Towards Galactic Archaeology with PFS
PFSによる銀河考古学に向けて

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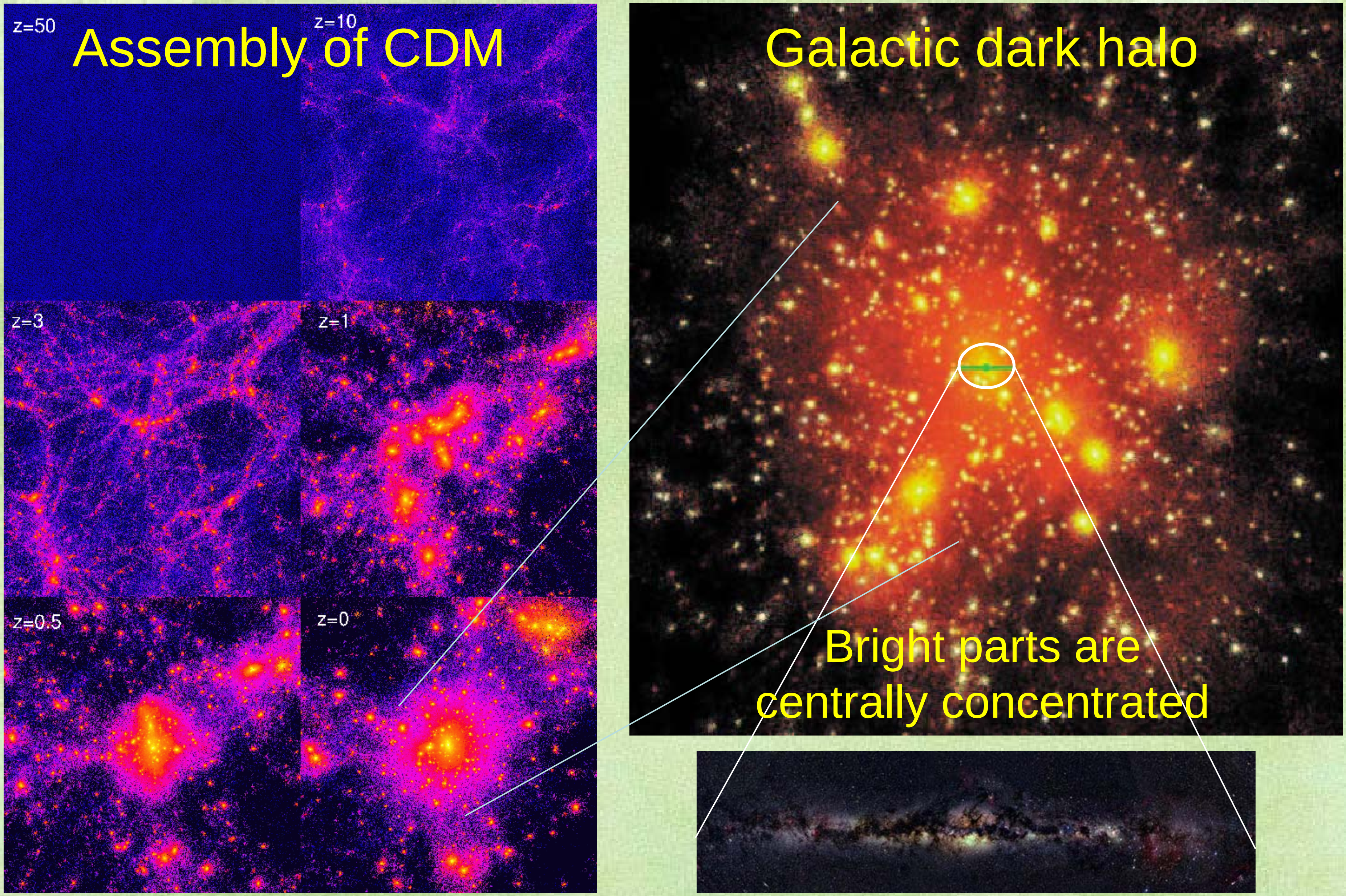
Galaxy formation in CDM paradim



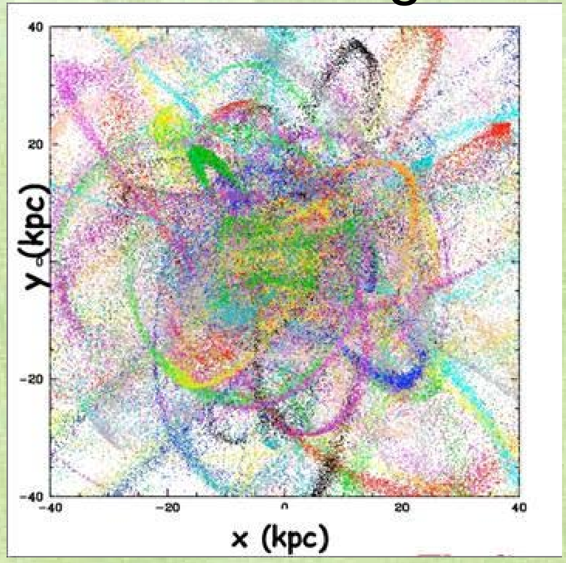
Main issues in GA

1. Formation of Galactic structures
   - ✓ Merging history of the Milky Way?
   - ✓ Formation process of each Galactic component?
   - ✓ Is MW different from M31? If so, why?
2. Nature of galactic dark matter
   - ✓ Missing satellites problem?
   - ✓ Properties of luminous satellites? How many there?
   - ✓ Dark matter profiles? Cuspy or cored?

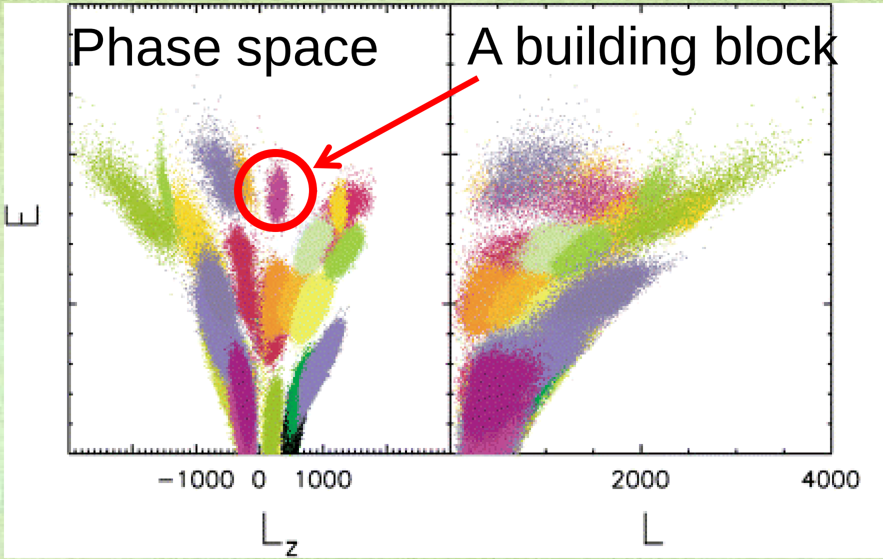
All are recorded in old stellar populations

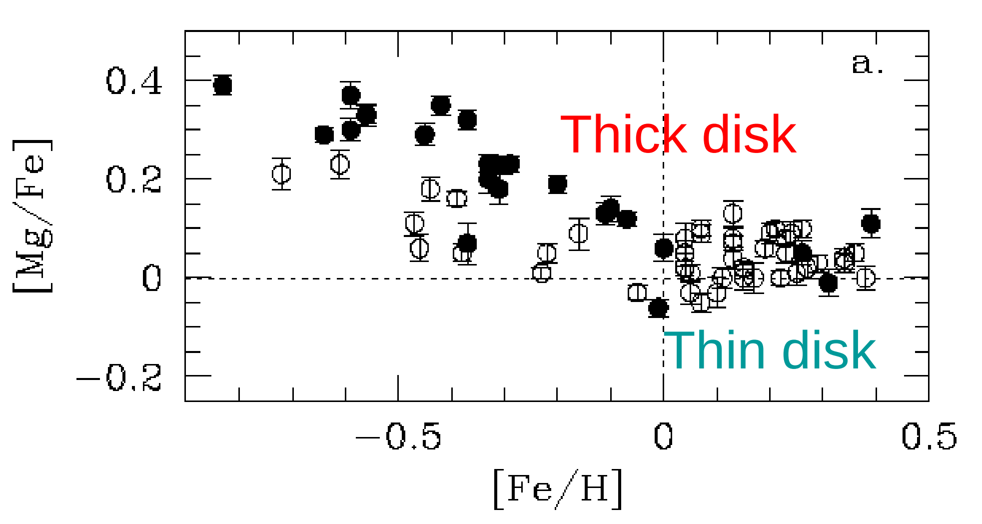
Fossil records of galaxy formation

Debris of building blocks



- Space and velocity distributions of ancient stars
  - ✓ Past collapse and merging events
  - ✓ Tracer of dark matter profiles
- Chemical abundance of ancient stars
  - ✓ Star formation and chemical evolution



