RECONSTRUCTING THE ACCRETION HISTORY OF THE GALACTIC STELLAR HALO FROM CHEMICAL ABUNDANCE RATIO DISTRIBUTIONS (CARDs)

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Simulations of Halo Accretion

Credit: James Bullock

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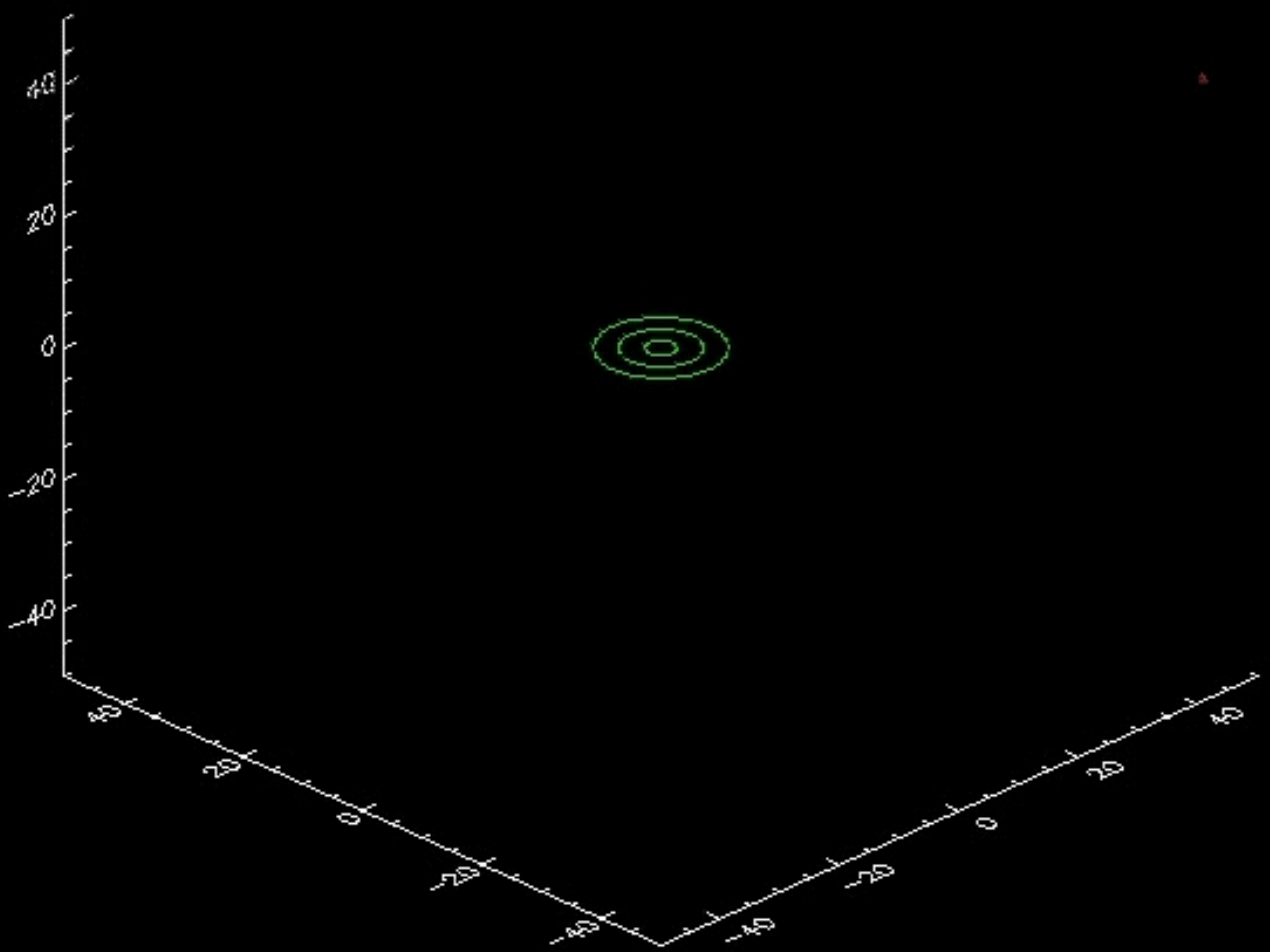

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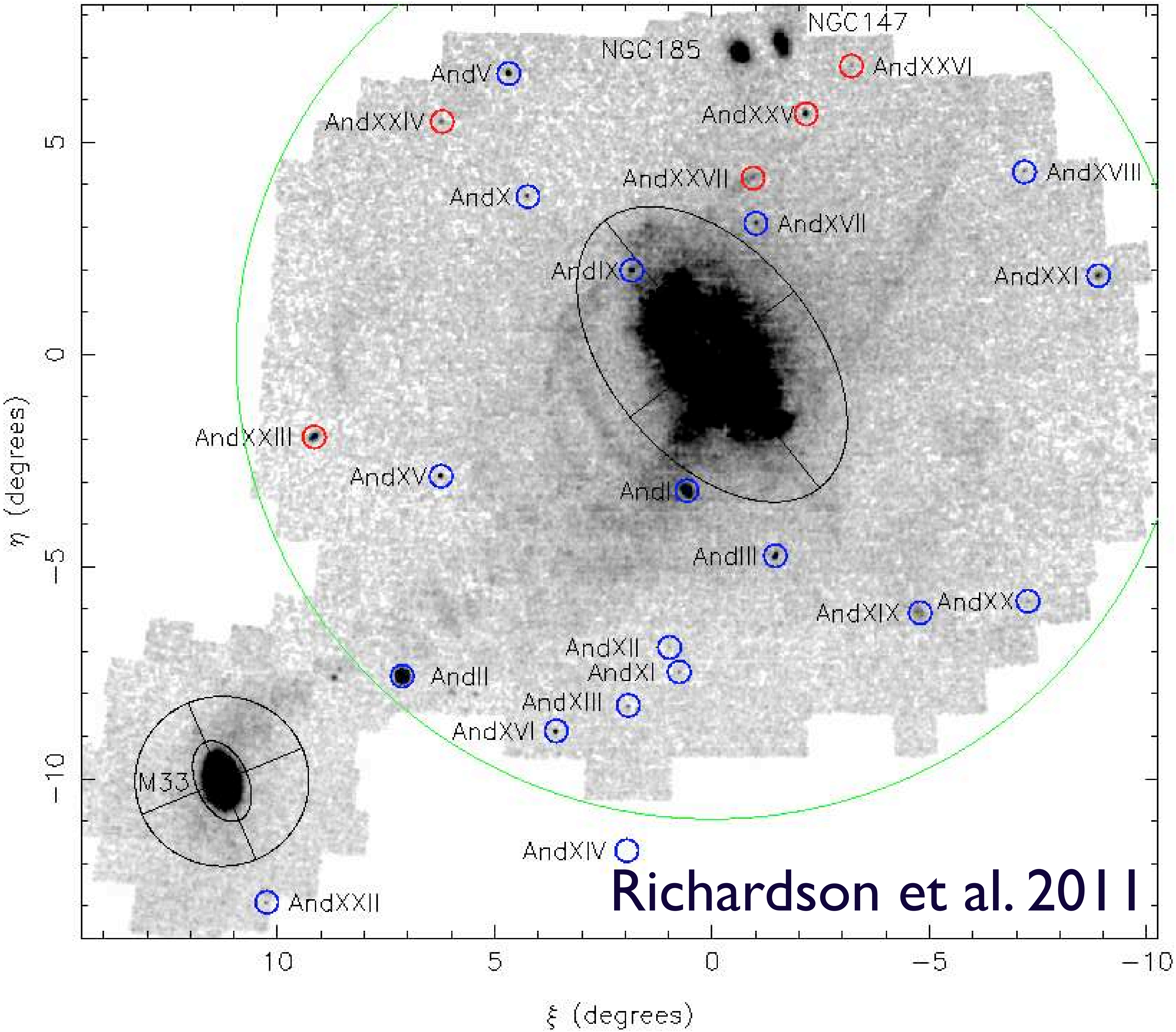
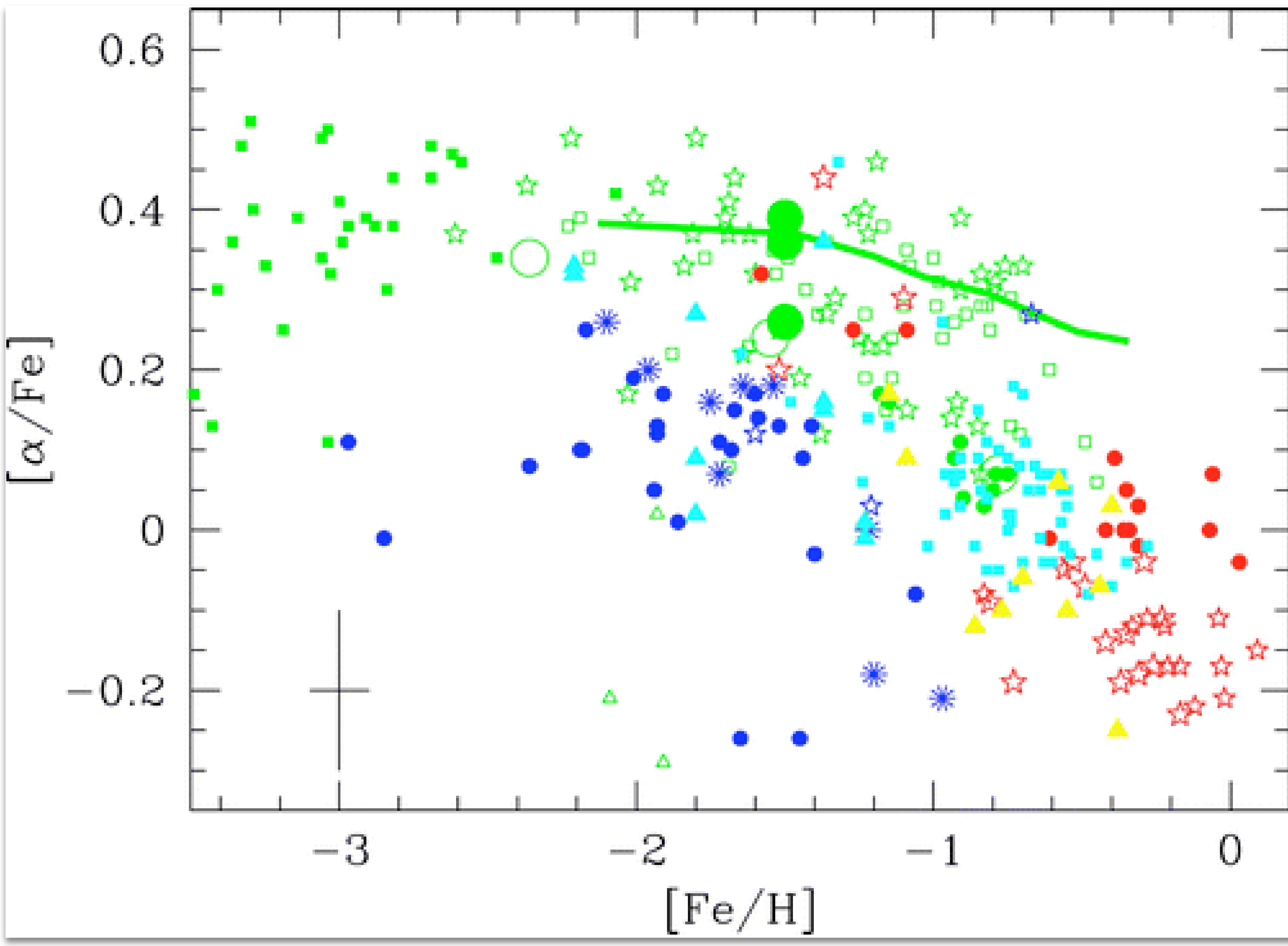
Observations of Hierarchical Merging



