The Local Group as a Time Machine

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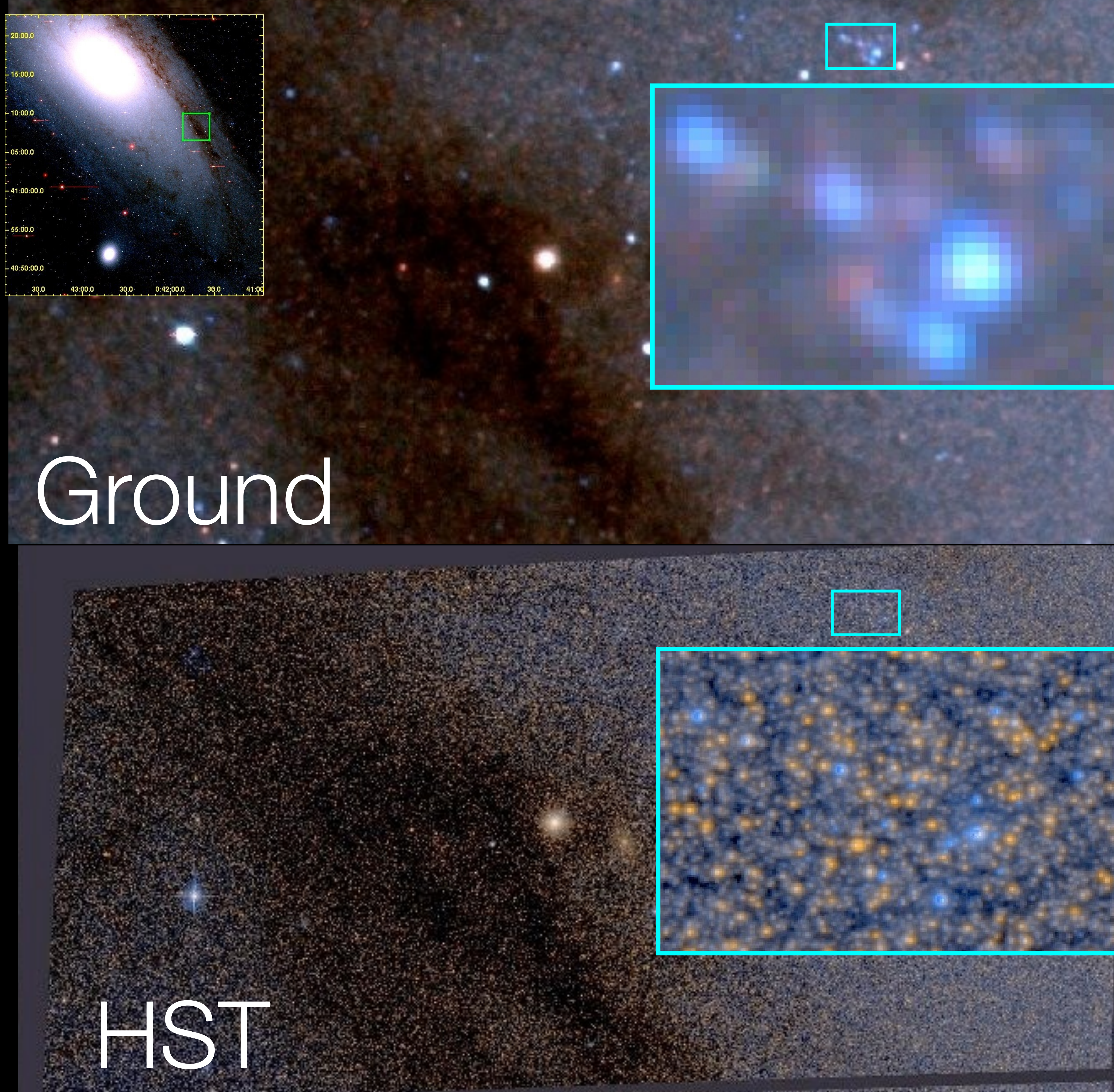
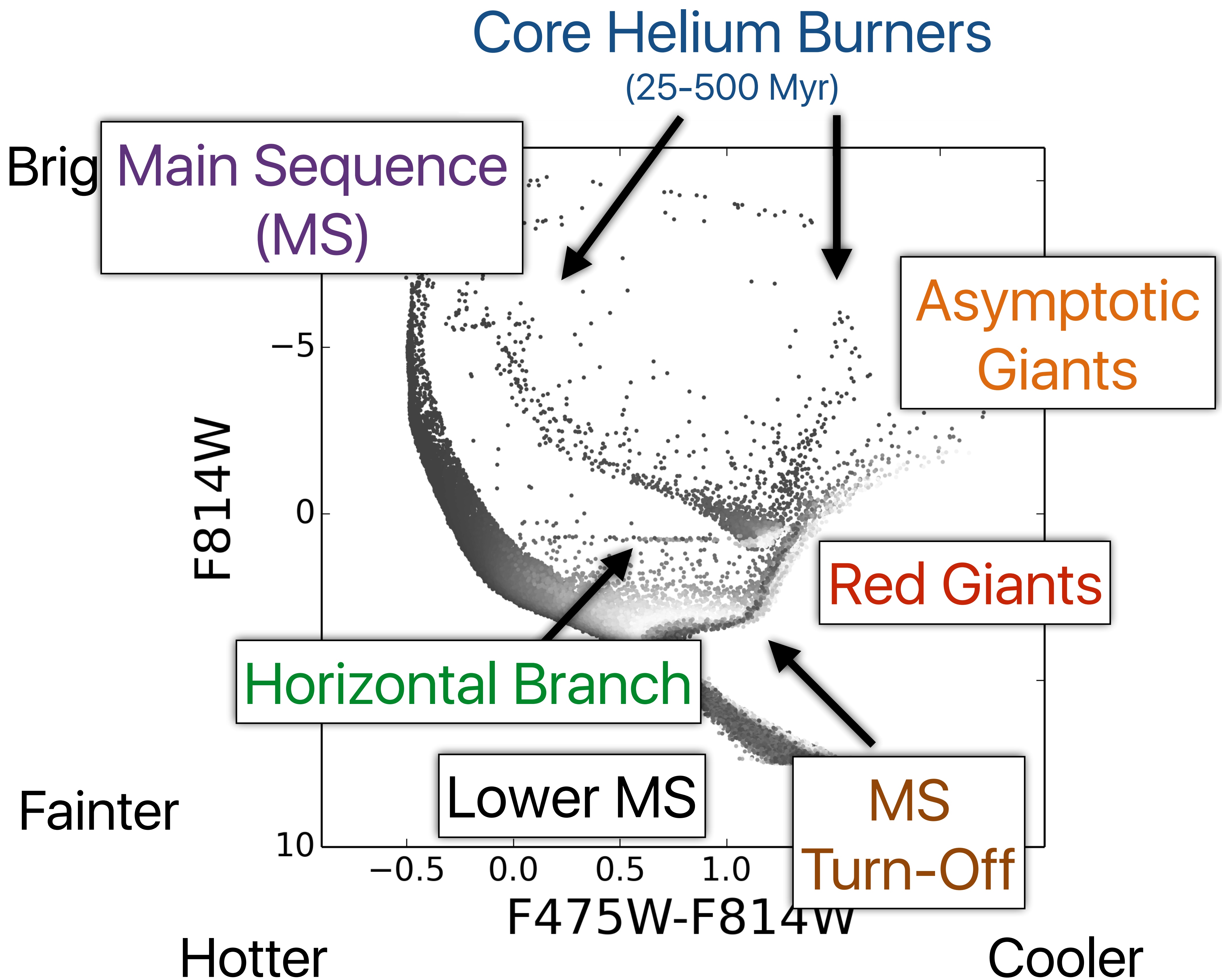
High Angular Resolution Imaging needed to overcome crowding



Optical Color-Magnitude Diagrams



Science from Resolved Stars

- **Distance Ladder and Local Value of H_0**

  RR Lyrae: e.g., Beaton+ 2016

  Cepheids: e.g., Riess+ 2016

  TRGB: e.g., Tully+ 2013

- **Extinction and Attenuation**

  ~20 pc resolution Extinction Map of M31: Dalcanton+ 2016

  Galactic Attenuation Curve: R_V=3.3, 0.2 dex scatter: Schlafly+ 2016

- **Stellar IMF**

  IMF Slope > 1 $M_\odot$ in M31 Steeper than Kroupa/Salpeter: Weisz+ 2015

  IMF Slope < 1$M_\odot$ systematically varies in dwarf galaxies: Geha+ 2013

- **Stellar Archaeology: Near-Field, Far-Field Connection**

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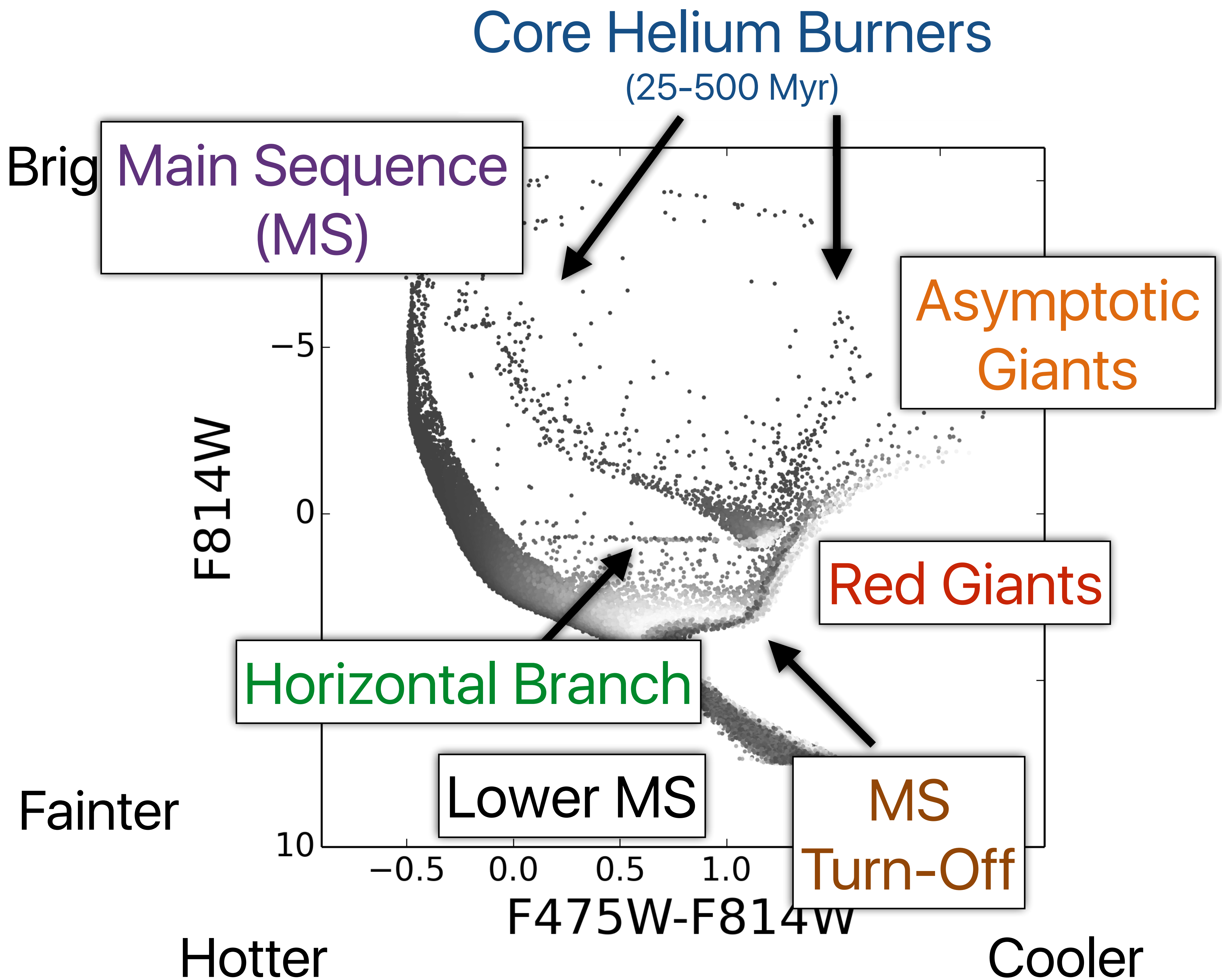
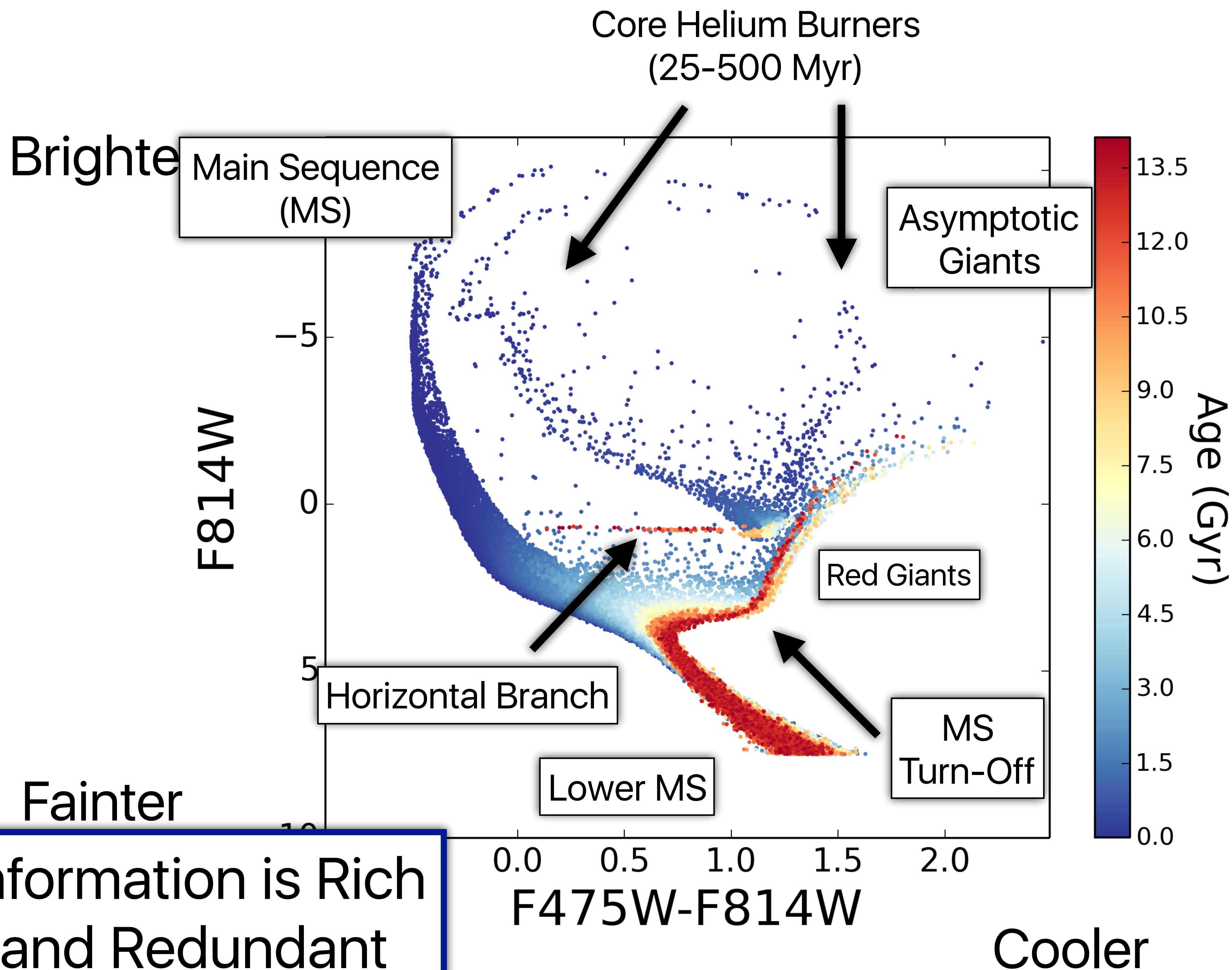
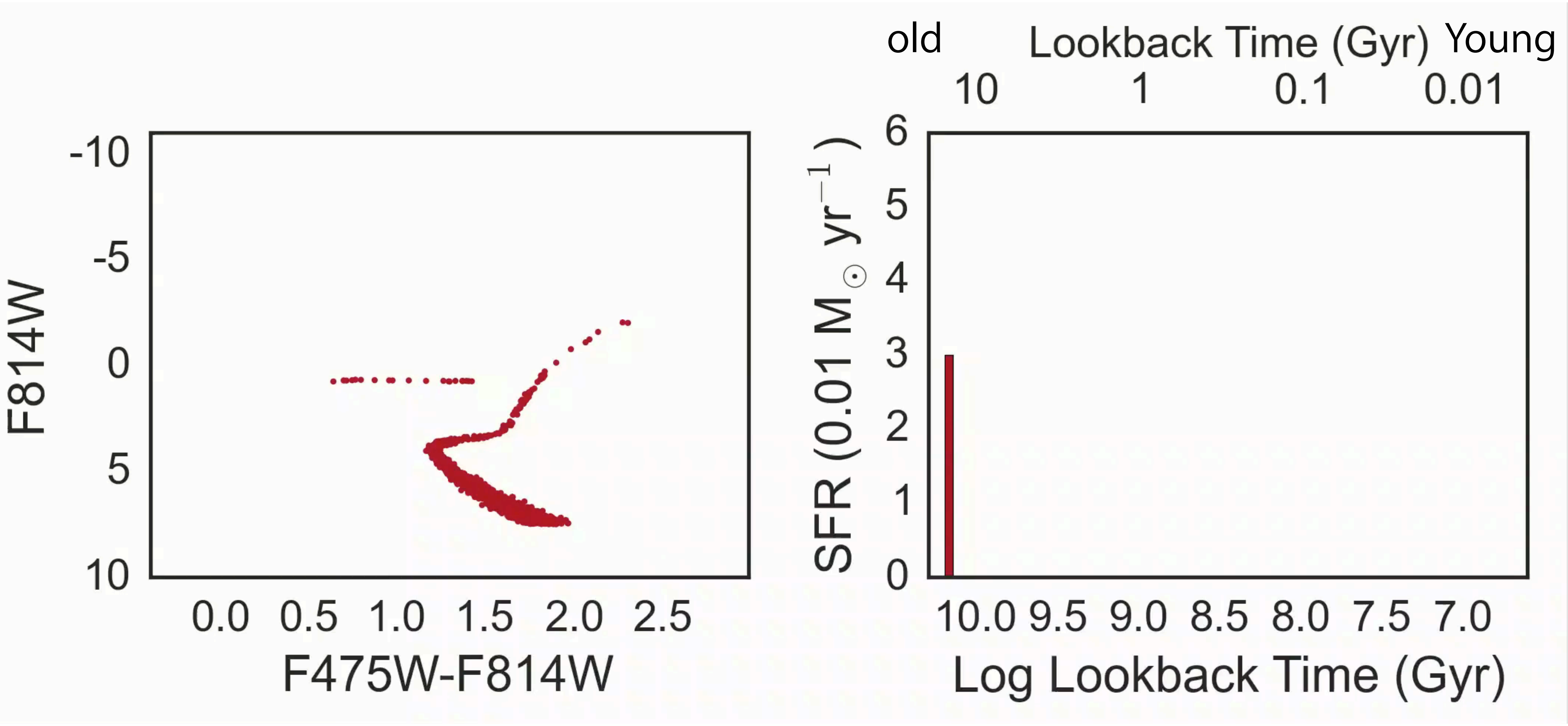


