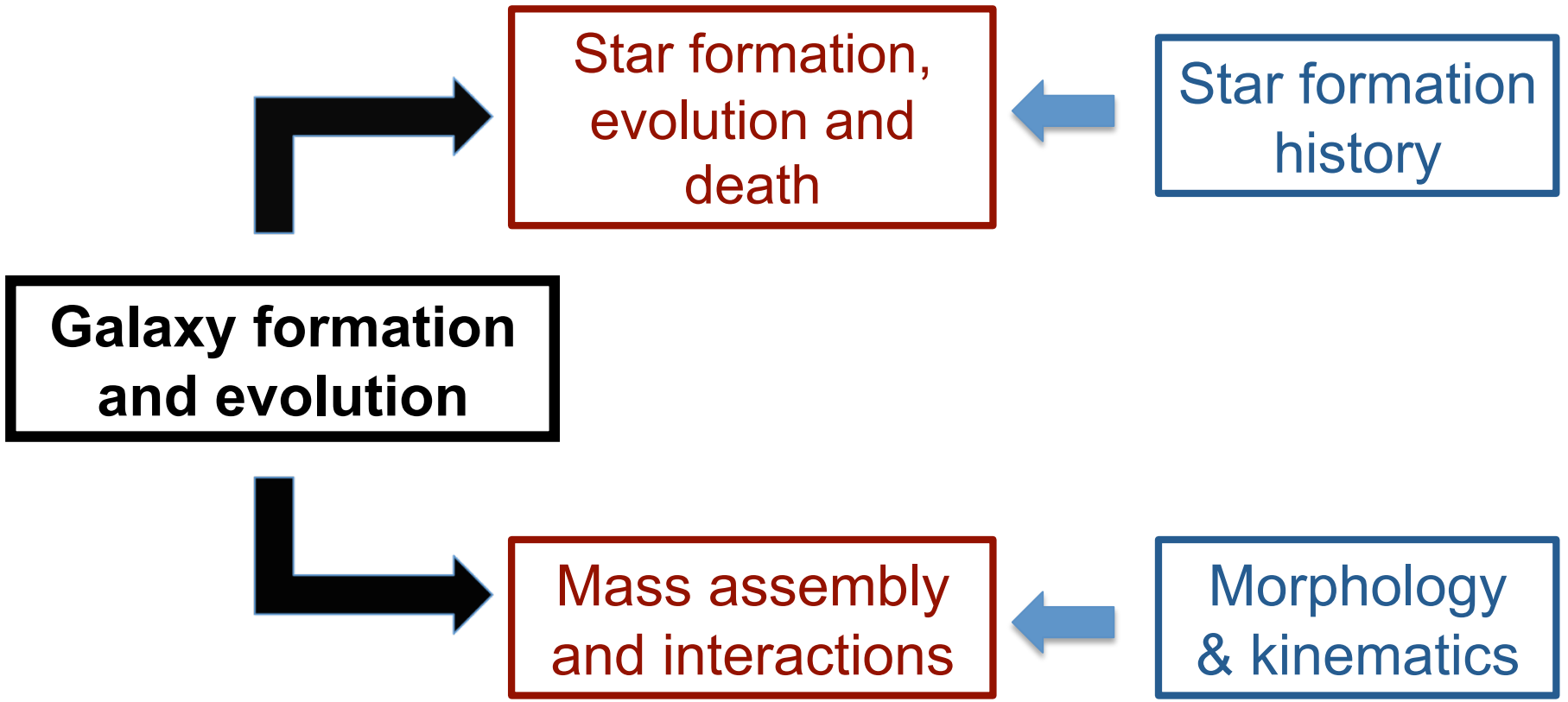
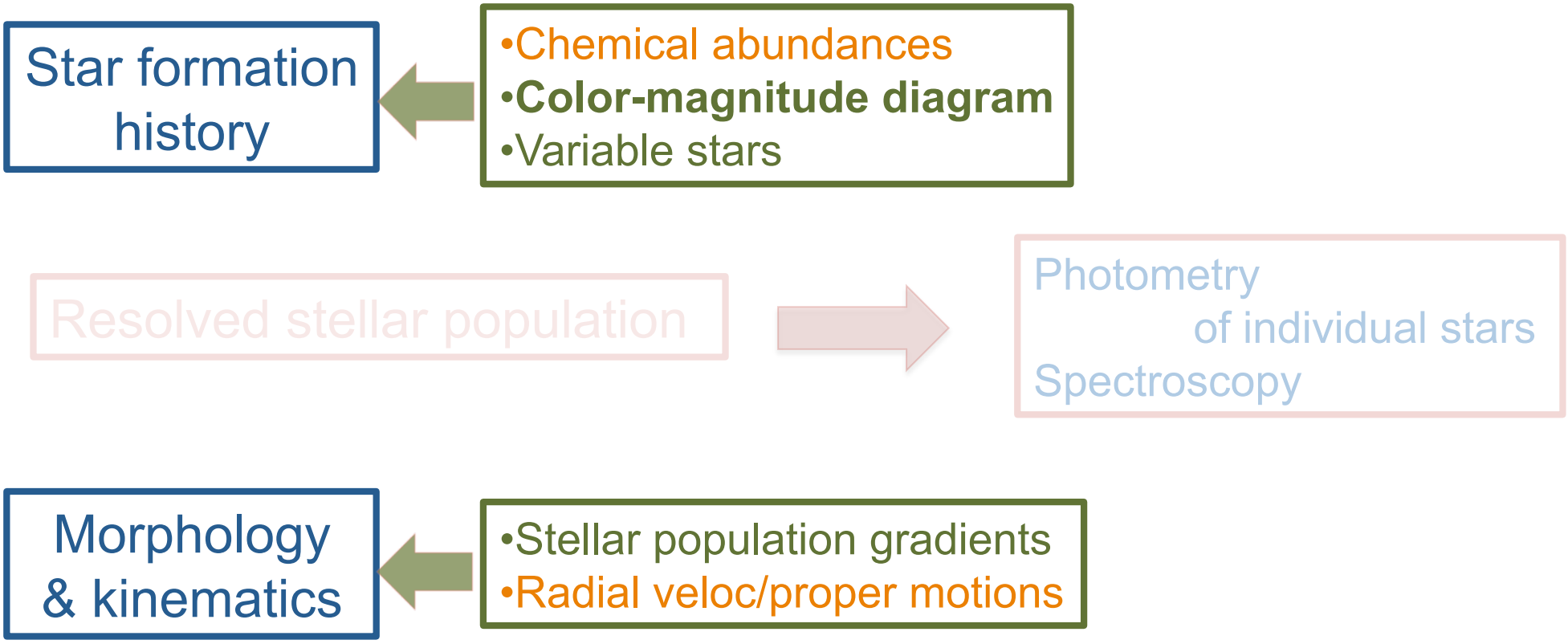
Nearby galaxies: prospects with ELTs

Carme Gallart (IAC)


Star formation, evolution and death
Star formation history
Galaxy formation and evolution
Mass assembly and interactions
Morphology & kinematics

Resolved stellar population

Photometry
of individual stars
Spectroscopy


Star formation history
•Chemical abundances
•Color-magnitude diagram
•Variable stars
Resolved stellar population
Photometry
of individual stars
Spectroscopy
Morphology & kinematics
•Stellar population gradients
•Radial veloc/proper motions

ELTs (or GSMTs) main science drivers in relation to ‘Nearby Galaxies’

1. Photometry:

-SFH of nearby galaxies.
Ultimate goal: to resolve a giant elliptical galaxy
-Origin of the IMF

2. Spectroscopy:

-Chemodynamical structure of galaxies
-Probing chemical evolution in the LG and beyond
-First stars in MW & satellites through analysis of extremely metal poor stars

PLAN

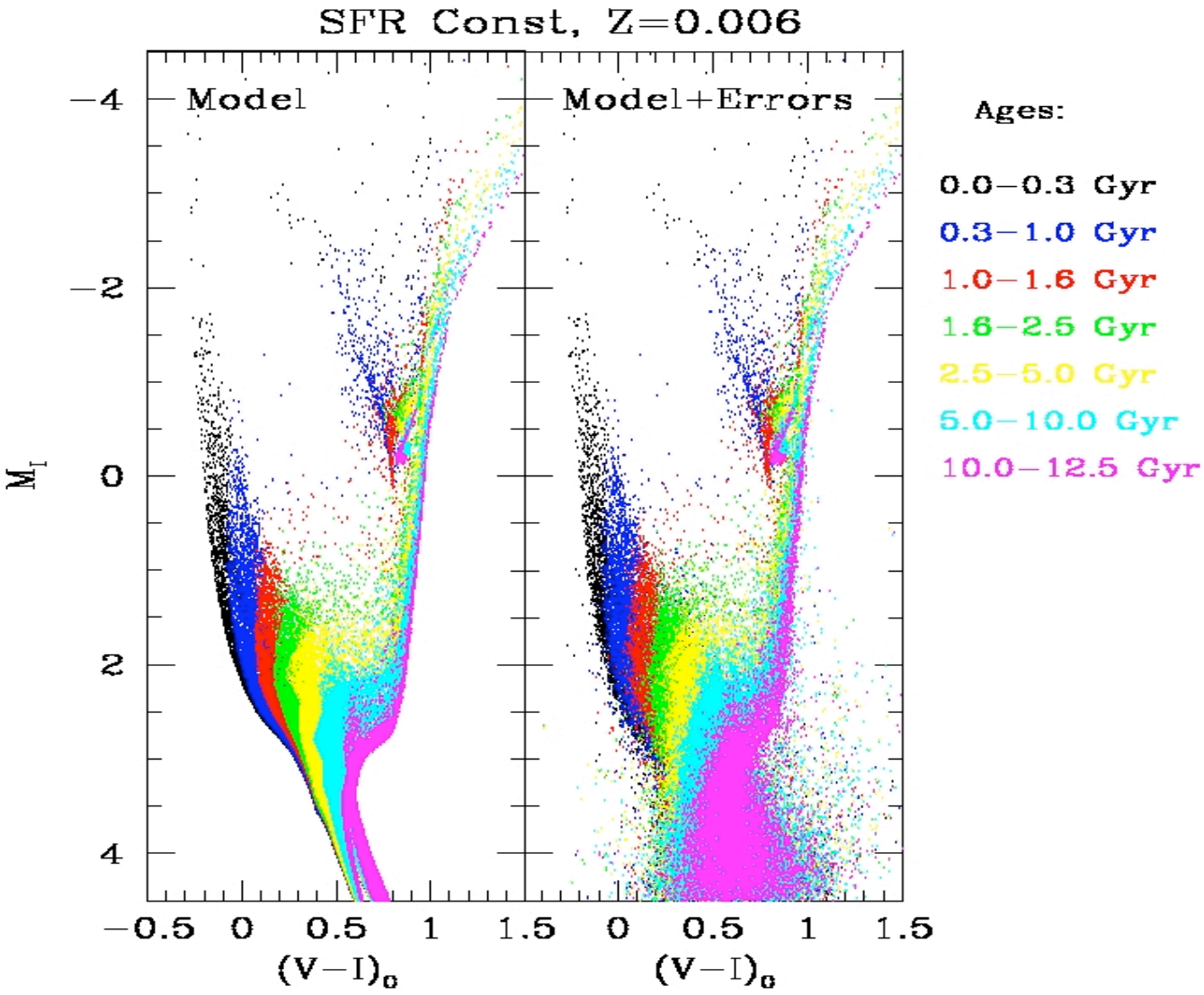
-Discuss methodology currently used to address these topics

