The dawn of galaxy formation from a chemo-archeological perspective

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Chemical evolution: metal budget

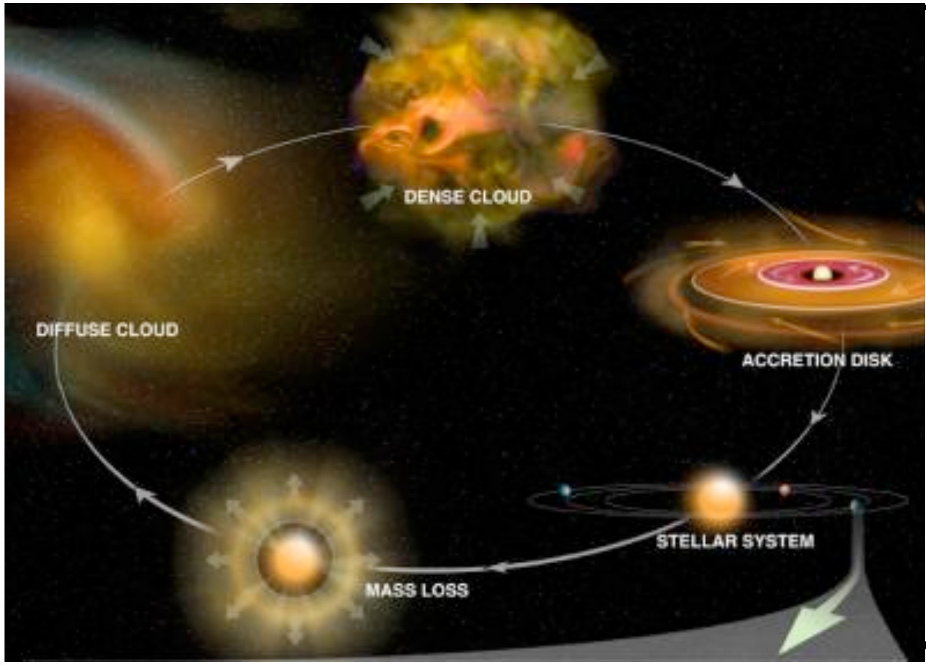
Low [Fe/H]
Low [α/Fe]?

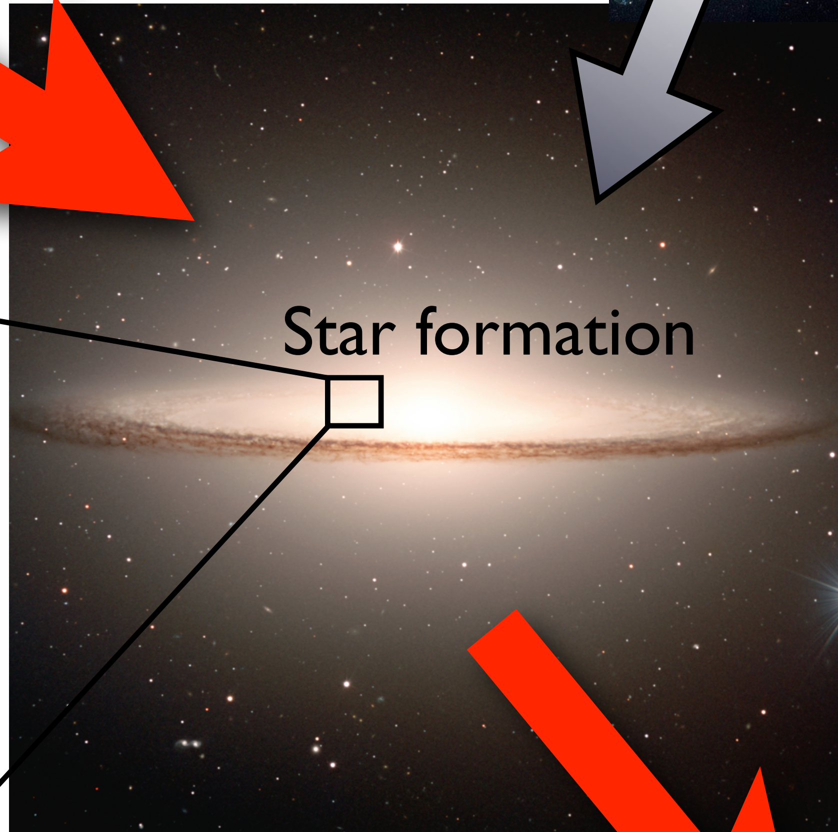
Low Z?

Gas accretion

Merging

Enrichment with time:
[Fe/H] increases!



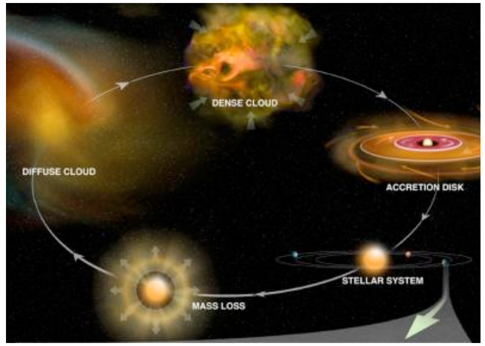


Star formation

Winds

High Z?

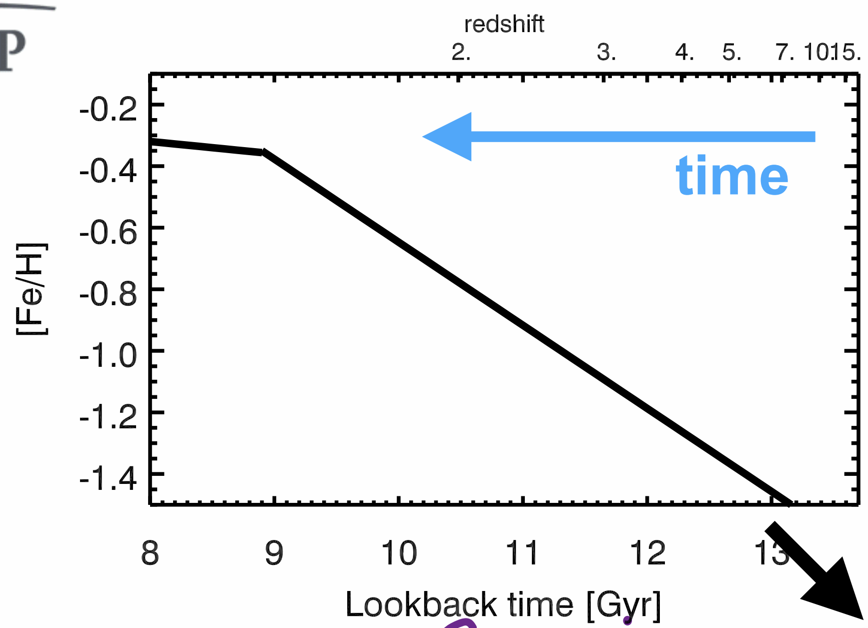
The three agents of chemical enrichment

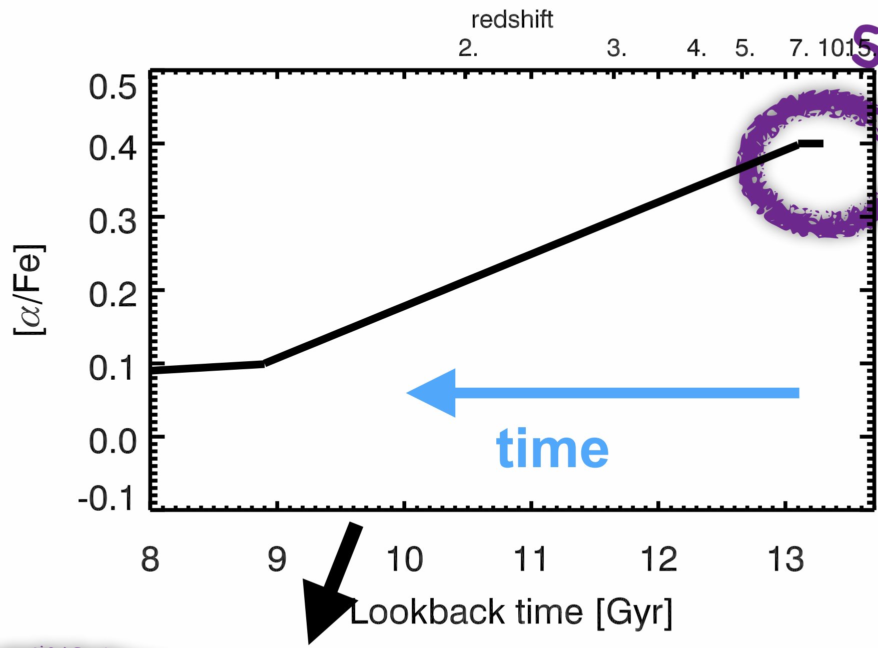


- SNe II:
  - **timescale <10 Myr**
  - produce Fe and α-elements, intrinsic [α/Fe]~0.4
  - α-elements: ((C), O,) Ne, **Mg**, Si, S, Ar(, Ca)
- SNe Ia:
  - **timescale of >30 Myr**, debated
  - produce Fe, raise [Fe/H], lower [α/Fe]
- AGB stars
  - timescale >100 Myr
  - produce C and s-process elements: Sr, Y, Zr, Ba, La, Ce, Nd, Sm, Pb

