41st ESLAB Symposium - May 2007

The impact of HST on European Astronomy

STAR FORMATION HISTORIES OF RESOLVED STELLAR POPULATIONS

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Thanks to collaborations with:

A.Aloisi, L.Angeretti, F.Annibali, L.Greggio, A.Nota, E.Sabbi

… and many others

STAR FORMATION HISTORIES OF RESOLVED STELLAR POPULATIONS

Nowadays one of the most active research fields thanks to HST, with greatest impact on/of European Astronomy

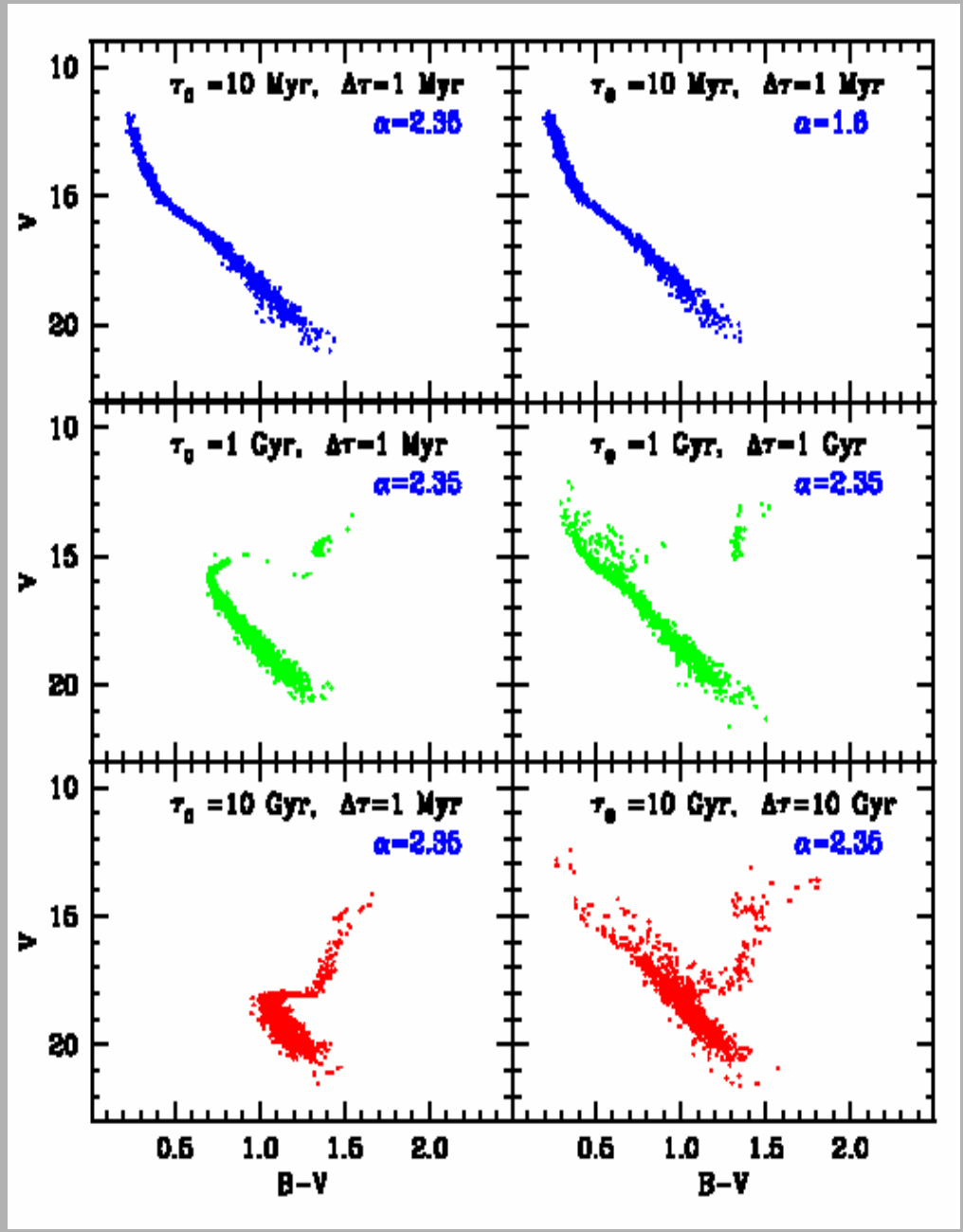
In the last ten years we have had a large number of HST treasury/legacy/regular programs aimed at the derivation of the SFHs of resolved nearby galaxies, with many people and groups involved on both sides of the Atlantic (e.g. Aloisi, Aparicio, Brown, Cole, Dalcanton, Dolphin, Gallart, Greggio, Harris, Held, Rejkuba, Schulte-Ladbeck, Skillman, Tolstoy, Tosi, Vallenari, Valls-Gabaud, etc**.) and with large impact on our understanding of galaxy evolution.**

It all started 20 years ago, when the synthetic CMD method to derive the SFH was developed in Europe (☺ **)**

Effect on CMD of:
SF epoch and duration, IMF

hypothetical stellar system (open cluster)

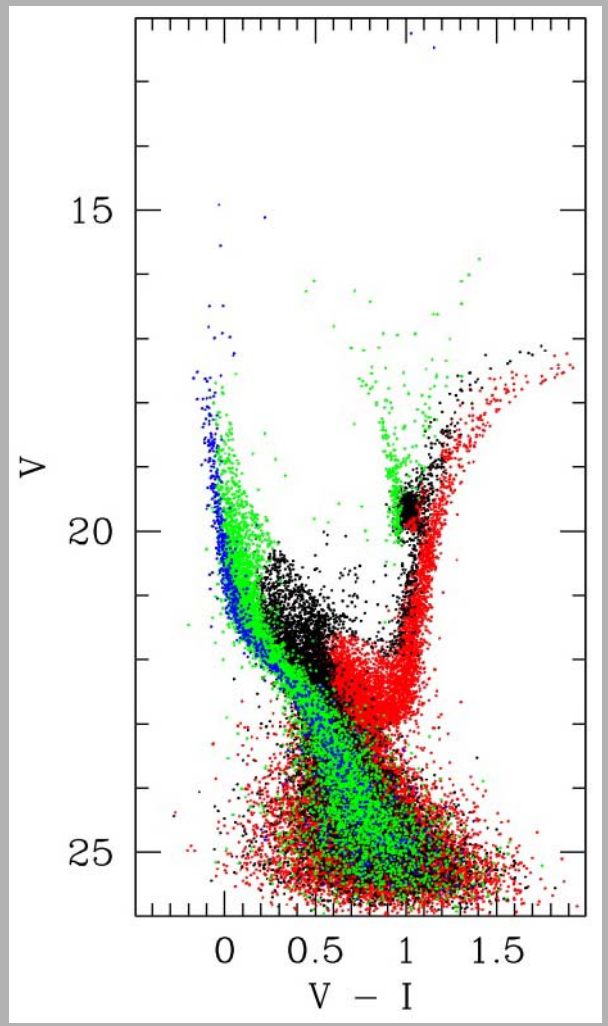
$(m\text{-}M)_0$ = 12.5,
E(B-V) = 0.45
1000 resolved stars



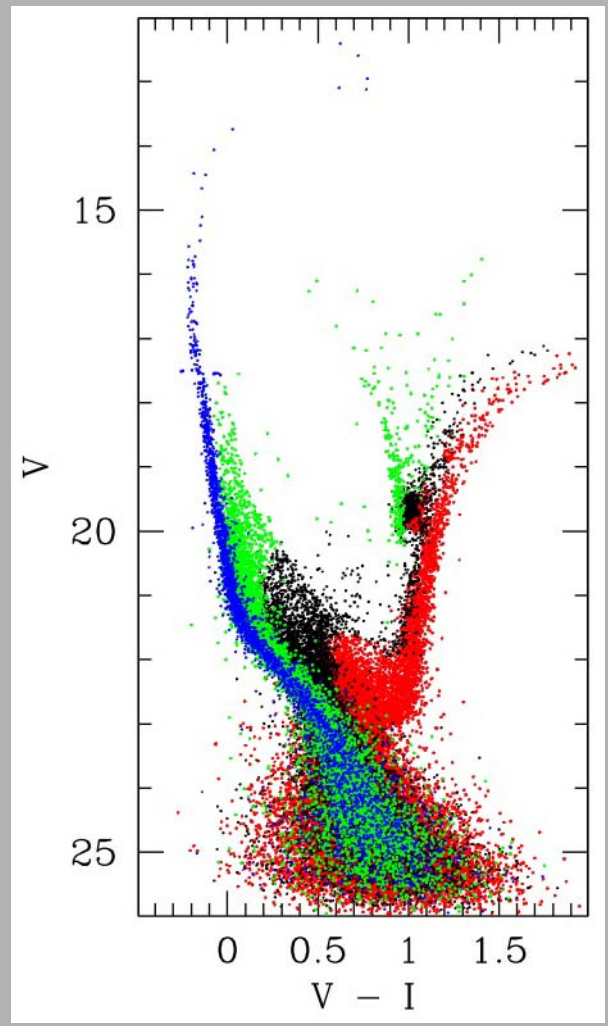
Padova tracks with Z=0.02 (Bressan et al. 93)

Synthetic CMD of 50000 stars with $(m-M)_0$=19, E(B-V)=0.08 (e.g. an SMC region) and WFPC2 photometric conditions

- age < 0.1 Gyr
- 0.1 - 1 Gyr
- 1 - 3 Gyr
- > 3 Gyr



SFR=const since 13 Gyr



SFR=const from 13 Gyr to 100 Myr ago + burst since 20 Myr

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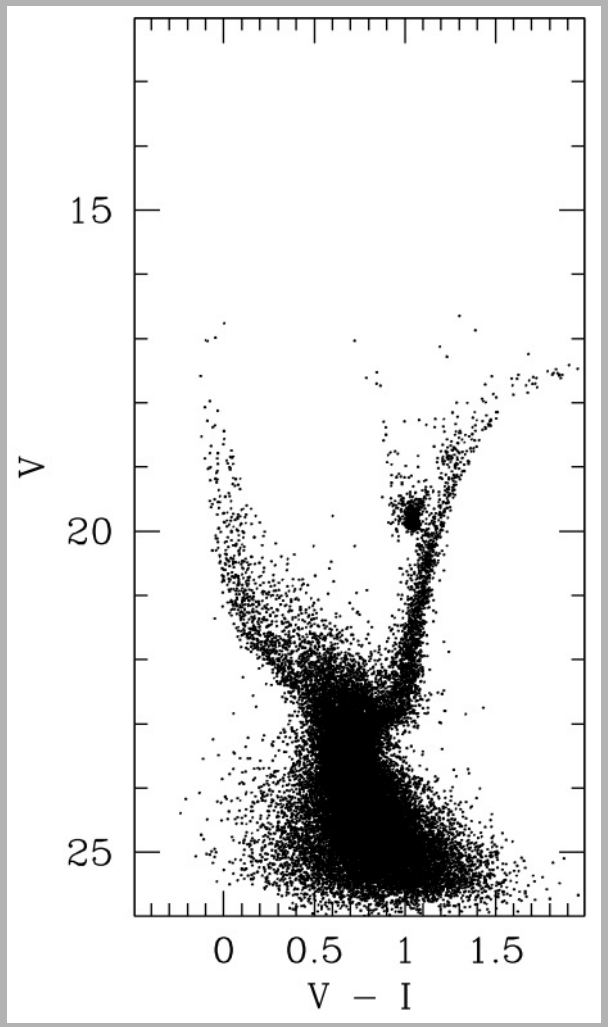
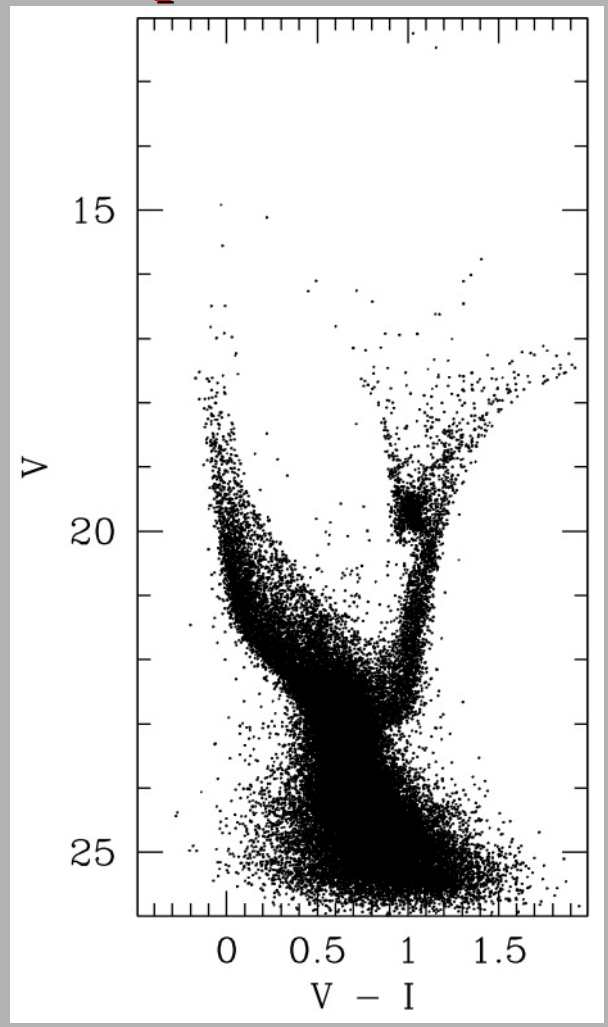
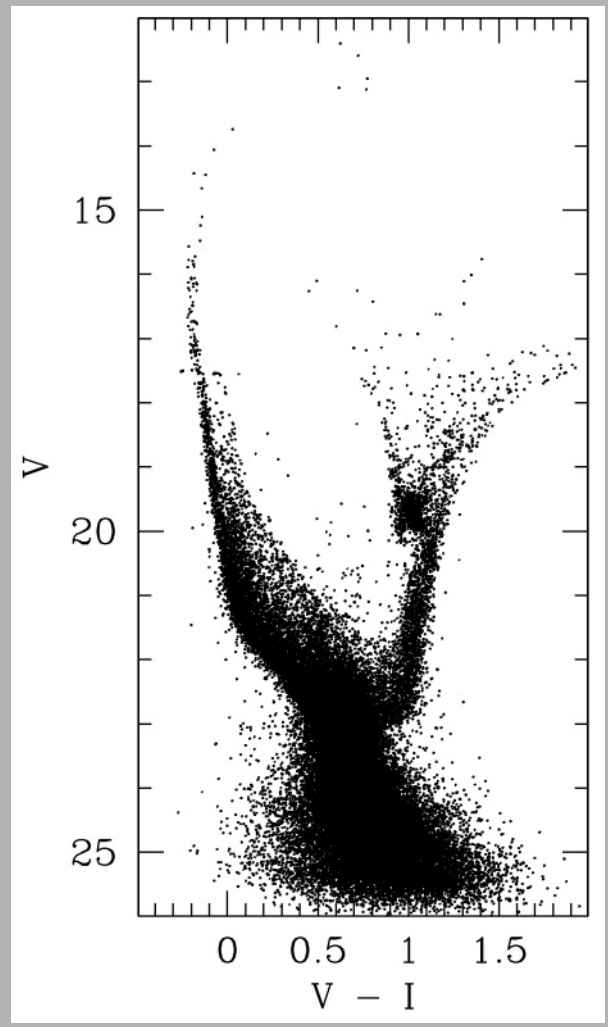


