New insight into the mass assembly of the halos of the Local Group spirals

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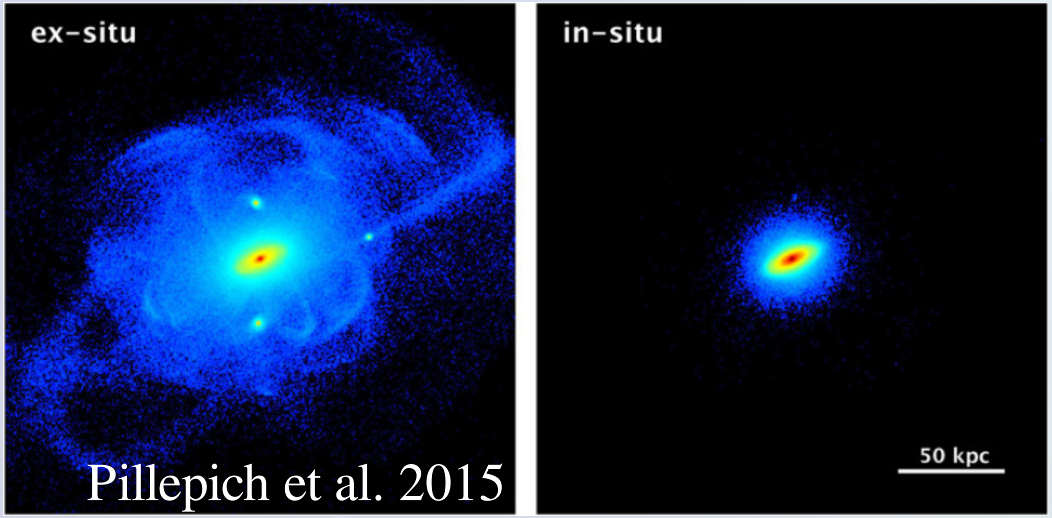
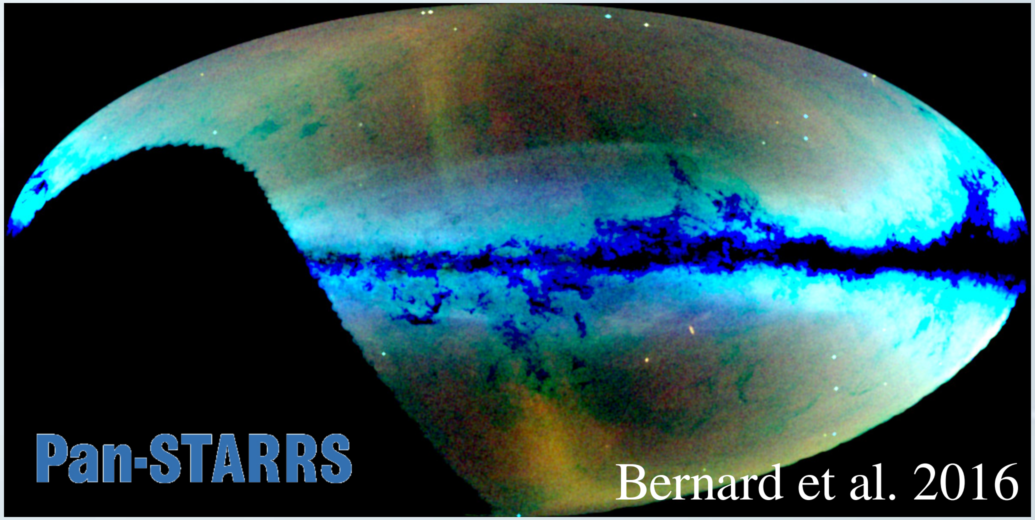
The composition and formation of stellar halos

- ~1% of the total stellar mass of Milky Way
- Mostly old and metal-poor
- Possibly made of 2 components: inner and outer (e.g. Carollo+07)
- Significant/dominant accreted component
- Nature of the progenitors?



Pillepich et al. 2015



Bernard et al. 2016

Outline

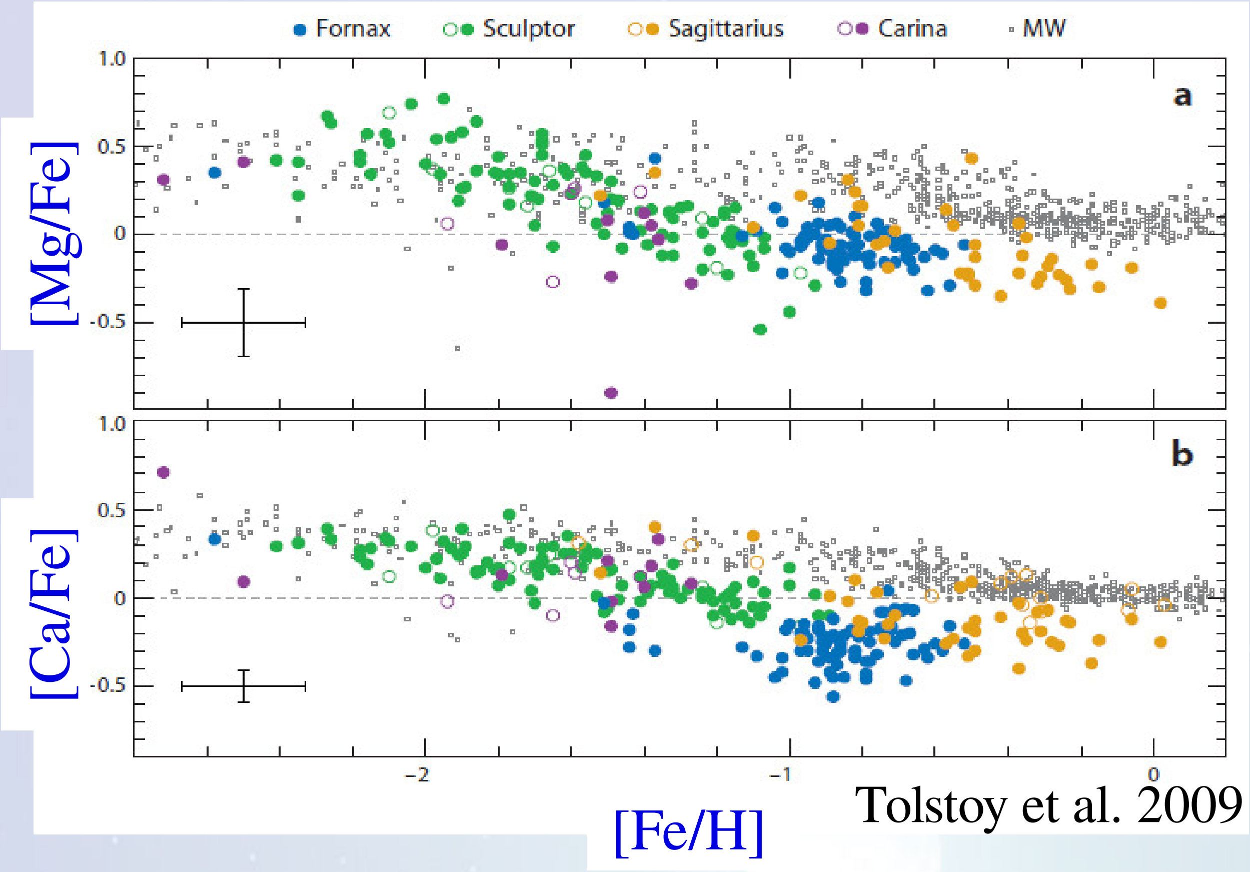
- Local cosmology with RR Lyrae stars: on the building blocks of the Milky Way and M31 halos

Giuliana Fiorentino (INAF-Bologna)
Fiorentino et al. 2015, ApJ Letters, 798, 12

Matteo Monelli (IAC, Tenerife)
Monelli et al. 2016, ApJ, submitted

- Nature and origin of halo substructures in M31 from their star formation histories

