The Metallicity Gradients in the Disks From SEGUE

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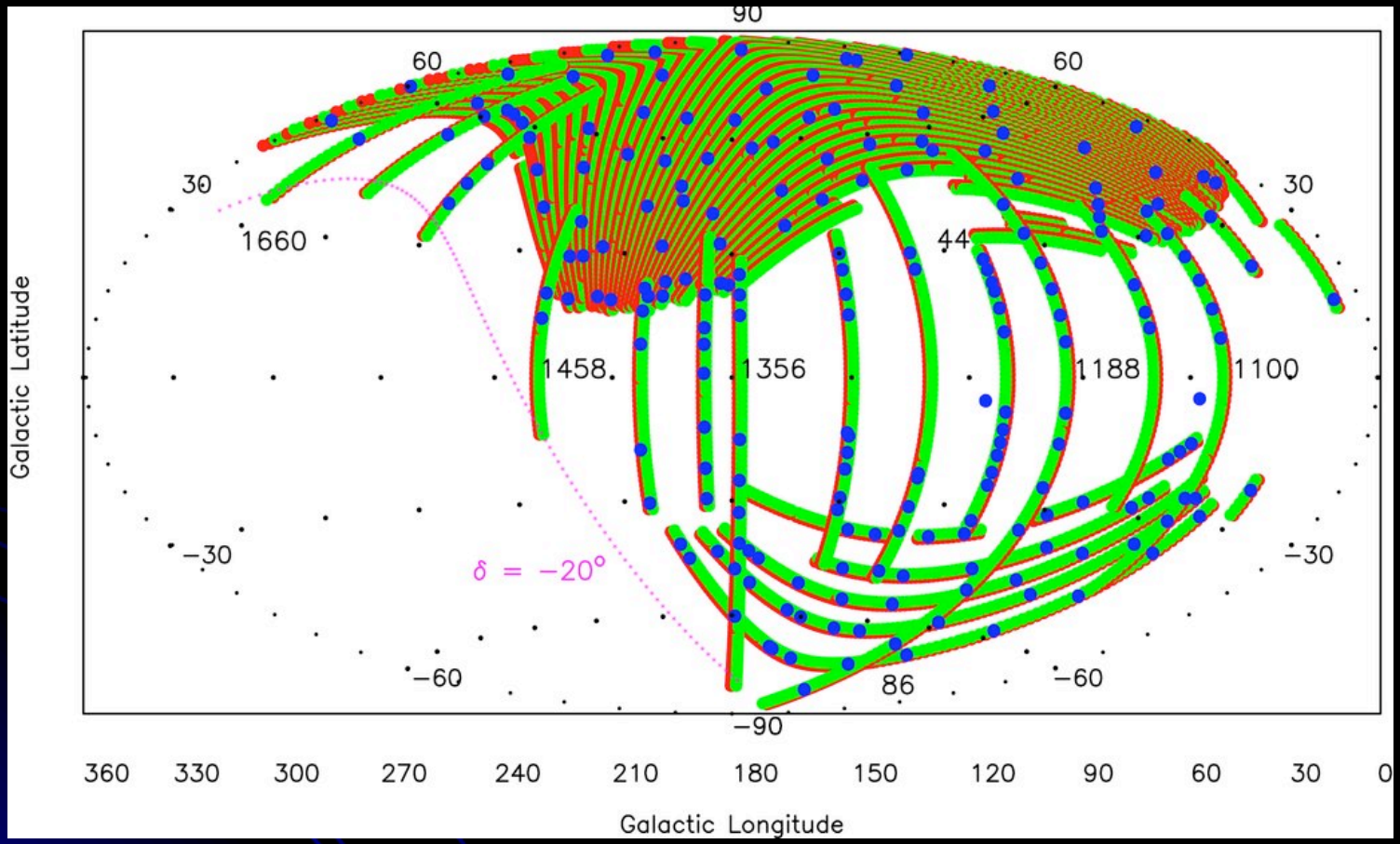
Outline of talk

- Overview of SDSS/SEGUE survey
- Metallicity gradients from SEGUE
  - Radial gradient from Cheng, et al. 2012
  - Vertical gradient from Schlesinger, et al. 2012
- APOGEE and seismology
  - APOKASC
  - CoRoT

SEGUE Footprint



Yanny et al. 2009

Sloan Digital Sky Survey Overview

- Each plate observes 7 square degrees
- Variety of target categories
  - Color and magnitude cuts from photometry
- Stellar spectra processed through the SSPP (Lee et al. 2011)
- All SEGUE/SEGUE2 data now released
- Improvements in stellar parameters in Data Release 9

SEGUE Survey In Perspective

- Now outside the solar neighborhood – not one MDF
- No kinematic or alpha selection used (for these studies)
- Fainter stars = lower resolution (R~18000) abundance information considerably less
- Target selection algorithm based on public data

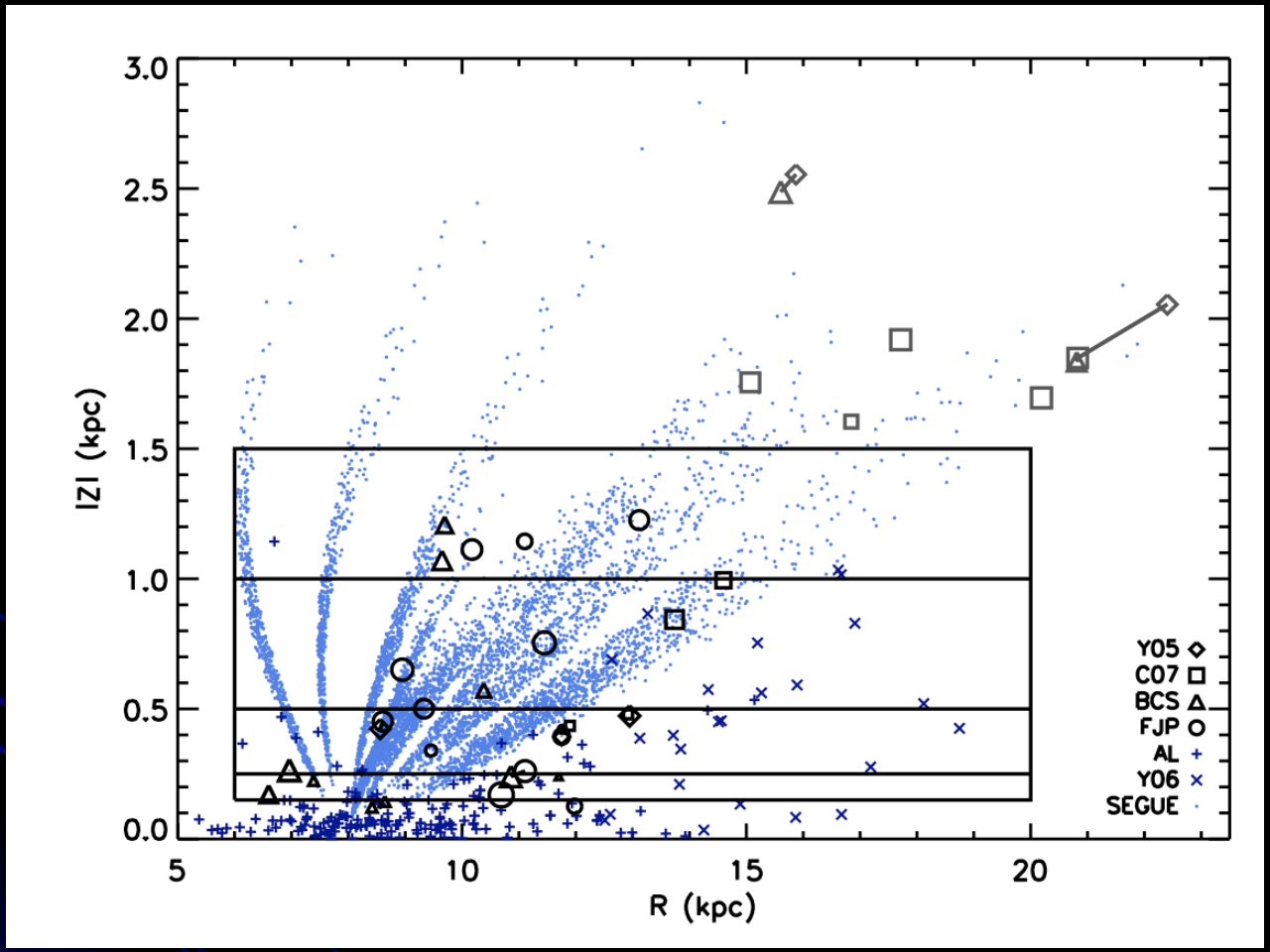
Correcting for Selection Biases

- Incomplete sampling
  - Function of l, b
- Magnitude range not sampled proportionally
- Color cuts correspond to different mass ranges depending on metallicity
- Age effects (not a problem for the G/K sample)
- Correlated distance/metallicity errors
- Testing by “observing” models

