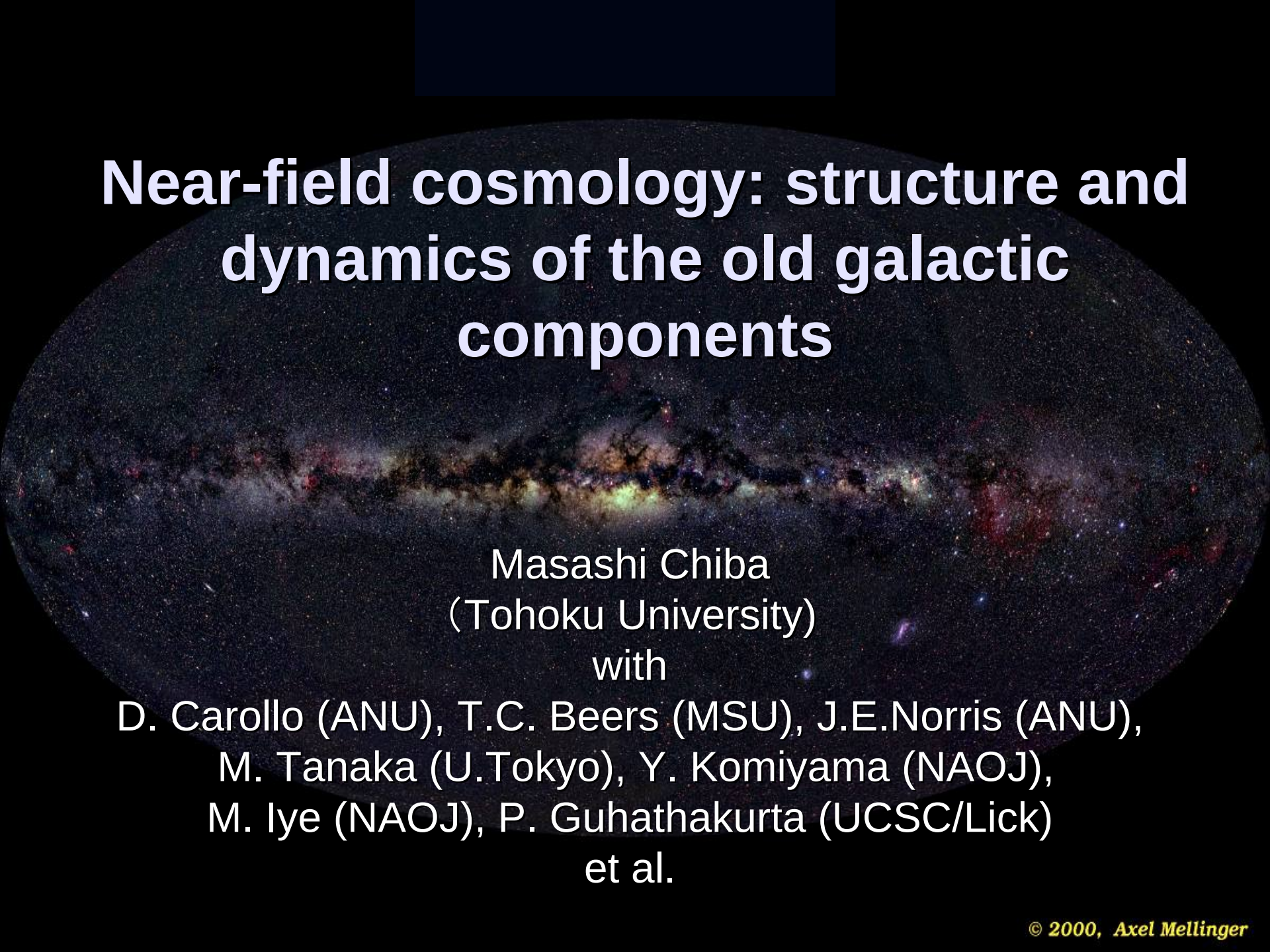
Near-field cosmology: structure and dynamics of the old galactic components



Masashi Chiba
（Tohoku University)
with
D. Carollo (ANU), T.C. Beers (MSU), J.E.Norris (ANU),
M. Tanaka (U.Tokyo), Y. Komiyama (NAOJ),
M. Iye (NAOJ), P. Guhathakurta (UCSC/Lick)
et al.

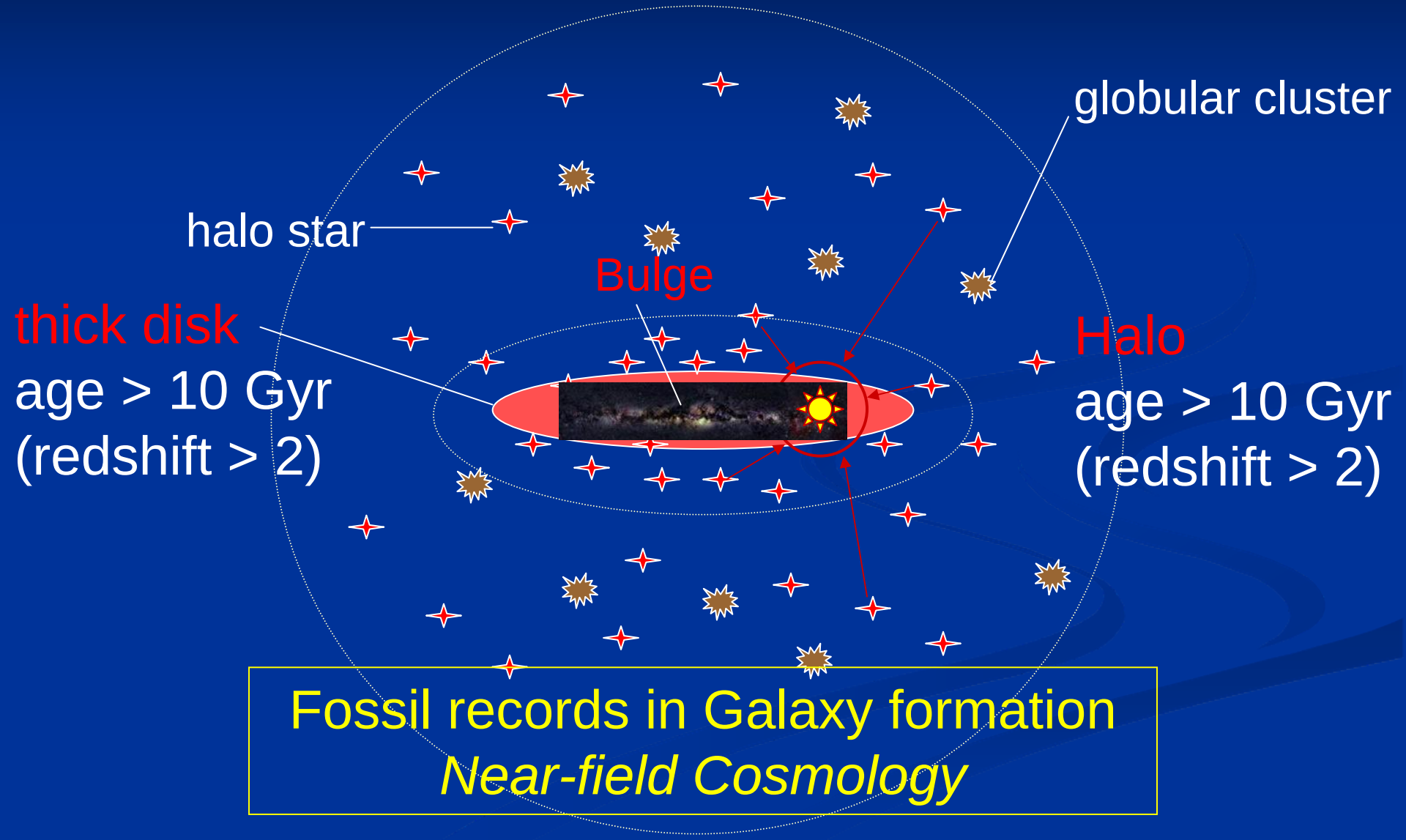
Milky Way

- In Japanese: “River of Heaven” 天の川
- In Chinese/Japanese: “Silver River” 銀河

- In Buddhism, “River” is the gateway to the heaven (or hell)

