A wide-field view of the Phoenix transition type dwarf galaxy

(Battaglia et al., MNRAS accepted, airXv/1205.2704)

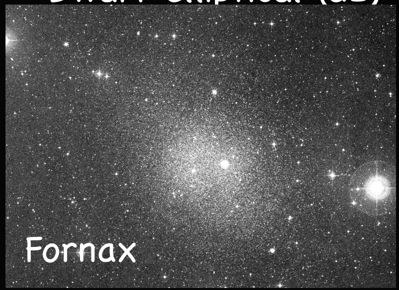
Giuseppina Battaglia

INAF - Astronomical Observatory of Bologna

With thanks to M.Rejkuba, E.Tolstoy, M.Irwin & G.Beccari

Different dwarf types in the Local Group

Dwarf spheroidal (dSph) and Dwarf elliptical (dE)



Ultra faint

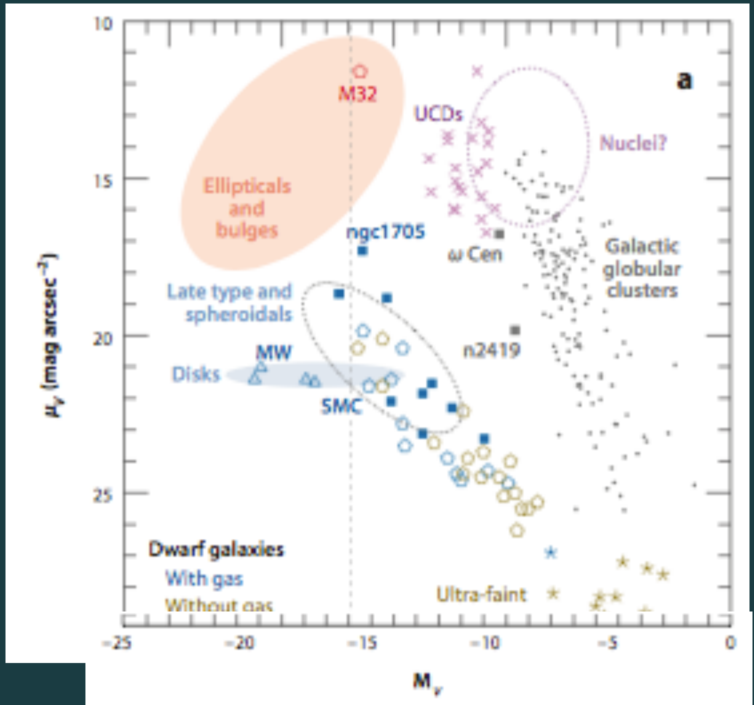
Dwarf irregular (dIrr)

Transition dwarf (dT)

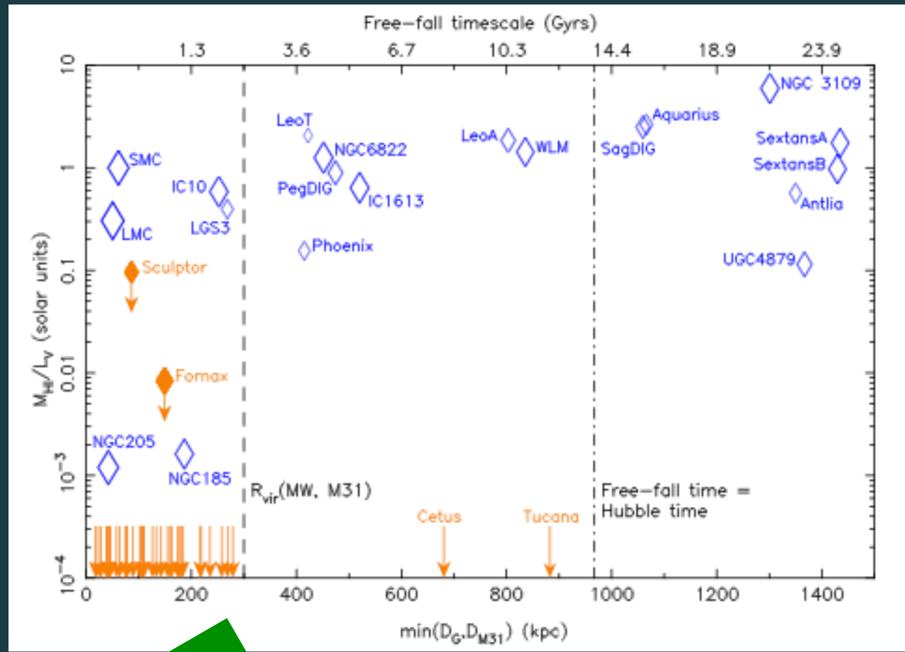
	Early-types	Late-types	Transition-types
Presence of gas	✗ (yes in some dE)	✓	✓
Current SF	✗ (yes in some dE)	✓	✗
Internal kinematics	Mainly dominated by dispersion (except in some dE)	Gas rotating or disordered (stars?)	Gas disordered (stars?)

Continuum of properties

Tolstoy, Hill & Tosi 2009, ARAA



Local Group morphology density relation



McConnachie 2012

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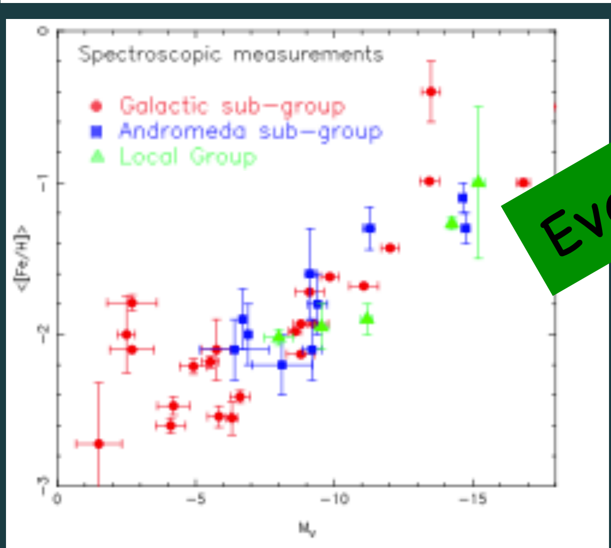


Evolutionary link?

Can dIrrs transform into dSphs? And how?

