Spectroscopy of resolved stellar populations in the Local Group

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Spectroscopy of resolved stellar populations in the Local Group

1- dIrr – dSph galaxies: the missing link

2- Chosen poblems in nucleosynthesis: lithium

3- First stars fossils in the local group

LAGRANGE

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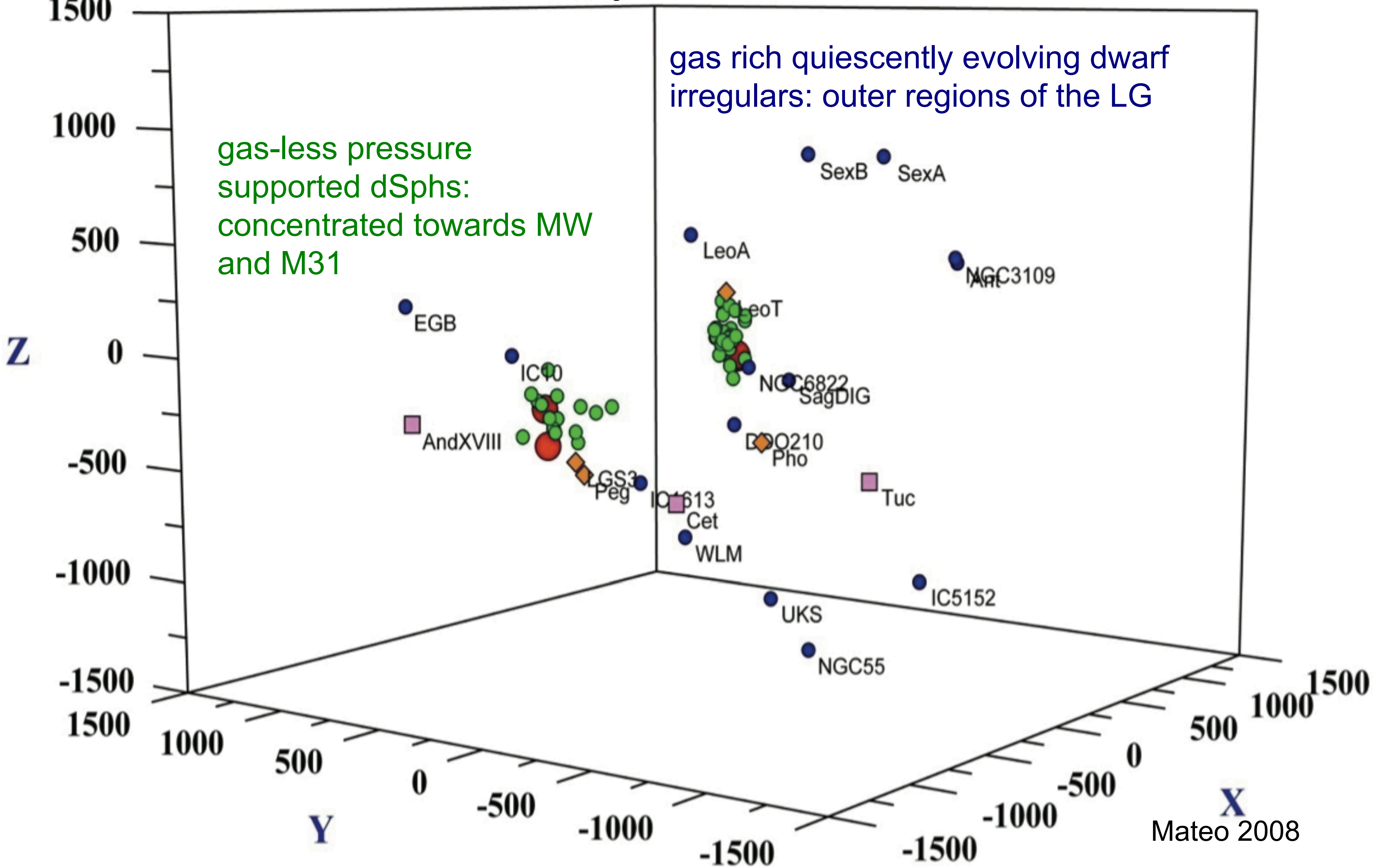
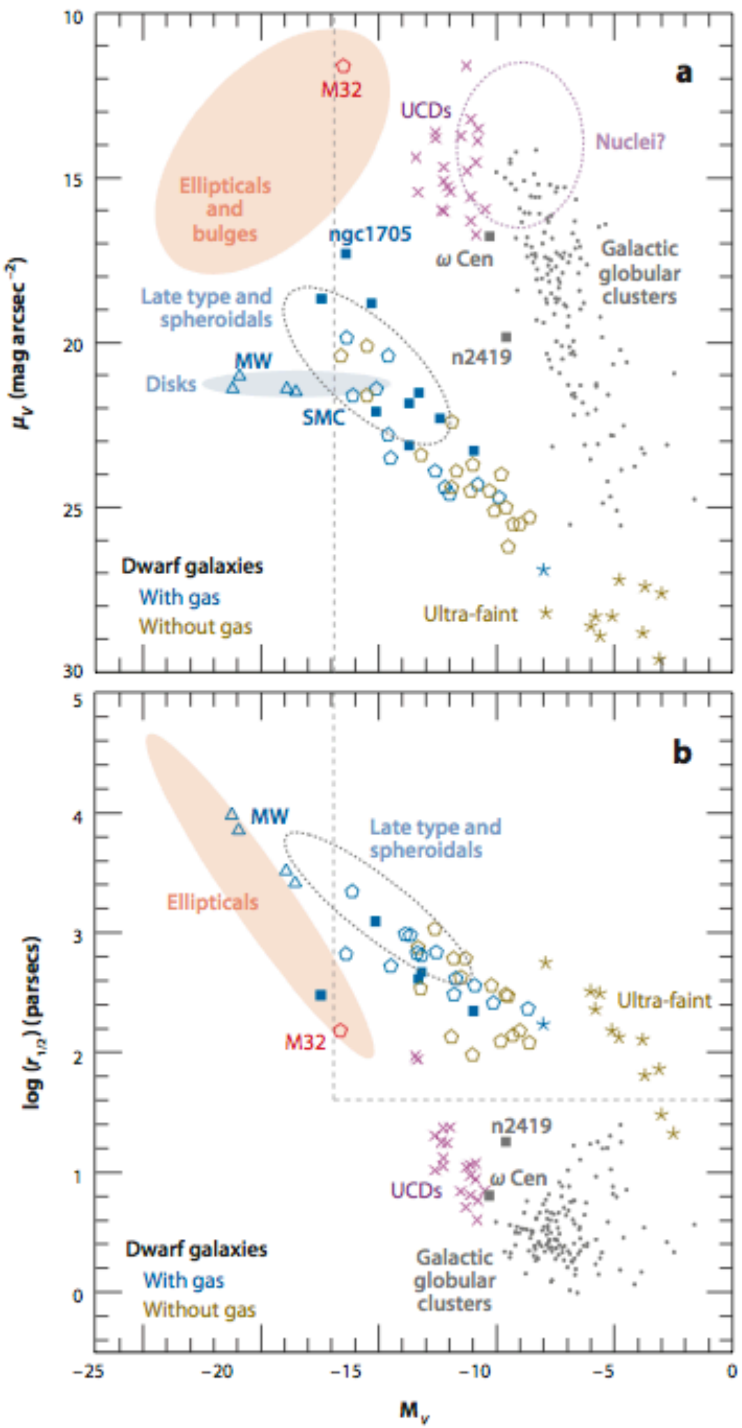
A dwarf galaxy census in the Local group: dSph vs dIrr



