Stars & Stellar Populations with a 4 to 8m UV/O Space Telescope

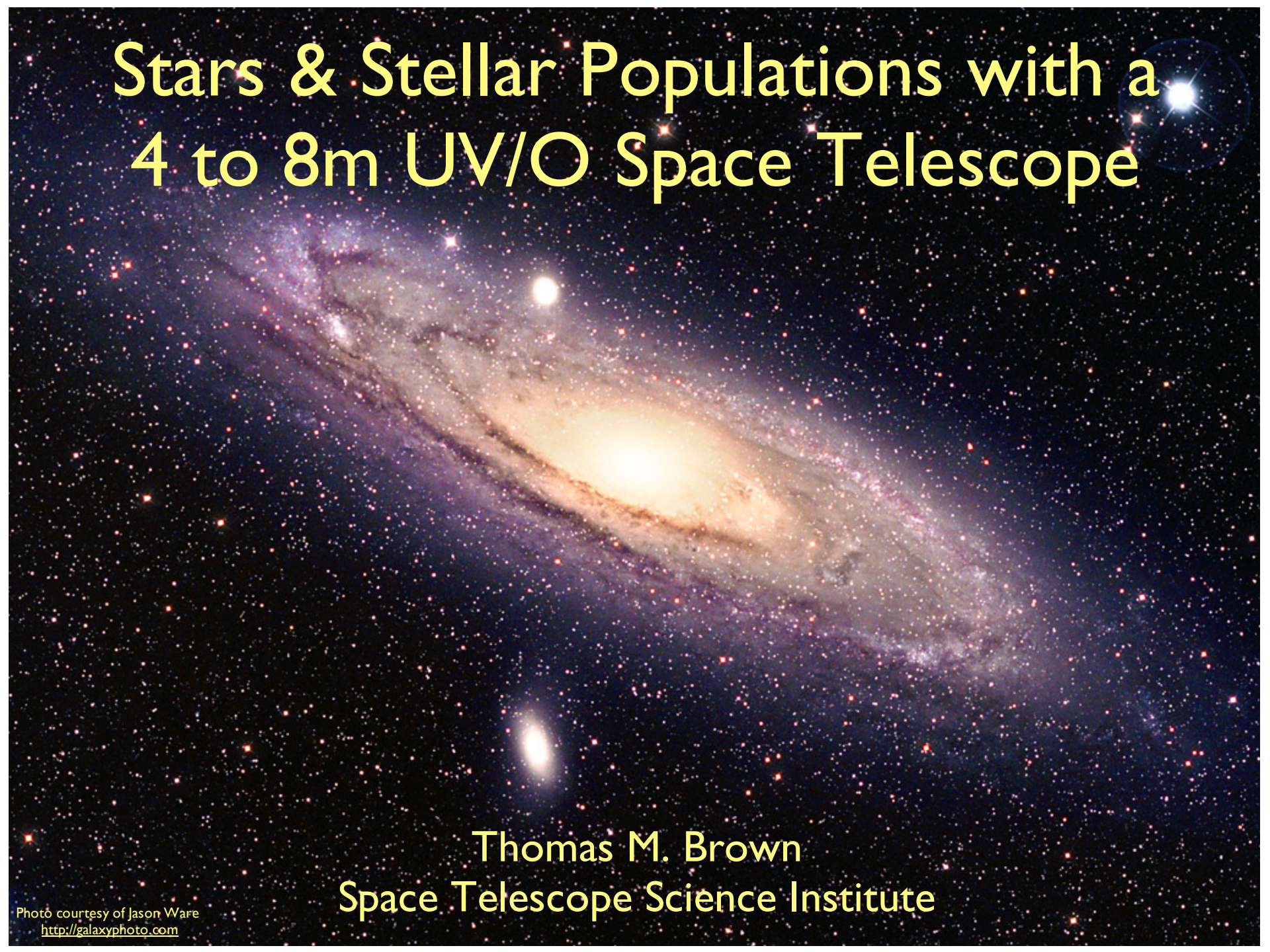

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Photo courtesy of Jason Ware
http://galaxyphoto.com

Enabling Breakthroughs

- Serendipity aside, groundbreaking progress usually comes from two avenues:
  - Order-of-magnitude gains in sample or signal
  - Crossing new thresholds
- Background-limited observations of faint stars make enormous gains with aperture:

$$\text{Exposure time} \propto \text{aperture}^{-4}$$

(for fixed luminosity & distance)

$$\text{Volume} \propto \text{aperture}^{3}$$

(for fixed luminosity & exposure time)

Need for space platforms

- Much of this work requires
  - ✦ stable high-precision photometry & astrometry
  - ✦ tens of thousands of stars
  - ✦ crowded fields several arcmin across
  - ✦ low sky backgrounds
  - ✦ dynamic range: tiny fraction of L_{SUN} to 10,000x brighter
  - ✦ access to the optical & UV
- Ground telescopes can provide high-resolution imaging, but not with the contrast & stability over wide fields achieved from space, not yet in the optical, and never in the UV
- Large ground telescopes (e.g., TMT) will not be able to

Case 1:

Star Formation Histories

Two primary ways to explore the formation of galaxies

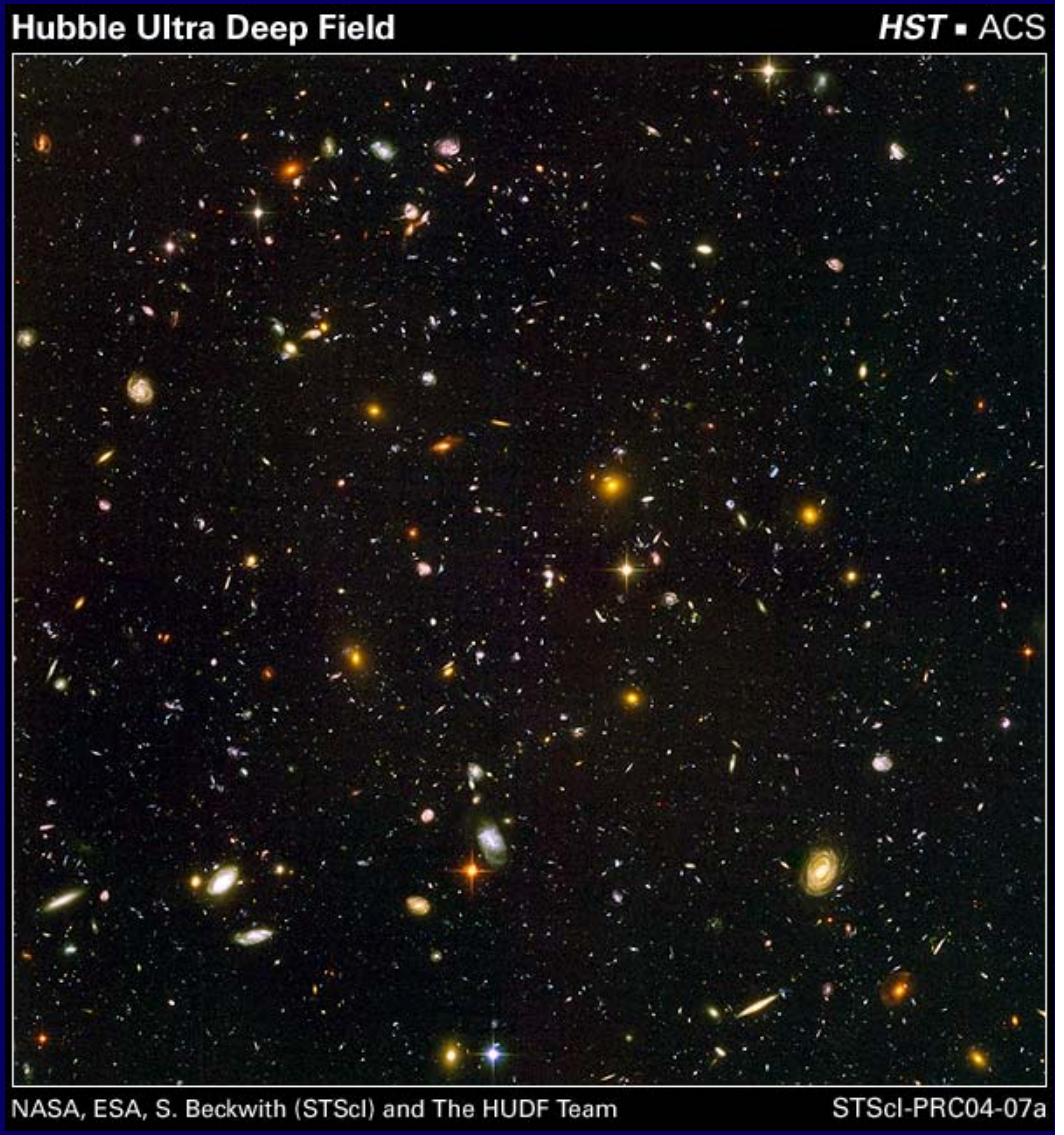
- High-redshift observations (e.g., HDF, GOODS, UDF)
- "Stellar archaeology" in resolved stellar populations of nearby galaxies
- These methods are complementary