What processes dominate the evolution of such small galaxies? (potential well, interactions with large spiral…)

Spatial distribution of stellar populations (e.g. age/metallicity gradients)

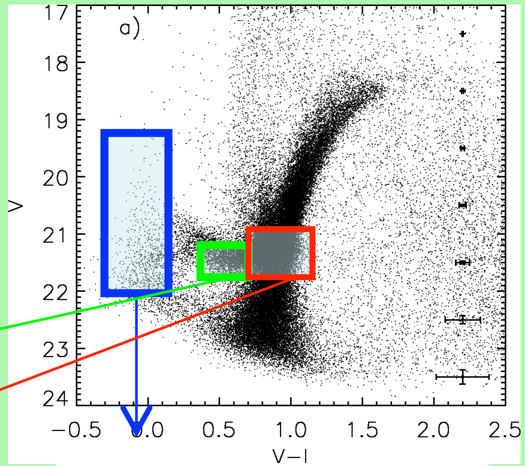
It give us information on how star formation proceeds throughout the object

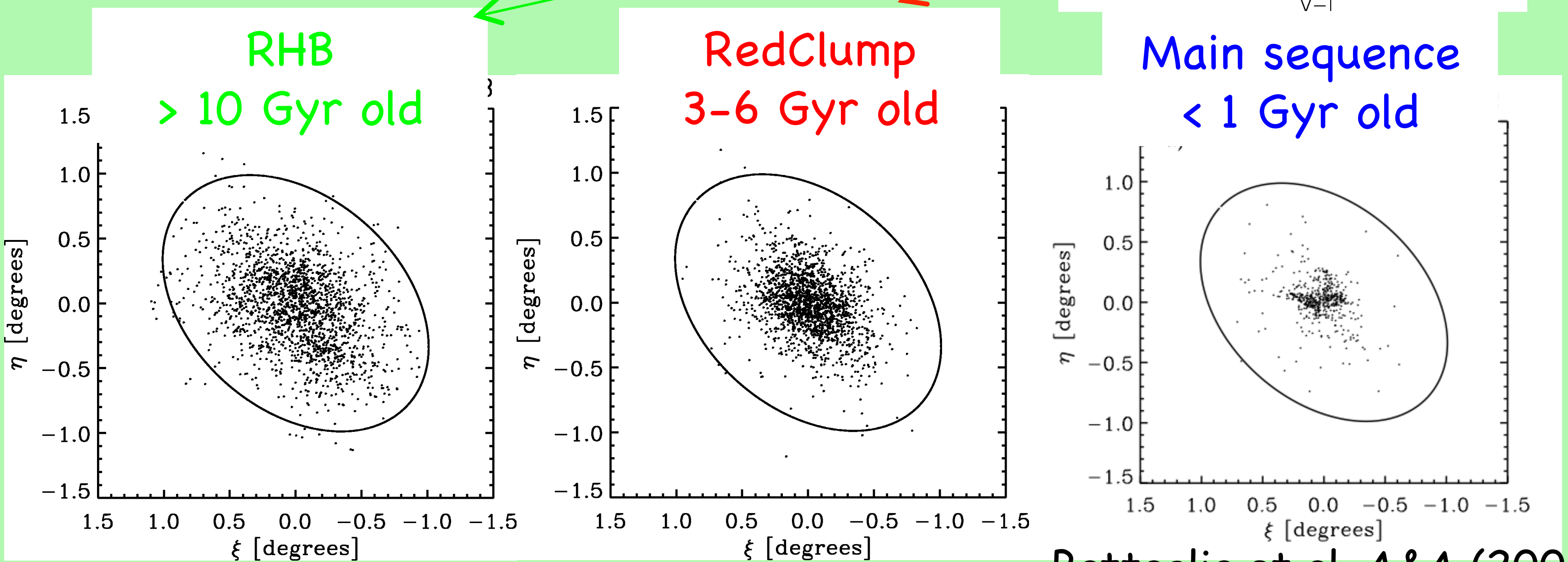
-> extended envelopes of RGB stars more extended than the young bright blue stars are very common (see reference list in Stinson et al. 2009)

-> stellar population gradients found in several Local Group galaxies (e.g. Harbeck et al. 2001, Tolstoy et al. 2004, Battaglia 2006, 2011)

Spatial variation of stellar population: Fornax

(L_V = 2 x 10^7 Lsun; d = 140 kpc)





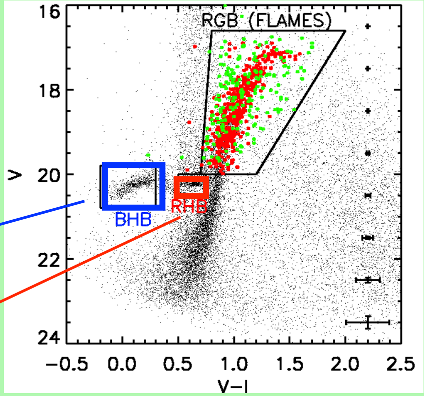
Battaglia et al. A&A (2006)

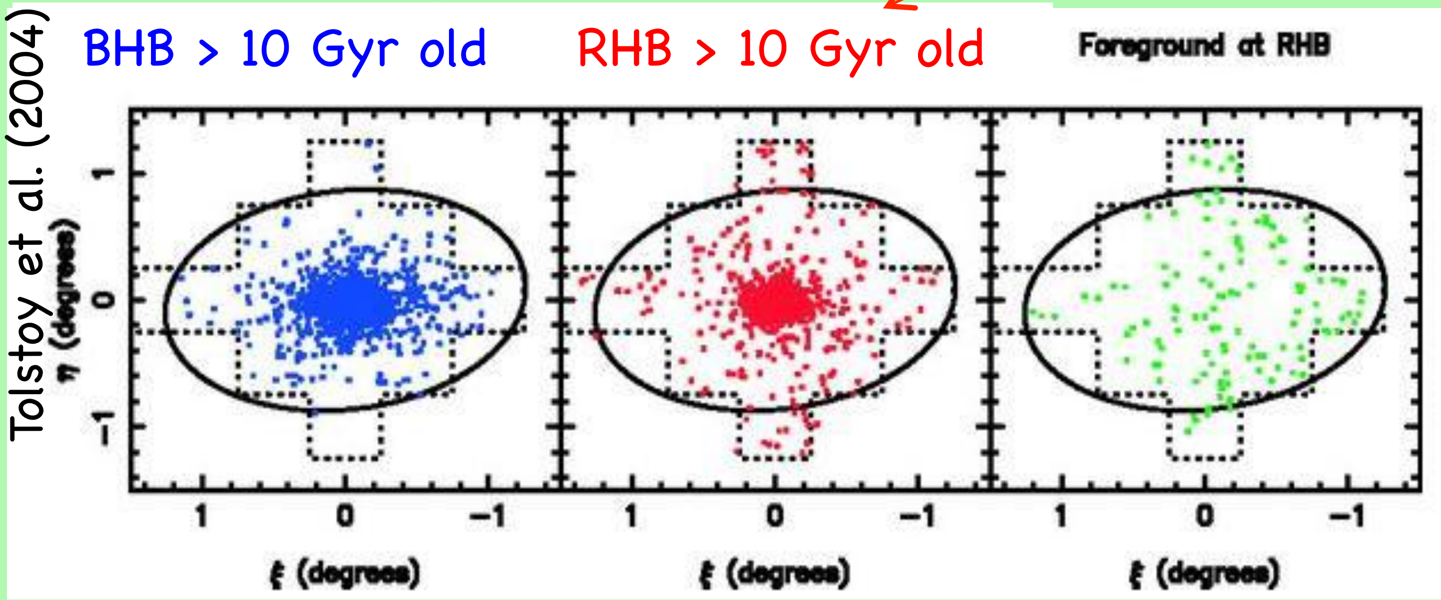
The average age increases at larger projected radii (see also Harbeck et al. 2001)

<u>Plummer fit b_intermediate-age = 17 arcmin; b_old = 25 arcmin</u>

Young stars (MS, < 1 Gyr) found mainly in the center, with asymmetric distribution (see also Stetson et al.1998)

Spatial variation of stellar population: Sculptor
(L_V = 2 x 10^6 Lsun; d = 80 kpc)