Stellar Age Information from CMDs



Information is Rich
and Redundant

From CMDs to SFHs

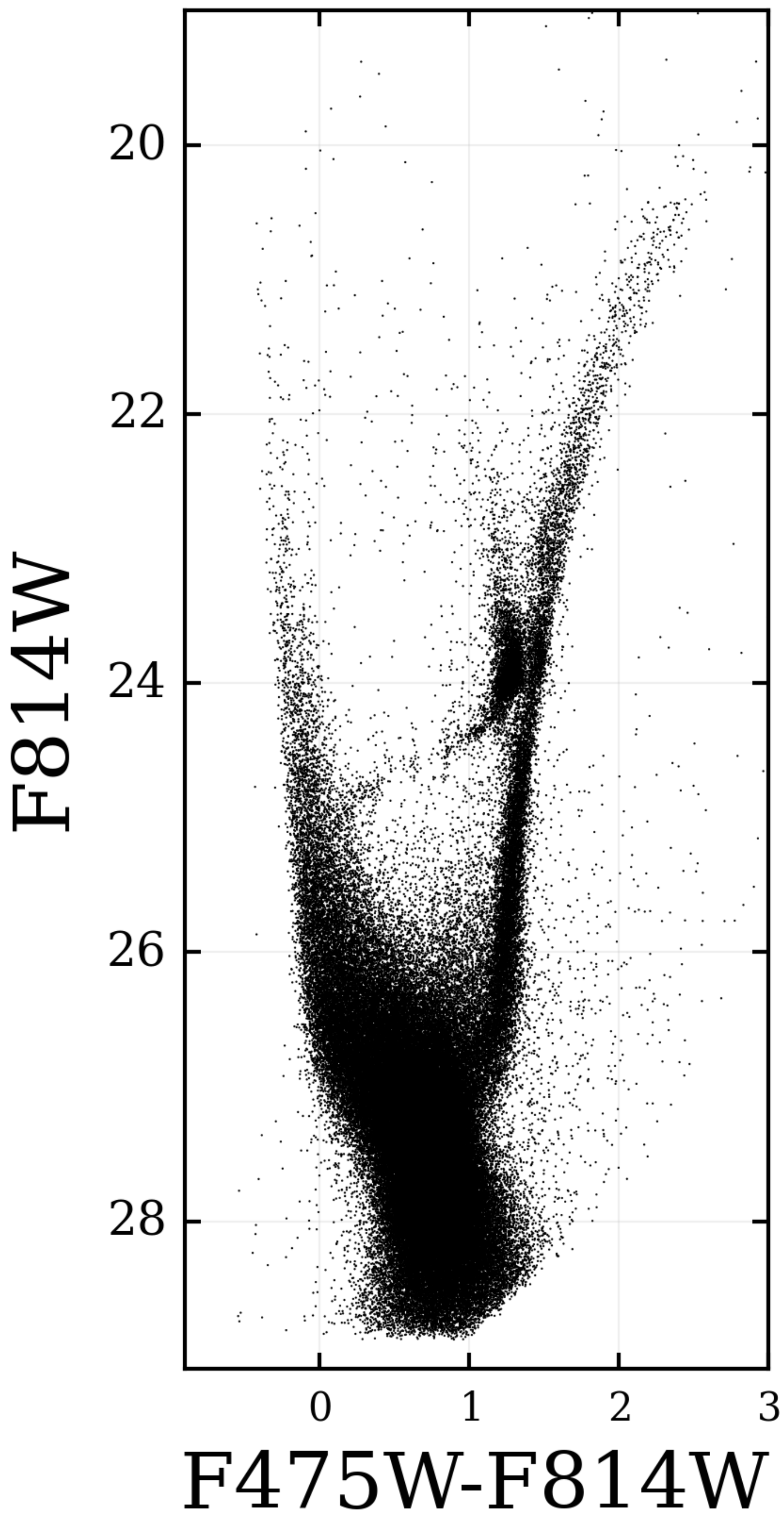


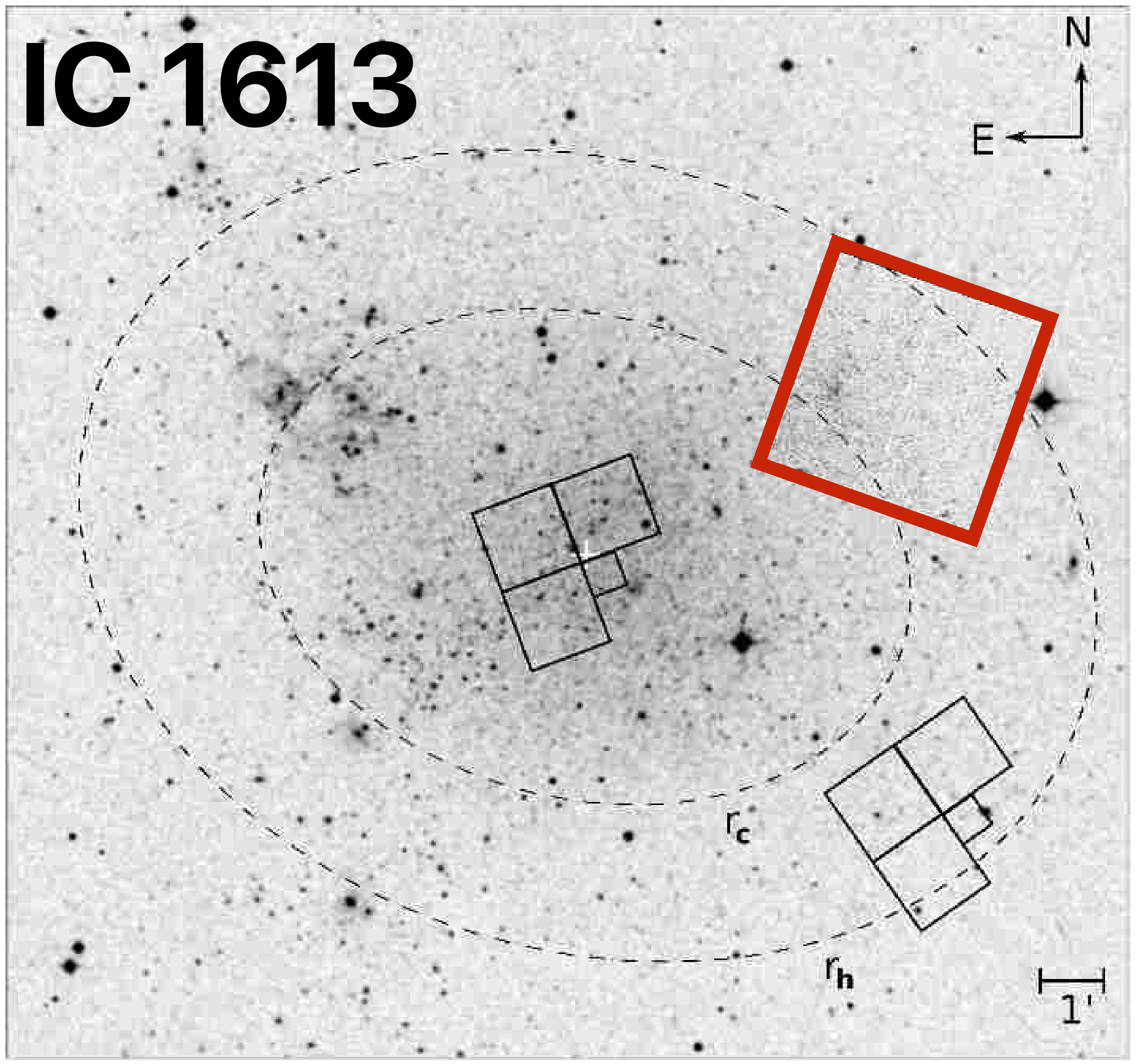
CMDs are the sum of simple stellar populations.

Measured SFHs are "non-parametric".

1000s of parameters (age, metallicity, etc.), fully probabilistic

Example Star Formation History





D ~ 800 kpc

$M_\star \sim 10^8\ M_\odot$

$Z \sim 0.08\ Z_\odot$

Skillman+ (2014)

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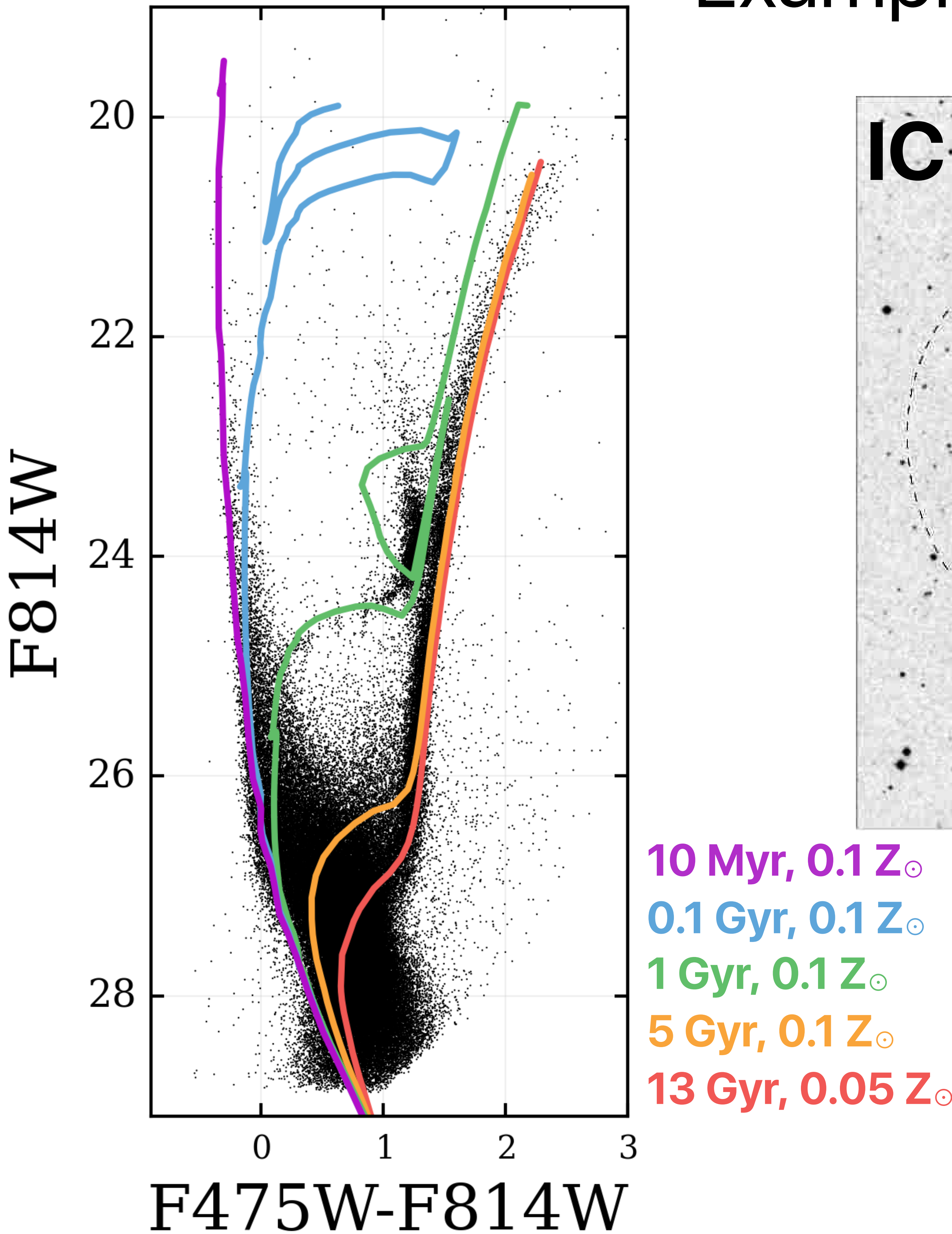

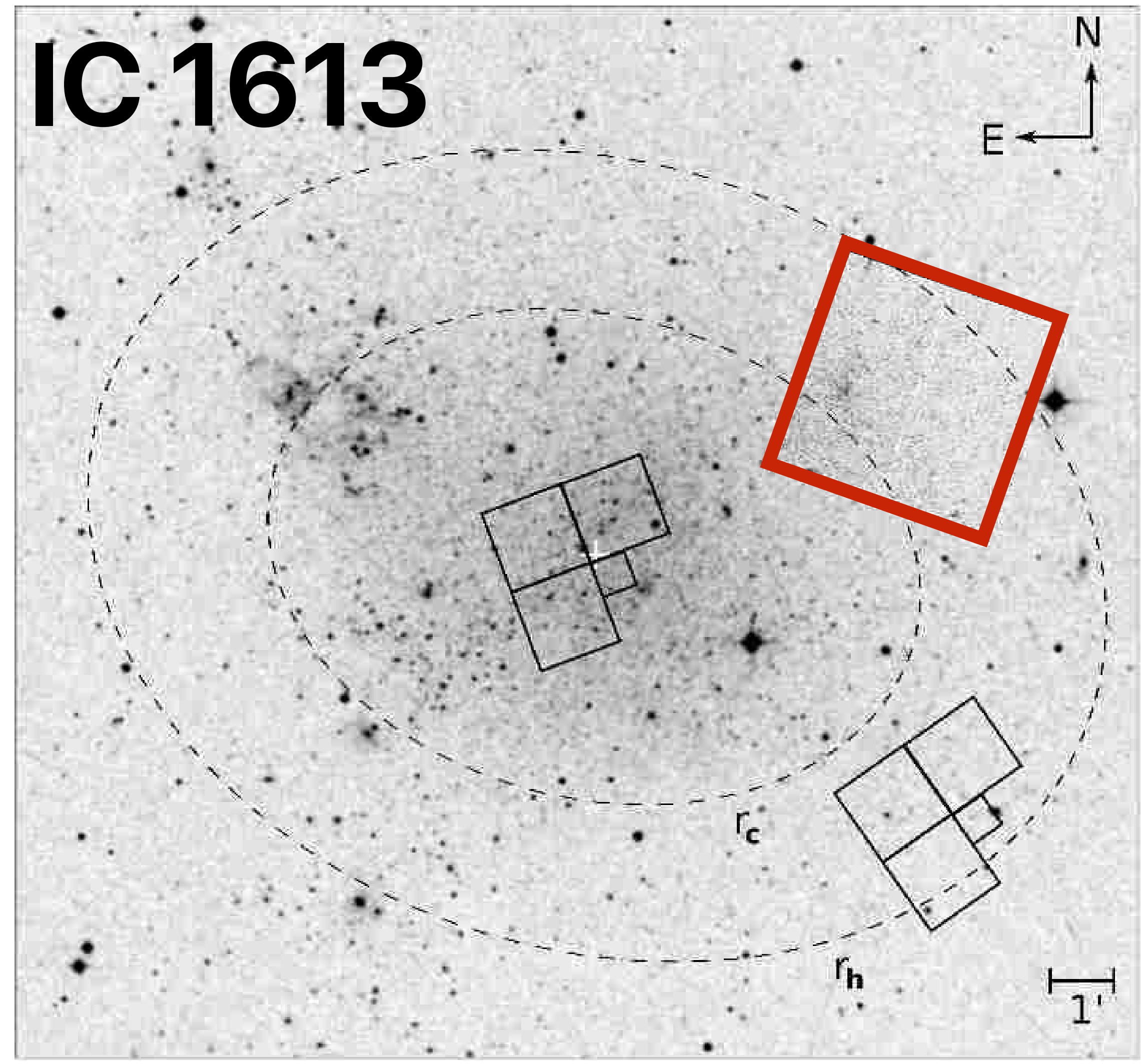

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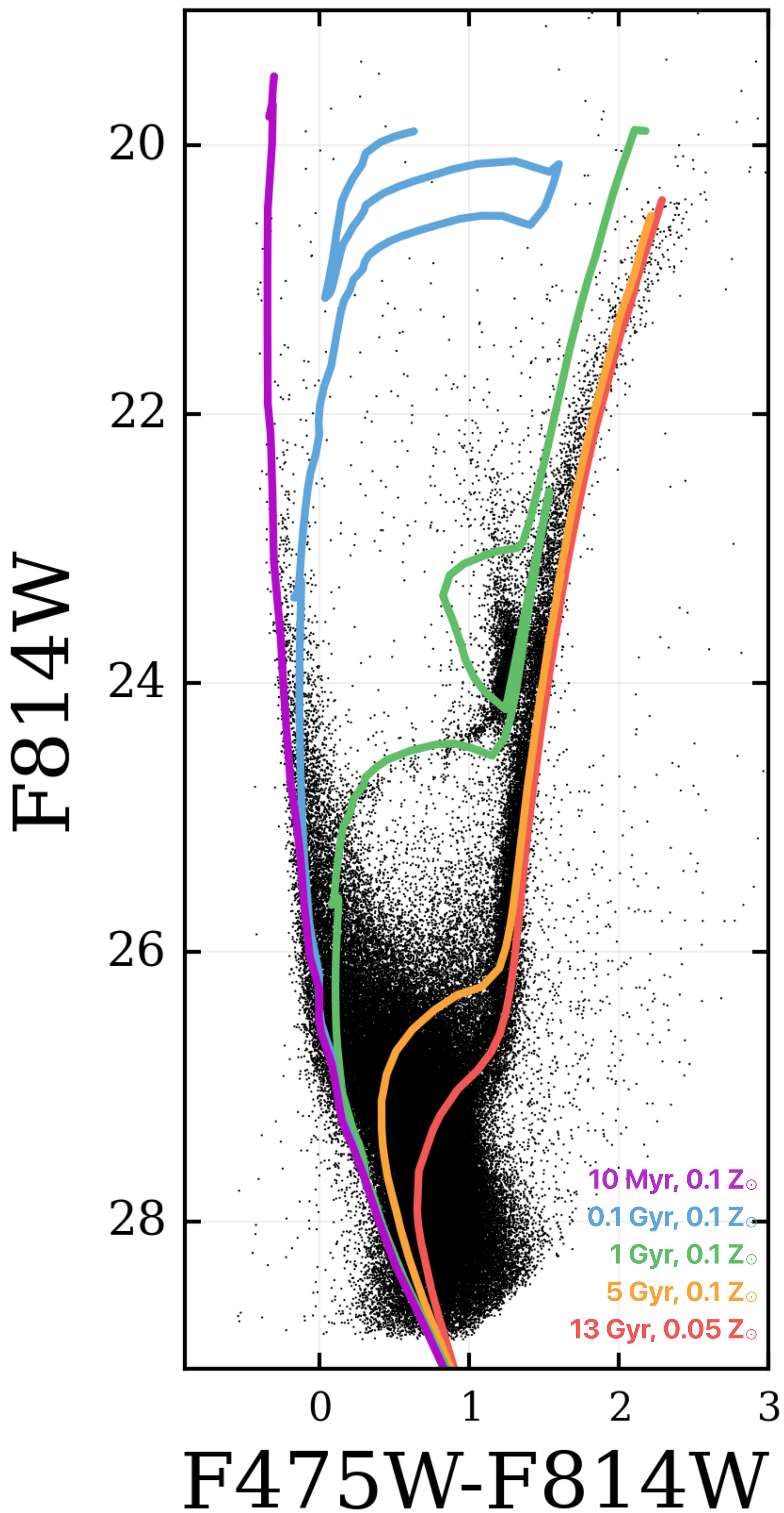

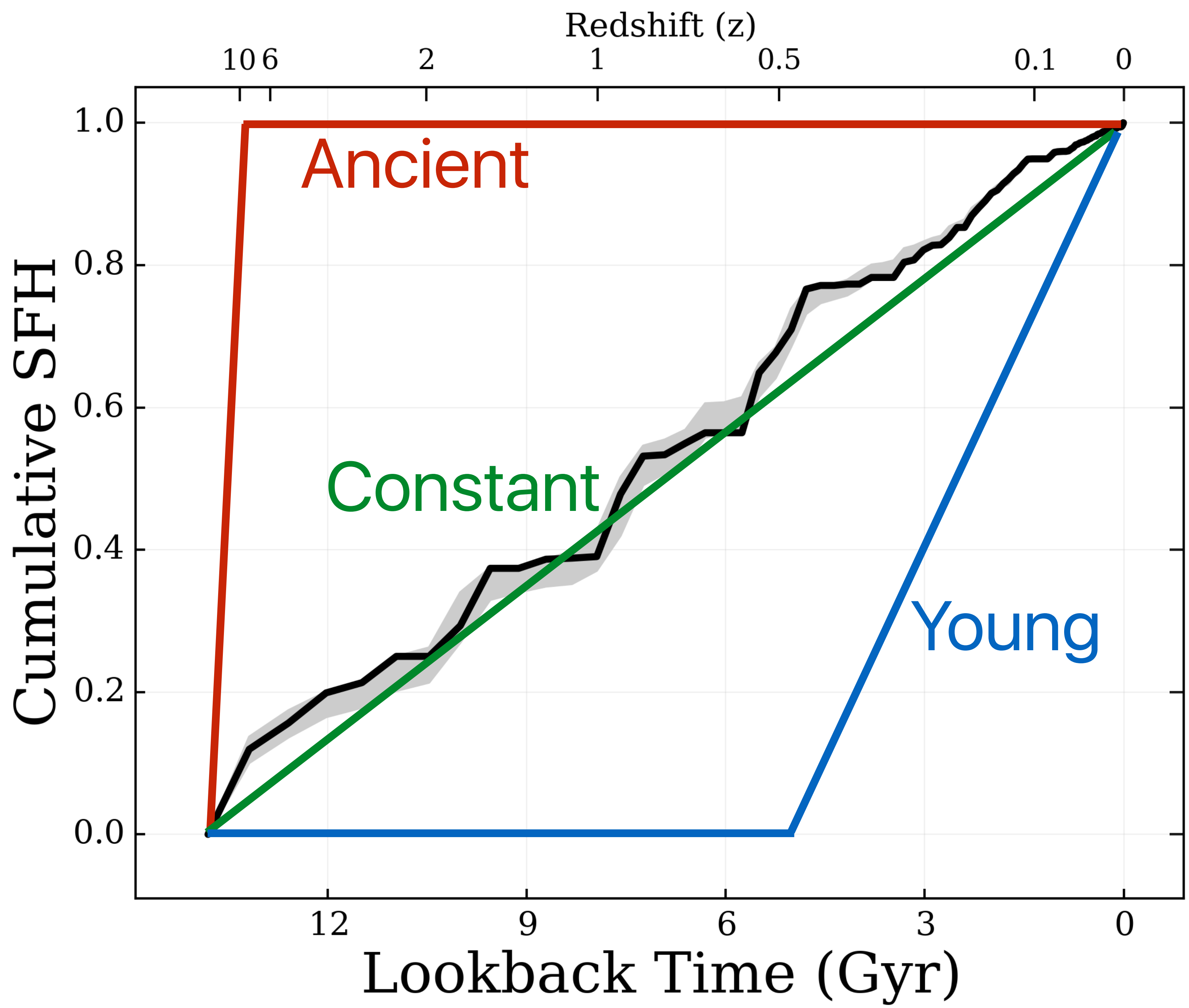

Skillman+ (2014)

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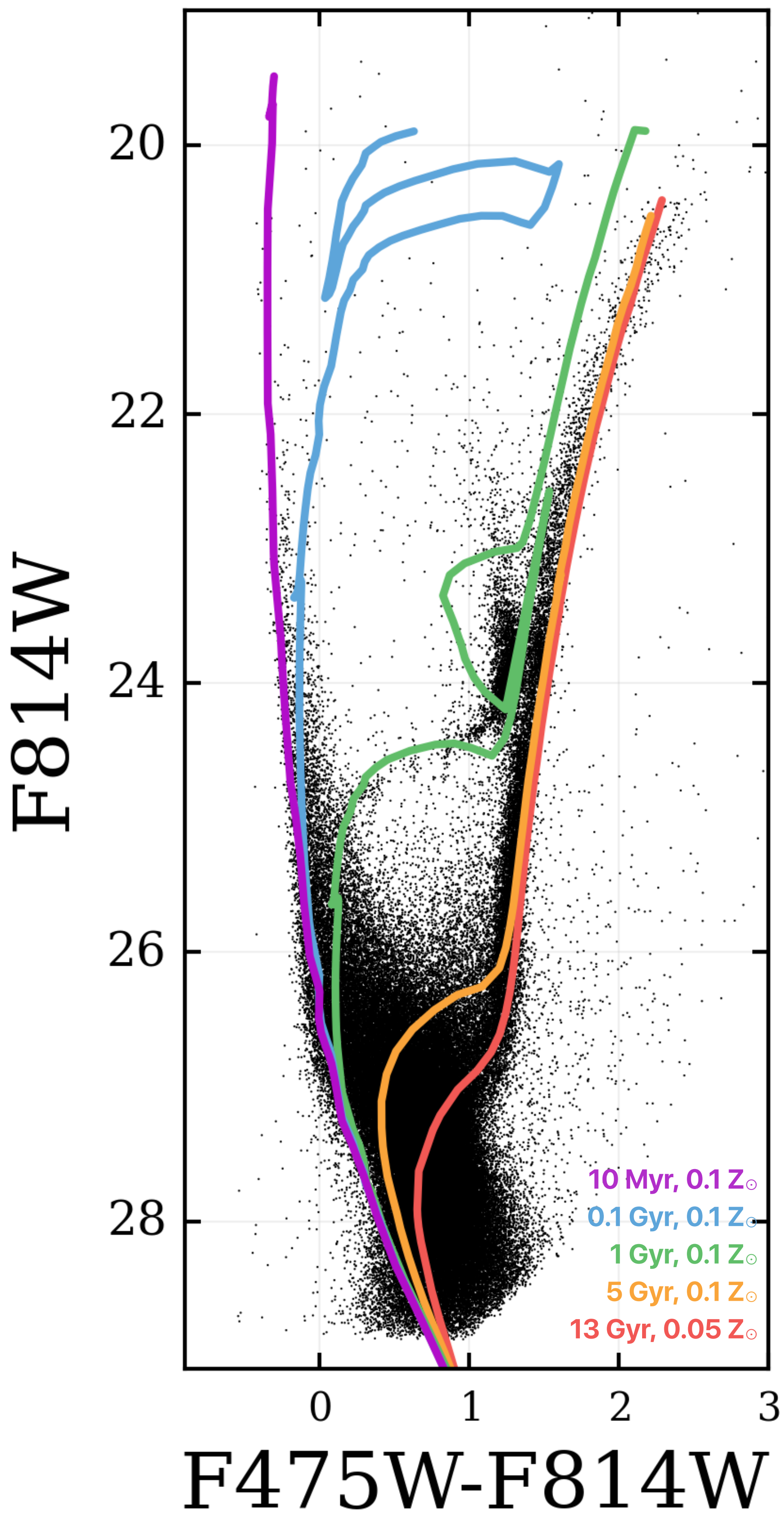

