The abundance distribution in the thin disk

Carlos Allende Prieto

Overview

1. Metallicity distribution in the solar neighborhood
2. Abundance ratios
3. Leaving the solar neighborhood
4. APOGEE: status, prospects, and (too) early results

Metallicity distribution in the solar neighborhood

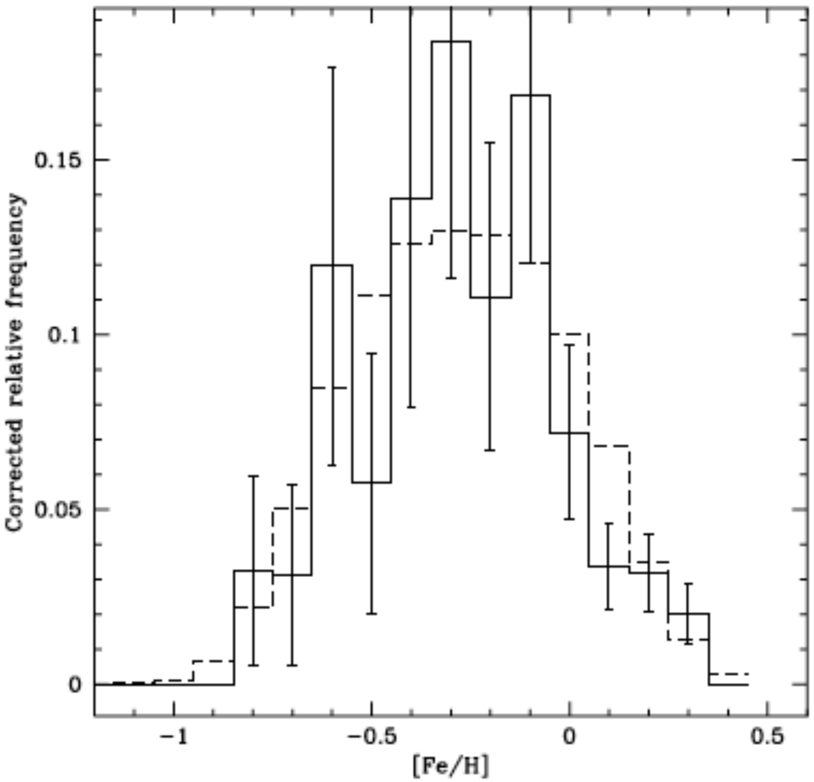


Fig. 4. The histogram of [Fe/H] values, for stars hotter than 5100 K (continuous line), together with the theoretical fit to the data (dashed).

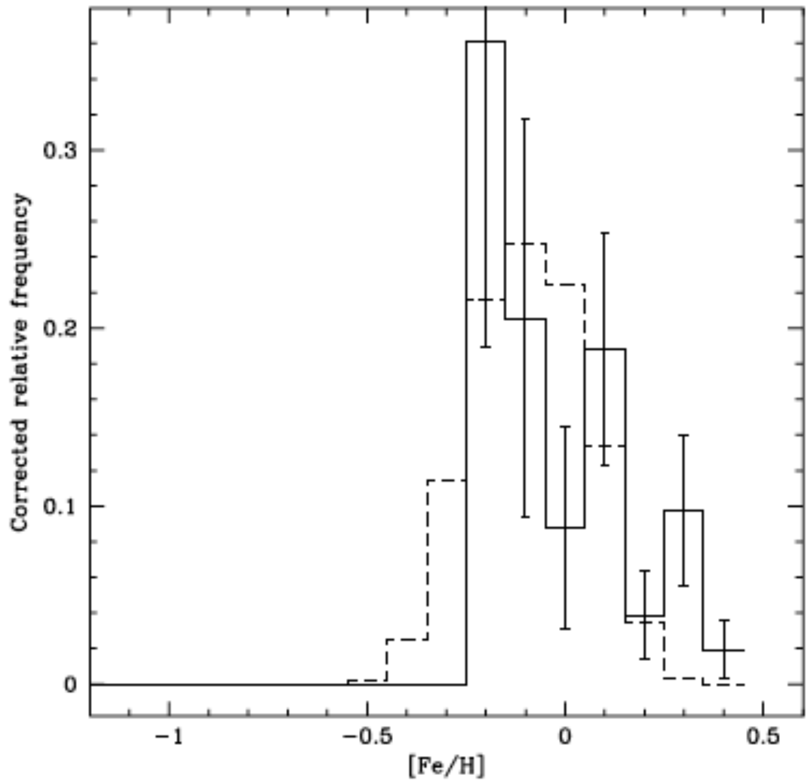


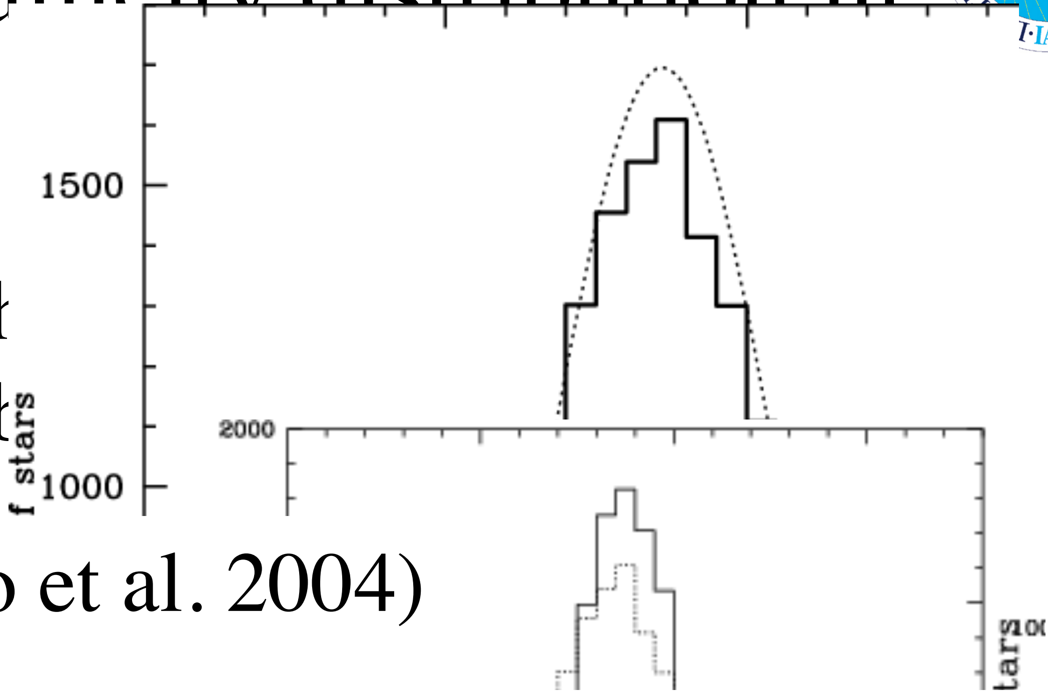
Fig. 5. The histogram of [Fe/H] values, for stars cooler than 5100 K (continuous line), together with the theoretical fit to the data (dashed).

Favata et al. 1997

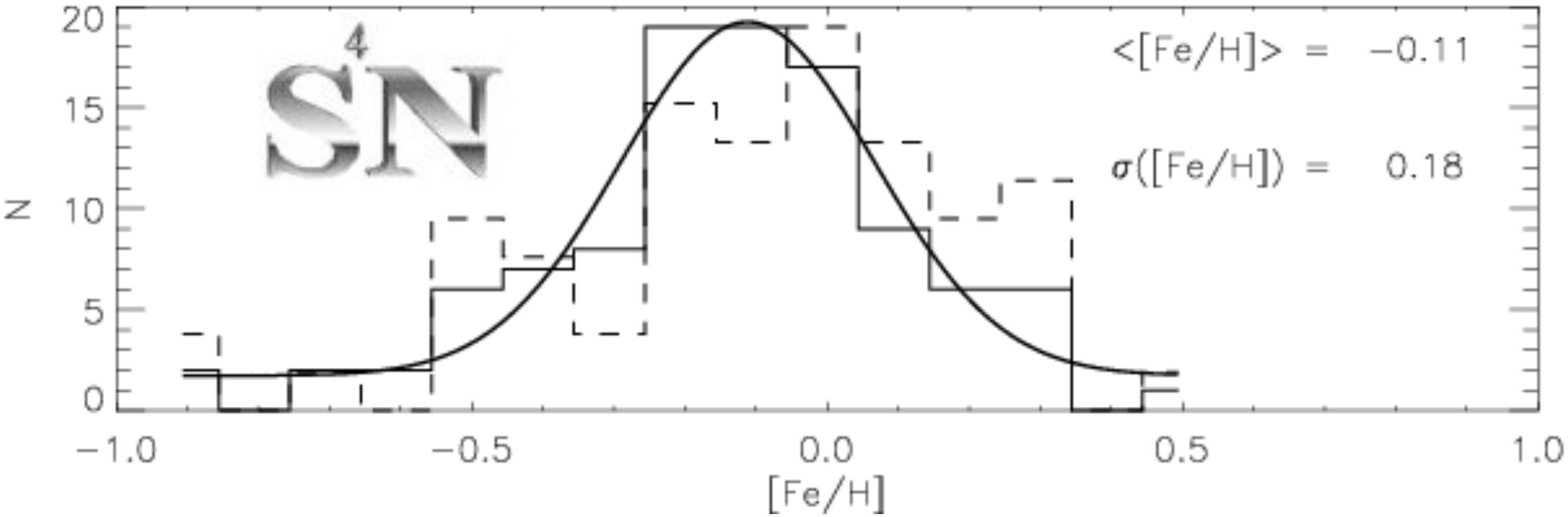
[Fe/H]

Metallicity distribution in the

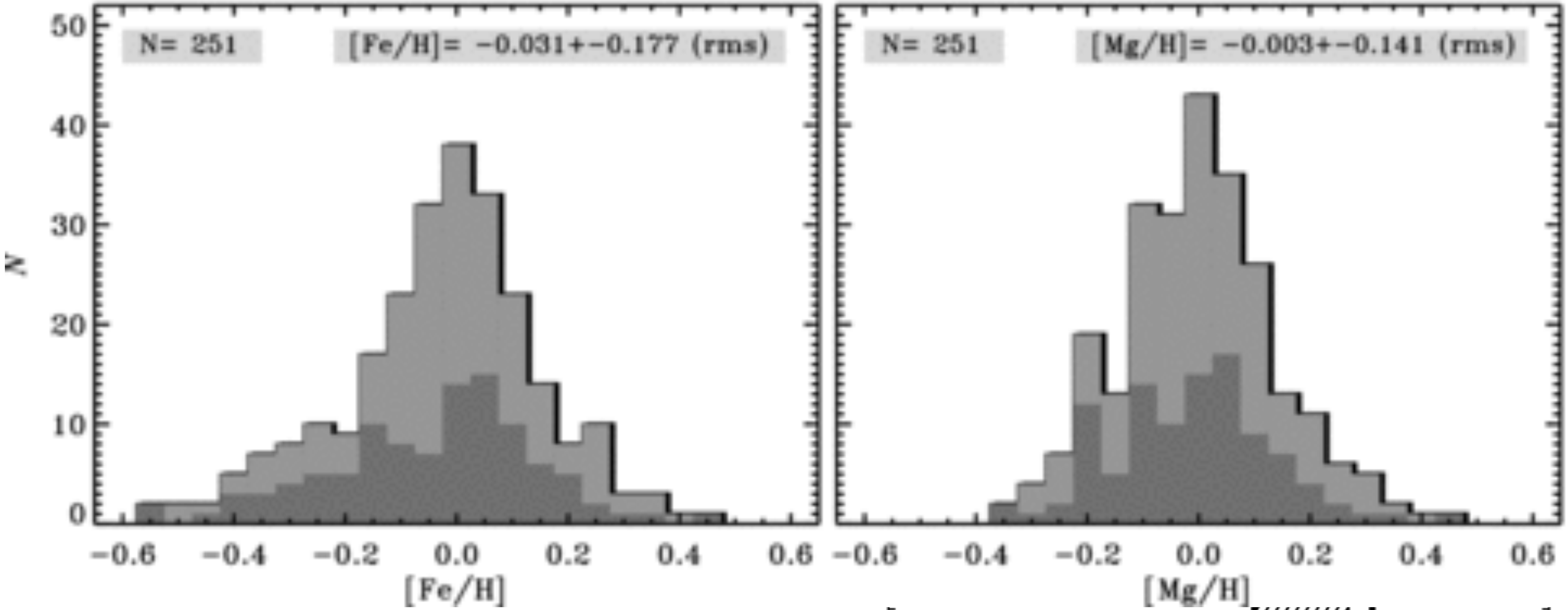
- Geneva-Copenl al. 2004, Holmb



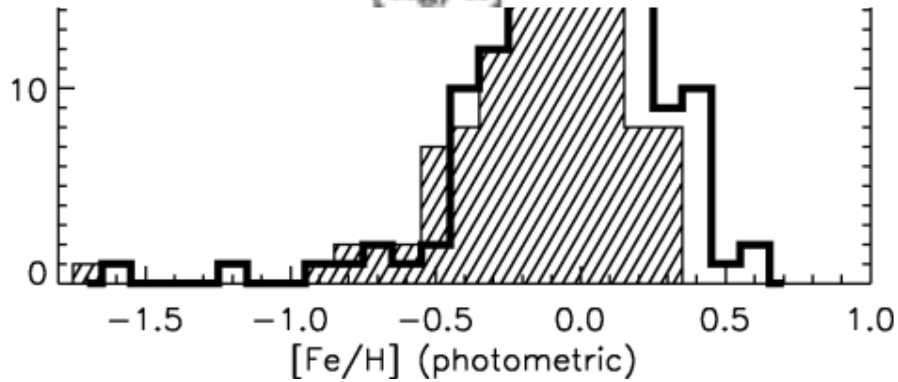
•S^4N (Allende Prieto et al. 2004)