- Stellar halo "sub-structure" found using star counts
- Dynamical models can be applied to "extract" recent accretion history
- "Phase mixing" limits the scope of dynamical modeling (no streams)

Motivation



green - halo
blue - low mass dSph
yellow - dIrr
red - Sgr
cyan - LMC

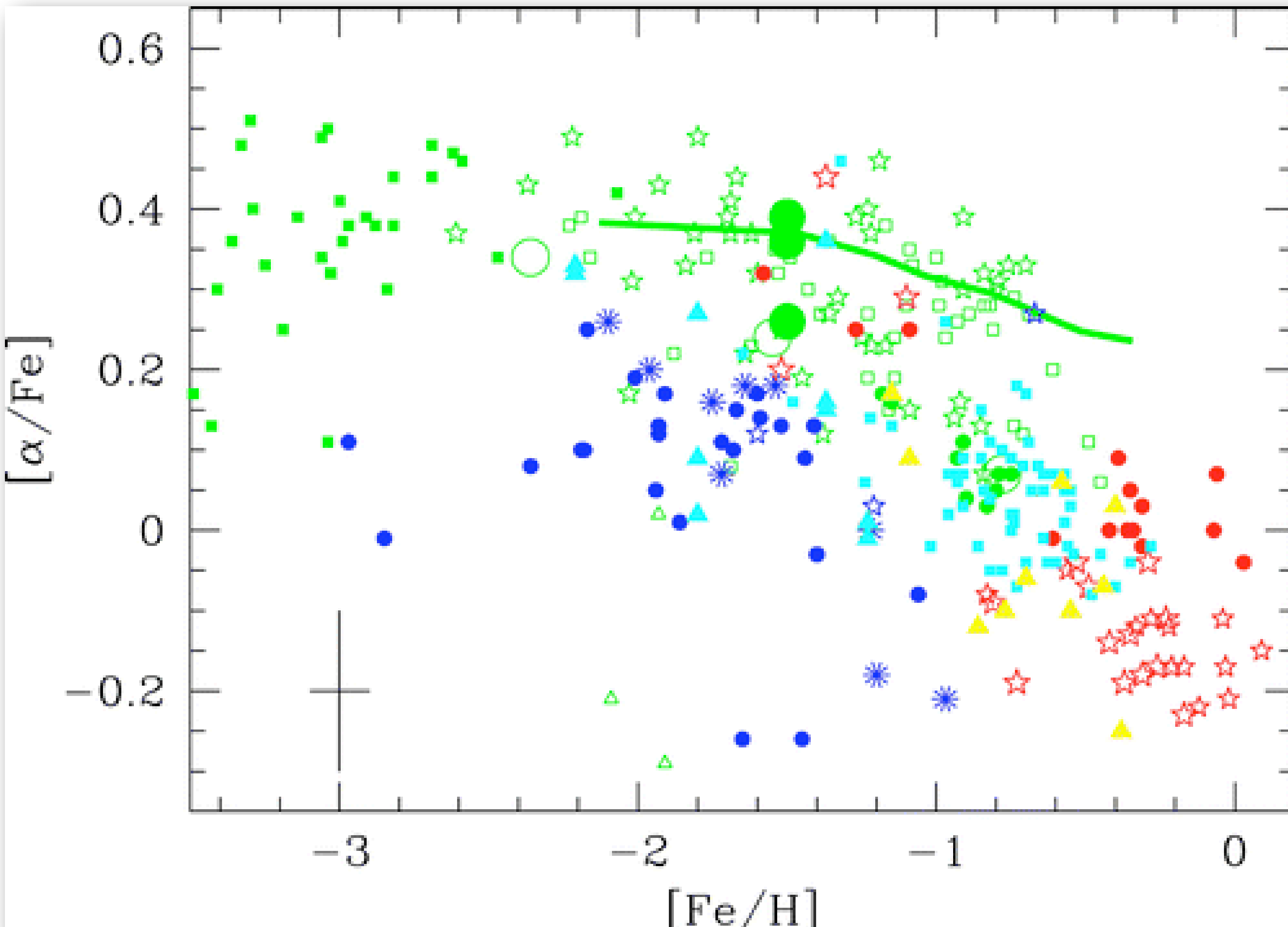
(data compilation from Geisler et al, 2007)

- Observations indicate that dwarf galaxies lie "unique" locations in chemical abundance ratio distribution (CARD) space

Reconstructing the Galaxy's Accretion History

Theory: Accretion Events are recorded in the Halo's Chemical Abundance Ratio Distributions

- "Chemical Tagging" - First envisioned as a means of tracing disk evolution (Freeman & Bland-Hawthorn 2002; Bland-Hawthorn & Freeman 2004)



- Galactic Genealogy

➡Stars "remember" their "genetic" ancestry - that is, chemical abundances inherited from previous generations of stars

green - halo
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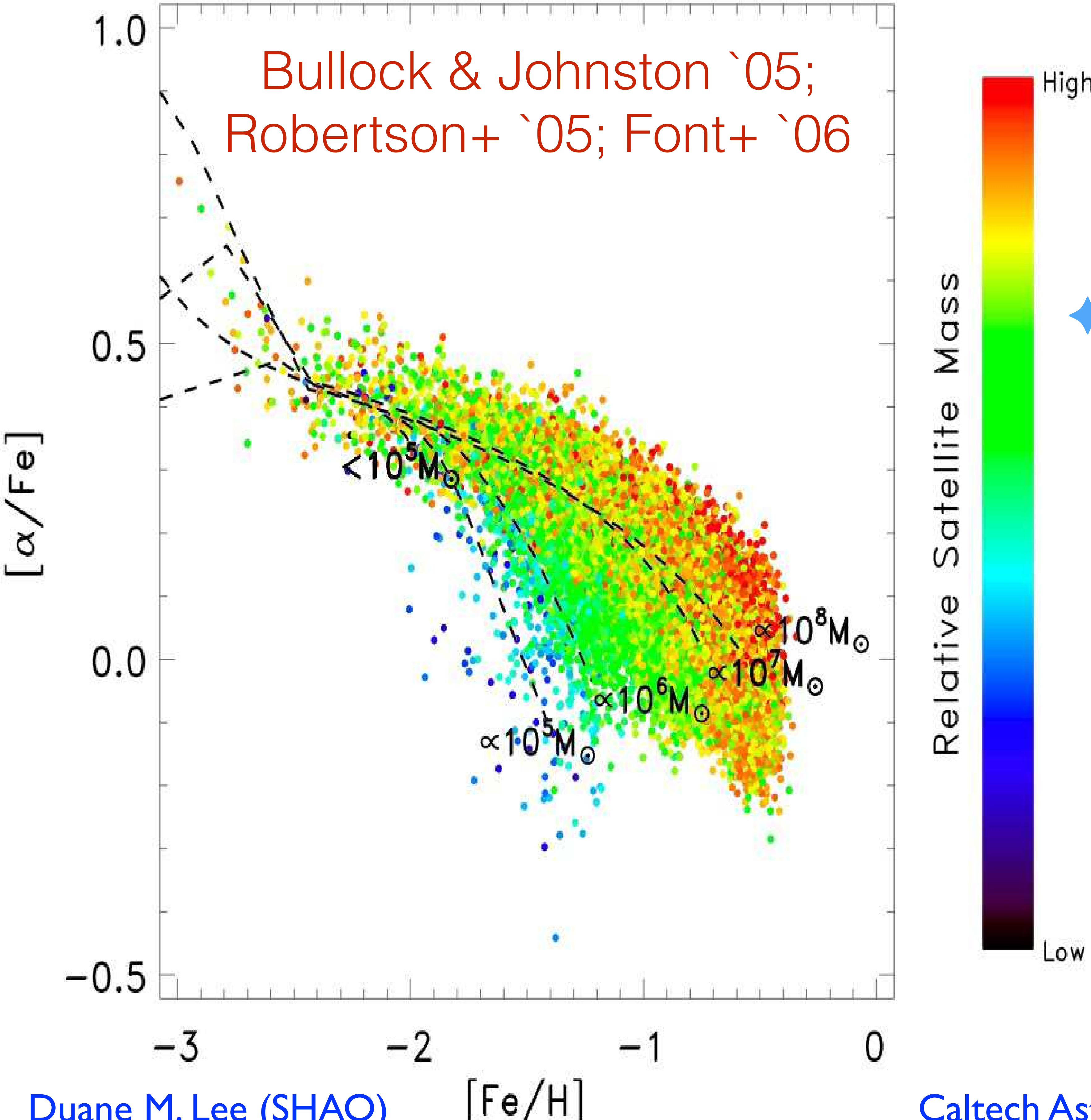
- Observations reveal trends in 2-D metallicity-space

➡ Metallicity distributions of satellites are correlated with their accretion time & mass