-Show examples of interesting results obtained with these methods

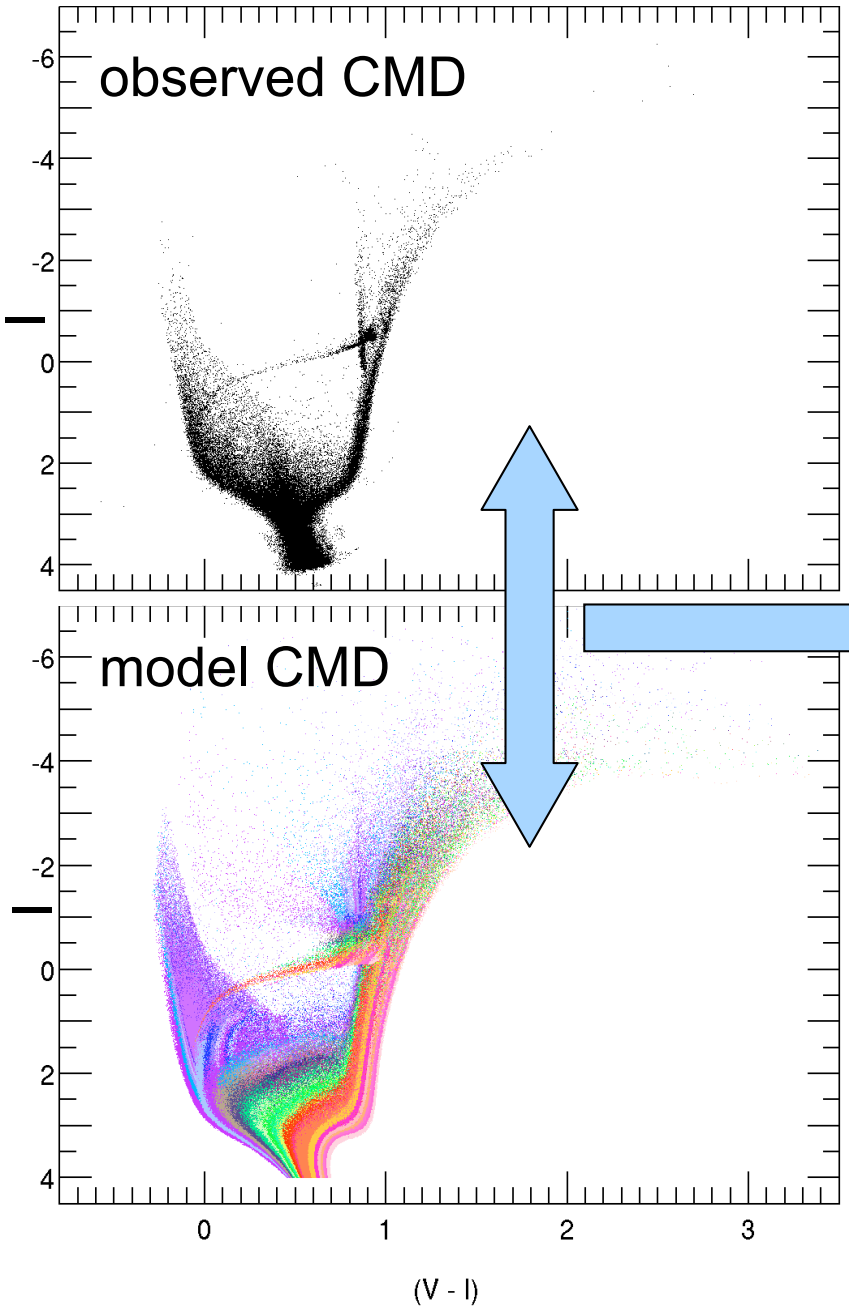
-Discuss how these studies can be extended with the ELTs

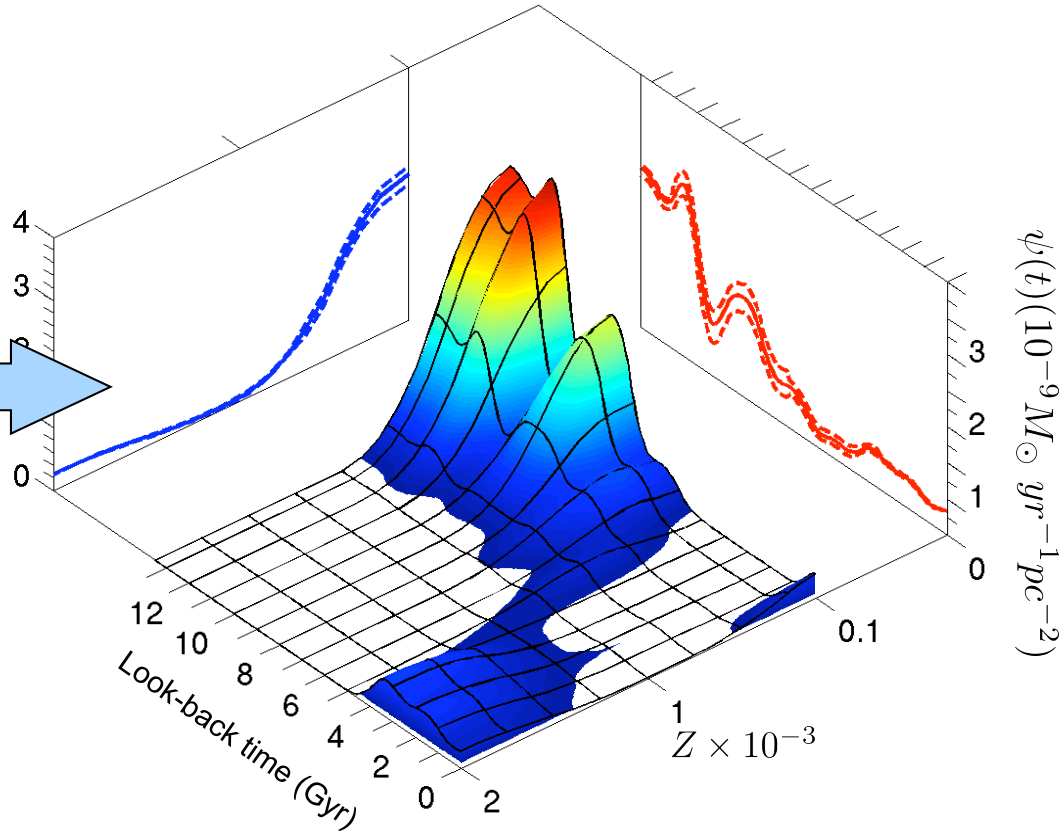
Methodology:

To derive acurate star formation histories (SFH):
need CMDs reaching old main sequence turnoffs (oMSTO)



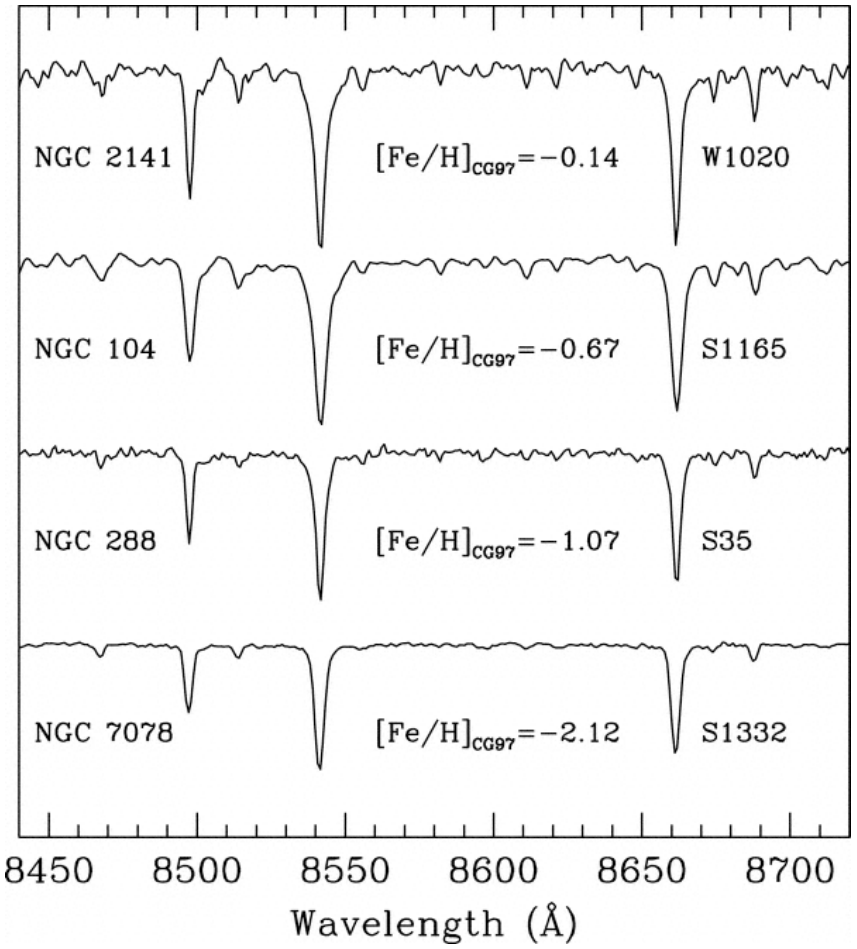
The distribution of stars in the observed CMD is compared with that of a number of *simple populations* in a model CMD.





A merit function is used to obtain the combination of simple stellar populations that best reproduces the observed CMD, i.e., the star formation rate and the chemical evolution law, as a function of time.

To derive metallicities and radial velocities,
need spectra of R≈5000 in, e.g. Ca II triplet region



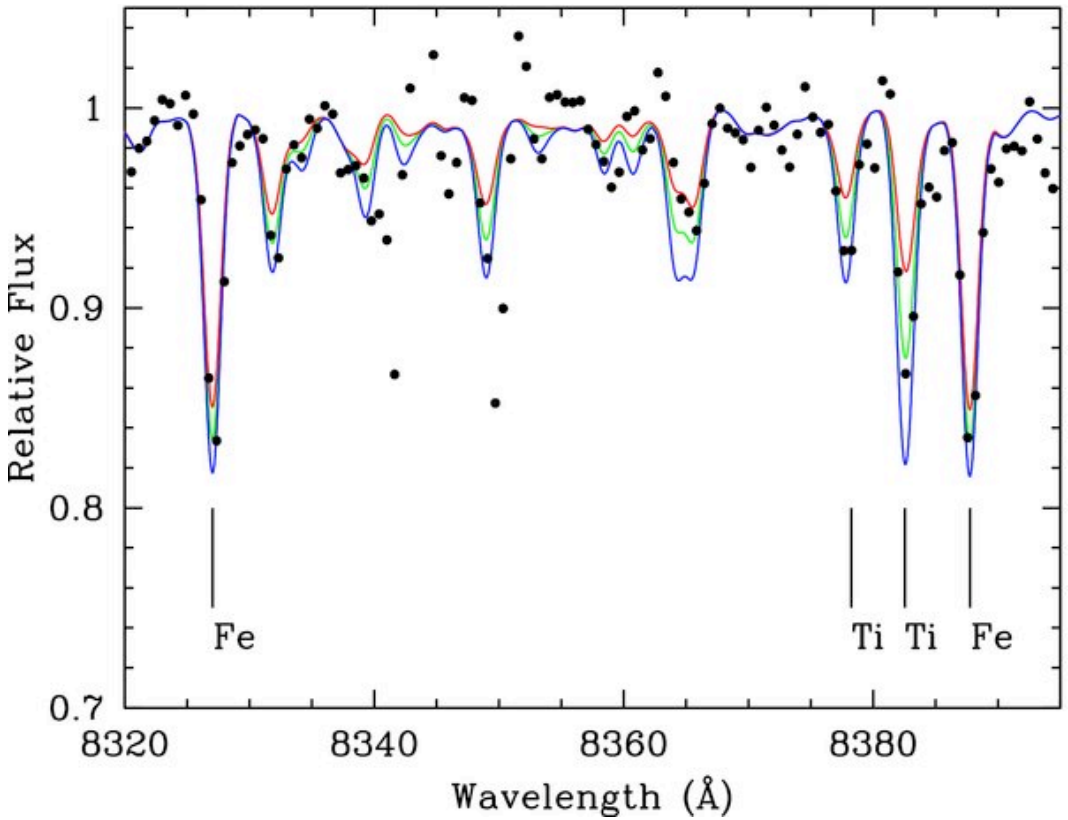
Empirical relation between
Ca EW and Fe:

$$[Fe/H]_{CG97} = -2.95 + 0.38\Sigma Ca + 0.23M_I$$

Carrera et al. 2007, AJ

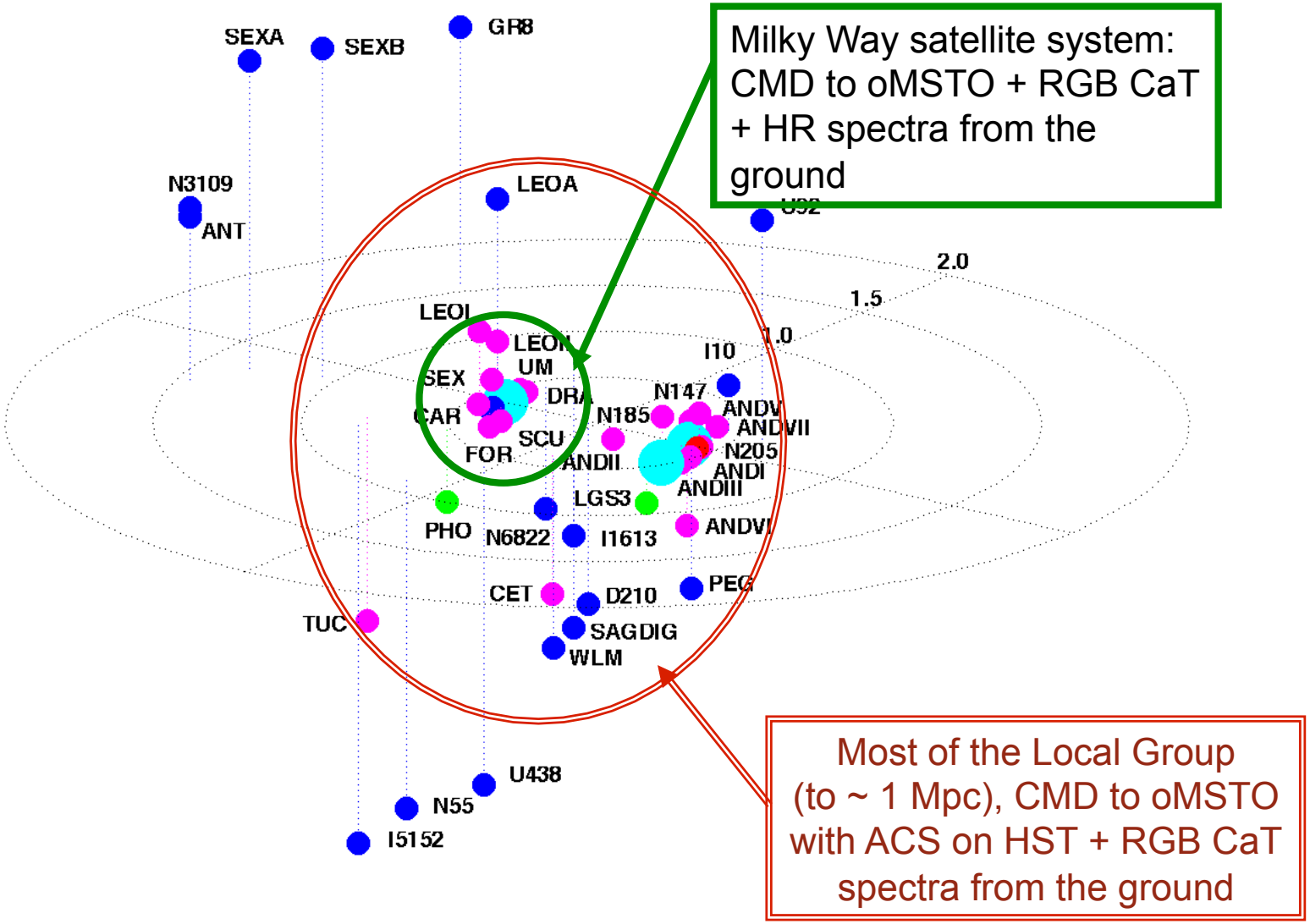
But also J-band spectroscopy;
talk by Chris Evans later…

