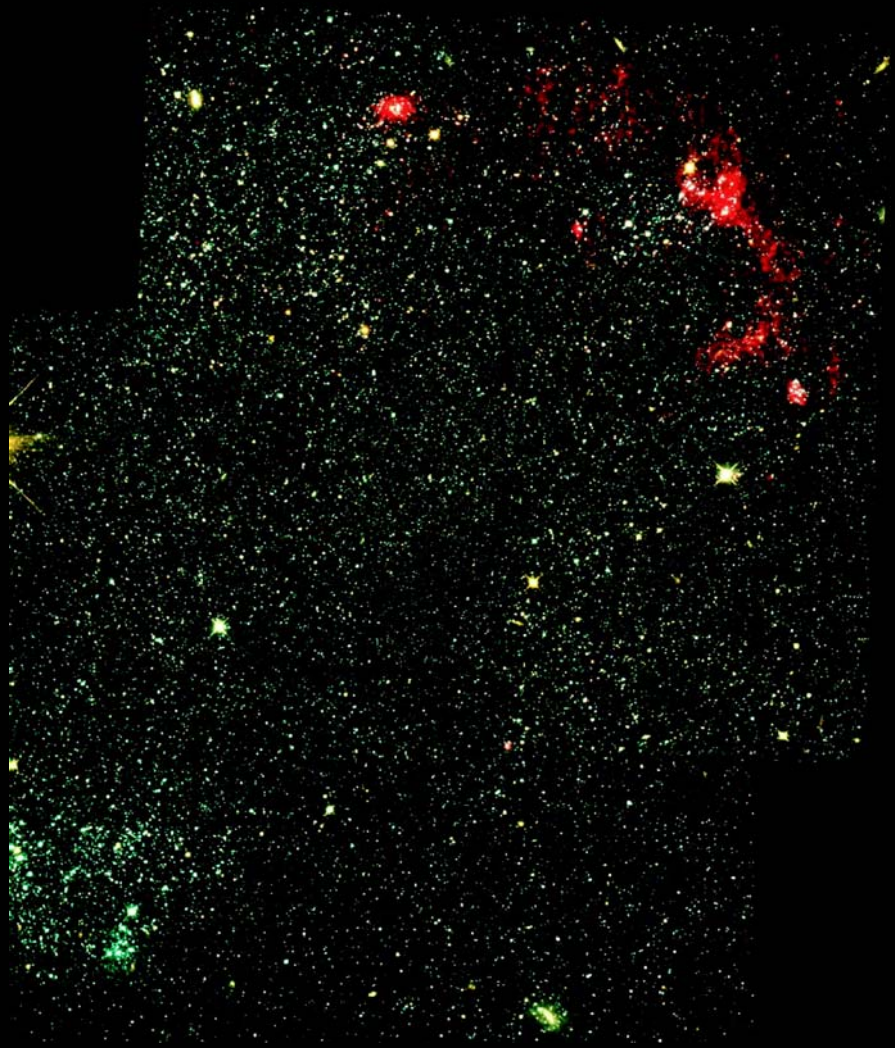
Comparing Local Group Dwarf Galaxies



Evan Skillman – U. Minnesota

Groups of Galaxies in the Nearby Universe – Santiago - 5/12/2005

Outline

I. The Dwarf Galaxies – A Quick Review
(The 2 (or 3) Families)

II. Deriving Star Formation Histories
(Emphasis on HST observations)

III. Comparing Star Formation Histories
(Can we keep it simple?)

IV. What processes dominate the differences?

V. What's Next?

Some Very Important People

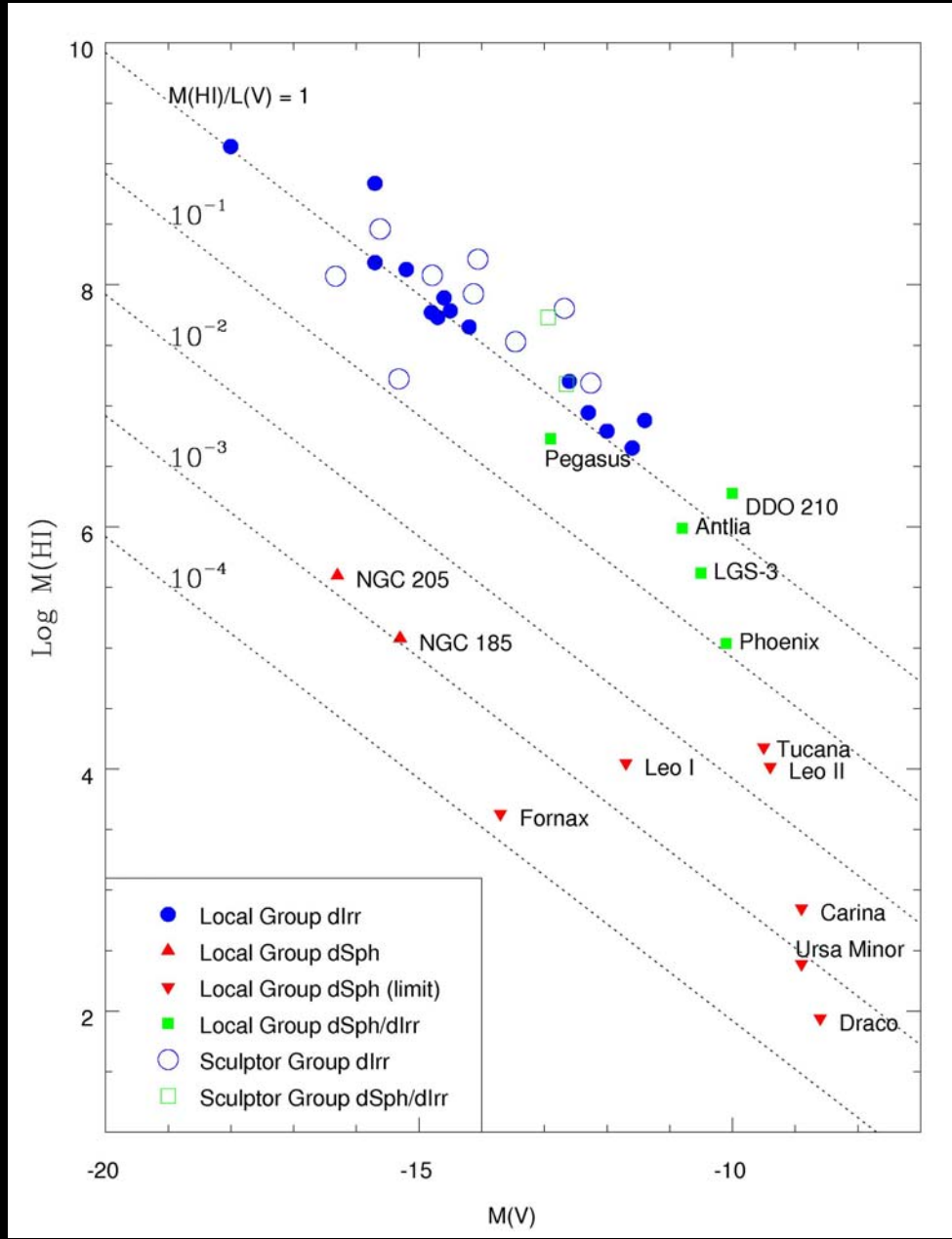
- Andrew Cole
- Andy Dolphin
- Mario Mateo
- Eline Tolstoy
- Robbie Dohm-Palmer
- Jay Gallagher
- Abi Saha

