# Star formation histories and evolution of nearby (dwarf) galaxies

**Monica Tosi**

OABO, June 15th 2016

**What are the SFH, chemical abundances, evidences of accretion/interactions of resolved star forming (dwarf) galaxies ?**
**To be combined with chemo-dynamical formation/evolution models to understand how galaxies form and evolve.**

**A topic of great interest and success in the Italian MA2 community**
**We need to maintain and improve our international ranking**

**Photometric studies**

**Star formations histories from the CMDs
of resolved stellar populations:**
(we pioneered the method,
now many groups have developed their own
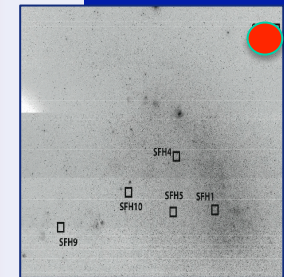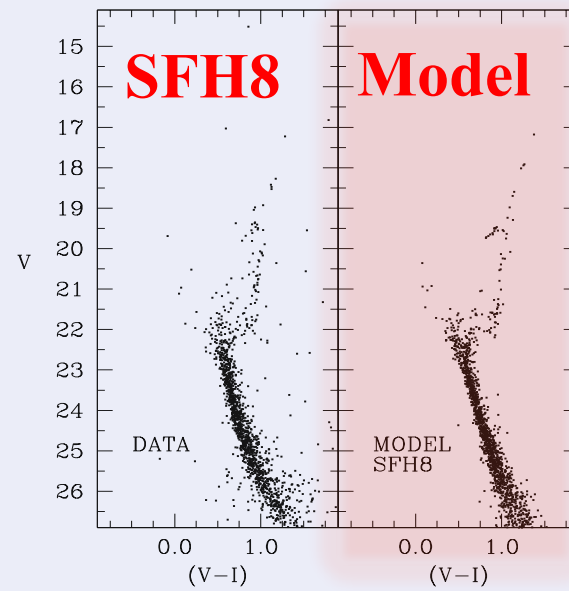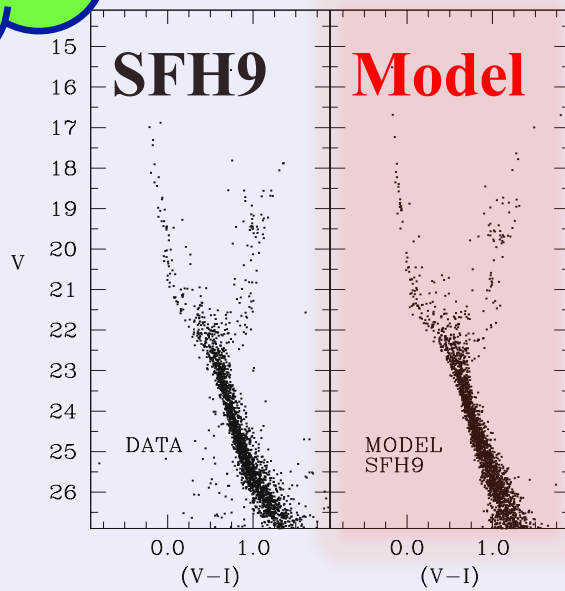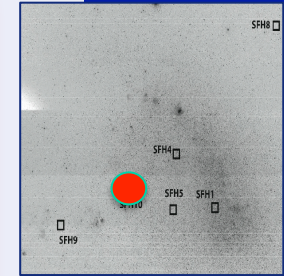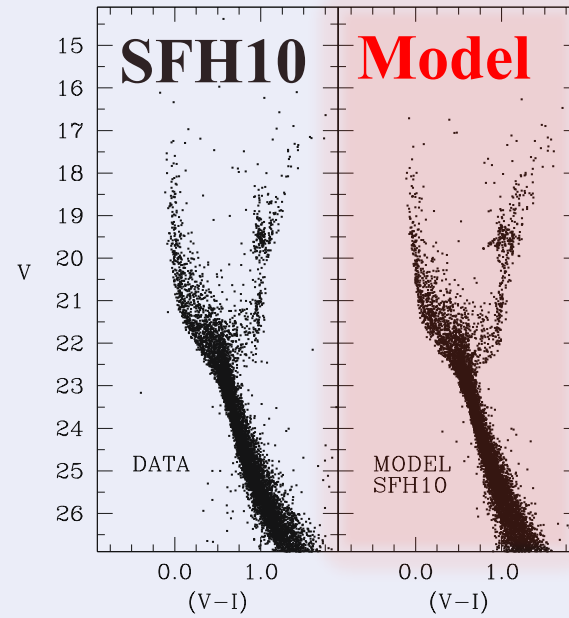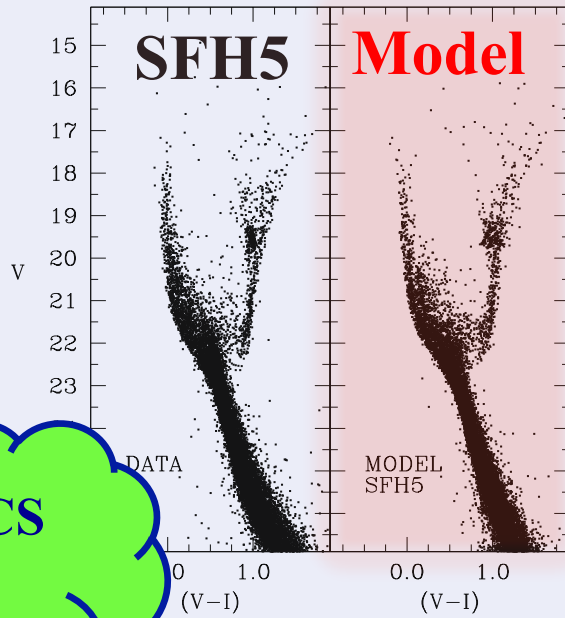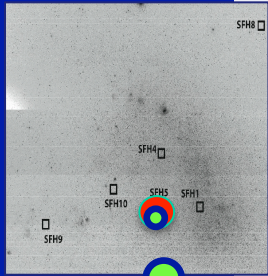procedures around the world)

**CMDs: the deeper, the tighter, the better**
(e.g. Tolstoy, Hill, Tosi 2009, ARAA, and many others)

⬇

**HST has been the best telescope so far**

6 HST/ACS fields in SMC

SFH5  Model

SFH10  Model

SFH9  Model

SFH8  Model

Cignoni+ (2013)