Metallicity distribution in



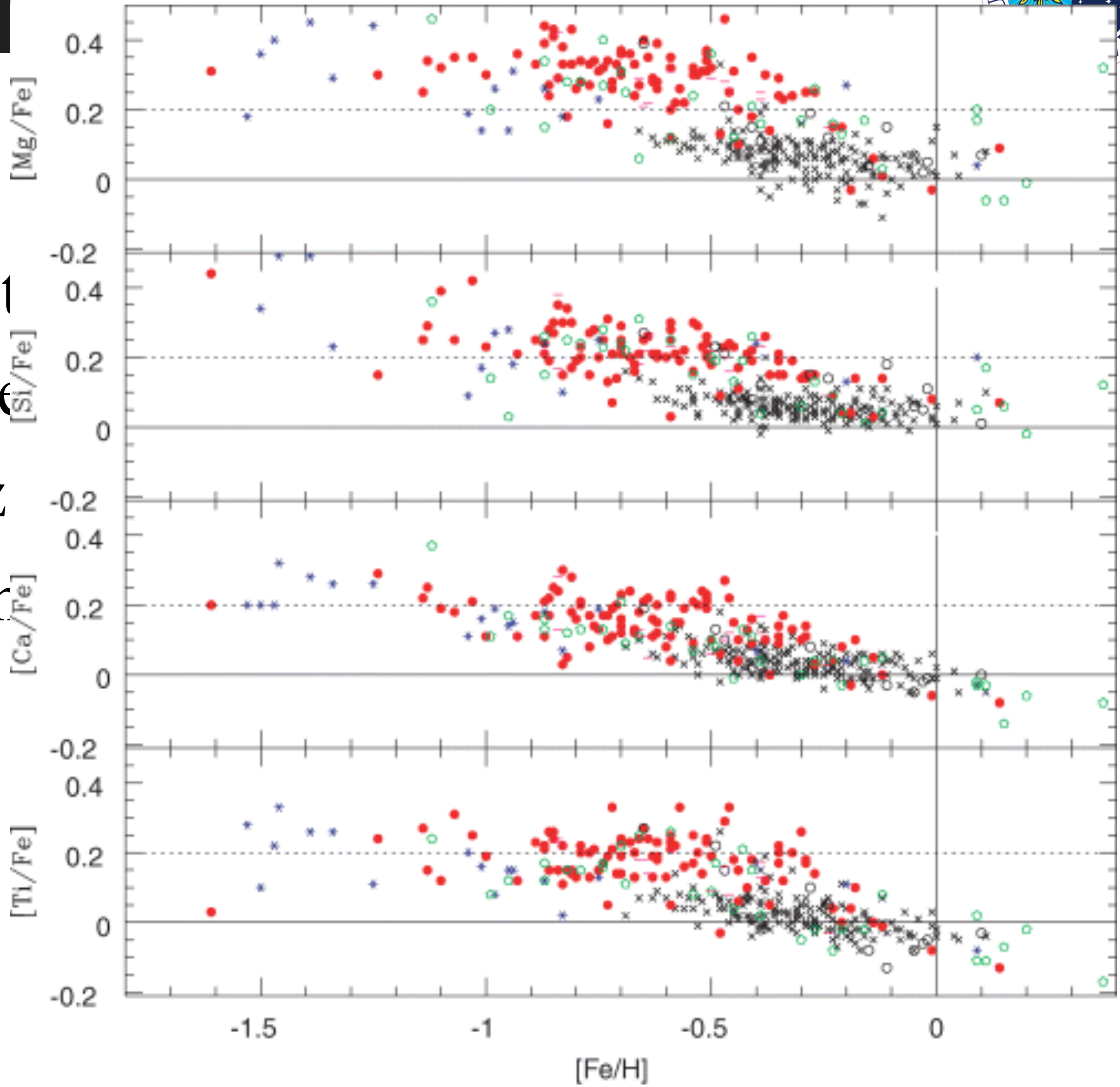
- Fuhrmann (1998-2011)



Issues

- Sample definition: Volume complete or not, definition of solar neighborhood, radial mixing, spectral types considered…
- Offsets: photometric calibrations of intermediate-band filters, systematic spectroscopic errors
- Population assignment: thin/thick disk membership

- Reddy et
- Bensby e
- Ramirez
- Fuhrman



Cosmic scatter

- Reddy et al. 2006

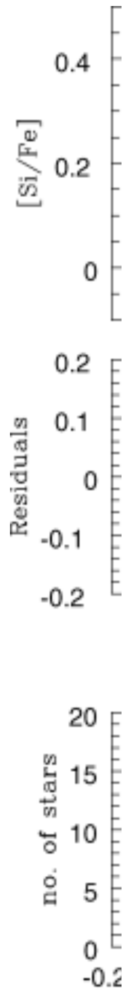


Table 8. The predicted uncertainty, σ_{mod} and the σ_{Gau} resulting from a Gaussian fit to the residuals for the thin- and thick-disc stars are given.

[X/Fe]	Thin disc		Thick disc	
	σ_{mod}	σ_{Gau}	σ_{mod}	σ_{Gau}
[Fe/H]	0.07	...	0.08	...
[C/Fe]	0.14	0.07	0.14	0.09
[O/Fe]	0.16	0.07	0.19	0.07
[Na/Fe]	0.03	0.04	0.05	0.07
[Mg/Fe]	0.04	0.04	0.05	0.07
[Al/Fe]	0.04	0.05	0.05	0.08
[Si/Fe]	0.05	0.04	0.07	0.06
[Ca/Fe]	0.03	0.04	0.03	0.06
[Sc/Fe]	0.11	0.05	0.11	0.09
[Ti/Fe]	0.03	0.04	0.06	0.06
[V/Fe]	0.04	0.04	0.06	0.10
[Cr/Fe]	0.02	0.03	0.03	0.04
[Mn/Fe]	0.04	0.04	0.03	0.04
[Co/Fe]	0.02	0.04	0.03	0.06
[Ni/Fe]	0.02	0.03	0.04	0.04
[Cu/Fe]	0.02	0.06	0.04	0.08
[Zn/Fe]	0.05	0.06	0.10	0.06
[Y/Fe]	0.09	0.07	0.11	0.12
[Zr/Fe[	0.10	0.07	0.11	0.12
[Ba/Fe]	0.12	0.08	0.12	0.11
[Ce/Fe]	0.11	0.08	0.11	0.10
[Nd/Fe]	0.10	0.07	0.11	0.09
[Eu/Fe]	0.11	0.08	0.13	0.08

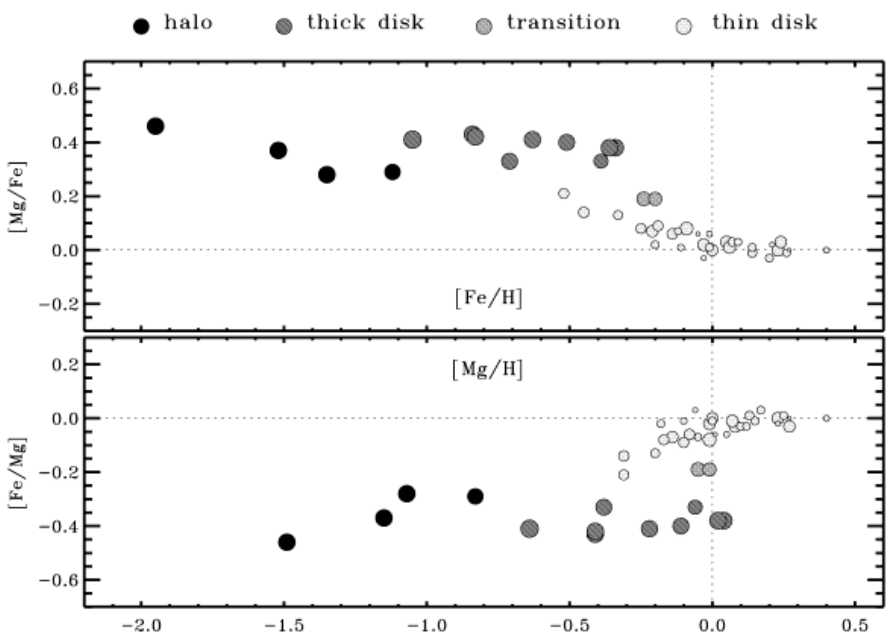
Abundance Scatter

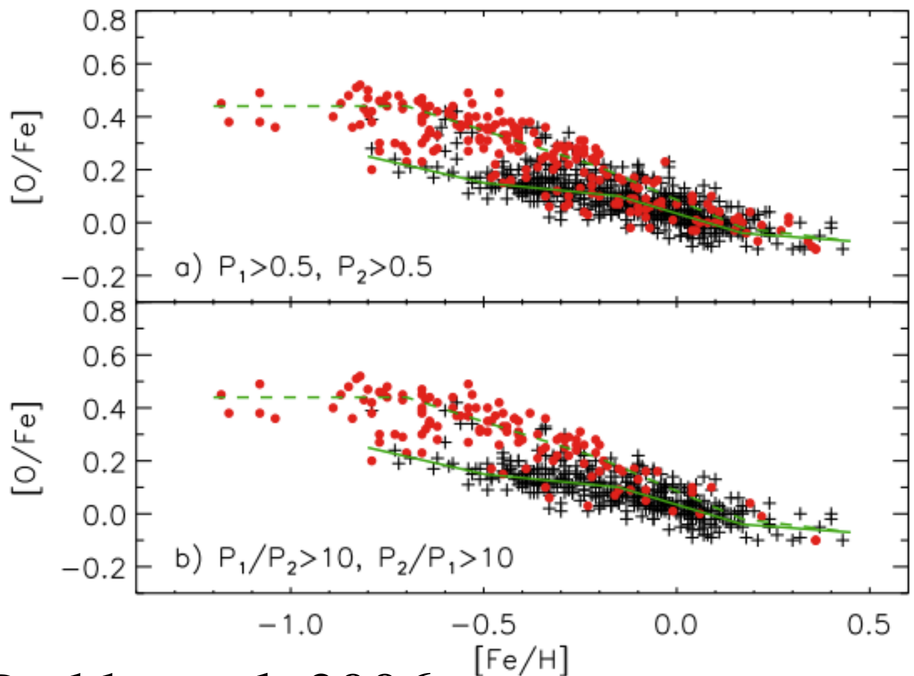
- Open clusters show tight abundance distributions, but dissolve quickly
- Most stellar disk structure in phase space due to dynamical effects (De Simone et al. 2004, Quillen & Minchev 2005, Chakrabarty 2007)

Population purity

- Thin/thick-disk dichotomy, or just one disk?
- Key for understanding the formation of the disk

