Oxygen in red giants from near-infrared OH lines: 3D effects and first results from

Puerto de la Cruz, May 14, 2012
Carlos Allende Prieto

Overview

1. APOGEE: status and prospects
2. A first look at APOGEE data and what they bring us in terms of C N O abundances
3. 3D effects on abundances from the H band

SDSSIII

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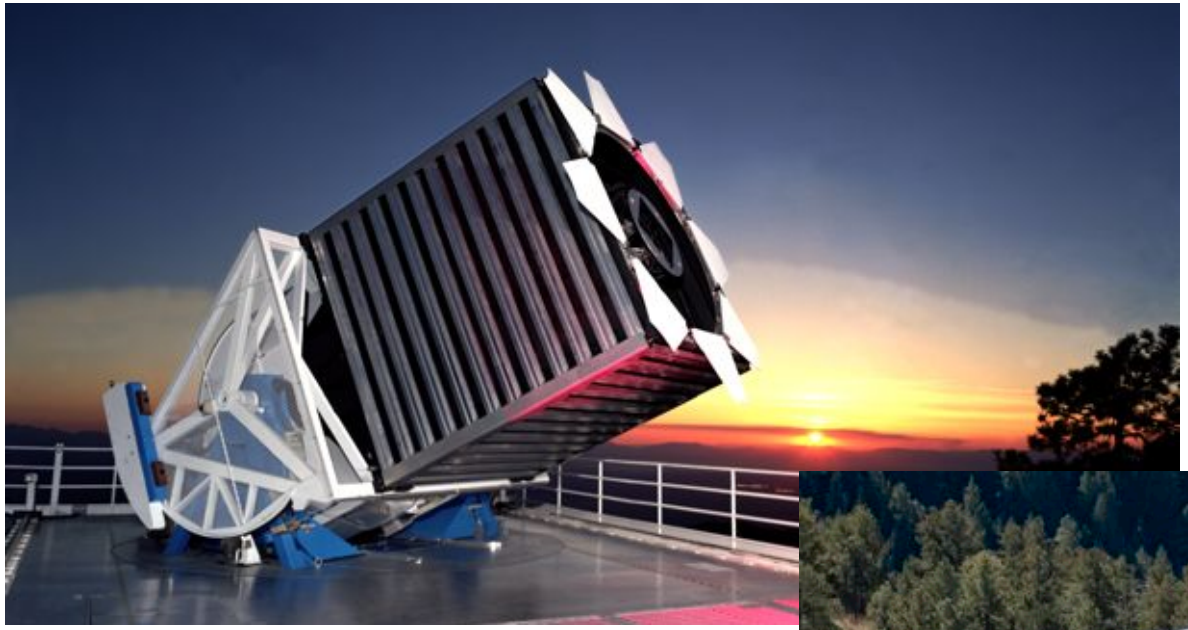
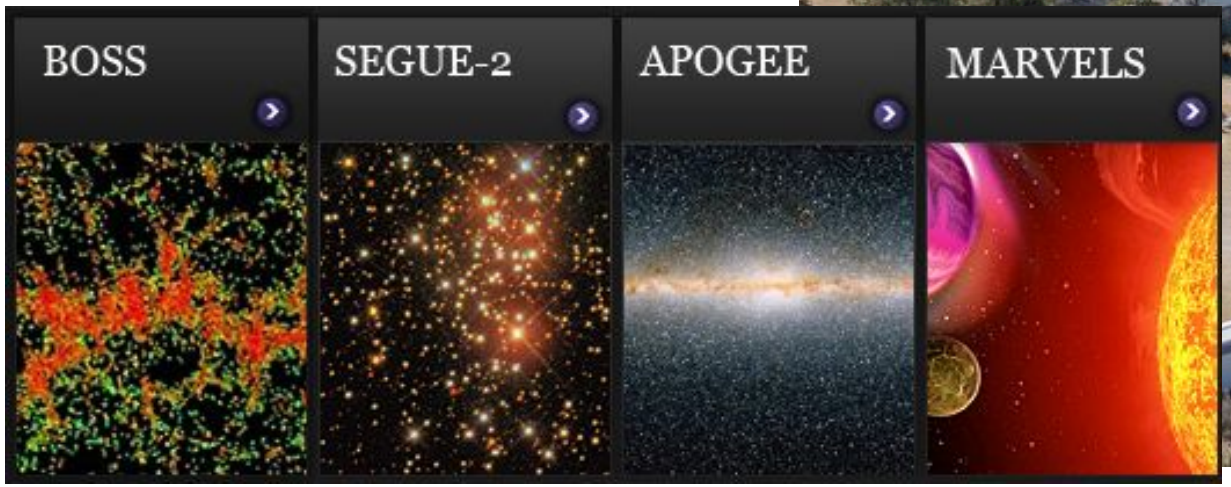
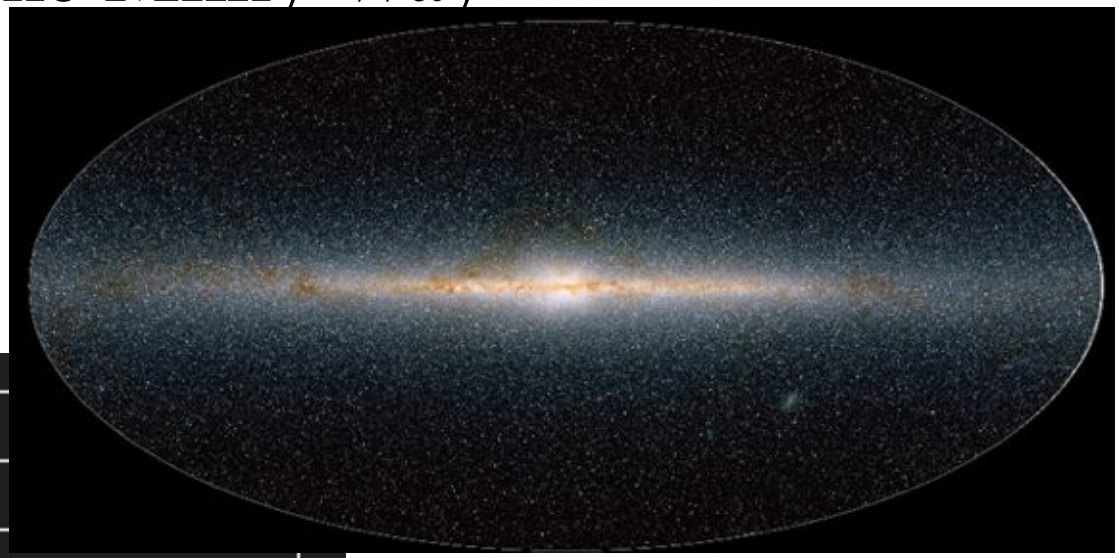


APOGEE



APOGEE

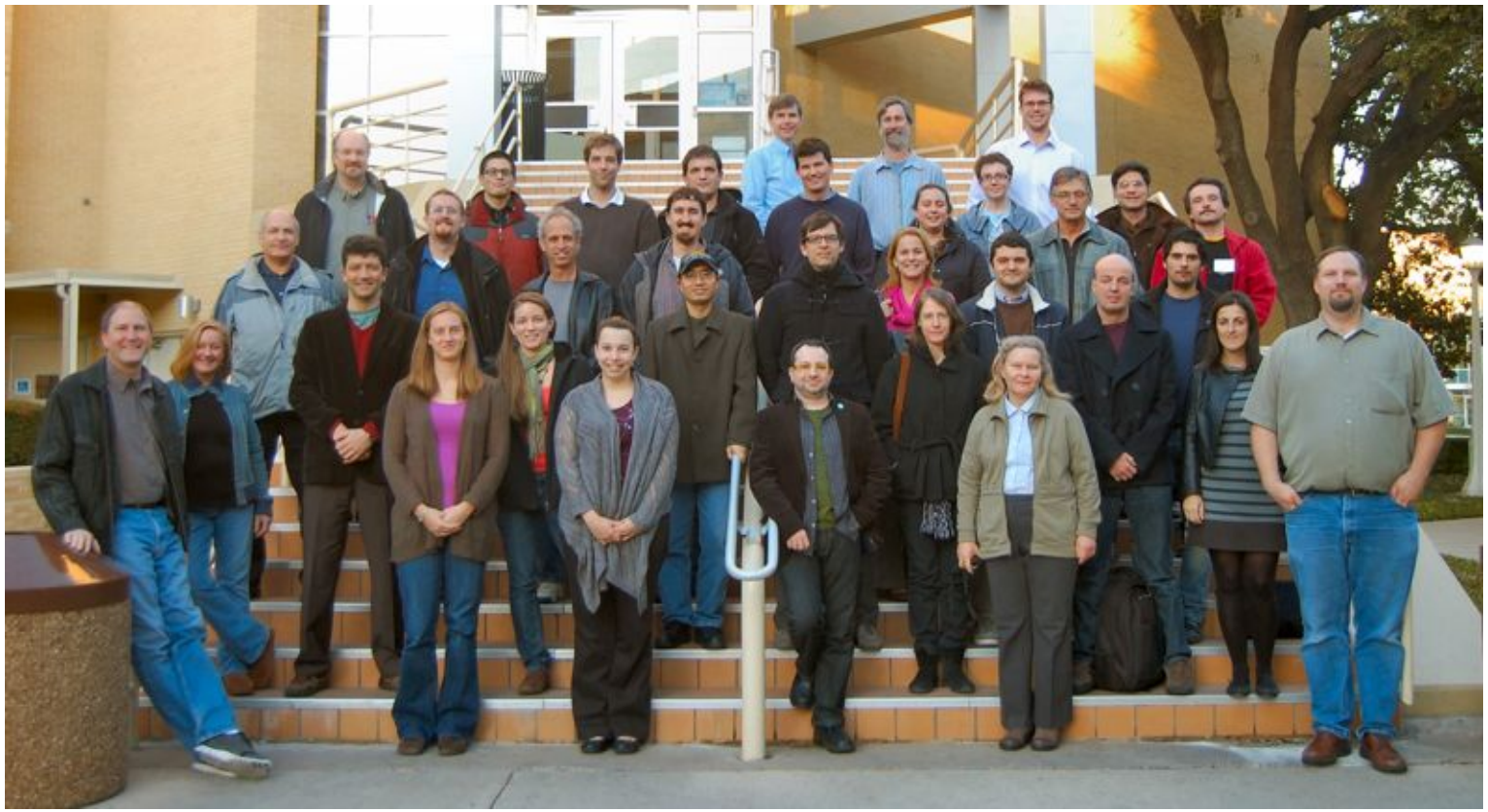
Mapping kinematics and chemical abundances across the Milky Way



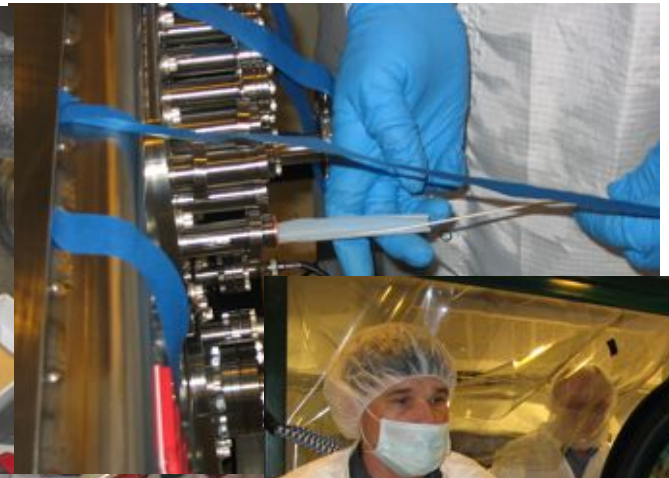
APOGEE at a glance
Bright time observations
Spring 2011 - Spring 2014
100,000 giant stars to magnitude H=12.5
Resolution R~20,000, typical S/N=100
Wavelengths 1.52-1.69 μm
Velocity error 0.5 km/s

