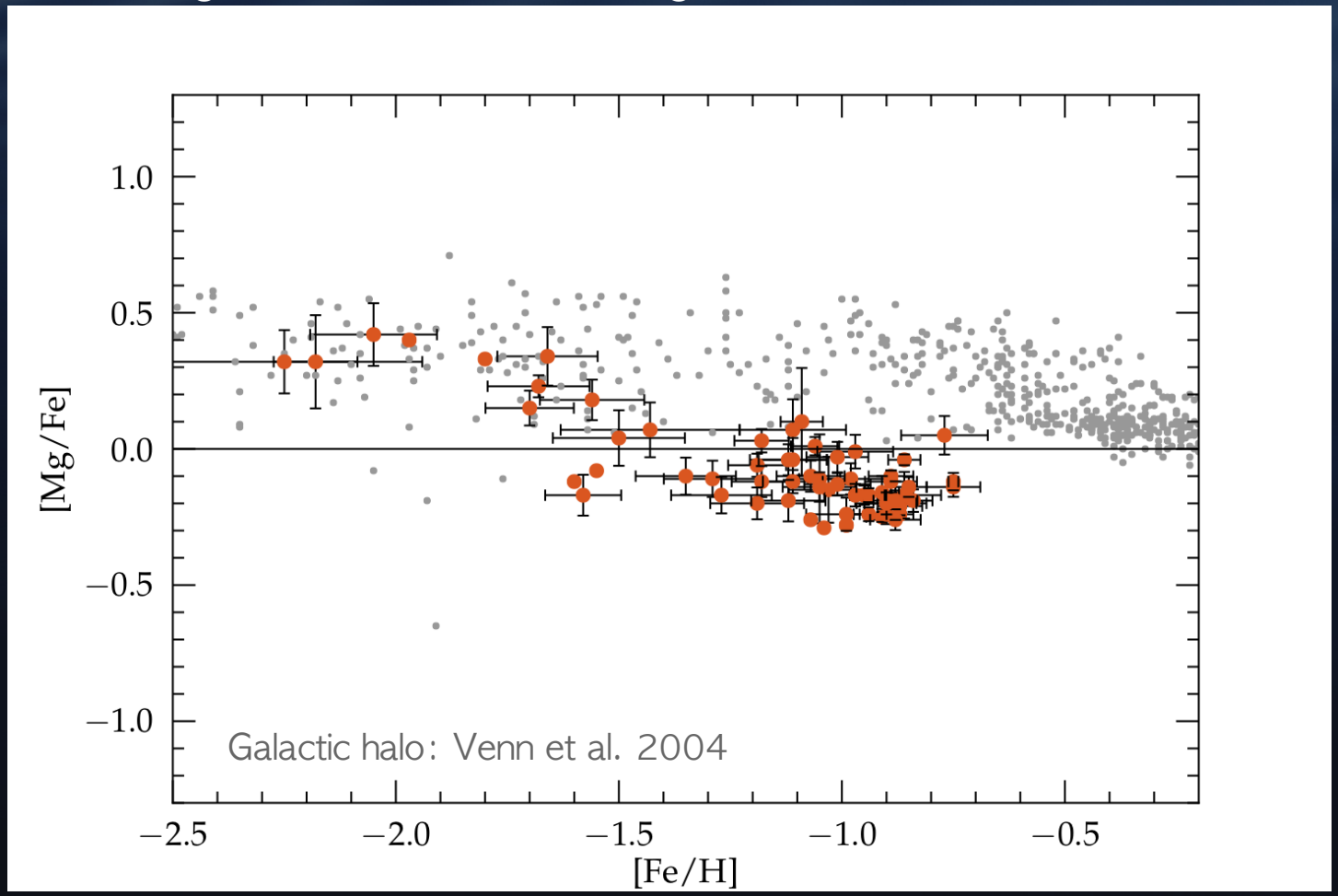
Alpha Elements



Alpha Elements

- "knee" at [Fe/H]~-1.9 dex indicates inefficient chemical enrichment in Fornax
- similar chemical enrichment to Sculptor (but: 10x less massive)

did Fornax gained mass later? merger? re-accretion?



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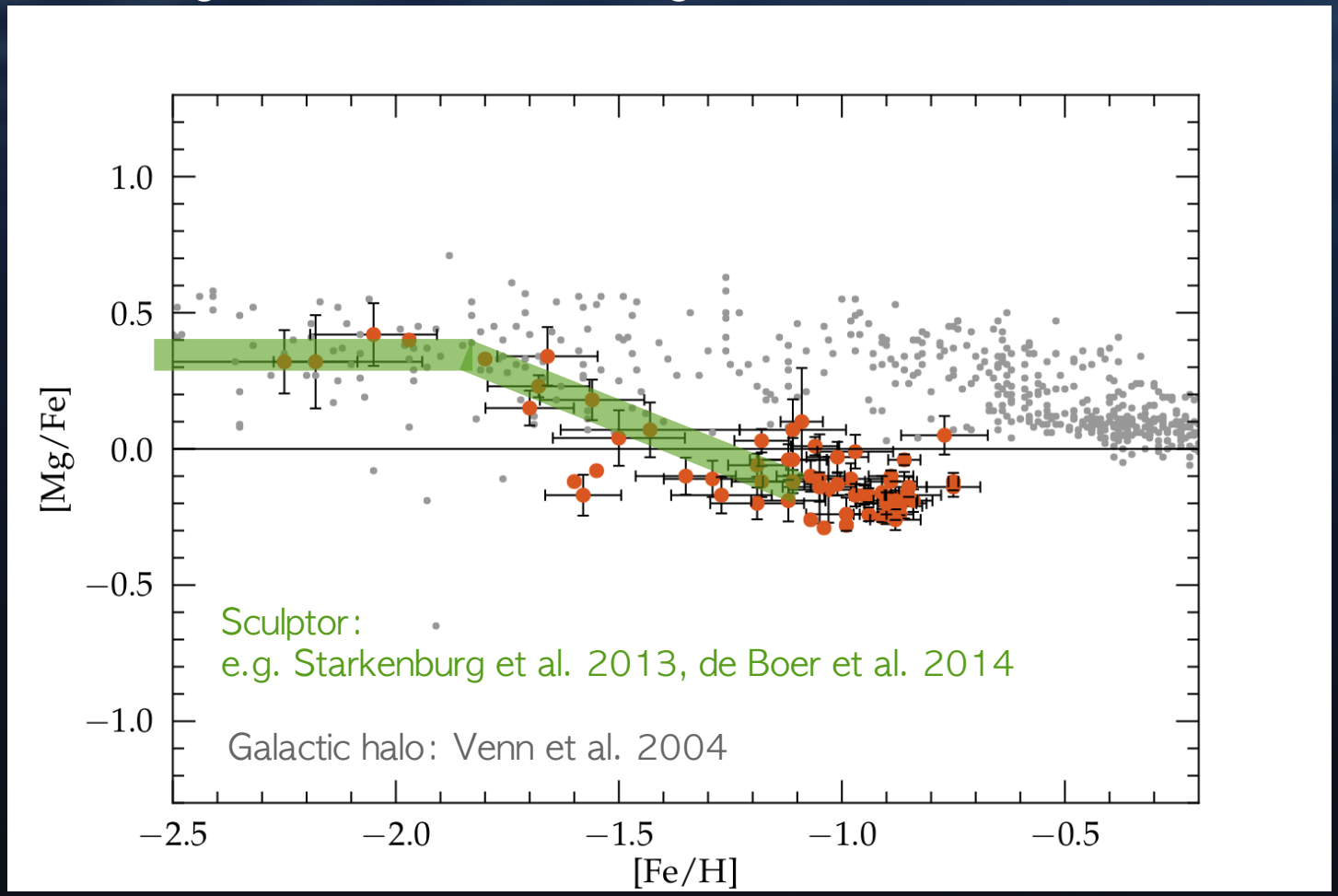
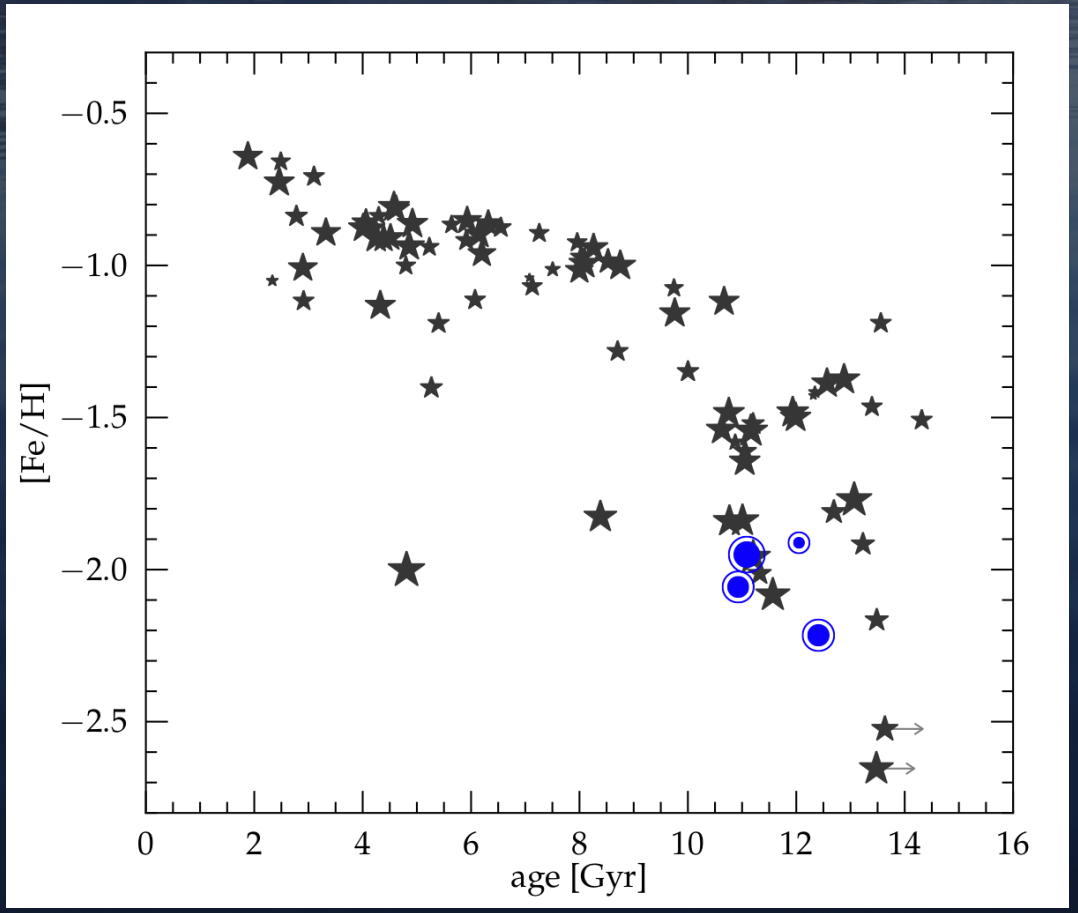