Milky Way as the gateway to Cosmology

Old components in the Milky Way

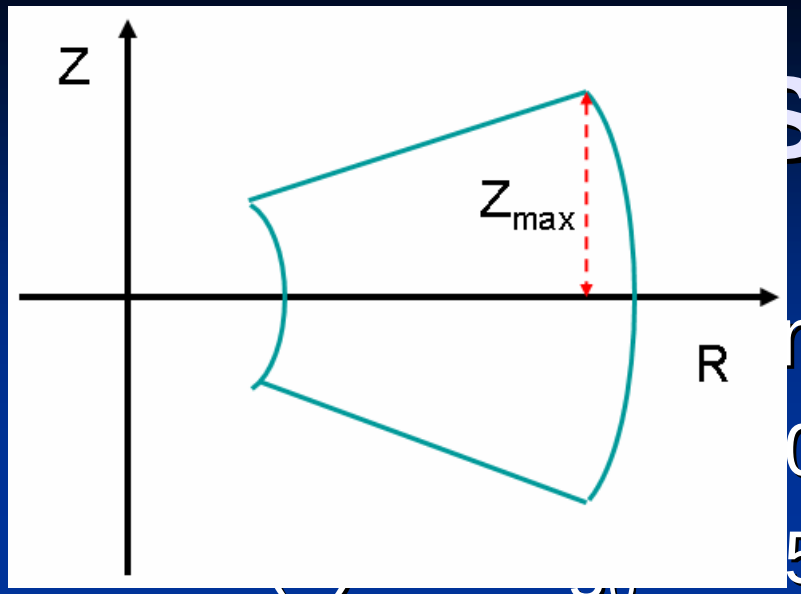


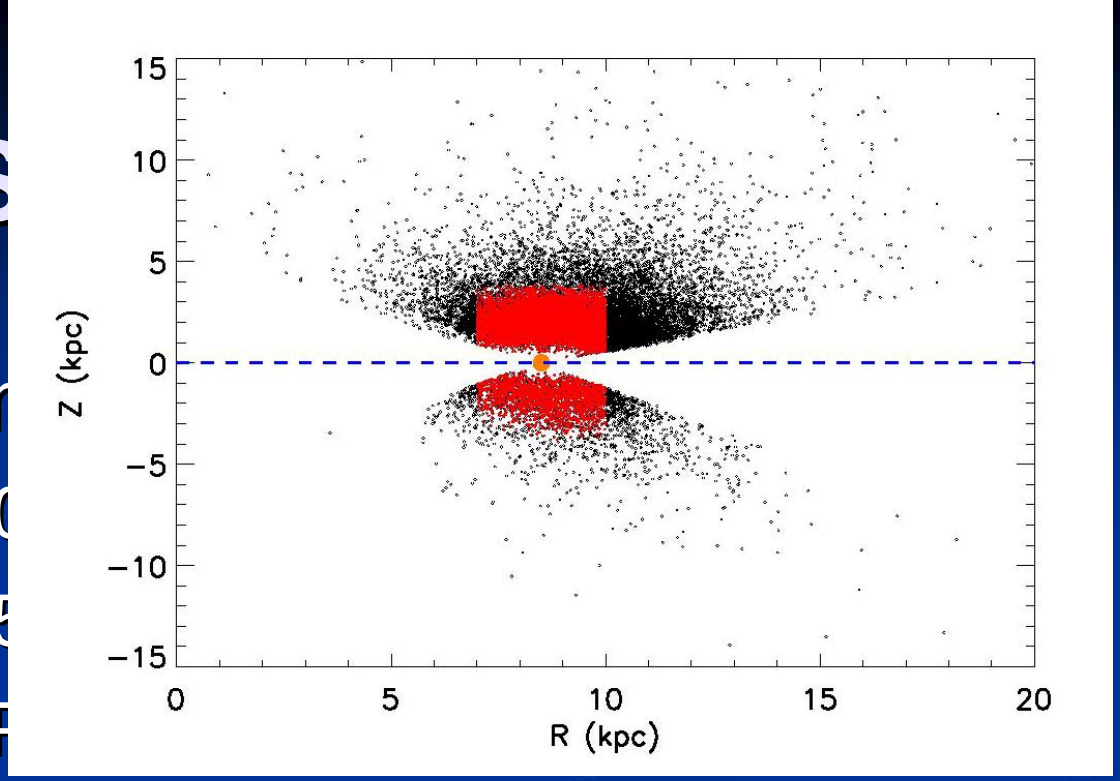
Fossil records in Galaxy formation

Near-field Cosmology

This work

- Structure of the Galactic halo from the largest stellar sample
  - Carollo et al. 2007, in press
- Structure of the Andromeda halo with Subaru
  - Tanaka et al. 2007 (arXiv0704.3328)





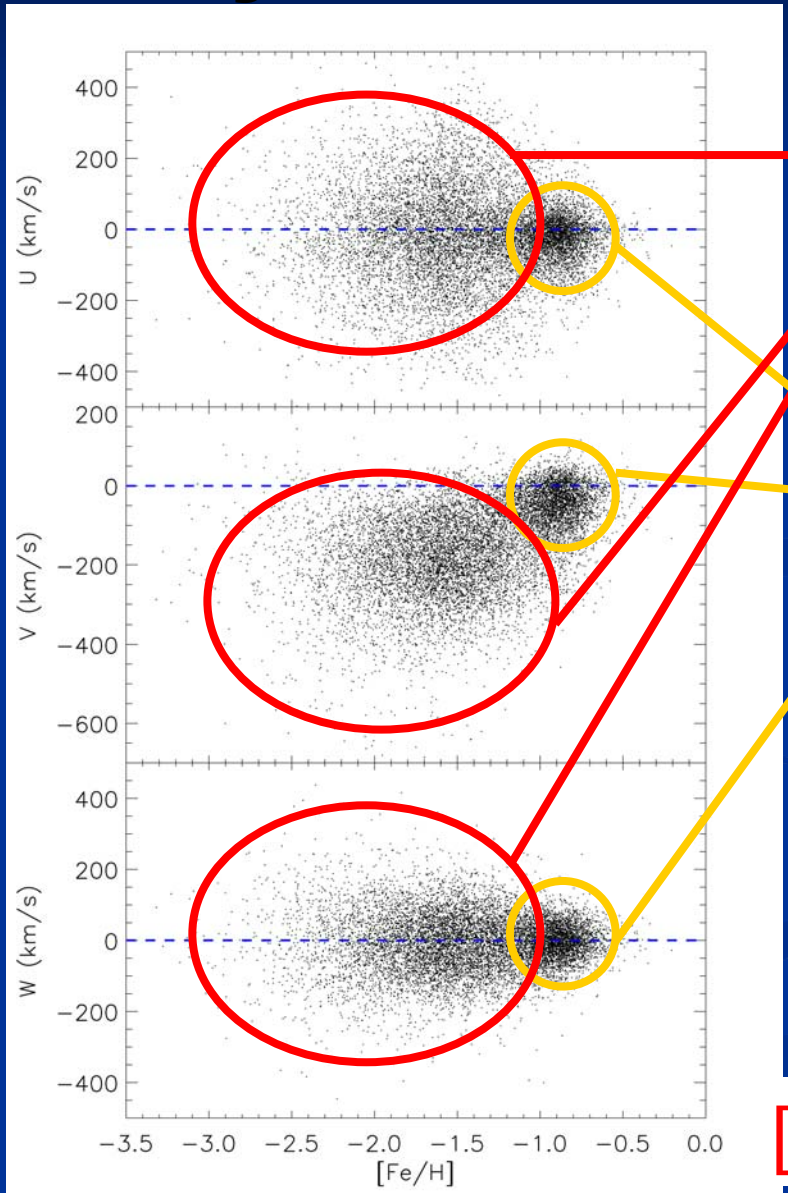
- SEGUE Stellar P
  - σ(Teff)=100-125K, σ(logg)=0.25, σ([Fe/H])=0.2
- Kinematic sample (over 10,000)
  - 5000K<Teff<6800K, d<4kpc, 7<R<10kpc
  - USNO-B PM, $\sigma(\mu)$=3-4 mas/yr
  - Orbits in a Galactic potential (Z_{max}, e …)