High resolution (HR) spectra used to obtain abundances of elements through modelling



Example of modelling a stellar spectra with MOOG.
Shetrone et al. 2009, AJ

THE LOCAL GROUP

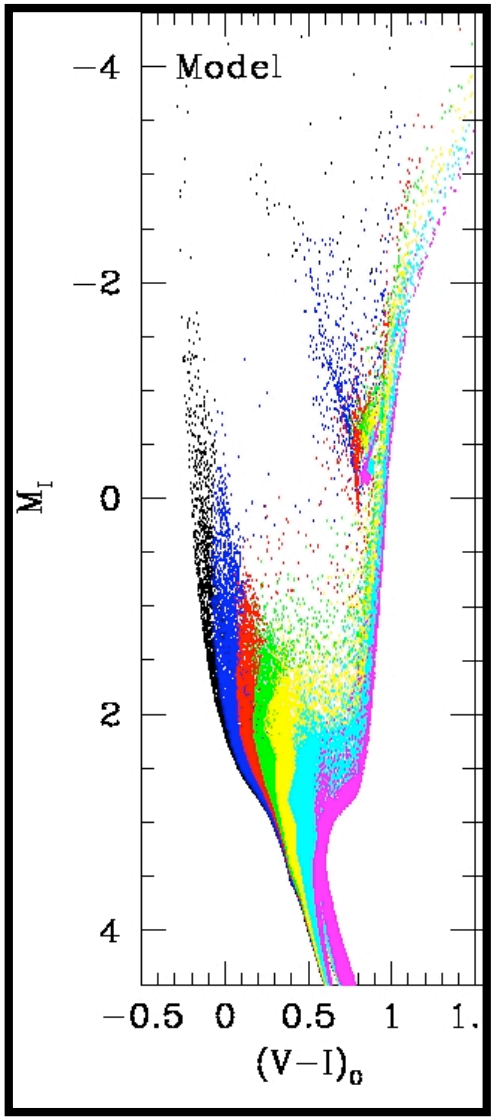


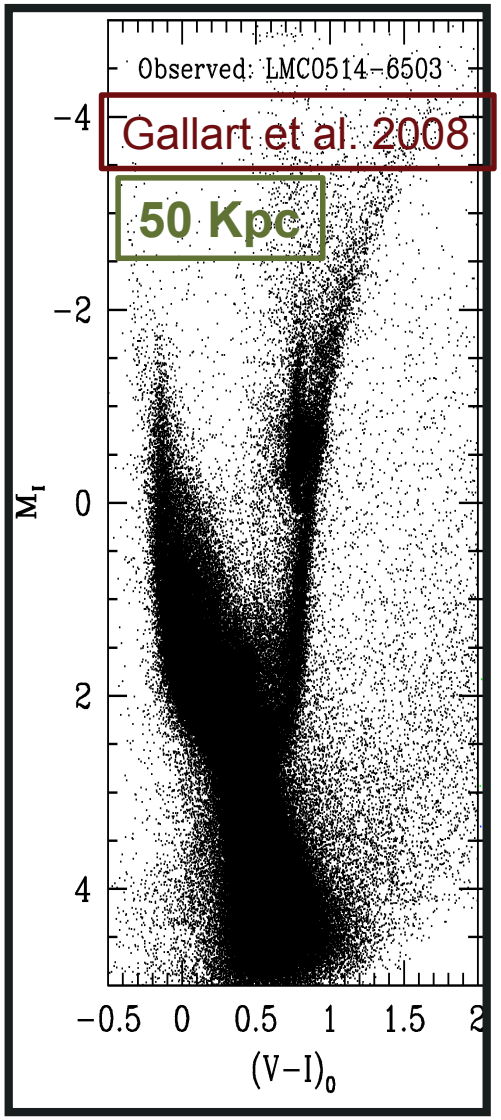
Milky Way satellite system: CMD to oMSTO + RGB CaT + HR spectra from the ground

Most of the Local Group (to ~ 1 Mpc), CMD to oMSTO with ACS on HST + RGB CaT spectra from the ground

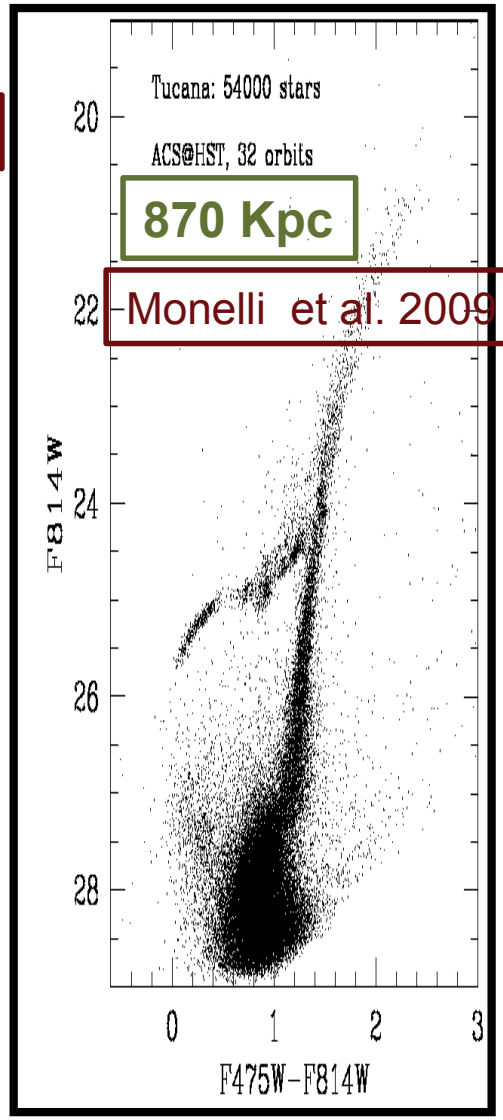
State of the art:

CMDs reaching the oldest Main Sequence Turnofffs

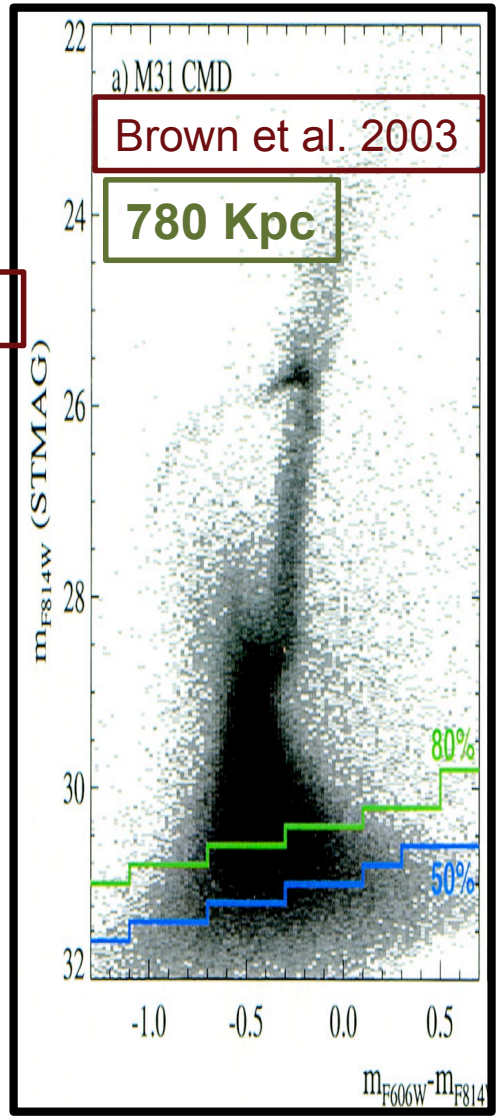




4m CTIO

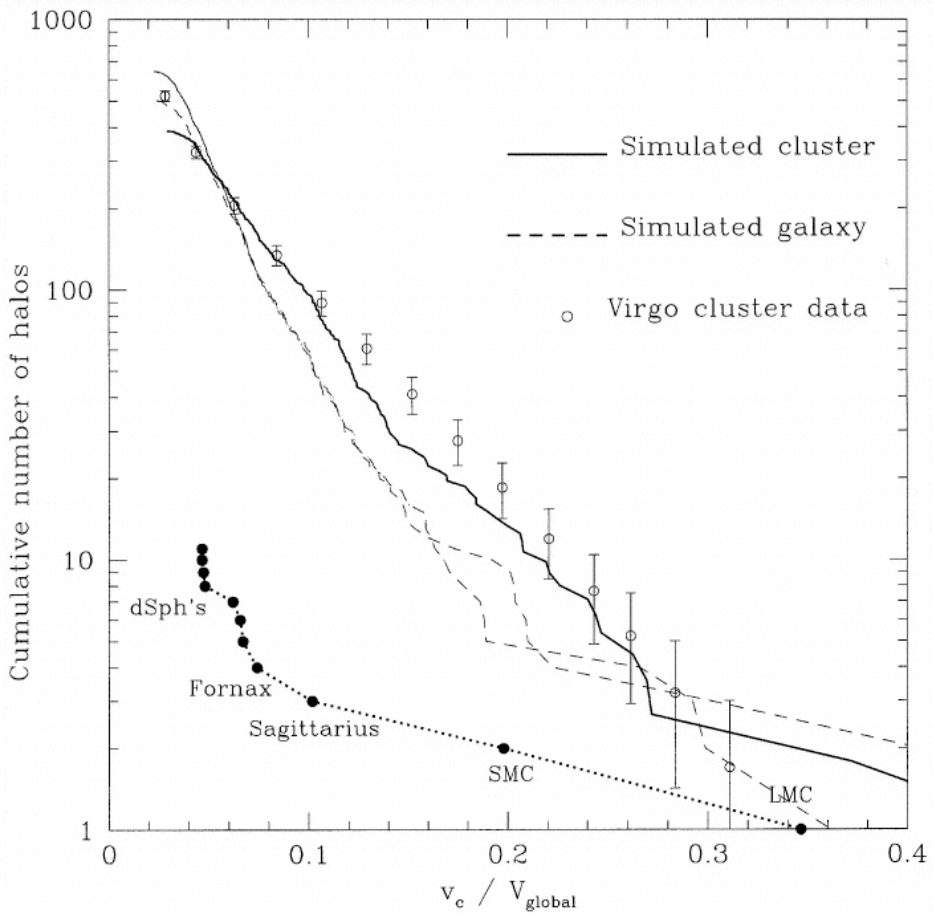


ACS@HST



ACS@HST

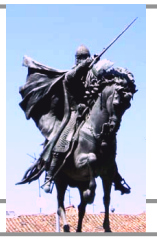
Was reionization able to stop star formation in the smallest galaxies?



Moore et al. 1999 ApJ

Was reionization able to stop star formation in the smallest galaxies?

The LCID project
Local Cosmology from Isolated Dwarfs



✧oMSTO photometry of 6 isolated Local Group dwarf galaxies.

