Stellar Population Synthesis: The Role of Adaptive Optics

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Nearby (2.5 Mpc) Dwarf Irregular Galaxy KKH 98
HST F475W (Blue), HST F814W (Green), Keck AO K-band (red)

Melbourne et al. 2011

Key Goal of Extragalactic Astronomy: Track the assembly of stars in galaxies across cosmic time.

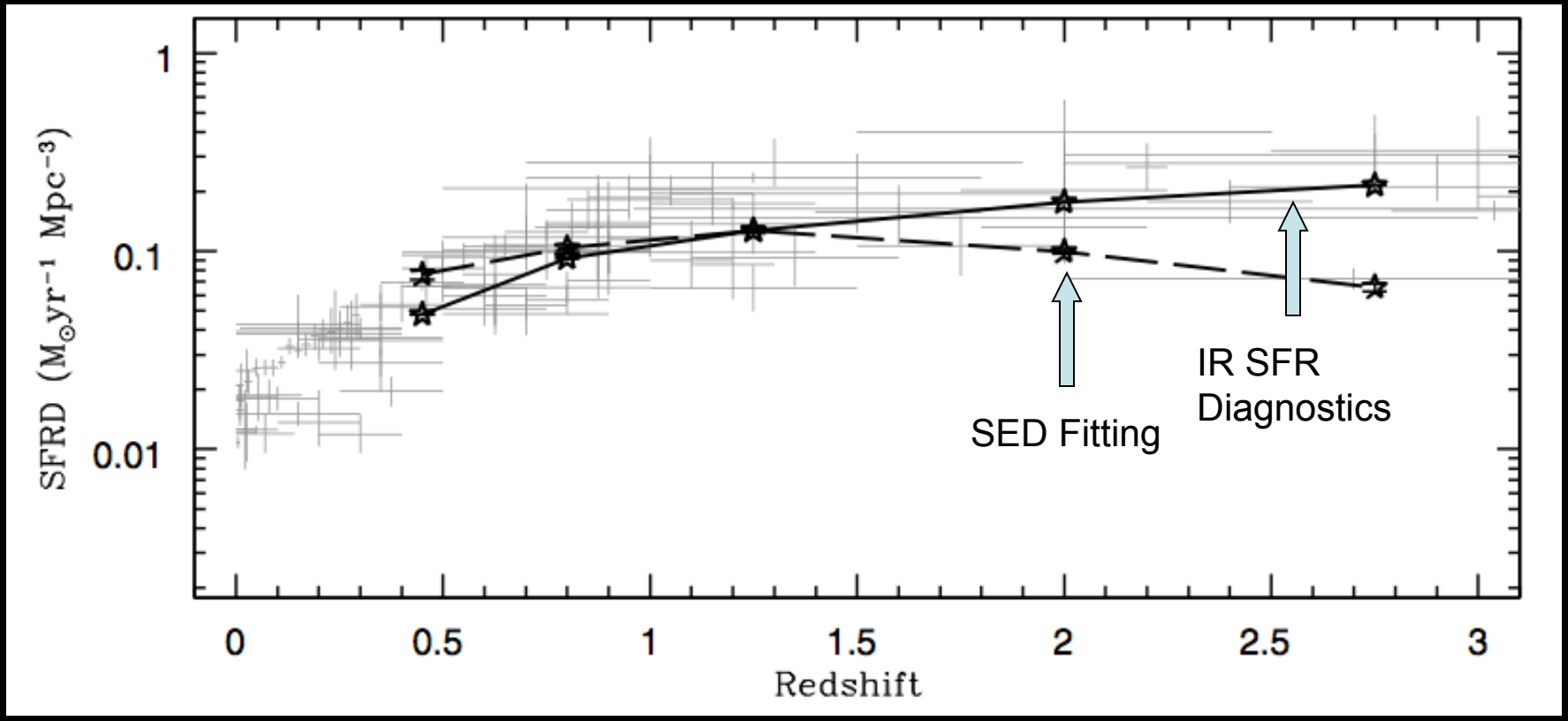
- When did the stars form?
- Where did they form?
- Why did they form?
- Where are those stars today?

Basically two approaches to answer these questions

1. Observe galaxies at different epochs and track the evolution of the samples.
2. Observe galaxies in the local universe in detail, and infer their past history.

Adaptive optics has a role in both approaches

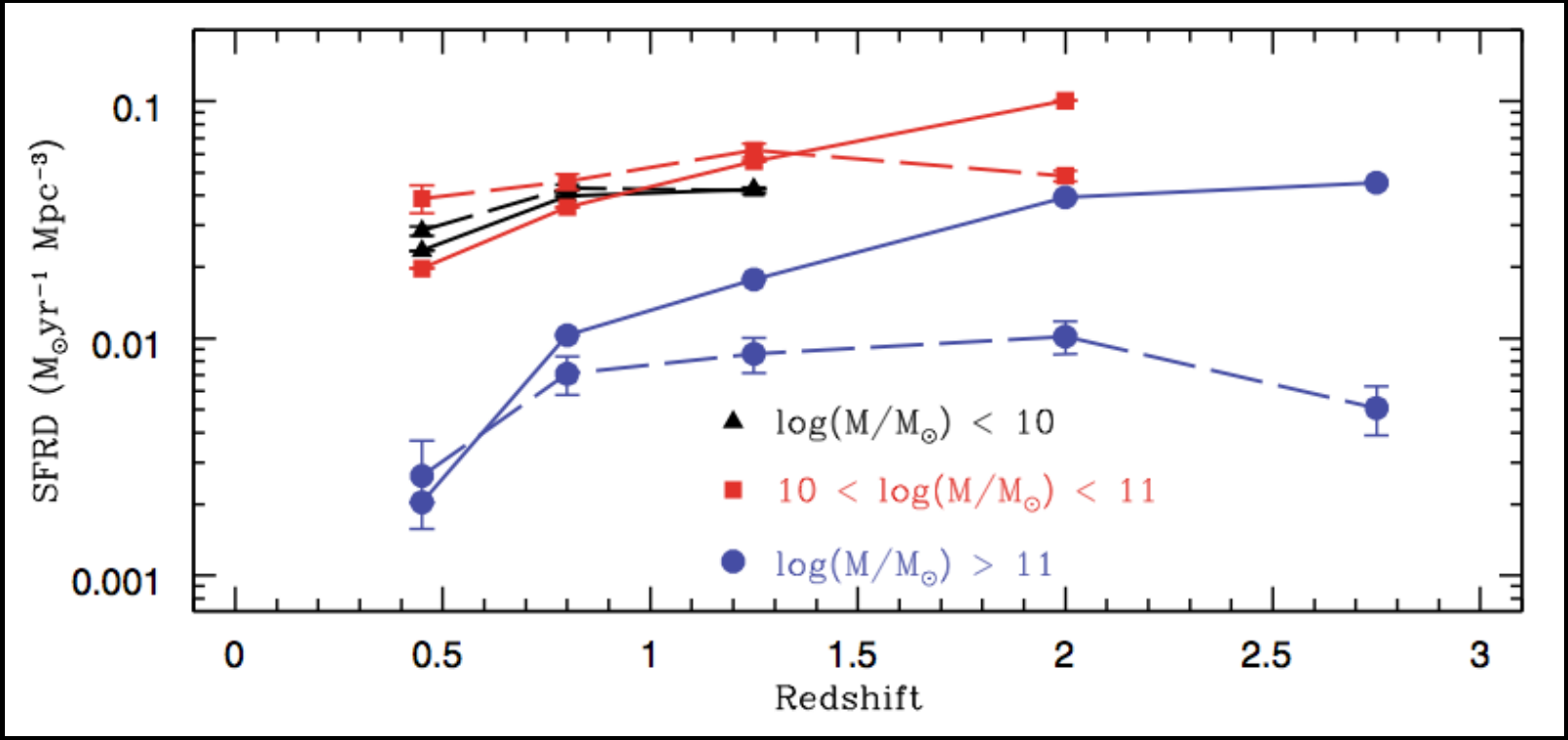
When were the stars formed?



Santini et al. 2009

Where were the stars formed?

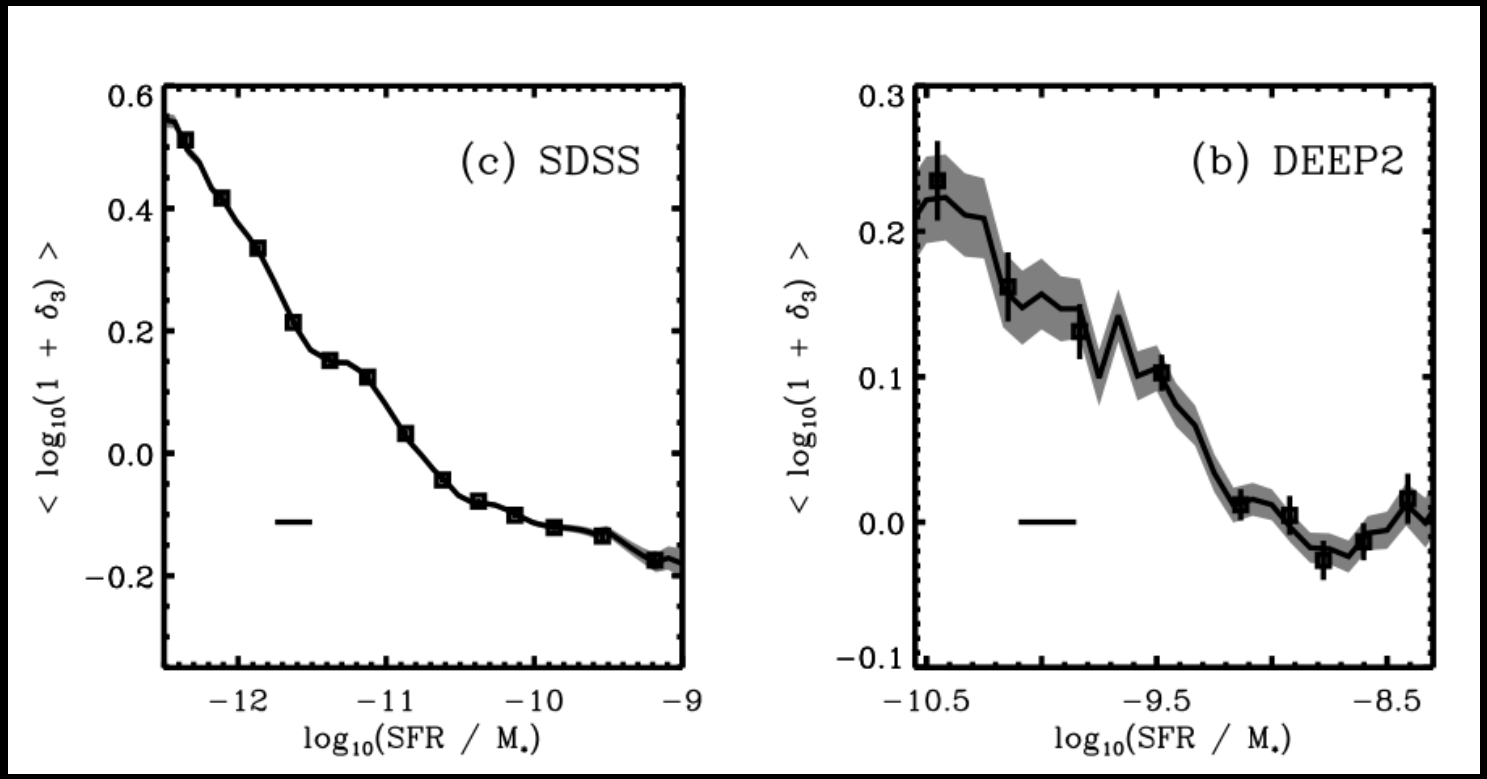
- SF as a function of Galaxy Mass



Santini et al. 2009

Where were the stars formed?