Mateo 2008

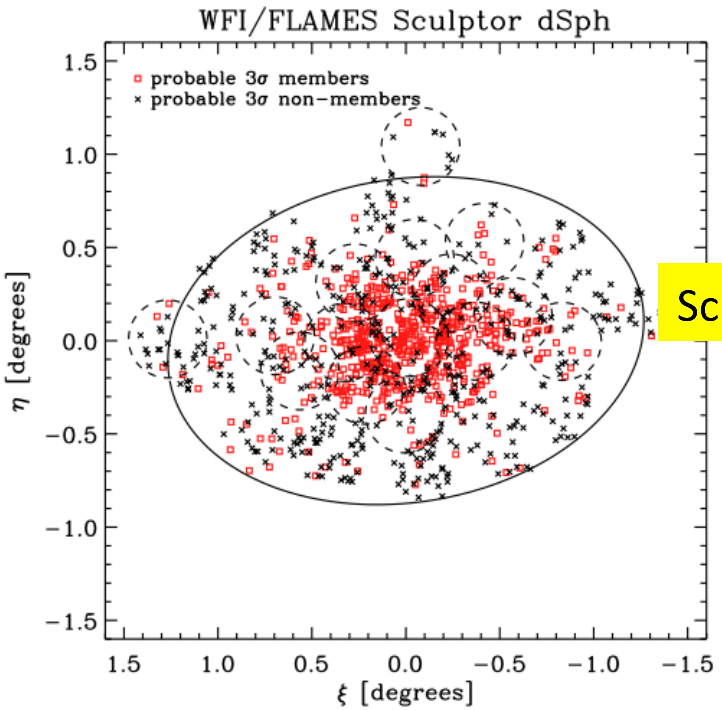


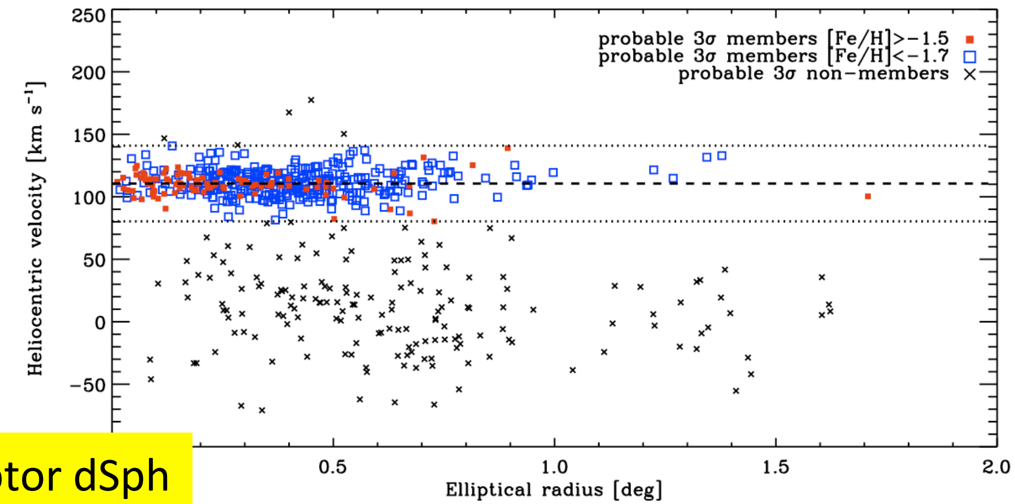
Dwarf galaxies: dSph and dIrr

- dIrr galaxies bear a unknown relation to dSph: are they simply the gas-rich counterpart of dSph (where gas was stripped by interactions/ram-pressure stripping) ?
  - dIrr live further away from the massive galaxies of the LG (MW and M31) than dSph (favors the stripping idea for the absence of gas is dSph)
  - structural properties tend to show that both families are related (see eg. Kormendy 2008, Tolstoy et al. 2009)
  - The lack of (or very slow) rotation in dSph tend to contradict such a relation

What we learnt of dSph galaxies (FLAMES@VLT)

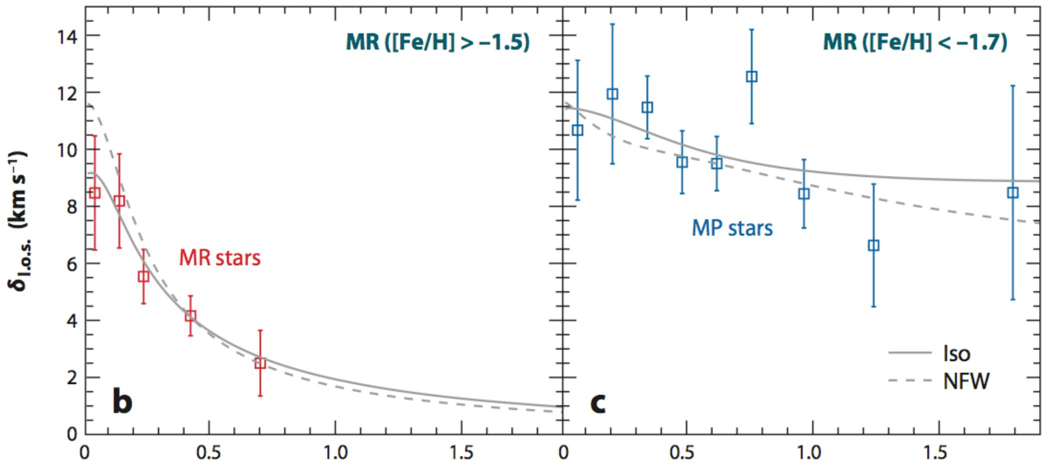
Tolstoy et al. 2004; Battaglia 2007 PhD; Battaglia et al. 2008 & 2009





Sculptor dSph

Metallicity radial variations coupled with kinematics

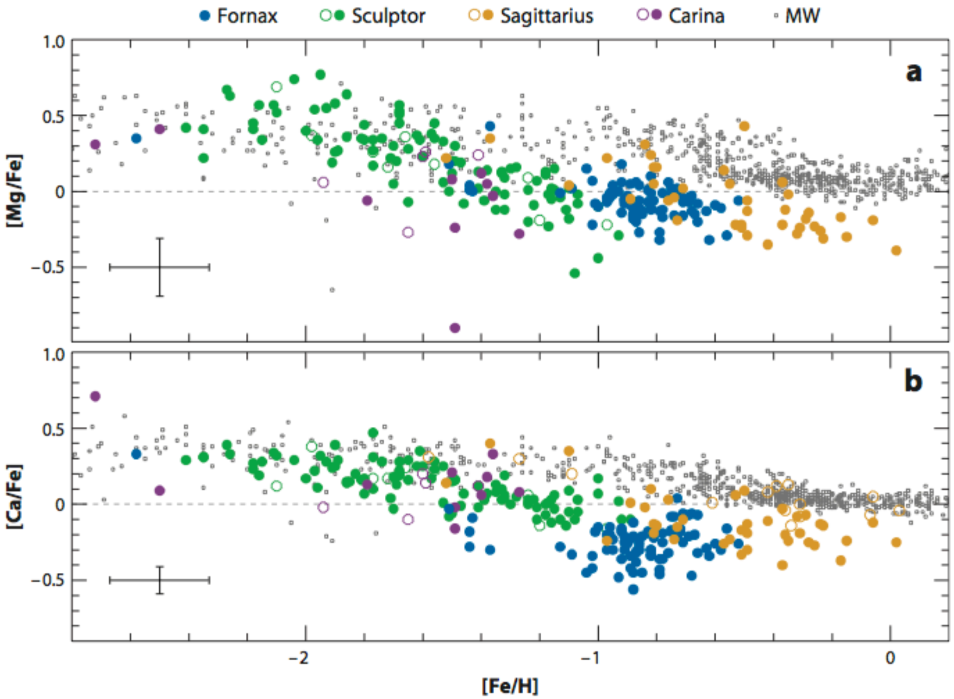


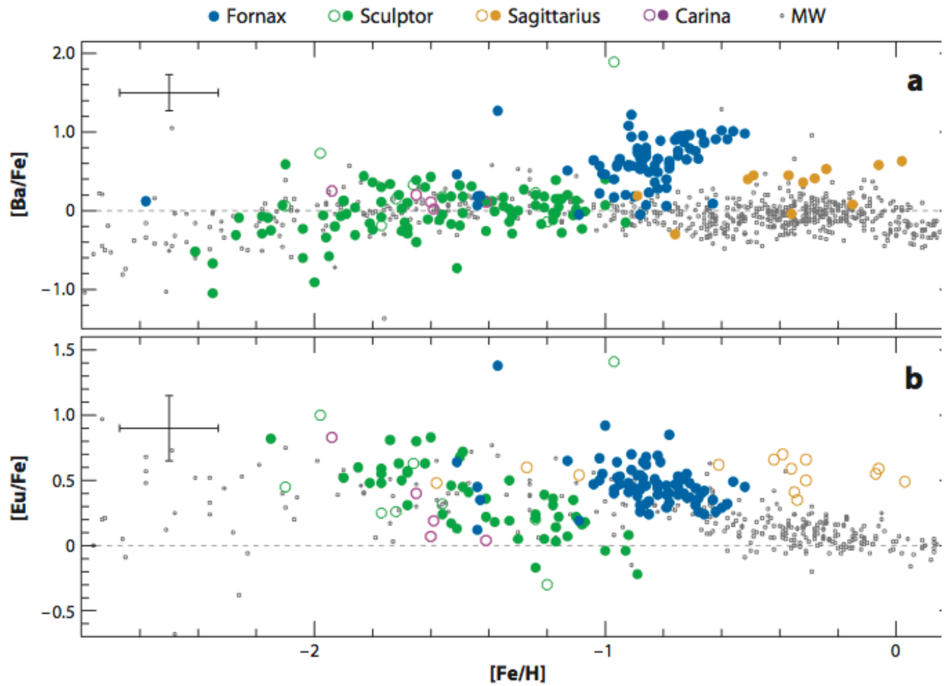
Help alleviate velocity anisotropy degeneracy with total mass:

M/L~160; $M=3\times10^{8}M_{\odot}$

Coupling kinematics and metallicities in dSph around the MW have revealed complex systems

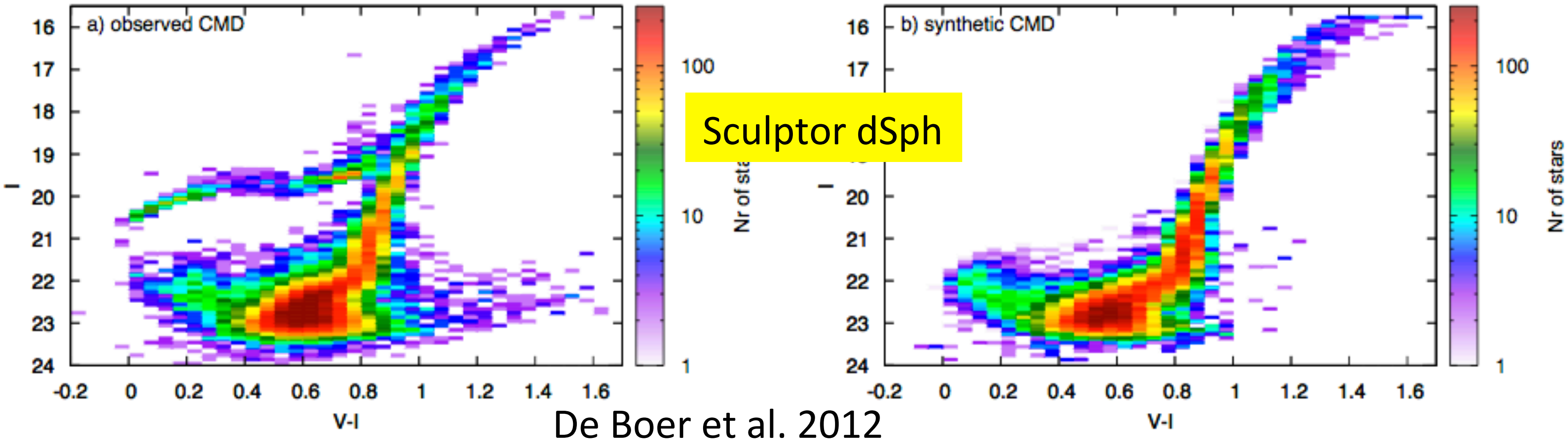
What we learnt of dSph galaxies (FLAMES@VLT)





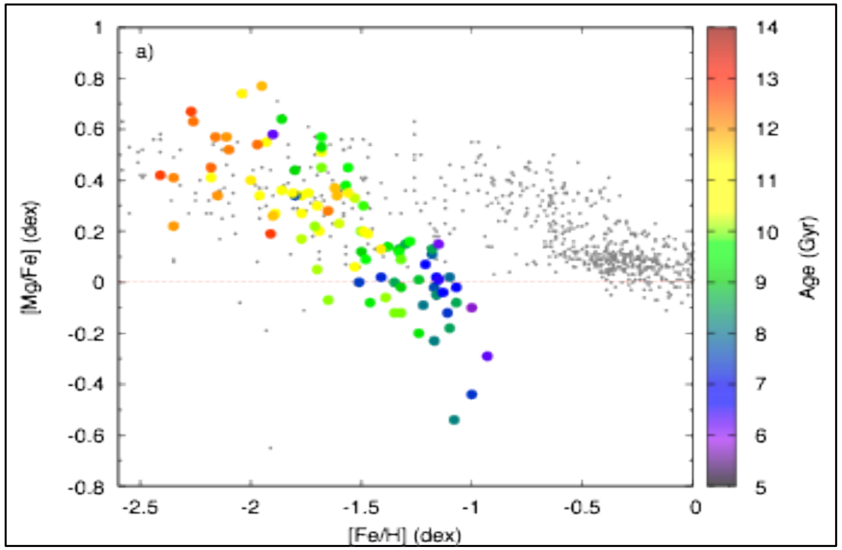
- Detailed abundances dSph around the MW have revealed distinct and intriguing chemical evolution (eg. Tolstoy, Hill, Tosi, ARAA 2009), that yields both information on:
  - the assembly of bigger galaxies (early merging is required)
  - the metal enrichment processes at the smallest galaxy scales (role of metal-losses, stochastic star formation, etc.)

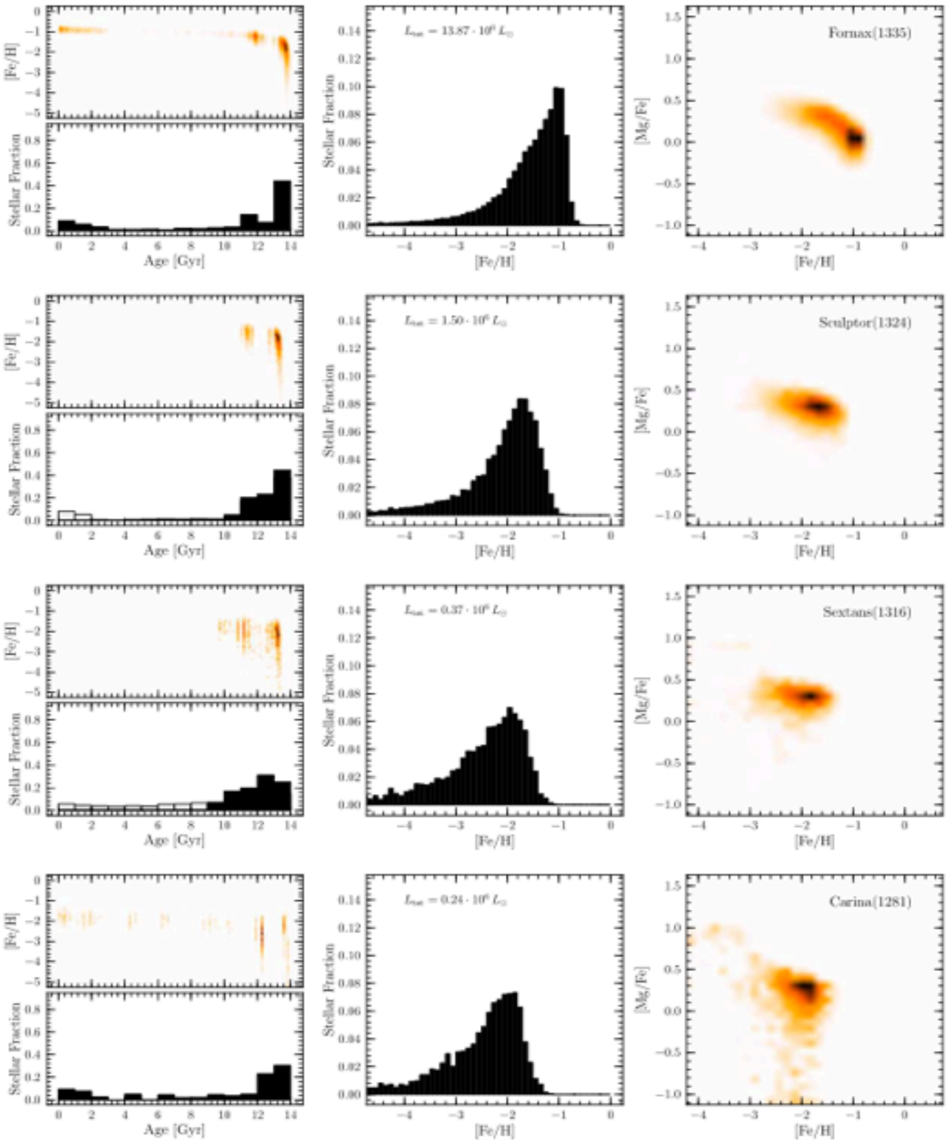
What we learnt of dSph galaxies (FLAMES@VLT + deep CMDs)



De Boer et al. 2012

Coupling deep CMDs, metallicity distributions and detailed abundances: coherent picture for star formation history and the timescale of metal-enrichment in a dSph galaxy.





Revaz & Jablonka 2012

code

dSph	L_V [10^6 $L_\odot$]	⟨[Fe/H]⟩	M/L	r_t [kpc]	σ [km/s]
Fornax	14	−1.17	12	2.08	11.7
Sculptor	1.4	−1.96	158	1.33	9.2
Sextans	0.41	−2.26	19	3.10	7.9
Carina	0.24	−1.86	88	0.58	6.6

Nbody-Tree-SPH code with simple chemistry (Mg, Fe): cosmologically motivated initial conditions, isolated galaxies, feedback treated with care.