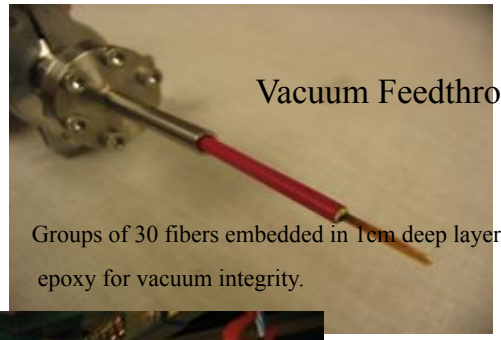
Meet the team

Science meeting January 13-15
Fort Worth, Texas



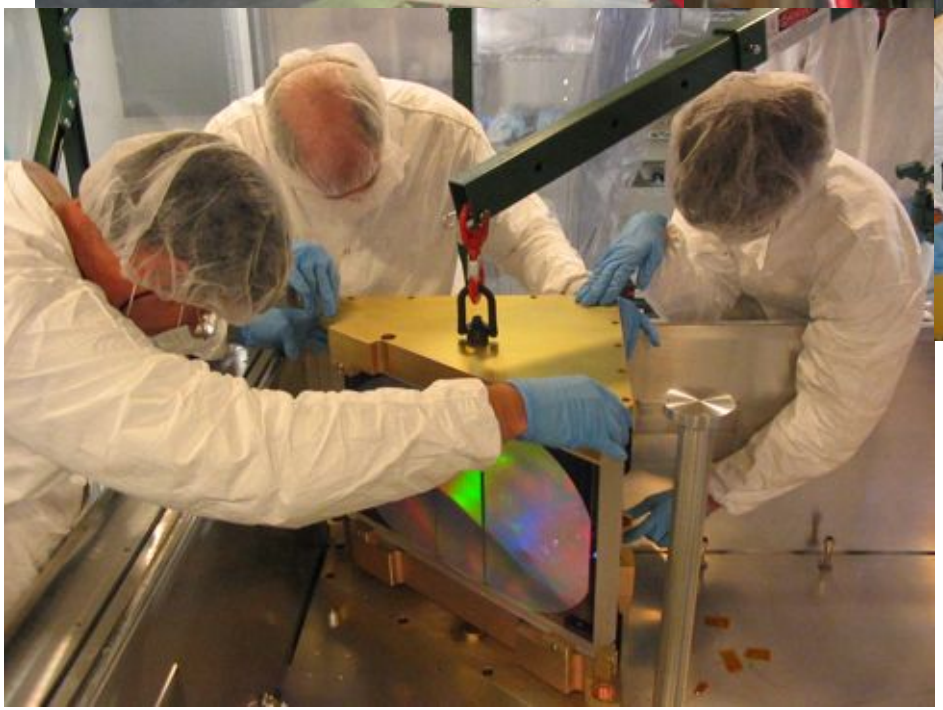
Novel Technologies

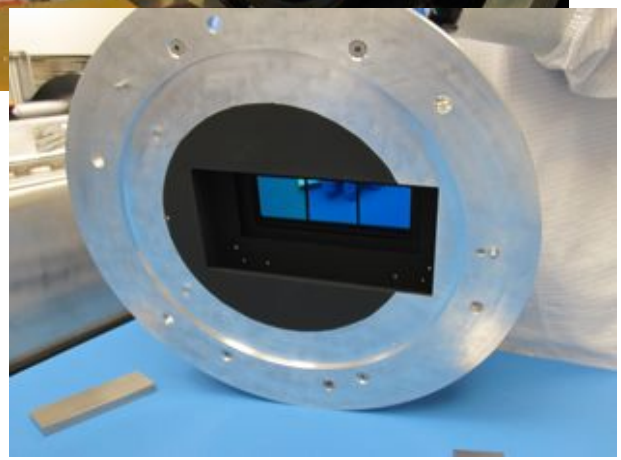




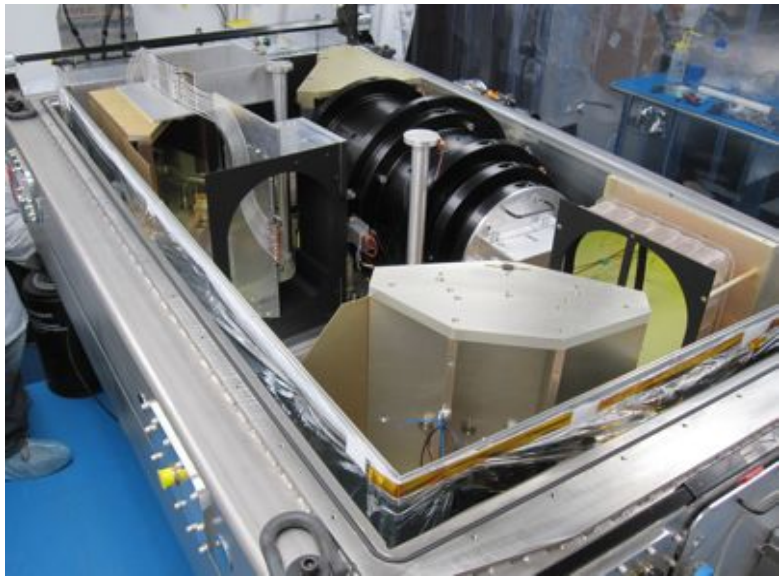
Vacuum Feedthrough

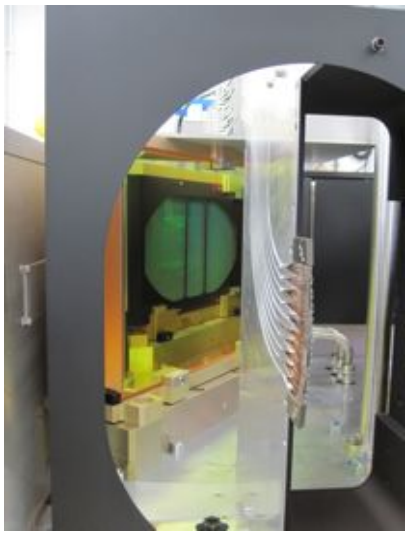
Groups of 30 fibers embedded in 1cm deep layer of epoxy for vacuum integrity.

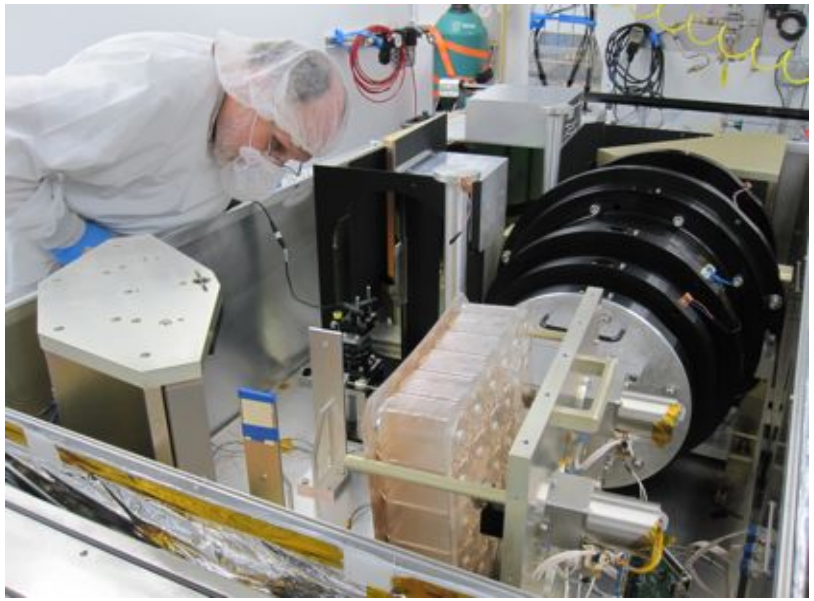




The APOGEE Instrument







APOGEE Installation

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



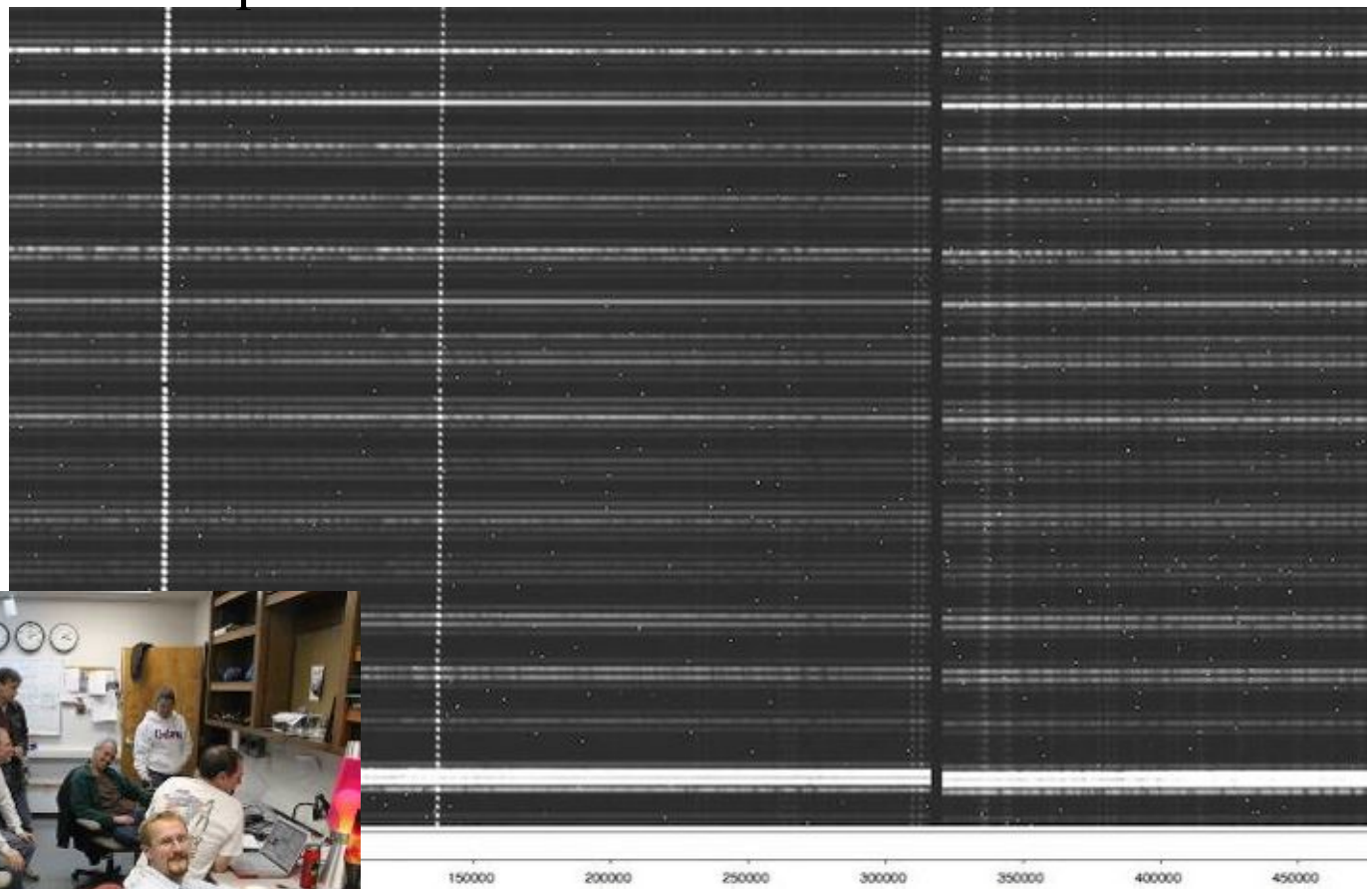




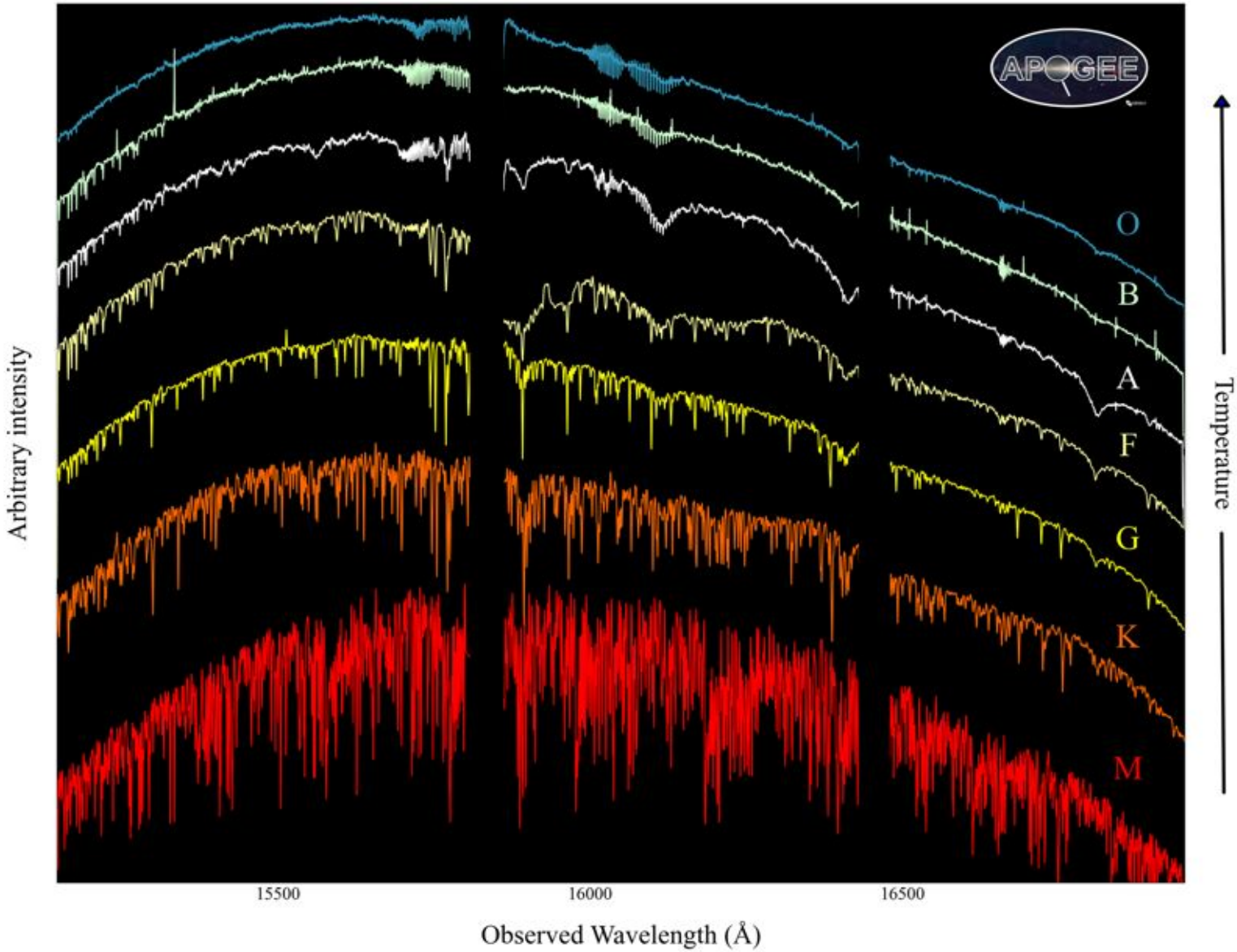
Photos by G. van Doren, D. Long, S. Majewski, O. Malanushenko, M. Nelson, J. Wilson