✧Derive complete SFHs to address:

-Effects of processes like cosmic re-ionization and SNe feedback

-Evolution of spatial structure (SFH as a function of radius)

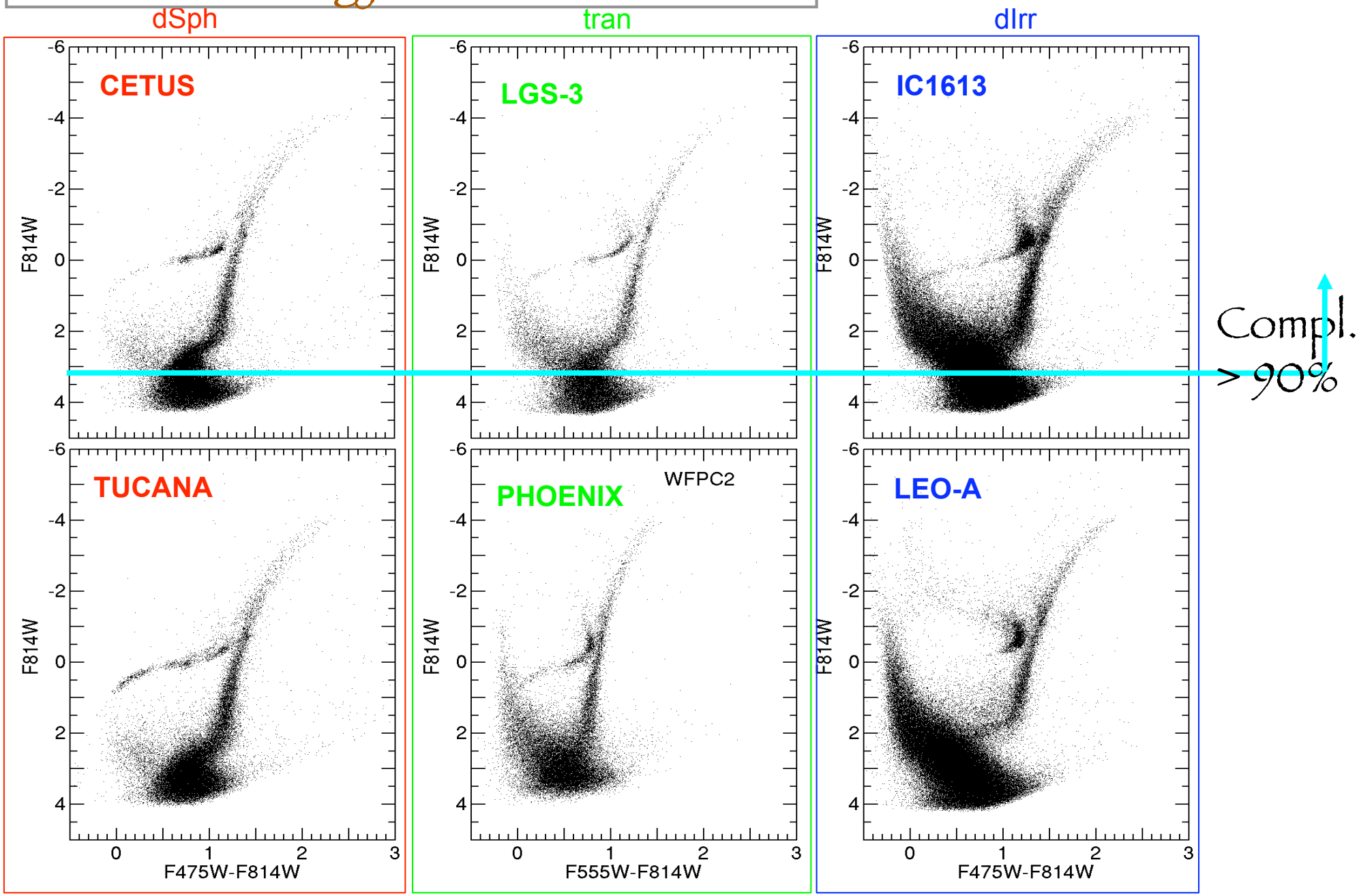
Project team

P.I.: **Gallart (IAC), Cole (U. Tasmania), Aparicio (IAC)**

Co-I: **Bernard** (ROE)**, Drozdovsky** (iac), **Hidalgo** (iac), **Monelli** (iac),. **Bertelli** (U. Padova), S. **Cassisi** (INAF-OA-Teramo), P. **Demarque**, (U. Yale), H.C. **Ferguson** (STScI), A. **Dolphin** (U. Arizona), J. **Gallagher** (U. Wisconsin), **Mayer** (U. Zurich), M. **Mateo** (U. Michigan), J. **Navarro** (U. Victoria), E. **Skillman** (U. Minnesota), P.B. **Stetson** (DAO), **E.Tolstoy** (Kapteyn).

The LCID project
Local Cosmology from Isolated Dwarfs

The CMDs

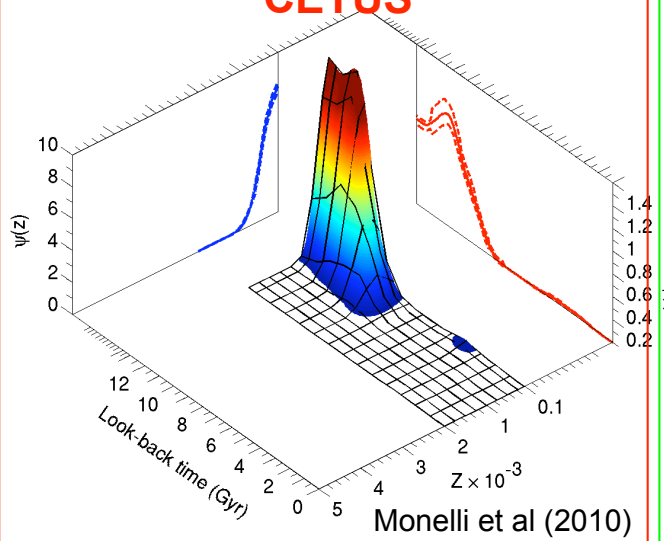


The LCID project
Local Cosmology from Isolated Dwarfs

The SFHs

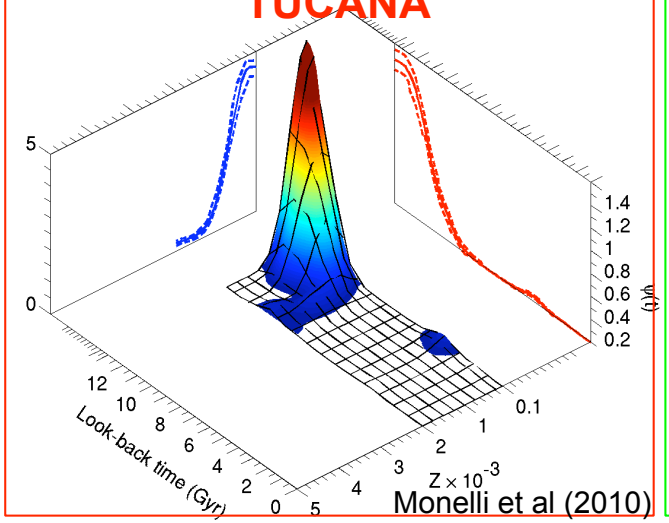
dSph

CETUS



Monelli et al (2010)

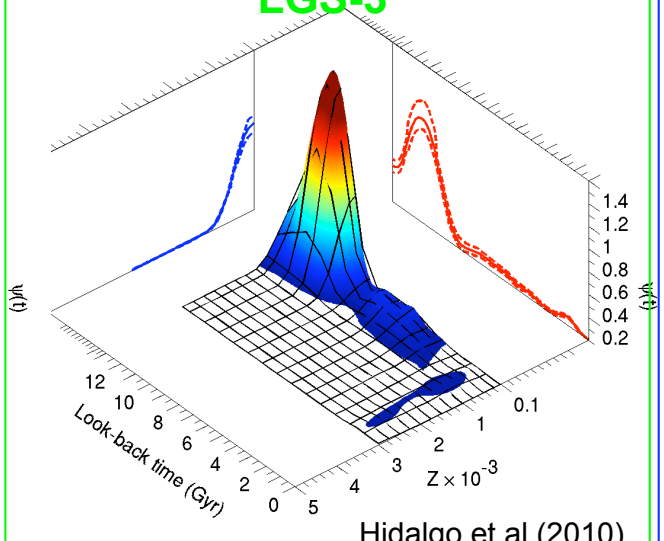
TUCANA



Monelli et al (2010)

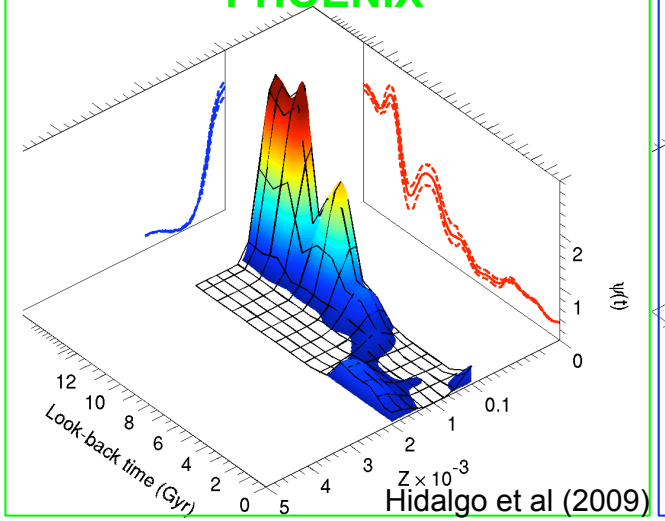
tran

LGS-3



Hidalgo et al (2010)

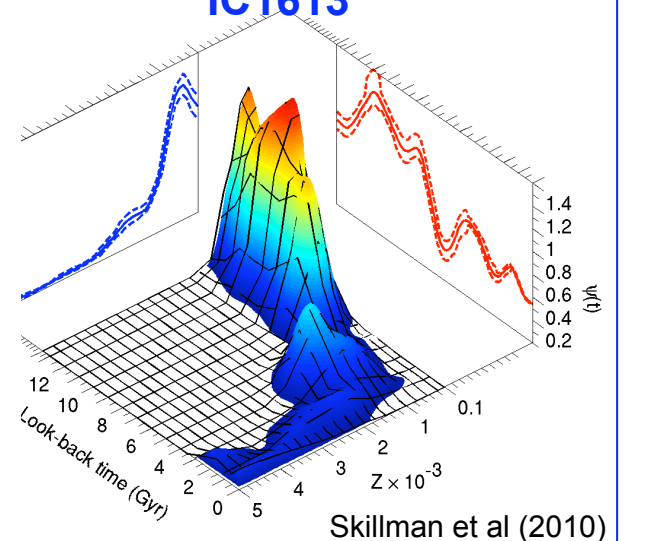
PHOENIX



Hidalgo et al (2009)

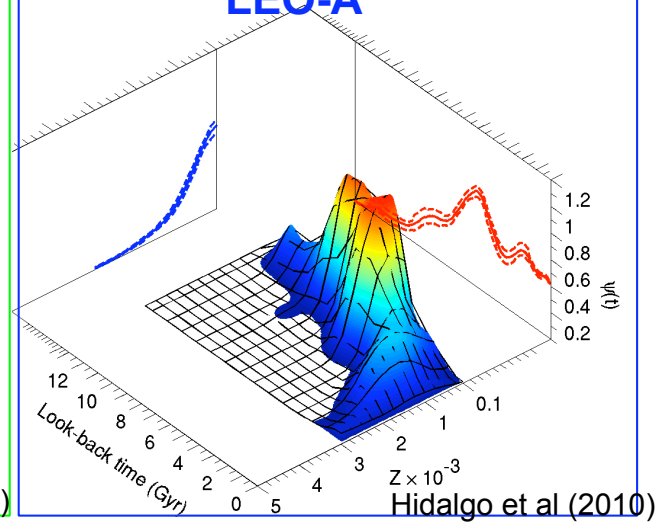
dIrr

IC1613



Skillman et al (2010)

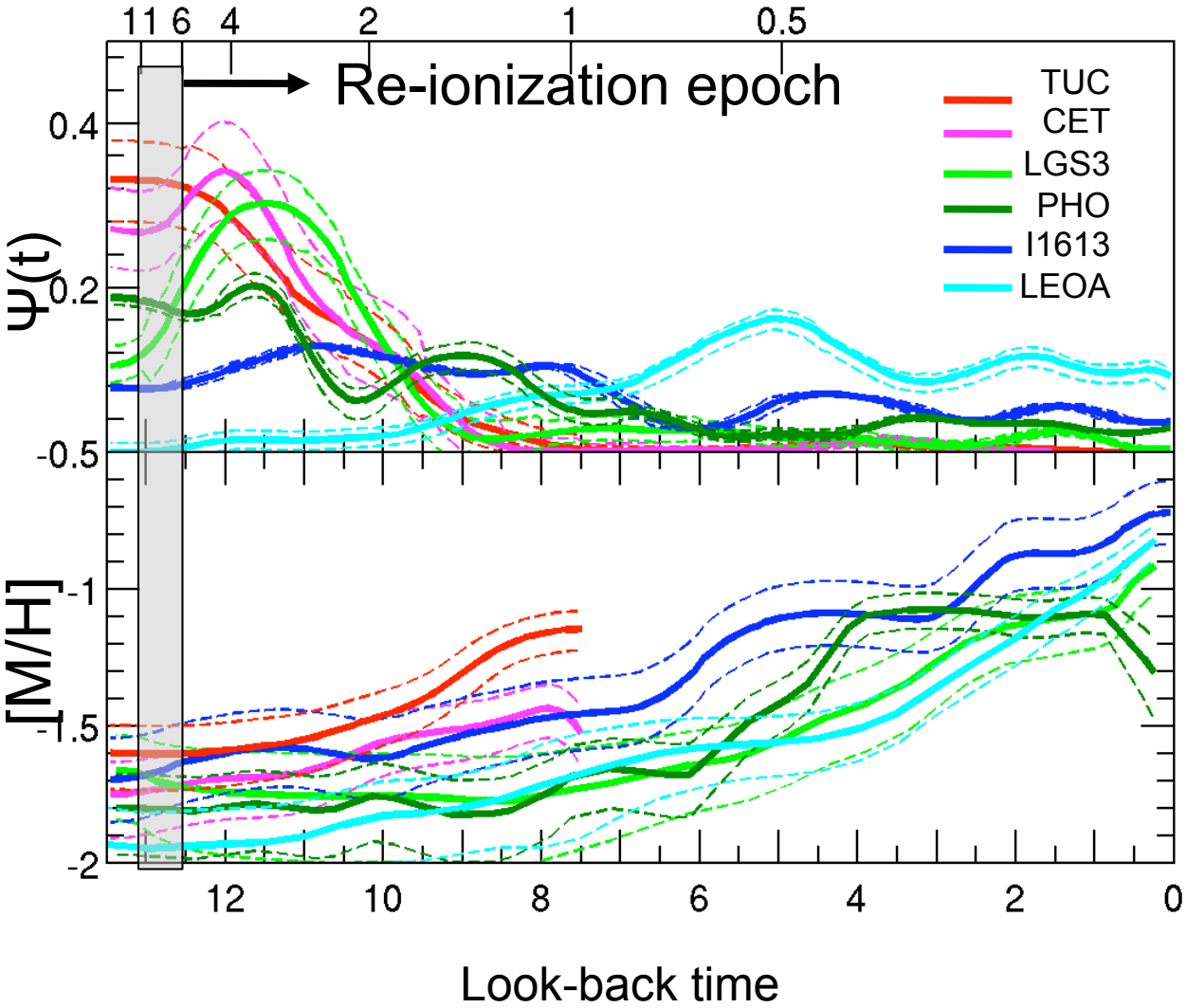
LEO-A



Hidalgo et al (2010)