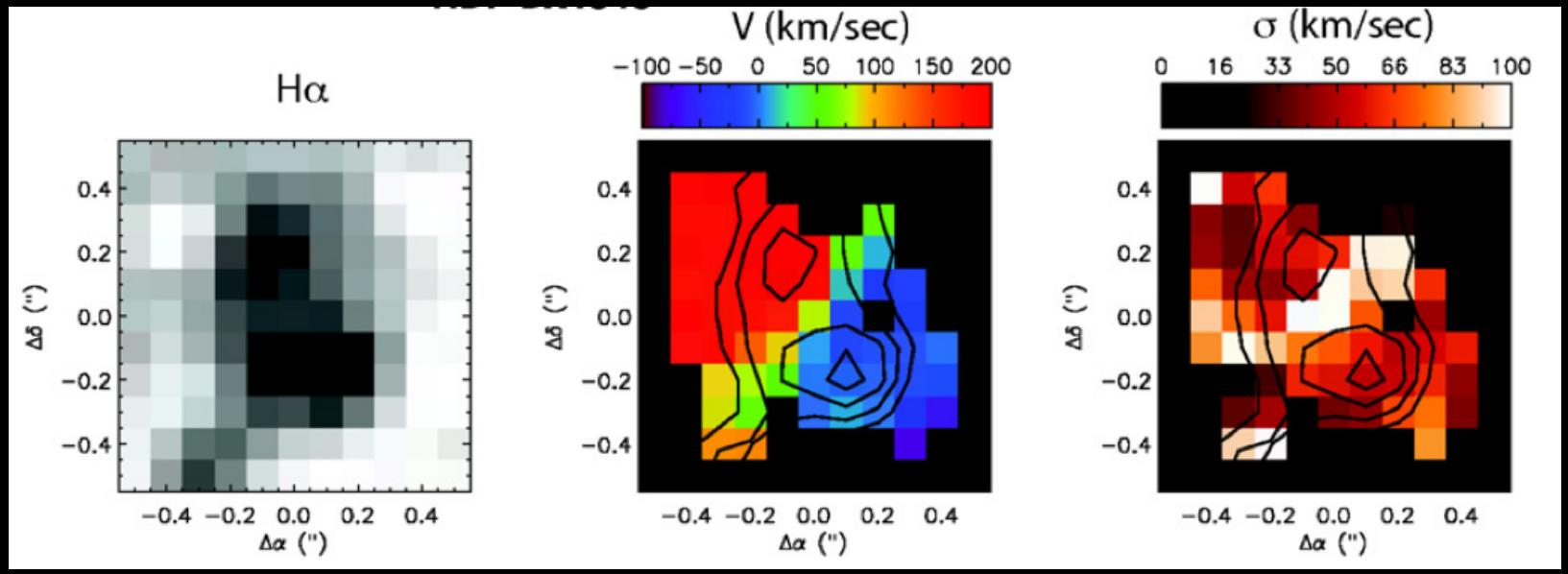
- SF as a function of Environment



Cooper et al. 2008

Where were the stars formed?

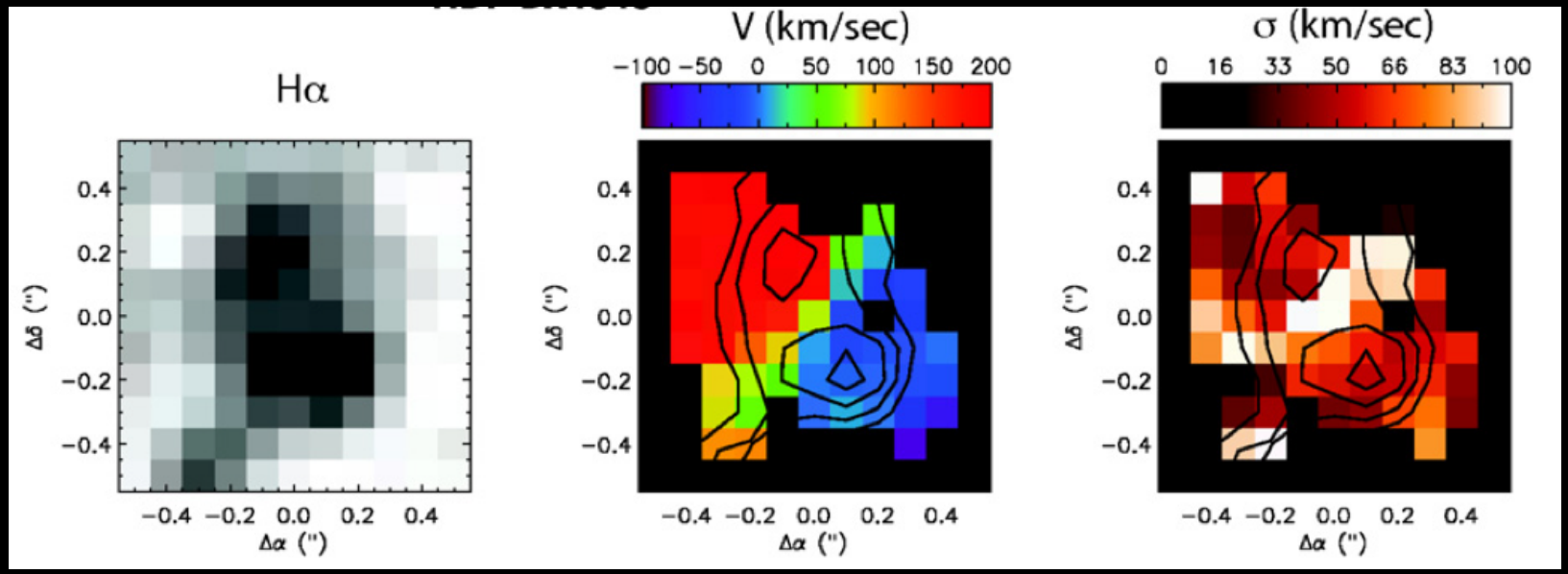
- SF as a function of Position in a Galaxy
- Spatially resolved spectral diagnostics (see Shelley's Talk)



Wright et al. 2009

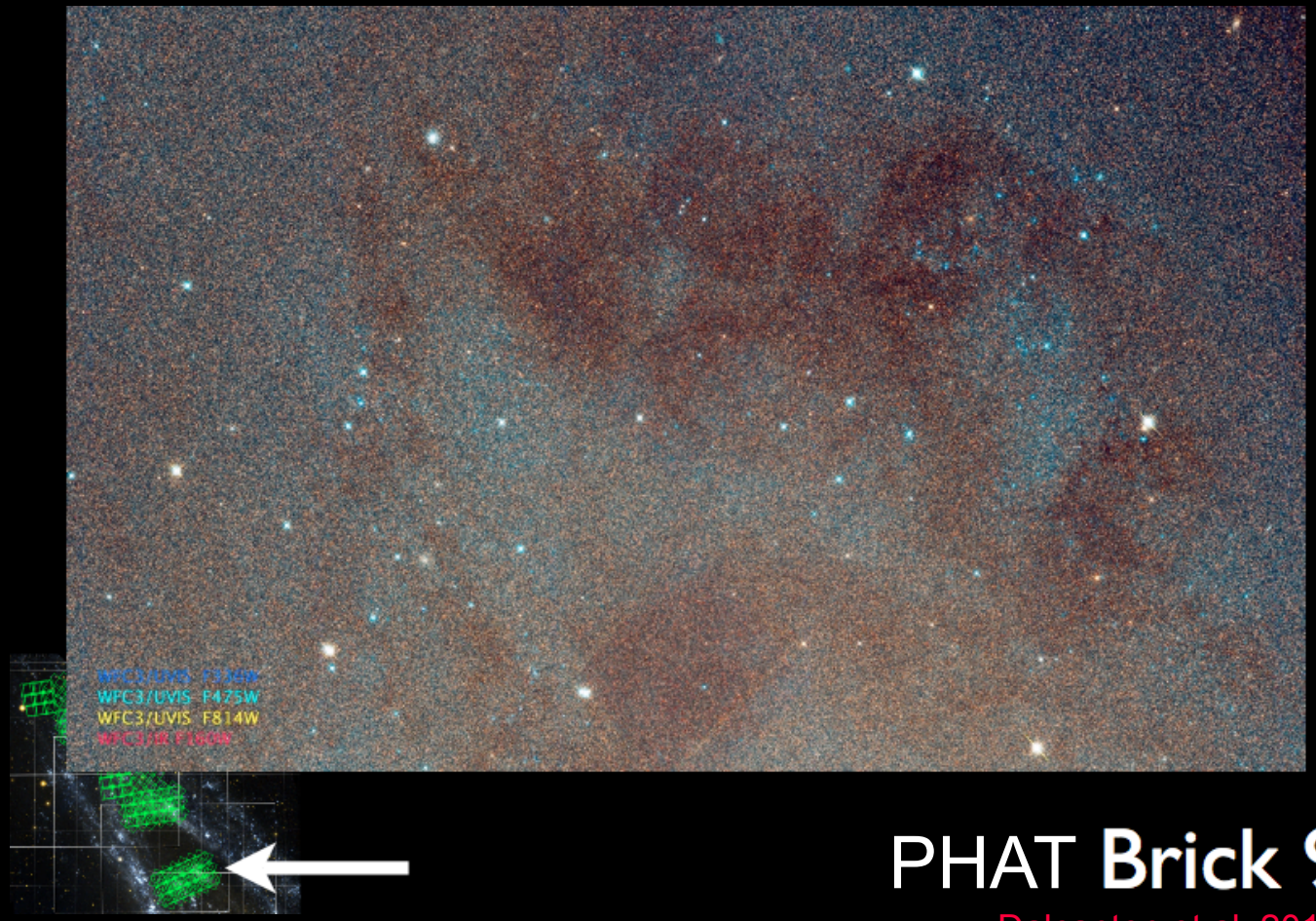
Why did the stars form?

- Roll of mergers vs. secular processes such as turbulent disks (Shelley's Talk)



Wright et al. 2009

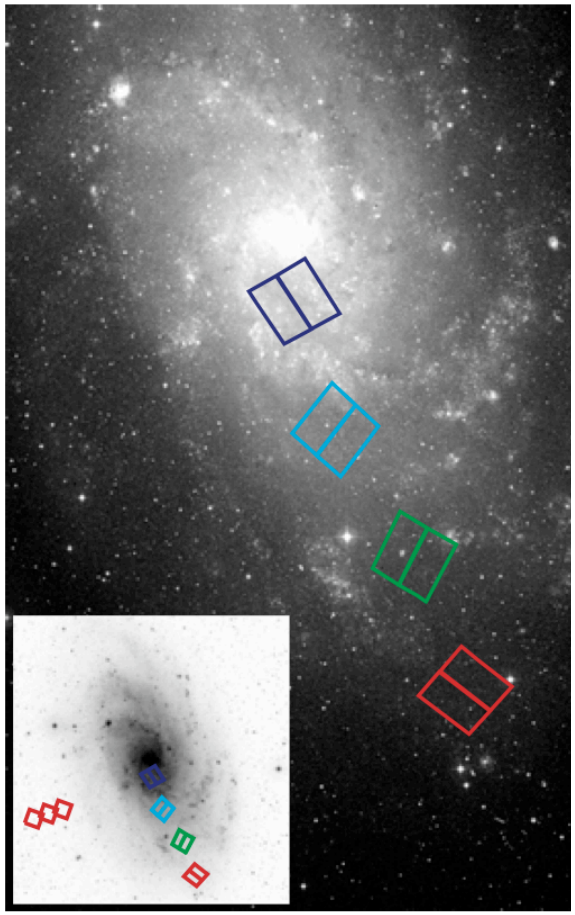
Where are those stars today? And how did they get there?