Advantages of high-z work:

- Directly observing evolution of galaxies with time
- Enormous galaxy sample available to such work

Disadvantages of high-z work:

- Properties of interest (age, metallicity, kinematics) are only measured in composite sense
- Measurements are prone to significant uncertainties and degeneracies
- Properties are measured on scale of resolution element



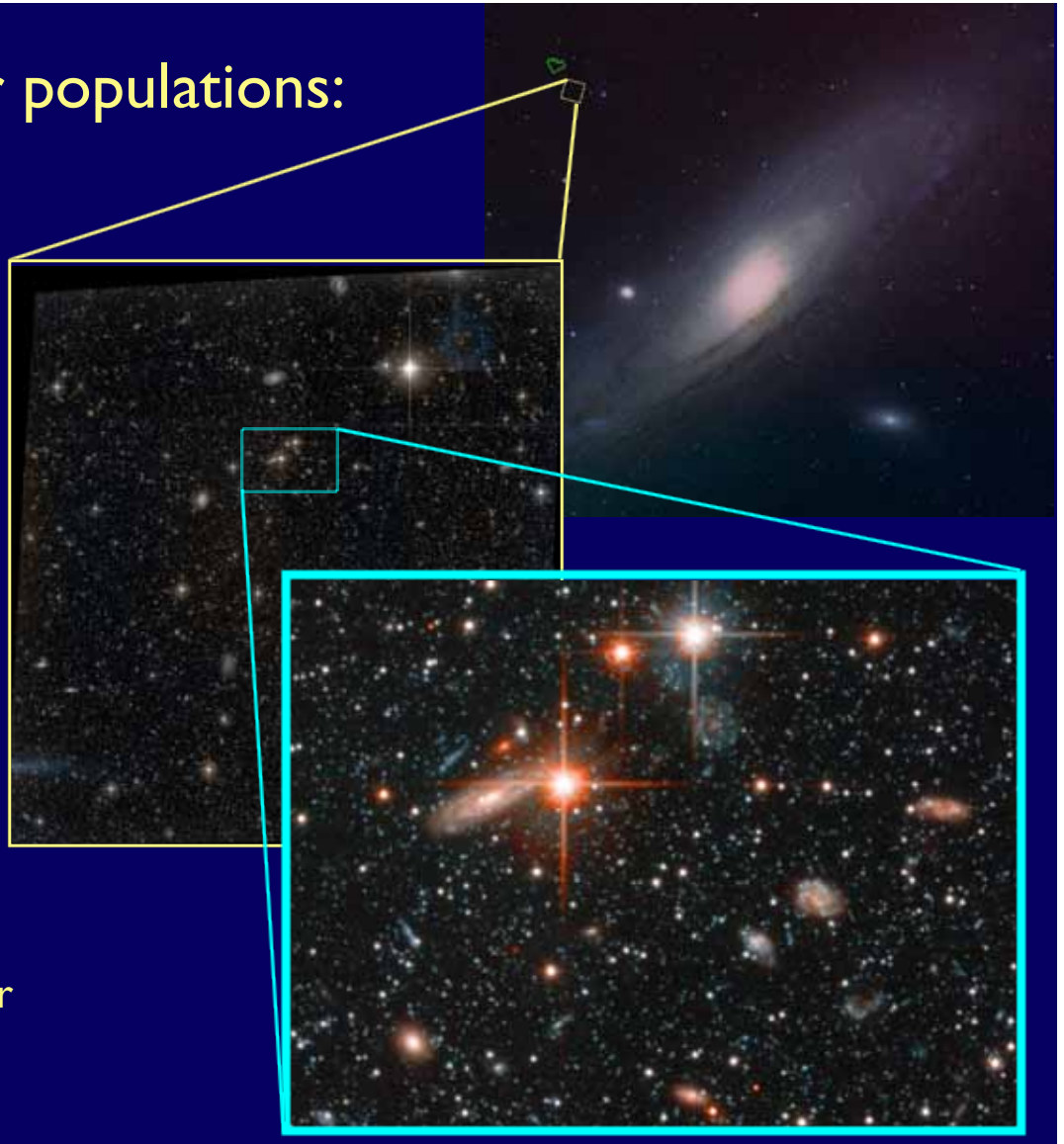
Progress requires pushing to time of first light and birth of galaxies (e.g., JWST)

Advantages of resolved stellar populations:

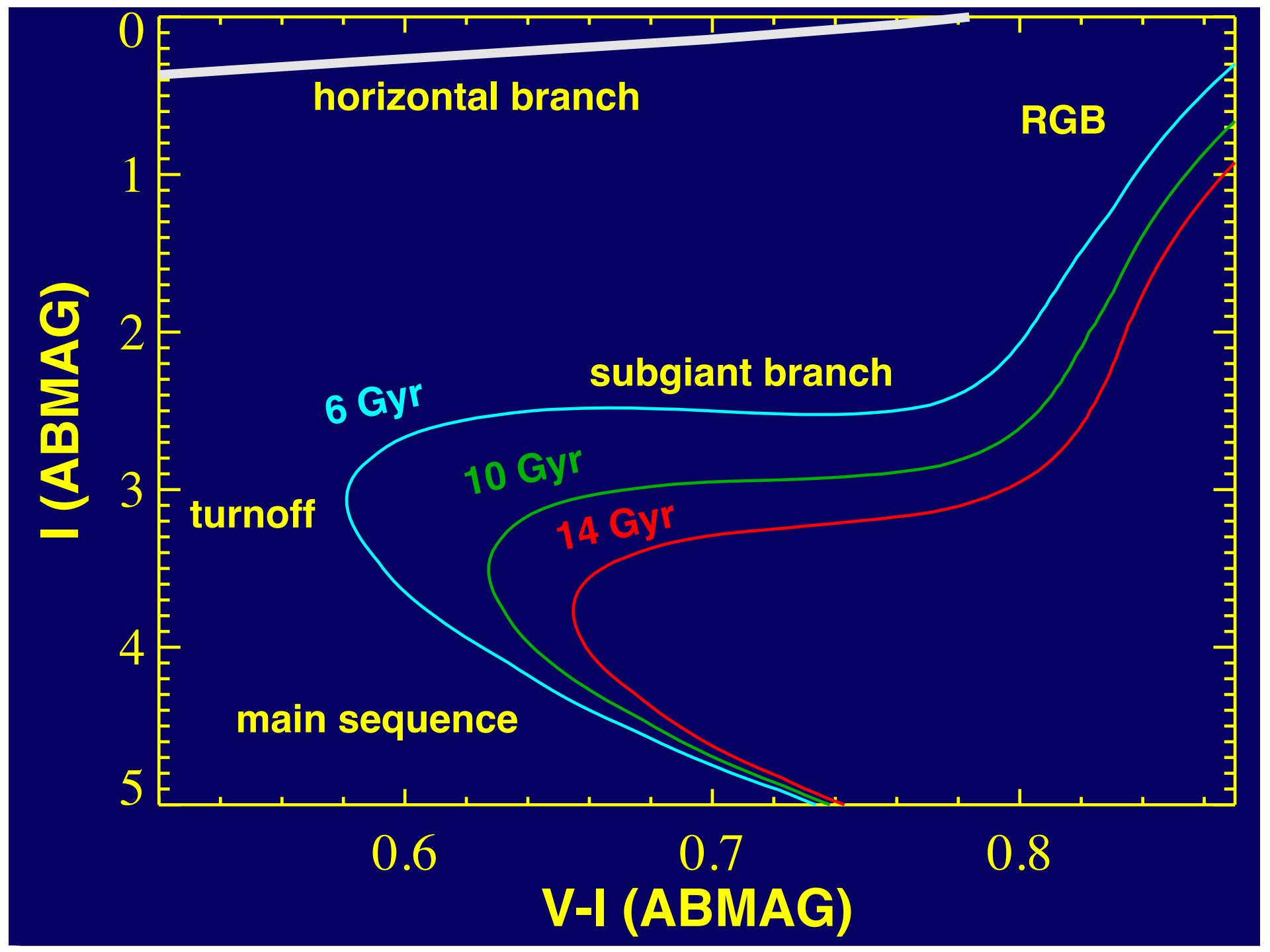
- Provides the most accurate methods for measuring kinematics, age, and metallicity
- Can probe all substructures within each galaxy

Disadvantages of resolved stellar populations:

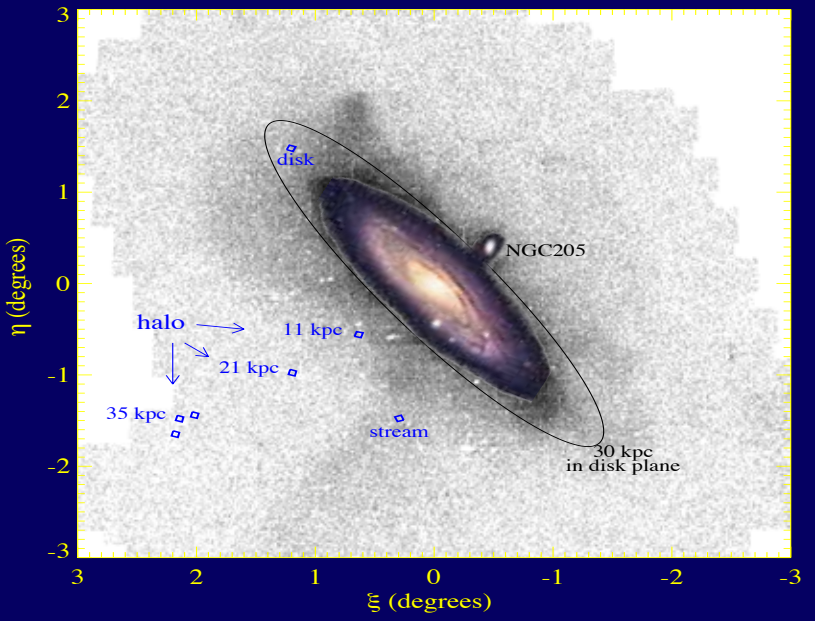
- Often limited to probing pencil-beams within galactic structures
- Local Group is cosmological backwater (small number of galaxies and not representative of all types)



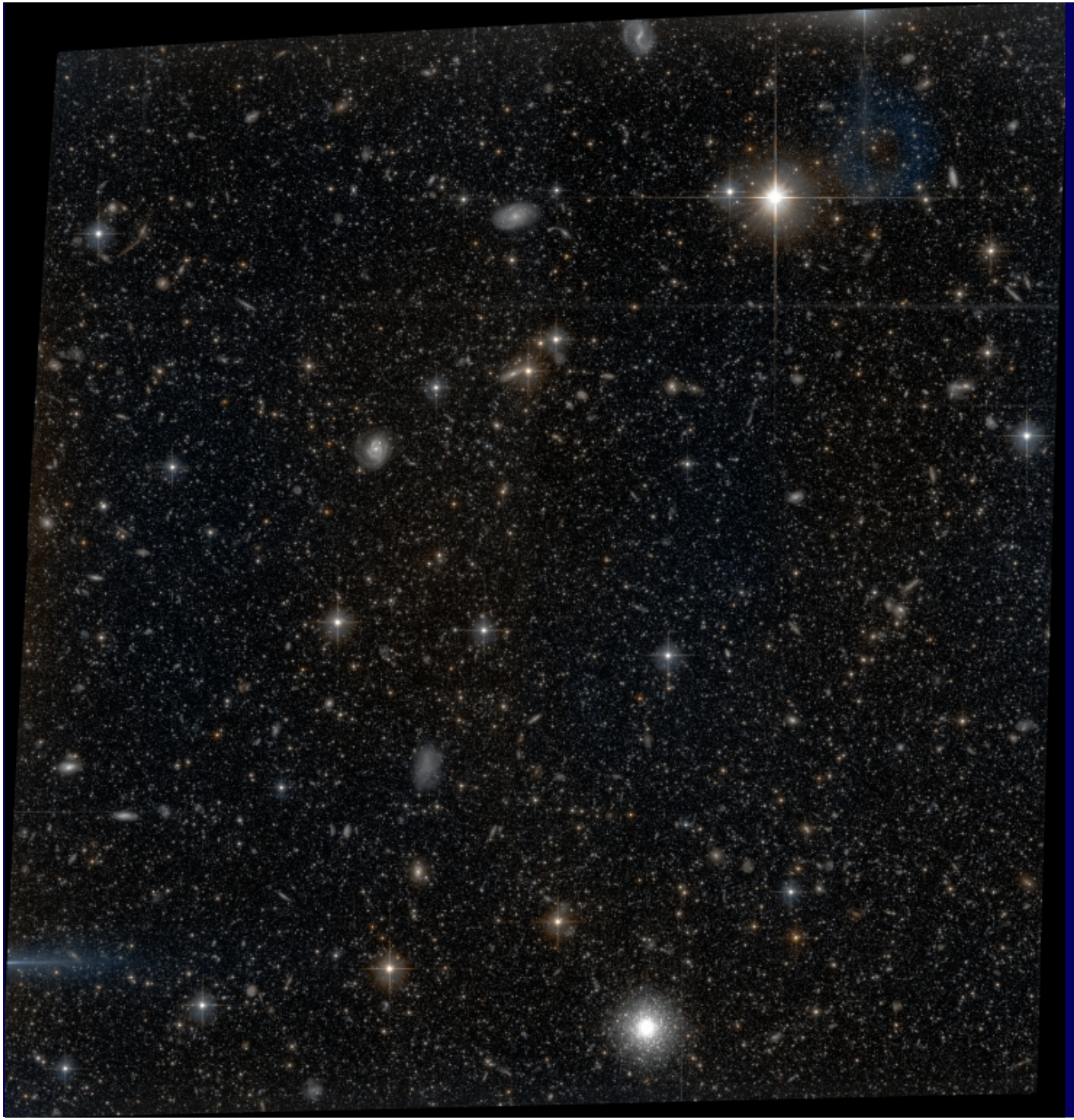
Progress requires reaching larger galaxy groups beyond the Local Group