2 GO Programs -- 11 papers on HST studies of nearby dwarf galaxies

Andy Dolphin, Jon Holtzman, and Dan Weisz

HST Archival Legacy Program: The History of Star Formation in the LG

Comparing the HI masses of the dwarf galaxy families

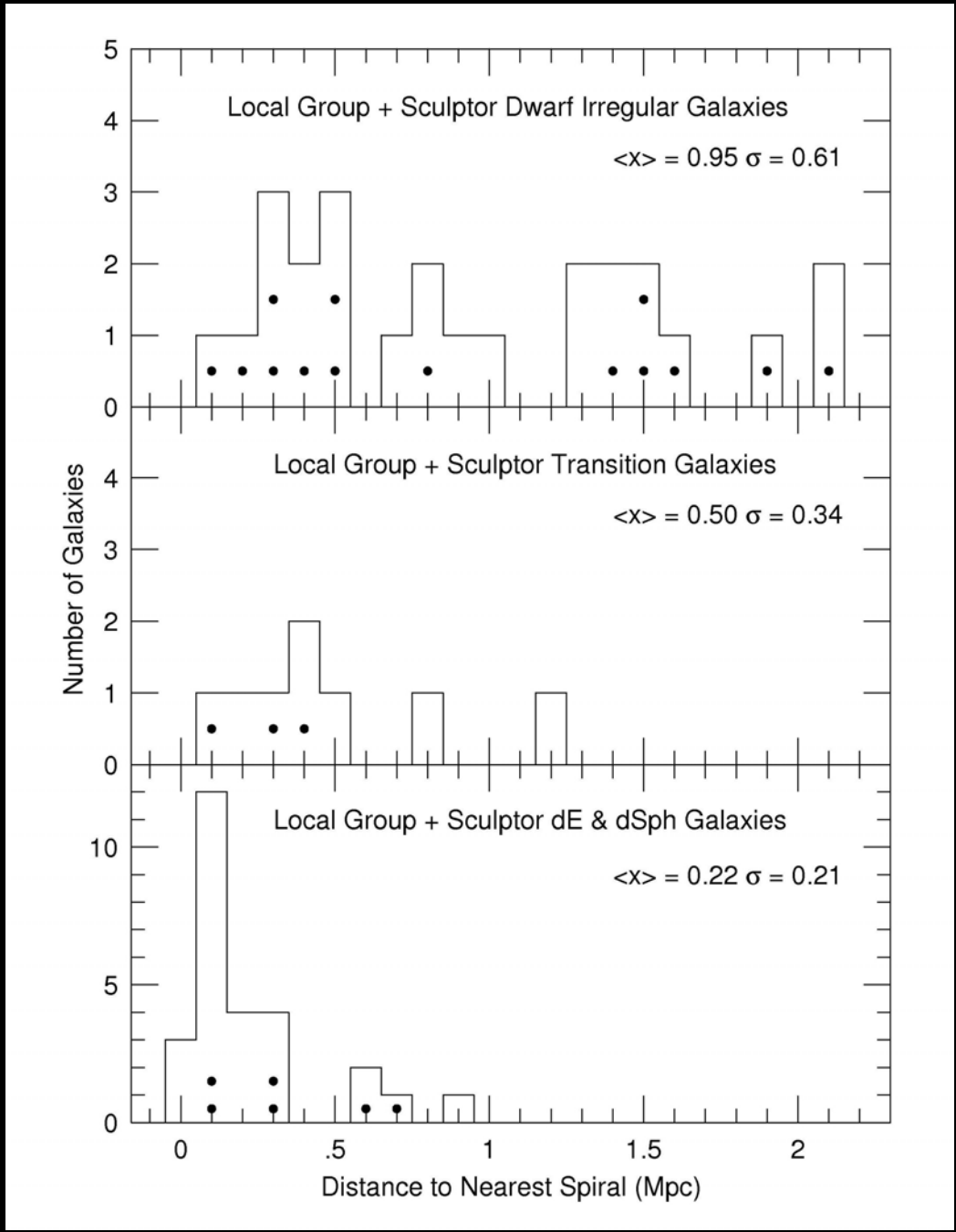


Important Characteristics

- dIrr & dSph have similar structures (Faber & Lin 1983; Kormendy 1985).
- Dwarfs show strong morphology-density relationships in groups and clusters.
- The low masses imply a fragility (e.g., Dekel & Silk 1986).
- The star formation histories of the MW dSph companions show a great variety (e.g., Mateo 1998).

Morphology – Density in the Local Group and the Sculptor Group

Skillman, Cote, & Miller (2003)



II. Deriving Star Formation Histories

- In principle, a complete census of the stars in a galaxy effectively determines the evolutionary history of that galaxy.
- Even a partial census can provide strong constraints.
- With increasing depth of photometry and coverage comes increasing precision in the reconstructed total star formation history.

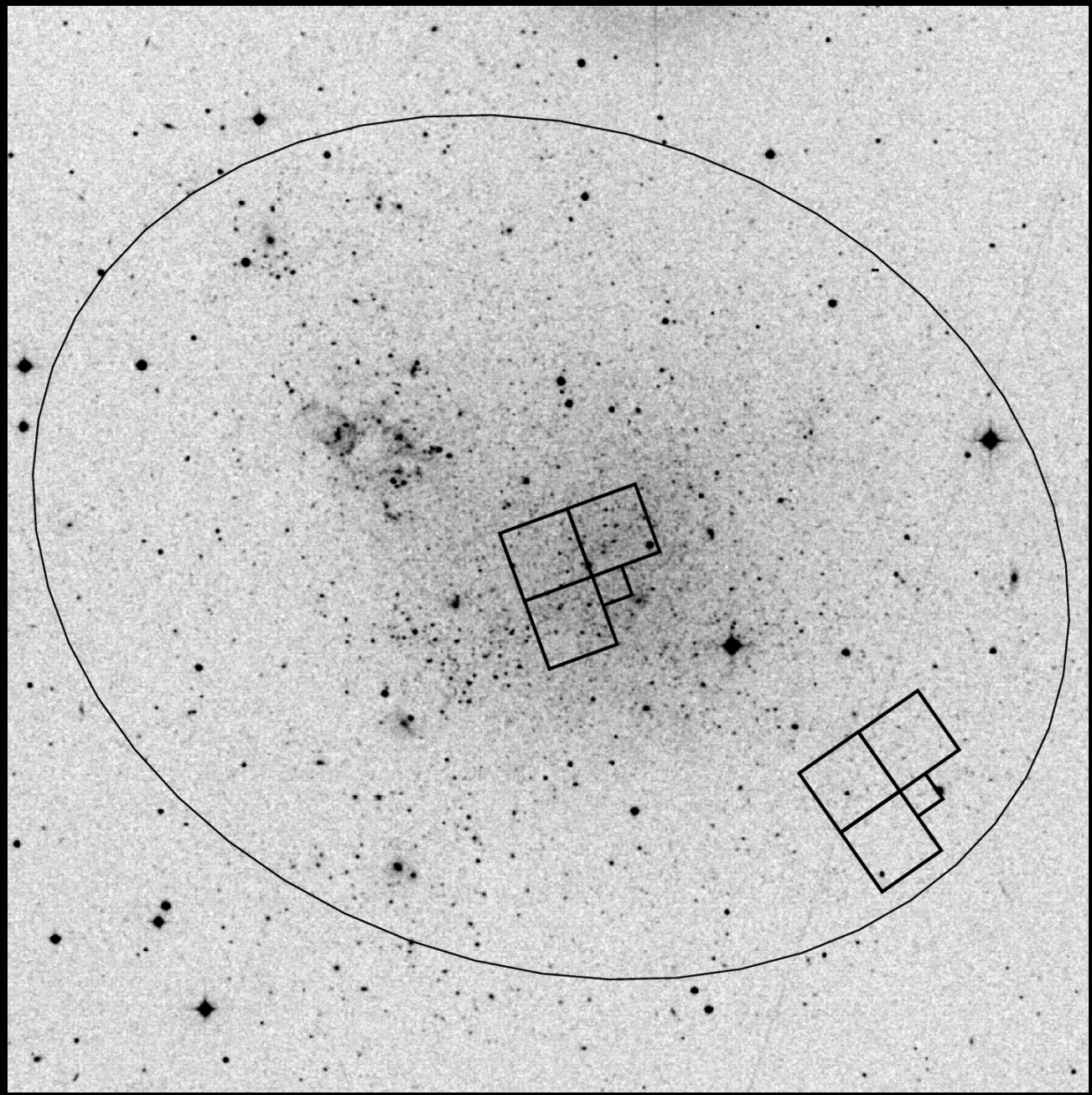
A Specific Example

IC 1613

Outer Field

Deep WFPC2 HST Observations

8 V, 16 I orbits

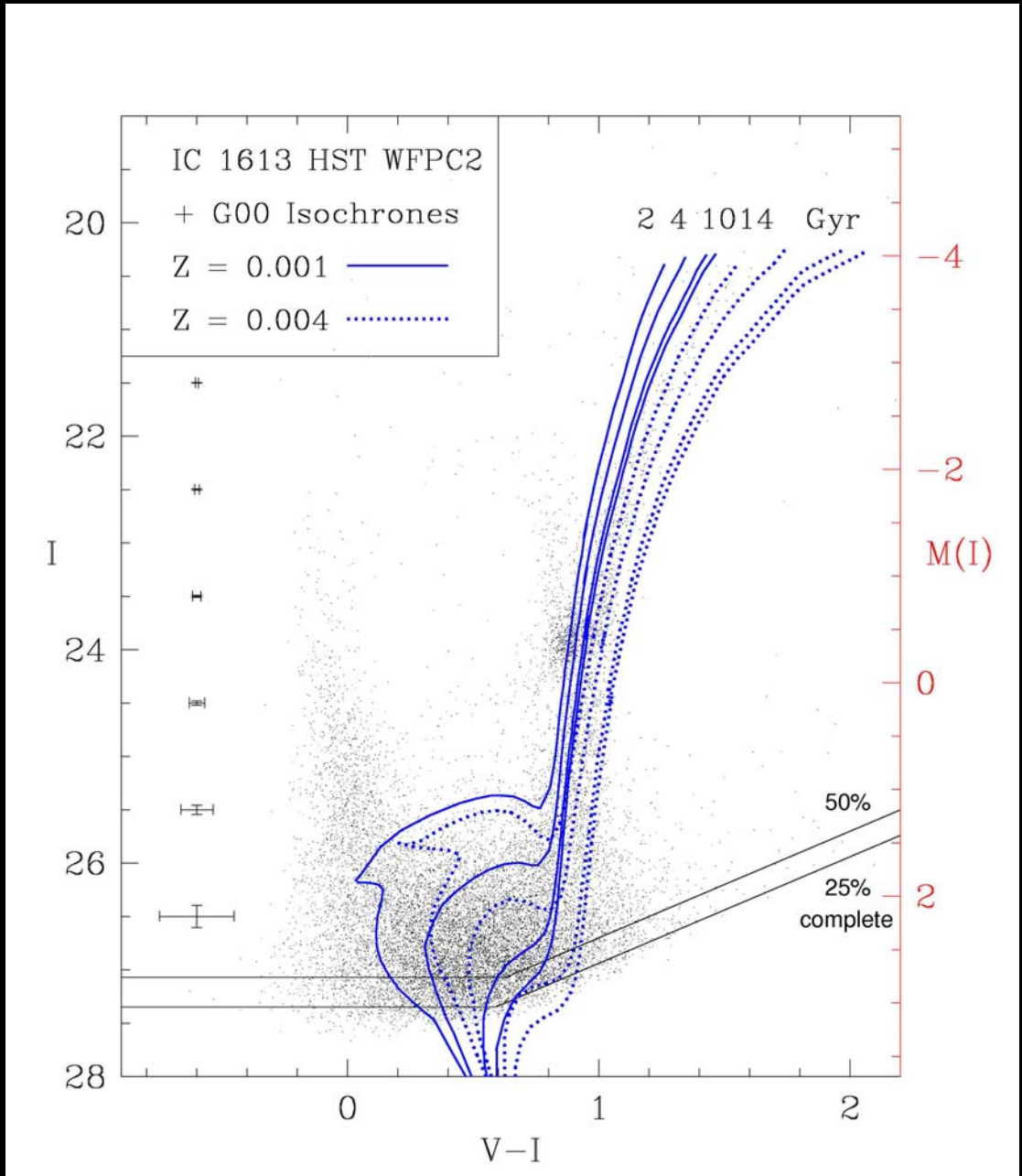


IC 1613

Outer Field

Deep WFPC2 HST Observations

The deepest color magnitude diagram of an isolated dwarf irregular galaxy to date