Reconstructing the Galaxy's Accretion History

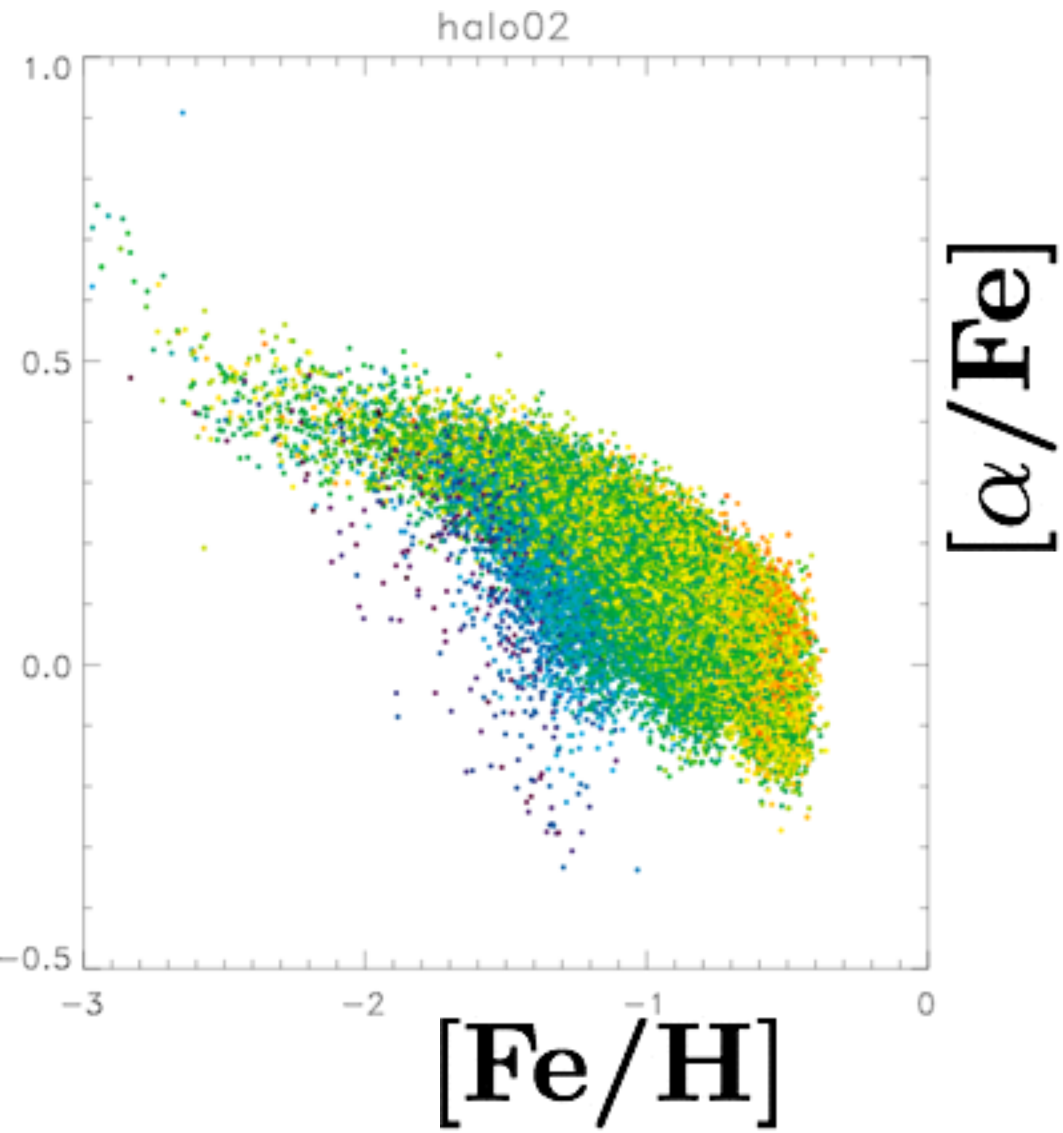


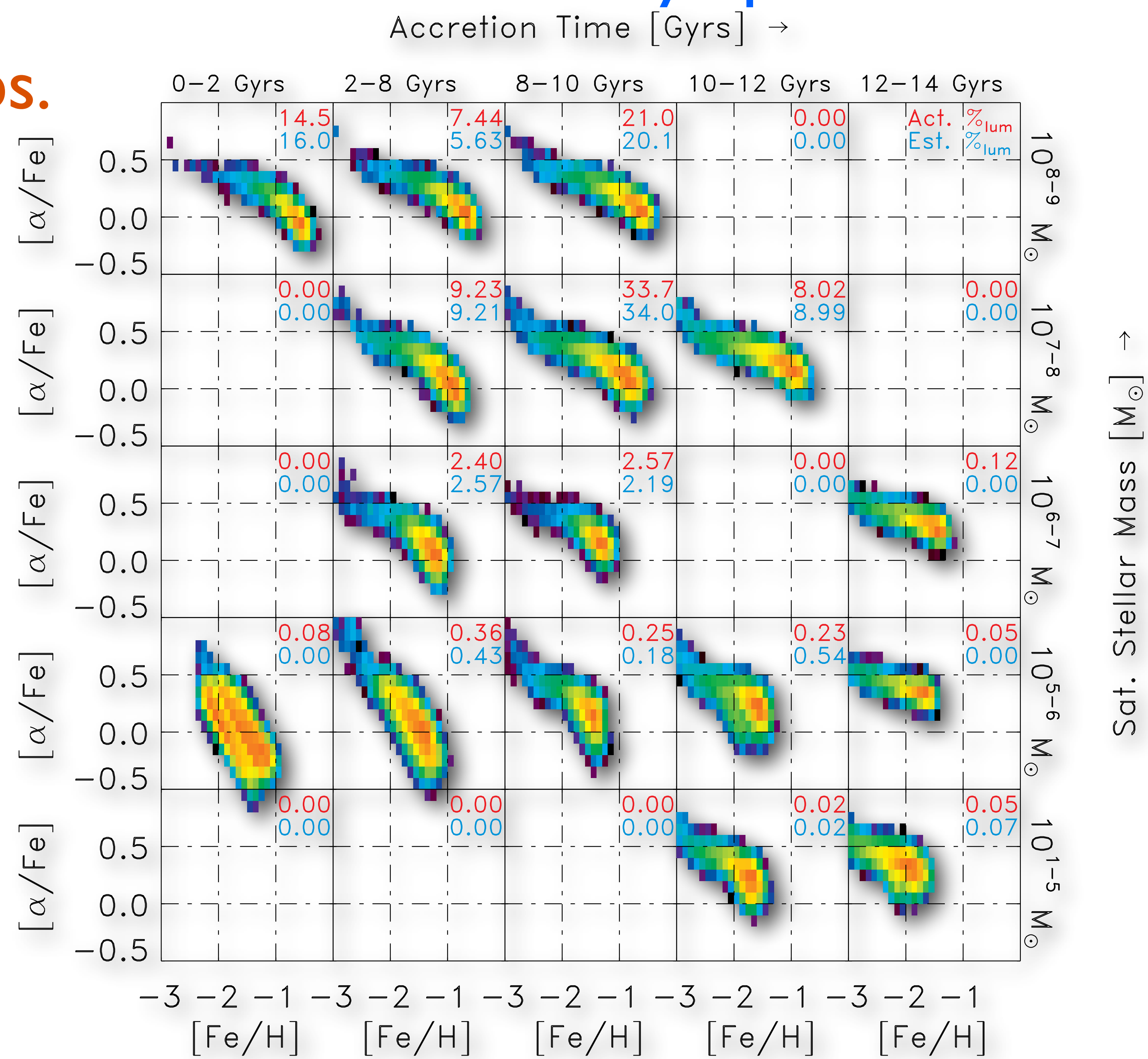
- Models indicate the same "distinctive" locations in CARD space

Models: Accretion Events & the Halo's CARD

- Can we reconstruct the accretion history of the Galactic halo from stellar distributions in 2-D metallicity-space?

0.1 dex errors for mock obs.





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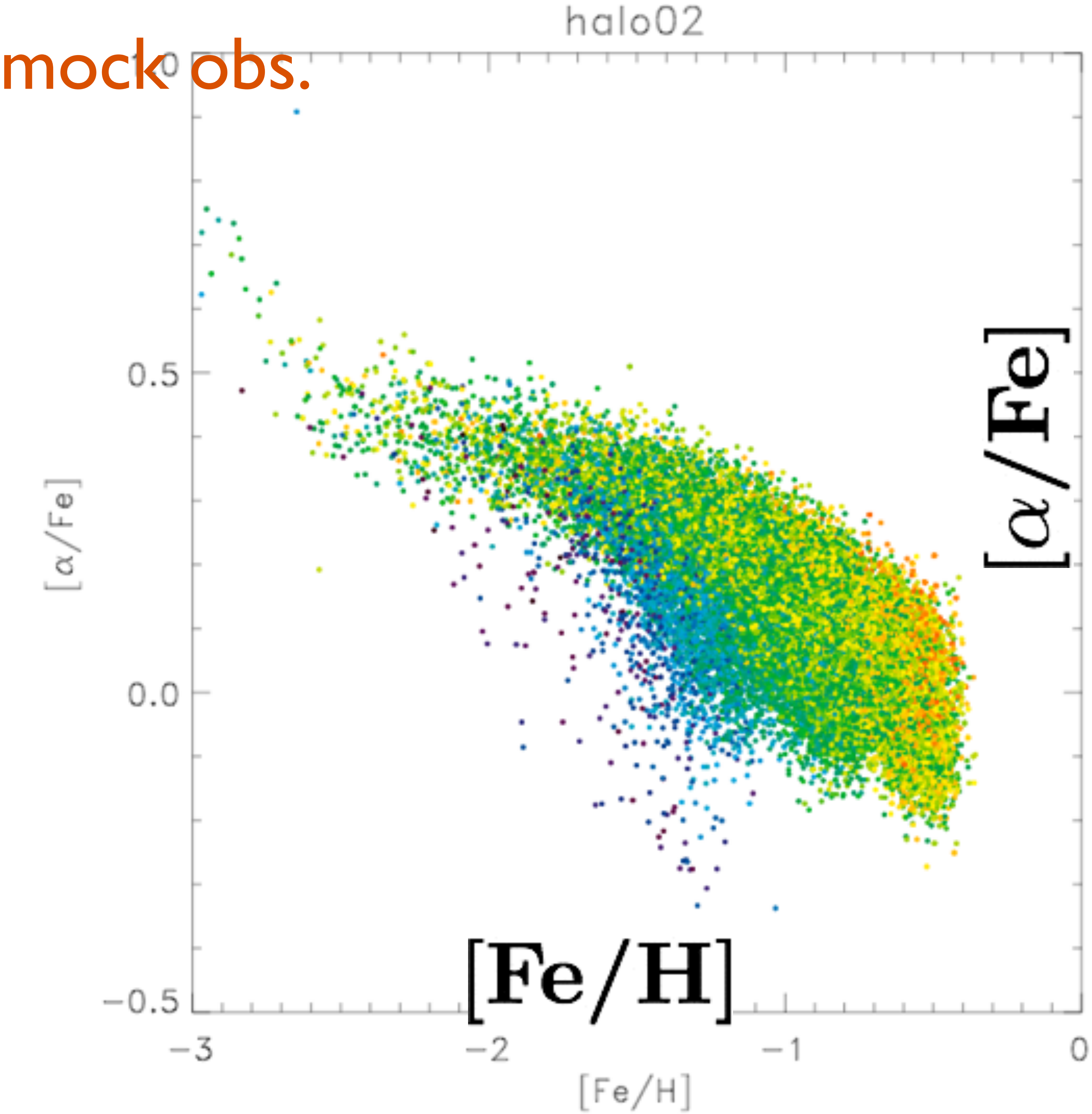