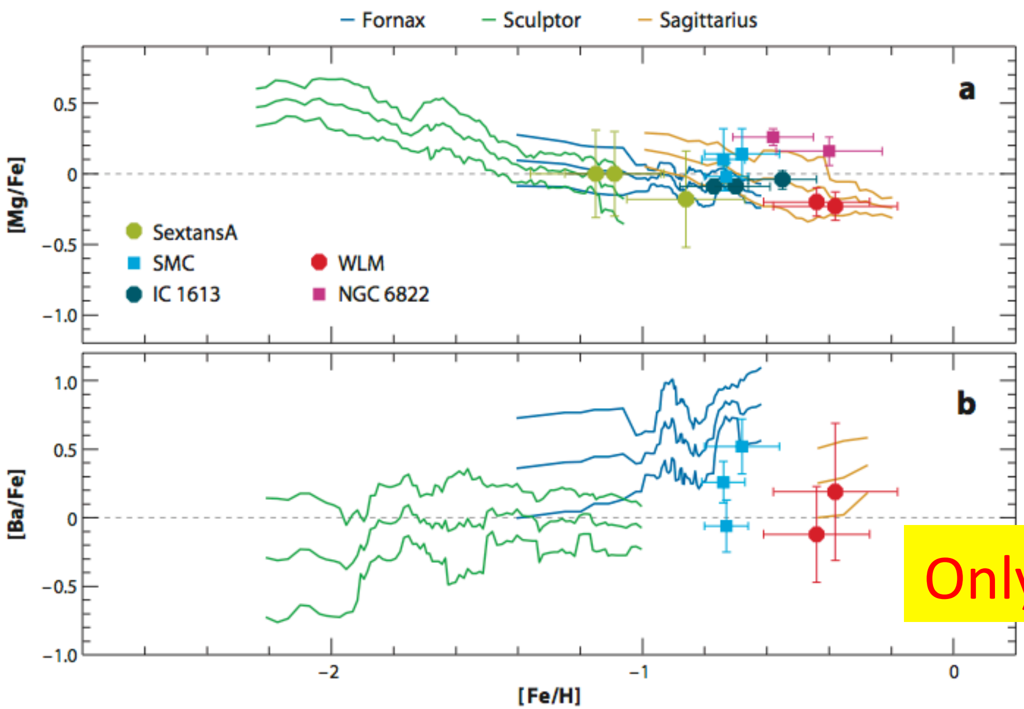
varying Mtot, ρ_g, r_{max}, c_*, (ε_{SN}, t_{ad})

reproduces L-metallicity and M/L-L relations

dSphs	#	M_{tot} 10^8 $M_\odot$	$\rho_{c,gas}$ m_H/cm^3	r_{max} kpc	$c_\star$ -	ϵ_{SN} -	t_{trunc} Gyr	L_V 10^6 $L_\odot$	⟨[Fe/H]⟩	r_t kpc	$\sigma_\star$ km/s	σ_{DM} km/s	M_{gas} 10^7 $M_\odot$	M_{stars} 10^7 $M_\odot$	M_{halo} 10^7 $M_\odot$
Fornax	1335	7	0.059	7.1	0.05	0.03	-	13.9	−1.01	1.98	9.4	15.0	2.4	1.35	8.80
Sculptor	1324	5	0.029	9.6	0.05	0.03	9.1	1.50	−1.75	2.93	6.4	11.7	1.9	0.34	4.45
Sextans	1316	3	0.022	8.0	0.05	0.03	4.7	0.37	−2.09	1.58	4.2	9.7	0.5	0.07	1.04
Carina	1281	1	0.022	3.5	0.1	0.03	-	0.24	−1.93	0.76	3.1	7.2	0.2	0.02	0.63

Currently: « present-day » composition of dIrrs

- dIrr galaxies have well known gas and young material characteristics (rotation, abundances in nebular gaz, detailed abundances in a few very young supergiants –limits of UVES@VLT possibilities)

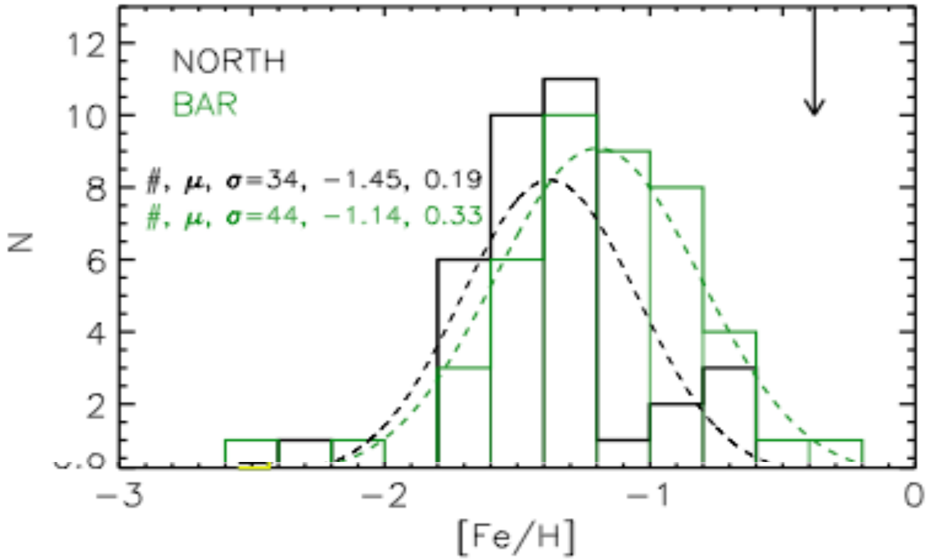


- A-type supergiants in WLM, NGC6822, IC1613, Sextans A: Venn et al. 2001, 2003, Kaufer et al. 2004
- AFK supergiants in the SMC: Hill et al. 1997; Luck et al. 1998; Venn 1999

Only end-point of the evolution!

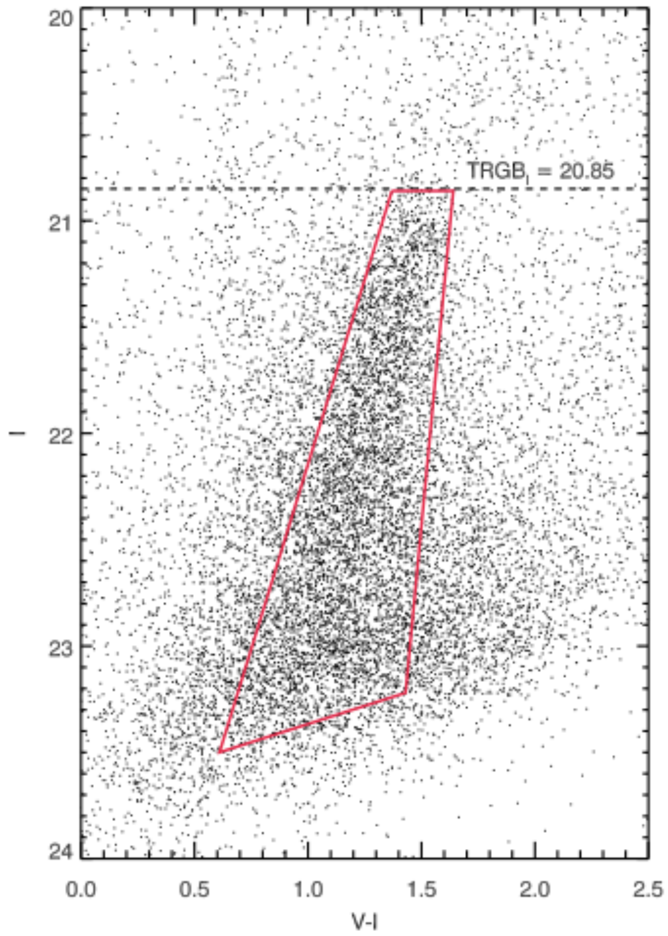
Nothing is known about the chemical properties of older stellar populations present in these galaxies (RGBs).