Milky Way halo vs. present day dwarf spheroidals

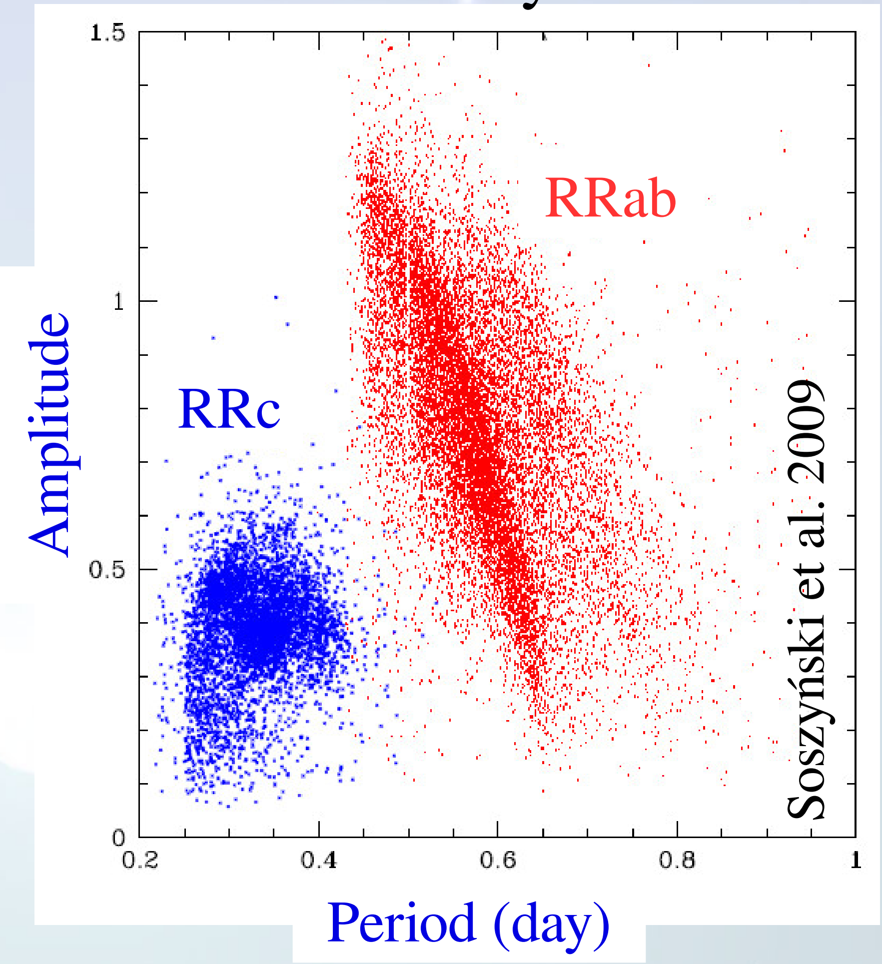


- Halo and *present day* dSph have different abundance patterns
- But: RGB stars in spectroscopic sample have a wide range of ages
- Could a 2-3 Gyr old Fornax or Sculptor have formed the halo?
- Purely old stellar tracer needed!

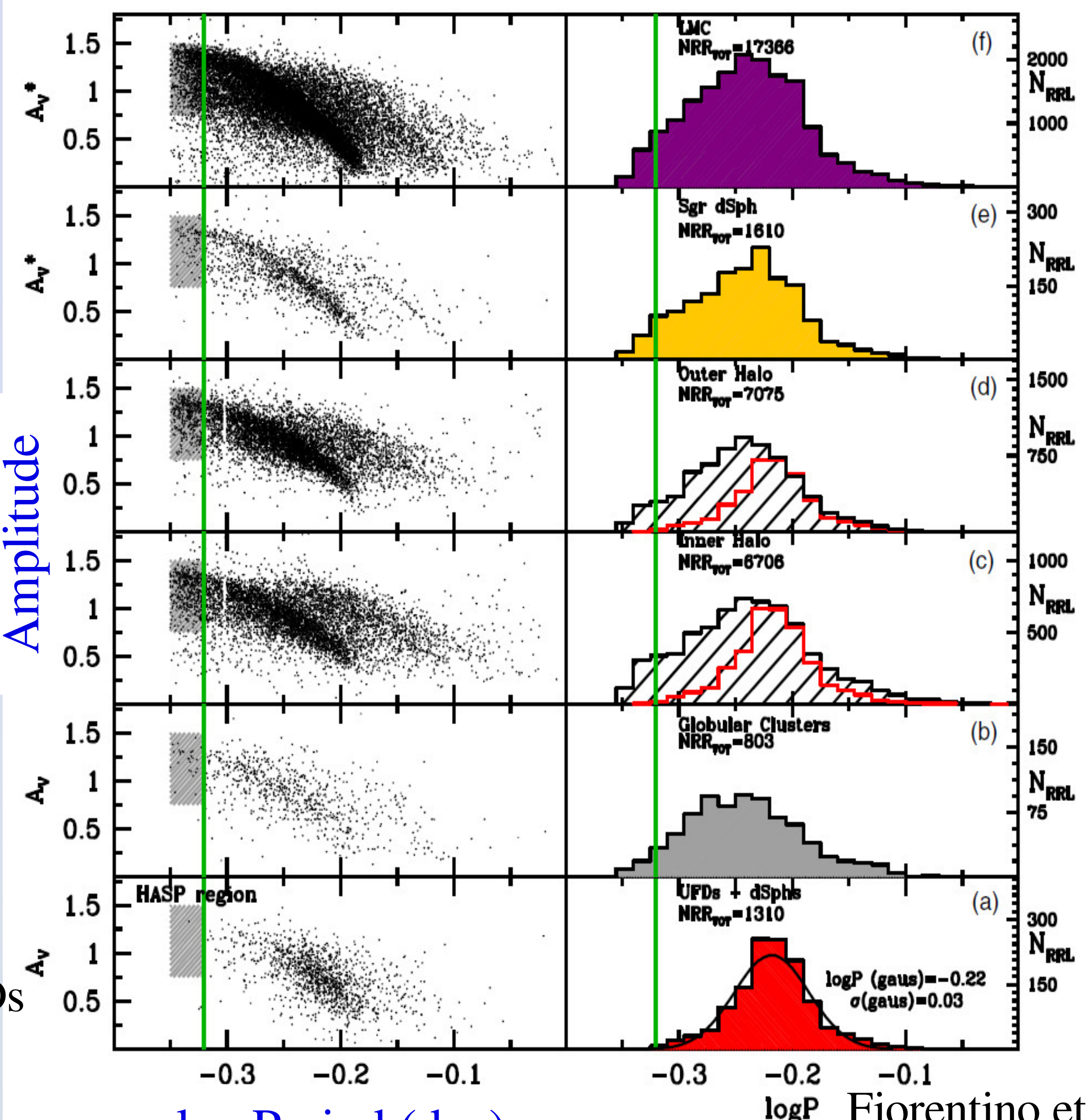
RR Lyrae stars

- Pulsating stars on horizontal-branch
- > 10 Gyr old
- Robust distance estimators
- Reddening-free parameters: period & amplitude
- Present in most environments

LMC RR Lyrae stars



RR Lyrae properties in various environments



Amplitude

log Period (day)