Effect of distance on star resolution
⟶ on reachable lookback times / stellar ages

inner SMC (ACS)   Leo A (ACS)   NGC 1569 (ACS)   I Zw18 (ACS)

dist = 61 kpc
$\tau$ = 15 Gyr

dist = 795 kpc
$\tau$ = 15 Gyr

dist = 3.4 Mpc
$\tau$ > 2 (10 ?) Gyr

dist = 18 Mpc
$\tau \geq$ 2 Gyr

TRGB

HB

12 Gyr MSTO

$M_I$

$(V - I)_0$   $(B - I)_0$   $(V - I)_0$   $(V - I)_0$
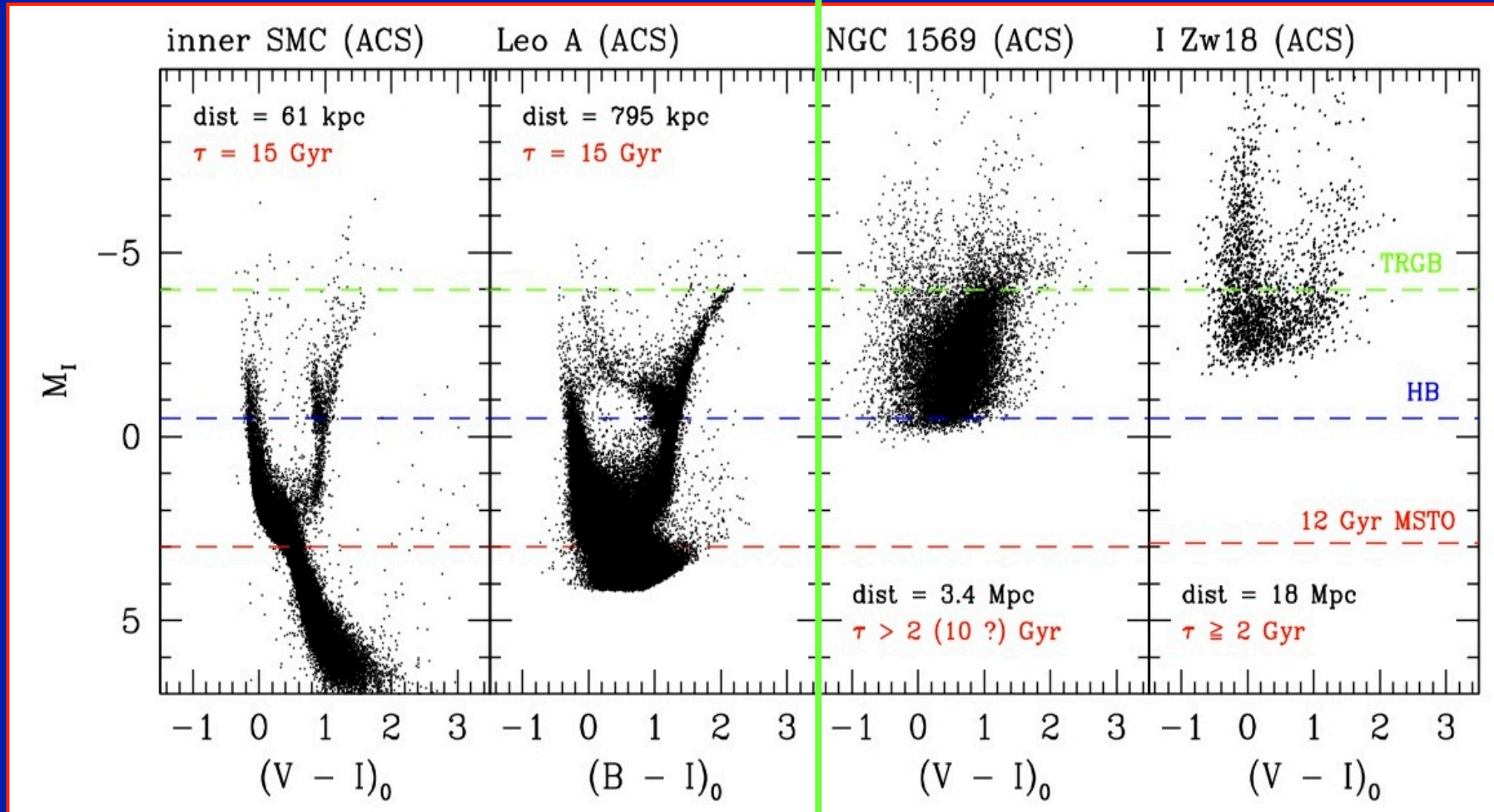
Local Group ⟷ Local Universe