Ramirez et al. 2012

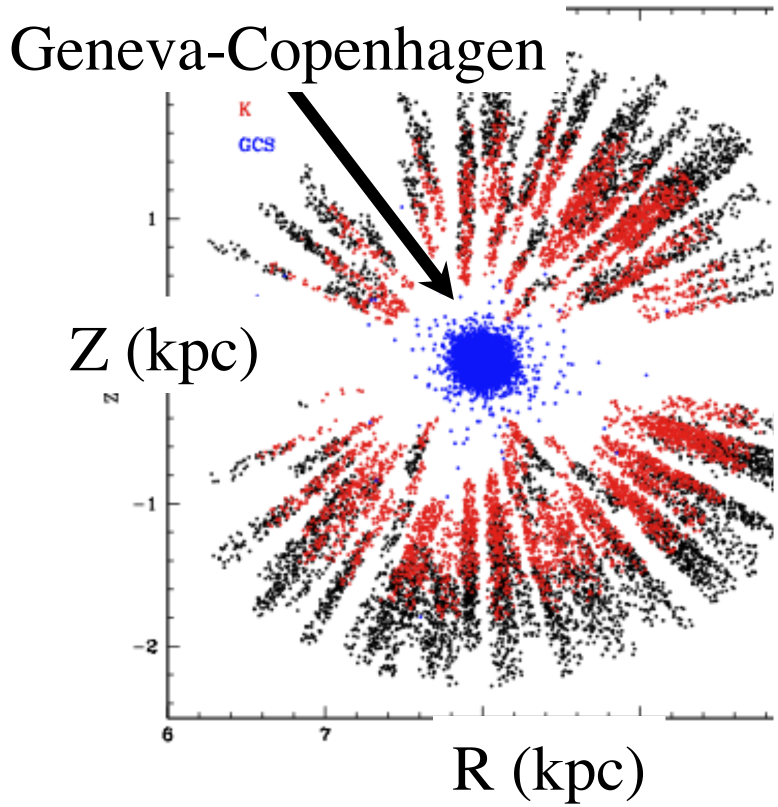


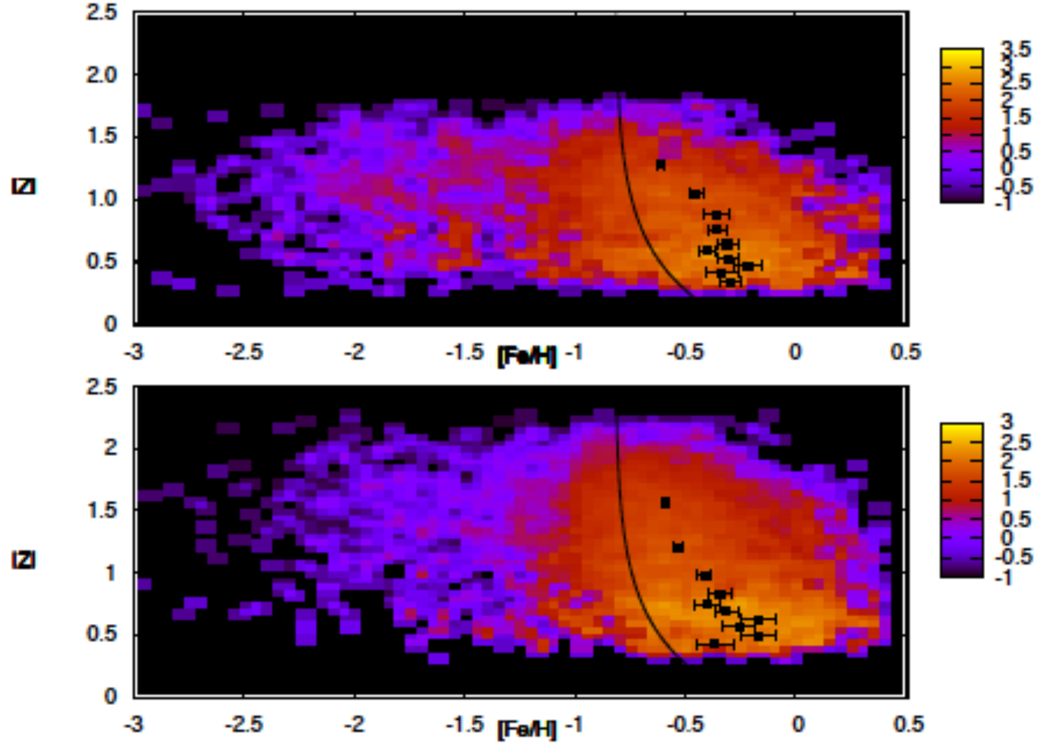


Fuhrmann 1998, Bensby et al. 2003 Reddy et al. 2006

Beyond the solar neighborhood

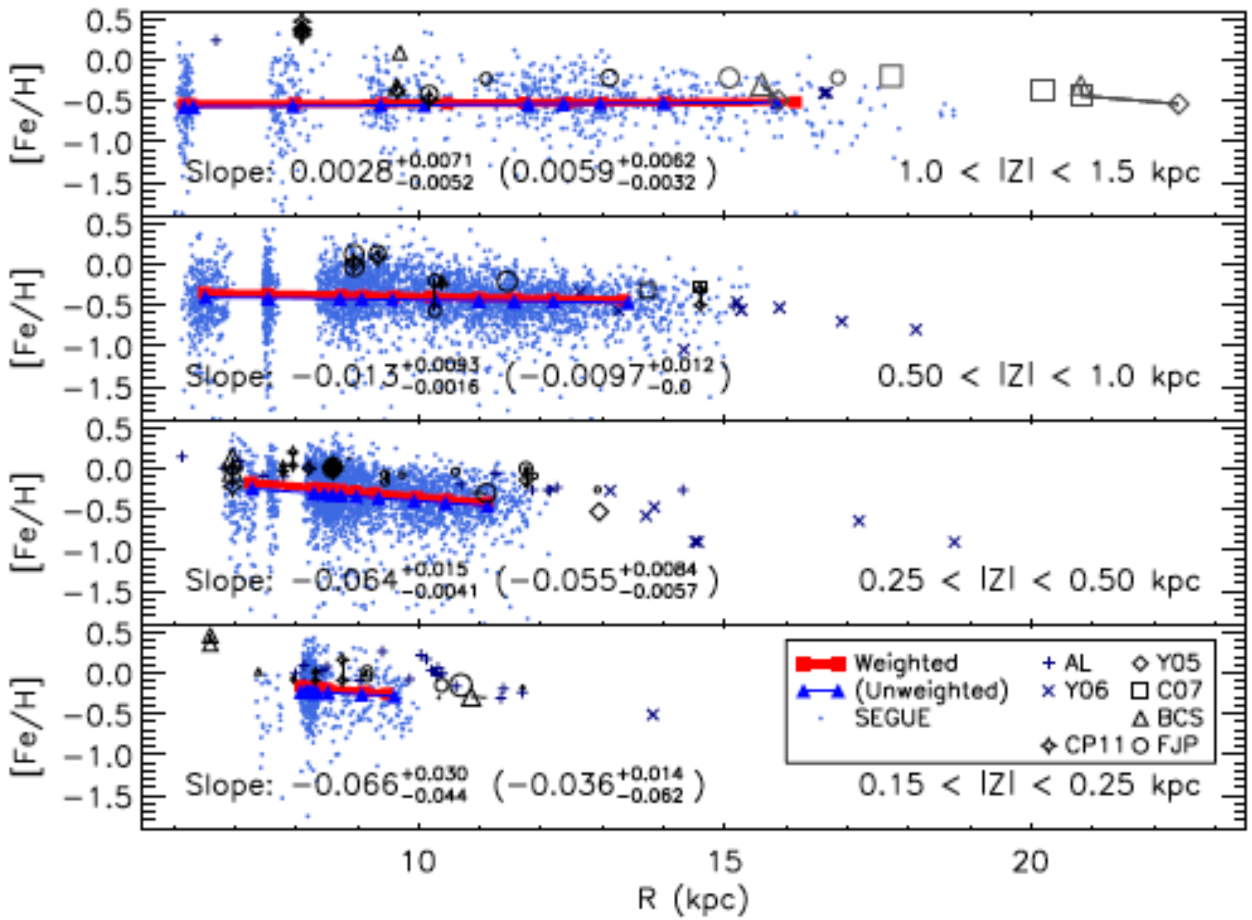
- Schlesinger et al. (2012): poor agreement with model metallicity distributions





SEGUE: FG dwarfs

- Cheng et al. 2012 (in line with gradients from open clusters - steeper than hot stars' gradient - talks by Eileen Friel and Norbert Przybilla tomorrow)



Era of large surveys

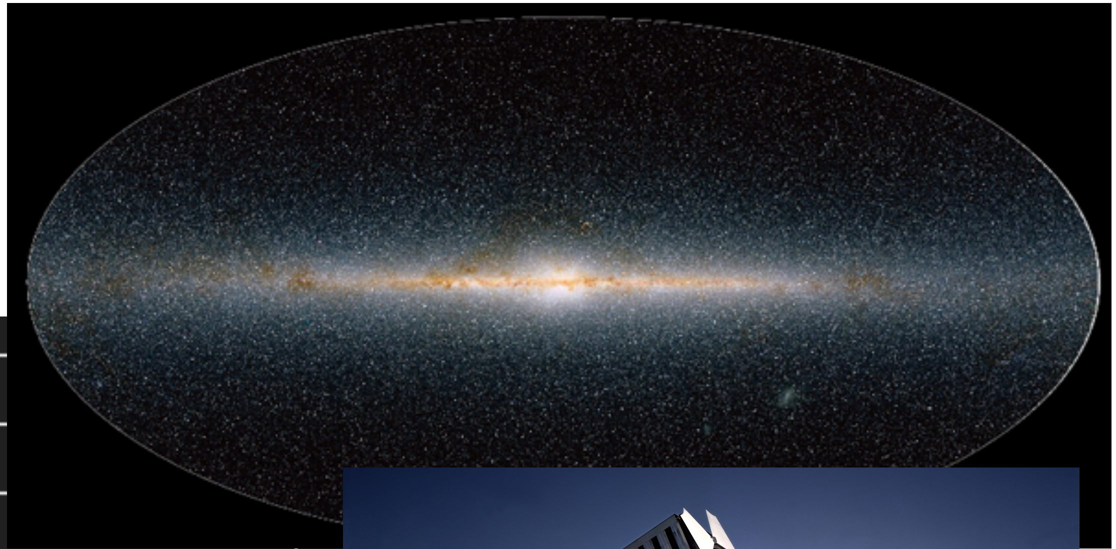
- SDSS (SEGUE -- see talks by Jennifer Johnson and Jennifer Sobeck on Thursday; continues with BOSS)
- RAVE (continues)
- Gaia (launch in 2013; see talk by Carme Jordi on Thursday)
- Gaia-ESO (ongoing; talk by Sofia Randich on Thursday)
- HERMES (soon to start; talk by Ken Freeman on Thursday)
- APOGEE (ongoing; this talk and Jennifer Johnson's talk on Thursday)

Era of large surveys

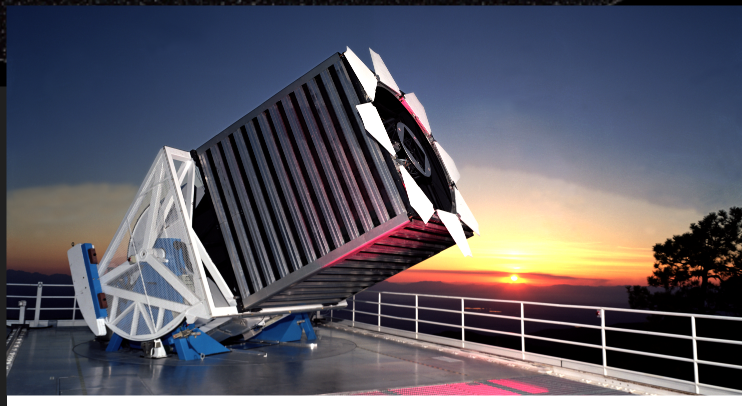
- Are we at risk of a data flood?
- Analysis will consist of comparing observed distributions to model/simulation distributions?

APOGEE

Mapping kinematics and chemical abundances across the Milky Way: with particular emphasis on the disk

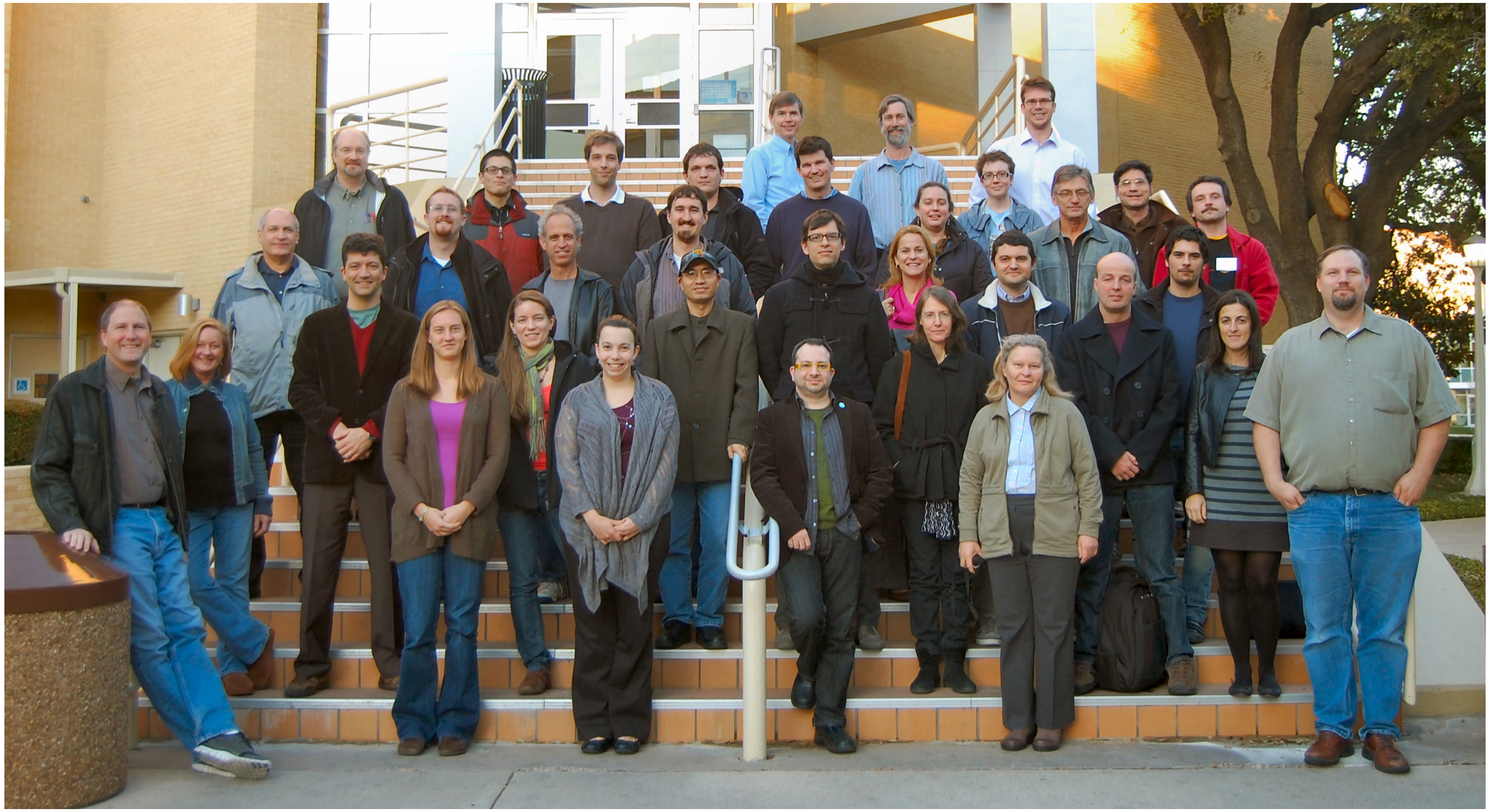


APOGEE at a glance
Bright time observations
Spring 2011 - Spring 2014
100,000 giant stars to magnitude H=12.5
Resolution R~20,000, typical S/N=100
Wavelengths 1.52-1.69 μm
Velocity error 0.5 km/s

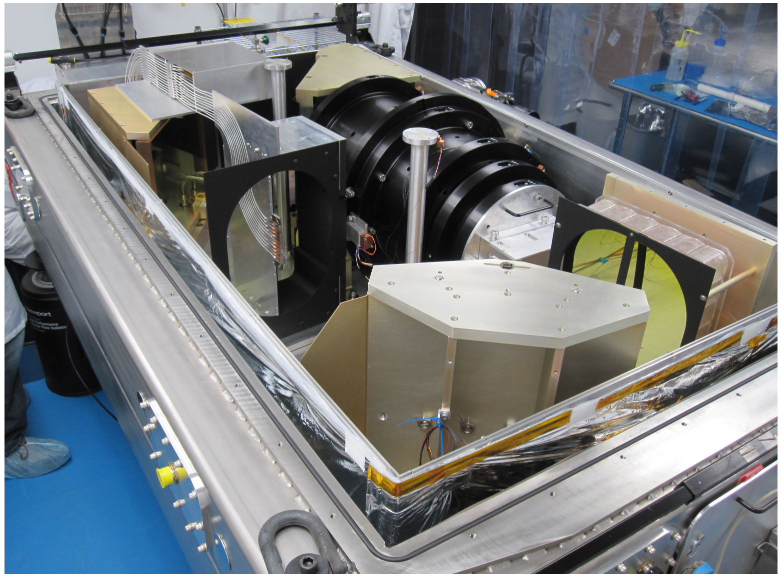


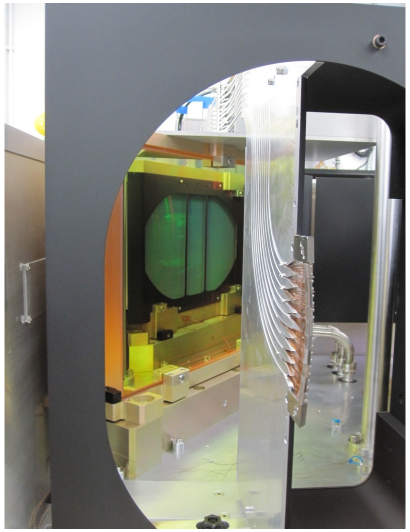
Meet the team

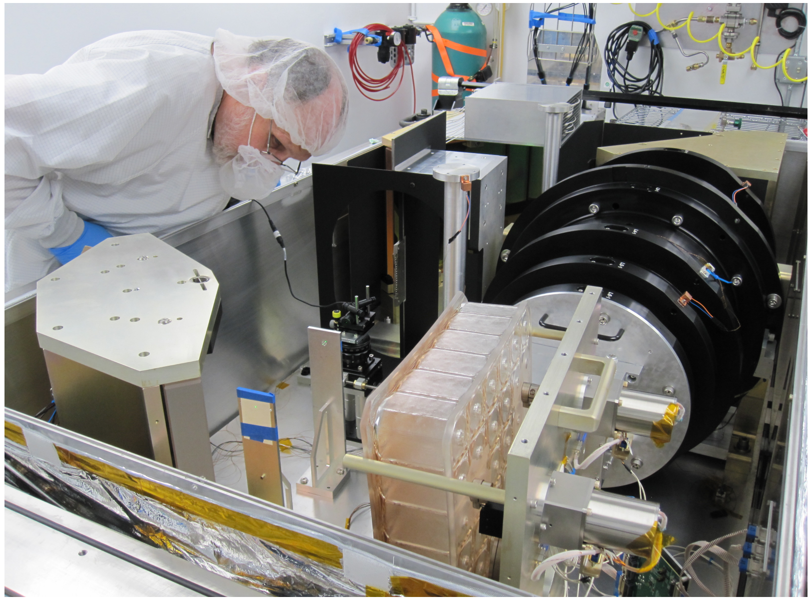
Science meeting January 13-15
Fort Worth, Texas



The APOGEE Instrument







APOGEE Installation

- April 25, 2011: Instrument arrives at Apache Point Observatory.