The age-metallicity relation

- non-linear enrichment
- GCs fall on field star sequence
- a triggered SF event at t=4Gyr?



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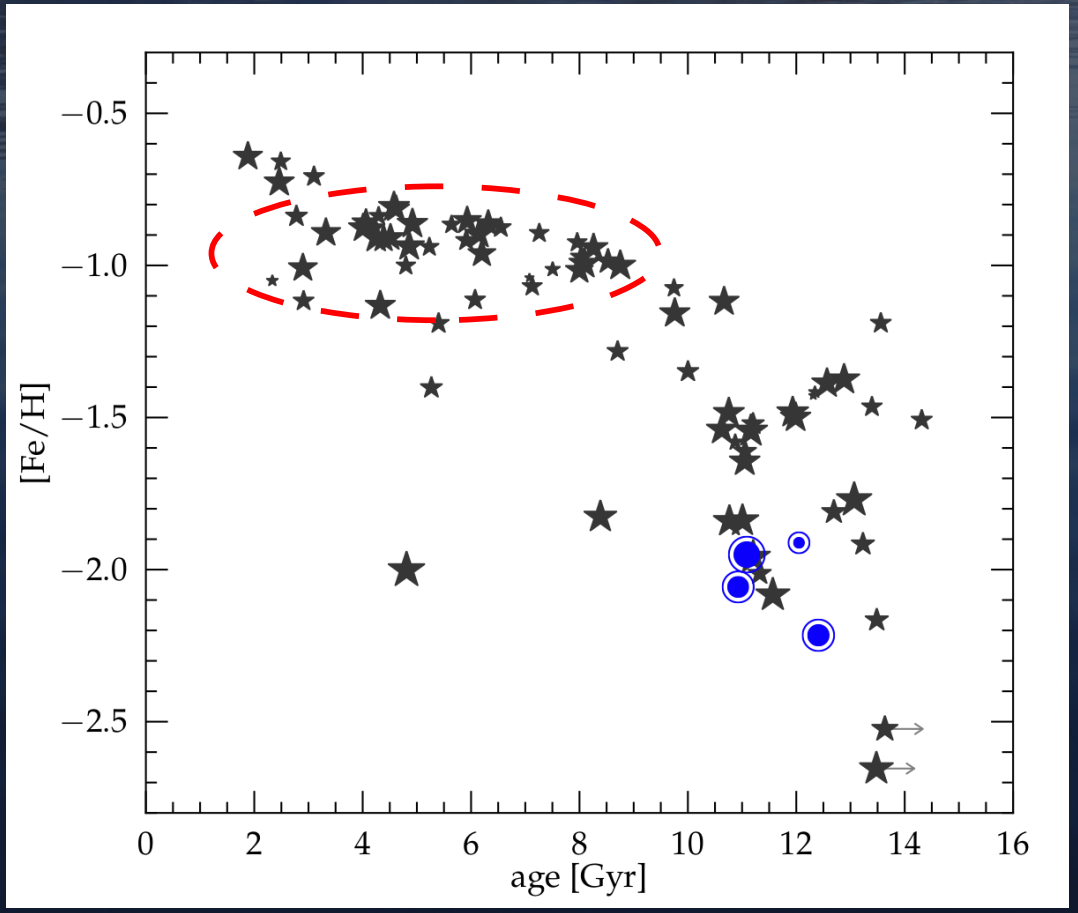

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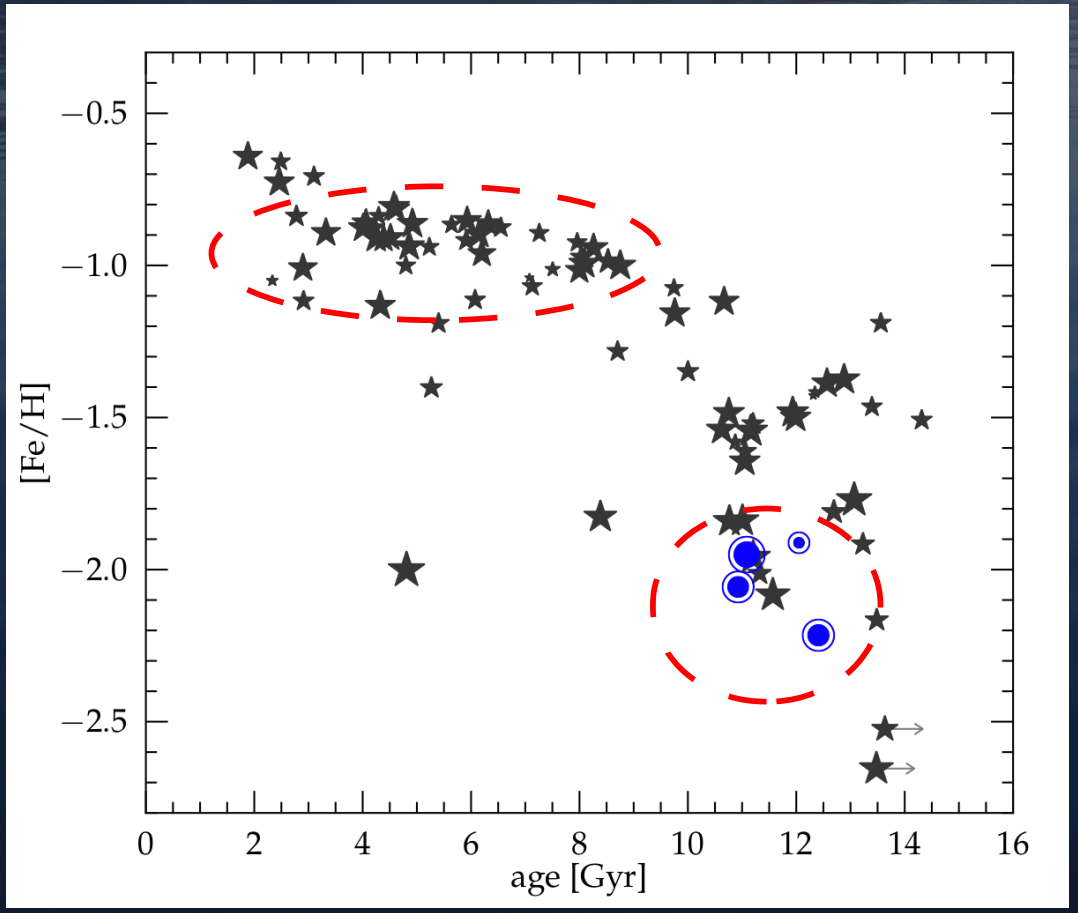