0
1
2
3
4
5
I (ABMAG)
horizontal branch
RGB
subgiant branch
6 Gyr
10 Gyr
14 Gyr
turnoff
main sequence
0.6
0.7
0.8
V-I (ABMAG)

In several large HST programs, we have mapped the star formation history in various M31 structures



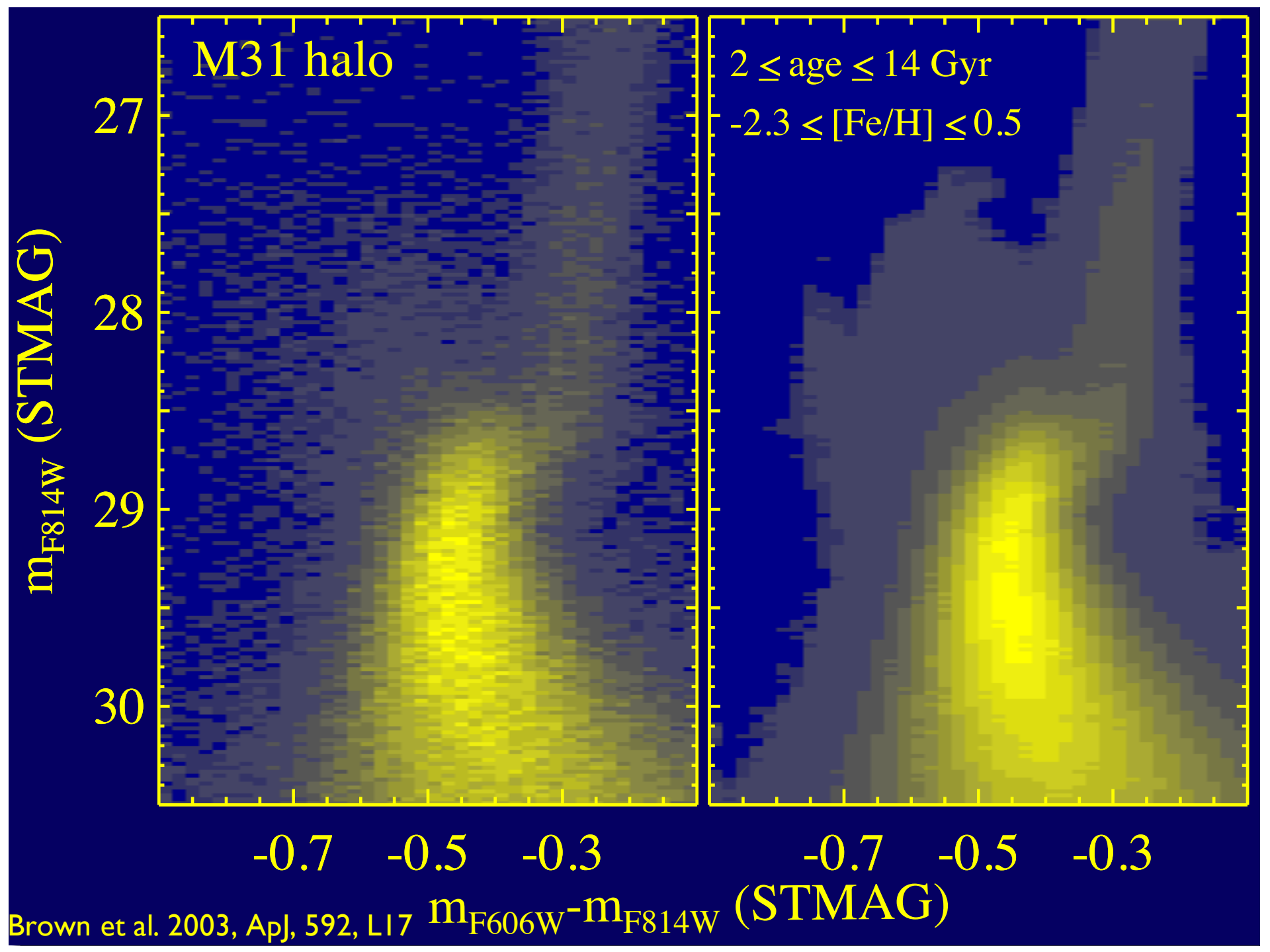
(star count map from Ferguson et al. 2002)



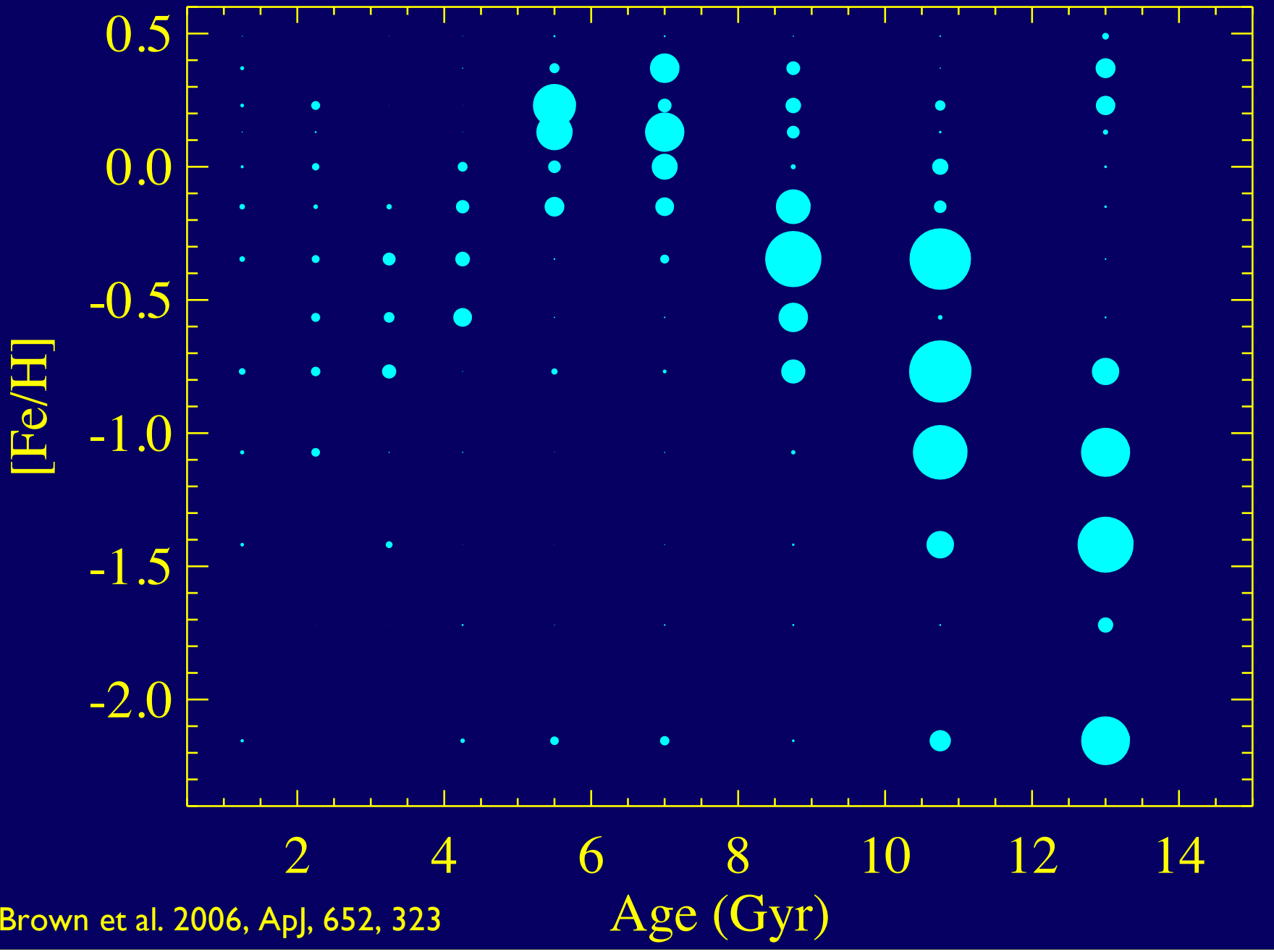
M31 inner halo
(11 kpc)