Chemical evolution expectations

Cosmic dawn stars

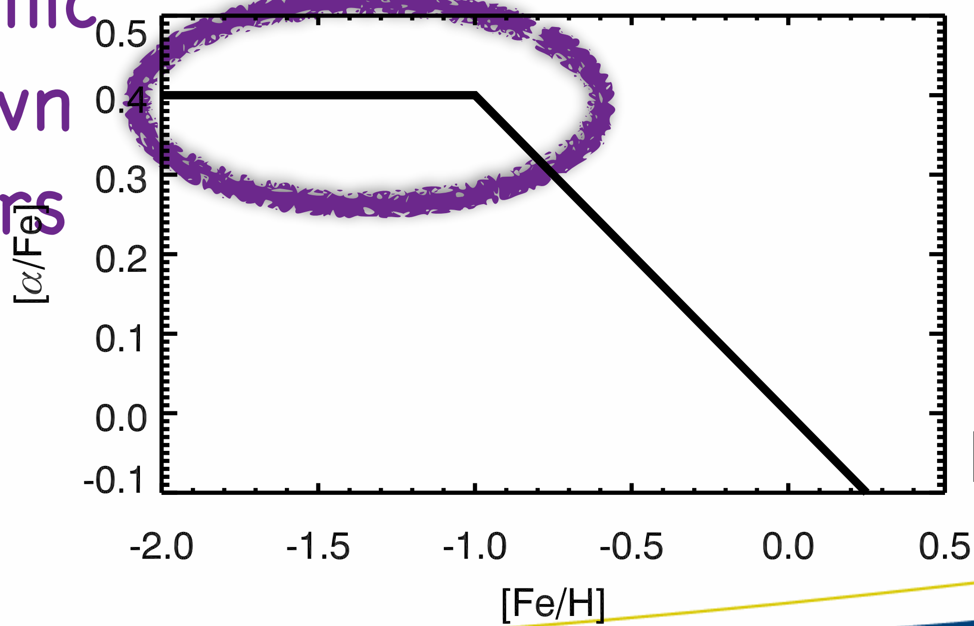




This is a cartoon, not a model!

3 parameters for each star: age, [Fe/H], [α/Fe]

Cosmic dawn stars



~~Timescale: 1-2*10^8 yrs 10 < z < 8.5~~

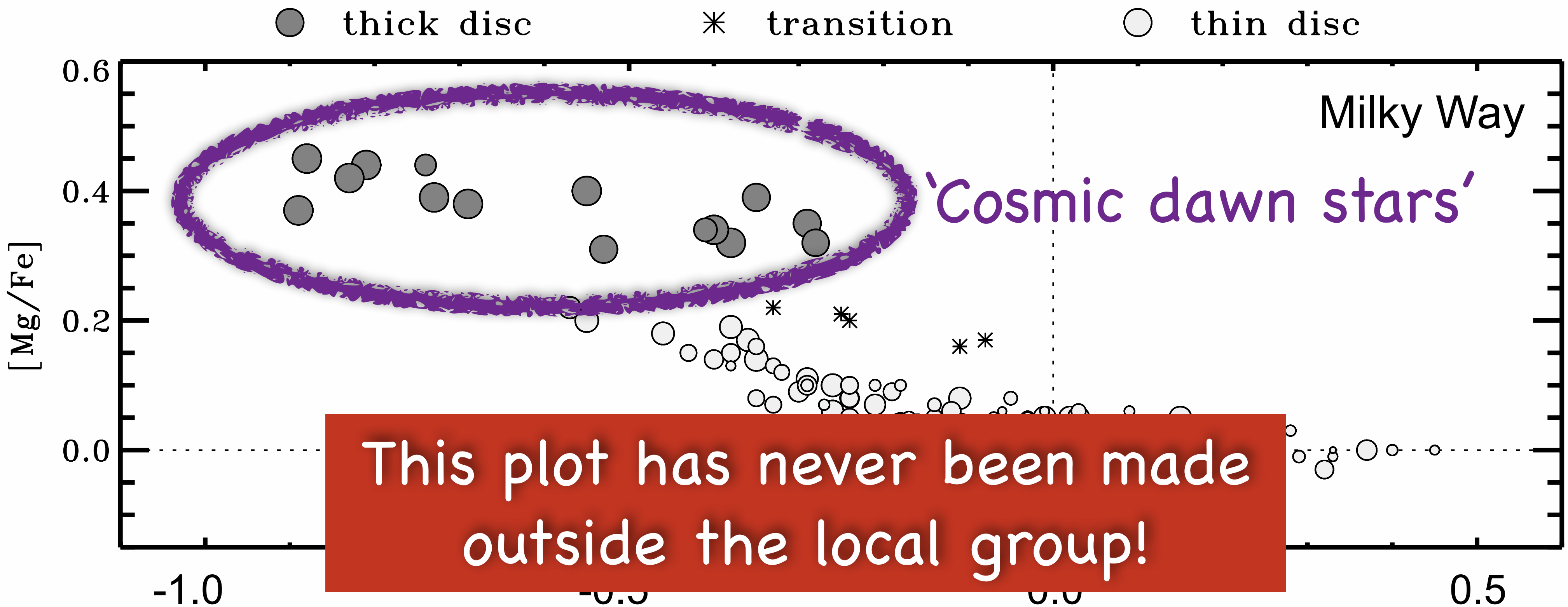
Wrong! Needs work!

Where can we look for these stars?

Method 1:
look back (this conference)

Method 2:
archeology (this talk)

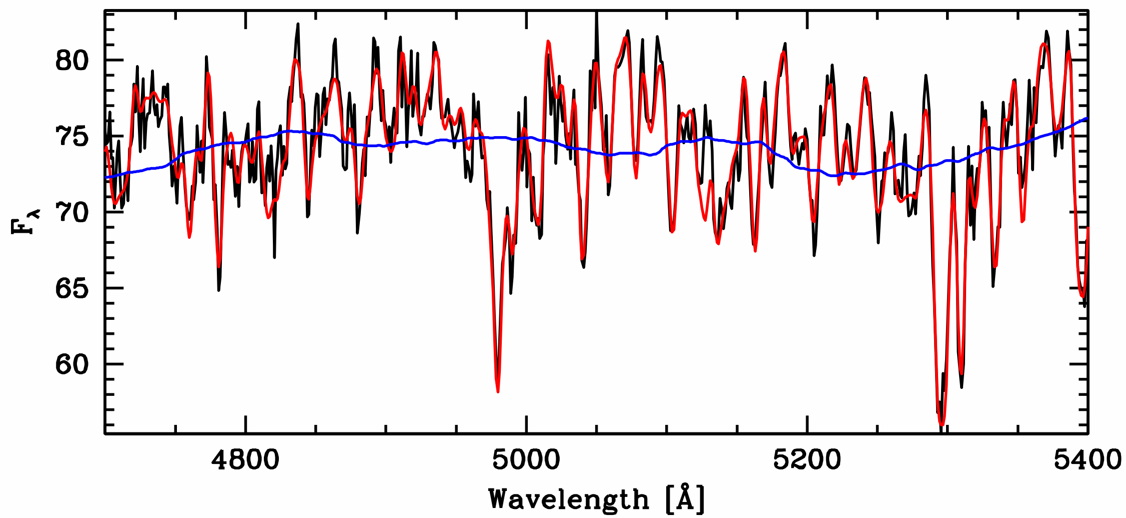
Cosmic dawn stars in the Milky Way

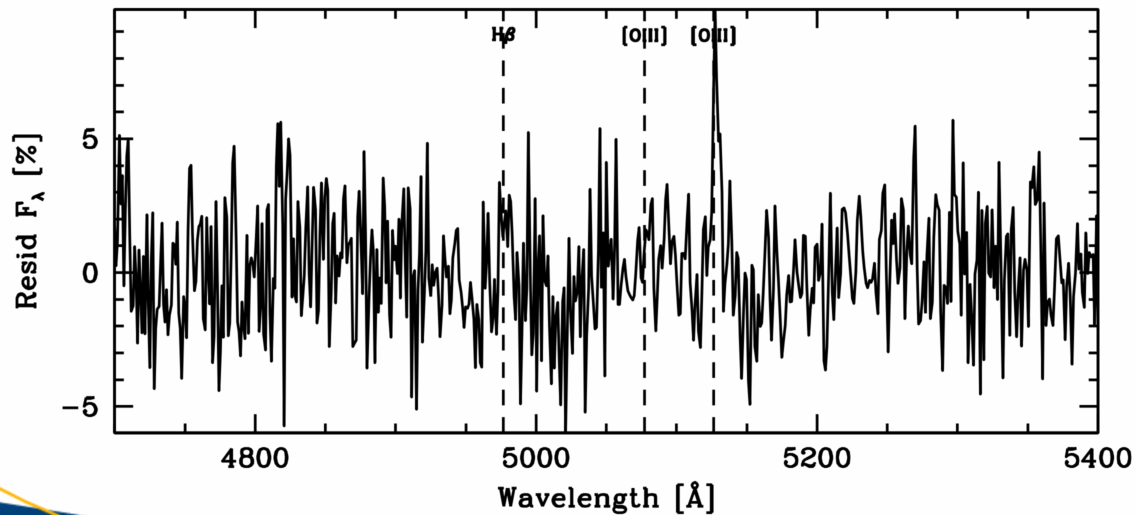


Fuhrmann 2008

This plot shows single stars

Method: Stellar population analysis of early type galaxy spectra





age
[Fe/H]
[α/Fe]