## the Local Group and beyond

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

⬇

## SFHs must be studied also outside the LG

⬇

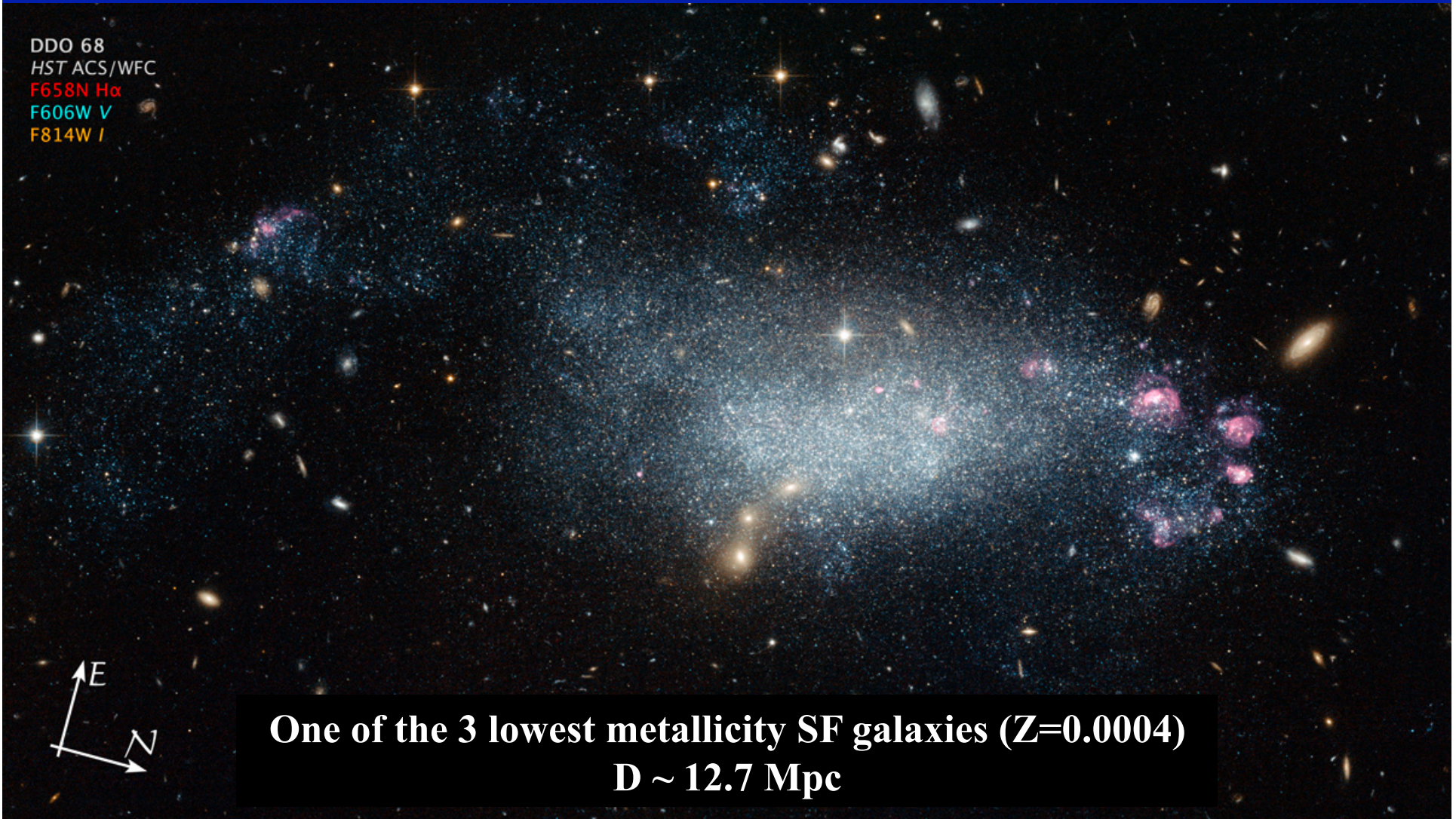## HST current key telescope

⬇

*Recommendation*: Keep HST alive as long as possible and let INAF and ASI fund our GO programs
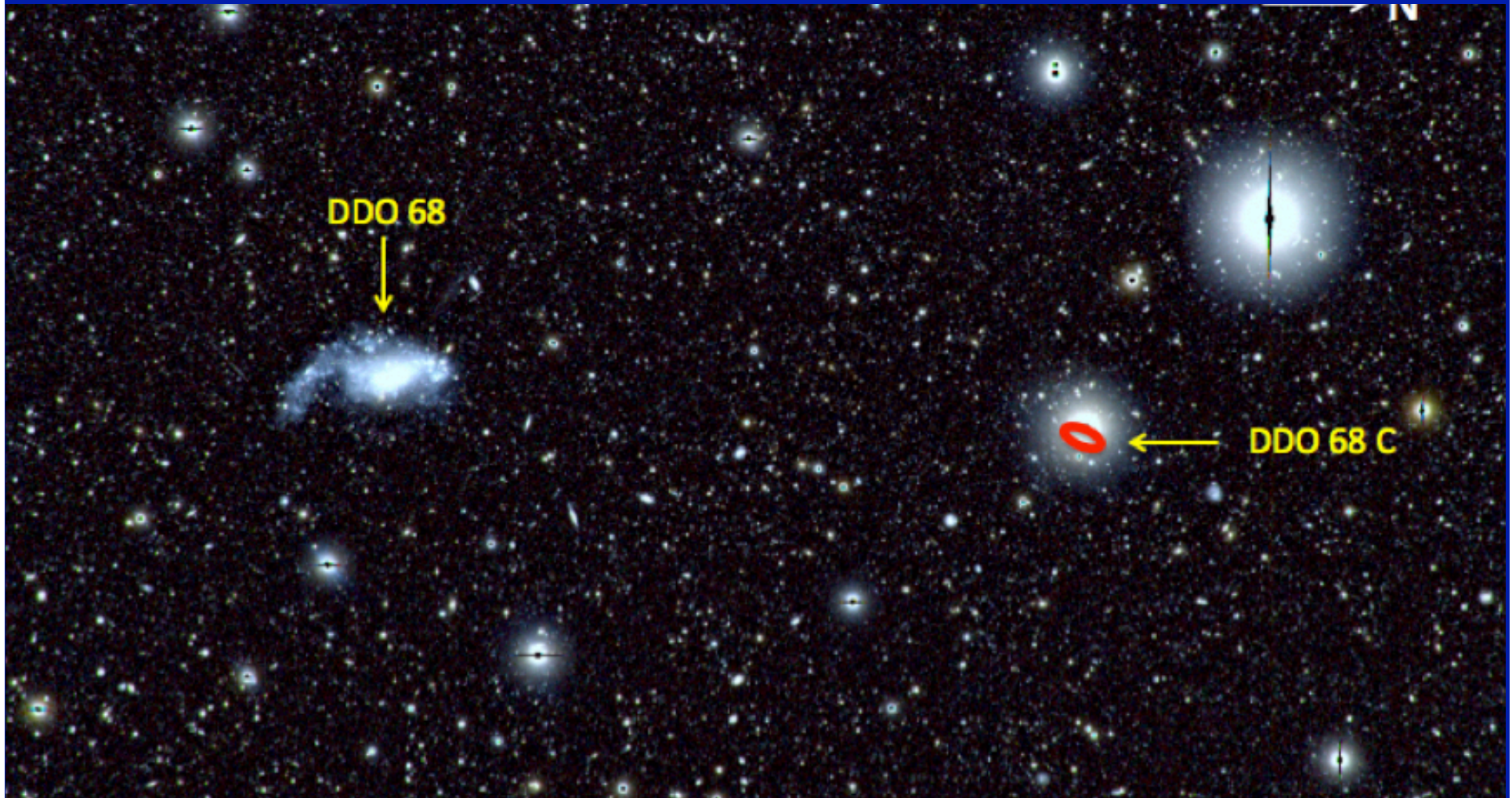
**SFH and chemo-dynamical evolution of a SF dwarf**