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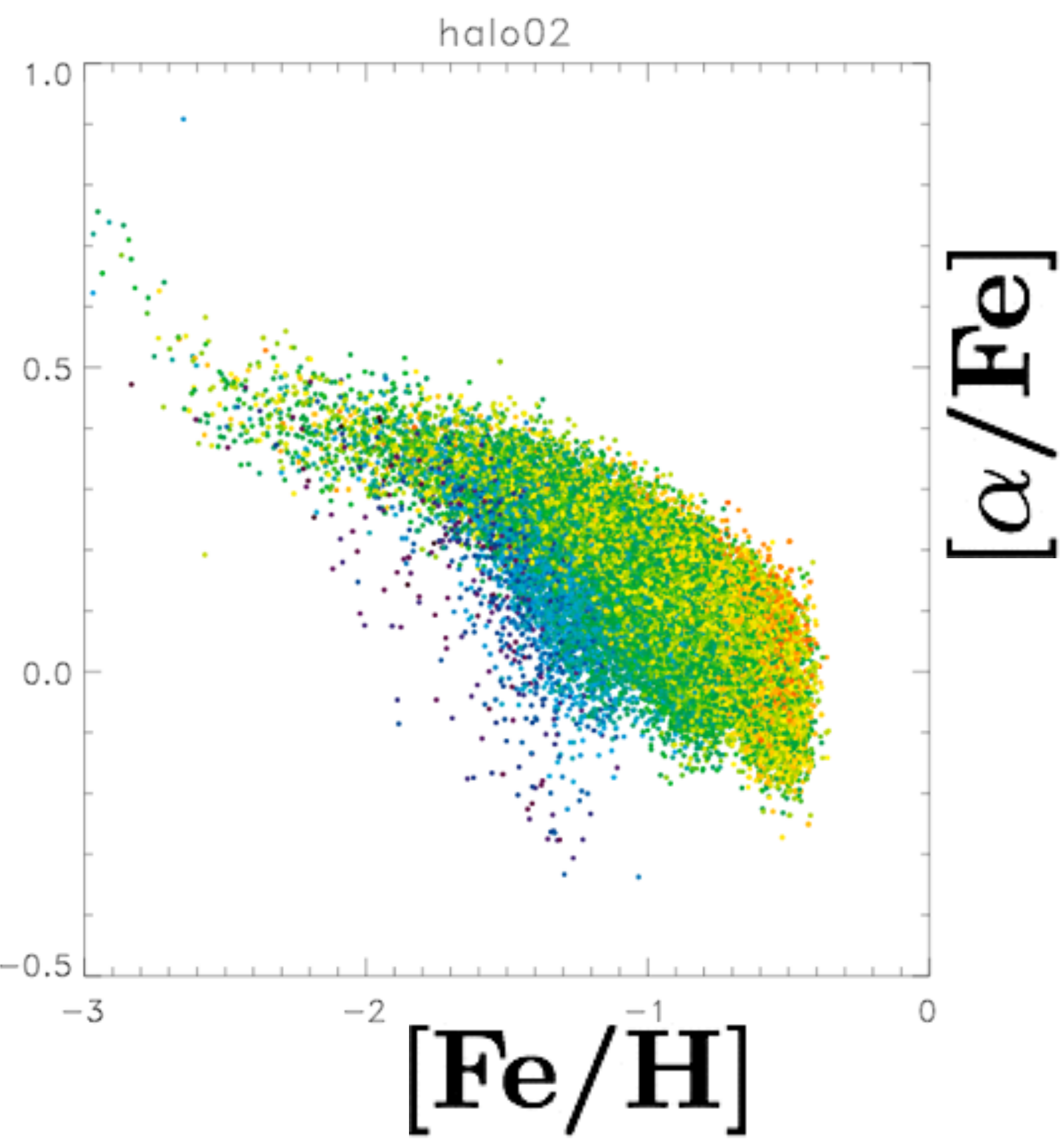