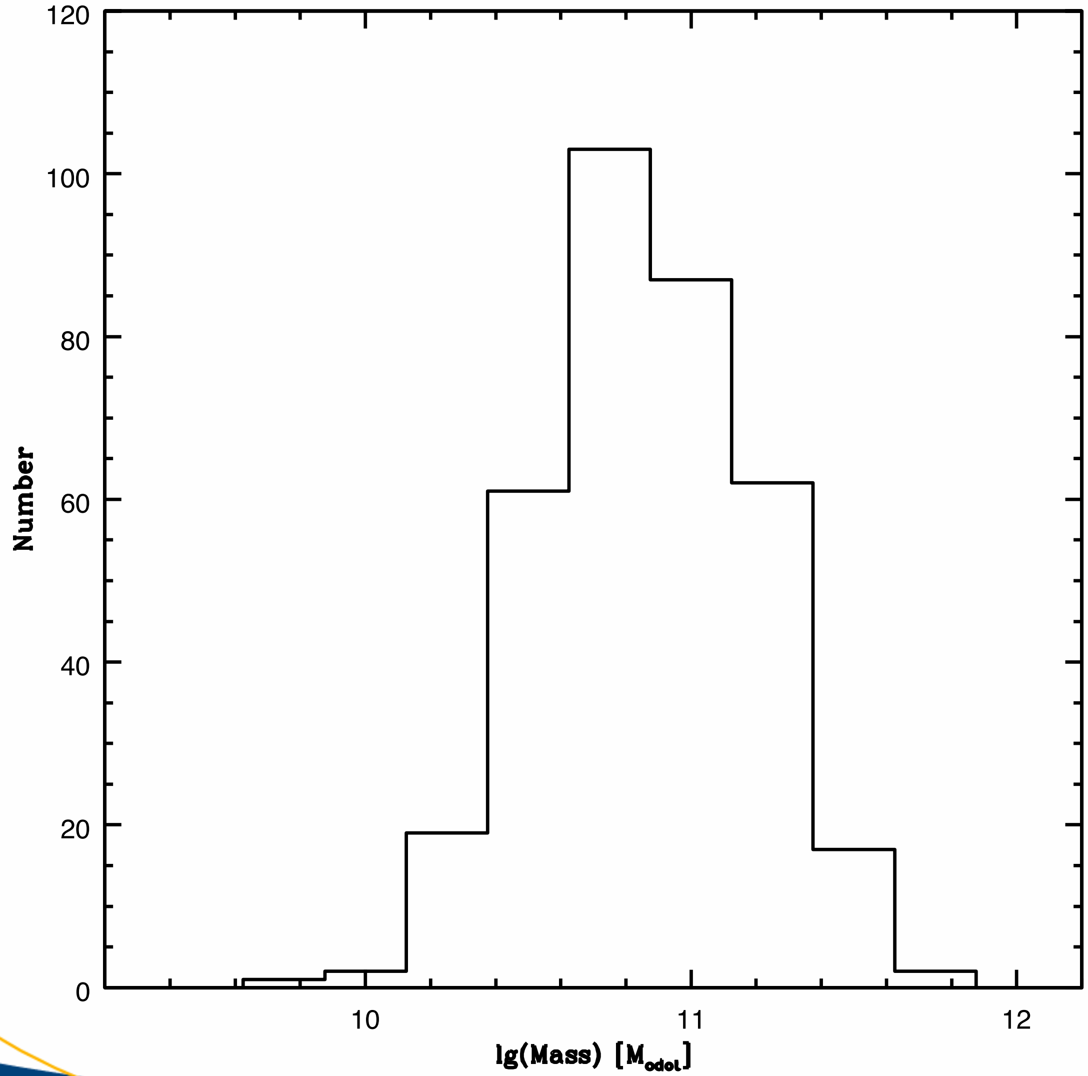
3 params per galaxy

Non-bayesian, "non-parametric" fitting

Beware of the ill-posed problem!!

Dust and continuum slope!!

