MOONS for Dwarf galaxies around the MW in the Gaia era

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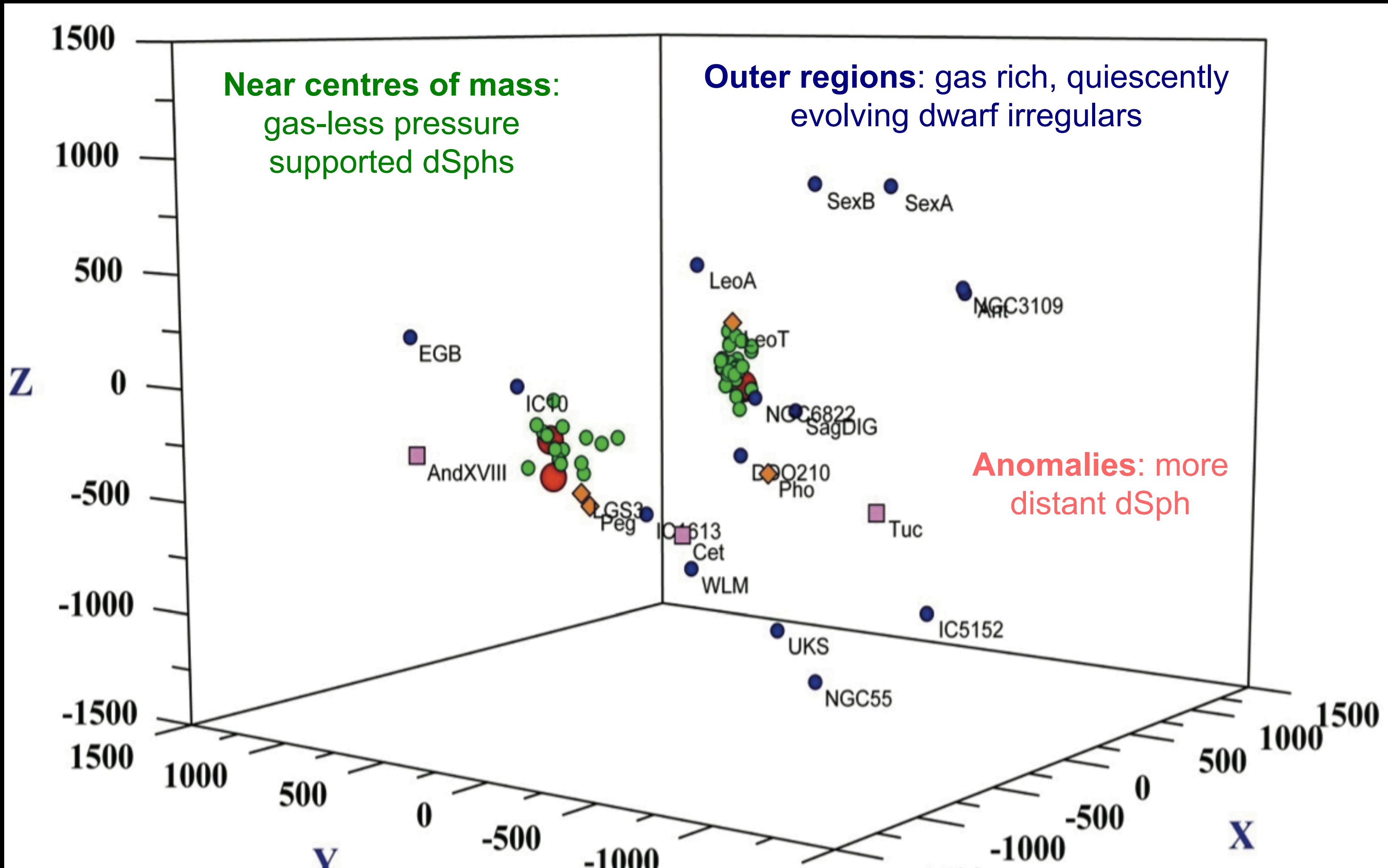
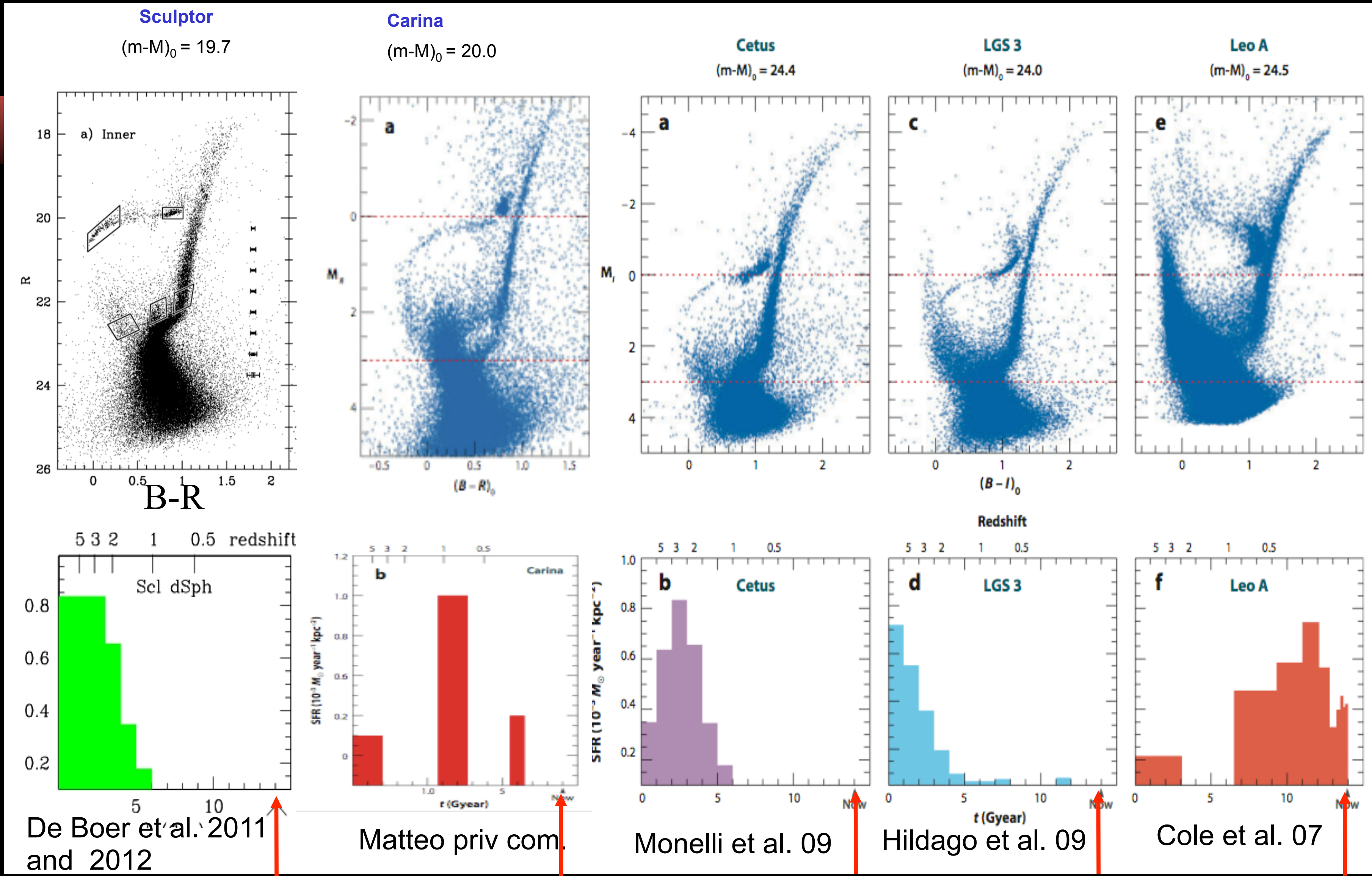
Local group dwarf galaxies