Older populations in dIrrs



Spectra (IR CaII triplet) of RGB can be readily observed for some dIrr, yielding metallicity distributions and radial velocities:

– See the pioneering work of Leaman et al. (2009, 2012, 2013) in WLM: but at a very high observing cost (here ~6h exposure per MOS configuration with FORS2@VLT or DEIMOS@Keck just reaching the tip of the RGB)



WLM: Leaman et al. 2009

dIrr with deep CMD

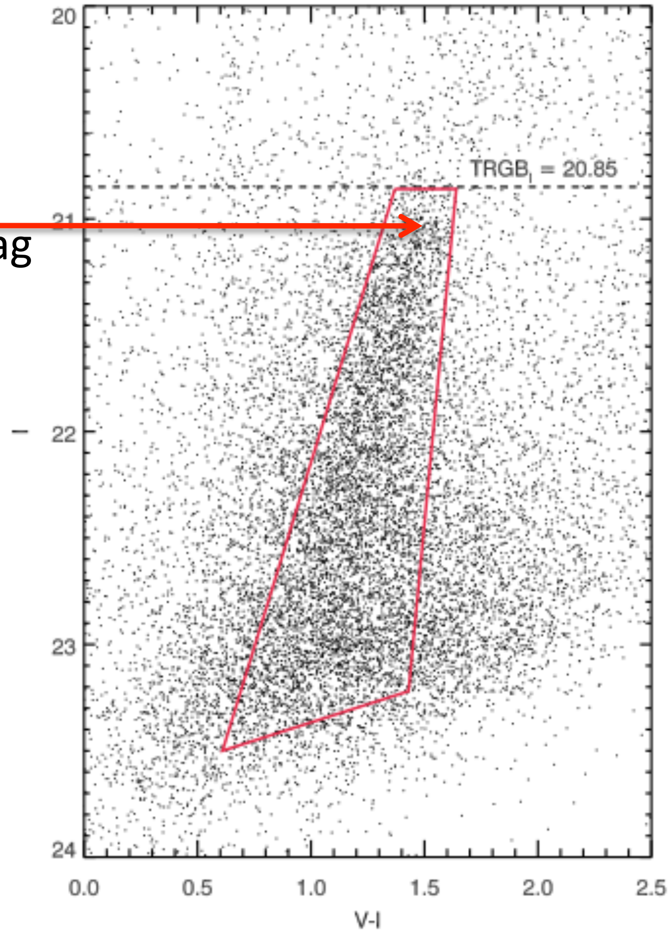
Low-res RGBs

High-res Supergiants

Galaxy	D (kpc)	M_V[a]	r_b (′)[b]	Look-back[c]	≤10 Myr	1–8 Gyr	≥10 Gyr	Spectroscopy LR[d]	Spectroscopy HR[d]	Spectroscopy HII
(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)[e]	(10)	(11)	(12)
WLM	978 ± 20 [1]	−14.6	5.5	HB	✓	✓	✓	[3]	[4]	[5]
Sextans B	1370 ± 180 [6]	−14.2	3.9	RGB	✓	✓	?	...	...	[8]
NGC 3109	1300 ± 200 [9]	−15.8	13.3	RGB	✓	✓	?	...	[11]	[12]
NGC 6822	460 ± 5 [13]	−15.1	40	RGB	✓	✓	?	[15]	[16]	[17]
				HB	✓	✓	RRL[19]			
Leo A	800 ± 40 [20]	−11.7	3.9	oMSTO	✓	✓	RRL[20]	[22]	...	[23]
Sextans A	1320 ± 40 [24]	−14.5	4.0	HB	✓	✓	?	...	[26]	[8, 27]
IC 1613	721 ± 5 [28]	−14.6	11 ± 3	MSTO	✓	✓	✓	...	[30]	[31]
				oMSTO	✓	✓	✓			
SagDIG	1050 ± 50 [33]	−12.2	1.7	HB	✓	✓	✓	...	...	[34]
Pegasus	919 ± 30 [35]	−12.8	3.9	RGB	✓	✓	?	...	...	[37]
DDO 210[6]	1071 ± 39 [35]	−10.6	1.6	HB	x	✓	✓	...	...	x
LGS 3[f]	620 ± 20 [39]	−9.9	14.5 ± 4.5	HB	x	✓	✓	[40]	...	x
				oMSTO	x	✓	✓			
Phoenix[f]	406 ± 13 [42]	−10.1	>8.6	HB	x	✓	✓	[44]	...	x
Leo T[f]	400 ± 40 [45]	−8.0 [45]	1.4 [45]	HB	x	✓	?	[47]	...	...
SMC	59.7 ± 2.2 [48]	−16.1	320	oMSTO	✓	✓	✓	[50]	[51]	[52]
				MSTO	✓	✓	✓			
				oMSTO	✓	✓	✓			
				oMSTO	✓	✓	✓			
GR 8	2200 ± 400 [56, 57]	−12.3 [58]	1.0 [58]	RGB	✓	✓	?	...	...	[59]

1- Chemical evolution of dIrr: Requirements for an ELT-MOS

I=21
V~22.5 mag



WLM (D=978kpc)

Abundances of ~20 elements in large samples of RGB stars of all ages of dIrr in the Local Group:

ELT requirements:

- R≥15,000 - 20,000
- visible VR(I)
- I≥21 SNR≥30
- Multiplex: anything above 10 is useful; typical densities of targets >10-100/ armin^2 (or >70 per ELT FoV)

Star-forming dIrr

HST/STIS Imaging Spectroscopy of I Zw 18 (Brown et al. 2002)

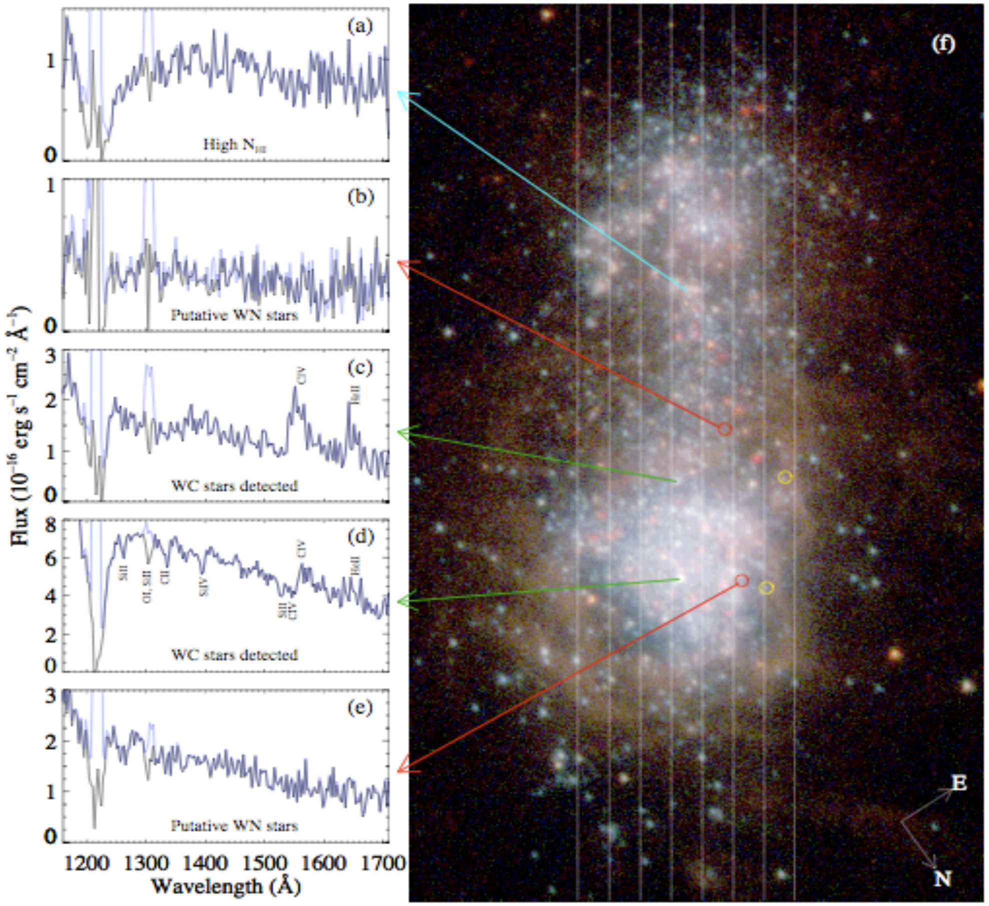
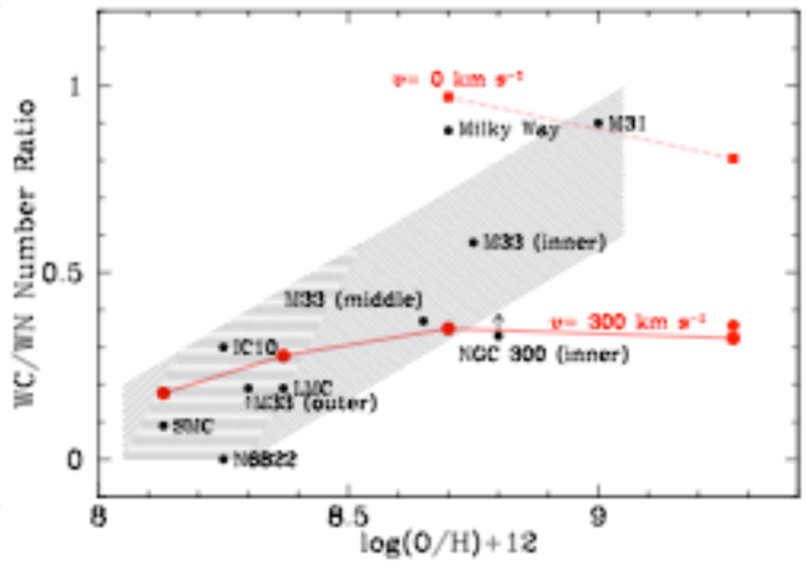