In Sculptor, spatial variations of the stellar population mix are seen already among ancient stars

<u>Plummer fit   b_RHB = 9 arcmin;   b_BHB = 15 arcmin</u>

Some possible mechanism

- Removal of gas from external regions over different time scales

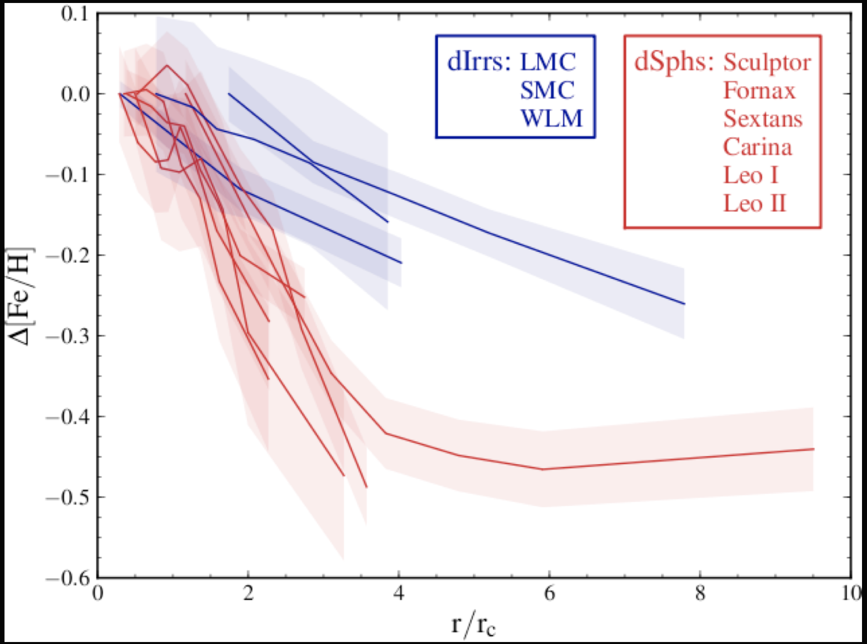
  -> gas/metals removed because of SNae explosions

  -> gas removed from external factors (e.g. ram pressure stripping)

- Natural evolution of the gas (e.g. models from Stinson et al. 2009, Schroyen et al. 2011)

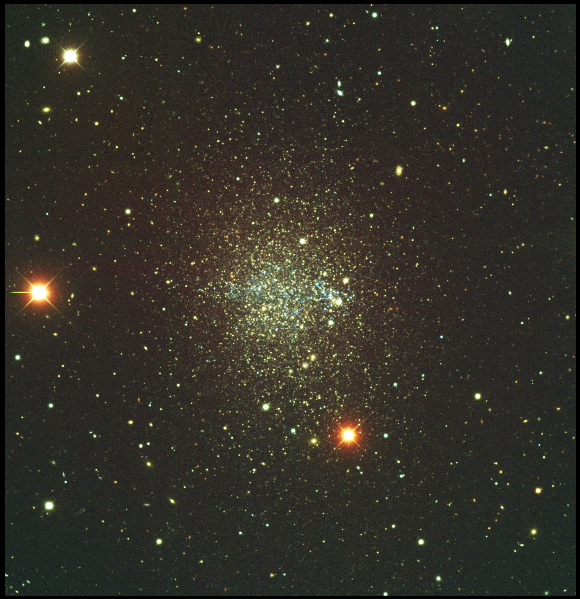
Whatever the mechanism is, it can act on rather different timescales (Fornax vs Sculptor)

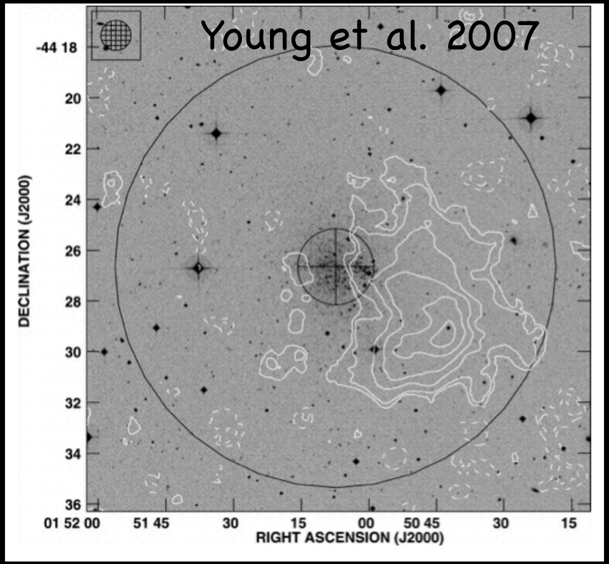
Leaman et al. submitted



Phoenix

- Phoenix is the closest of the 5 Local Group transition type dwarfs (d=400 kpc)
- Lv ~ 0.9 x 10^6 Lsun, Mv = -10 (in between Carina and Sculptor)
- MHI ~ 0.1 x 10^6 Msun
- Even basic parameters such as its extent and optical systemic velocity are very uncertain





The Phoenix transition type (d= 400 kpc)

Its star formation history has been well studied (e.g. Hidalgo et al. 2009)

Extended halo of RGB stars (e.g. Martinez-Delgado et al. 1999)