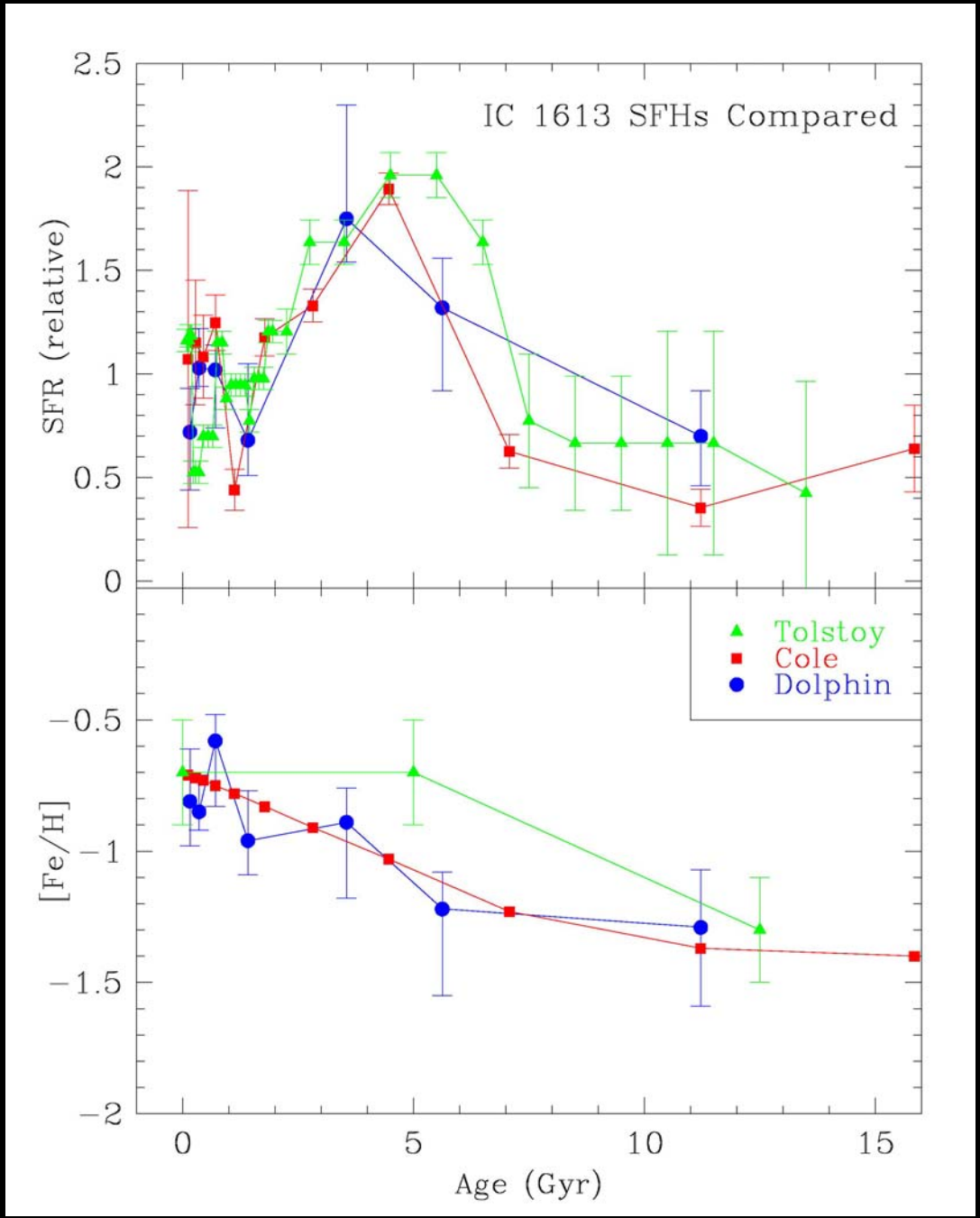
IC 1613

Outer Field

Deep HST Observations

3 Independent SFHs in good agreement

Star Formation appears to be “delayed” until intermediate ages.



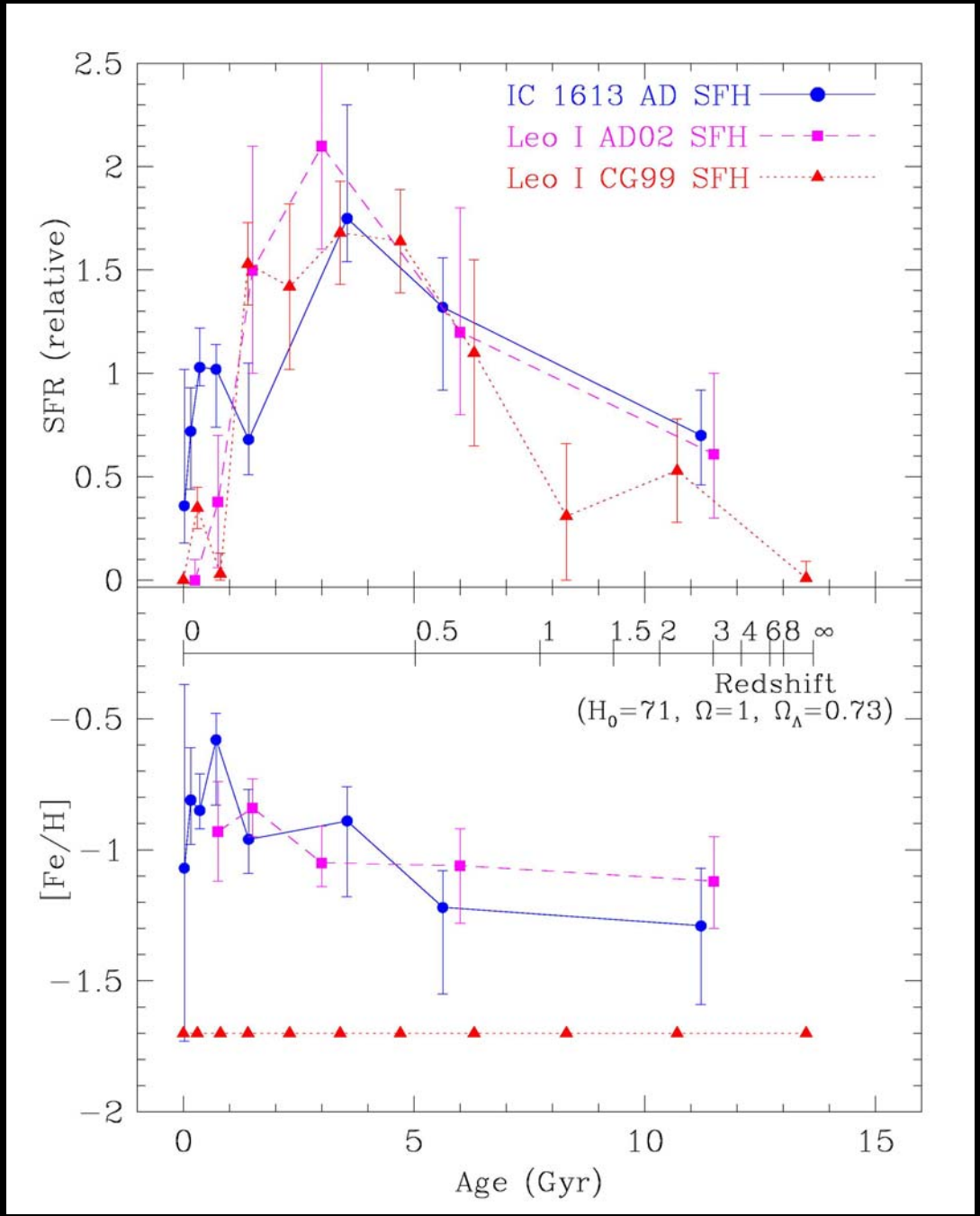
IC 1613

Outer Field

Deep HST Observations

SFH Compared with Leo I (dSph)

A dwarf spheroidal galaxy and a dwarf irregular galaxy appear to have nearly identical star formation histories.