LMC

Sagittarius

Outer halo

Inner halo

Globulars

dSph

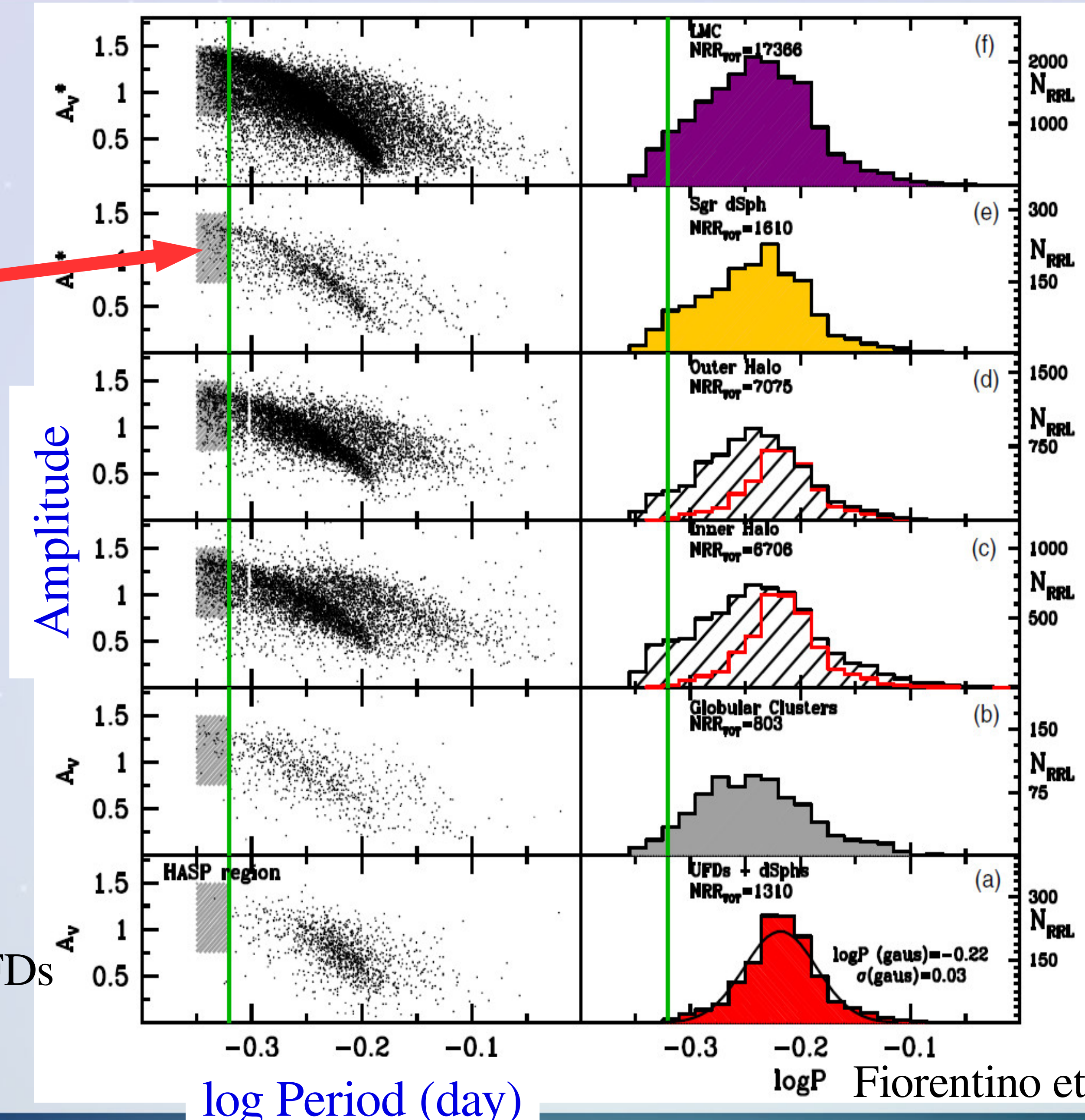
Draco, Carina, Sculptor,
Leo I, Cetus, Tucana + UFDs