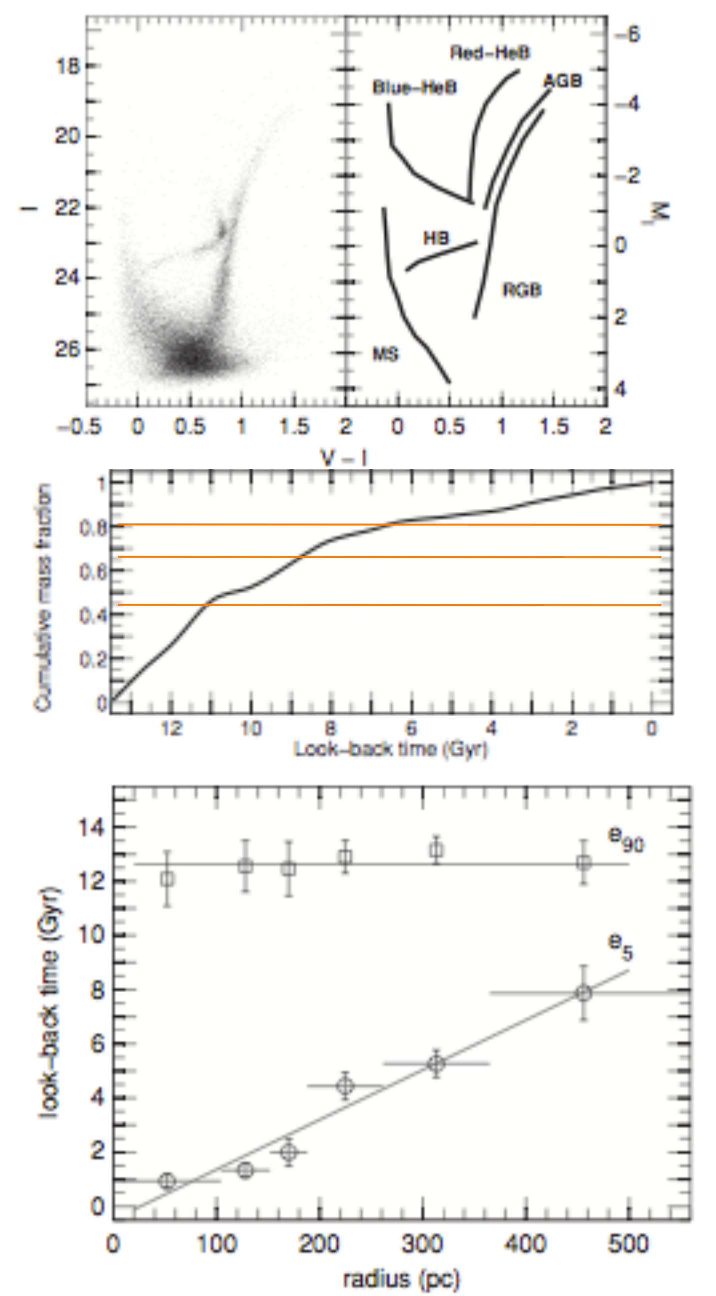


Figure 16. 90th percentile (e_{90}; open squares) and 5th percentile (e_5; open circles) of the star age distribution. In both cases, vertical bars are rms dispersions and horizontal bars show the interval of age embraced by the associated value.

LCID project, Hidalgo et al. (2009)

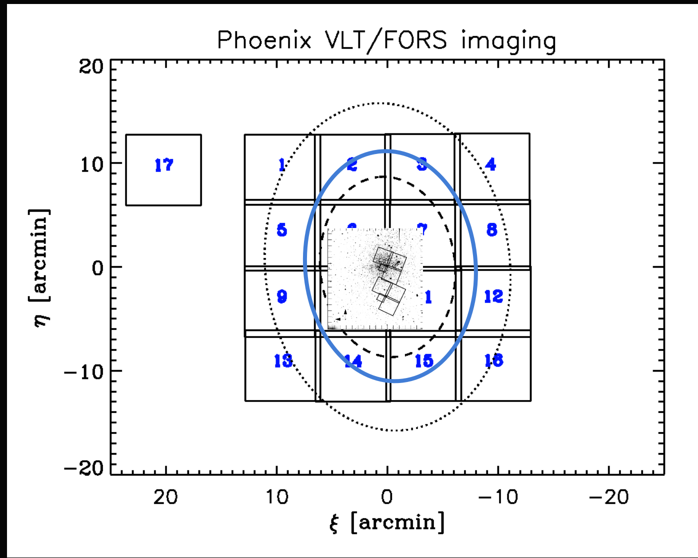
VLT/FORS data

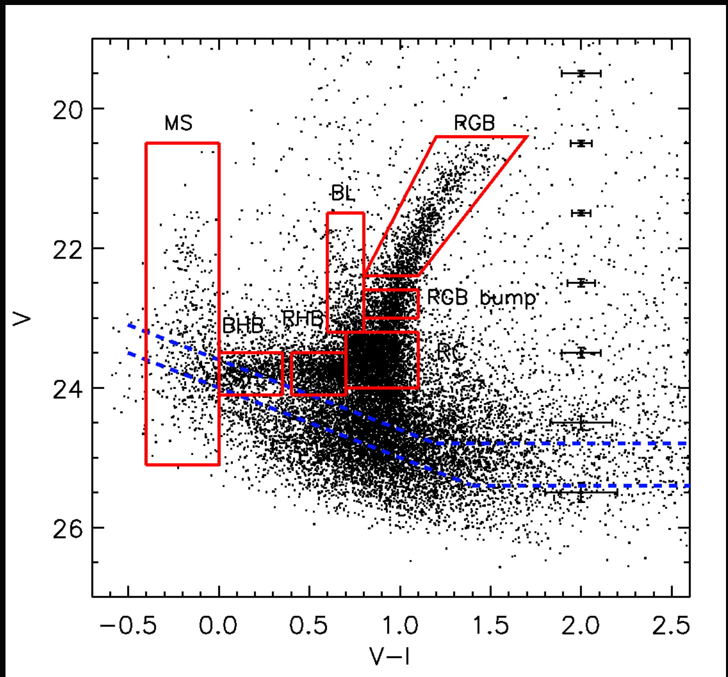
•Photometry in V and I band (3 x 120s, 5x 90s):

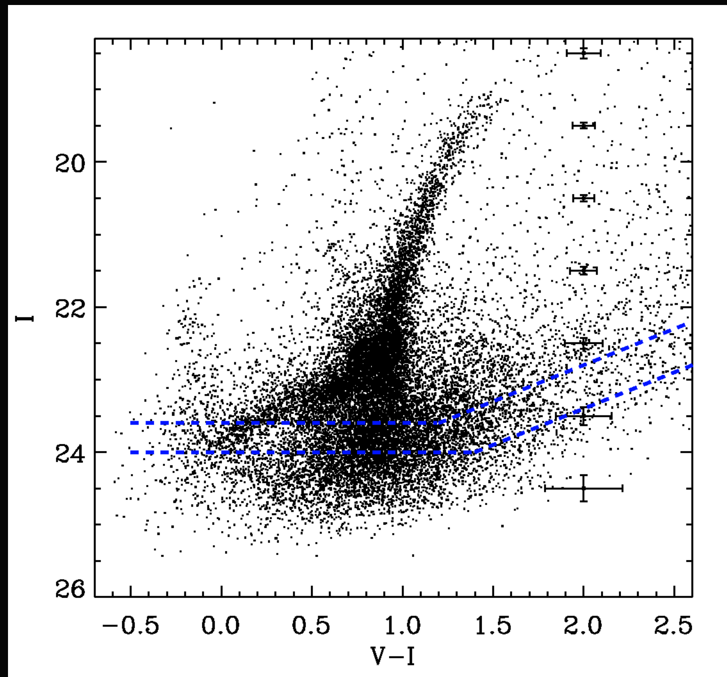
16 pointings (26 arcmin x 26 arcmin) + 1 displaced one

S/N = 10 at V = 24.8, I = 23.6 (this is also the 50% completeness level at R > 1.5arcmin from artificial star tests)

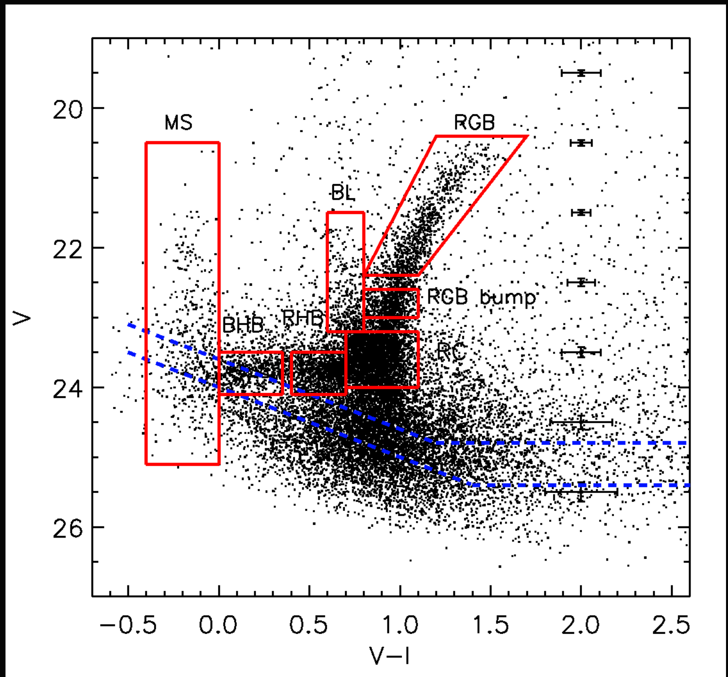
•CaII Triplet spectroscopy of about 150 RGB stars (work in progress)

