Stellar Populations out to Virgo

What would be the gain?

• Larger range of galaxy type and environment to study in detail

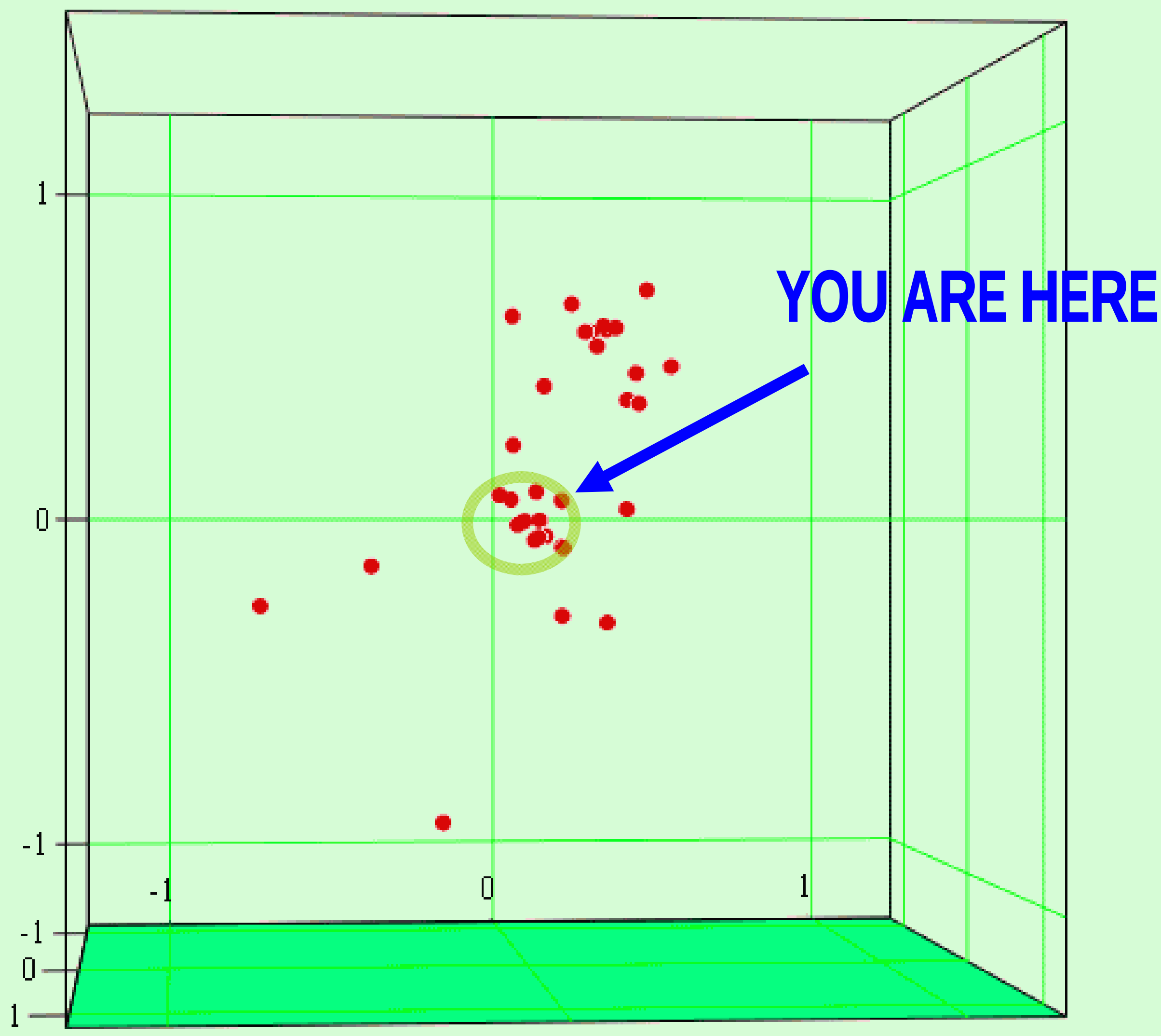
The value of this should not be under estimated

Resolved stars - the techniques are established - the scientific case is solid and well founded

Detailed means:

accurate photometry and spectroscopy of individual stars.

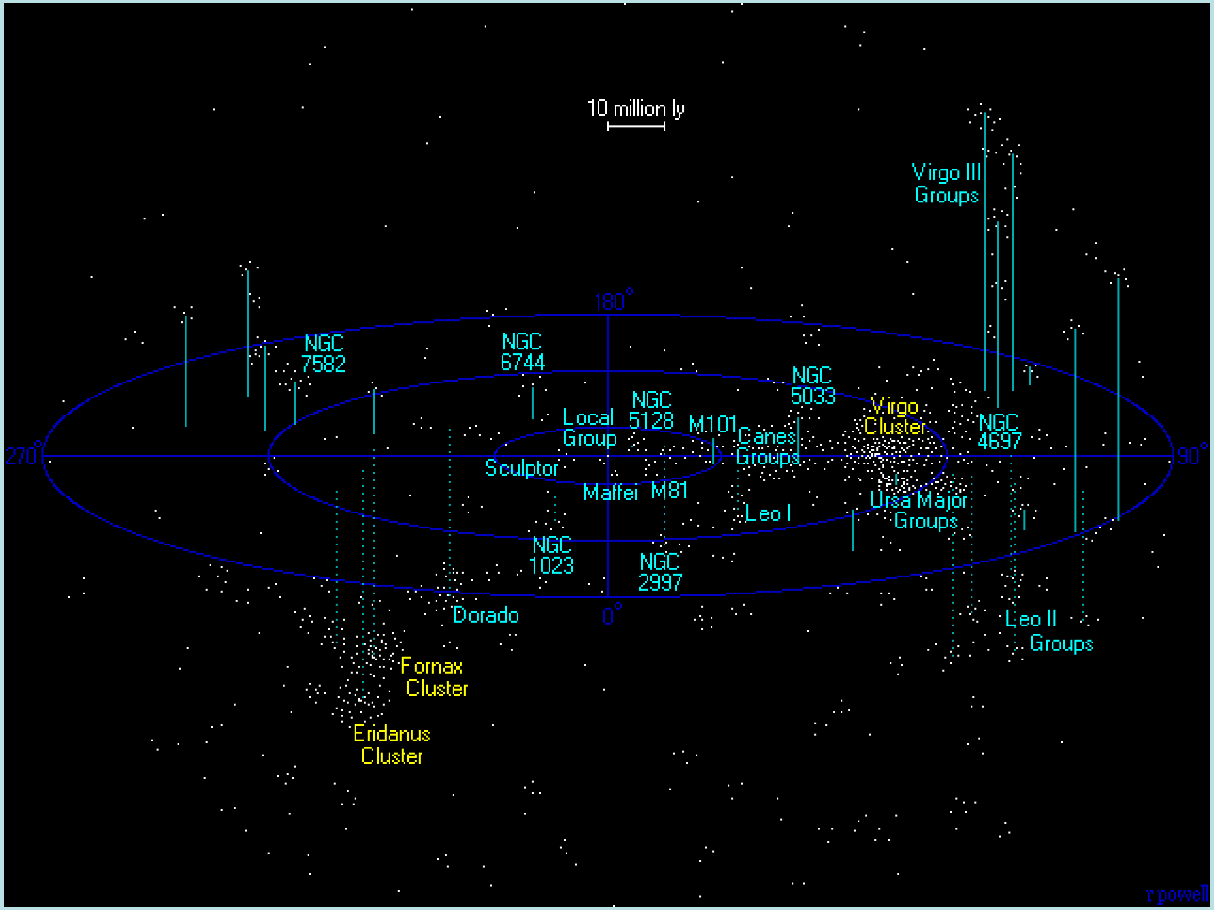
The local Group



Local Galaxy Group Positions (X-Y = Earth equatorial plane, Z=polar axis)

Scale units = Megaparsecs Location 0,0 = Earth

(X2, Y2, Z2)