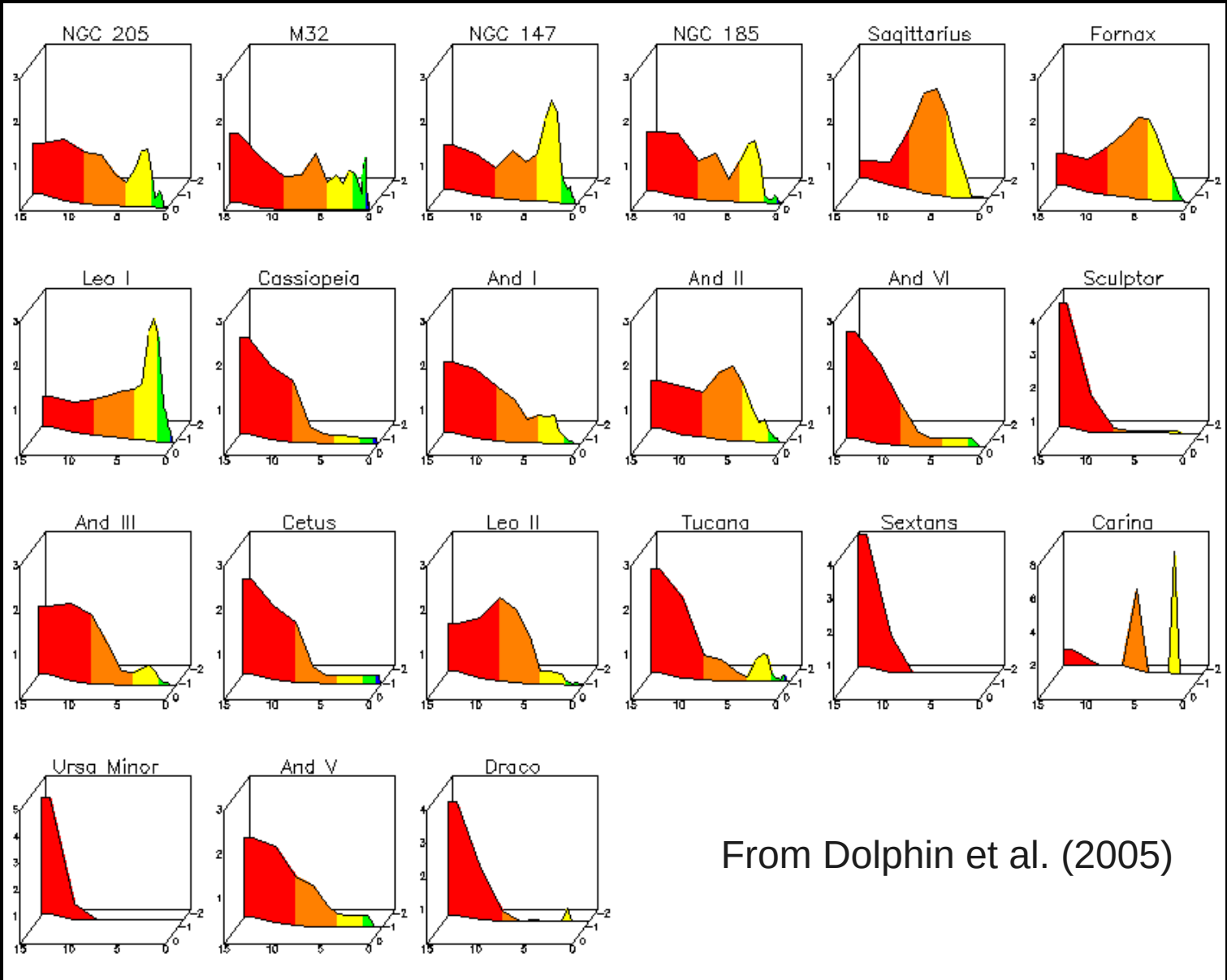


III. Comparing Star Formation Histories

- What is the ideal way to compare star formation histories?
- Uniformity of analysis is certainly important.
- Focus on robust measures is also key (e.g., measure the climate, not the weather).

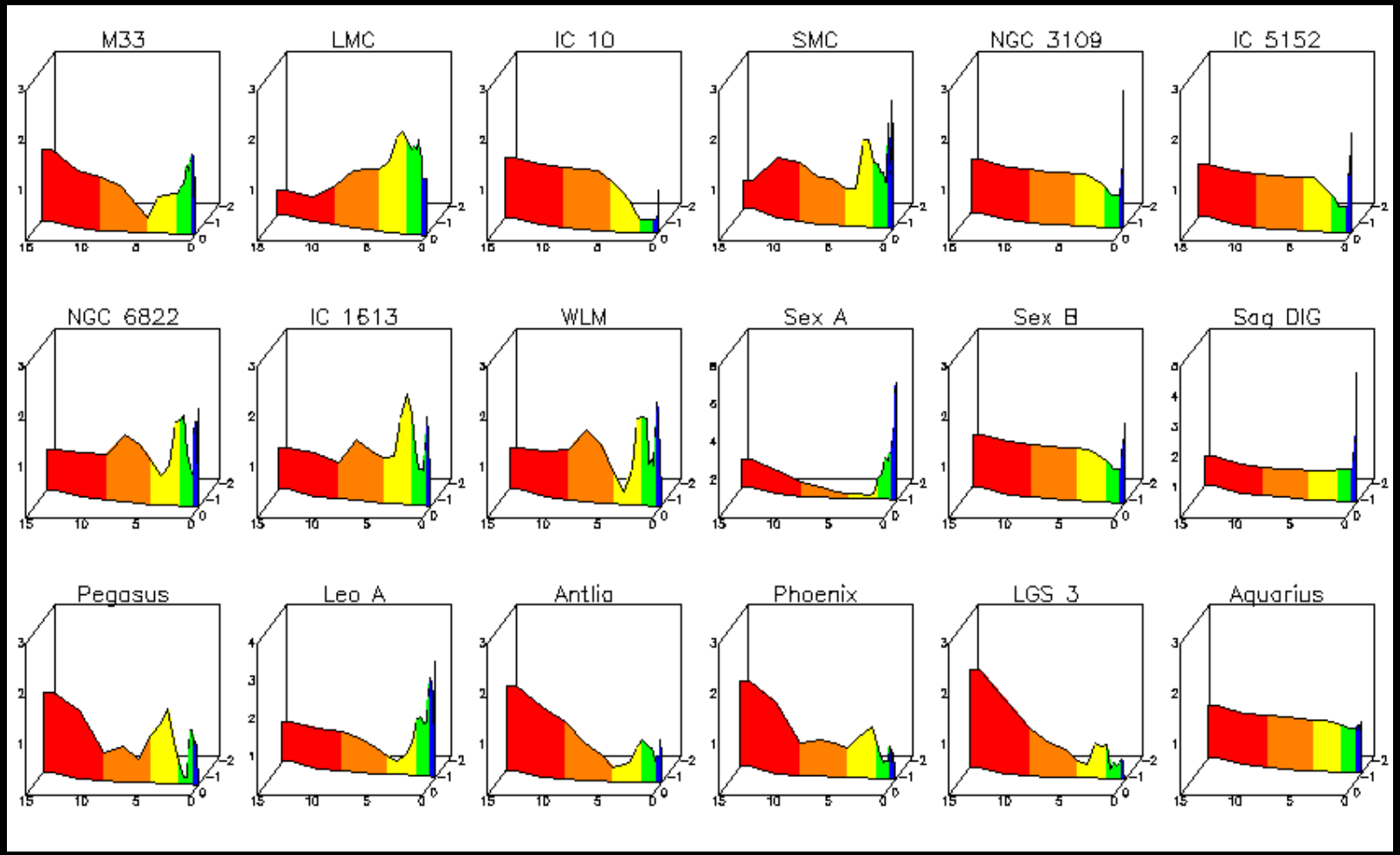
An HST Archival Legacy Program

- Holtzman and Dolphin have constructed an archive of all HST WFPC2 photometry in Local Group galaxies.
- Together with Weisz and EDS, the dwarf galaxies are being analyzed in a uniform manner.
- The most recent stellar evolution models are used.
- Systematic uncertainties in the isochrones are estimated.
- Random errors are quantified using Monte Carlo techniques.
- Well defined statistical measures are identified.



From Dolphin et al. (2005)

Preliminary Results: Hodge Population Boxes for the LG dwarf ellipticals



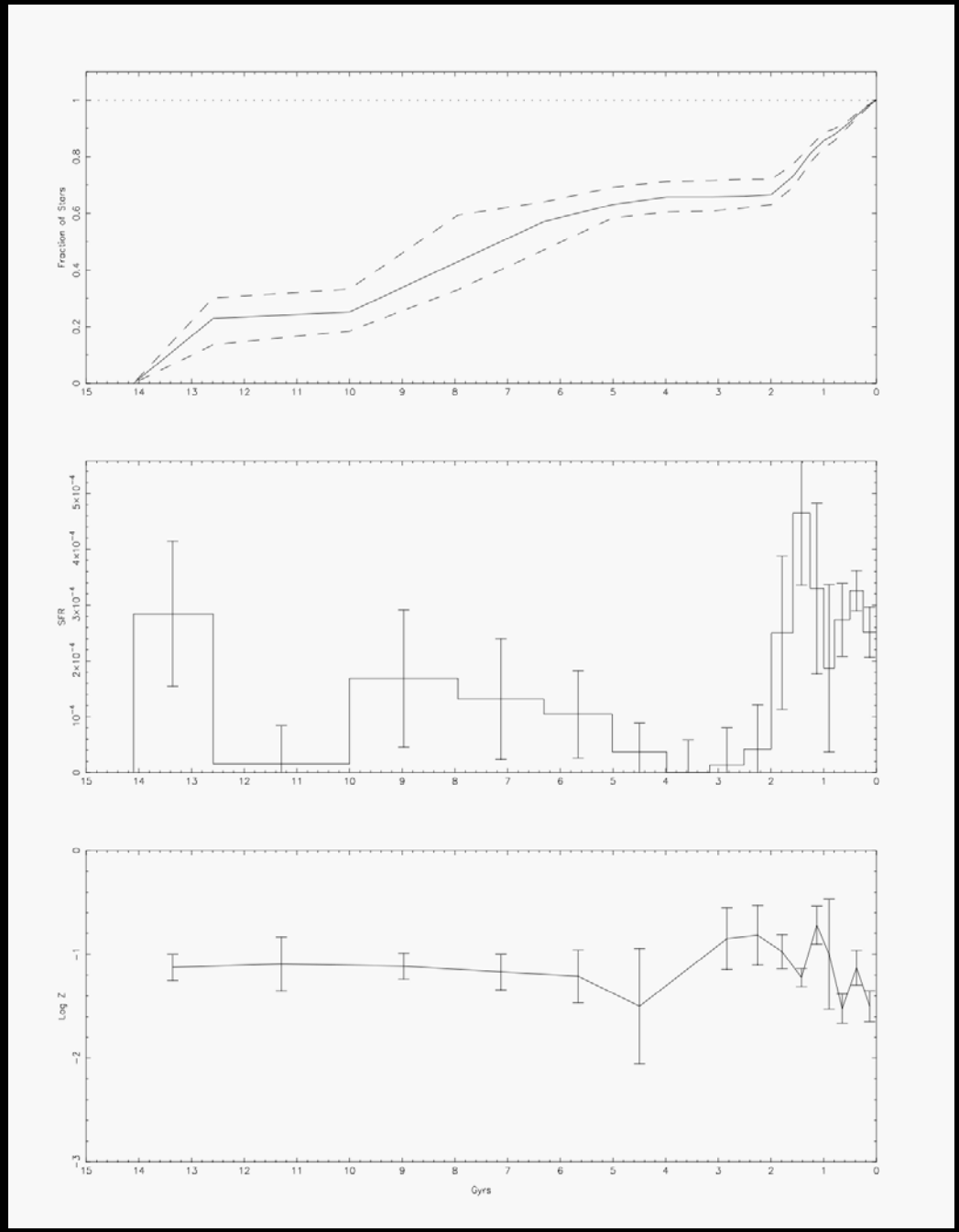
Preliminary Results: Hodge Population Boxes for the LG dwarf irregulars and transition types. From Dolphin et al. (2005)