Fiorentino et al. 2015

RR Lyrae properties in various environments

HASP:
High-amplitude
Short-period

P < 0.48 day
~ 6-8 %

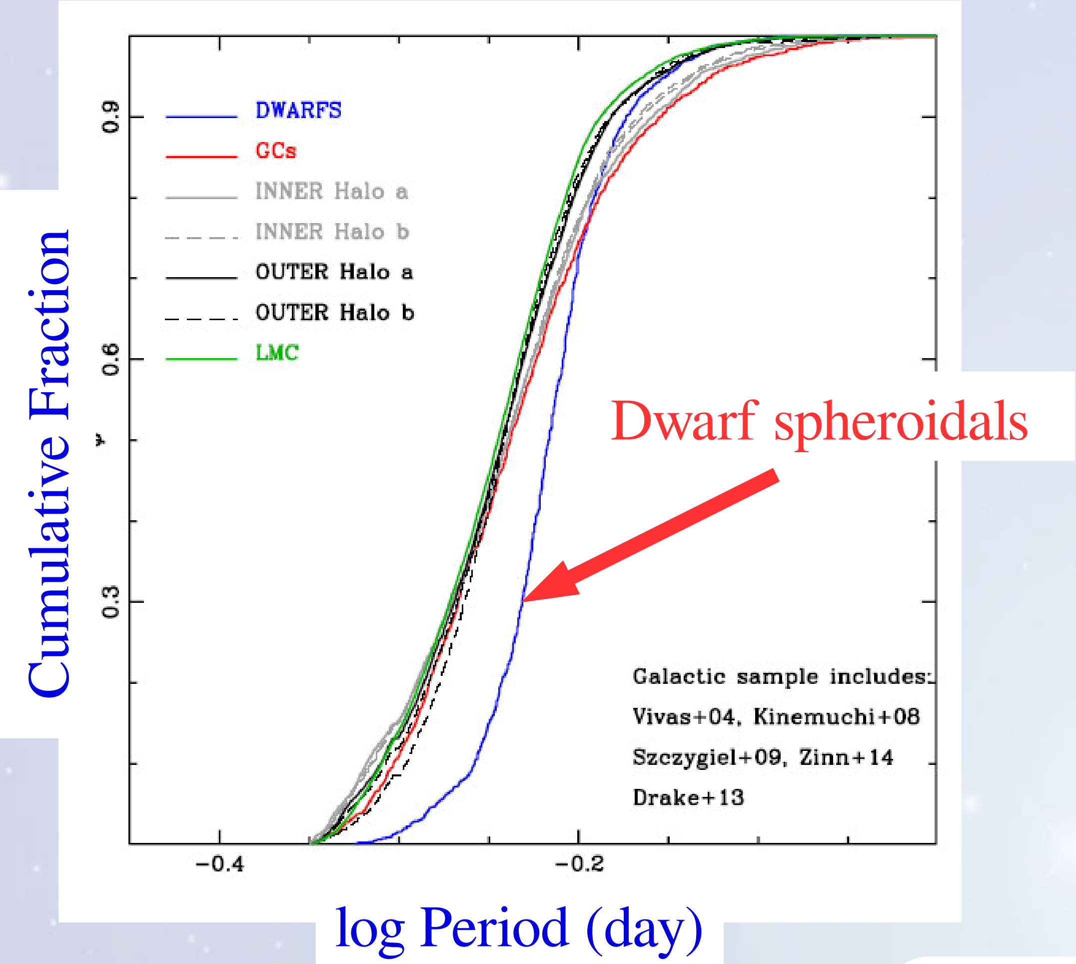


LMC
Sagittarius
Outer halo
Inner halo
Globulars
dSph

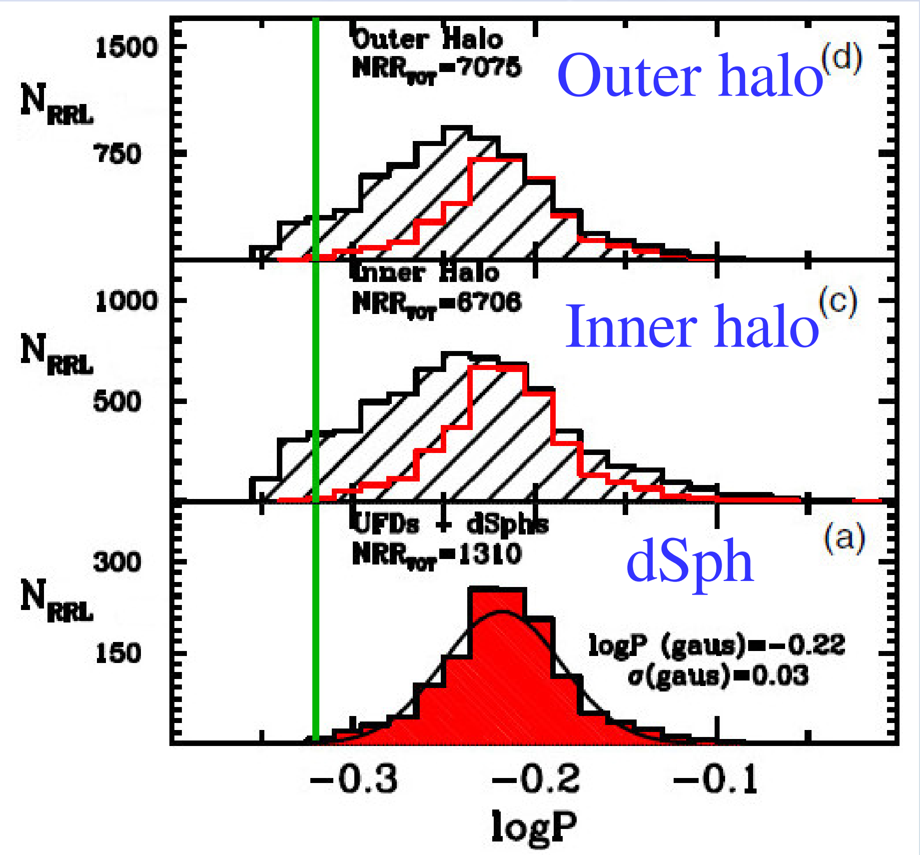
Draco, Carina, Sculptor,
Leo I, Cetus, Tucana + UFDs

Fiorentino et al. 2015

Lack of HASPs in dSph is very significant



Stetson et al. 2014



Fiorentino et al. 2015

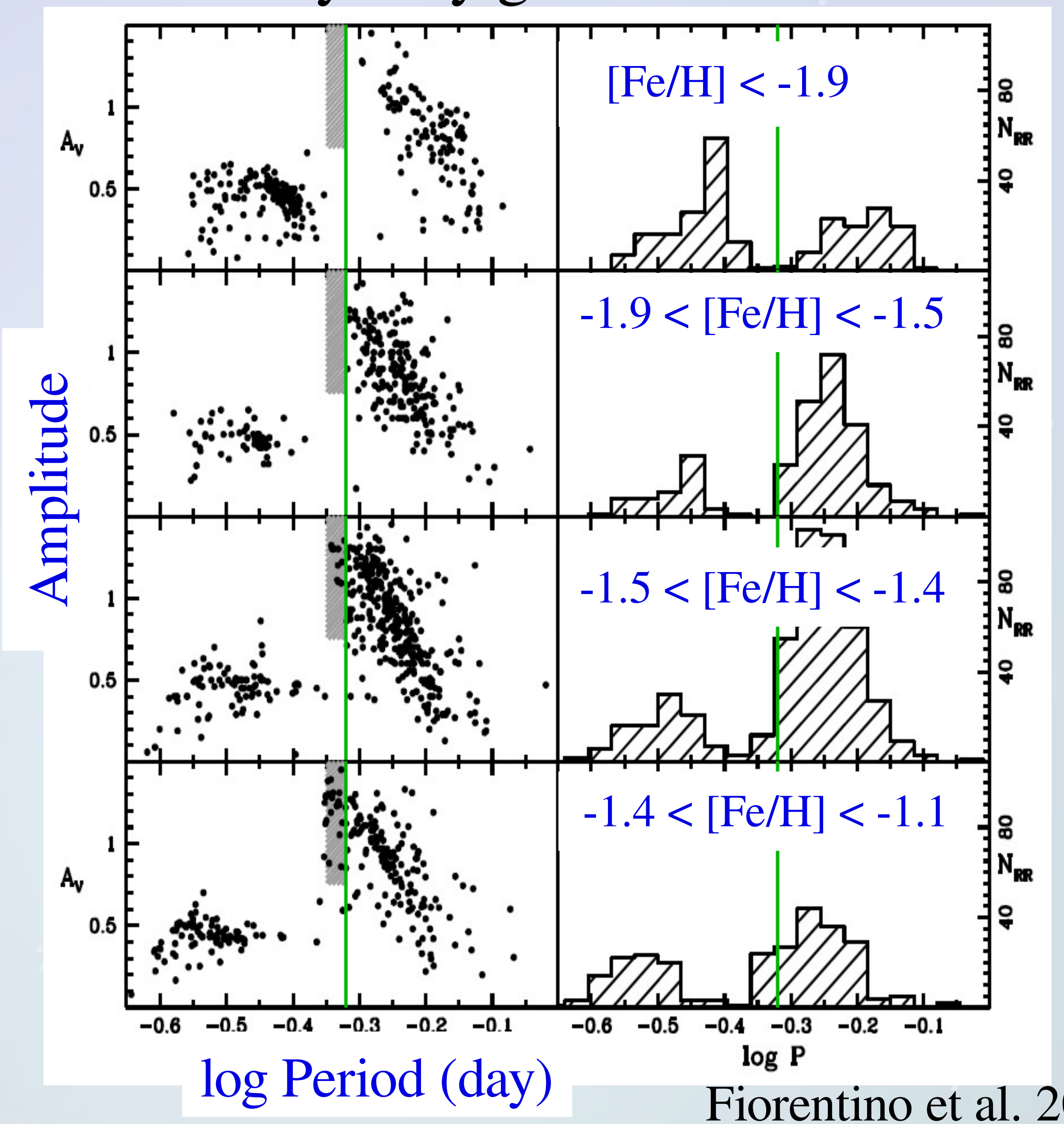
Galaxies similar to present day dSph have only contributed ~10-20% of the halo stellar mass

Origin of the HASP?