210 x 210
arcsec

800 x 800 pc

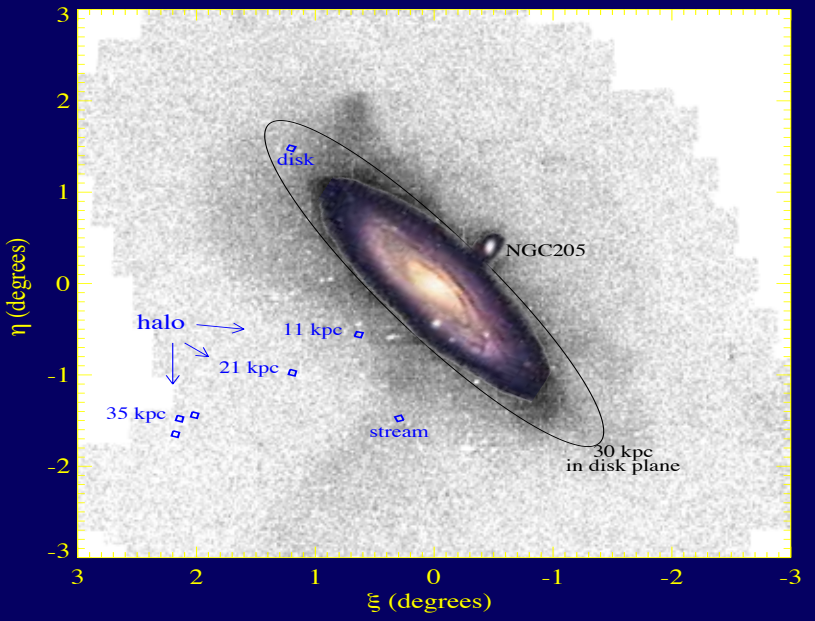

M31 halo
2 ≤ age ≤ 14 Gyr
-2.3 ≤ [Fe/H] ≤ 0.5
27
28
29
30
m_{F814W} (STMAG)
-0.7
-0.5
-0.3
-0.7
-0.5
-0.3
m_{F606W}-m_{F814W} (STMAG)
Brown et al. 2003, ApJ, 592, L17

Halo Distribution in Age and Metallicity



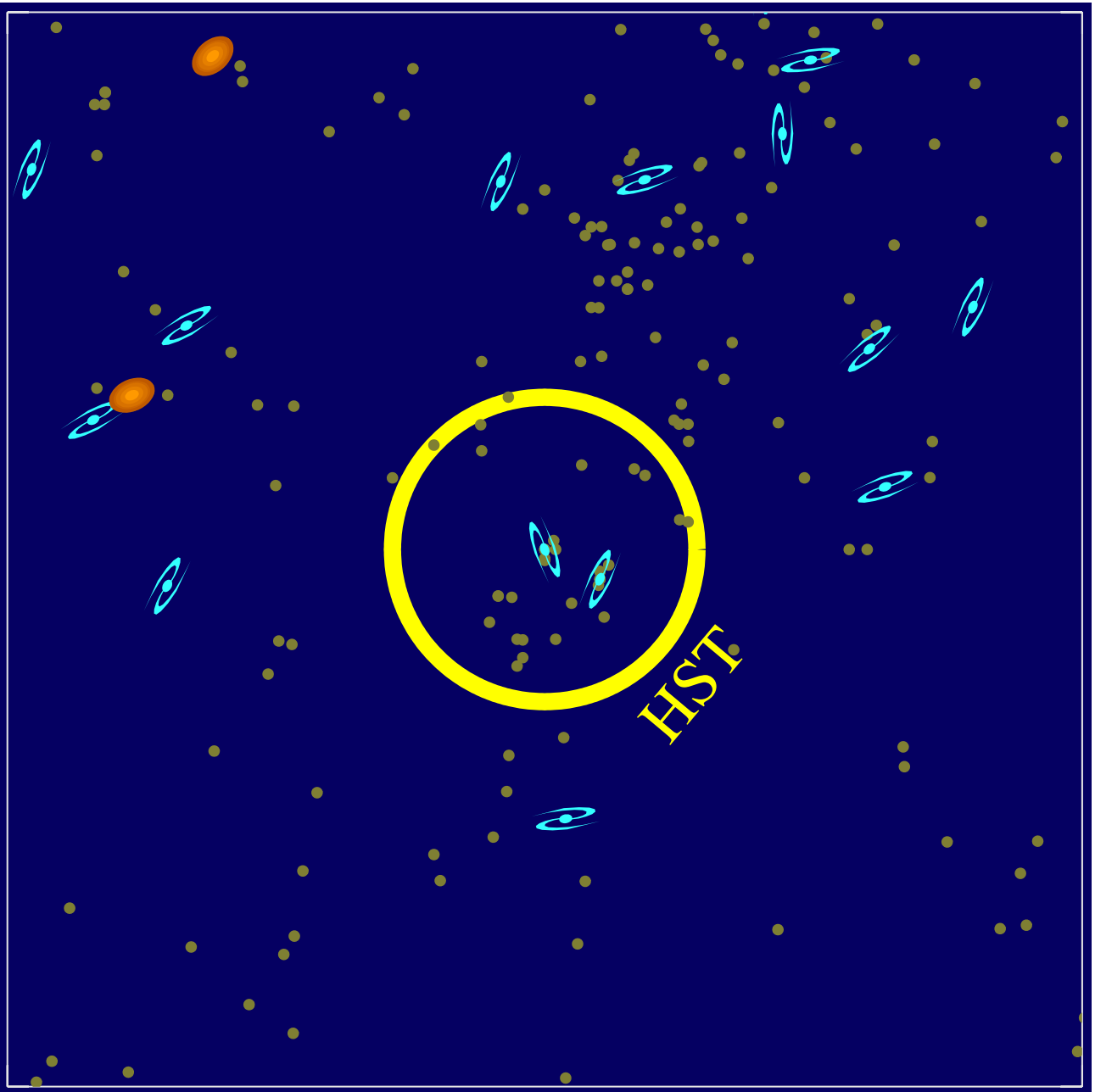
Brown et al. 2006, ApJ, 652, 323

- Older ages at larger radii, but extended star formation history exists everywhere (Brown et al. 2008)
- Similarities between inner halo and stream imply stream debris pollutes inner halo (Brown et al. 2006)
- Outer disk resembles thick disk population of solar neighborhood (Brown et al. 2006)