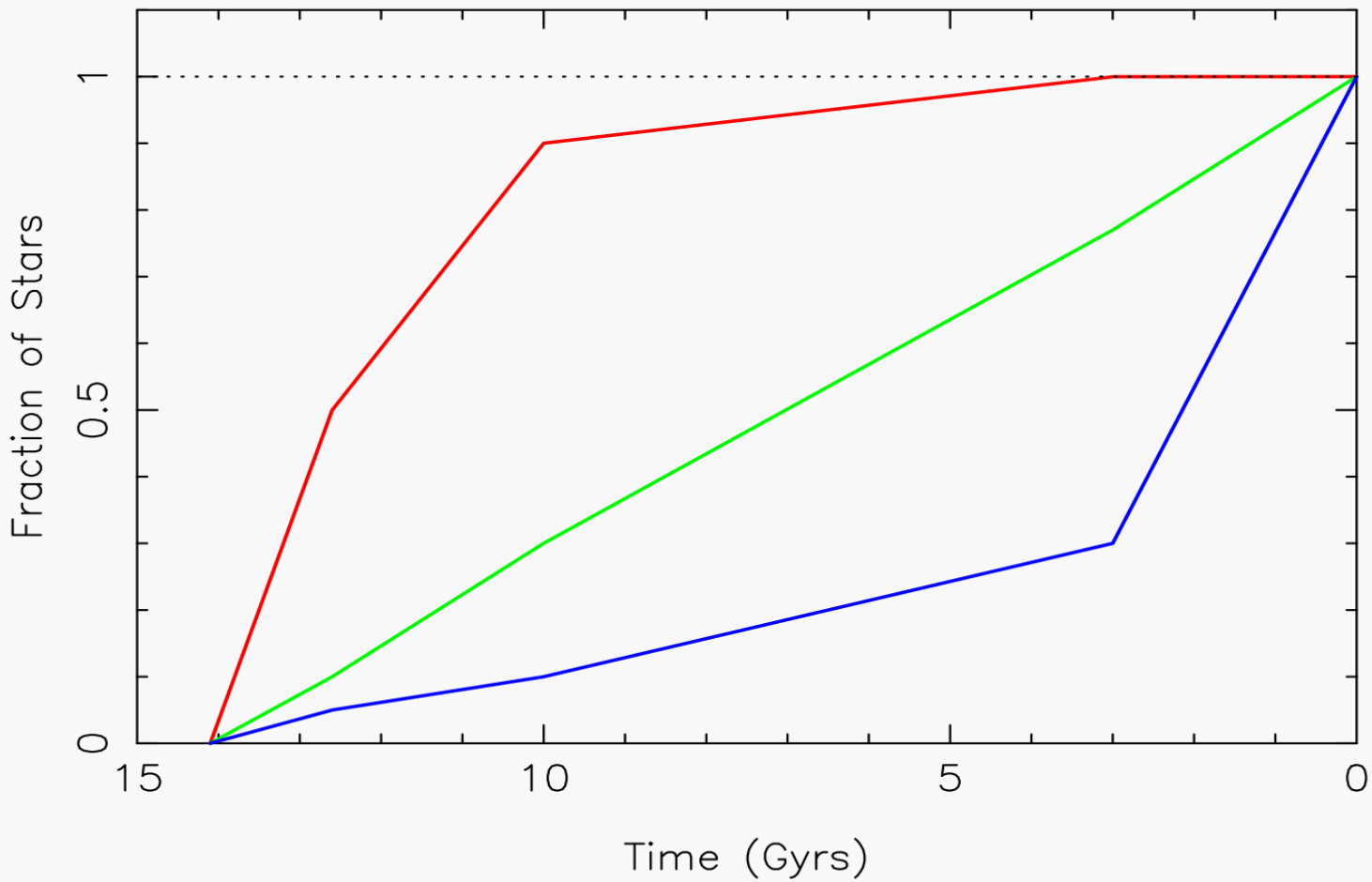
Example solution for a single field (in Leo A). SFH in middle plot; chemical enrichment history in lower plot.

Note: Errors in adjacent time bins are correlated.

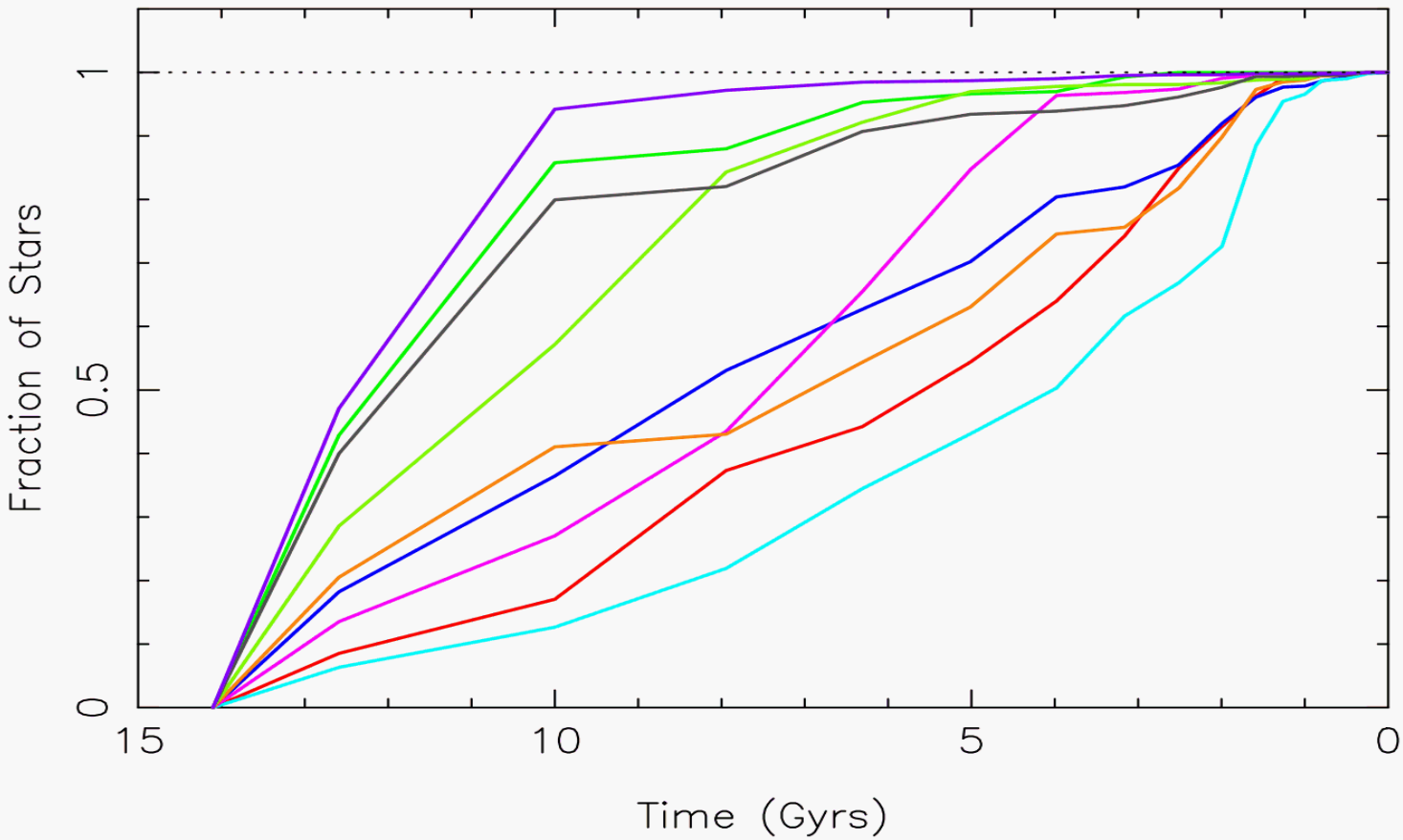
Impression of SFH affected by time binning.

The cumulative star formation (top plot) is a more robust measure.