- Shorter period with increasing metallicity

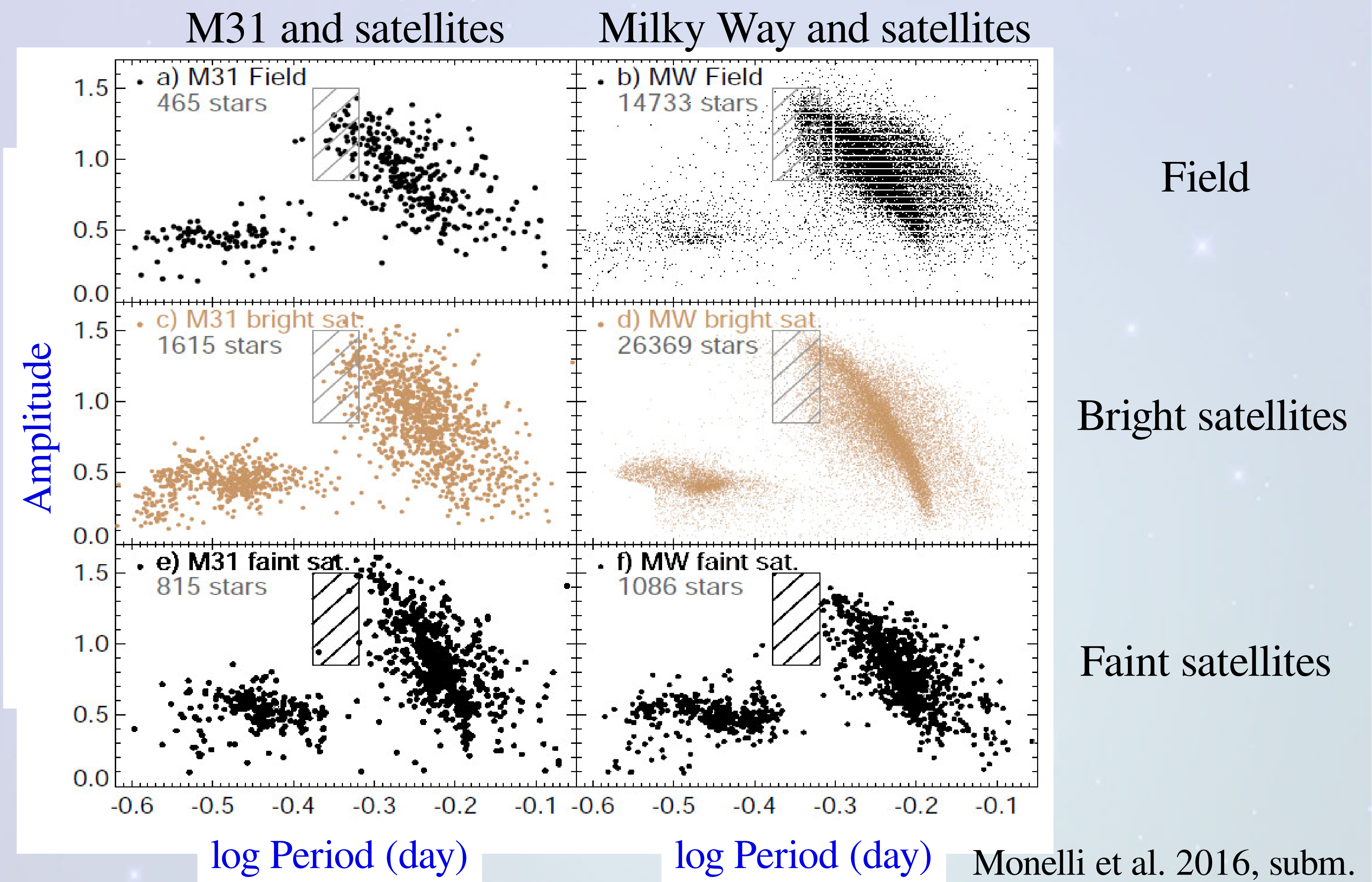
HASPs come from progenitors sufficiently massive to enrich to [Fe/H] > -1.5 by redshift ~2

Milky Way globular clusters



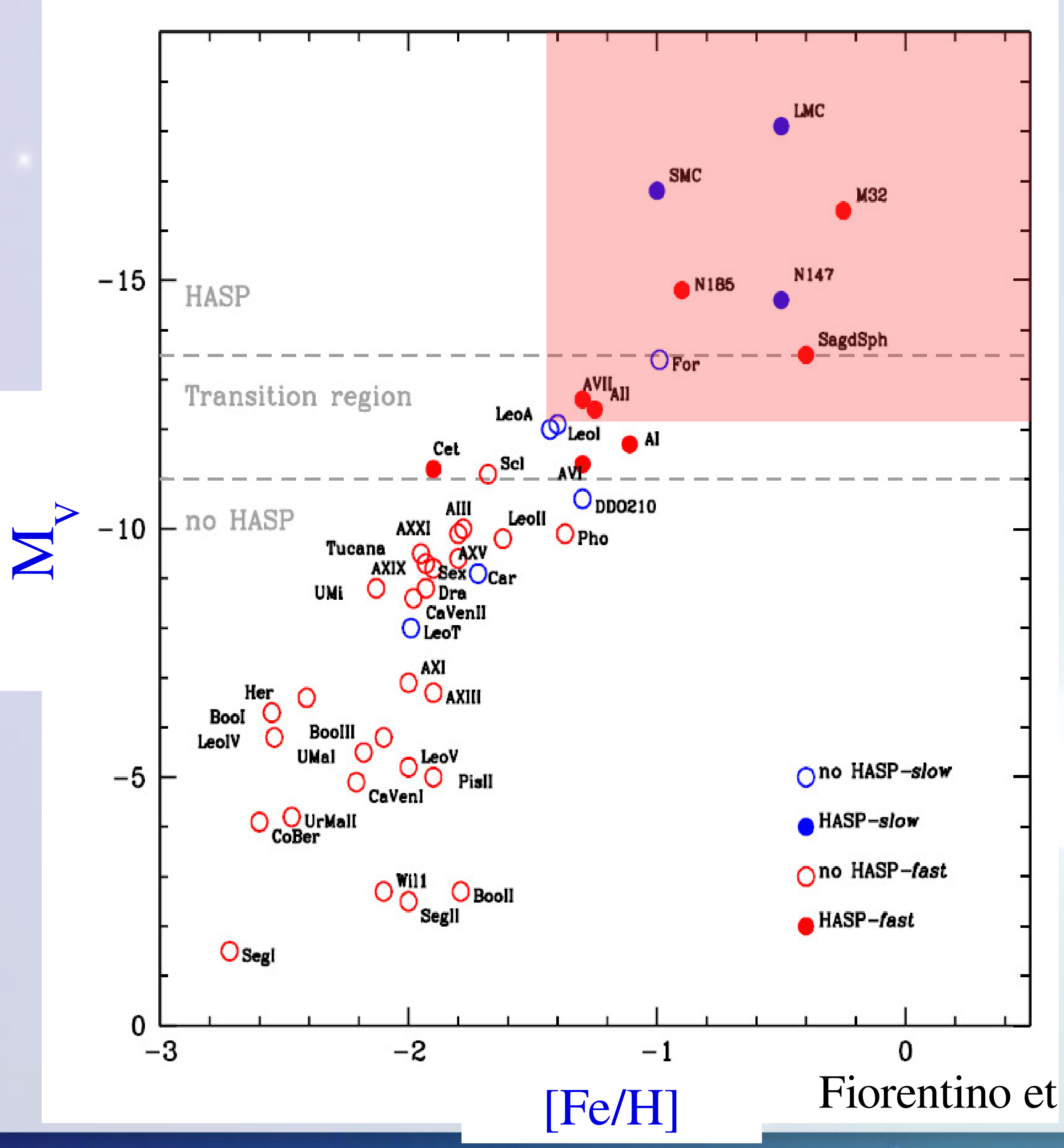
Fiorentino et al. 2015

Comparison between M31 and the Milky Way



Monelli et al. 2016, subm.

Summary of Part I



Fiorentino et al. 2016, subm.