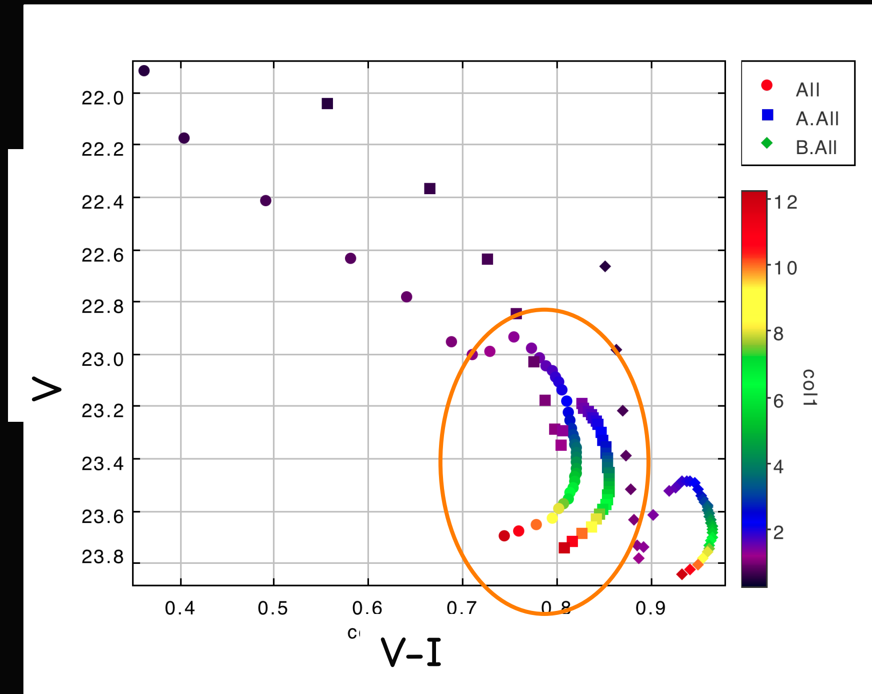






CMD and age indicators





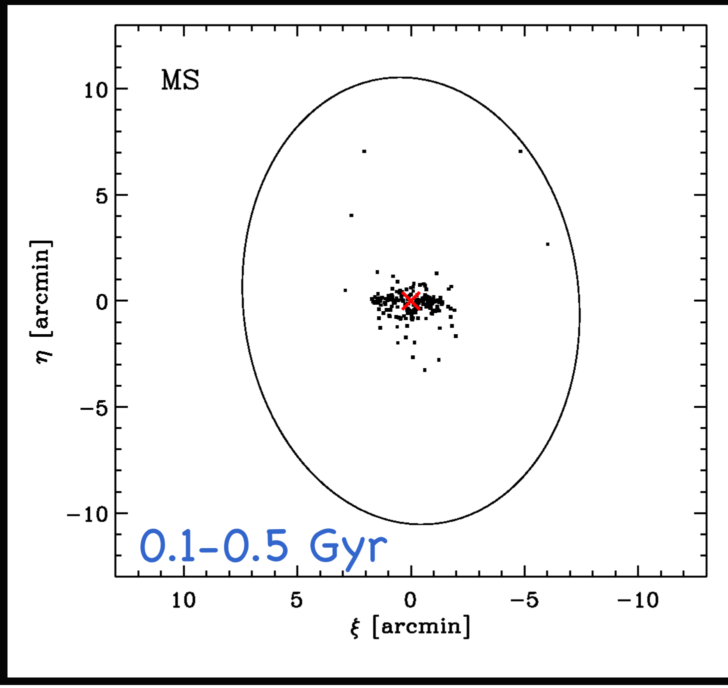
MS : 0.1-0.5 Gyr old
BL : 0.5- 1 Gyr old
RC1 (V [23.2:23.4]): 2-5 Gyr old
RC2 (V [23.4:23.6]): 5-8 Gyr old
RC3 (V [23.6:23.8]): 8-12 Gyr old
HB : > 10 Gyr old

Red clump magnitude and color as a function of age and Z from Girardi & Salaris (2001)

Z < 2 x 10^-3 (from CEH of Hidalgo et al. 2009)

Spatial distribution as a function of age

- The younger the stars the more concentrated their spatial distribution
- Similar to what seen in MW dSphs
- Also isolated dSphs show a similar behaviour (e.g. Tucana, perhaps not Cetus); similarities & differences are still to be quantified
- Normal evolution of the gas in systems mainly supported by velocity dispersion? (e.g. models of Stinson et al. 2009)



	King			Sersic			Exponential		Plummer	
	r_c[']	r_t[']	χ^2_{red}	R_S[']	m	χ^2_{red}	$r_{Ex,h}$[']	χ^2_{red}	b[']	χ^2_{red}
BL	0.73±0.13	9.53±0.70	1.0	0.53±0.26	1.25±0.24	0.9	0.86±0.05	0.9	1.47±0.09	0.9
RC (23.2-23.4)	1.11±0.09	9.98±0.32	1.9	1.45±0.27	0.82±0.11	1.1	1.05±0.04	1.2	1.79±0.06	1.9
RC (23.4-23.6)	1.37±0.08	10.40±0.25	2.4	2.10±0.26	0.66±0.08	0.8	1.17±0.03	1.5	2.00±0.06	3.0
RC (23.6-23.8)	1.91±0.09	10.66±0.23	2.0	2.54±0.23	0.62±0.07	1.1	1.37±0.03	2.1	2.36±0.06	3.7
RHB	2.40±0.13	10.42±0.18	2.2	2.85±0.19	0.61±0.04	1.9	1.48±0.03	3.5	2.57±0.04	5.8
BHB 10	2.68±0.33	10.72±0.61	1.3	2.87±0.47	0.65±0.10	1.2	1.63±0.07	1.5	2.89±0.15	1.8

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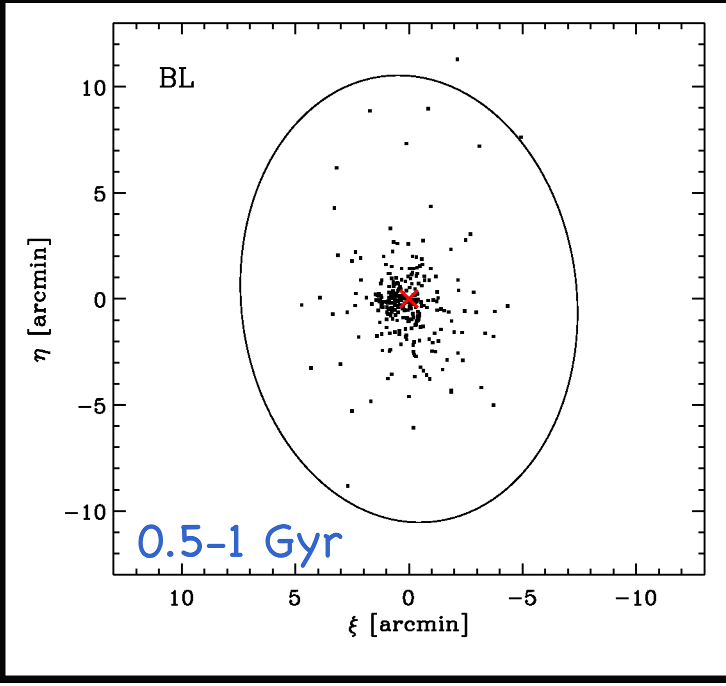