Sample



2286 ETGs from SDSS

S/N>40

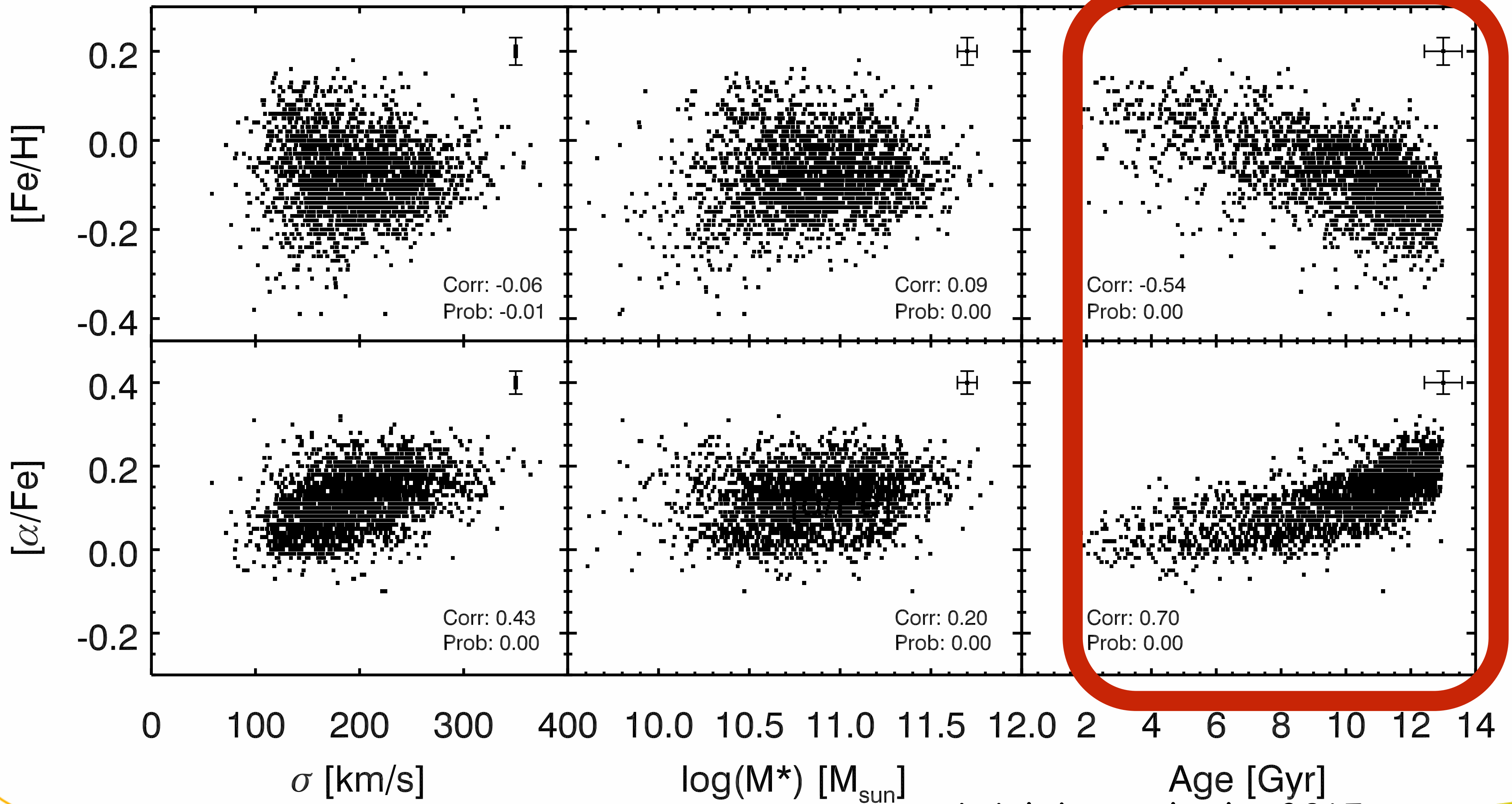
$40 < \sigma < 375$ km/s

r-band concentration C>2.8

S/N < 3 all emission lines

Stellar population relations in ETGs

Bonus slides



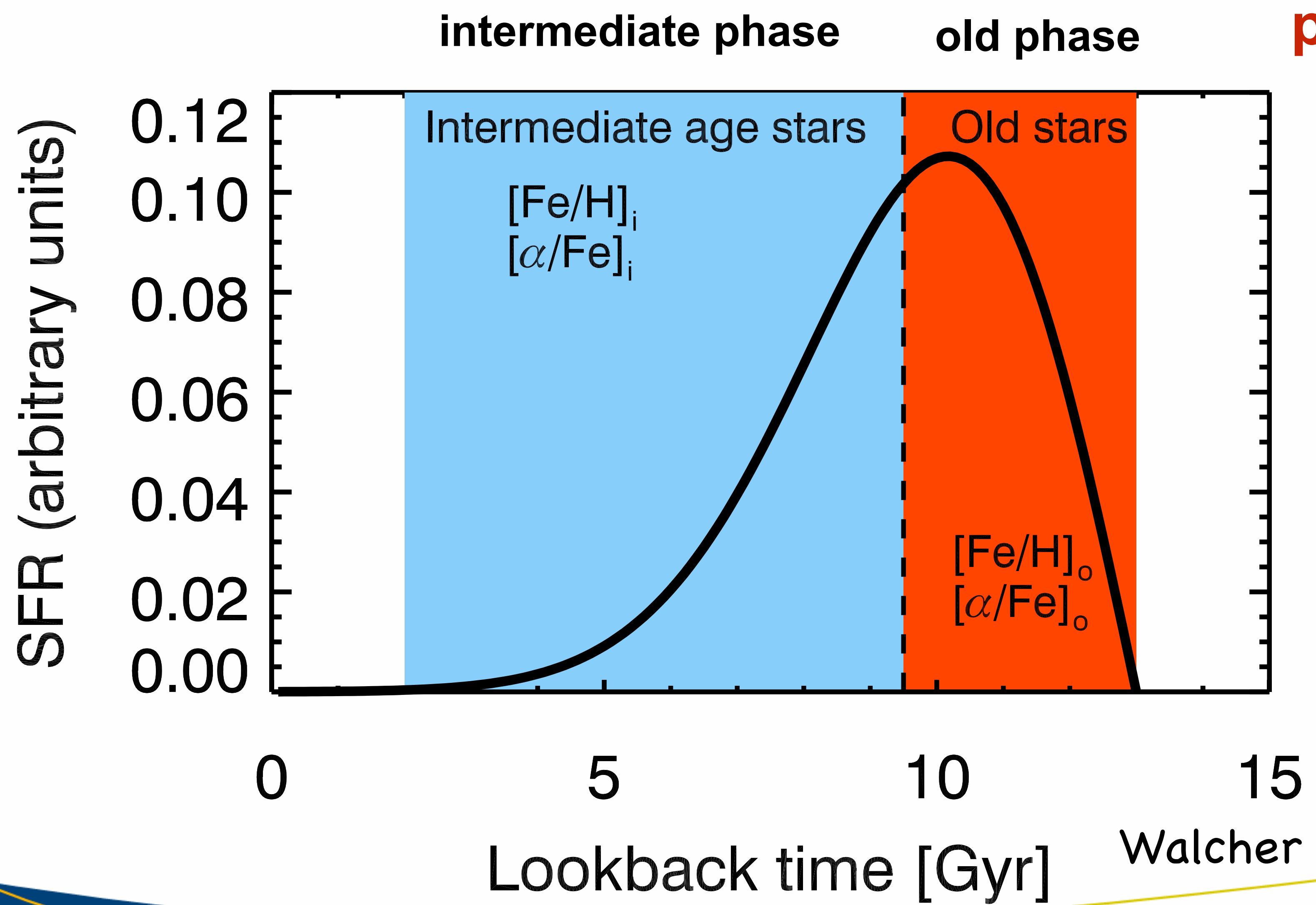
Walcher et al., 2015

What’s new?

- Use of “new” (Coelho+07, Walcher+09) generation of stellar population models (spectral effects and isochrone effects of α-enhancement)
- Use of full spectrum (not only indices)
- Rigorous treatment of degeneracy errors
- Split of star formation history into old and intermediate age stellar populations

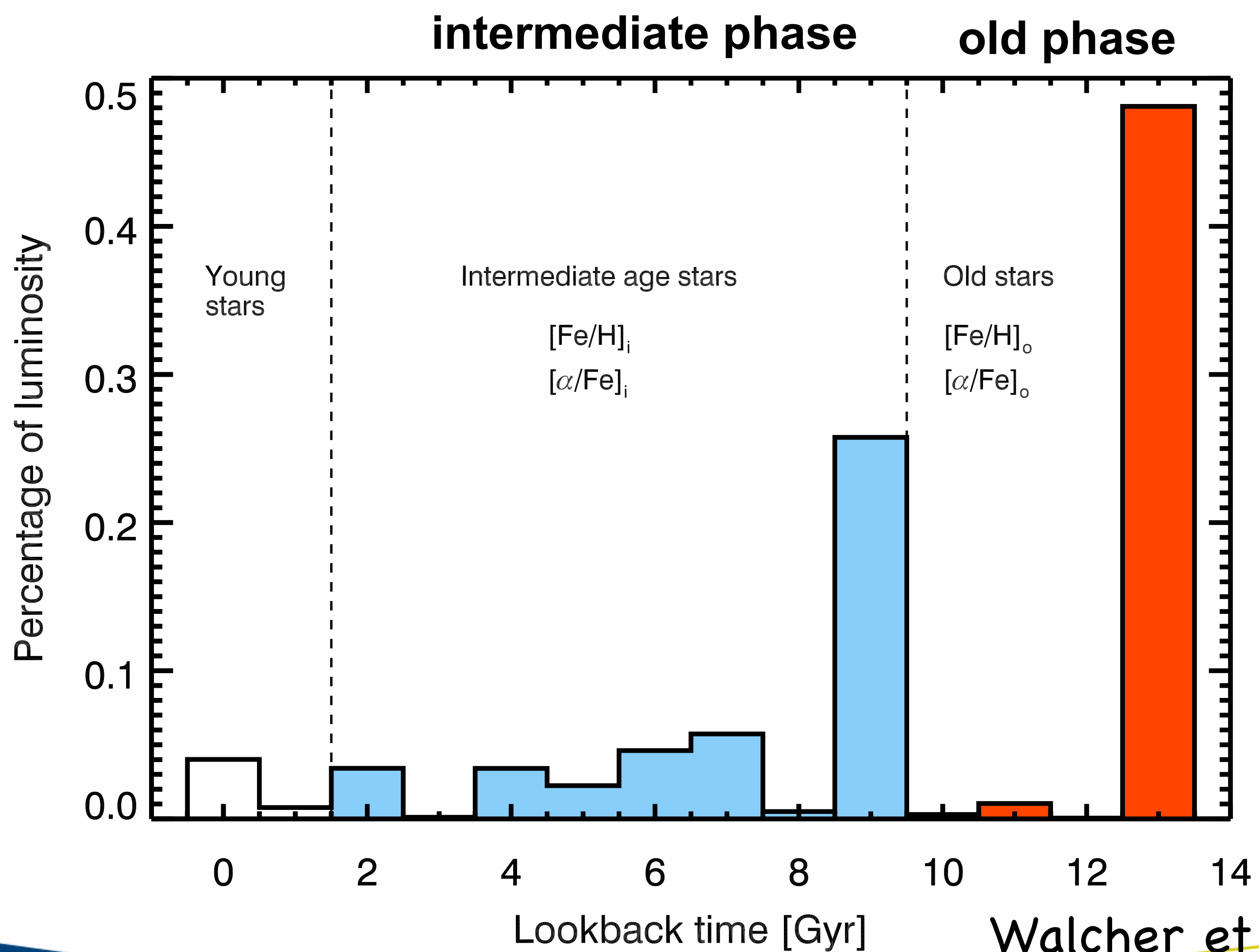
For our ETGs can split enrichment history in two