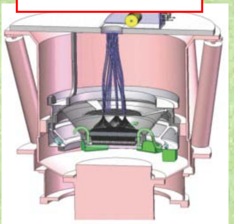


Galactic astronomy through resolved stars

- Photometry :
  - ✓ mag., color (→ color-mag. diagram)
- Spectroscopy :
  - ✓ metallicity (→ age), V_{rad} (kinematics)
  - ✓ abundance pattern (→ SF & chemical evol.)
- Astrometry :
  - ✓ proper motion, distance (→ 6d phase space)

HSC (+SDSS)

PFS

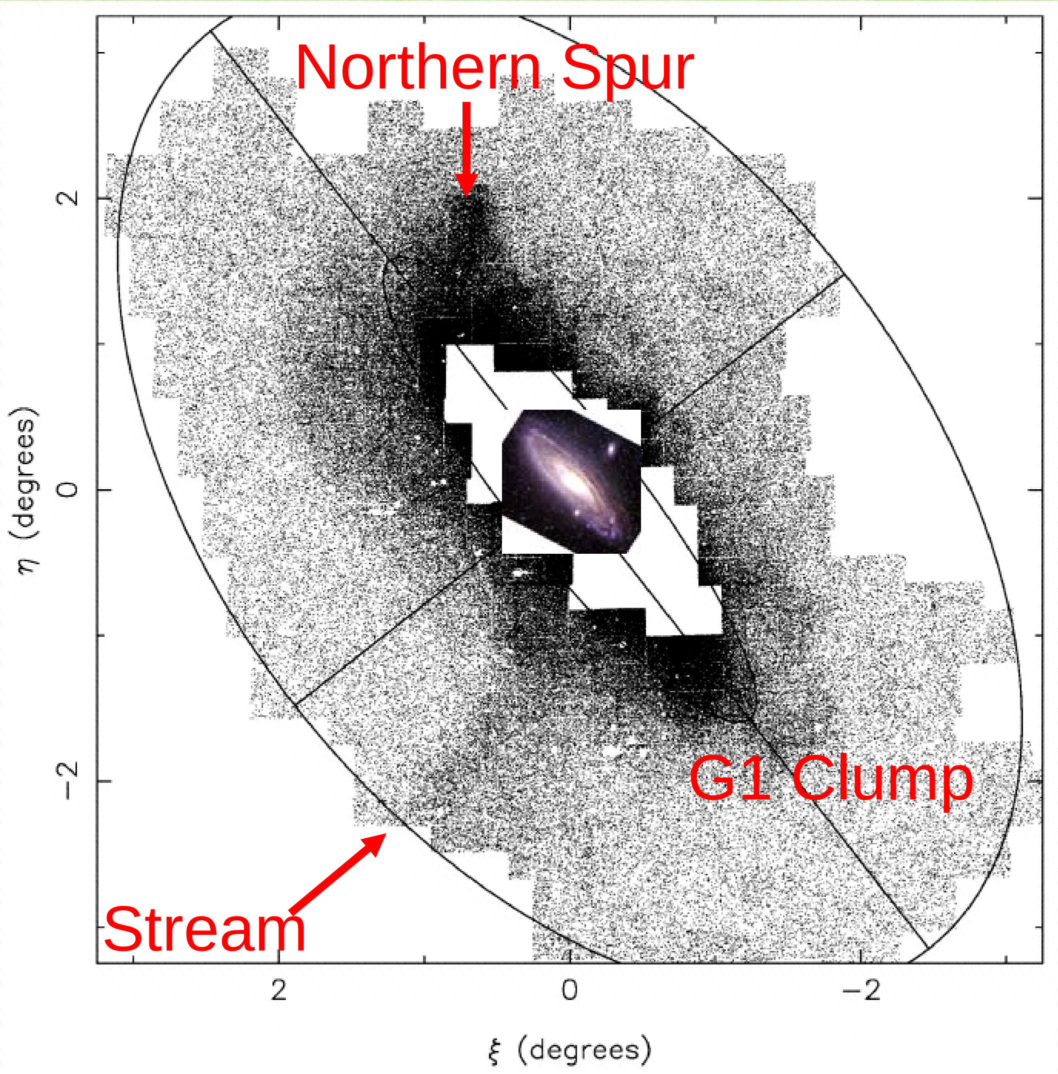


Gaia

Structure, dynamics, star formation and chemical evolution