FIG. 1– Far-UV spectra and broad-band imaging of I Zw 18. Panel a: The spectrum with the broadest Ly-α absorption and thus the highest N_{HI}, with (black) and without (blue) airglow subtraction. Panels b and e: Spectra of regions for previously reported WN detections (de Mello et al. 1998); we find no evidence for WN stars. Panels c and d: Spectra of clusters with WC stars; note the C IV He II emission lines. Panel f: Composite HST imaging of I Zw 18 in 3 bandpasses (blue = STIS/FUV/F25SRF2, green = STIS/NUV/F25QTZ, red = WFPC2/F555W). The seven adjacent positions of the STIS slit are marked (white lines). Many of the old stars reported by Aloisi et al. (1999) appear as faint red stars here, but some are UV-bright, indicating a hotter temperature or a hot companion. Yellow circles mark two regions where we find possible narrow He II emission but no associated C IV emission. The deMello et al. (1998) WN detections are encircled in red.

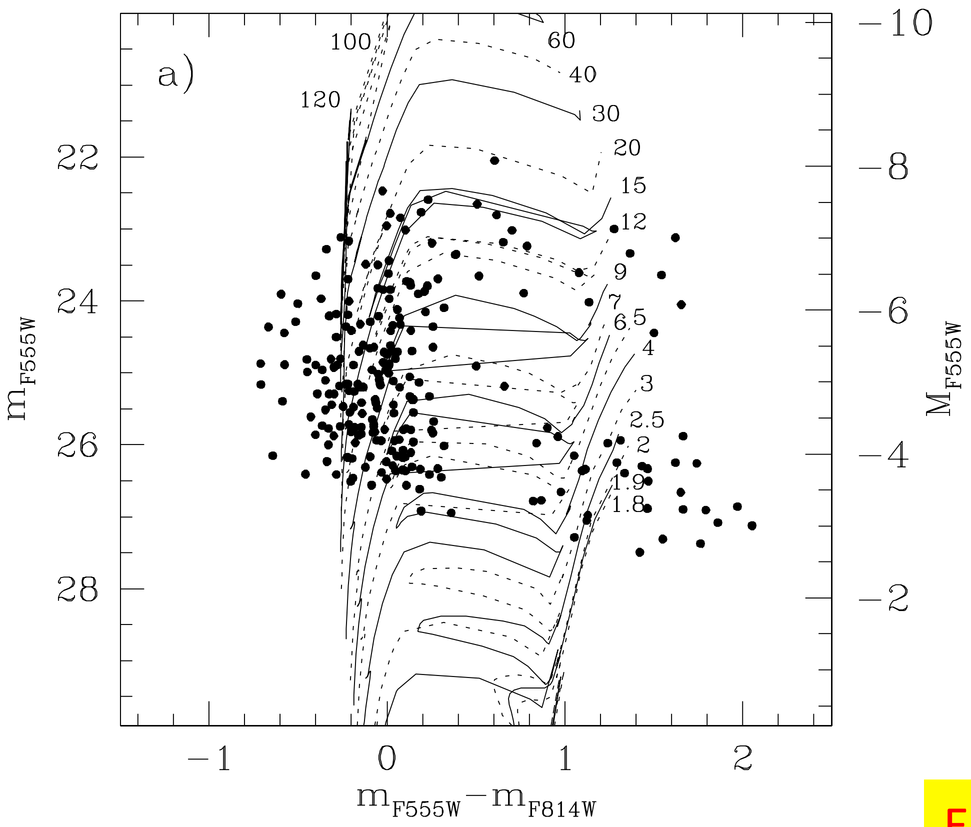
Detection of several WR-WC stars in I Zw18, unexpected by low-metallicity Geneva evolutionary models



Meynet & Maeder 2005

Star-forming dIrr

HST/WFPC2 Imaging of I Zw 18 (Aloisi et al. 1999)

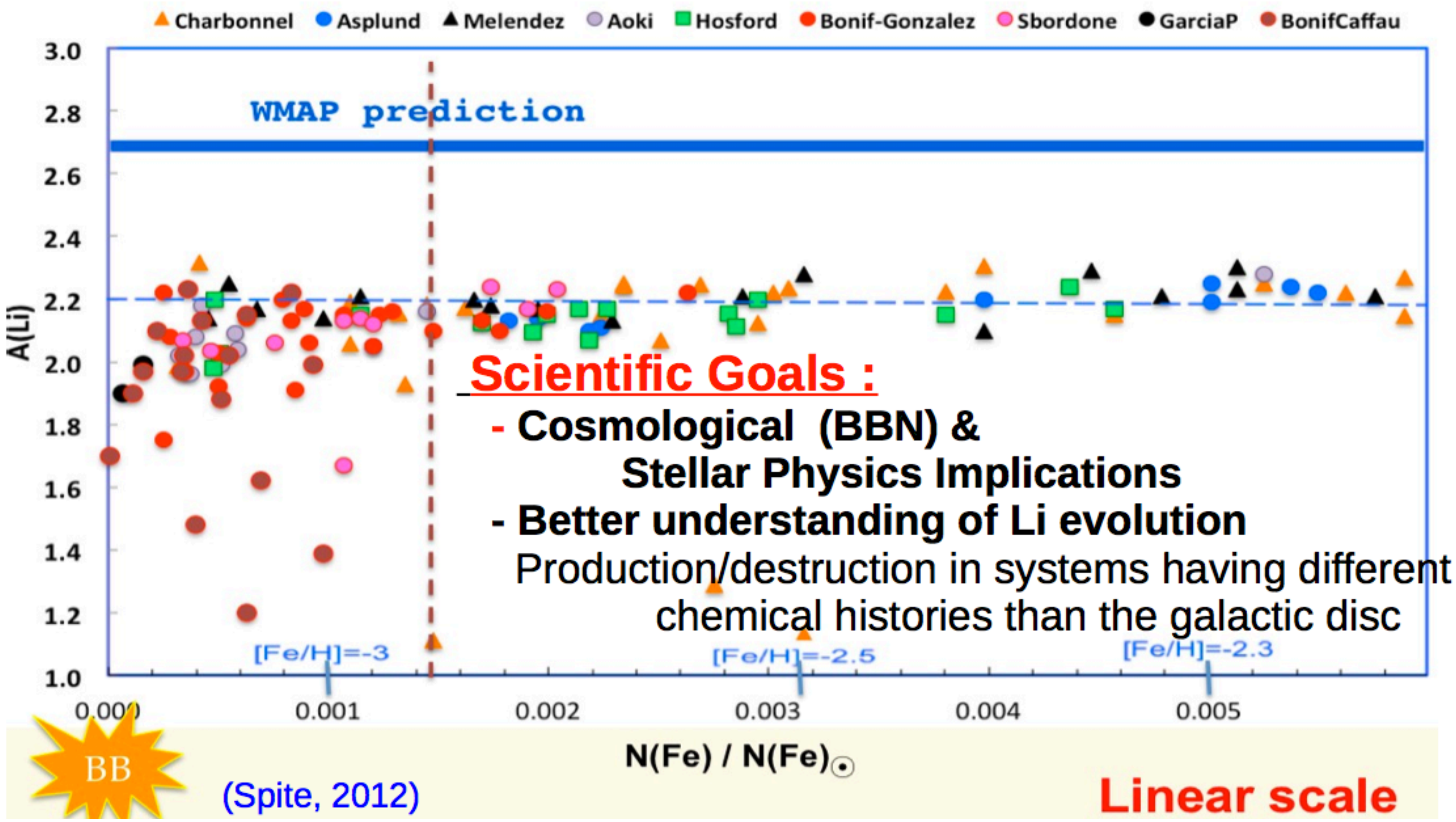


ELT requirements:

- R ≥ 5,000 - 10,000
- visible VR(I)
- V≥23 SNR≥30
- Multiplex: above 10 is useful