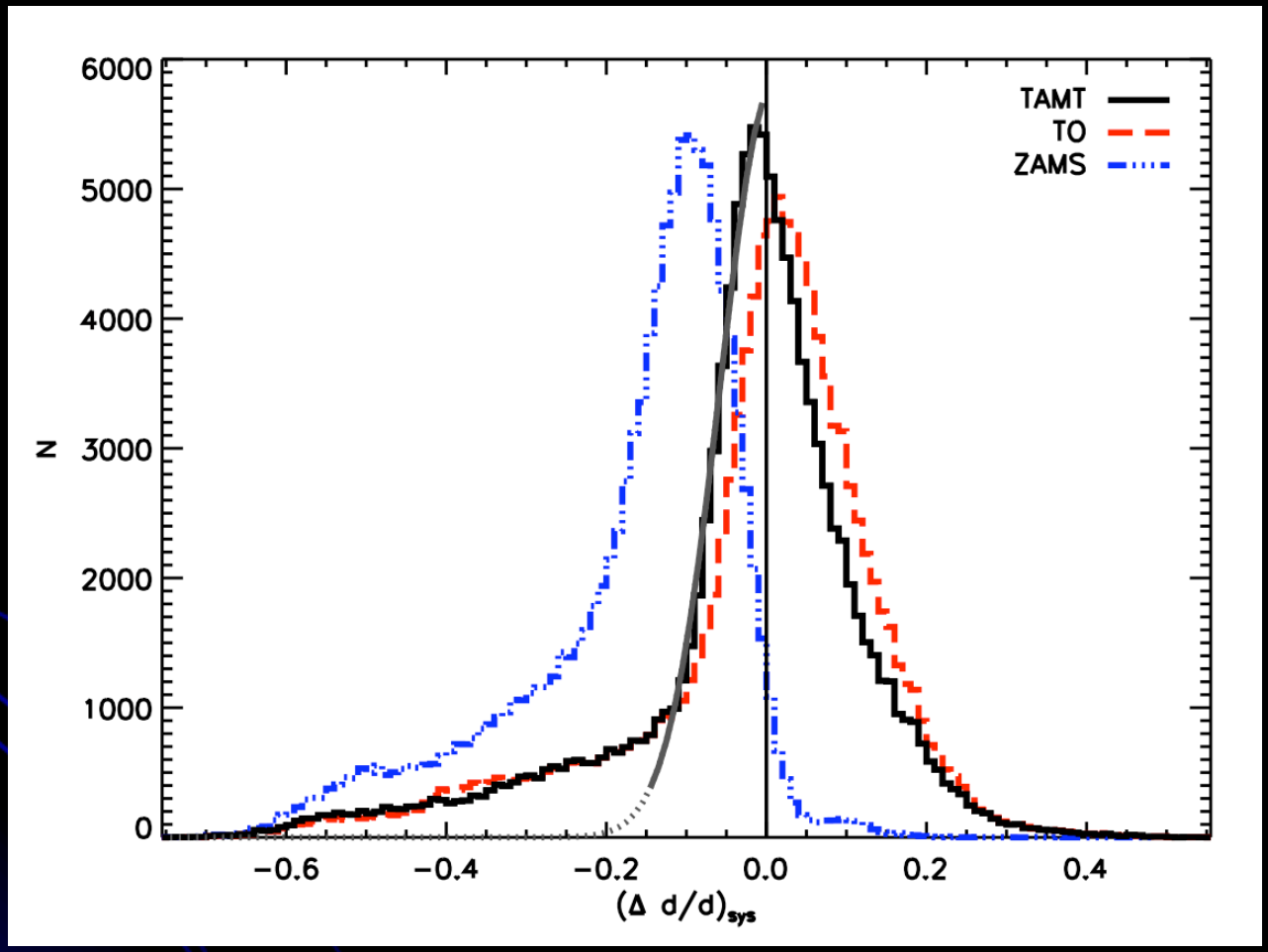
Radial Metallicity Gradient
Cheng et al. 2012

- 22 low-latitude plates yielding 7010 stars
- Blue color cut
- Distances sensitive to age
- Spectroscopic parameters for Teff, logg, and [Fe/H] used because of high and variable reddening
- Tested on Galactic models