6 params per galaxy



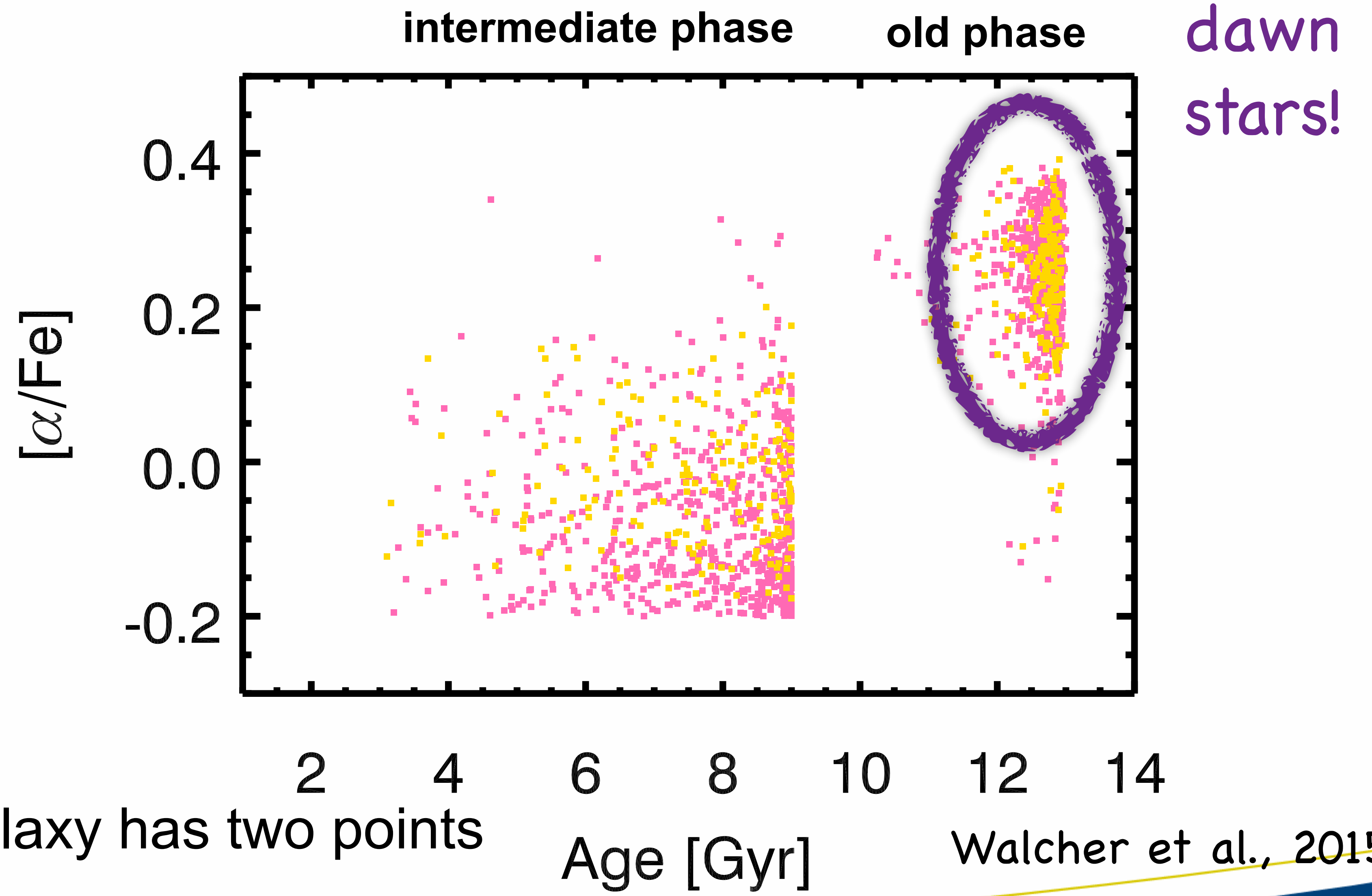
Walcher et al., 2015

For our ETGs can split enrichment history in two



Walcher et al., 2015

Young stars in ETGs are NOT α-enhanced!