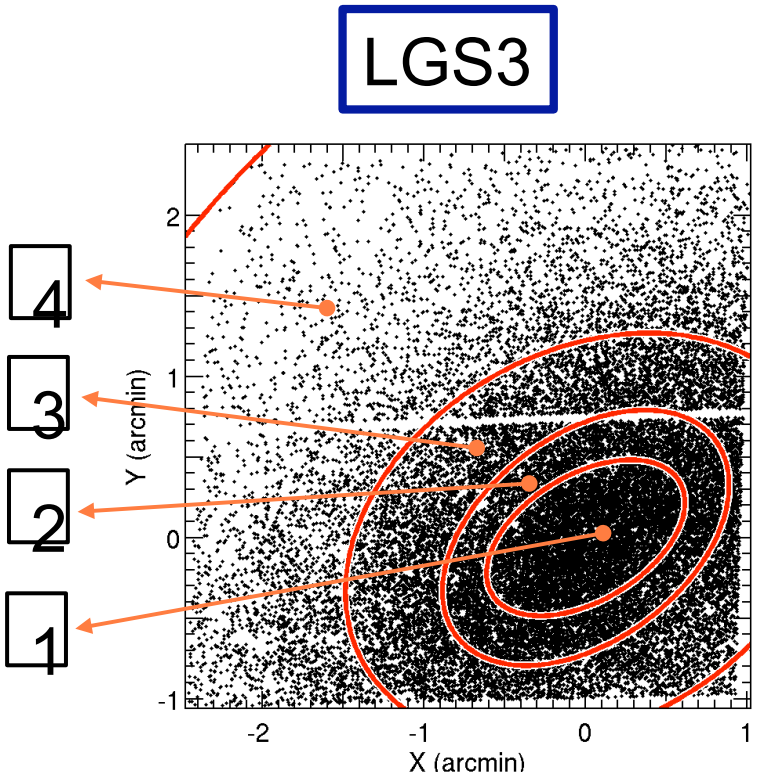
MORE GAS CONTENT

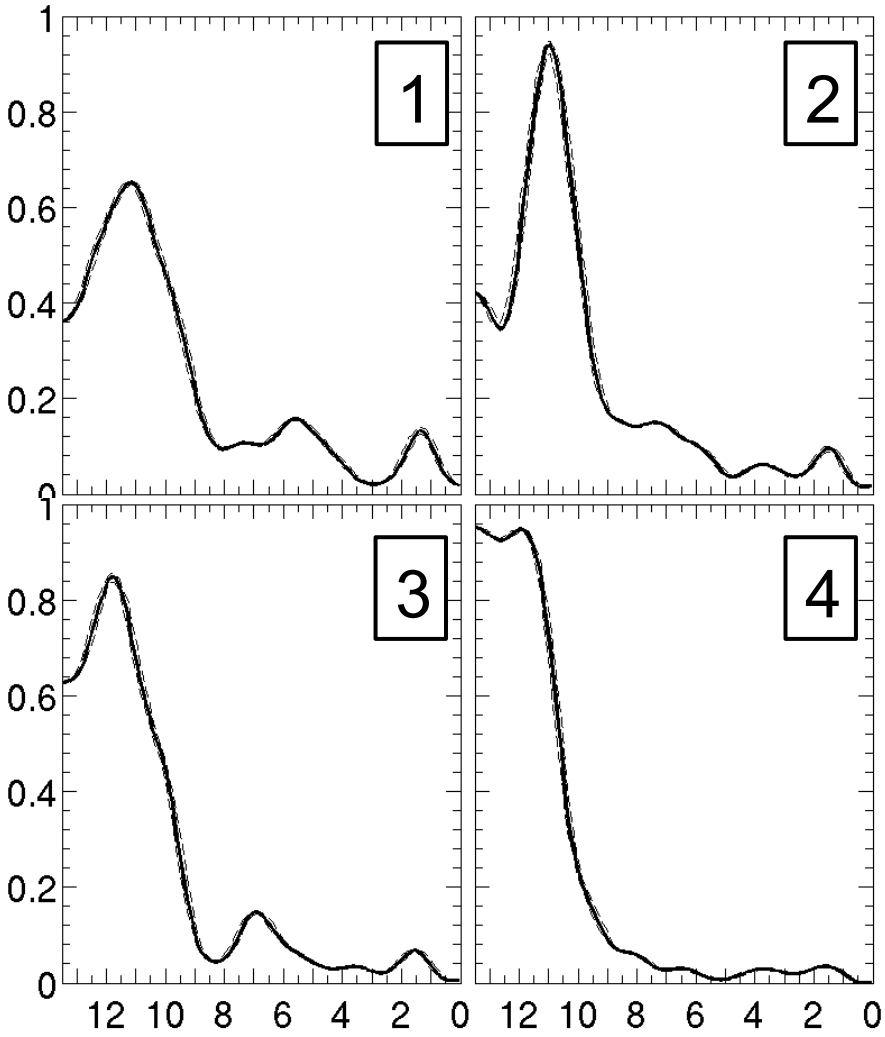
Was reionization able to stop star formation in the smallest galaxies?



Reionization seems to have not stopped star formation in any of these galaxies.

Structure formation in the smallest galaxies



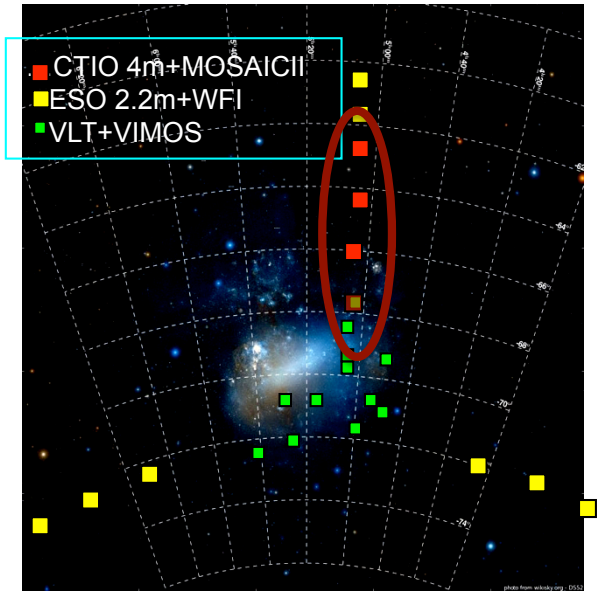


Hidalgo et al. 2011, in prep

Look-back time

LMC star formation history and population gradients: do small disks form inside-out?

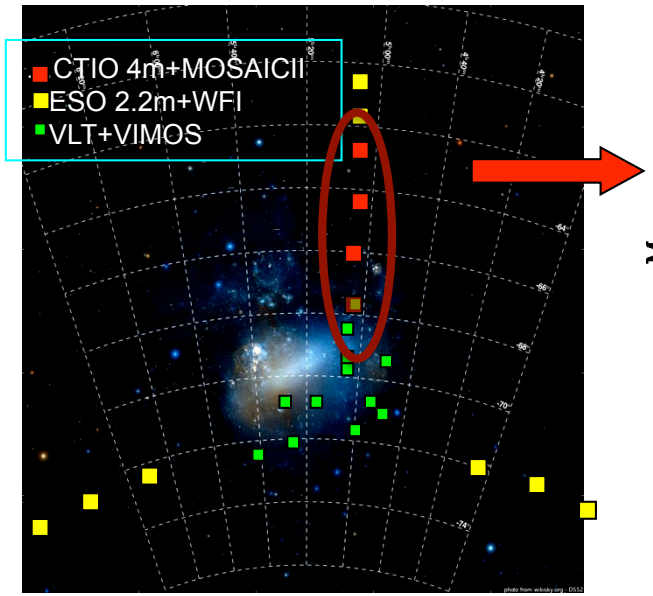
LMC star formation history and population gradients: do small disks form inside-out?

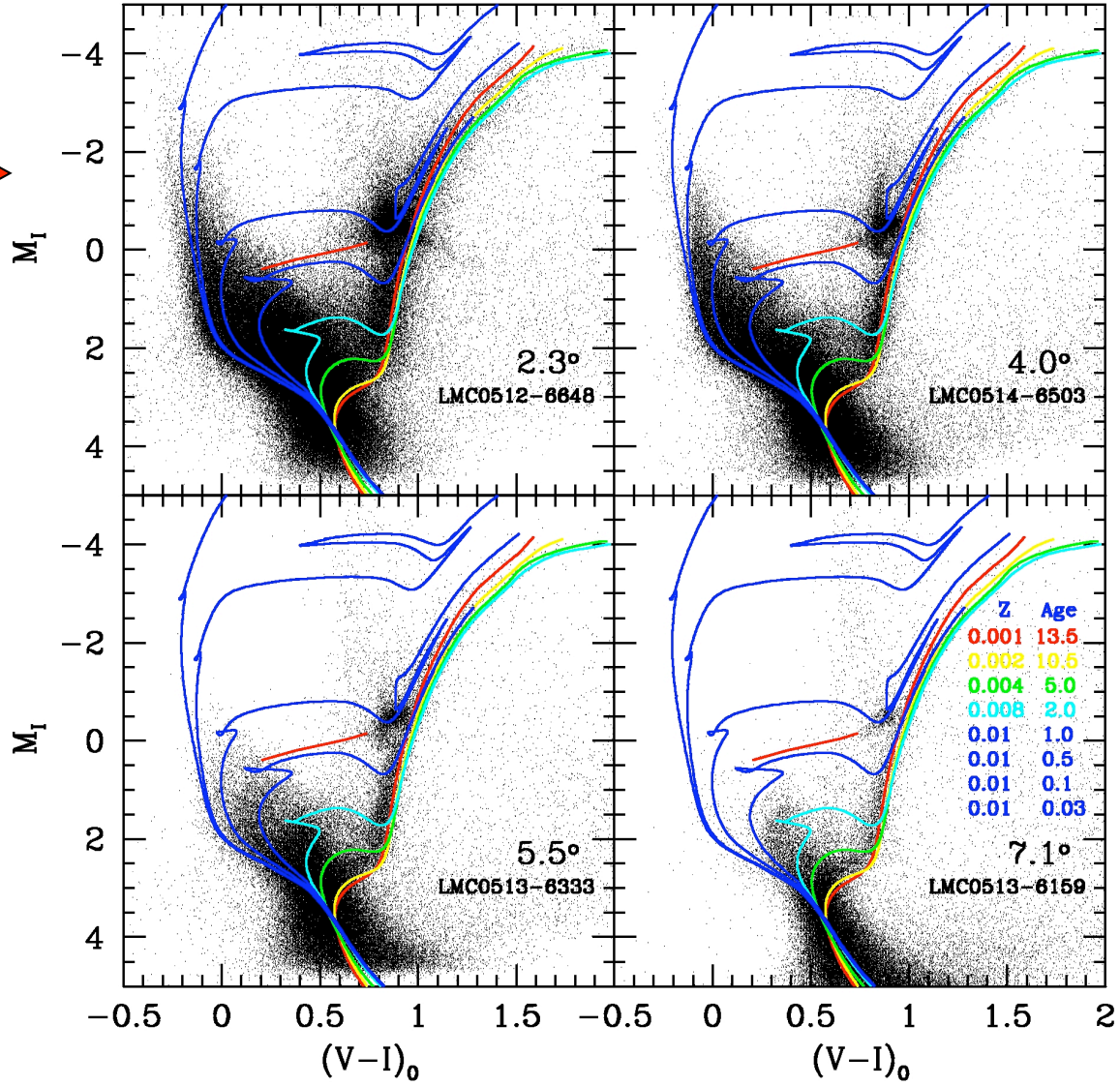


Project using MOSA (+DECam) @4m CTIO + WFI @ 2.2m ESO + VIMOS @VLT

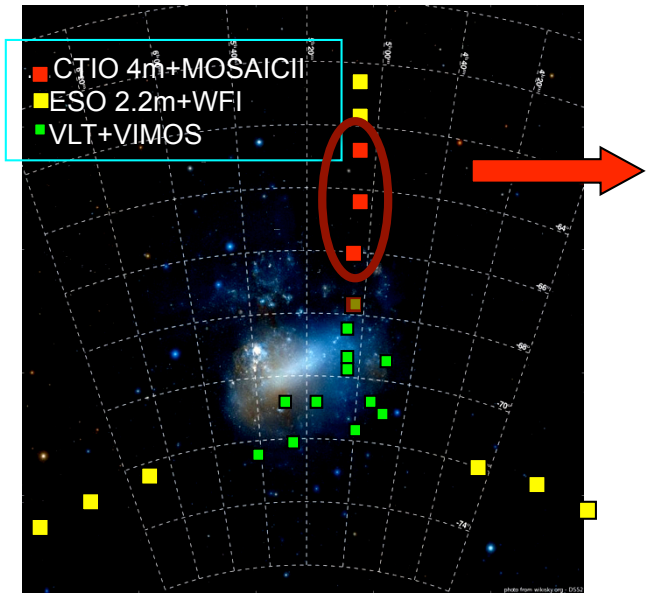
with Monelli, Gallart, Hidalgo, Meschin, Aparicio, Bono, Cassisi, Stetson, Walker