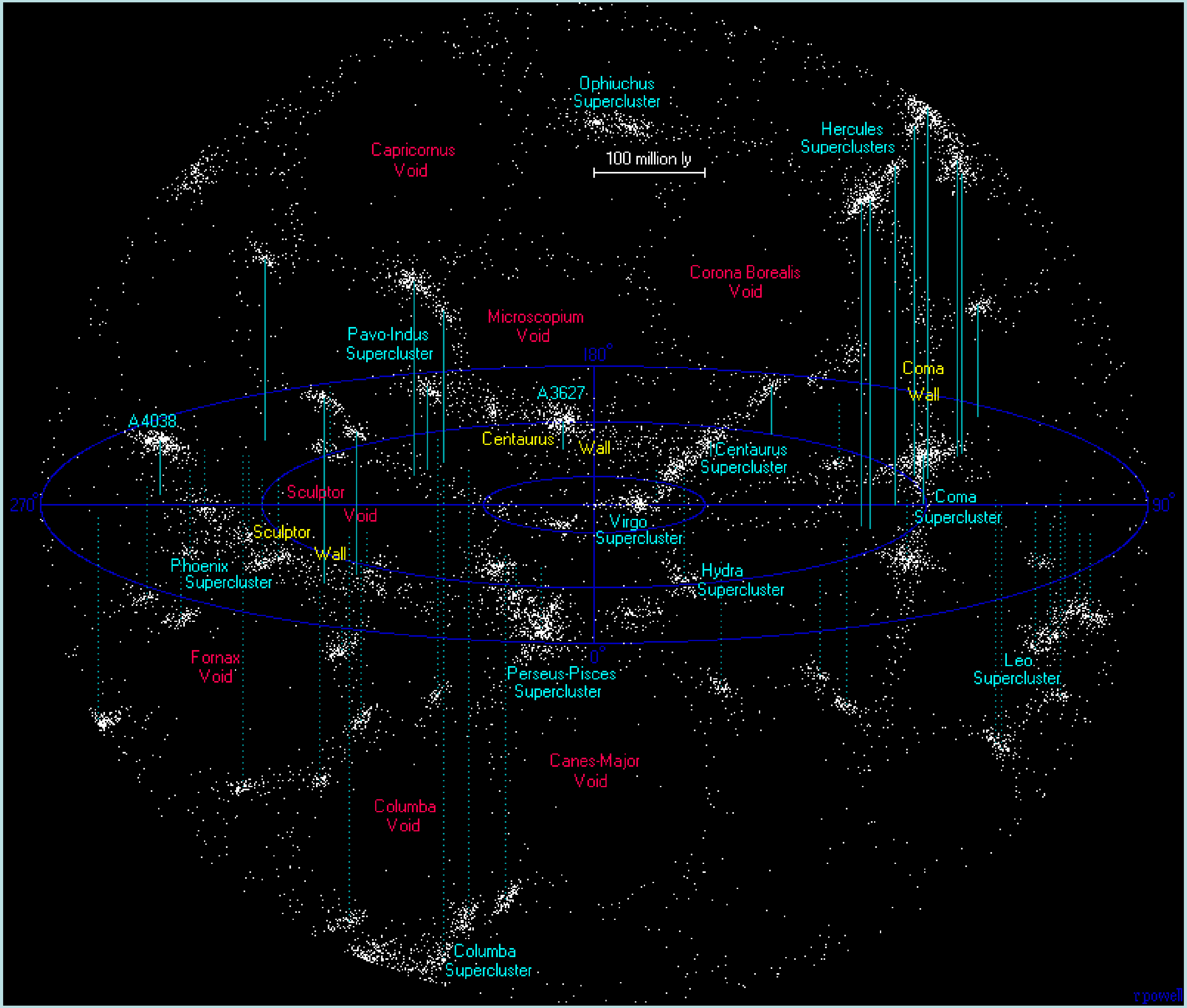


Number of galaxy groups within 100 million light years = 200

Number of large galaxies within 100 million light years = 2,500

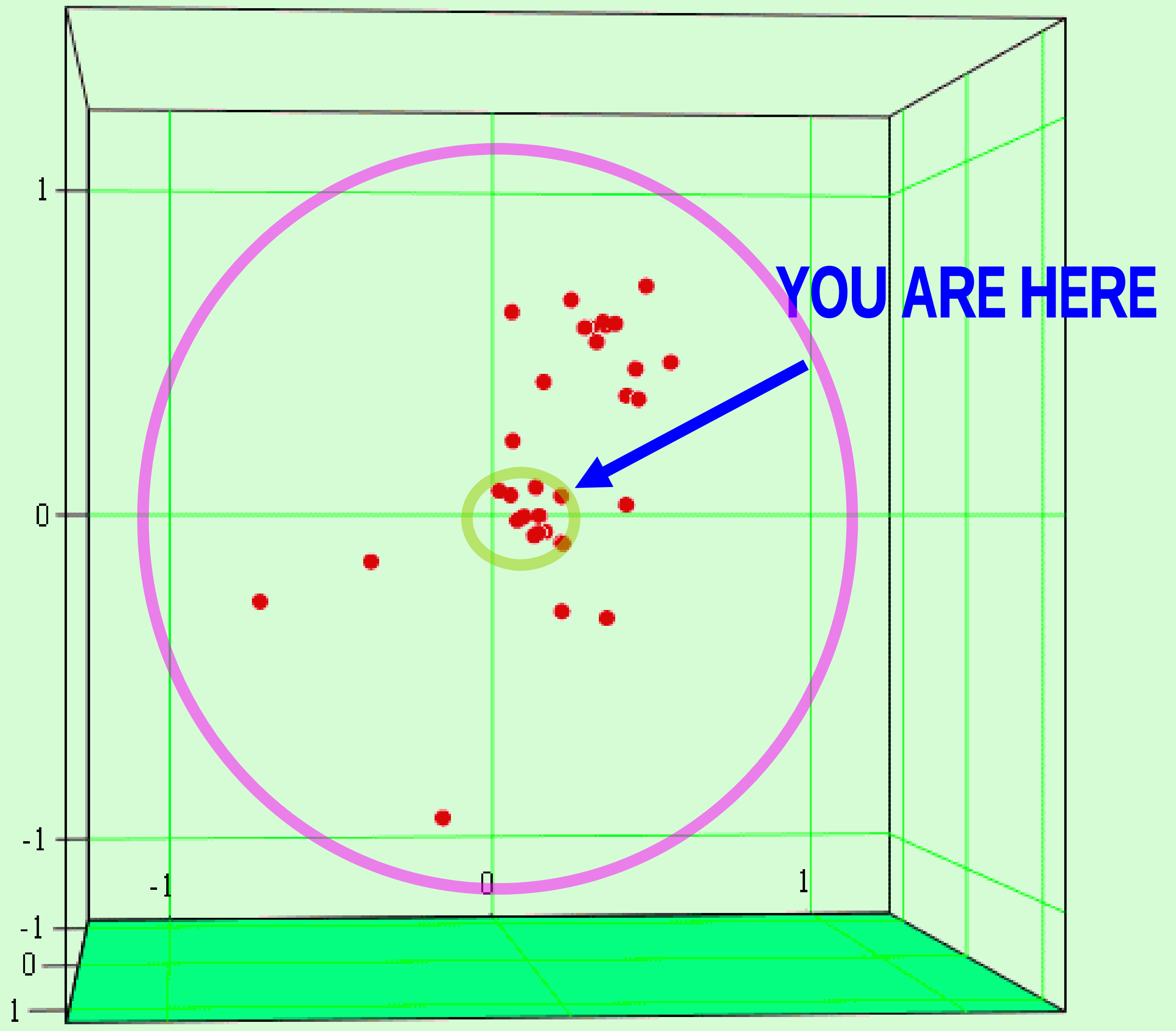
Number of dwarf galaxies within 100 million light years = 25,000

Number of stars within 100 million light years = 200 trillion



Ophiuchus Supercluster
Hercules Superclusters
100 million ly
Capricornus Void
Corona Borealis Void
Microscopium Void
Pavo-Indus Supercluster
180°
Coma Wall
A3627
A4038
Centaurus Wall
Centaurus Supercluster
Sculptor Void
270°
Coma Supercluster
90°
Virgo Supercluster
Sculptor Wall
Phoenix Supercluster
Hydra Supercluster
Fornax Void
0°
Perseus-Pisces Supercluster
Leo Supercluster
Canes-Major Void
Columba Void
Columba Supercluster
r.powell

The local Group

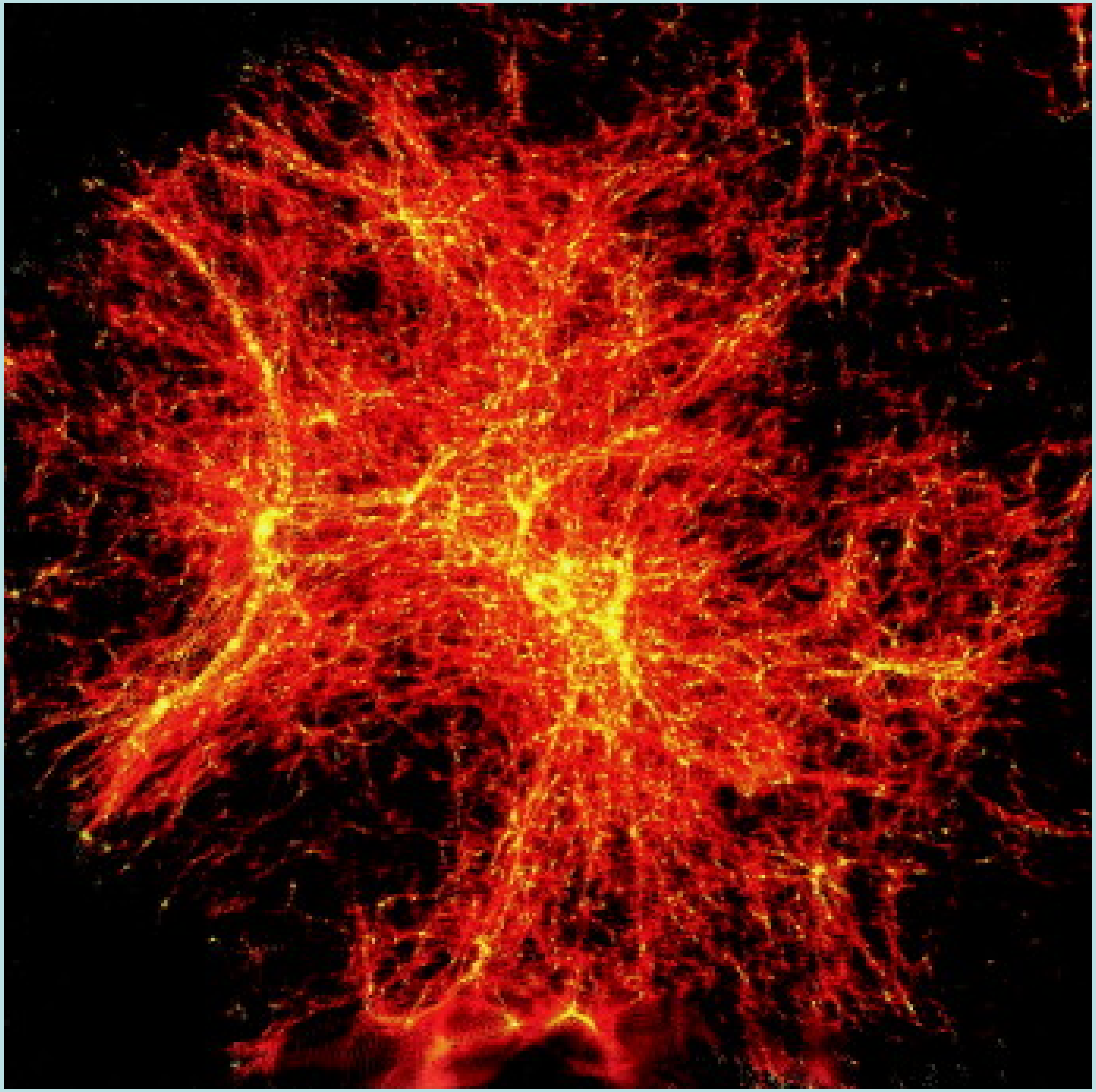


Local Galaxy Group Positions (X-Y = Earth equatorial plane, Z=polar axis)
Scale units = Megaparsecs Location 0,0 = Earth

To study the history of galaxy formation need to study the old (faint) stellar populations - look at red giant branch stars ($M_V = 0$ to $M_V = -3$) and horizontal branch stars ($M_V = 0$).

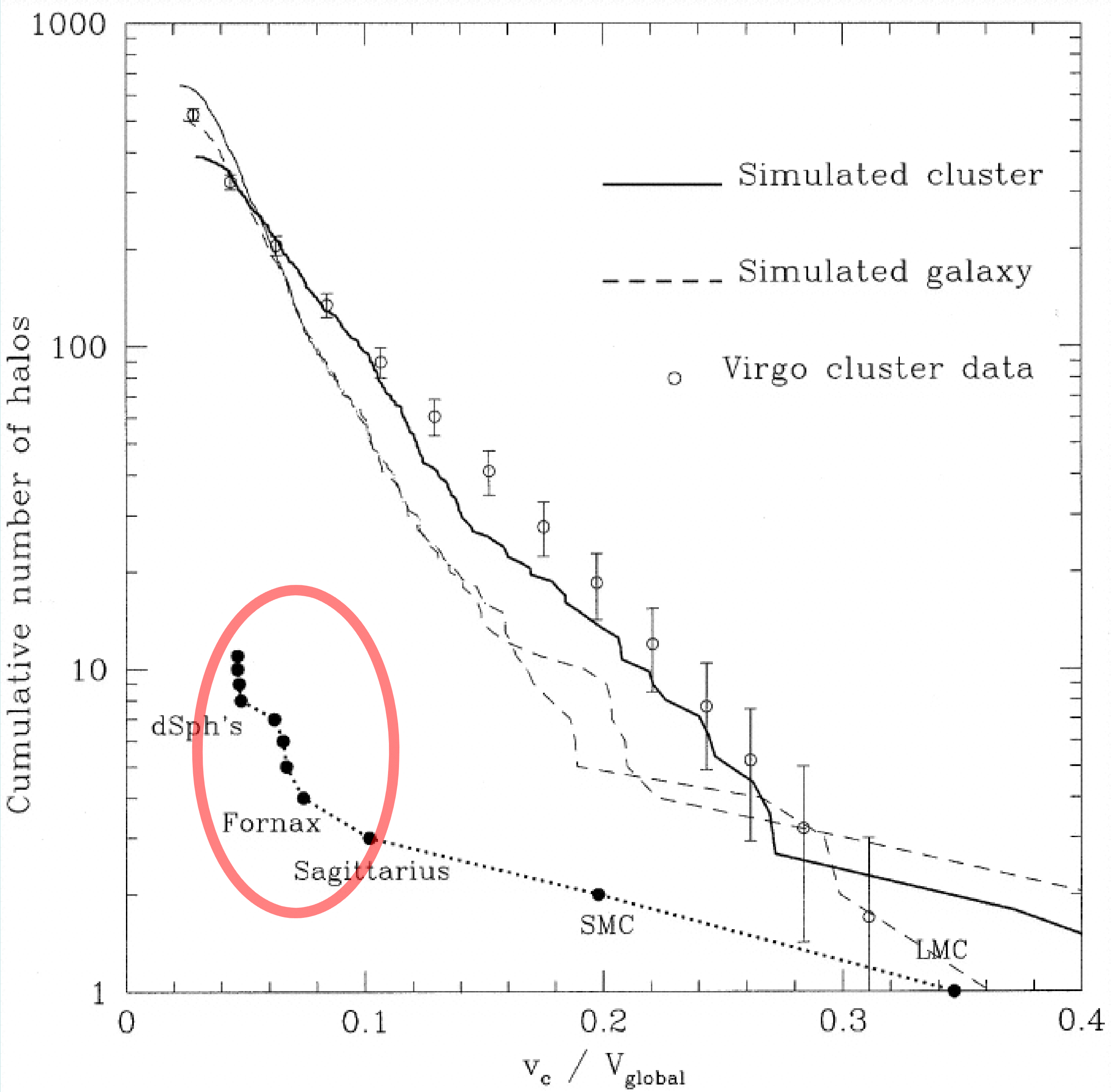
Distribution of mass at z=10 (1Gyr after BigBang) in a 6Mpc region - size of present day halo