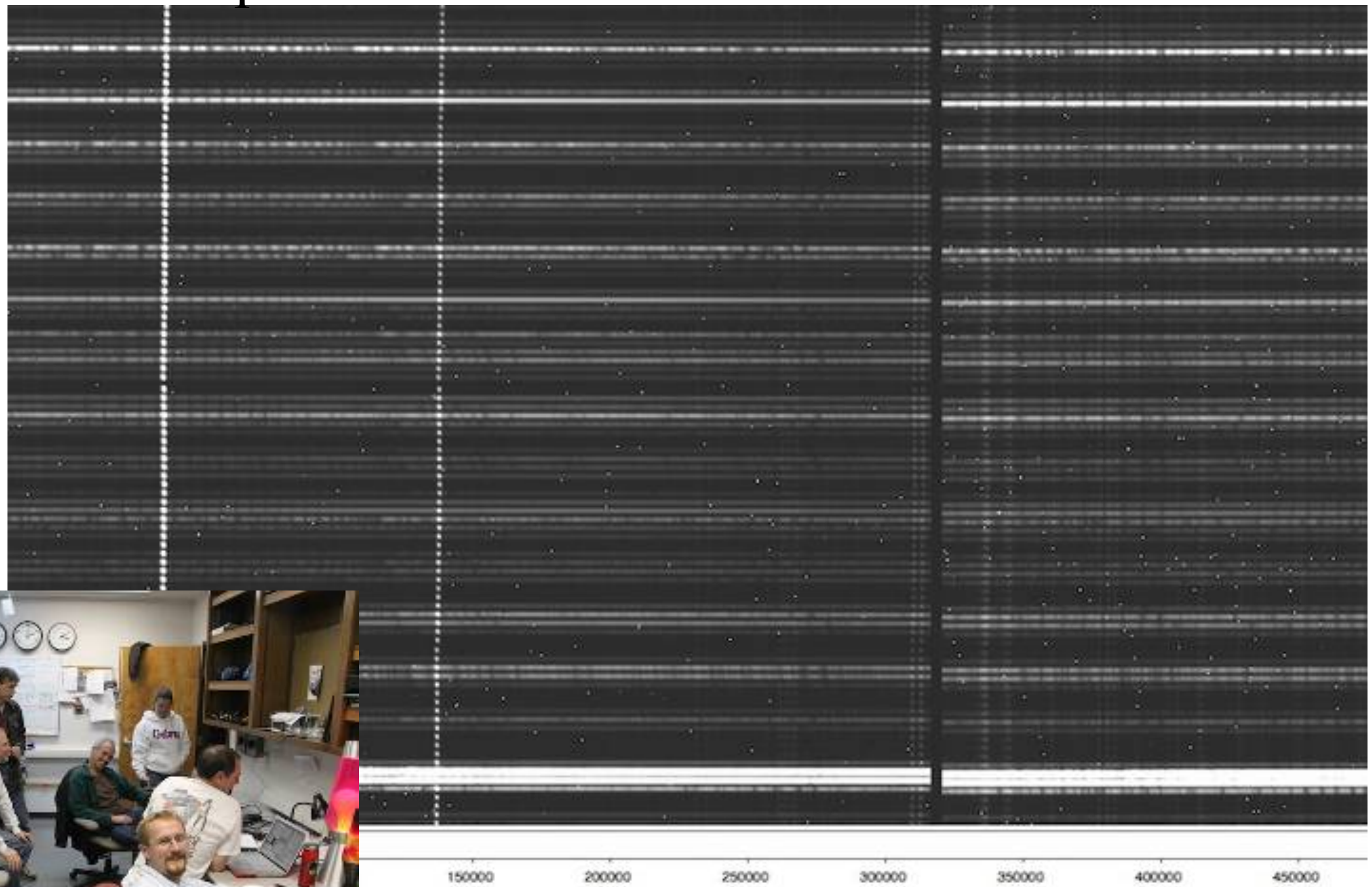




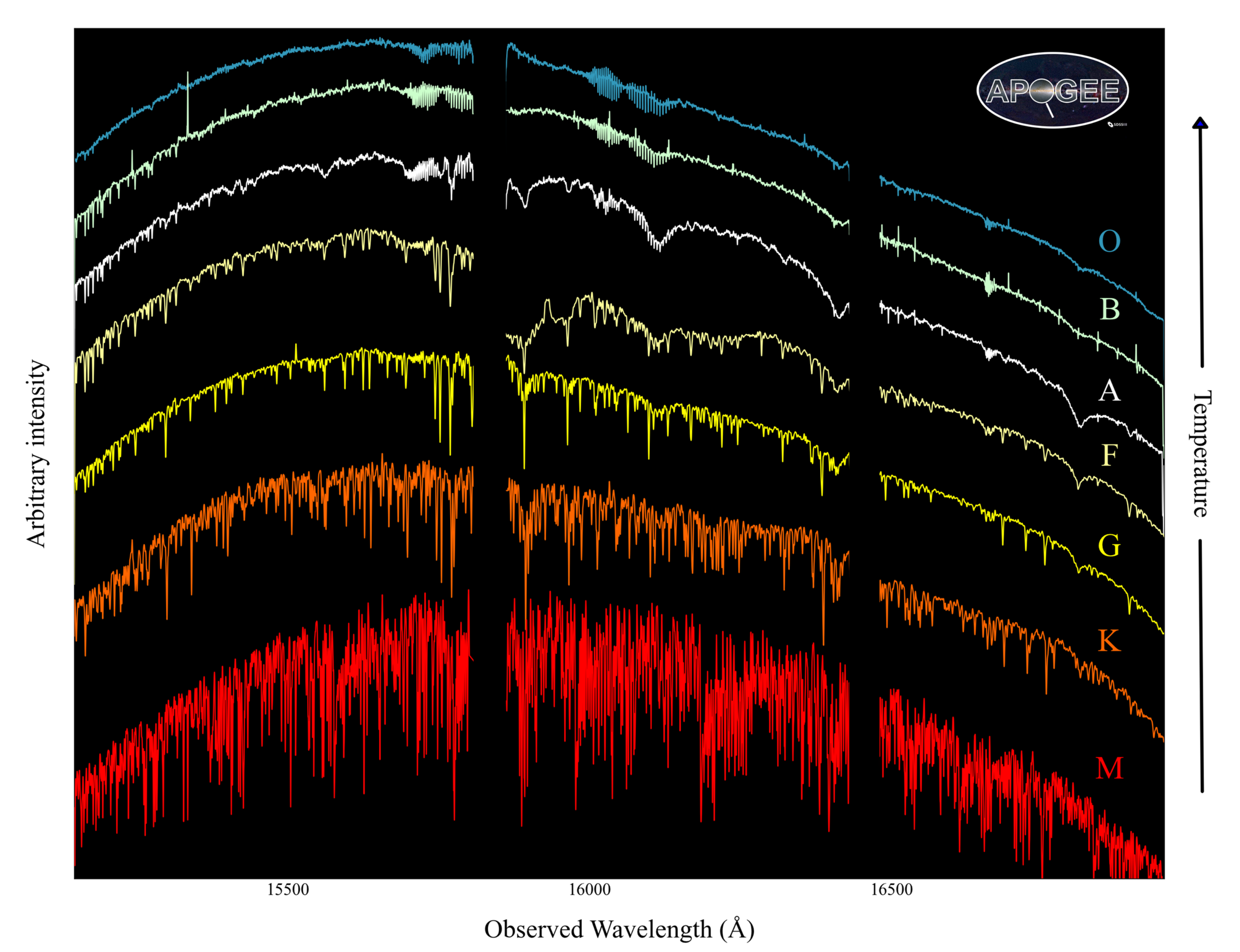
Photos by G. van Doren, D. Long, S. Majewski, O. Malanushenko, M. Nelson, J. Wilson

APOGEE First Light

- May 6, 2011: First observations with 2.5-m telescope.
  - Within a few months of planned timelines from 2006/2008.



Sample APOGEE Spectra



Observing the Bulge

First APOGEE+Sloan 2.5-m observations of Galactic bulge, May 2011.
(in full moon, at >2 airmasses, and towards lights of El Paso).

Photo by S.R. Majewski

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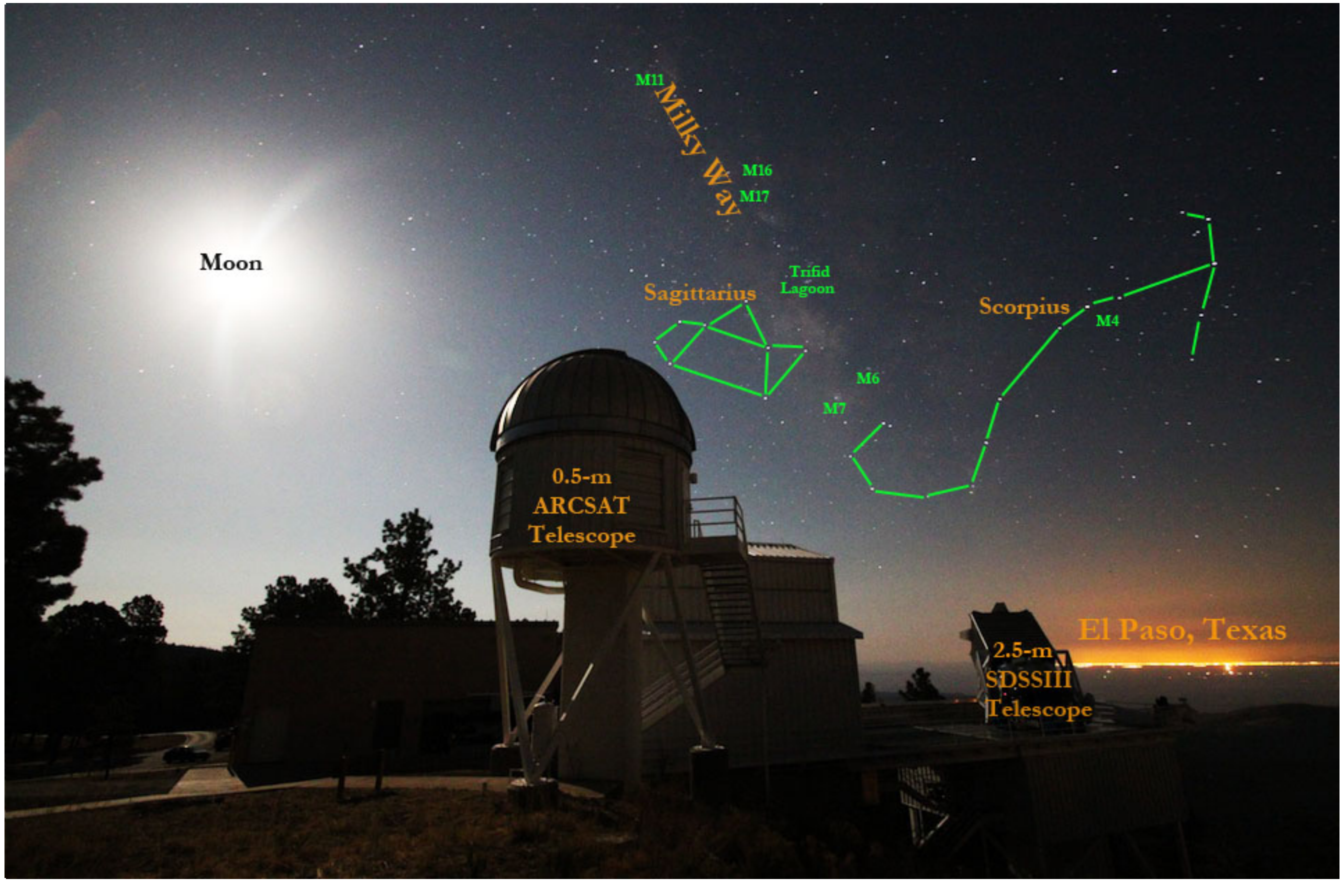


Photo by S.R. Majewski

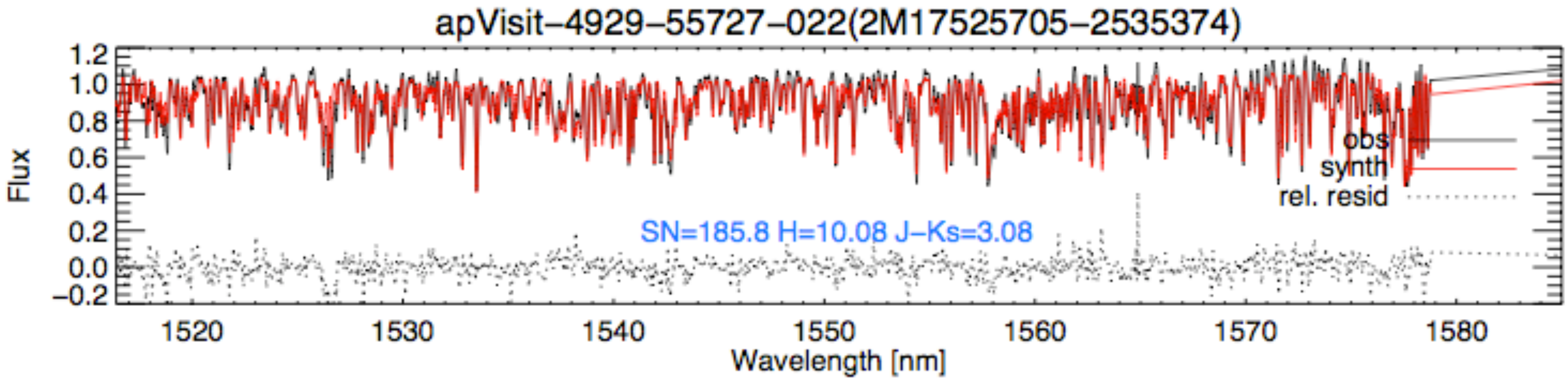
Observations to Date

May 2011-May 2012 “Science” Observations (> 100 nights):

>400 separate plates

>100,000 science spectra

bulge, [Fe/H] ~ -0.2



APOGEE pipelines

- Fully automated spectral extraction pipeline: dither combine, background (OH emission and telluric modelling) subtractrion, radial velocities, spectral classification