2- Tracing the Li plateau in other systems

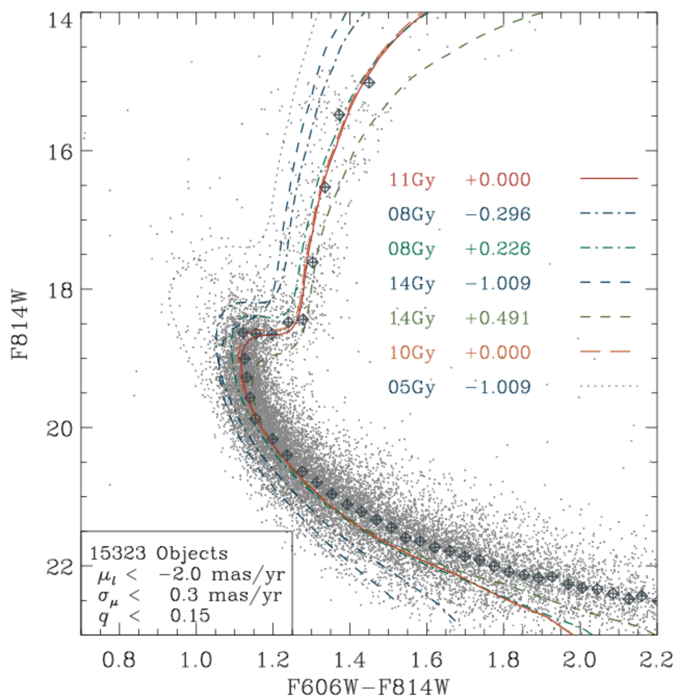
^{7}Li in warm metal-poor stars (Turn-off stars)



Tracing initial (pre-stellar dilution) Li requires to measure it in un-evolved warm stars

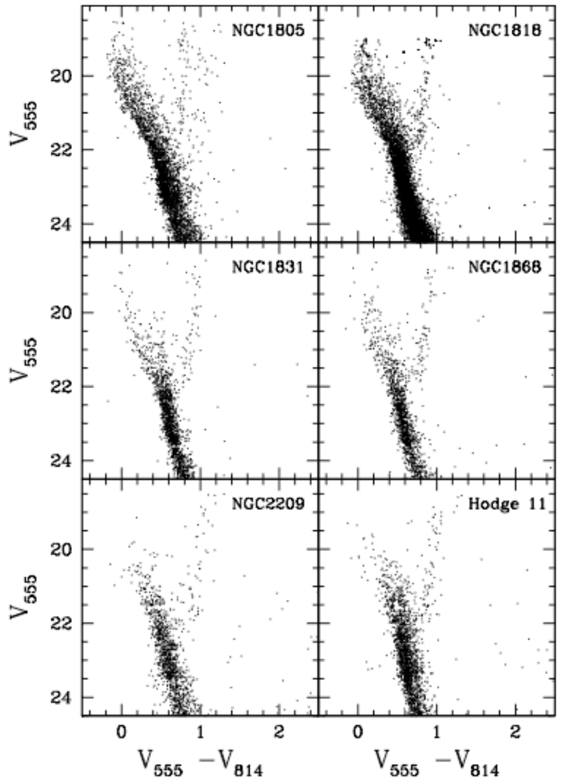
2- Tracing the Li plateau in other systems

Lithium plateau (plateau, its cosmological and/or stellar physics implications) in different environments: probing the oldest generations of stars in:



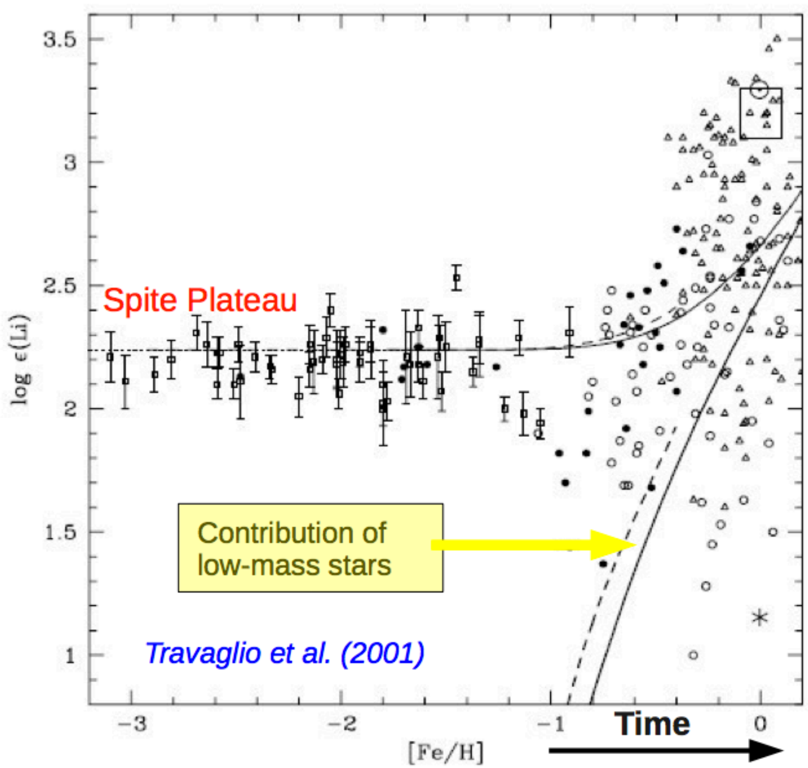
Clarksson et al. 2008, propper-motion cleaned CMD of a Bulge field (l,b)=(1.2◦,-2.6◦)

- Galactic bulge (in low E(B-V) regions): I=19, V~20.2
- Magellanic clouds V~22 (LMC)



Javiel et al. 2005: HST CMD of LMC fields around globular clusters

2- Extragalactic Lithium evolution



ELT requirements:

- R≥15,000 - 20,000
- R (650-680nm)
- V~20-22 SNR≥80
- Multiplex: the larger the better

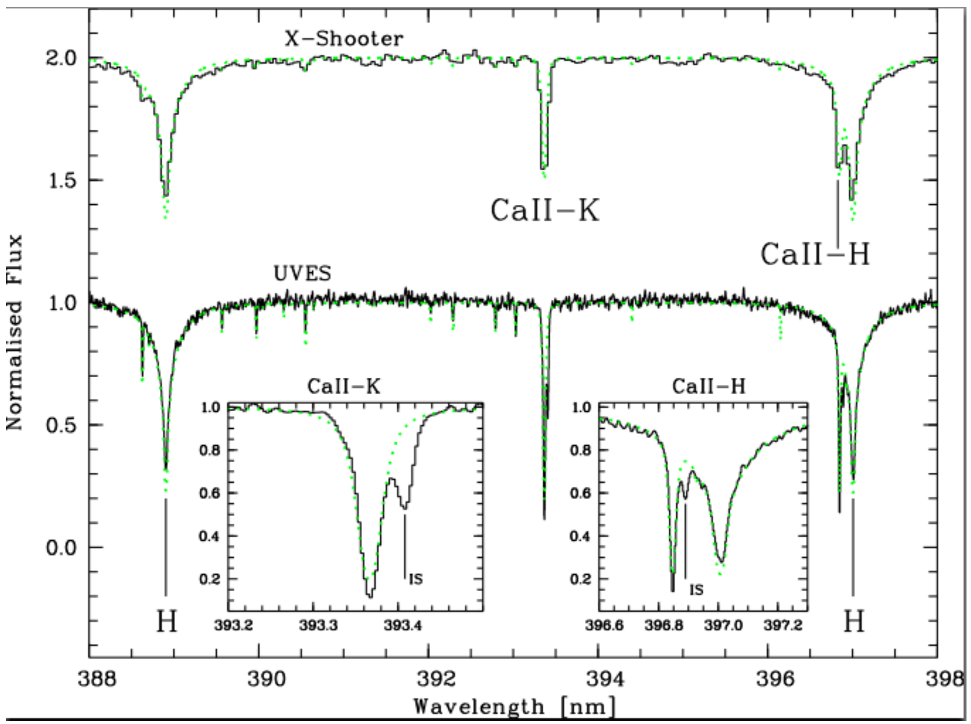
Lithium evolution along the Magellanic clouds chemical evolution:

− the increase of Li along the evolution of the galactic disc has long been a puzzle (efficiency of Li-production vs Li-distruction in stellar generations)

− moving into a different realisation of this enrichment process (the MCs were more metal-poor than the MW disc at a given time/age) will yield essential constraints on Li production by low-mass stars as a function of metallicity

3- First stars relics in the Local Group

- Extremely metal-poor stars at z=0 are (the first?) low-mass stars that bear the fossil traces of their deceased population III (metal-free) parents
- Most of our knowledge so far (metallicity distribution, metallicity floor, detailed compositions of the most metal-poor stars) is inferred from the most metal-poor stars in the Milky-Way halo stars (needles in a haystack: so far less than 10 stars are known with [Fe/H]<-4)



