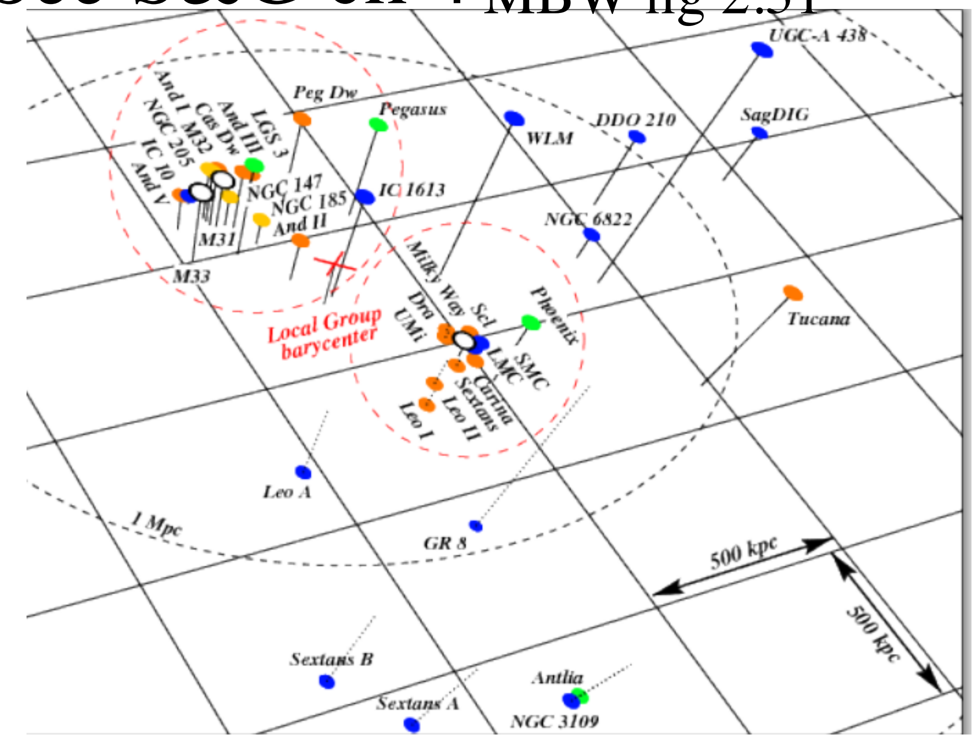
Local Group See S&G ch 4 MBW fig 2.31



- Our galactic neighborhood consists of one more 'giant' spiral (M31, Andromeda), a smaller spiral M33 and lots of (>35 galaxies), most of which are dwarf ellipticals and irregulars with low mass; **most are satellites of MW, M31 or M33**
- The gravitational interaction between these systems is complex but the local group is apparently bound.
- Major advantages
  - close and bright- all nearby enough that individual stars can be well measured as well as HI, H_2, IR, x-ray sources and even γ-rays
  - wider sample of universe than MW (e.g. range of metallicities, star formation rate etc etc) to be studied in detail
  - allows study of dark matter on larger scales and first glimpse at galaxy formation
  - calibration of Cepheid distance scale

ARA&A1999, V 9, pp 273-318 The local group of galaxies S. van den Bergh
Star formation histories in local group dwarf galaxies Skillman, Evan D.
New Astronomy Reviews, v. 49, iss. 7-9 p. 453-460.