SFR=$e^{-t/\tau}$ since 13 Gyr
τ=5 Gyr



SFR=const since 13 Gyr



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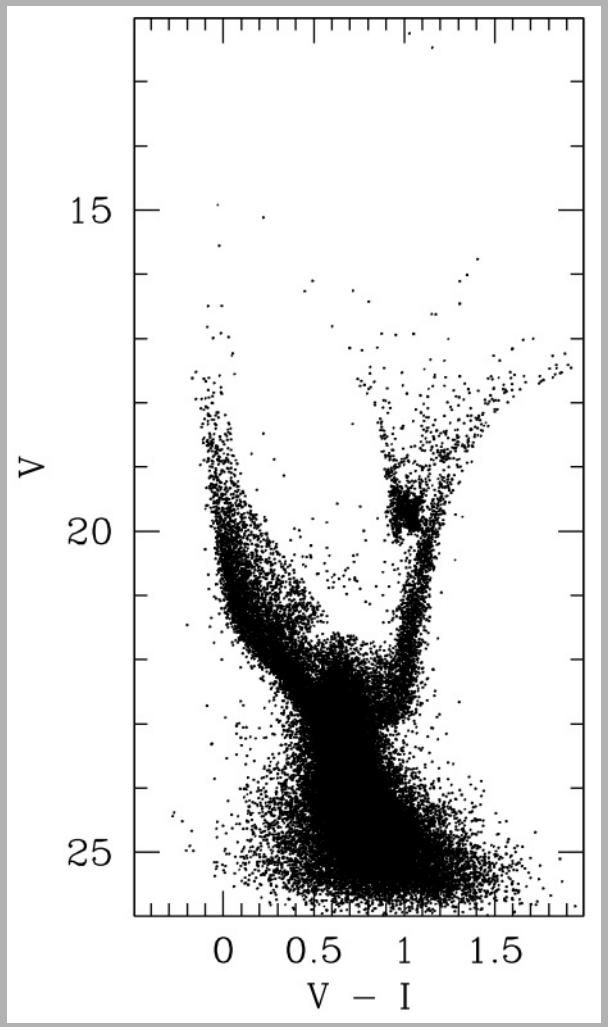
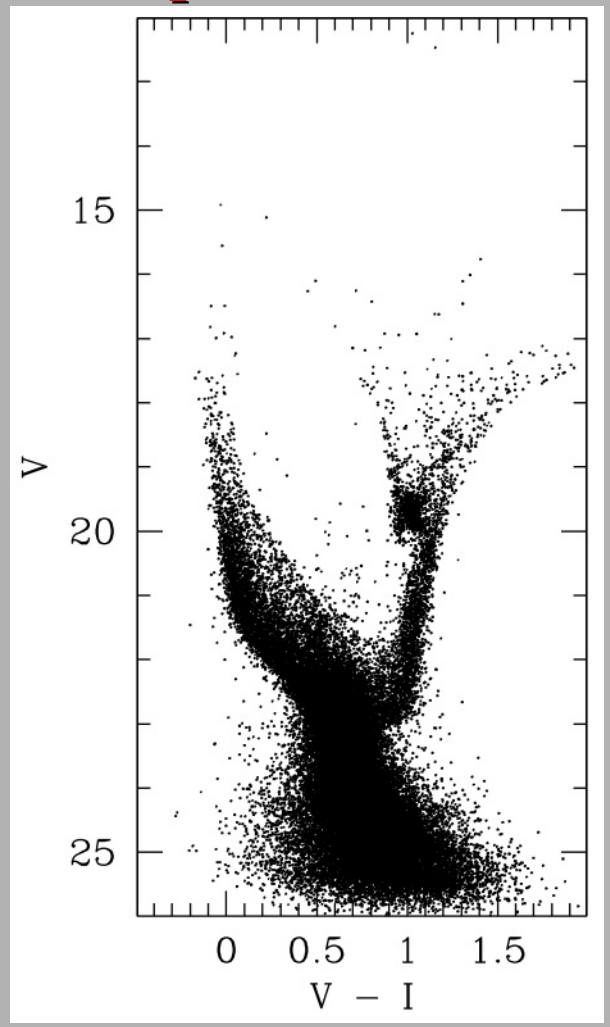
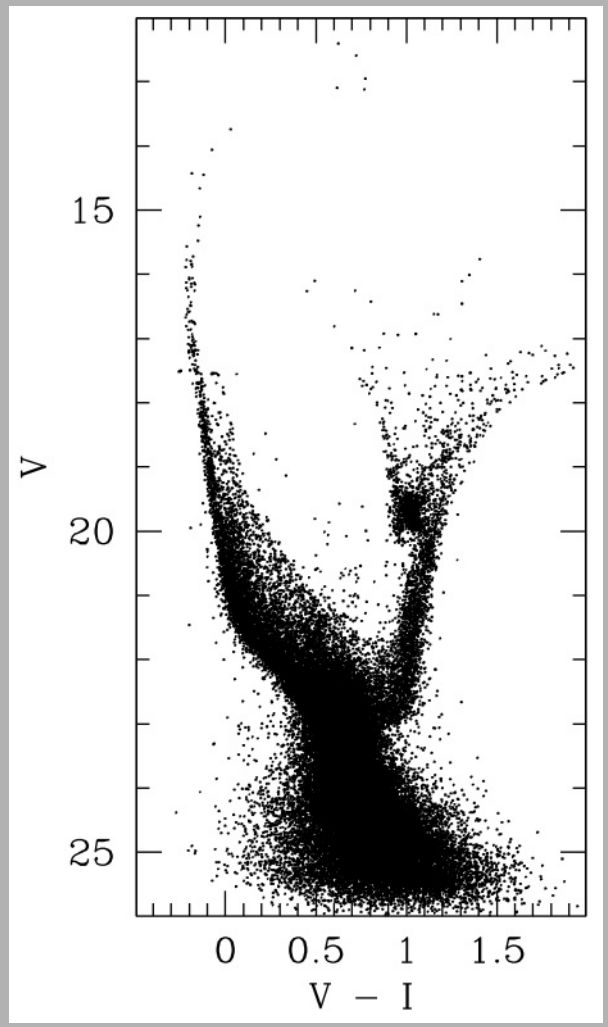
Synthetic CMD of 50000 stars
with $(m\text{-}M)_0$=19, E(B-V)=0.08 (e.g. an SMC region) and WFPC2 photometric conditions



SFR=const since 13 Gyr with gap 3-2 Gyr ago



SFR=const since 13 Gyr



SFR=const from 13 Gyr to 100 Myr ago + burst since 20 Myr

SFH from synthetic Colour-Magnitude Diagrams

Method

Based on complete sets of homogeneous stellar evolution tracks (e.g., Geneva, Padova, etc.) with various metallicities

Creates synthetic CMDs with the observed number of stars, taking into account all the theoretical parameters (age, metallicity, IMF, SFR, stochastic effects of small number statistics) and observational uncertainties (photometric errors, incompleteness, blending)

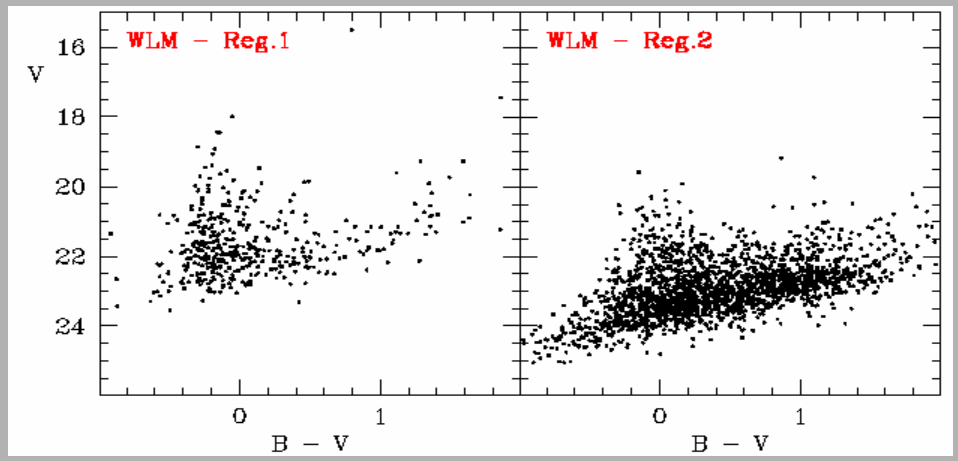
Provides: starting epoch, duration and SFR of the SF episodes, number of episodes and intervals, IMF, hints on Z

A good model must reproduce all the features of observational CMD and LFs. We may not get unique results, but we can sensibly reduce the range of possible evolutionary scenarios of the examined region

(Tosi et al. 1991, Greggio et al. 1998)

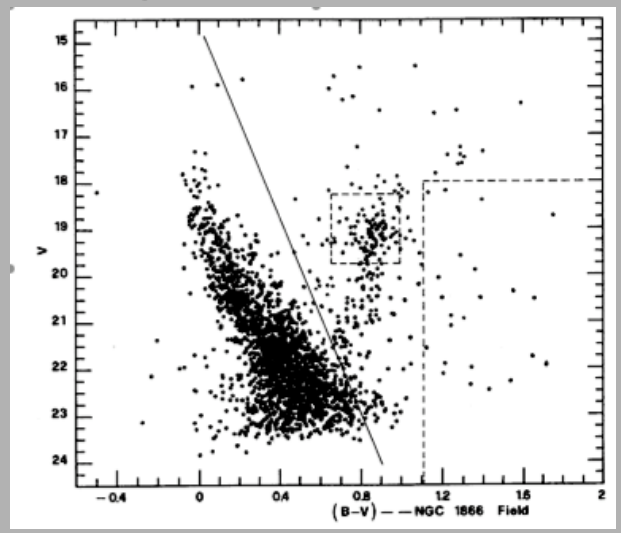
SFH from synthetic CMDs: the impact of European astronomy

Bologna group (Tosi, Greggio …)



WLM (Ferraro et al. 89)
1.5m & 2.2 m, La Silla

Padova group (Bertelli, Chiosi…)

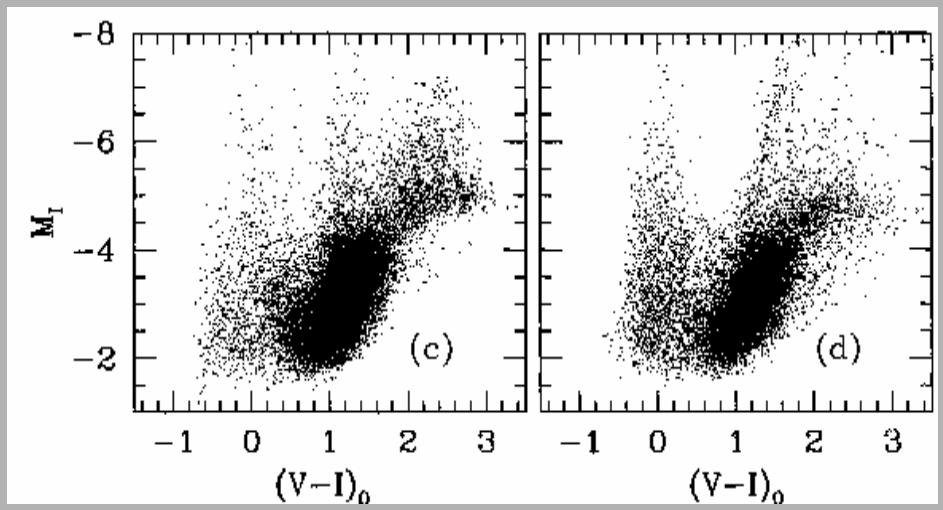


LMC (Bertelli et al. 92)
4m, CTIO

First applications, with ground-based, relatively small telescopes showed that the SF in late-type dwarfs occurs in long episodes of moderate activity separated by short quiescent phases, gasps (Marconi et al.1995) and not bursts, and differs from one region to another in spite of the tiny size of the system

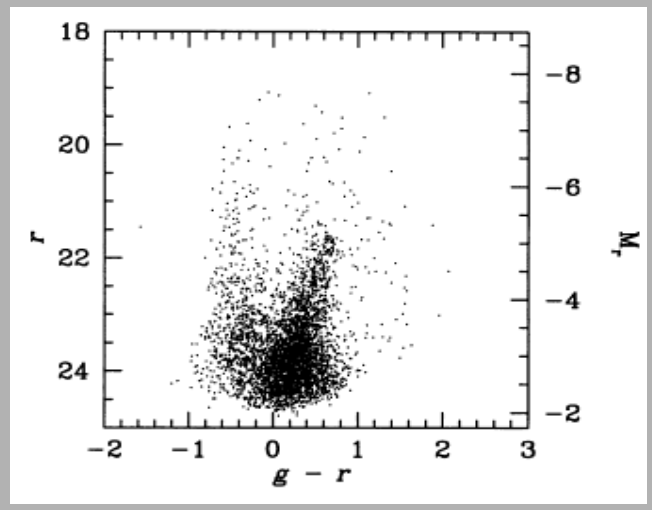
SFH from synthetic CMD method: the impact of European astronomy

the Canarias - Padova group
(Aparicio, Bertelli, Chiosi, Gallart …)



NGC 6822
2.5m INT, Canarias
Gallart et al. 96

Tolstoy's "group"



Leo A
2.1m, KPNO
Tolstoy 96

SFH from synthetic CMD method: the impact of European astronomy

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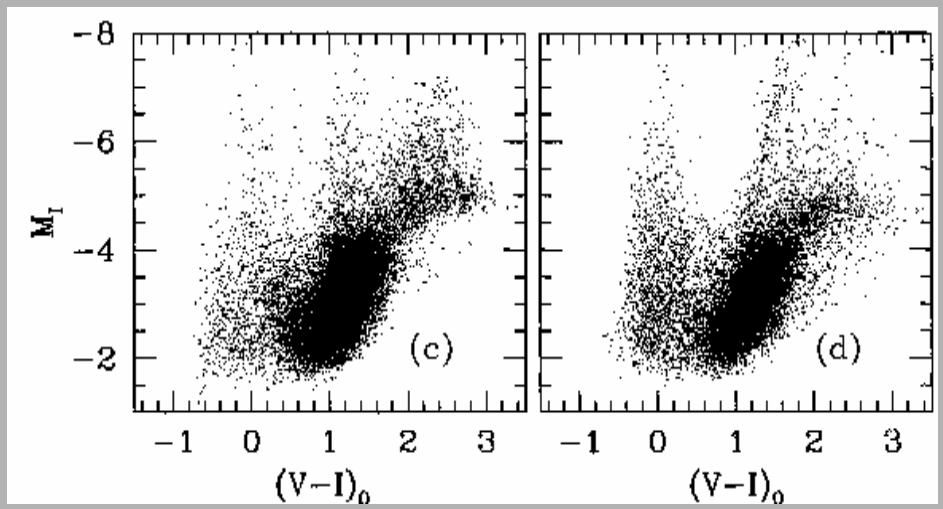