Velocity distribution

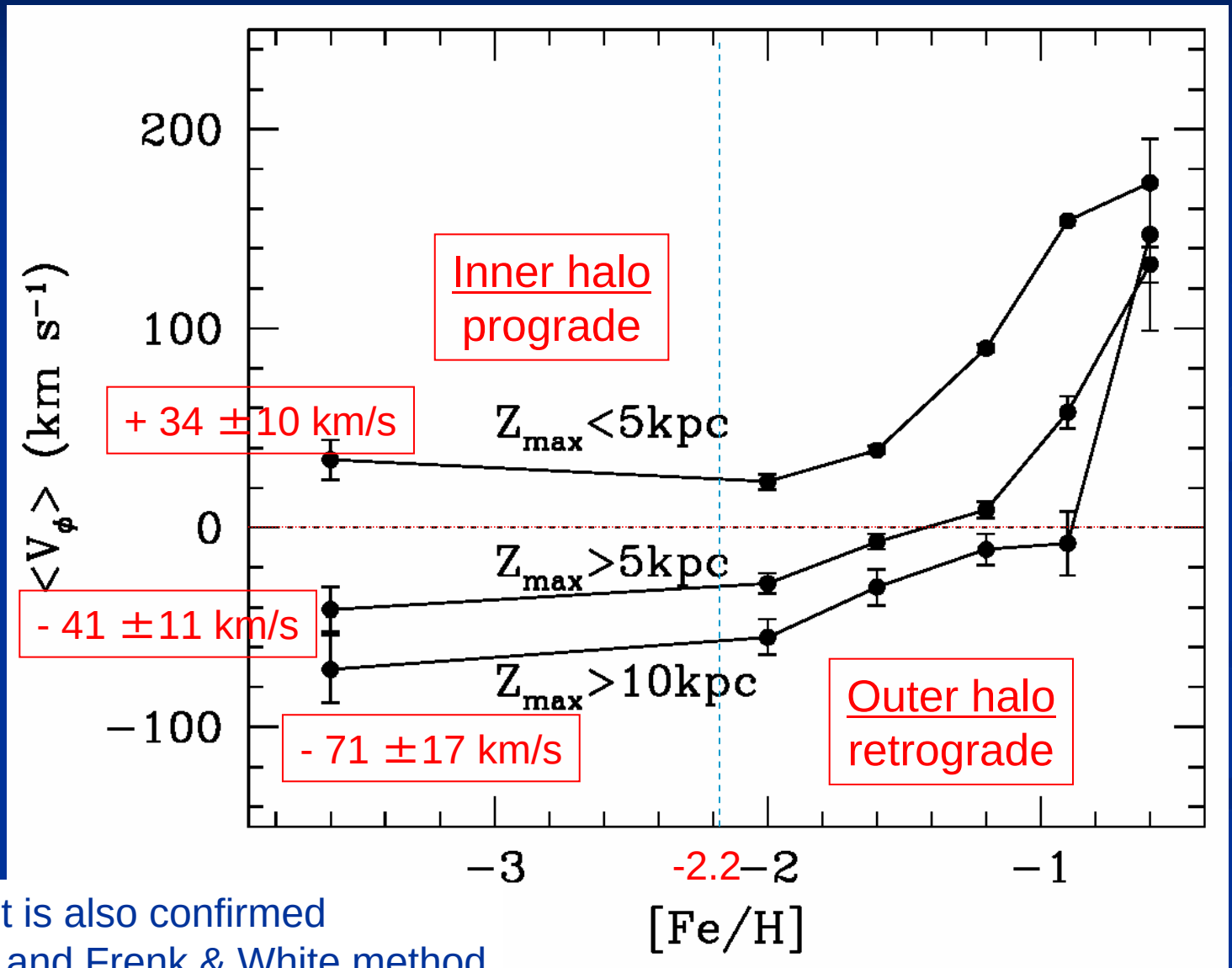
U

V

W



Mean rotation velocity



This result is also confirmed using V_{los} and Frenk & White method

Distribution o

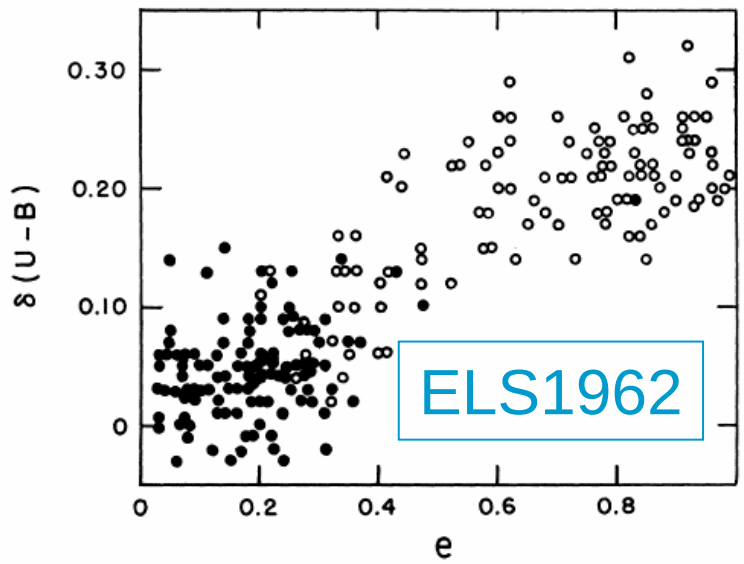
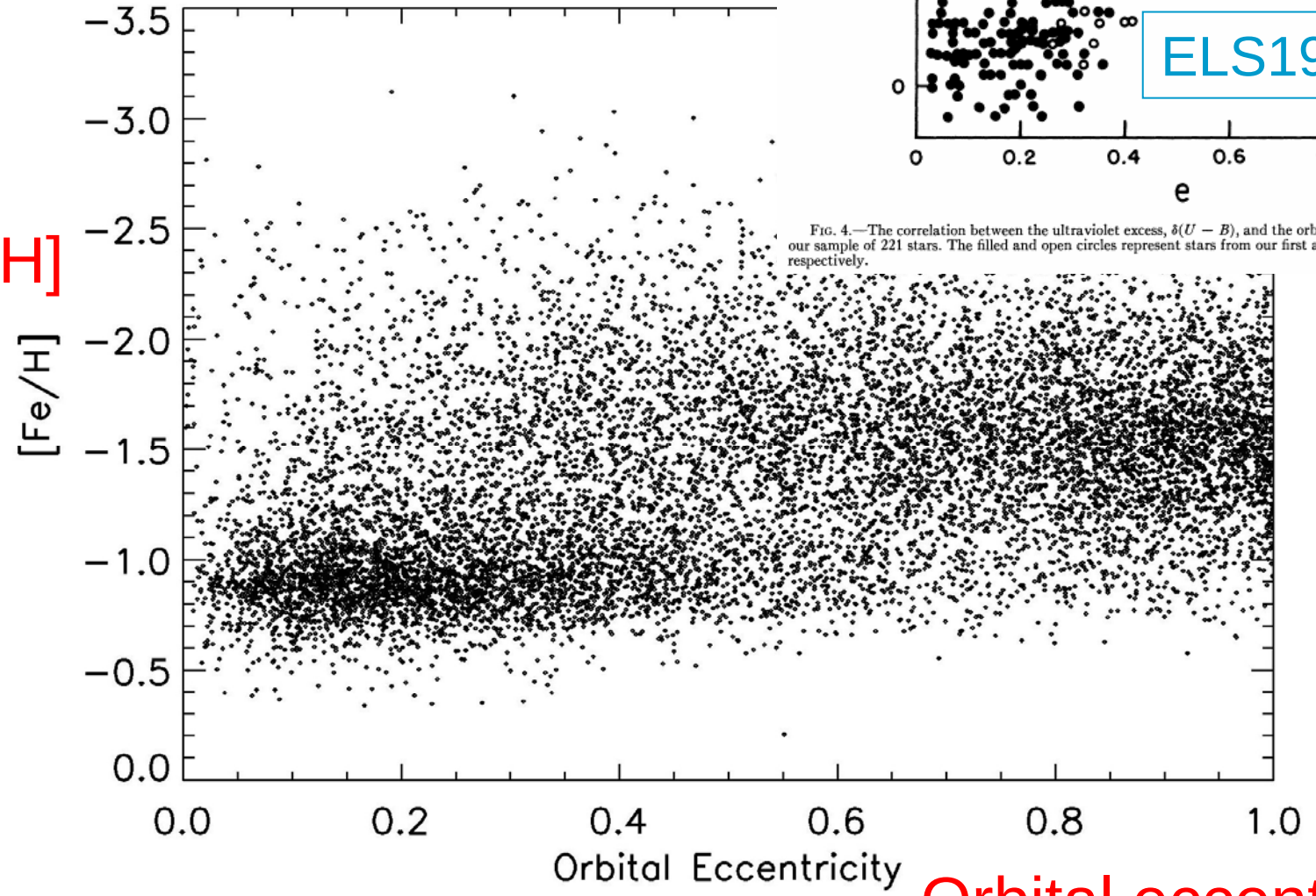


FIG. 4.—The correlation between the ultraviolet excess, $\delta(U-B)$, and the orbital eccentricity, e, for our sample of 221 stars. The filled and open circles represent stars from our first and second catalogues, respectively.

[Fe/H]