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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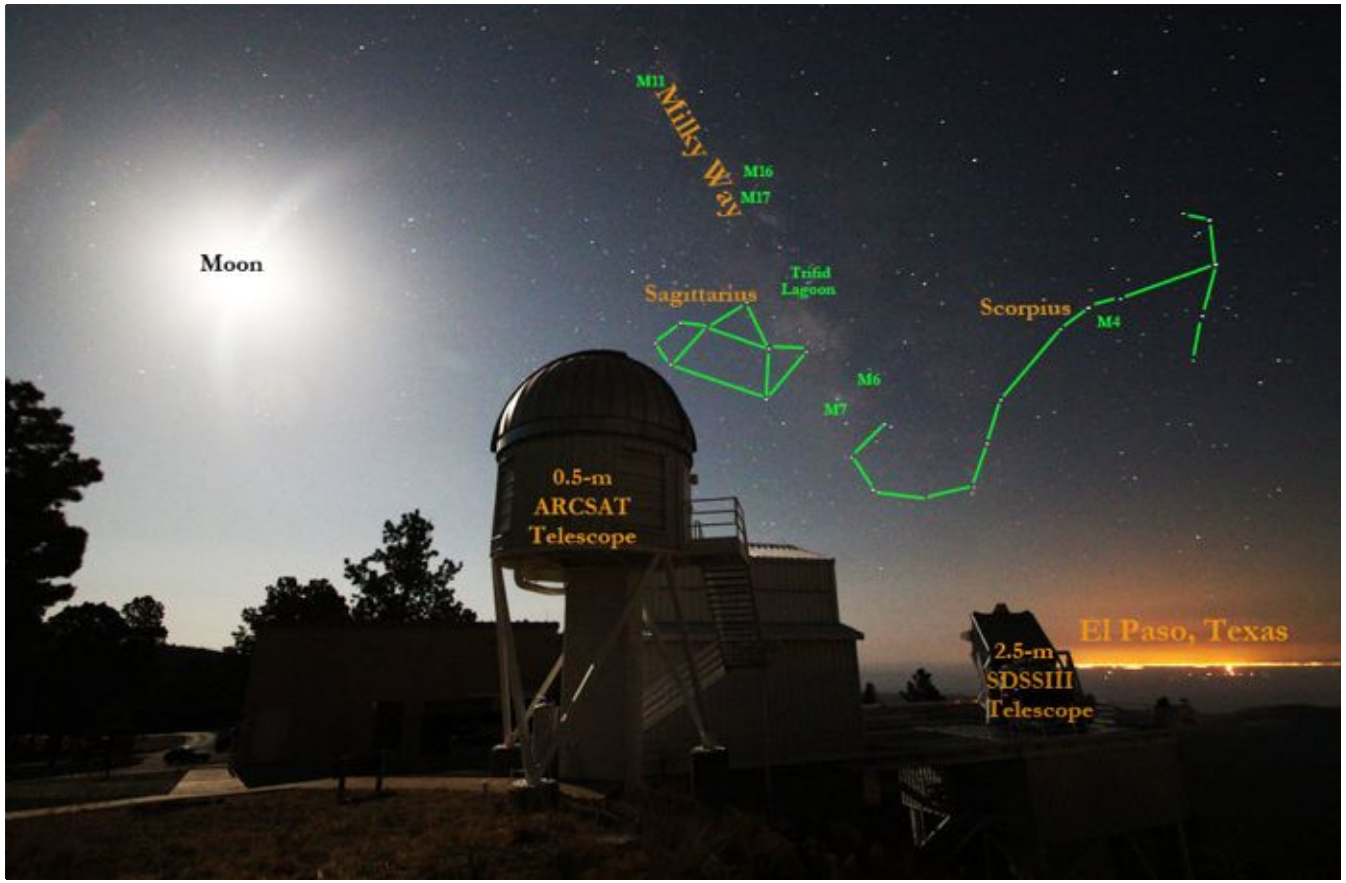
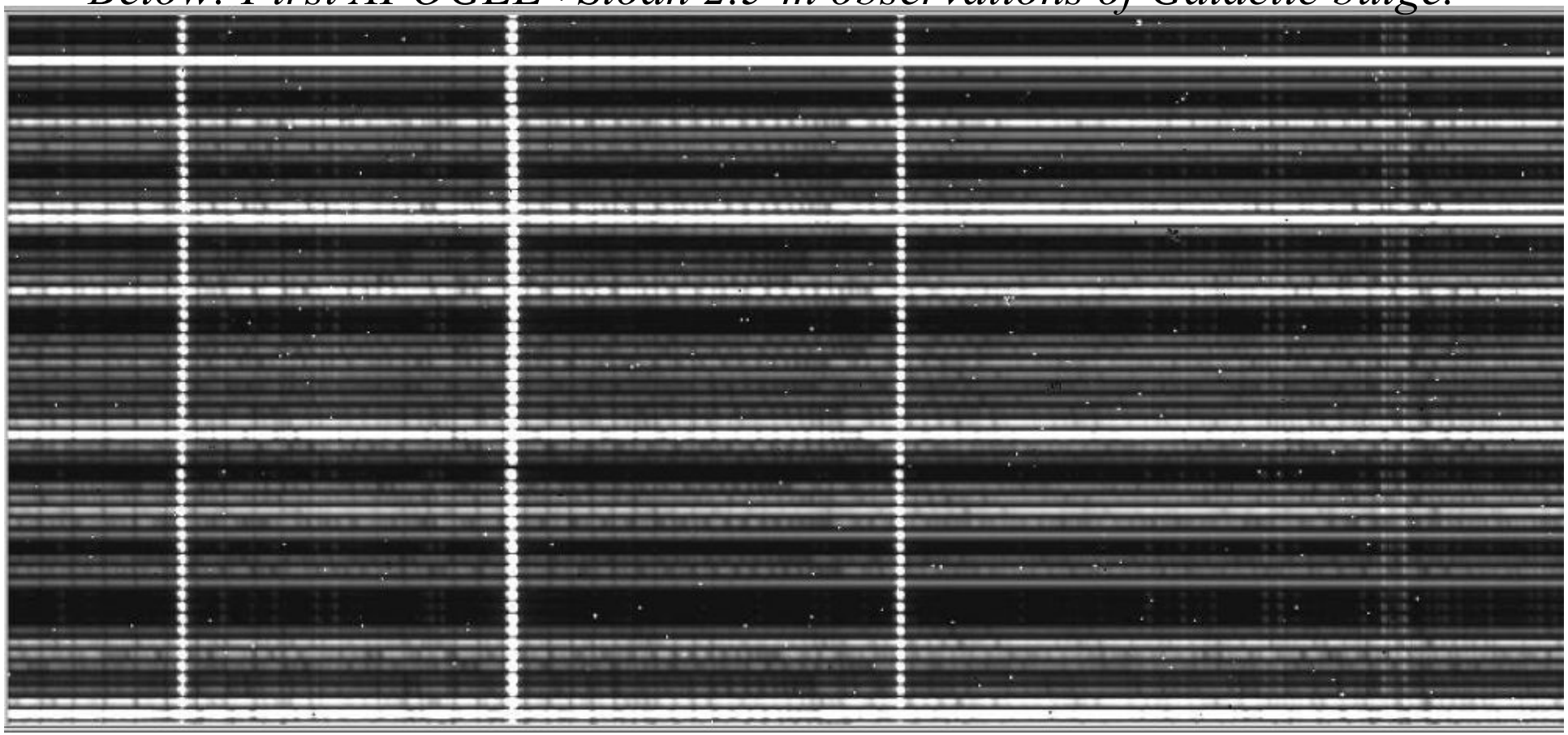


Photo by S.R. Majewski

APOGEE First Month

- May 11-22: First full APOGEE bright run.

Below: First APOGEE+Sloan 2.5-m observations of Galactic bulge.

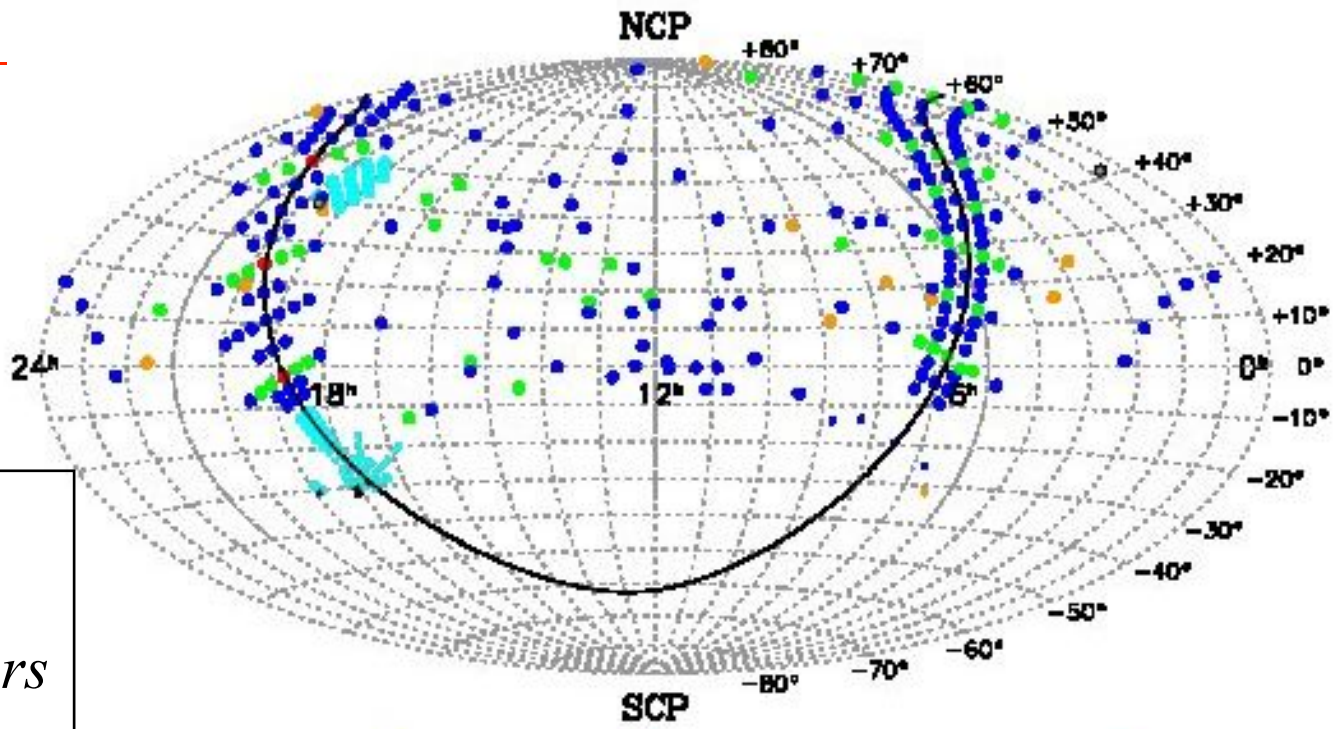


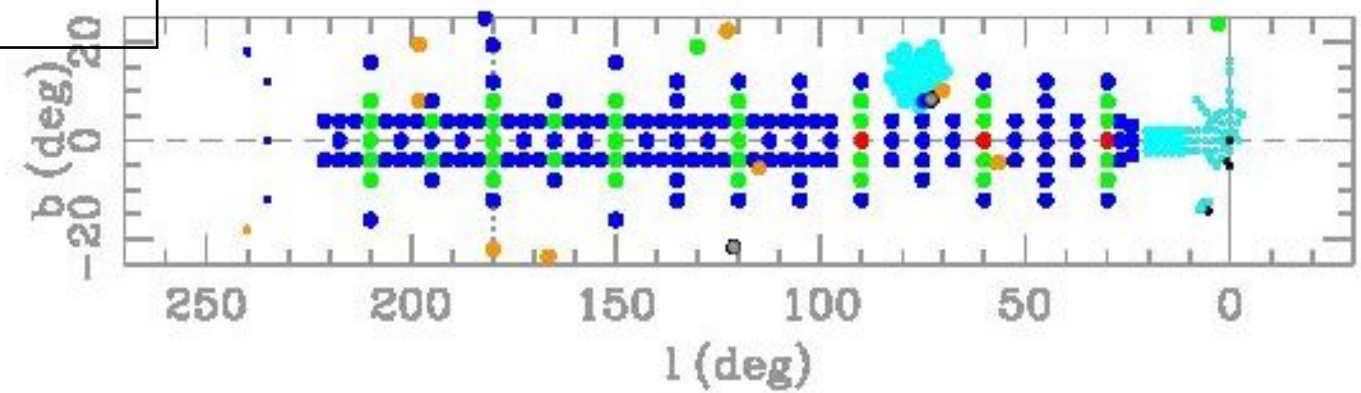
Field Selection

Field Center Plan:

24 hour
12 hour
3 hour (science)
3 hour (calibration)
1 hour

~343 fields
~600 star clusters
~116,000 science stars
Kepler fields



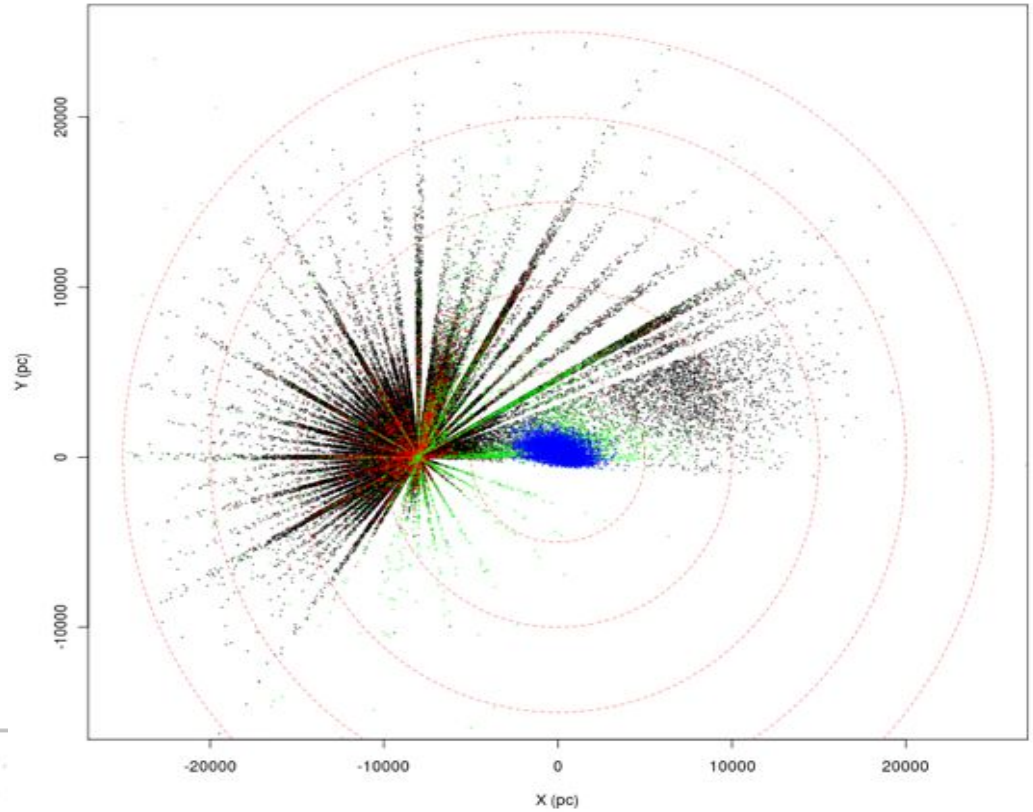


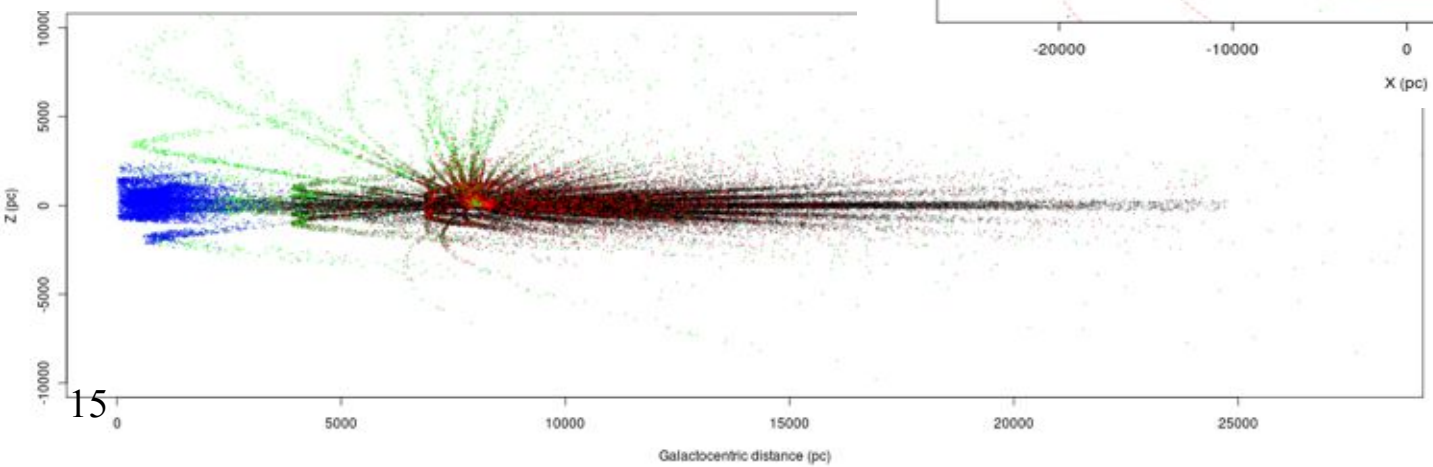
Anticipated Spatial Distribution

For currently selected fields

Bulge	*8000 stars*
Thin disk	*84100 stars*
Thick disk	*4300 stars*
Halo	*4500 stars*

79% giants





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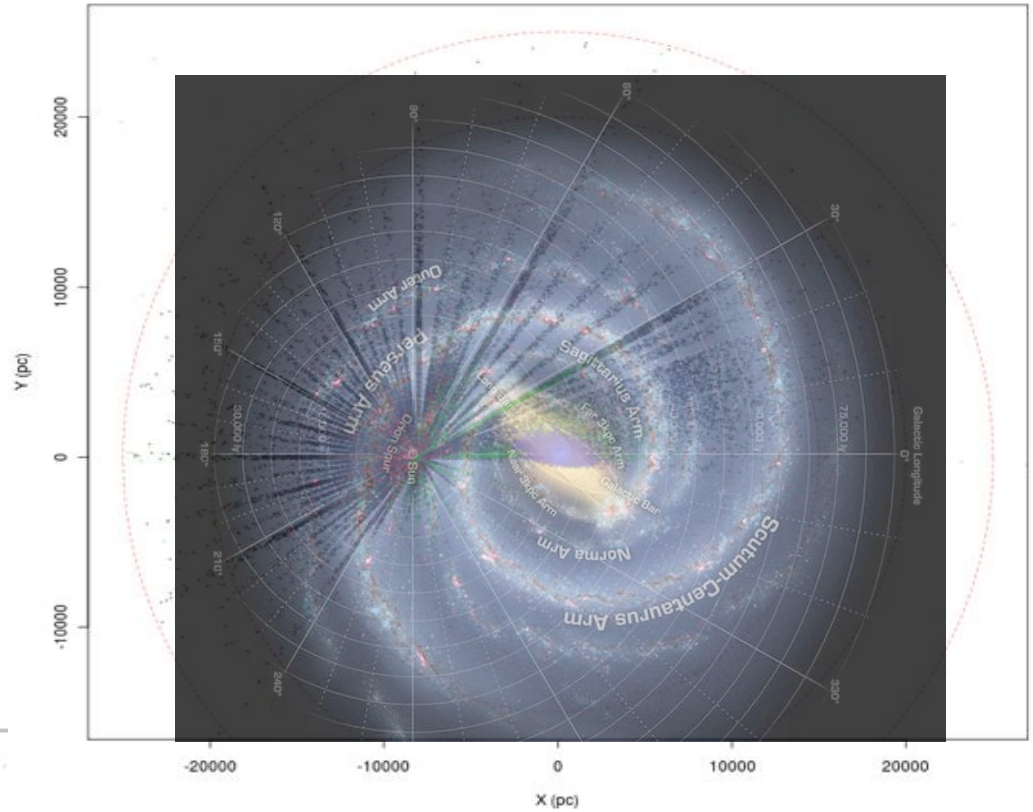
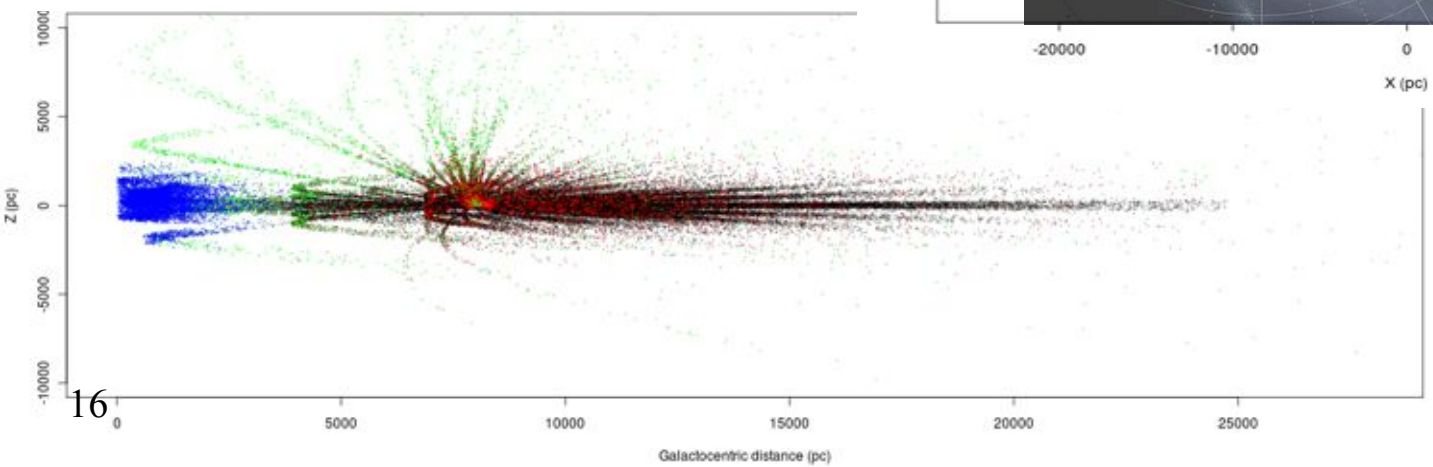