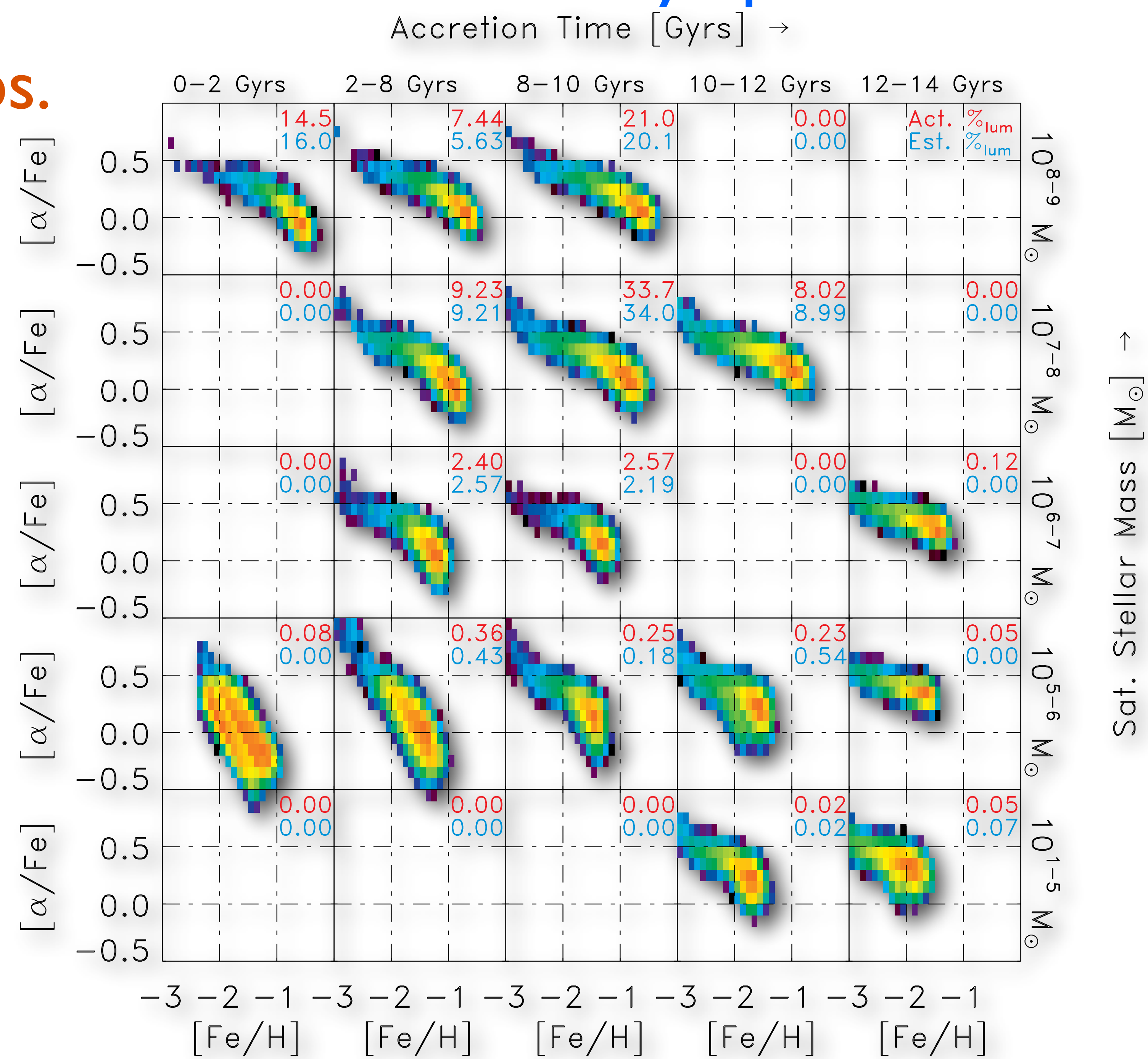

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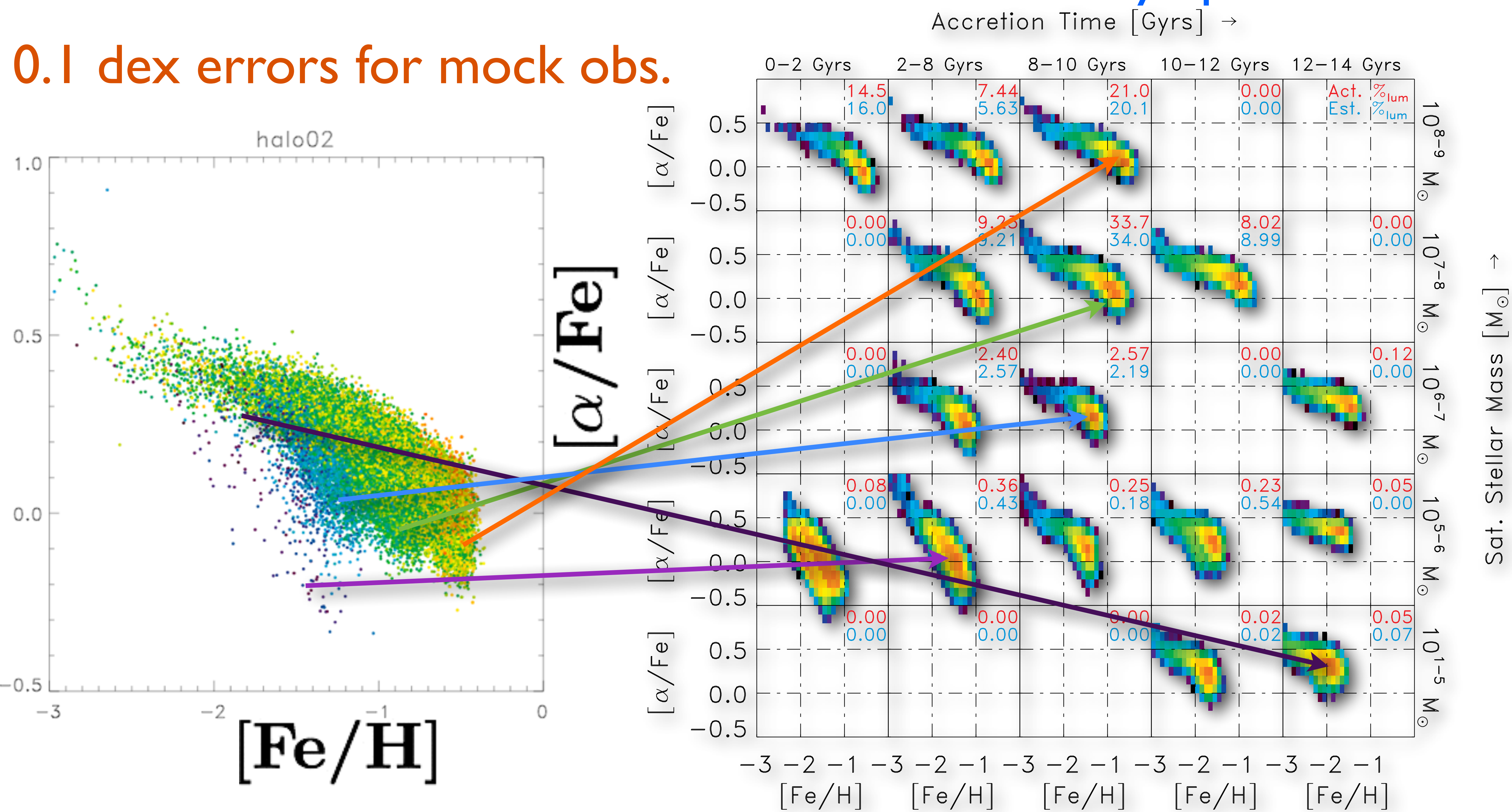
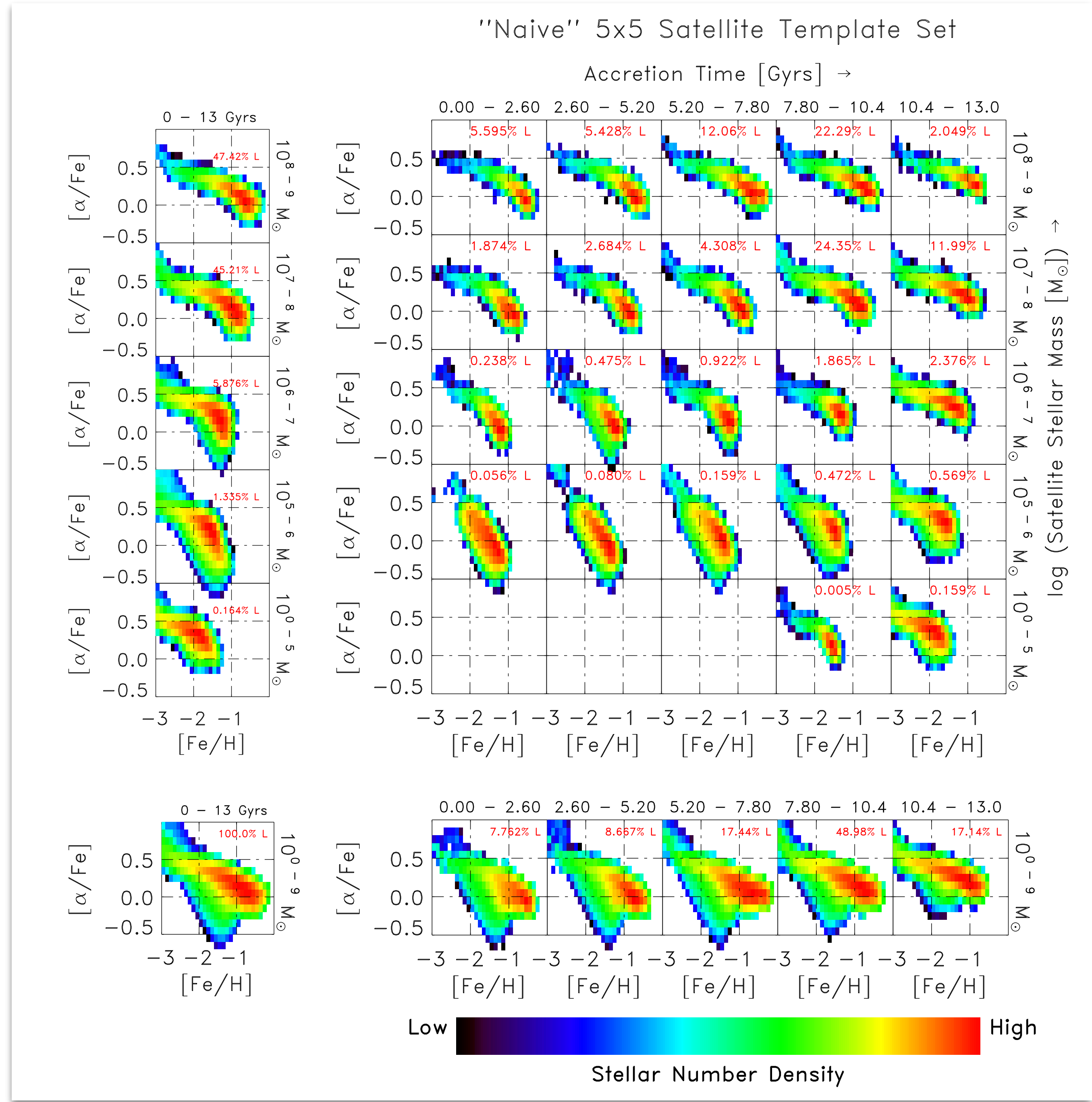


Summary of Method

- Construct satellite template sets (STS) to use in generative mixture models of “MW-like” halos
- We apply the EM algorithm to simulated halo accretion data using STS
- Obtain estimates for the rel. contributions to the total luminosity of each simulated halo



Parameterizing Accretion History

$$\boxed{F(x_n) = \sum A_i * F_i\,(x_n, M_{sat}, t_{acc});\ \sum A_i = 1}$$

$F(x_n)$ => distribution of observed halo stars in *C*-space
(n = # of tracked elements)

A_i => accretion history of the halo

$F_i\,(x_n, M_{sat}, t_{acc})$ => chemical abundance [ratio] distributions of models of dwarfs/accreted systems

Use the Expectation-Maximization Algorithm to determine model contributions to the simulated halos

Evaluating our EM Estimates

$$\langle \mathrm{FoE} \rangle = \sum_{j=1}^{m} w_j \cdot \mathrm{FoE}_j$$

"Factor-of-Error" values (FoE) = the $\max(A_{EM}/A_T, A_T/A_{EM})$

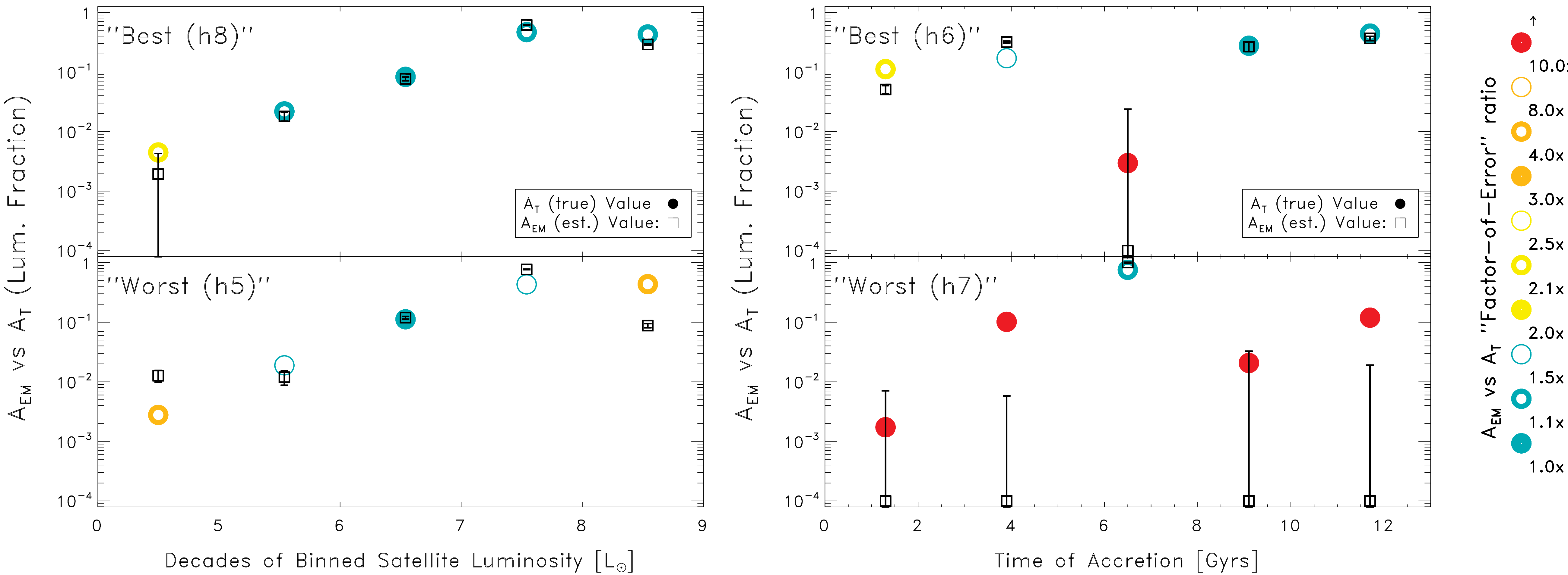
j = indicates the j^{th} satellite templates

m = # of satellite templates

w_j => weighting for average Factor-of-Error <FoE> value

- $w_j = m^{-1}$ (uniform weighting) is used for the general valuation of EM estimates (A_{EM}) in the study