Mateo 2008, Garching workshop

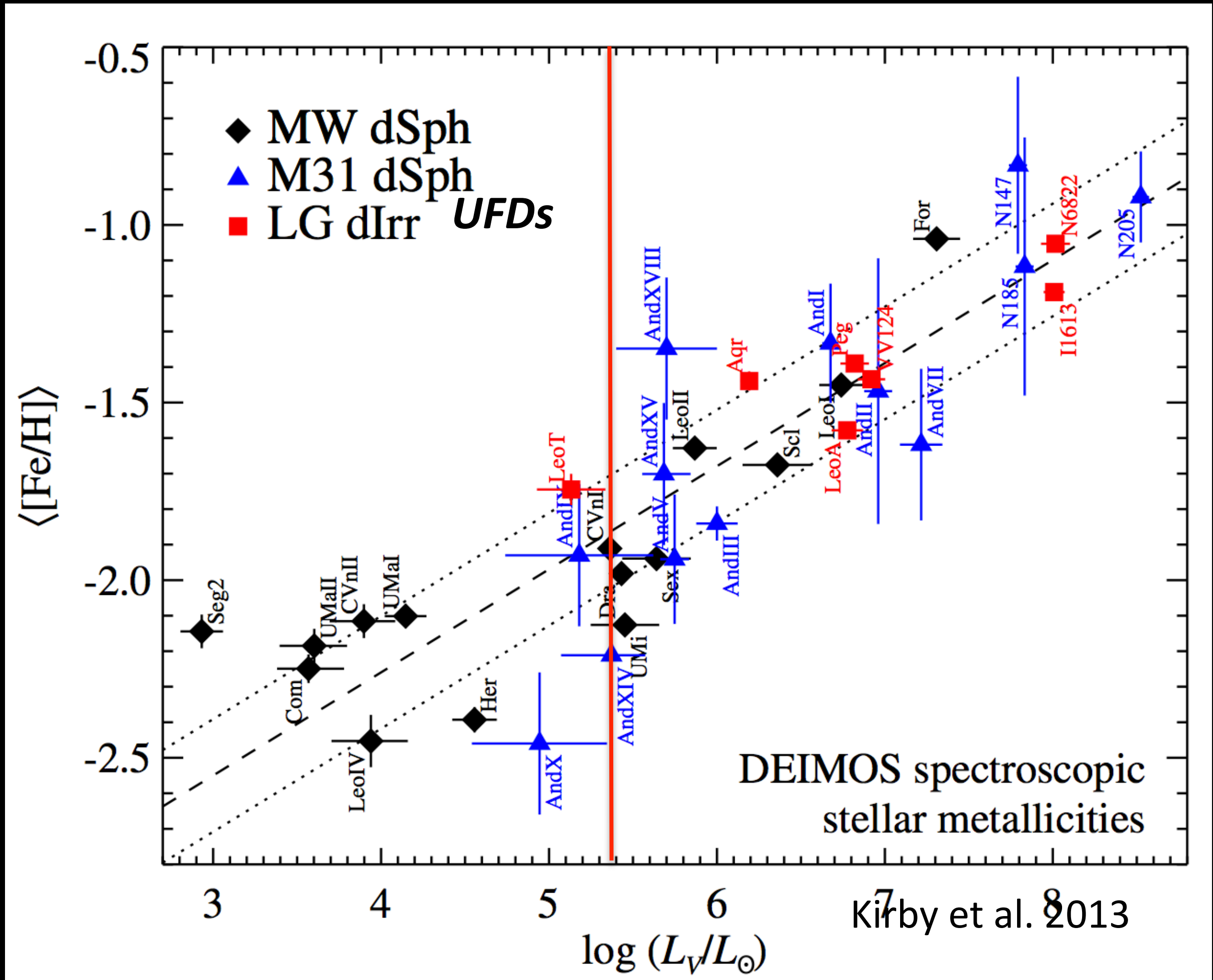
Various star formation histories



NOW

Tolstoy, Hill & Tosi ARAA 2009

Scaling relations: Luminosity– metallicity relation

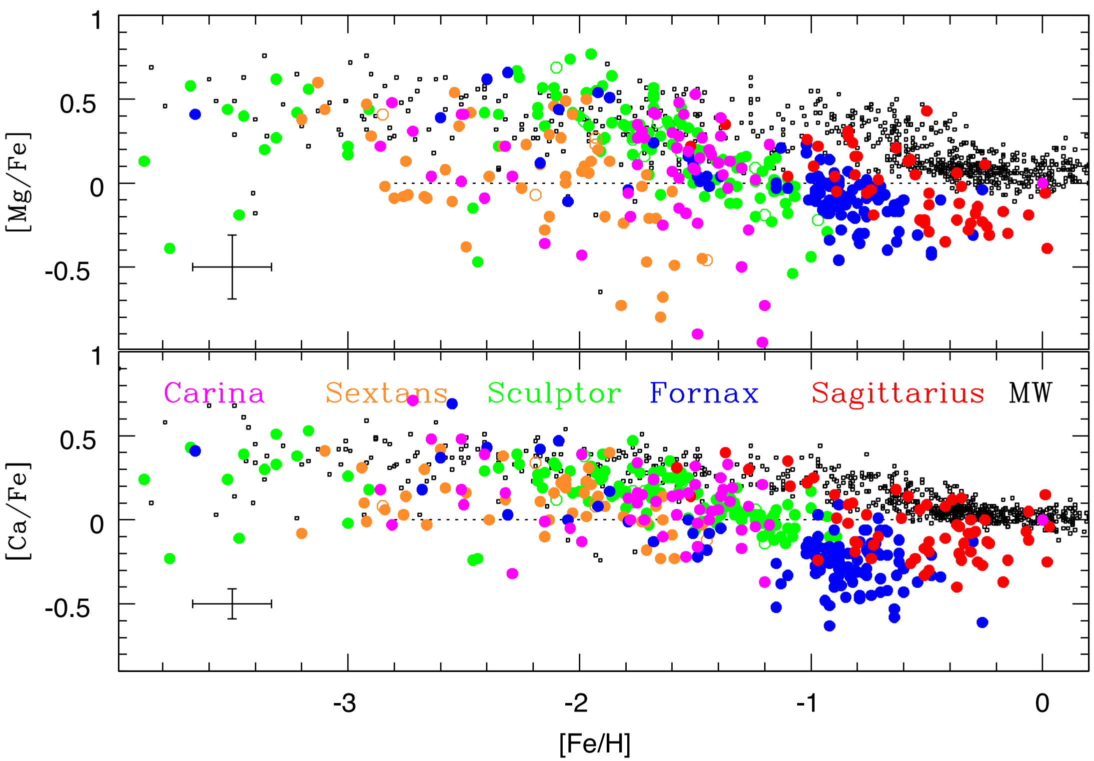


Mean metallicity scales remarkably with the luminosity of the system for dIrr, dSph and UFDs

Sgr Carretta et al. 2010, Sbordone et al. 2007,McWilliam et al. 2005
Fornax Lemasle et al. 2015, Hendricks et al. 2014, Letarte et al. 2010, Tafelmayer et al. 2010
Sculptor Jablonka et al. 2015, Simon et al. 2014, Tafelmayer et al. 2010, Tolstoy Hill Tosi 2009, Geisler et al. 2005, Shetrone et al. 2003,
Sextans **R. Theler et al. 2015 PhD**, Shetrone et al. 2003, Aoki et al 2009, Tafelmayer et al. 2010
Carina Venn et al. 2013, Lemasle et al. 2013, Koch etal. 2008
Milky-Way Venn et al. 2004

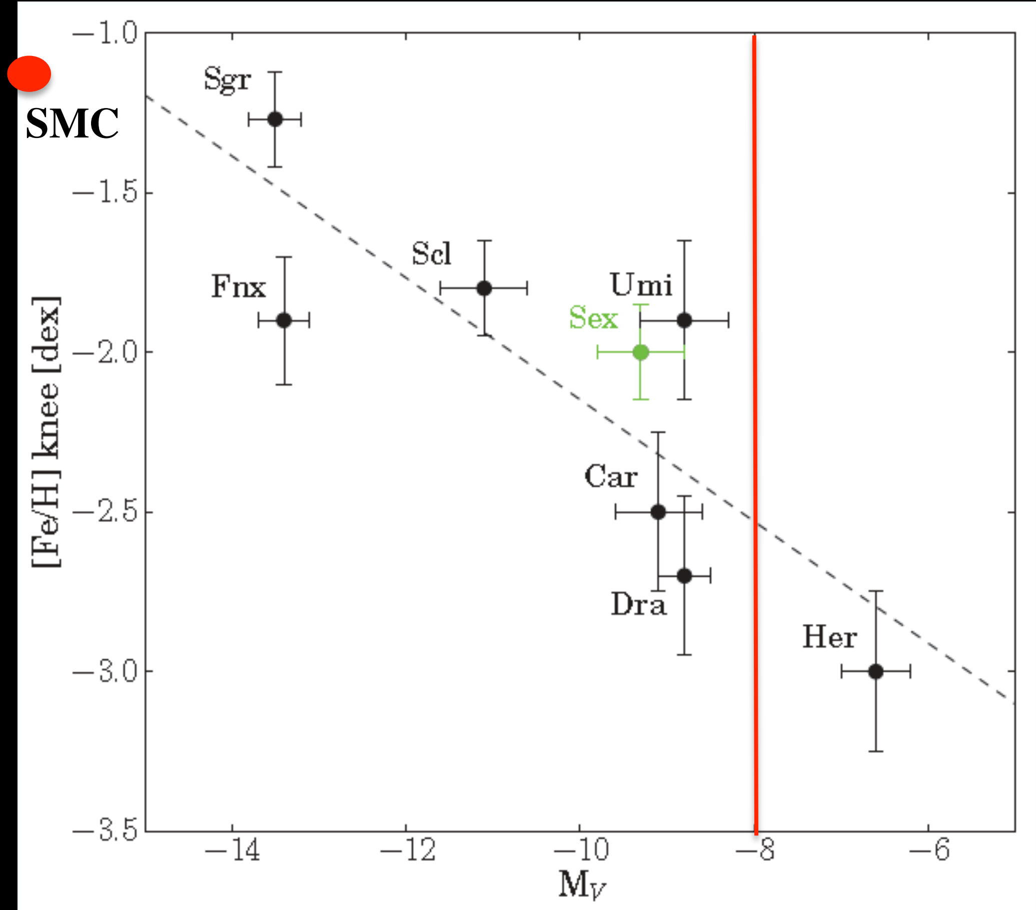
Distinct evolution

- Each galaxy occupies a different locus - evolutionary track
- [α/Fe] « knee » metallicity
  - Linked to SFH
  - Linked tp the ability of galaxies to retain metals
  - → correlates with total L of the galaxy
- reflected on mean metallicity (<[Fe/H]>-Mv relation)



- Dispersion: probably present in Sextans, and even more in -> inhomogeneous mixing / stochastic sampling of IMF
- Similar to UFDs

Scaling relations:
Mv-α/Fe "knee" relation



Sextans: Theler et al. 2015 (Phd)
Her: Vargas et al. 2013
Dra: Cohen & Huang 2010
Umi: Cohen & Huang 2010
Car: Lemasle et al. 2013
Scl: Tolstoy Hill Tosi 2009
Fnx: Lemasle et al. 2014, Hendricks et al. 2014
Sgr: de Boer et al. 2014
SMC: Mucciarelli et al. 2014

More luminous systems reach higher metallicities before the onset of SNIa ([a/Fe] decrease)