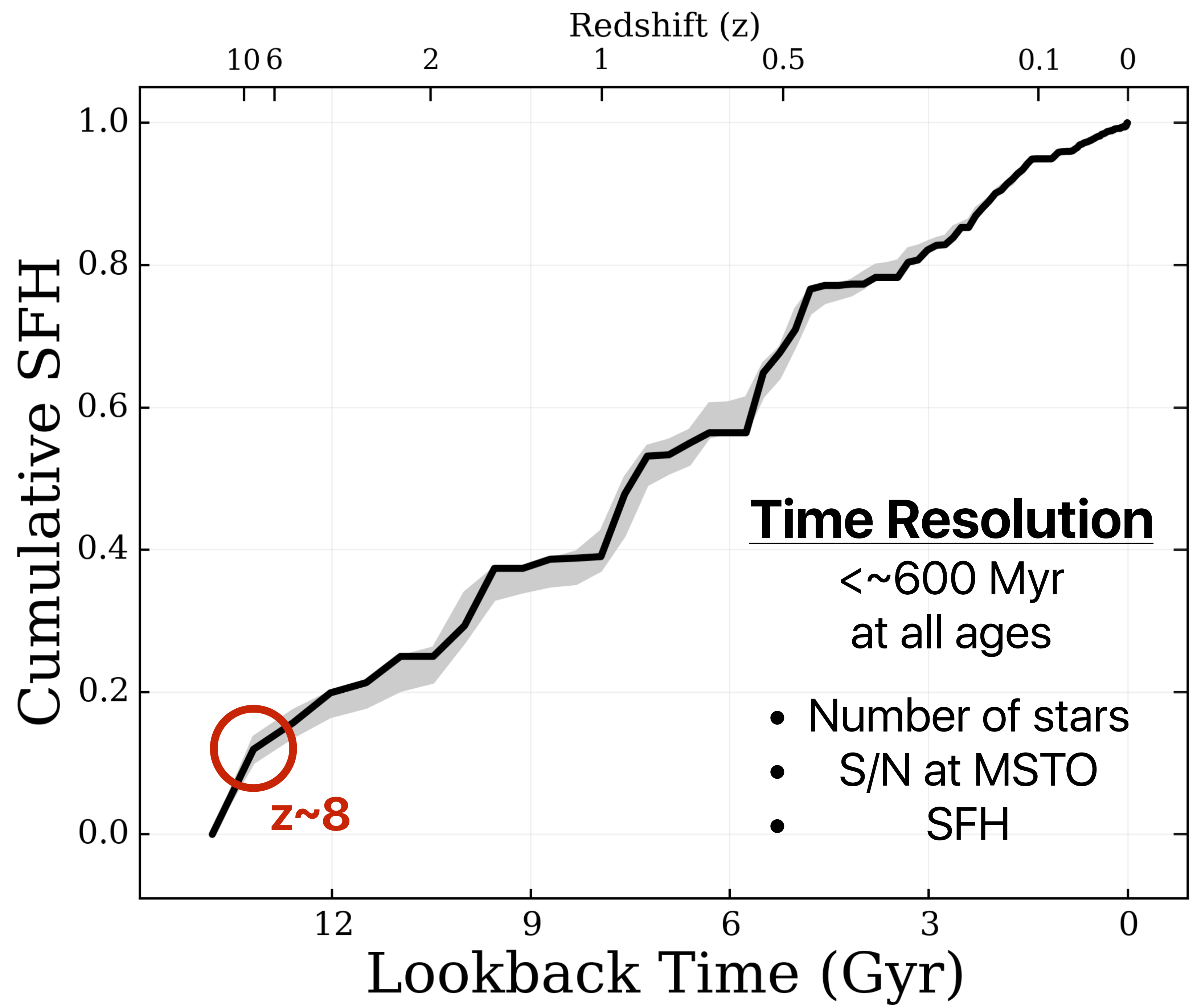

Skillman+ (2014)

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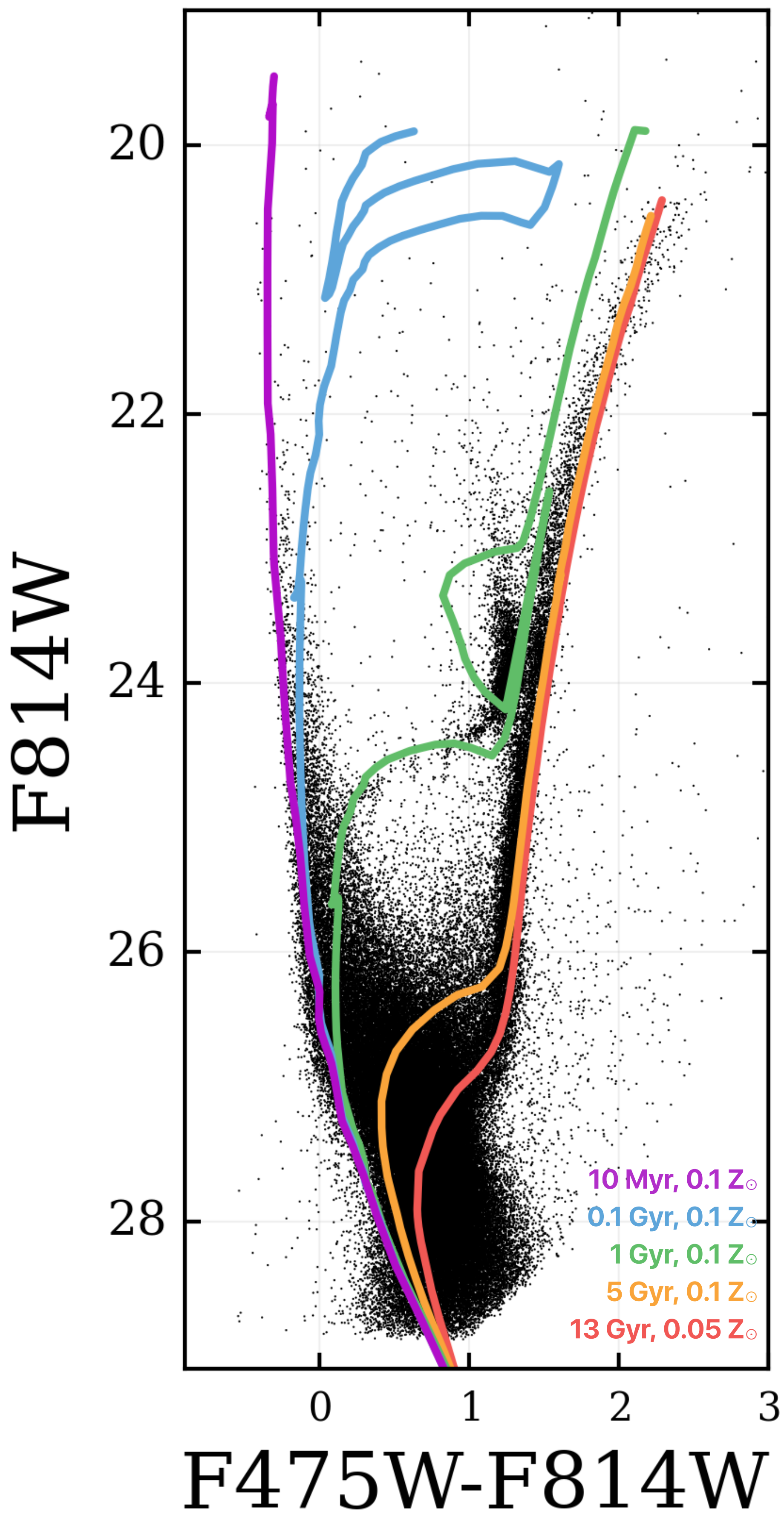
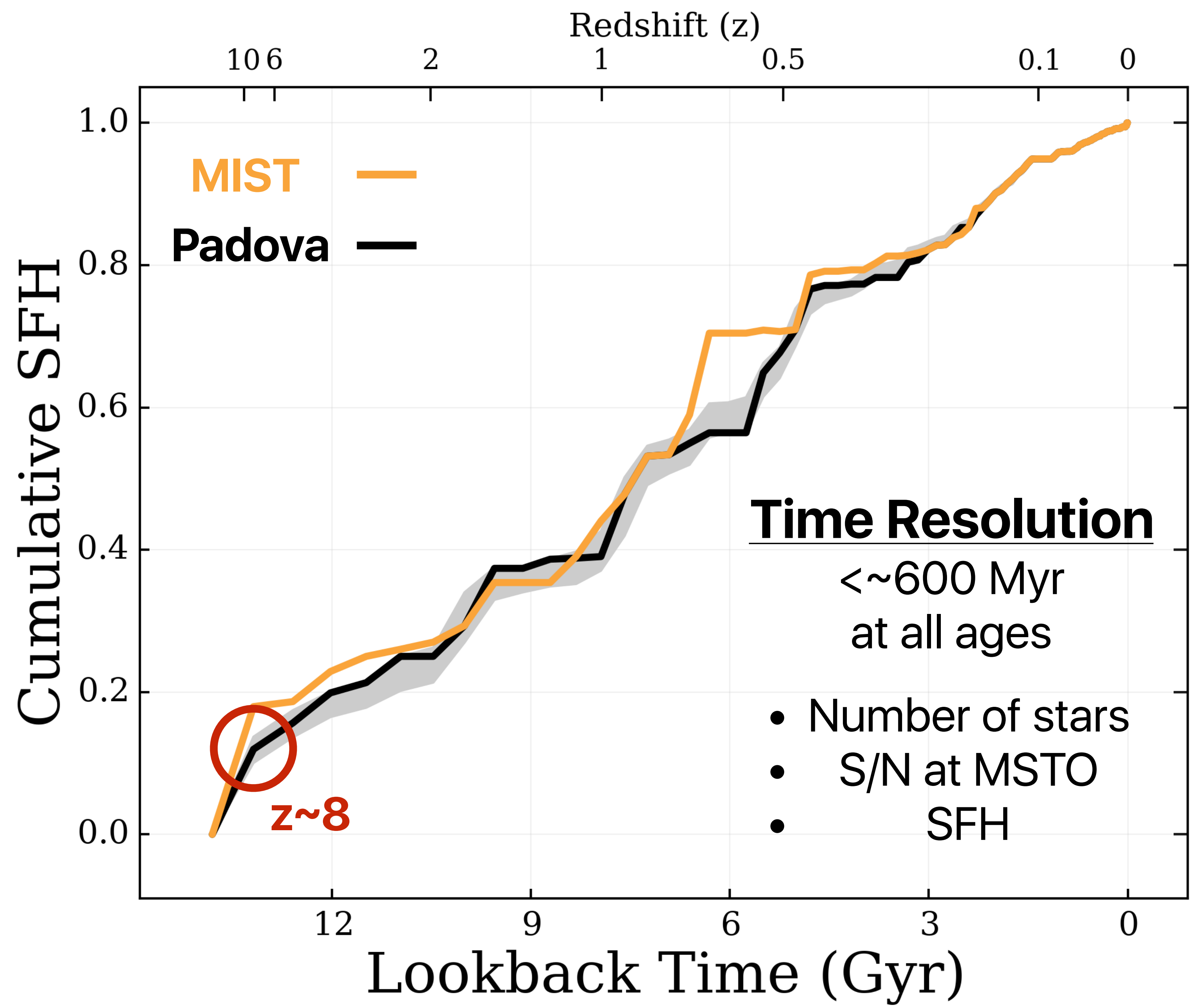
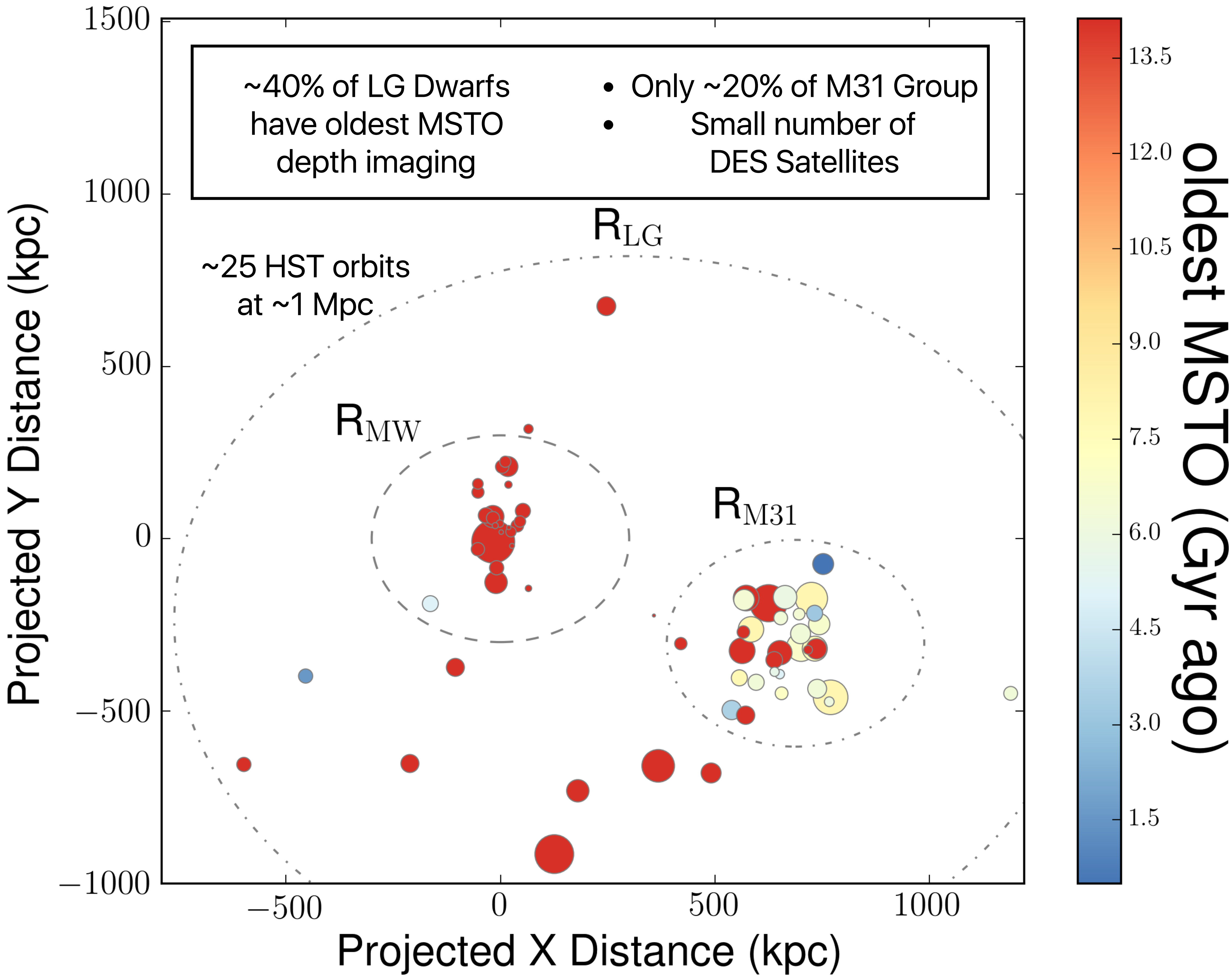




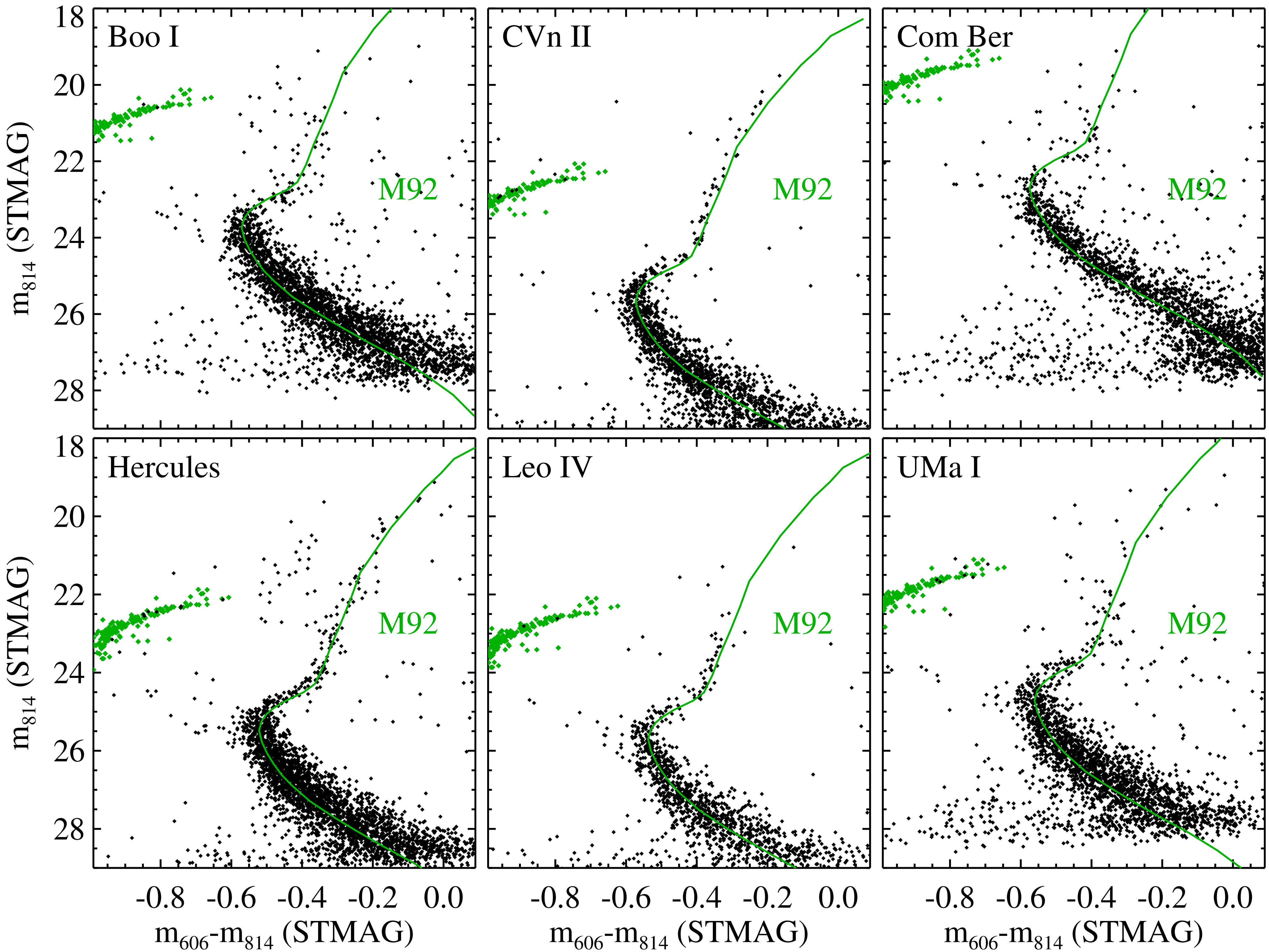
Skillman+ (2014)