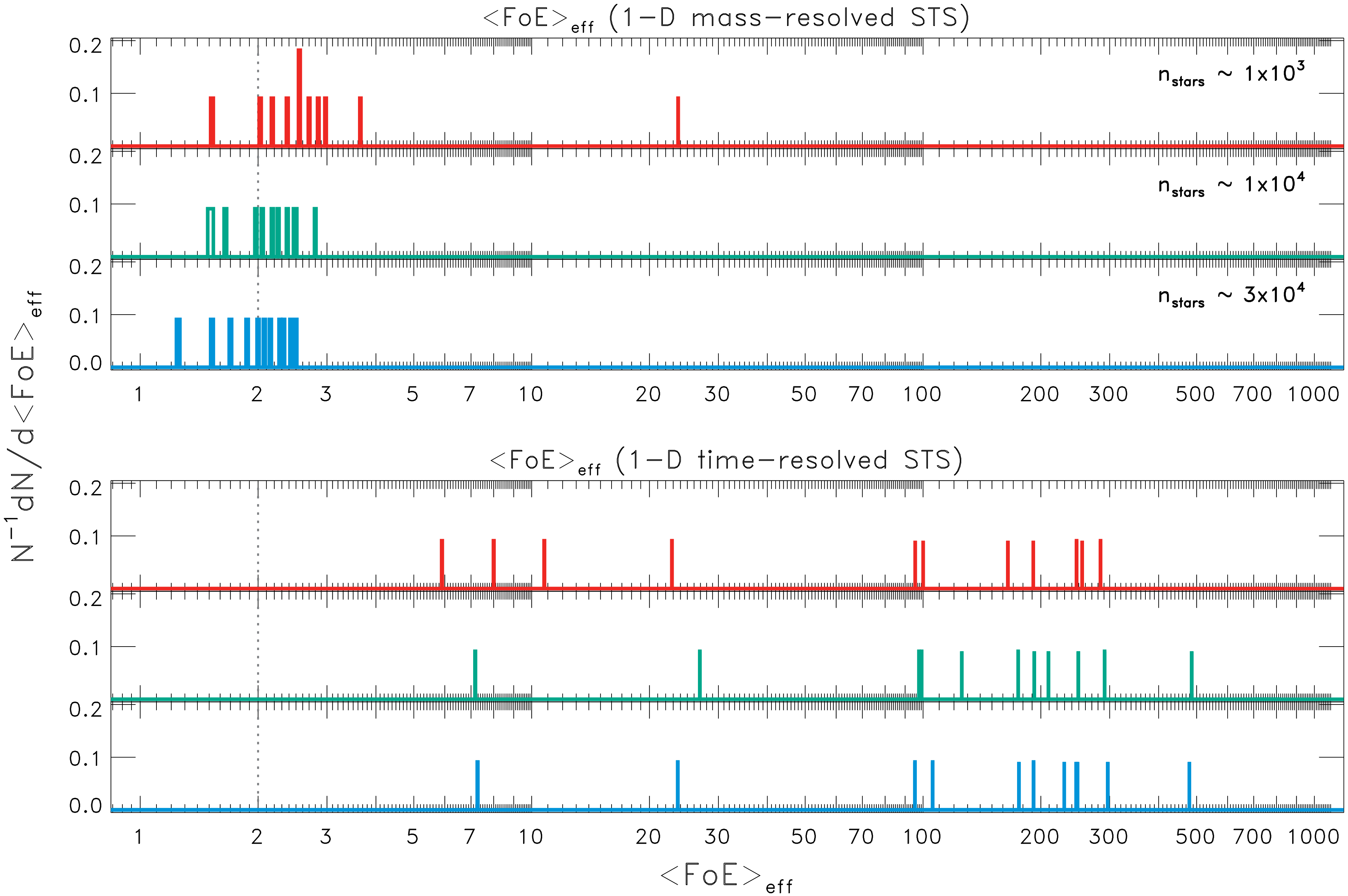
Some Notable Results I



- Results indicate that we can recover a majority of the luminosity function (LF) of the halo in most cases examined with "high precision" — i.e., within a FoE = 2

Reconstructing the Galaxy's Accretion History

Accuracy of stellar mass fractions across halo realizations: <FoE>



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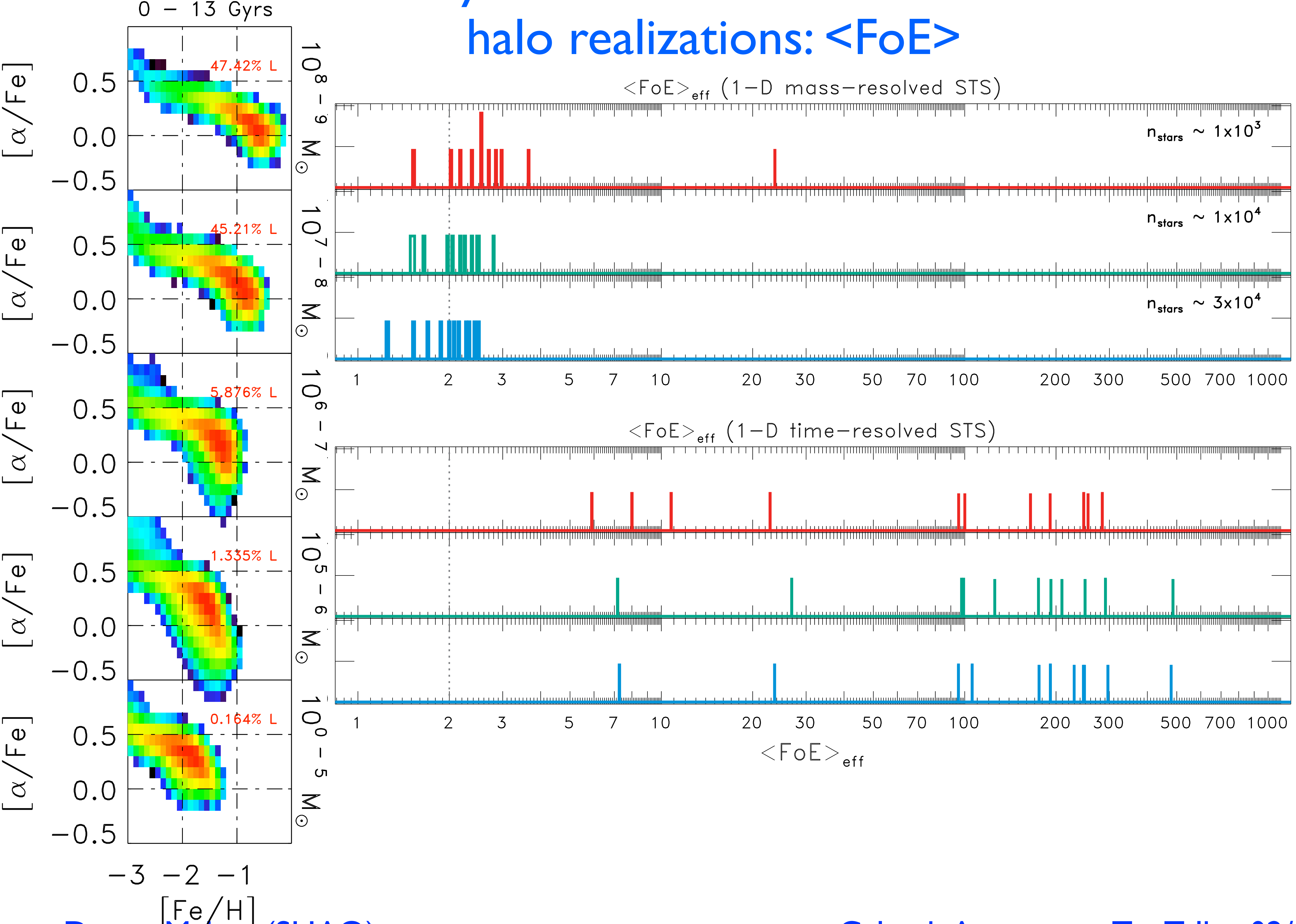