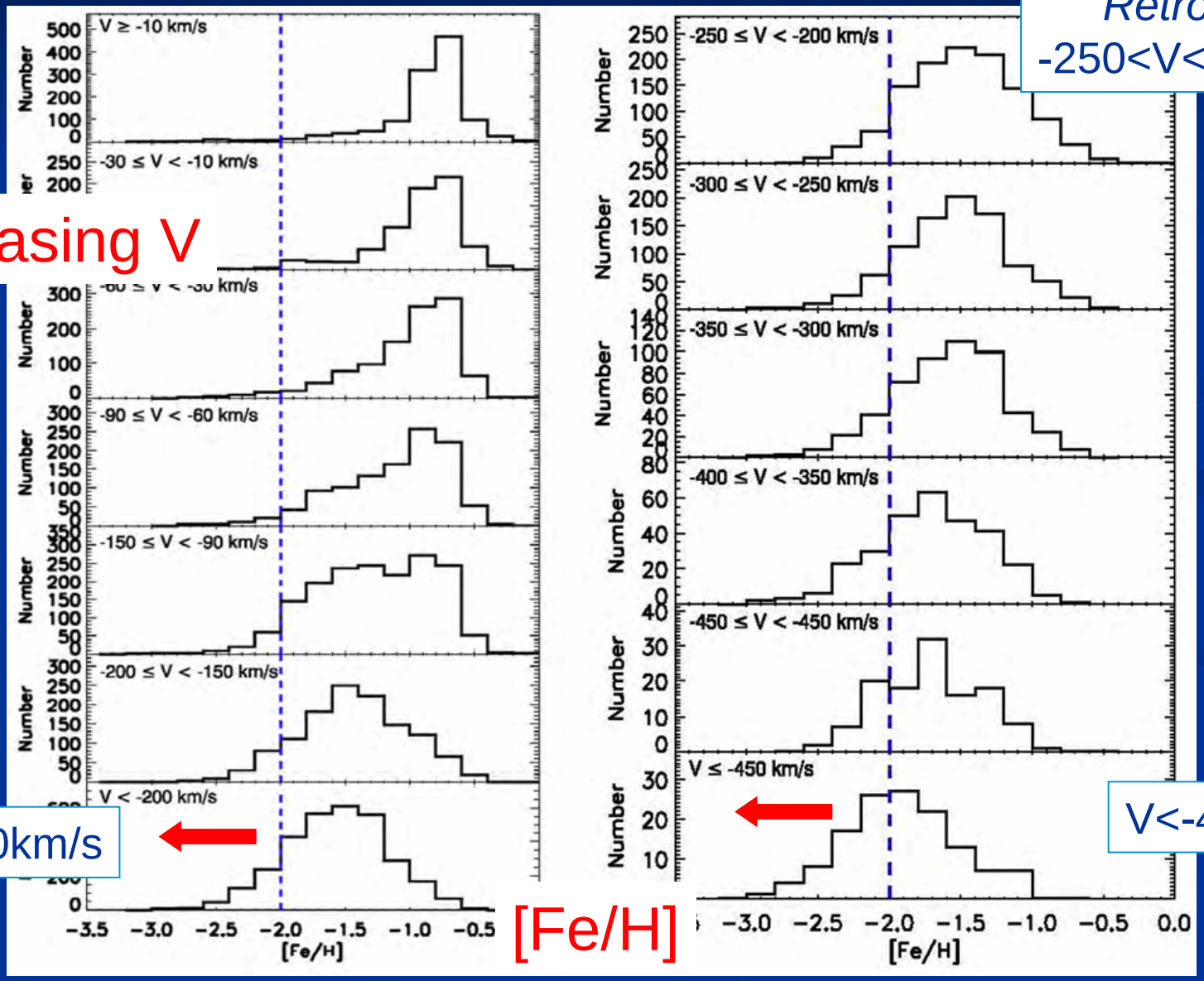


Orbital eccentricity

Metallicity distribution

Retrograde
-250<V<-200km/s

Decreasing V



V<-200km/s

V<-400km/s

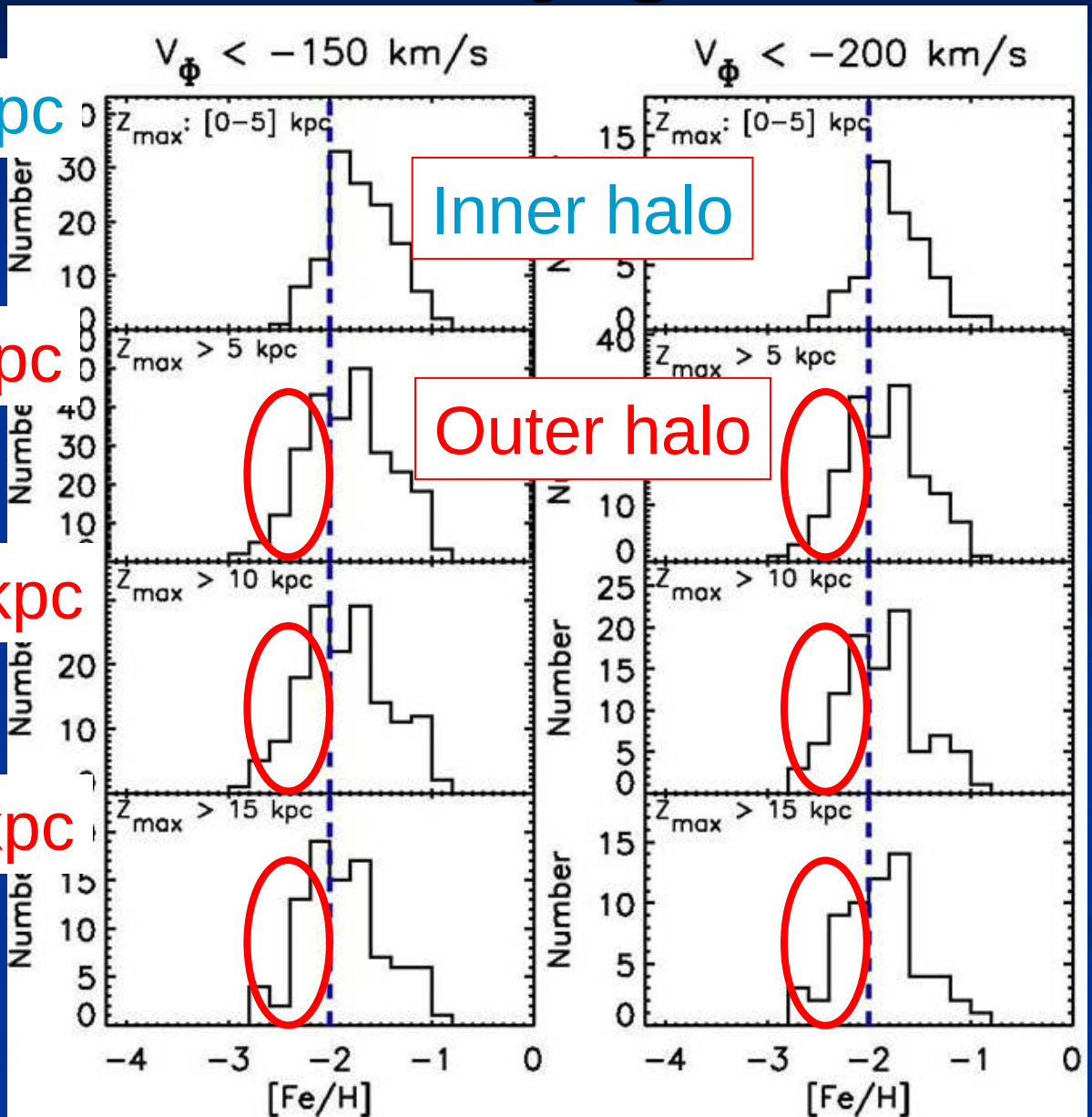
Metallicity gradient

Z_{max} < 5 kpc

Z_{max} > 5 kpc

Z_{max} > 10kpc

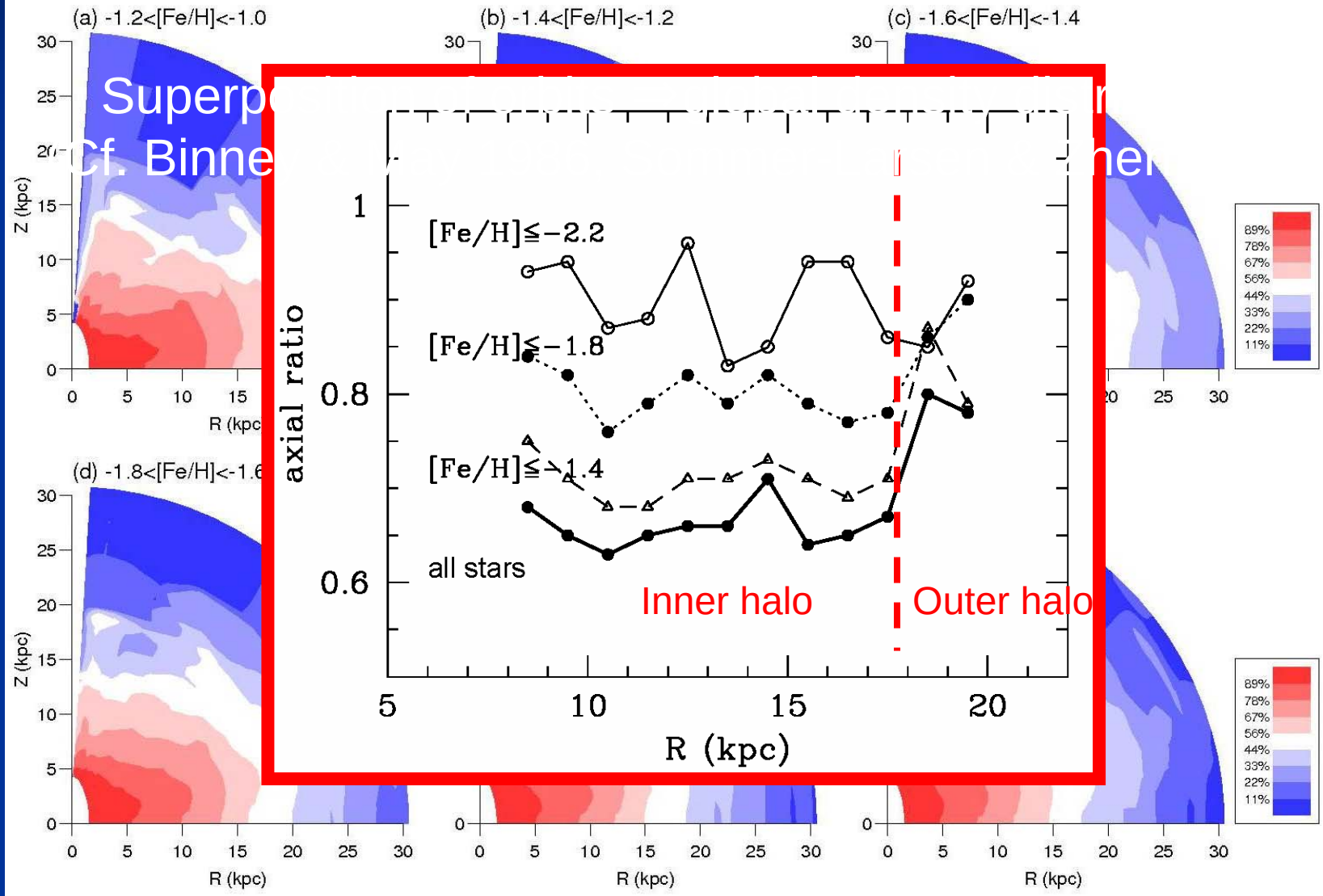
Z_{max} > 15kpc



Inner halo

Outer halo

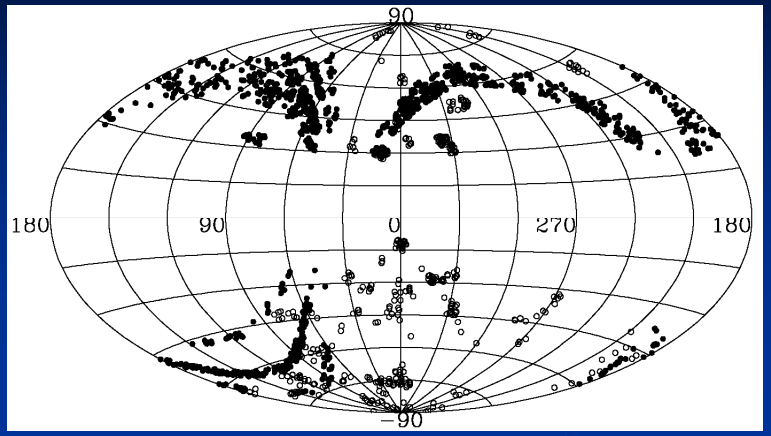
Global density distribution



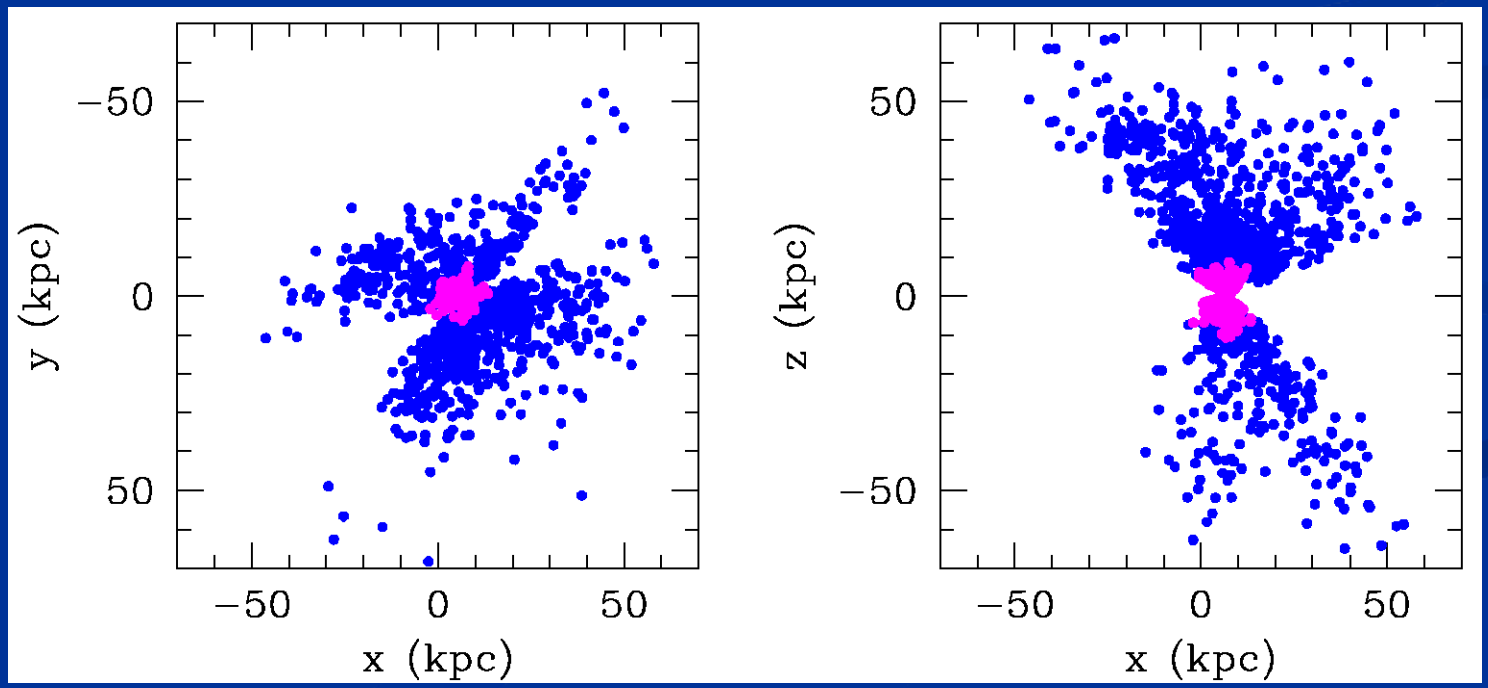