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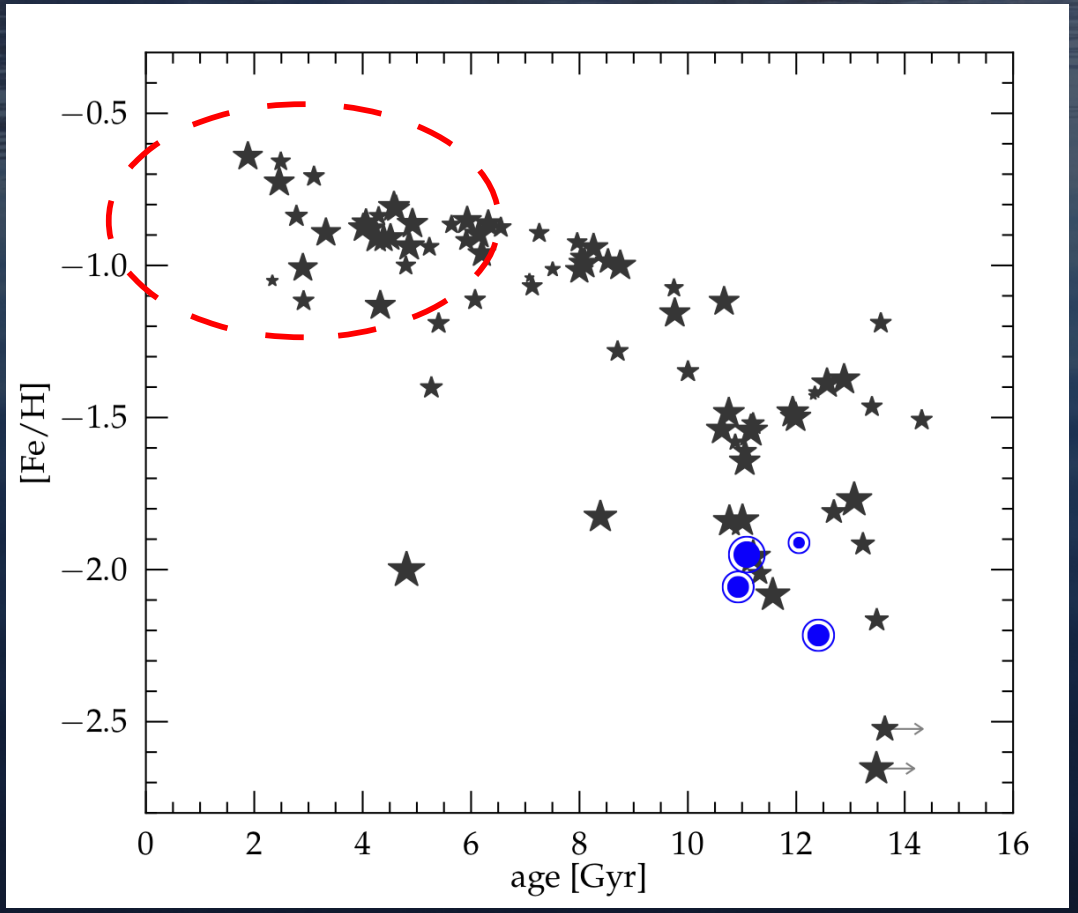

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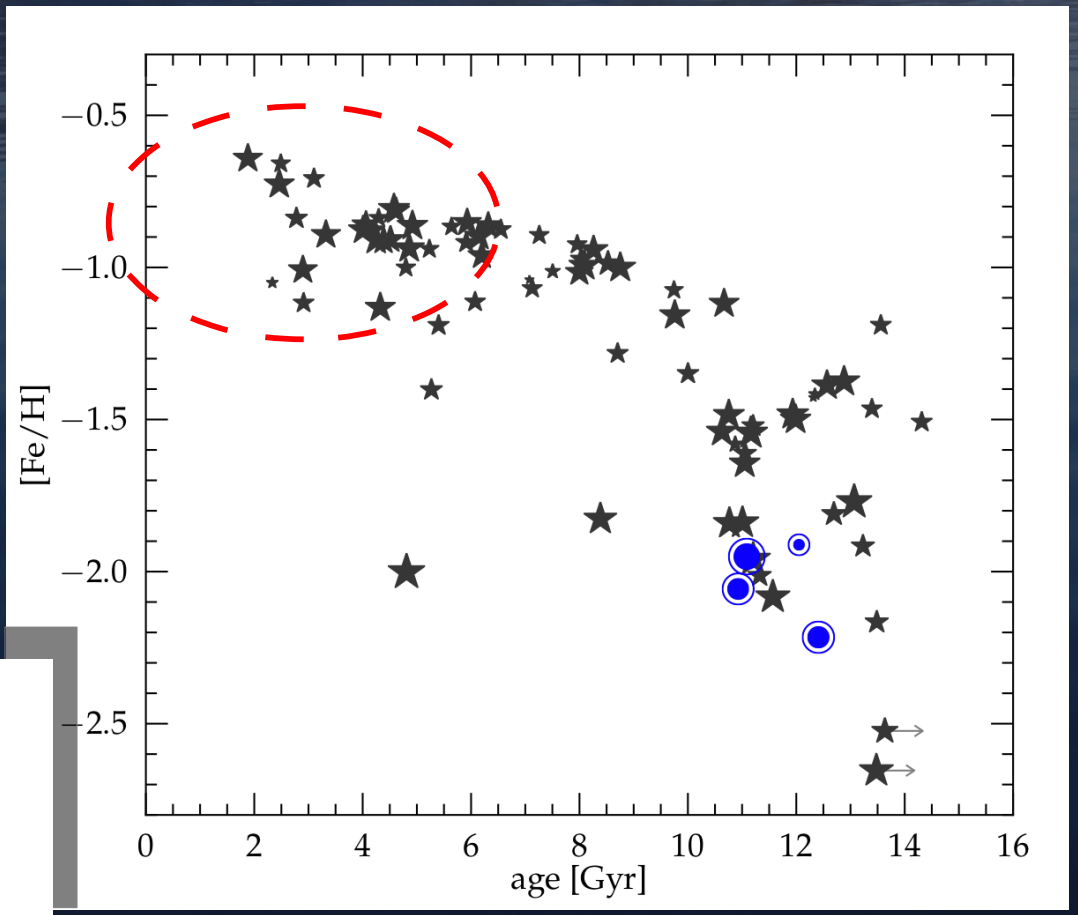
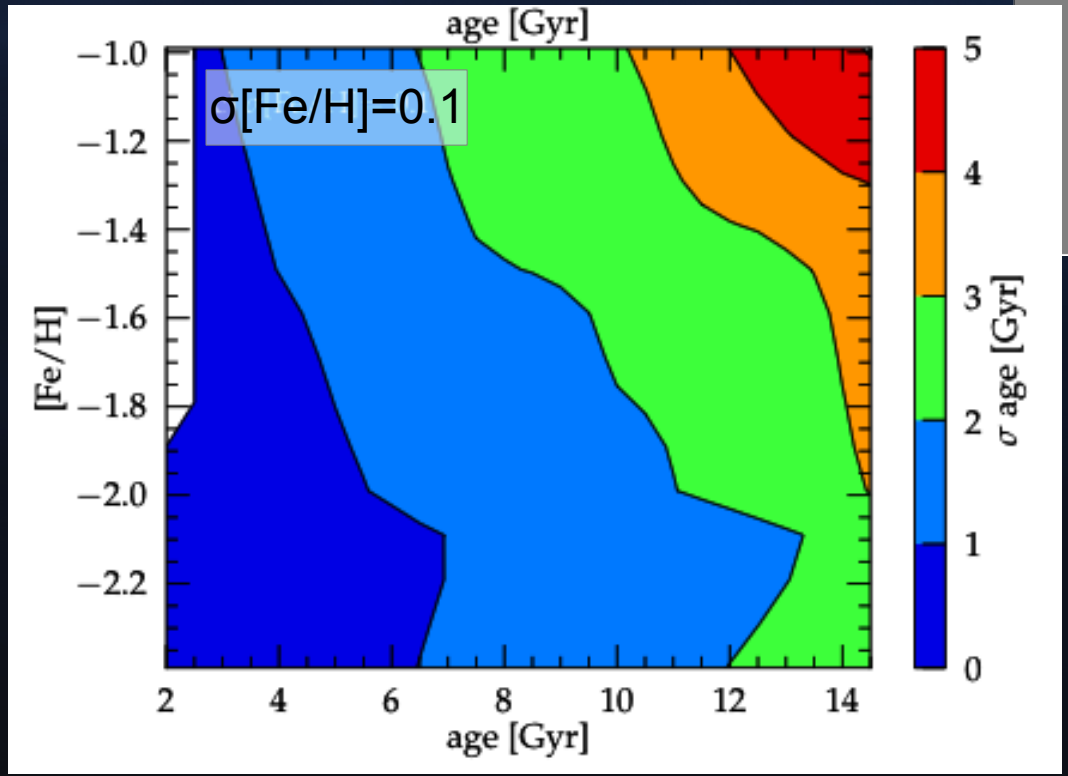