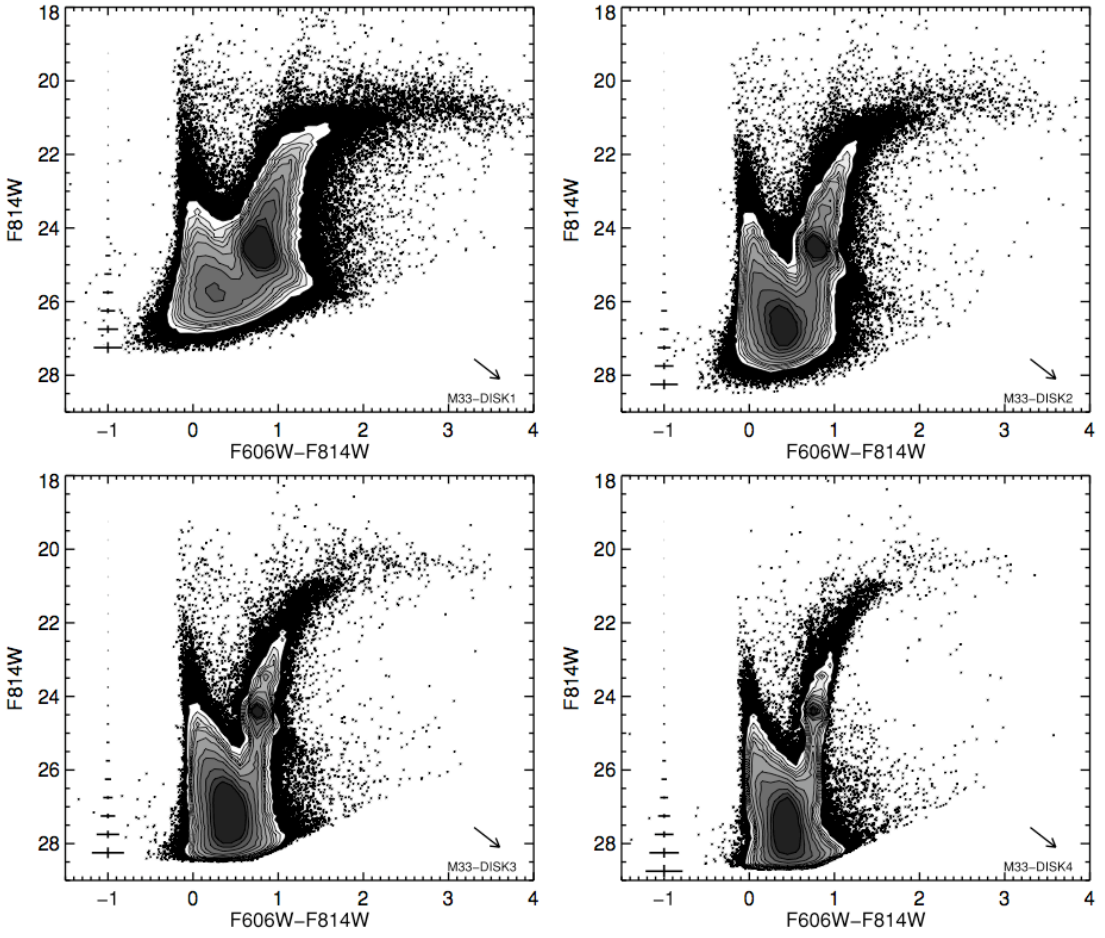
PHAT Brick 9

Dalcanton et al. 2012

Resolved stellar populations, a tool for answering these questions

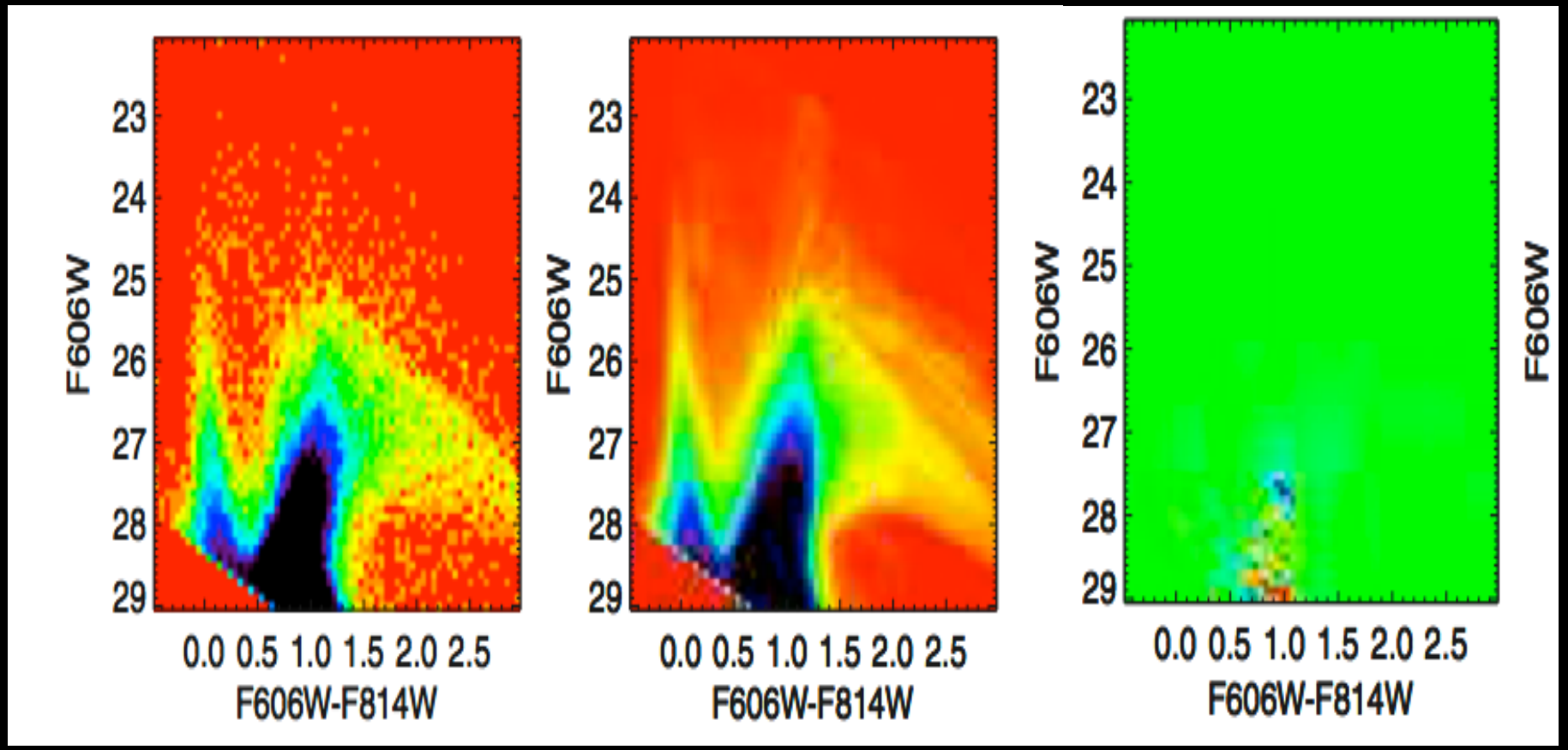


M33 HST ACS fields



Williams et al. 2009

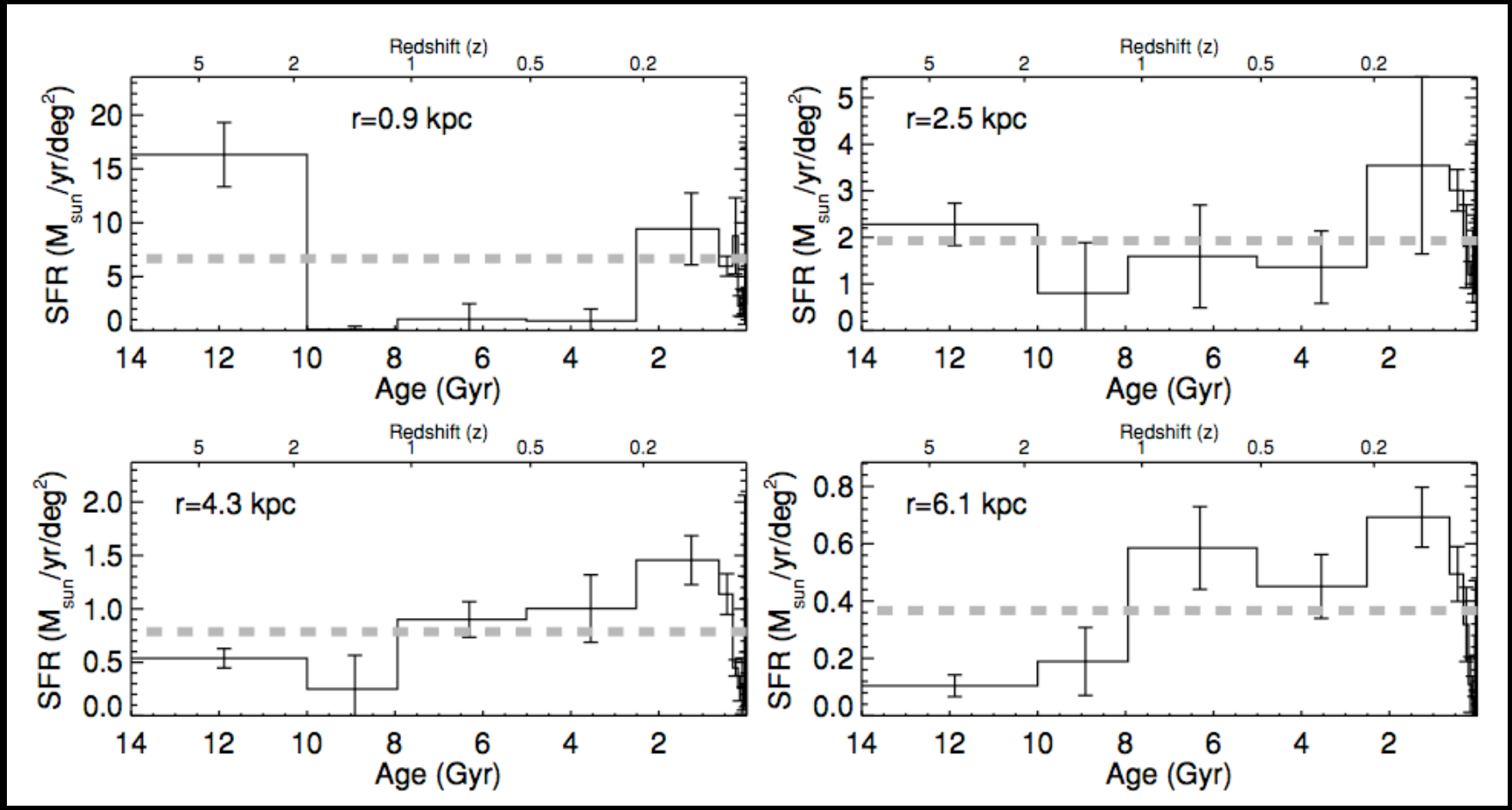
We model the stellar population and quantify the SFH



Williams et al. 2009

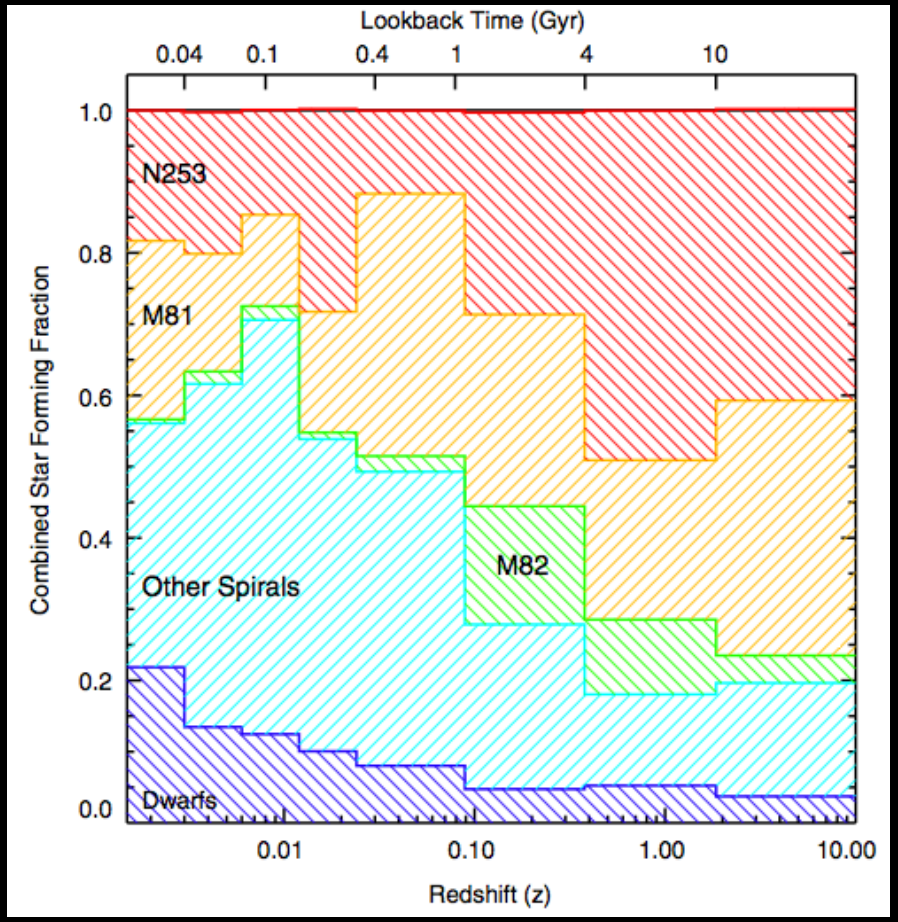
High-resolution imaging reveals where and when stars are formed