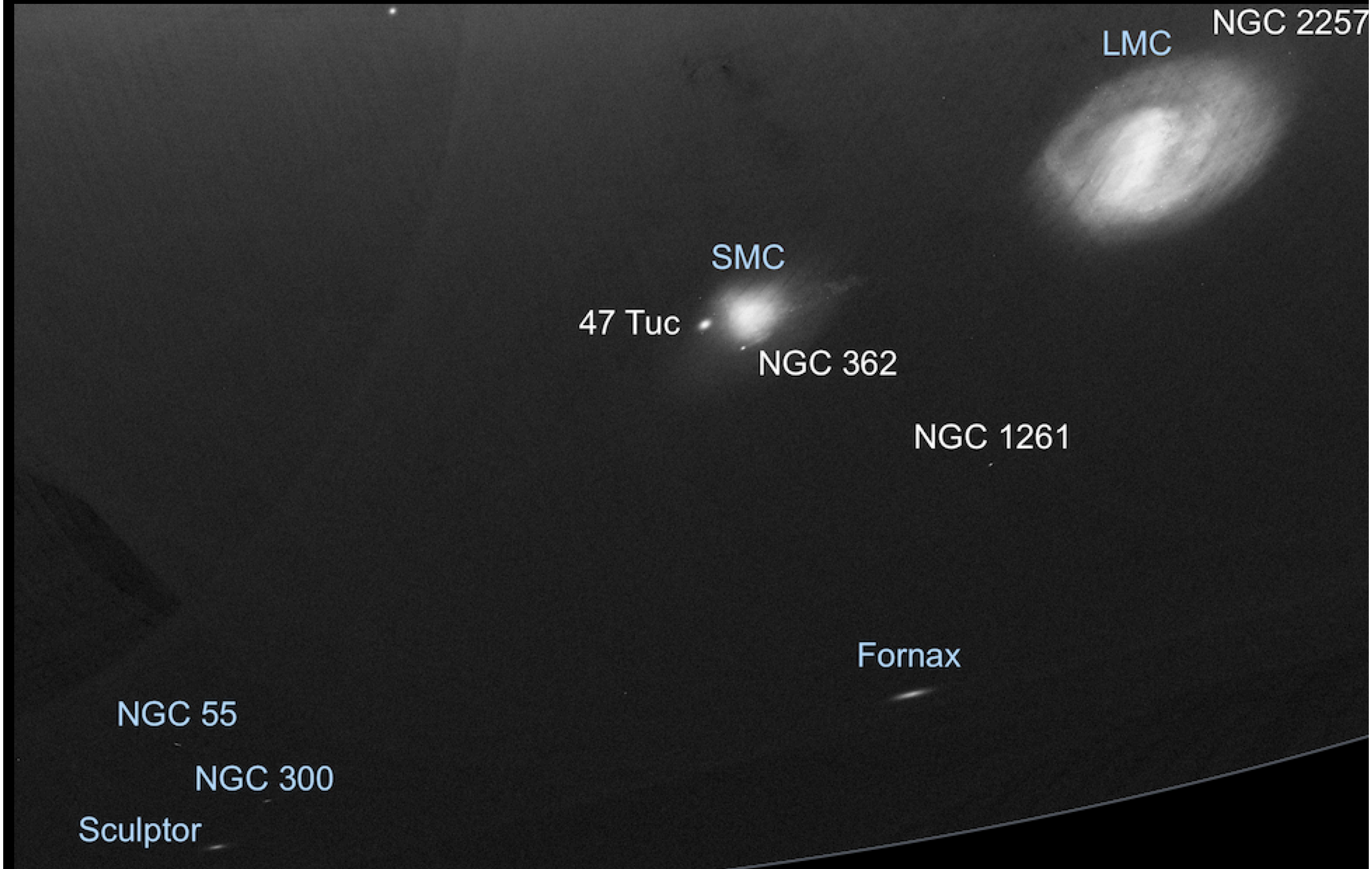
✓Expected if a system's ability to retain metals is correlated with its mass
✓Expected if star formation proceeds at low-level.

What about Gaia for MW satellites ?

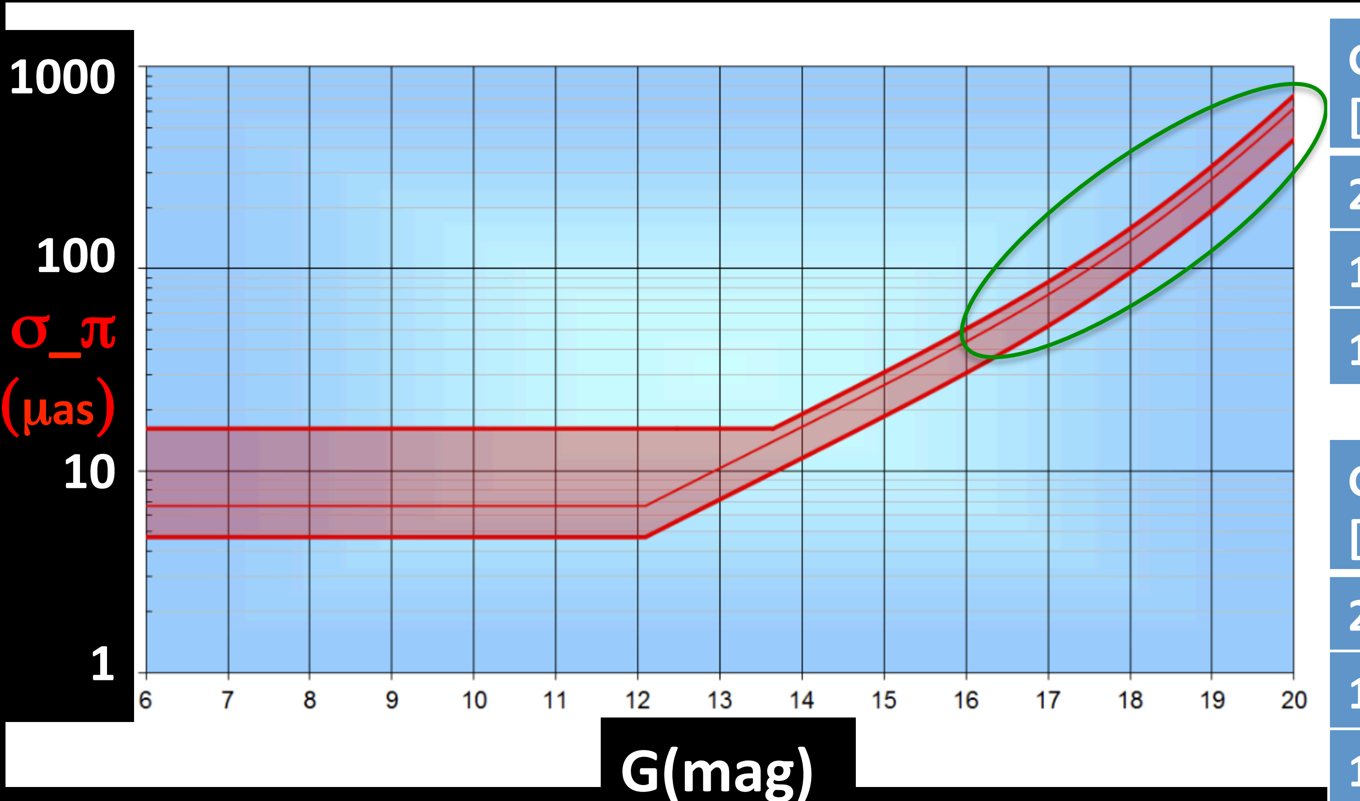
- Scaling relations and yet variety
  - In situ evolution: sure
  - How much does environment play a rôle ?
- Signs of interactions; co-planar orbits ?
  - Systemic motions in 3D
  - Gaia as an wide field imager: detect tidal tails (eg Carina)
- Internal dynamics
  - Total masses, DM content
  - DM profiles
  - chemo-dynamics

→ Where Gaia can transform the scene....

Magellanic Clouds in Gaia DR1



Gaia performances for MW satellites



G [mag]	D=50kpc [kpc]	100kpc [kpc]
20	1570	6270
18	342	1370
16	109	436

G [mag]	D=5kpc [kpc]	10kpc [kpc]
20	15.7	62.7
18	3.4	13.7
16	1.1	4.4

- Parallaxes:
  - not competitive for dSph distances (wrt eg. RR Lyr, MSTO, …)
  - Very useful for sorting interlopers (foreground non-members)