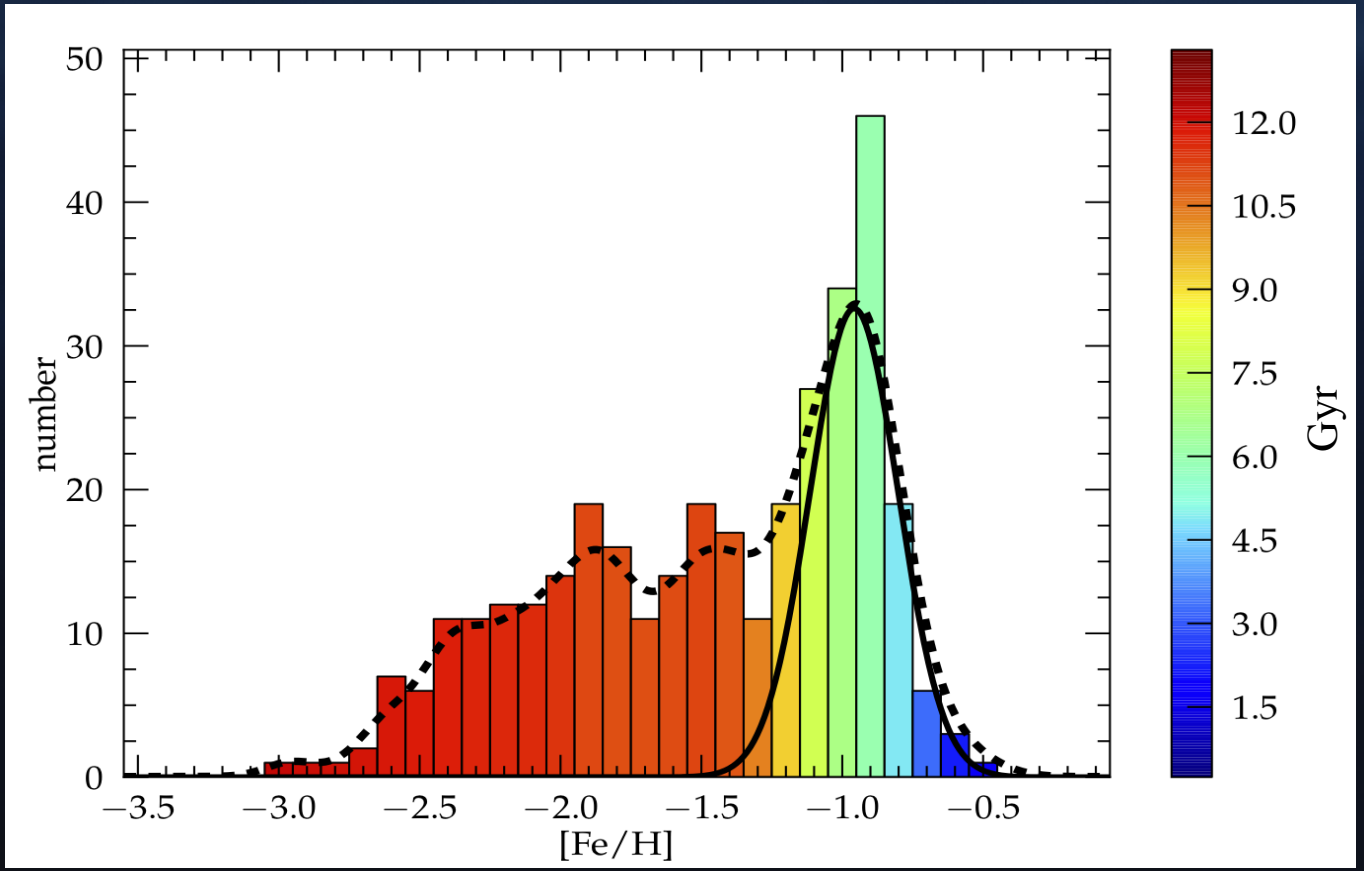
careful interpretation:
large uncertainties!

Fornax vs. Sculptor

- both galaxies built-up the same metallicity budget during the first ~7 Gyr

- the outskirts of Fornax evolved identically to Sculptor during the first Gyrs

What caused the difference thereafter?



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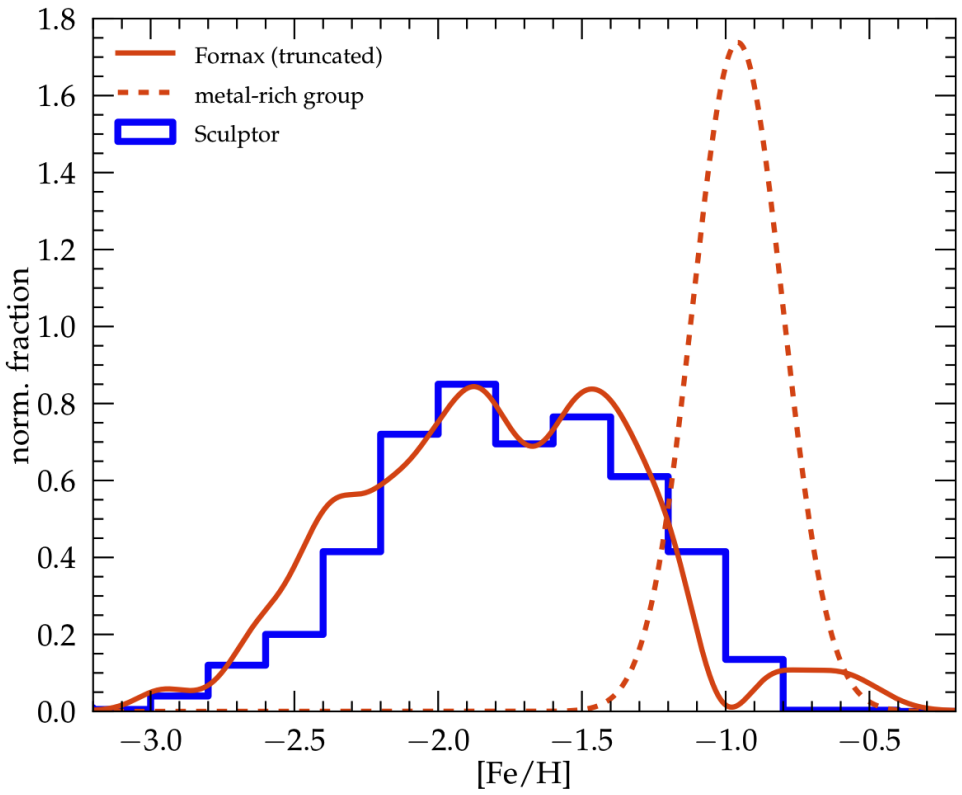

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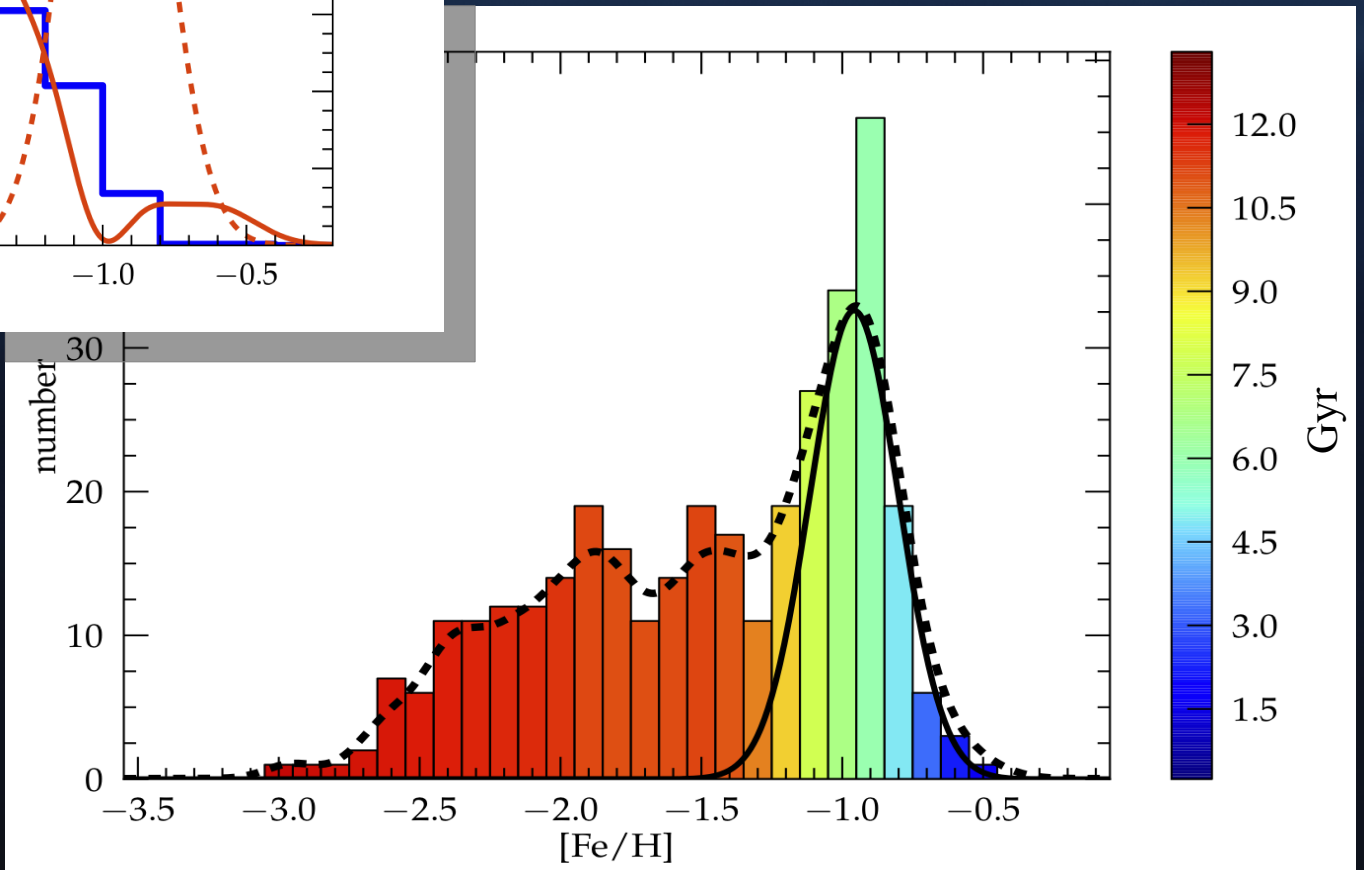
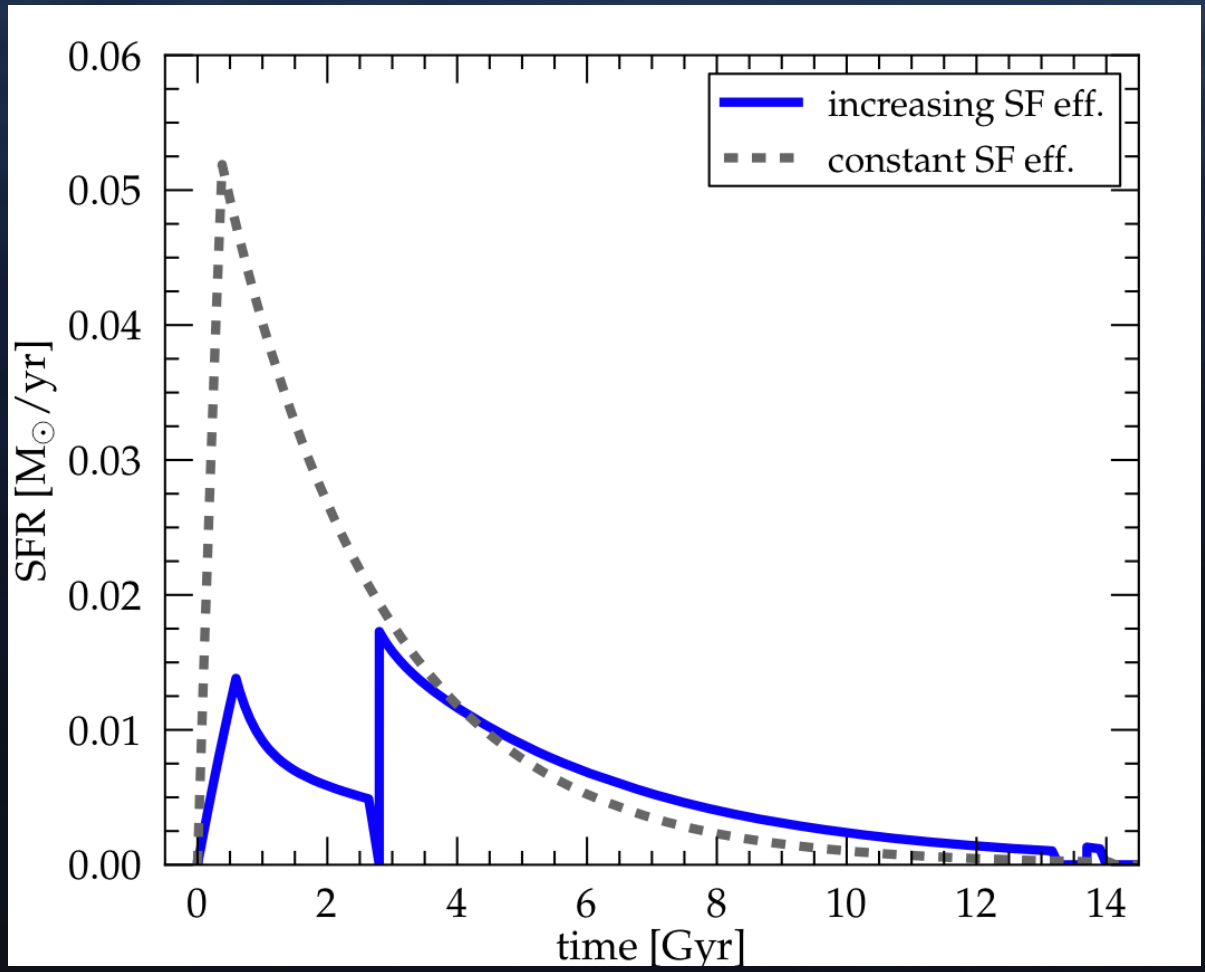