⇒ galaxy formation and evolution

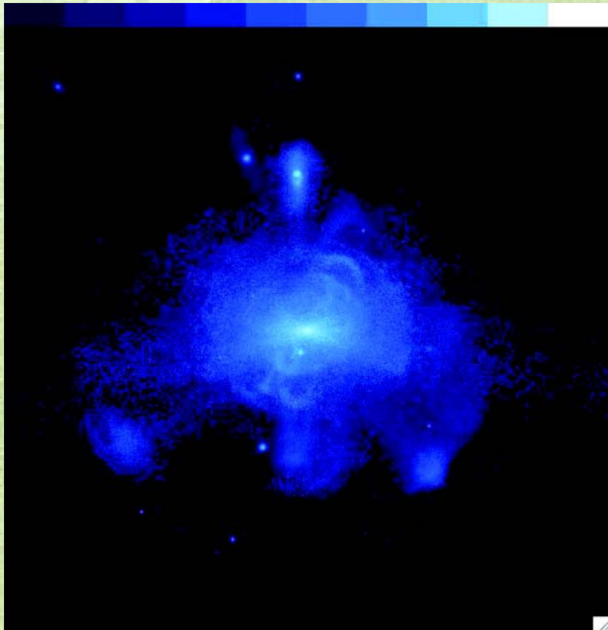
Substructures in the M31 halo

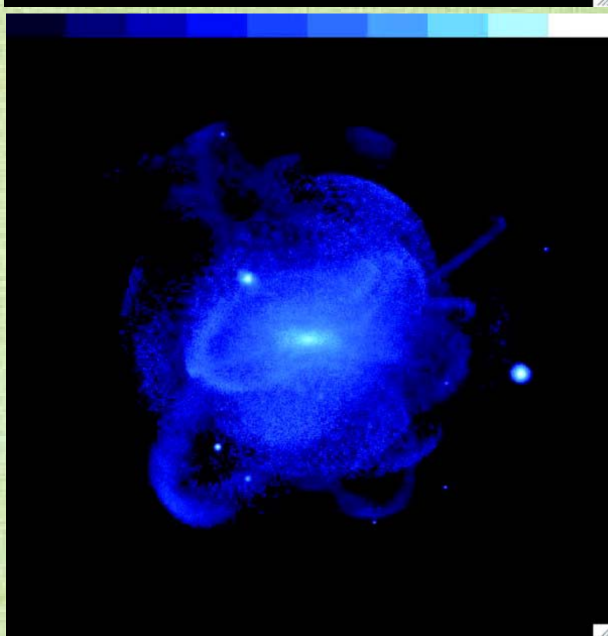


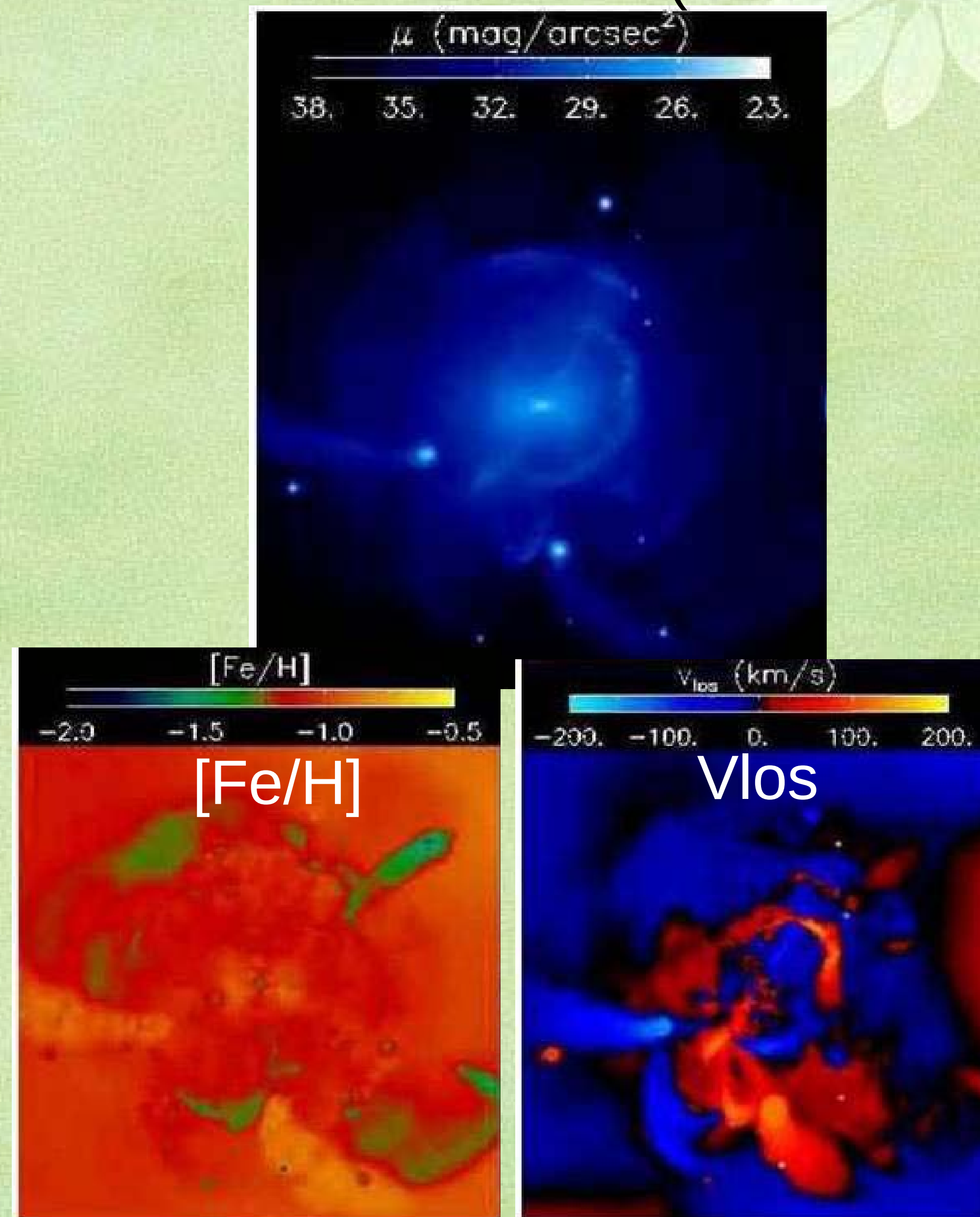
Ferguson+02

Several stellar halos in CDM models

(Johnston+08)

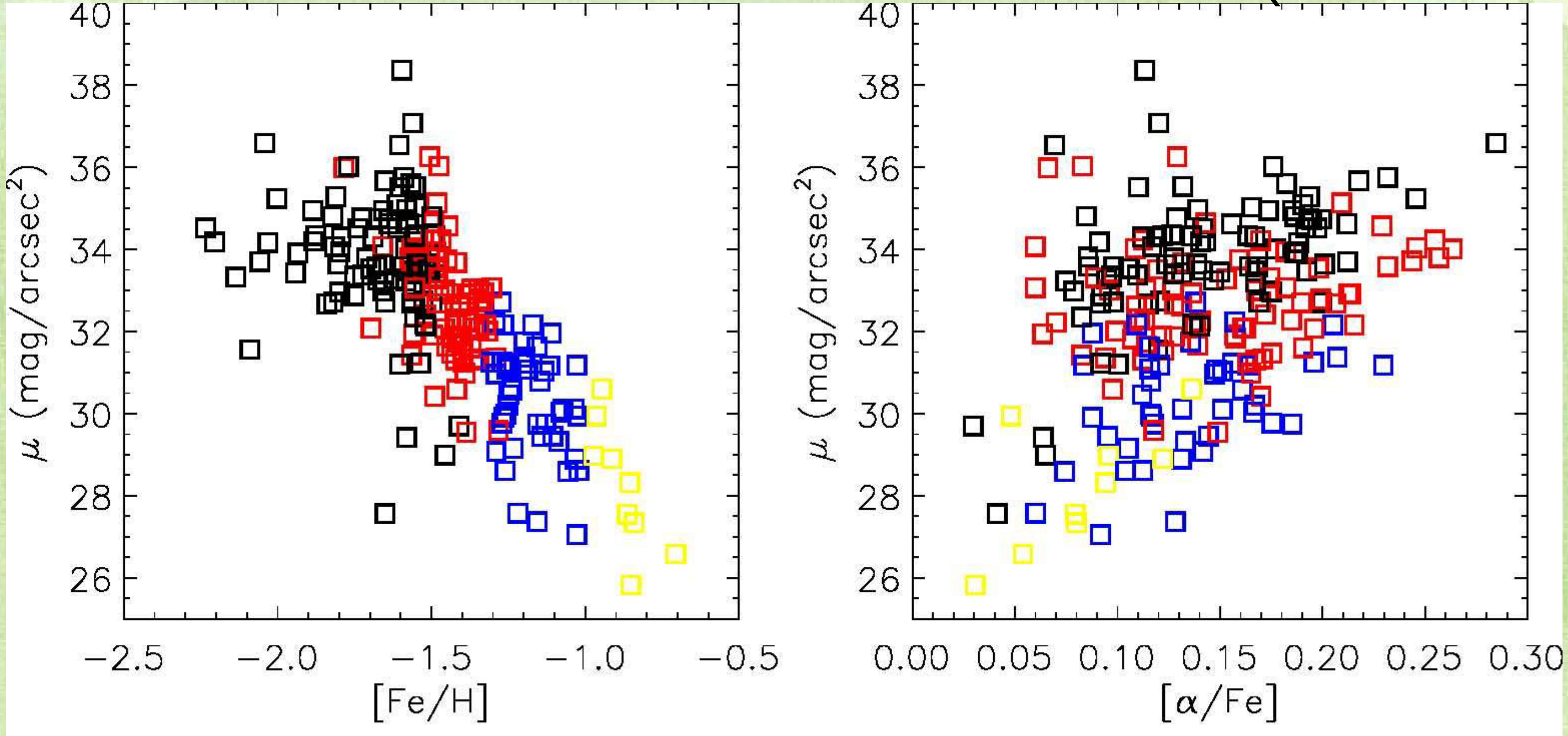






Extracting merging history in M31

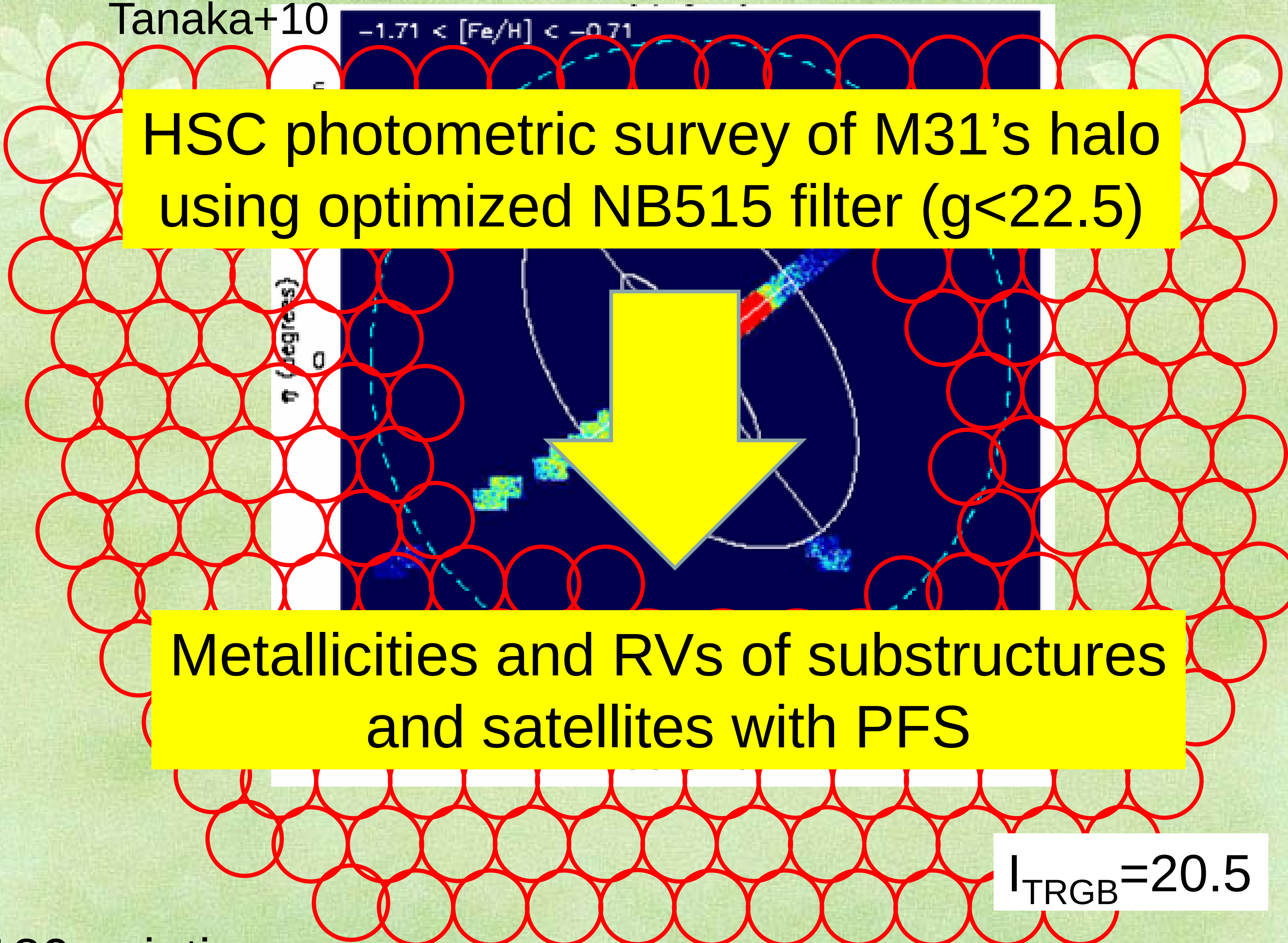
(Johnston+08)