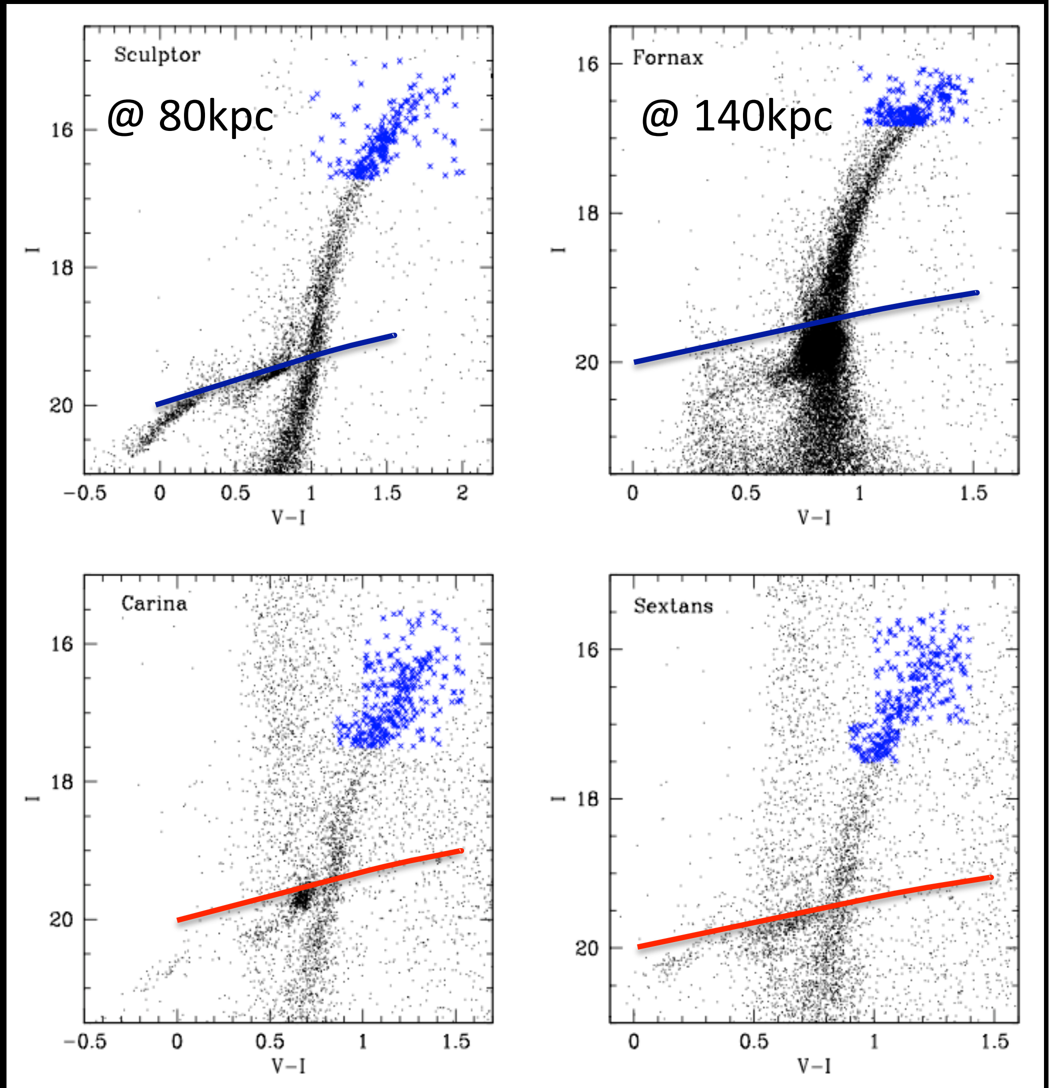
Gaia performances for MW satellites

G mag	Err-μ [μas]	eVt @ 10kpc [km/s]	eVt @ 50kpc [km/s]	eVt @ 80kpc [km/s]	eVt @ 100kpc [km/s]
16	23	1.1	5,4	8.7	10.9
18	72	3.4	17.1	27.4	34.3
20	330	15.6	78.2	125.1	156.4

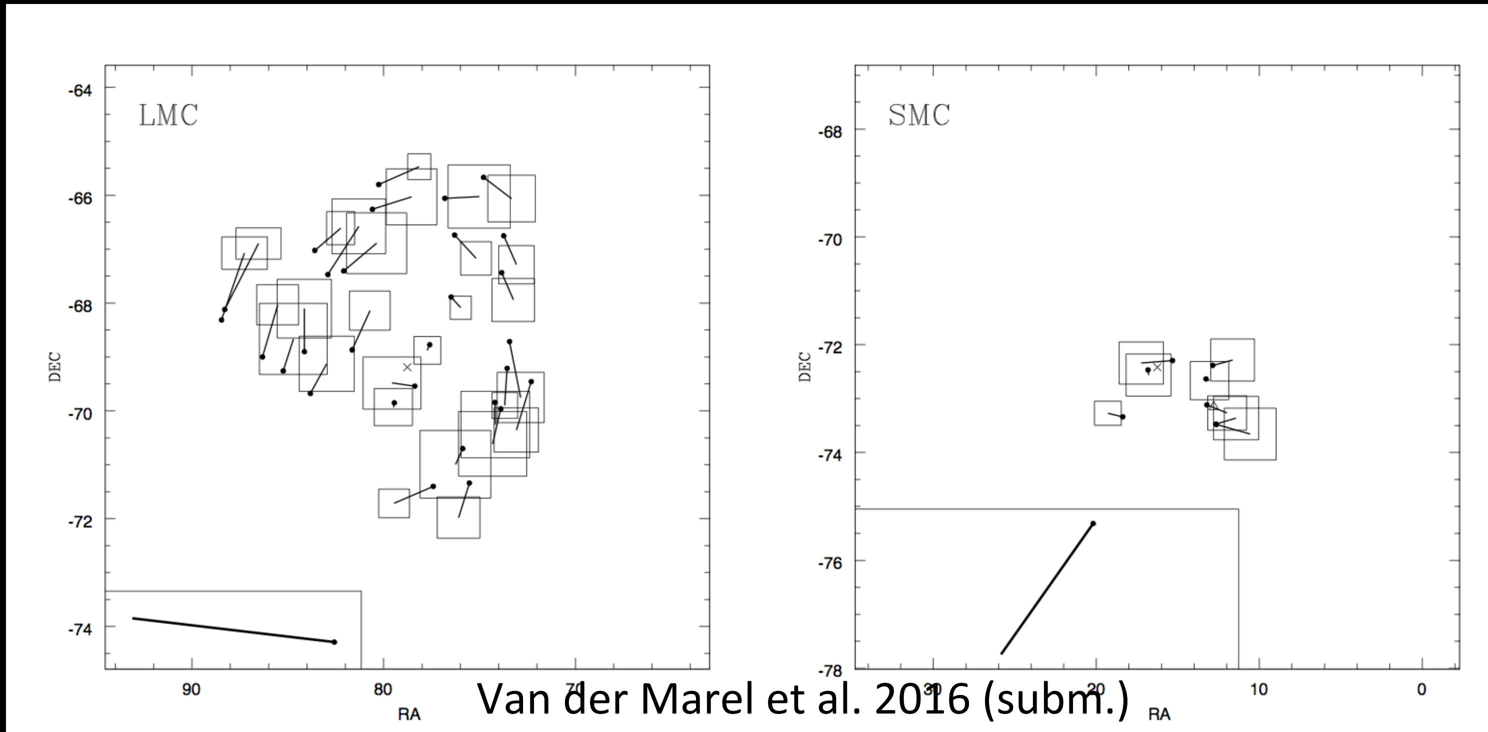
- **individual μ to 20--300 μas** in the relevant magnitude range for dSph RGBs
- **mean μ to ~10 μas** for G~20 RGB stars in a dSph system (to be compared to current estimates with ~200 μas precision on **mean** motions from HST, eg. Piatek 2005,2006, 2007)
- translate to errors in **individual transverse motions** of 10 to 150km/s for the faintest stars at 100kpc. (to be compared to internal σV~5-10km/s)
- Assuming 1000 RGB per system in the range G~18-20 will give **mean transverse motions** to better than 5km/s at 100kpc.

The “good case” of Scl

- Cleaned membership based on foreground π to R_{tidal}
- ~few hundred RGBs expected with transverse motions better than 20km/s. -> Mass determination to 10-15%; Core/Cusp discrimination to 2.5σ (Evslin 2015)
- >1000 RGBs with individual motions between 20 and 100km/s; mean motion to 2-3 km/s ! -> orbit of the satellite
- Internal dynamics of dSph (eg. discriminate different populations, detect rotation, …) -> LSST…