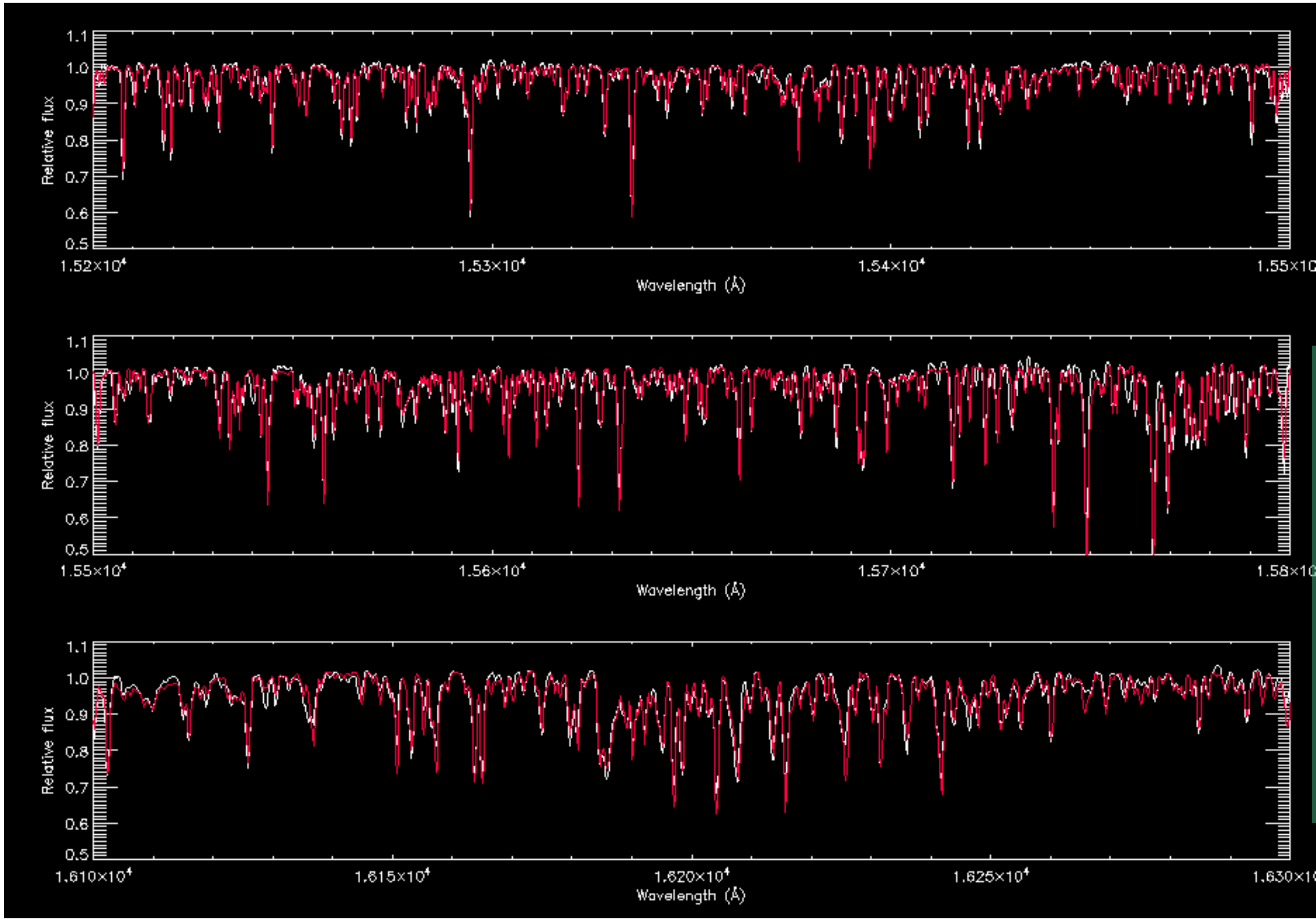
OPERATIONAL

- Fully automated spectral analysis pipeline: 7 parameters (Teff,logg,micro,Fe/H, C/Fe,N/Fe, [illegible]/Fe) and covariances, 15 elemental abundances plus uncertainties

OPERATIONAL for stellar Parameters, abundances to follow

Abundances & Stellar Parameters

Example: Automated fitting of Arcturus spectrum

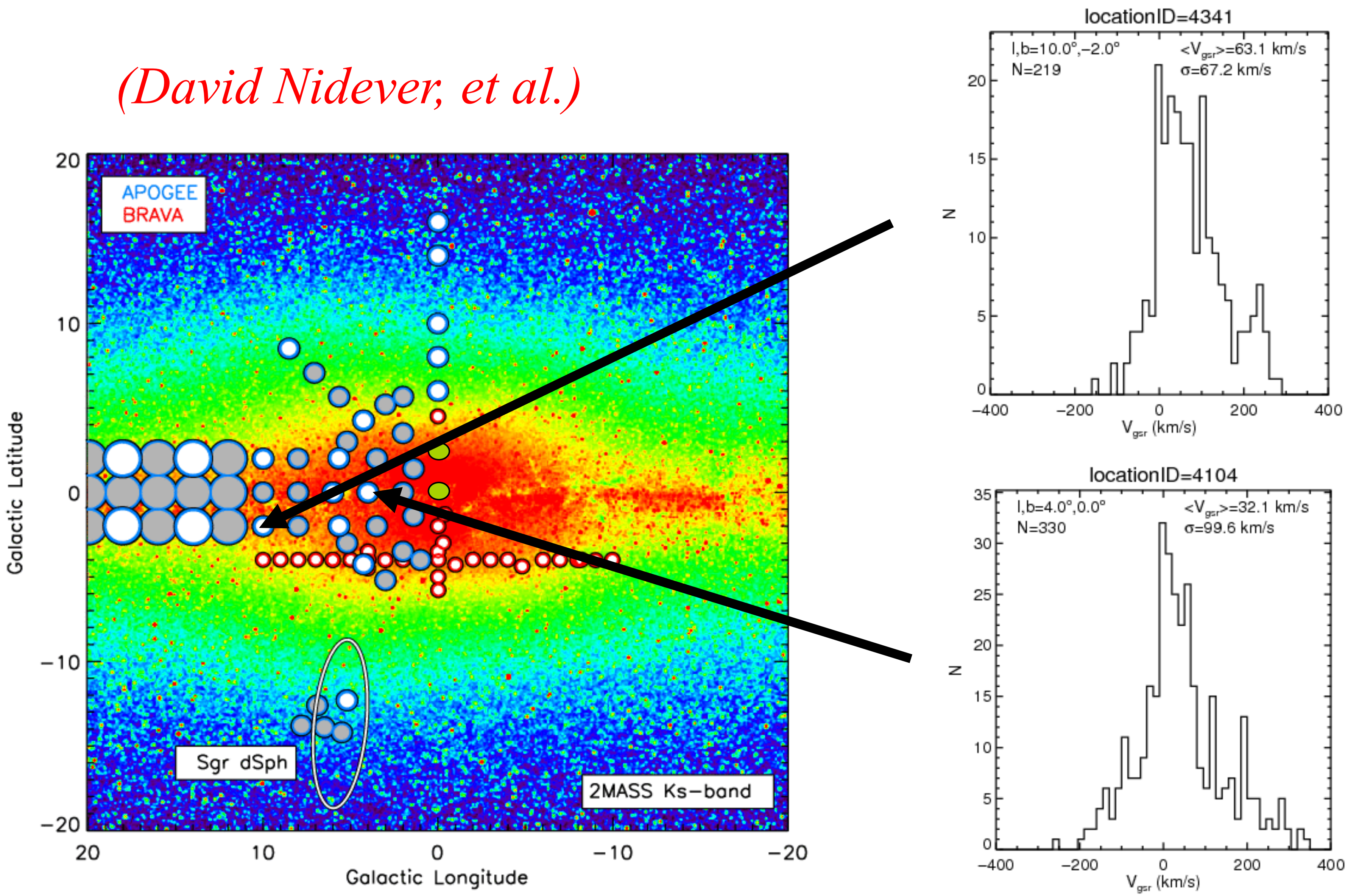


T_{eff}=4408 K
Log g=2.13
Log_{10}([illegible])=0.33
[Fe/H]=-0.56
[C/Fe]=+0.44
[N/Fe]=+0.02
[O/Fe]=+0.50

Automated fitting of Arcturus spectrum (Hinkle et al.) at R=30,000

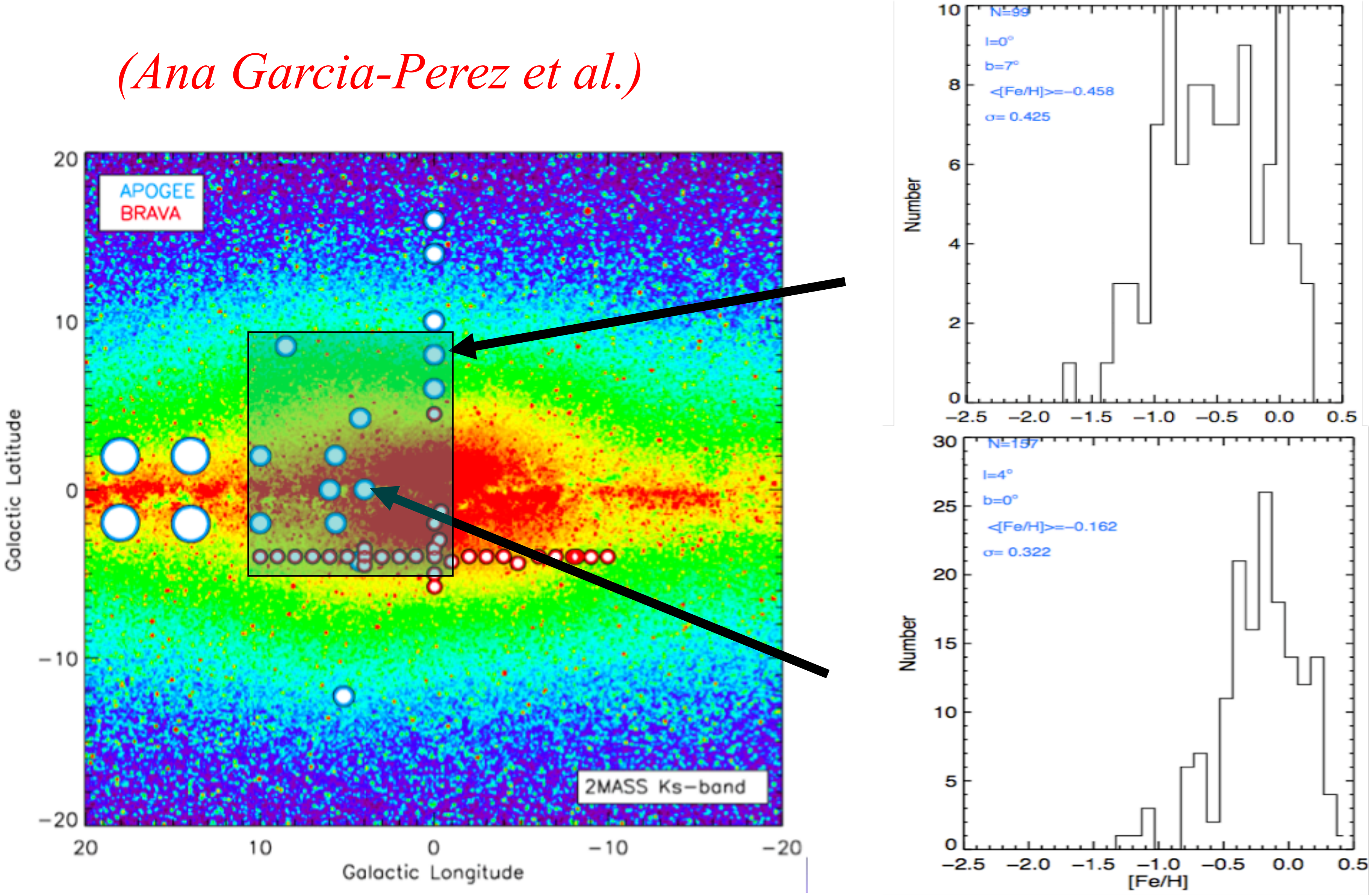
Early Results: Bulge Radial Velocities

(David Nidever, et al.)



Early Results: Bulge Metallicities

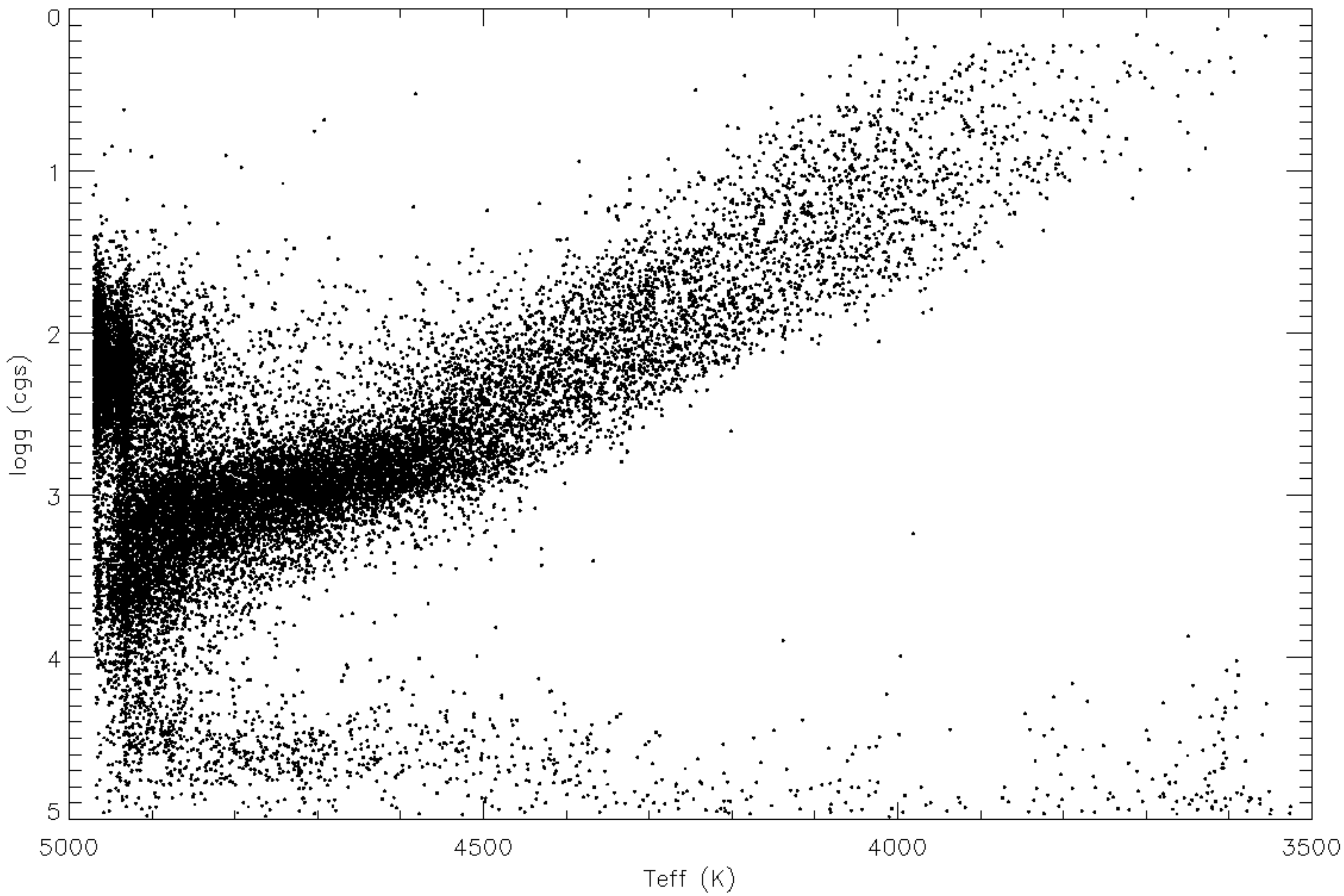
(Ana Garcia-Perez et al.)