Identify and count the number of streams delineated by μ, [Fe/H], and V_{rad}
⇒ Probability distribution of streams

Tanaka+10

HSC photometric survey of M31's halo using optimized NB515 filter (g<22.5)

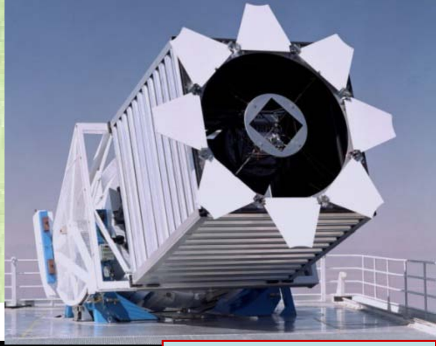


Metallicities and RVs of substructures and satellites with PFS

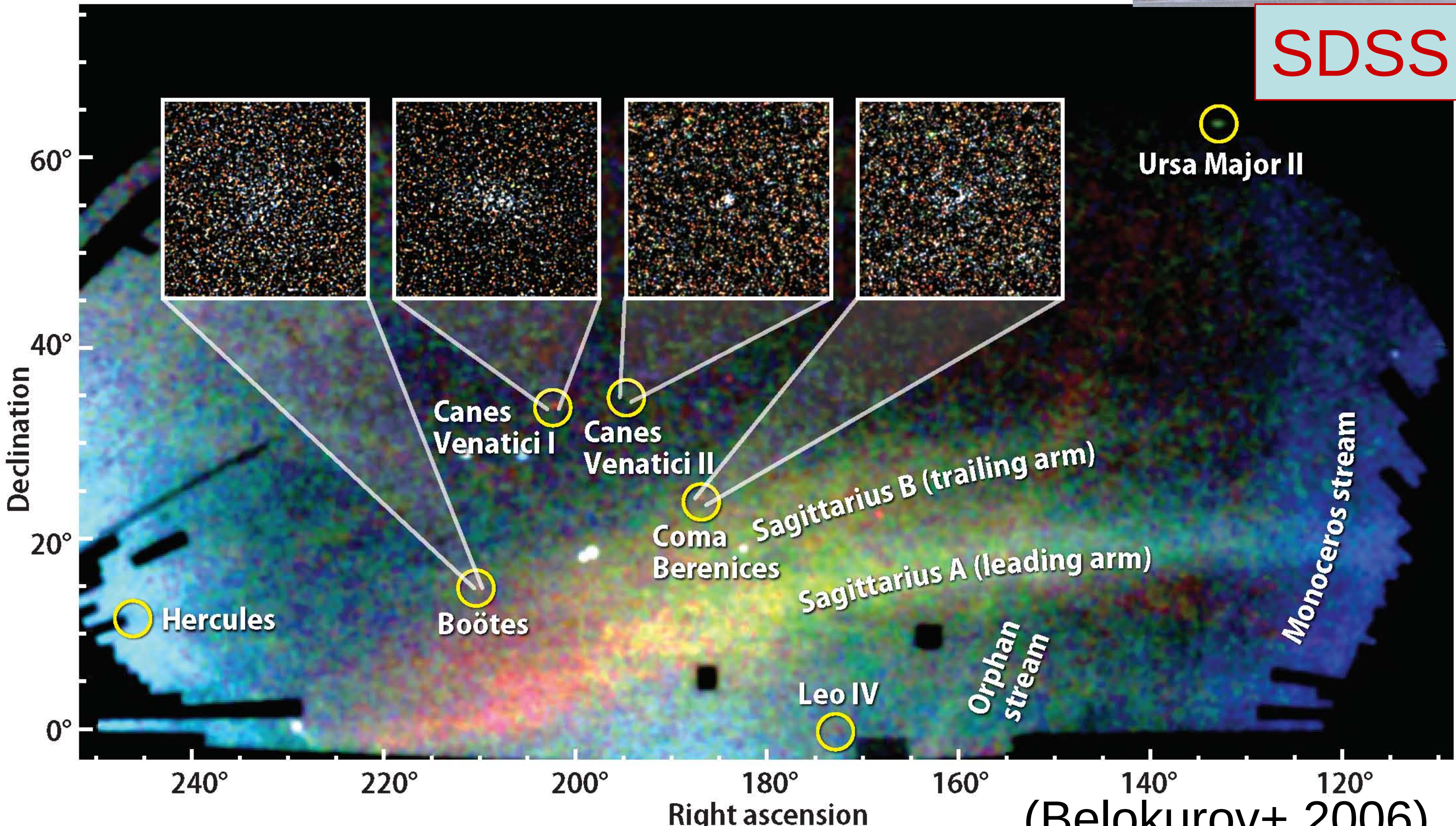
I_{TRGB}=20.5

180 pointings

Substructures in the MW halo (tidal debris of building blocks)

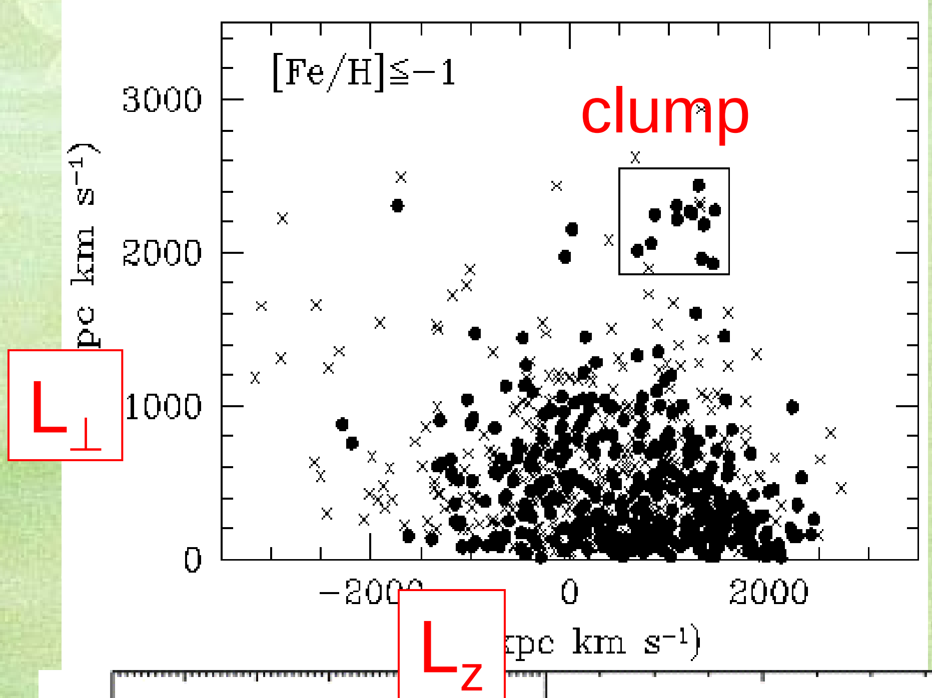


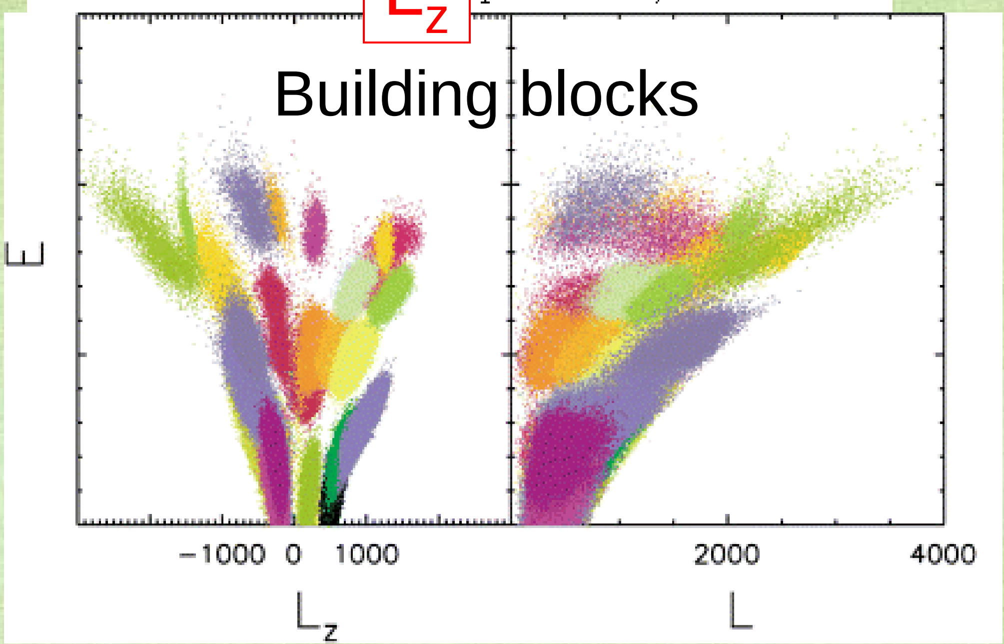
SDSS



(Belokurov+ 2006)