Modelling the chemical evolution in Fornax

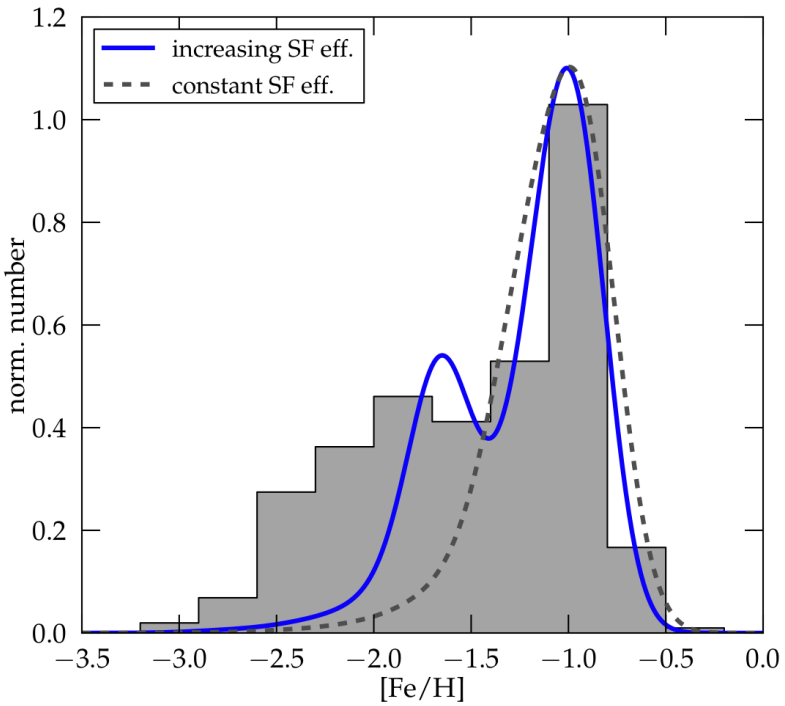
constant SF efficiency
increasing SF efficiency

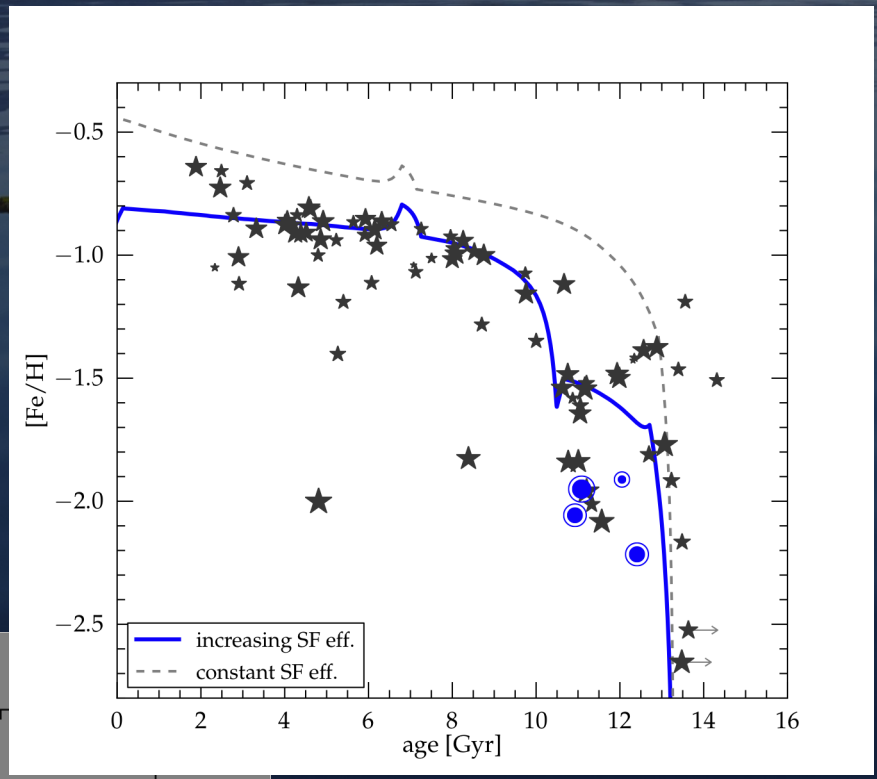
Episodes of SF	Periods (Gyrs)	$\nu\ (Gyr^{-1})$
1	0.0 – 14.0	0.380
3	0 – 2.6; 2.8 – 13.2; 13.7 – 14.0	0.095; 0.348; 0.469

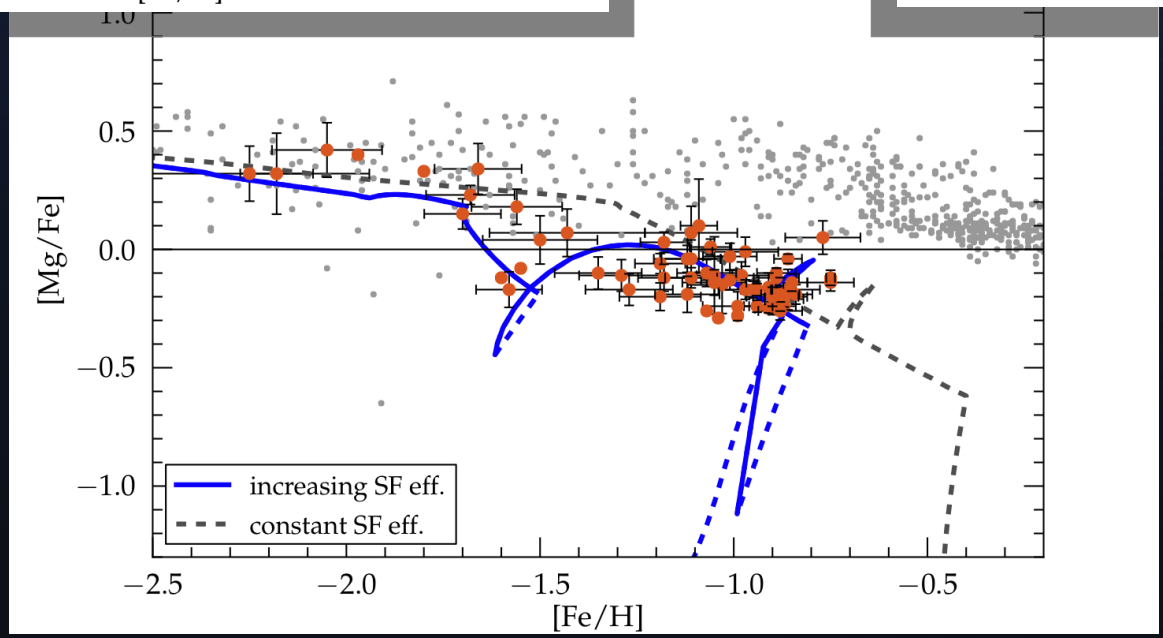


- We use a leaky-box model. For details about the model in general, see Lanfranchi et al. 2003, 2004