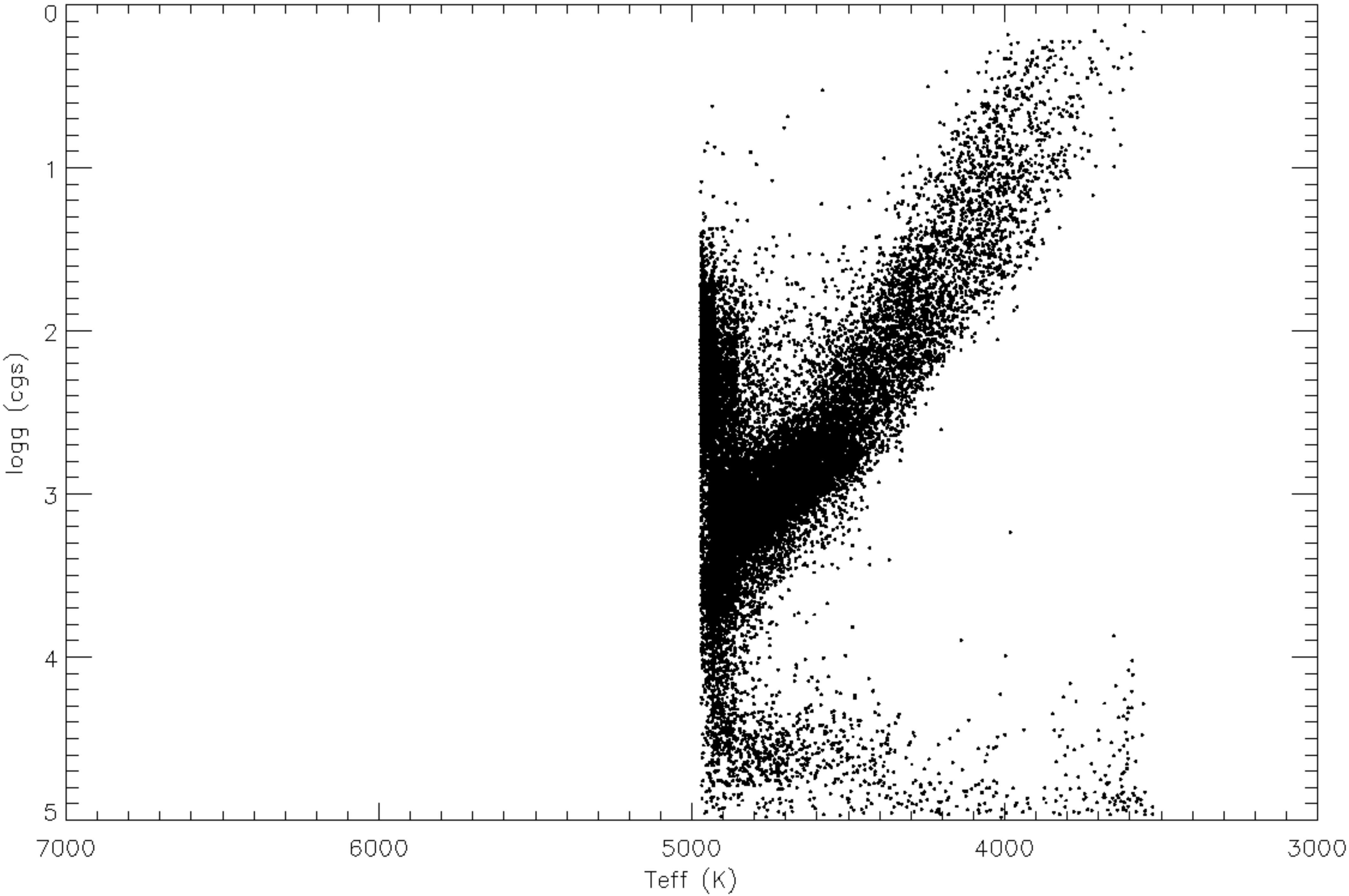


Preliminary APOGEE results

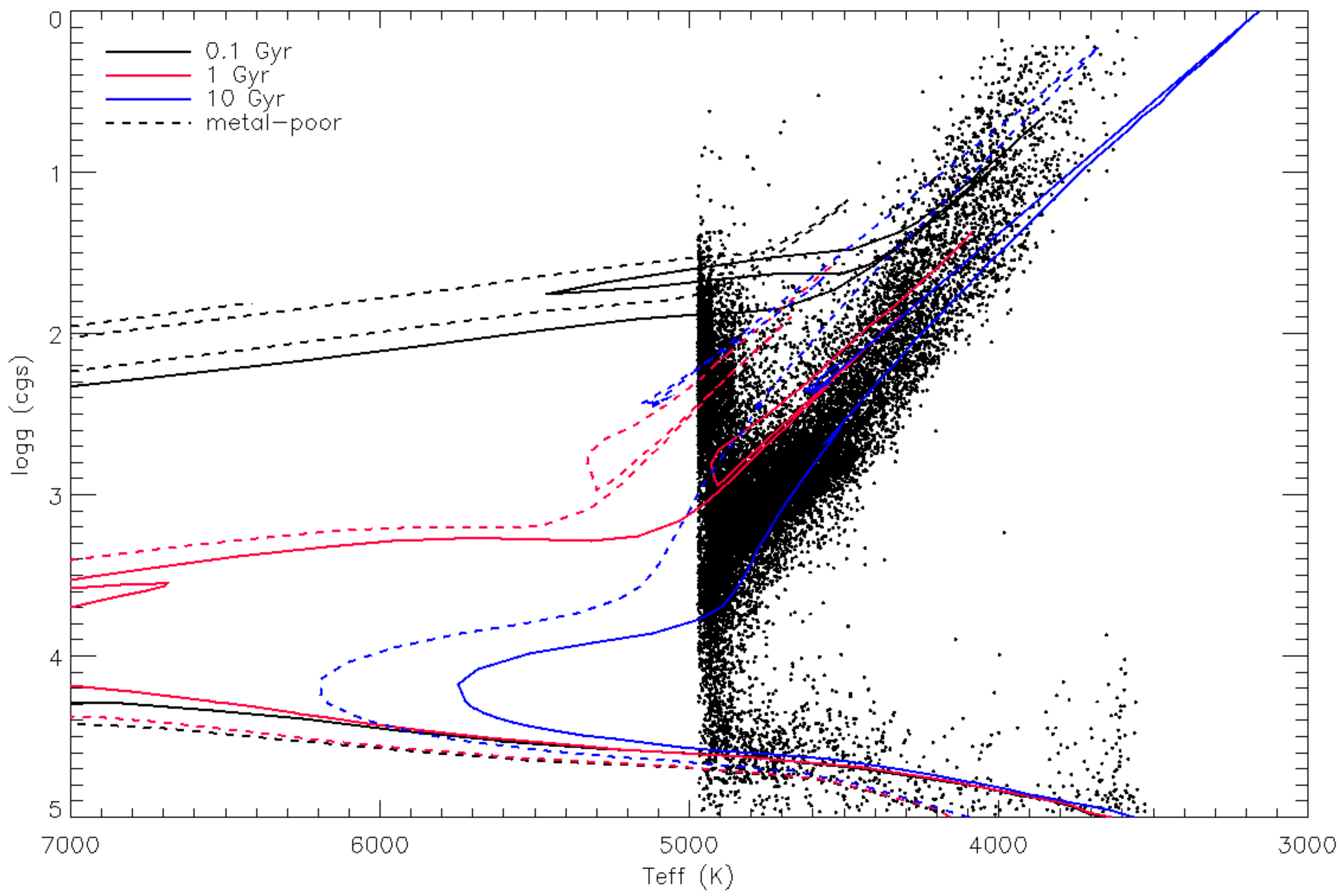
- One of the primary goals for APOGEE is to track the evolution of carbon, nitrogen and oxygen in the Galaxy, focusing on the disk, and disentangle Galactic evolution from stellar evolution.
- Advantages of H-band are 1) low extinction 2) CN/CO/OH bands to constrain CNO abundances.

Atmospheric parameters





0
1
2
3
4
5
logg (cgs)
7000
6000
5000
4000
3000
Teff (K)

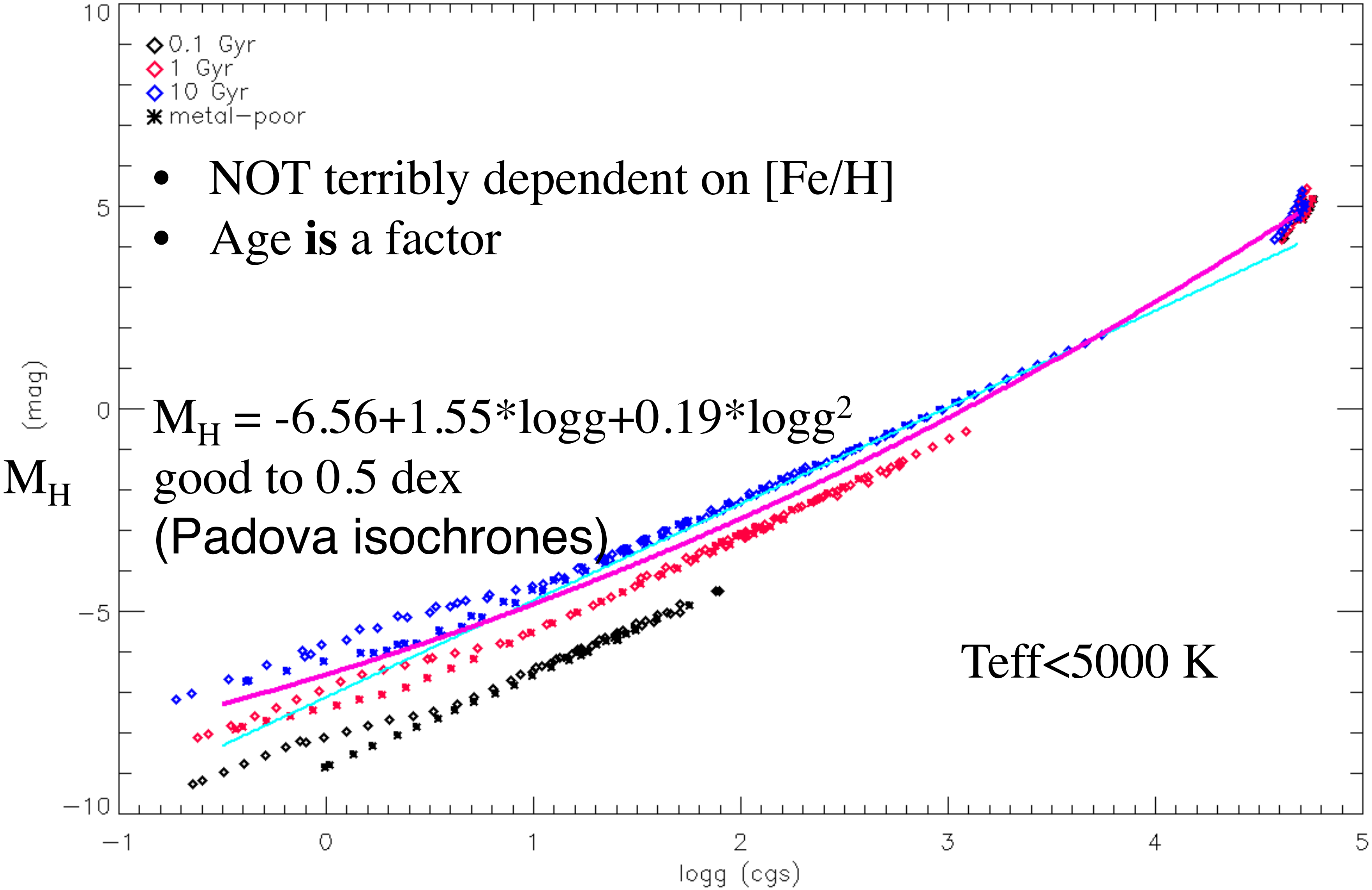

0.1 Gyr
1 Gyr
10 Gyr
metal-poor
logg (cgs)
Teff (K)
0
1
2
3
4
5
7000
6000
5000
4000
3000

luminosities

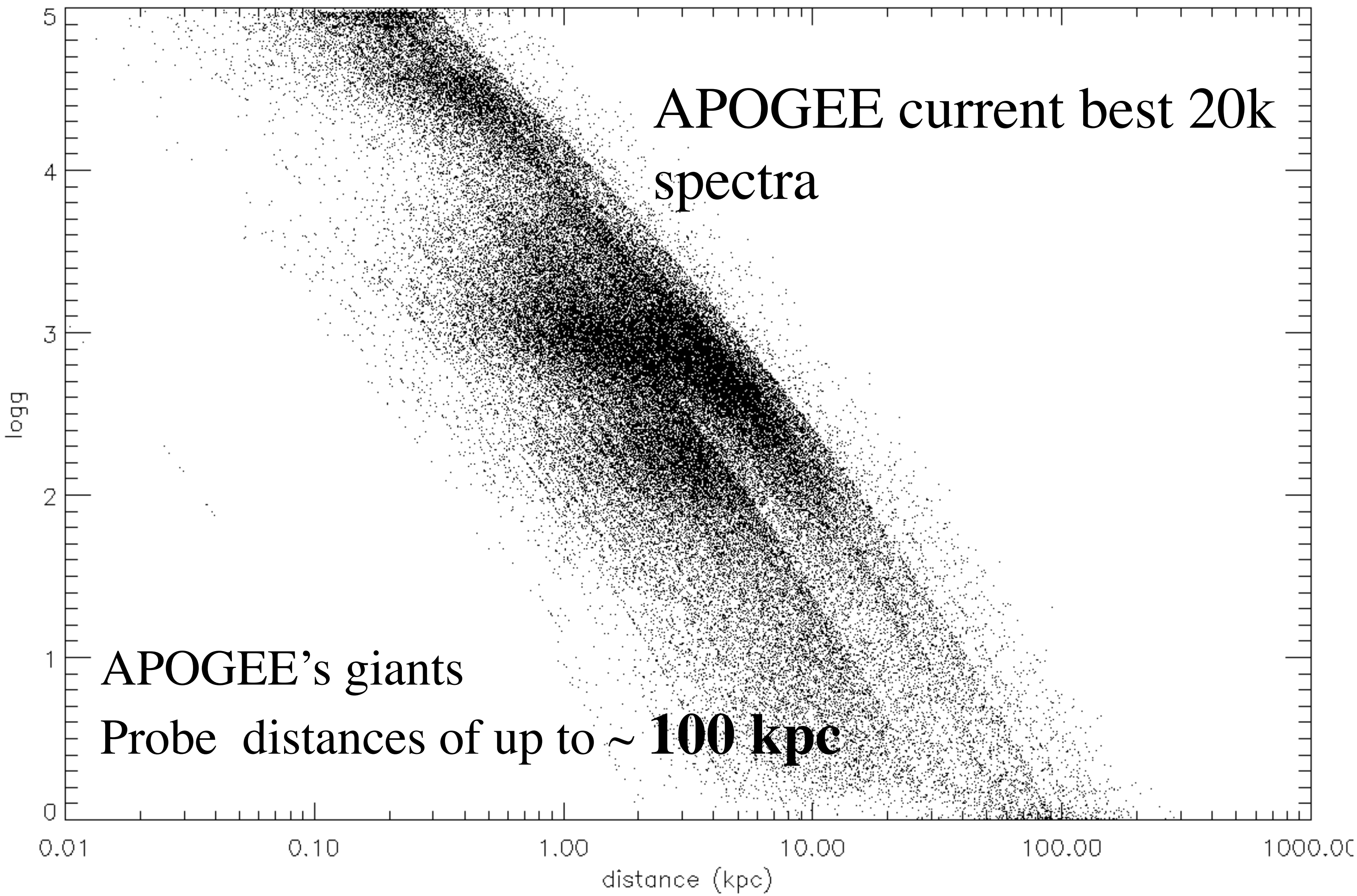
- NOT terribly dependent on [Fe/H]
- Age **is** a factor