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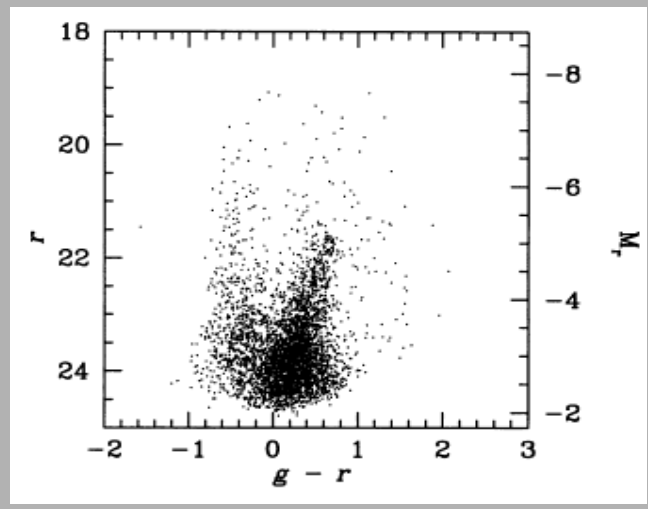
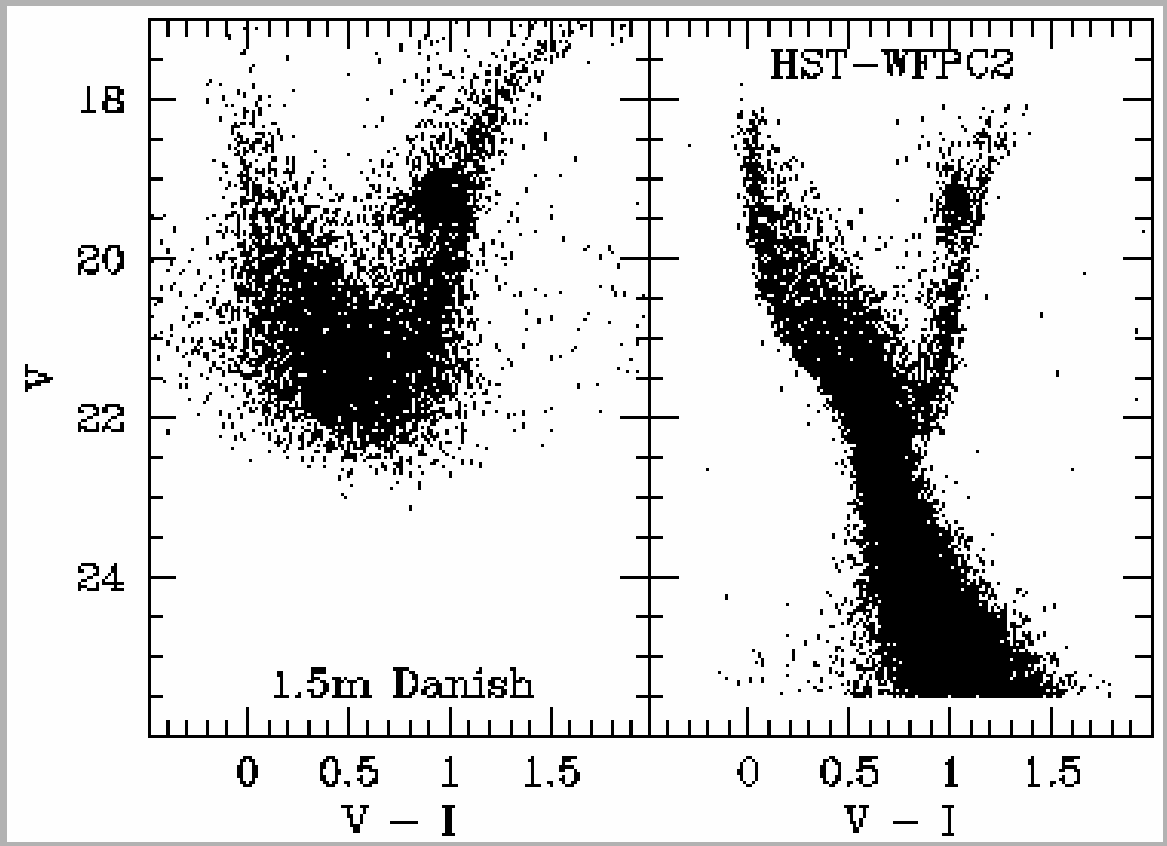


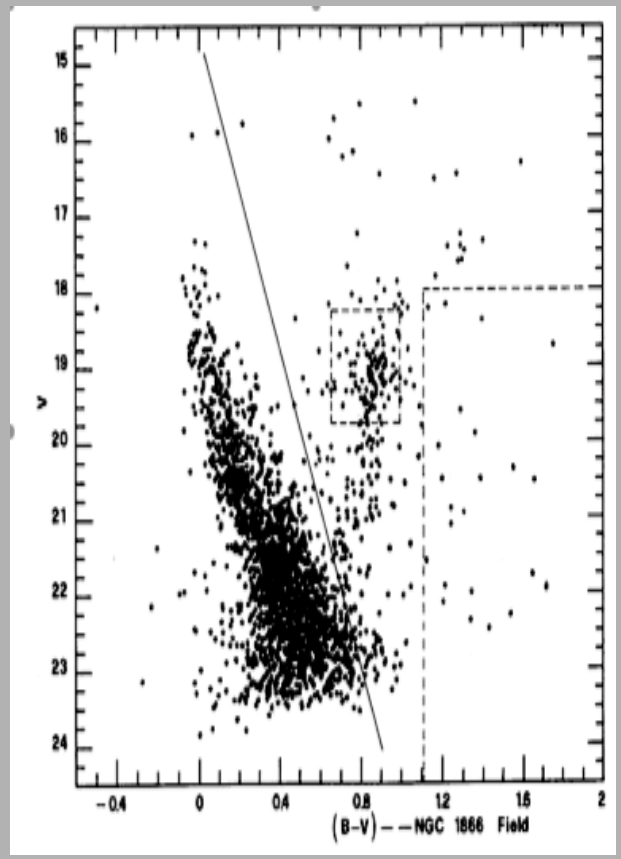
Leo A
2.1m, KPNO
Tolstoy 96

then, HST became available …

the HST effect: WFPC2

Smecker-Hane et al. 02



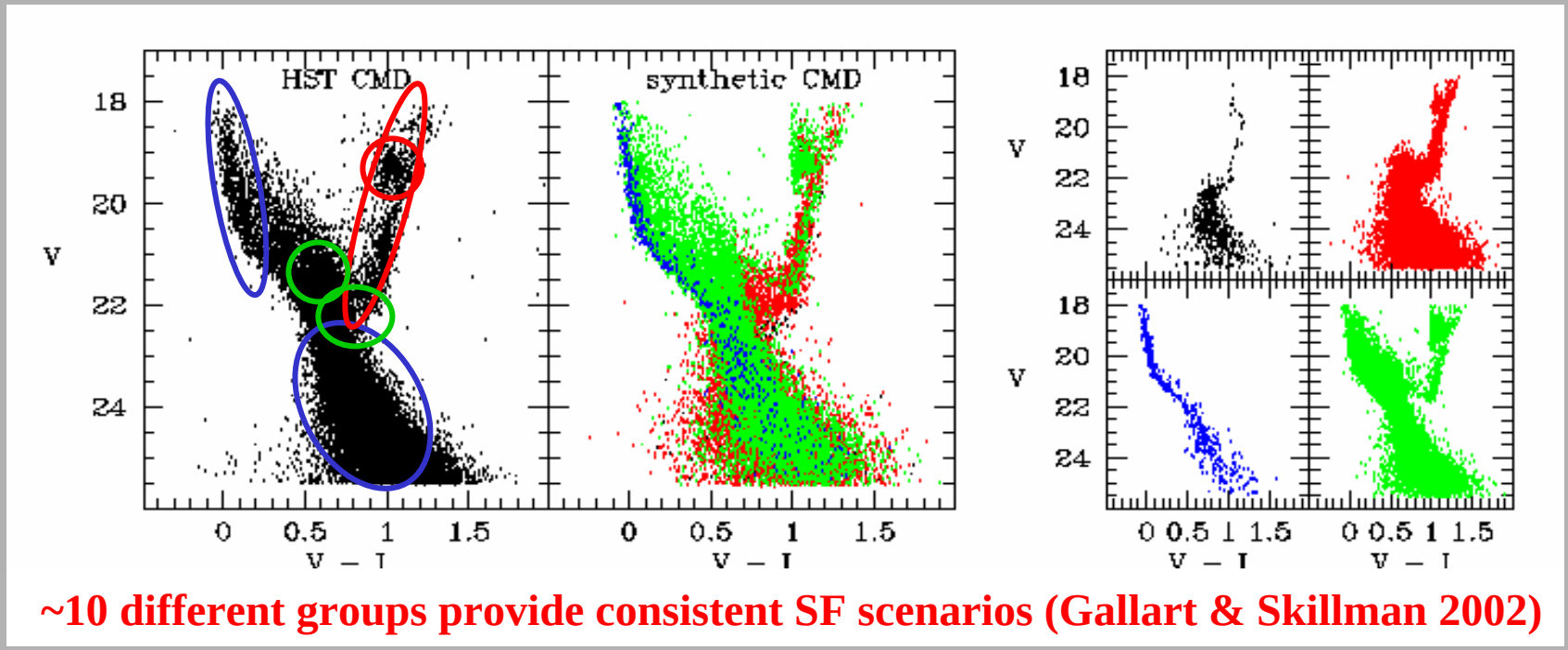


4m CTIO

LMC bar

much deeper and tighter CMDs =>
a worldwide burst of groups using synthetic CMD method

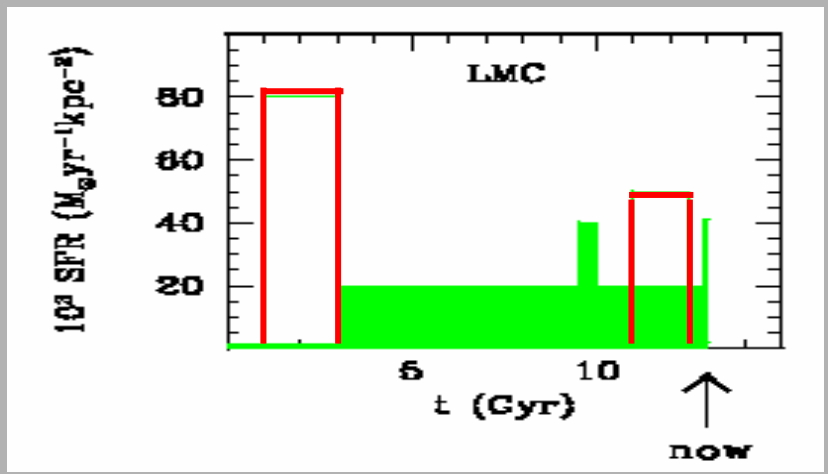
the Coimbra experiment on the LMC bar



~10 different groups provide consistent SF scenarios (Gallart & Skillman 2002)

observational CMD: Smecker-Hane et al. 2002

synthetic CMD: Tosi et al. 2002

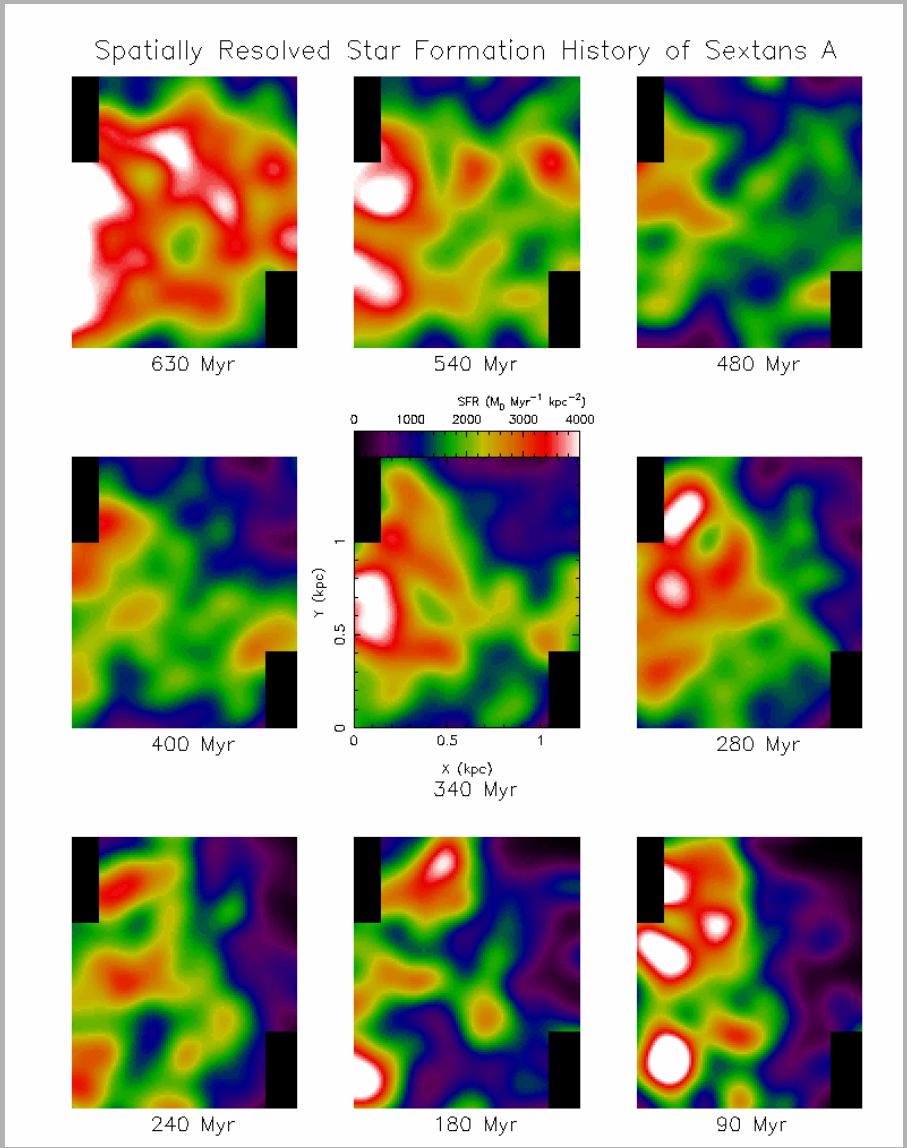


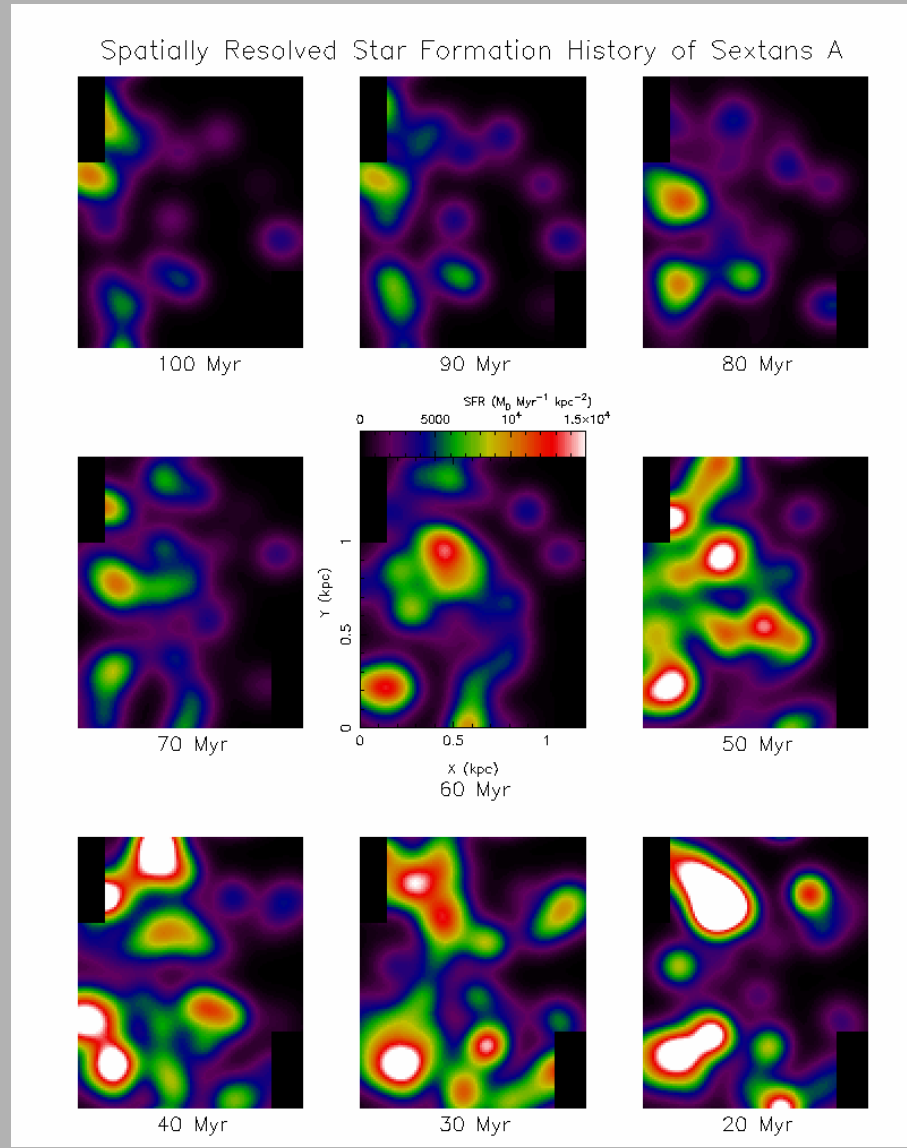
1) fairly continuous SF
2) different from cluster SFH