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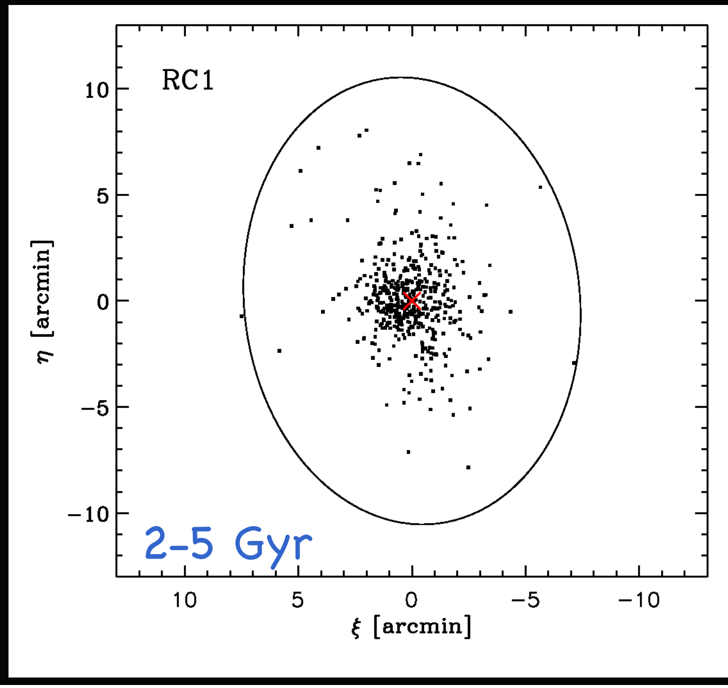

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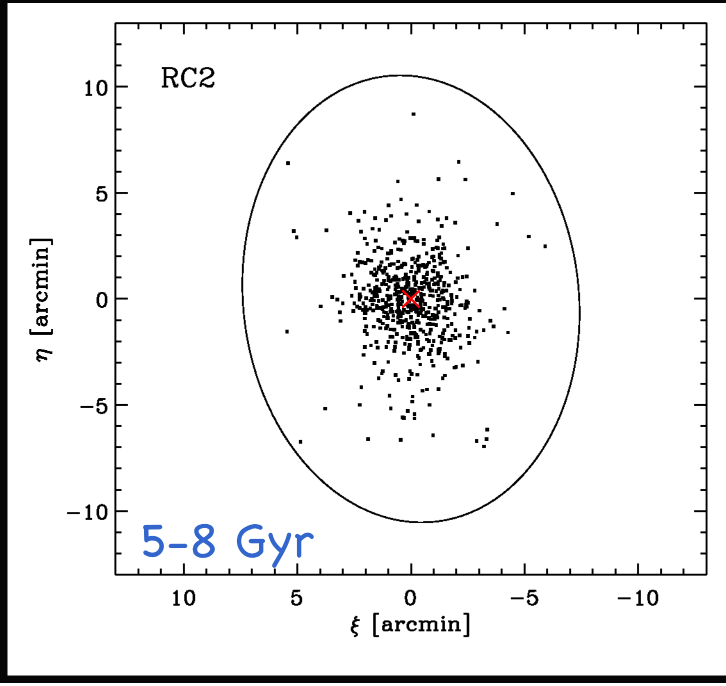

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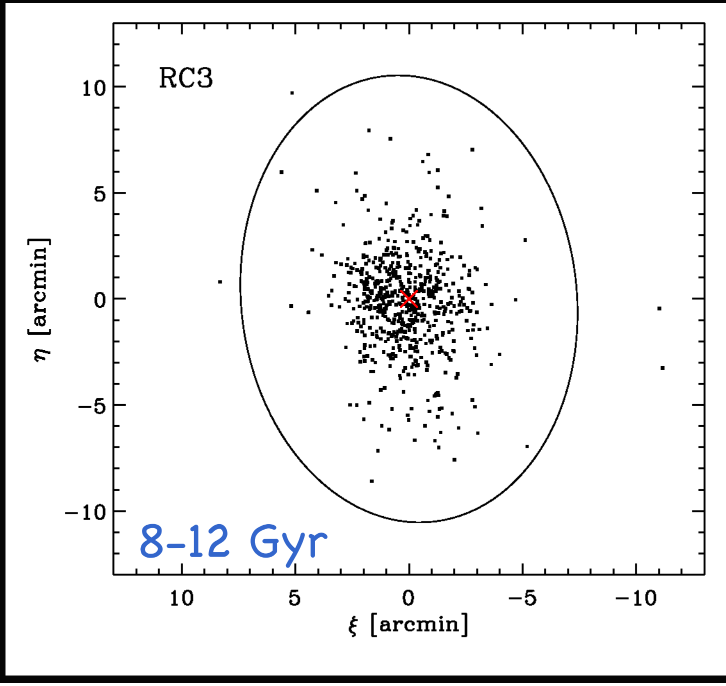

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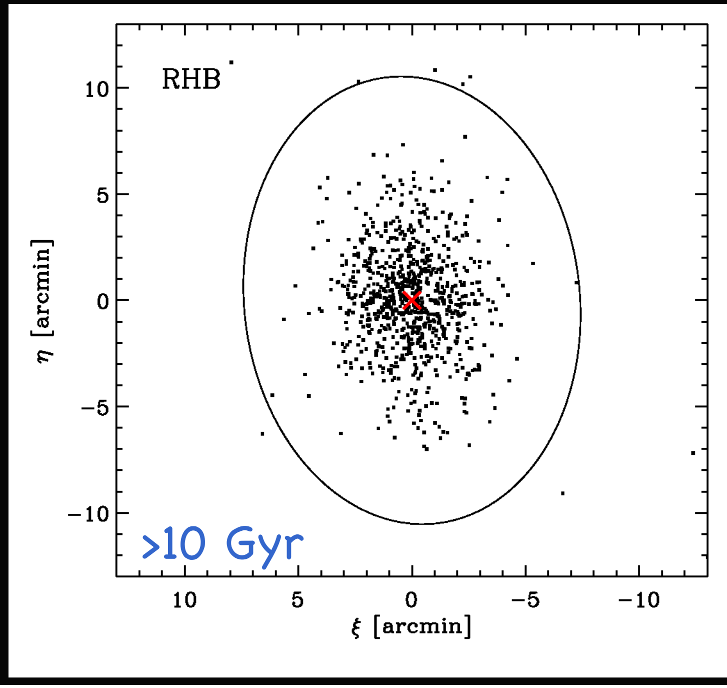