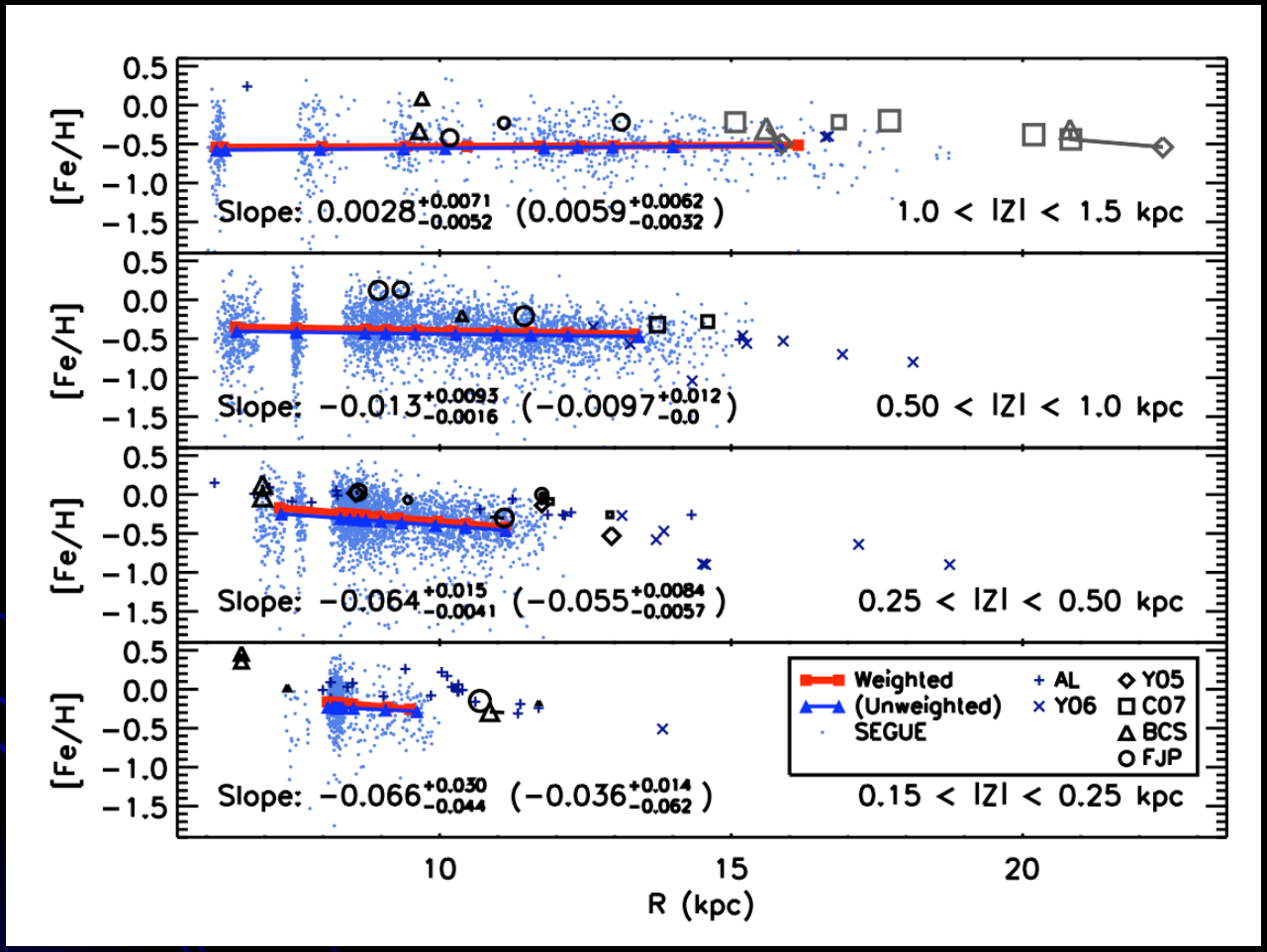
Location of Sample in R-Z plane



Age Impacts on Distances



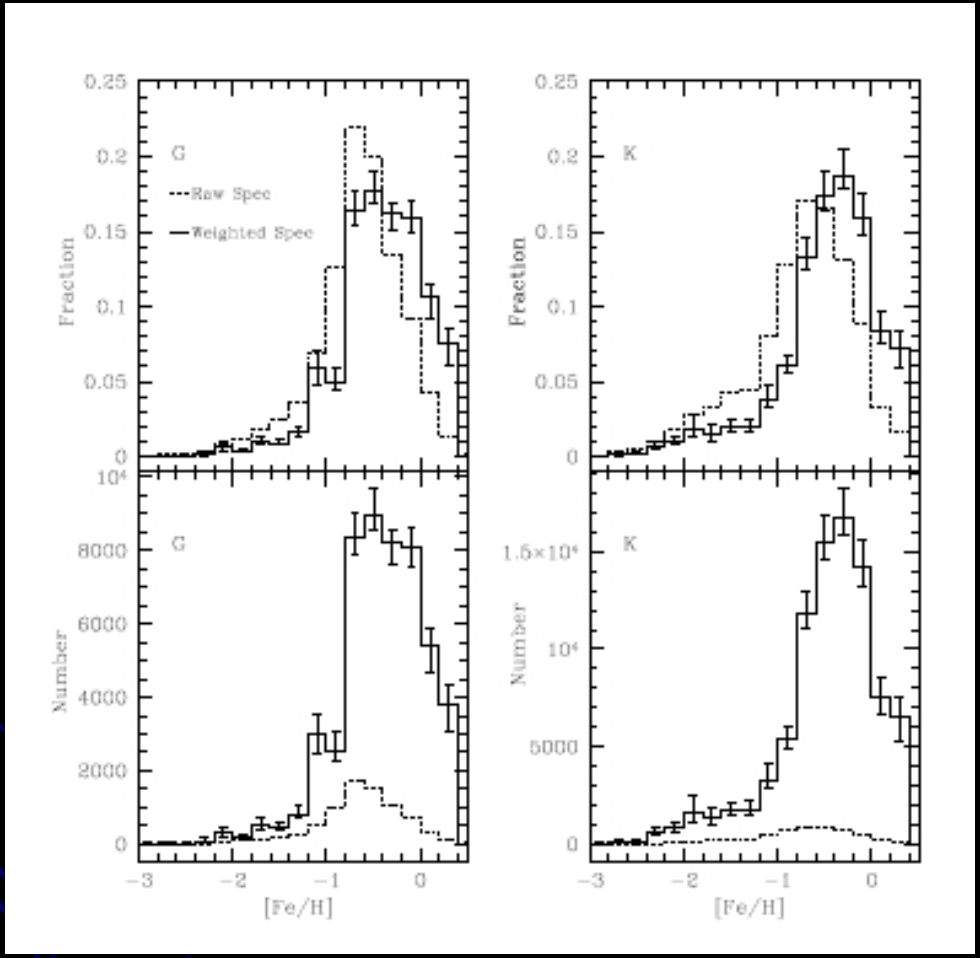
Radial Gradient changes with Z



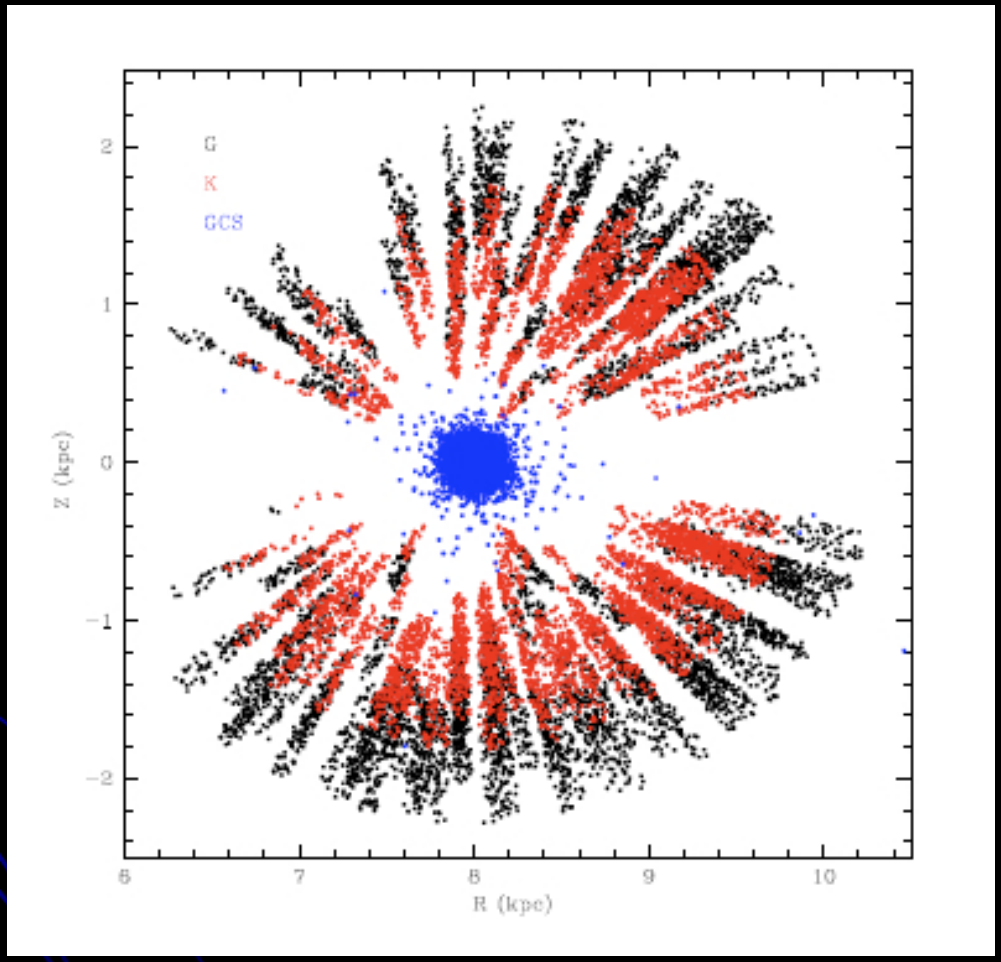
Vertical Metallicity Gradient Schlesinger et al. 2012

- G and K stars were heavily targeted by SEGUE
- "G dwarfs"
  - $0.48 < g\text{-}r_0 < 0.55$
  - 24,270 stars with S/N > 10
  - 1.59-2.29 kpc for "volume completeness"
- "K dwarfs"
  - $0.55 < g\text{-}r_0 < 0.75$
  - 16,847 stars with S/N > 10
  - 1.19-1.84 kpc for "volume completeness"