Spatially resolved SFH

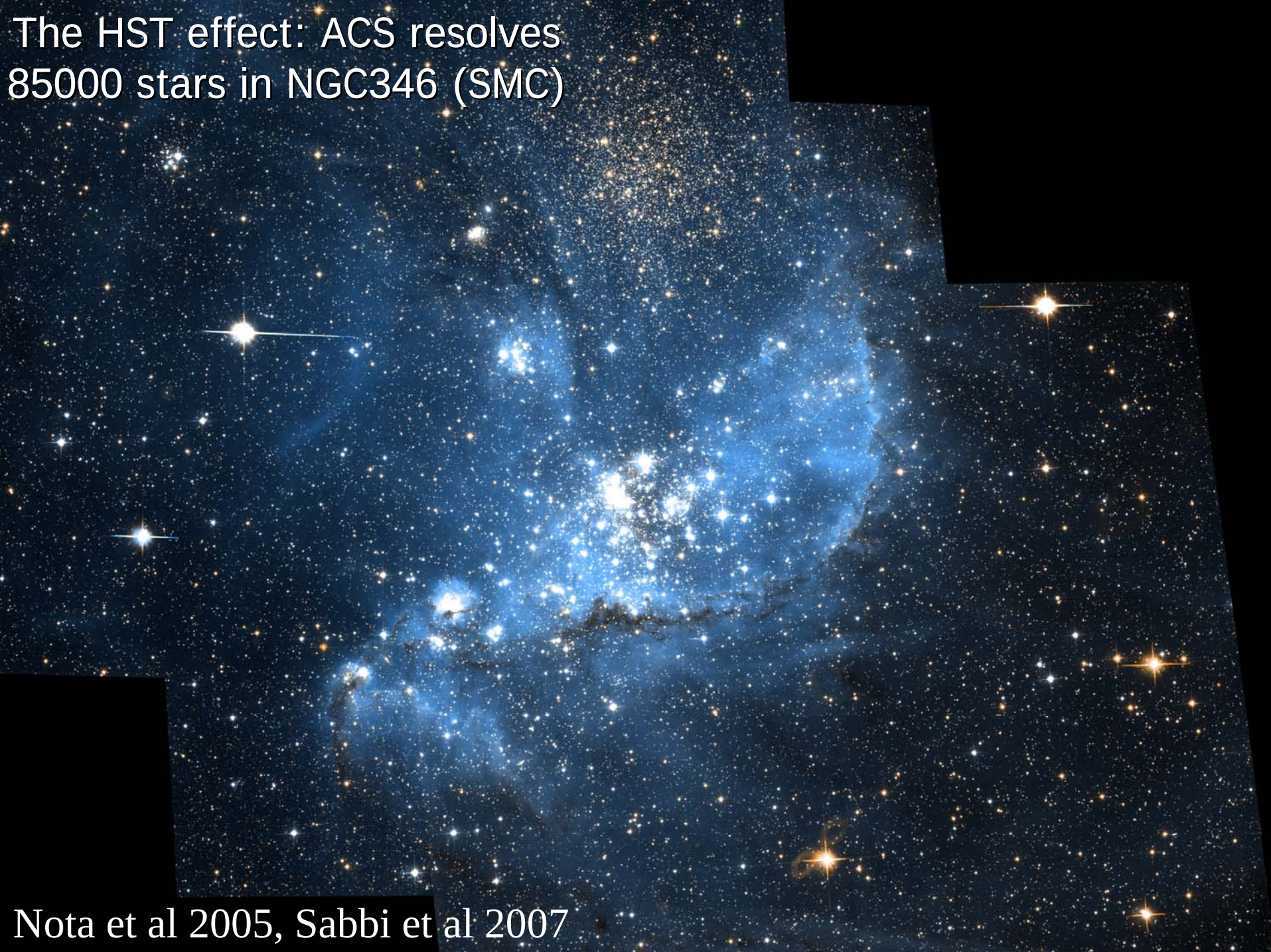
Sextans A

Dohm-Palmer et al. 2002

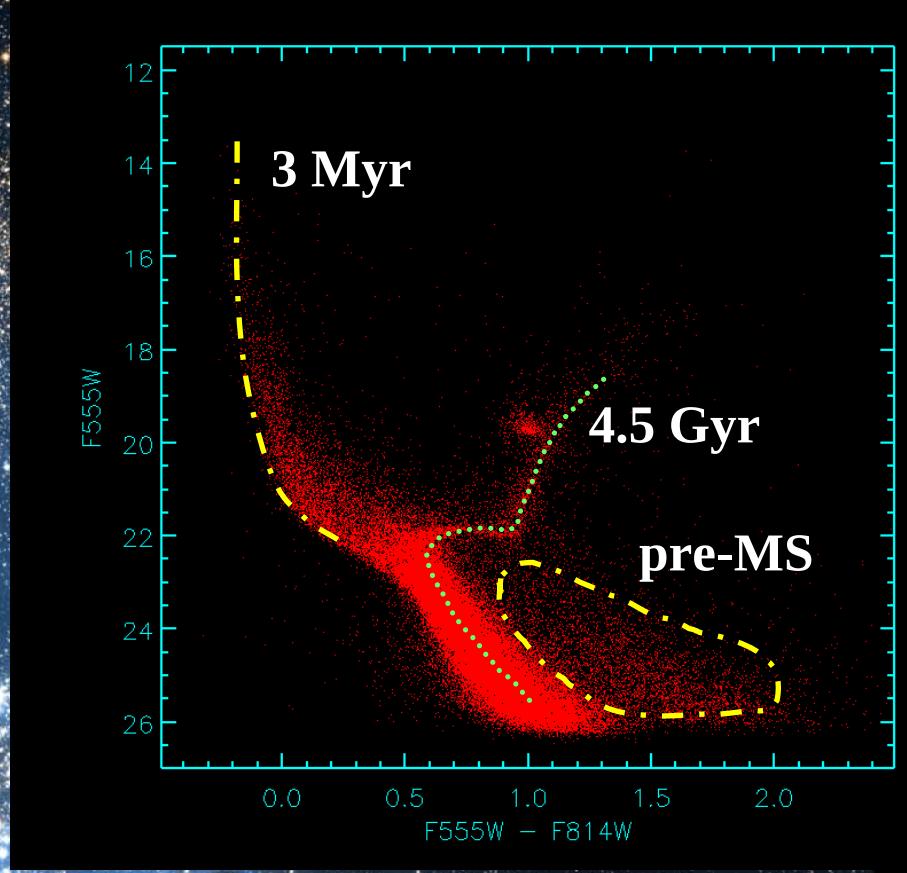




fairly continuous SF: gasping rather than bursting


The HST effect: ACS resolves
85000 stars in NGC346 (SMC)
Nota et al 2005, Sabbi et al 2007

The HST effect: ACS resolves 85000 stars in NGC346 (SMC)



Nota et al 2005, Sabbi et al 2007

the Local Group and beyond

Local Group galaxies:

Photometric resolution of individual stars is possible down to fainter/older objects in all galactic regions

⬇

long lookback time (up to Hubble time) for SFH is reachable and space distribution of SF is derivable

More distant galaxies:

Distance makes crowding much more severe and even HST has not resolved yet stars as faint as the MS-TO

⬇

lookback time ranges from a few tens of Myr to several Gyr (reached only in outer, less crowded regions) and space distribution is derivable only in a few cases

However, LG galaxies are not representative of all existing types: ellipticals and BCDs (i.e. the most and the least evolved ones) are not present here

⬇

SFHs must be studied also outside the LG

WFPC2 – NIC2:
BVJH

NGC 1569

2.2 Mpc

Strong starburst dIrr, evidence of galactic winds

WFPC2 – NIC2 :
UBVIJH

NGC 1705

5.1 Mpc

Strong starburst BCD, evidence of galactic winds

WFPC2 – ACS:
BVI

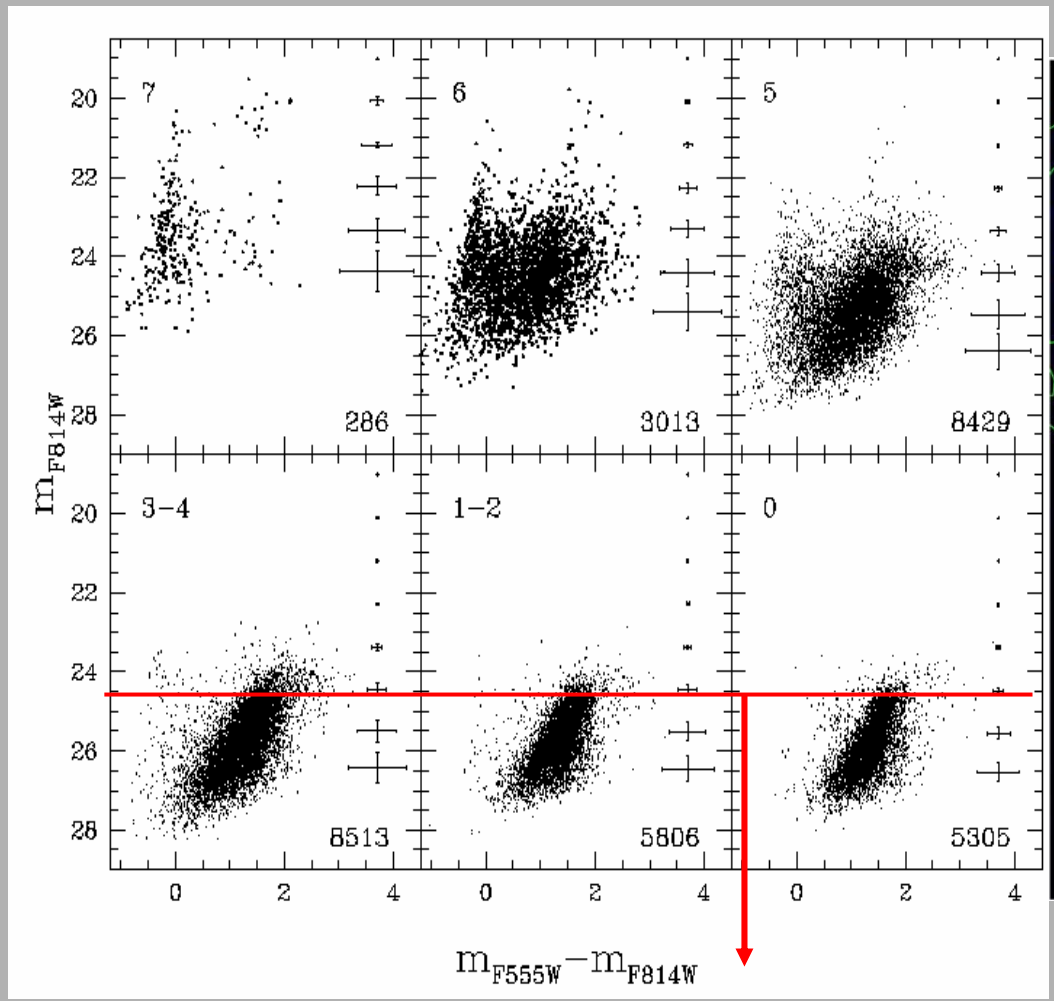
IZw18

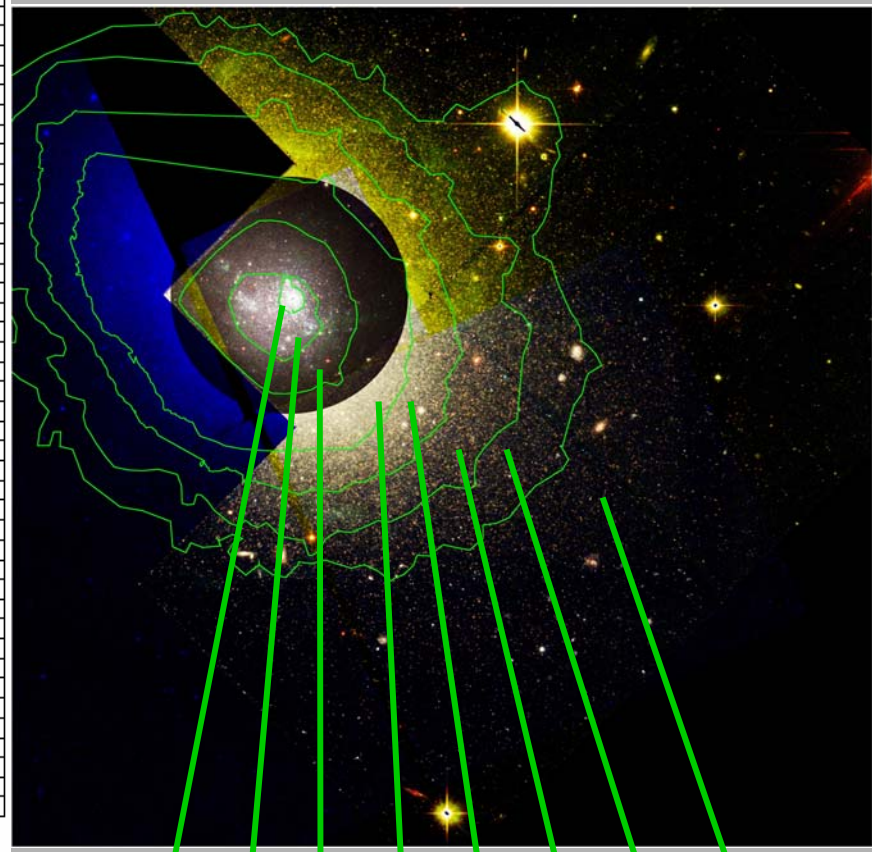
10 – 20 Mpc

Most metal poor BCD, winds ?