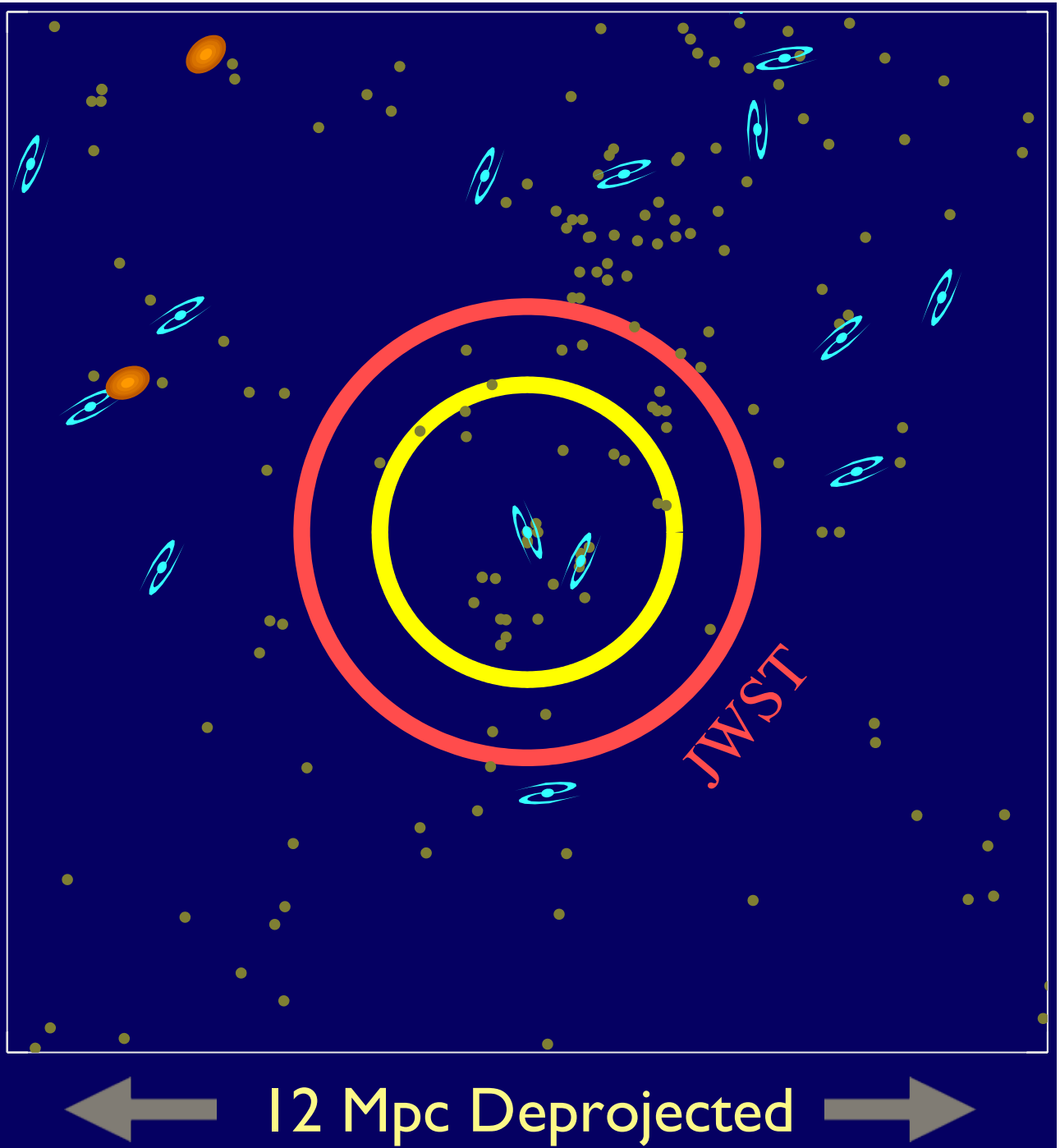
(star count map from Ferguson et al. 2002)

In 100 hours of observations split between two wide bands, HST can measure star formation histories in the outskirts of Local Group galaxies



In the same observing time, JWST could measure star formation histories in over 3x the volume

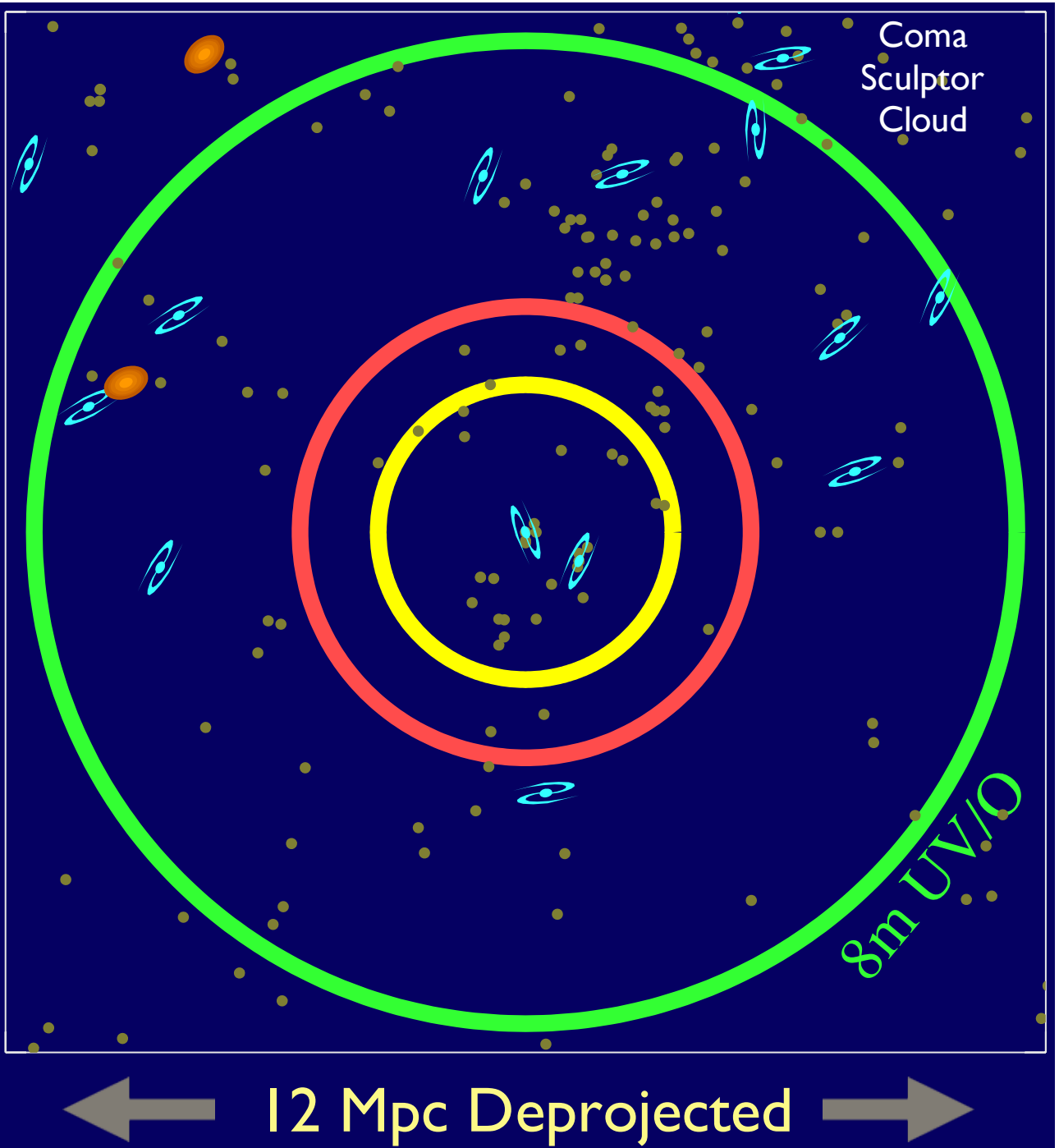
Alternatively, JWST could measure these histories in nearby galaxies over 5x faster