**DDO 68**

DDO 68
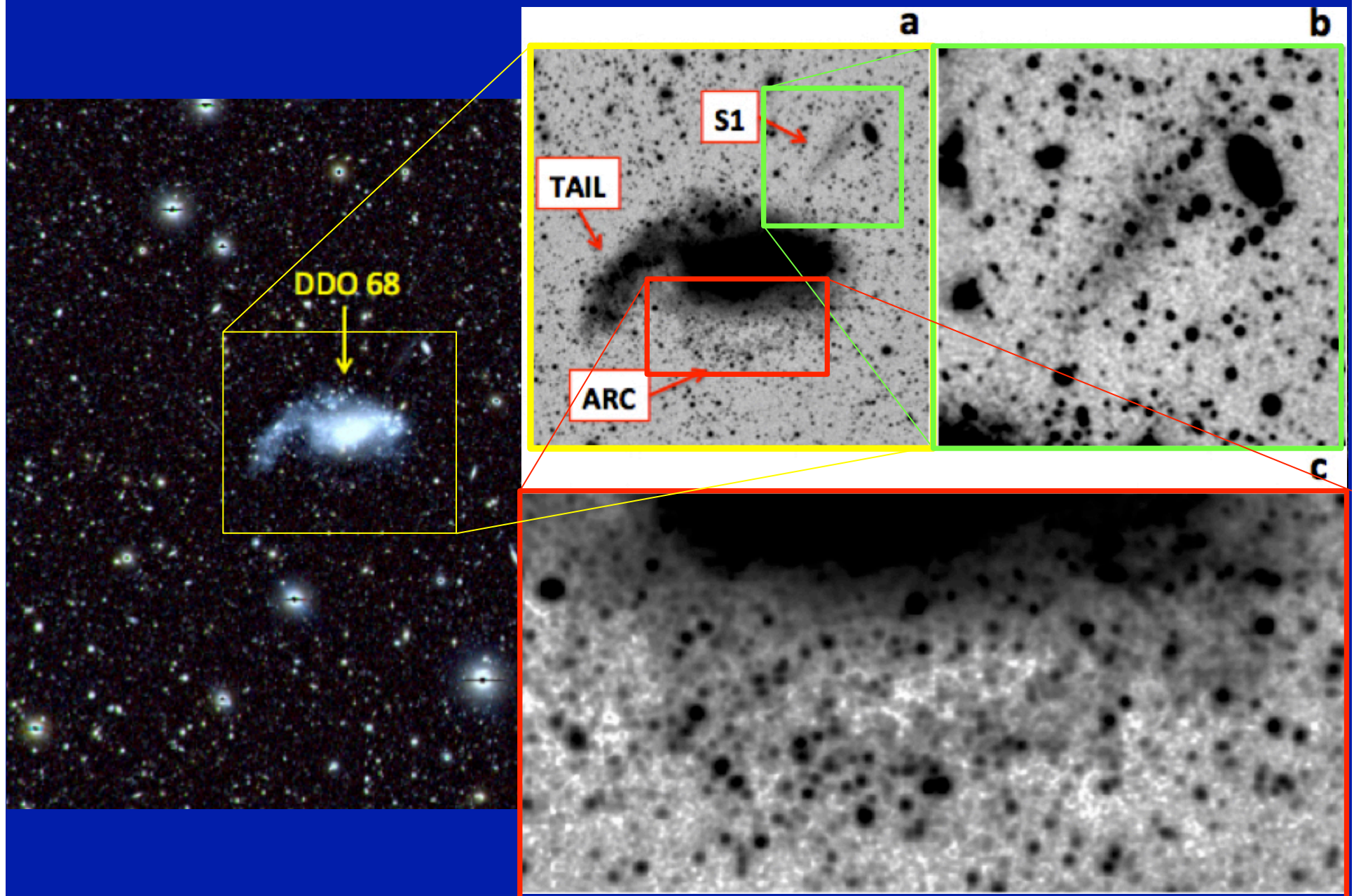*HST* ACS/WFC
F658N Hα
F606W *V*
F814W *I*

E

N

One of the 3 lowest metallicity SF galaxies (Z=0.0004)
D ~ 12.7 Mpc

# LBT is very useful too
## e.g. to look for streams and satellites
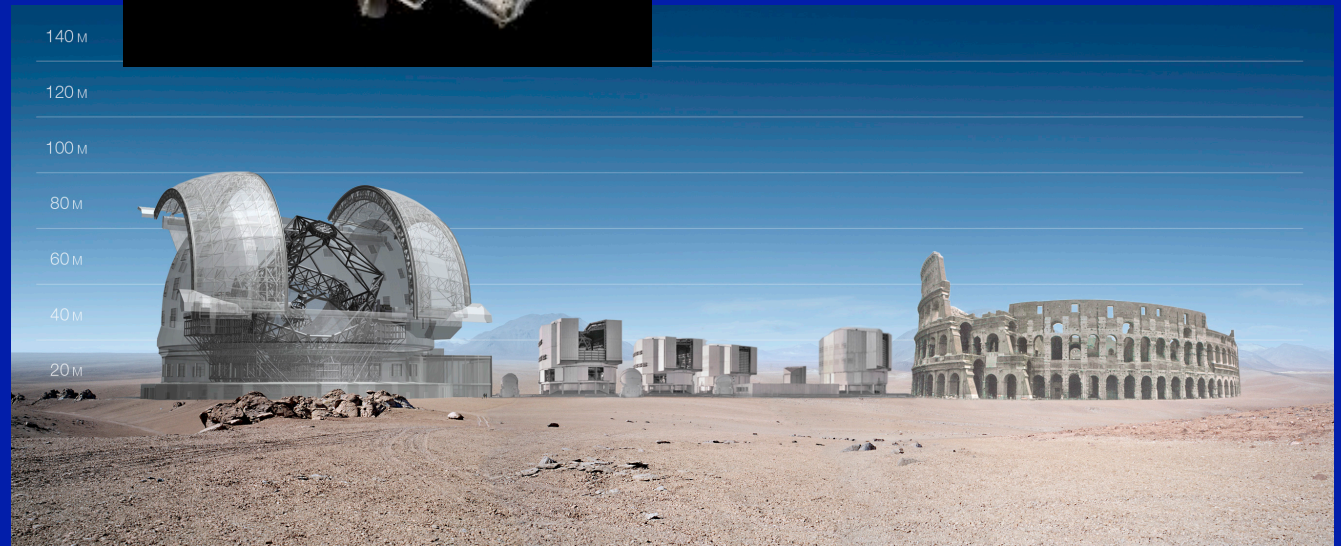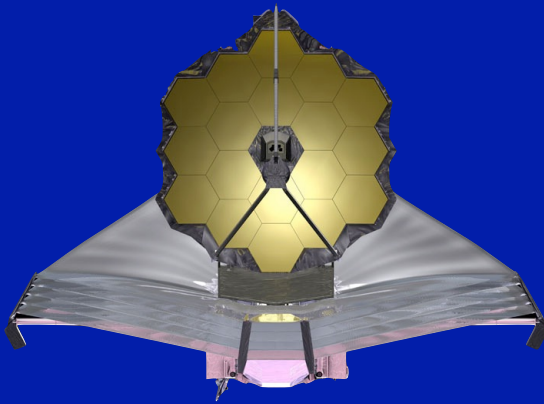## (certainly better than GTC !!!)