Different regions in NGC 1705

Tosi et al. 01





7 6 5 4 3 2 1 0

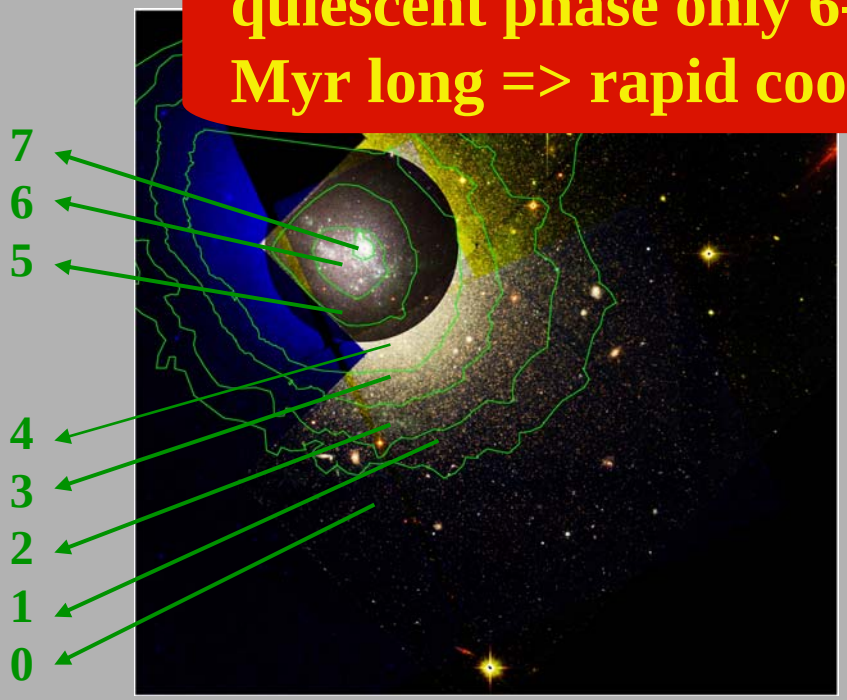
T-RGB very well defined
=> $(m\text{-}M)_0$ = 28.54 ± 0.26
=> D = 5.1 ± 0.6 Mpc

NGC1705: a post-starburst BCD already back to SF activity

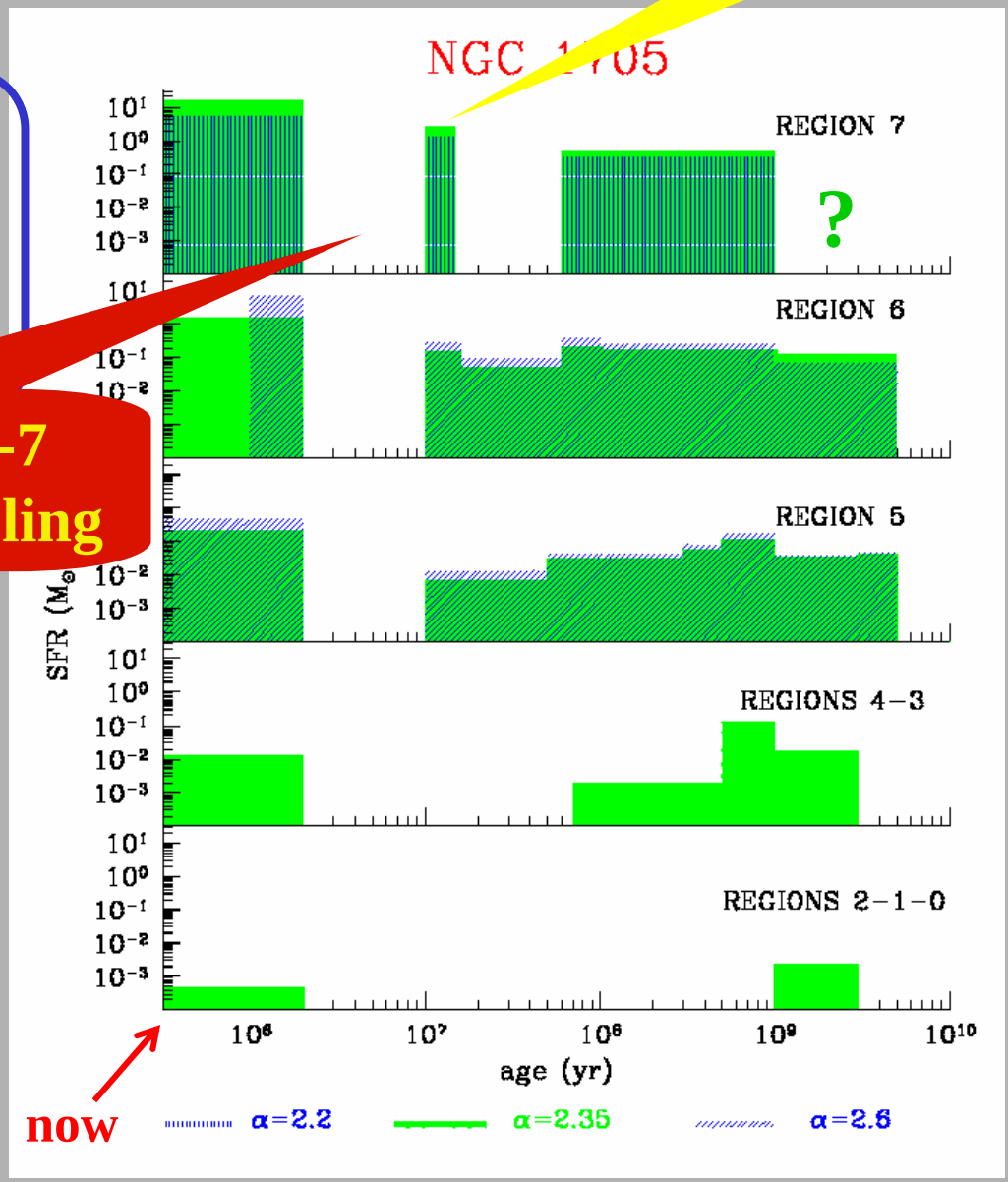
wind source

1) Some SF 5 - 1 Gyr ago
2) Some SF 1 - 0.02 Gyr ago
3) Strong central SF 17 - 10 Myr ago
4) No SF anywhere 10 - 3 Myr ago
5) Strong SF everywhere 3-0 Myr a

quiescent phase only 6-7 Myr long => rapid cooling



Annibali et al. 03



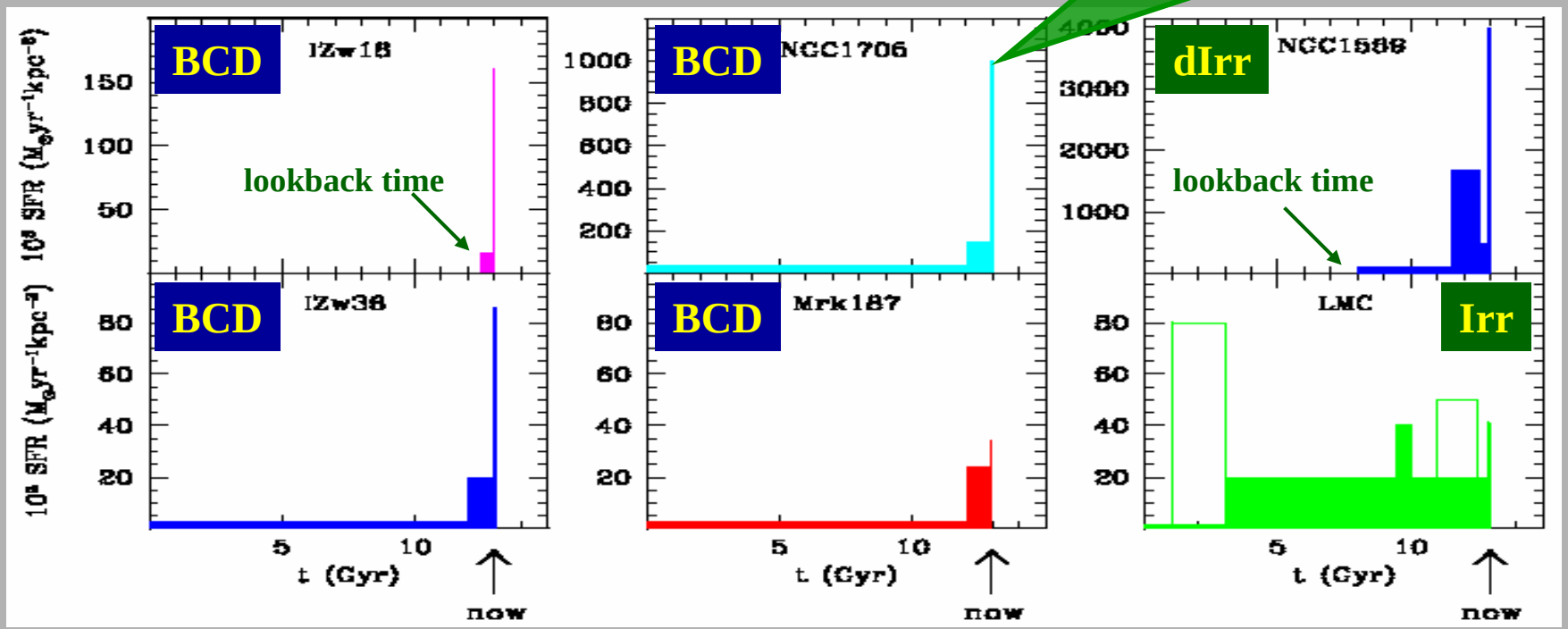
starburst dwarfs
studied with HST & CMD method

WFPC2 - NICMOS

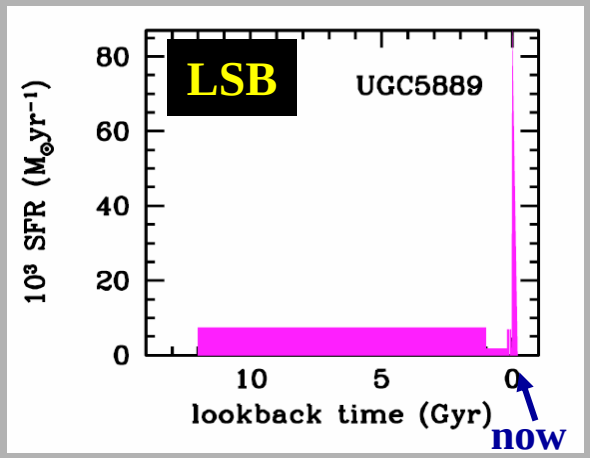
ACS

Galaxy	D (Mpc)	SFR ($M_\odot$ yr^{-1})	12+log(O/H)	Reference
I Zw 18	10-12	3-10 10^{-3}	7.18	Aloisi et al. 99
VII Zw 403	4.4	1.3 10^{-2}	7.69	Lynds et al. 98
UGCA 290	6.7	1.1 10^{-2}	?	Crone et al. 00, 01
I Zw 36	5.8	2.5 10^{-2}	7.77	Schulte-Ladbeck et al. 01
NGC 6789	3.6	4.0 10^{-2}	7.7?	Drozdovsky et al. 01
UGC 5272	5.5	6 10^{-3}	7.83	Hopp et al. 01
MrK 178	4.2	$\leq$ 10^{-2}	7.95	Schulte-Ladbeck et al. 00
NGC 4214	2.7	8 10^{-2}	8.27	Drozdovsky et al. 02
NGC 1569	2.2	5 10^{-1}	8.31	Greggio et al. 98, Angeretti et al. 05
NGC 1705	5.1	3 10^{-1}	8.36	Annibali et al.
I Zw 18	?	?	7.18	HST-C14 PI Aloisi
SBS 1415+437	13.6	?	7.60	HST-C14 PI Aloisi
NGC 4449	4 ?	?	8.32	HST-C14 PI Aloisi

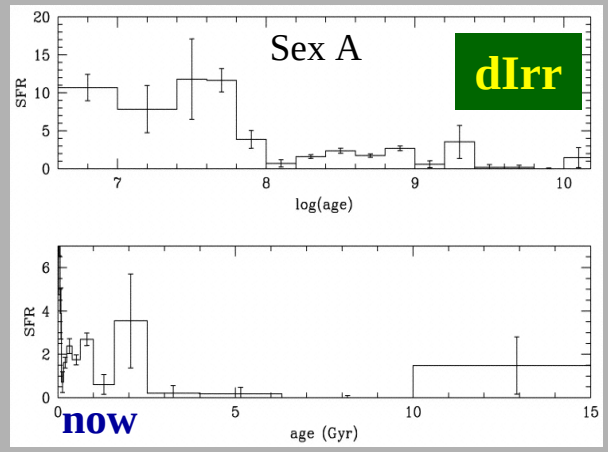
recent burst over gasping regime



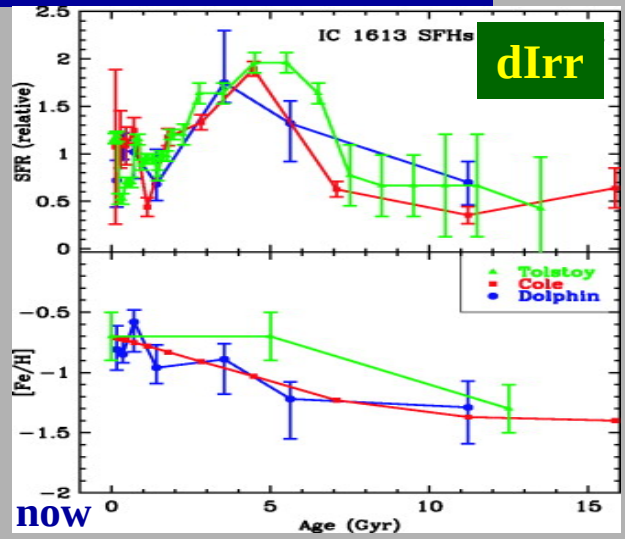
Late-type galaxies studied with HST & CMD method