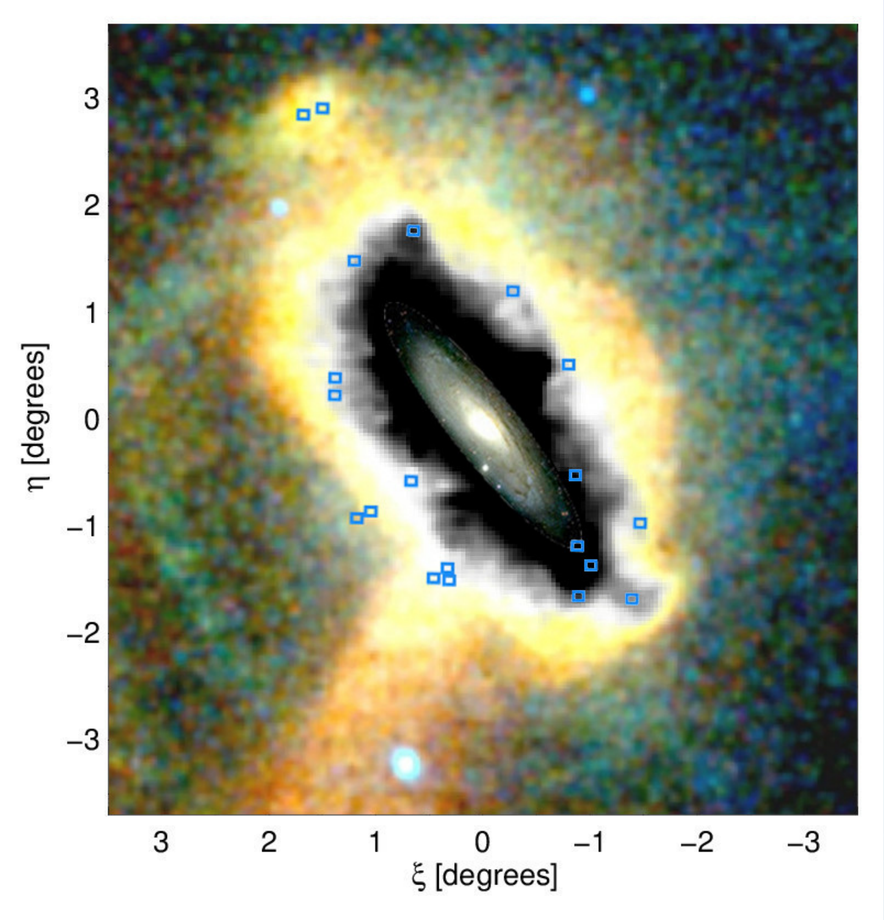
- galaxies similar to present day dSph did not have a dominant role building the halo (<20%)
- halo mainly built from few massive progenitors (M_V < -12)
- see also Bullock & Johnston 2005, Kirby et al. 2015: [C/Fe], Deason et al. 2015: BSS-to-BHB ratio, talk by A. Recio-Blanco

Part II:

Origin of the substructures in the inner halo of M31

Deep HST survey of the Andromeda outskirts

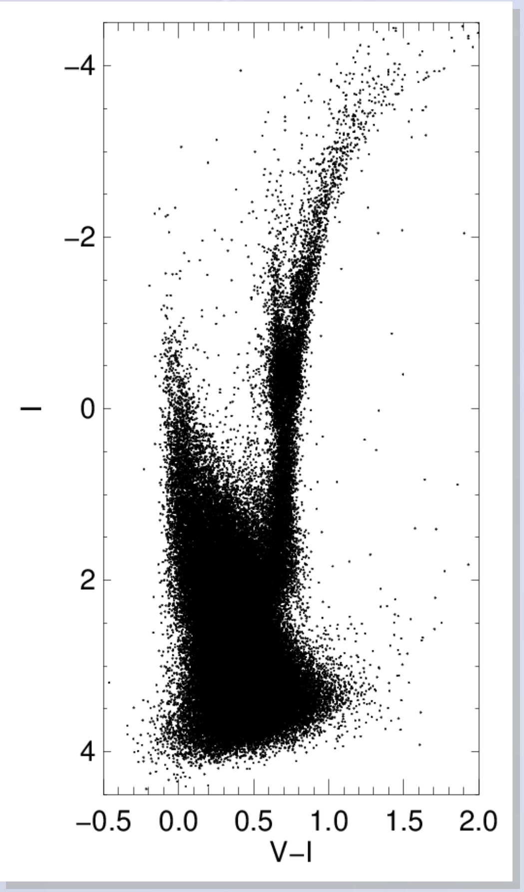
Stellar density around Andromeda
+16 HST fields (73 orbits)



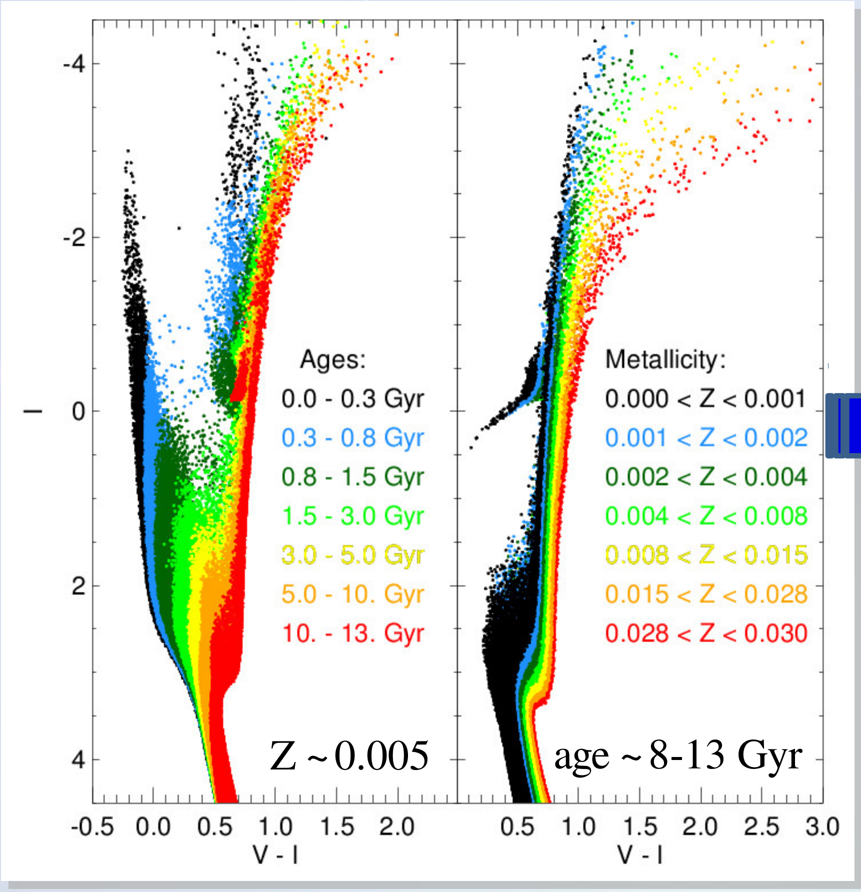
- 16 fields observed with the *Hubble Space Telescope*
- 13 kpc < R_{proj} < 45 kpc
- Substructures:
  - 14 fields
  - 3 orbits per pointings
- Outer disc
  - 3 fields
  - 10-13 orits per pointings