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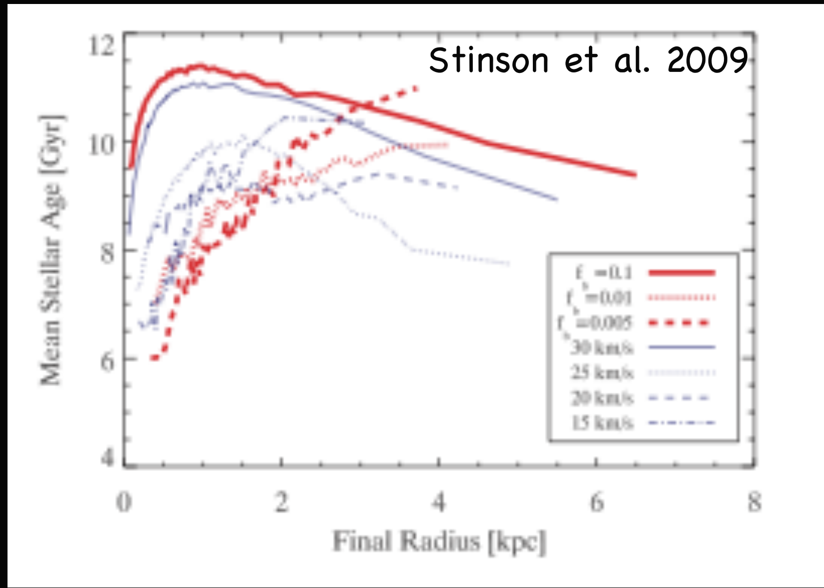
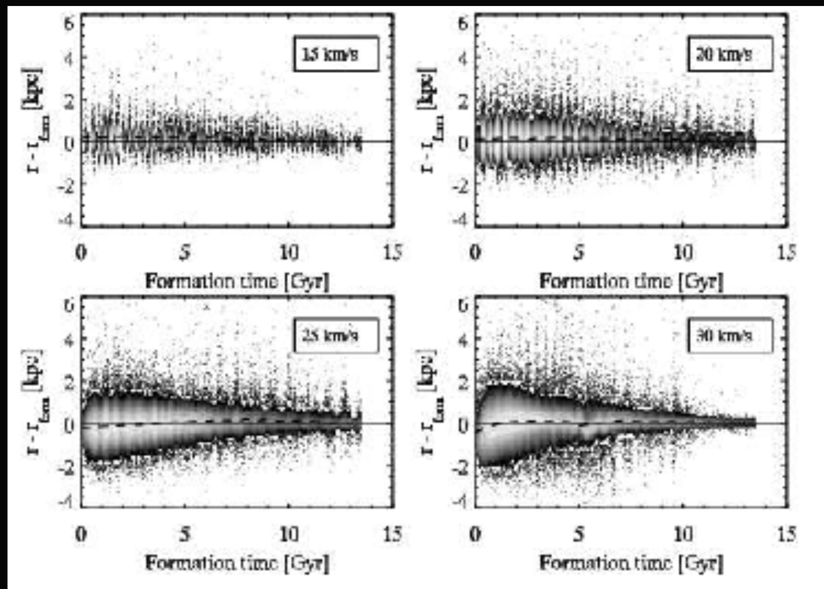
Natural evolution of the gas?

- In the lower mass galaxies the envelope inside which star formation occurred contracts as the supply of gas diminished and pressure support is reduced (Stinson et al. 2009)

- Some amount of radial migration present (Stinson et al. 2009)

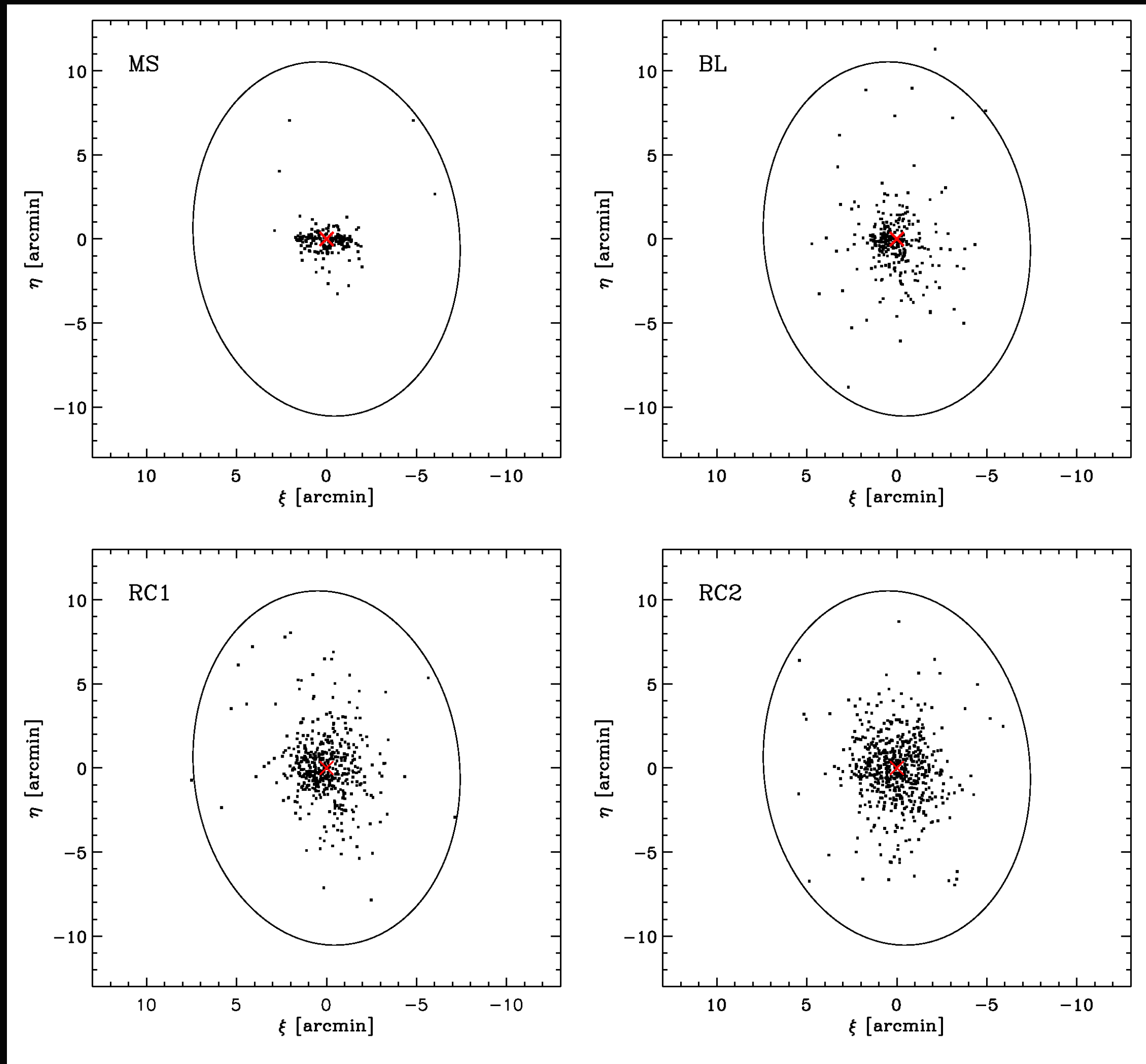
- Angular momentum as a "second parameter" in driving stellar population gradients (Schroyen et al. 2011)