Image of Local Group to Scale S&G Fig 4.1

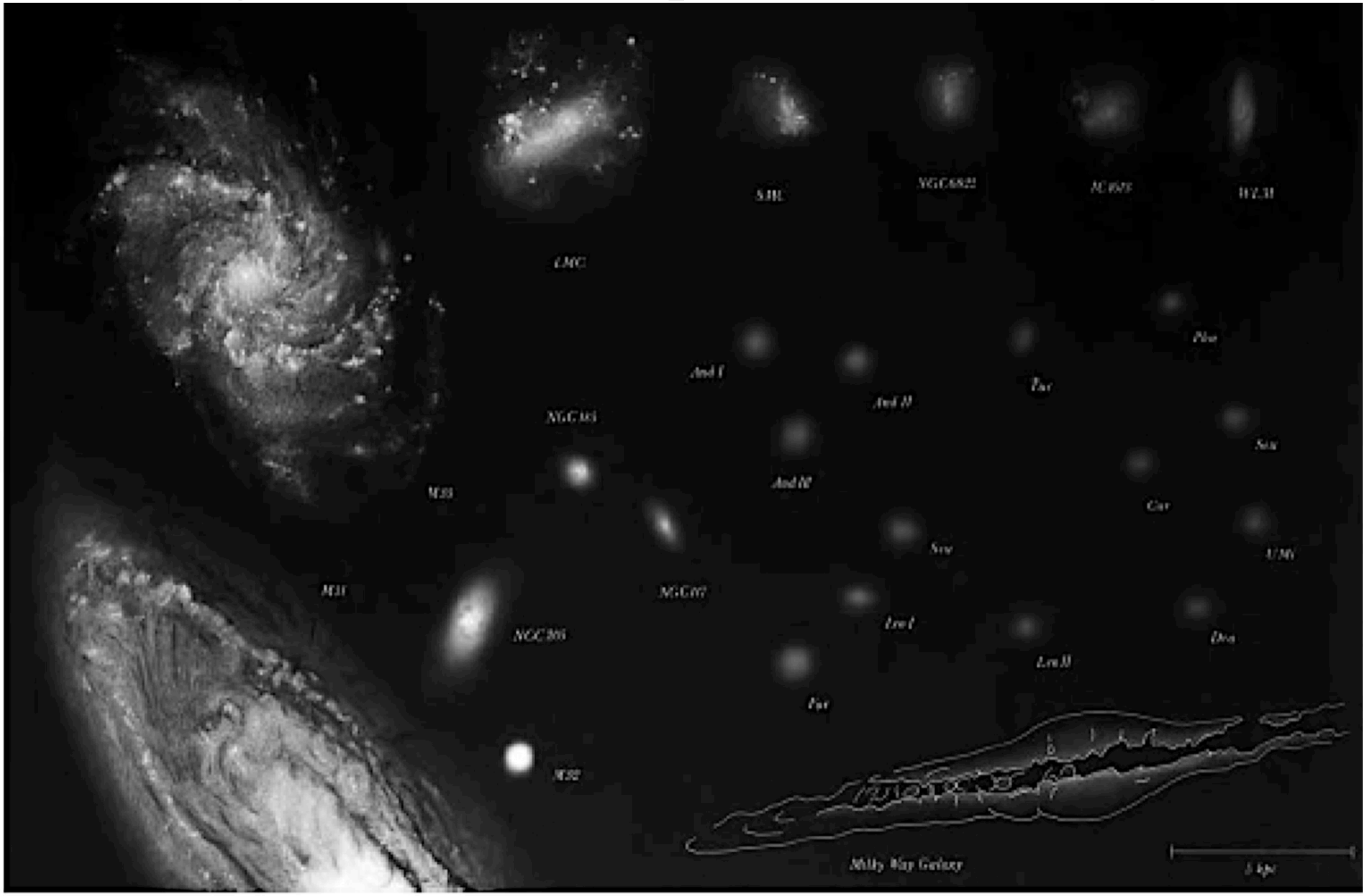


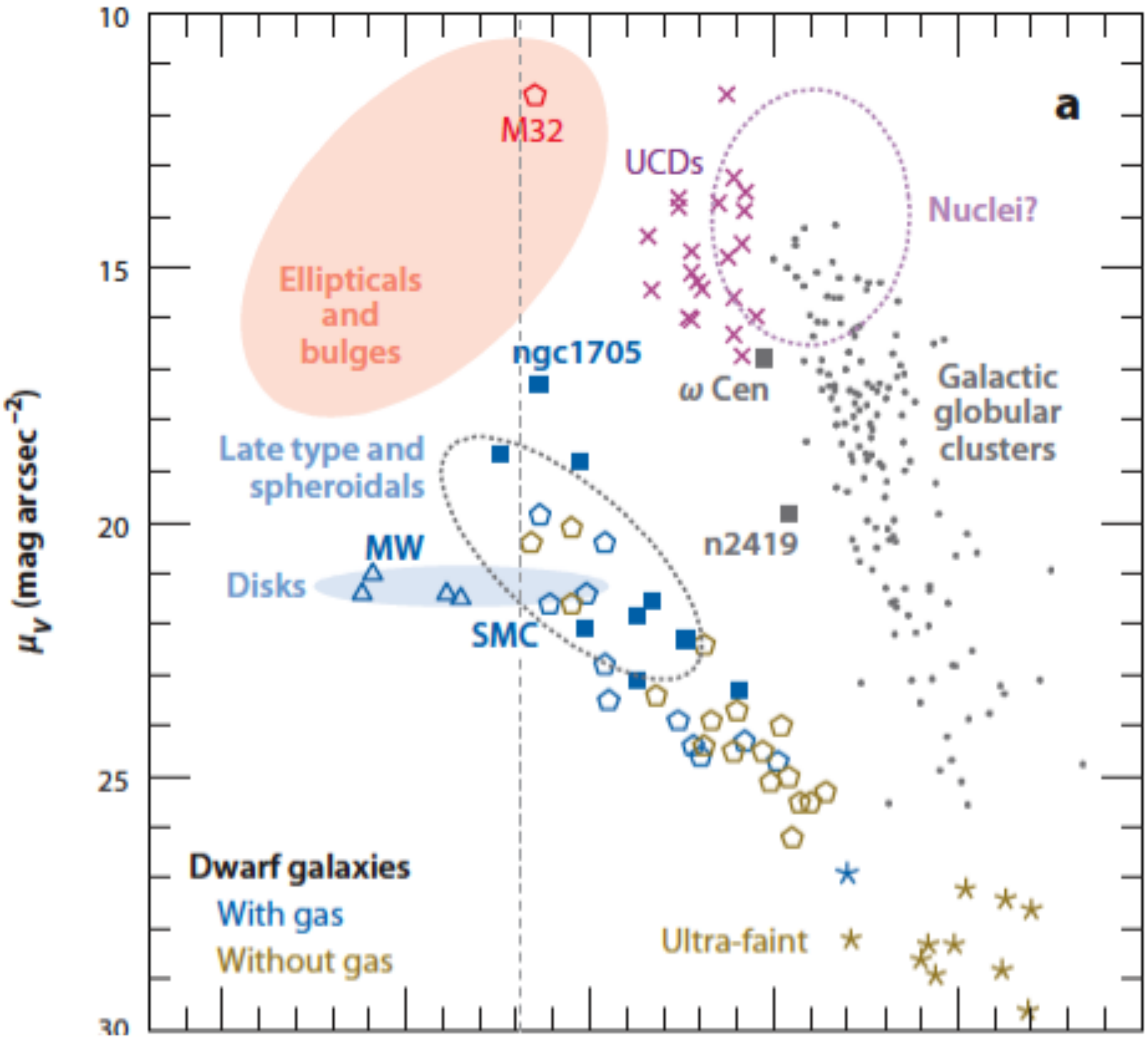
Fig. 4.1. Galaxies of the Local Group, shown to the same linear scale, and to the same level of surface brightness. The spiral and irregular galaxies stand out clearly, while the dwarf spheroidals are barely visible – B. Binggeli.