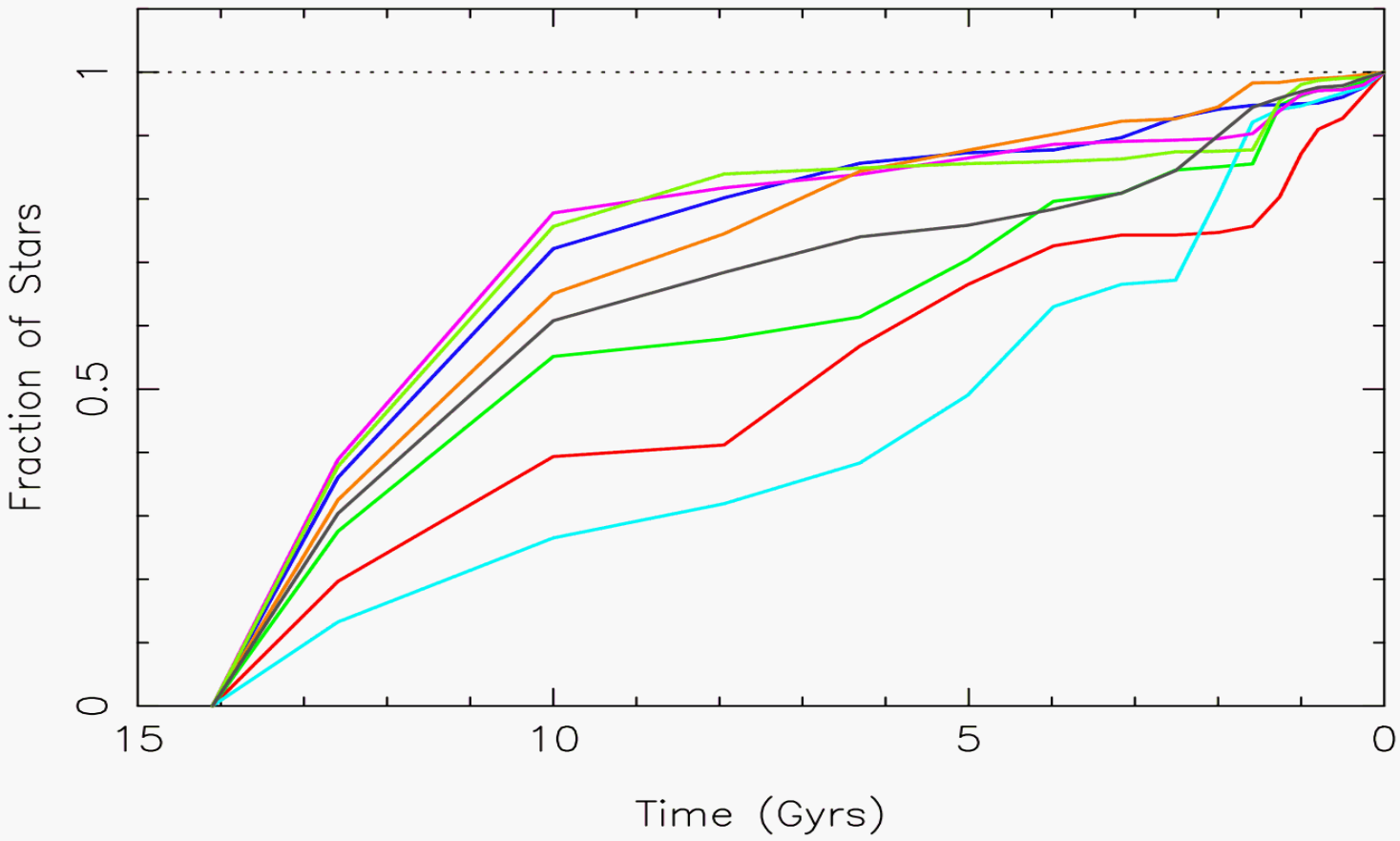




Schematic Holtzman diagram



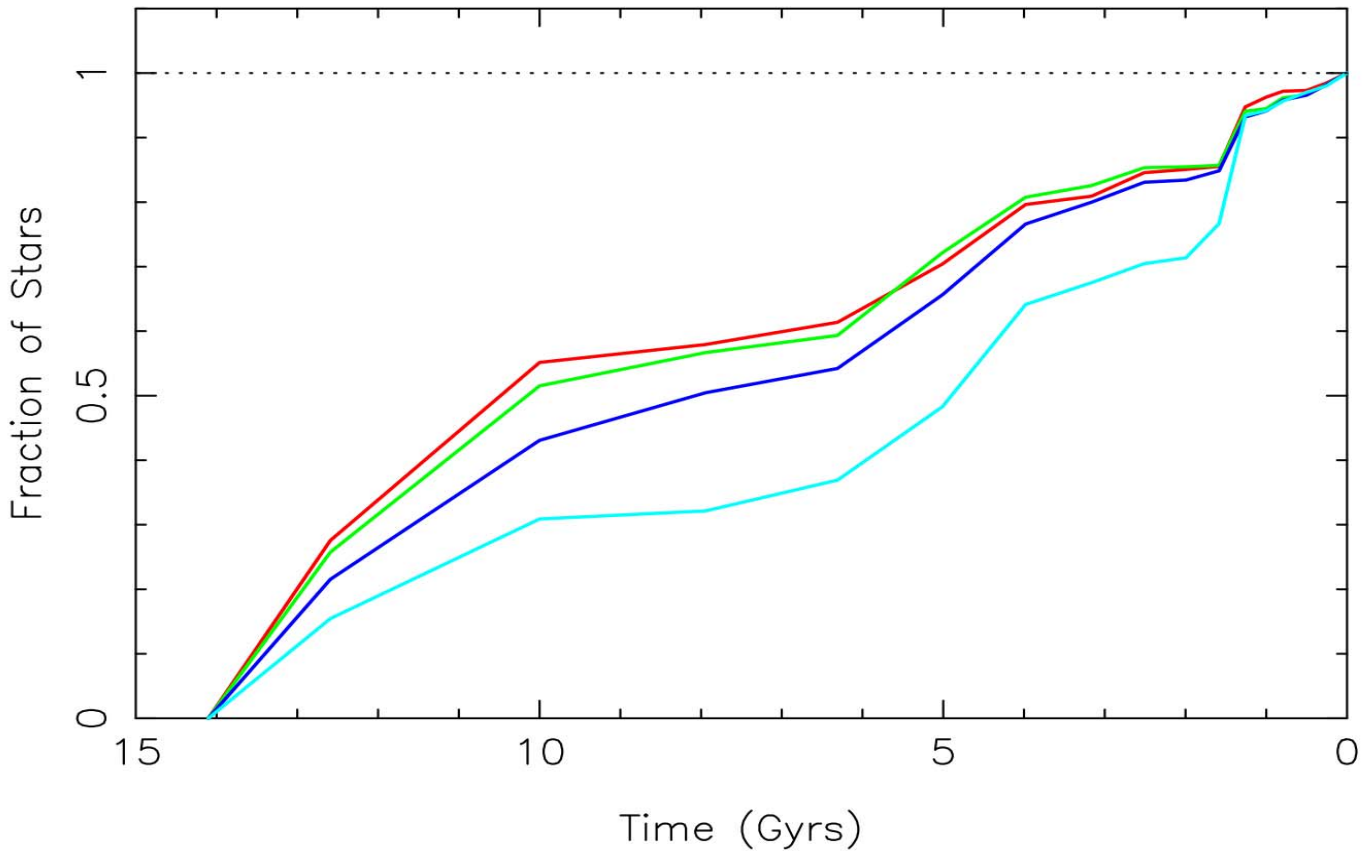
Holtzman diagram of dSphs in the Local Group



Holtzman diagram of dIrrs and transition types in the Local Group

What About Radial Gradients?

- Both dSphs and dIrrs show evidence of radial gradients in their stellar populations in the sense of more concentrated younger and more metal rich stars.
- Are star formation histories dominated by local or global variations?



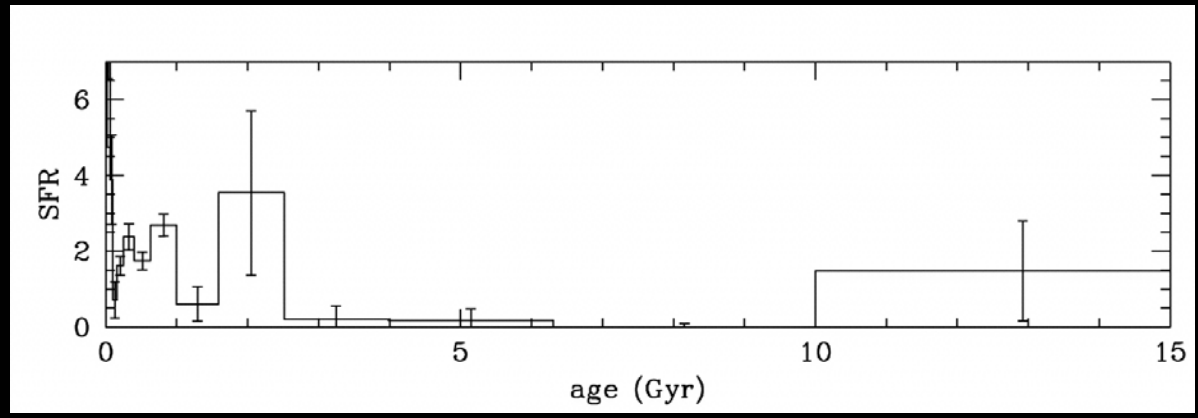
Holtzman diagram of multiple fields in the dwarf irregular NGC 6822

IV. What Processes Matter?

- The star formation histories of the different types of dwarf galaxies appear to show similar ranges in variety.
- What are the possible processes which determine their differences?
- Historically, the favored explanation for SFH variations has been interactions.
- Can we determine the dominant processes on a case-by-case basis or even on a statistical basis?