- for details about the Fornax model, see Hendricks et al. 2014a, b

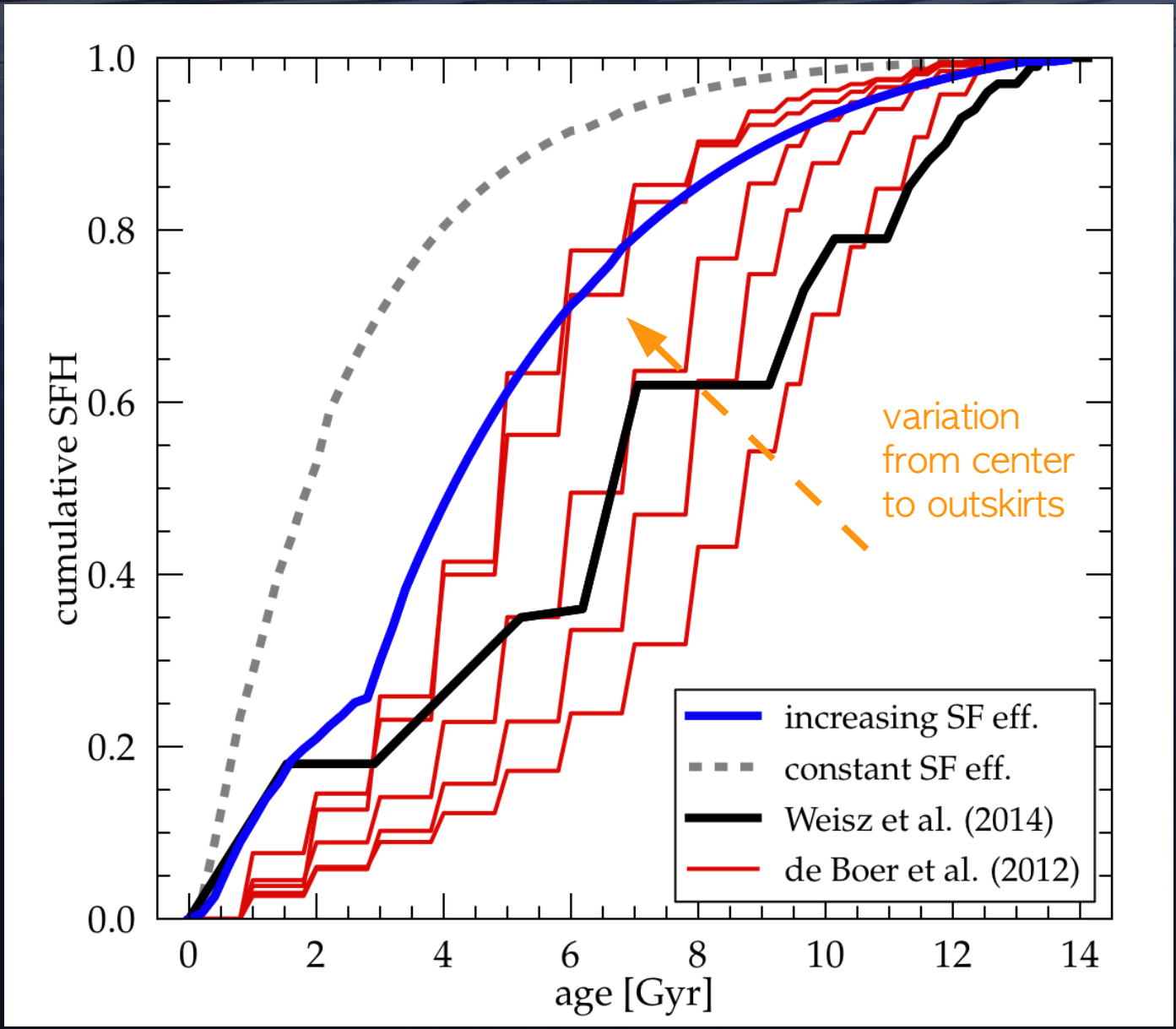






- a leaky-box model can only reproduce our data, when Fornax' SF efficiency **increased over time.**

Chemical vs. Photometric Star Formation History



distance to center:

- r ~ 10′
- r ~ 6′
- ~ 15′
- ~ 21′
- ~ 28′
- ~ 40′
- r ~ 34′

excellent agreement between photometric SFHs and the prediction from our model…

…if **radial variations** are taken into account.

Summary

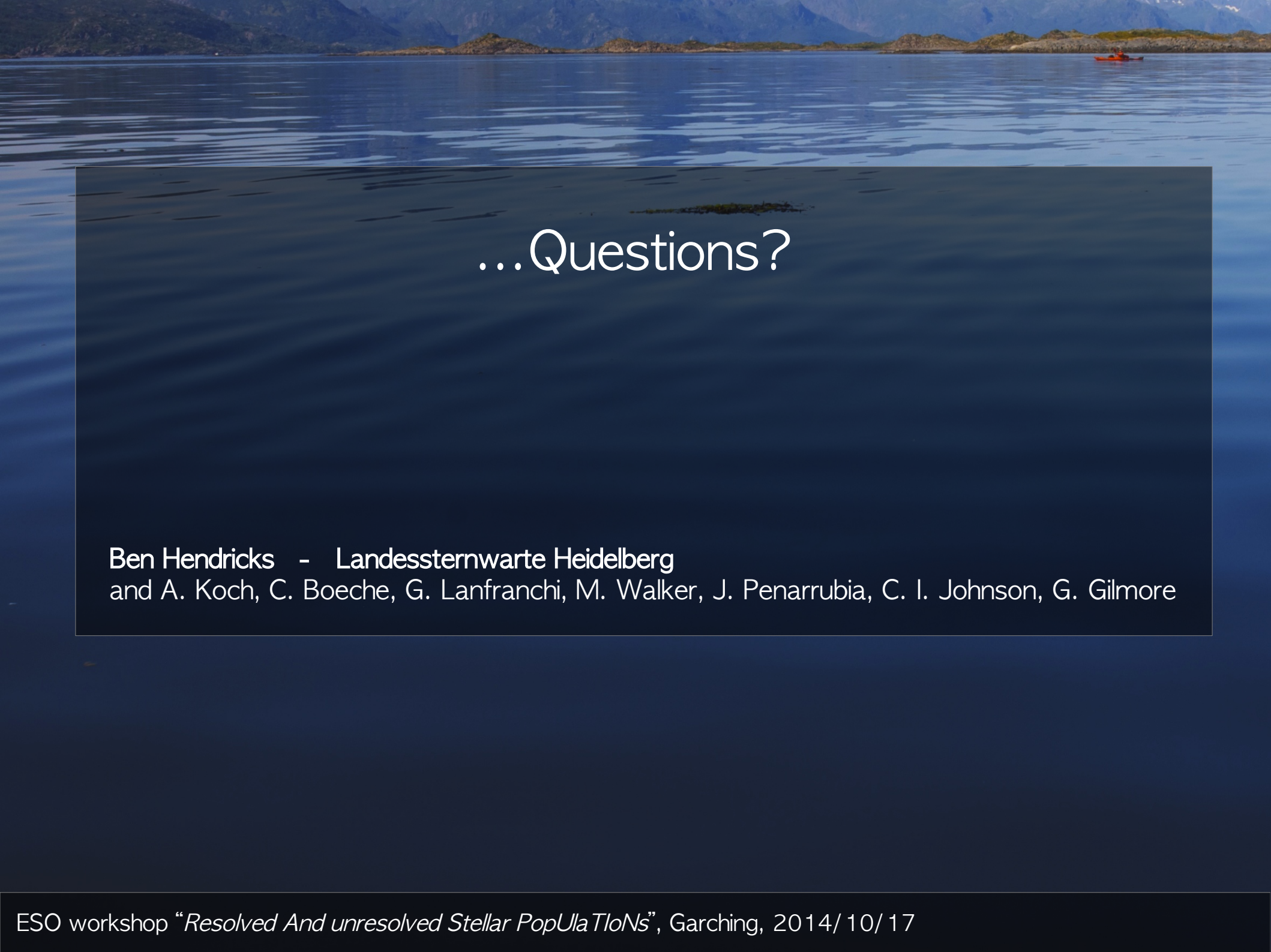
- Understanding the **variations within dSphs** is important to understand their evolution and their interaction with their host galaxy. Local samples may be mis-interpreted.

- We provide the first **HR spectroscopic sample from the outskirts of Fornax**, from which we determined RVs, [Fe/H], alpha-elements and stellar ages.

- Fornax' early evolution (at large radii) is very similar to the less massive Sculptor dSph, indicated by a knee in the alpha-elements at [Fe/H]=-1.9 dex and an identical MDF for stars older than ~7 Gyrs.