Field Horizontal Branch (FHB) stars as halo tracers

- Bright and many
- Accurate distance is available

⇒ halo kinematics,
mass distribution of a dark halo

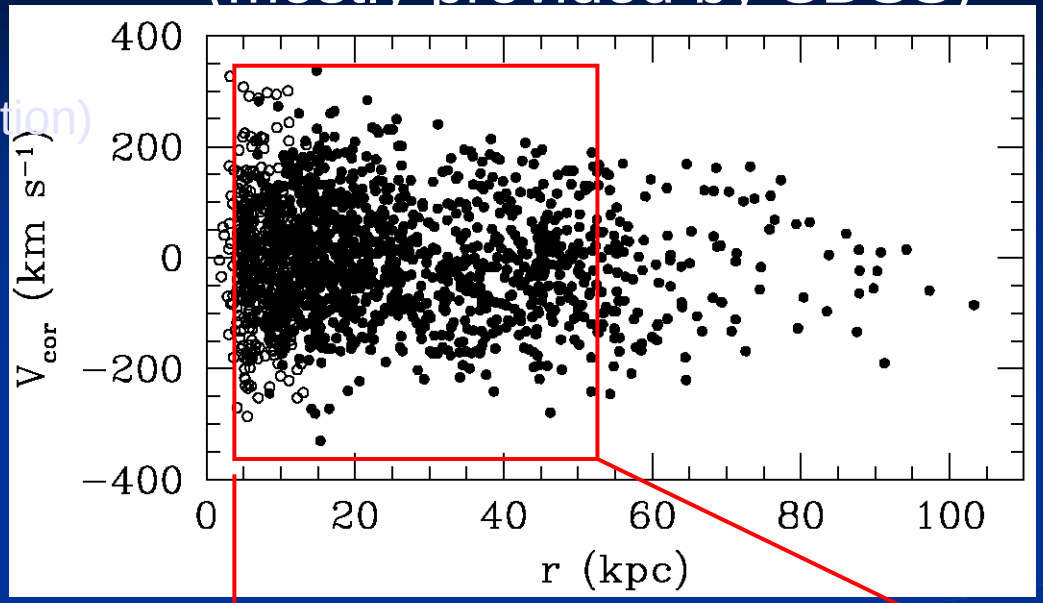


This work
using 444 FHBs in Wilhelm et al. (1999)
1169 FHBs in Sirko et al. (2003) (SDSS) ⇒ 5 < d < 100 kpc

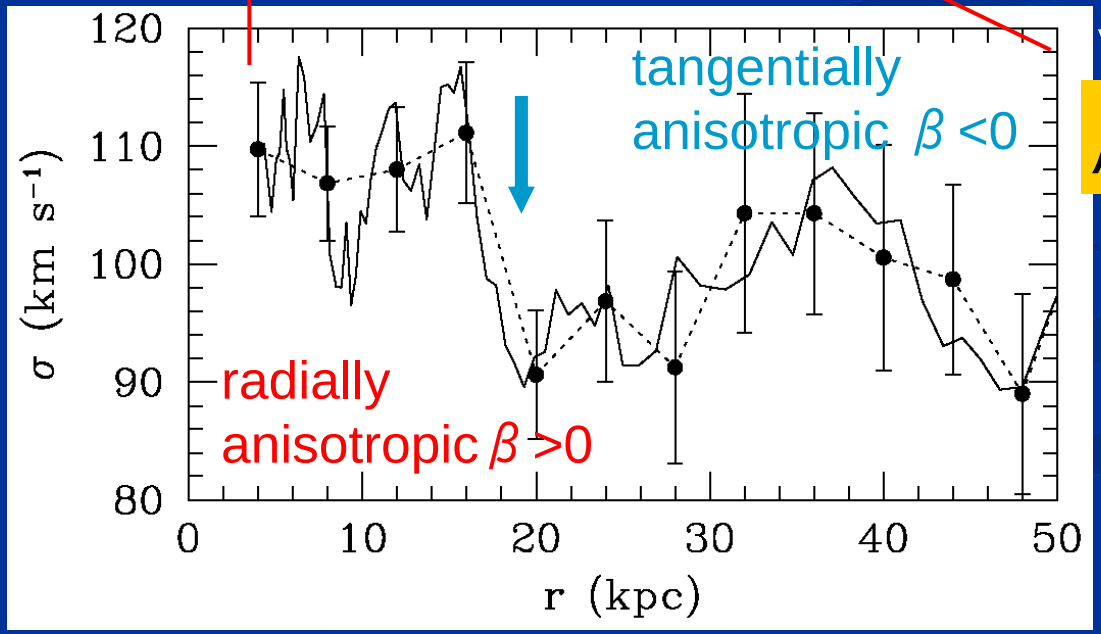


L-o-s velocities of 1613 FHB stars (mostly provided by SDSS)

V_{corr} vs. r
(corrected for LSR+solar motion)