# LBT is very useful too

# What about the future ?
# To resolve stellar pops in galaxies beyond LG:
# still HST + JWST + E-ELT

# Resolved stellar populations anchor our knowledge of the Universe

**JWST Characteristics**
1.) Superb sensitivity at near-infrared wavelengths.
2.) Multiple imaging and spectroscopic modes with fine sampling.
3.) High spatial resolution.
4.) Relatively large fields of view.

**Synergy with other facilities**
1.) Extremely large telescopes (E-ELT, TMT, GMT)
2.) Upcoming large surveys (EUCLID, LSST)
3.) HST will hopefully still be around.

adapted slide from Jason Kalirai (Project Scientist - James Webb Space Telescope)

# Halo Formation –
# Dwarf Galaxies and Globular Clusters
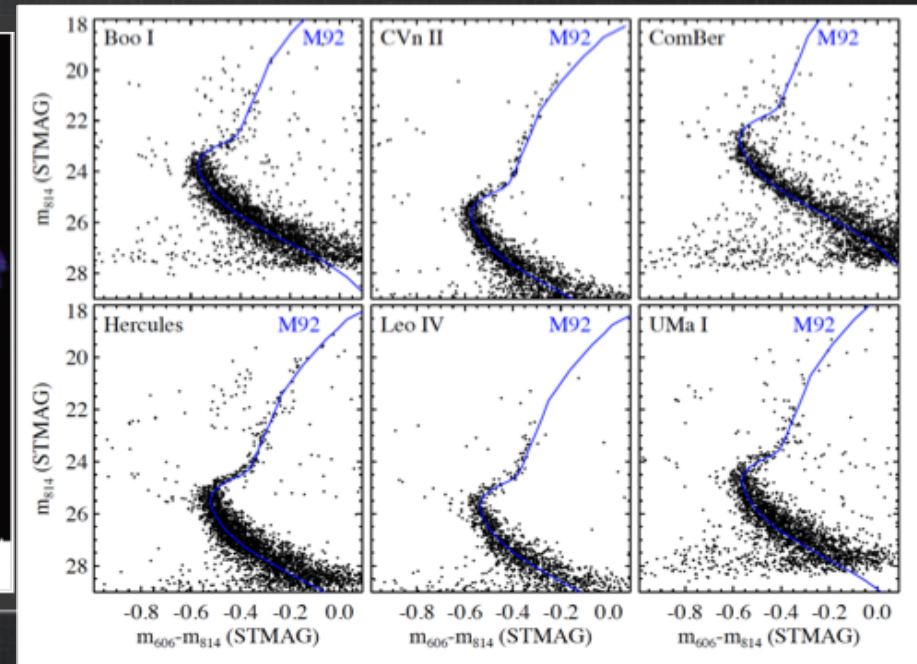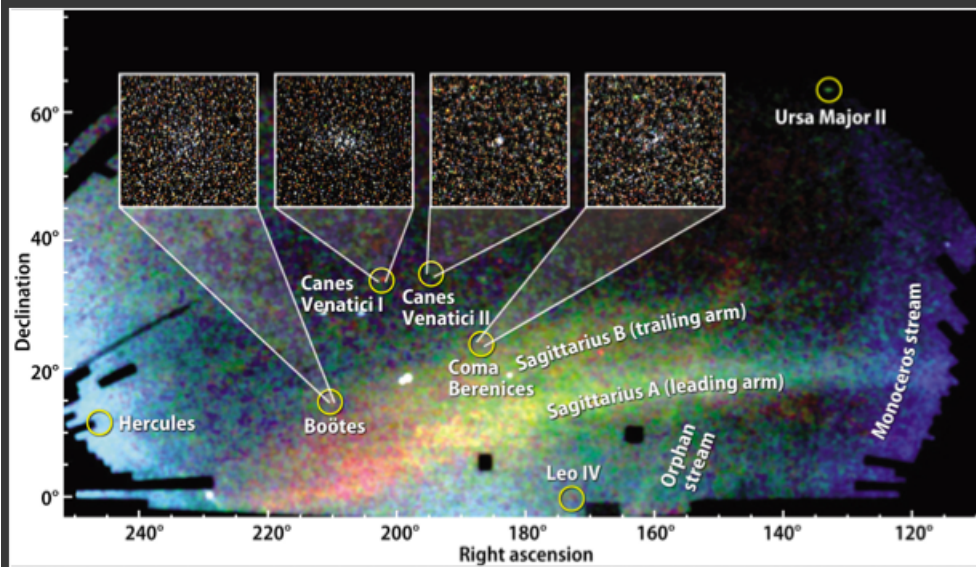


Belokurov et al.

Brown et al. (2014)

## Many Outstanding Problems

1) Is the census of small satellites consistent with CDM predictions on galactic scales?
2) Is there a low luminosity threshold for galaxy formation?
3) Is the spatial distribution of dSphs (planar vs spherical) consistent with CDM?
4) Can we test different DM models with 3D resolved velocities?
5) Do sub-Gyr age measurements reveal any cosmologically-driven synchronization in the SFHs?
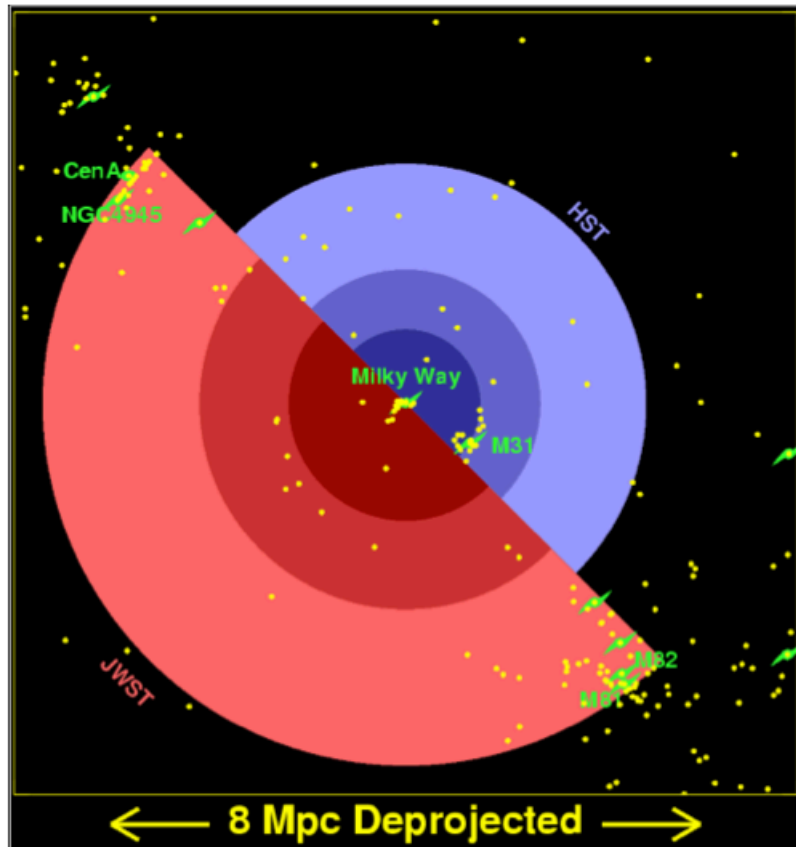
...