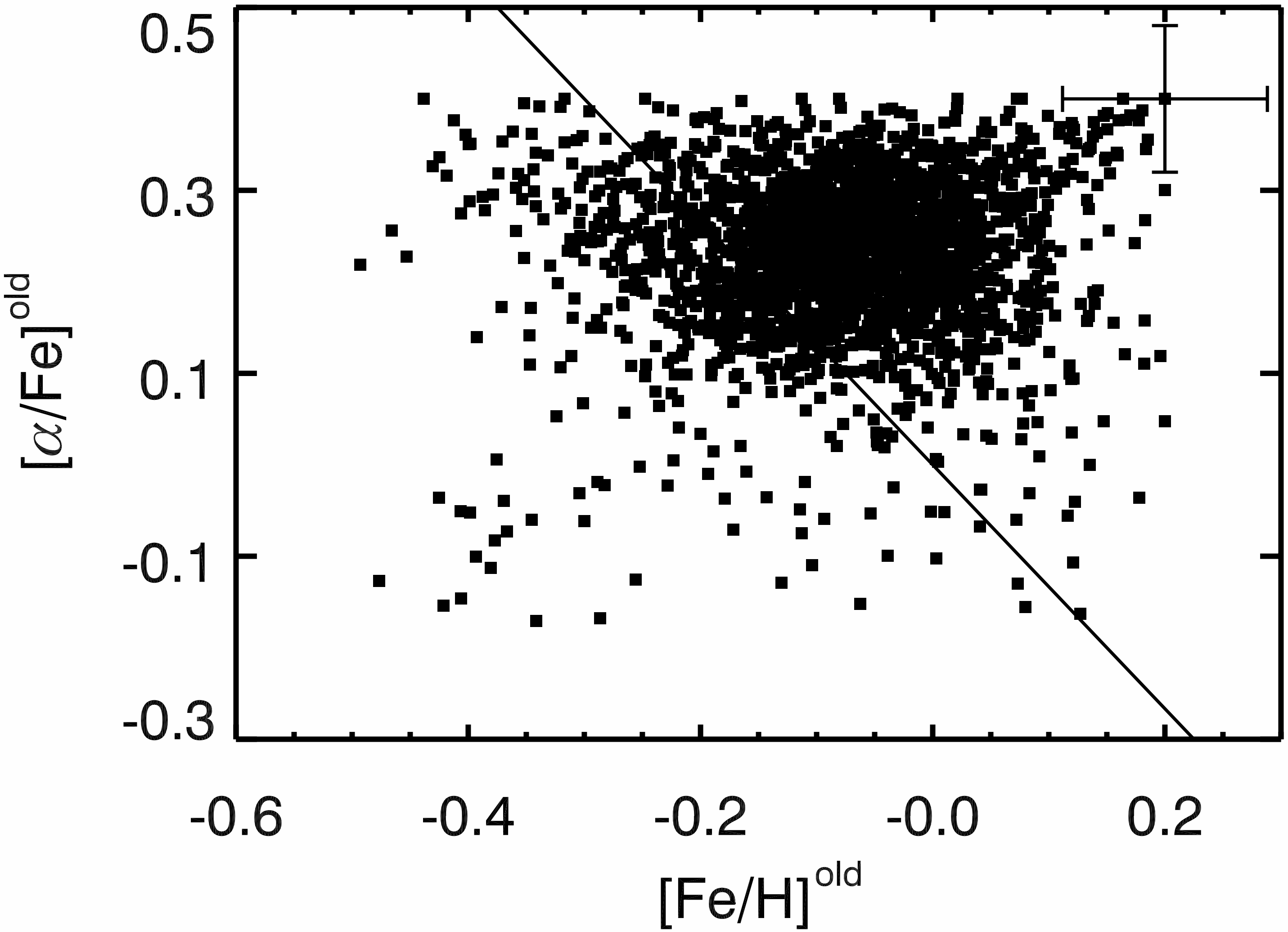
Every galaxy has two points

Walcher et al., 2015

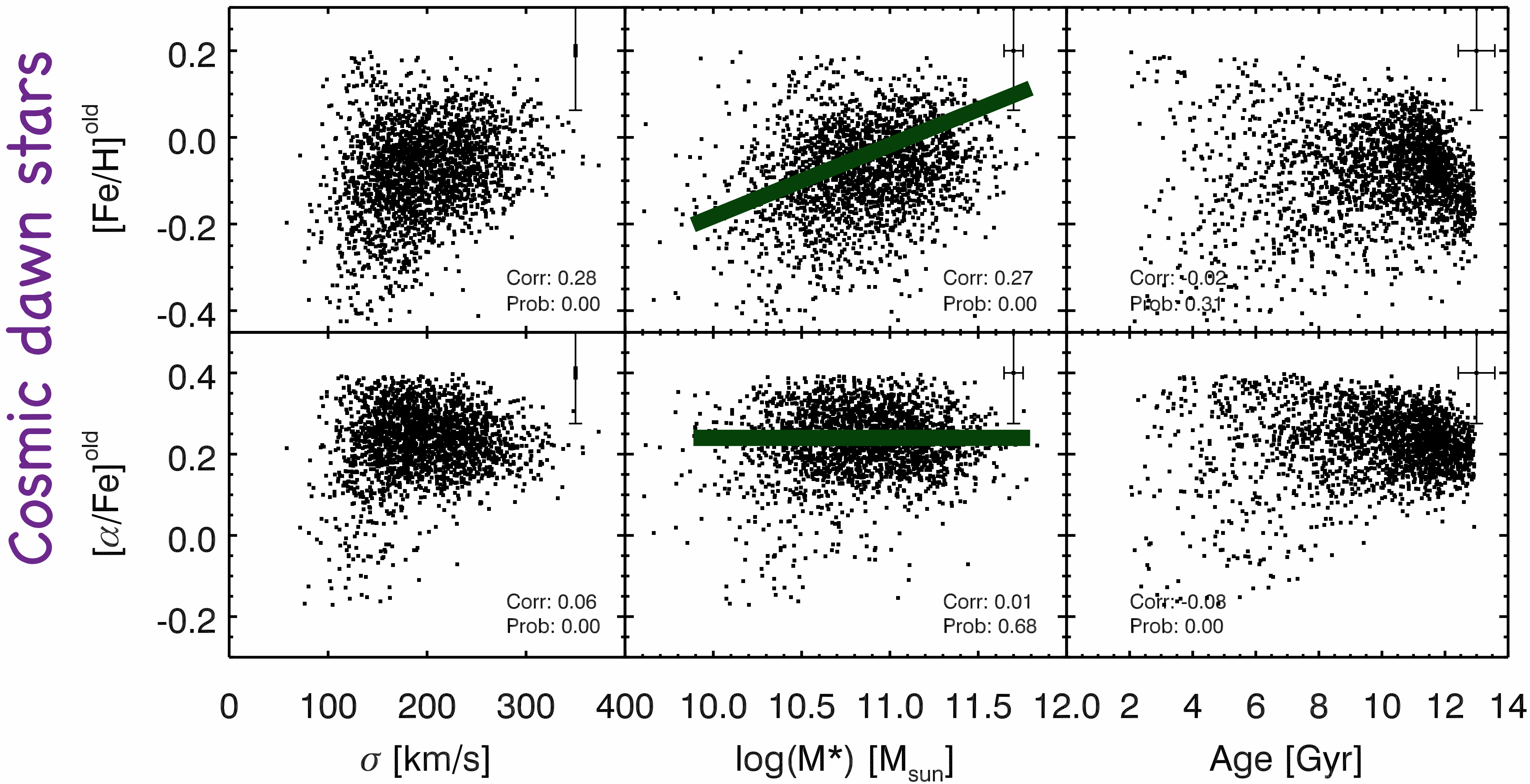
Steidel's data

Metal-rich, α-enhanced stars

Krieks's data

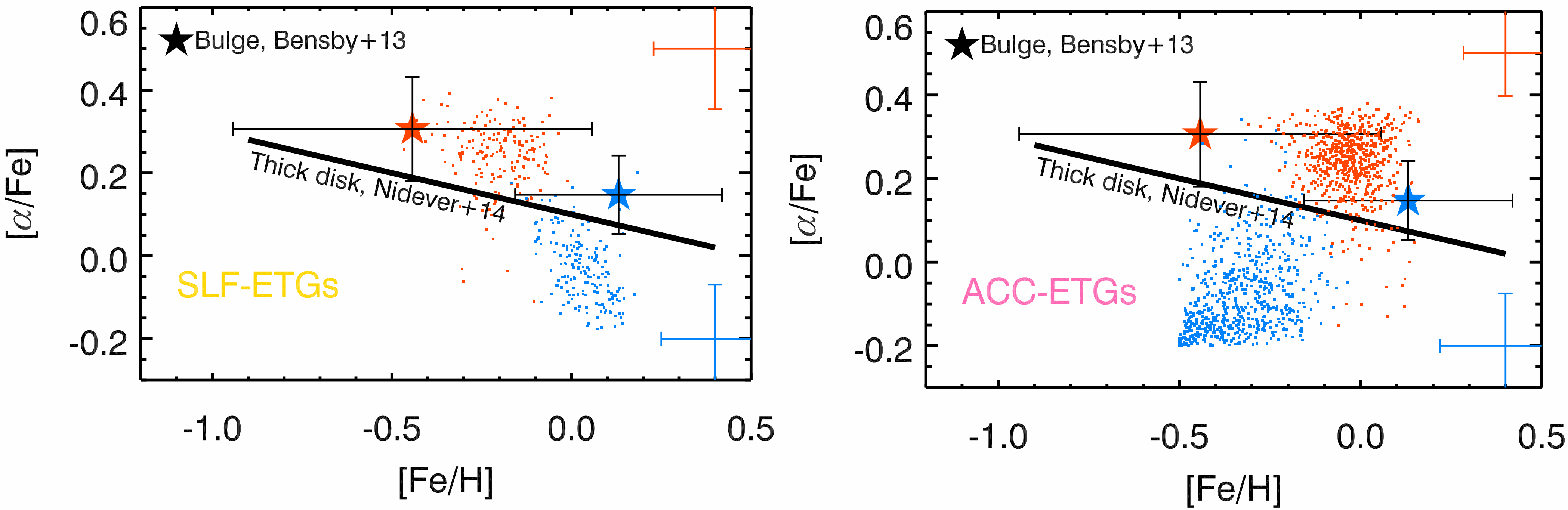


How cosmic dawn properties depend on todays values



Todays' values for all stars in ETG

Late mass growth of massive gals



Self-enriched
10-20%
of sample

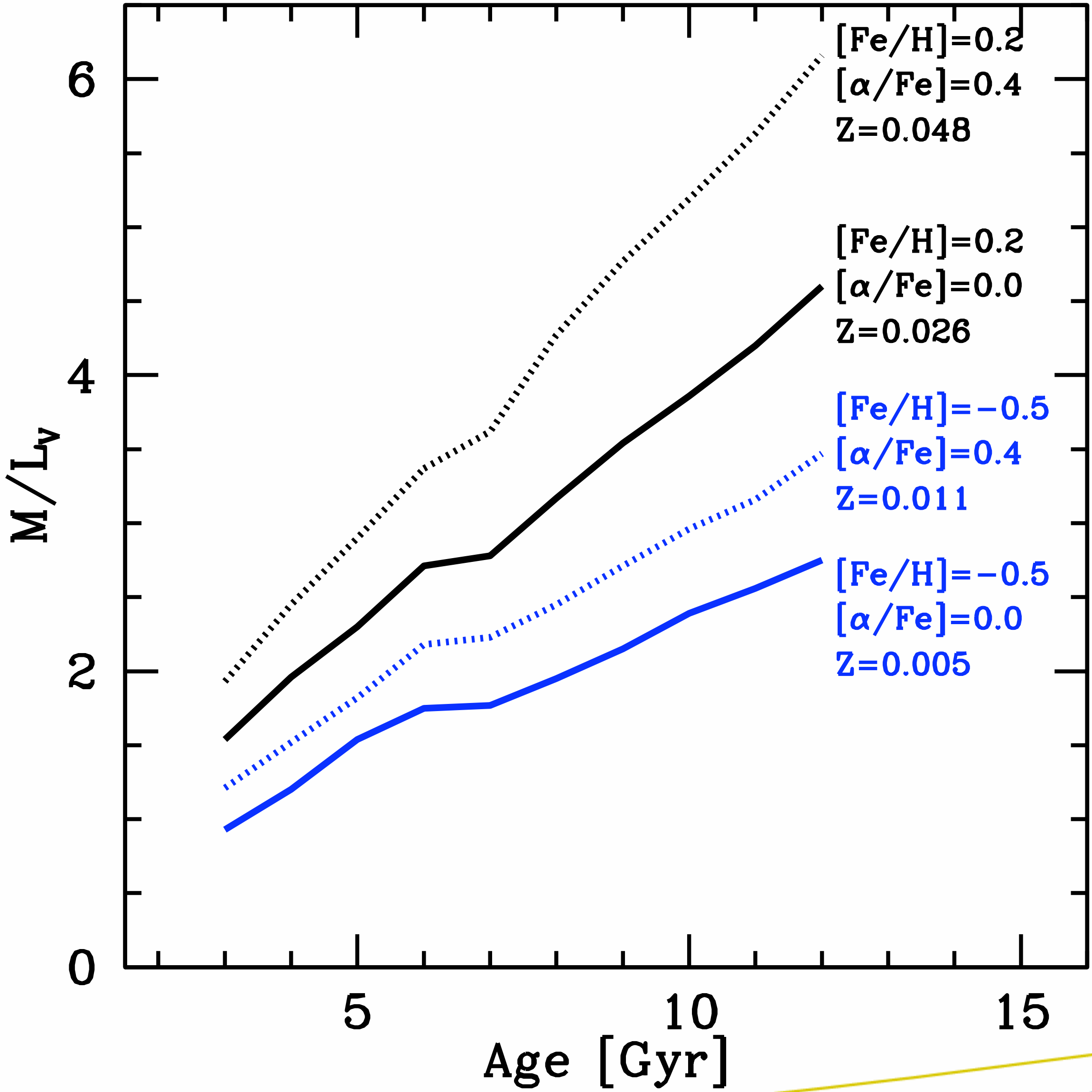
Accretion
dominated
80-90%

Walcher et al., 2015

Reminder: opacities - Mass-to-light

Solid:
todays
stars

Dotted:
cosmic
dawn
stars



Walcher et al., 2009

Conclusions

- The extended star formation histories of early-type galaxies can be resolved.
- Cosmic dawn stars in massive galaxies are metal-rich, α-enhanced stars.
- Beware of opacity changes in the UV for α-enhanced stellar populations!
- Not all enrichment histories are rising in metallicity!
- If you are not tired of archeology, there is a bonus on the next slides about SNeIa…