σ vs. r

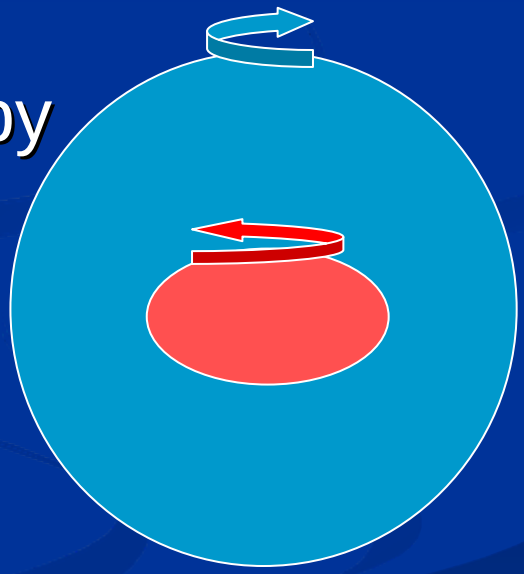


Velocity anisotropy

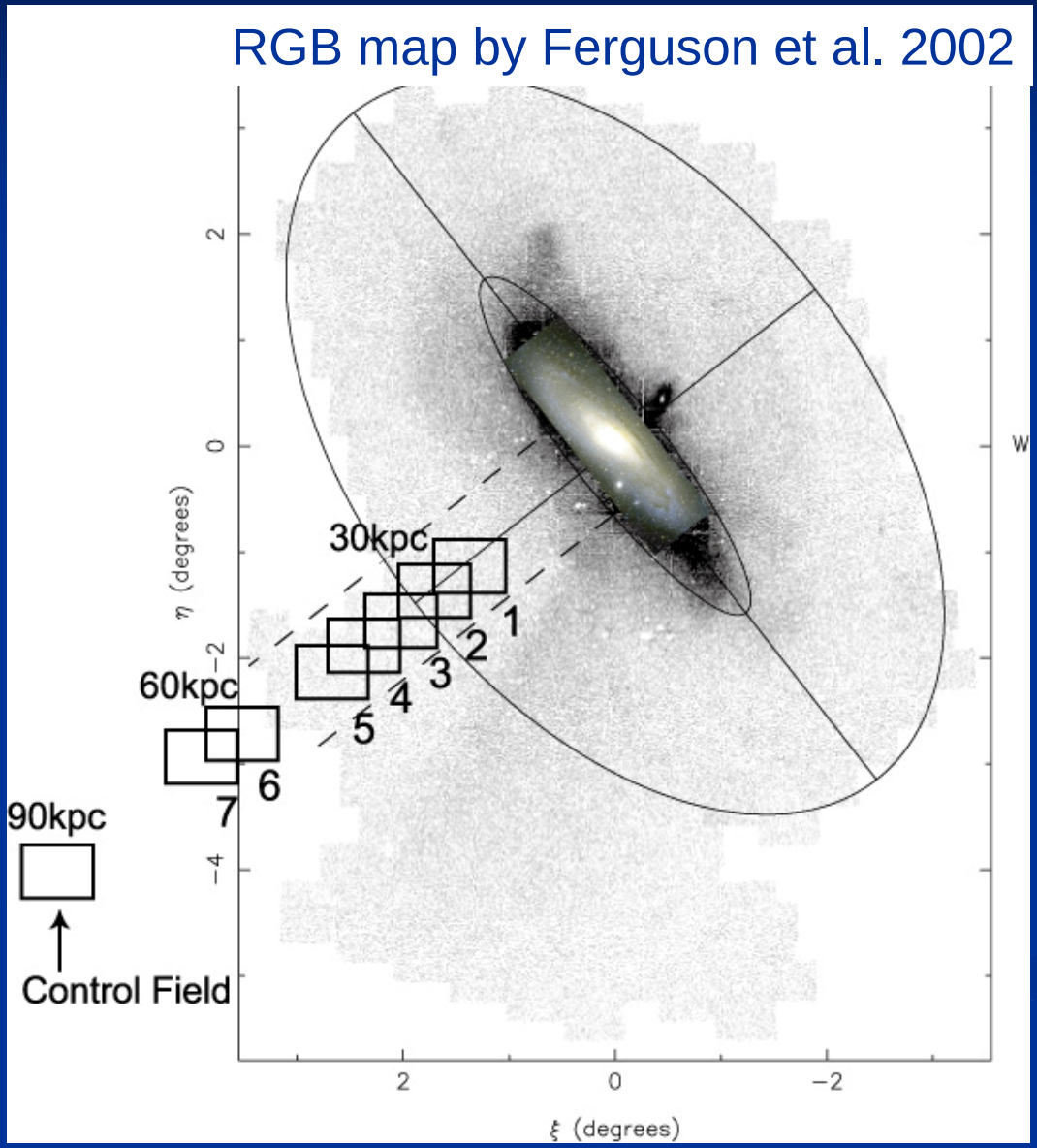
$$\beta = 1 - \sigma_t^2 / \sigma_r^2$$

Summary: Duality of the Galactic halo

- Inner halo
  - |z|<5-10 kpc, R<15-20 kpc
  - MDF peaked at [Fe/H] ~ -1.6
  - Prograde rotation, radial anisotropy
  - Flattened density distribution
- Outer halo
  - |z|>5-10 kpc, R>15-20 kpc
  - MDF peaked at [Fe/H] ~ -2.2
  - Retrograde rotation, tangential anisotropy
  - Spherical density distribution