Local Group Galaxies -Wide Range of Luminosity

- Local Group dwarfs galaxies trace out a narrow line in the surface brightness luminosity- plane

(Tolstoy et al 2009)

see table 4.1 in S&G



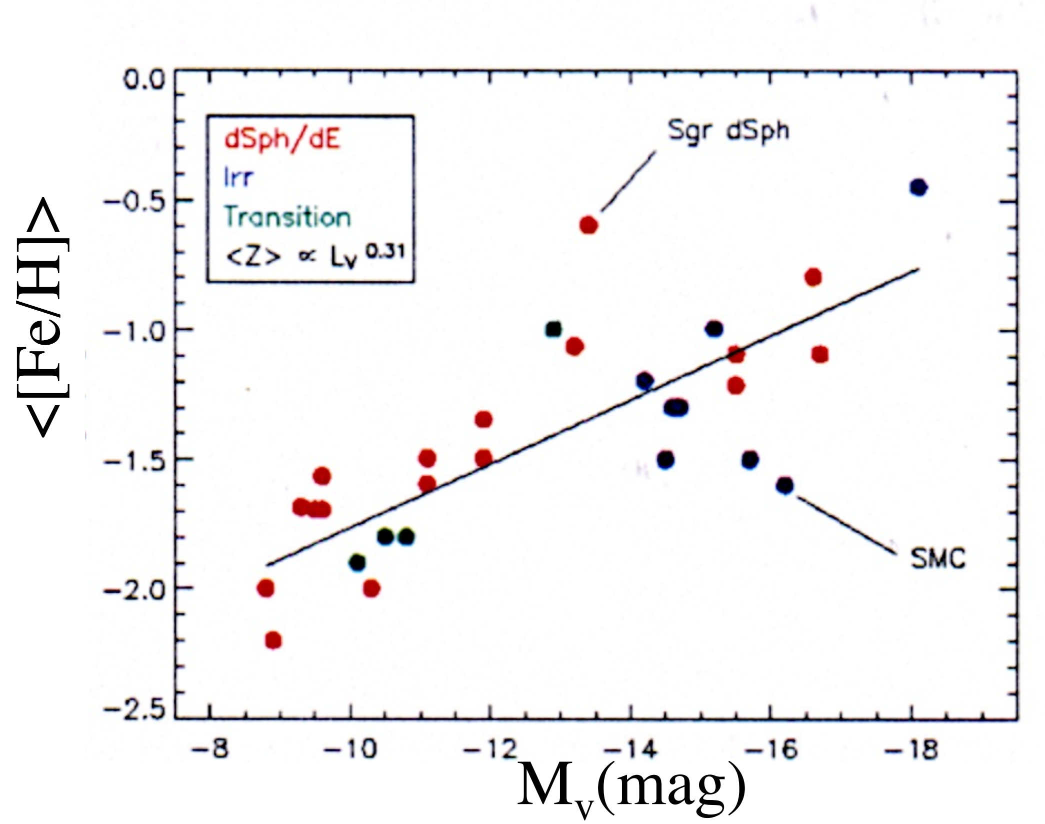
-25 -20 -15 -10 -5

$-M_V$

Wide Range of Luminosities

- MW/M31~$2\times10^{10} L_{v\odot}$
- LMC~$2\times10^{9} L_{v\odot}$
- Formax dSph $1\times10^{7}{}_{v}L_{\odot}$
- Carina dSph $3\times10^{5} L_{v\odot}$