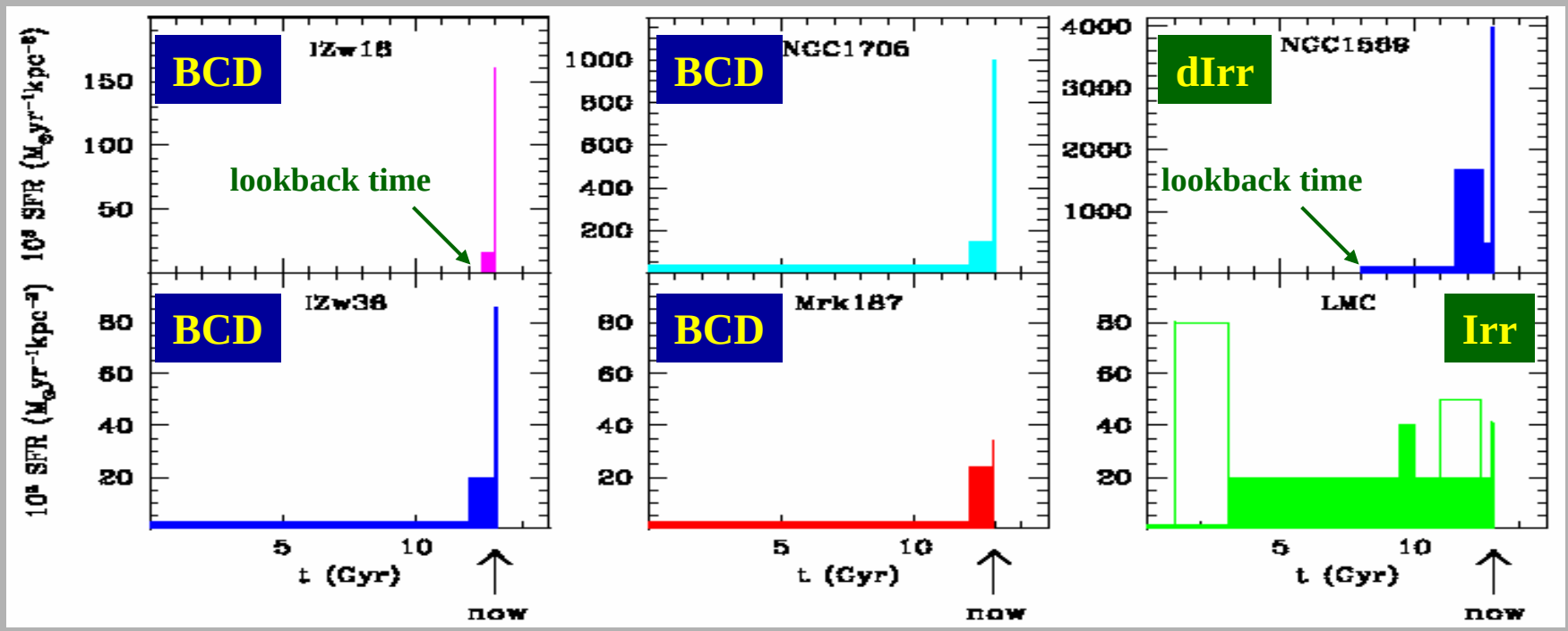
Vallenari et al 05



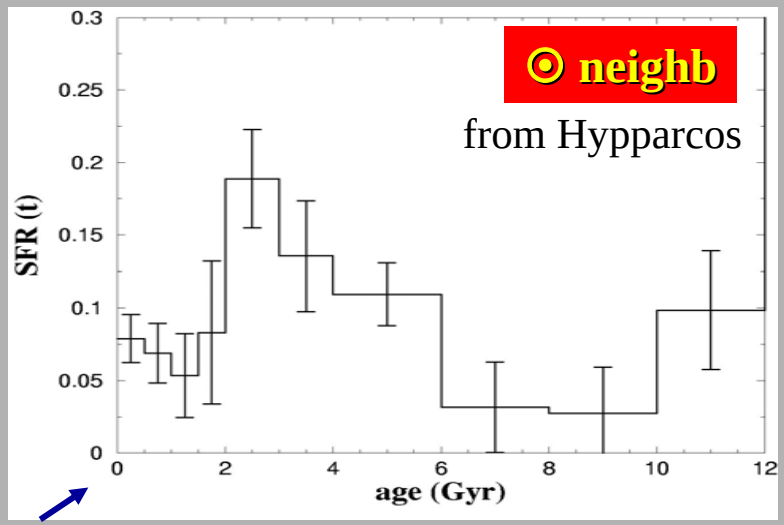
Dolphin et al. 03



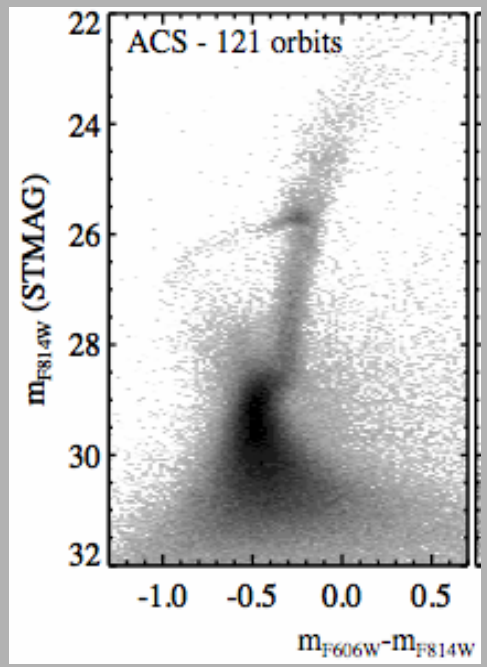
Skillman et al 03

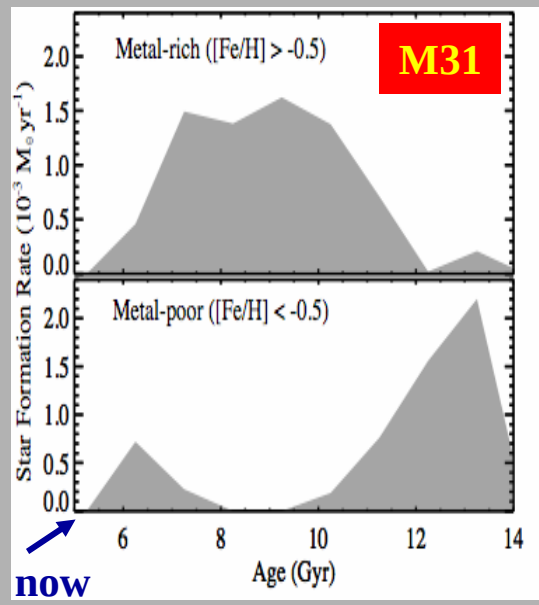


Spirals studied with CMD method

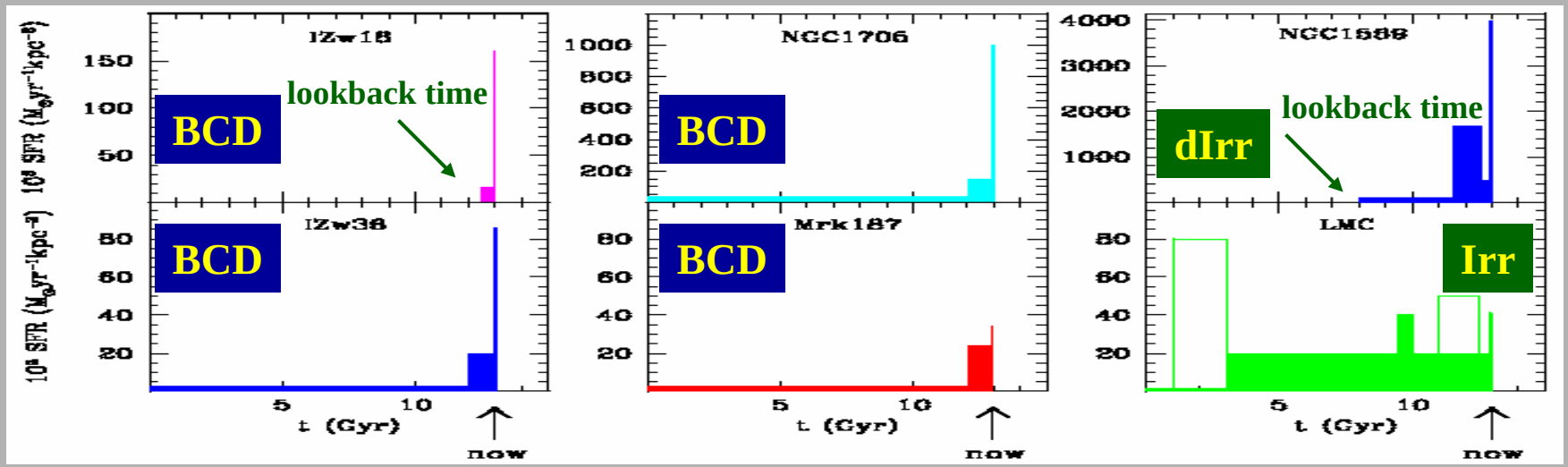


Cignoni et al 06

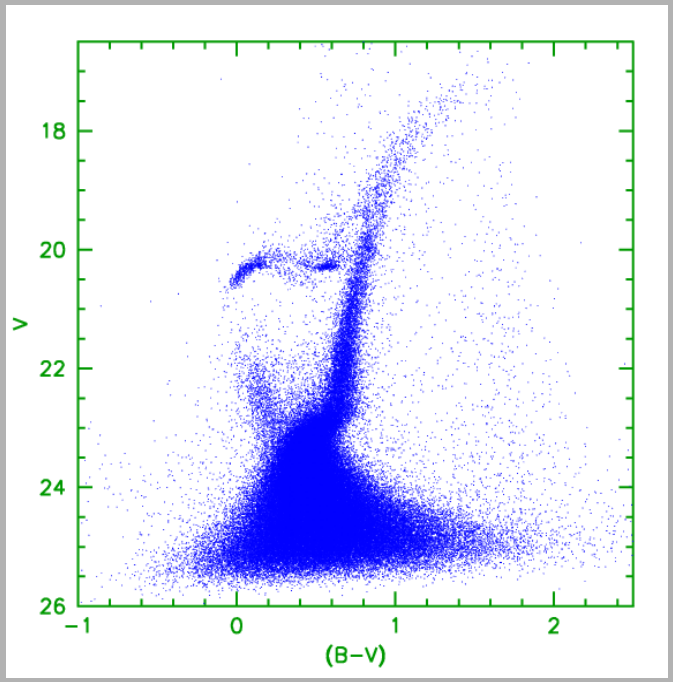


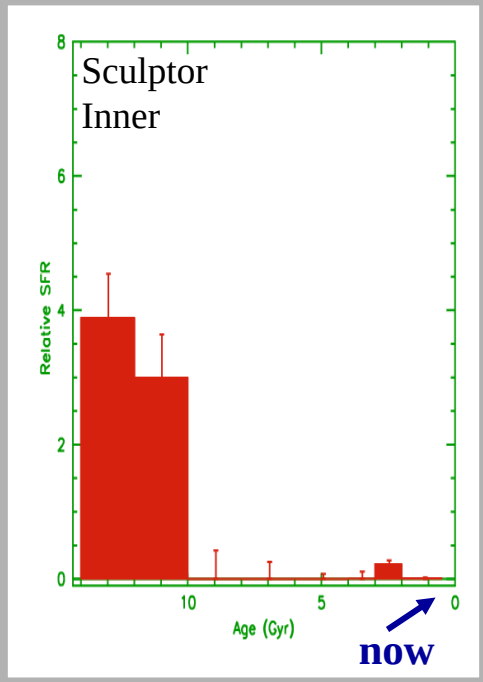


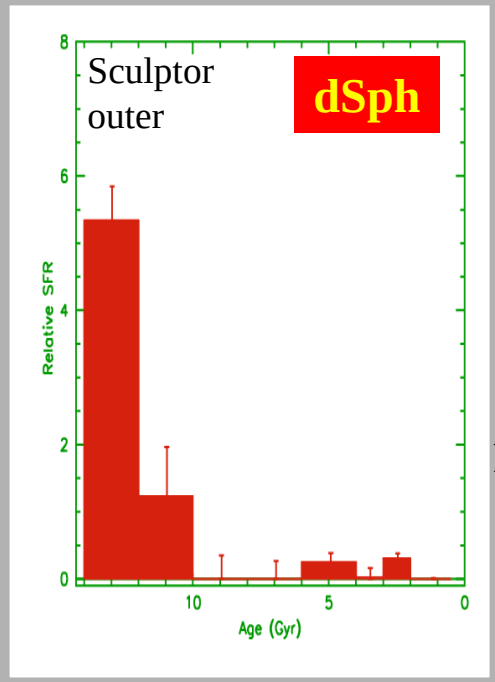
Brown 03



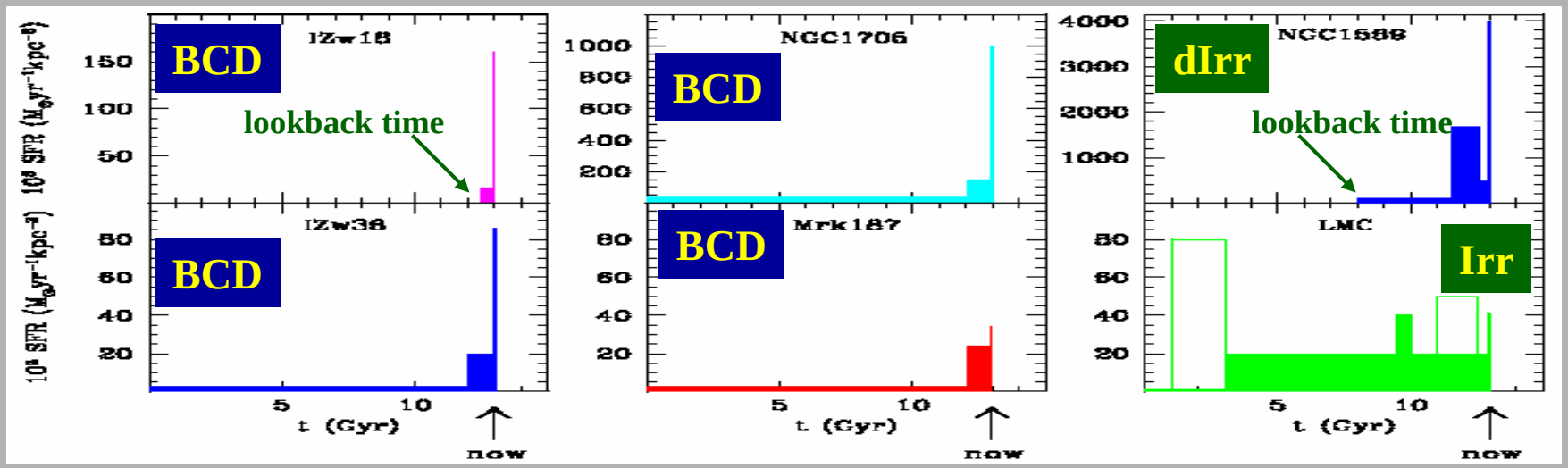
Early-type galaxies studied with CMD method







Rizzi 03



General results

a) No evidence of long interruptions in SF activity, except in early-types
b) No frequent evidence of strong SF bursts in late-type dwarfs (NGC1569 and NGC1705 exceptions among those already studied via CMDs)
c) No galaxy currently at first SF episode (all examined ones already active at reached lookback time)