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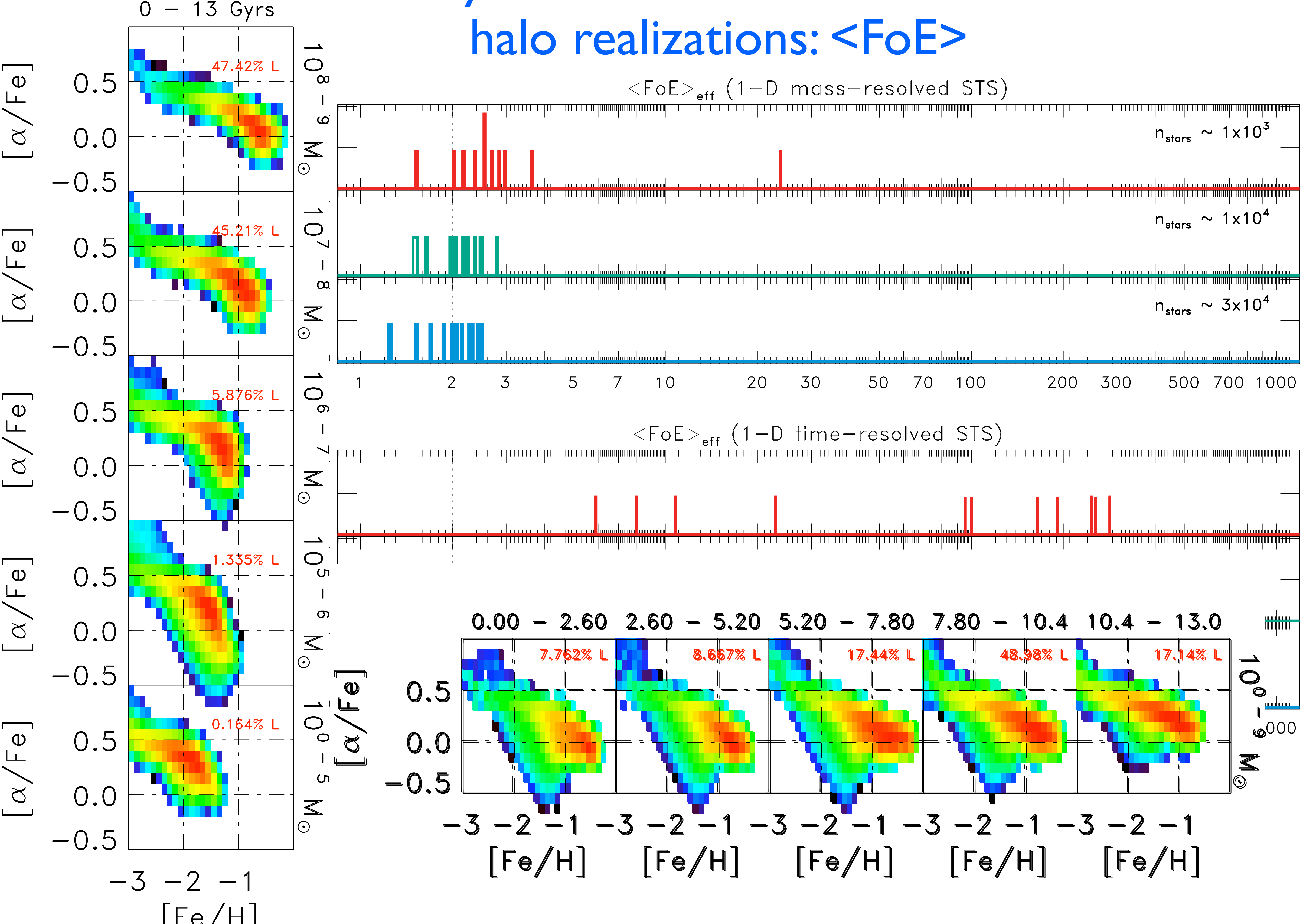
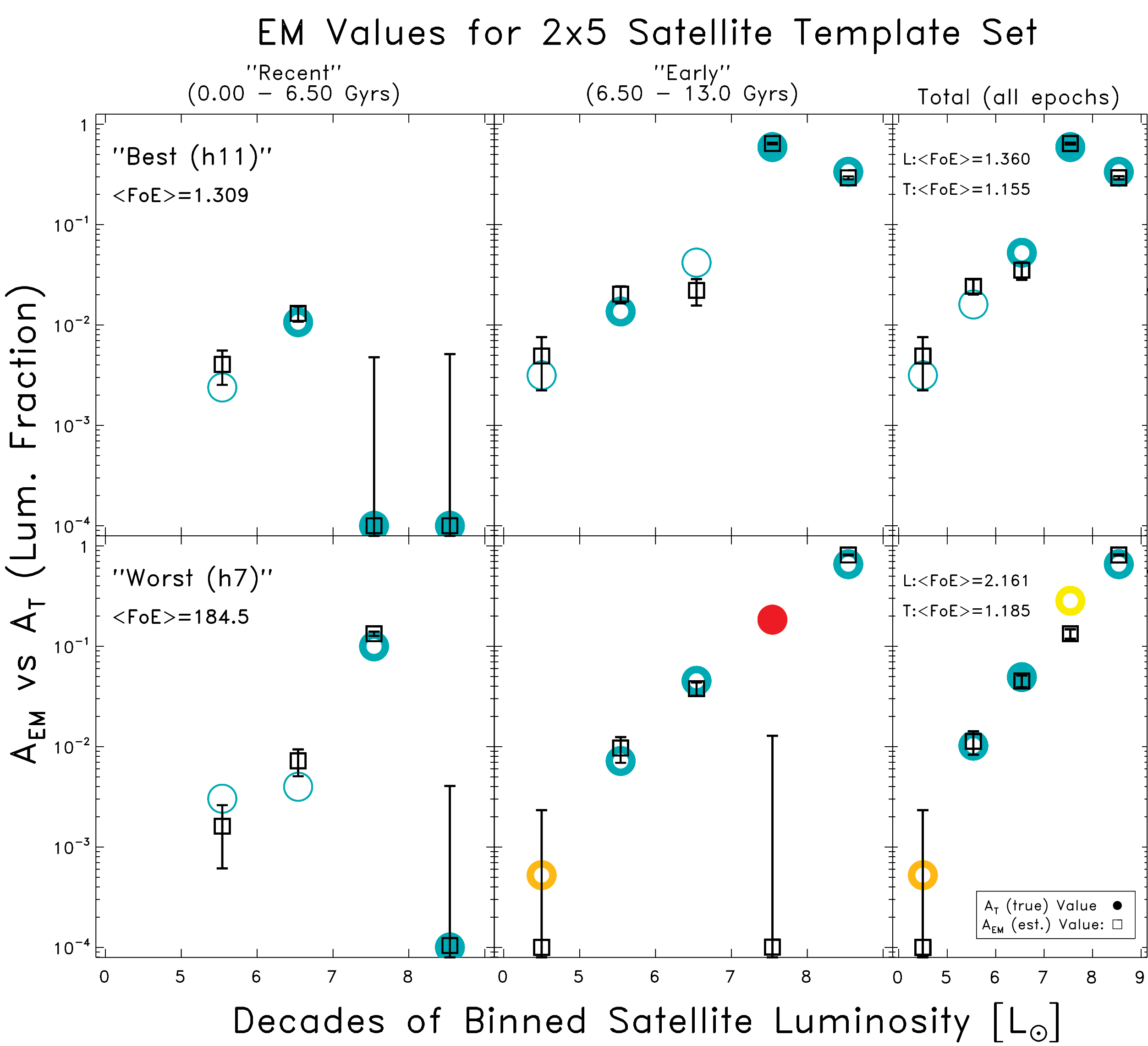
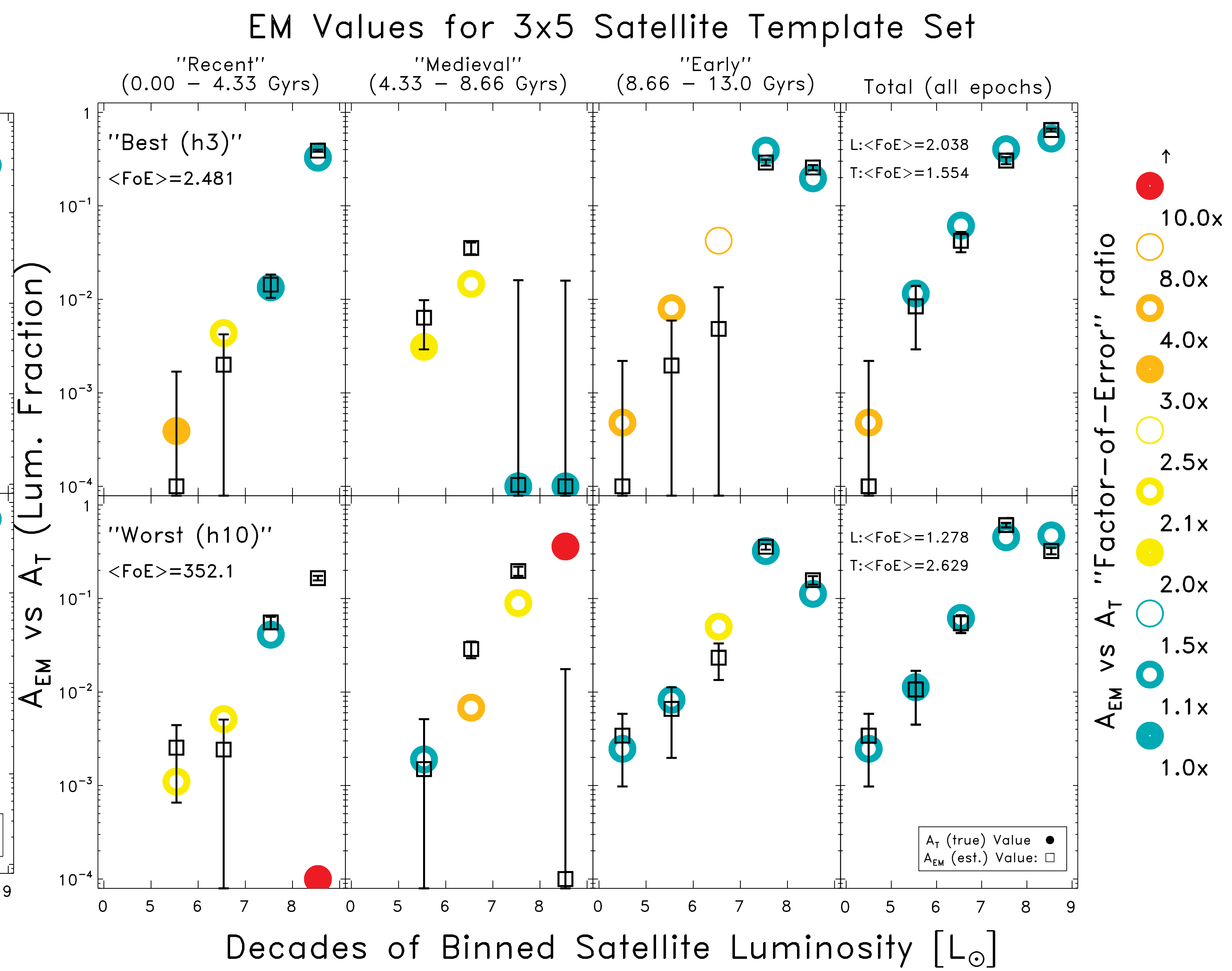