- Because of closeness and relative brightness of stars the Color Magnitude Diagram combined with Spectroscopy of resolved stars can produce 'accurate'
  - star formation histories
  - Chemical evolution

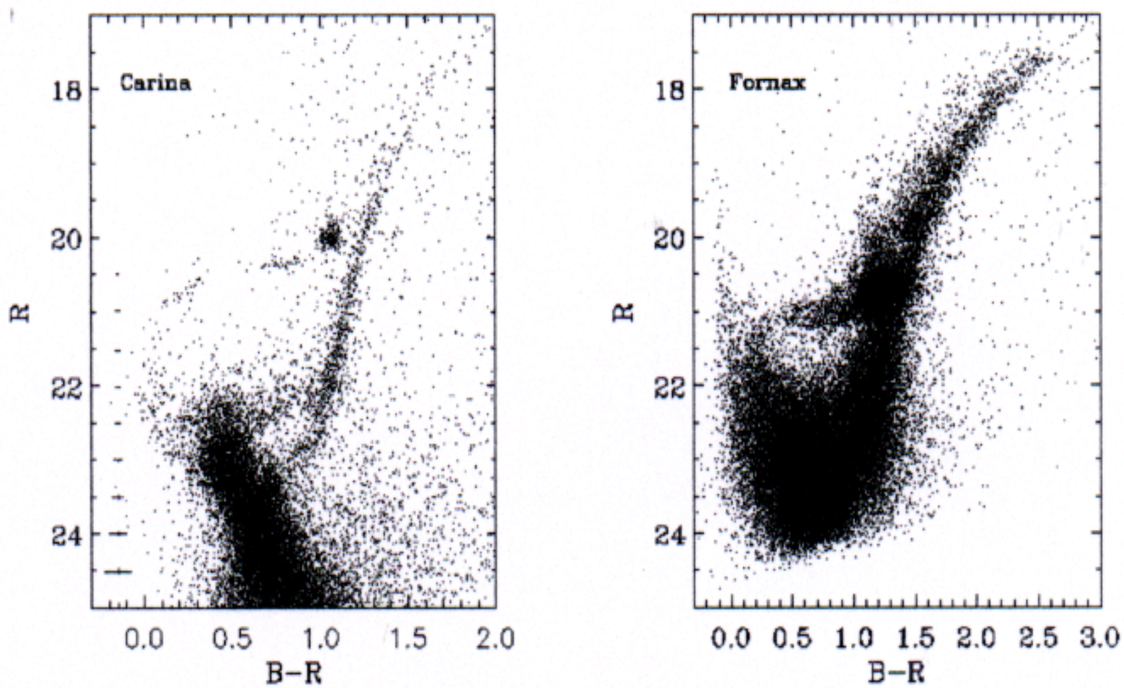


T. Smecker-Hane

Despite wide variety of 'local' environments (near/far from MW/M31) trends in chemical composition seem to depend primarily on galaxies properties