Extracting merging history in MW





Metal-poor stars in angular momentum space (Hipparcos sample)

- measurement error of a few 100 (kpc km/s) smears out substructures

Astrometry with *Gaia*

precise distances and proper motions

- resolves each of substructures (Building blocks of the stellar halo)

Gaia

Cf. Hipparcos
V<12, 1mas

Astrometry:
- V=15, 12~25 μas
- V=20, ~300 μas

Photometry:
- V < 20

RV measurement:
- <u>V < 17 (150M stars)</u>
- R~10000,
- λ=8450-8750A (CaT)
- ΔV_{rad}~15 km/s

[Fe/H] measurement:
- <u>V<13</u>

Constraints on accretion time of a satellite

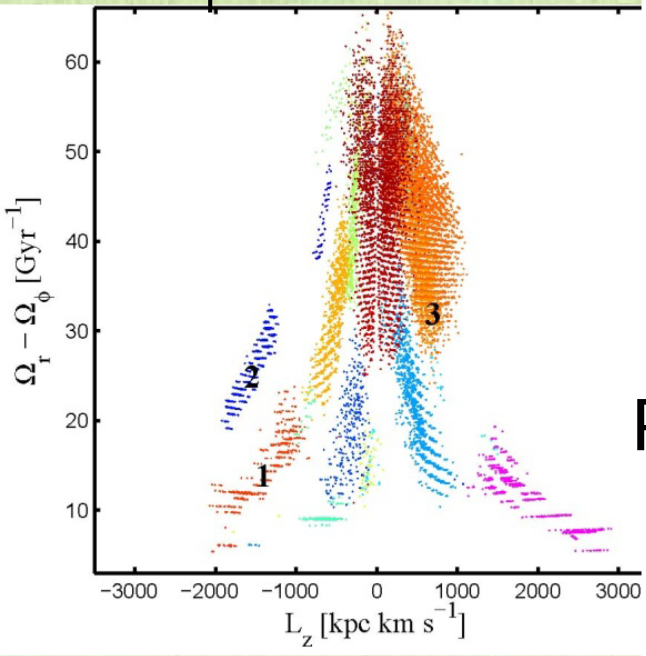
(McMillan & Binney 2008, Gomez et al. 2010)

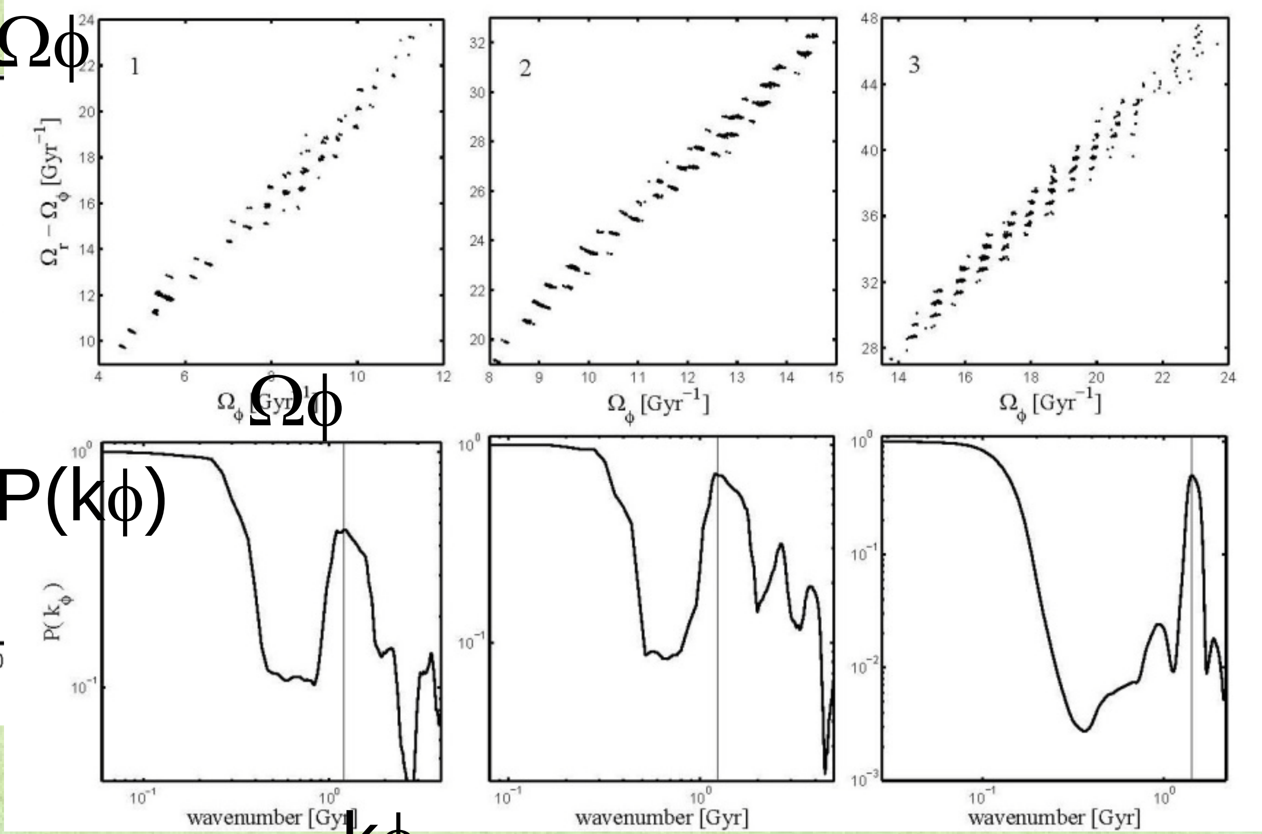
⇒ Extracting merging history in the MW

Orbital freq.

Ωr-$\Omega\phi$

Ωr-$\Omega\phi$





$\Omega\phi$

$P(k\phi)$

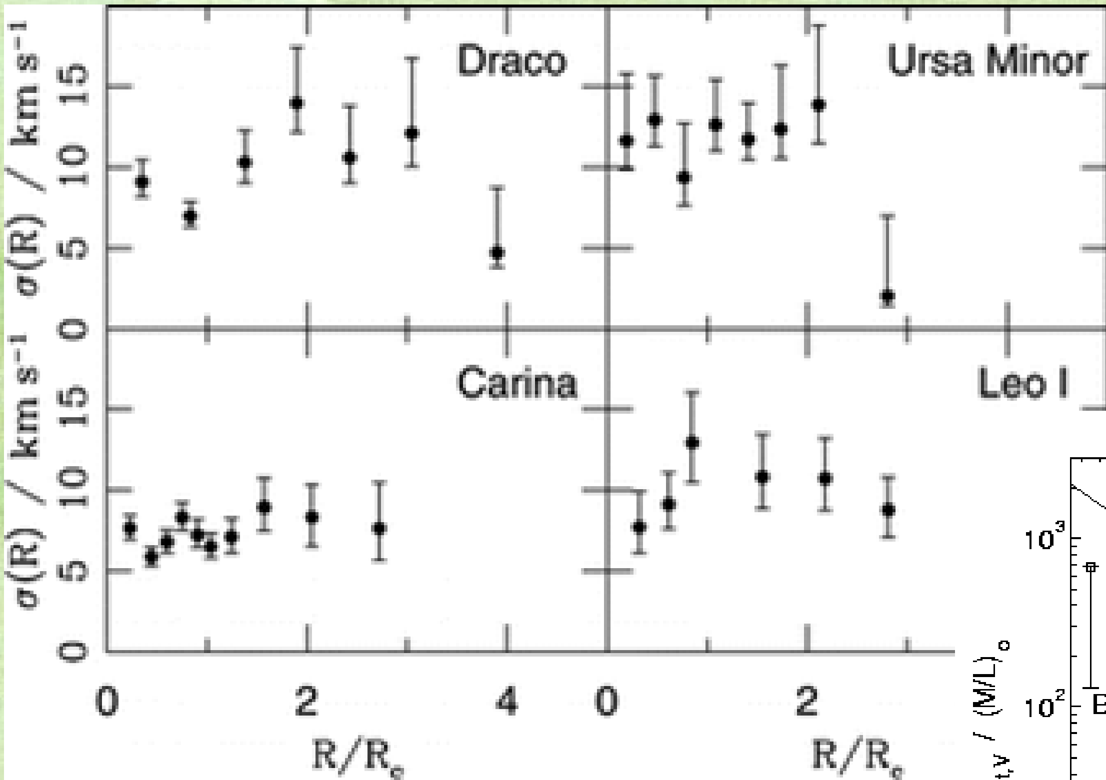
Lz

$k\phi$

7.9 Gyr 8.9 Gyr 7.6 Gyr

DSphs as ideal sites for DM study (via. velocity dispersion profiles)