Depth of CMDs in Local Group Dwarfs



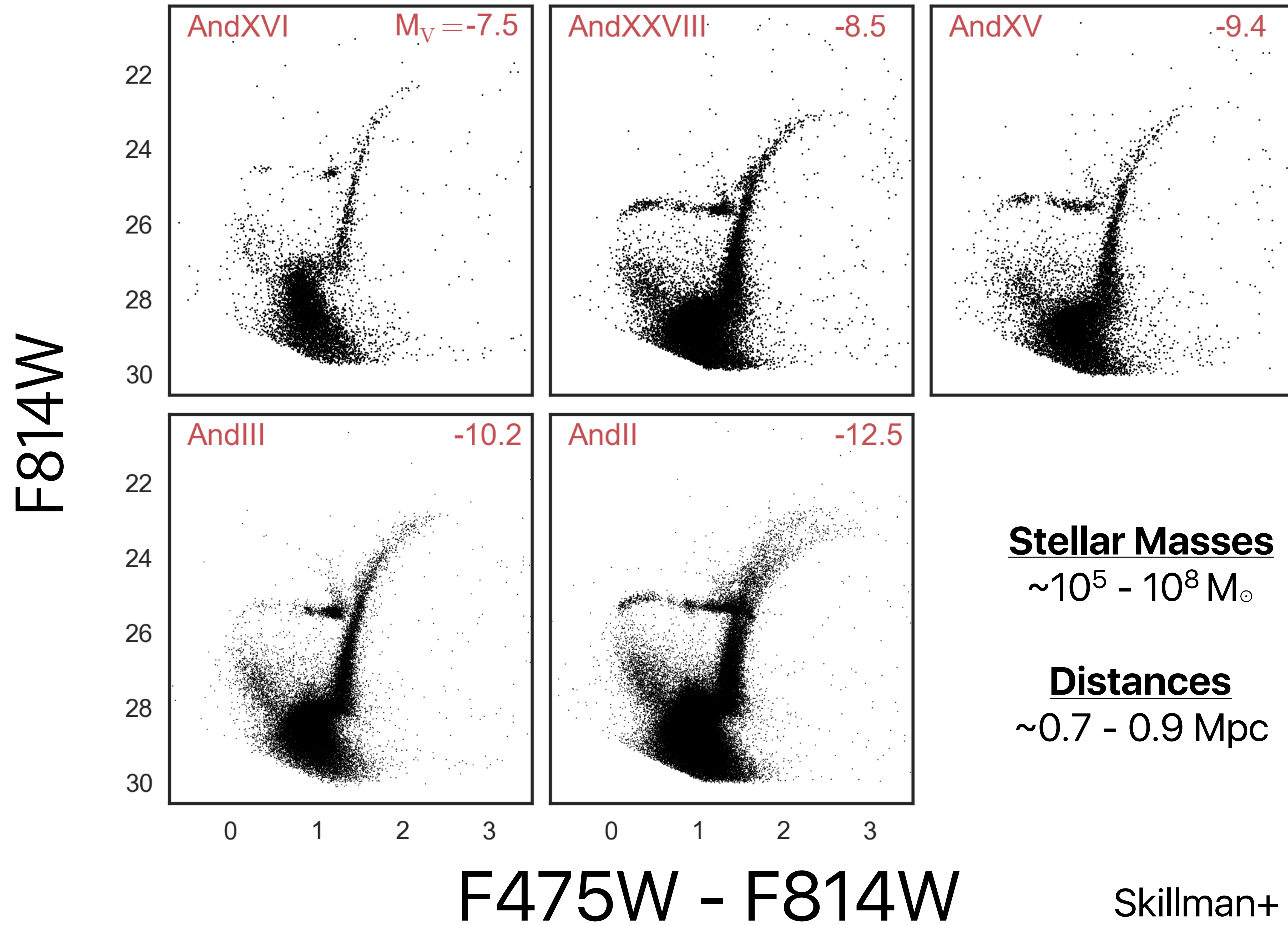
Milky Way 'Ultra-Faint' Dwarfs

Stellar Masses <10⁵ M☉ **Distances** <0.3 Mpc



Brown+ 2014

M31 Satellites



Stellar Masses

~10^5 - 10^8 $M_\odot$

Distances

~0.7 – 0.9 Mpc

Skillman+ 2016

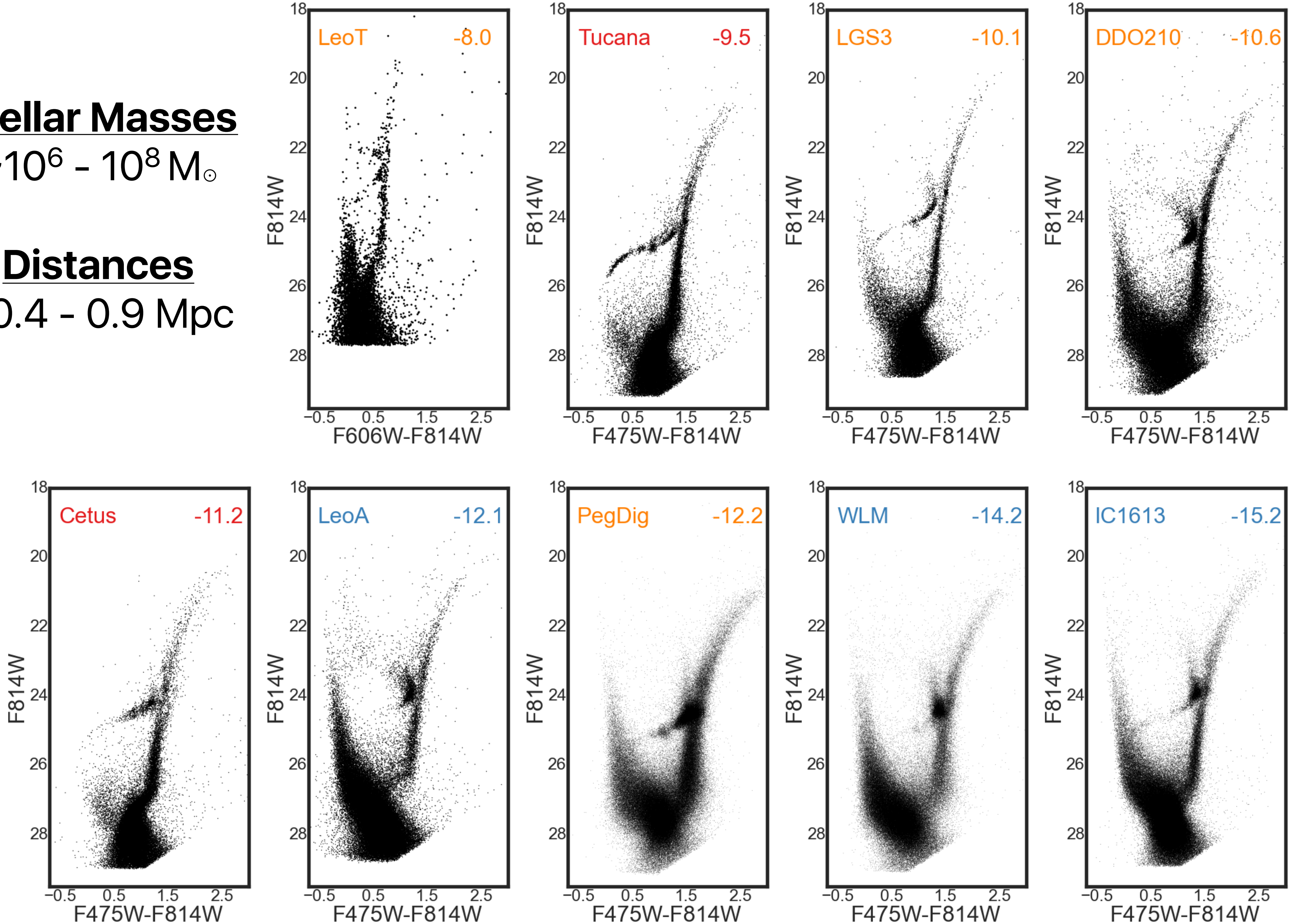
“Isolated” or “Field” Dwarfs

Stellar Masses

~10^6 - 10^8 $M_\odot$

Distances

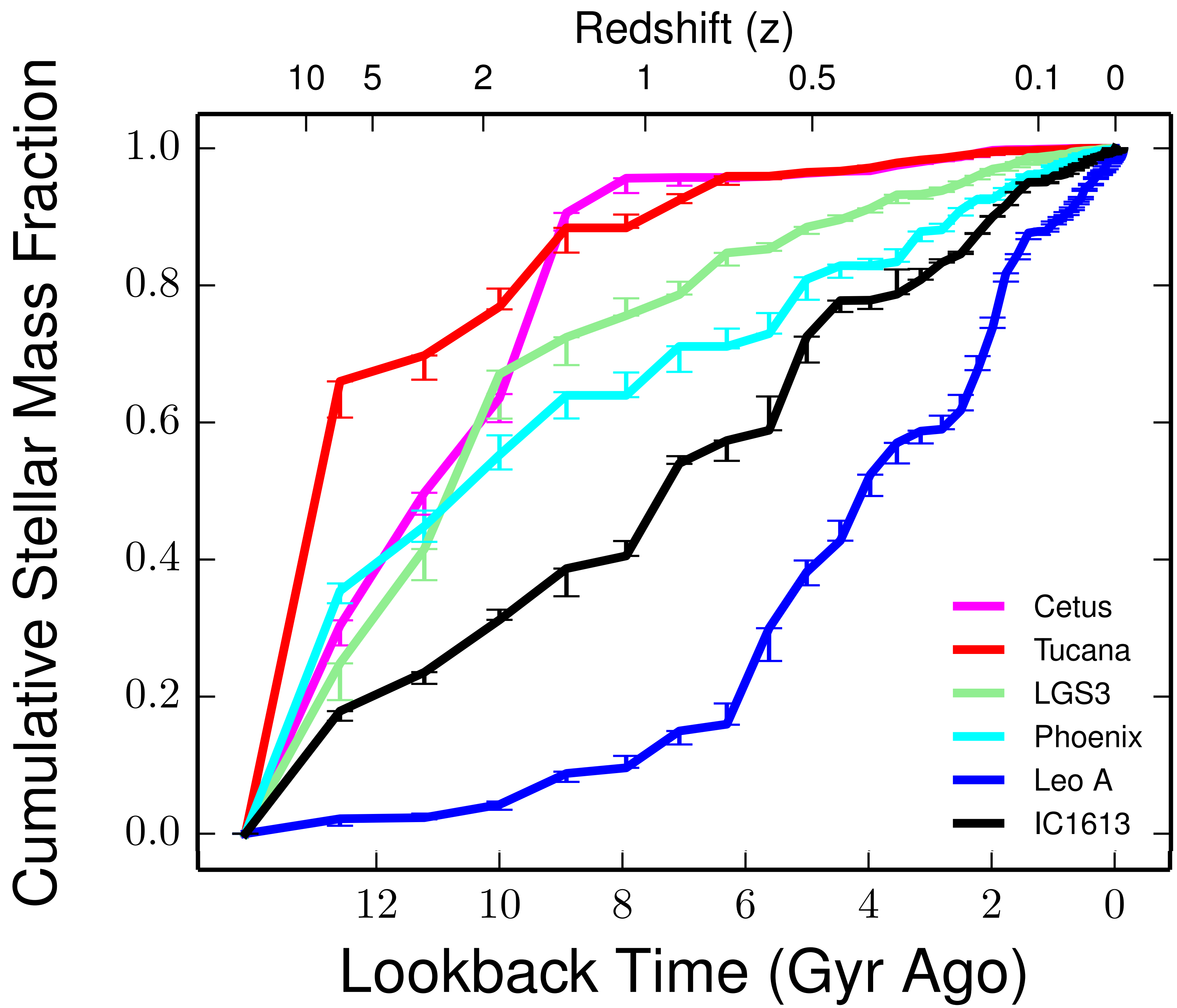
~0.4 - 0.9 Mpc



e.g., Gallart+ 2015

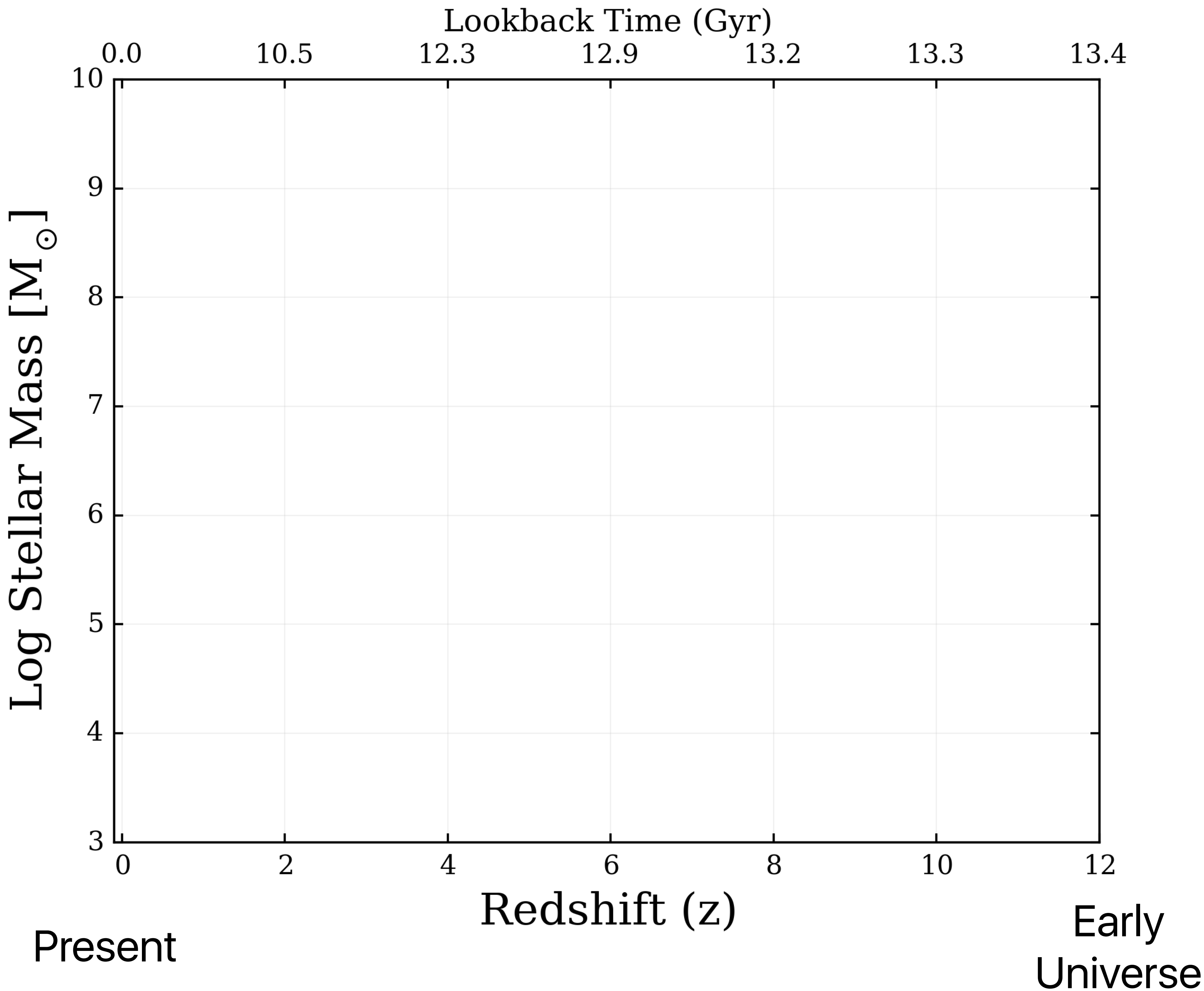
HST programs led by Gallart, Cole, Weisz, ...

Diversity in Low-Mass Galaxy SFHs



Skillman+ 2014

Low-Mass Galaxies Across Cosmic Time



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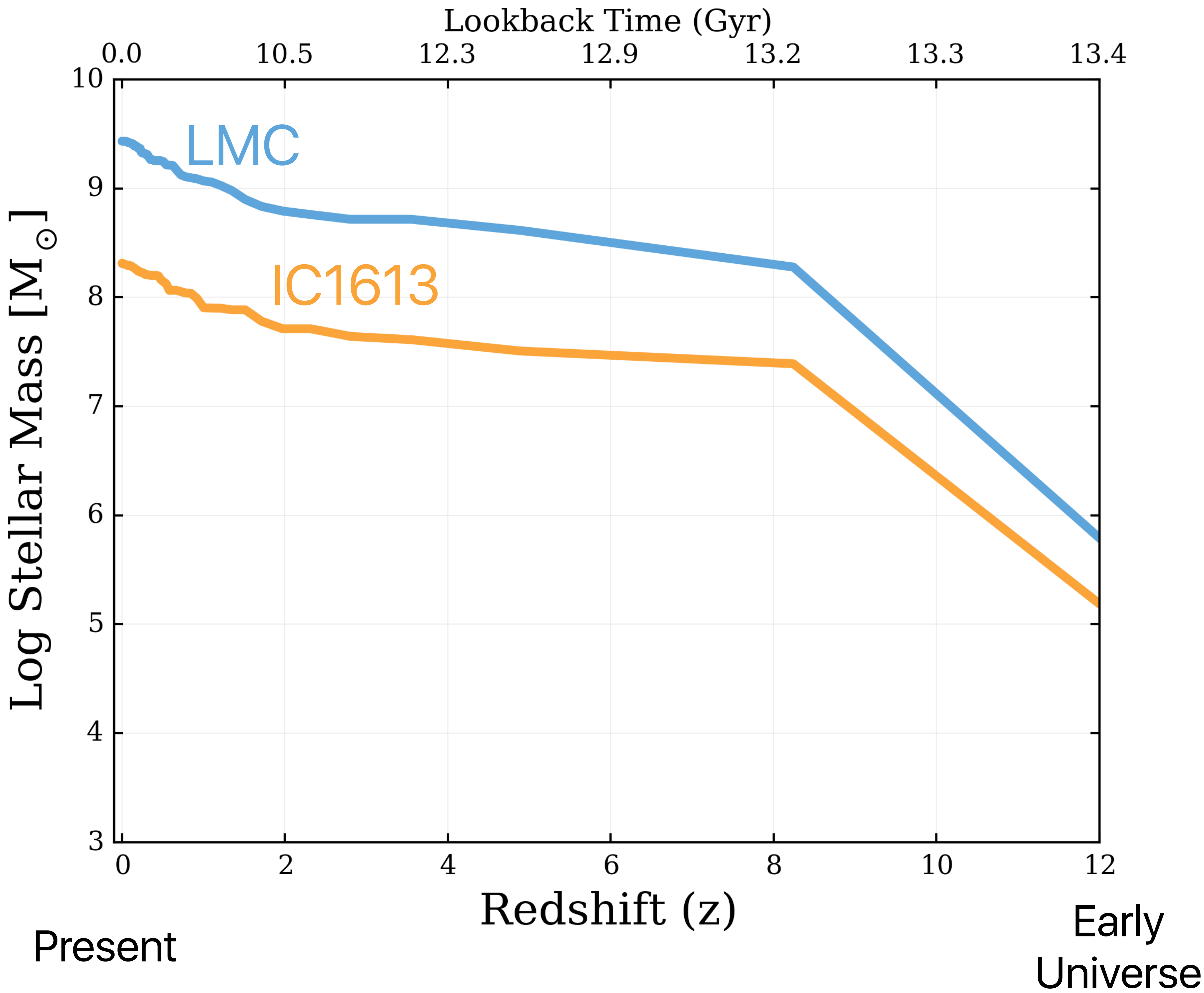

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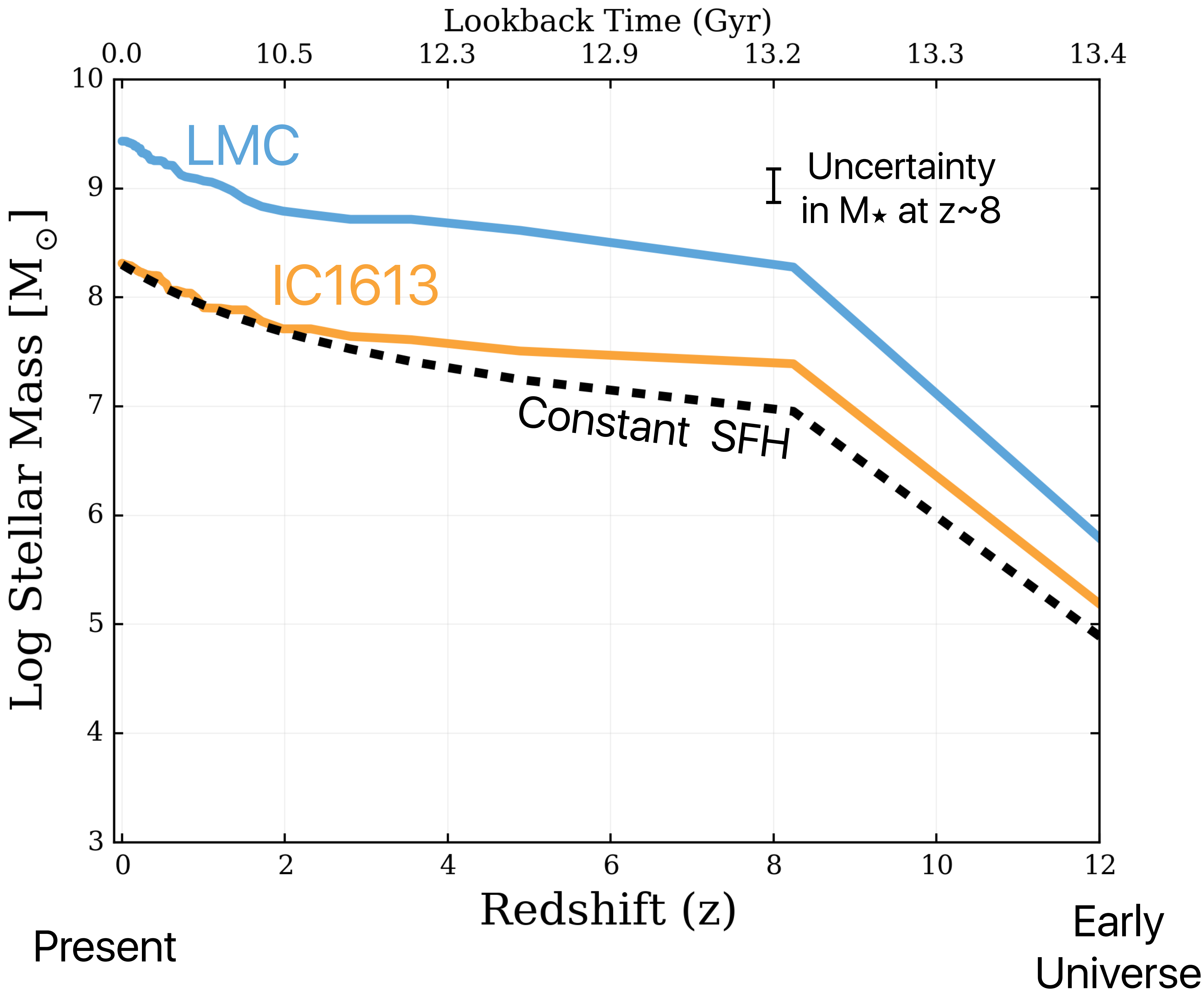

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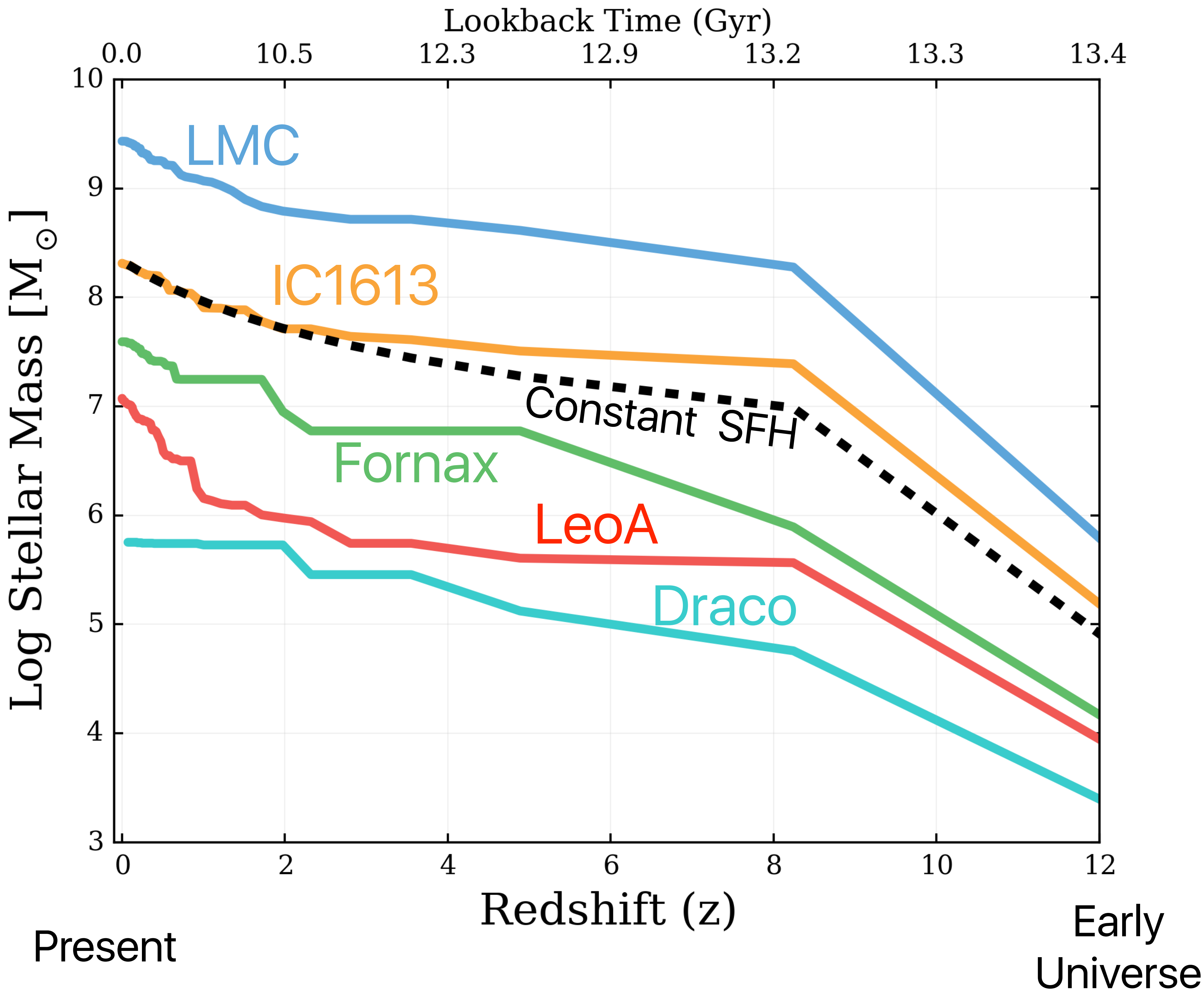