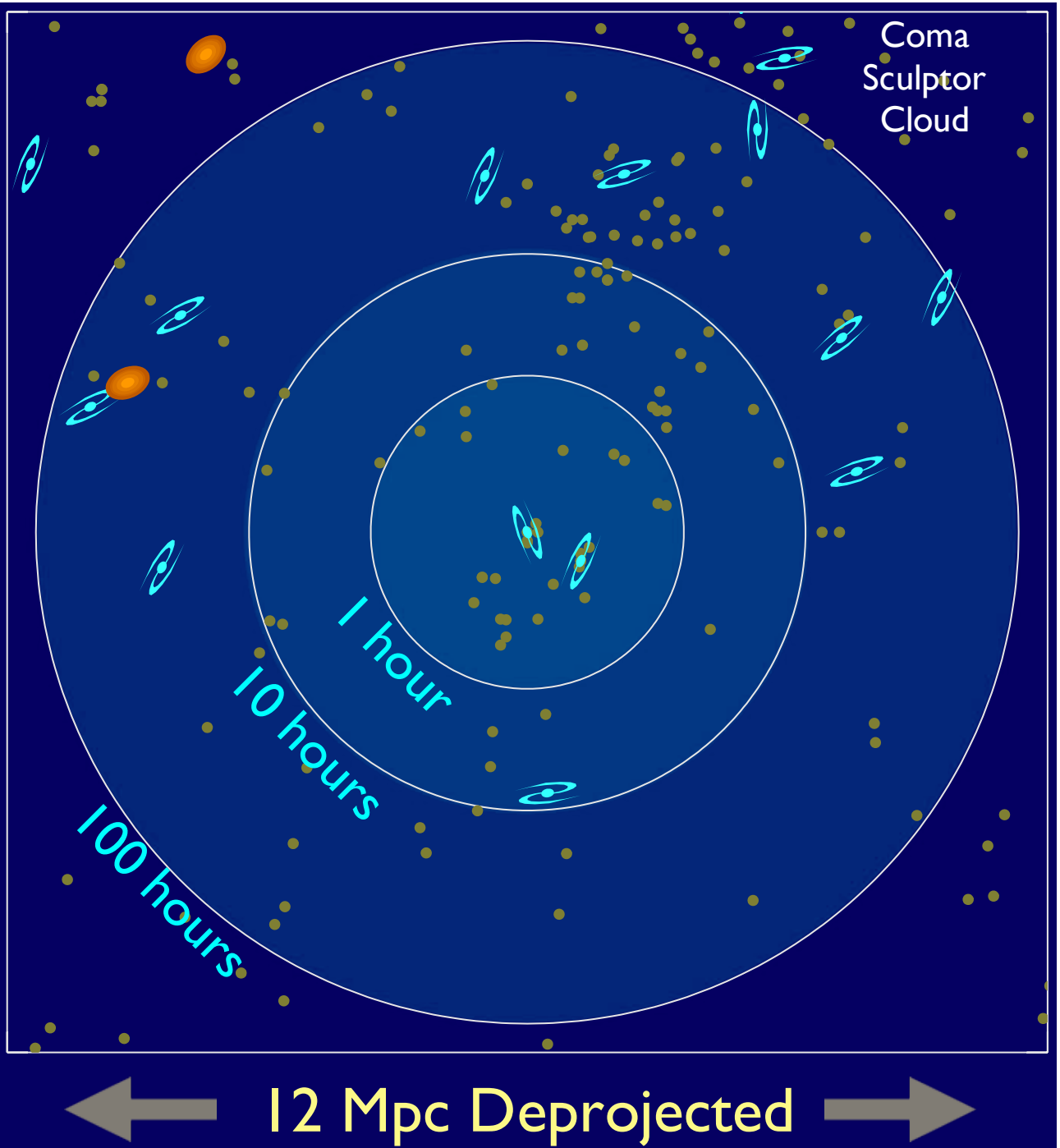
Large UV/Optical space telescopes begin making enormous gains

An 8m telescope could measure star formation histories in:

- 100s of dwarfs
  - incl. half a dozen low-Z starbursts (thanks A. Aloisi)
- dozen giant spirals
- giant elliptical



An 8 meter UV/Optical space telescope could very quickly explore many sightlines through relatively nearby galaxies, and probe more crowded regions in these galaxies (e.g., M31 bulge)



Case 2:

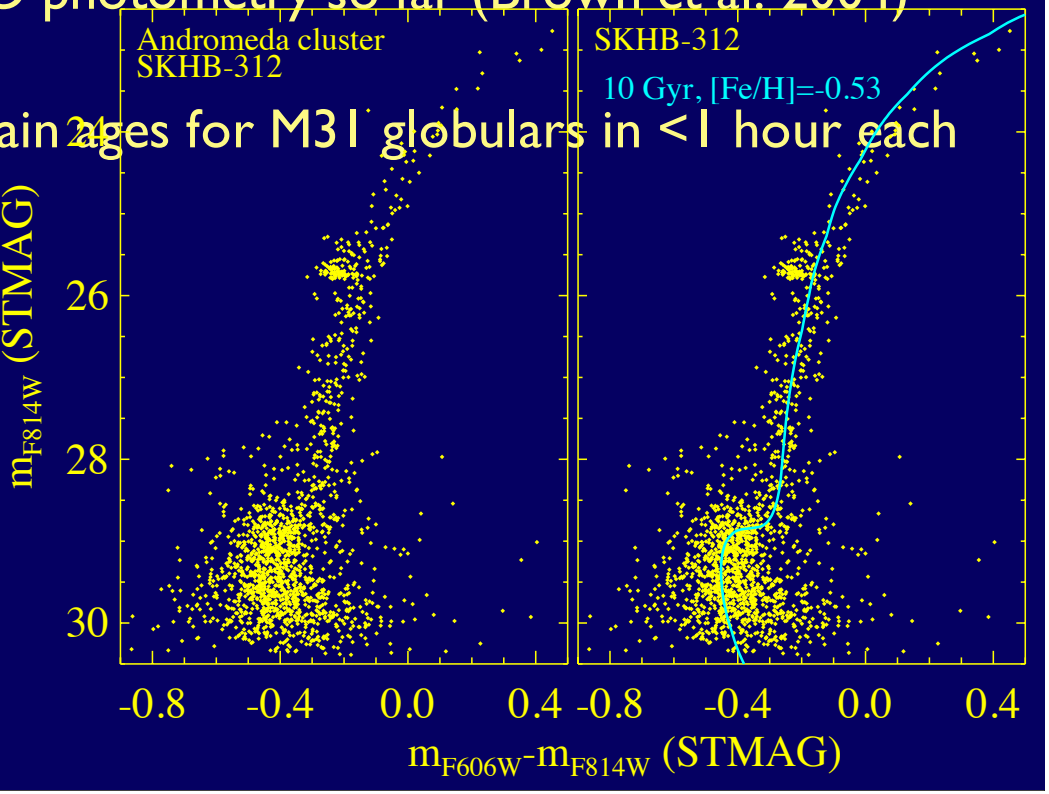
Globular Cluster Systems of the Local Group