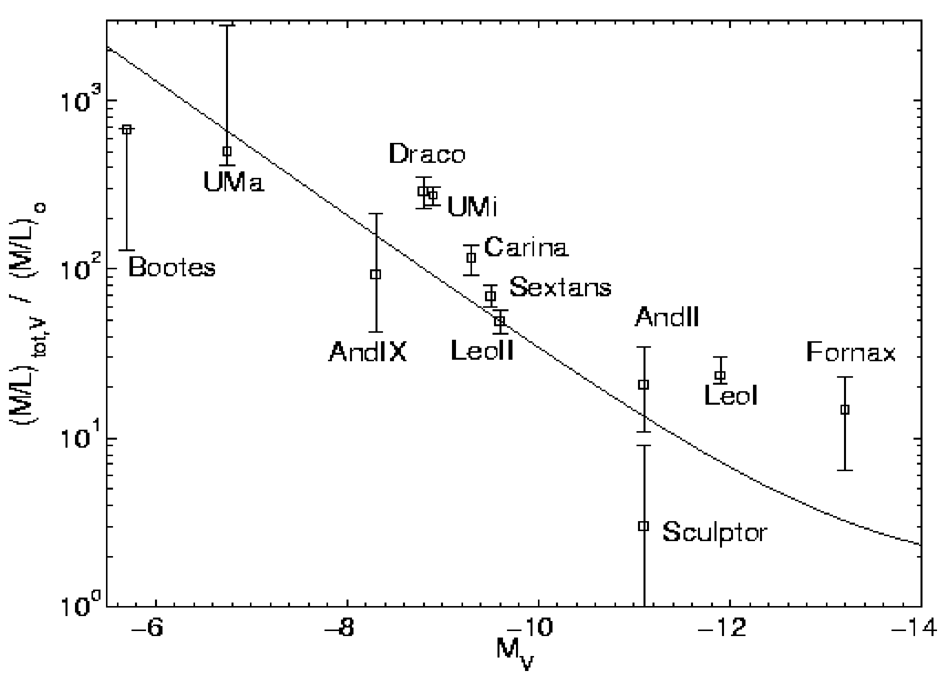
Gilmore+07



σ ~ a few to 10 km/s

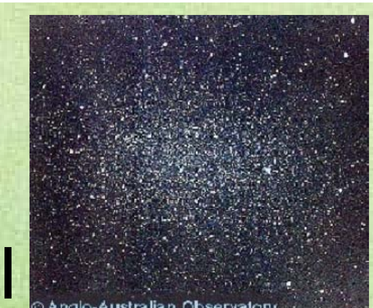
<u>DM dominated</u>

Cuspy or core?

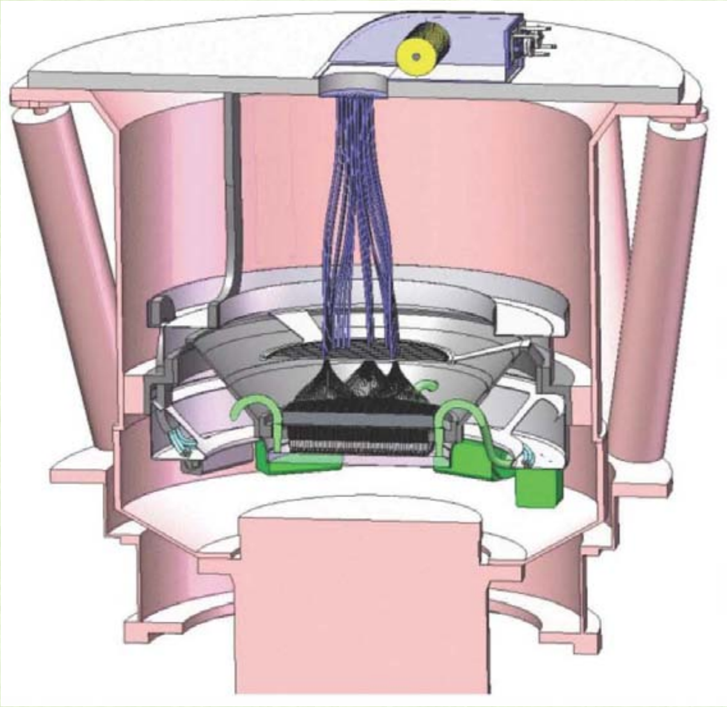


Car

Leo I



PFS
(Prime Focus Spectrograph)



FOV: 1.77 sq deg
(1.5 deg diameter)
2400 to 3000
fiber positioners
40 sec reconfig. time
λ: 600~1000nm +more?
R: 3000 +more?

Requested performance of PFS

1. Ability to measure RVs and [Fe/H] for many stars at the same time
   - Best synergy with Gaia, i.e., 15<V<20
   - Enable to determine σ of dSphs and streams accurately, i.e., $\Delta V_{rad} < 2$ km/s
   - Enable to observe M31 stars with $I_{TRGB}=20.5$, i.e., $V_{lim} \sim 21.5$
2. Ability to follow up high-res. spectroscopy for reasonable number of stars at the same time
   - R=3-40000, λ<9000A, a few 100 fibers, V<17

WFMOS study
Team A & B

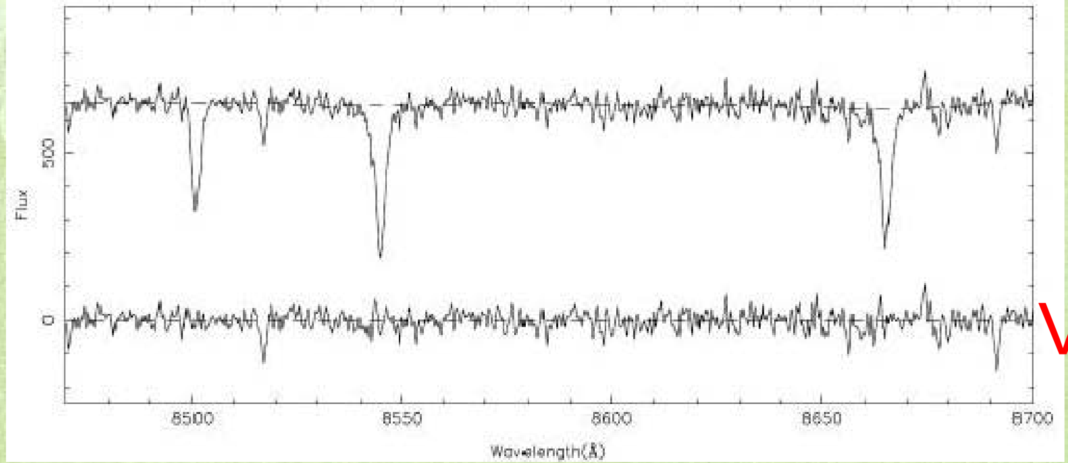
1. LR mode for metallicities and kinematics
   A) V< 21.5, Δ[Fe/H]~0.2, ΔV_{rad} ~10 km/s, S/N~50, R~1800, λ=3900-9000A using SEGUE pipeline
   B) V< 20, Δ[Fe/H]~0.1, ΔV_{rad} ~2 km/s, S/N~10-15, R~5000, λ=4800-5500A (Mgb) & 8150-8850A (CaT)
2. HR mode for chemical tagging

   V< 17, Δ[Fe/H]<0.1, S/N~100-150

   A) R~30000, (1) λ=6280-6593A (2) 5015-5268A (3) 6456-6608A (4) 8380-8804A (5) 4112-4322A
   B) R~20000, λ=4800-6800A

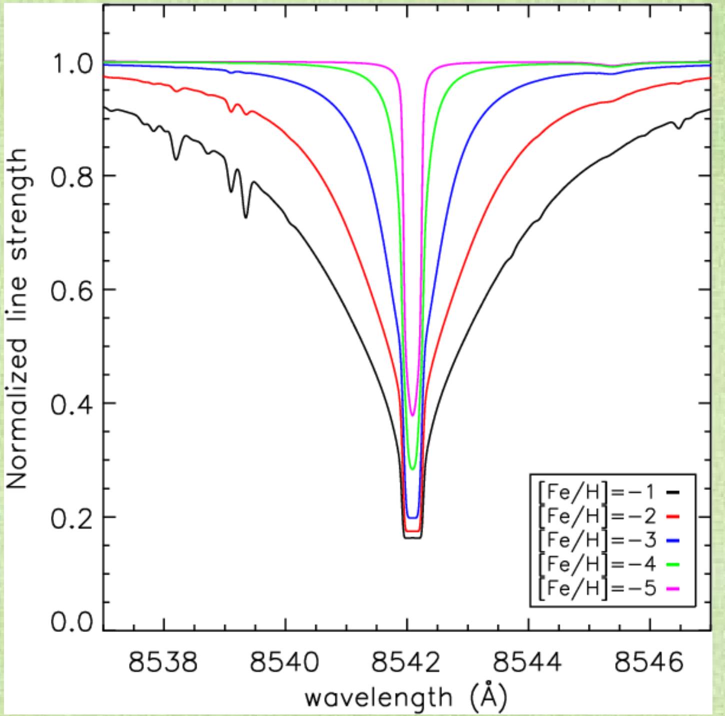
1000-2000deg^2, 100-280nights for each mode