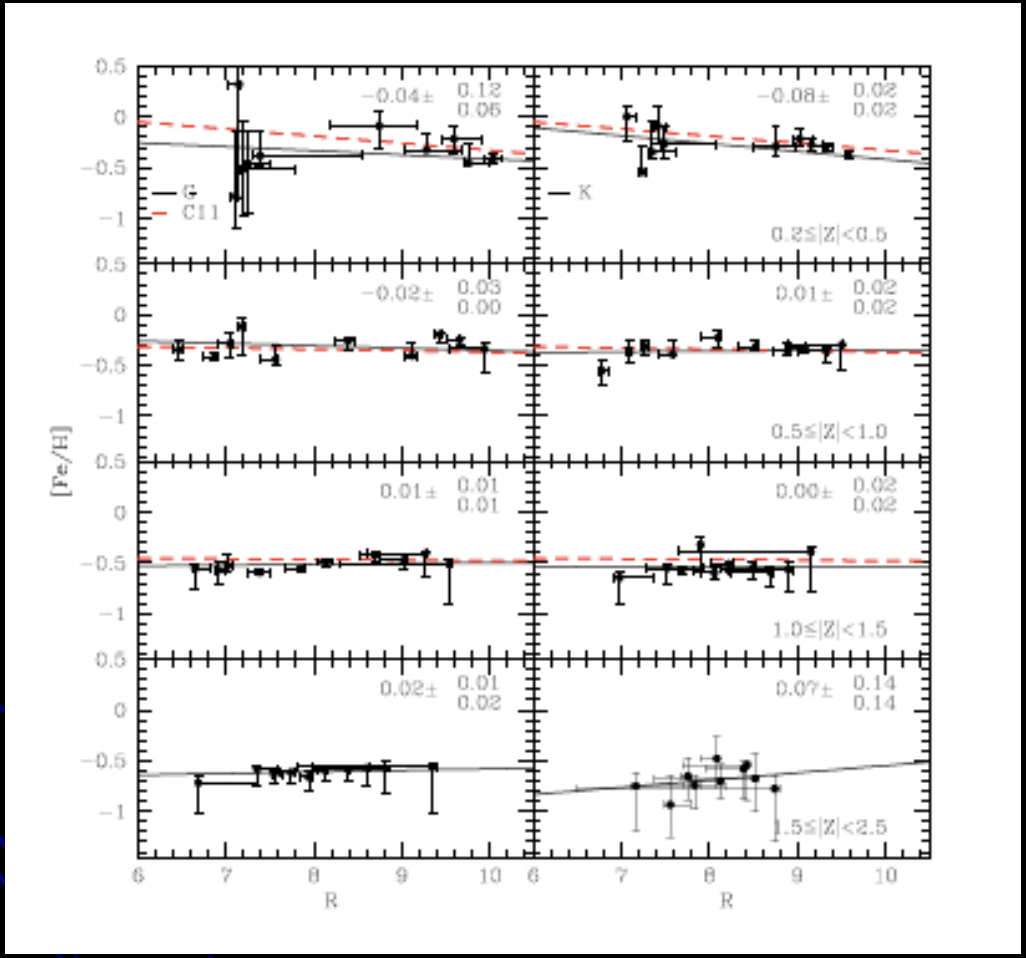
Correcting for target selection



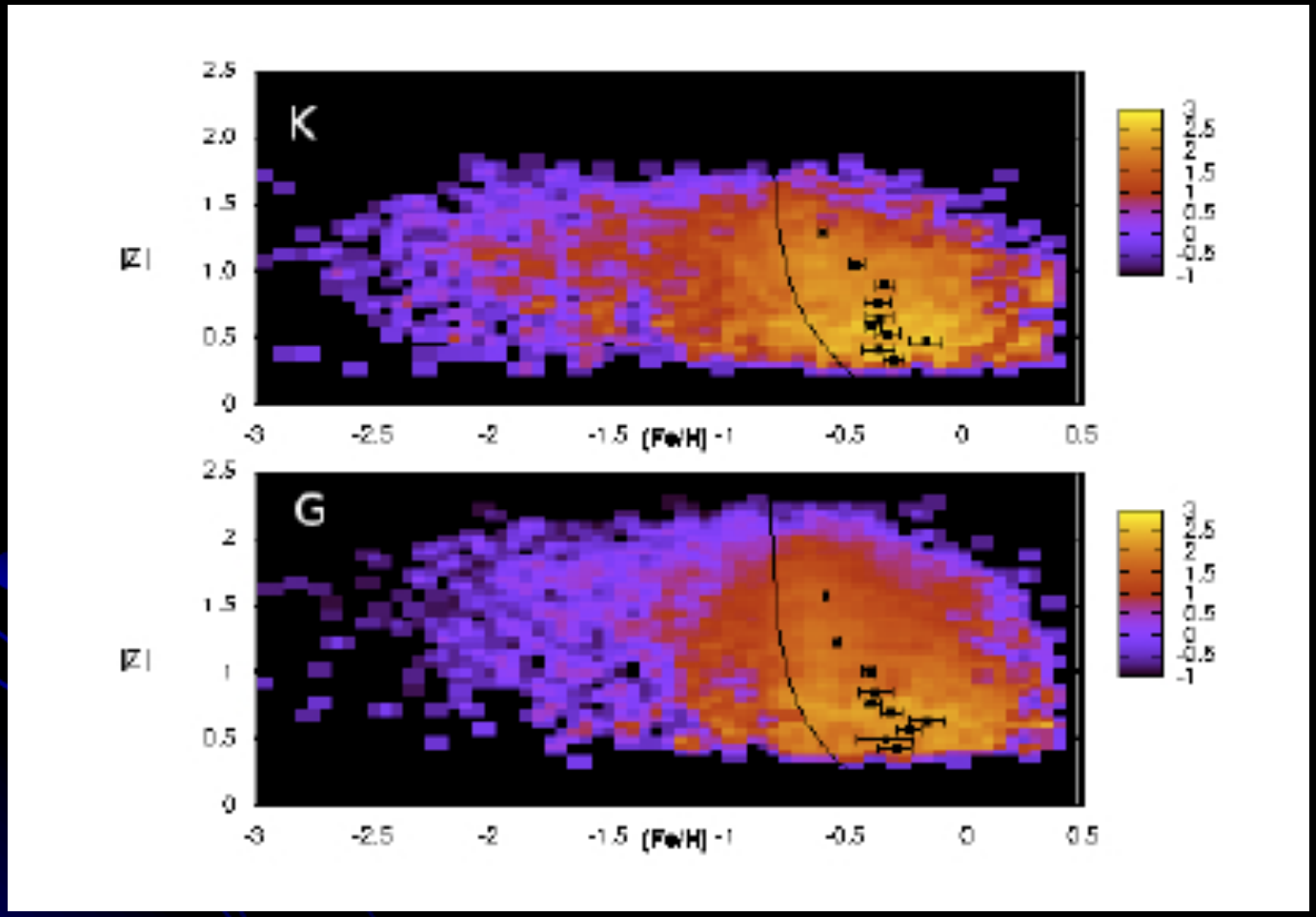
GCS and SEGUE comparison



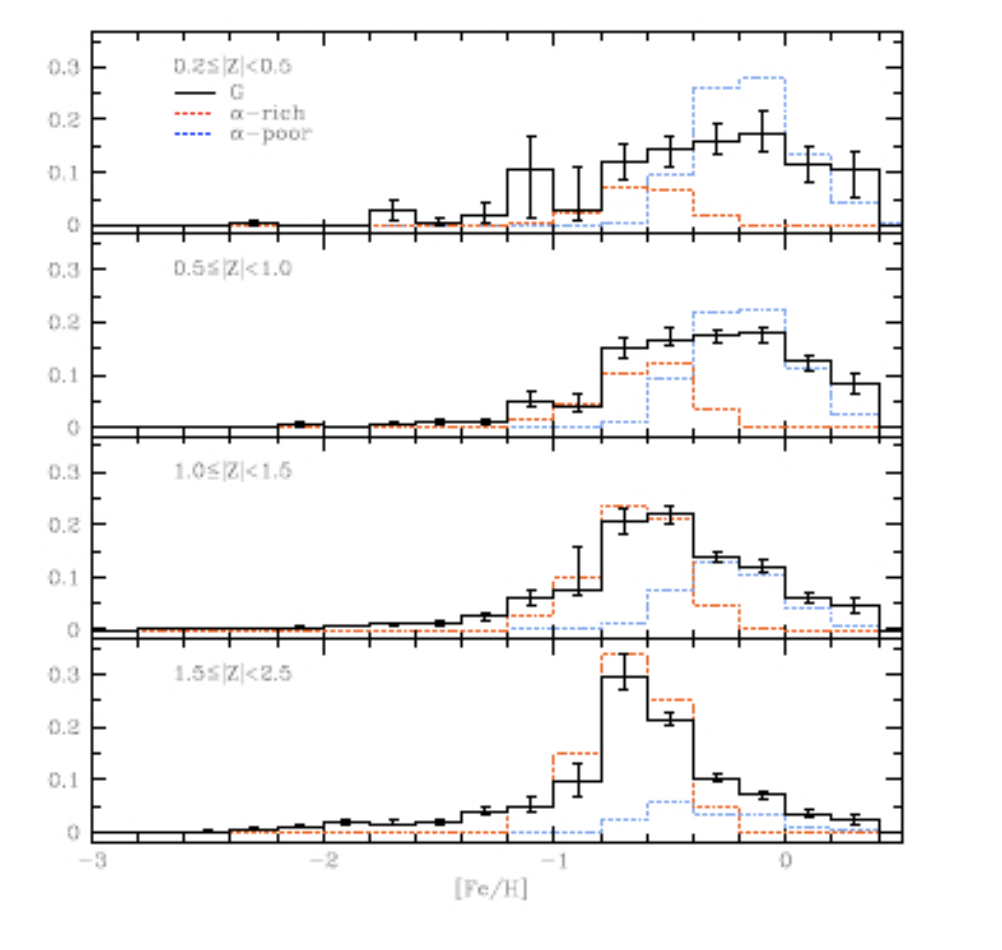
Radial Gradient -- Agrees with Cheng et al. 2012