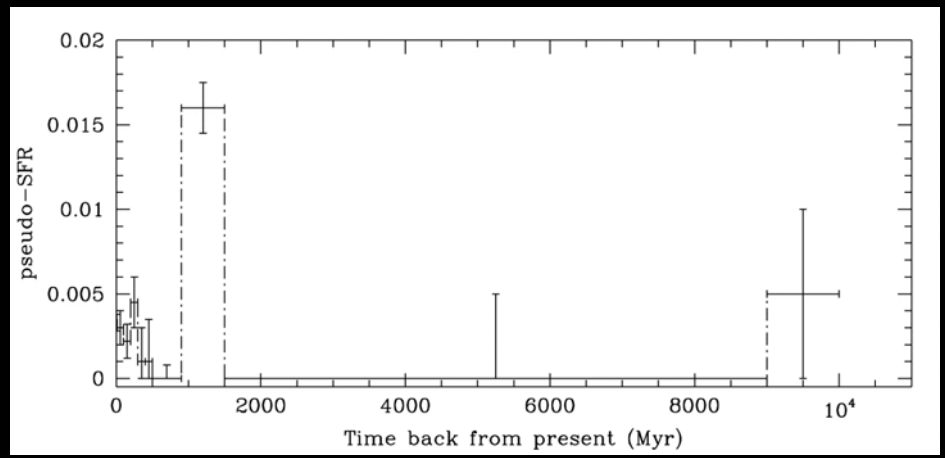
Sextans A
Total Star Formation History

(Dolphin et al. 2003)



Leo A
Total Star Formation History

(Tolstoy et al. 1998)



In some low mass, dwarf irregular galaxies, star formation appears to be delayed to very late times. Is this evidence of suppression of star formation by background radiation?

Example Transition type

Phoenix dSph/dIrr

D = 0.41 Mpc

Star formation as recent as 100 Myr ago (Martinez-Delgado et al. 1999; Held et al. 1999; Holtzman et al. 2000)

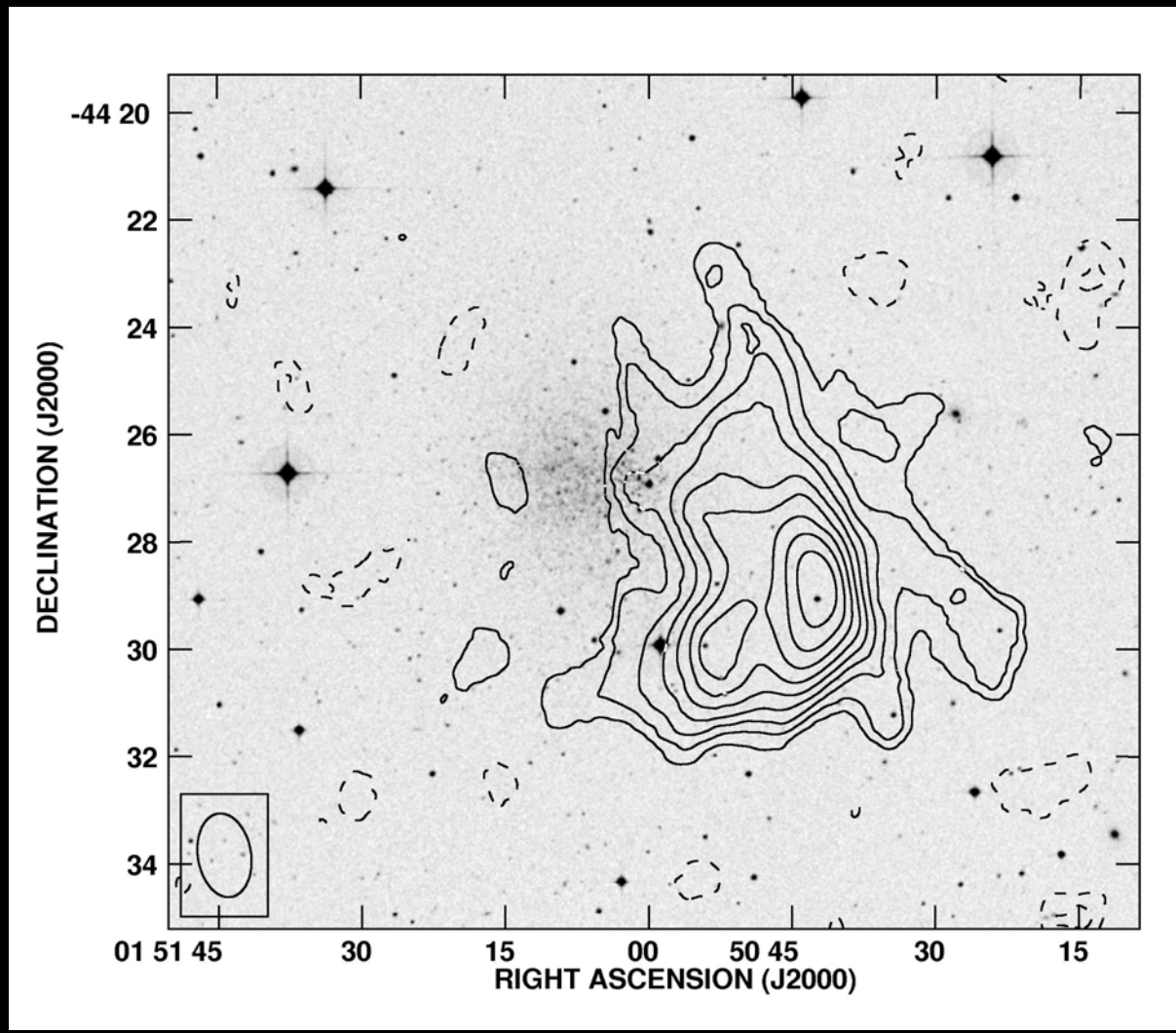
Phoenix dSph/dIrr in HI

(new VLA Observations with Lisa Young)

HI mean velocity = -20 km/s (Young & Lo 1997)

Stars mean velocity = -13 km/s (Irwin & Tolstoy 2002)

The creation of a dSph from a dIrr?



What Are Dwarfs Telling Us?

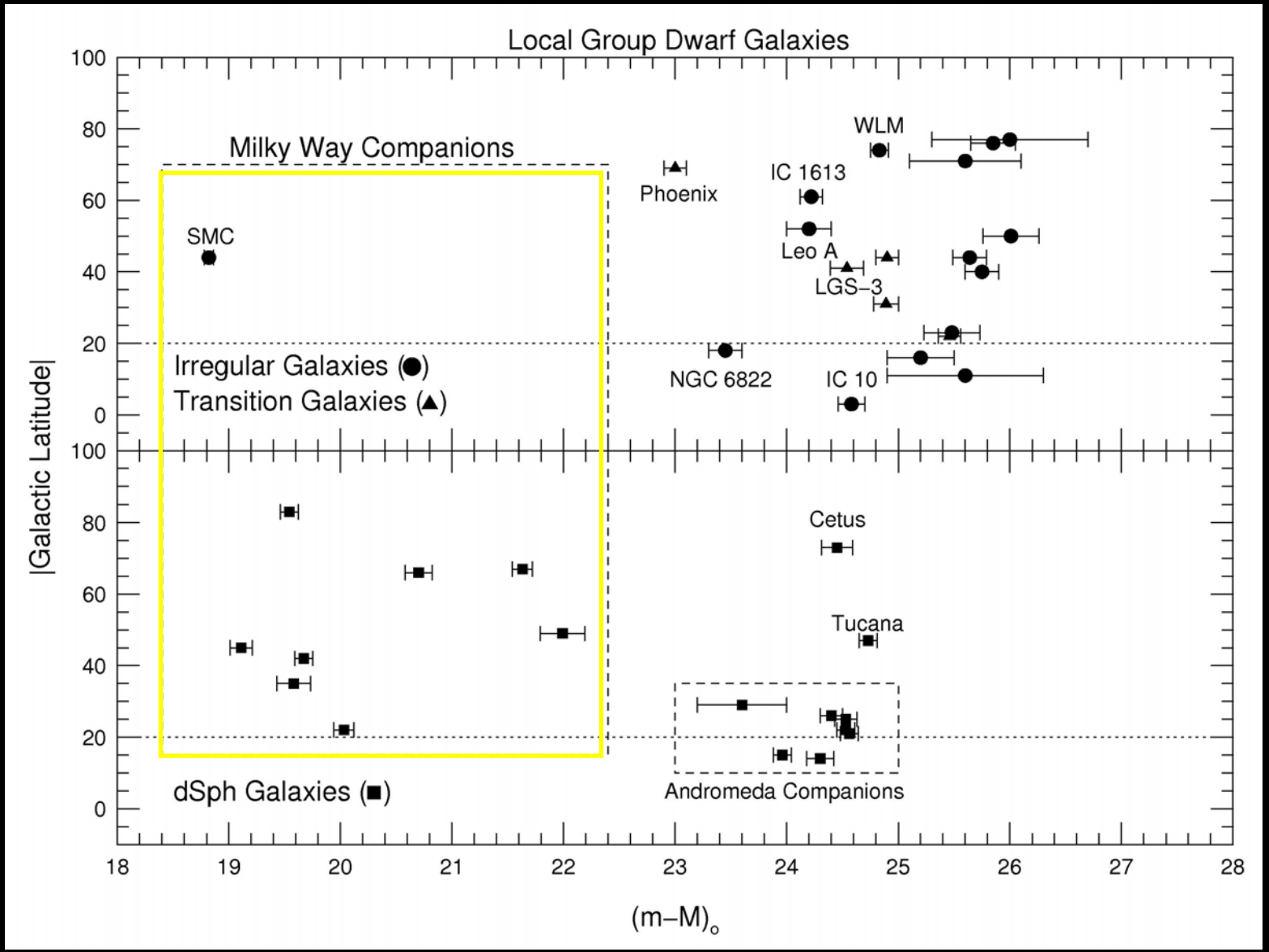
- All dwarfs show evidence of ~10 Gyr stars.
- SFHs show a large variety. Certainly in the MW dSph companions, but also in the dIrrs.
- The SFHs may be revealing the effects of x-ray background from re-ionization (delayed galaxy formation, squelching, suppression).
- Since there are probably several channels for dIrr => dSph conversion, dwarfs hold great promise for telling us about environment.