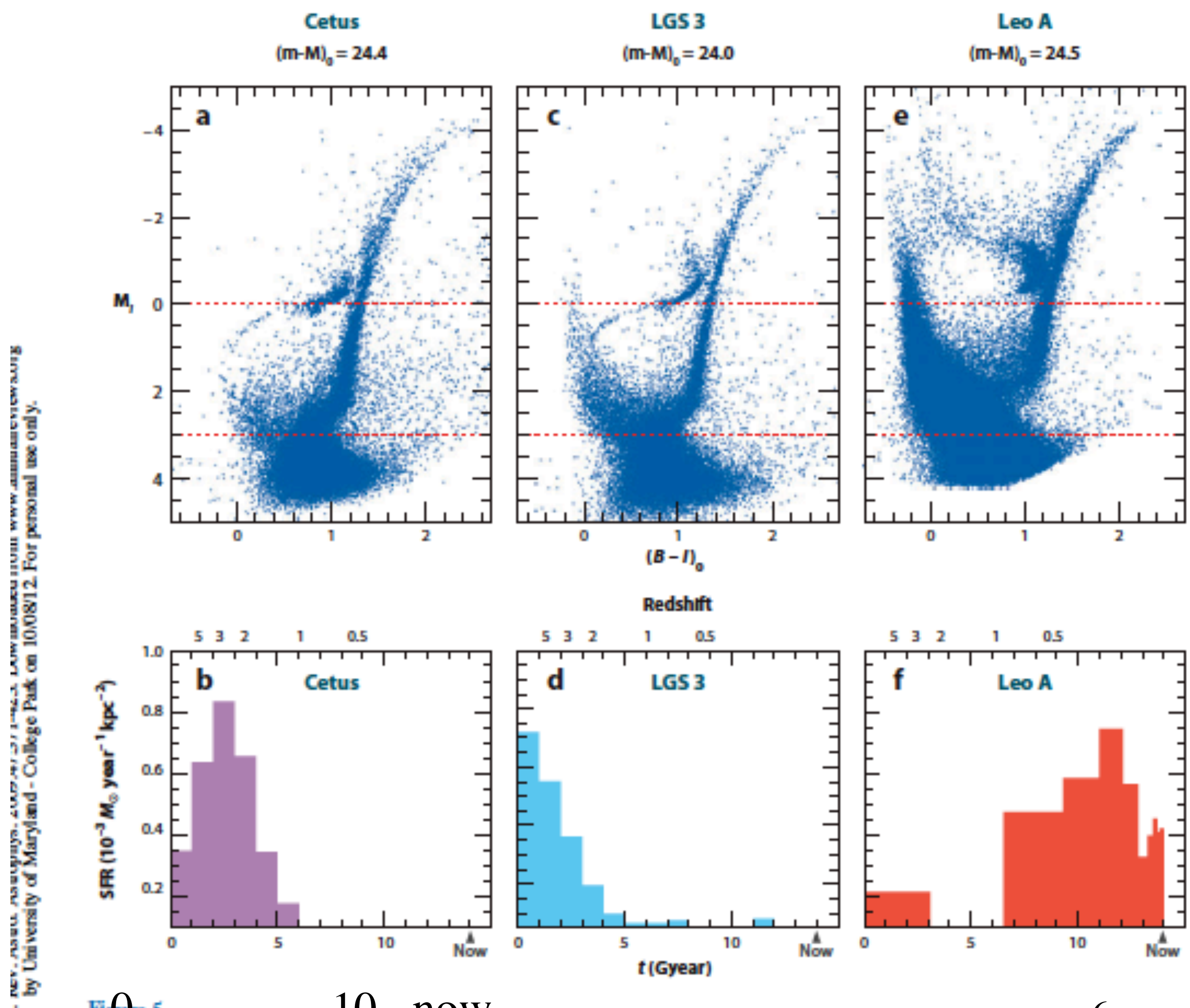
Star Formation Histories

- Analysis of CMDs shows presence of both old and (some) young stars in the dwarfs -complex SF history
- The galaxies do not show the same SF history- despite their physical proximity and being in a bound system
- Their relative chemical abundances show some differences with low metallicity stars in the MW.



Star Formation Histories Local Group Dwarfs

- With HST can observed color magnitude diagram for individual stars in local group galaxies
- Using the techniques discussed earlier can invert this to get the star formation history
- Note 2 extremes: very old systems Cetus, wide range of SF histories (Leo A)
- (Tolstoy, Hill, Tosi Annual Reviews 2009)