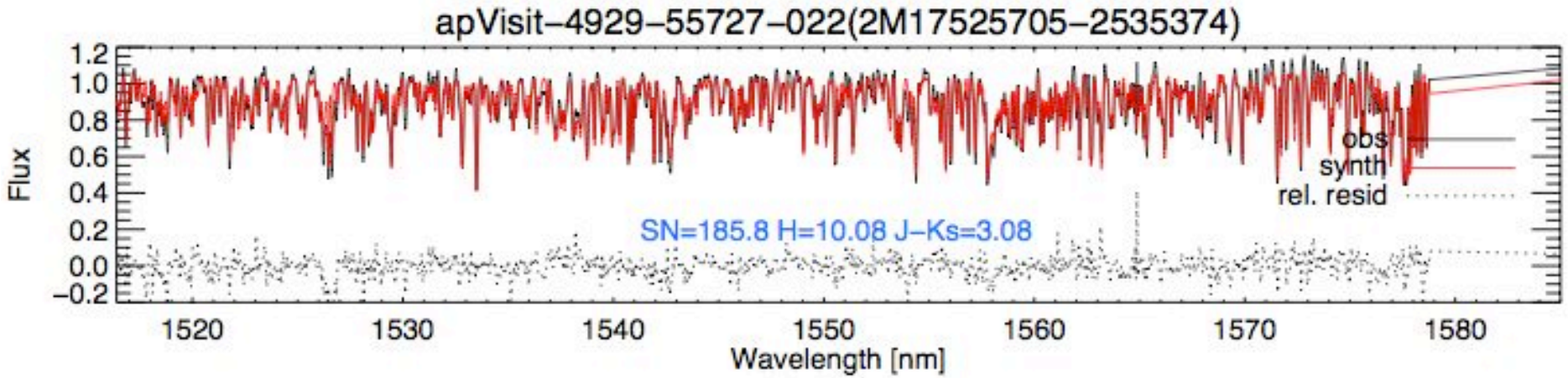
Observations to Date

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

>400 separate plates

>100,000 science spectra

bulge, [Fe/H] ~ -0.2



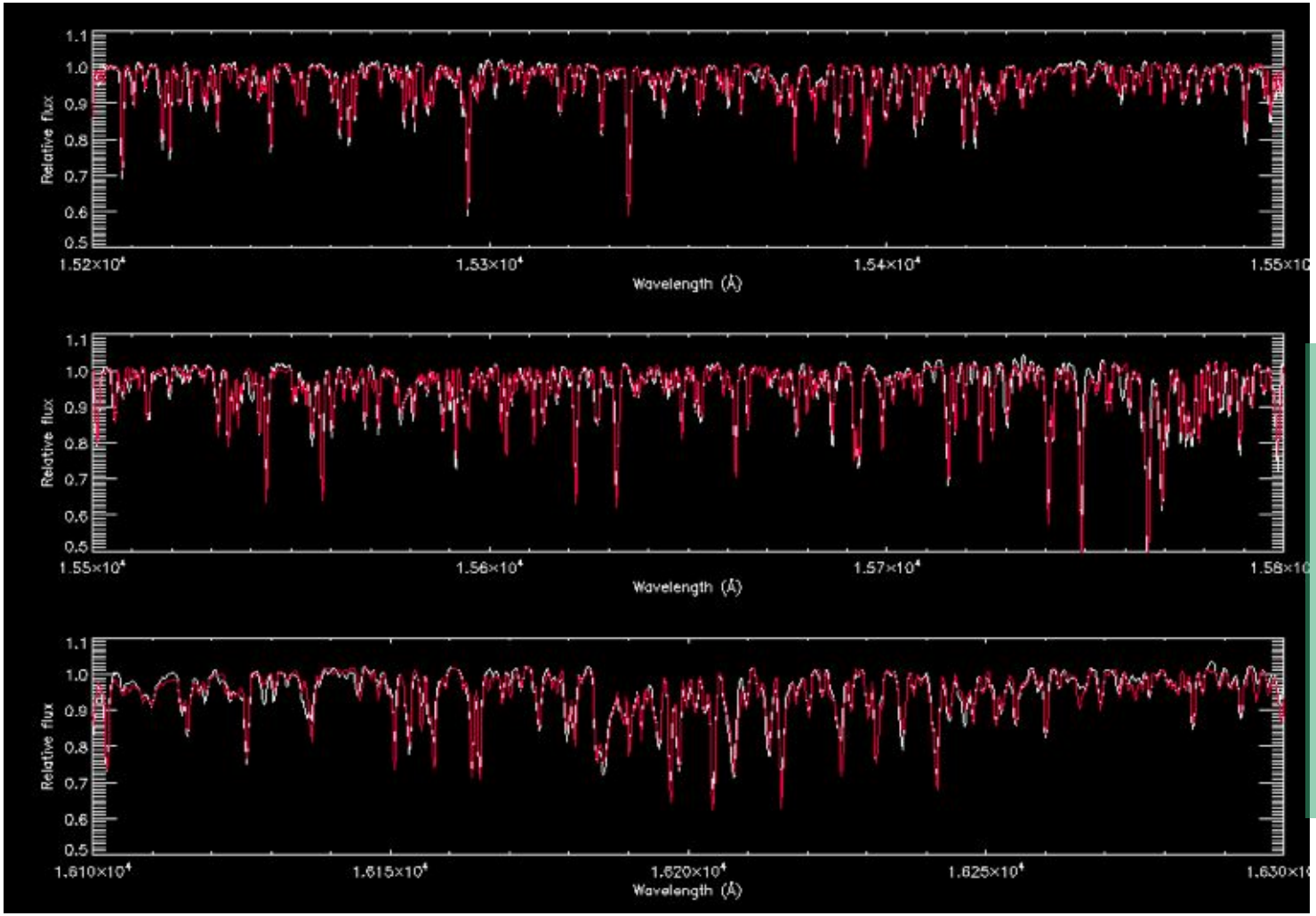
APOGEE pipelines

- 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, α/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
$Log_{10}(\xi)$=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

Data Products

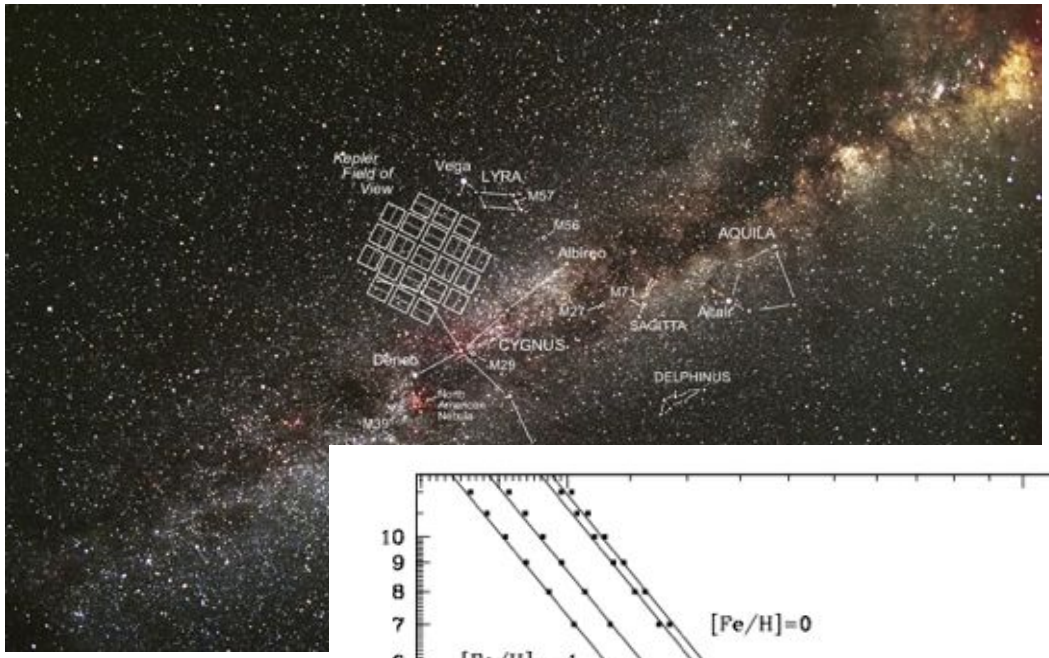
- Target selection information
- Spectra across full APOGEE spectral window (1.51-1.69 μm)
- Velocity data (< 70 m/s precision)
- Stellar atmospheric parameters from matches to synthetic libraries
- Chemical abundances (≤ 0.1 dex internal accuracy)
  - Na, Mg, Al, Si, S, K, Ca, Ti, V, Mn, Co, Ni

– First public releases in DR10 (2013)

APOGEE-Kepler Asteroseismology and Chemical Abundances Collaboration (APOKASC)

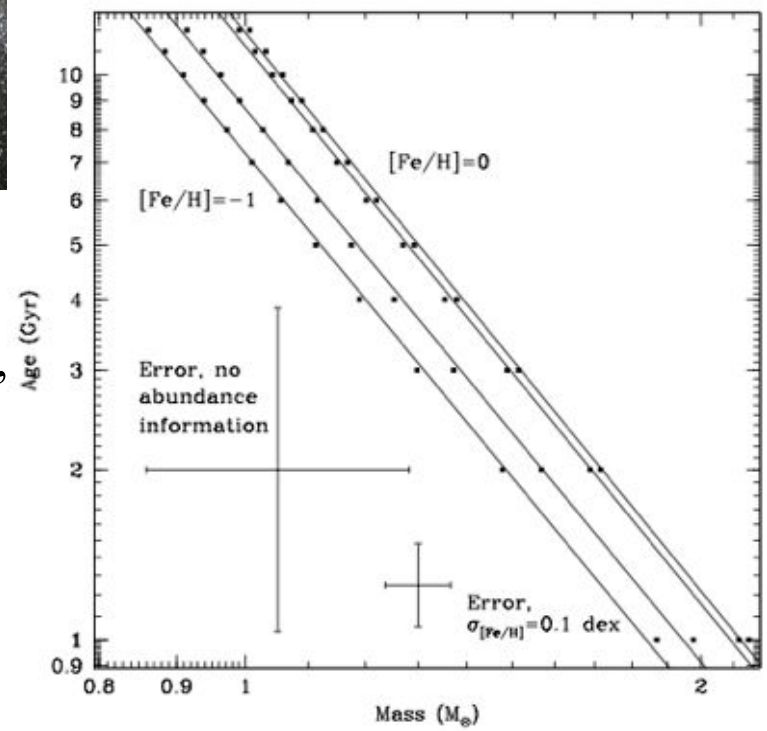
APOGEE Kepler field visits

- 21 x 2 visits, ~10,000 stars



- Kepler measures asteroseismic frequencies for ~10k giants:
  - gravity
  - radius
  - mass
- APOGEE provides abundances:
  - Combined w/asteroseismic info
    ages to 18% for field stars 1-5 kpc away!
  - Strict constraints on chemical evolution models, beyond solar neighborhood.
  - Also observing CoRoT targets.
  - Calibrate APOGEE pipelines.

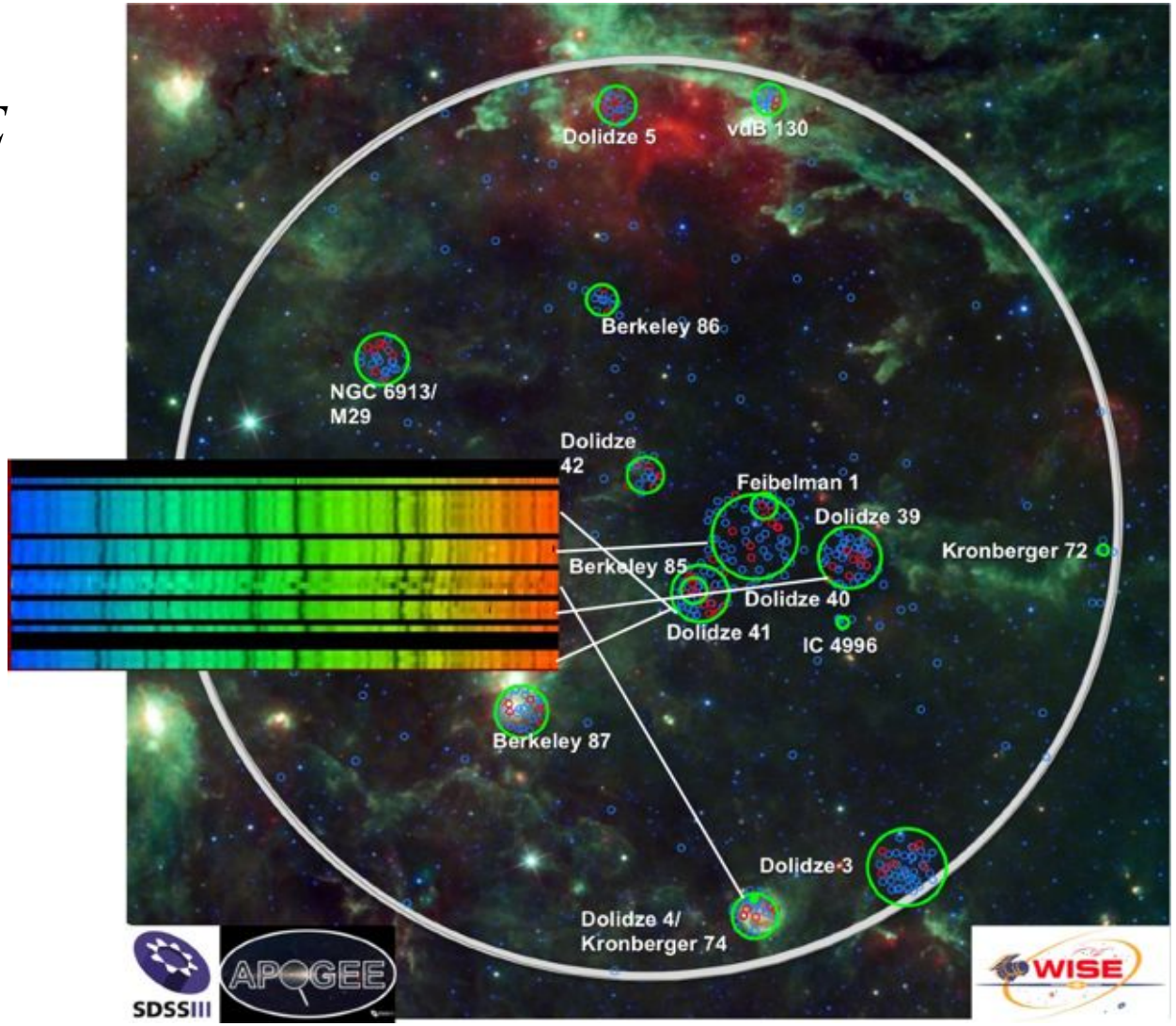
APOGEE also observing
eclipsing binaries, transit hosts in Kepler field.



Early Results: First Light Plates Clusters in Cygnus

(Peter Frinchaboy et al.)

WISE image of APOGEE first light field.