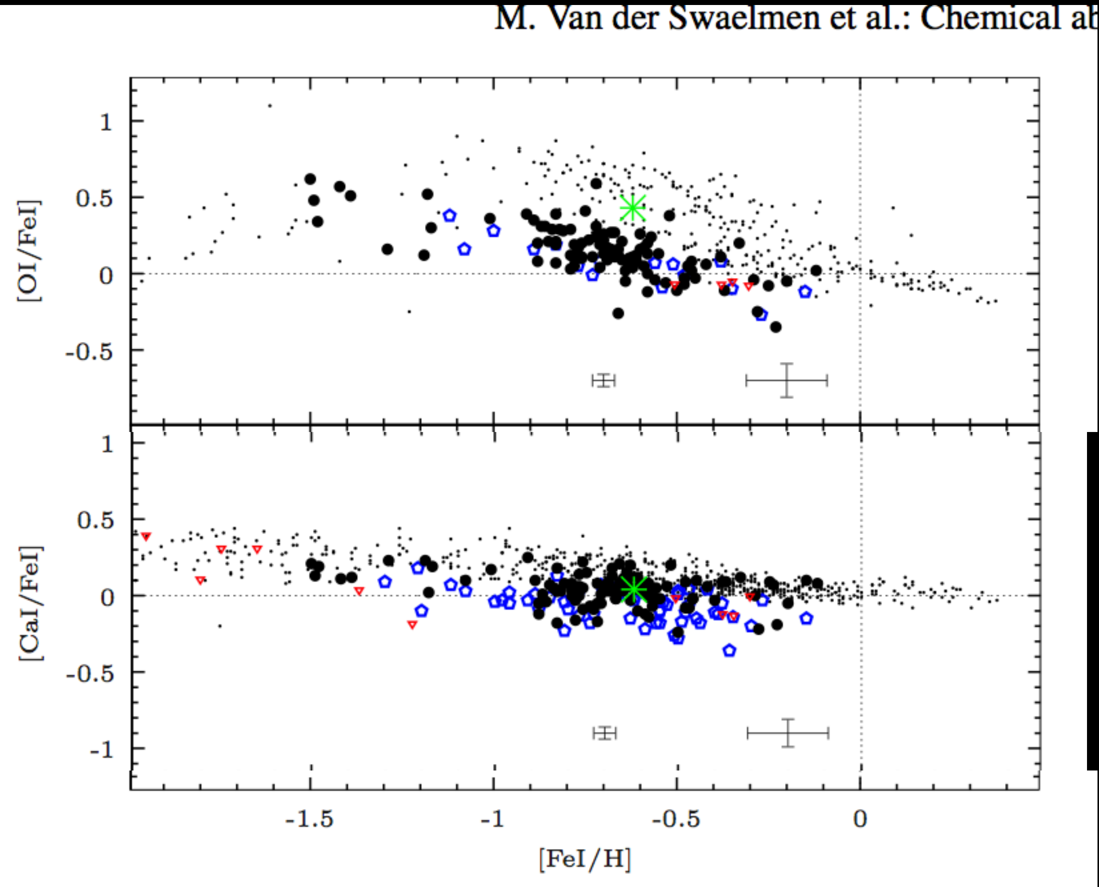
Gaia DR1 (TGAS) for the MCs

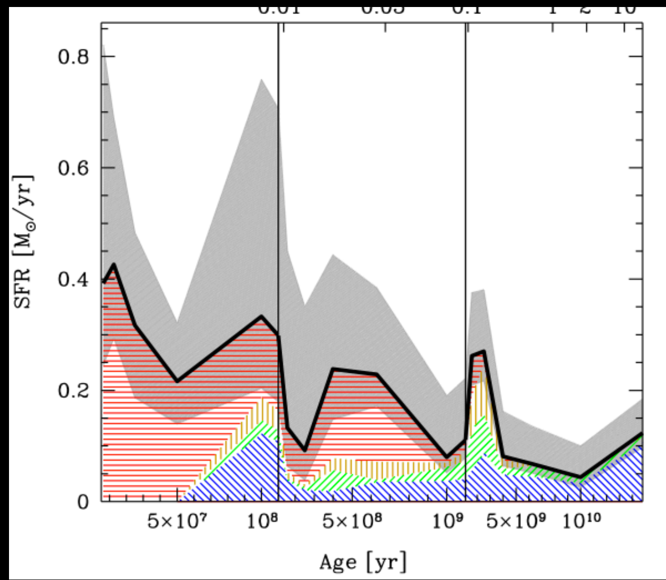


Van der Marel et al. 2016 (subm.)

- 29 supergiants in the LMC and 8 in the SMC
- Center of Mass motion comparable with HST PPM
- Detection of the internal rotation

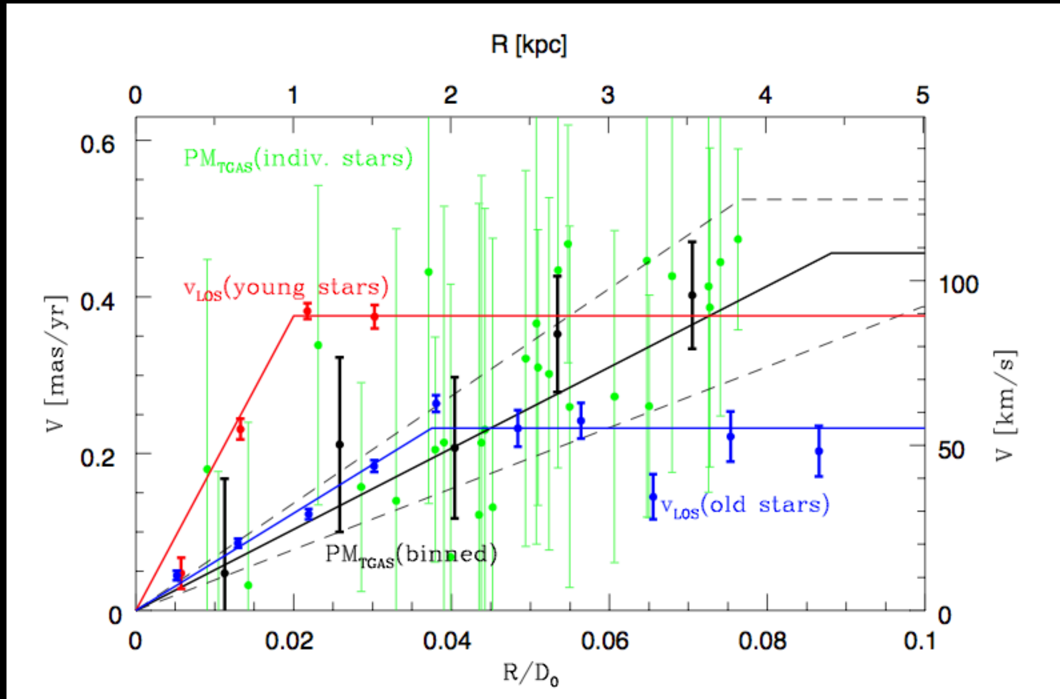
LMC: a small nearby disc





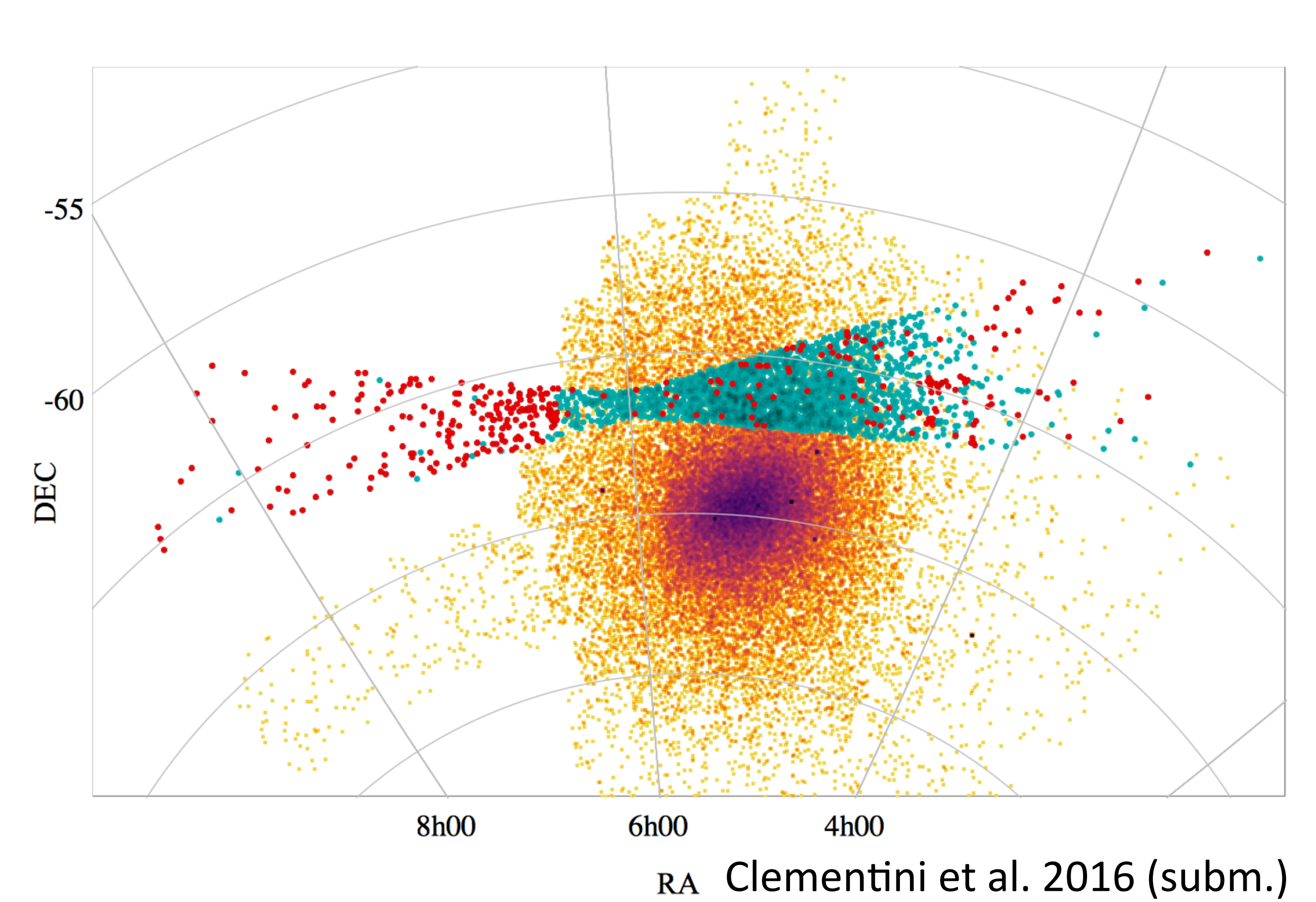
- LMC : disc evolution at the lowest mass regime, with 2 enhanced star forming epochs. No large gradient across the disc.
- Also a slow chemical evolution
- No clue on the LMC halo (or hardly)

LMC disc dynamics



- Age dependence of the kinematics (Van der Marel et al. 2014)

The LMC halo



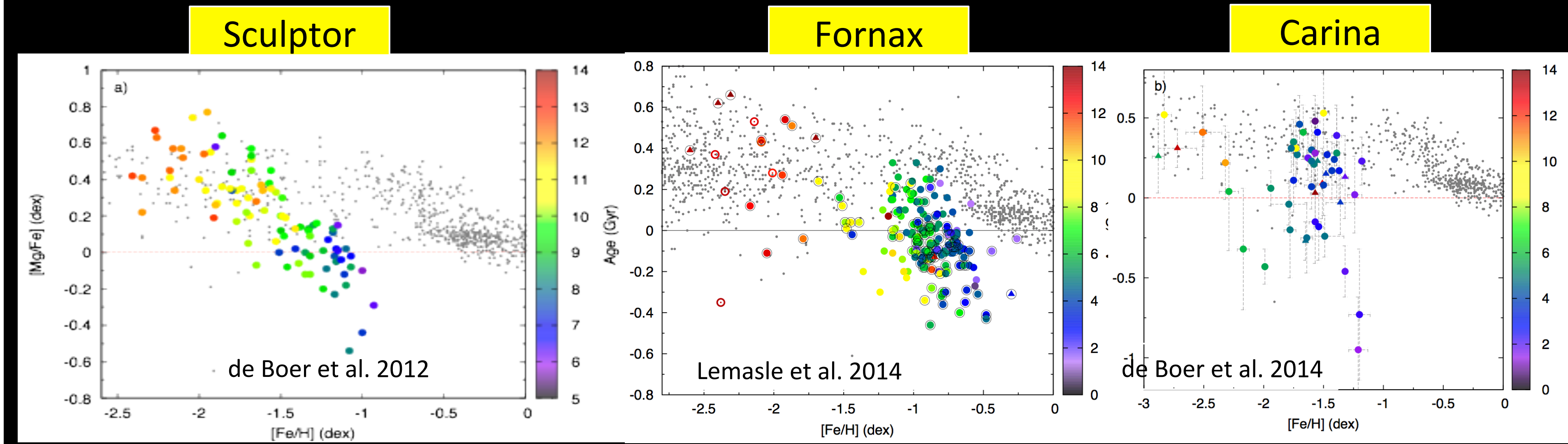
Clementini et al. 2016 (subm.)