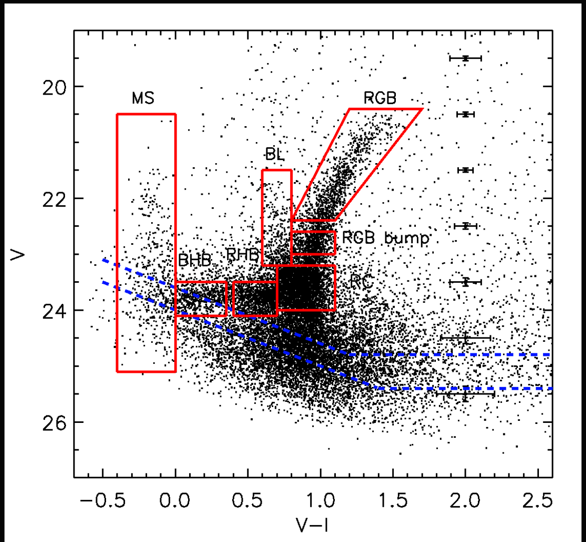
Distribution becomes more regular with increasing age

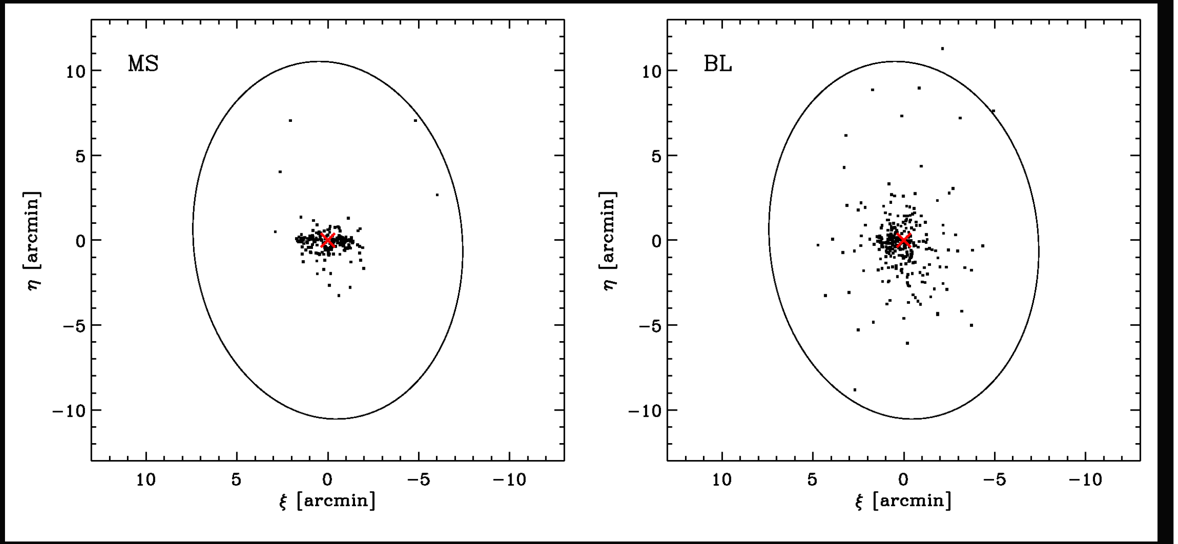
Distribution becomes more regular and spheroidal the older the stars -> effect of diffusion to larger distances?

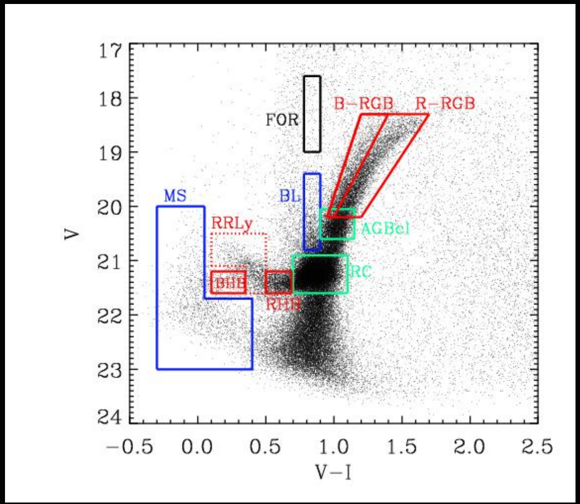


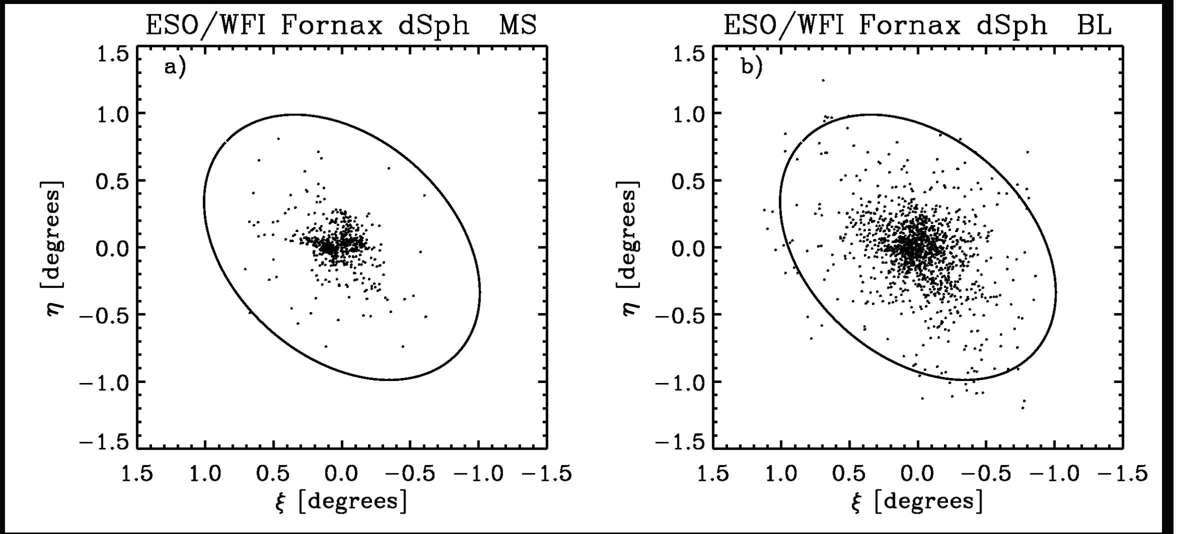
Distribution of young stars: Phoenix & Fornax

Battaglia et al. 2012, airXv/1205.2704









Summary

- The depth of the photometry, combined to the large area covered, enabled us to explore in a very direct way how the stellar population mix varies across the face of the galaxy
- An age gradient is present; similar to what found in Milky Way dSphs
- Increasingly featureless distribution the older the stars, similar to the Fornax dSph
- Detailed observations that should be helpful to theorists!
- To be complemented by FORS spectroscopic data for about 150 RGB stars -> metallicity gradients/internal kinematics