MDF as a function of height

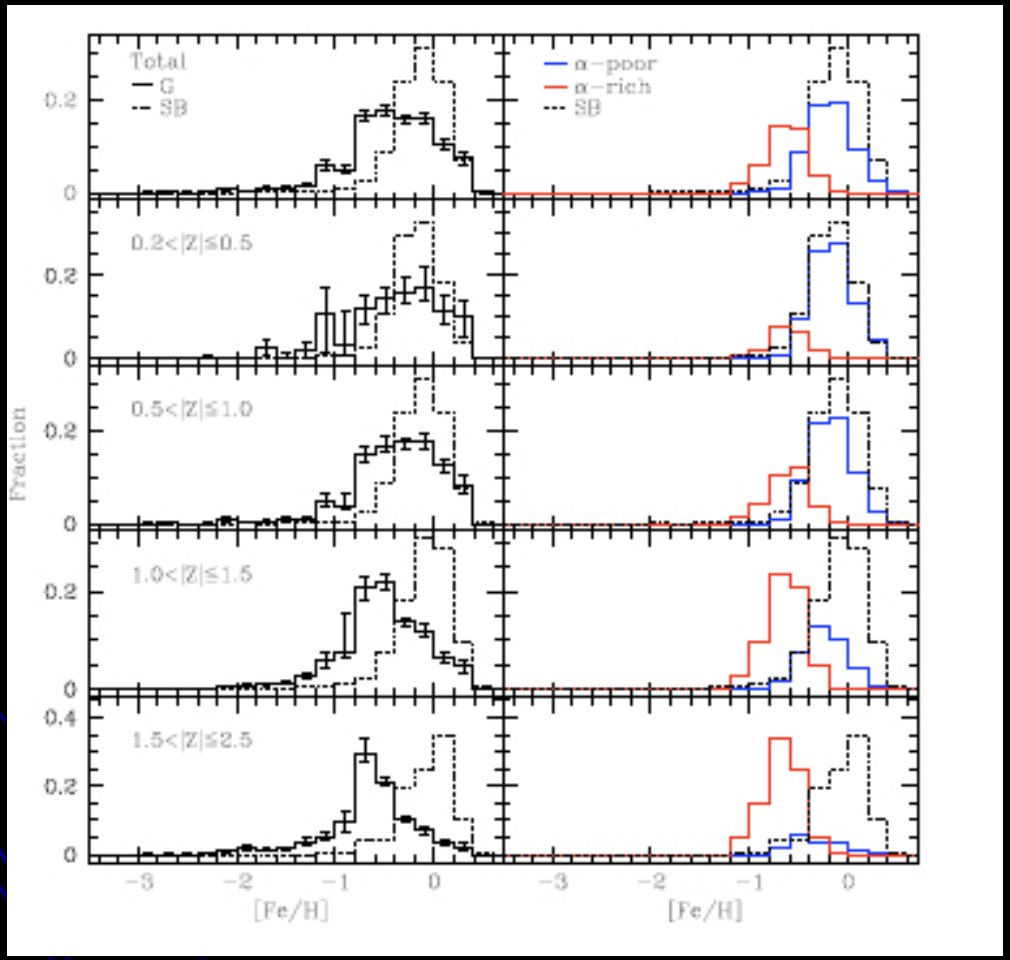


Shift due to increasing α-rich population



Alpha histograms from
Lee et al. 2011

Strong disagreement with Galactic models



AGES

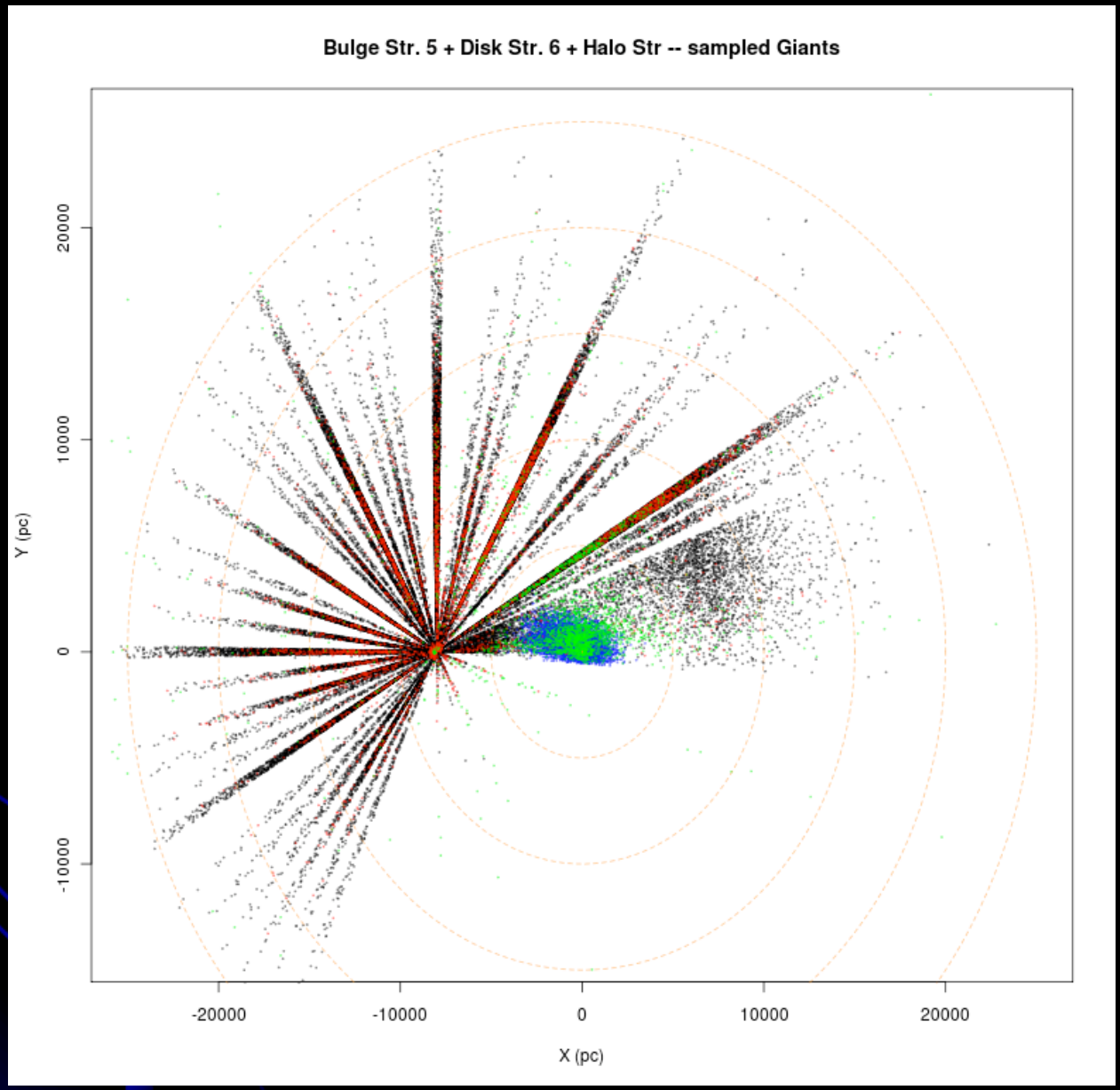
- Powerful test of disk formation/evolution models
- Open cluster provide accurate ages, but do not cover all of parameter space
- Great hope from Gaia – both direct and indirect improvement in ages
- APOGEE + asteroseismology for red giant ages

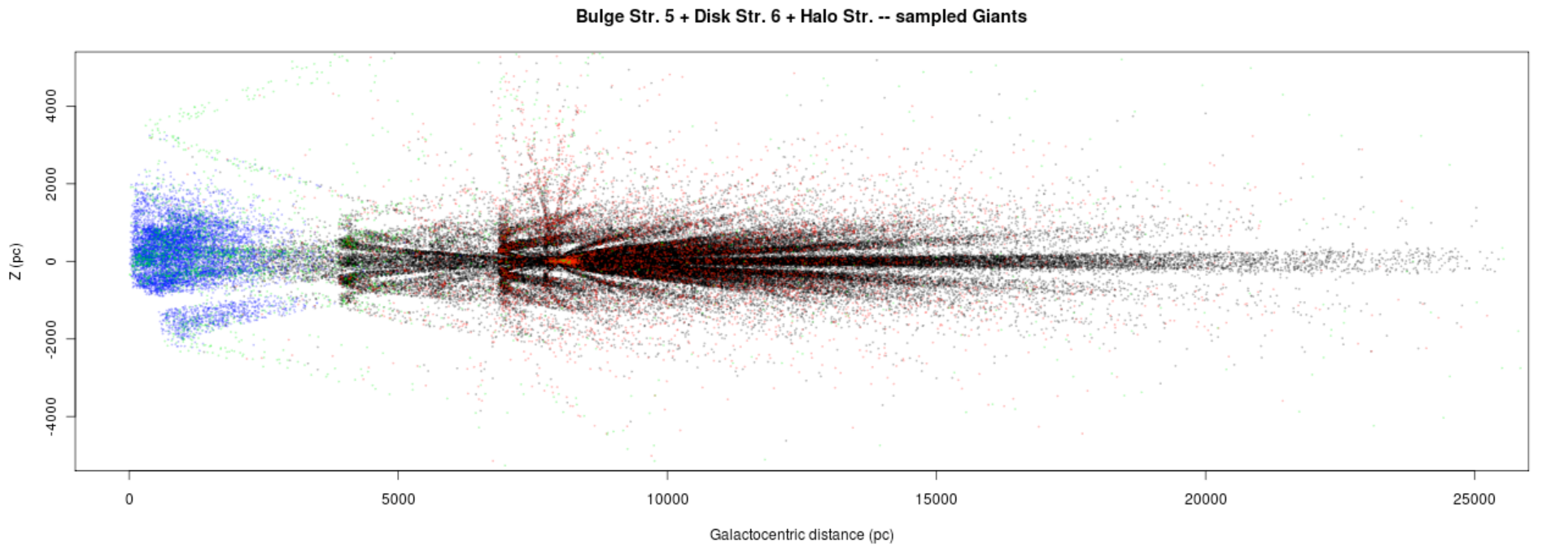
Ages for Red Giants

- Red giants are luminous and can be seen to large distances
- Mass of red giant = mass of star than just exhausted its hydrogen
- But mass difficult to determine based on position in HR diagram.