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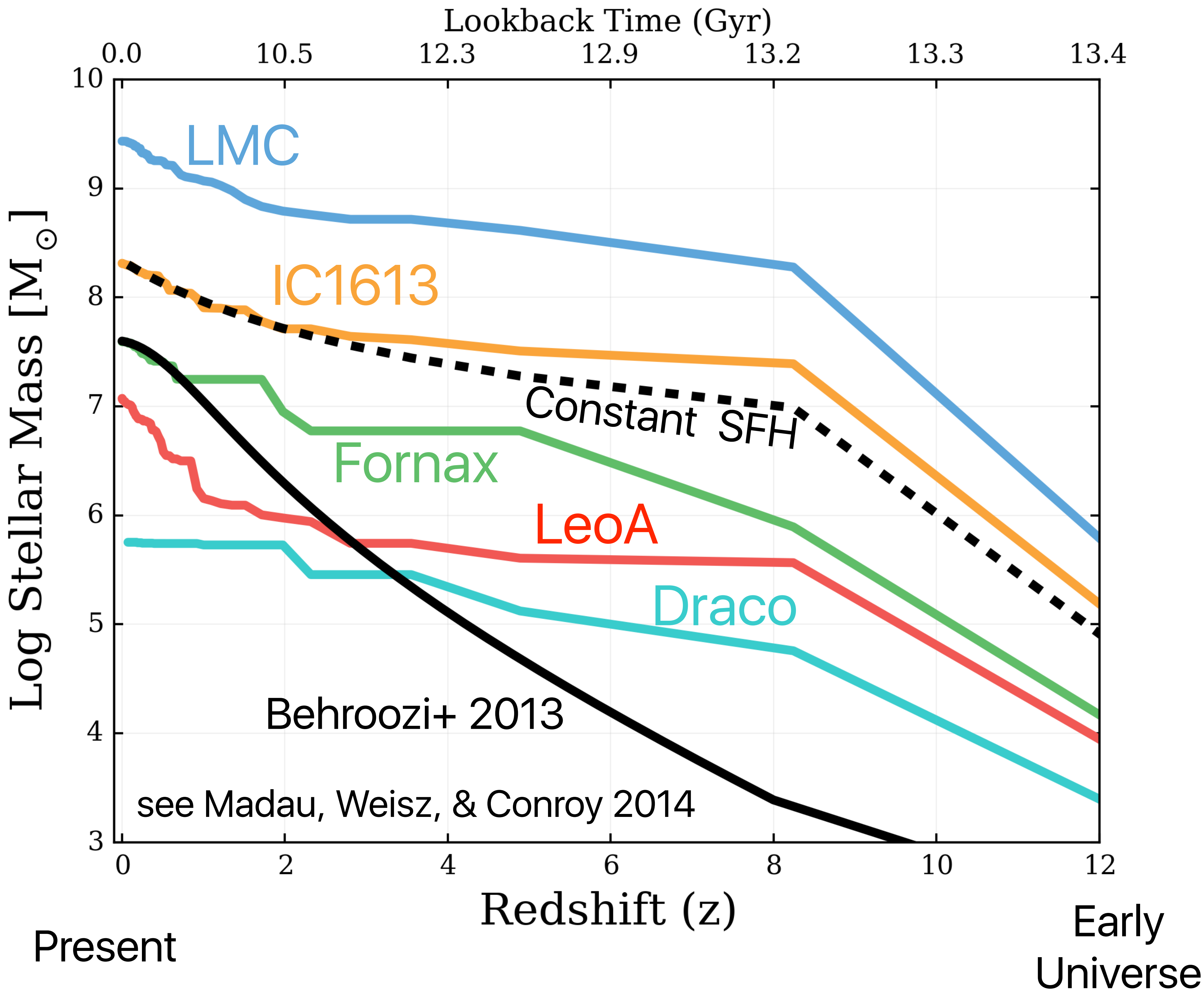

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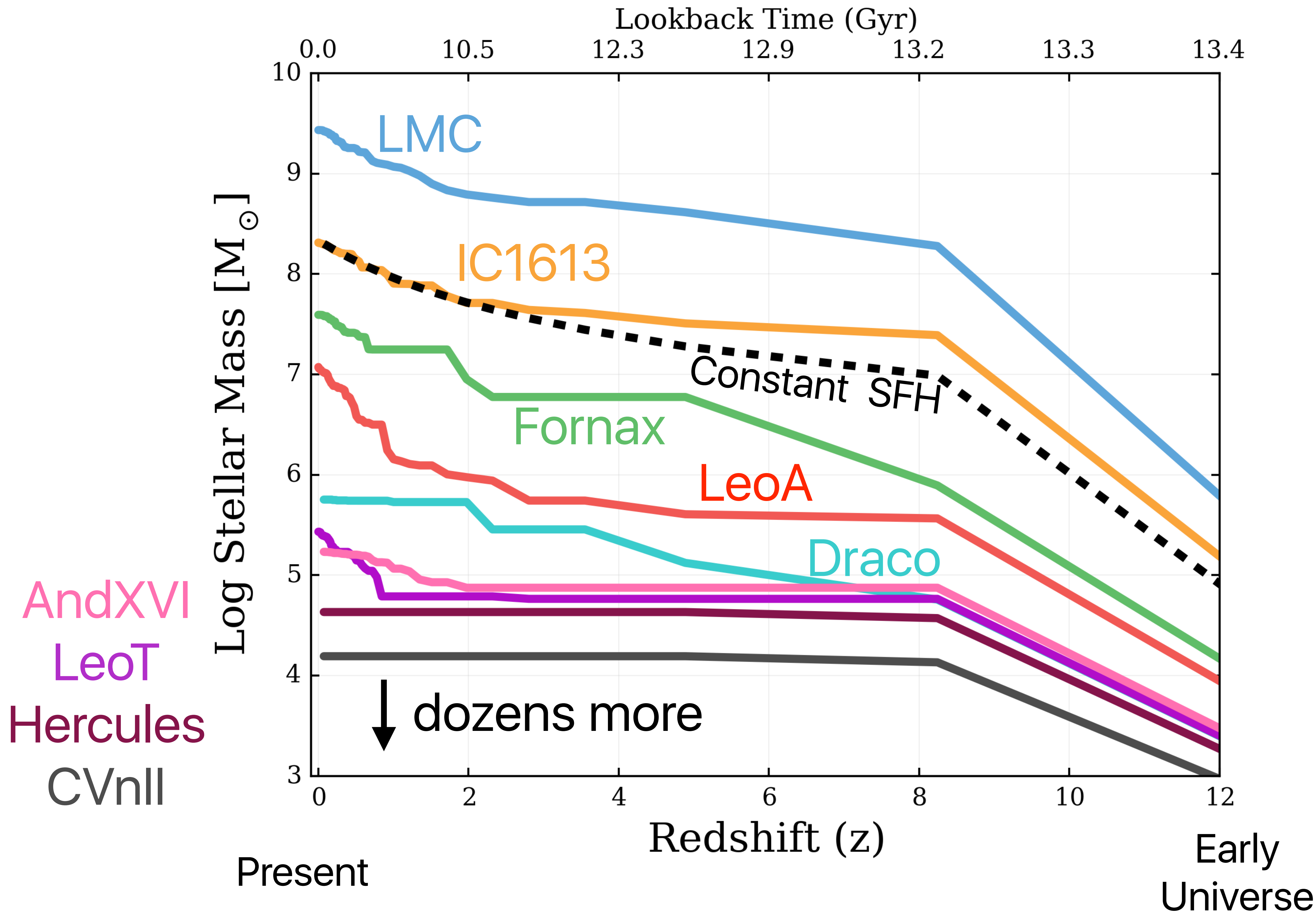

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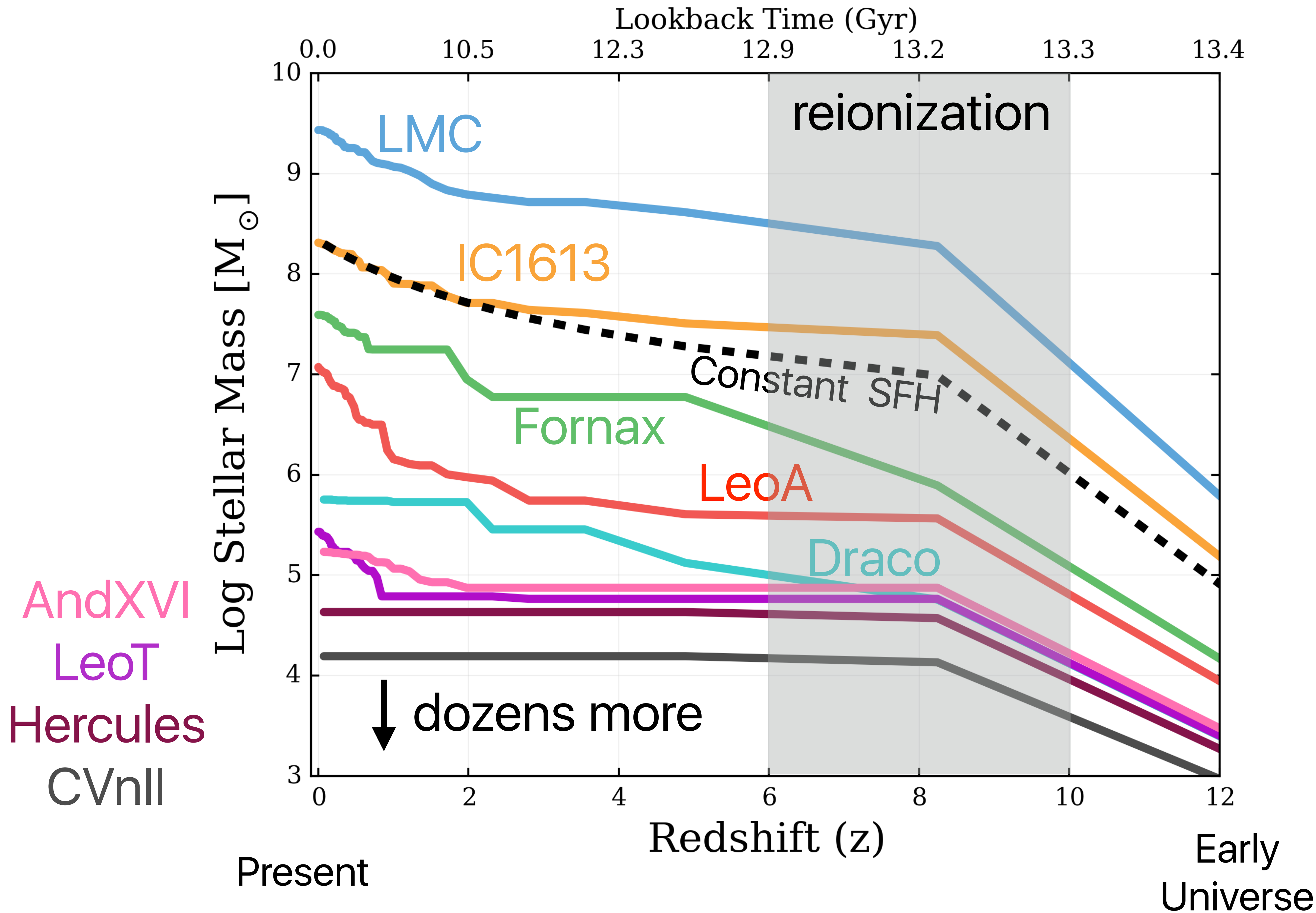

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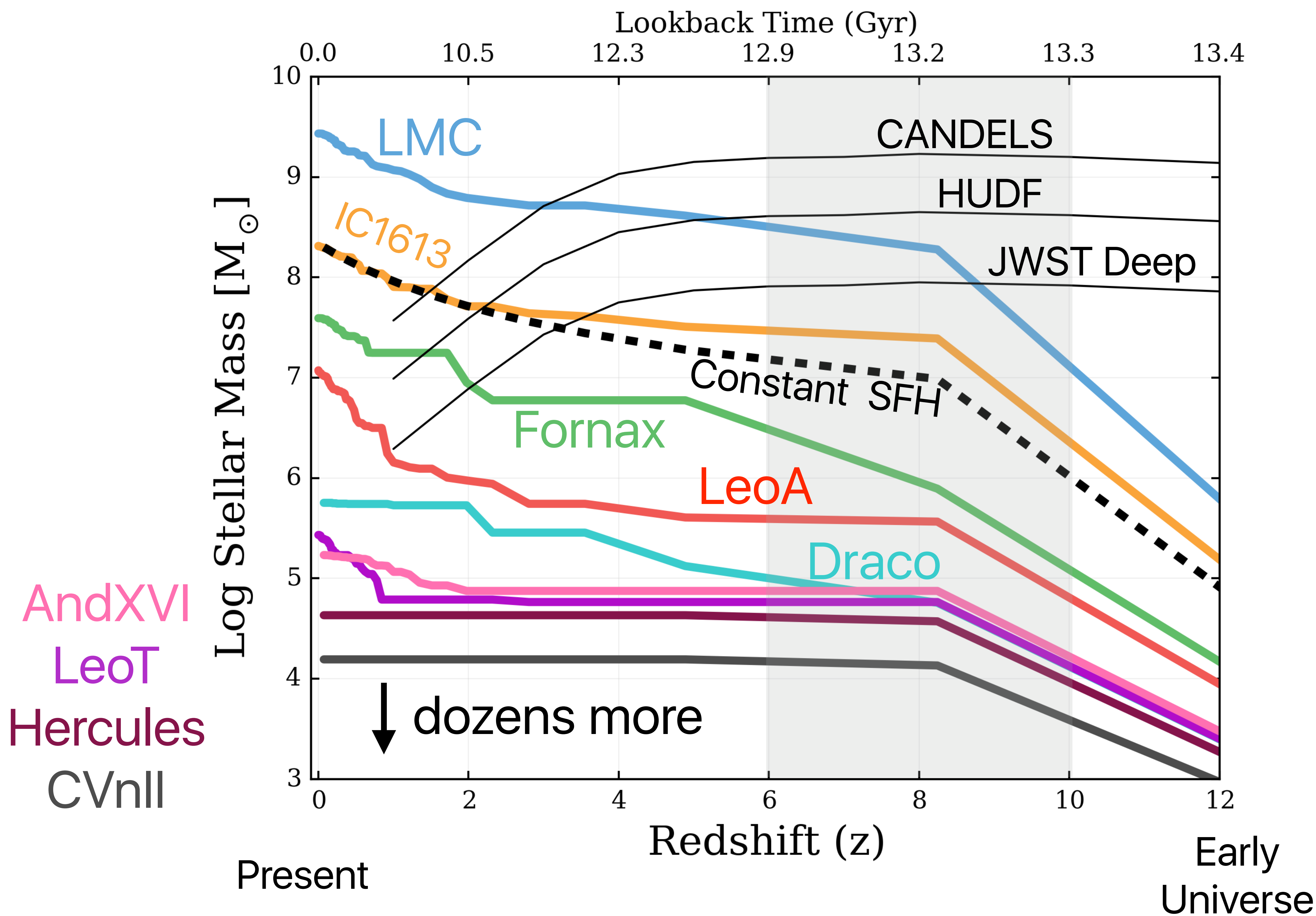
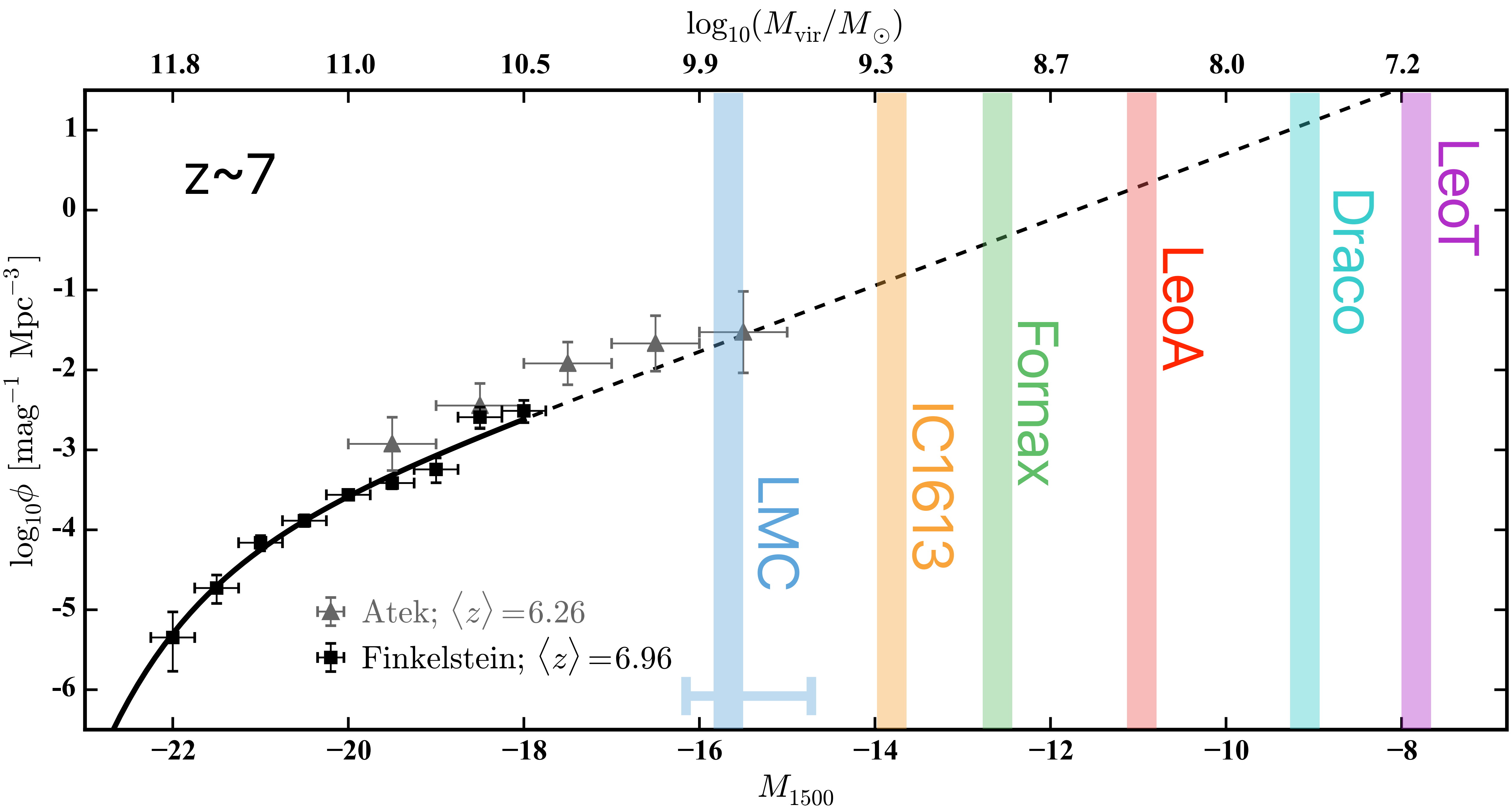