Reconstructing the Galaxy's Accretion History

Some Notable Results II





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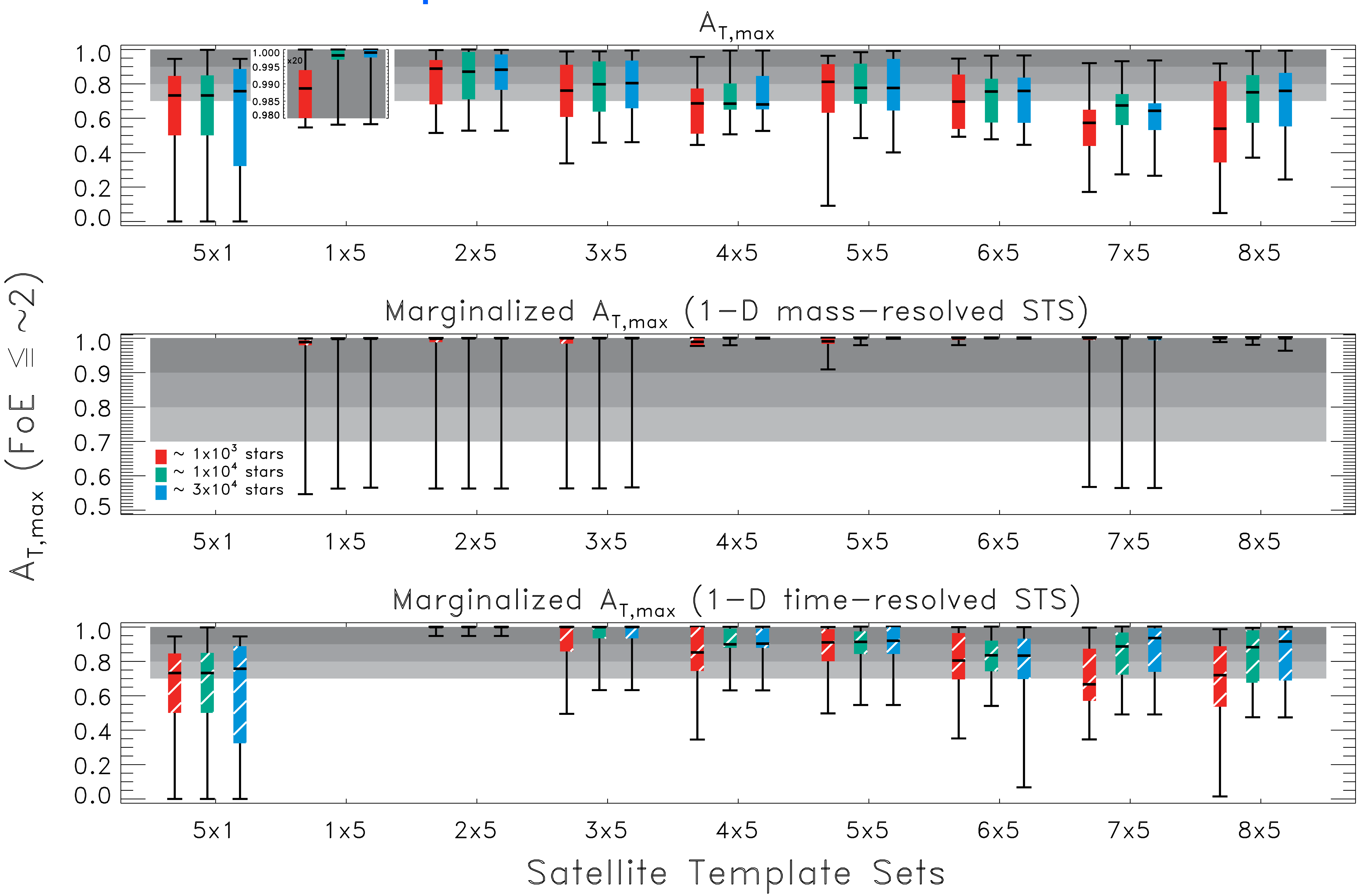
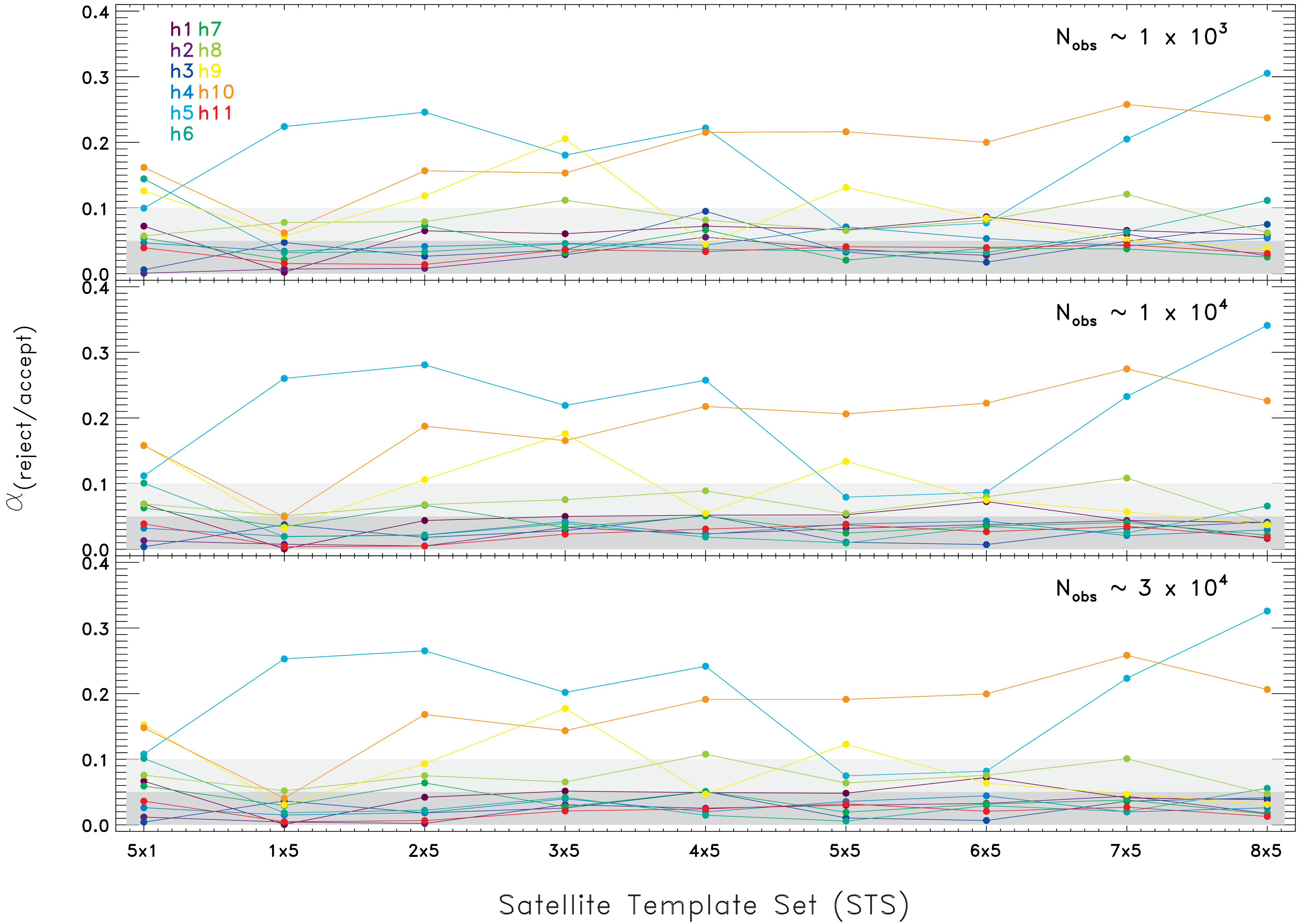
Comparison of results across all STS

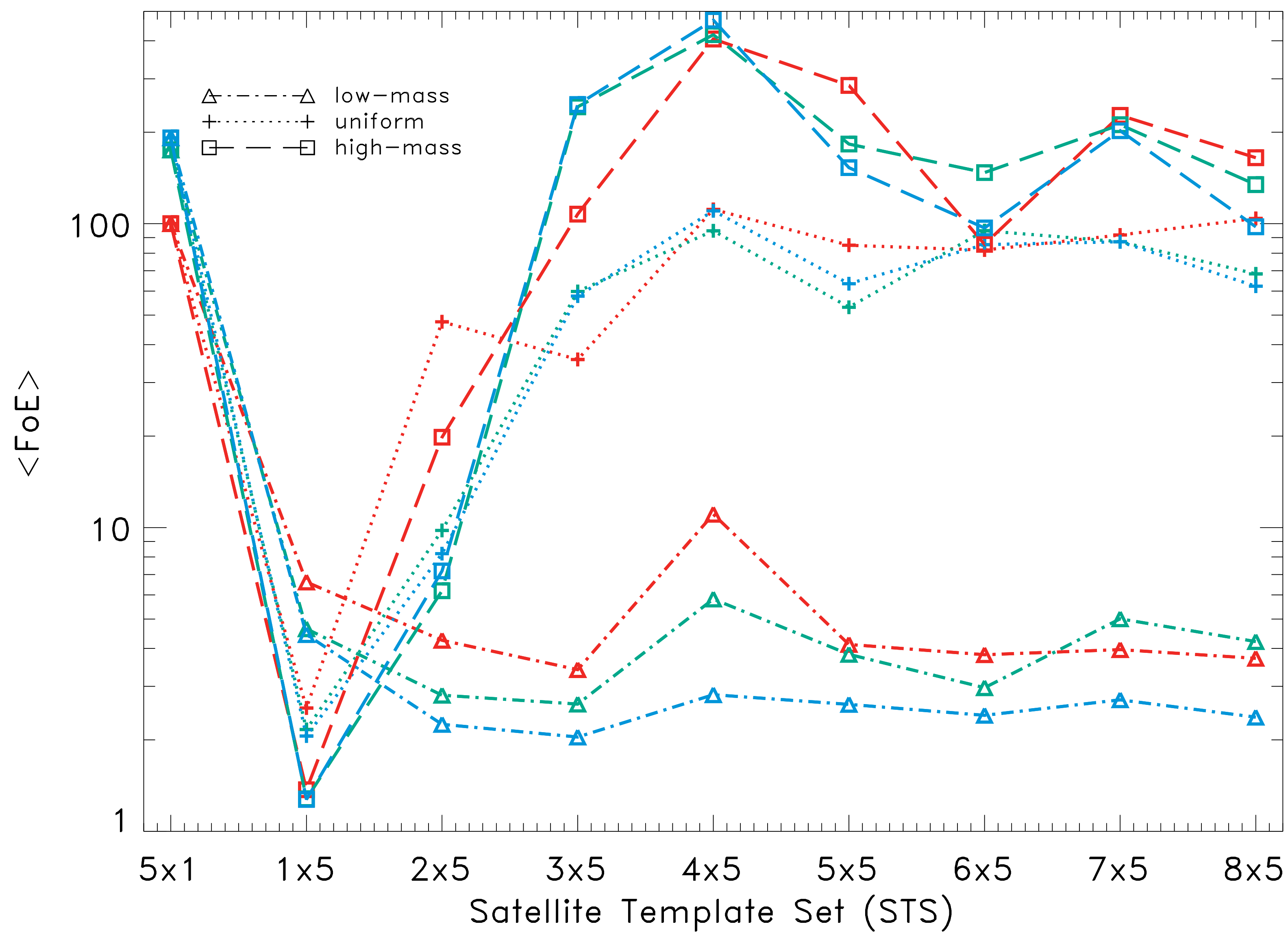


Reconstructing the Galaxy's Accretion History

Reliability of results across all STS



Some Notable Results III



- $w_j = (A_T)_J^{-1}$ is used for low-mass dwarf weights
- $w_j = (A_T)_J$ is used for high-mass dwarf weights

- Method is particularly sensitive to older accretion events involving low-luminous dwarfs e.g. ultra-faint dwarfs — precisely those events that are too ancient to be seen by phase-space studies of stars and too faint to be seen by high-z studies of the early Universe.

• Test of simulation models: # of "stars" observed range from ~10^3 - 3×10^4

• Planned APOGEE halo observations: #'s range from ~1000, ~10,000, 25,000+ halo field stars

(from G. Zasowski et al. 2013)

What about LAMOST???

Summary: Typically, we can recover the accretion history for ≳75-90% of the total stellar halo mass to within a factor of ~2 in sim halos

Future Work: Development of more realistic CARD models for dwarf galaxy templates

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