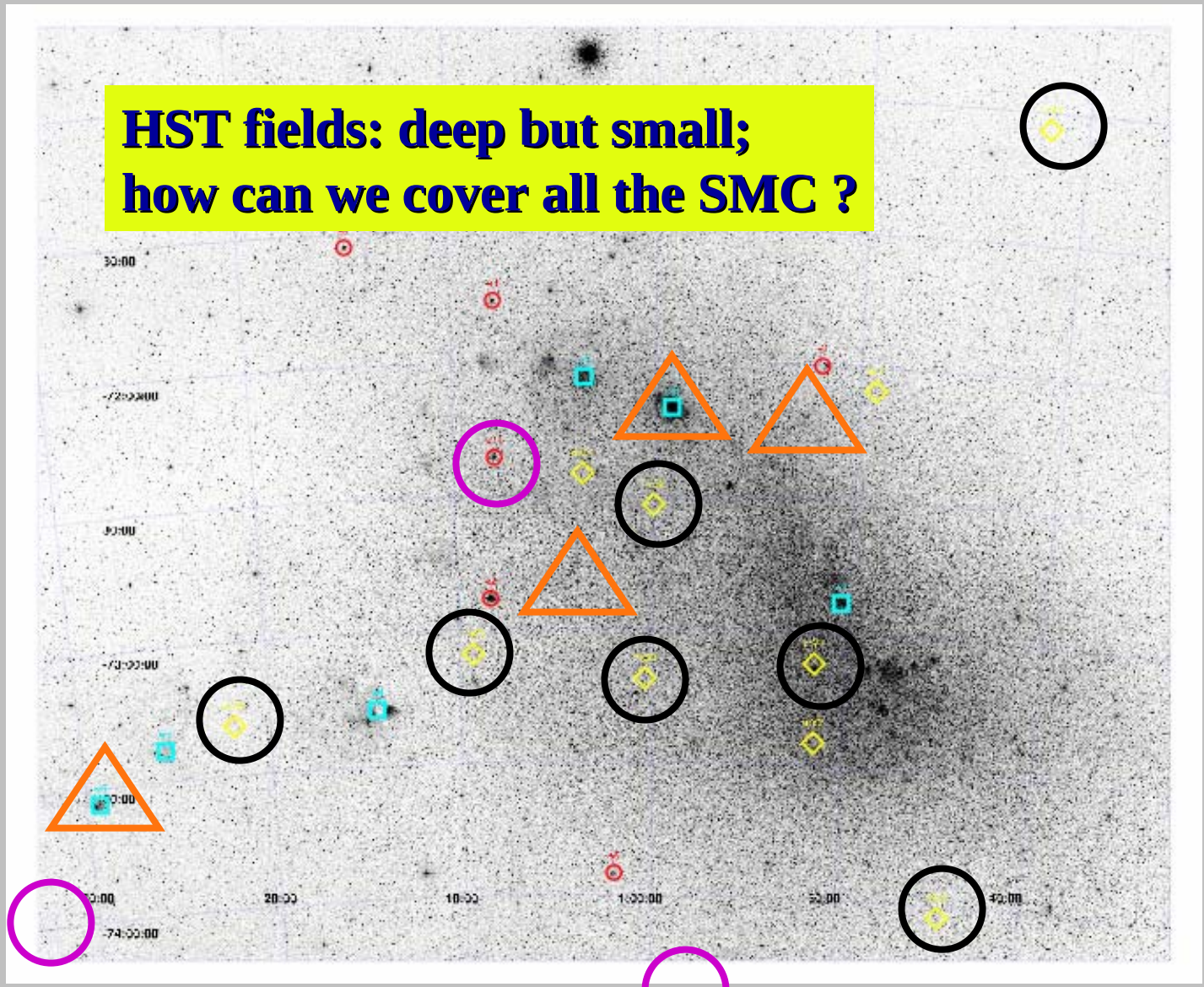
1) Gasping rather than bursting SF regime in late-type galaxies (both in Local Group and beyond)
2) No significant difference between BCDs and dIrrs, except for current SFR
3) Small (if any) contribution of dwarfs to faint blue galaxy excess at intermediate redshift (SFR too low)
4) Ages old in all dwarfs

HST follow-up and European Astronomy:

wide field imaging (WFI, VST, VISTA)
and
high-res spectroscopy (FLAMES)

The effect of the combination of HST with European instruments:
a quantum leap in galaxy evolution studies

The SMC in Space and Time (HST-C13, PIs Nota & Gallagher)



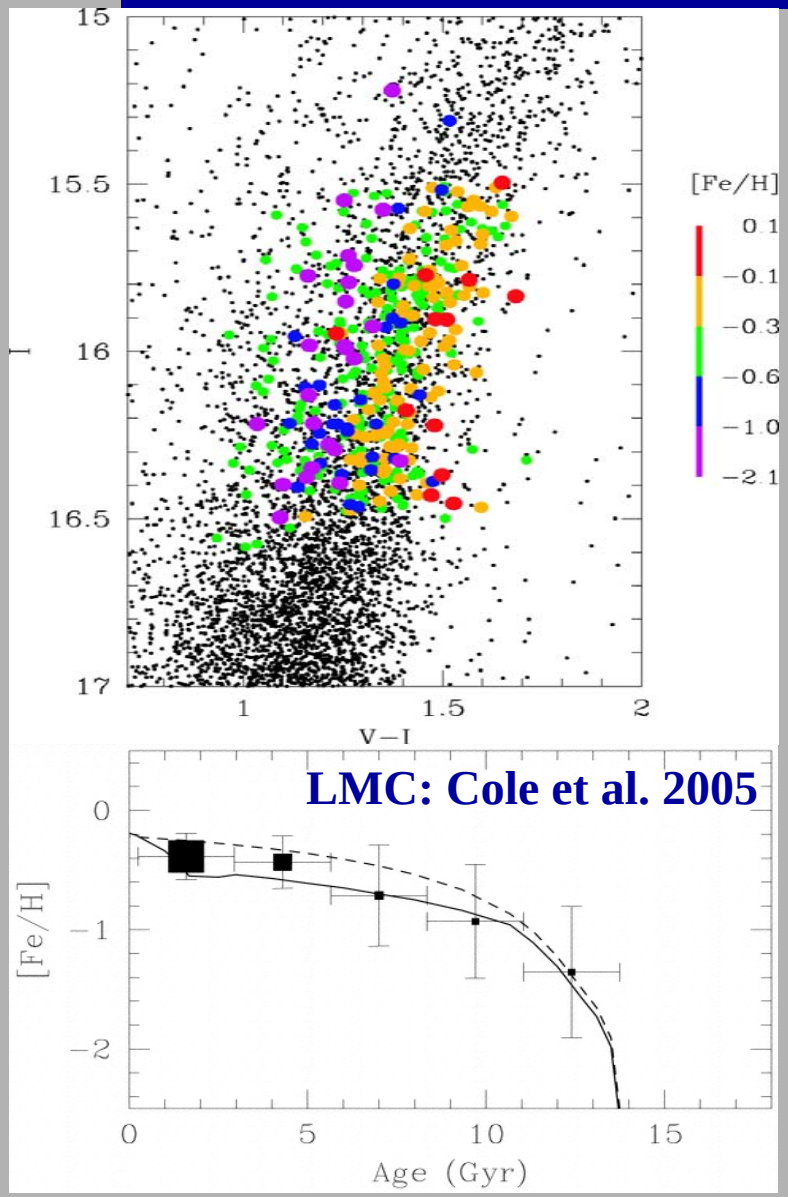
The SMC in Space and Time (VST-GTO, PI Ripepi)

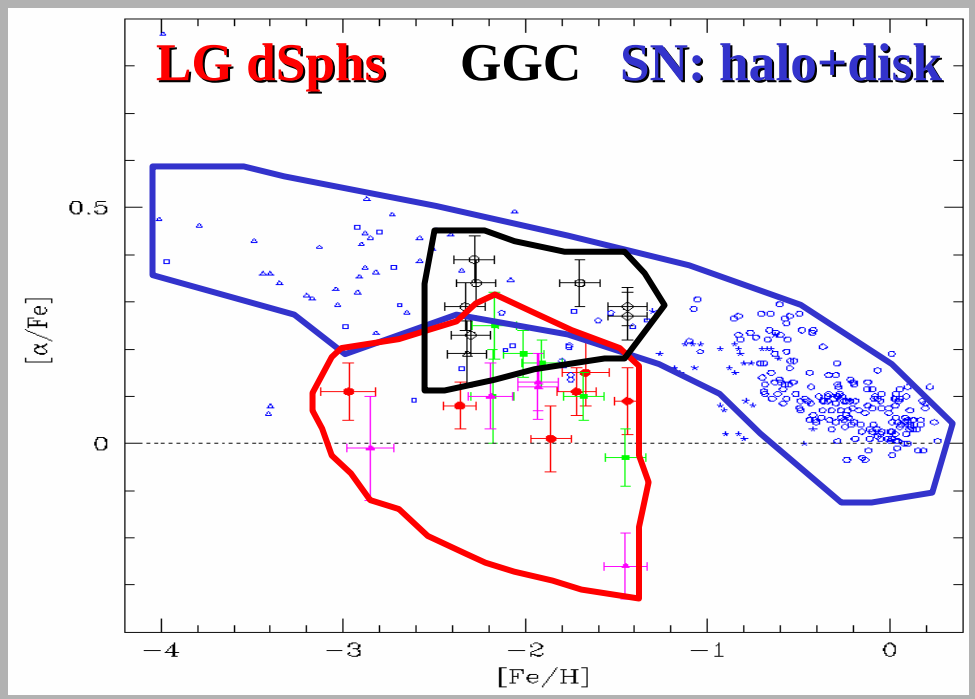
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

See also the VISTA Public Survey, PI Cioni

the (near ?) future

HST photometry + high-res spectroscopy: a perfect combination to study galaxy evolution