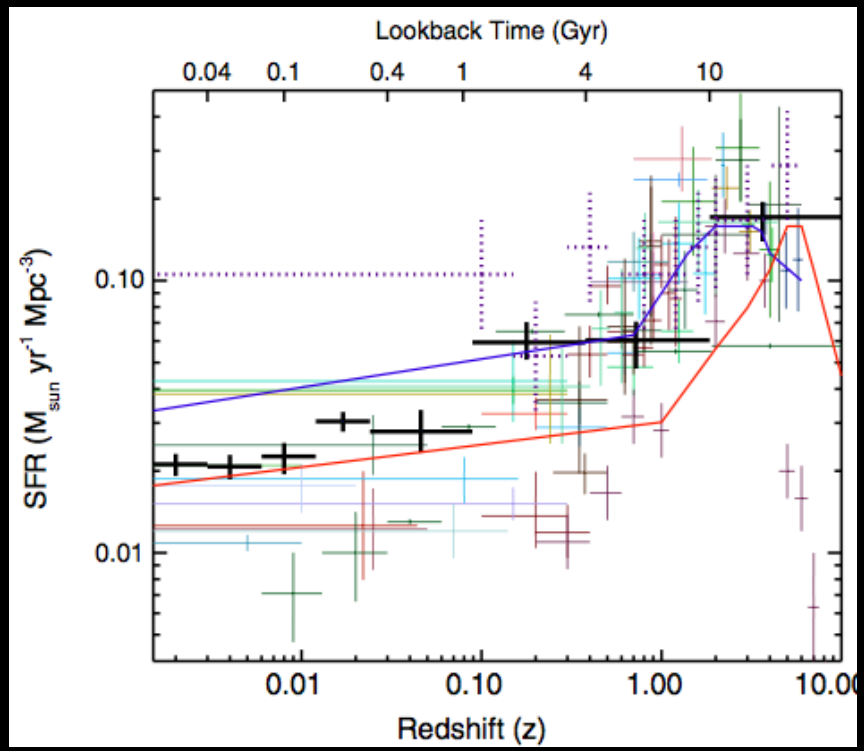
M33 shows evidence for inside-out disk growth



Williams et al. 2009

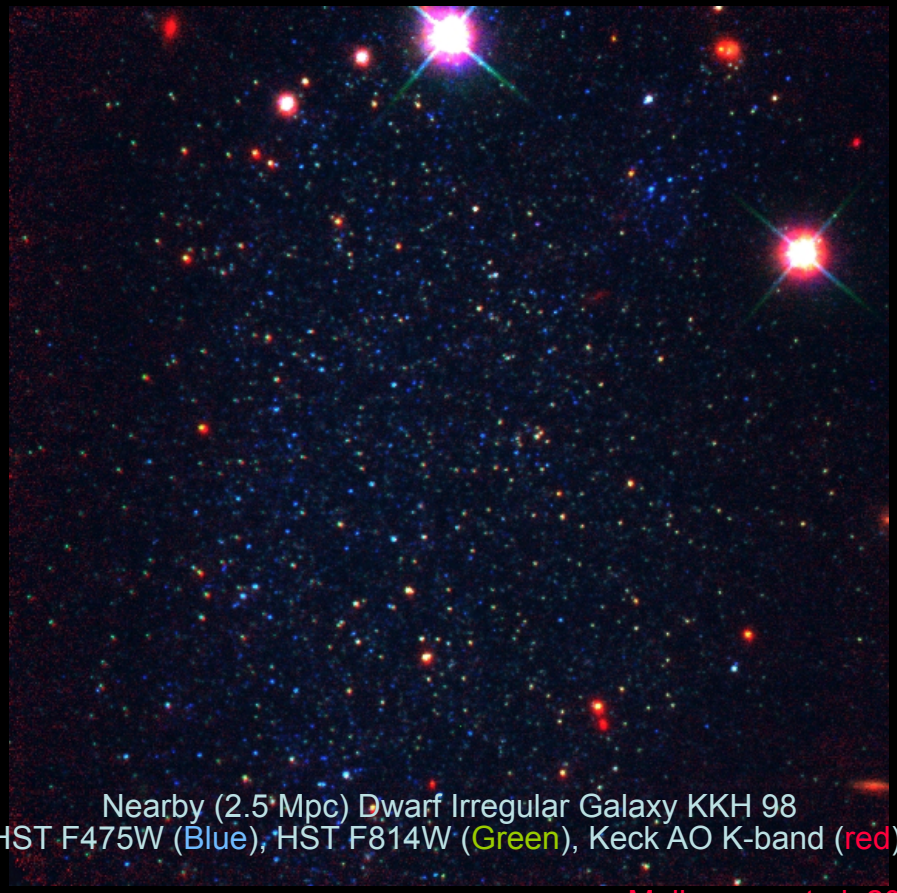
HST has provided the star formation history of the most nearby galaxies





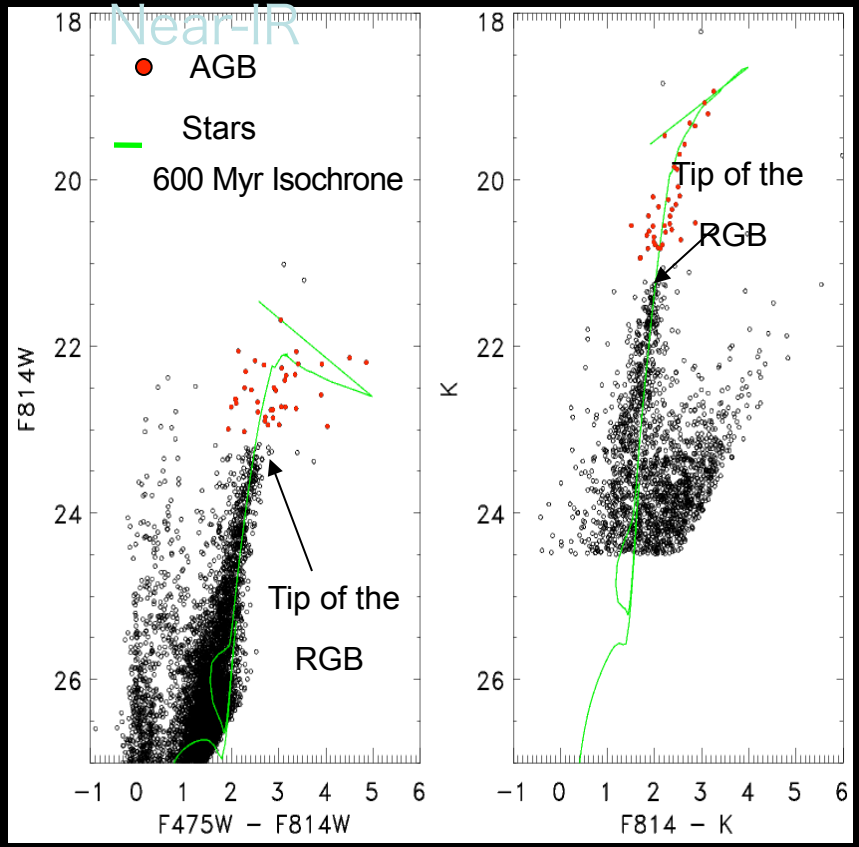
Williams et al. 2011

Can we accomplish a similar program with adaptive optics?



Nearby (2.5 Mpc) Dwarf Irregular Galaxy KKH 98
HST F475W (Blue), HST F814W (Green), Keck AO K-band (red)

Optical
Near-IR

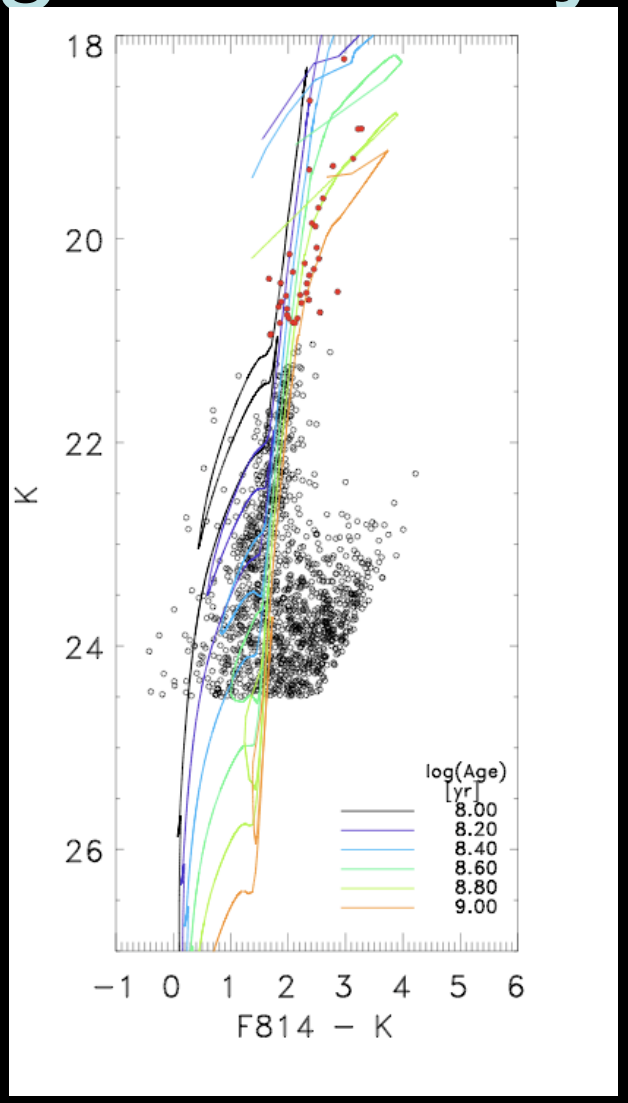


Melbourne et al. 2011

The AGB is good tracer of recent star formation (e.g 0.1 - 2 Gyr)

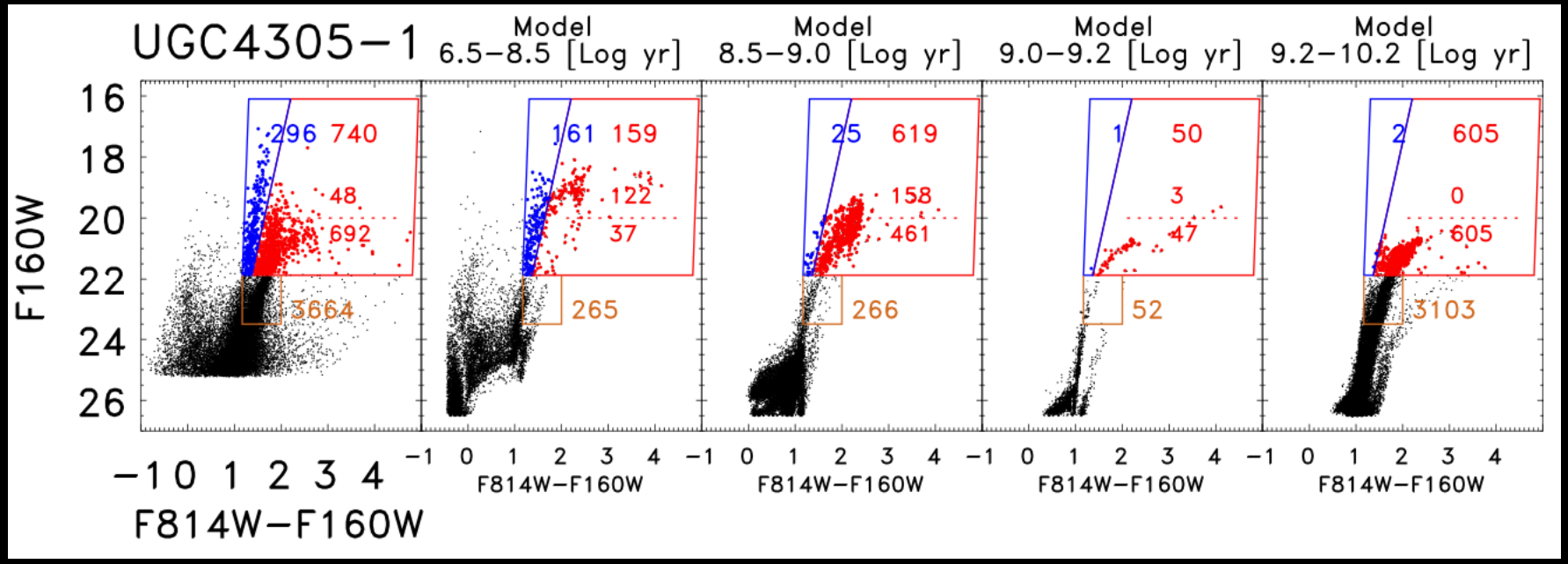
AGB STARS

- Very Luminous in the Near-IR.
- Spatially sparse.
- Lie in Unique Sequences in Near-IR CMDs