Cold
Dark
Matter



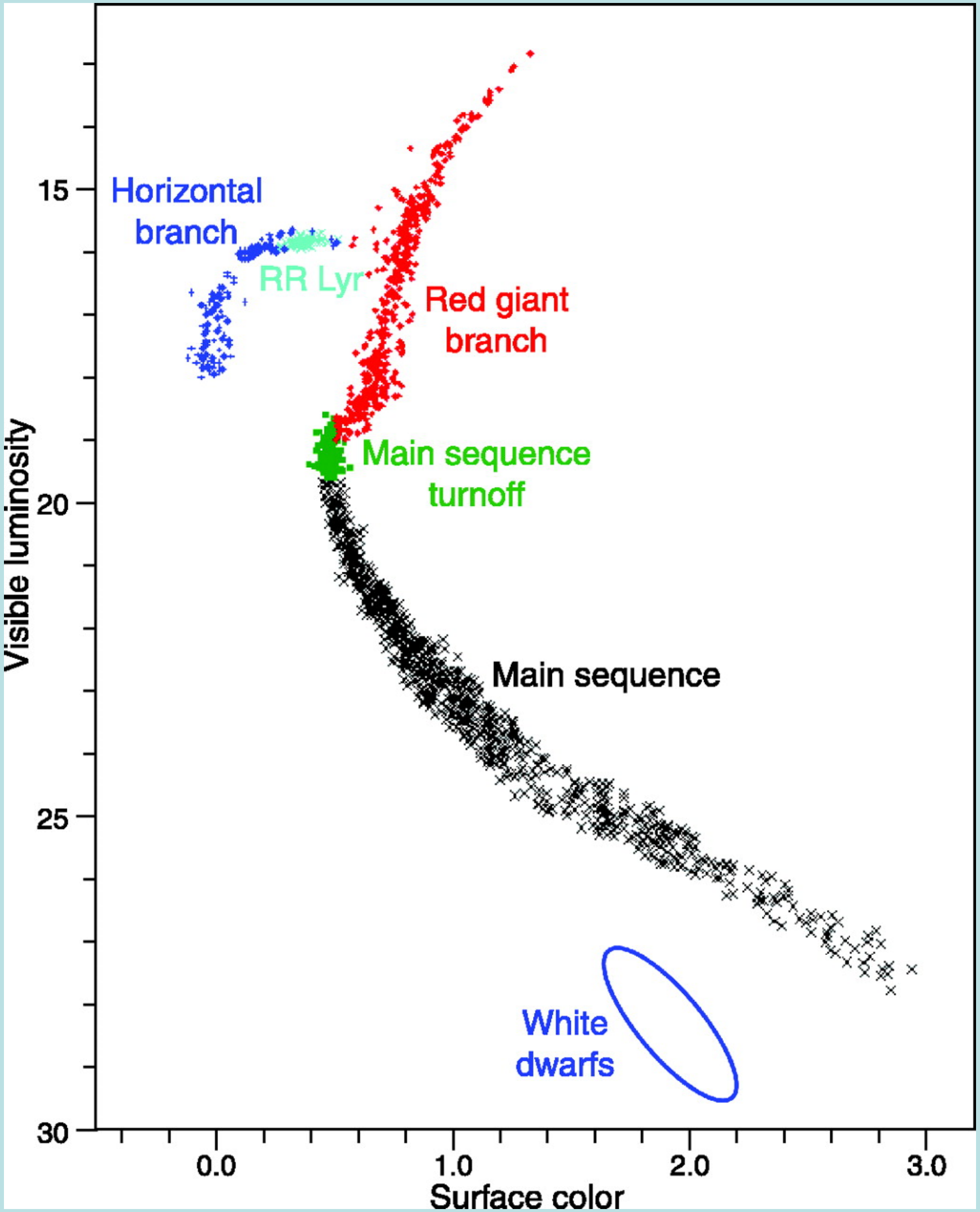
Moore et al. 1999 ApJL, 524, 19

Dwarf Spheroidal GALAXIES: THE SMALLEST UNIT



Moore et al. 1999

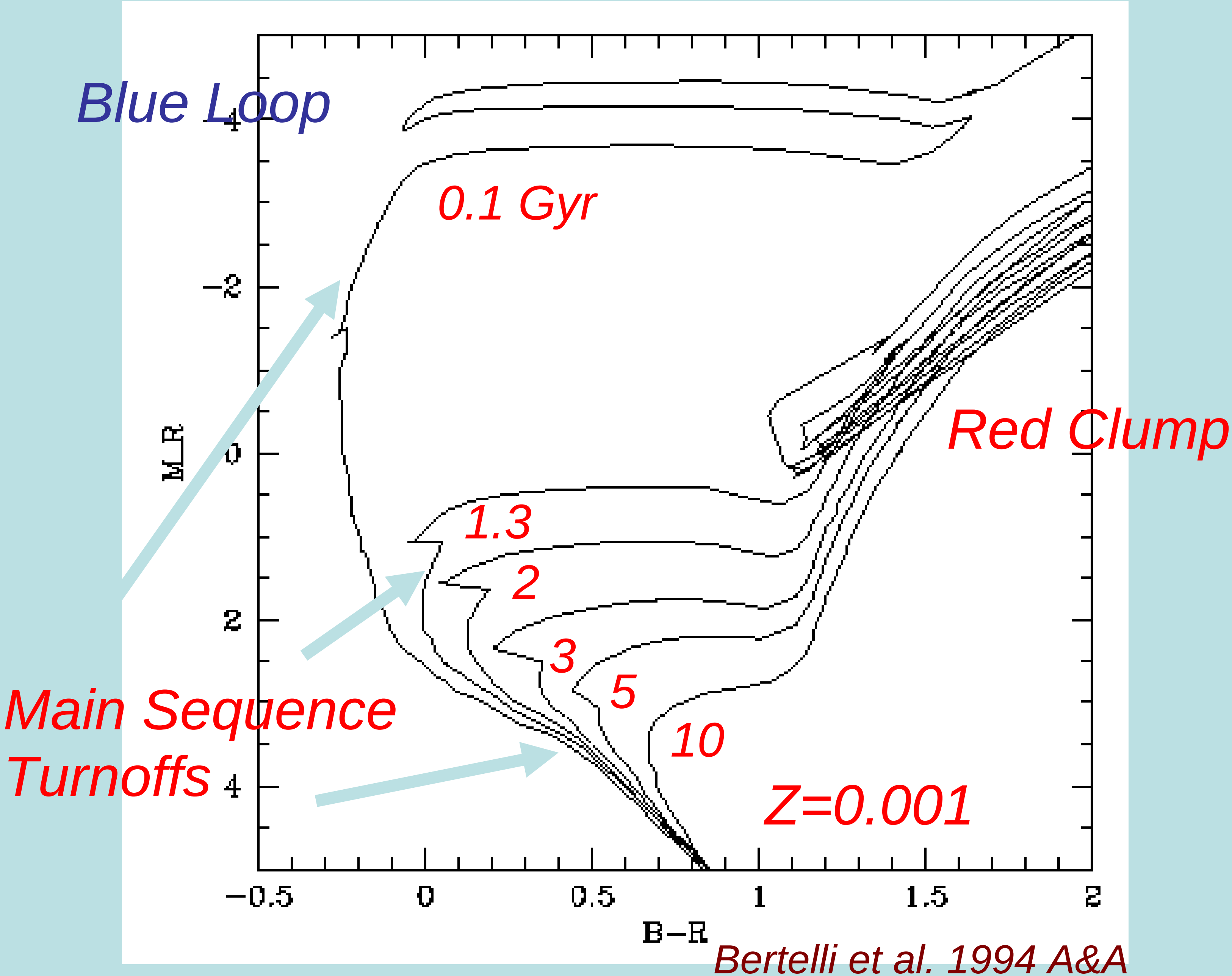
Stars as galaxy evolution probes

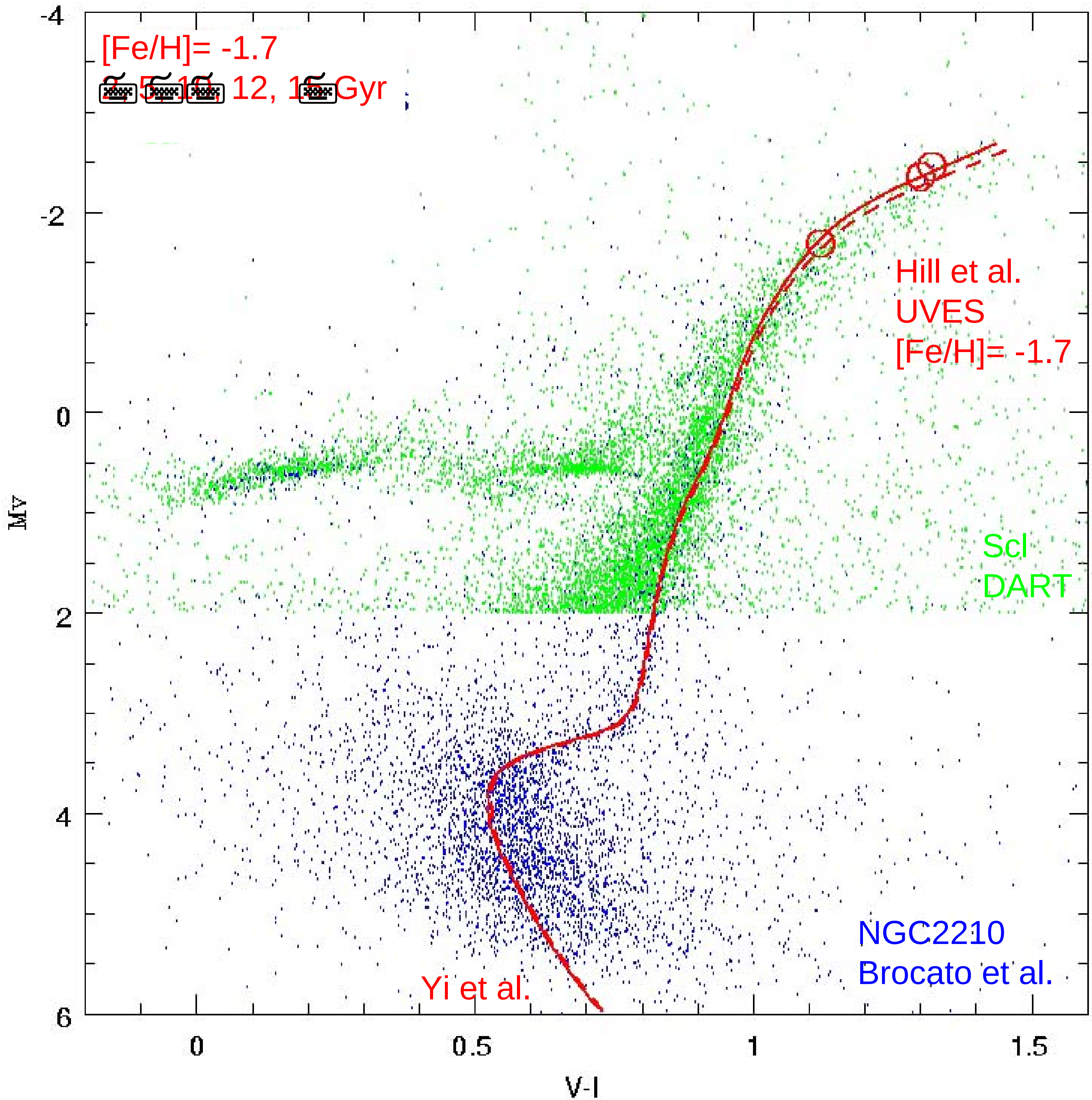


Globular Cluster: ancient, single age stellar population.