- Chemical evolution models require an **increase in the SF efficiency** over time in order to fit all extracted chemical properties.

- We find several indications that Fornax and/or Sculptor **experienced environmental impact** such as merger events, accretion/stripping of gas.



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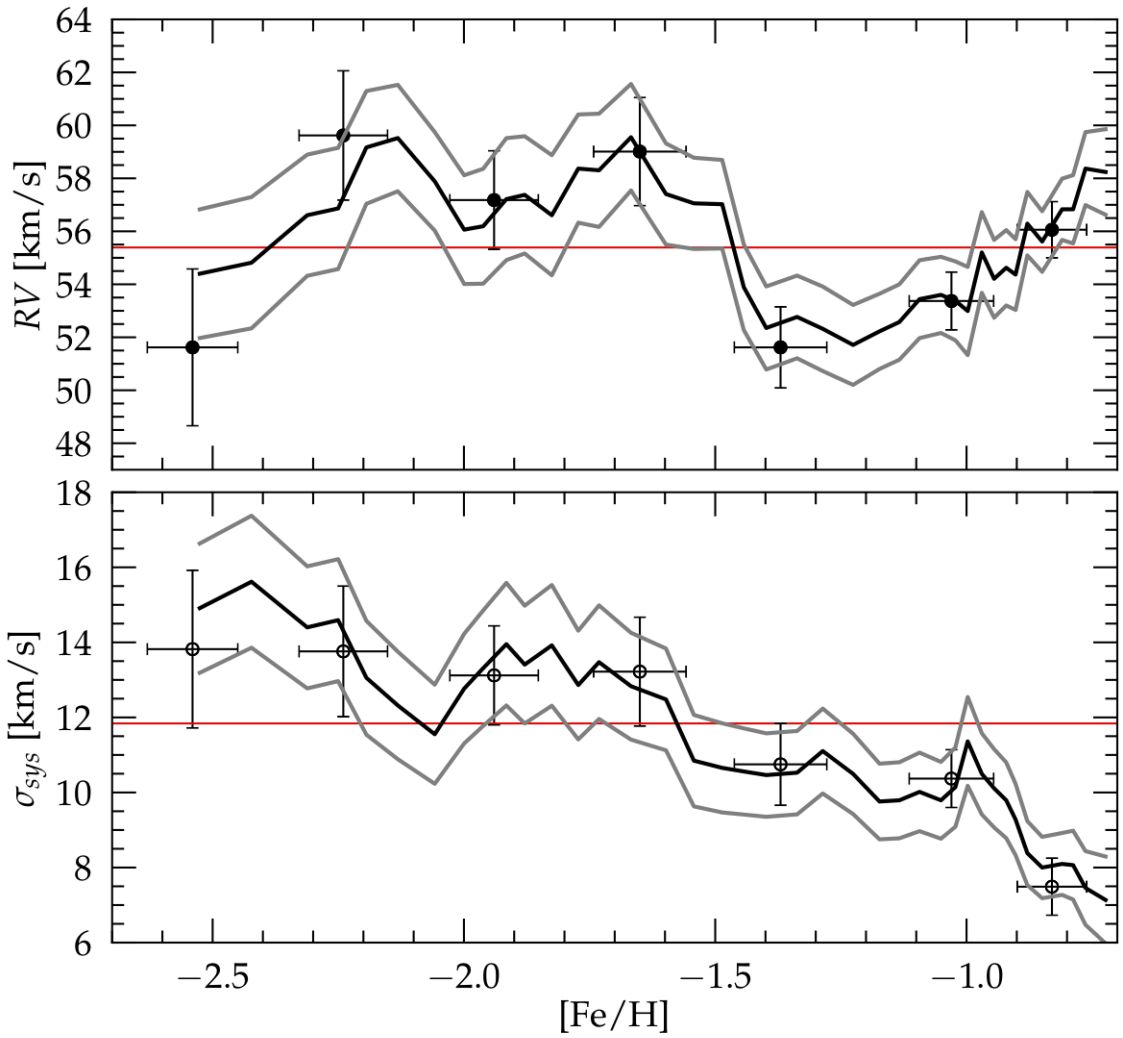
Dynamical Complexity



- significant **variations** in the radial velocities
- significant **trend** in the velocity dispersion
- non-Gaussian sub-structure

signature of wet merger?

signature of accretion of (metal-poor) GC stars?

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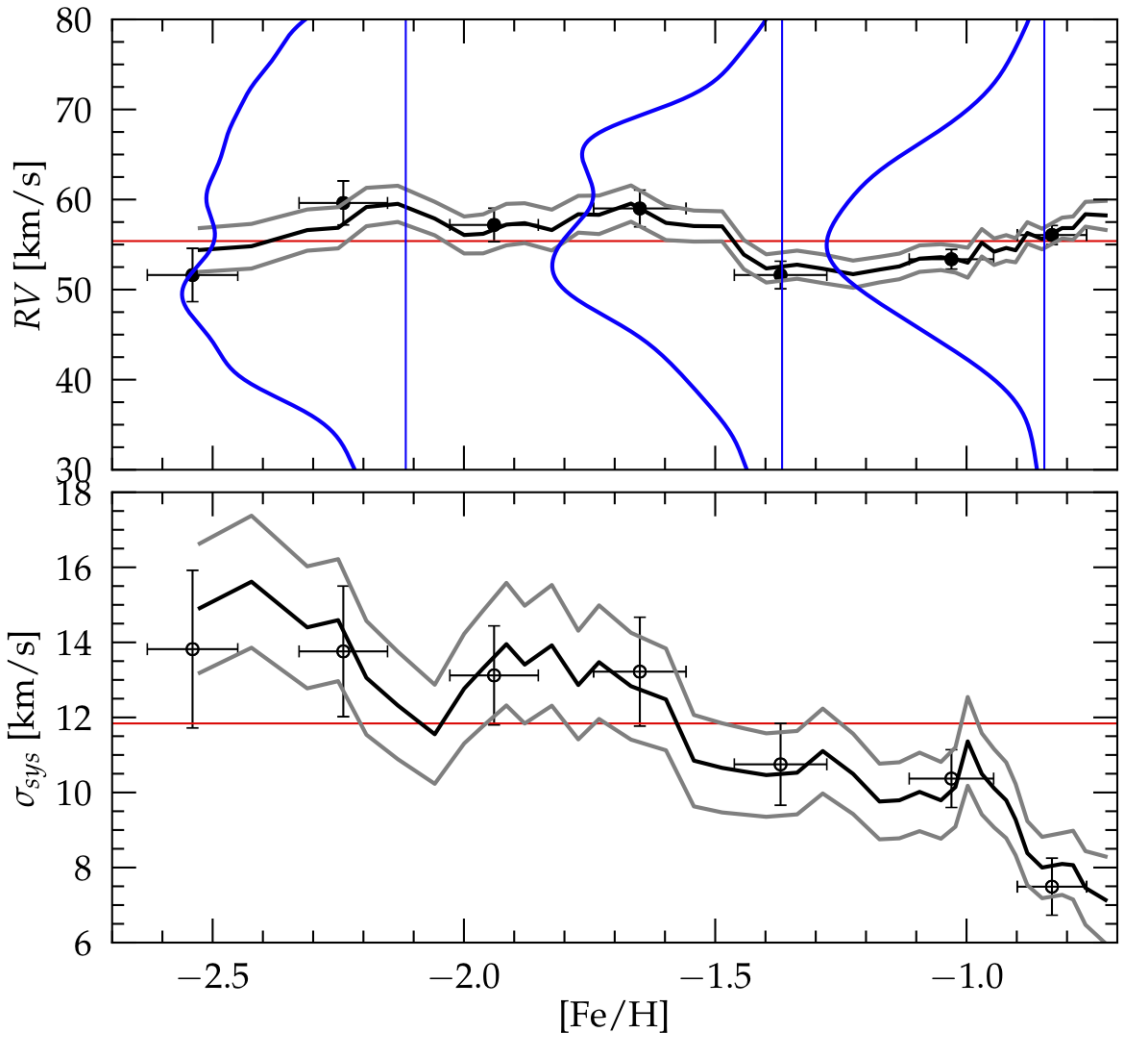