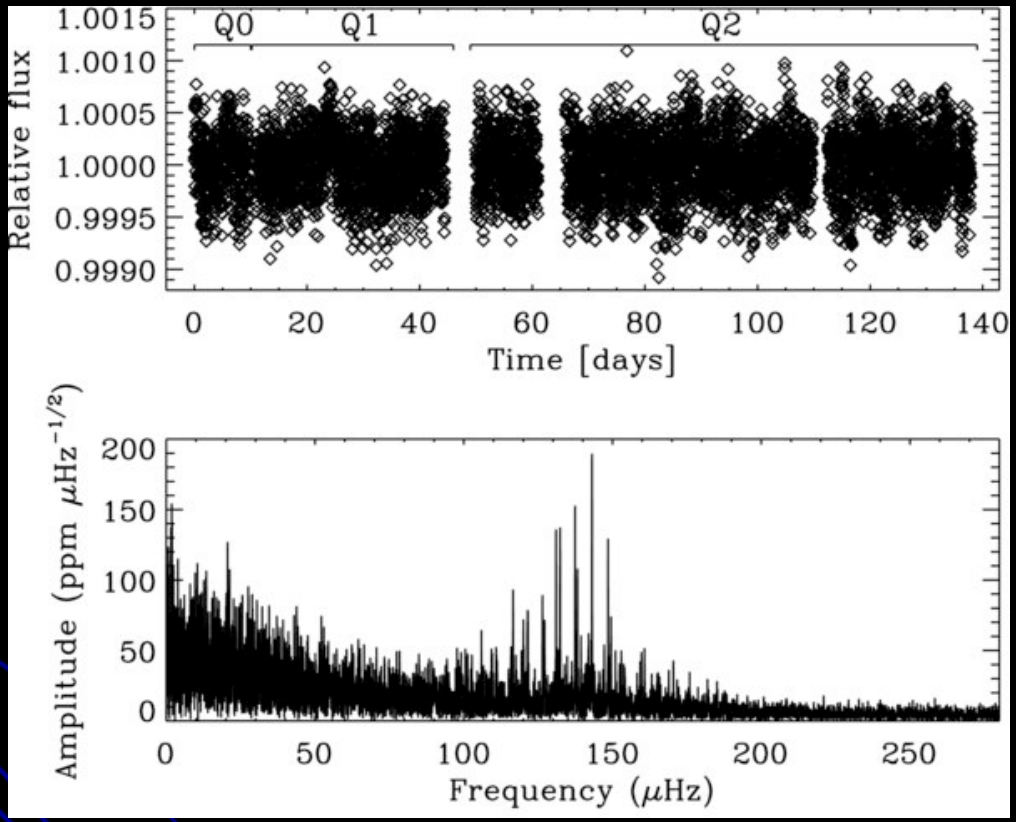
SDSS3 -- APOGEE

- H-band survey of Galactic populations
- 100,000 stars (80% red giants)
- R~25,000
- 15 elements – including C, N, O, Na, Mg, Ca, Mn, Fe, Co, Ni
- Targeted from 2MASS


Bulge Str. 5 + Disk Str. 6 + Halo Str -- sampled Giants
Y (pc)
20000
10000
0
-10000
-20000
-10000
0
10000
20000
X (pc)

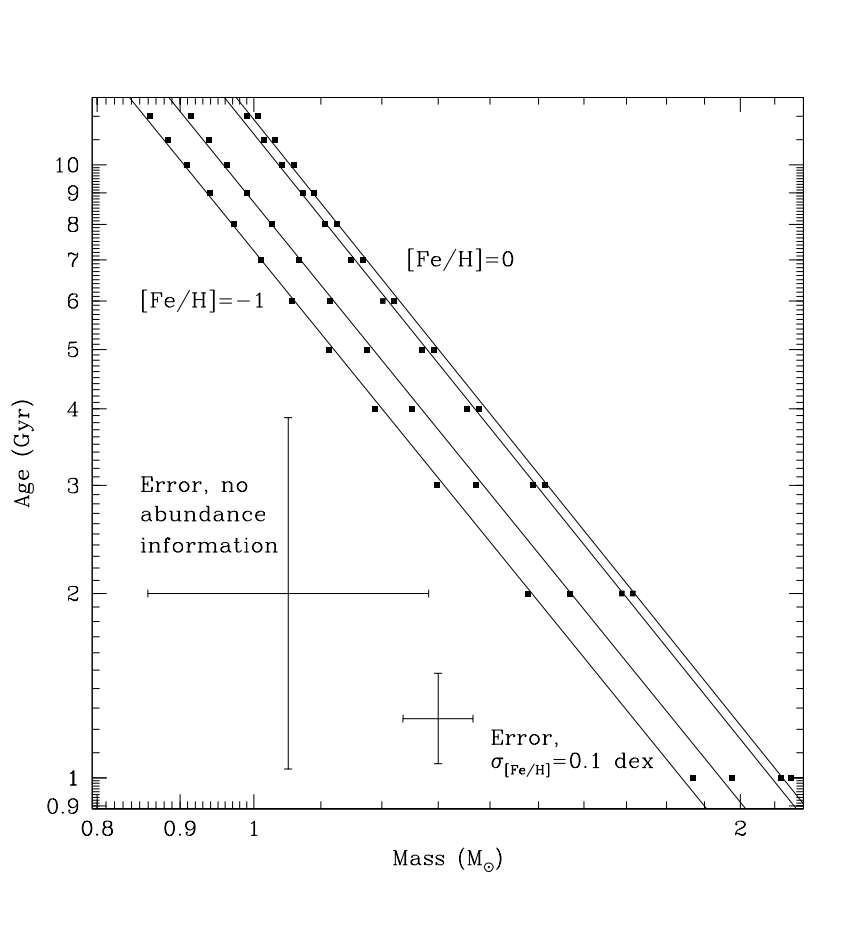

Bulge Str. 5 + Disk Str. 6 + Halo Str. -- sampled Giants
Z (pc)
4000
2000
0
-2000
-4000
0
5000
10000
15000
20000
25000
Galactocentric distance (pc)