Quantifying the star formation history: Color-magnitude diagram fitting

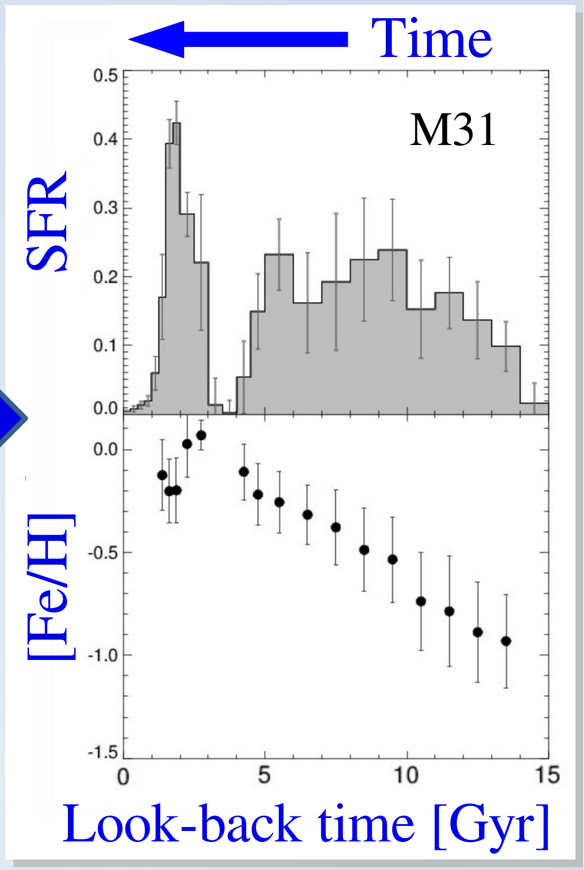
Observations



Stellar evolution models



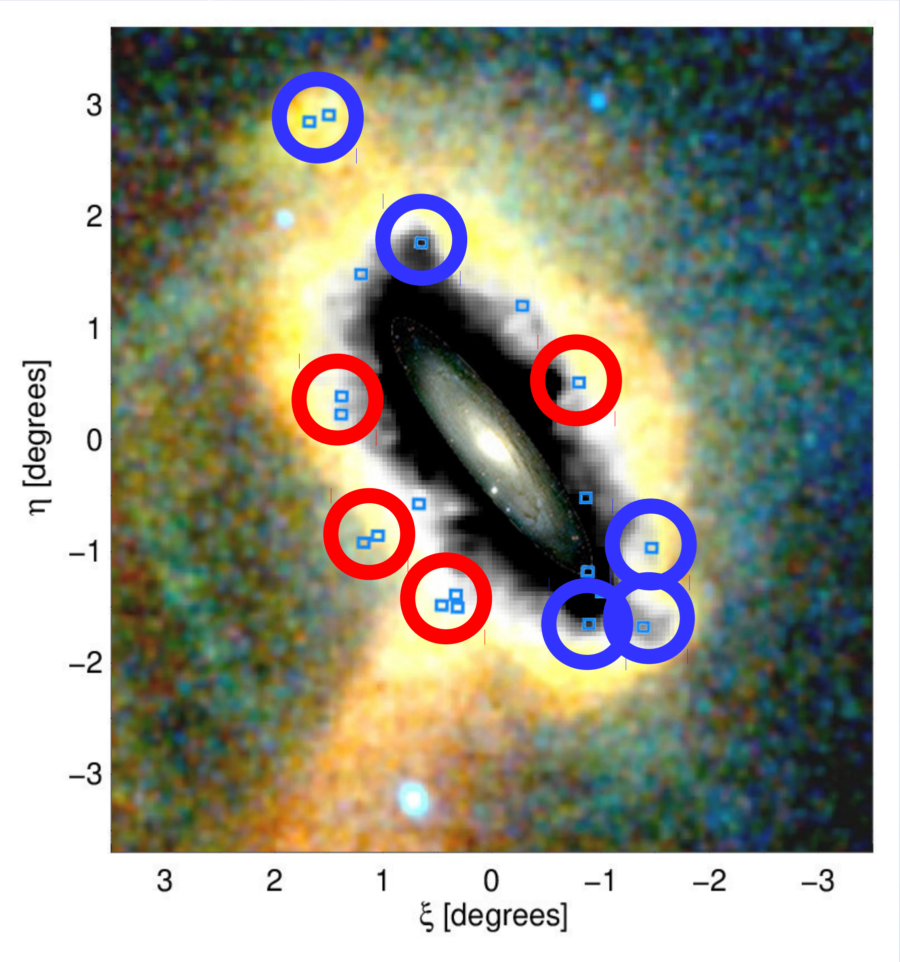
Star formation history



- Estimate the age and metallicity with an accuracy of 10-20%

The nature and origin of the substructures

(Bernard et al. 2012, 2015a, 2015b)

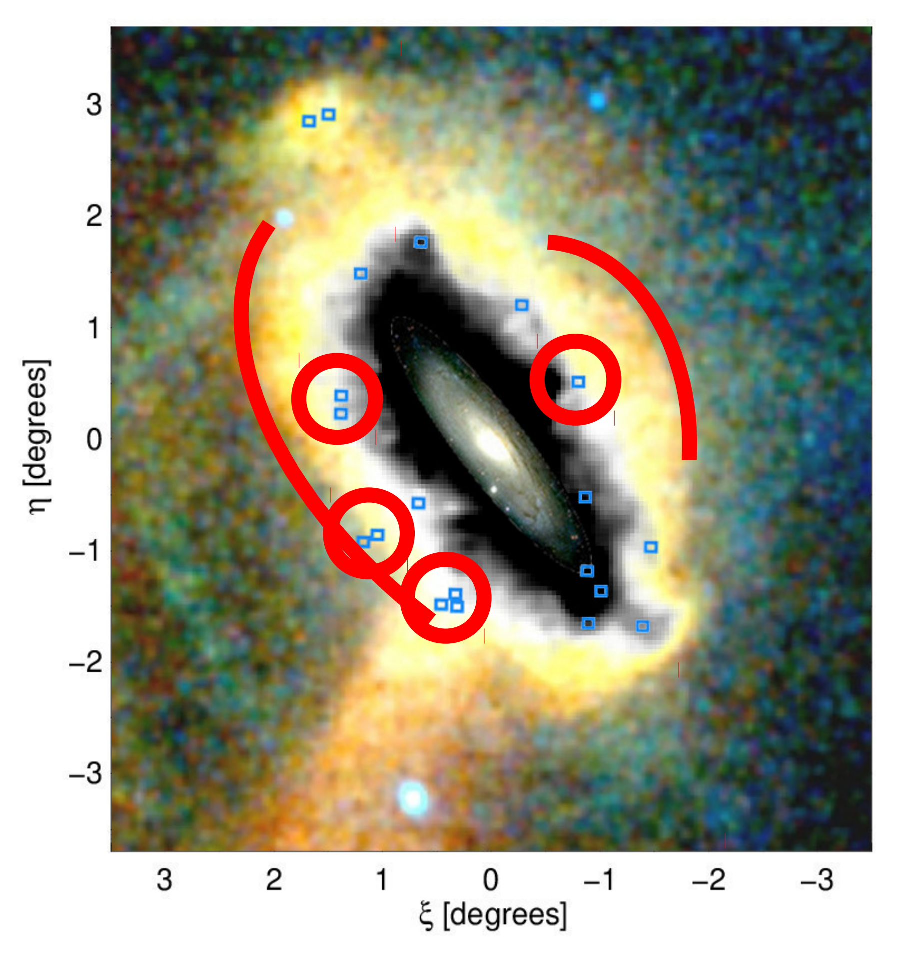


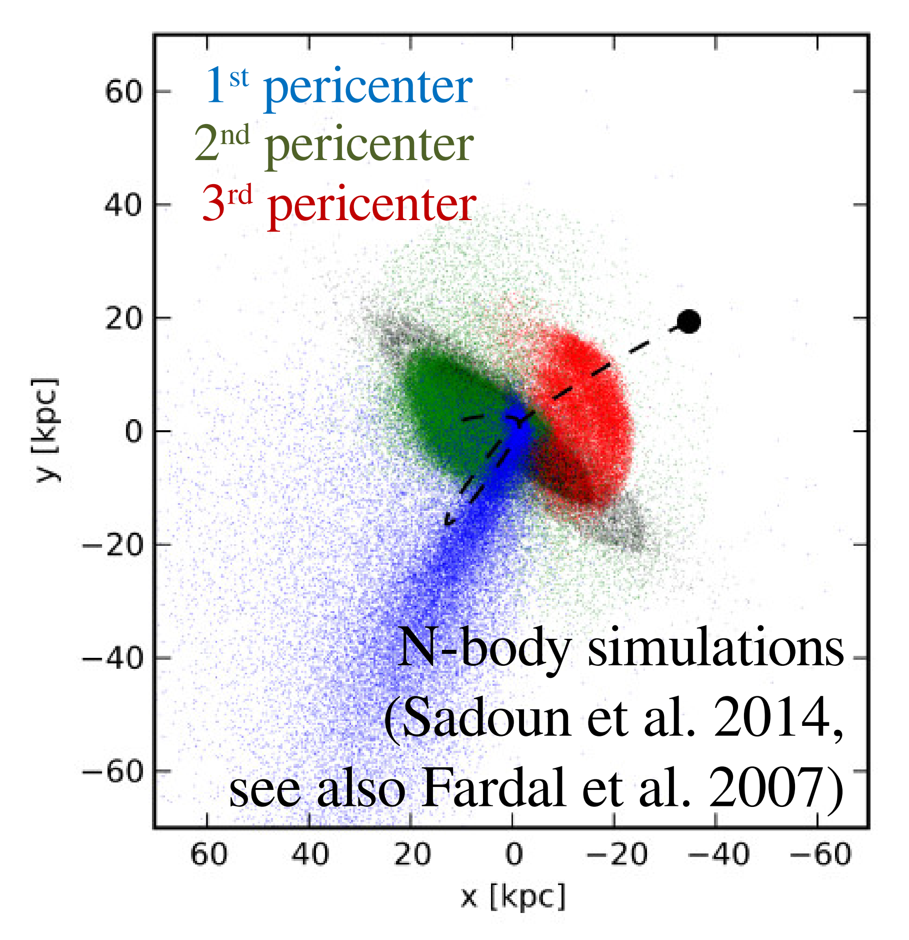
Two main origins for the substructures:

- Debris from the Giant Stellar Stream (red circles)
- Debris from the disc (blue circles)

The nature and origin of the substructures: stream-like fields

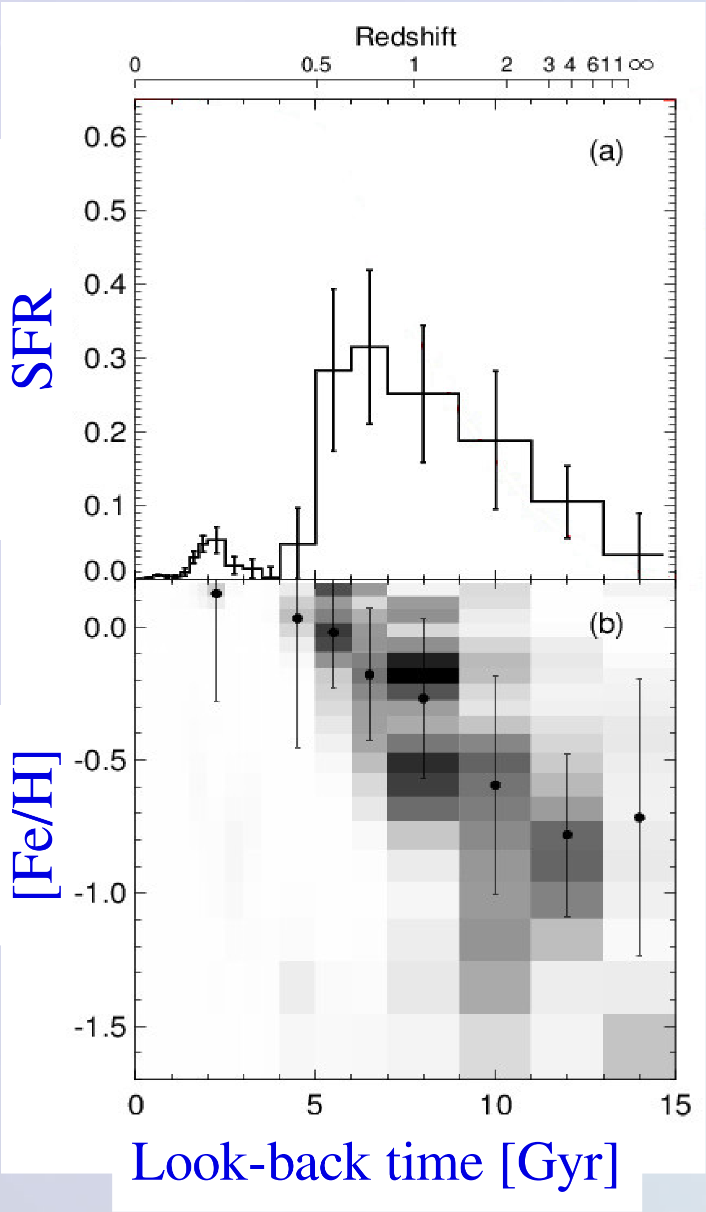
(Bernard et al. 2012, 2015a, 2015b)





The northeast and western shelves are debris from the GSS

The progenitor of the Giant Stellar Stream

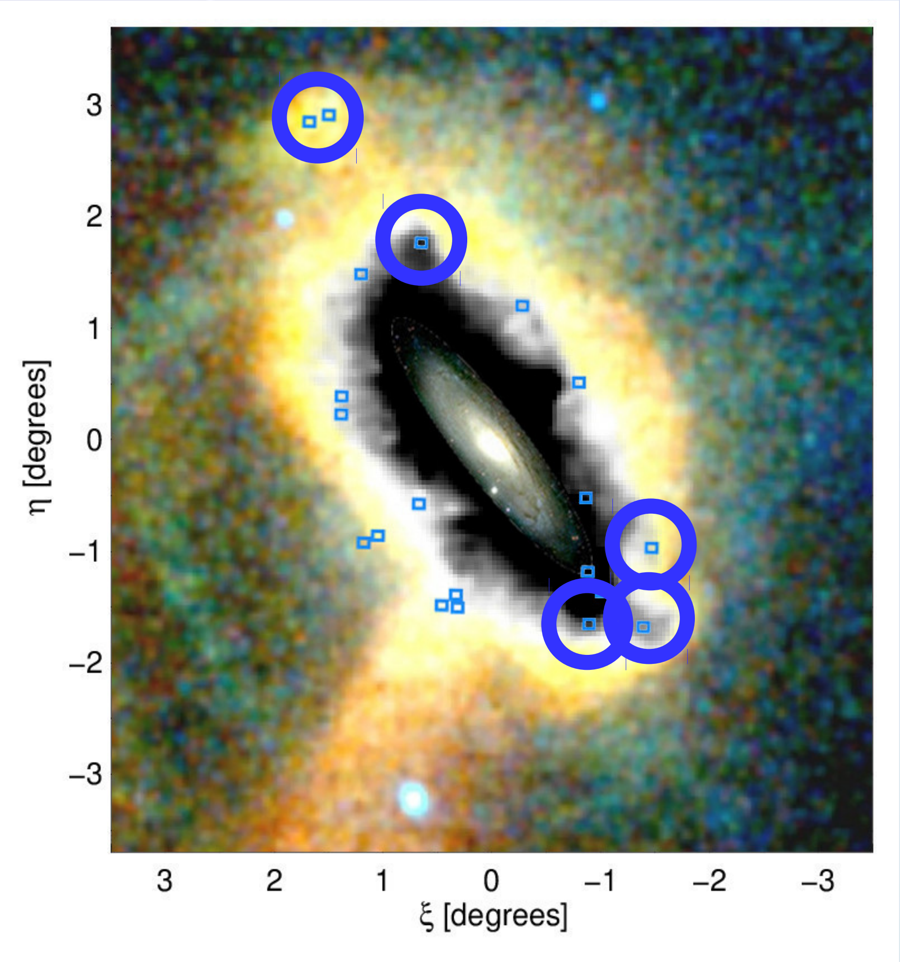


- No star formation in the past ~5 Gyr
- No gas associated with the Giant Stream (e.g. Lewis et al. 2013)
- Fast chemical enrichment, typical of dense stellar systems

Progenitor was a dwarf elliptical (or a bulge)

The nature and origin of the substructures

(Bernard et al. 2012, 2015a, 2015b)



- Fields dominated by material from the thin disc, rather than accreted stuff
- Kinematics evidence of disc stars in the halo (e.g. Dorman et al. 2013)
- Disc kinematics out to R~70 kpc (Ibata et al. 2005)

Inner halo contains many stars
Kicked-out from the disc

Summary of Part II

- Origin of the inner halo substructures:
  - Stream-like fields dominated by debris from the GSS progenitor
  - Disc-like-fields: AMR/dynamics indicate material from the disc
- Giant Stream AMR consistent with elliptical progenitor

Work in progress:

- Application of CMD-fitting technique to the Milky Way components and substructures using *Gaia* parallaxes