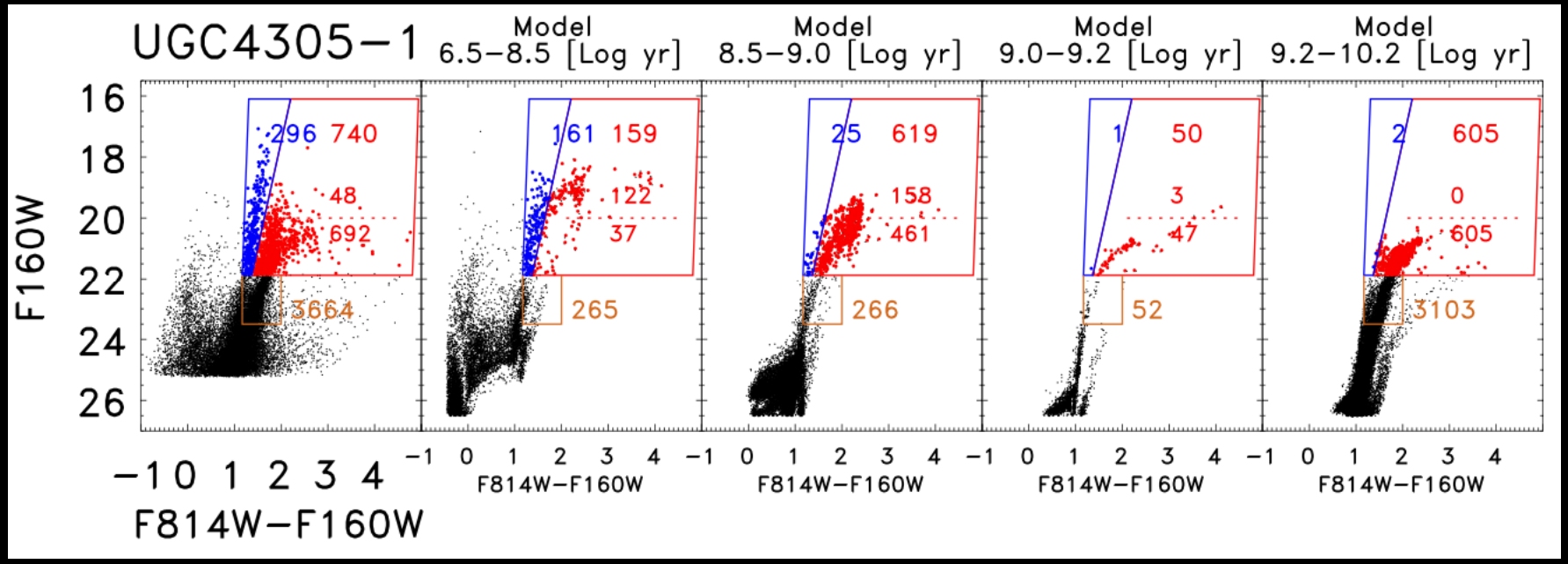
Melbourne et al. 2011

The RGB traces older stellar populations



Melbourne et al. 2012

Massive, Red (core) Helium Burning (RHeB) Stars Trace Younger Populations

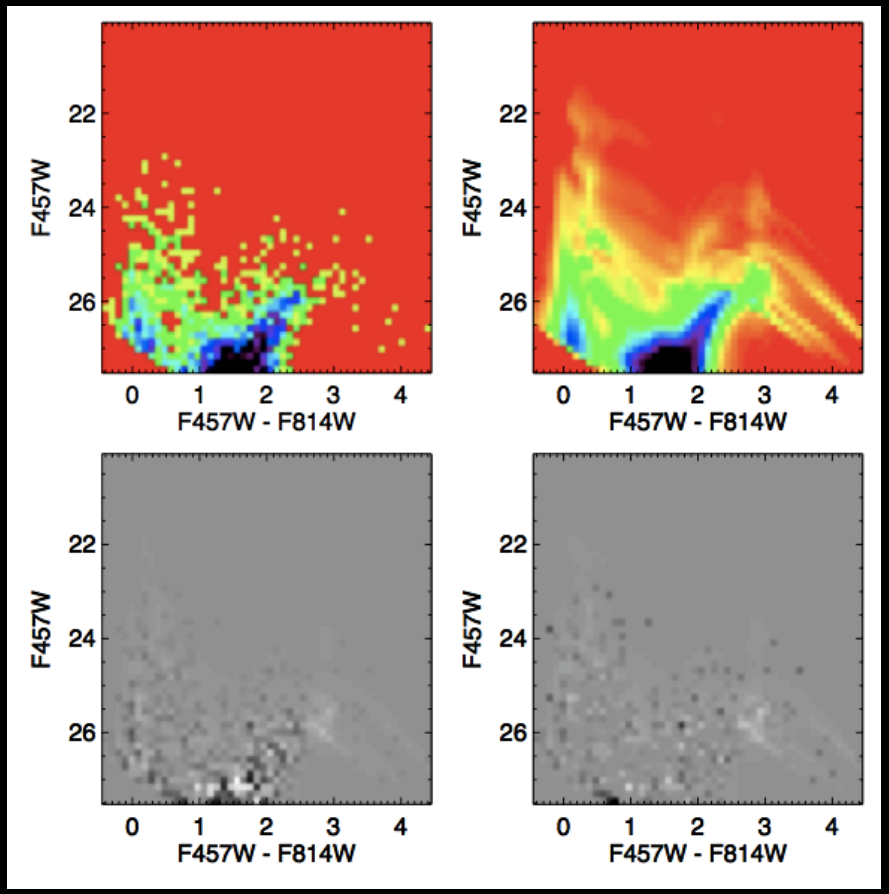


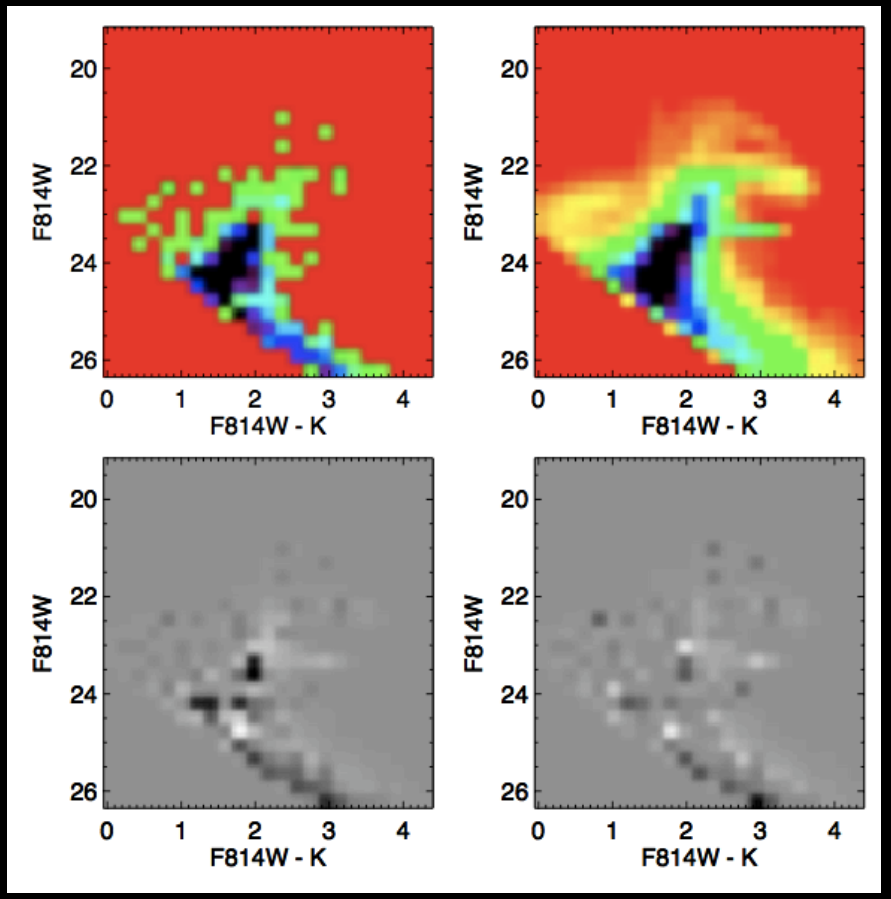
Melbourne et al. 2012

CMD's of model stellar populations match the data

Optical

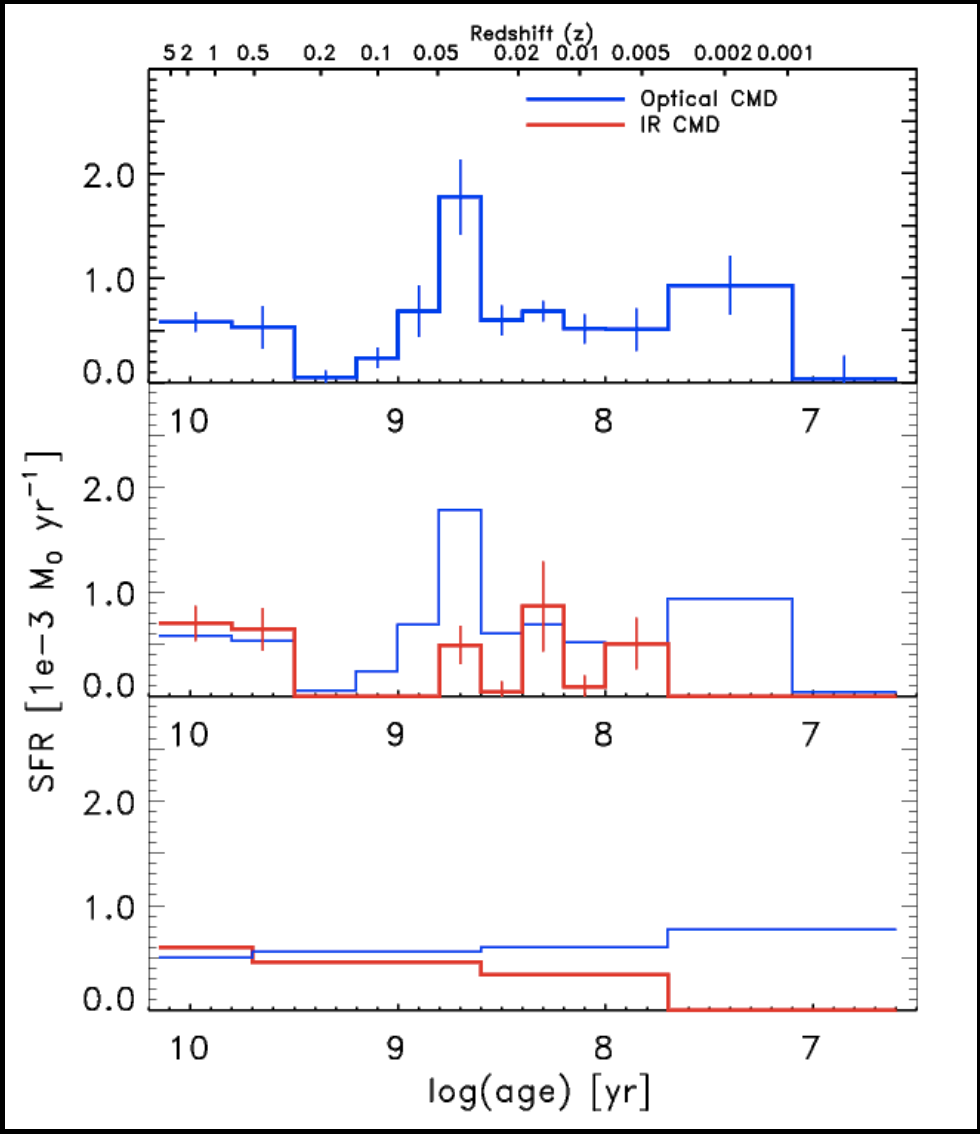
IR





Melbourne et al. 2011

Optical/NIR star formation histories match except where the AGB is most important