- Milky Way has ~160 globulars, M31 has ~460 globulars
- Milky Way clusters are nearly all old (> 10 Gyr)
- Photometry & spectroscopy of M31 globulars indicate a possibly wide age spread (3-13 Gyr; e.g., Puzia et al. 2005, Fan et al. 2010, Perina et al. 2011)
- One M31 globular has MSTO photometry so far (Brown et al. 2004)

tain ages for M31 globulars in <1 hour each

SKHB-312

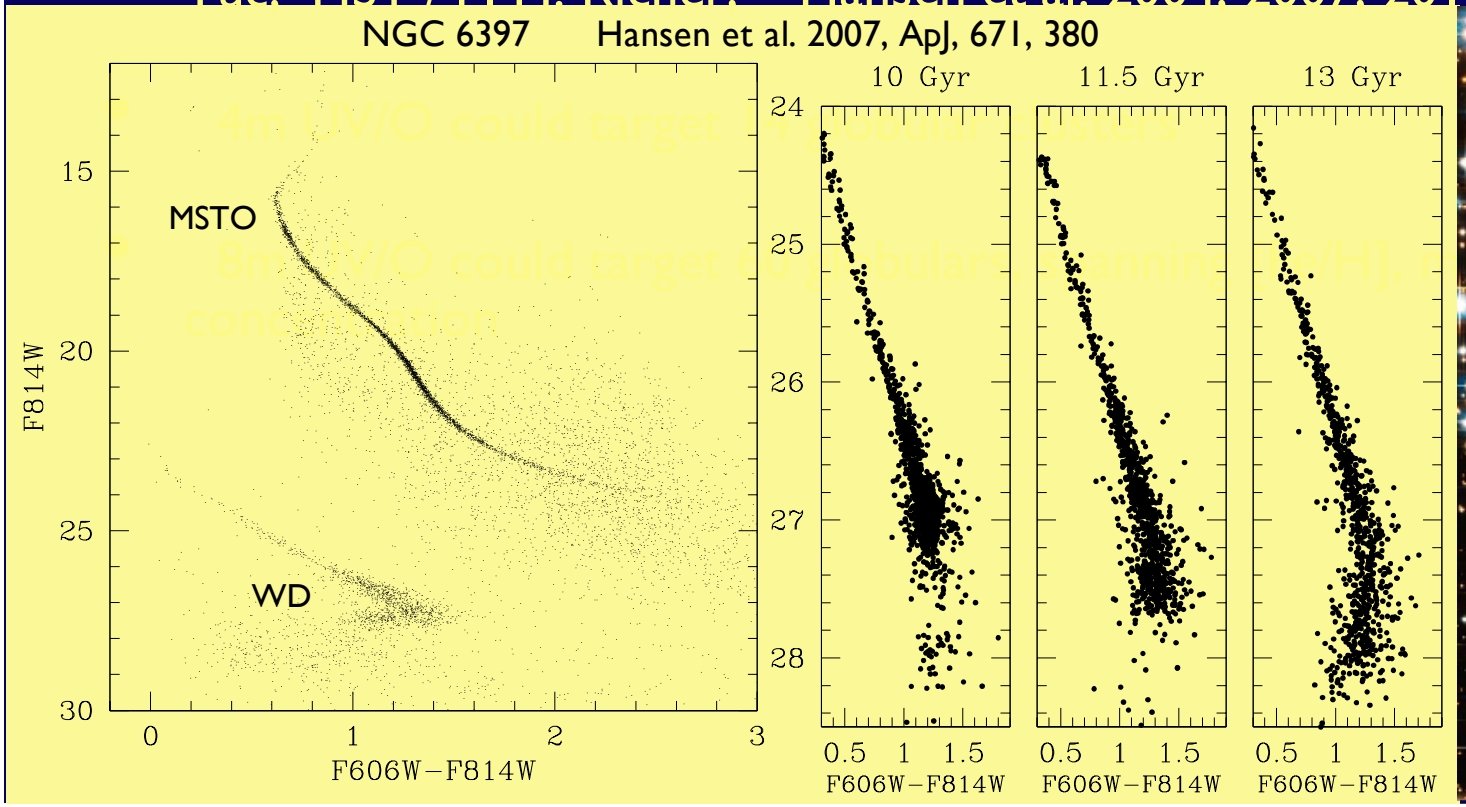
Brown et al. 2004, ApJ, 613,

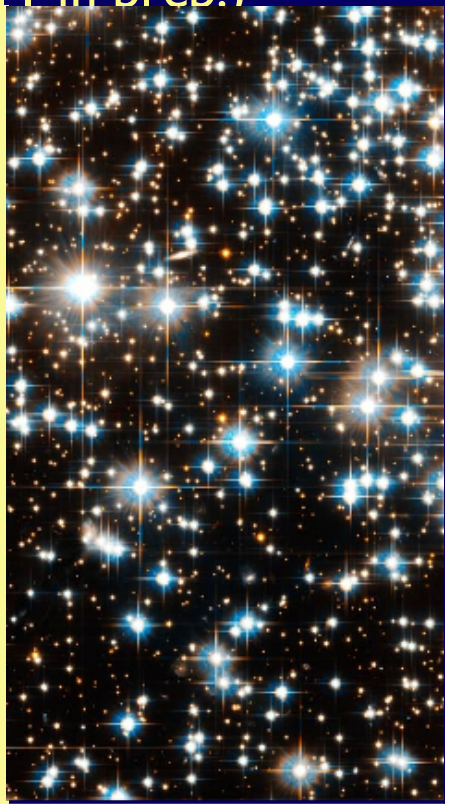


Case 3:

White Dwarf Cooling Curve in Galactic Globular Clusters

- Provides accurate age, independent of MSTO age, tests of stellar evolution
- Also probe H-burning limit in the same cluster (thanks A Dotter)
- WD termination is ~13 mag fainter than MSTO at old ages (~12 Gyr)
- Only characterized in 3 nearby globulars to date (M4, NGC 6397, 47 Tuc; HST / PI H. Richer, Hansen et al. 2004, 2007, 2011 in prep.)





Case 4:

Black Holes in Galactic Globular Clusters

- Galaxies host super-massive black holes (SMBHs), but the existence of intermediate-mass black holes (IMBHs) in globulars remains inconclusive
- SMBHs scale as either (bulge mass)^{1} or (velocity dispersion)^{4}
- Current limits on IMBHs in 5 globulars do not rule out masses scaled from SMBHs, and do not probe core-collapsed clusters due to crowding
- UV/O telescope in 4 – 8m range could probe core-collapsed clusters and scaling of SMBHs

Omega Cen

Anderson & van der Marel, 2010, ApJ, 710, 1032

van der Marel & Anderson, 2010, ApJ, 710, 1063

(thanks J. Anderson)

Examples needing UV spectroscopy

- D. Lennon: Extend our knowledge of stellar mass loss in hot stars to low Z (below that of the SMC)
  - Appropriate galaxies (at metallicities below quarter-solar with enough hot supergiants) are at 5 - 10 Mpc (i.e., beyond HST/COS)
- R. Osten: Detect astrospheres in cool stars - mass loss, planetary habitability, angular momentum loss
  - Requires increasing the sample beyond the dozen stars within 30 pc
- D. Soderblom: Determine basic structural properties (masses, radii) for young magnetically-active stars
  - Requires binary systems currently beyond reach of HST

Summary

- Much of the work on local stellar populations is limited to small samples due to prohibitively expensive observations
- An 8m UV/O telescope makes enormous gains:
  - ~120x faster observations in HST-sampled volume
  - ~35x larger volume sampled in a given time
- Star formation histories throughout the Local Group and reaching into the Coma Sculptor Cloud
- Ages for other large globular cluster systems
- WD cooling curve ages for dozens of globulars
- Confirm/reject IMBHs in globulars scaled from SMBHs