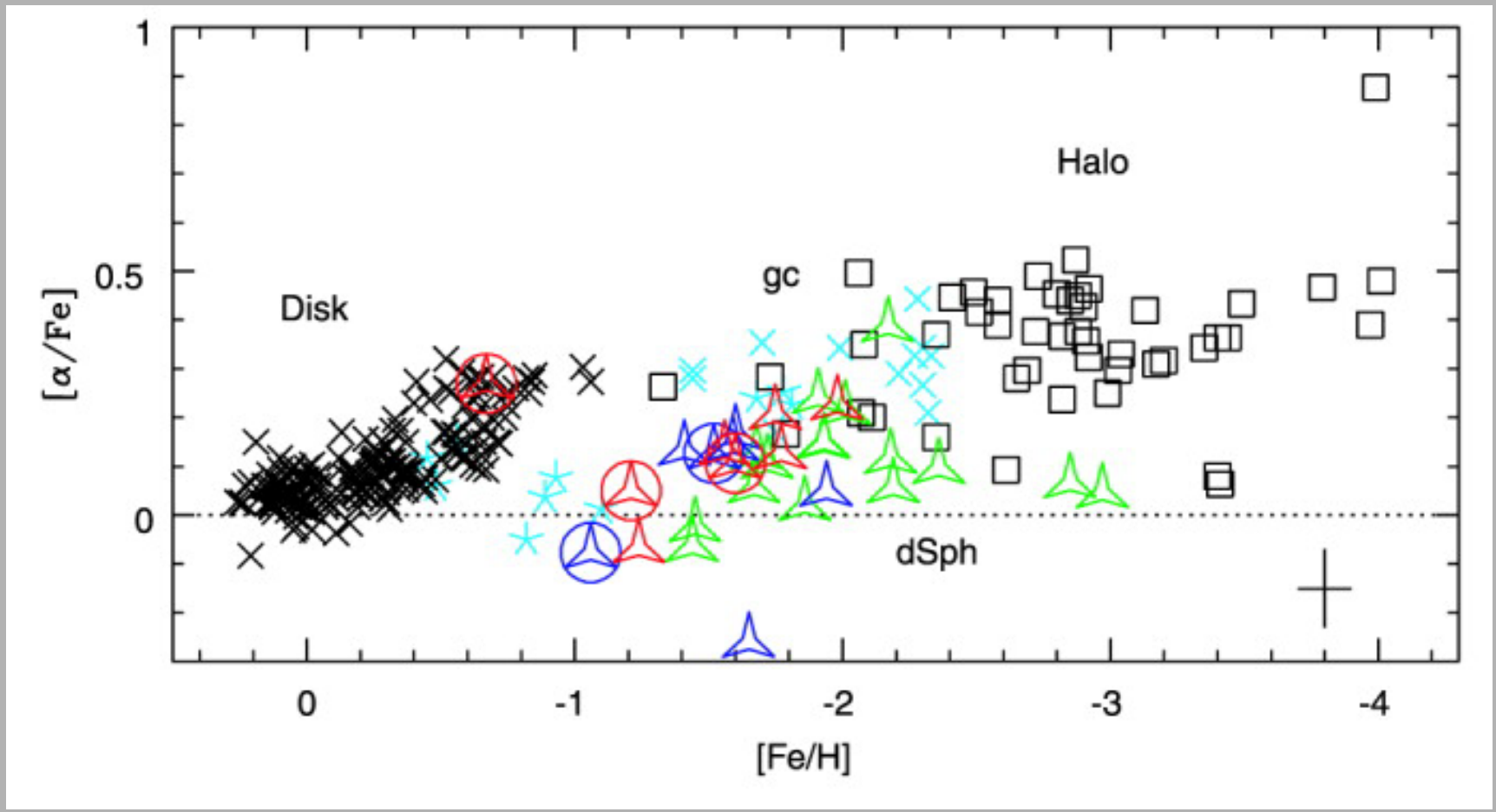
Shetrone et al 2001

Very unlikely that ○ is built only by mergers of ○

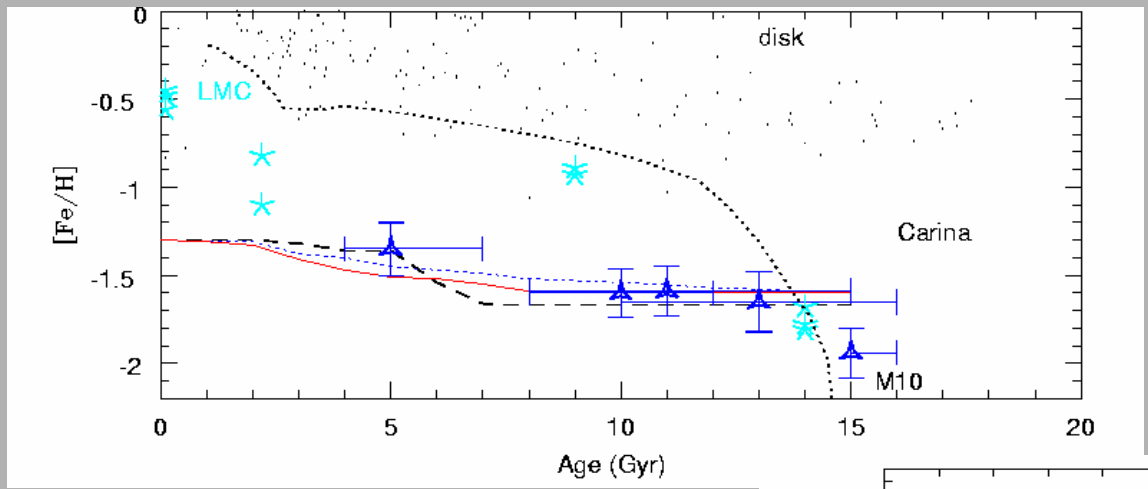
the present

dSphs in the Local Group

Tolstoy et al 03

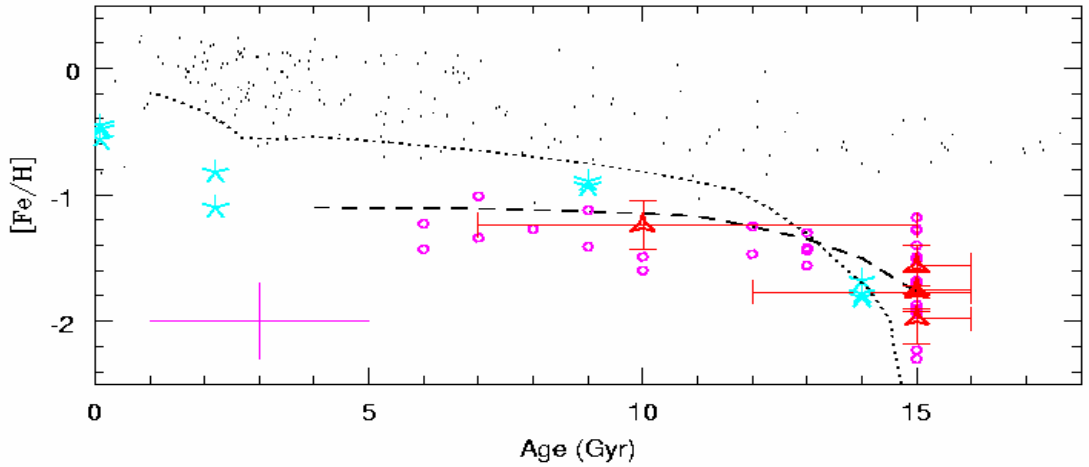


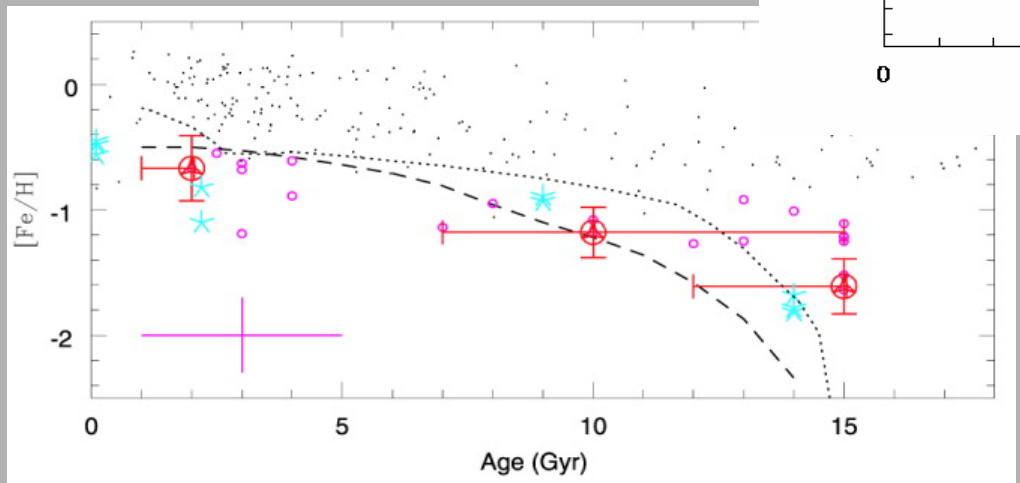
AMRs in nearby galaxies: entering a new era



Carina

Sculptor





Fornax

(Tolstoy et al 03)

The new era:
e.g. evolution models for individual dwarfs

SFH and IMF from HST CMDs, abundances and age-metallicity relation (if any) from spectroscopy

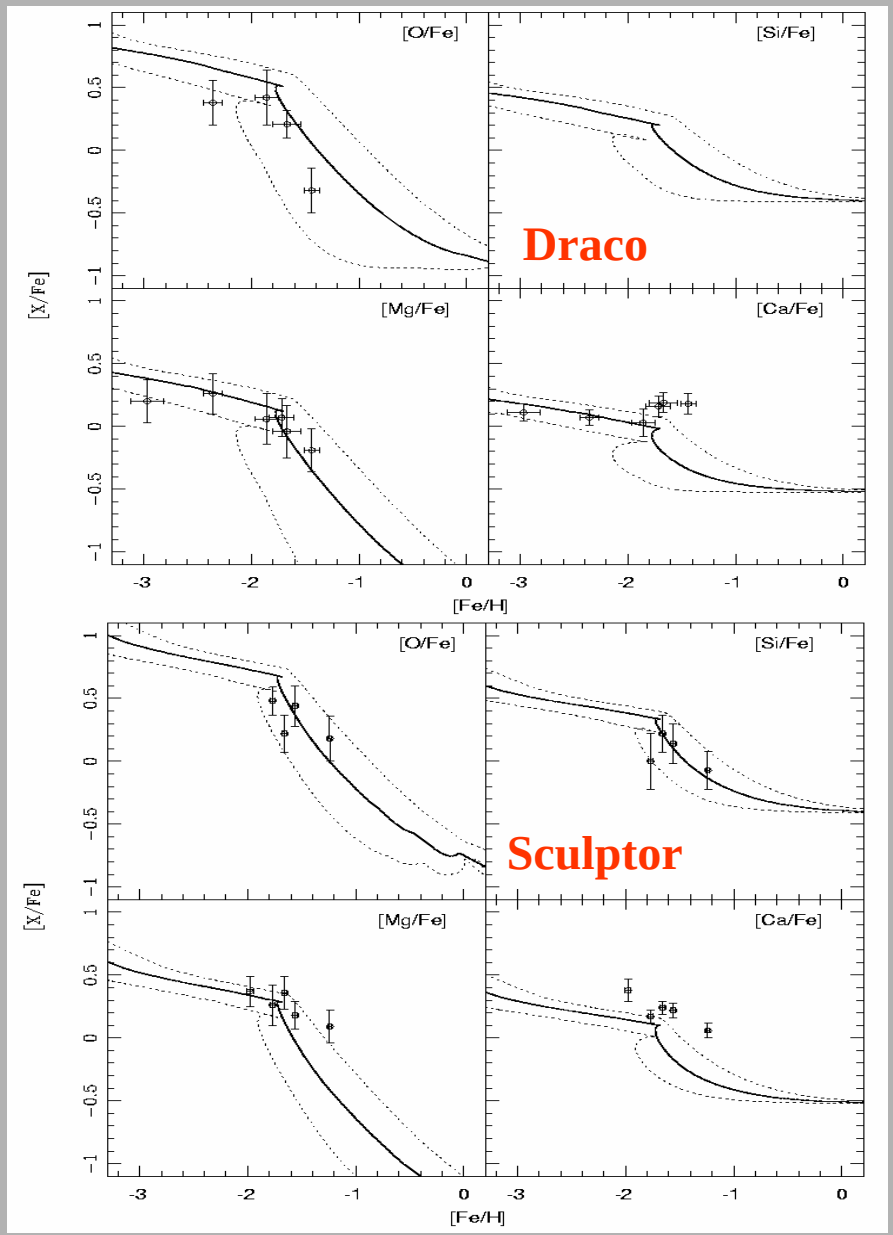
standard chemical evolution models

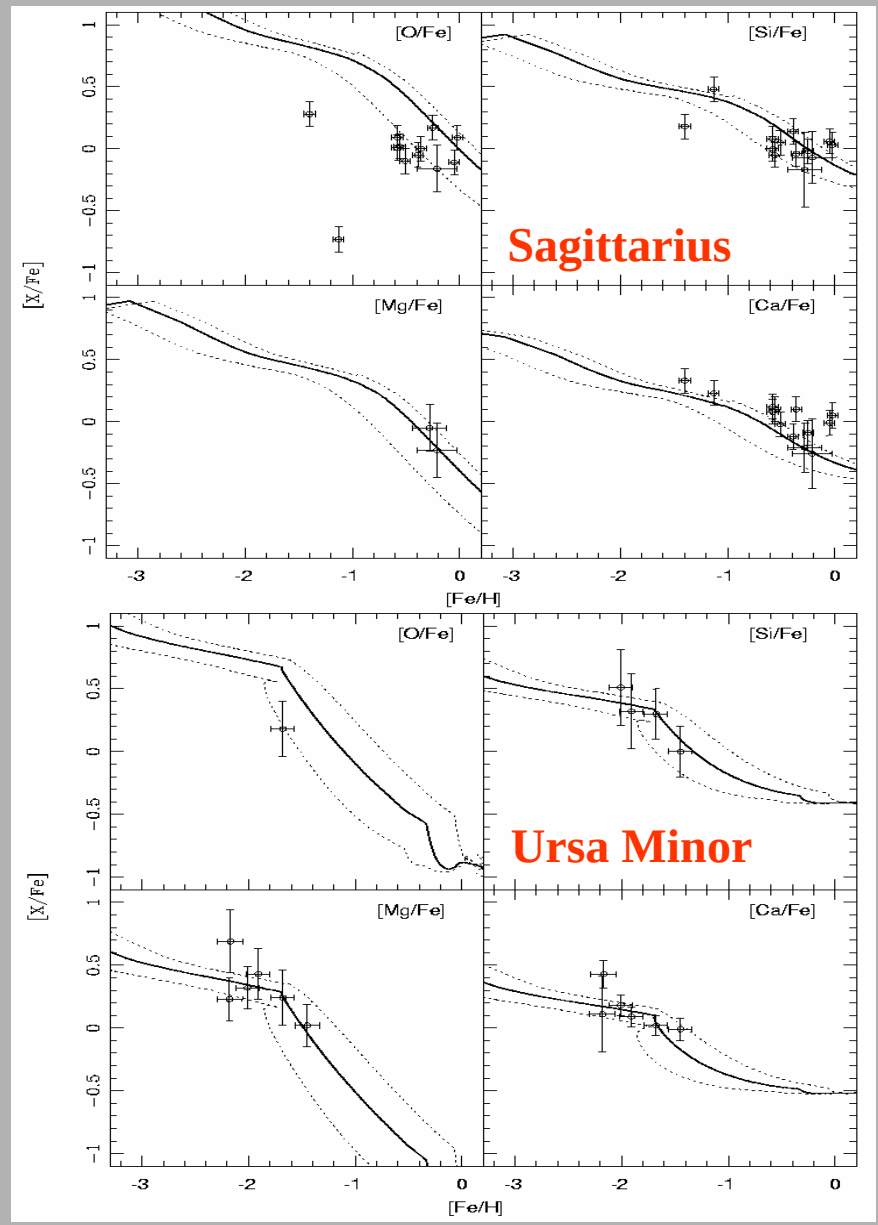
(e.g. Carigi et al 99, Lanfranchi & Matteucci, Romano et al 06**)**

chemo-dynamical models

(e.g Recchi et al 01, Recchi et al 06**)**

chemical evolution models for Local Group dSph's (Lanfranchi & Matteucci 2004)

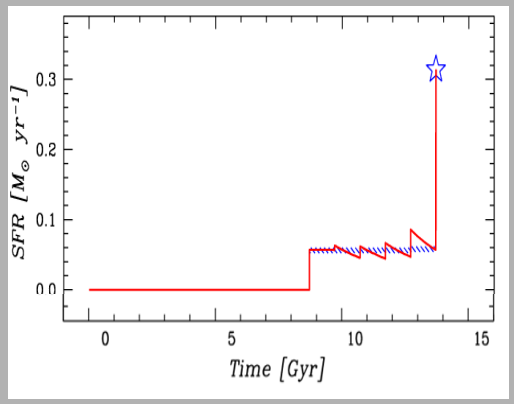


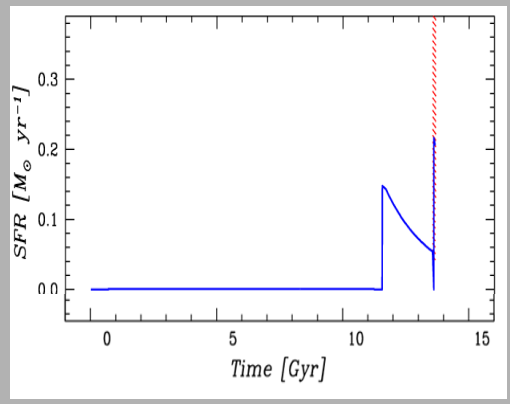


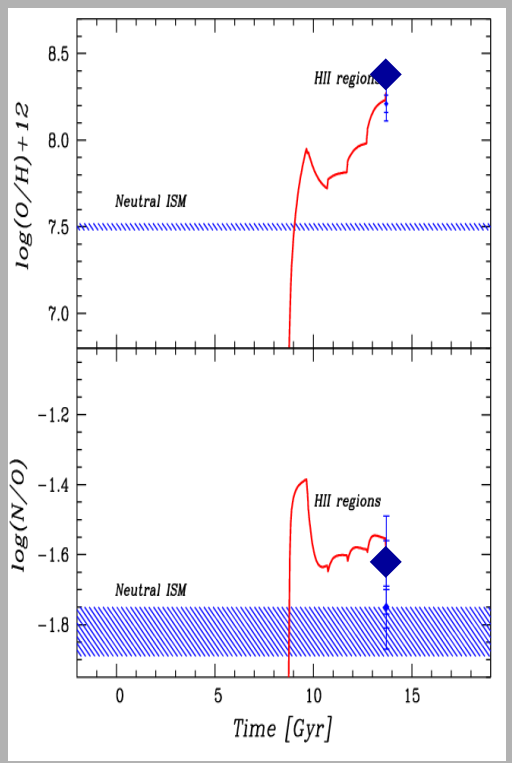
Salpeter's IMF; SFH from CMDs => low SF efficiency; high wind efficiency

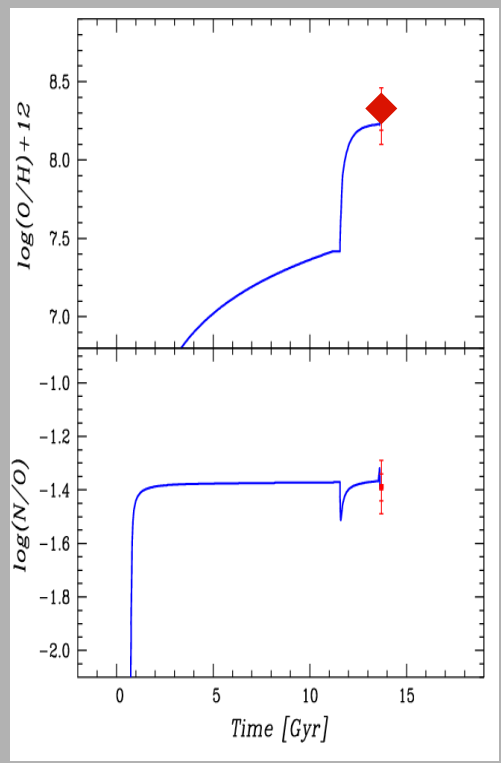
chemical evolution models for late-type dwarfs (Romano, Tosi, Matteucci 2006)

NGC1705

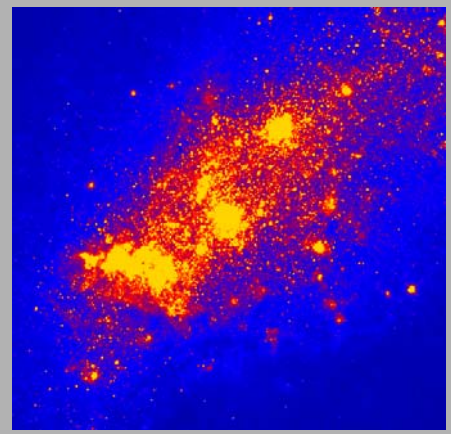








NGC1569



SF and IMF from HST CMDs => high SF efficiency, high wind efficiency

The impact of HST
on European Astronomy has been great:

Long life to HST !

the end