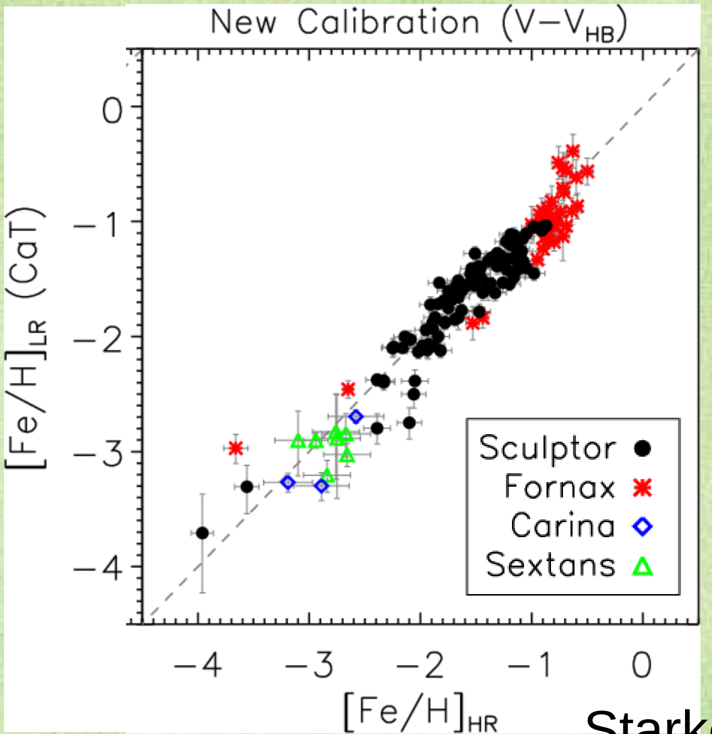
Ca II triplet as [Fe/H] indicator



Reduced EW
W'(ΣCa,V_{HB}-V)

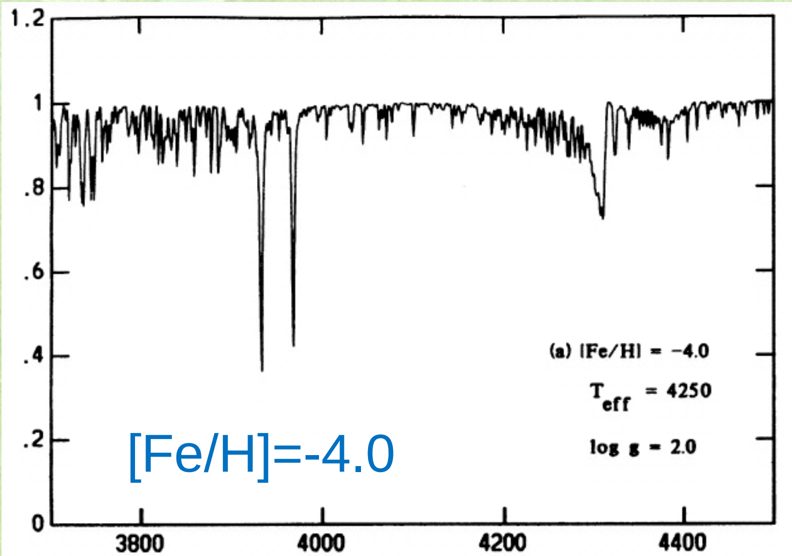
Valid for RGBs with
-4 <~ [Fe/H]<-0.5

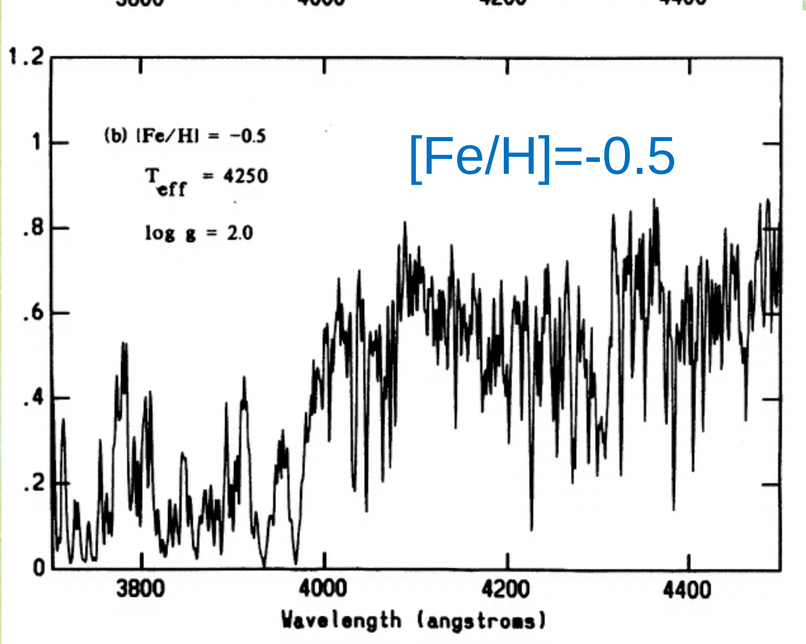




Starkenburg+10

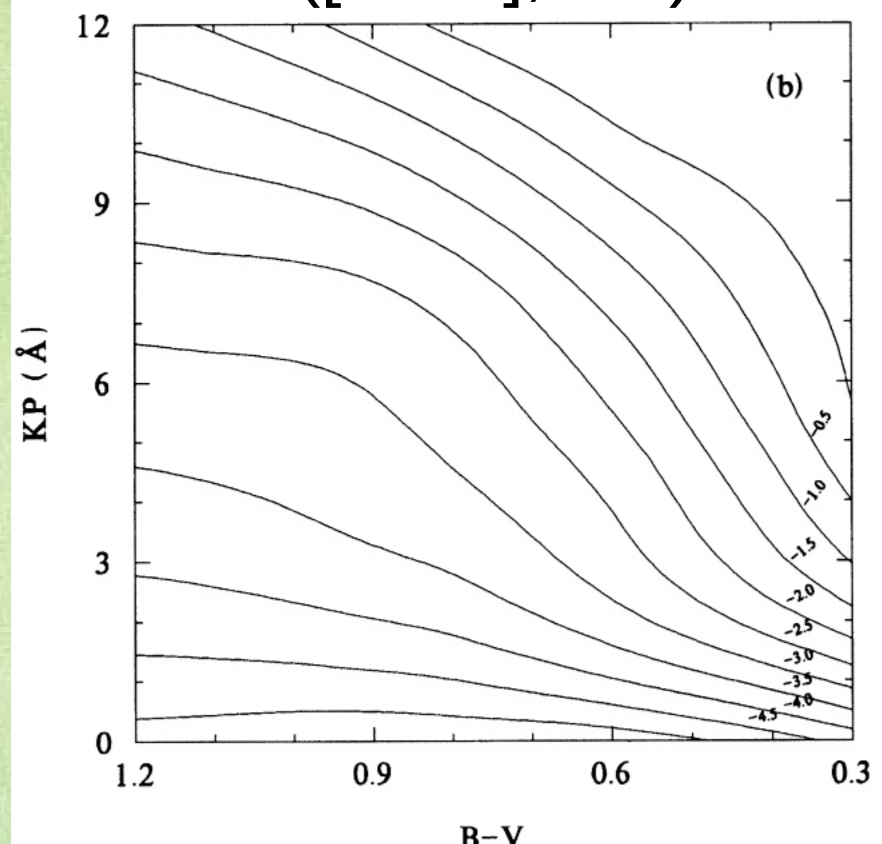
Ca II HK as [Fe/H] indicator





Valid for both dwarfs and giants with -4.0<[Fe/H]<0.5

KP([Fe/H],B-V)