Optical data

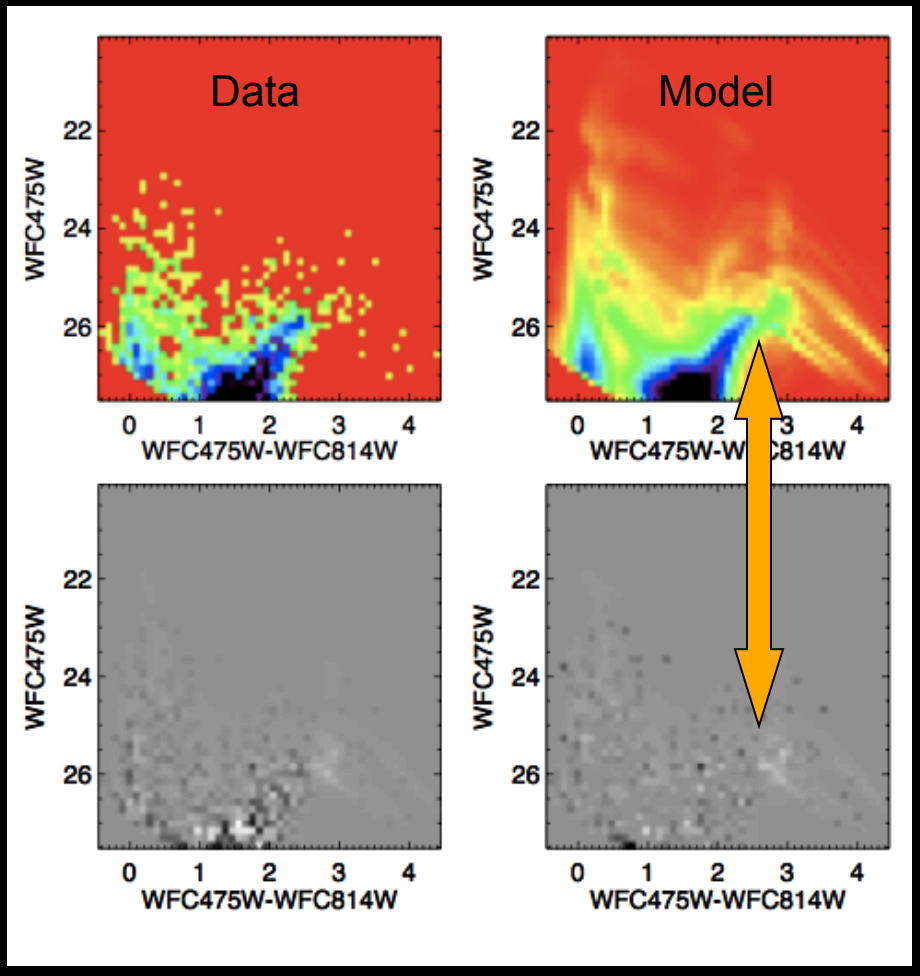
Near-IR data

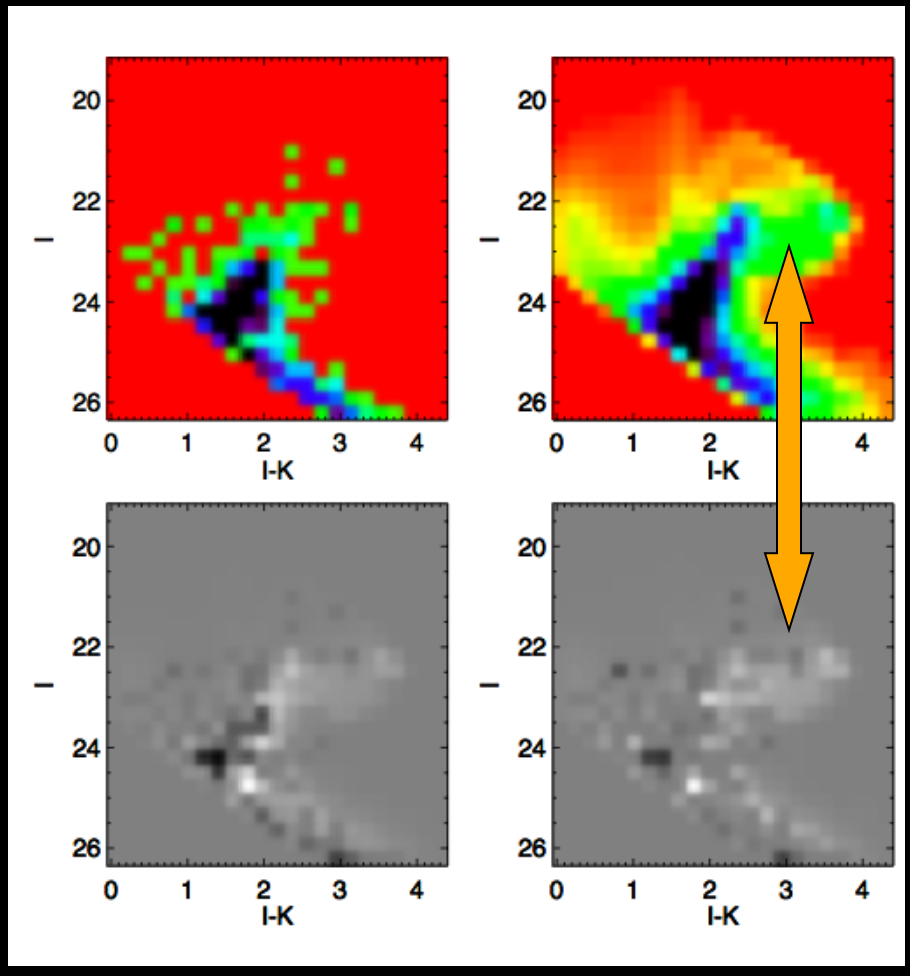
Melbourne et al. 2011

Population synthesis models over-produce the AGB

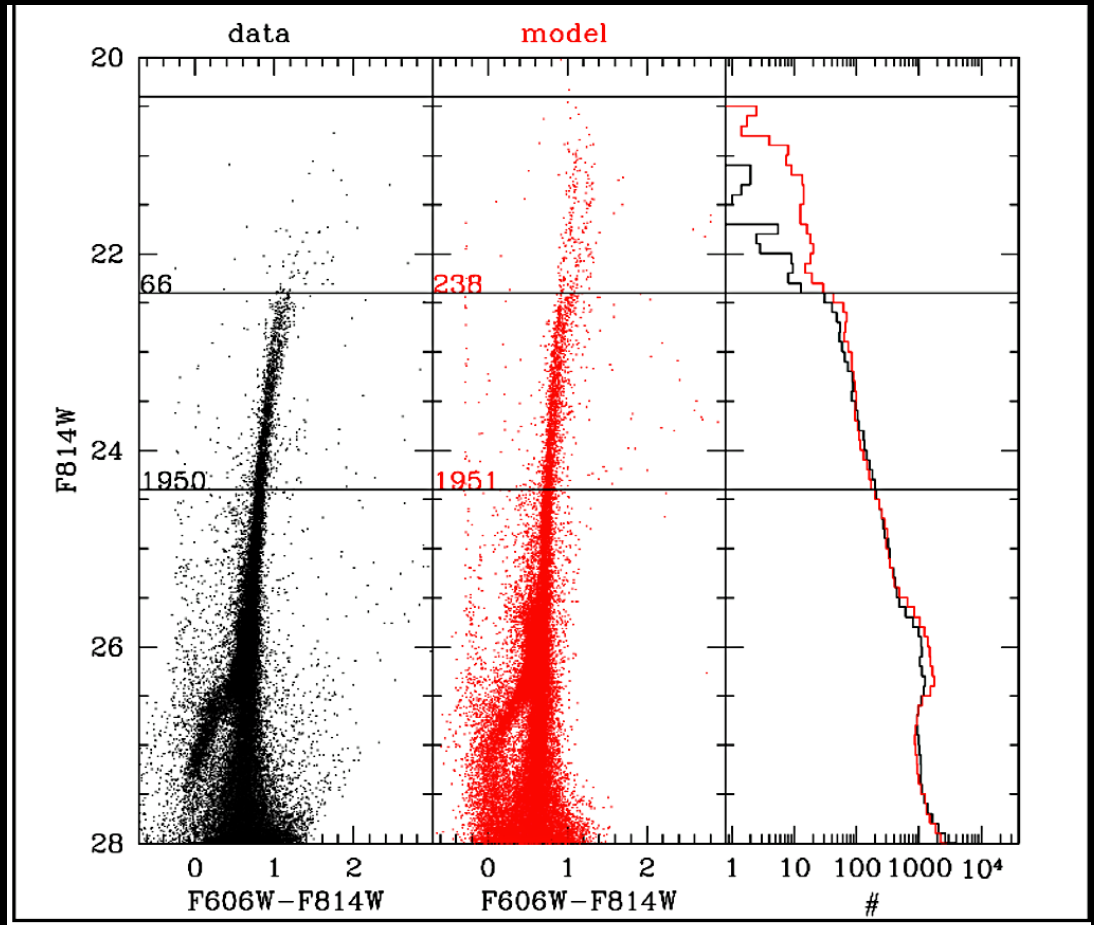
Optical

IR



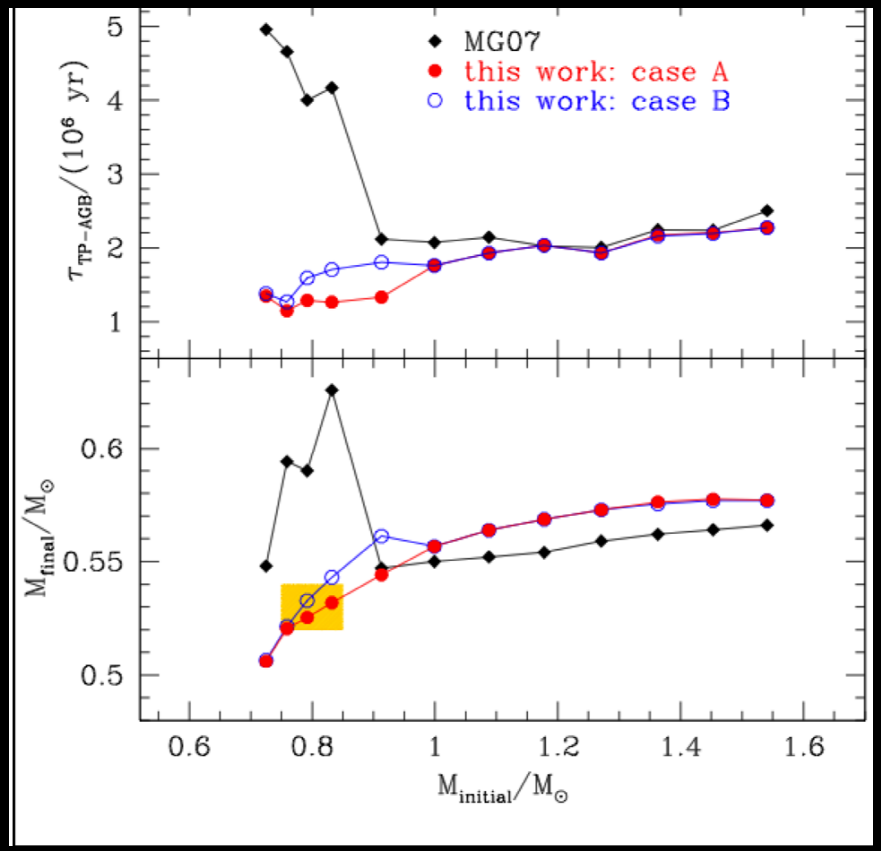


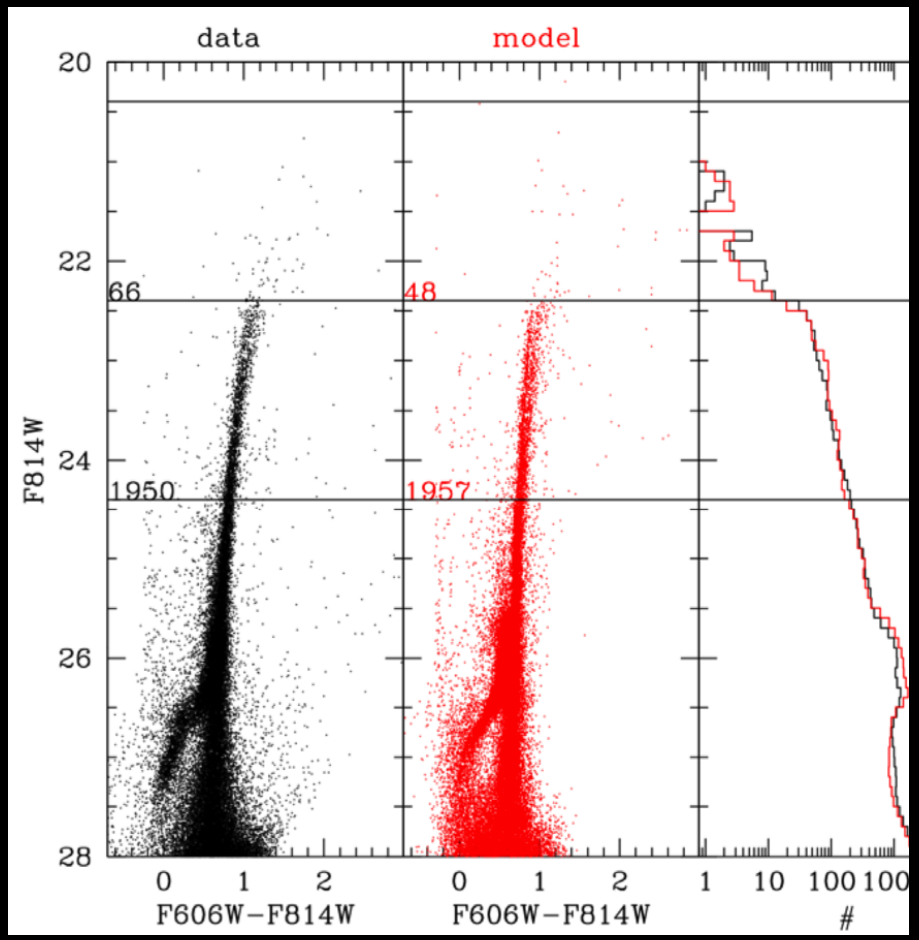
Studies like these are leading to improved AGB models



Girardi et al. 2010

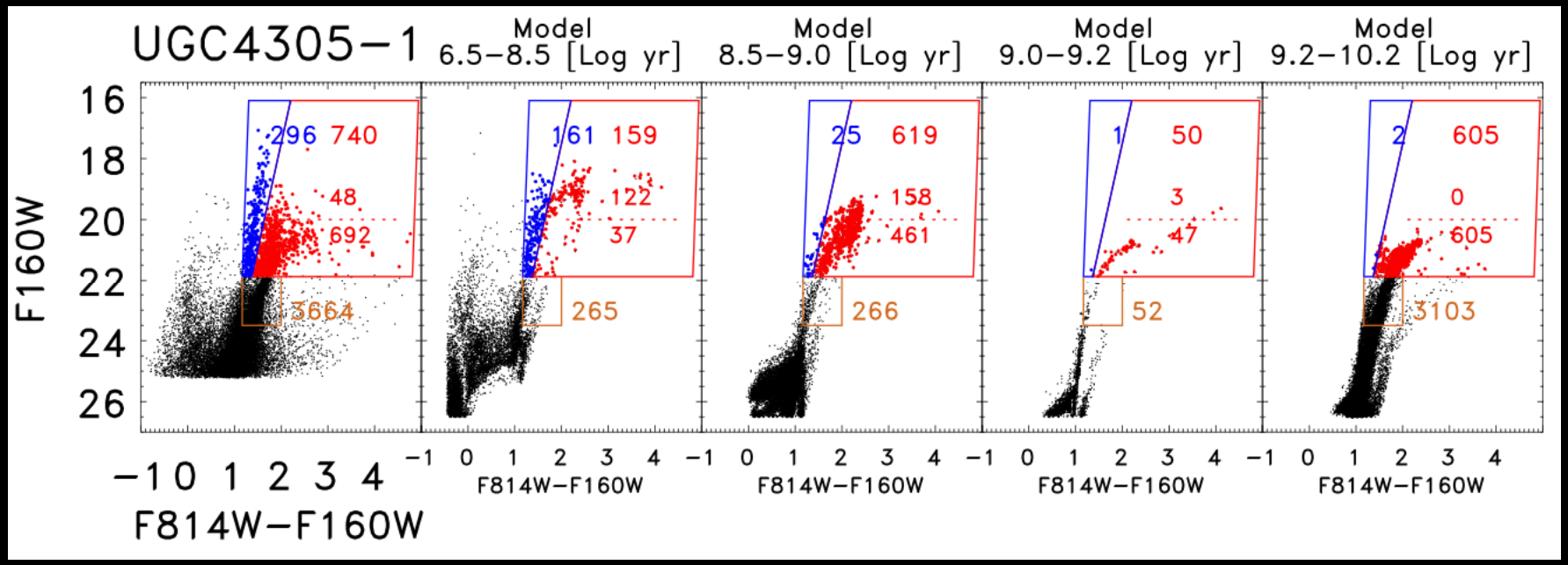
Old (low-mass) AGB found to have shorter lifetimes than expected