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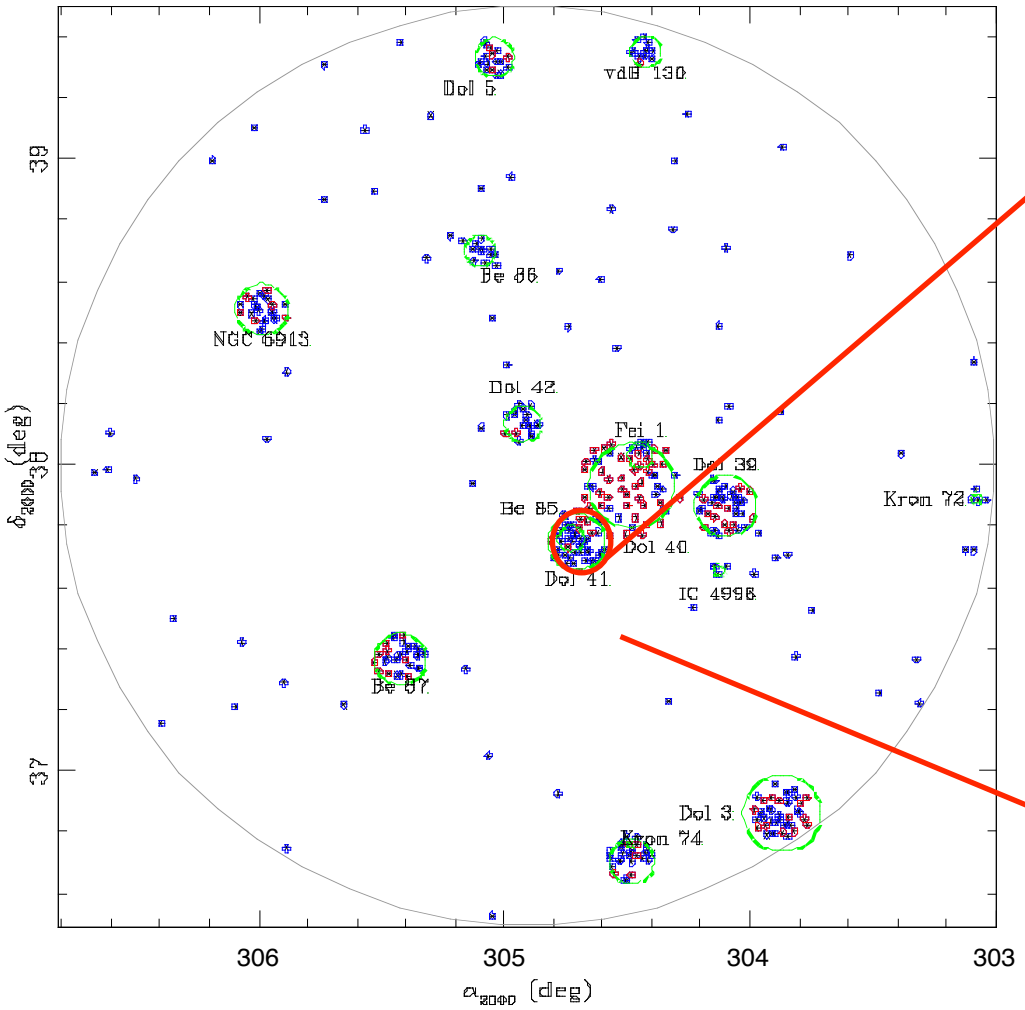
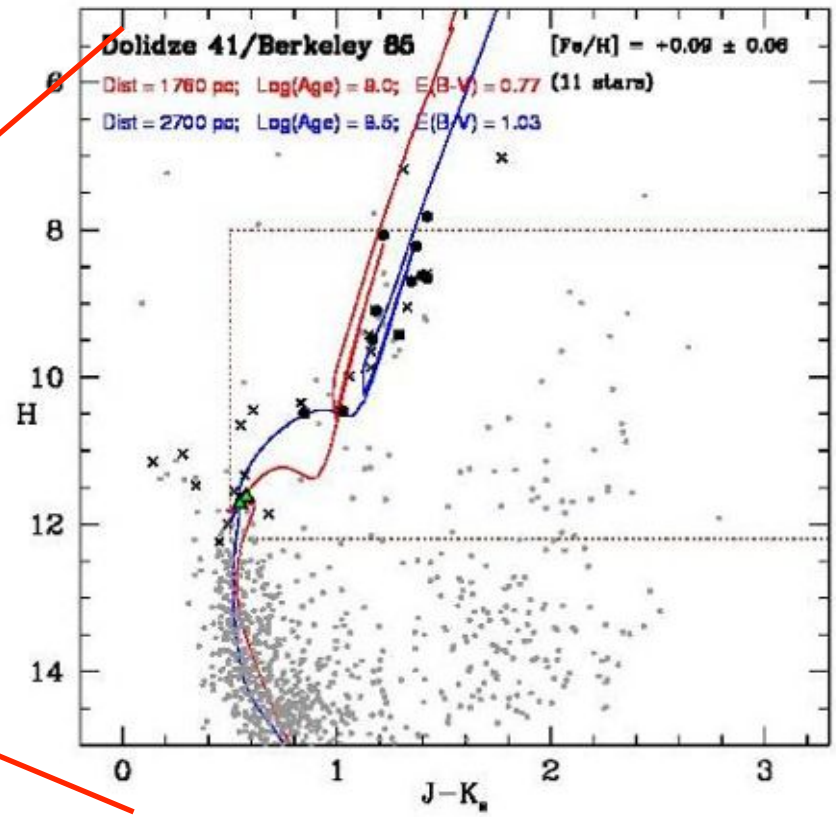
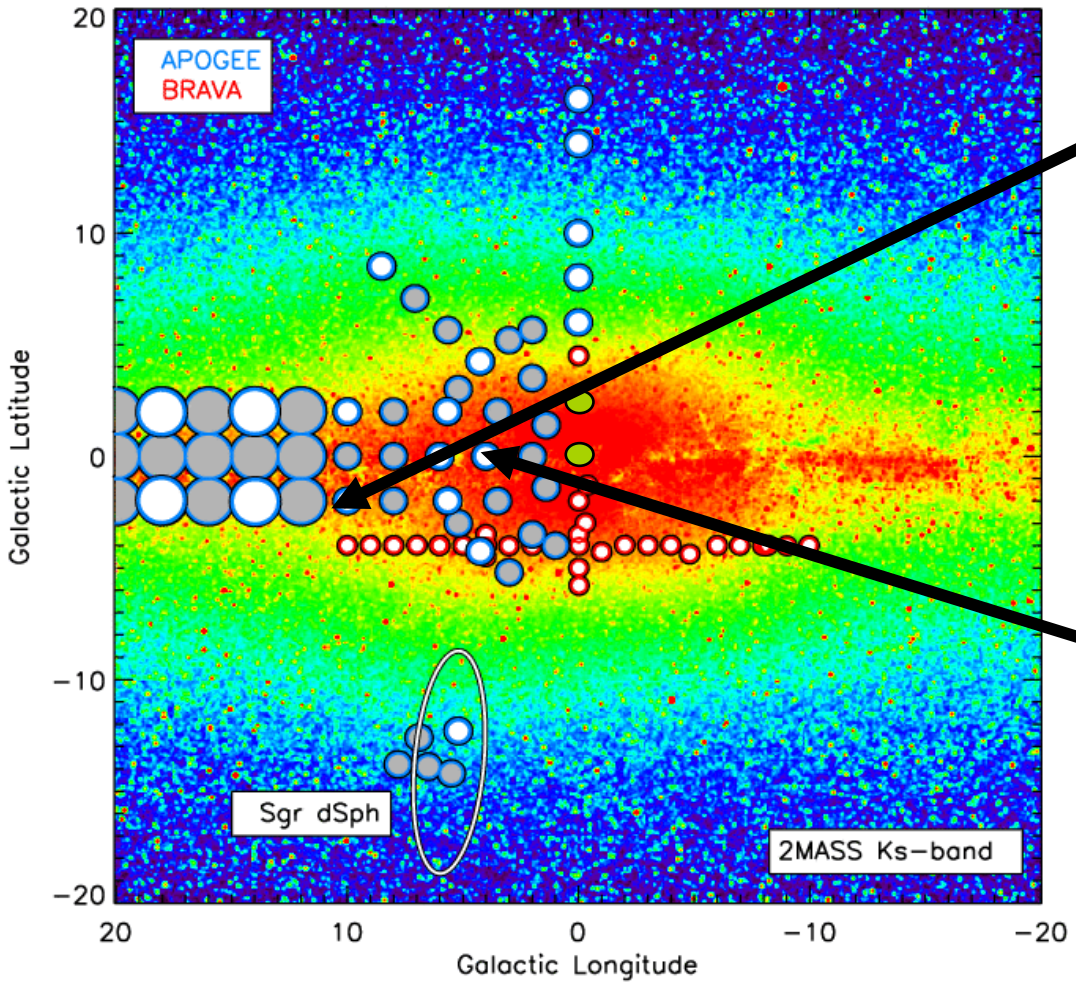
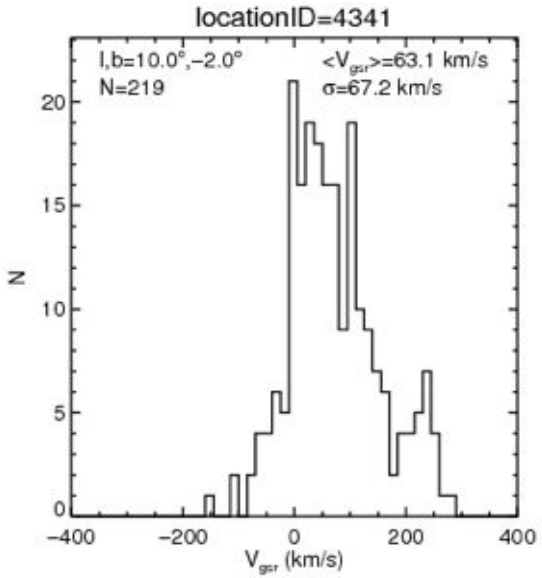


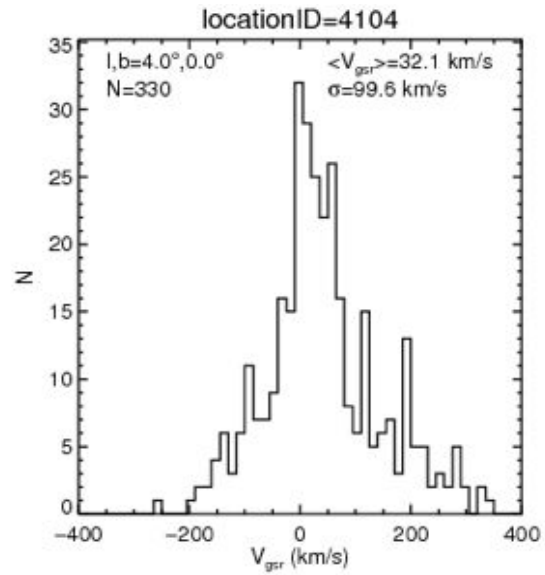


Early Results: Bulge Radial Velocities

(David Nidever, et al.)