$M_H = -6.56+1.55*\log g+0.19*\log g^2$
good to 0.5 dex
(Padova isochrones)

Teff<5000 K

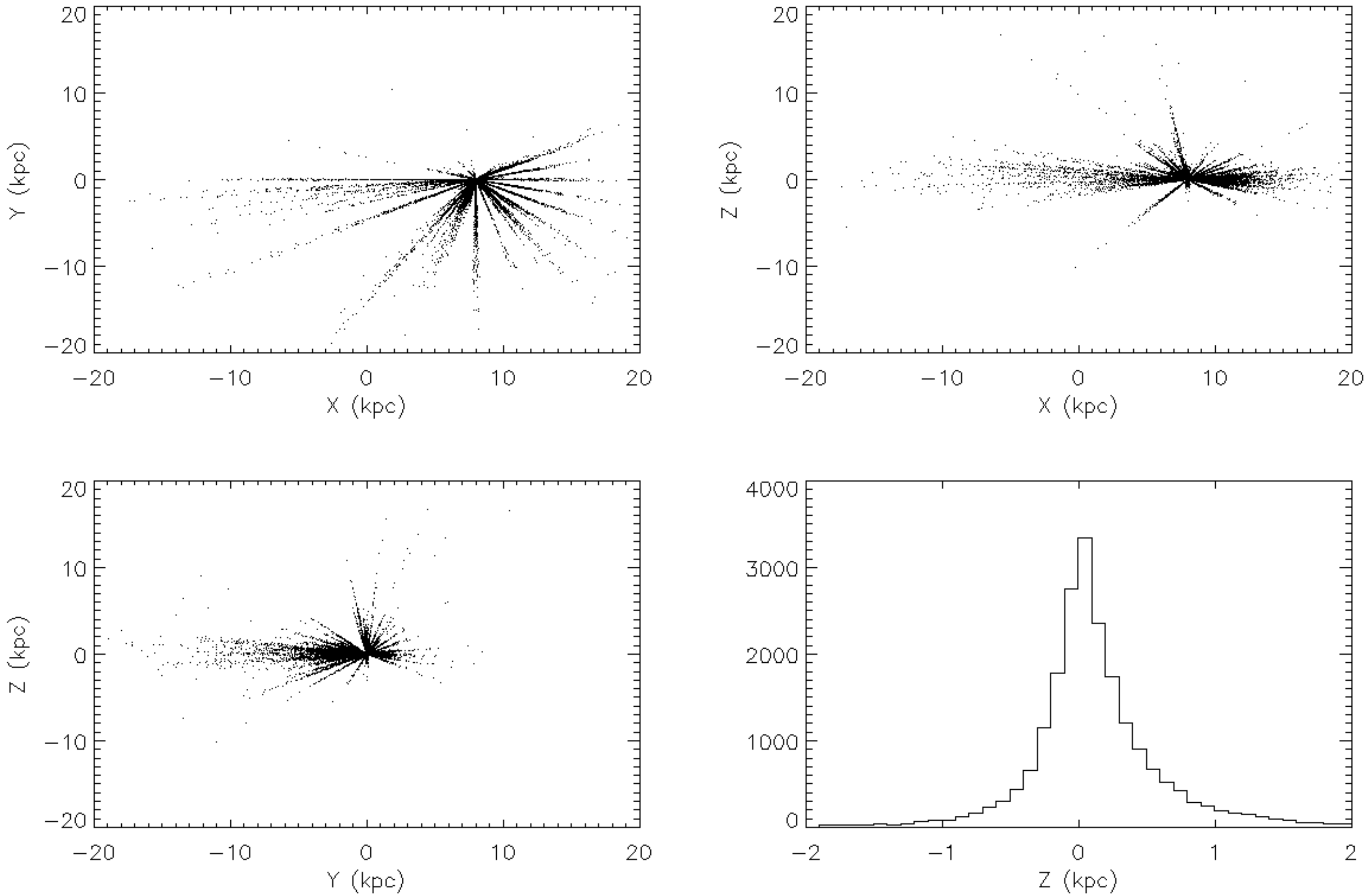


distances

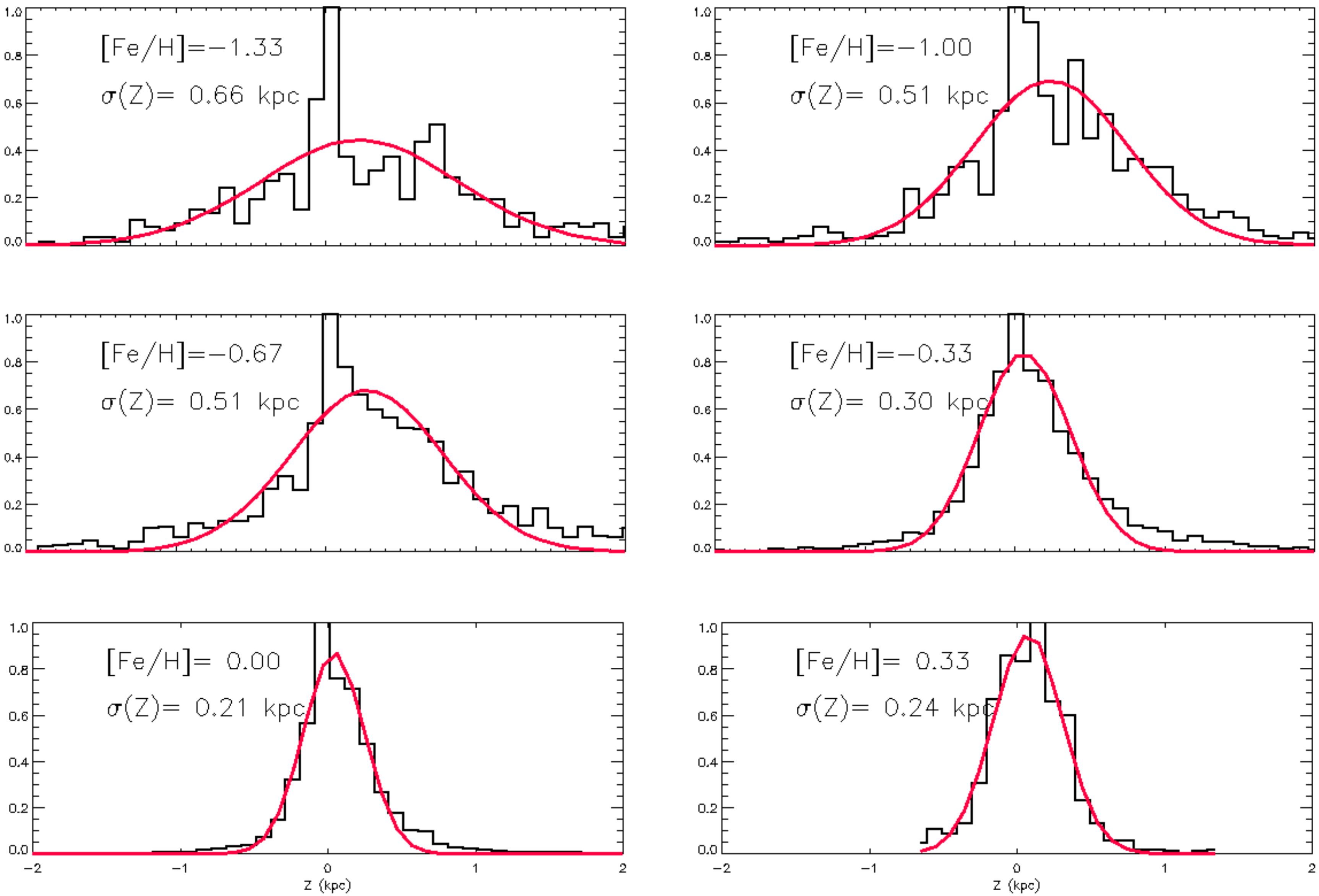


APOGEE current best 20k spectra
APOGEE's giants
Probe distances of up to ~ **100 kpc**
logg
5
4
3
2
1
0
0.01
0.10
1.00
10.00
100.00
distance (kpc)