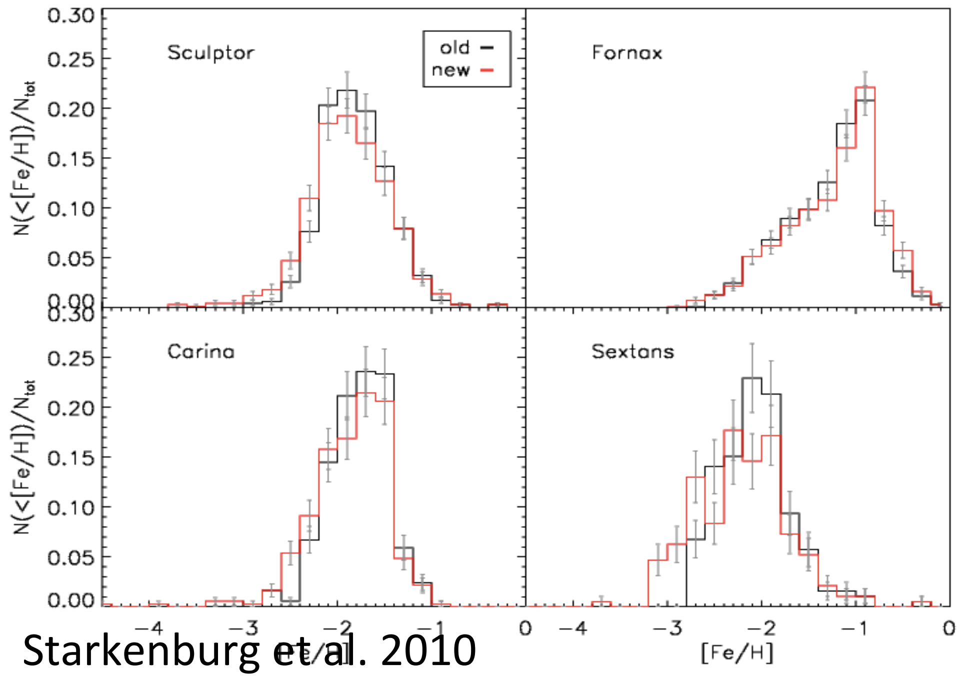
Tracking extremely metal-poor stars in different galaxy hosts thoughout the Local Group will allow to answer :

– Does the formation of first stars depend on the parent (galactic) halo ?

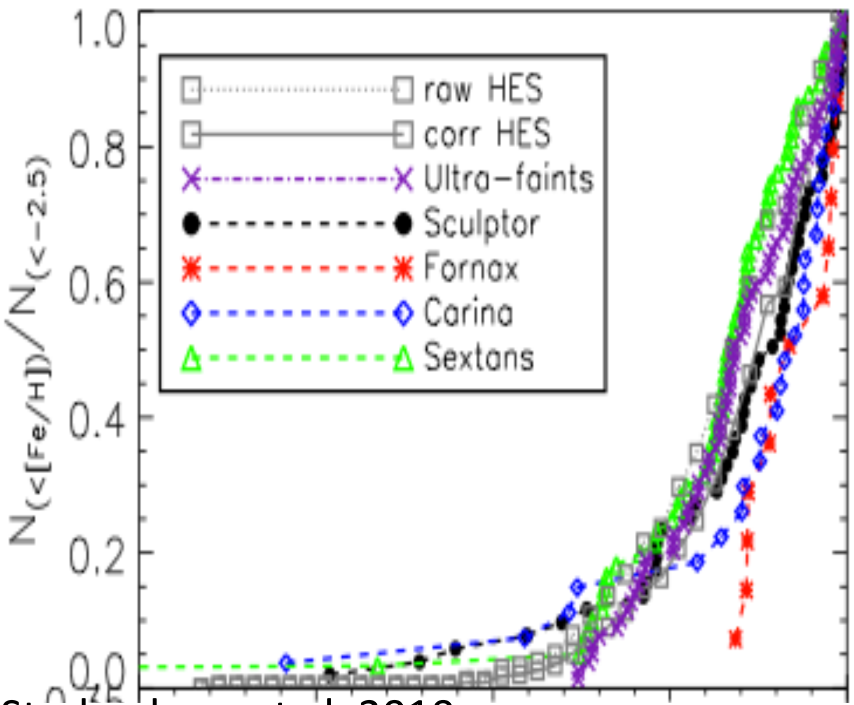
–How low is the true metallicity floor for low-mass star formation ? How does it depend on the Carbon content ? [better statistics, unreachable in the MW alone]

3- First stars relics in the Local Group

We already know that extremely metal-poor stars exist in dSph galaxies



Starkenburg et al. 2010



Starkenburg et al. 2010

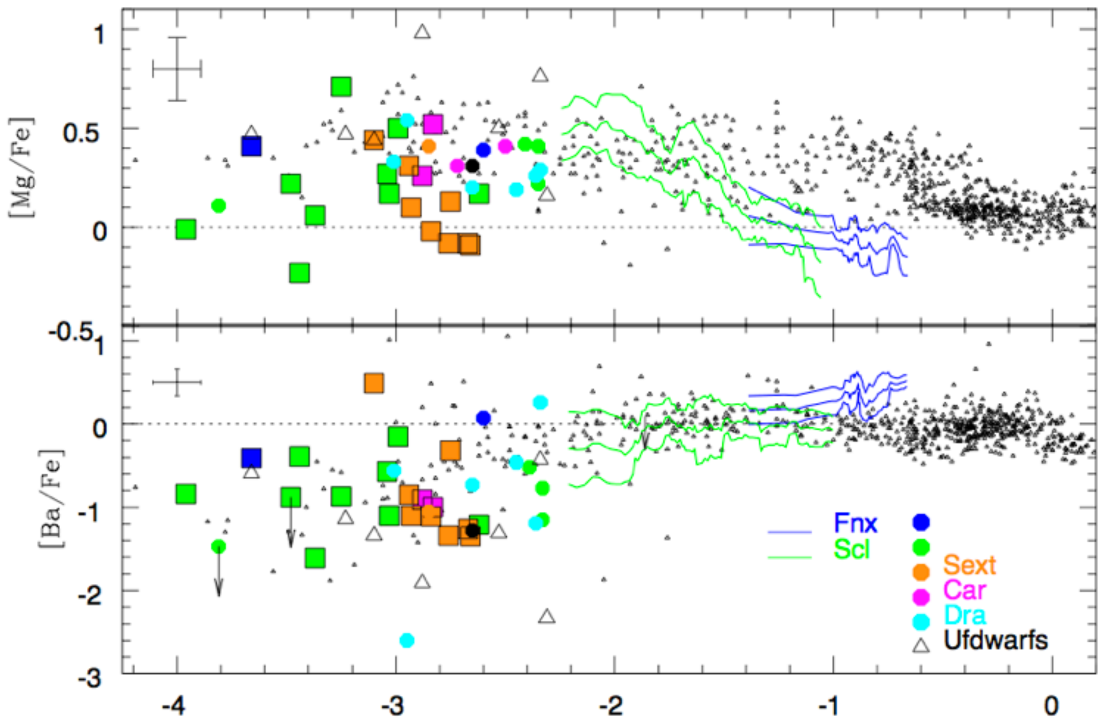
Calibrated to the low-Z regime, CaII triplet survey (DART) yields metallicities down to -4.
The shape of the low-Z tail is undistiguishable from that of the MW halo ([Fe/H]<-2.5)

3- First stars relics in the Local Group

The ELT/HR will allow to characterizing low-Z stars with exquisite accuracies in dSph in the Local Group

ELT requirements:

- R≥ 20,000
- (B)V (380-500nm)
- V~20 SNR≥80 (RGB stars)
- Multiplex: none



Pioneering work (10m telescopes, low SNR):

- Subaru (Aoki et al. 2009)
- VLT/UVES (Tafelmeyer et al. 2010: **Fnx, Scl, Sext**)
- VLT/Xshooter (Starkenburg et al. in prep, **Scl**)
- Magellan/MIKE (Venn et al. 2011 subm., **Car**)

Shetrone et al. 2001, 2003
Koch et al. 2008, 2009
Cohen &Huang 2009
Frebel et al. 2009, 2010
Tolstoy, Hill, Tosi 2009

Key points

- Kinematics and chemical abundances to unveil SFH, formation and evolution of LG galaxies
- Precise abundances necessary to disantangle diverse populations

-> **High spectral resolution (R ~ 15000 -20000)**

- B, V spectral range required

MOSAIC