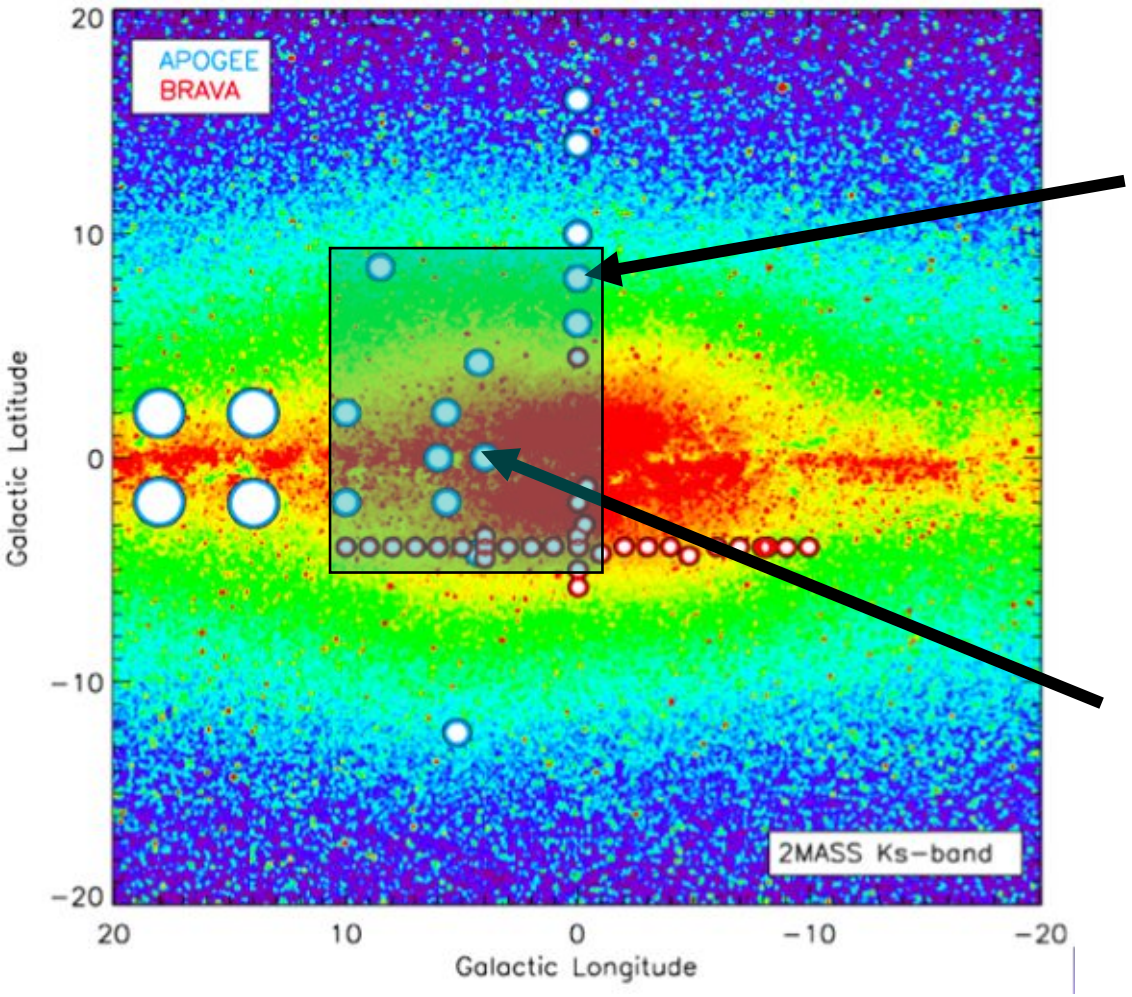


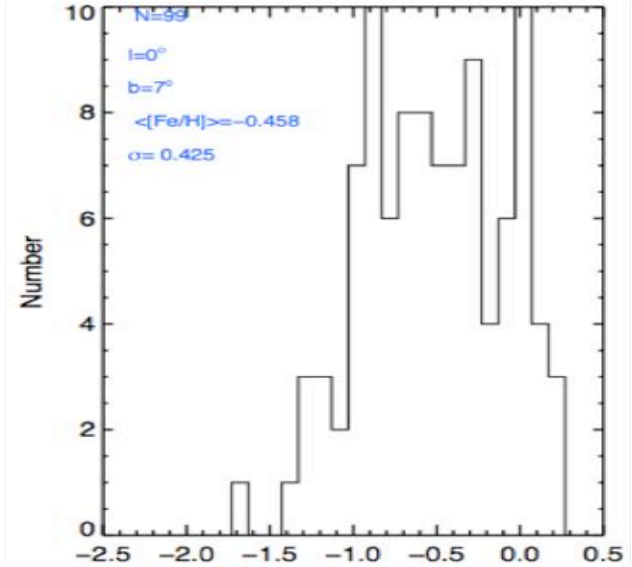


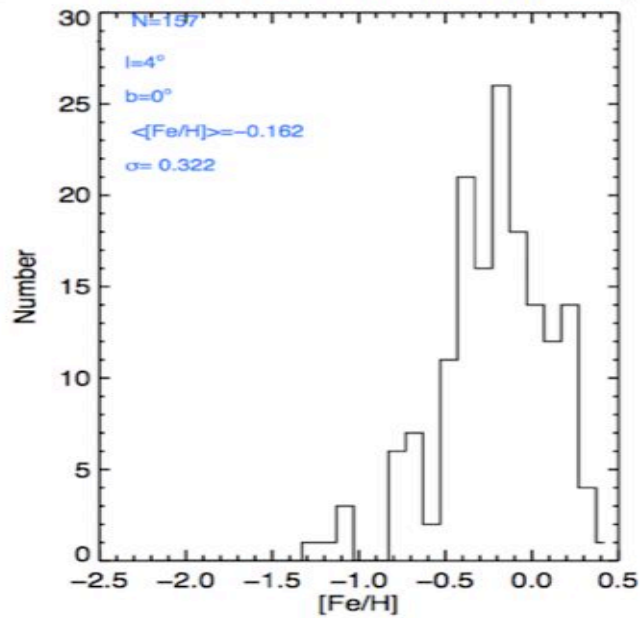


Early Results: Bulge Metallicities

(Ana Garcia-Perez et al.)



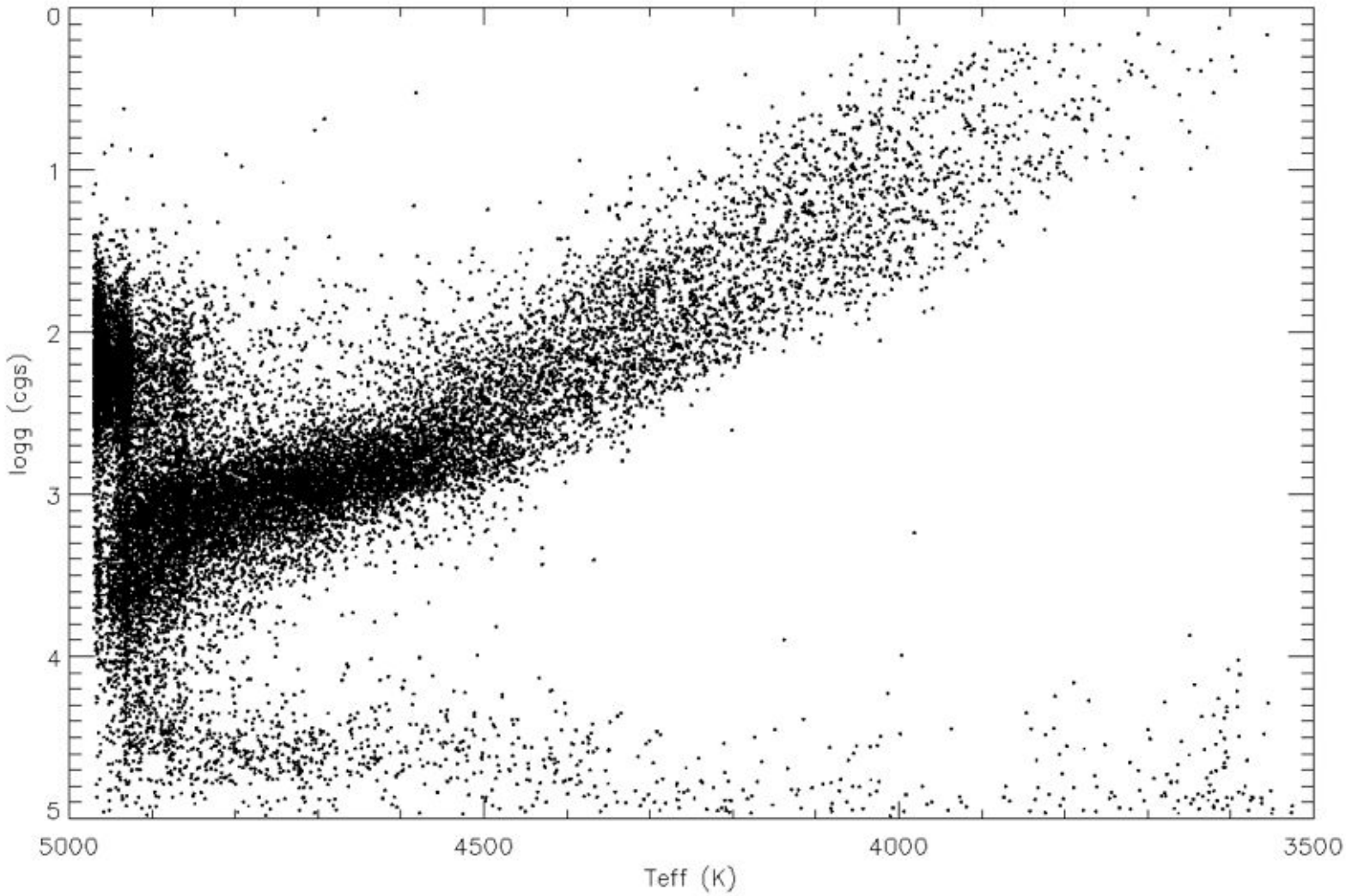


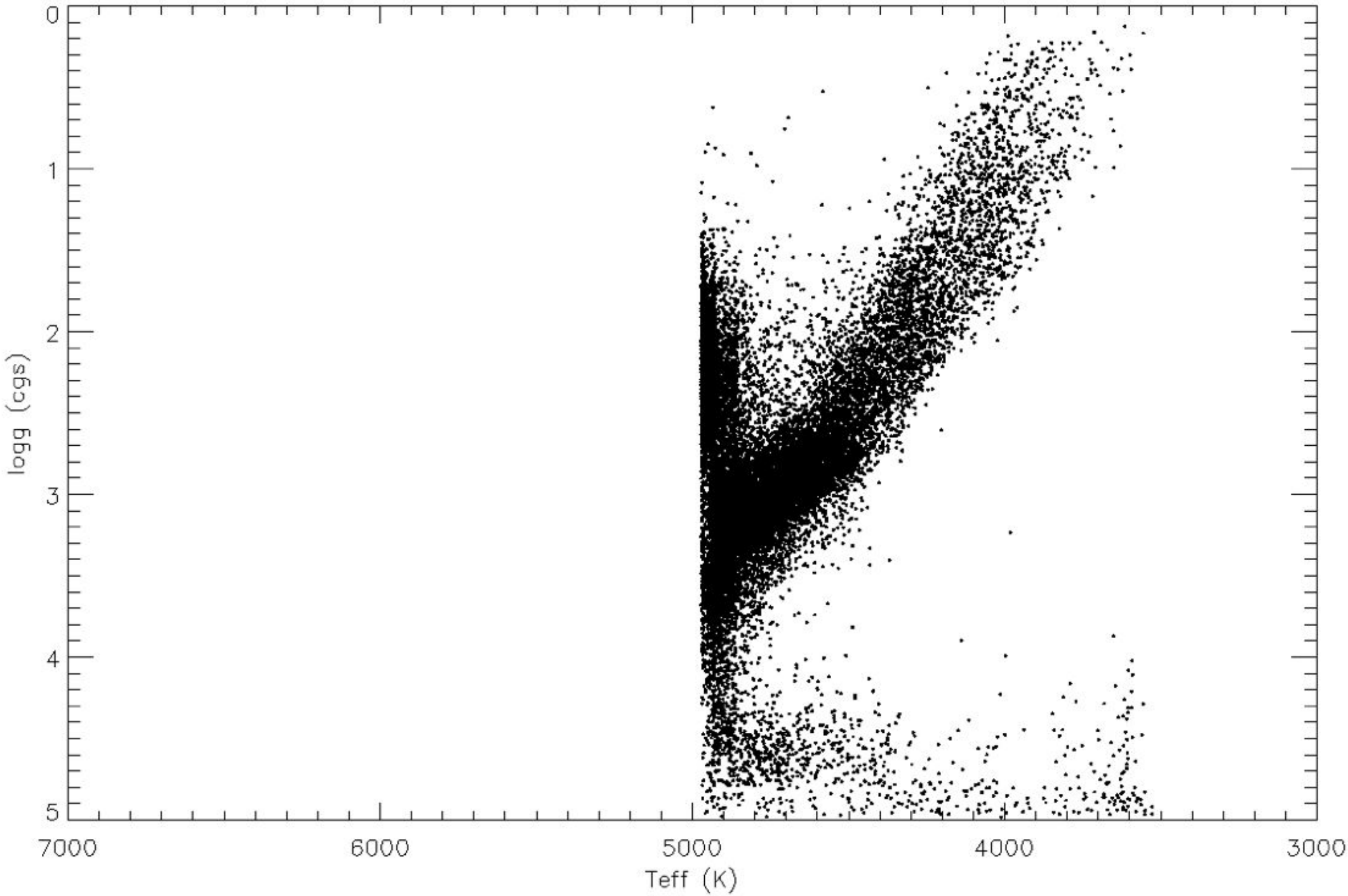


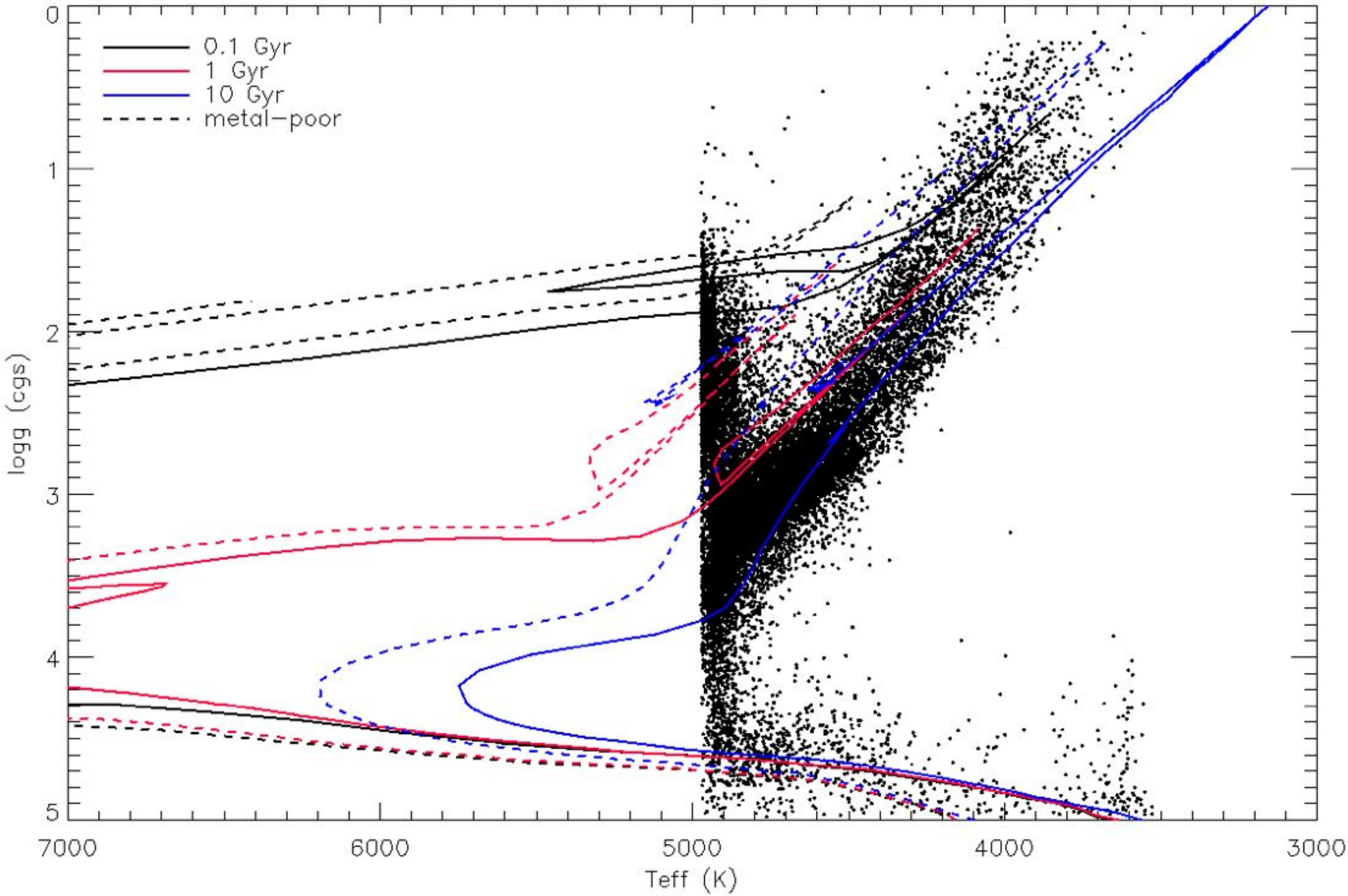
APOGEE and oxygen

- 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.