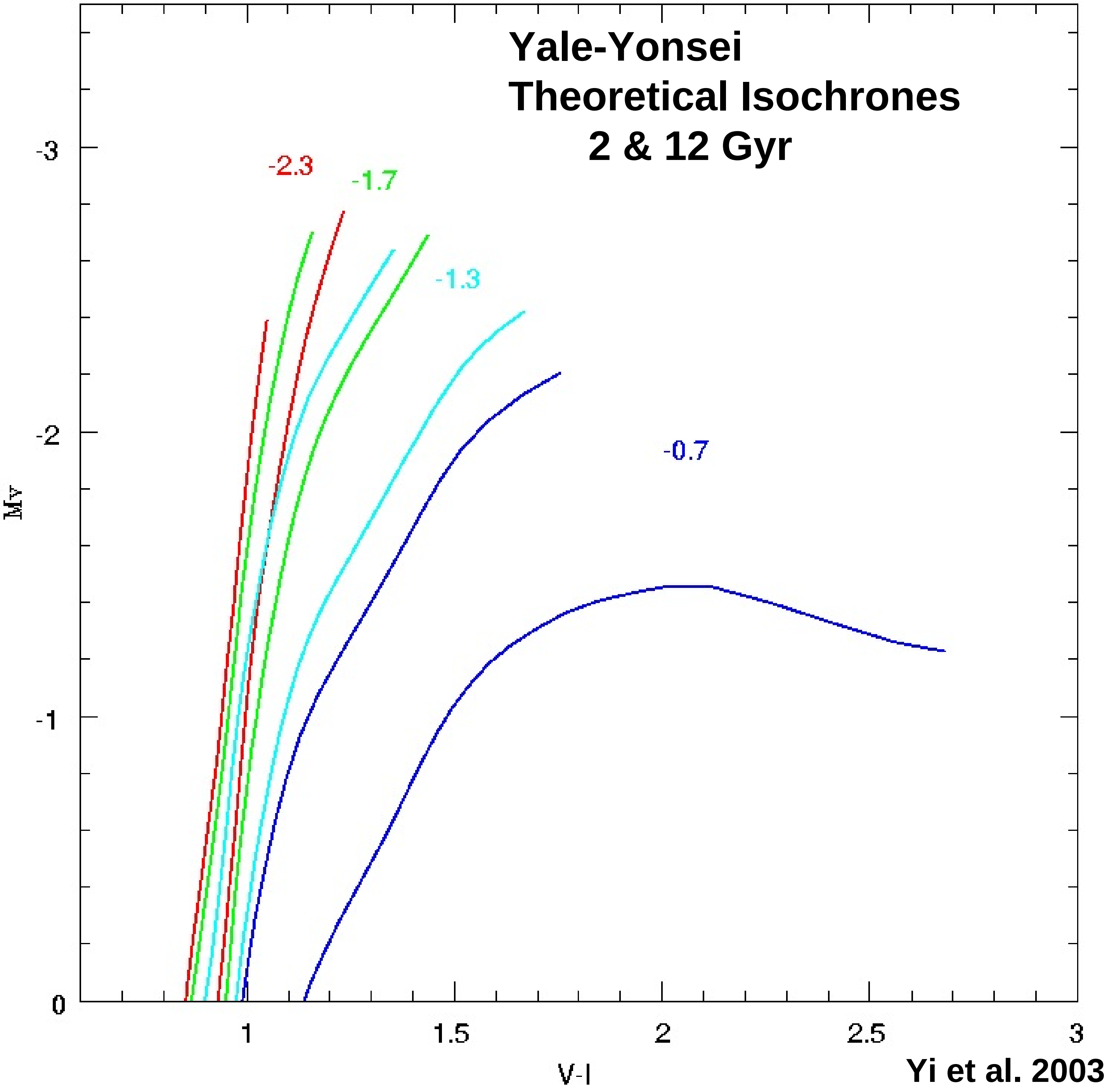
Krauss & Chaboyer 2003

Star-formation Histories

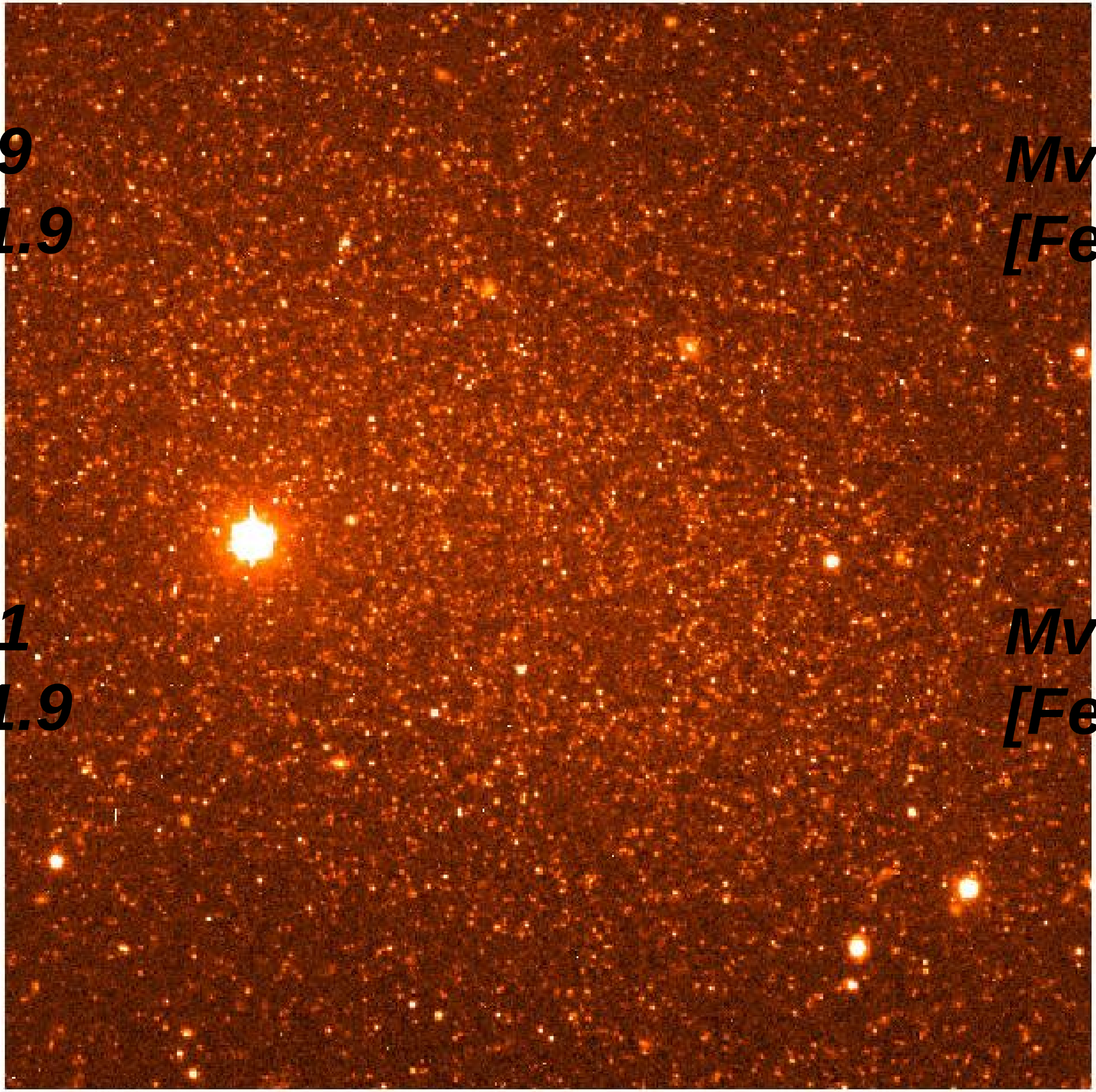




[Fe/H]= -1.7
2, 5, 10, 12, 15 Gyr
Hill et al.
UVES
[Fe/H]= -1.7
Scl
DART
NGC2210
Brocato et al.
Yi et al.
Mv
V-I
-4
-2
0
2
4
6
0
0.5
1
1.5


Yale-Yonsei
Theoretical Isochrones
2 & 12 Gyr
-2.3
-1.7
-1.3
-0.7
-3
-2
-1
0
1
1.5
2
2.5
3
Mv
V-I
Yi et al. 2003

FORS1



Mv = -10.9
[Fe/H]= -1.9

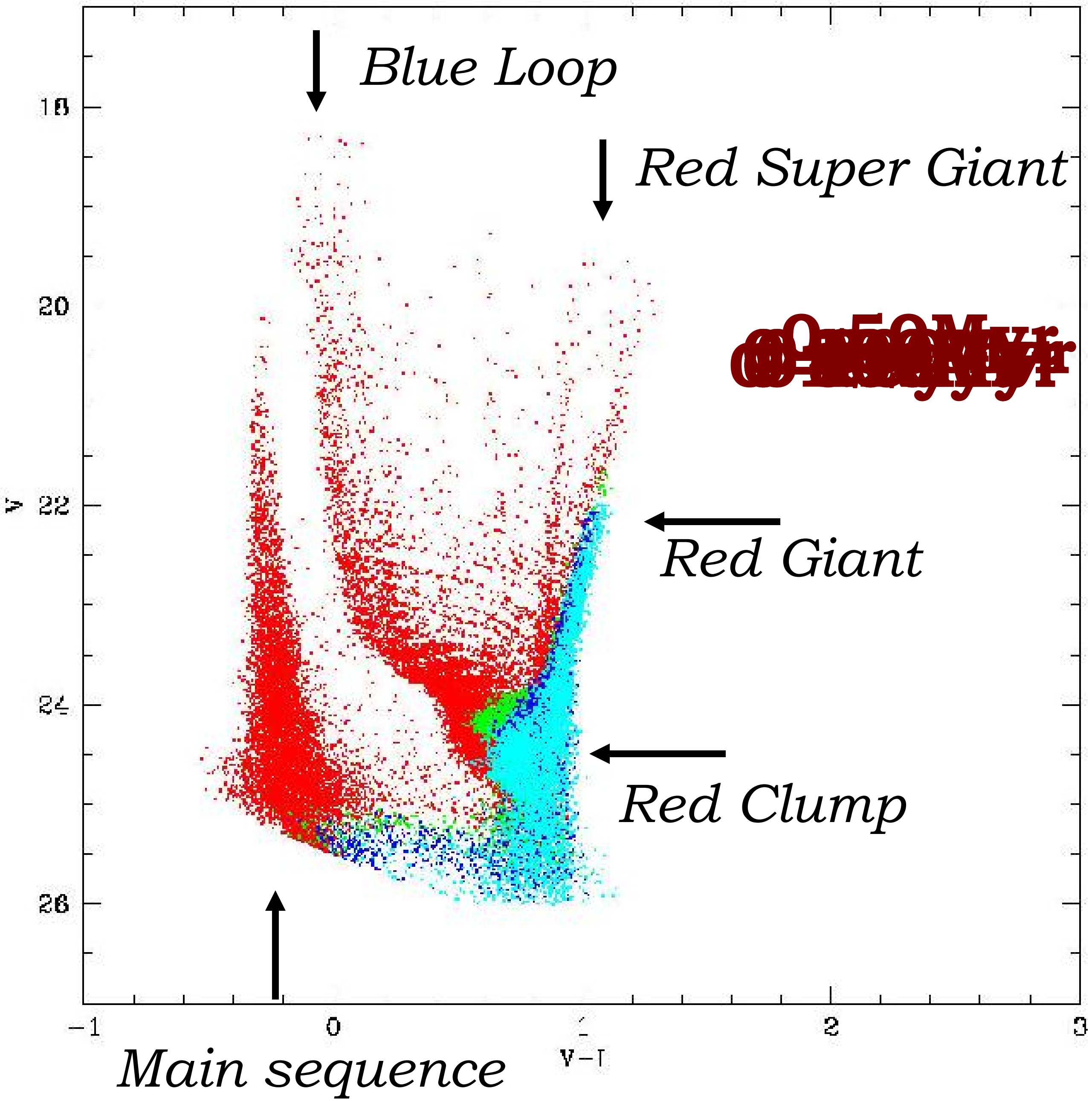
Mv = -10.1
[Fe/H]= -1.9

Mv = -9.8
[Fe/H]= -1.8

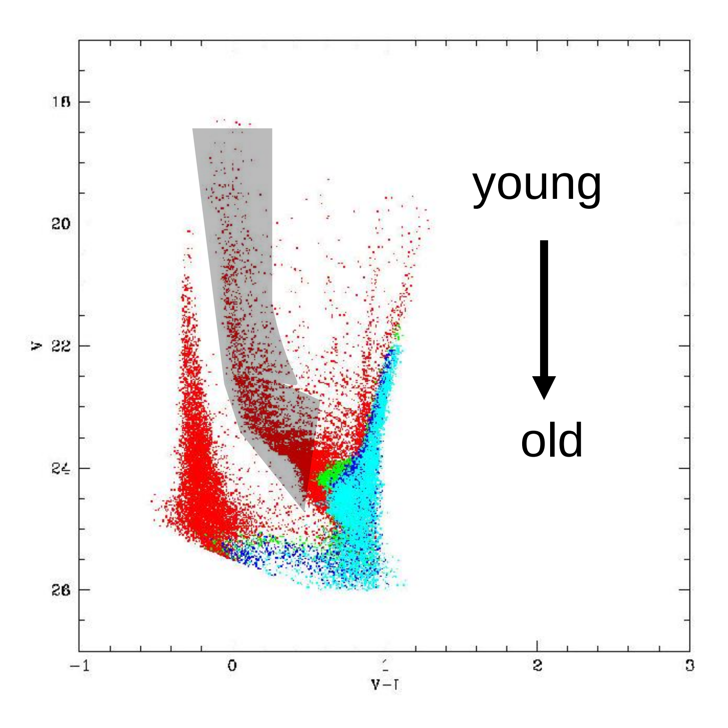
Mv = -6.5
[Fe/H]= -1.7

Tolstoy et al 2000, ESO Messenger

Measuring galaxy evolution:



To study the star formation processes on a galactic scale - the fainter the stars the further back the history can be directly traced. Massive (short lived) stars can be Mv -8 but to trace blue loops stars (stars can be up to 800Myr old) need to go to about Mv -1.