Self-similarity in chemical evolution and the delay time distribution of SNe Ia

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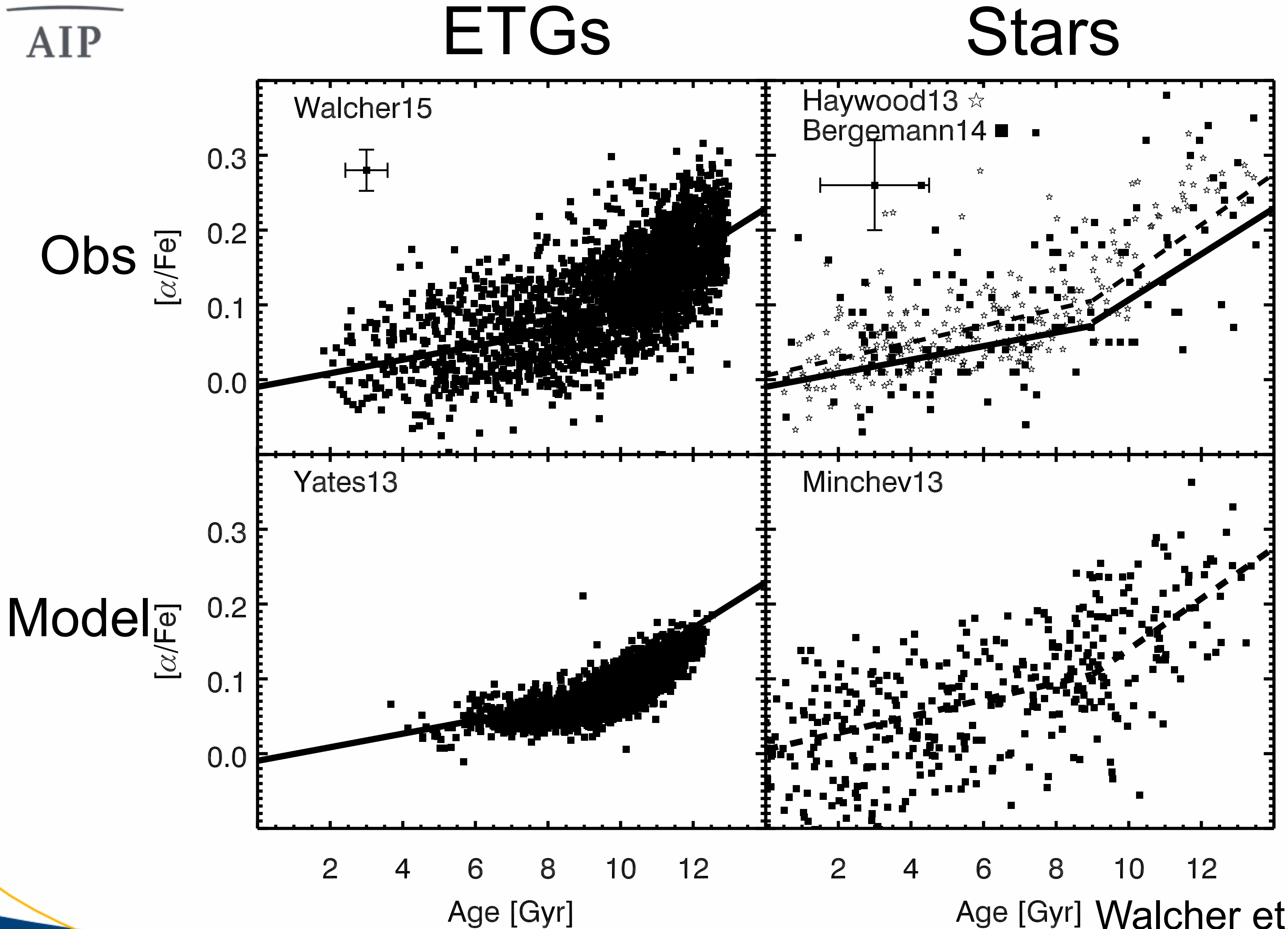
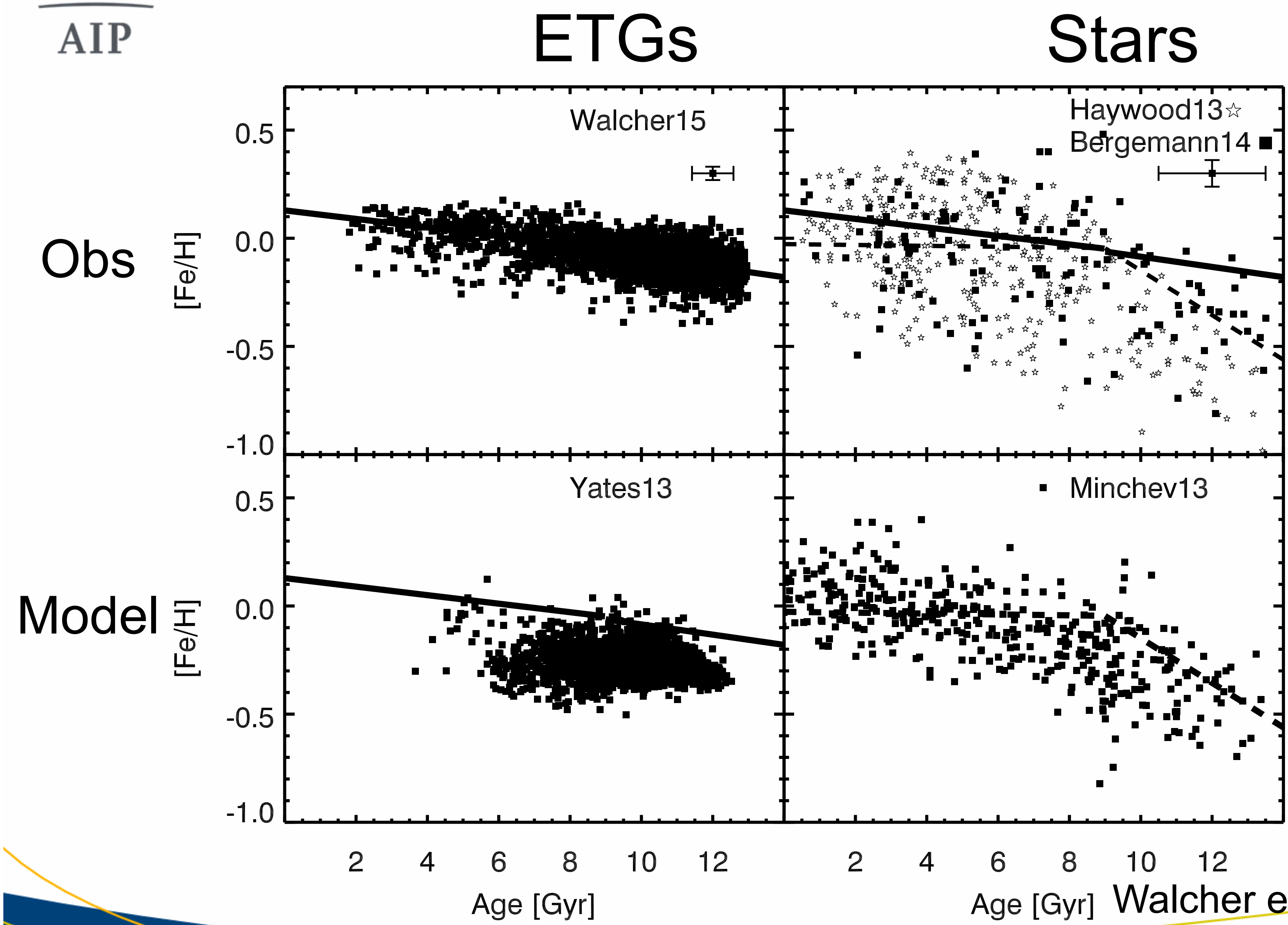
Age - [α/Fe] similar!!



Walcher et al, subm.

Age - [Fe/H] ??

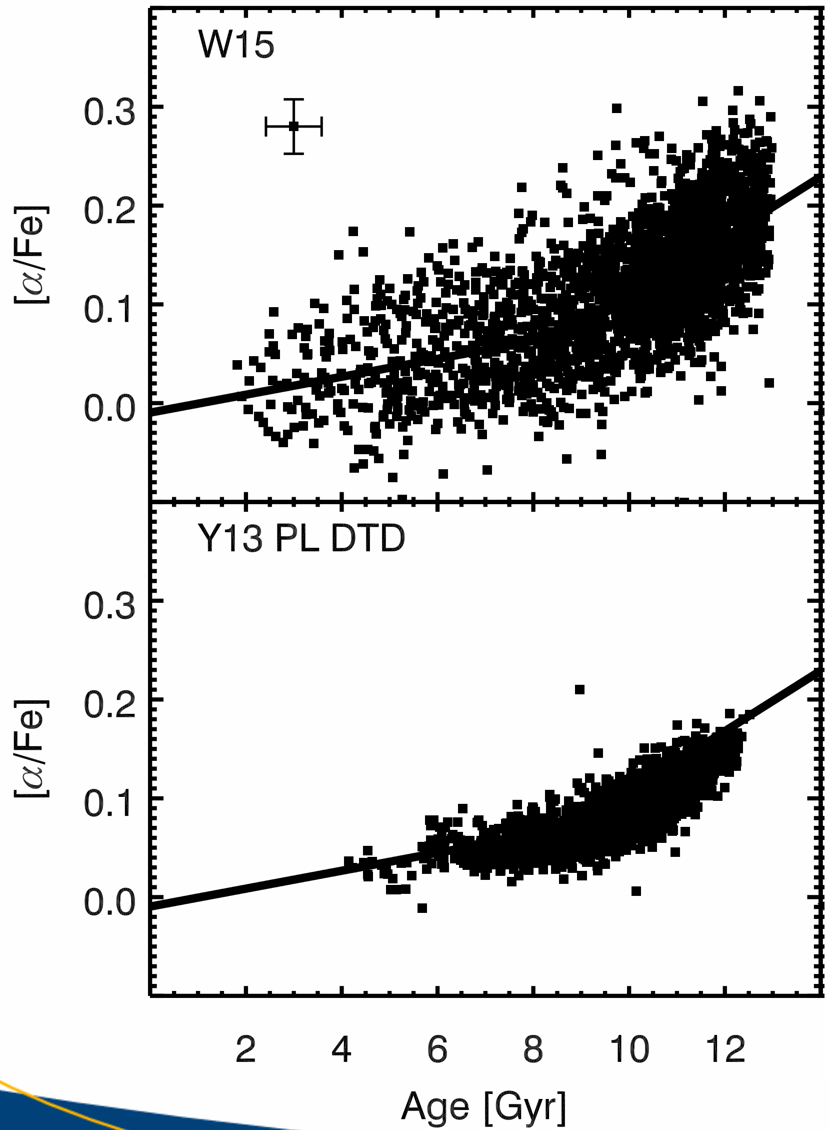
Different, thus star formation histories must be different as well



Walcher et al, subm.