Why it doesn’t Matter

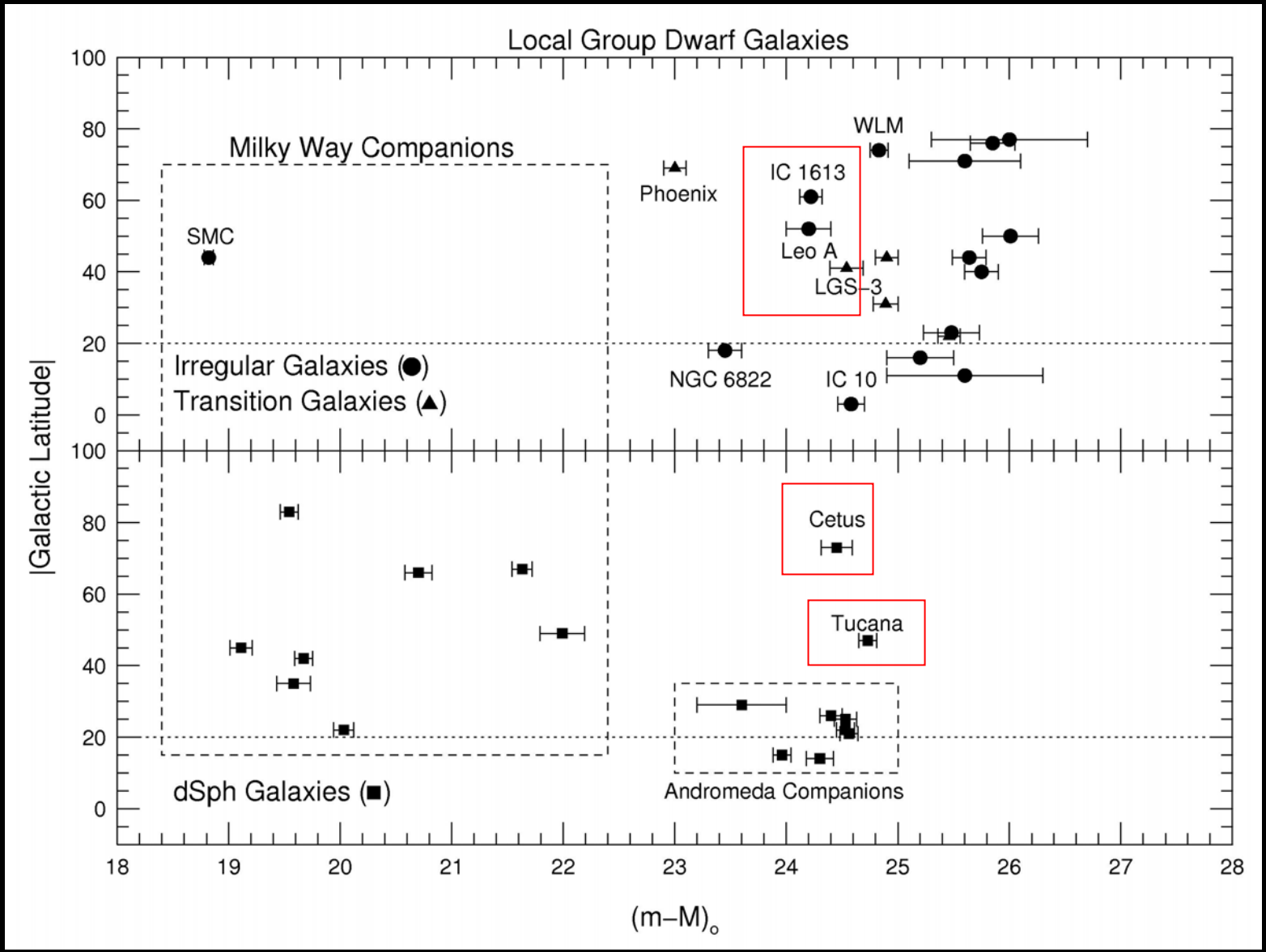
- Why isn’t the signature of the process which removes the gas obvious in the structural parameters?
- Perhaps the uniformity of the dark matter halos dominates all other factors, so, in the end, all low mass systems without cold gas end up looking the same (Dekel & Silk 1986)

V. What's Next

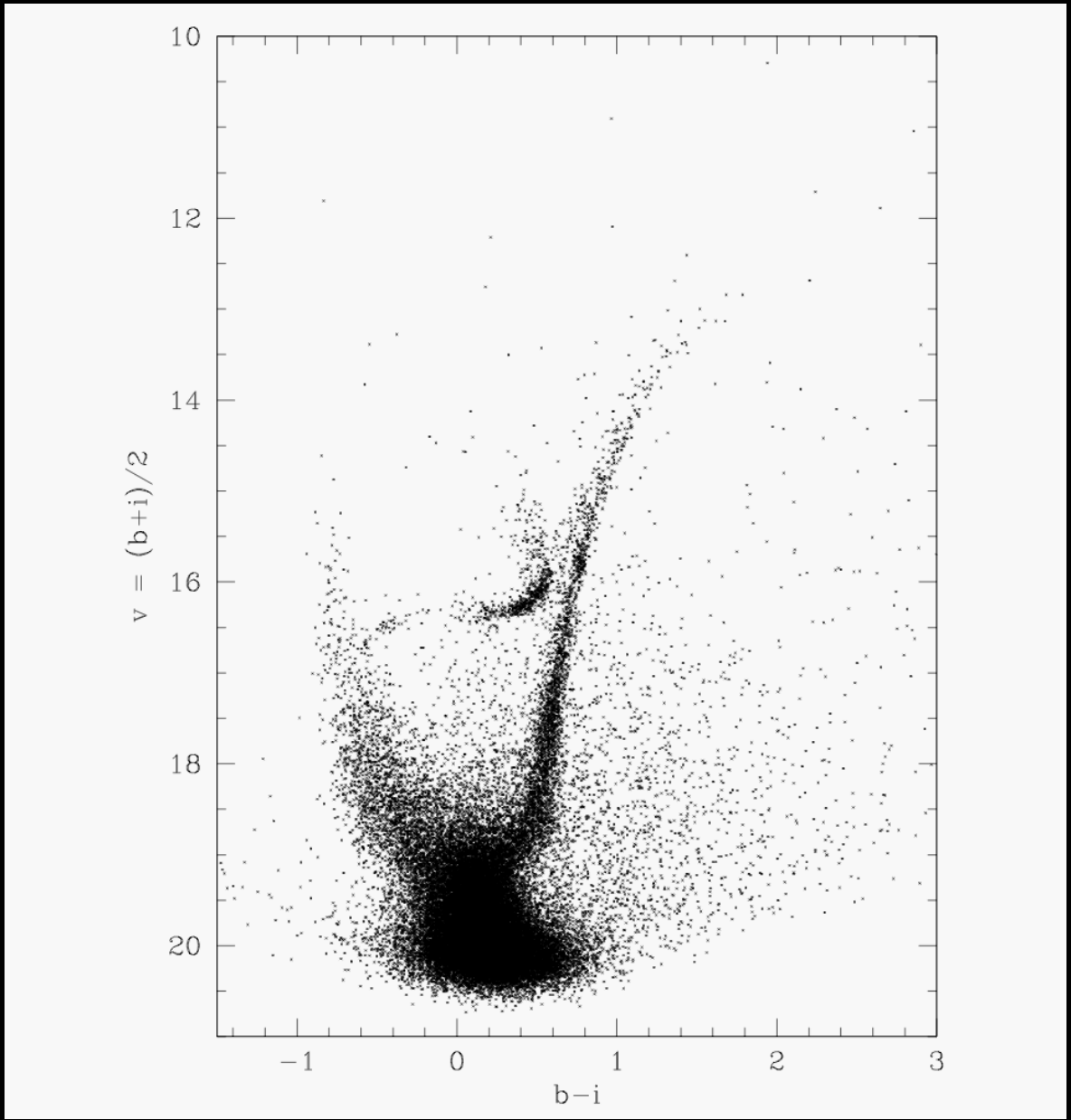
- If suppression of star formation by the background ionizing radiation is important, we expect to see the effects in the star formation histories of dwarf galaxies.
- Deep color-magnitude diagrams of the nearest dwarf irregulars are needed to provide secure star formation histories.
- Two programs for 5 Local Group dwarfs have been awarded to do this in cycle 14 with HST ACS imaging (PIs = Carme Gallart, Andrew Cole).



Our view of dwarf galaxy evolution is biased by the MW companions.



Our new HST targets are the nearest isolated dwarf galaxies.



Our first data: LGS-3 (reduction by Peter Stetson).

Something Exciting:

- The improved time resolution at earlier ages will allow us to test early evolution of dwarfs.
- Combining with WFPC2 fields allows us to study the radial gradients which appear to be ubiquitous.
- We have sufficiently long observations and sensitivity to survey the RR Lyraes.

Summary:

- Local Group Dwarfs can provide us with SFHs for a large sample of galaxies.
- The star formation histories of dwarf irregular and dwarf spheroidal galaxies show more similarities than differences.
- The global star formation histories point to important processes that determine the evolutionary state (morphology).
- The goal is a dynamic (not static) view of the Local Group.