Kepler Light curve

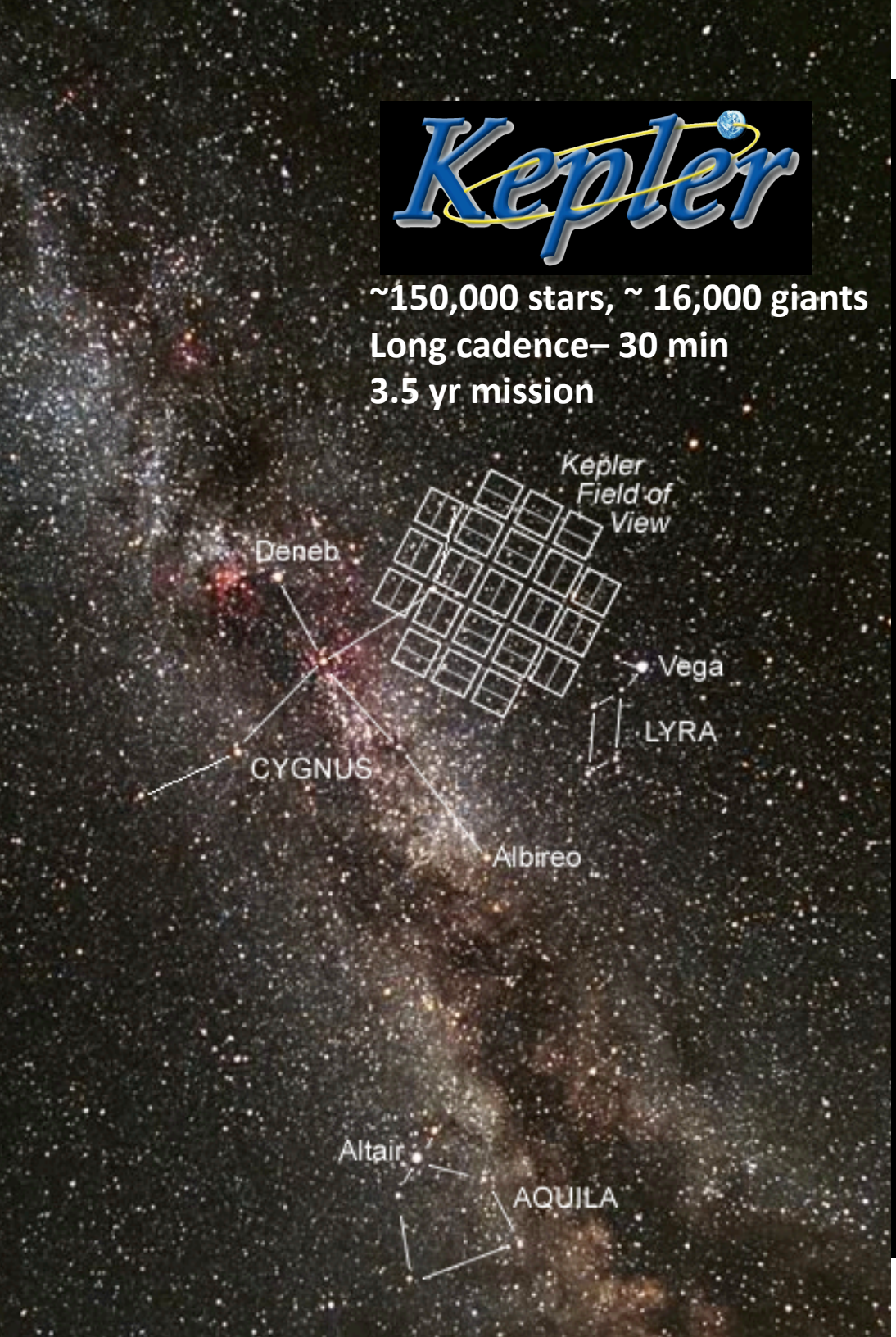


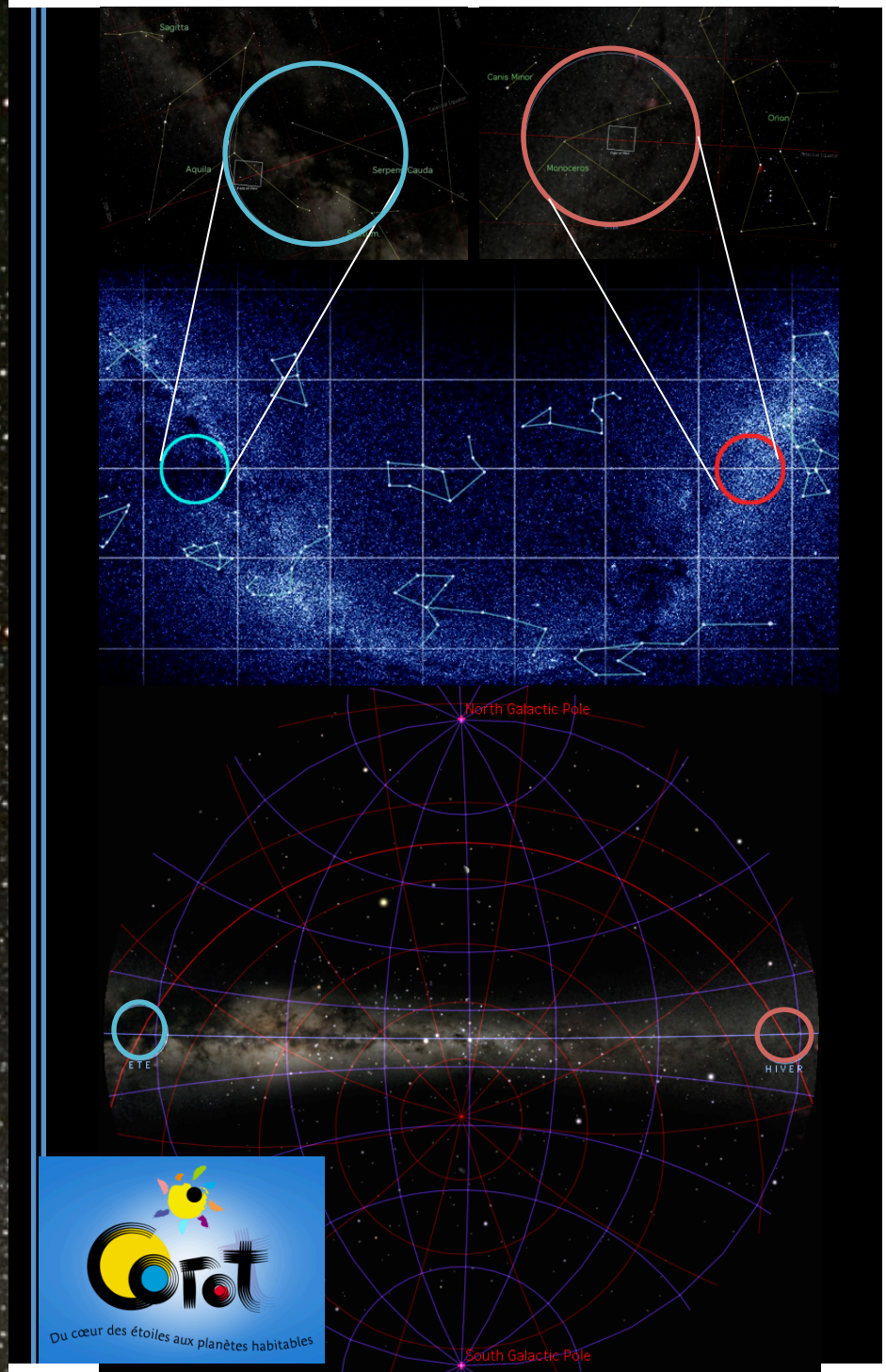
Huber et al. 2010

With Mass and Metallicity – Age!

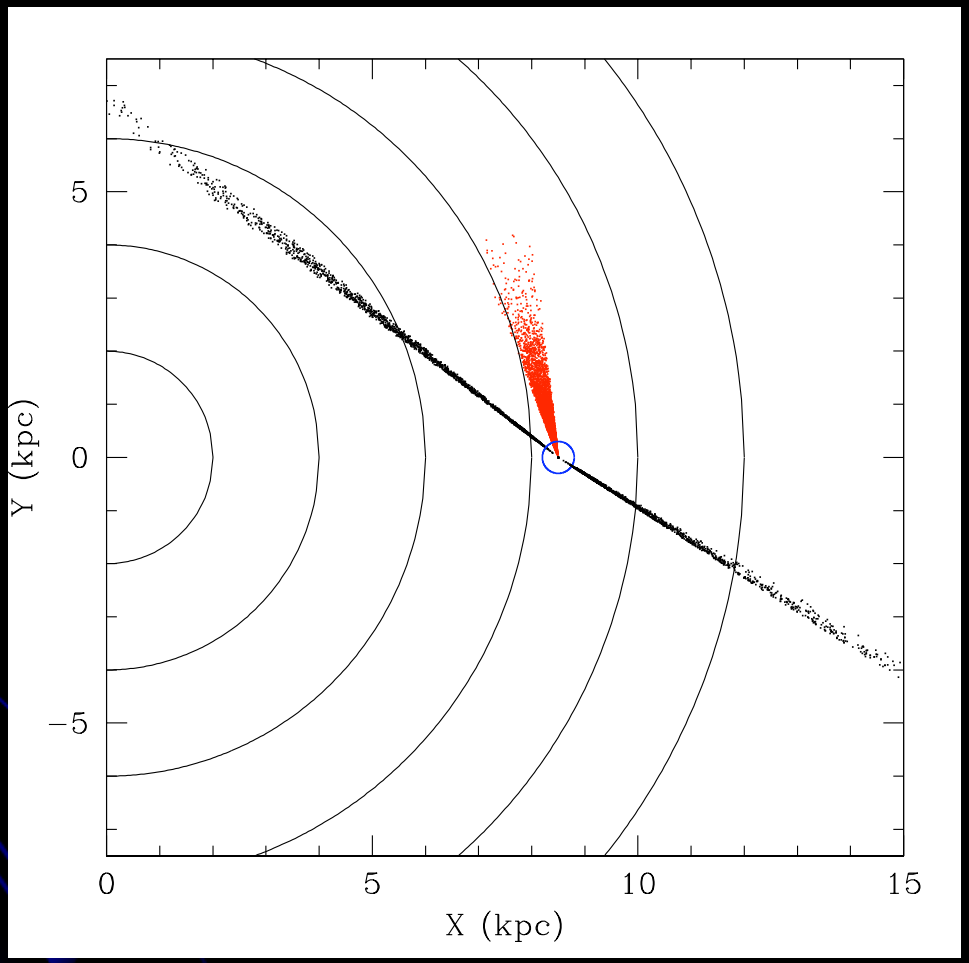


- Using scaling relations OK to first order
- For better analysis, compare measured frequencies with predicted frequencies from models, including composition information
- Gai et al. 2010 Mosser et al. 2011, Kallinger et al. 2010, Metcalfe et al. 2010