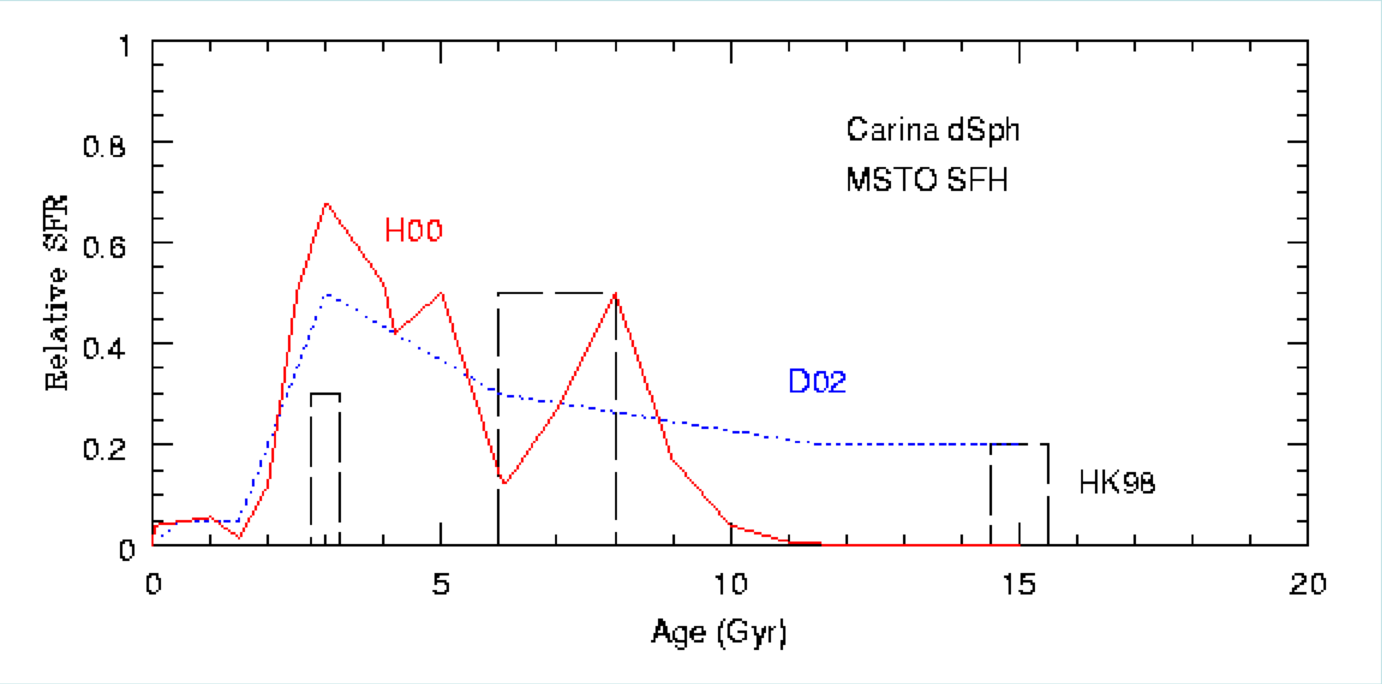


QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Movie of Sextans A
Recent star formation
Dohm-Palmer et al.

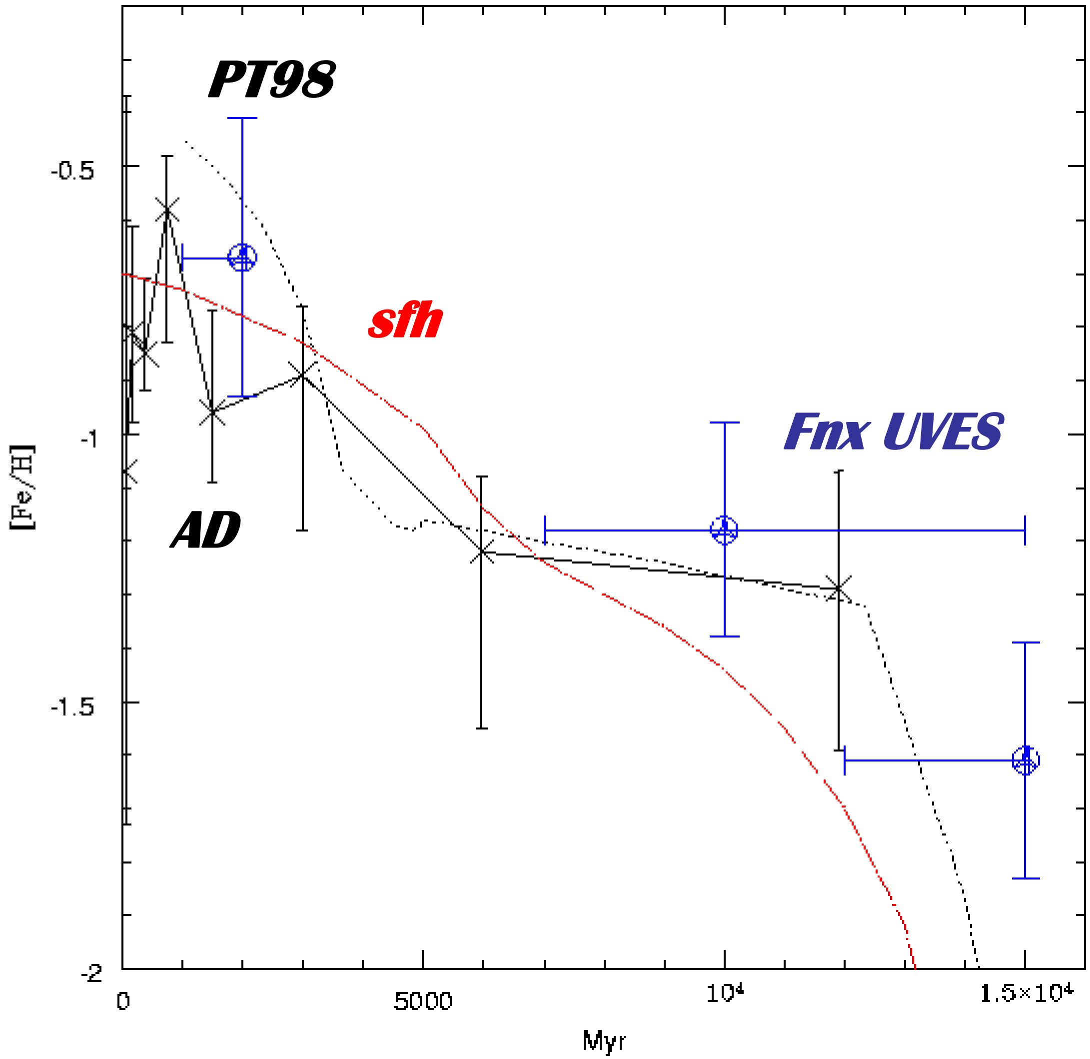
I also looked into IR CMDs - in principle interesting
In practise more work needs to be done.

Star-Formation Histories…



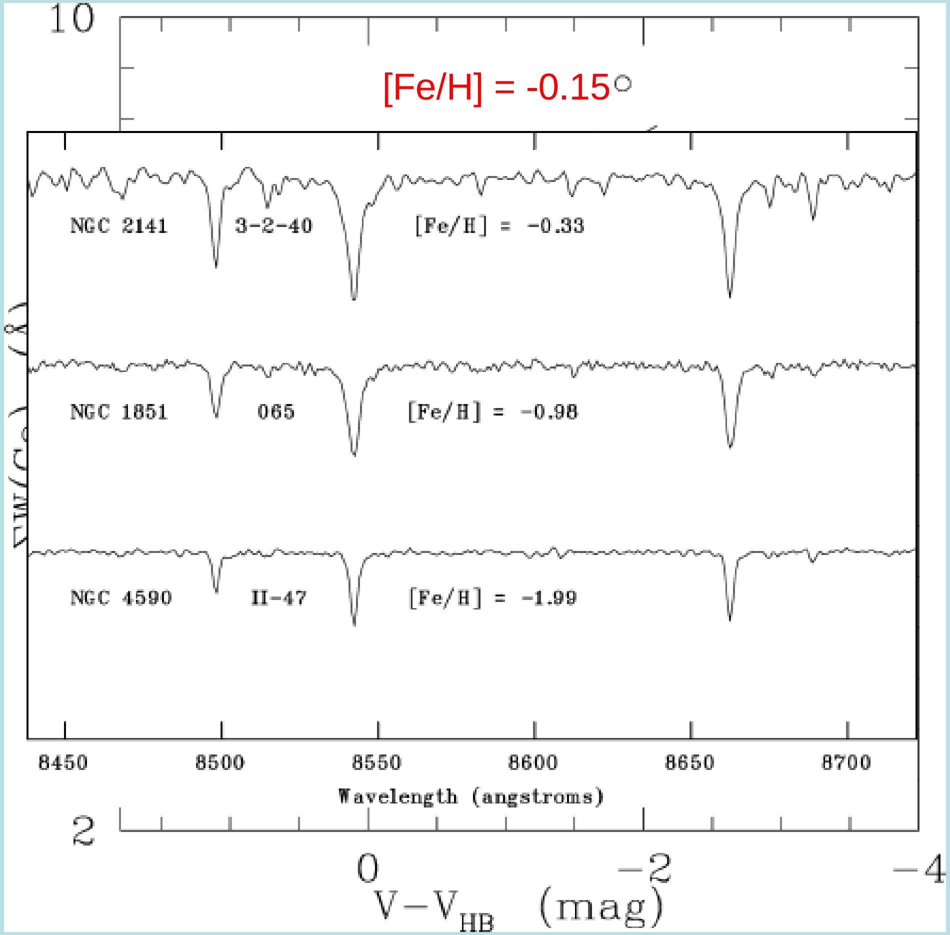
Hurley-Keller et al 98	[Fe/H] –2.1	+/- 0.1 (WF)
Hernandez et al 00	-2.0	0.2 (HST)
Dolphin 02	-1.2	0.4 (HST)

IC1613 – SFH & ZFH from WFPC2 Imaging



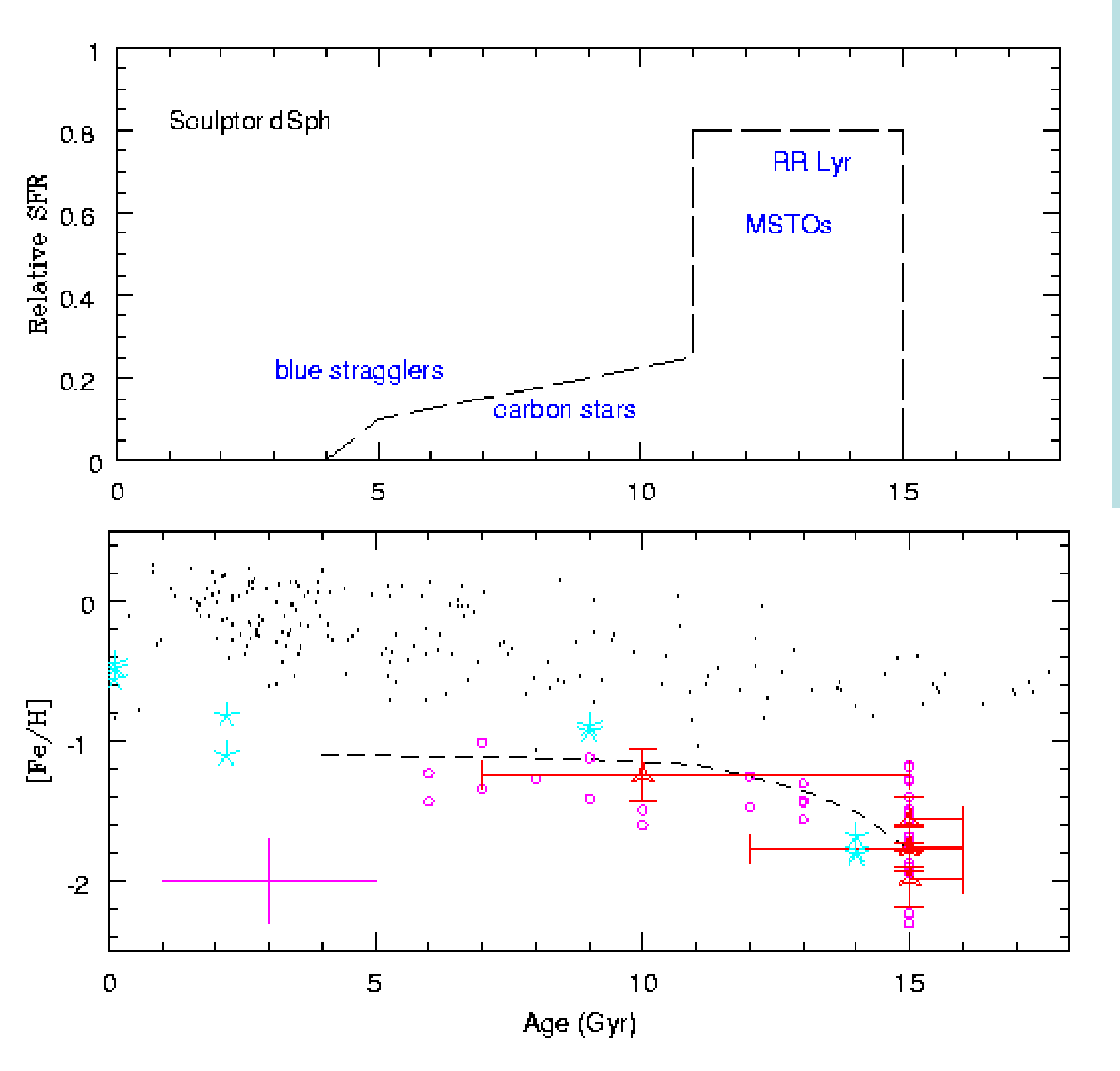
Skillman, Tolstoy, Cole, Dolphin et al. ApJ, in press