Andromeda Halo

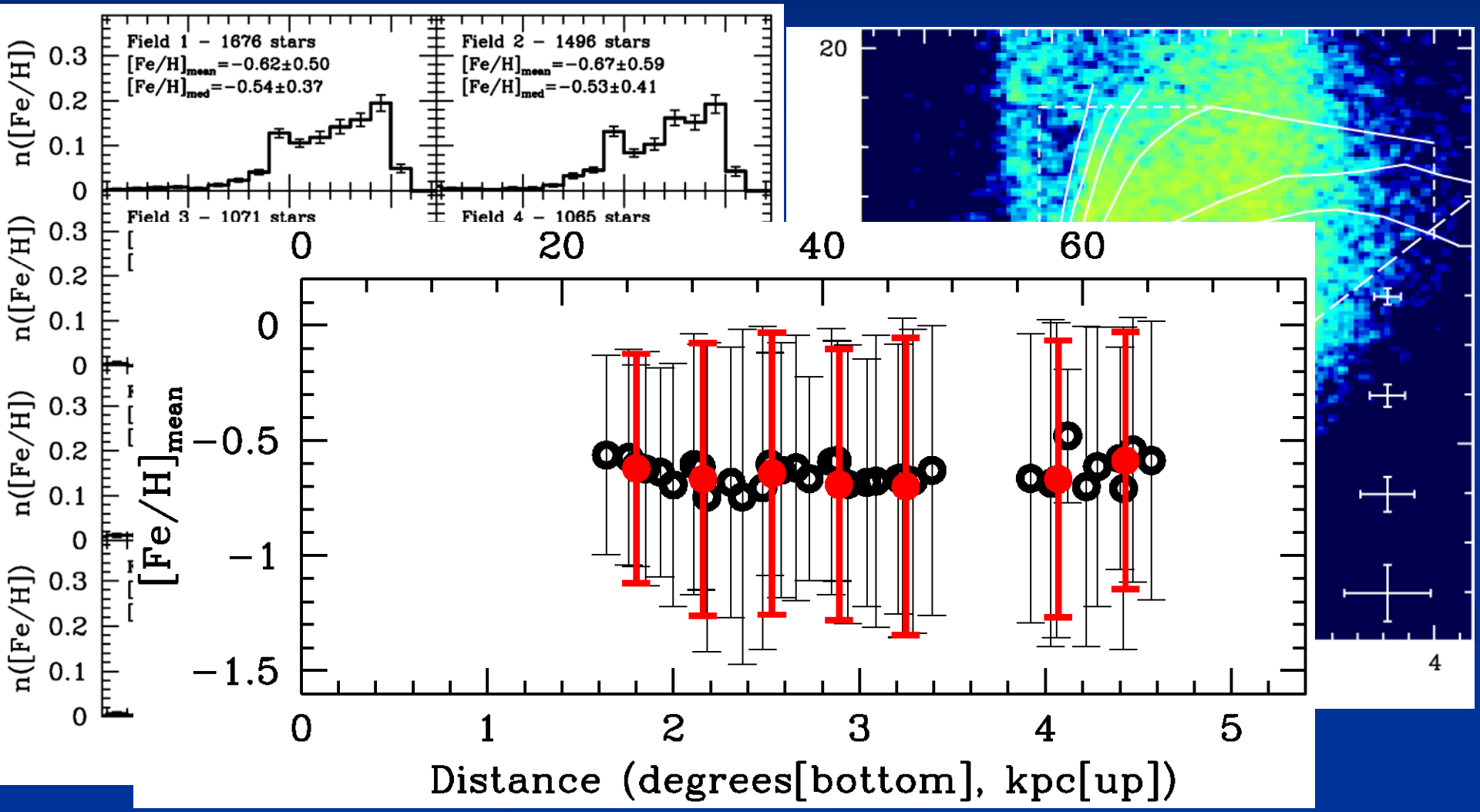


Suprime-Cam pointings

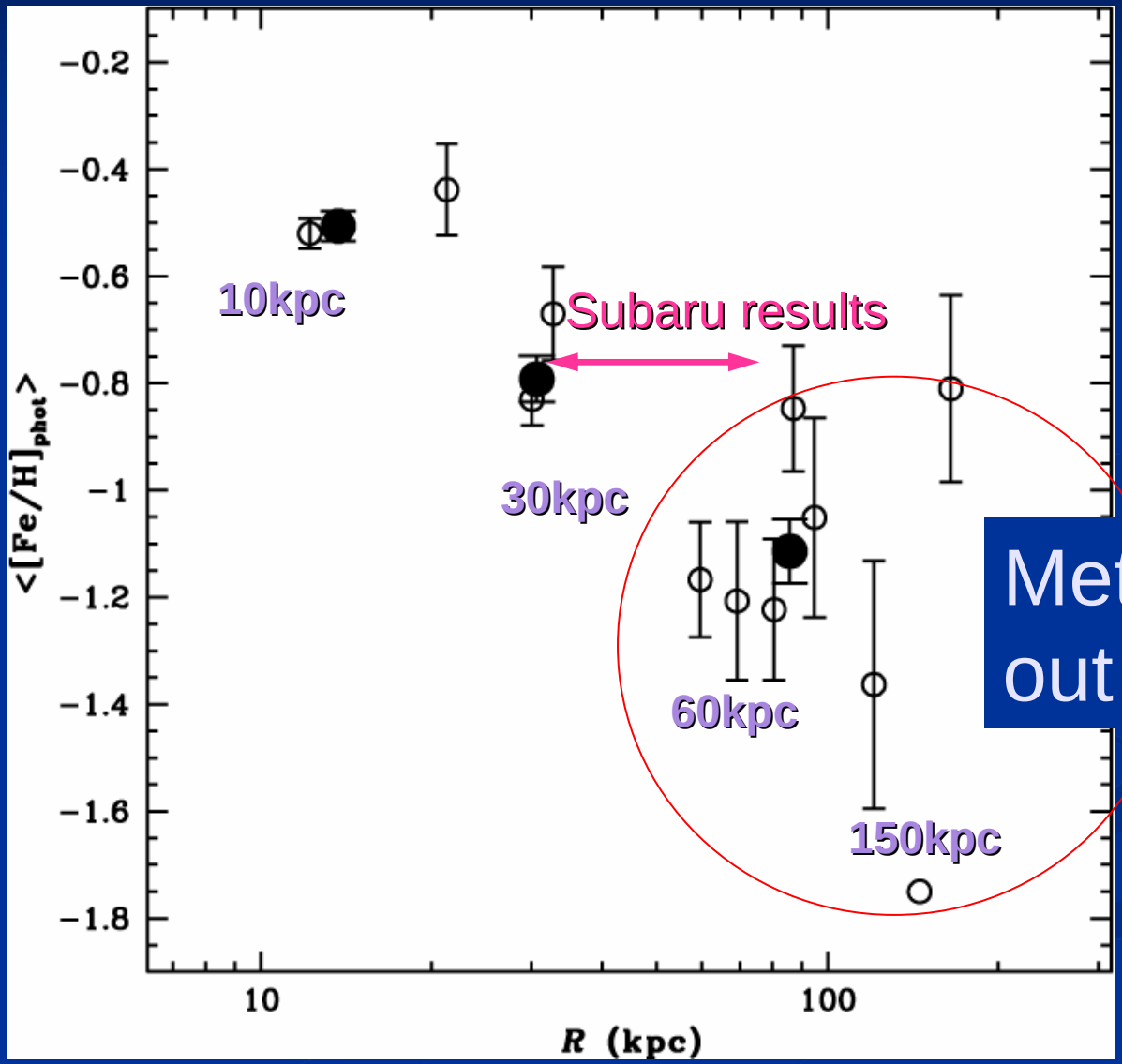
- Aug 12-15, 2004 seeing >~ 1” (!)
- Aug 2 & Dec 5, 2005
- V, Ic

(Tanaka et al. 2007)

Metallicity distribution



Metallicity gradient in outer parts (Karilai et al. 2006, Keck/DEIMOS)