- Gaia DR1 RR Lyr in the South Eclipting Pole region
- Another indication of the large extent of the LMC halo

What more do we need ?

- Kinematics
  - 3D kinematics to solve DM profiles, but also rotation, etc.
  - so far 1D kinematics. Gaia PMM, but need to complement Gaia with los Vr in all dSph (notably the centers, down to G=20) and in the LMC/SMC systems (G>16)
- Chemistry:
  - A chemical survey with individual elements key to undertand the growth of discs (eg. α elements cf solar neighborhood).
  - Ages are essential (whether from isochrones, α elements, or C/N for RGB ages) cf Martig et al. 2016
  - Chemical tagging: need precise chemical abundances to trace assembly of these systems
  - Chemo-dynamics: current "global" chemistry is poor (limited to center of systems || tiny regions in the case of LMC disc or SMC/Sgr). Lack of spatial coverage; most metal-poor end; LMC Halo !
  - Ages: very limited sets of stars with "reasonable" isochrone ages

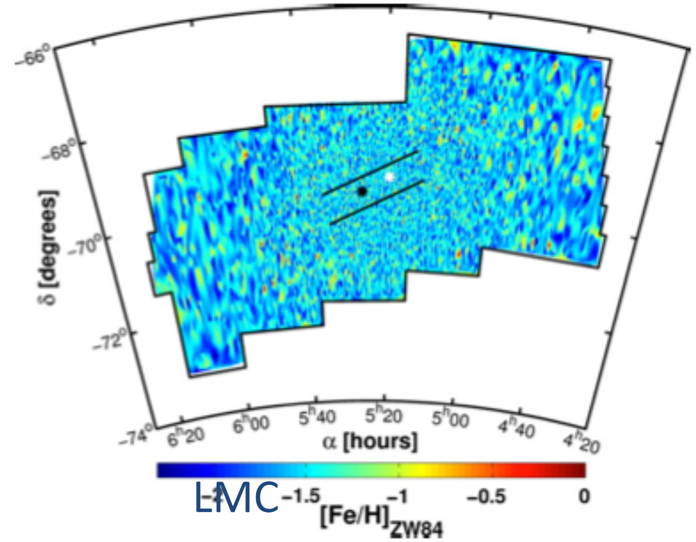
Age – vs Chemistry



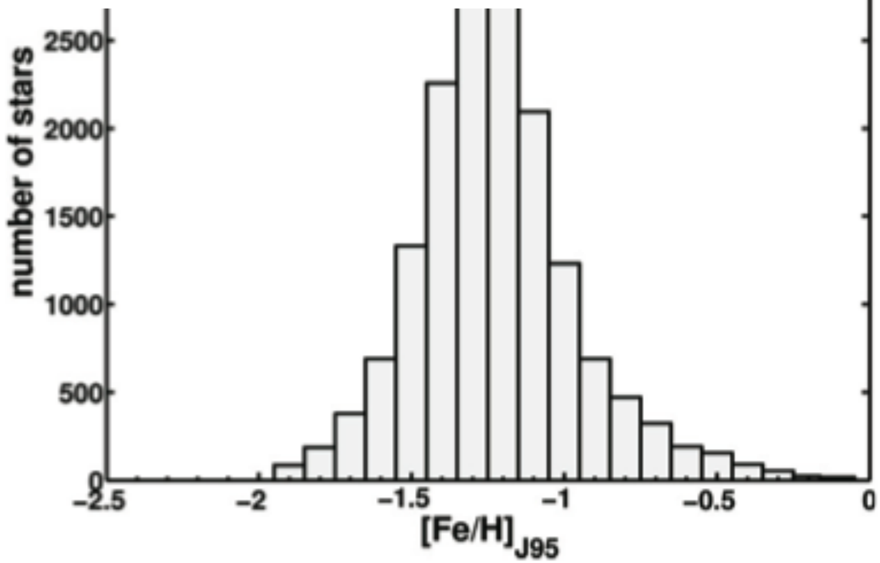
- The SFH can be used to constrain solutions to derive more robust ages on the RGB
- The SNIa (knee) in Scl and Fnx occurred 2Gyrs after the start of SF
- Carina seems to show a much more complexe structure (multiple bursts)

Metal-poor stars ?

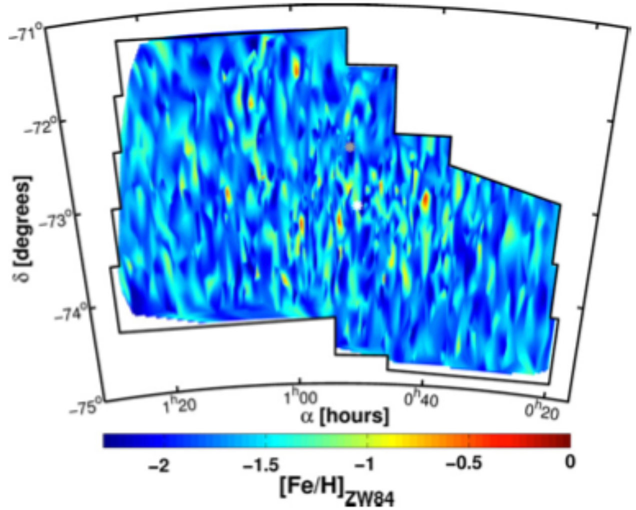
mples in both clouds
oor tails (if any).
nd presumably meta



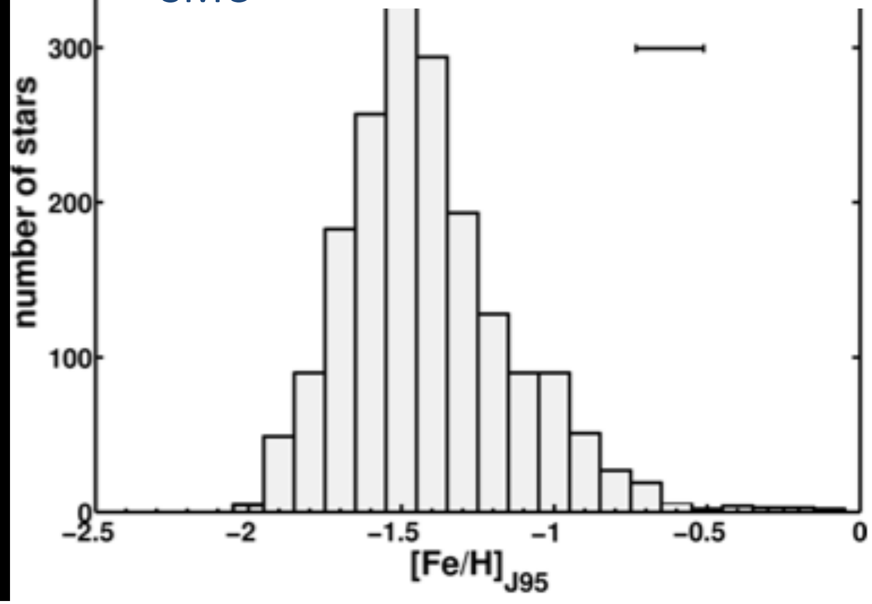
LMC



Haschke et al. 2012 (OGLE III RRLyr)



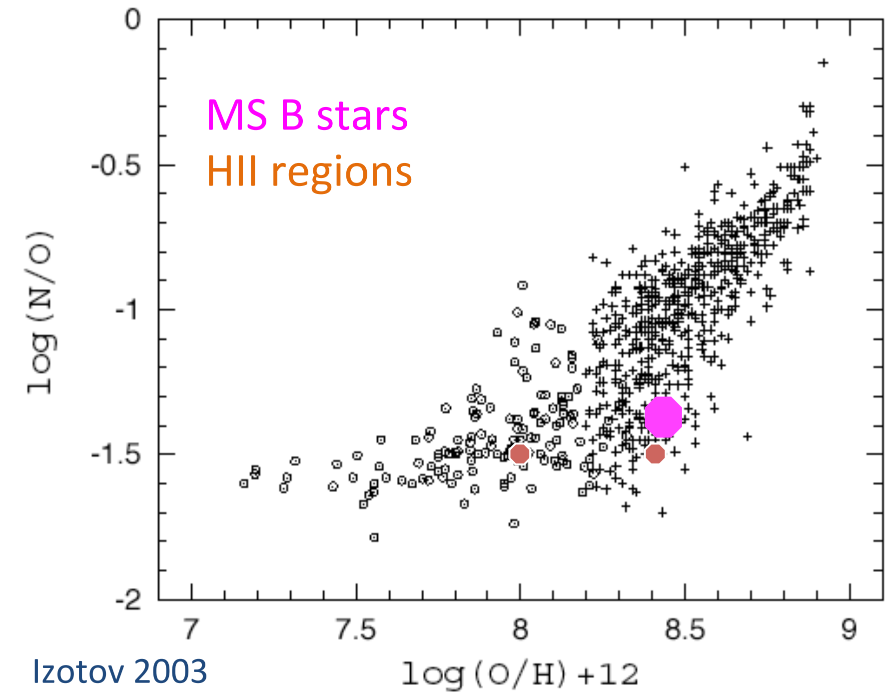
SMC



A case for Carbon and Nitrogen

HII regions: review by Garnett 2000 IAU Symp 190

log(X/H)-log(X/H)orion	Orion (Esteban et al. 98)	LMC	SMC
C	8.49	-0.59	-1.09
N	7.78	-0.88	-1.28
O	8.72	-0.32	-0.72
Ne	7.89	-0.29	-0.69
S	7.17	-0.47	-0.87
Ar	6.8	-0.60	-0.90