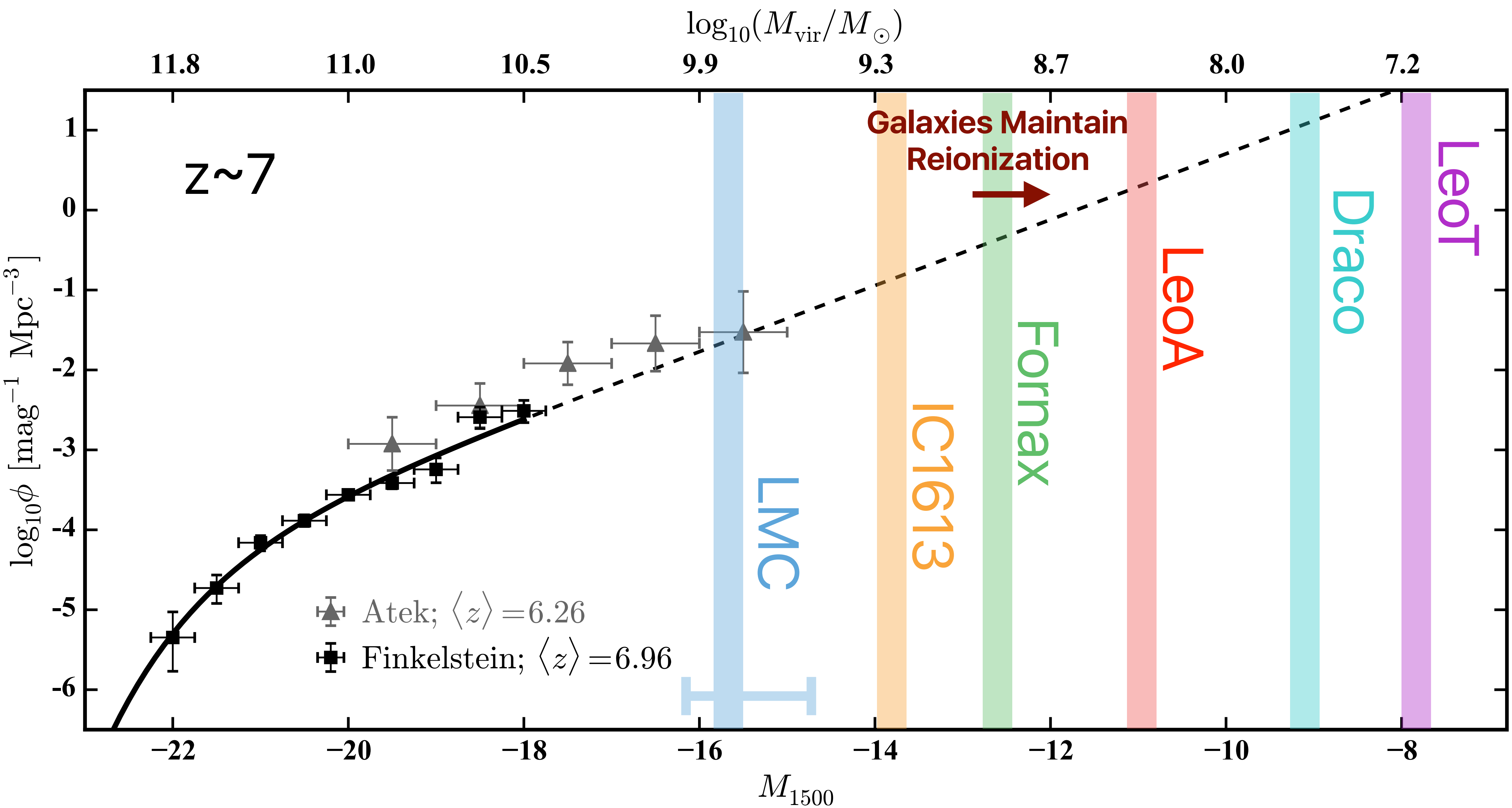
Local Group Dwarf Galaxy Ancestors



SFHs + Population Synthesis models → $M_{UV}(z)$

Weisz+ 2014; Boylan-Kolchin+ 2015

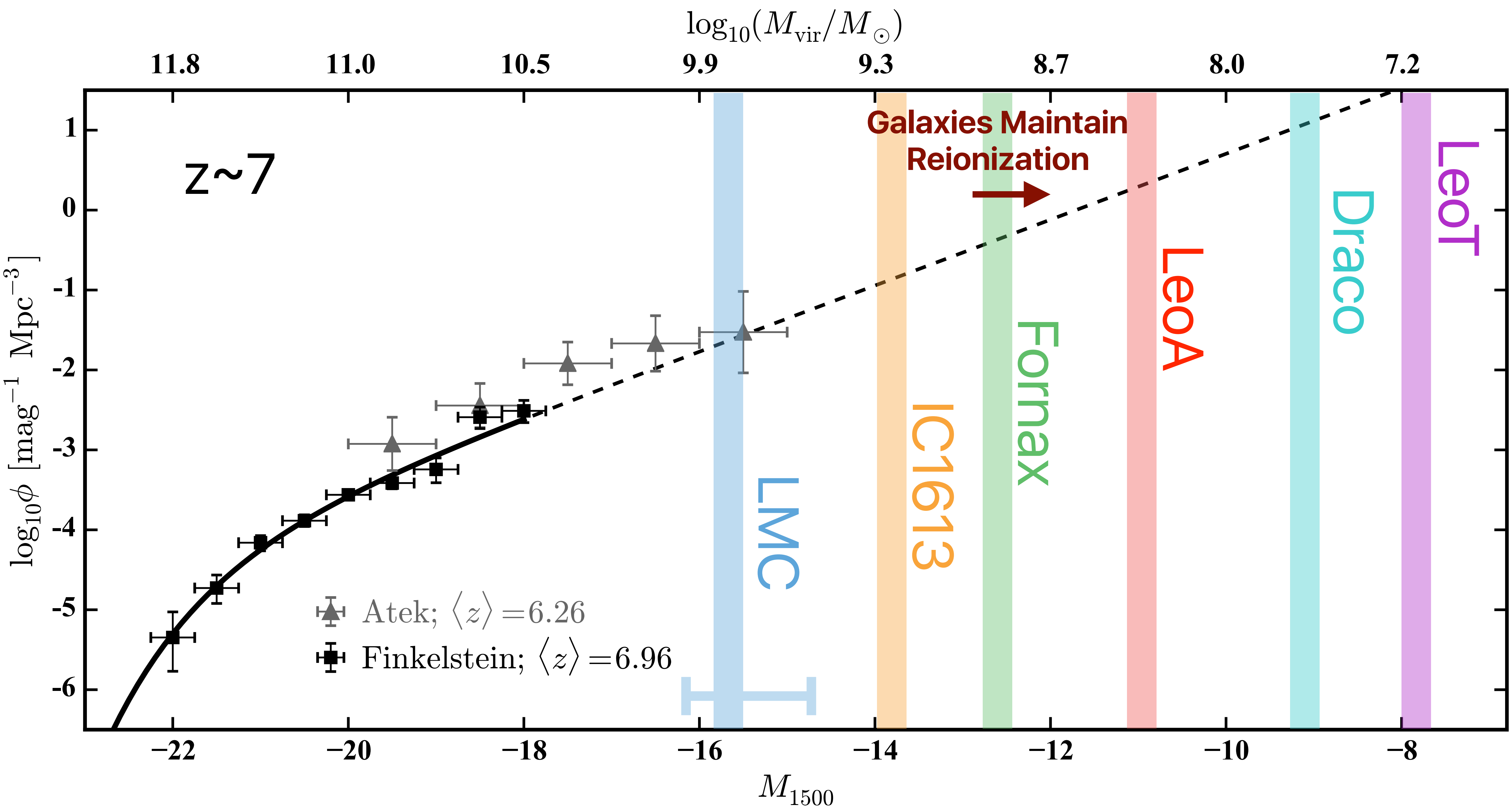
Local Group Dwarf Galaxy Ancestors



Ancestors of Fornax and Leo A -like galaxies needed to maintain reionization

Weisz+ 2014; Boylan-Kolchin+ 2015

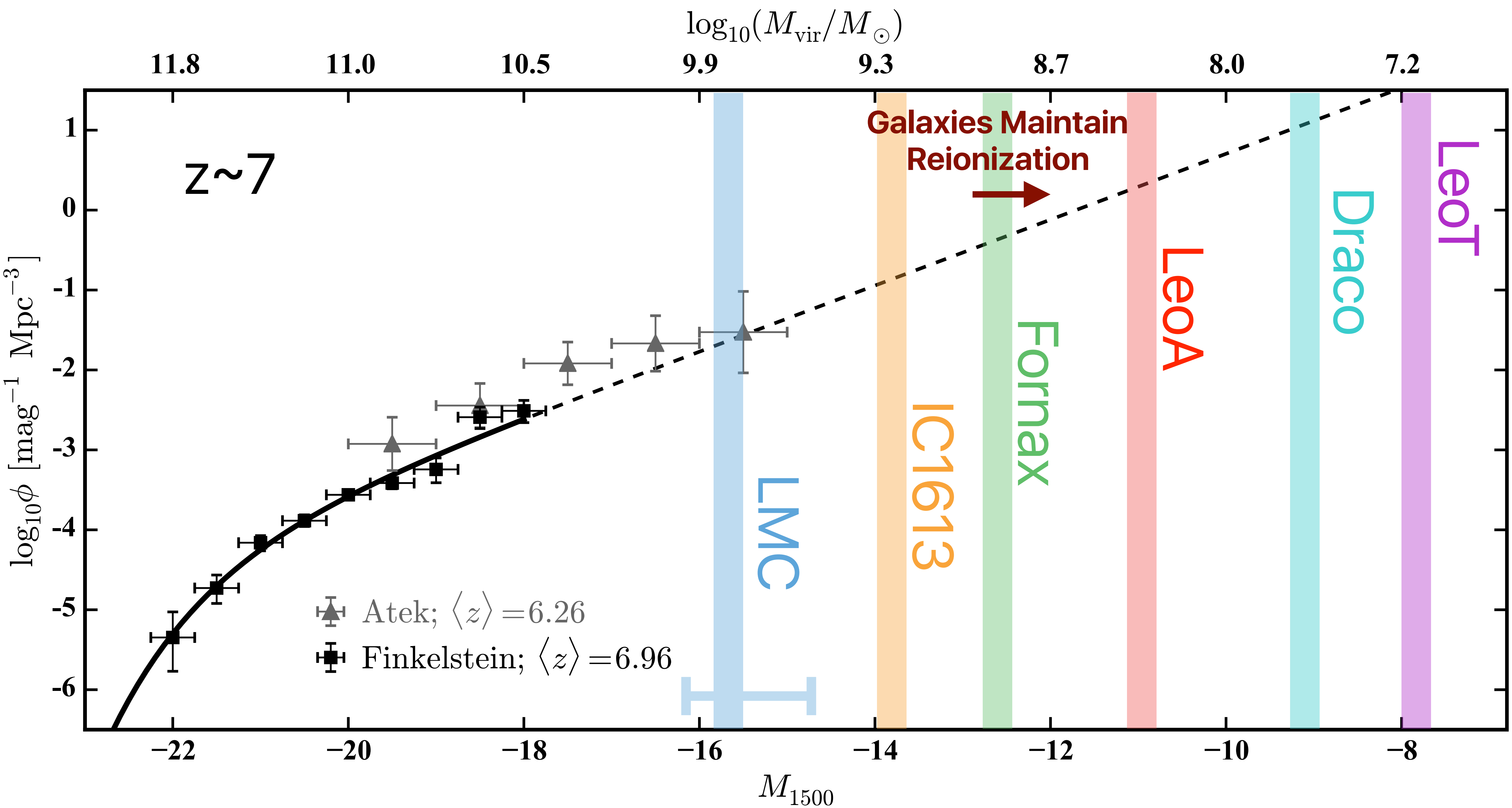
Local Group Dwarf Galaxy Ancestors



There is a substantial population of very faint galaxies: $M_{UV}(z\sim7) > -8$ (or fainter!).

Weisz+ 2014; Boylan-Kolchin+ 2015

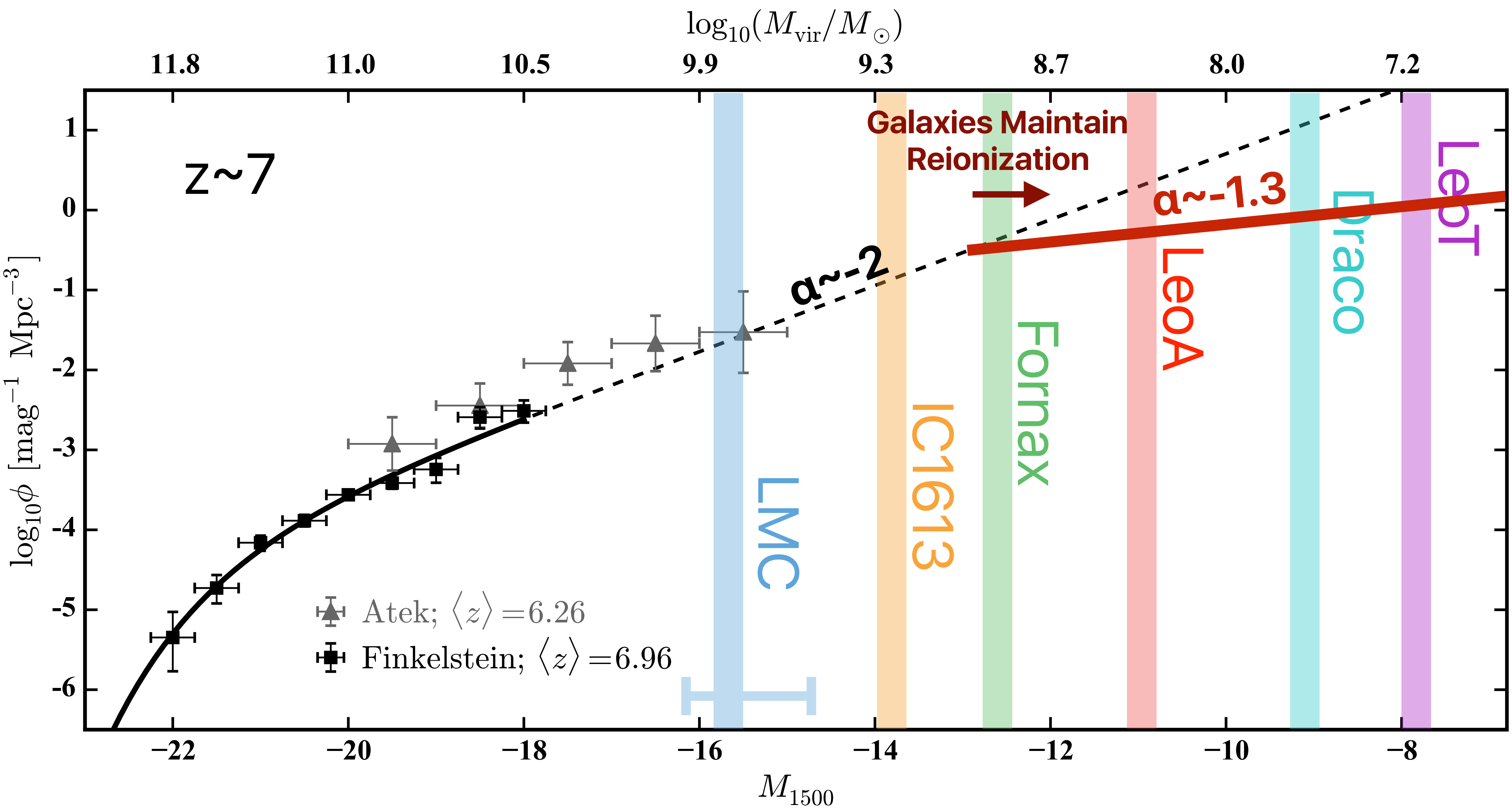
Local Group Dwarf Galaxy Ancestors



But...

Weisz+ 2014; Boylan-Kolchin+ 2015

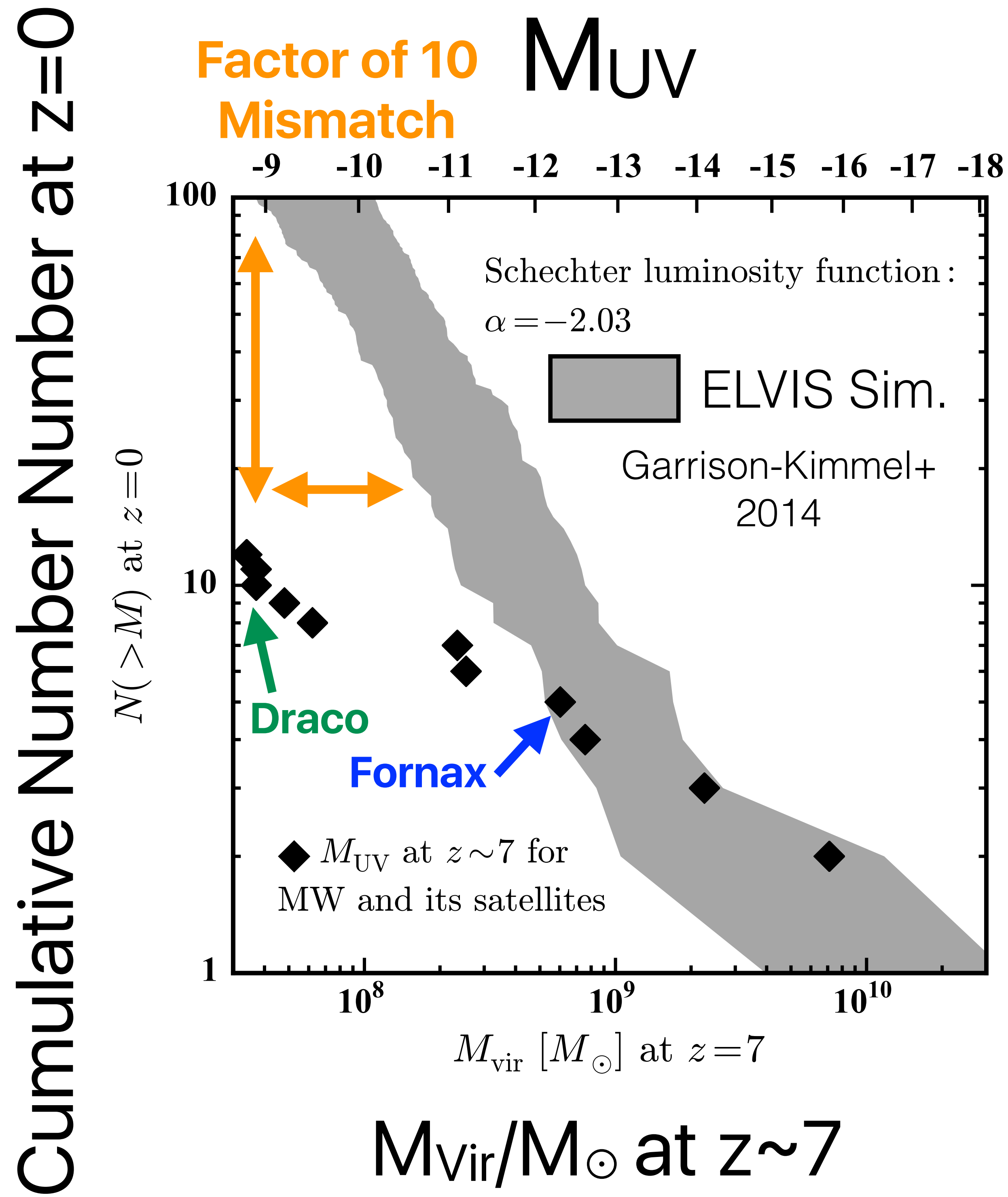
Local Group Dwarf Galaxy Ancestors



- steep faint-end slopes from high-z over-predict faint LG galaxy counts

Weisz+ 2014; Boylan-Kolchin+ 2014, 2015

How many MW satellites should we see based on the high-z UVLF?



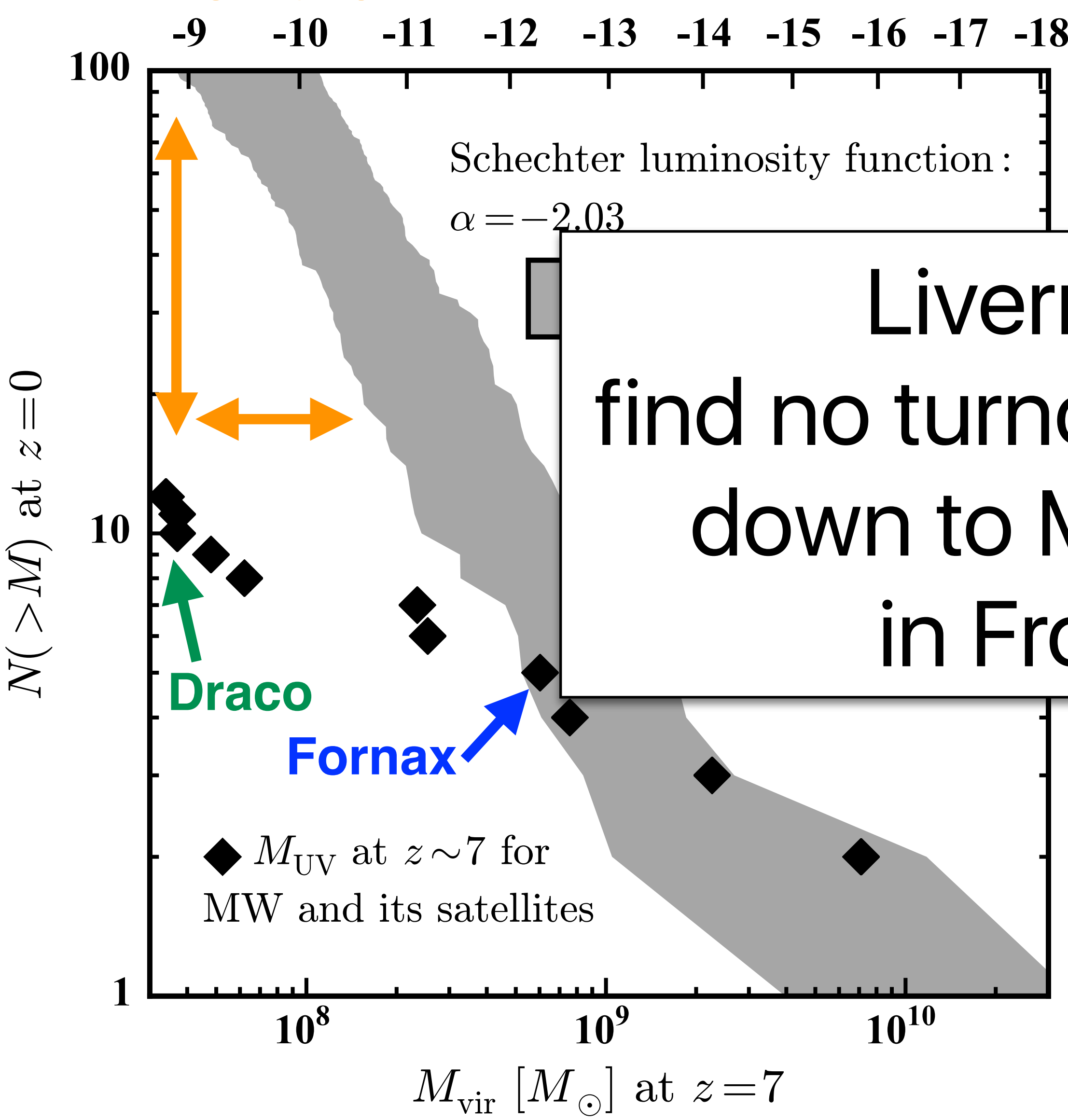
Boylan-Kolchin+ 2015

How many MW satellites should we see based on the high-z UVLF?

Cumulative Number at z=0

Factor of 10 Mismatch

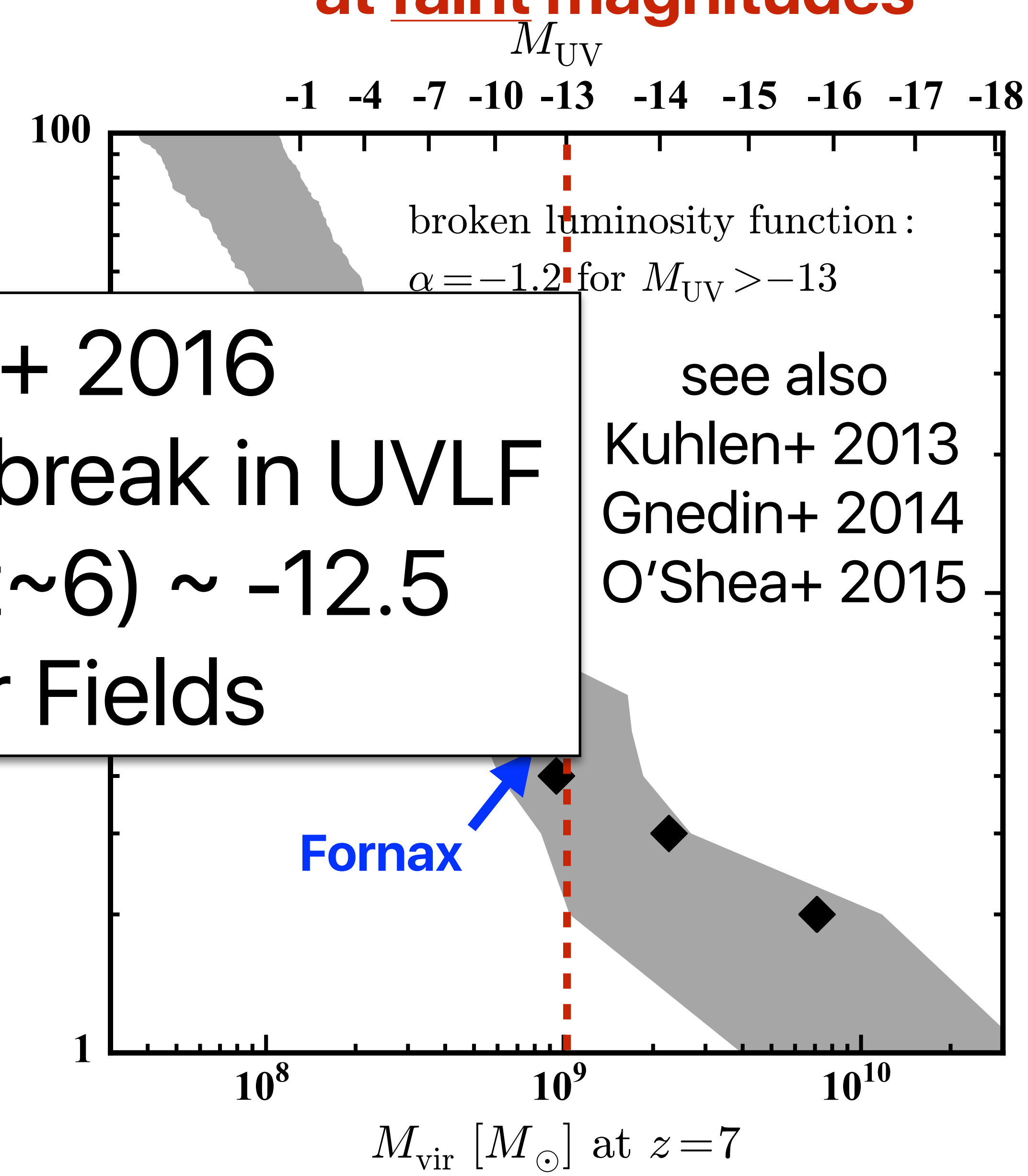
M_{UV}



$M_{Vir}/M_\odot$ at z~7

Boylan-Kolchin+ 2015

Broken LF slope at faint magnitudes

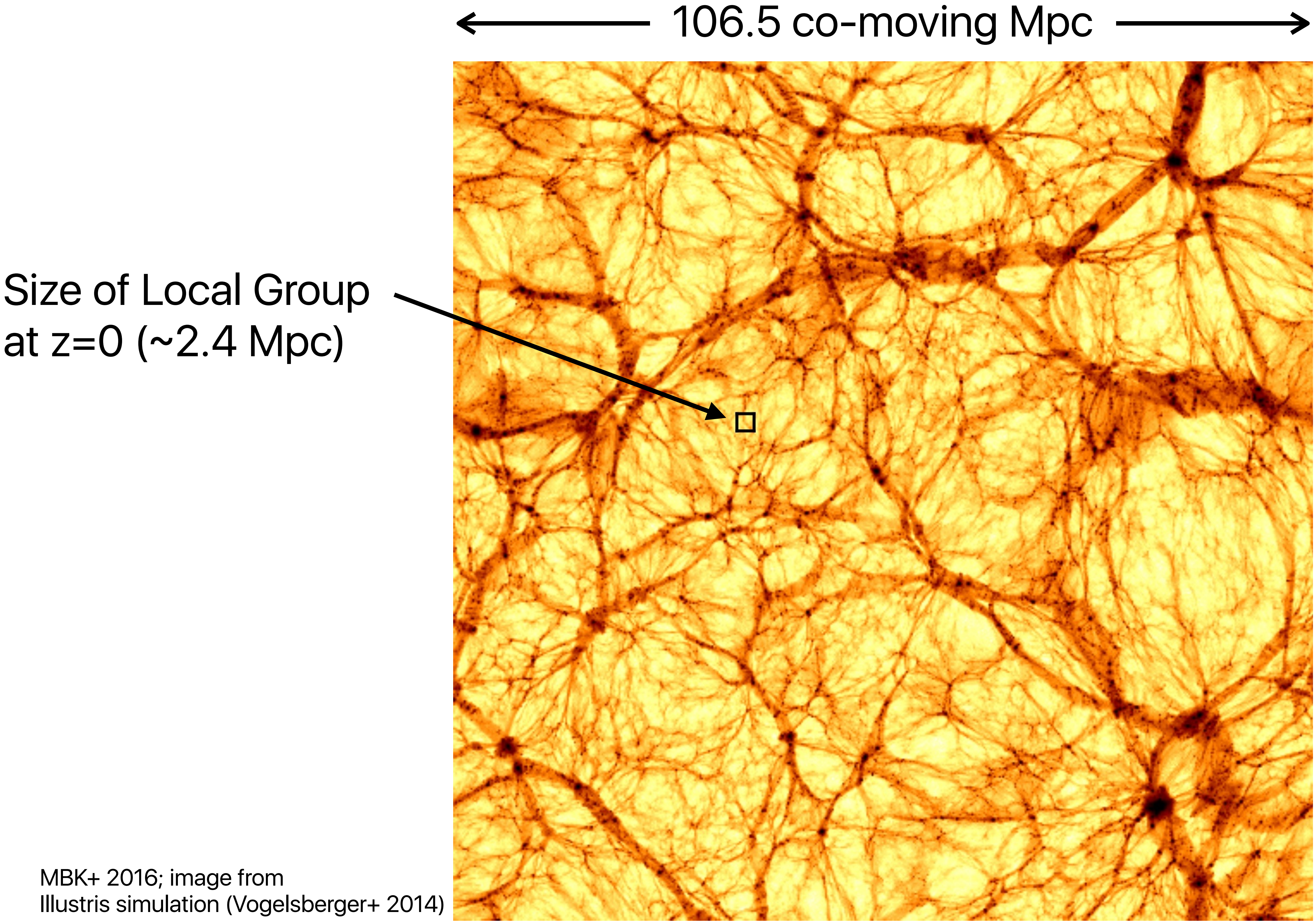


Livermore+ 2016
find no turnover/break in UVLF
down to M_{UV}(z~6) ~ -12.5
in Frontier Fields