Kepler
~150,000 stars, ~ 16,000 giants
Long cadence– 30 min
3.5 yr mission
Kepler Field of View
Deneb
Vega
LYRA
CYGNUS
Albireo
Altair
AQUILA


Sagitta
Aquila
Serpens Cauda
Canis Minor
Monoceros
Orion
North Galactic Pole
ETE
HIVER
South Galactic Pole
Gaia
Du cœur des étoiles aux planètes habitables

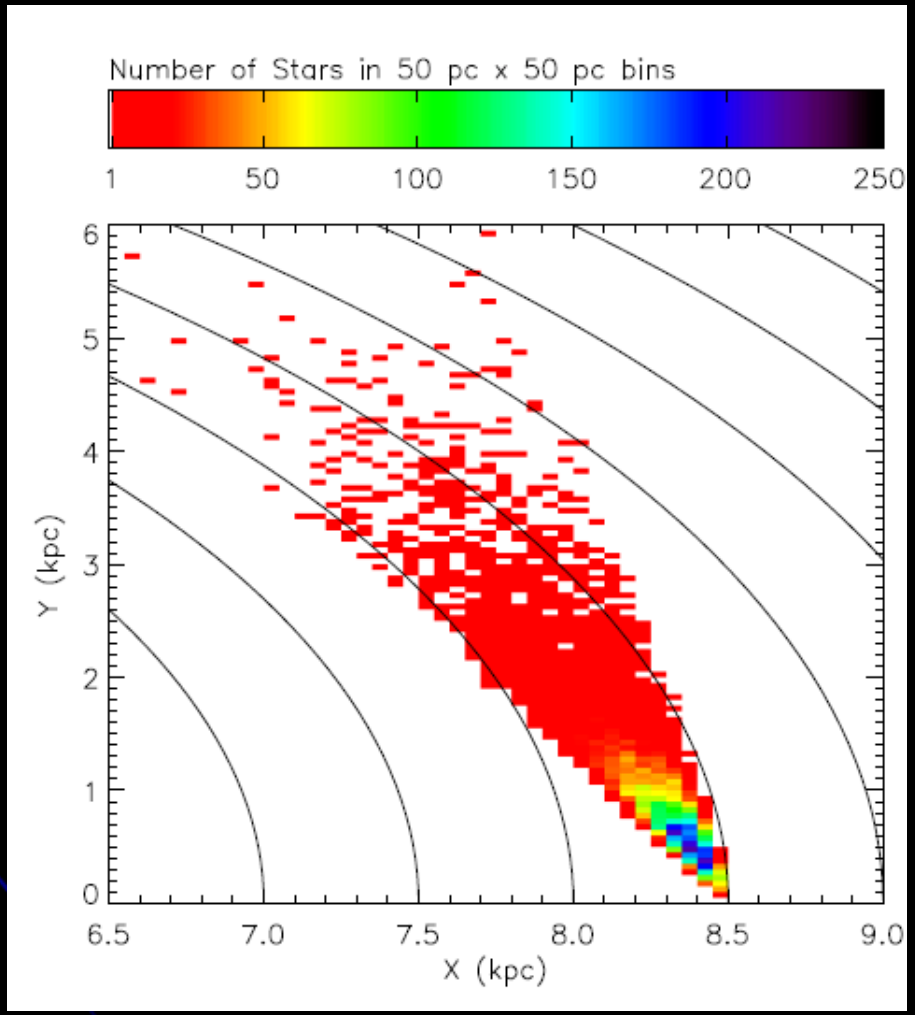
Looking Across the Galaxy



Abundances from APOGEE

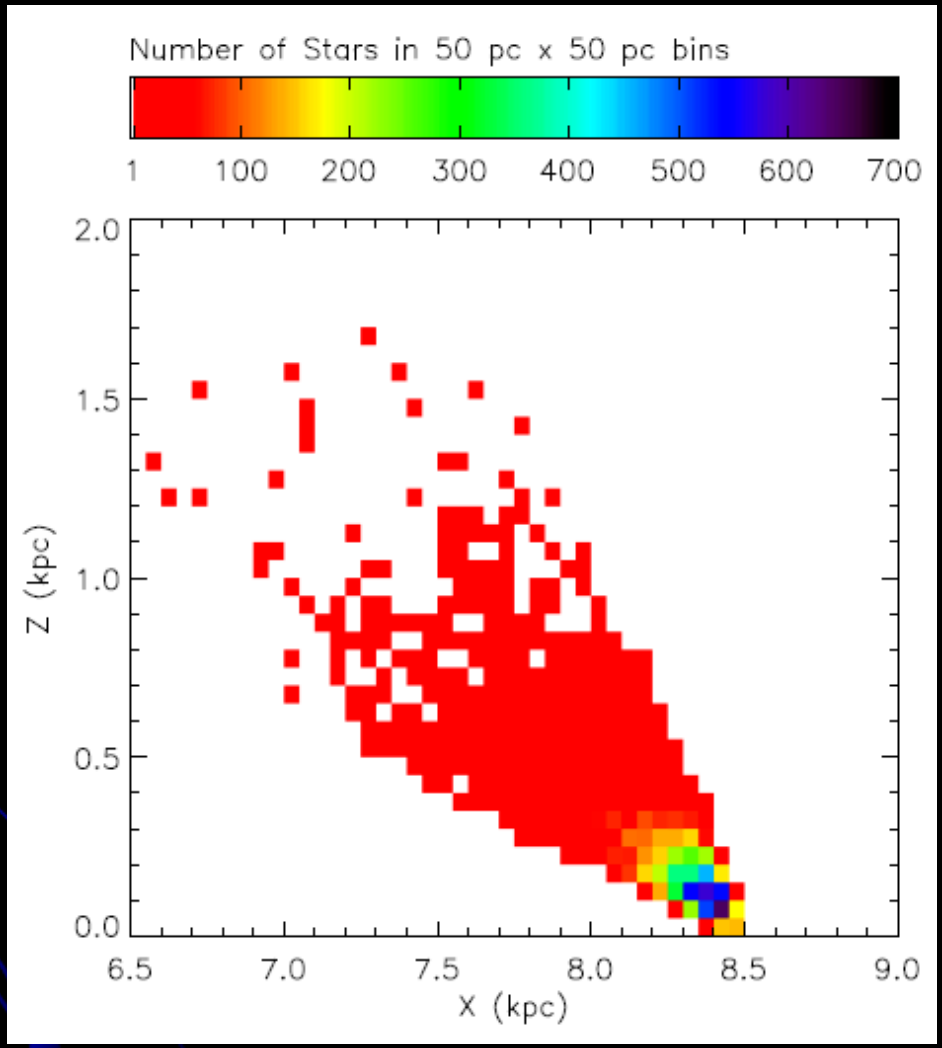
- The APOKASC collaboration will get H-band spectra for ~10,000 stars in the Kepler field
  - 8,000 red giants and red clump stars
  - > 1,000 already observed
  - 1,000 asteroseismic dwarfs
  - 1,000 dwarfs with rotation ages
- In addition, ~300 CoRoT targets will be observed

Along the Solar Circle



GC

Thick Disk


Number of Stars in 50 pc x 50 pc bins
1
100
200
300
400
500
600
700
2.0
1.5
1.0
0.5
0.0
Z (kpc)
6.5
7.0
7.5
8.0
8.5
9.0
X (kpc)

Seismic Ages -- complementary

- Accurate distances from Gaia will be very useful for increasing the number of stars with well-measured ages
- Ages are determined from the mass which is derived from the seismic frequencies
- Measuring frequencies accurately depends on brightness of star, not distance
- Ages also independent of reddening
- Different systematic dependence on stellar models

Conclusions

- Radial gradient flattens with increasing Z
- Vertical metallicity gradient
  - Consistent with transition from “thin” to “thick” disk
  - Inconsistent with Galactic models that are tuned to match GCS
- Understanding the formation and evolution of the disk requires accurate ages
- Poised to make large advances in this area!