+ Main Sequence B stars (Korn et al. 2002, 2000) : confirm the low C and N

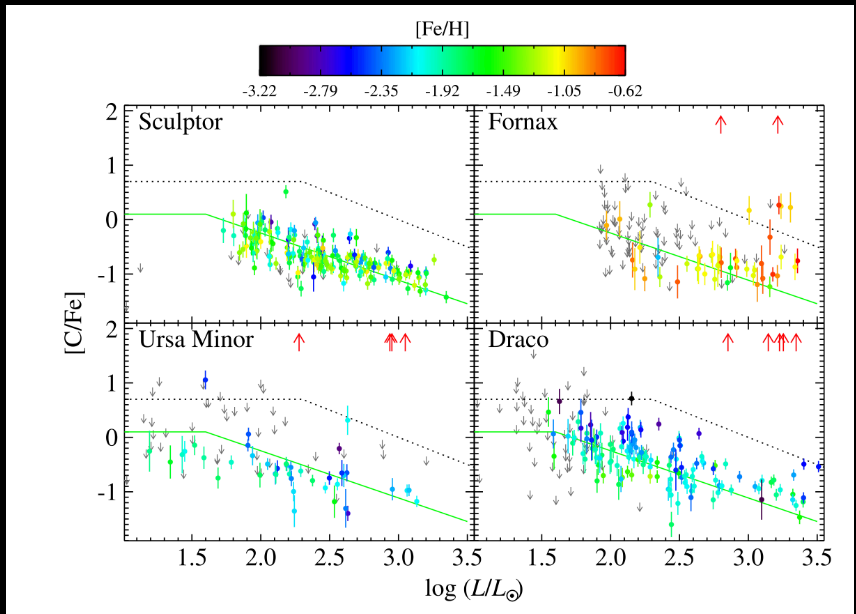
→Nitrogen close to primary → low-mass stars production not yet dominant ???

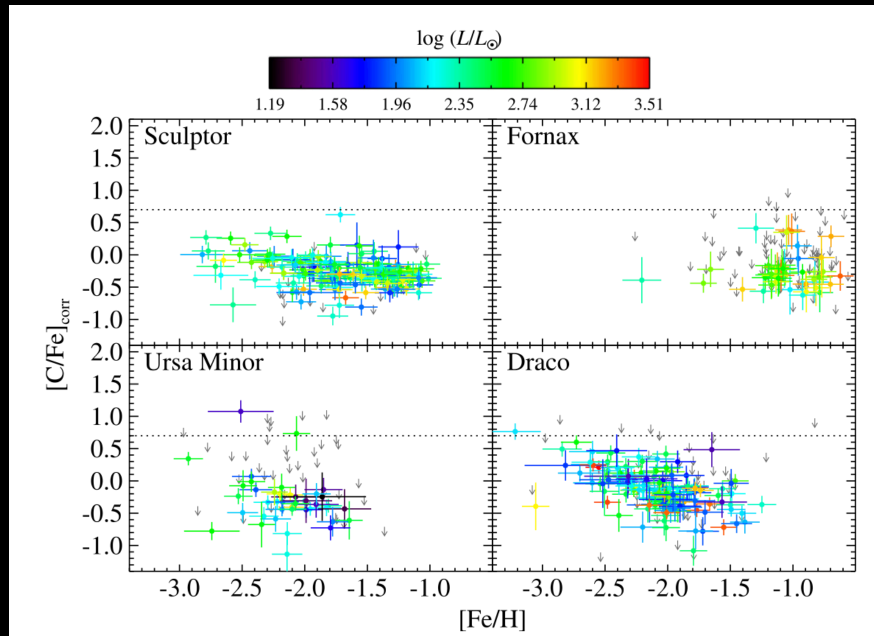
→ Need to understand the evolution of C and N in the LMC/SMC with time (age)

→ To access original N (or C) in evolved stars, need C,N,O abundances

→ MOONS HR H bands perfect match for CNO (all 3 needed to disentangle mixing)

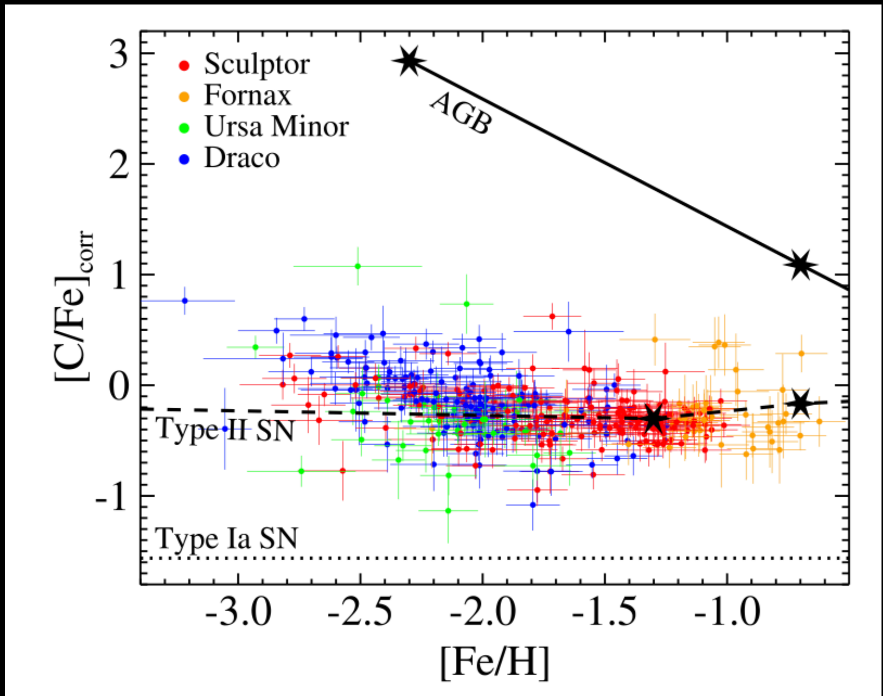
Carbon and Nitrogen in dSph

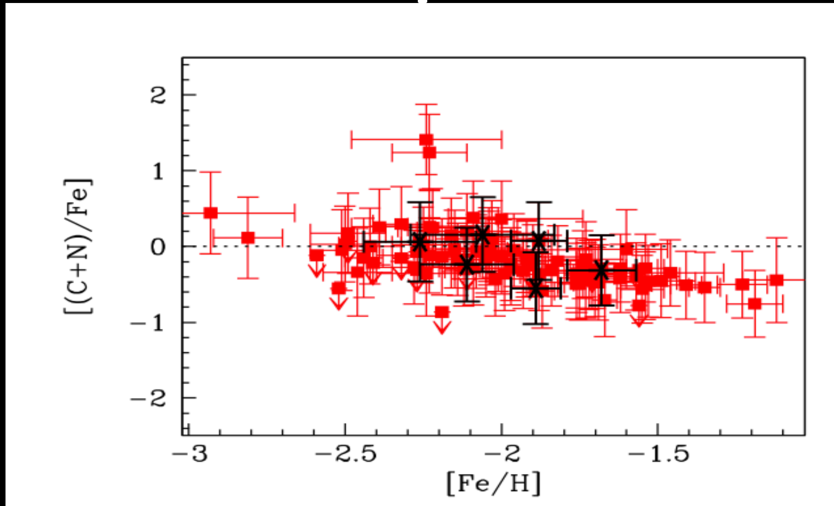


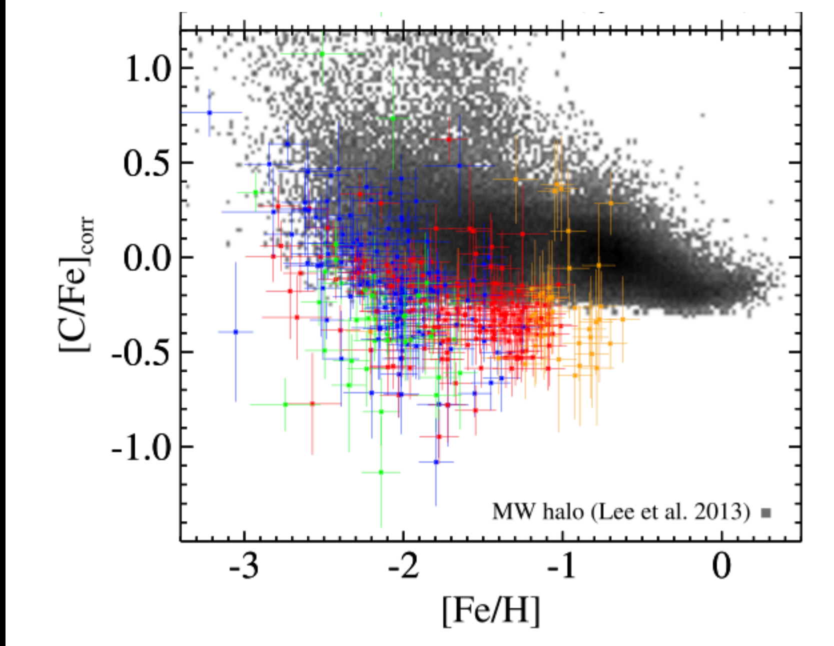


- Assuming a C-L relation to correct for mixing

A case for C and N: dSph







- Decline of C/Fe with Fe : explained by met-dependant yeilds of AGBs + onset of C-poor SNIa ?
- in dSph not seen in the MW halo (ditto alpha elements) nor disc