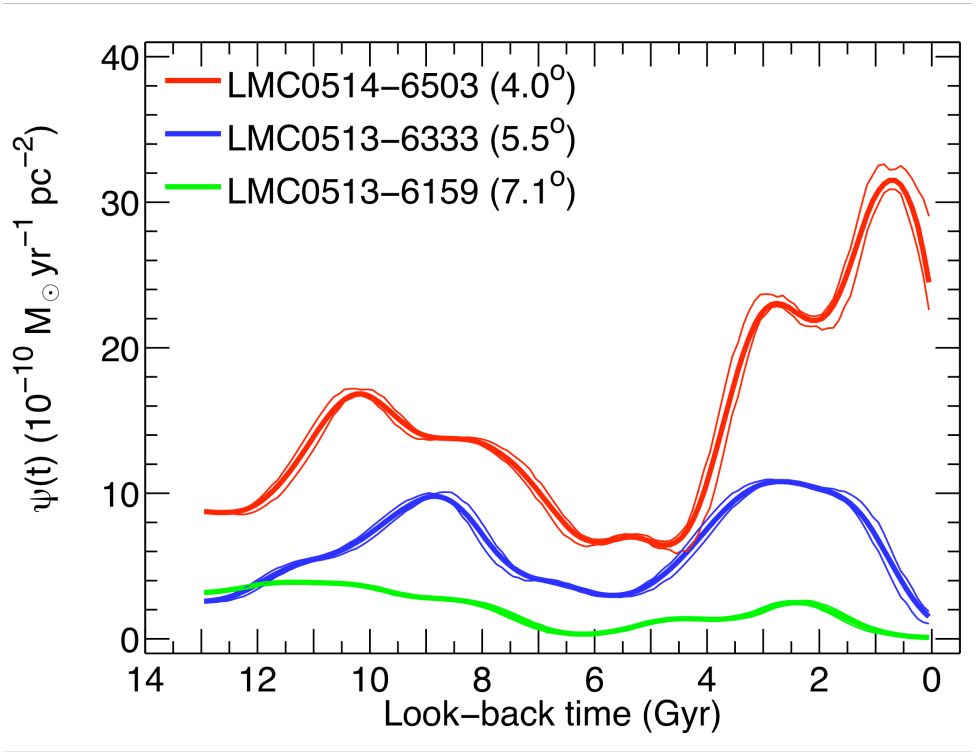
LMC star formation history and population gradients: do small disks form inside-out?





LMC star formation history and population gradients: do small disks form inside-out?



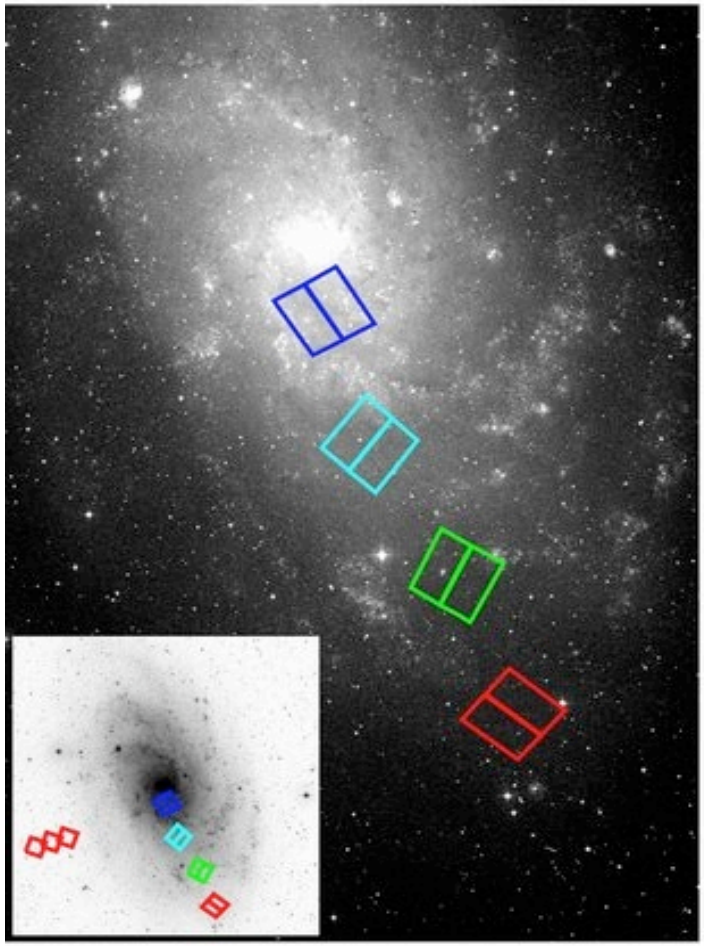


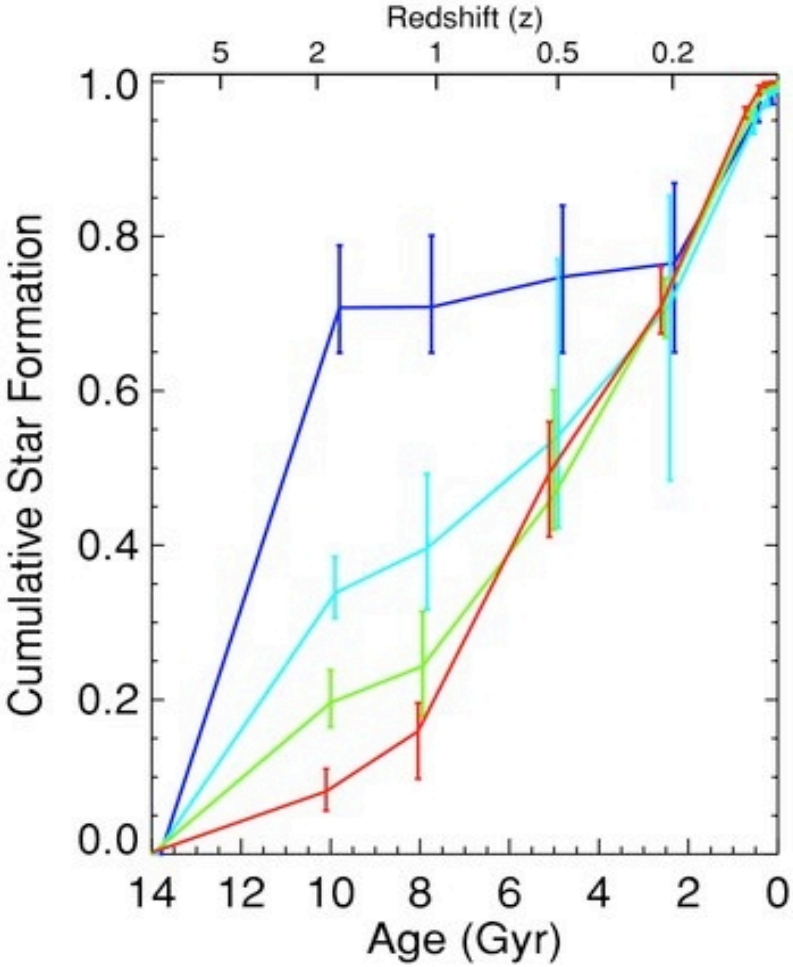
Meschin 2011, PhDT

M33 star formation history and population gradients.
Do small spiral galaxies form inside-out?

M33 star formation history and population gradients.
Do small spiral galaxies form inside-out?

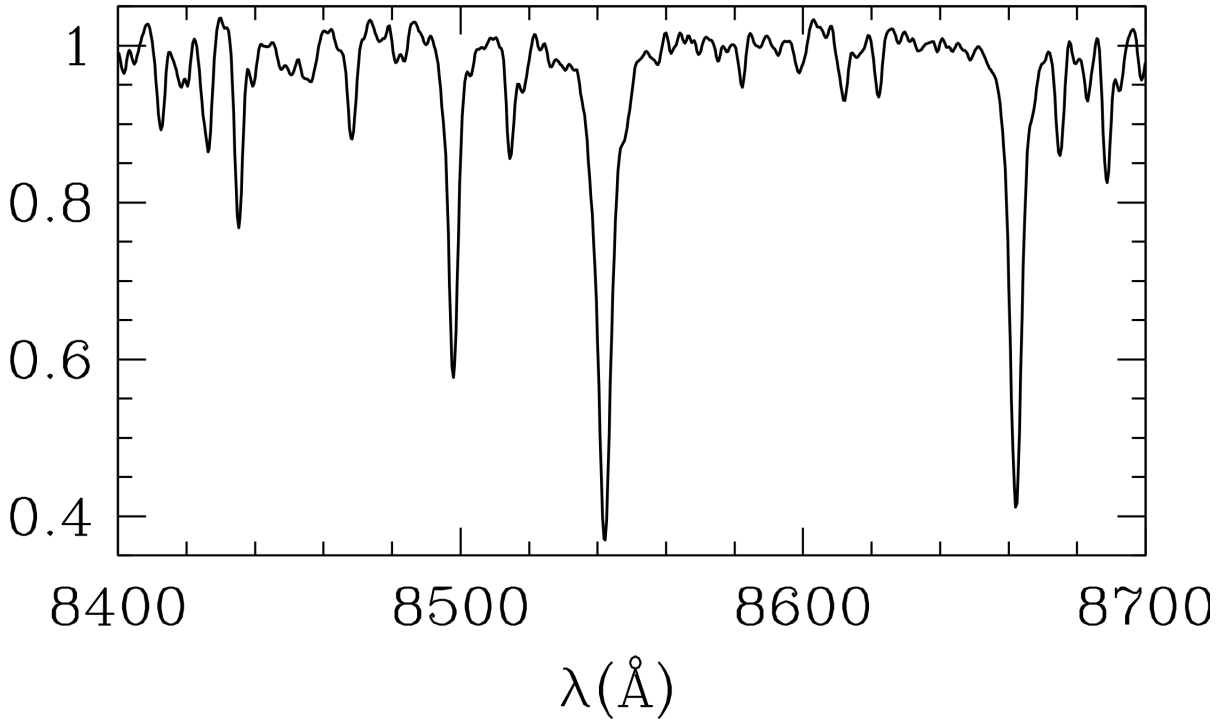
86 ACS orbits



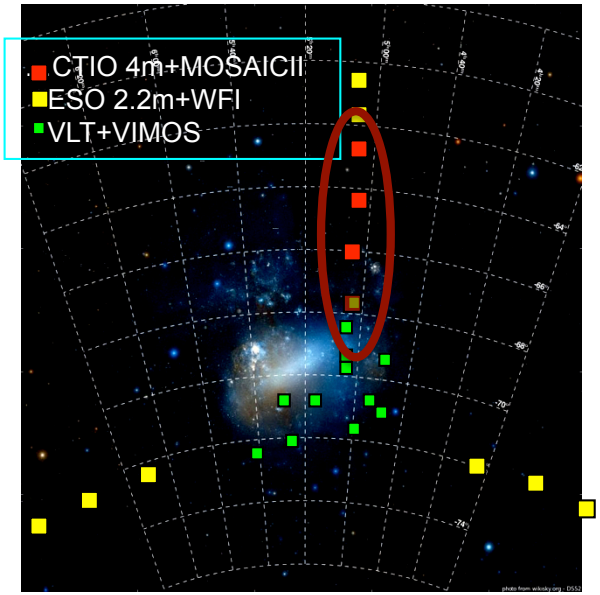


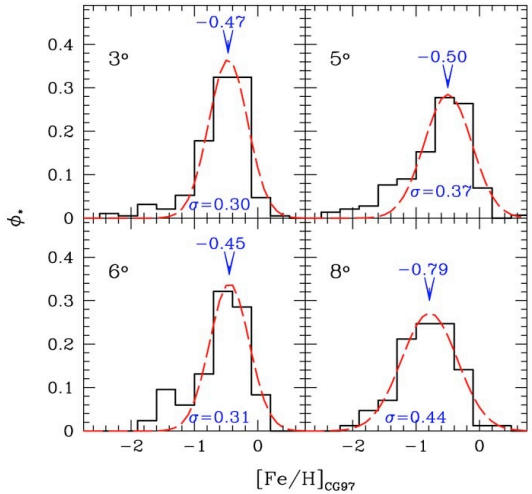
Williams et al. 2009, ApJL

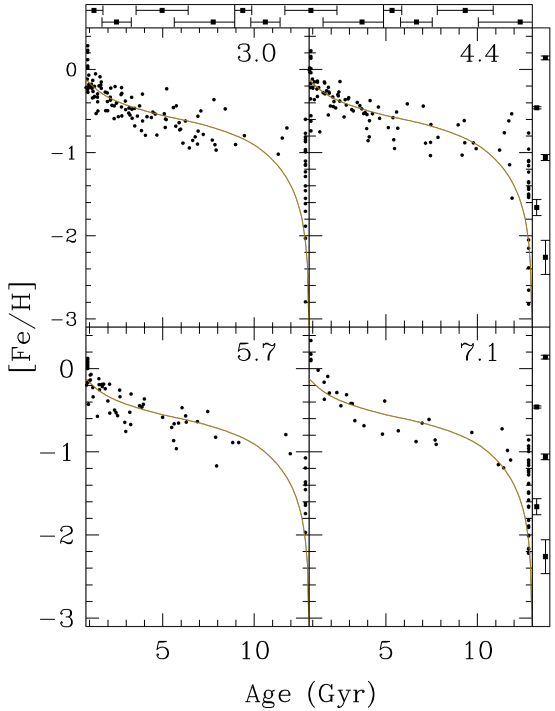
CaT spectroscopy… hundreds of spectra from Hydra, WYFFOS, FORS, FLAMES…