Courtesy J. Kalirai

# Current situation

CFHT, SDSS, DECam, Pan-STARRS Hubble and 8-10m's
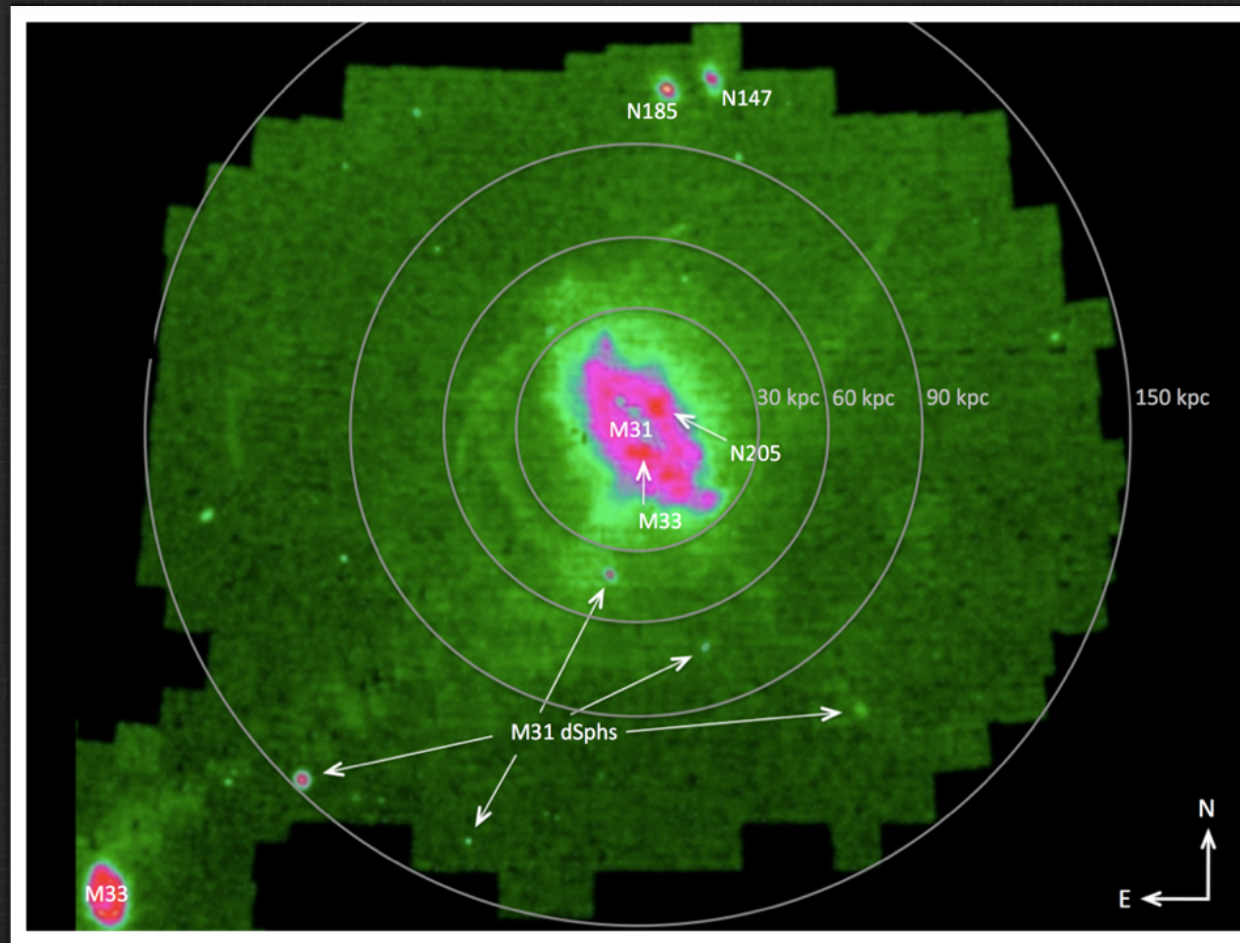


McConnachie et al. (2009)

Courtesy J. Kalirai

## Increasing Survey Area with JWST



← 8 Mpc Deprojected →

from Brown et al. 2008 White Paper on Studying Resolved Stellar Populations with JWST

The volume of space that can be surveyed in 10, 100, and 1000 hrs reaching 0.5 mag below the Main Sequence turnoff in a 12 Gyr old population.

1 Mpc, m-M=25 oMSTO~29; HB~24.7

1.7 Mpc, m-M=26.1 oMSTO~30.1; HB~25.8

4 Mpc, m-M=28 oMSTO~32; HB~27.7

| Object | $(m-M)_0$ | $\theta$(1 pc) |
|---|---|---|
| LMC | 18.5 | 4" |
| M31 | 24.3 | 0.3" |
| Sculptor Group | 26.5 | 0.1" |
| M81/82 | 27.8 | 0.06" |
| Cen A | 28.5 | 0.04" |
| Leo Group | 30.0 | 0.02" |
| Virgo Cluster | 31.2 | 12 mas |
| Fornax cluster | 32.0 | 11 mas |
| 50Mpc | 33.5 | 4 mas |
| Arp220 | 34.5 | 2 mas |
| Perseus Cluster | 34.5 | 2 mas |
| Stephan's Quintet | 35.0 | 2 mas |
| Coma Cluster | 35.0 | 2 mas |
| Redshift z~0.1 | 38.5 | 0.5mas |
| Redshift z~0.3 | 41 | 0.2mas |

Due to ASI's early decision, Italy is not directly part of JWST
(although Italians are eligible as GOs as ESA members)

*Recommendation*: INAF should look for ways to bring us in !
(at least with INAF or ASI funding GO approved programs)

# E-ELT

The Italian groups of Maory and Micado are simulating the photometry expected with E-ELT