Call for a LMC/SMC suvey

- To uncover the 3 D kinematics of the LMC stellar populations (disc, halo) [==complement Gaia in Vlos] → MOONs can do it BEFORE 4MOST, and better in the densest fields.
- A chemo-dynamical survey to uncover the hierarchical (or not) origin of the LMC halo + understand LMC-SMC interactions → MOONs can do it, NOT 4MOST
- A chemical survey with individual elements key to undertand the growth of LMC discs (eg. α elements cf solar neighborhood) → MOONs can do it, NOT 4MOST
- A chemical survey to understand the enrichment of carbon & nitrogen.
- A chemical survey for age-proxies or age-precision
- [Including RGBs and RRLyr]

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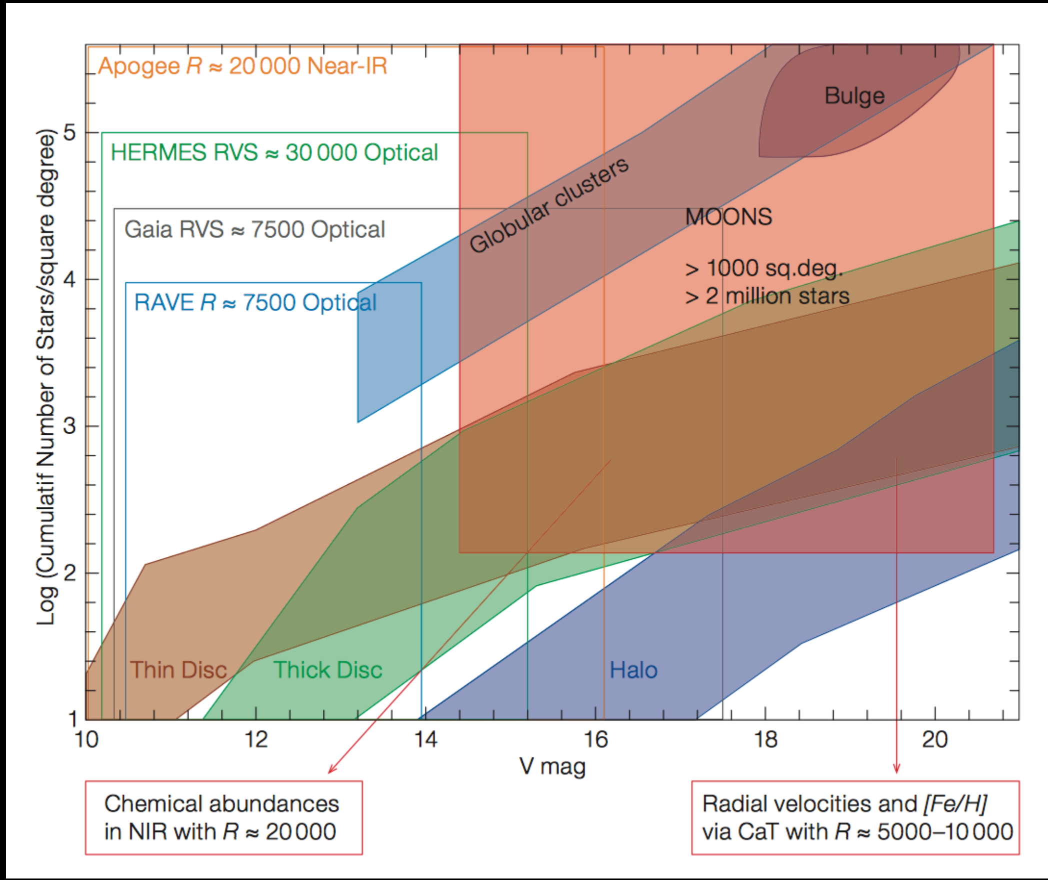
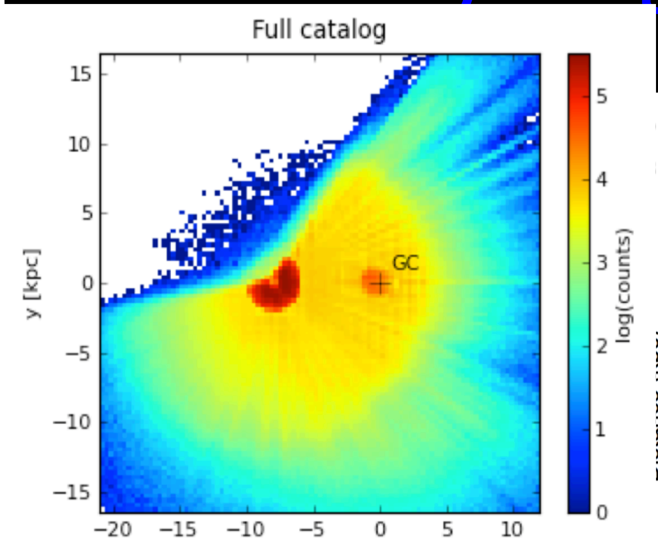
MOONS & FLAMES heritage

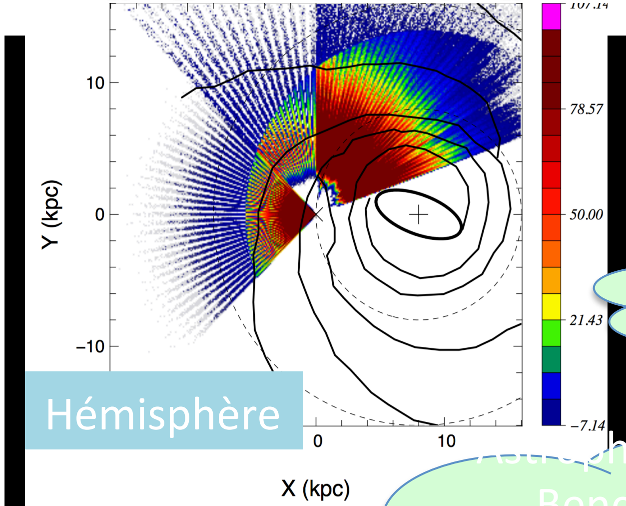
MOONS:

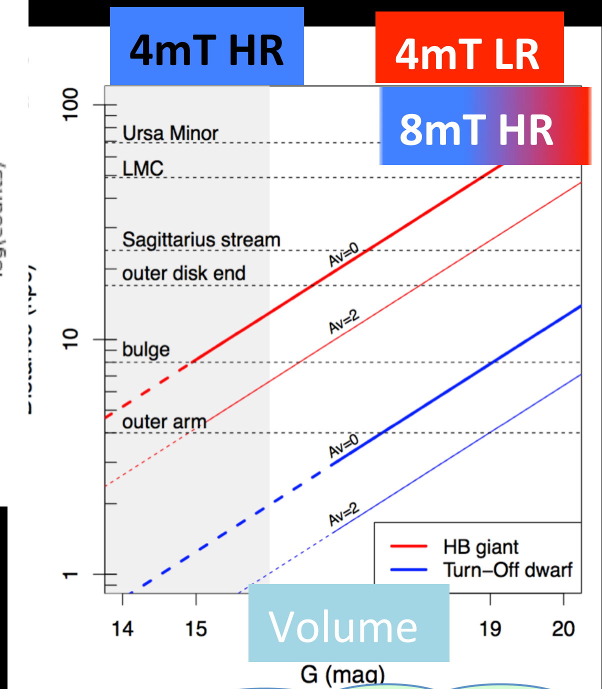
- same FOV as FLAMES, multiplex x4-7 – well suited for MCs
- >3x more efficient wrt to FLAMES
- R~20,000 wavelength region (H band): ideal for detailed chemical abundances, of Fe, alpha elements (Mg, Ca, Ti..), C, N, O of metal-rich and intermediate metalicity stars. → well suited in particular for LMC, SMC, Sgr.
- RI medium-resolution: wider than FLAMES LR08; ideal for stellar los velocities and metallicities down to [Fe/H]<-4

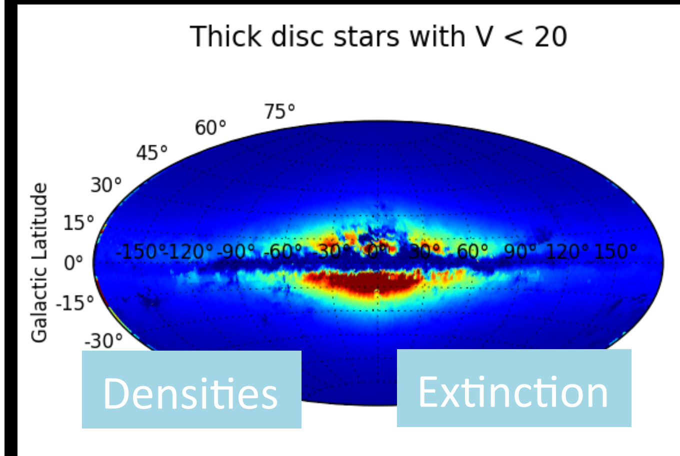


Synergies : European MOS









Survey overlap for cross-calibration

Spectro analysis methods

Astrophysical calibrations:
- Benchmarks (Gaia & al.)
- Asteroseismo (CoRoT, Kepler, K2)
- Clusters, ...

Data mining methods