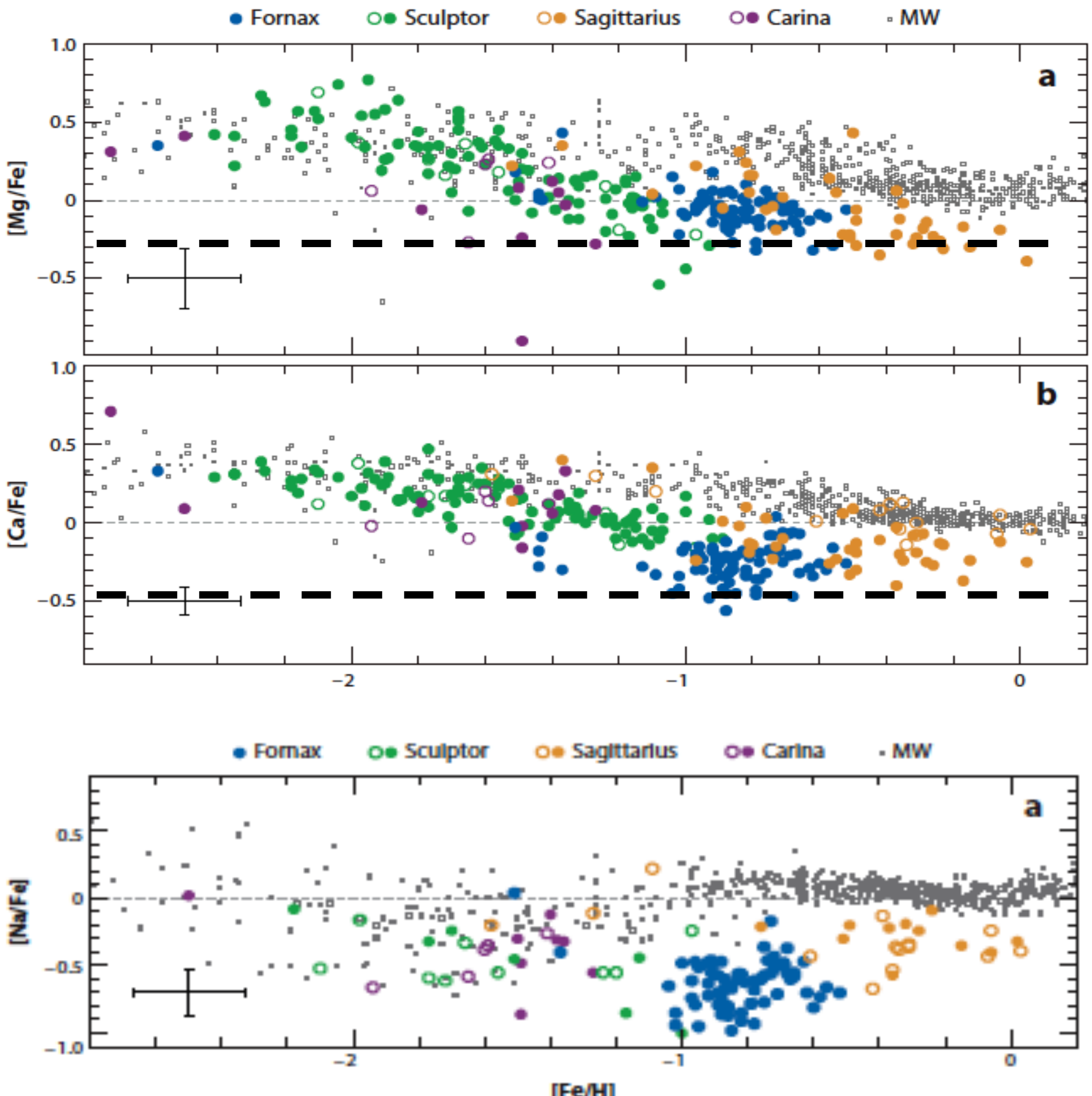


0 10 now

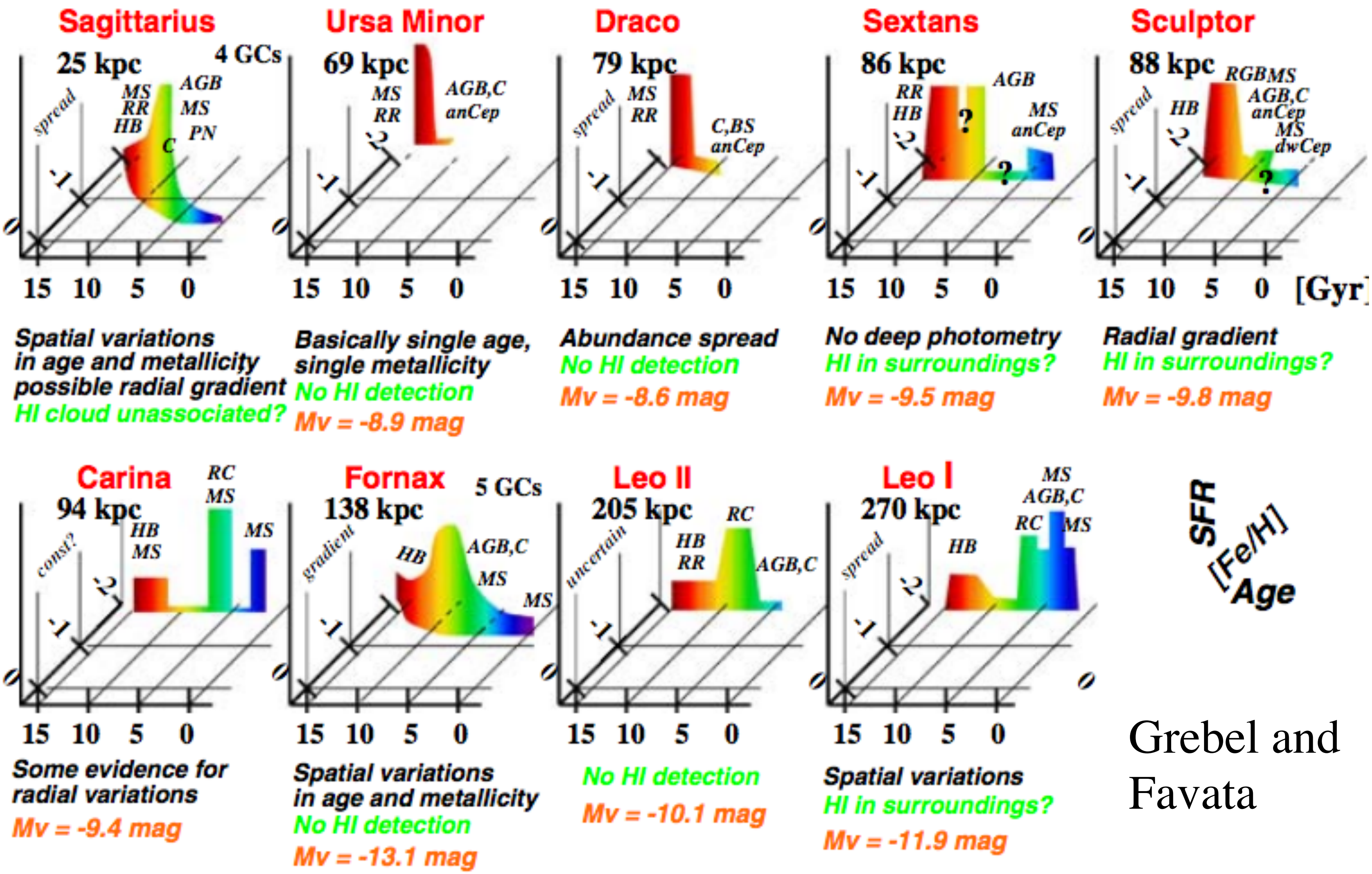
t (Gyr)