What determines age-[α/Fe]?

We just learned it is not the star formation history



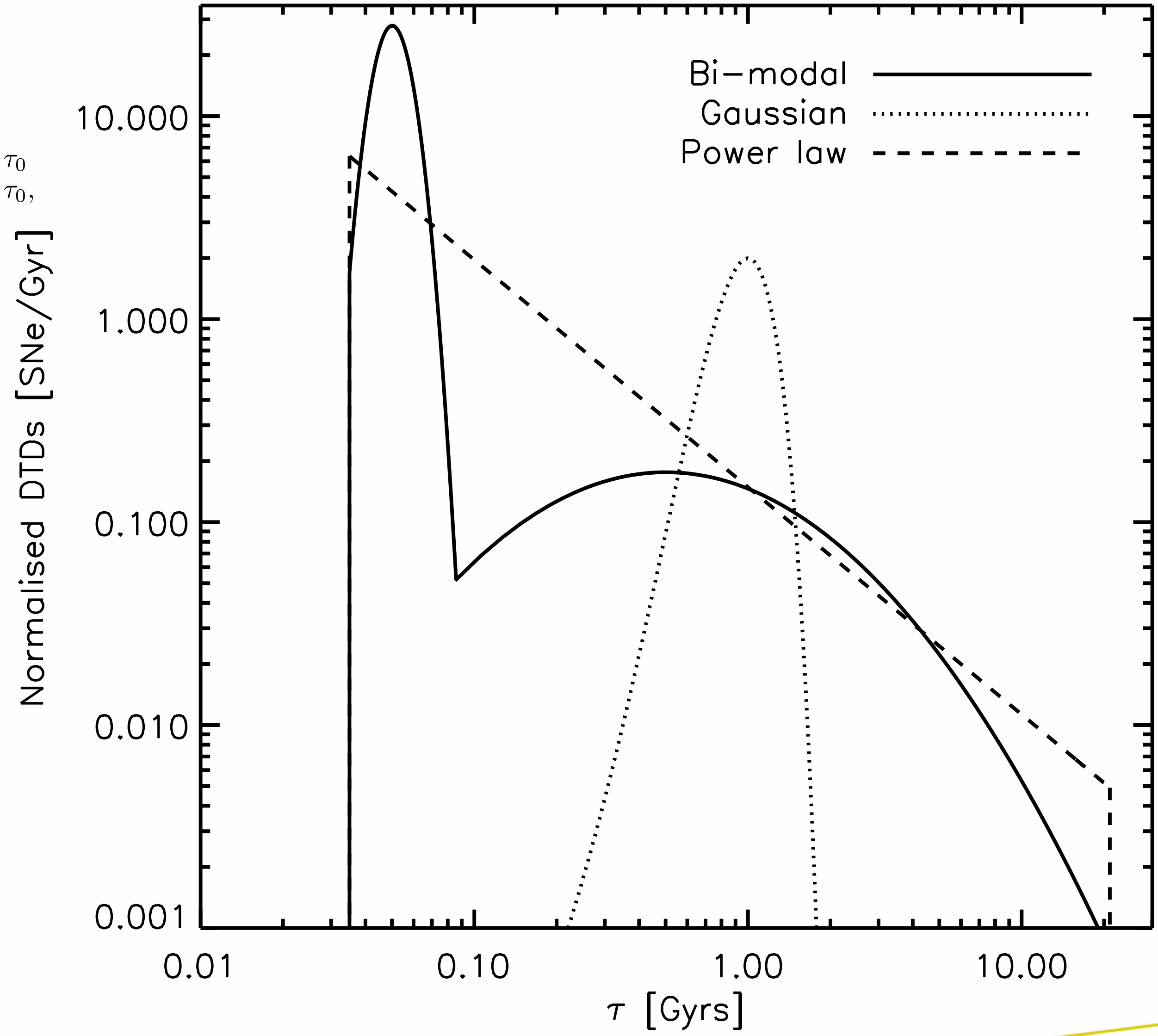
Age [Gyr] Walcher et al, subm.

Delay Time Distribution of SNe Ia

$$\log(\mathrm{DTD_{BM}}) = \begin{cases} 1.4 - 50(\log(\tau/\mathrm{yr}) - 7.7)^2 & \text{if } \tau < \tau_0 \\ -0.8 - 0.9(\log(\tau/\mathrm{yr}) - 8.7)^2 & \text{if } \tau > \tau_0, \end{cases}$$

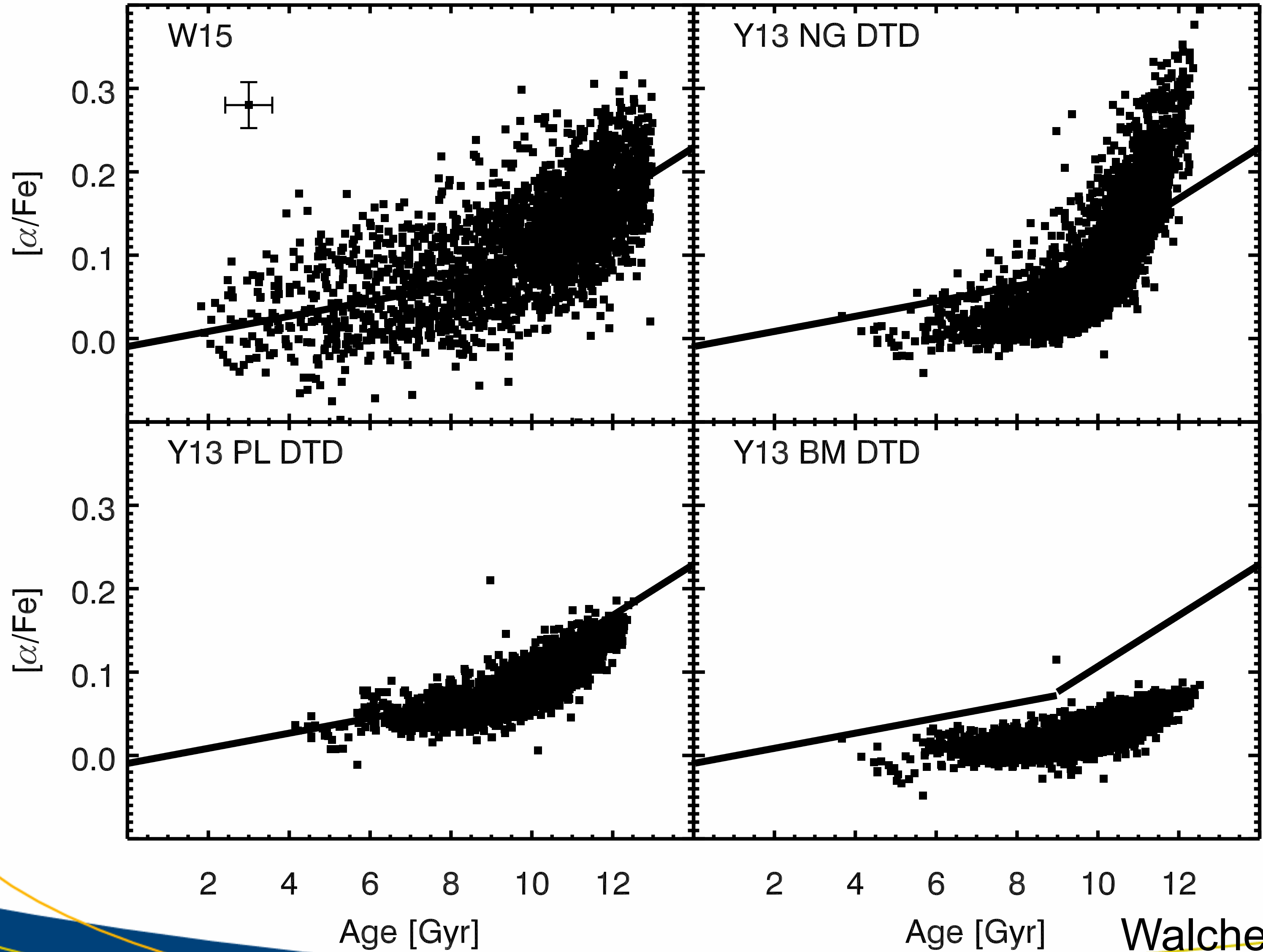
$$\mathrm{DTD_{NG}} = \frac{1}{\sqrt{2\pi\sigma_\tau^2}} e^{-(\tau-\tau_c)^2/2\sigma_\tau^2}.$$

$$\mathrm{DTD_{PL}} = a(\tau/\mathrm{Gyr})^{-1.12}$$



What determines age-[α/Fe]?

It is the DTD of SNeIa!



Power law DTD starts after ~30 Myr!

Fully consistent with work by Matteucci et al. for Milky Way

Walcher et al, subm.

Conclusions

- The extended star formation histories of early-type galaxies can be resolved.
- Cosmic dawn stars in massive galaxies are metal-rich, α-enhanced stars.
- Beware of opacity changes in the UV for α-enhanced stellar populations!
- Not all enrichment histories are rising in metallicity!
- The SNe Ia DTD derived from ETGs and chemical arguments is a power law.

AIP