see also
Kuhlen+ 2013
Gnedin+ 2014
O'Shea+ 2015

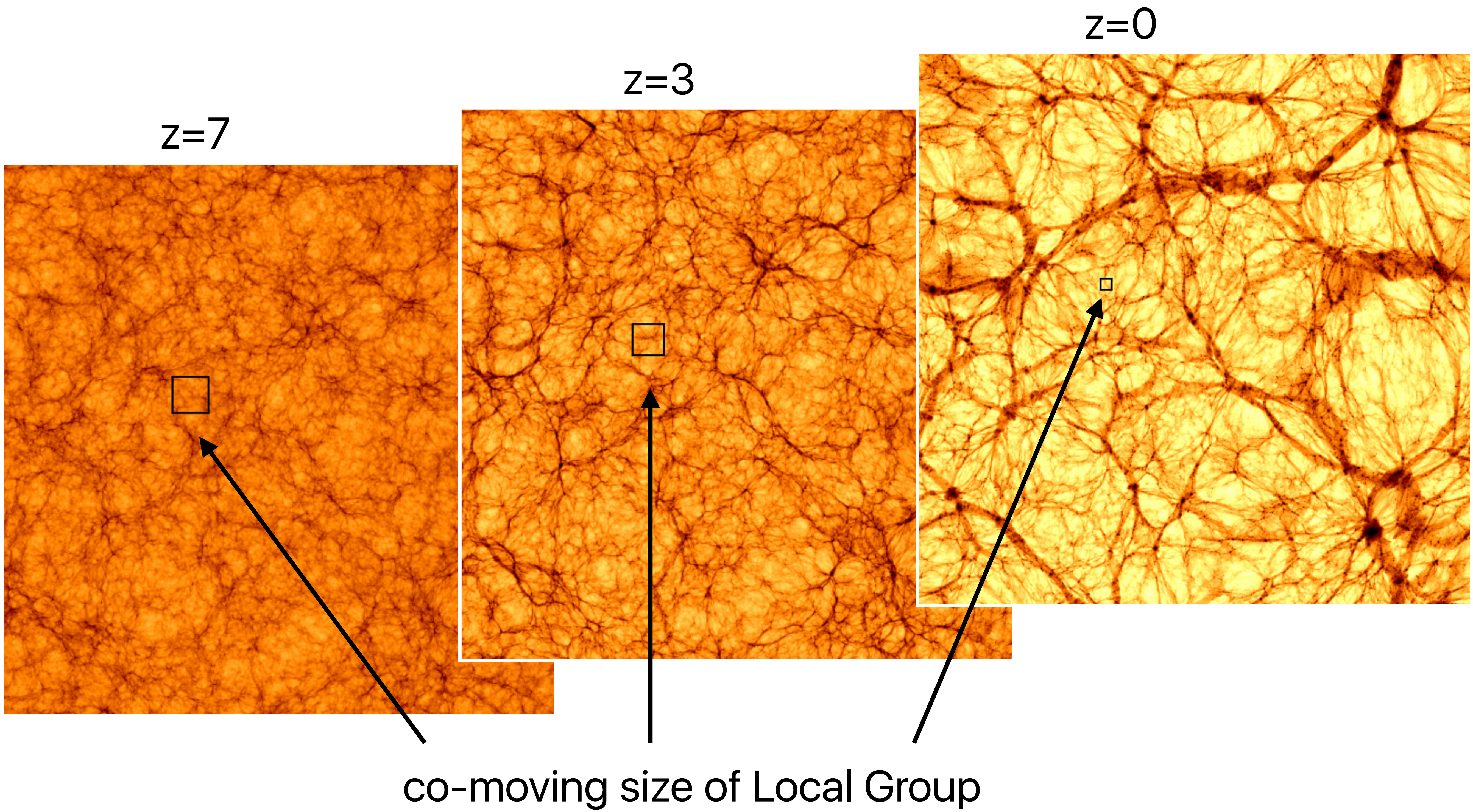
Changes SHM relation,
Faint galaxies live in more massive halos, ...

The Local Group in Cosmological Context

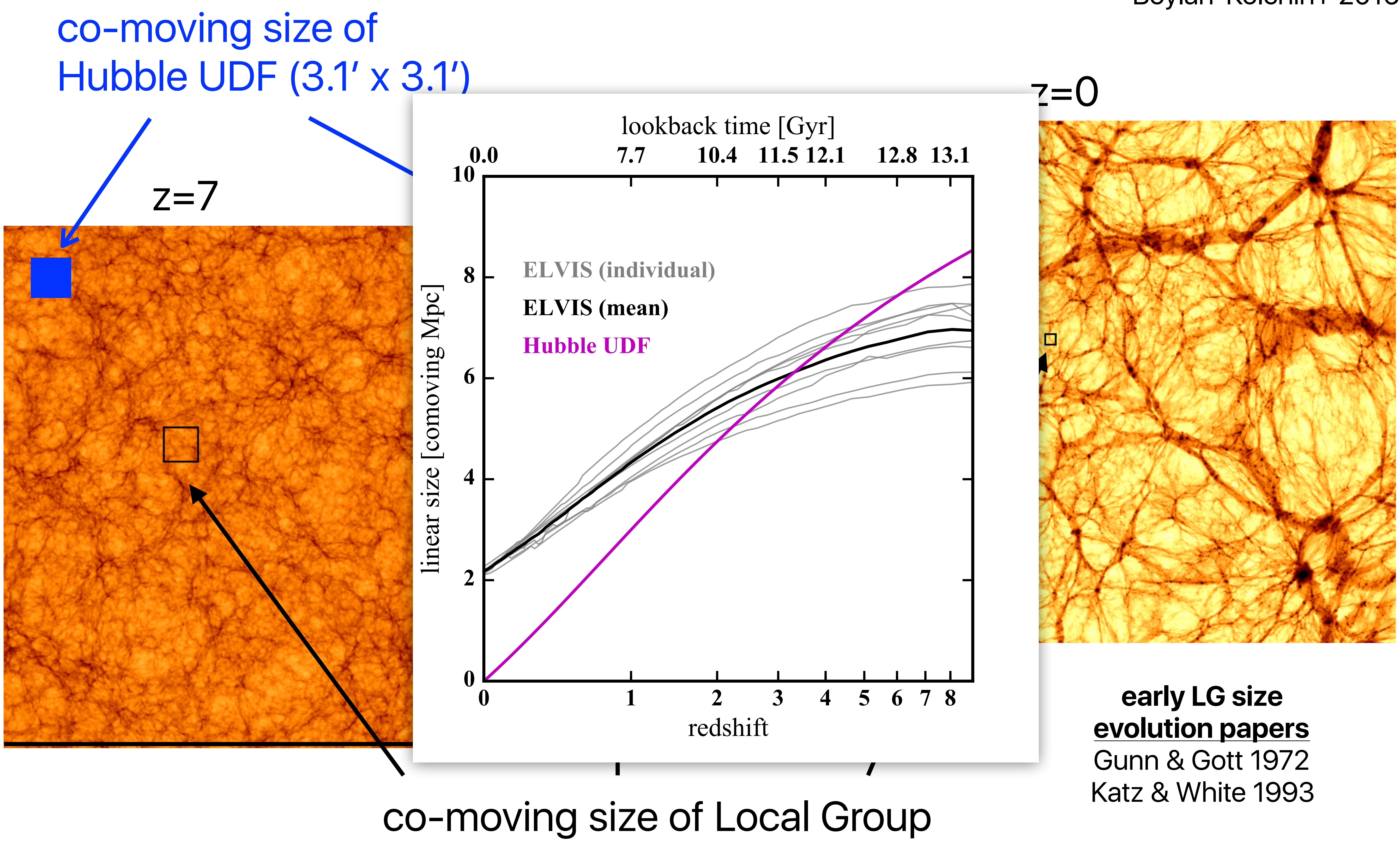


MBK+ 2016; image from
Illustris simulation (Vogelsberger+ 2014)

Boylan-Kolchin+ 2016

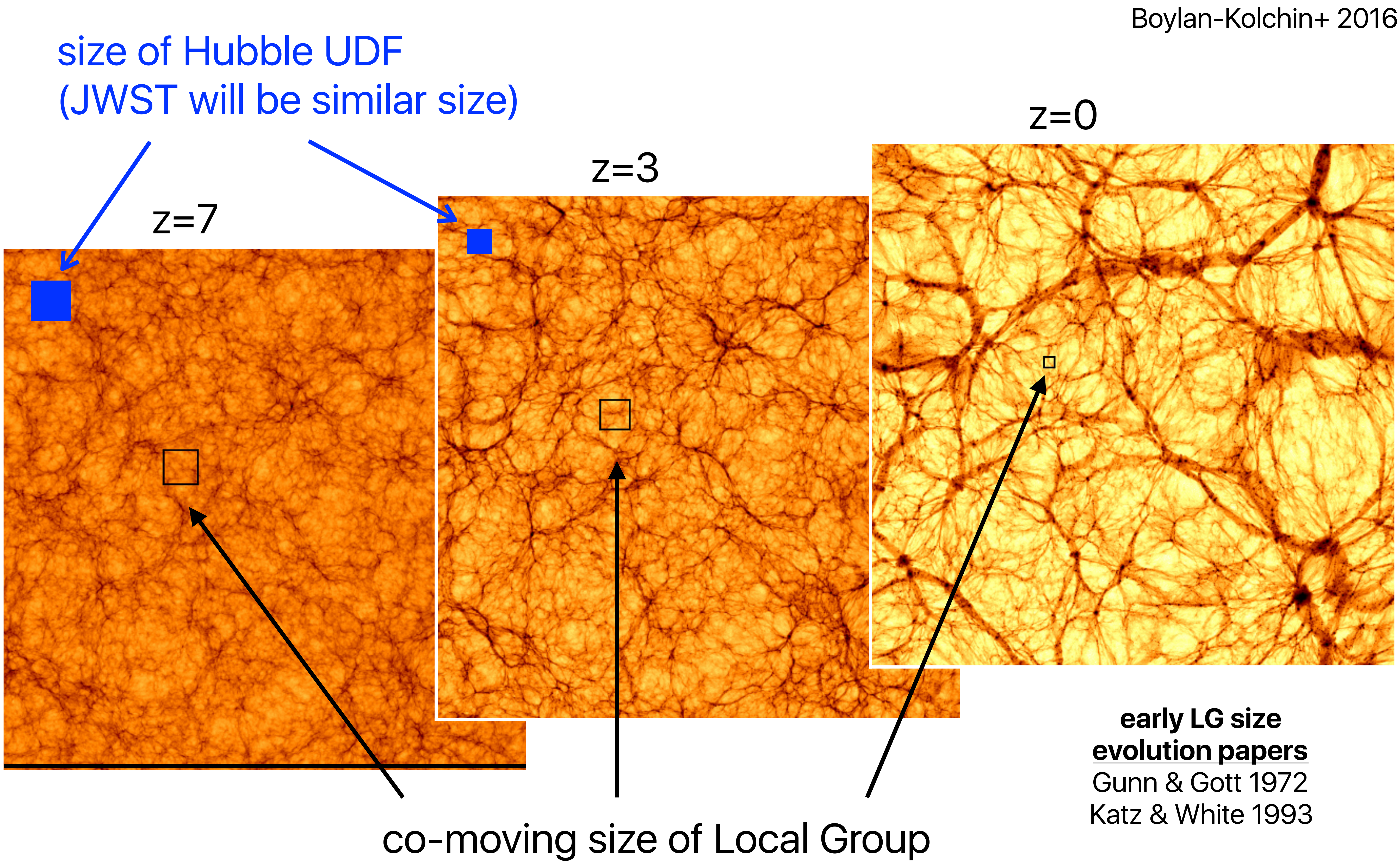


Boylan-Kolchin+ 2016



early LG size
evolution papers
Gunn & Gott 1972
Katz & White 1993

For most of the history of the Universe, the progenitors of the Local Group cover a larger area on the sky than the Hubble UDF



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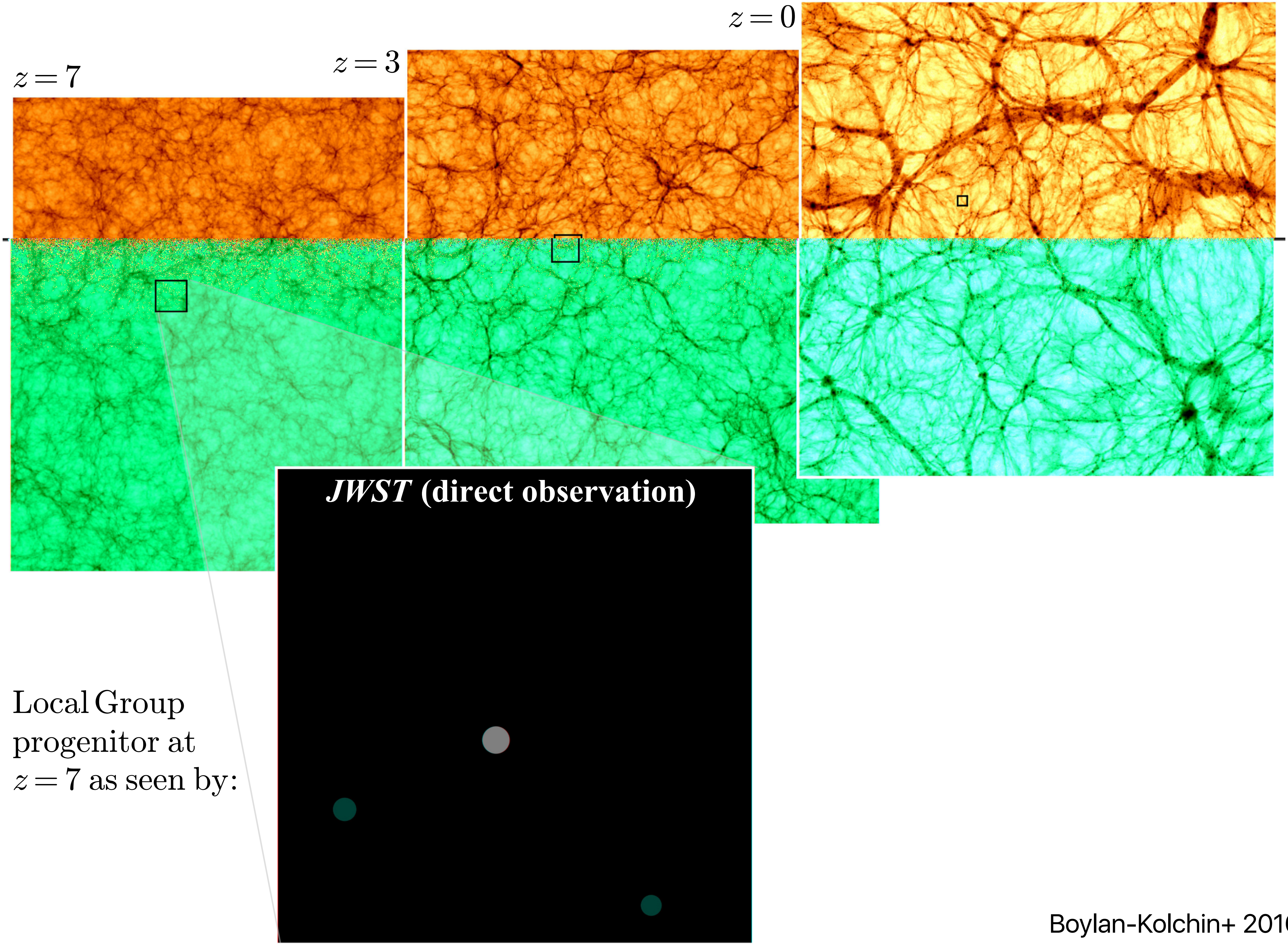
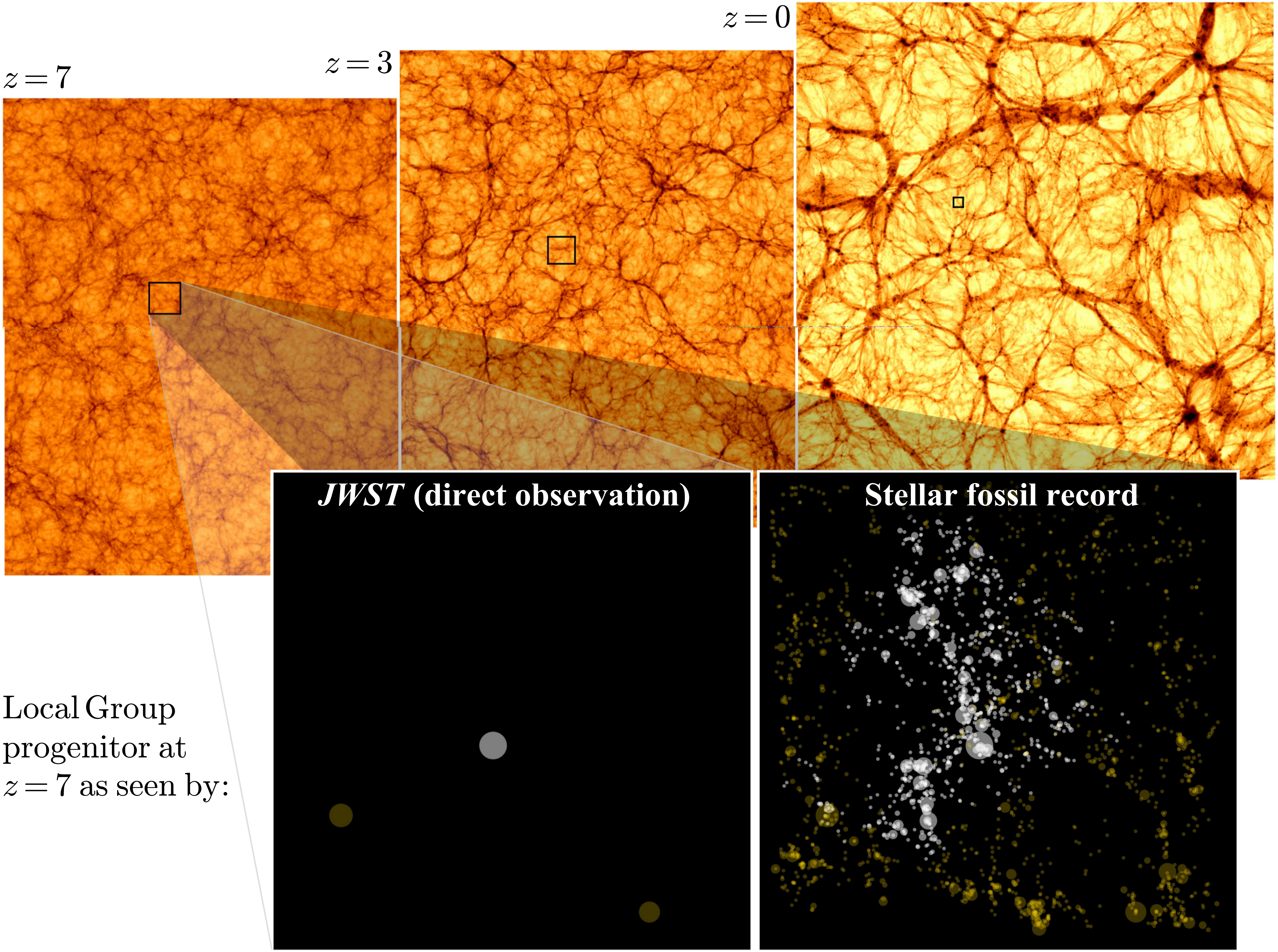
Boylan-Kolchin+ 2016