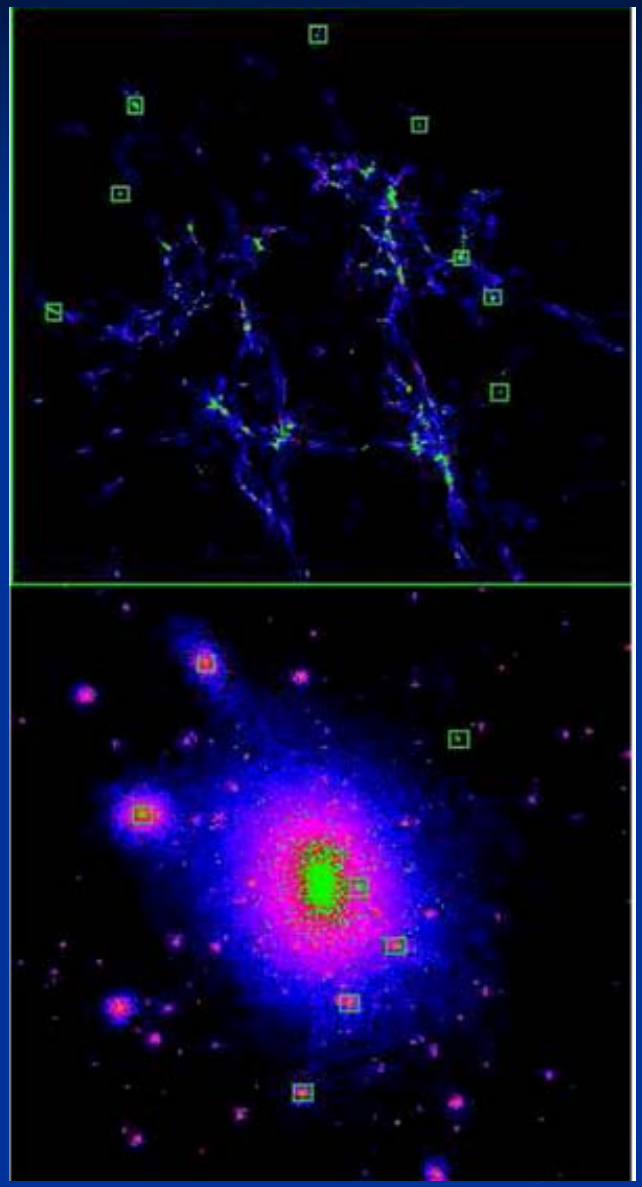


Metal-poor out to 150kpc

Prediction of ΛCDM models

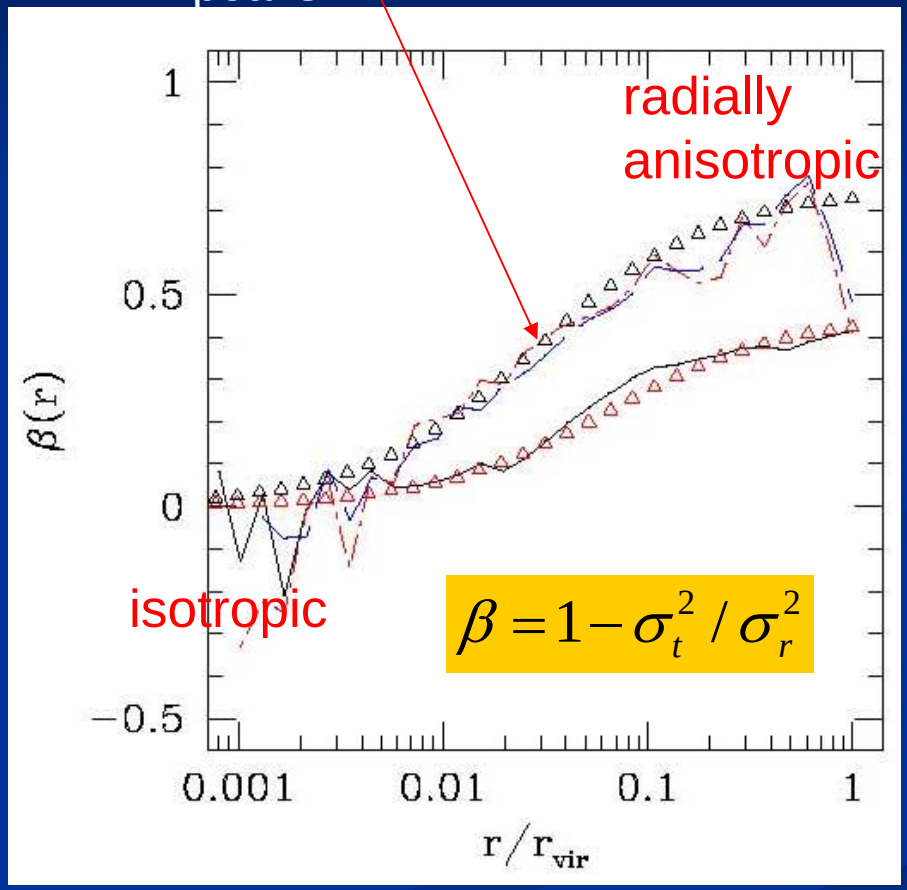
Z=12

Z=0



Moore et al. 2006

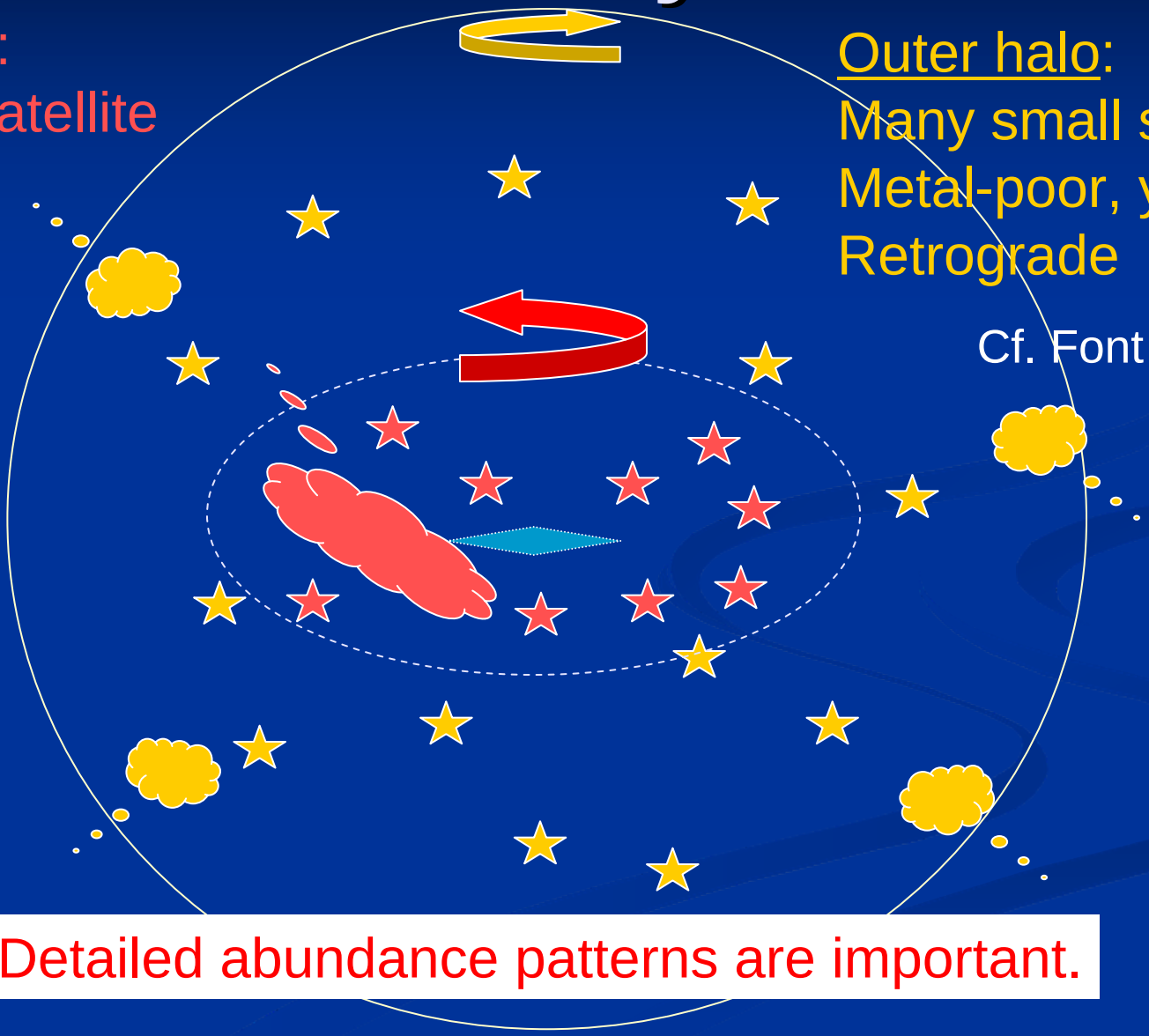
Velocity distribution of 2.5 σ density peaks



Diemand, Madau, Moore 2005

Picture of Galaxy formation

Inner halo:
Massive satellite
Metal-rich
Prograde



Outer halo:
Many small satellites
Metal-poor, young?
Retrograde

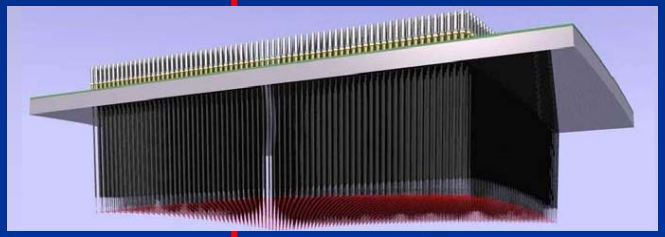
Cf. Font et al. 2007

Detailed abundance patterns are important.

WFMOS

1. Dark energy survey (determination of w)
2. Galactic archaeology survey

~4500 targets in a FOV~1.5deg,
R~2000, 40000 (3000, 1500 fibers)
Operation 2012? ~



~1400 stars
@V~17

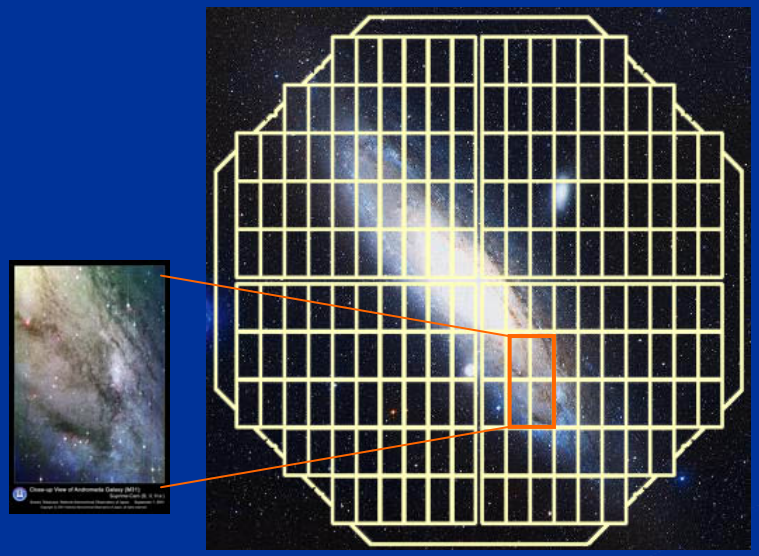
Original plan :

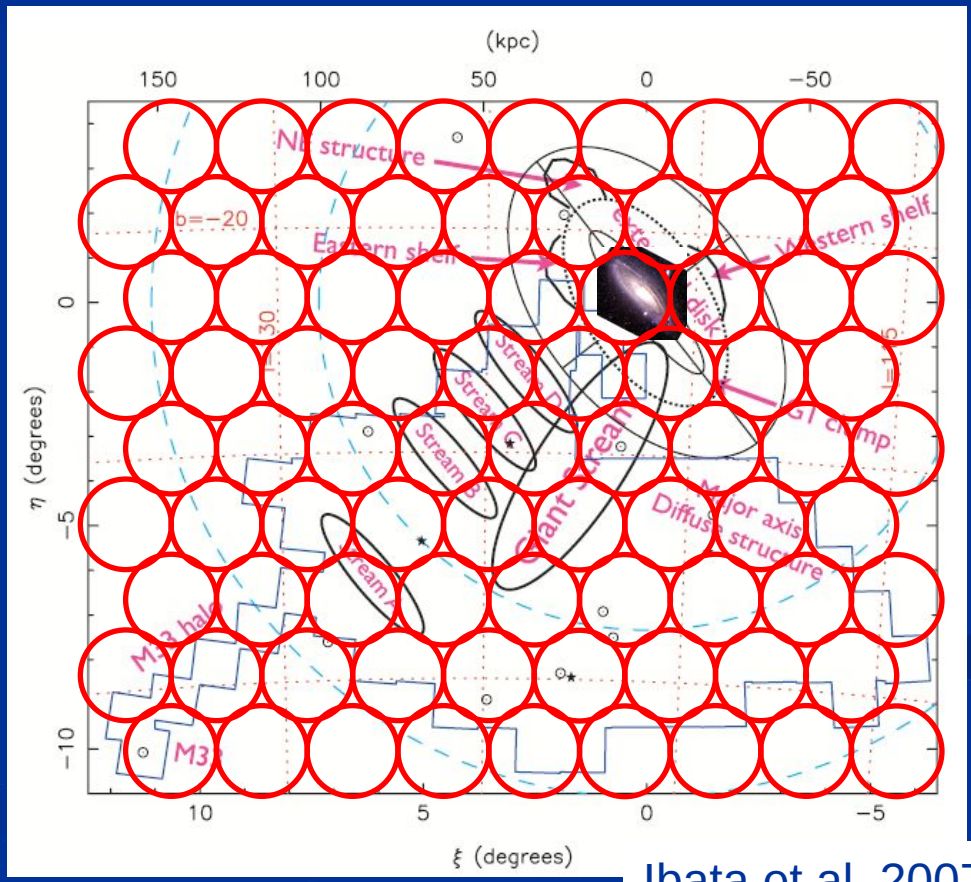
- Low resolution mode R ~ 2000, 17<V<22
  radial velocity & abundance
  0.5 million stars, 500 deg^2, 140 nights
- High resolution mode R ~ 40000, V<17
  abundance pattern
  1.5 million stars, 3000 deg^2, 490 nights

HyperSuprime Cam

Adapted from Komiyama-san's viewgraph

- 81 HSC pointings required to cover 254 deg^2
- HSC can image deeper than HB in 1 hour under moderate seeing (~0".7)
- Total: 20 nights required
  - 2 color bands (g, i)





Ibata et al. 2007

Conclusions

- The Galactic halo shows clear duality, i.e., the inner and outer halo components.
- The Andromeda halo shows a metallicity gradient, but its duality is yet unclear.
- These properties are to be explained by galaxy formation models.
- Great progress in this field is anticipated with HyperSuprime, WFMOS, and GAIA.