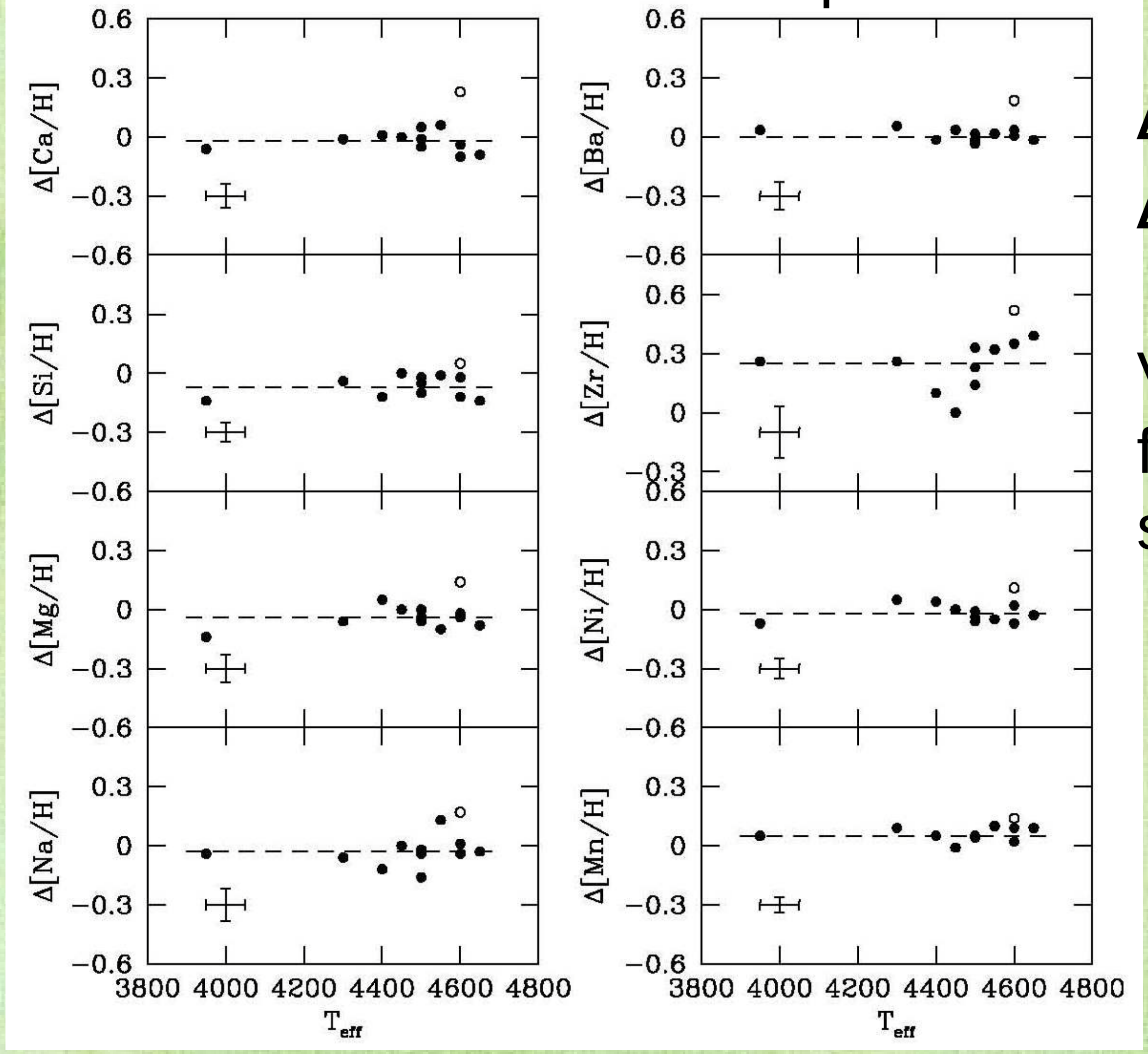


Beerrs+99

Chemical tagging?

De Silva+07

Abundance variation in an open cluster



ΔMg ~0.05 dex

ΔFe ~0.02 dex

Very precise spectroscopy for many stars (million stars) is required!

すばるでやるか?

恐らくNo

Best step towards GA with PFS

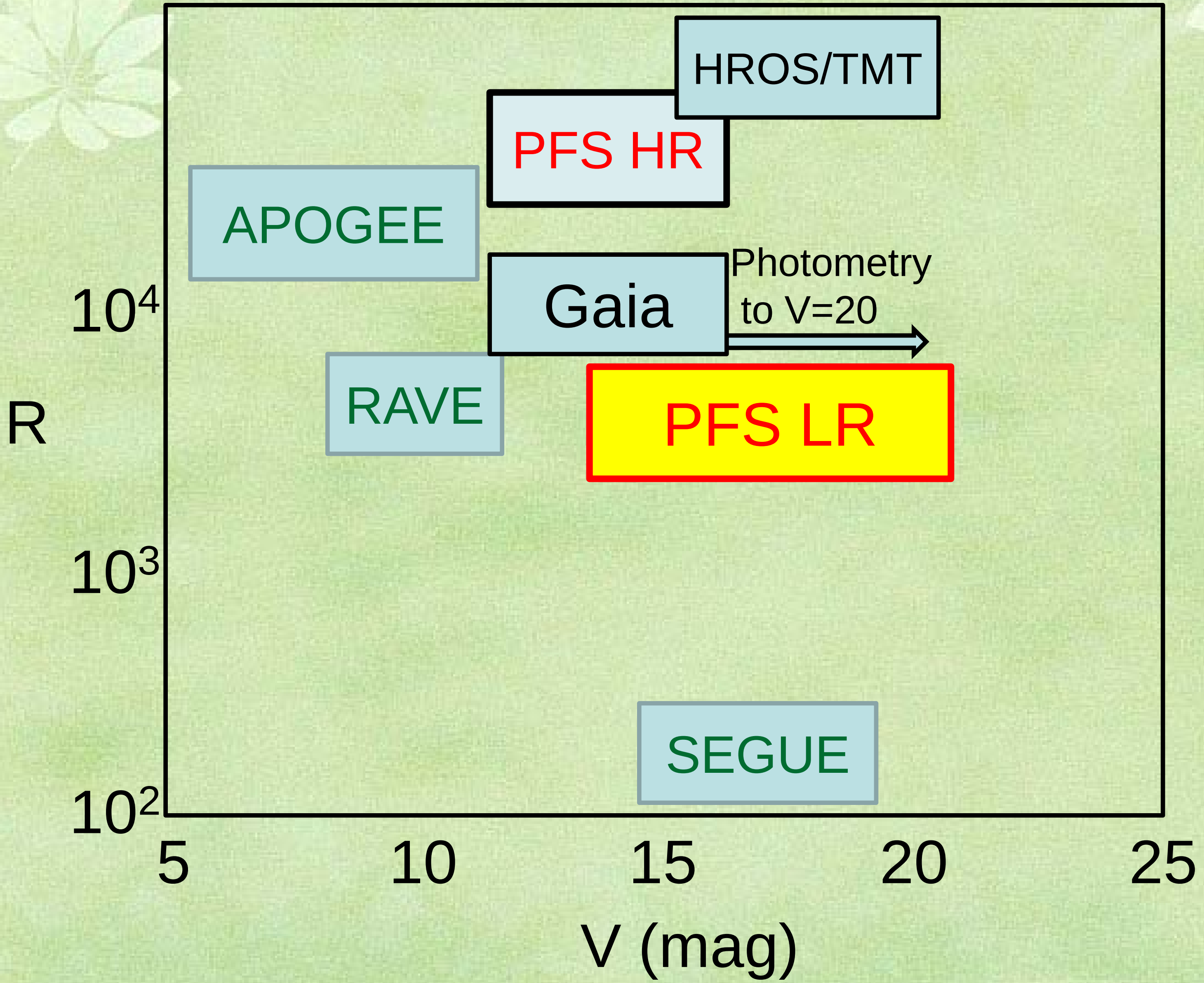
1. PFS LR in perfect synergy with Gaia
   - R=5000, λ=3900-9000A, ~3000 fibers
   - RVs and [Fe/H]s for million stars
     with 17<V<21.5, Δ[Fe/H]~0.1, ΔV_{rad}<2 km/s
   - Discover many substructures and identify merger history

Table 5. Predicted Log star counts per square degree in the V-band

V	|b| = 20°	30°	60°	90°
17	3.36	3.12	2.67	2.55
18	3.61	3.35	2.87	2.74
19	3.85	3.56	3.05	2.92
20	4.06	3.75	3.23	3.09
21	4.24	3.91	3.39	3.25
22	4.38	4.05	3.54	3.38

~1400 stars/PFS field
@V=17,b=|45|

2. PFS HR for follow-up studies
   - R=40000, (1) λ=6280-6593A
     (2) 5015-5268A (3) 6456-6608A (4) 8380-8804A
     (5) 4112-4322A , ~200 fibers, with V<17
   - Chemical history of each merging progenitor


HROS/TMT
PFS HR
APOGEE
Photometry
to V=20
Gaia
10^4
RAVE
PFS LR
R
10^3
SEGUE
10^2
5
10
15
20
25
V (mag)

End