LMC chemical enrichment history from CaT metallicities





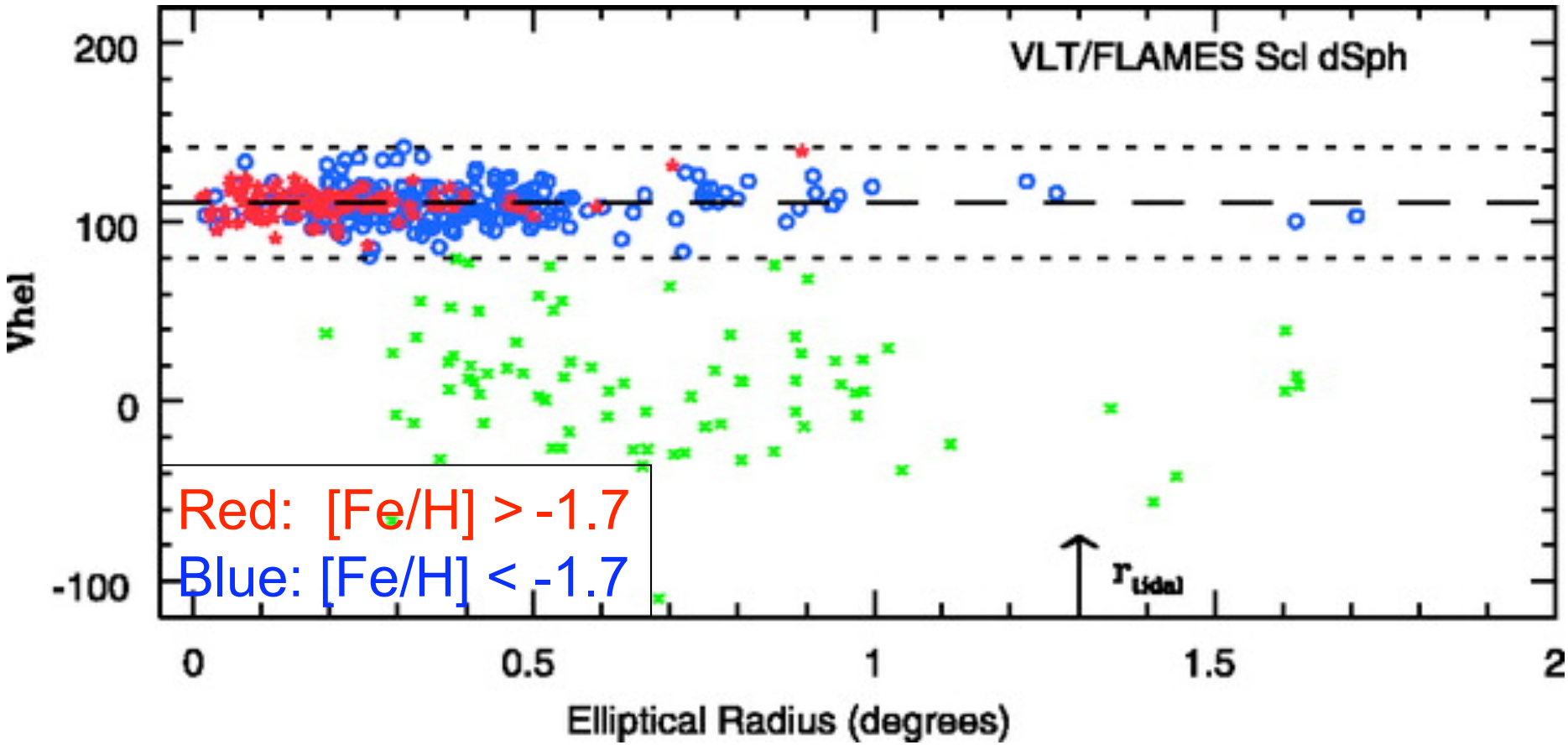


Carrera et al. 2008a, AJ

Similar results for the SMC; Carrera et al. 2008b, AJ

Chemodynamical sub-structure in Sculptor dSph

DART team

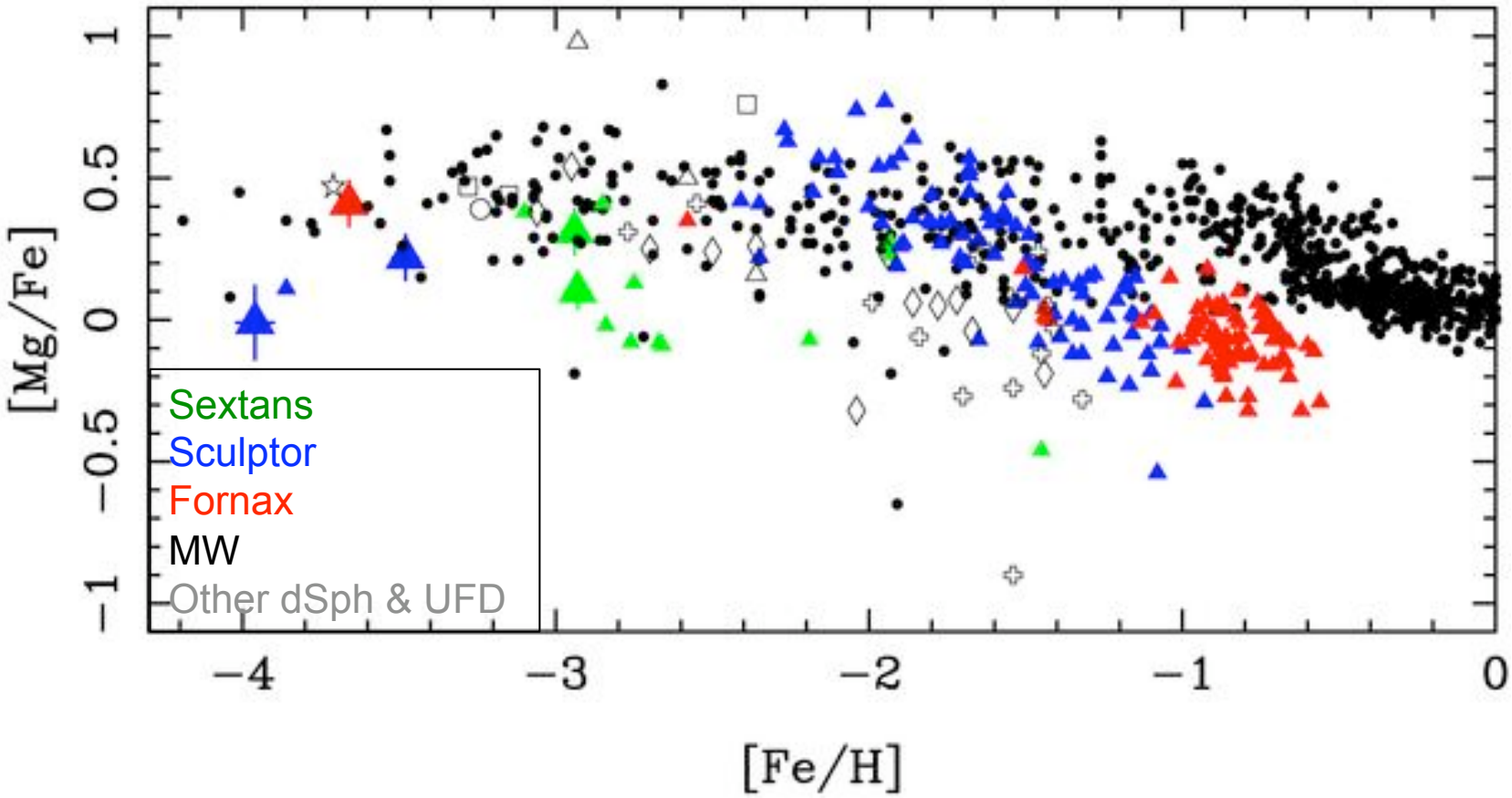


Tolstoy et al. 2004, ApJL
Battaglia et al. 2008, ApJ

HR spectroscopy: from few stars with Keck-HIRES & VLT-UVES, to many hundreds with FLAMES@VLT…

Extremely metal poor stars and α-enrichment history in dSph

DART team



Tafelmeyer et al. 2010 A&A

Prospects with ELTs and surveys:

ELTs (or GSMTs) main science drivers in relation to ‘Nearby Galaxies’

1. Photometry:

-SFH of nearby galaxies.
Ultimate goal: to resolve a giant elliptical galaxy
-Origin of the IMF

2. Spectroscopy:

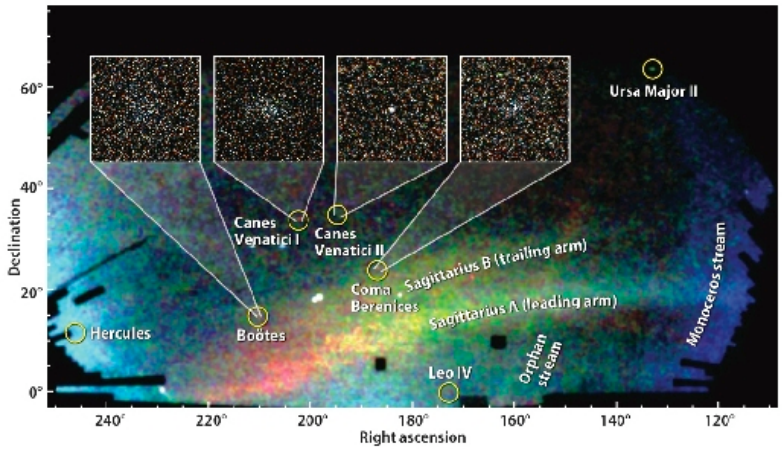
-Chemodynamical structure of galaxies
-Probing chemical evolution in the LG and beyond
-First stars in MW & satellites through analysis of extremely metal poor stars

Some surveys main science drivers in relation to ‘Nearby Galaxies’

SDSS

-Observed 1/4 of the whole sky
-Imaging limiting mag: ≈ 22 single; 0.4”pix
-Spectra R≈2000; S/N>4/pix @ g=20.2
-Relevant SDSS-III surveys (structure, formation and evolution of the Galaxy):
SEGUE: Imaging & spectra of > 360,000 stars in disk and spheroid➔ age, composition and phase space
APOGEE: IR HR spectra of 100,000 stars in all galactic components

Skymapper in the south



Some surveys main science drivers in relation to 'Nearby Galaxies'

Pan-STARRS

-Whole sky from Hawaii imaged 3 x / dark lunar cycle.
-Limiting mag: ≈ 24 single / ≈29.4 stacked; 0.3"pix
-Among the key science programs:
5. Structure of MW and LG
6. Deep survey of M31
7. Massive stars and SNe progenitors
-Status: prototype telescope started operation 2010

LSST

-Survey of > 20,000 deg^2 of the southern sky. 8.4m, 1000x
-Limiting mag: r≈ 24.5 single/ 27.5 stacked; 0.2"pix
-1 out of 4 key science programs:
→Mapping the MW & MCs
-Status: operation starting 2020

-Depth implies possibility of studying RR Lyrae to 1Mpc and RGBs in outer parts of galaxies in nearest groups

‘Targeted’ surveys in relation to ‘Nearby Galaxies’

✧VMC survey (P.I. Cioni)

✧LCID project (P.I. Gallart)

✧A Survey of the Resolved Stellar Content of Nearby Galaxies Currently Forming Stars (P.I. Massey)