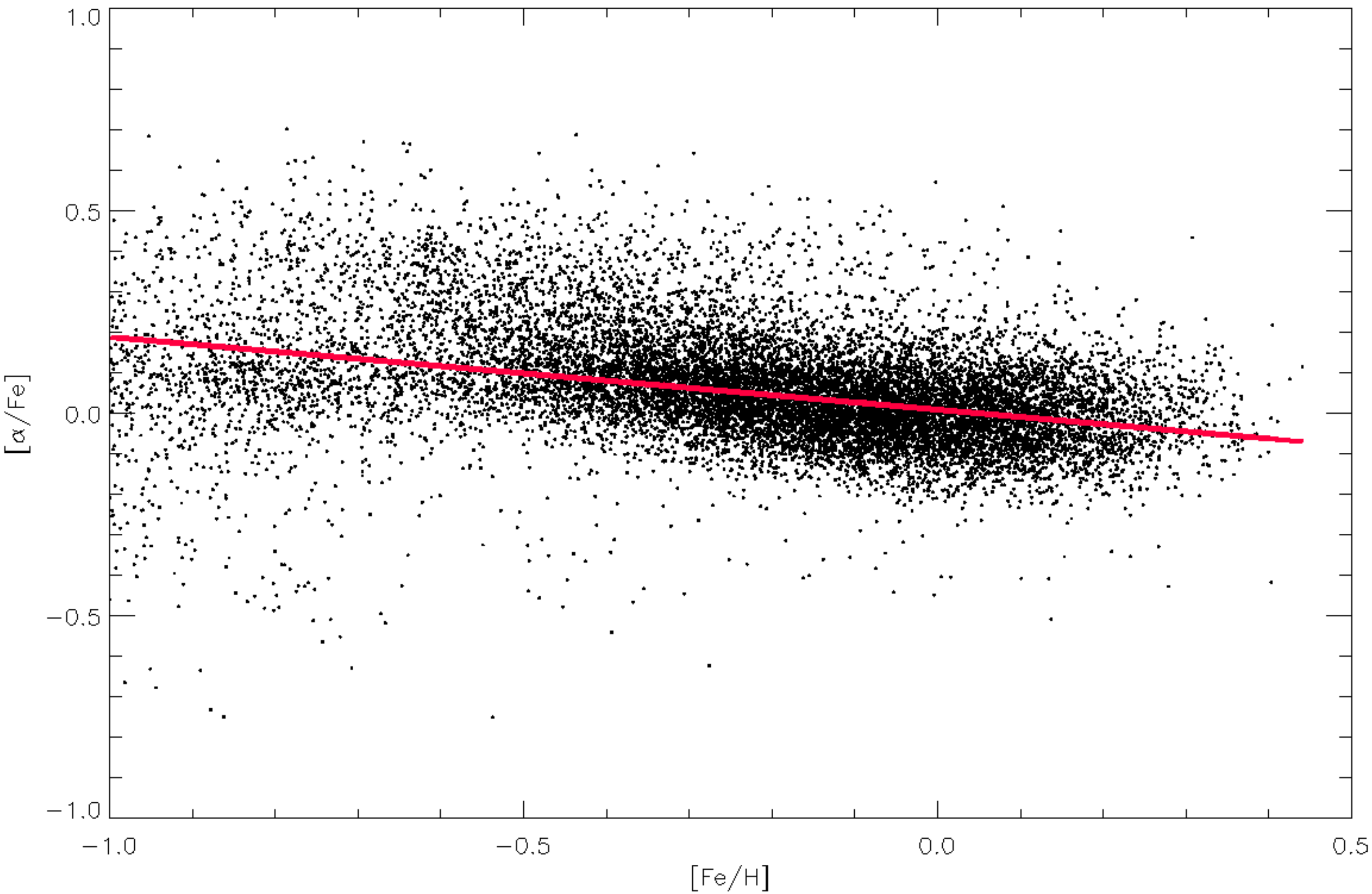
Sample distributions



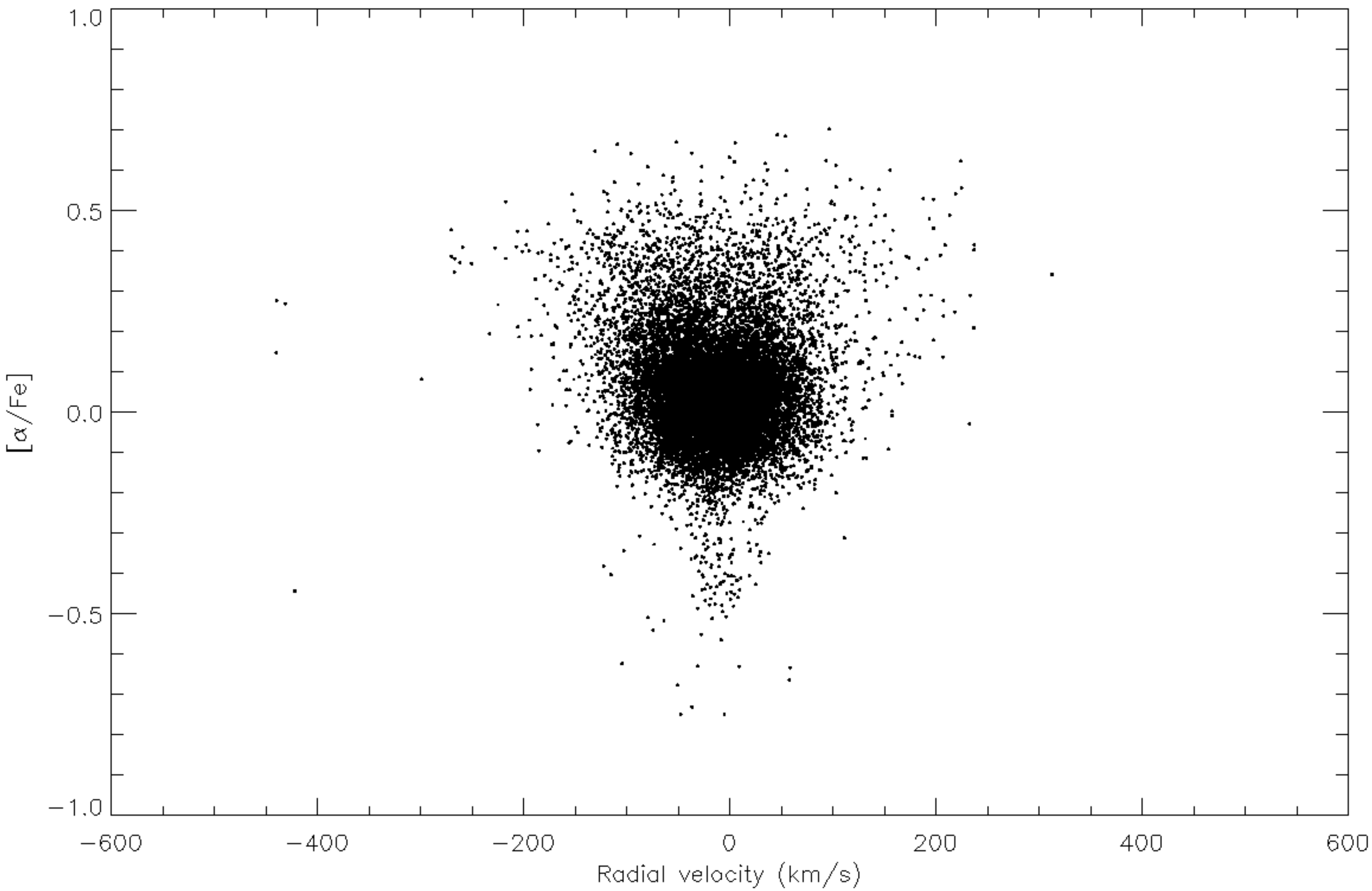
Scale height



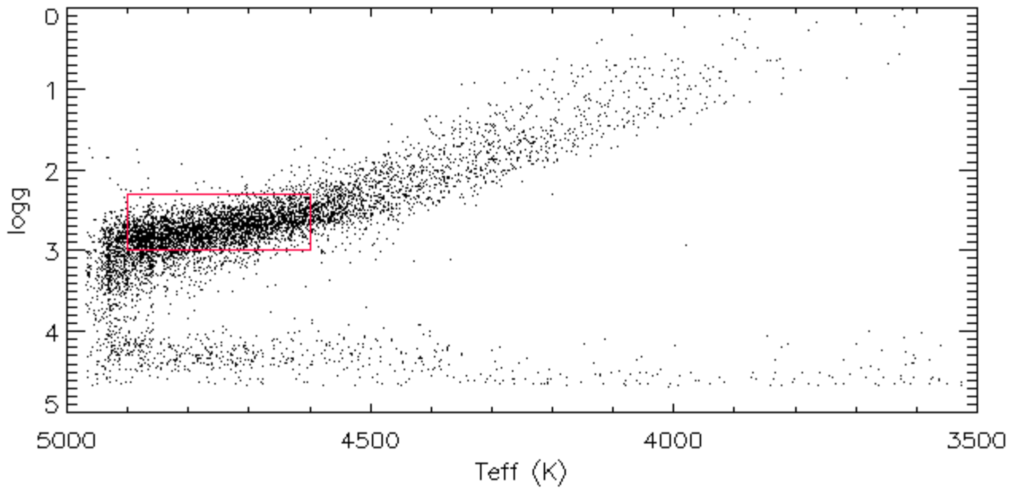
α/Fe (OH + Mg)

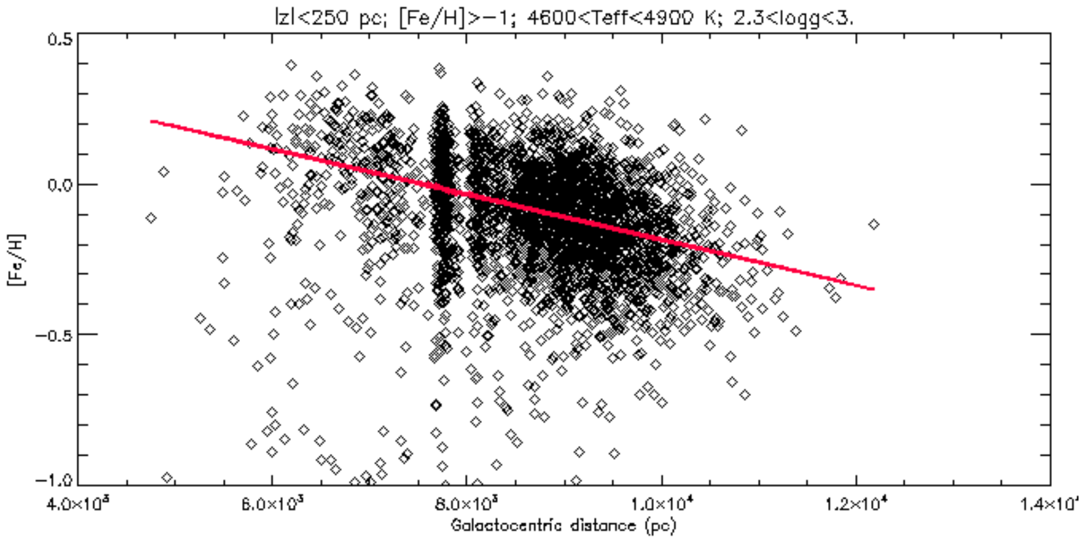


Chemistry + kinematics



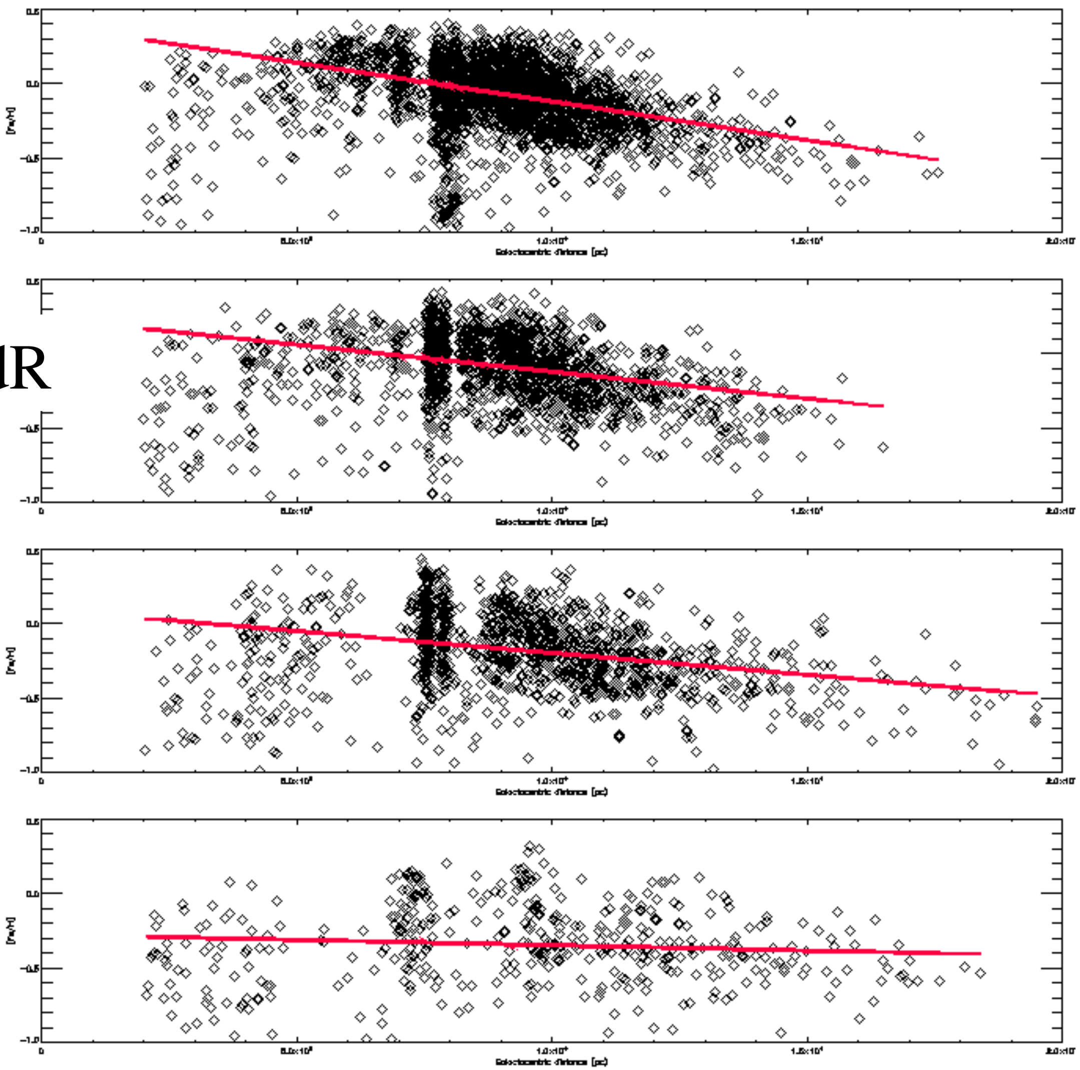
Abundance gradient





Abundance gradient

d[Fe/H]/dR



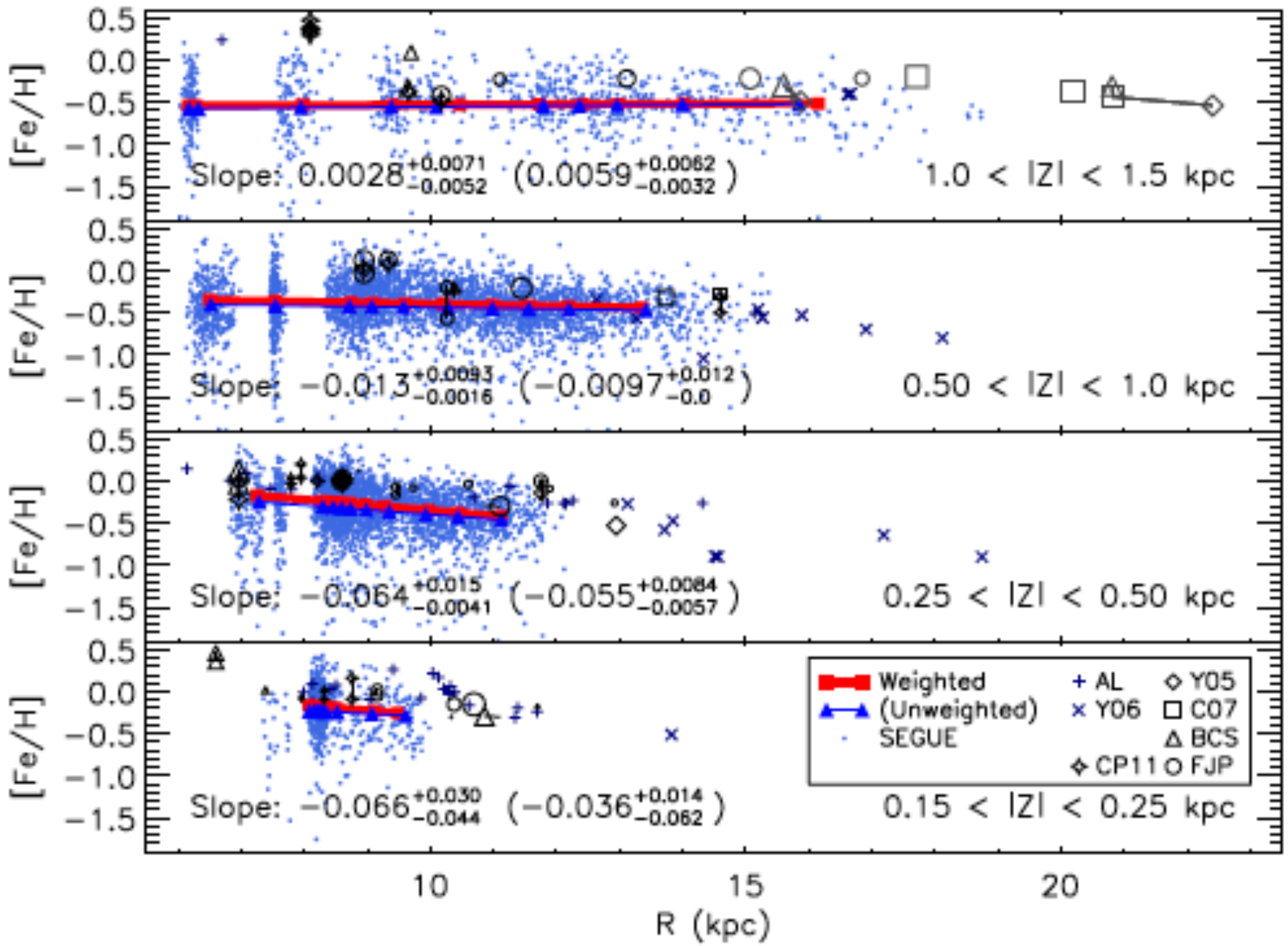
-0.06 dex/kpc
at |z|<0.25 kpc

-0.04 dex/kpc
At 0.25<|z|<0.5

-0.03 dex/kpc
At 0.5<|z|<1 kpc

~ 0.00 dex/kpc
at 1<|z|<1.5 kpc

Abundance gradient



SEGUE data, Cheng et al. 2012

Conclusions

- There is work to do in order to define unambiguously the thin disk and the solar neighborhood; maybe we shouldn't make a distinction
- Overall good agreement about the width of the metallicity distribution in the solar neighborhood, but not so about shape an zero point
- Tight abundance ratio distributions in the solar neighborhood: stars formed out of well mixed gas
- Expect great progress from ongoing/upcoming surveys: Gaia, APOGEE, HERMES, RAVE, Gaia-ESO…