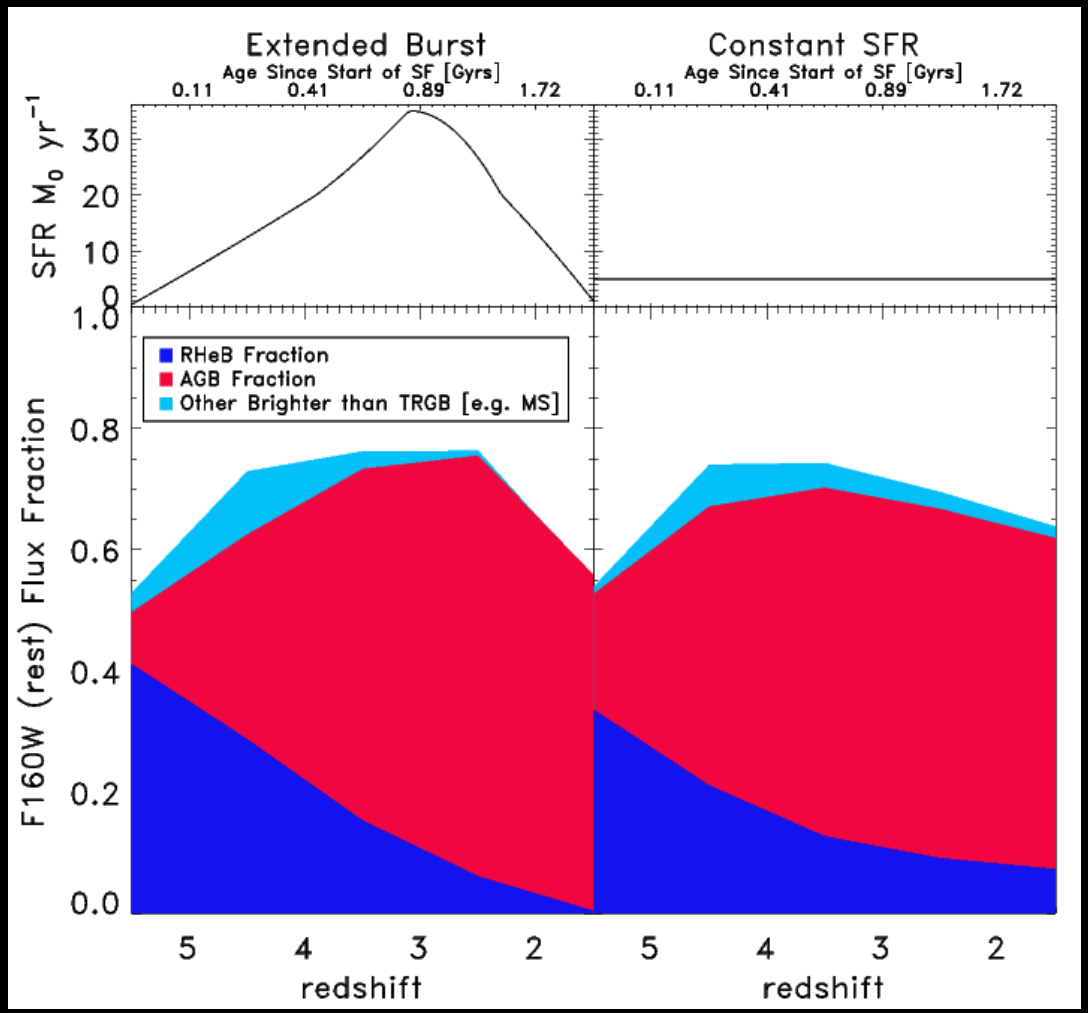
Girardi et al. 2010

Massive (younger) AGB may also have shorter lifetimes than expected



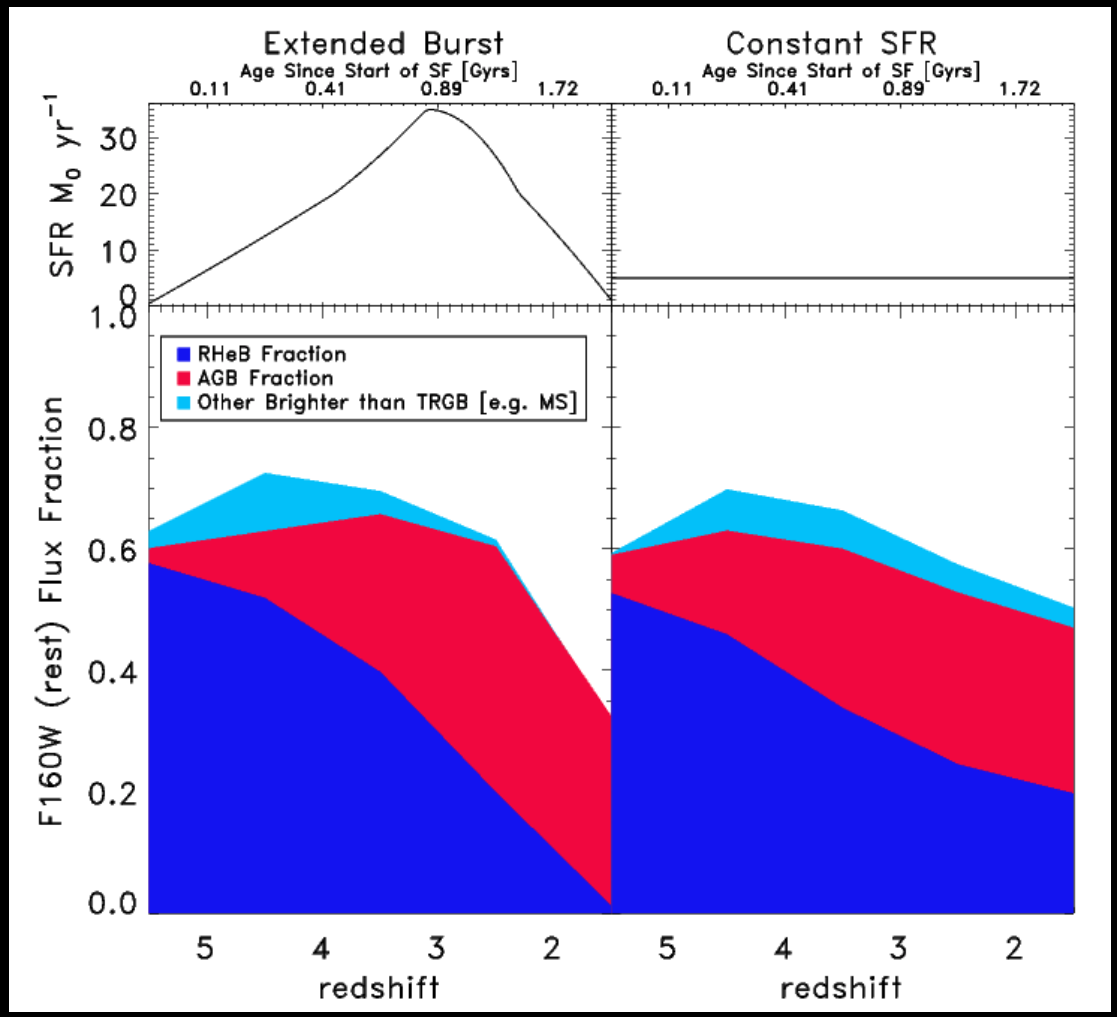
Melbourne et al. 2012

Model changes have implications for mass estimates of galaxies



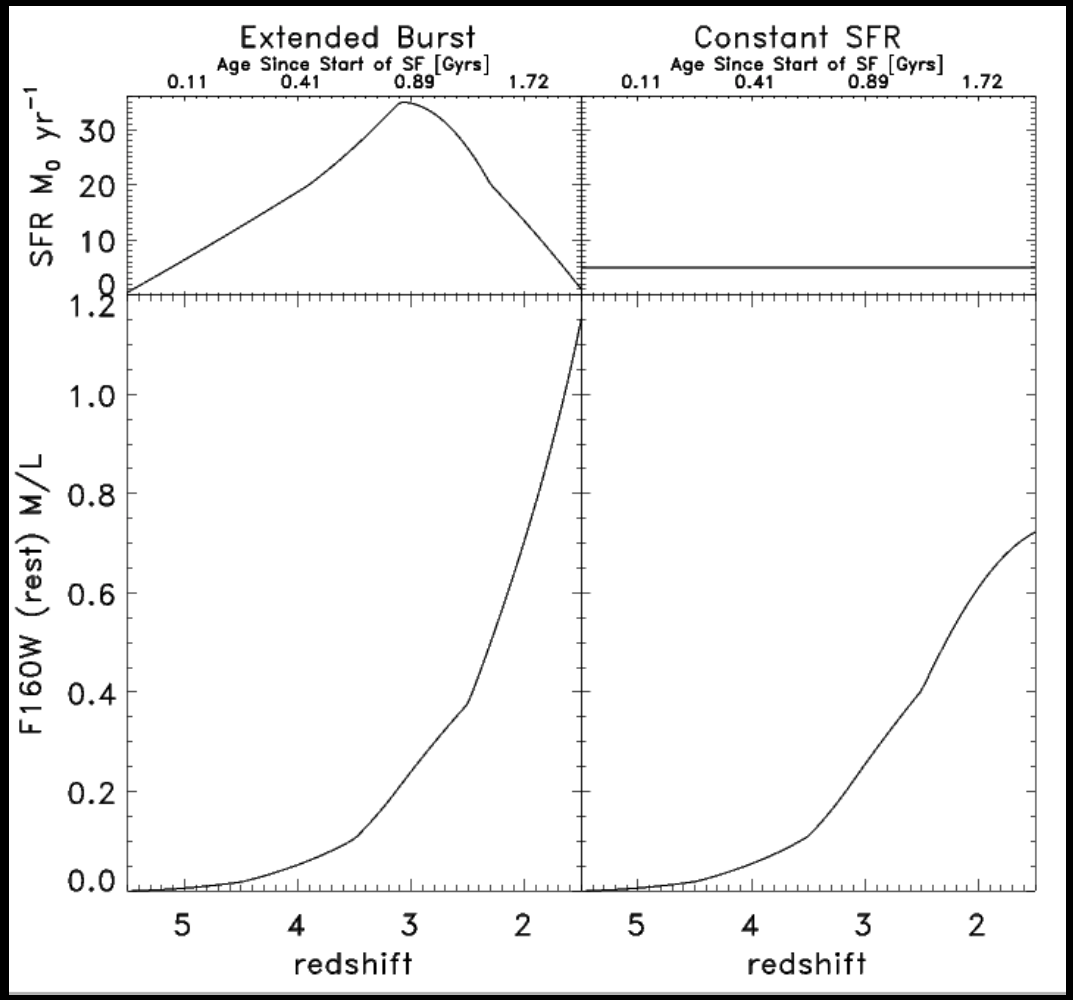
Melbourne et al. 2012

The smaller AGB contribution may be offset by larger RHeB contribution



Melbourne et al. 2012

RHeB and AGB lead to rapidly time-varying Mass/Light ratio

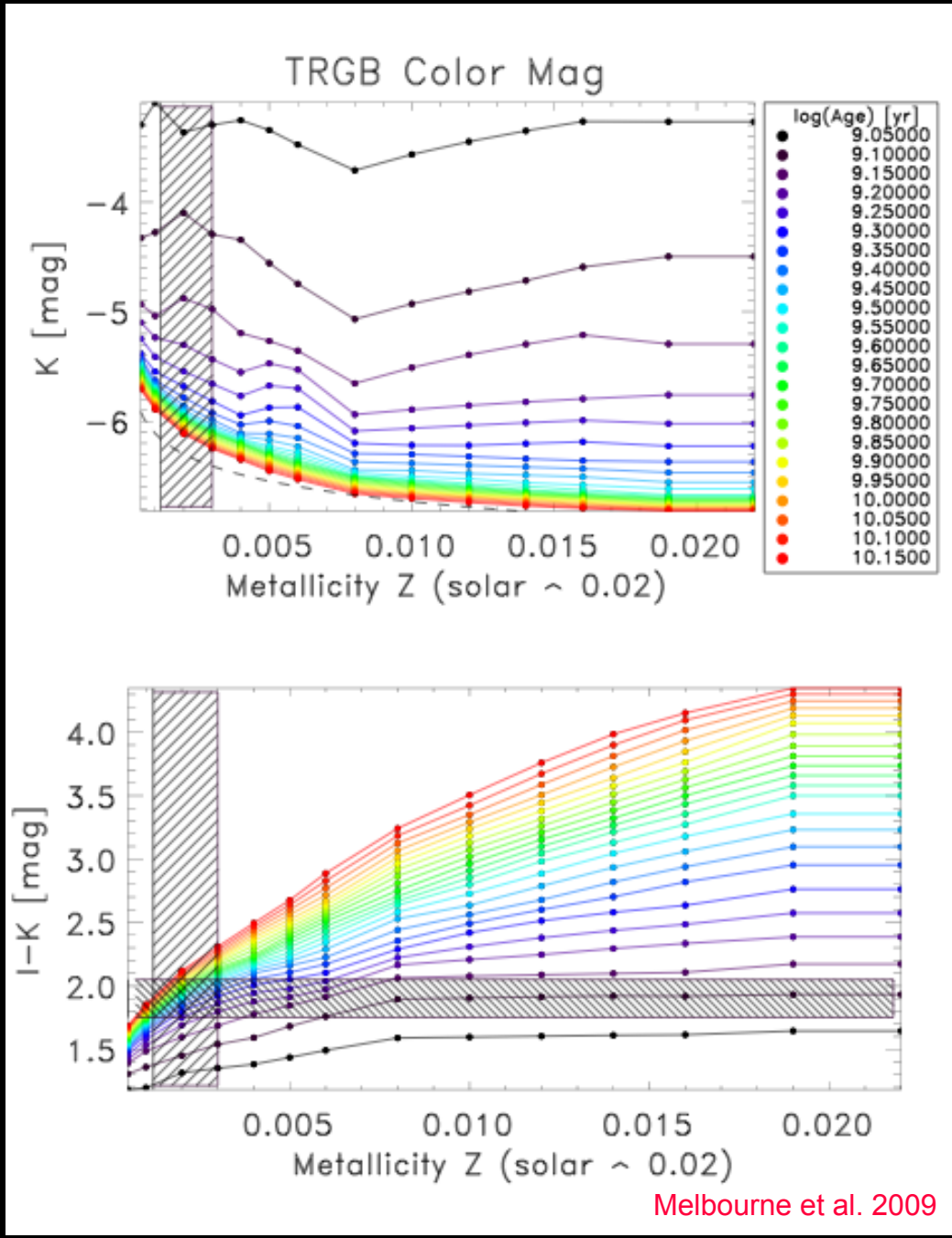


Melbourne et al. 2012

We showed that resolved near-IR photometry is good for:

1. Estimating Star formation histories
   Constraints on stellar evolution models
   Constraining masses of distant galaxies

Resolved NIR photometry is also great for estimating distances to galaxies



Melbourne et al. 2009

Future capabilities, focused on reaching faint flux levels with high fidelity, will allow for a tremendous leap in resolved stellar populations

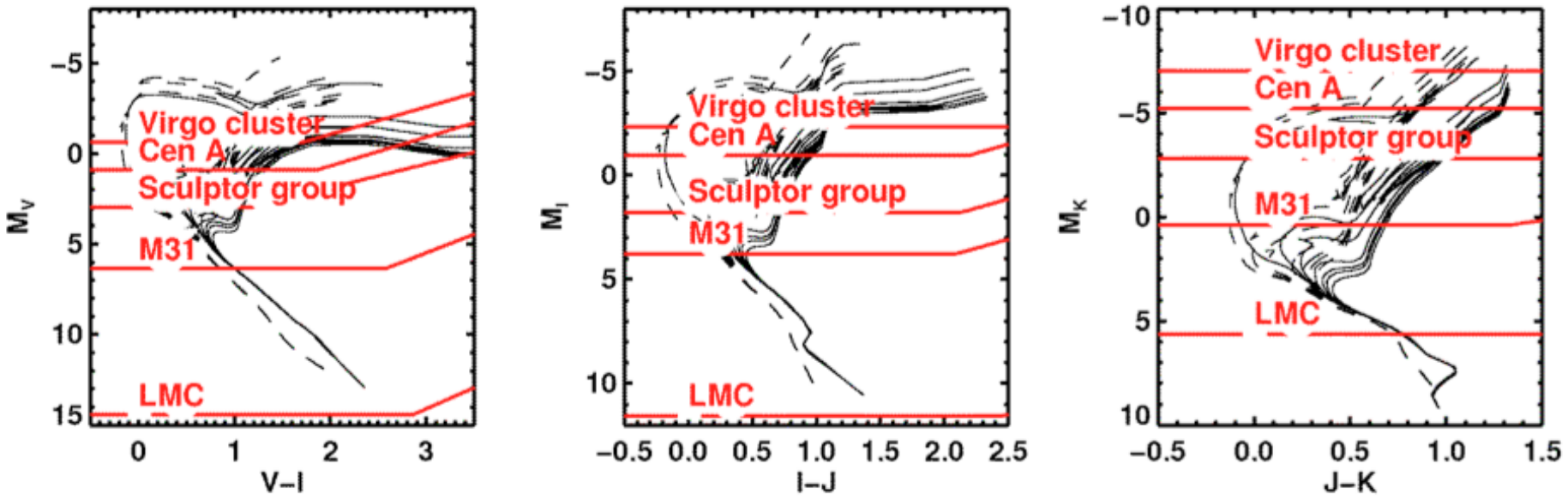
With Current Capabilities

- At Keck: typical 20 - 25% Strehl across 40” field
- Reach roughly 23 magnitude in 1 hour of integration
- Tip of the Red Giant Branch distances out to distance modulus of K=29 (~5 Mpc)
- Stellar pops in uncrowded regions to ~ 3.5 Mpc

With Future Capabilities

- With Strehl of 90%, could reach 1 - 1.5 mags deeper
- Tip of the red giant branch distances out to 10 Mpc
- With 30% Strehl in the optical can do stellar pops in crowded regions of more nearby galaxies

Crowding, strehl ratio, wavelength, and field of view all impact the potential science



Olsen et al. 2009

HST currently dominates the study of resolved stellar populations.

However, an AO instrument on an 8m class telescope providing strehl ratios of 90% in the near-IR or 30% in the optical (over a 1’ field) has the potential to transform the field.

For local galaxies, this instrument will answer, when the stars were formed, (to some extent) where they were formed, and where they are today.

For more distant galaxies, this instrument will provide the vital tests for stellar population synthesis models necessary to constrain ages and masses.