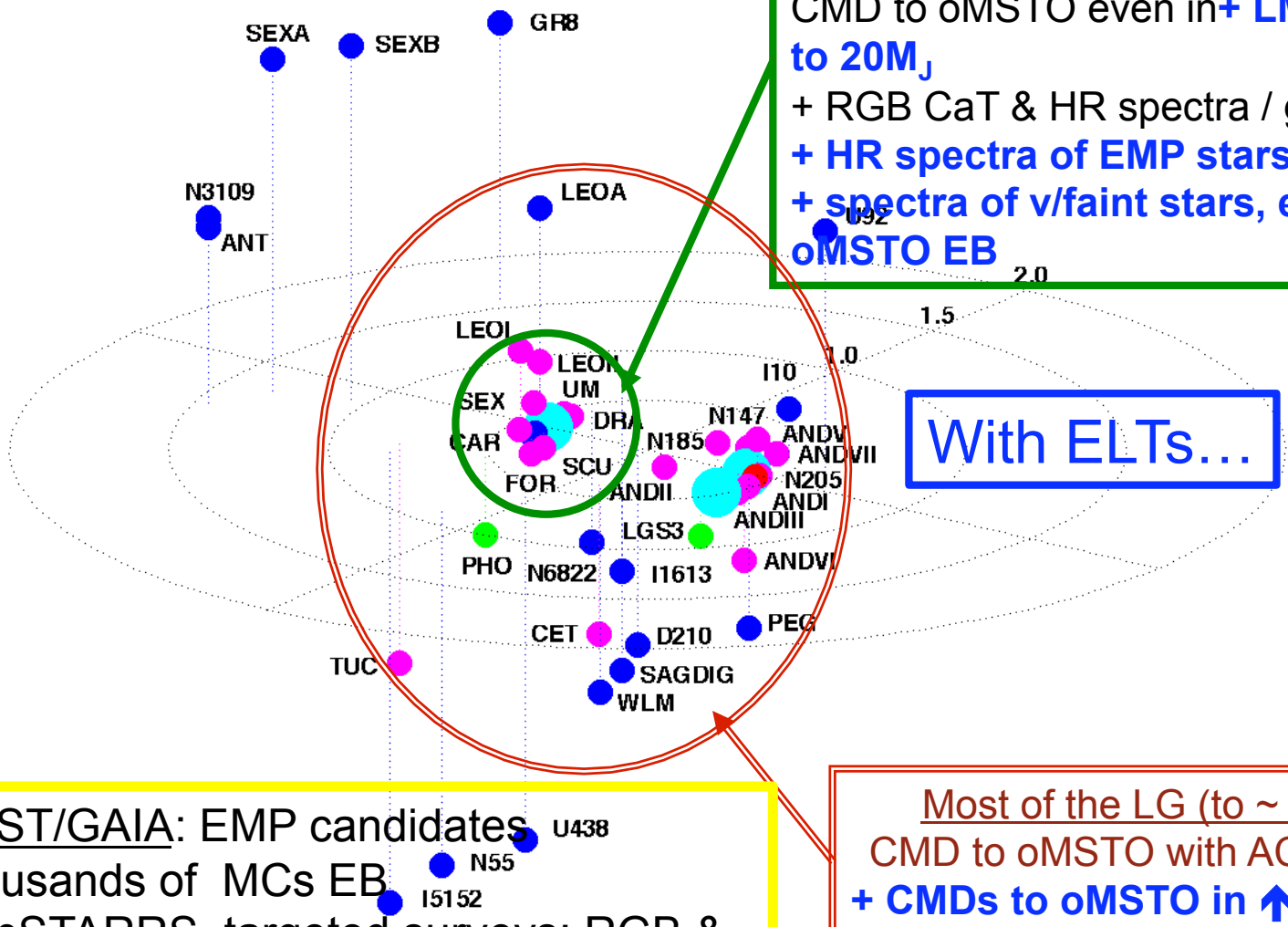
✧HST snapshot survey of nearby galaxy candidates (P.I. Seitzer)

✧The ACS Virgo and Fornax Cluster Surveys (P.I. Côté & Jordan)

✧The ANGST survey (P.I. Dalcanton)

✧ (…)

THE LOCAL GROUP



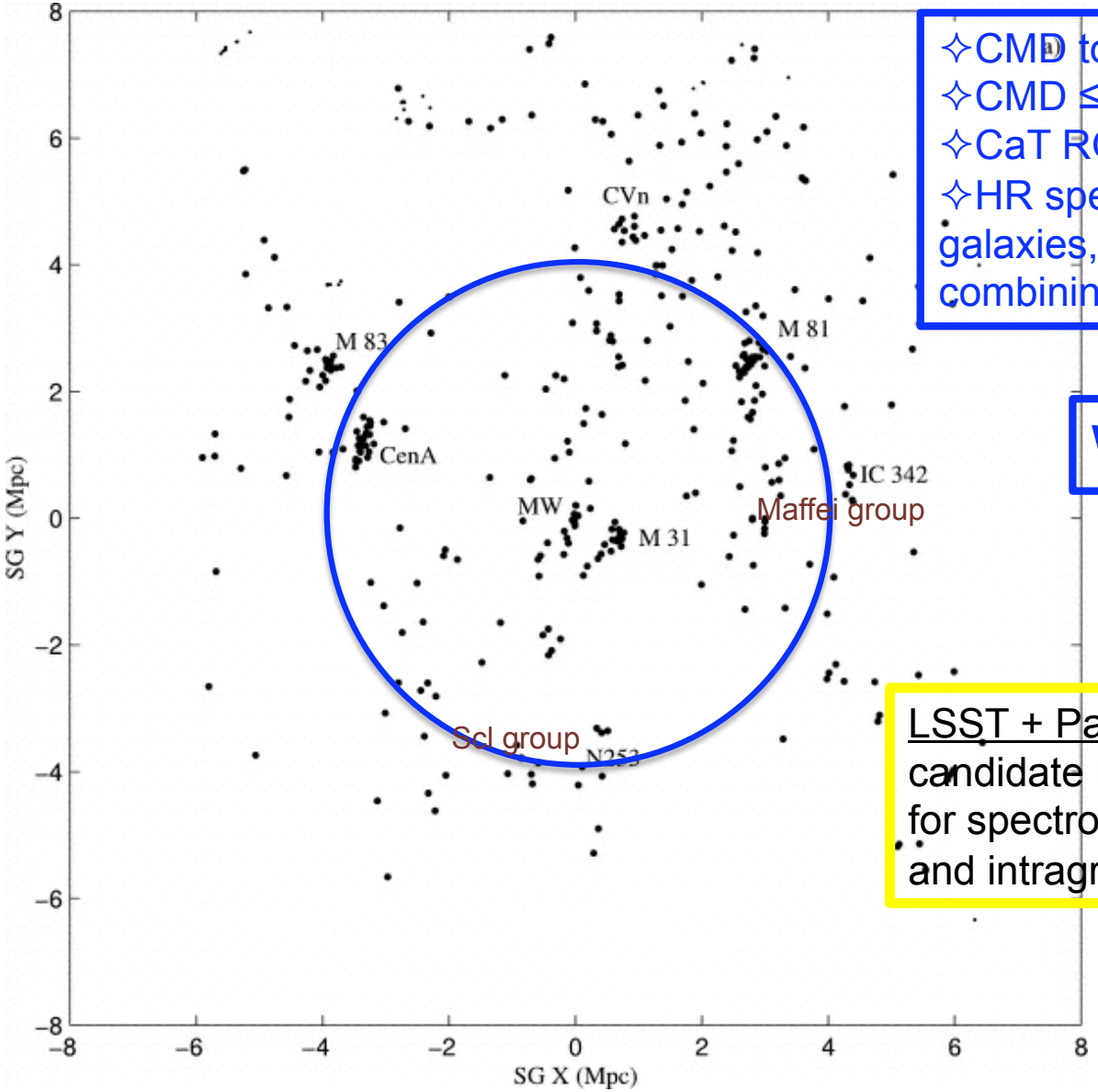
Milky Way satellite system:
CMD to oMSTO even in **+ LMC down to 20M_J**
+ RGB CaT & HR spectra / ground
+ HR spectra of EMP stars,
+ spectra of v/faint stars, e.g. MCs
oMSTO EB

With ELTs…

✧SDSS/LSST/GAIA: EMP candidates
✧LSST: thousands of MCs EB
✧LSST, PanSTARRS, targeted surveys: RGB & RR Lyr candidates for HR & LR spectra in the whole LG
✧LSST, PanSTARRS: LG 'Field' UFD?

Most of the LG (to ~ 1 Mpc):
CMD to oMSTO with ACS on HST
+ CMDs to oMSTO in ↑↑crowded
+ RGB CaT spectra / ground
+ RGB HR spectra

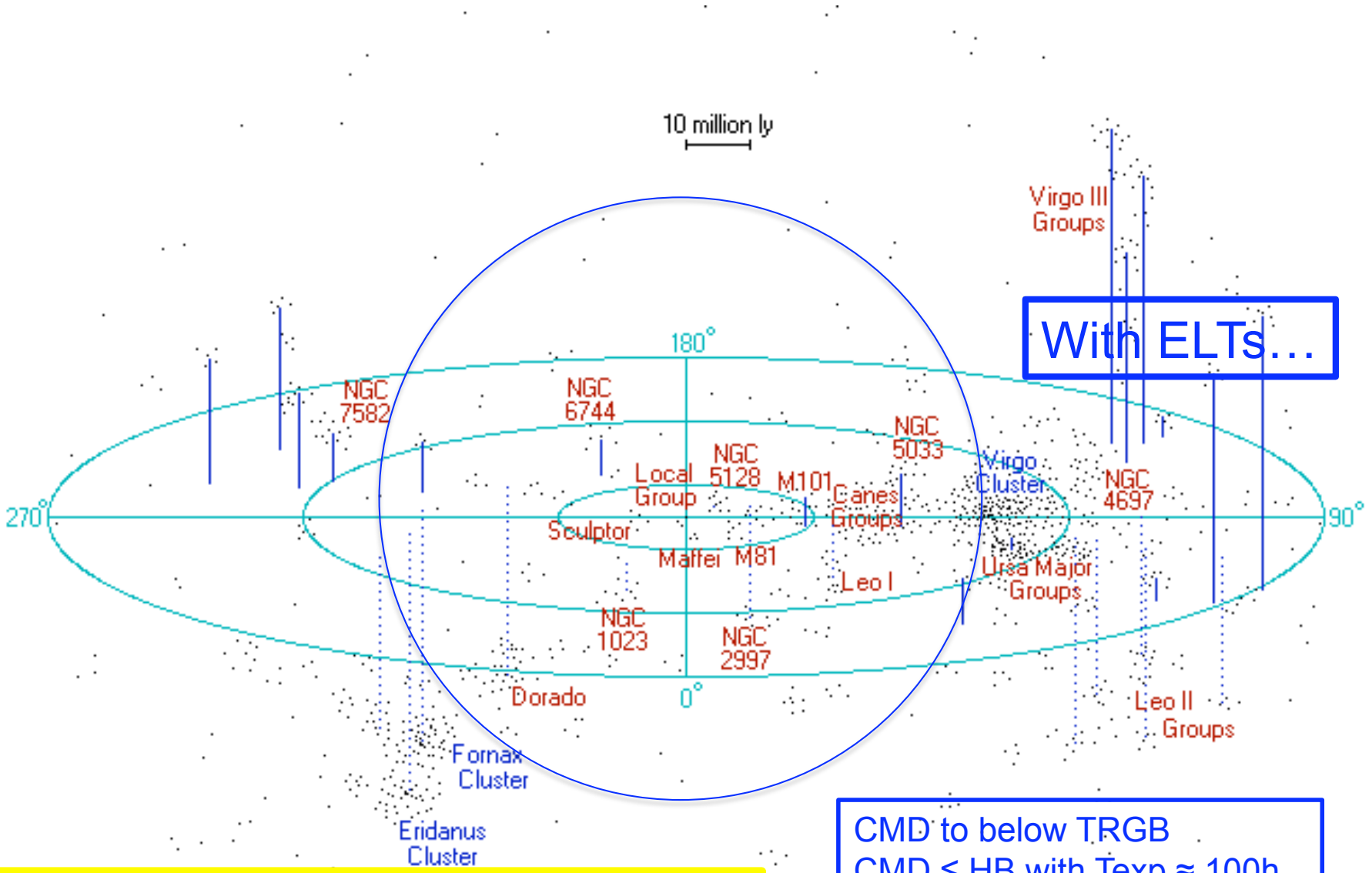
AND BEYOND: nearest groups



✧CMD to HB
✧CMD ≤ oMSTO Texp≈100h ➔ spirals
✧CaT RGB l.o.s veloc. & metallicities
✧HR spectra in RGB in outer parts of galaxies, young stars and GCs, or by combining spectra

With ELTs…

LSST + PanSTARRS + targeted surveys: candidate RGB, young stars, GCs & PNe for spectroscopy, in different galaxy types and intragroup.


10 million ly
Virgo III Groups
With ELTs…
180°
NGC 7582
NGC 6744
NGC 5033
NGC 5128
M101
Local Group
Virgo Cluster
NGC 4697
270°
90°
Canes Groups
Sculptor
Maffei
M81
Leo I
Ursa Major Groups
NGC 1023
NGC 2997
Dorado
0°
Leo II Groups
Fornax Cluster
Eridanus Cluster
CMD to below TRGB
CMD ≤ HB with Texp ≈ 100h
CaT spectra?? of indiv. stars?
HR spectra of brightest GCs
Targeted surveys: to select fields for deep CMDs, and GC candidates for spectroscopy
r powell

CONCLUSIONS

-Large, general surveys useful but not essential for most expected ELT ‘Nearby Galaxies’ science.

-Targeted surveys sufficient in most cases

-Feeding the giants with spectroscopy targets or to select fields for imaging.