Ca II Triplet



Cole et al. 2004

UVES – Sculptor dSph

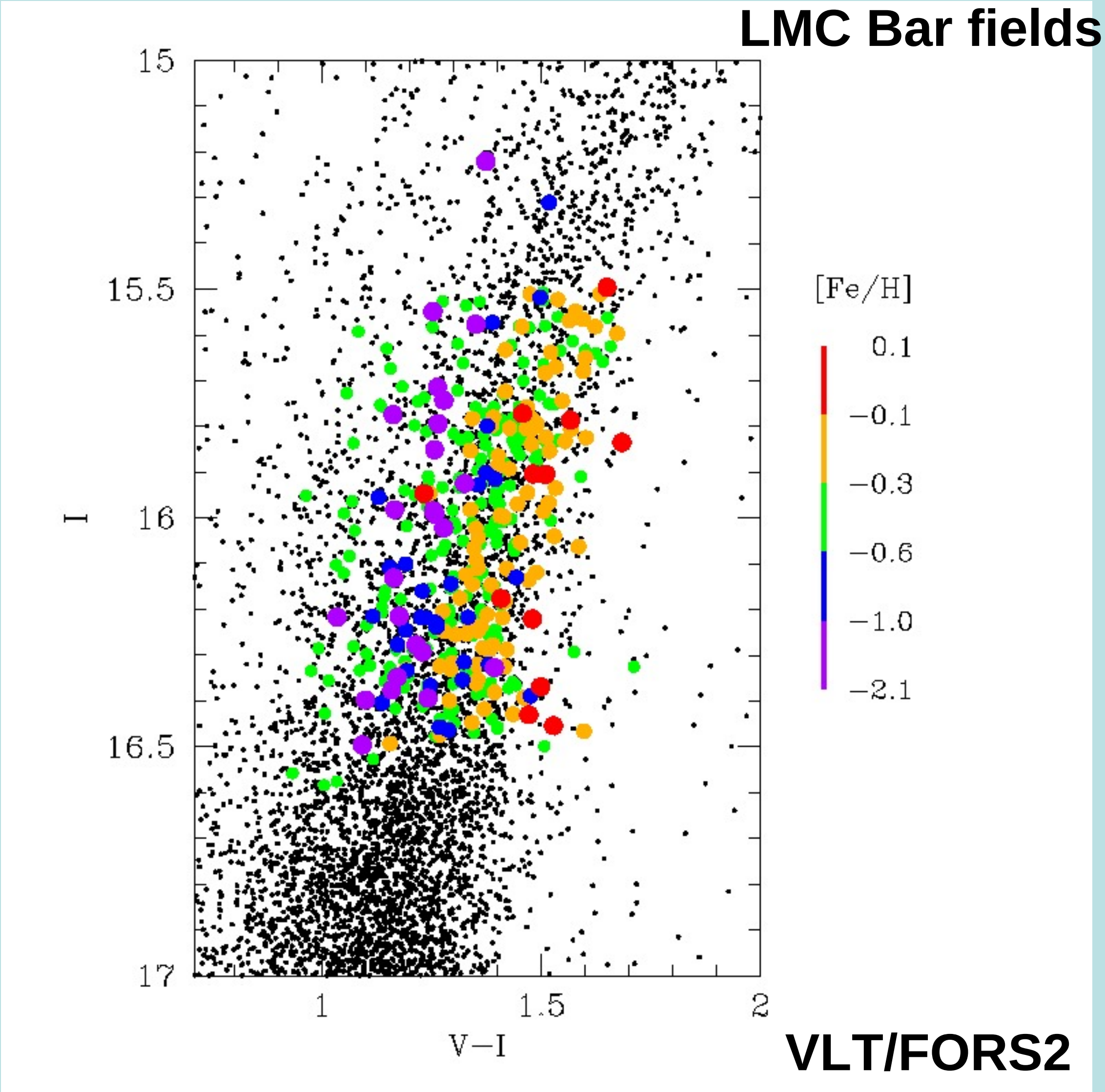


SFH

ZFH

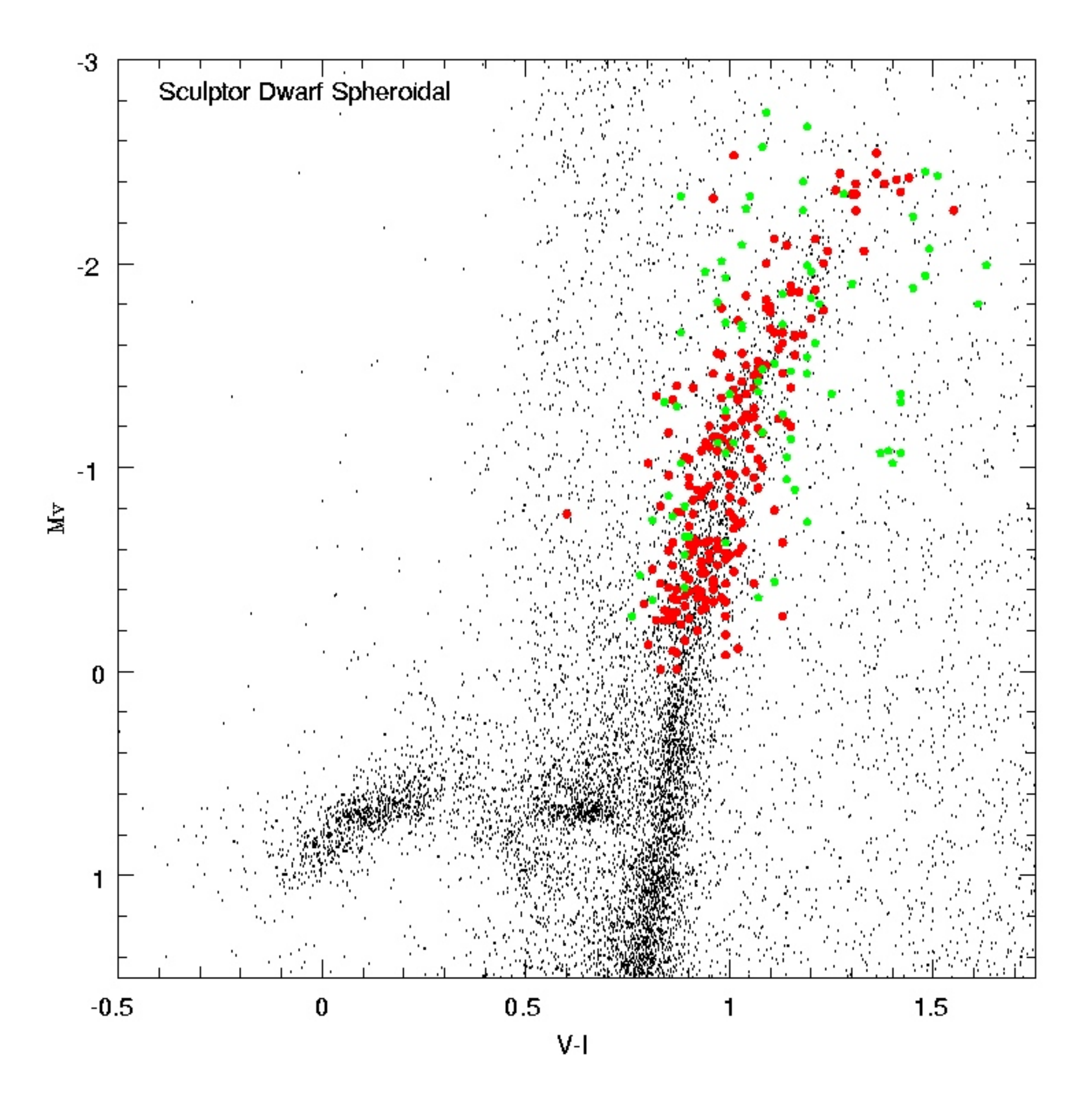
Tolstoy et al. 2003 AJ, 125, 707

Age-metallicty degeneracy (in the lmc)



Cole et al. submitted

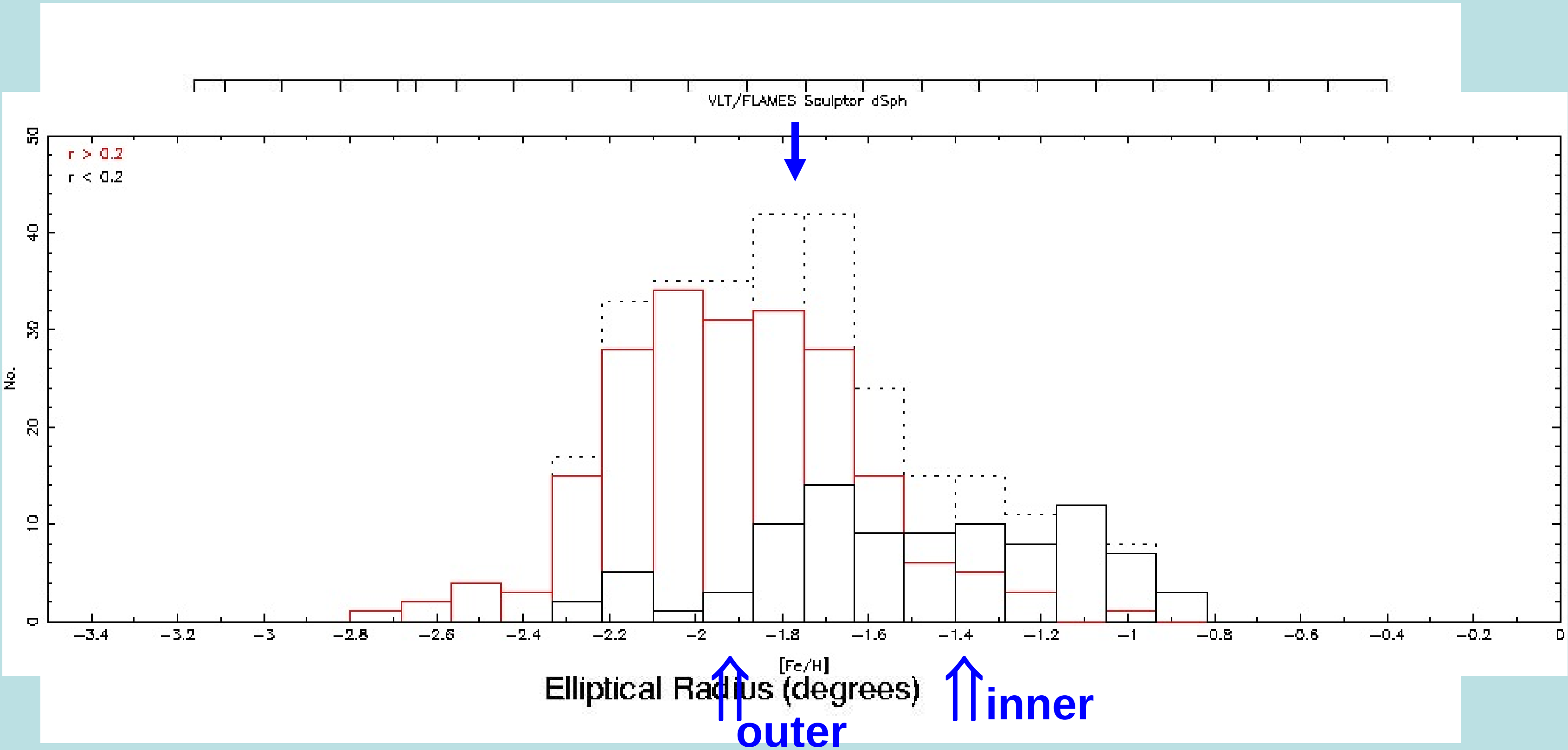
Sculptor dwarf spheroidal galaxy



DART Team, submitted to ApJL (Tolstoy et al.)