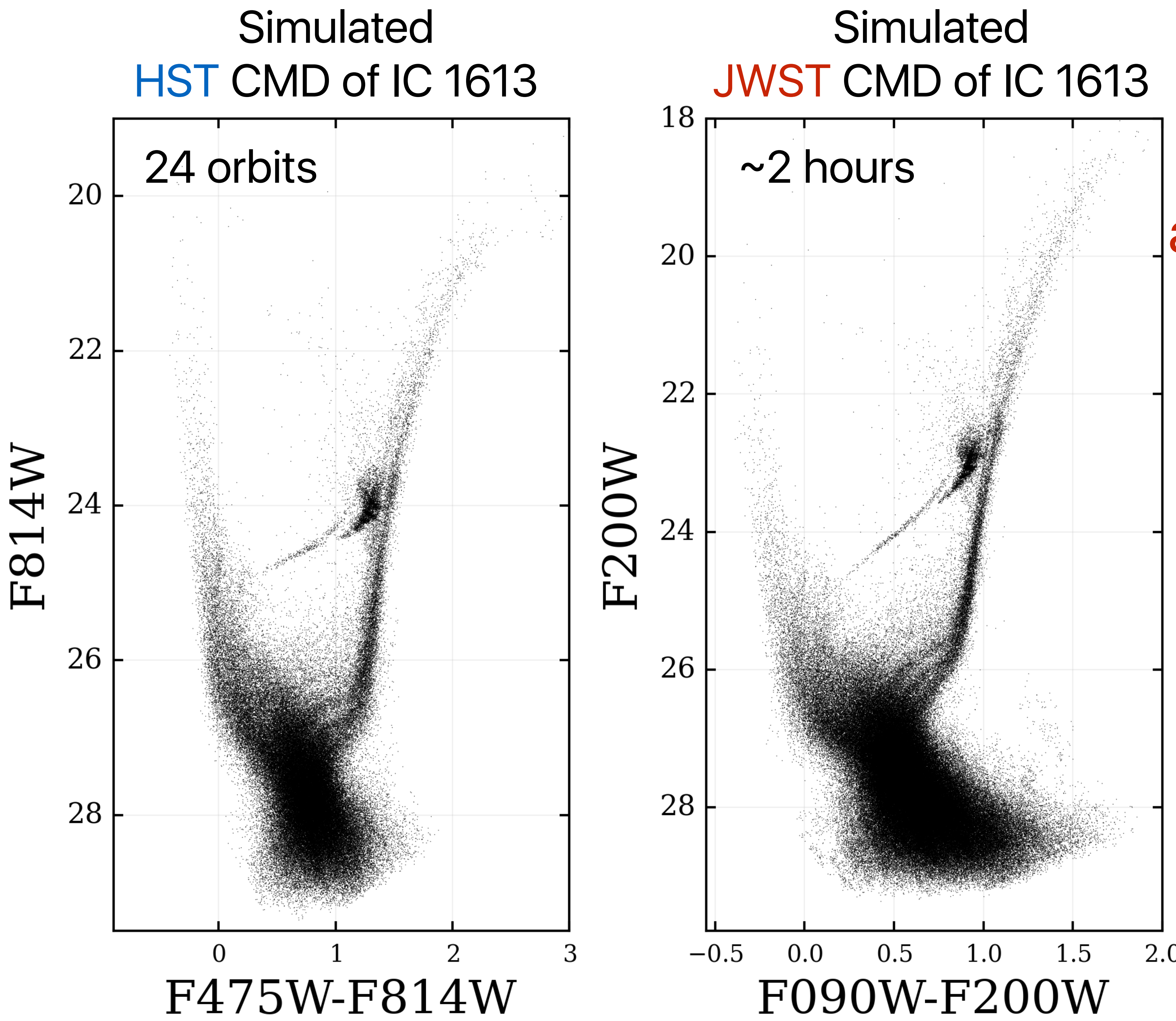


Boylan-Kolchin+ 2016

Boylan-Kolchin+ 2016



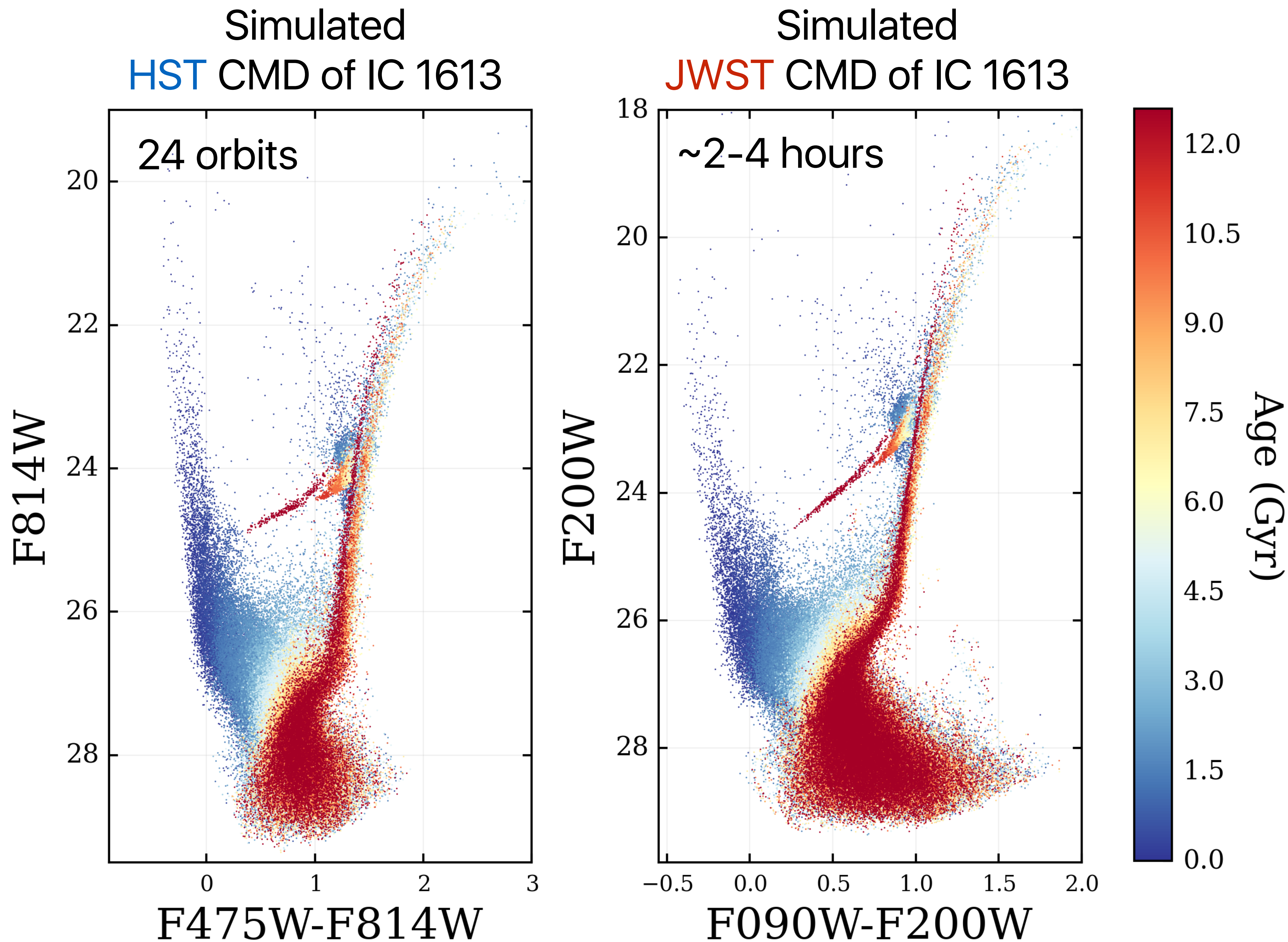
From optical to near-IR CMDs



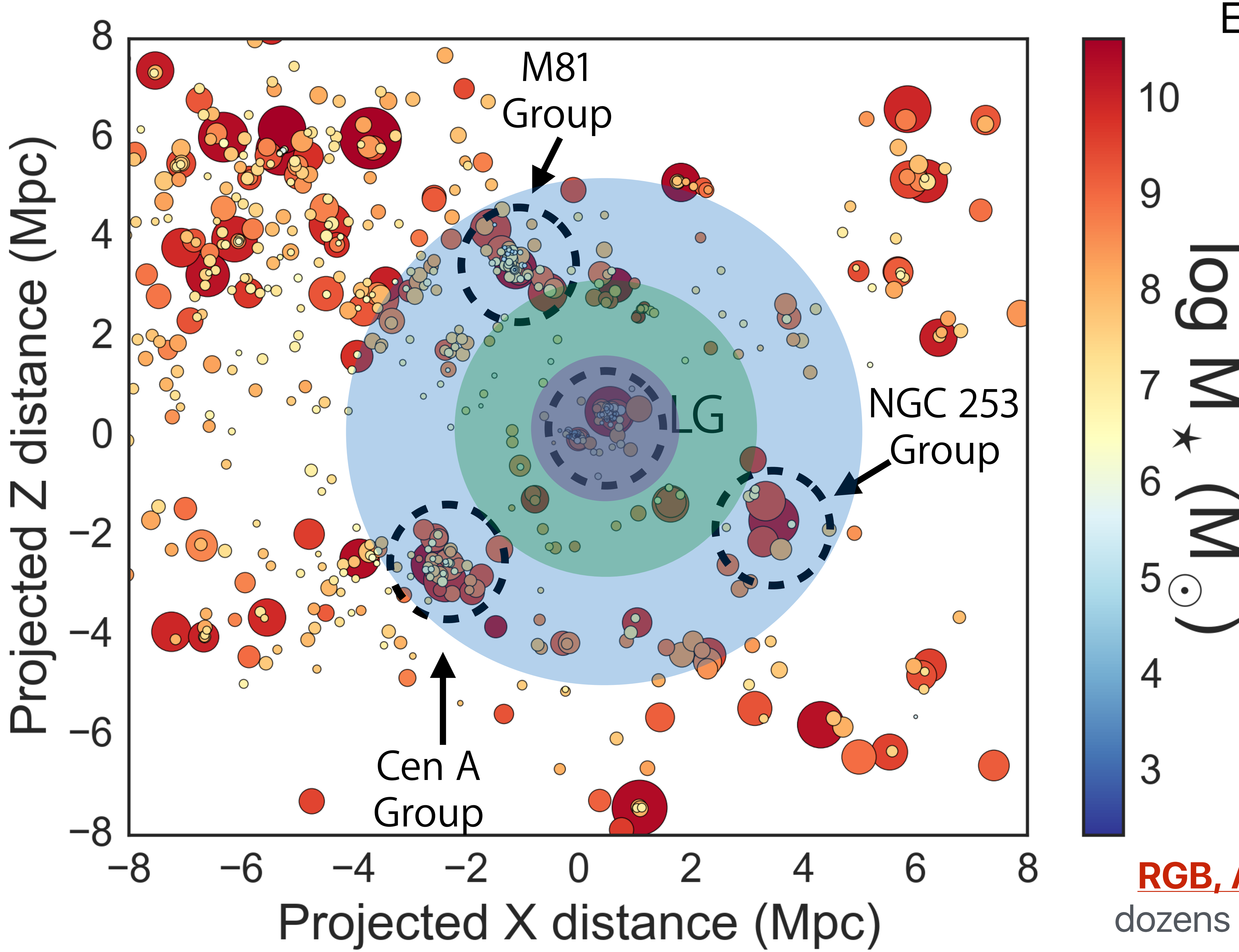
red stars are brighter, blue stars are fainter

temperature (color) range is compressed

From optical to near-IR CMDs



Resolving the Local Volume with JWST



Exposure Time for oMSTO per galaxy

Local Group:
~2-4 hours
(~7 Mpc at z~7)

2-3 Mpc:
~10-20 hours
(~10 Mpc at z~7)

~4-5 Mpc:
~100 hours
(includes outskirts of M81, Cen A...)

RGB, AGB, TRGB, etc
dozens of Mpc in modest exposure times

Summary

Resolved Stellar Populations in nearby dwarf galaxies are complimentary to deep-field HST/JWST observations

LG has similar size to HUDF / JWUDF for much of cosmic time

Extend sample to fainter mags than HUDF / JWUDF

HST has provided SFHs for ~40/100 LG galaxies with

$M_\star(z=0) \sim 10^3 - 10^9\ M_\odot$

$M_\star(z\sim7/8) \sim 10^3 - 10^9\ M_\odot$

$M_{UV}(z\sim7/8) \sim -16$ to 0

Some tensions

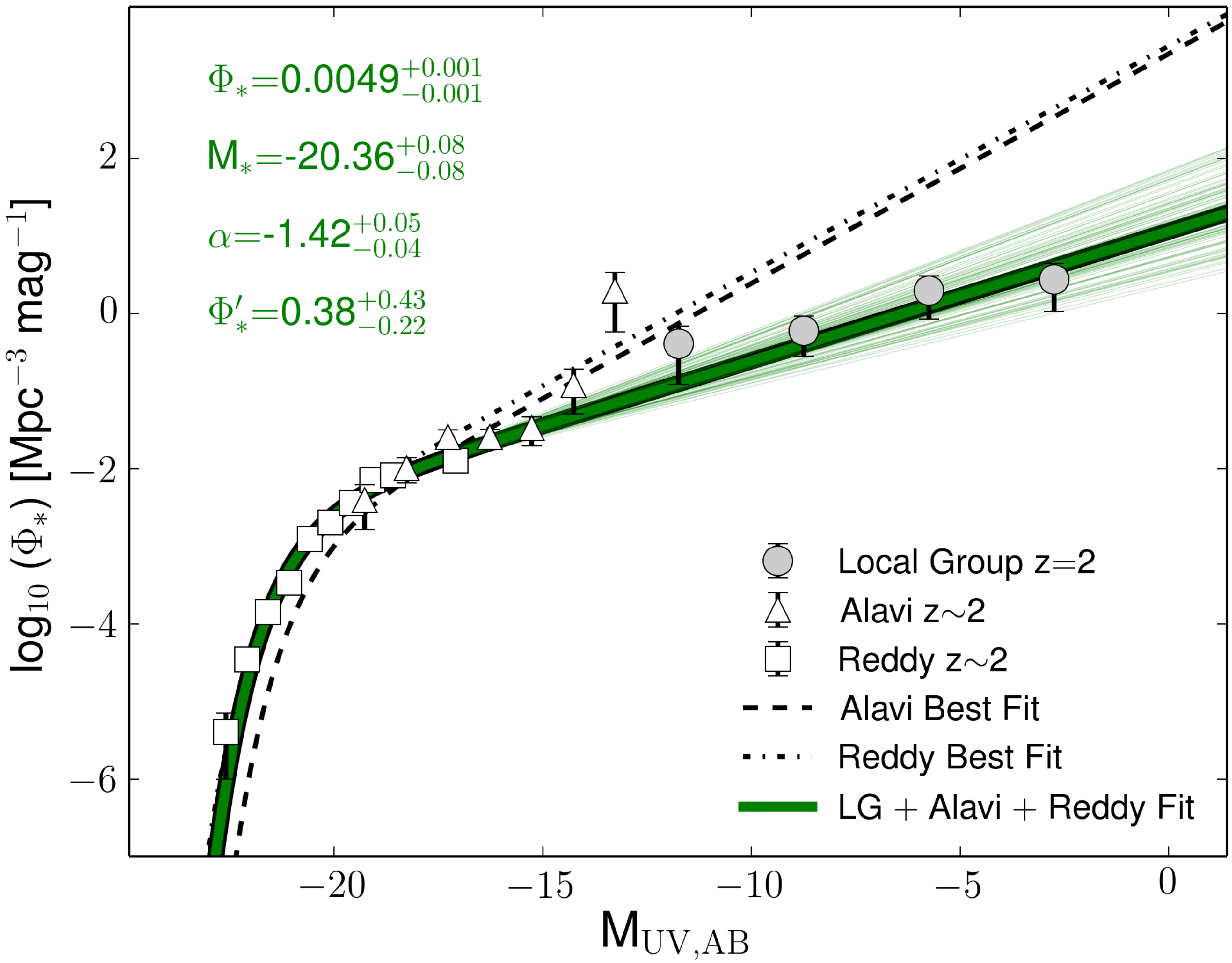
Discrepancies between high-z UVLF slope and low-z number counts

Galaxy simulations predict widely varying low-mass galaxy properties

HST: SFHs for ~100 galaxies within ~1 Mpc (7 Mpc at z~7)

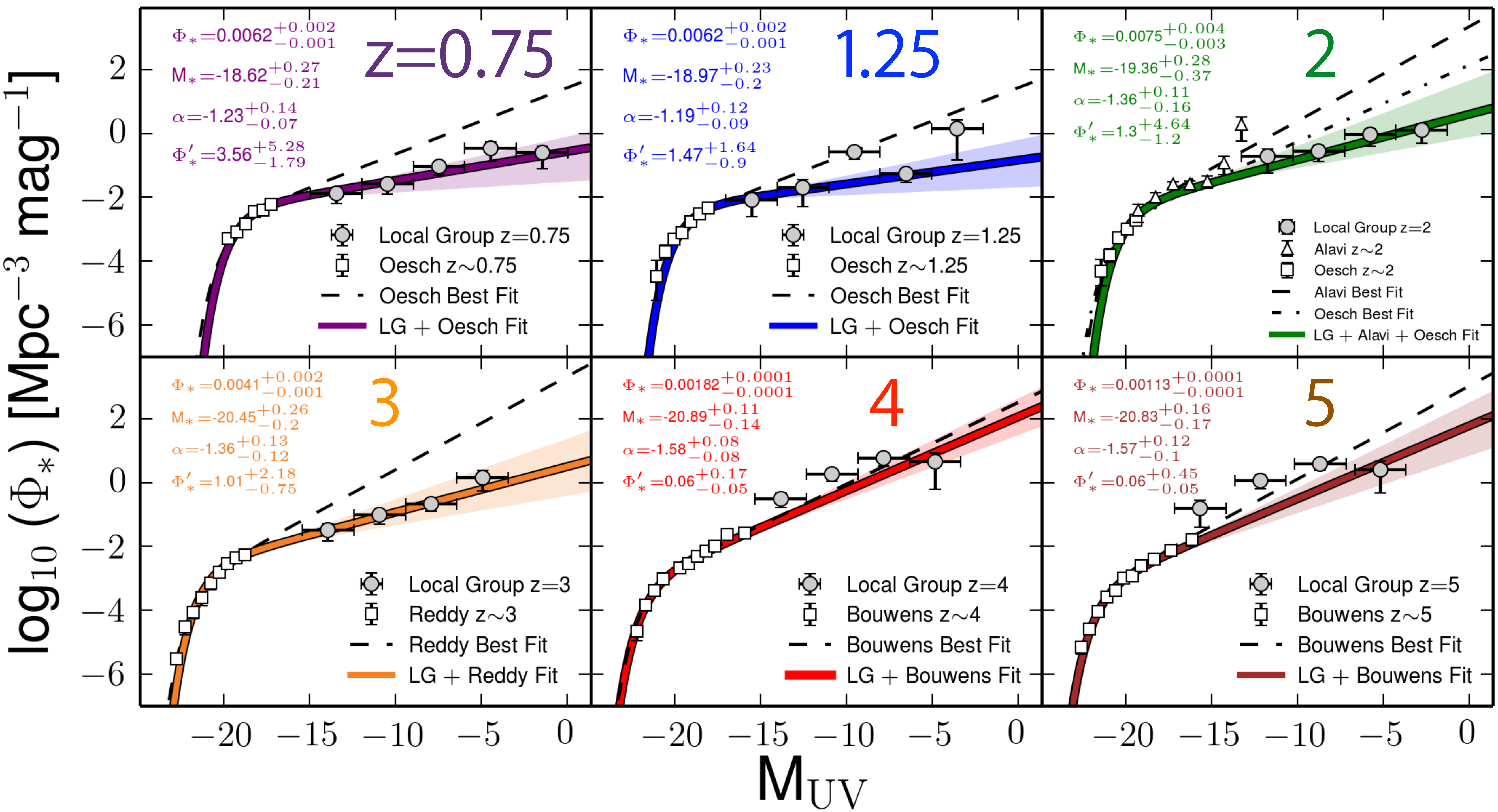
JWST: SFHs for 200+ galaxies within ~3 Mpc (XXX Mpc at z~7)

Far-Field + Near-Field: UV Luminosity Function at z~2



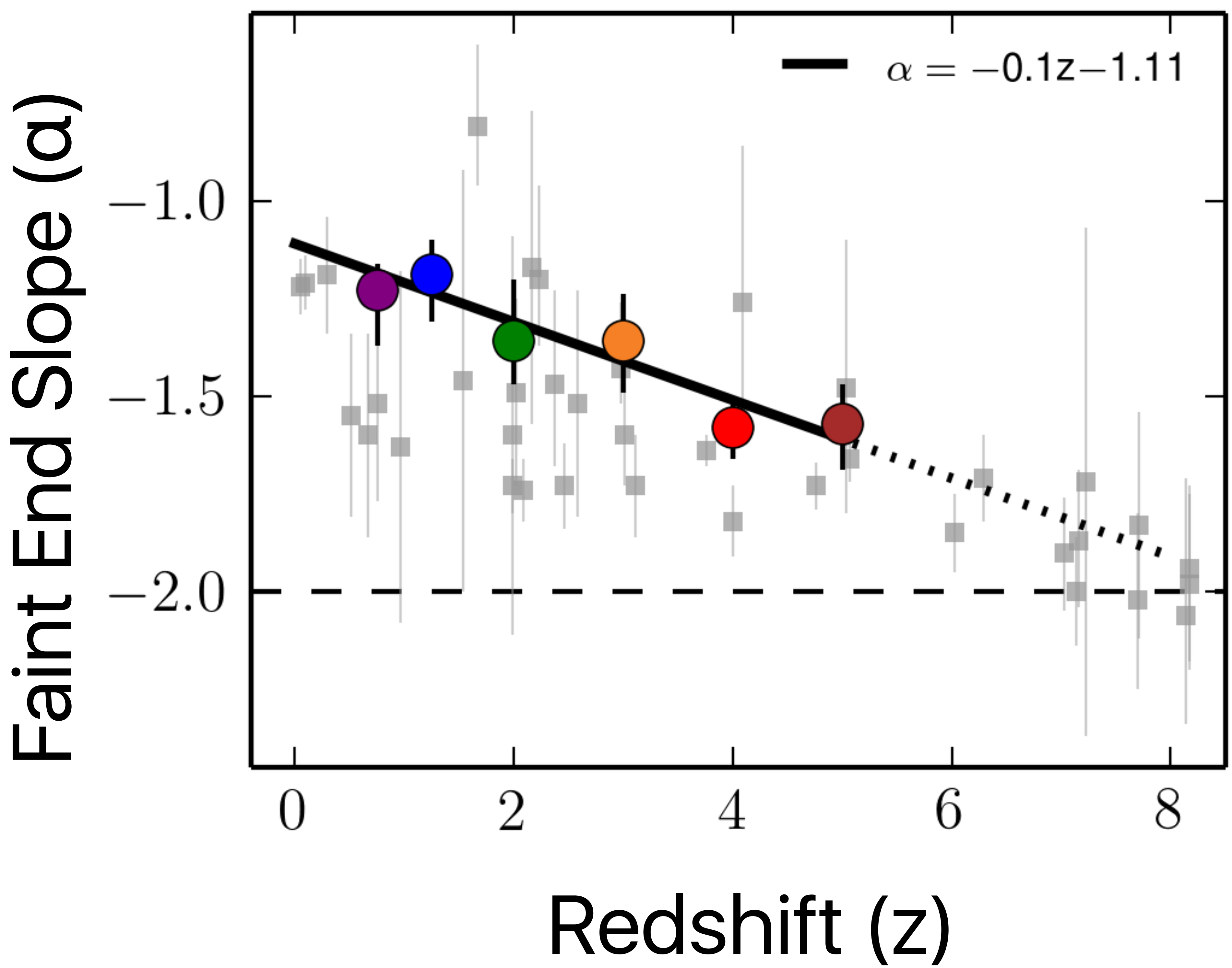
Reddy & Stidel 2009 Alavi+ 2014 Weisz, Johnson, & Conroy 2014

Far-Field + Near-Field: Evolution of the UVLF at Select Redshifts



Weisz, Johnson, & Conroy 2014

Redshift Evolution of Faint End UV Slope



Weisz, Johnson, & Conroy 2014