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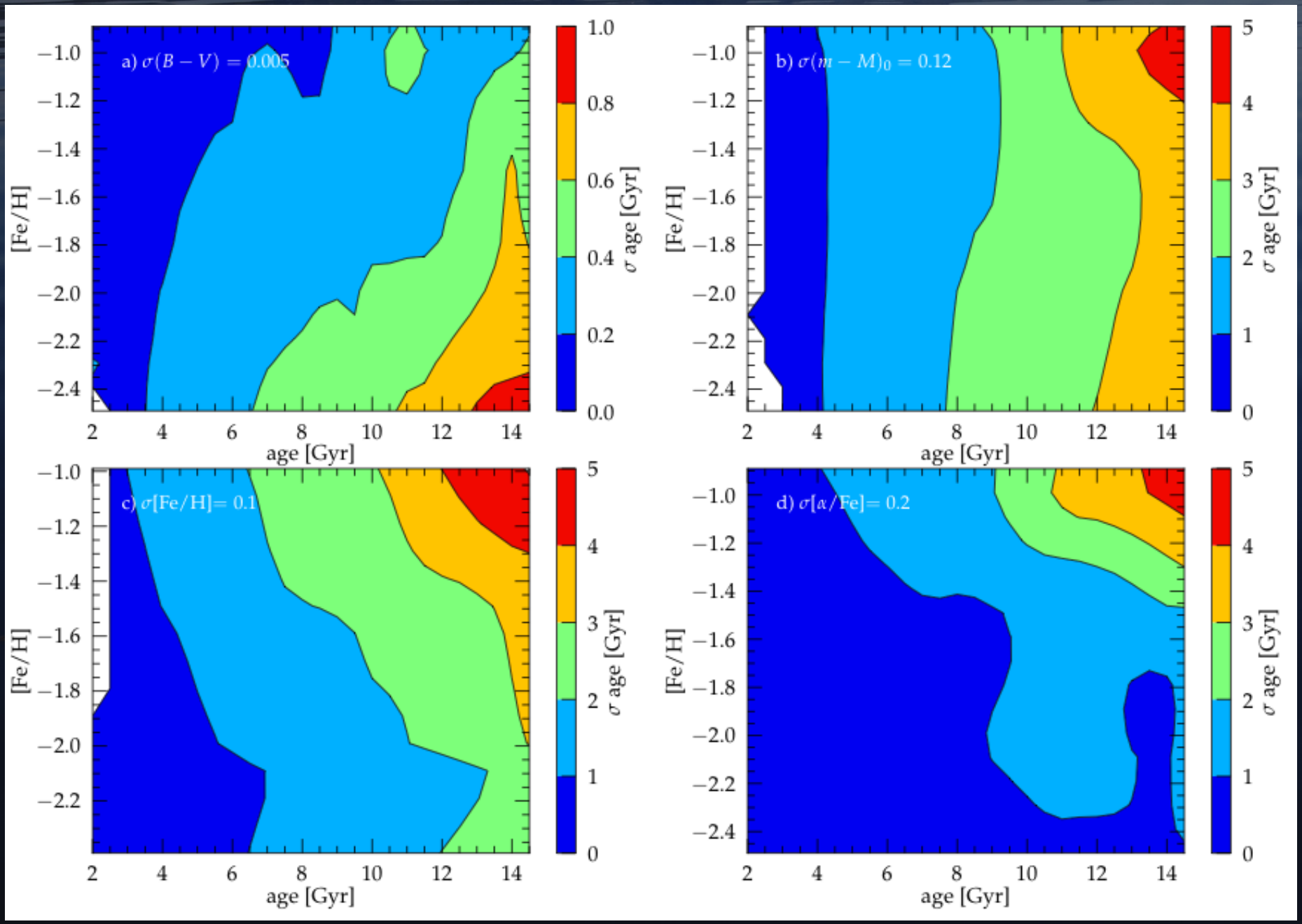
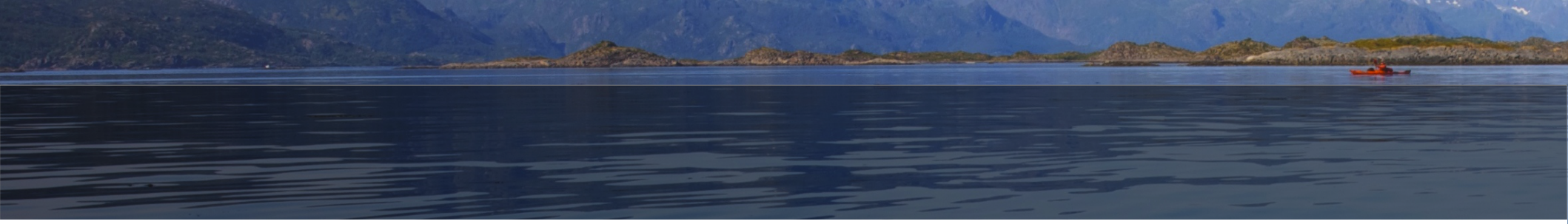
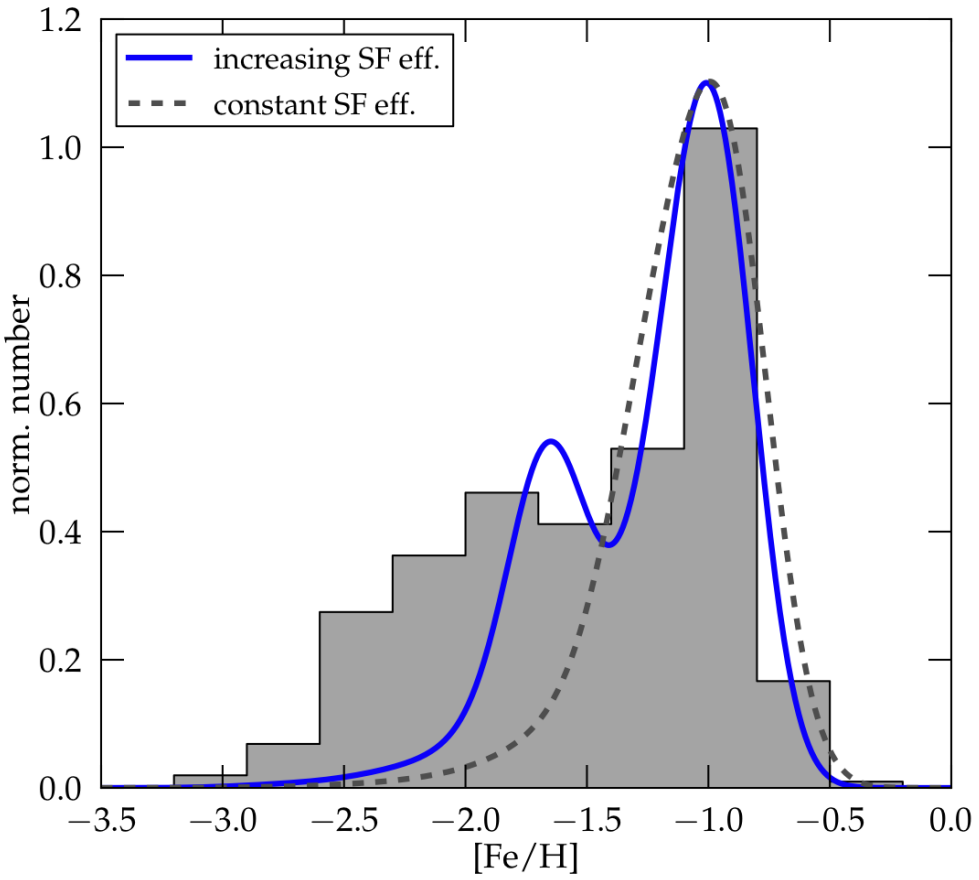
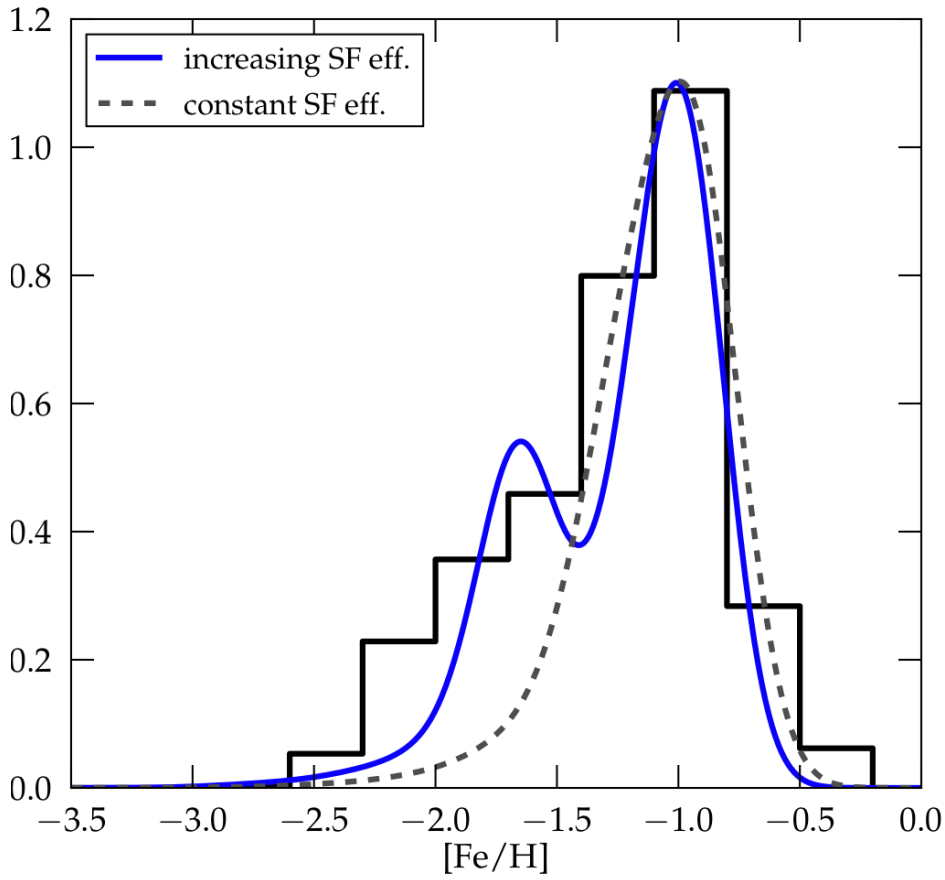

a) $\sigma(B-V) = 0.005$
b) $\sigma(m-M)_0 = 0.12$
c) σ[Fe/H]= 0.1
d) σ[α/Fe]= 0.2
[Fe/H]
age [Gyr]
σ age [Gyr]




increasing SF eff.
constant SF eff.
norm. number
[Fe/H]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0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−0.5
0.0