Sculptor dwarf spheroidal galaxy

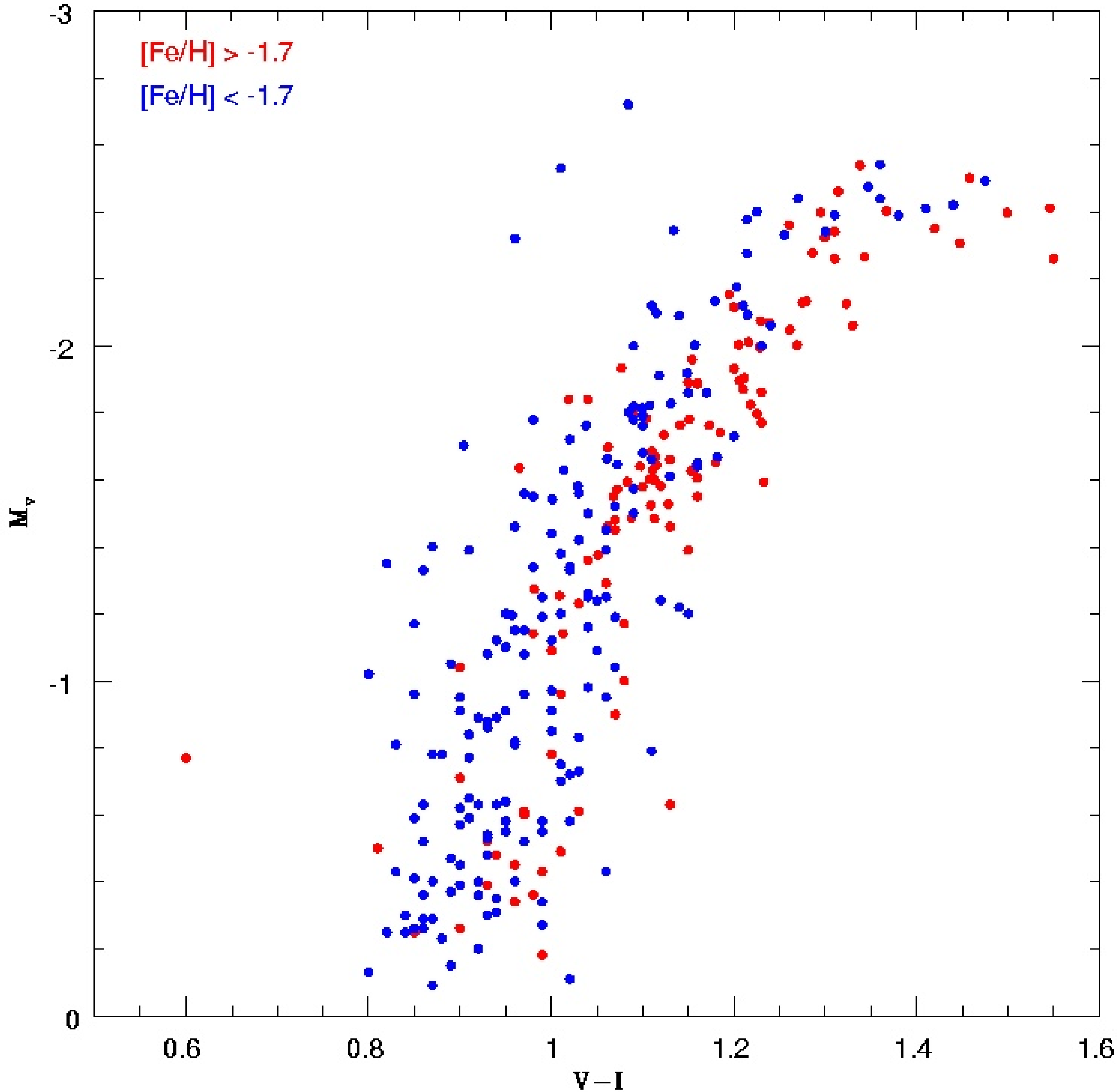
Abundance variation...



[Fe/H] distribution - depends *where* you look.

TWO POPULATIONS !?

DART Team, submitted to ApJL (Tolstoy et al.)



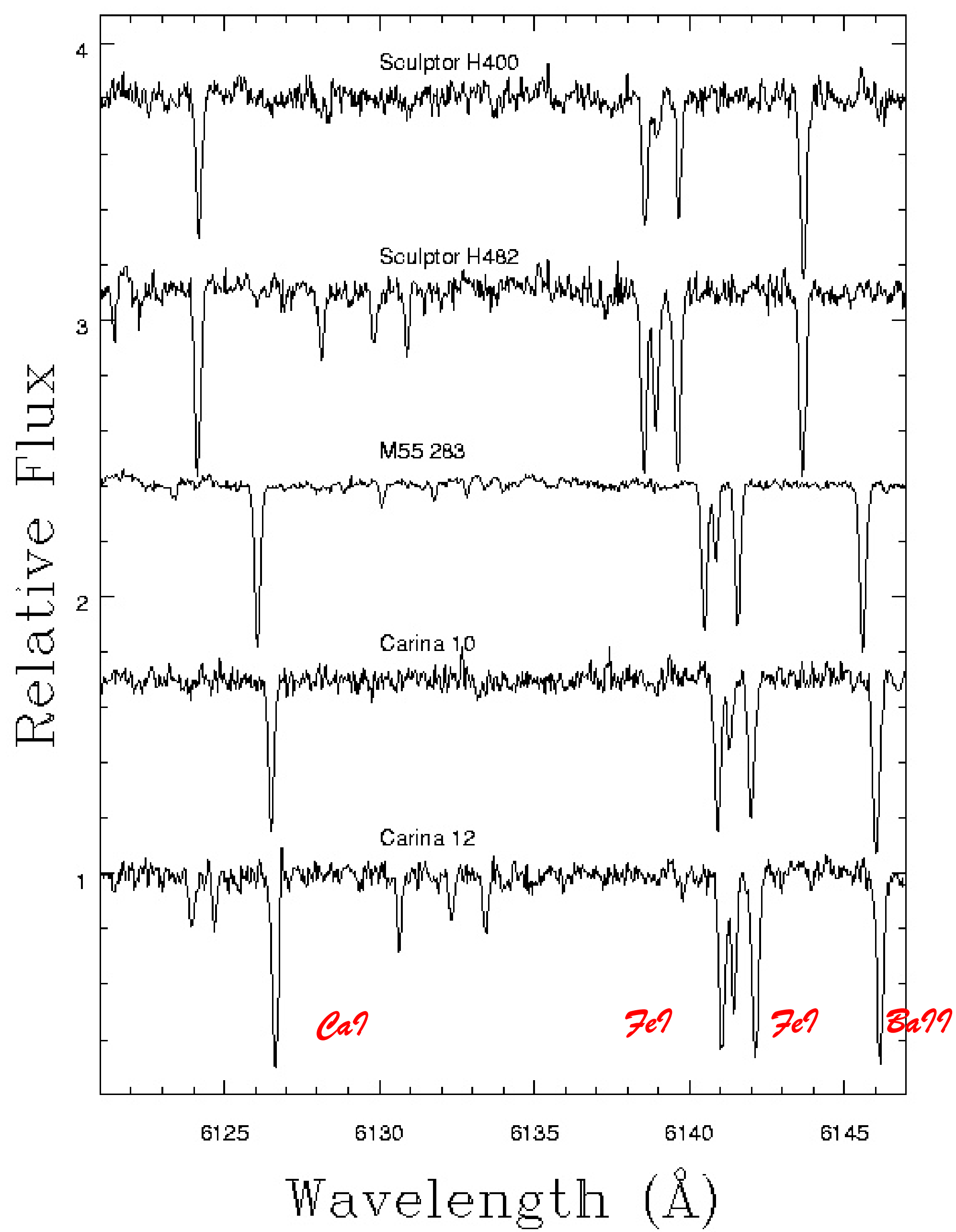
[Fe/H] > -1.7
[Fe/H] < -1.7
-3
-2
-1
0
M_V
0.6
0.8
1
1.2
1.4
1.6
V − I

UVES

R~40 000

Fe 80, 20
O 2
Na 5
Mg 3
Al 2
Si 5
Ca 9
Sc 1
Ti 9, 6
Cr 2
Mn 6
Co 2
Ni 3

Cu 2
Zn 1
Y 4
Ba 3
Nd 2
La 3
Eu 1



[Fe/H]
-2.1
-1.2
-1.8
-1.9
-1.4

Chemical Tagging:

<u>Light Elements</u> – e.g., O Na Mg Al
tracers of deep mixing abundances patterns
(globular clusters versus field stars)

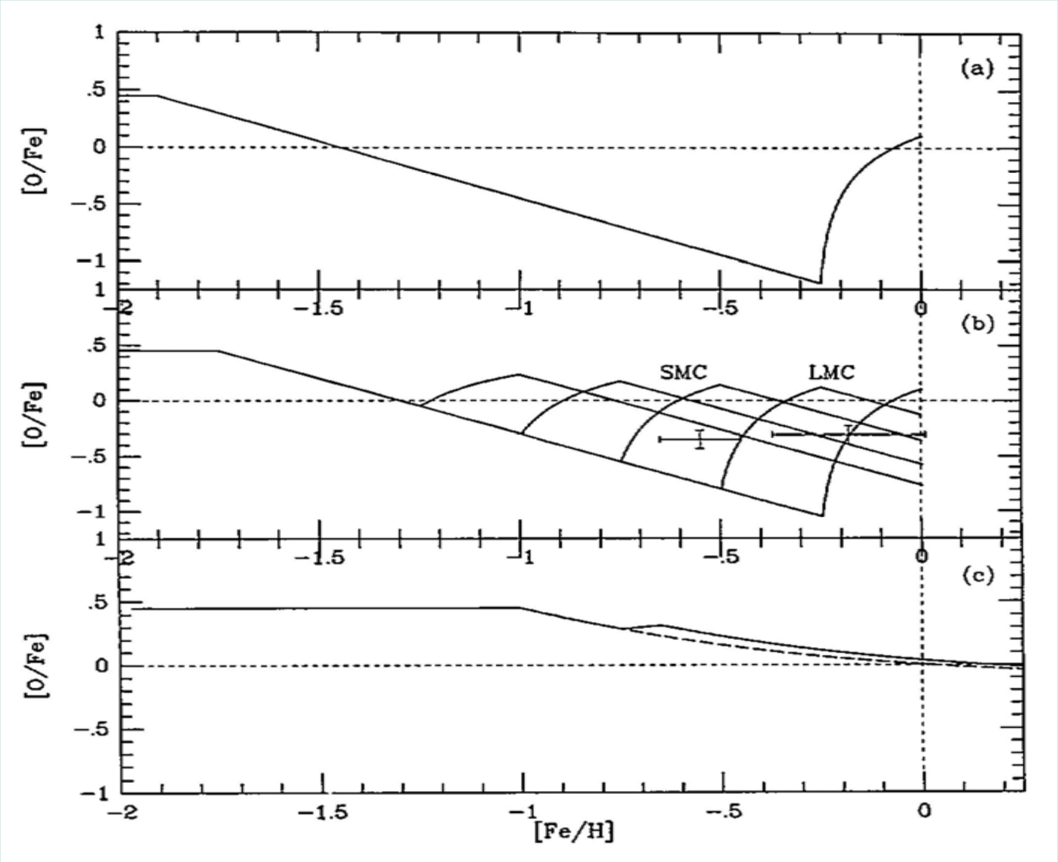
<u>α Elements</u> – e.g., O Mg Si Ca Ti
dominated by SNII
(low in dSph -> low sfr -> low mass SNII)

<u>Iron-peak Elements</u> e.g., V Cr Mn Co Ni Cu Zn
explosive nucleosynthesis (supernovae) Cu <->SNI ?