Metallicities In LG Dwarfs Vs MW

- Overall metallicity of LG dwarfs is low but some patterns similar others different to stars in MW (black dots- Tolstoy et al 2009)-
- How to reconcile their low observed metallicity with the fairly high SFR of the most metal-poor systems many of which are actively star-forming
- best answer metal-rich gas outflows, e.g. **galactic winds**, triggered by supernova explosions in systems with shallow potential wells, efficiently remove the metal-enriched gas from the system.
- In LG can wind models be well constrained by chemical abundance observations.

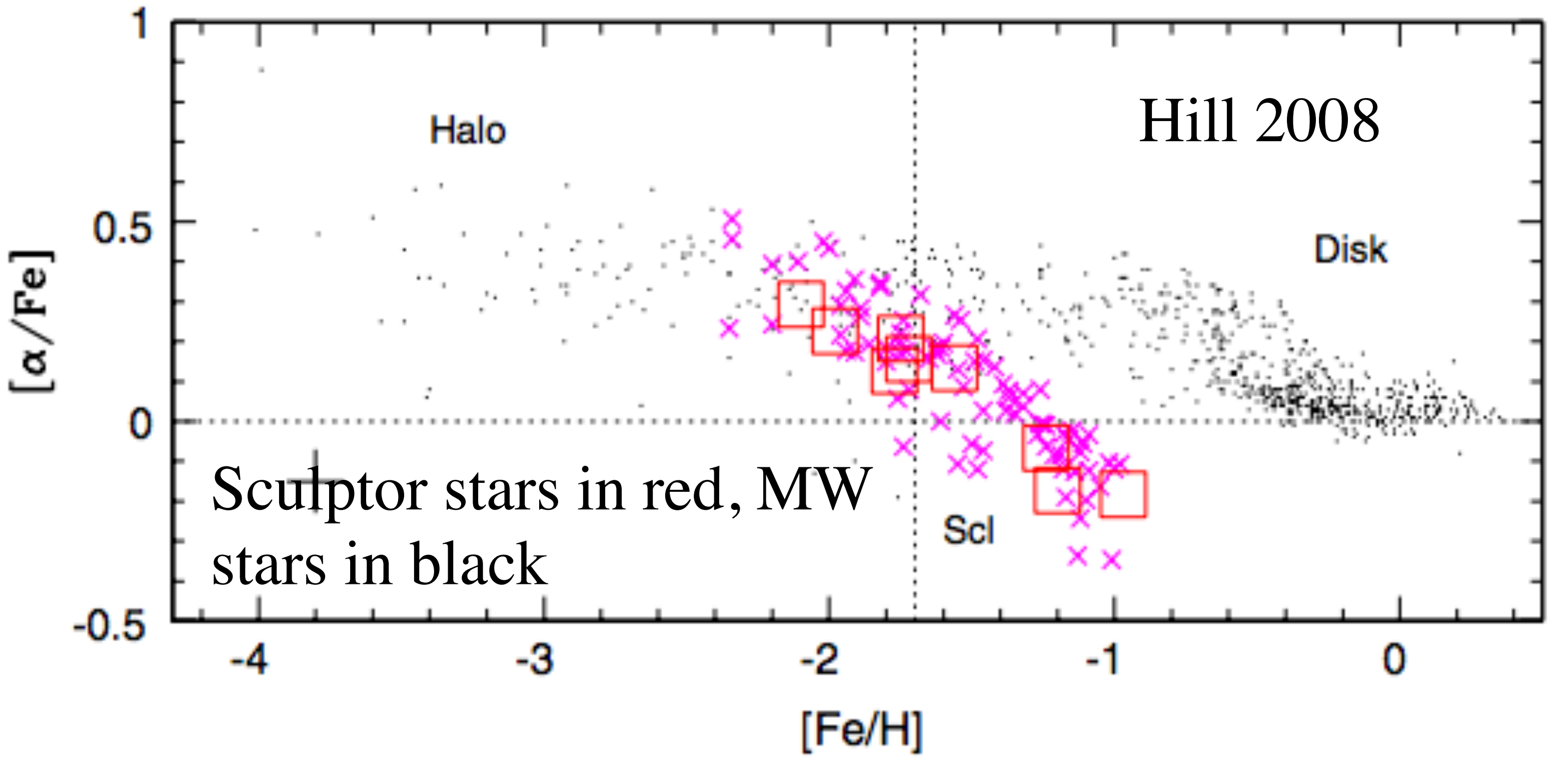


Hisotry of SFR In Local Group Dwarfs



Grebel and Favata

Abundances in Local Group Dwarfs



- Clear difference in metal generation history

Closed Box Approximation-Tinsley 1980, Fund. Of Cosmic Physics, 5, 287-388

- To get a feel for how chemical evolution and SF are related (S+G q 4.13-4.17)- but a different approach (Veilleux 2010)

- at time t, mass ΔM_{total} of stars formed, after the massive stars die left with $\Delta M_{low\ mass}$ which live 'forever',
- massive stars inject into ISM a mass $p\Delta M_{total}$ of heavy elements (p depends on the IMF and the yield of SN- normalized to total mass of stars).
- Assumptions: galaxies gas is well mixed, no infall or outflow, high mass stars return metals to ISM faster than time to form new stars)

$M_{total}=M_{gas}+M_{star}$=constant ($M_{baryons}$) ; M_h mass of heavy elements in gas $=ZM_{gas}$

dM'_{stars} =total mass made into stars, dM''_{stars} =amount of mass instantaneously returned to ISM enriched with metals

$dM_{stars}=dM'_{stars}-dM''_{stars}$ net matter turned into stars

define y as the yield of heavy elements- yM_h=mass of heavy elements returned to ISM

Closed Box- continued

- Net change in metal content of gas
- dM_h=y dM_{star} - Z dM_{star}=(y- Z) dM_{star}

- Change in Z since dM_g= -dM_{star} and Z=M_h/M_g then
- d Z=dM_h/M_g -M_h dM_g/M^2_g =(y- Z) dM_{star}/M_g +(M_h/M_g)(dM_{star}/M_g) =ydM_{star} /M_g
- d Z/dt=-y(dM_g/dt) M_g

- If we assume that the yield y is independent of time and metallicity (Z) then
- Z(t)= Z(0)-y ln $M_g(t)/M_g(0)$= Z(0)=yln μ metallicity of gas grows with time as log

mass of stars that have a metallicity less than Z(t) is M_{star}[< Z(t)]=M_{star}(t)=$M_g(0)$-M_g(t) or

M_{star}[< Z(t)]=M_g(0)*[1-exp((Z(t)- Z(0))/y]

when all the gas is gone mass of stars with metallicity Z, Z+d Z is

M_{star}[Z] α exp((Z(t)- Z(0))/y) d Z is we use this to derive the yield from data

Z(today)~ Z(0-yln[M_g(today)/M_g(0)]; Z(today)~0.7 Z_{sun}

since intial mass of gas was sum of gas today and stars today M_g(0)=M_g(today) +M_s(today) with M_g(today)~40$M_\odot/pc^2$ M_{stars}(today)~10$M_\odot/pc^2$

get y=0.43 Z_{sun} go to pg 180 in text to see sensitivity to average metallicity of stars

Closed Box- Problems

- Problem is that closed box connects todays gas and stars yet have systems like globulars with no gas and more or less uniform abundance.
- Also need to tweak yields and/or assumptions to get good fits to different systems like local group dwarfs.
- Also 'G dwarf' problem in MW (S+G pg 11) and different relative abundances (e.g C,N,O,Fe) amongst stars

- Go to more complex models - leaky box (e.g outflow); if assume outflow of metal enriched material g(t); if assume this is proportional to star formation rate $g(t)=cdM_s/dt$; result is $Z(t)= Z(0)-[(y/(1+c))*\ln[M_g(t)/M_g(0)]$- reduces effective yield but does not change relative abundances