**AETC** *(Advanced Exposure Time Calculator)*
*http:aetc.oapd.inaf.it*
*Falomo, Fantinel, Uslenghi*



Simulates images of astronomical objects with any combination of telescope, instrument and passband, using a suitable set of parameters which specify the observational set up.
One can simulate stellar fields (stellar list in input), or extended objects (μ distribution in input, or template)
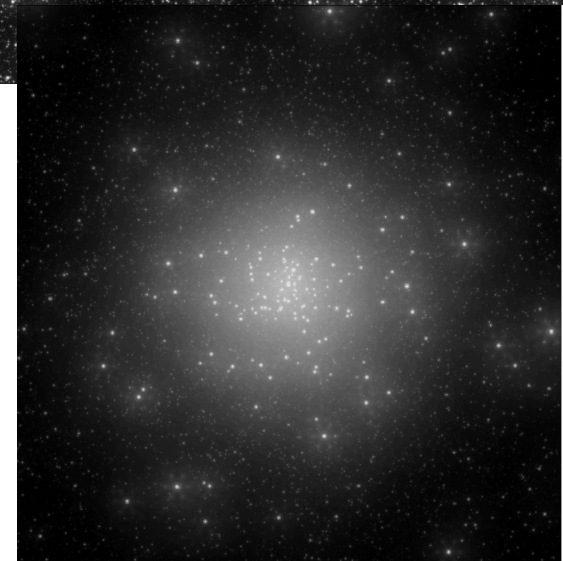
In Padova it is being used to construct end to end simulations of a number of science cases. Results can be found in the literature by the team
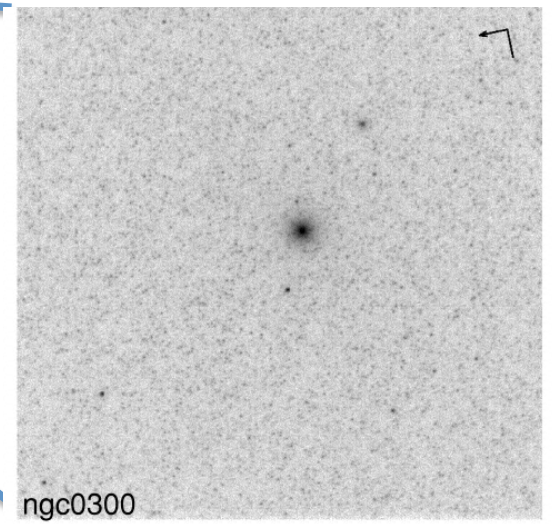(Greggio, Falomo, Gullieuszik, Schreiber, Zaggia Fantinel, Uslenghi)

courtesy L. Greggio

NGC 300: a spiral at a distance of ~ 2 Mpc hosting a NSC



**Nuclear Star Clusters: a very hot topic to be addressed with E-ELT**

Boker +, 2002, WFPC2 image

ngc0300

courtesy L. Greggio

Photometry with Starfinder

CMDs of objects detected
at different locations

The central parts are dominated
by the cluster population,
but the CMD is highly
incomplete
The outer parts are dominated
by the field population

The intermediate regions are
characterized by a good
photometry and most of the
stars
are cluster members.



$d = 2Mpc \quad age = 1Gyr$
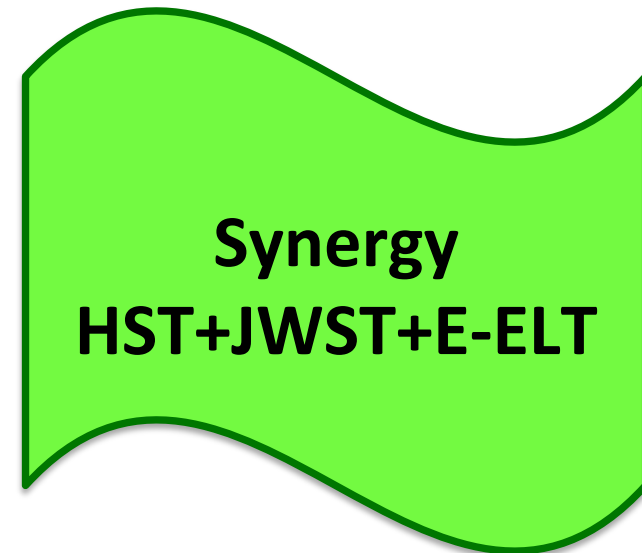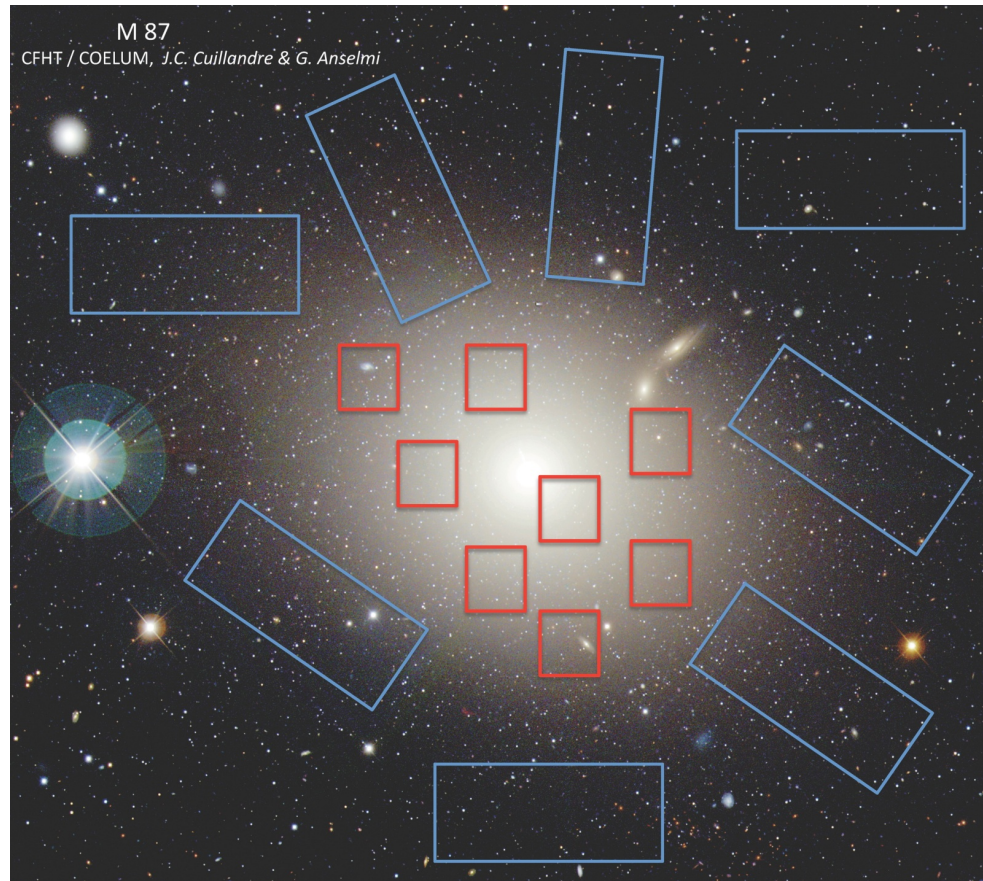
courtesy L. Greggio
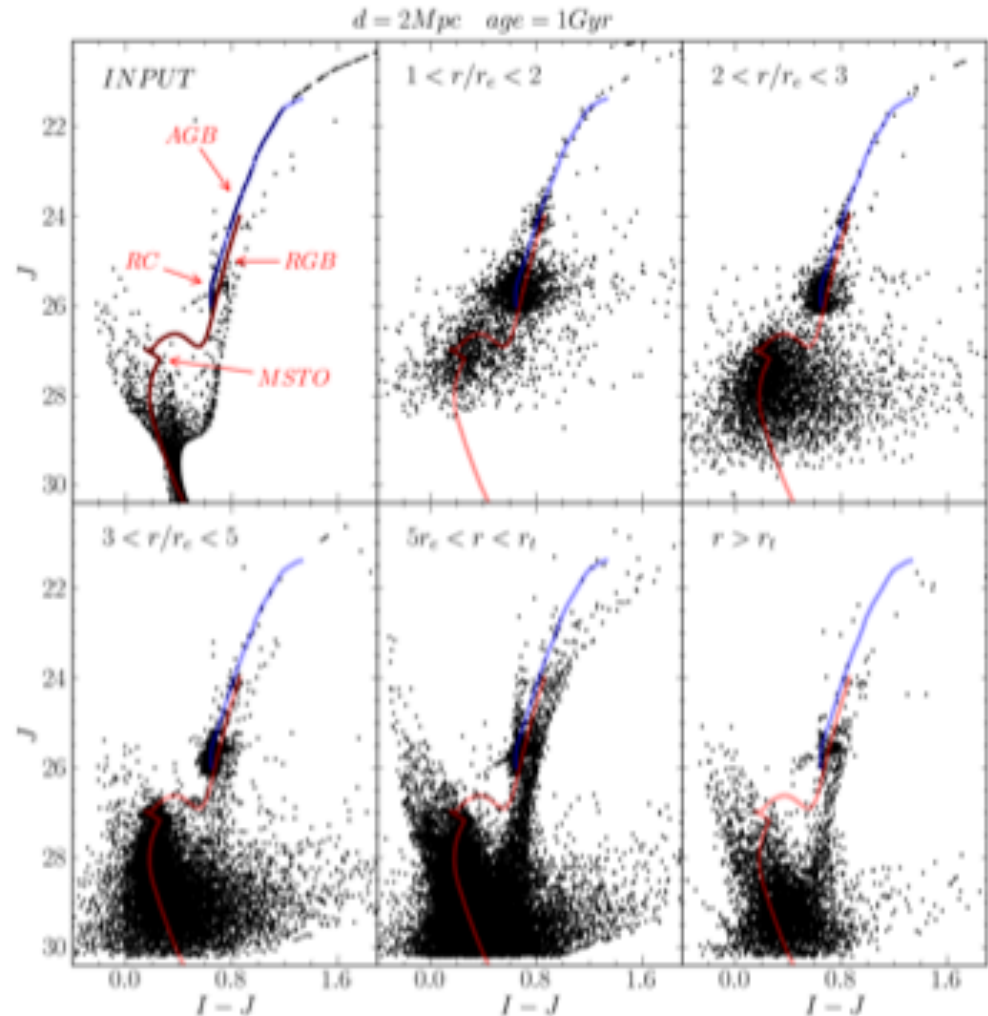
To conclude:

the exceptional resolution will open to the exploration of the very crowded inaccessible portions of galaxies, enabling detailed studies of the SFH in those regions where most of the action takes place

these studies require accurate photometry over a long wavelength baseline

we need at least one optical filter and we need a sharp, well sampled, and stable PSF

Synergy
HST+JWST+E-ELT



M 87
CFHT / COELUM, J.C. Cuillandre & G. Anselmi

courtesy L. Greggio

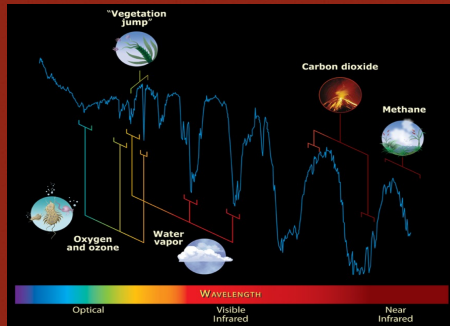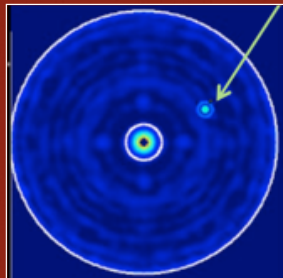# and then: ATLAST
# make sure we are in, if/when it goes



## The Next Great Leap In Astrophysics

### The ATLAST Reference Design

This ATLAST reference design is a 10 m-class observatory under assessment as a candidate for selection by the 2020 NRC Decadal Survey. It is designed to be a powerful general-purpose non-cryogenic observatory operating from 0.1 μm to 1.8+ μm and able to search for biomarkers in the spectra of candidate exoEarths in the Solar neighborhood.
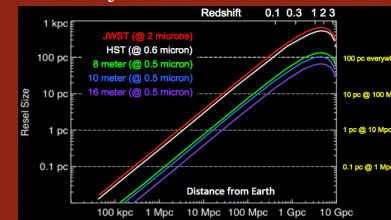
#### Breakthrough in UVOIR Resolution and Sensitivity throughout the Universe



HST (2.4m)   15m Space Telescope

~200 pc
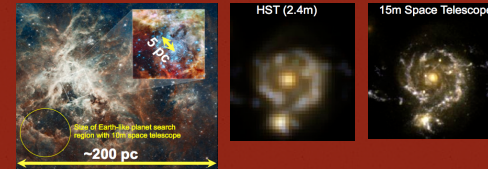
#### Resolve 100 pc Star-Forming Regions Everywhere in the Universe



#### Identification of Habitable Zone Planets and detection of Biosignatures



#### Tracing the History of Star Formation in all Types of Galaxies up to 10 Mpc
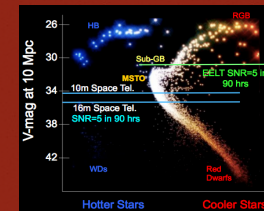
**What are the SFH, chemical abundances, evidences of accretion/interactions of resolved star forming dwarf galaxies ? To be combined with chemo-dynamical formation/evolution models to understand how galaxies form and evolve.**

**A topic of great interest and success in the Italian MA2 community**

*Recommendation*: Make us able to use successfully HST, JWST, E-ELT, ATLAST