<u>Heavy Elements</u> (Z > 30)
mix of r- and s- process elements
e.g., first s-process e.g., Y
second s-process e.g., Ba, Ce, Sm
r-process e.g., Eu

[O/Fe] ratios in star forming galaxies

Gilmore & Wyse (1991)



Initial short burst
+ recent burst

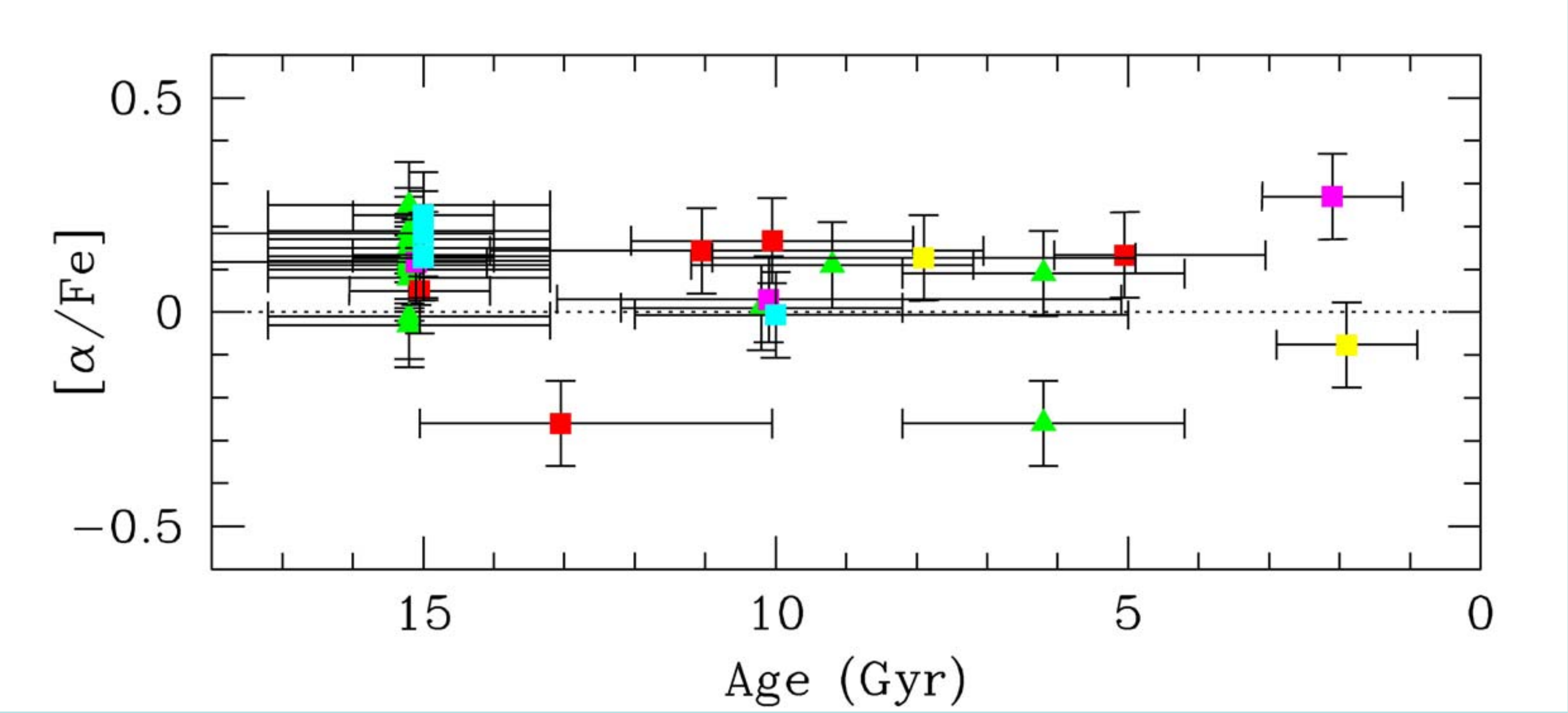
Series of later bursts

~ Continuous SF
+ small later burst
where
SNII:SNIa = 4:1

Low α/Fe in dSph must be related to SFH, but what else? blow-out, SNII yields, IMF, etc?

Why is α/Fe low in dSph's at all ages?

1. Low SNII yields? IMF? SFR? Blow-out? Stripping?
2. Is there really no time evolution?

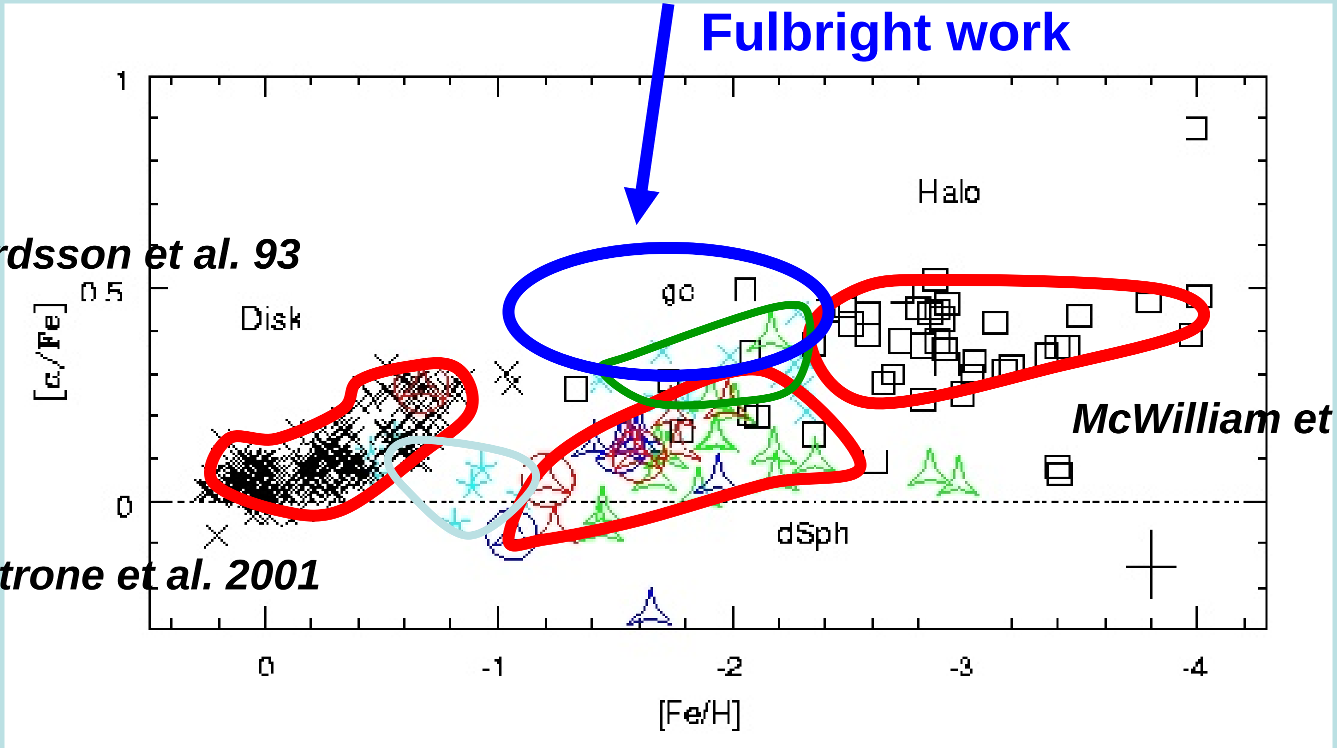


To disentangle further, examine each galaxy separately

Shetrone, Venn et al. 2003

Measuring Chemical Evolution: α-elements

dwarfs AREN'T obvious hierarchical fragments



α = (Mg + Ca + Ti) / 3

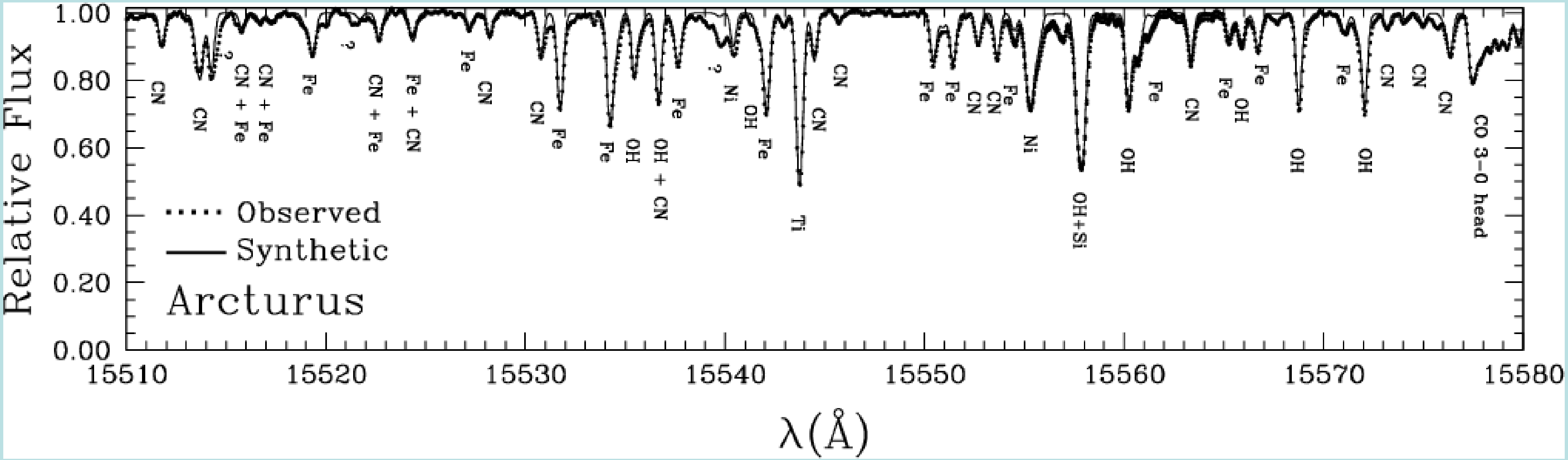
(early) gas rich merging?

!! Kim Venn's talk !!

Tolstoy et al. 2003

IR spectroscopy - there is some interesting information to be found - but mostly about reprocessing in stellar atmospheres.

IR Spectroscopy



Melendez et al. 2003

Theory produces a wealth of sophisticated models which can be compared with detailed data sets.

100m Virgo & beyond...

Imaging , V=35 in 10 hours, S/N=20

MSTOs @ Virgo

CaT V=28 17hours (S/N =20) LR8
5hours 600I

CaT @ Virgo

HR abundances V=25 16hours S/N=40 FLAMES/HR
24 15hours 40 UVES/580

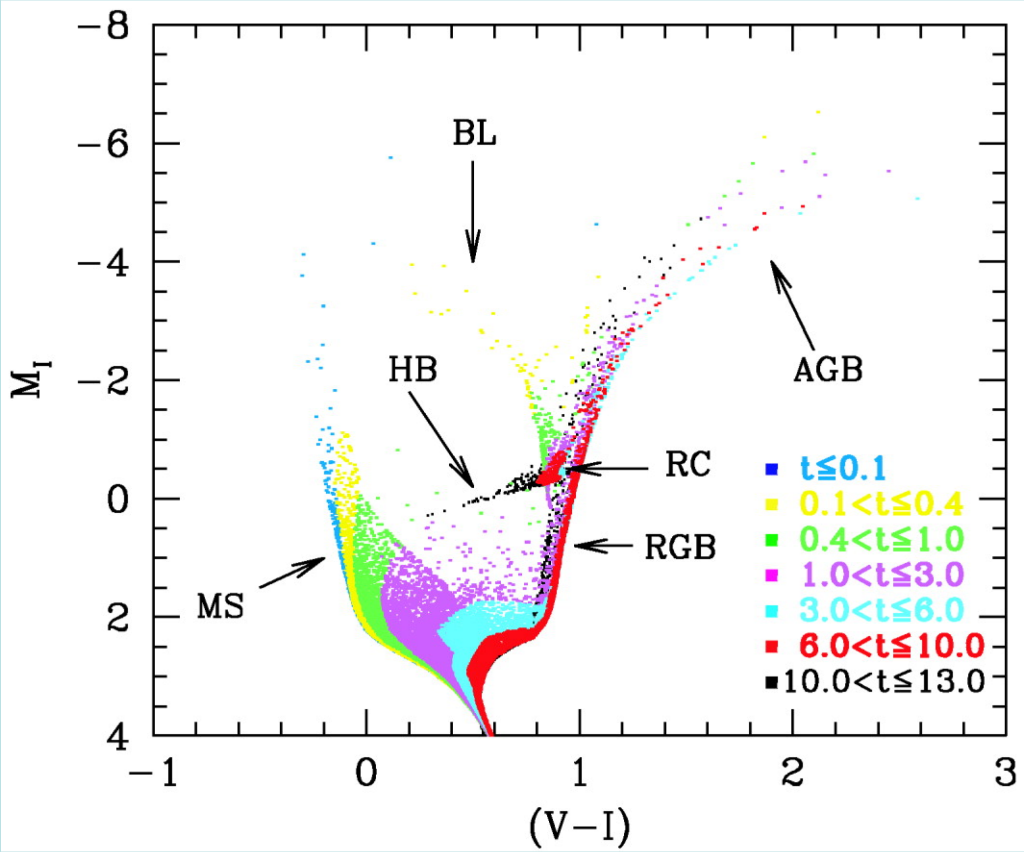
M31, CenA @ HR

Massive stars -8; TRGB -4; oldest MSTO +4

M31 & around - m-M=24 -25
VIIZw403, CenA□□□□□□ 28
IZw18 30
Virgo 31

Es with range of luminosity

Colour-Magnitude diagram analysis



Aparicio & Gallart 2004