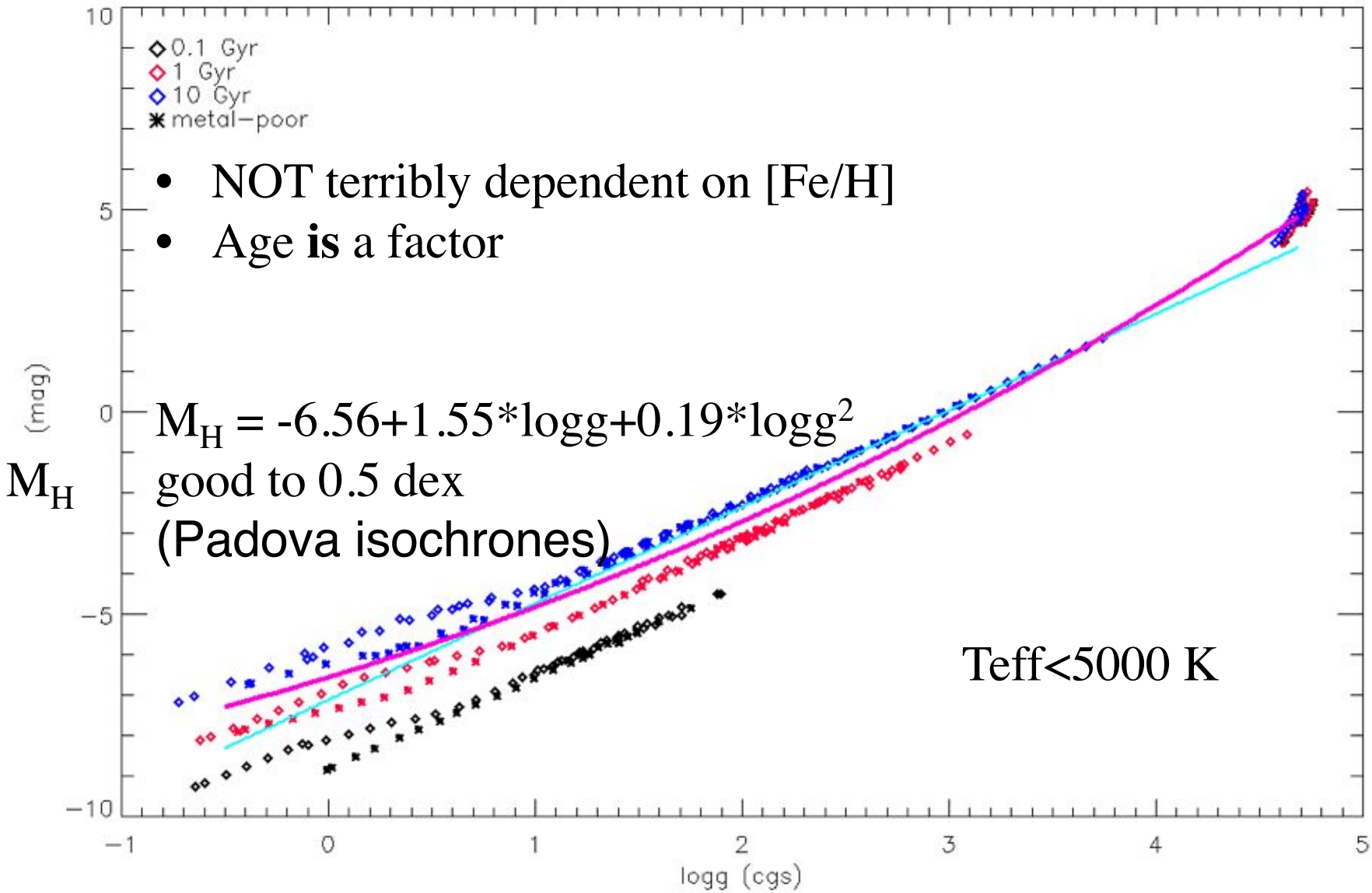
Atmospheric parameters




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

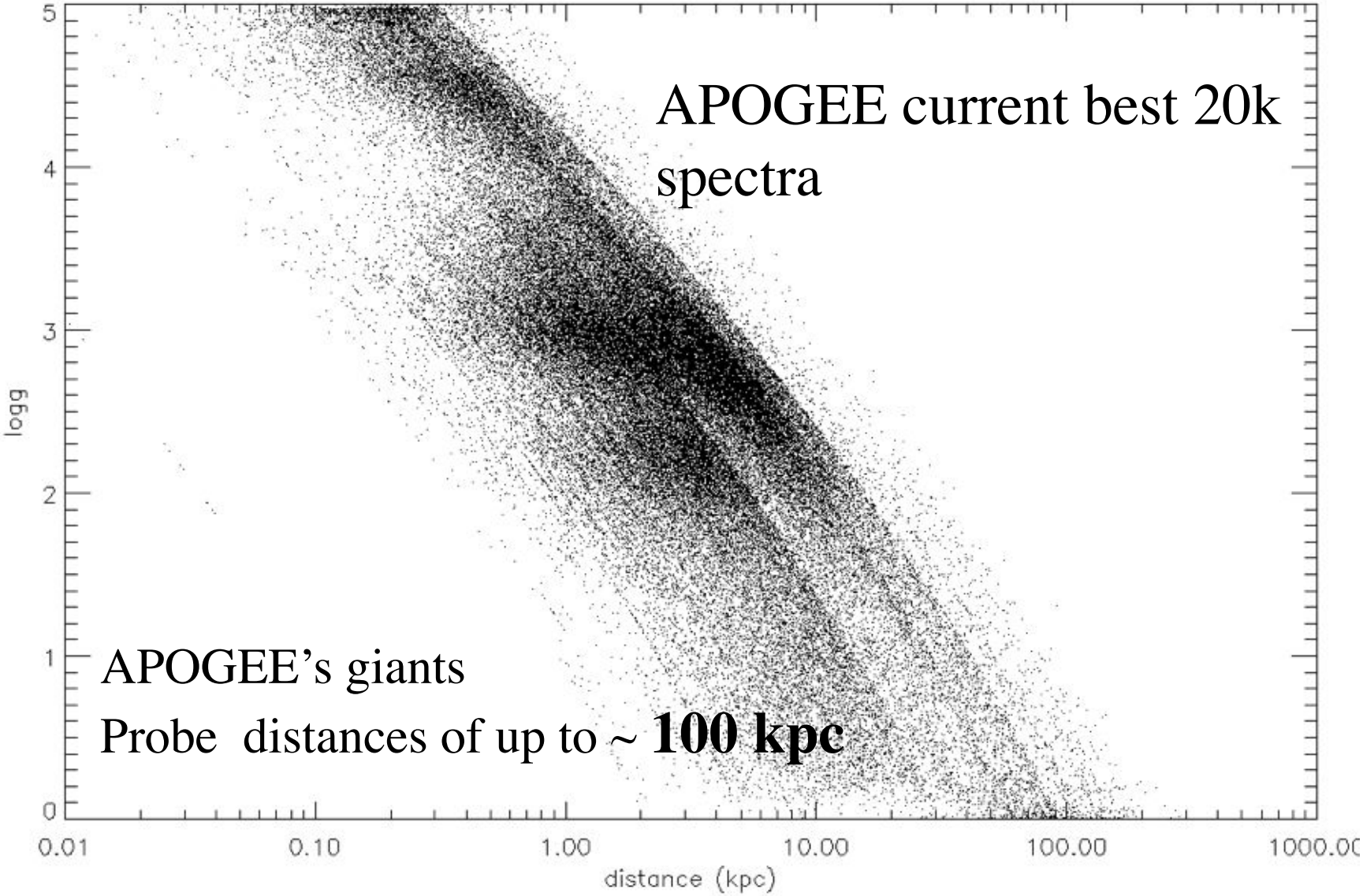


- NOT terribly dependent on [Fe/H]
- Age **is** a factor

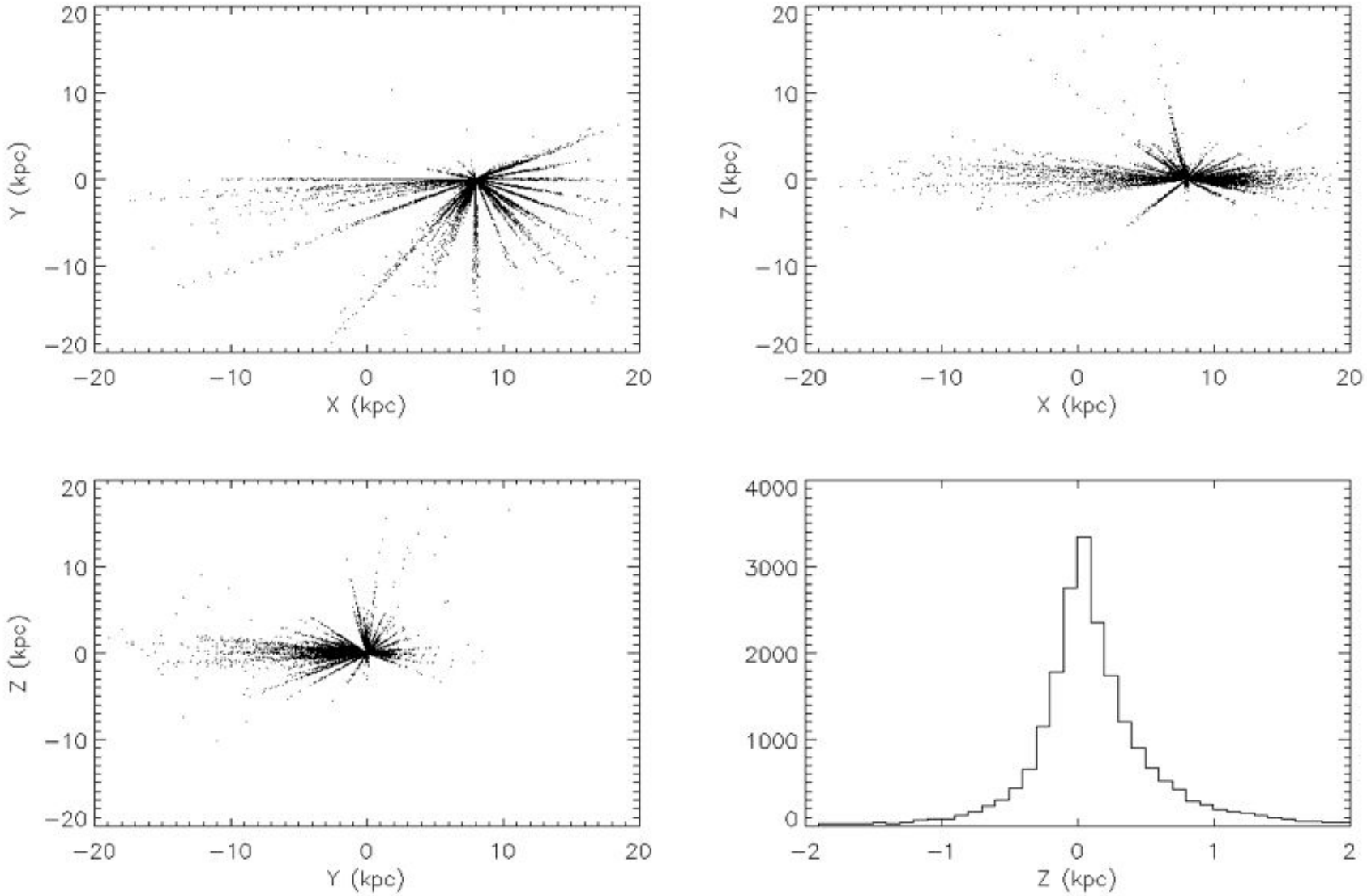
$M_H = -6.56+1.55*\log g+0.19*\log g^2$
good to 0.5 dex
(Padova isochrones)

Teff<5000 K

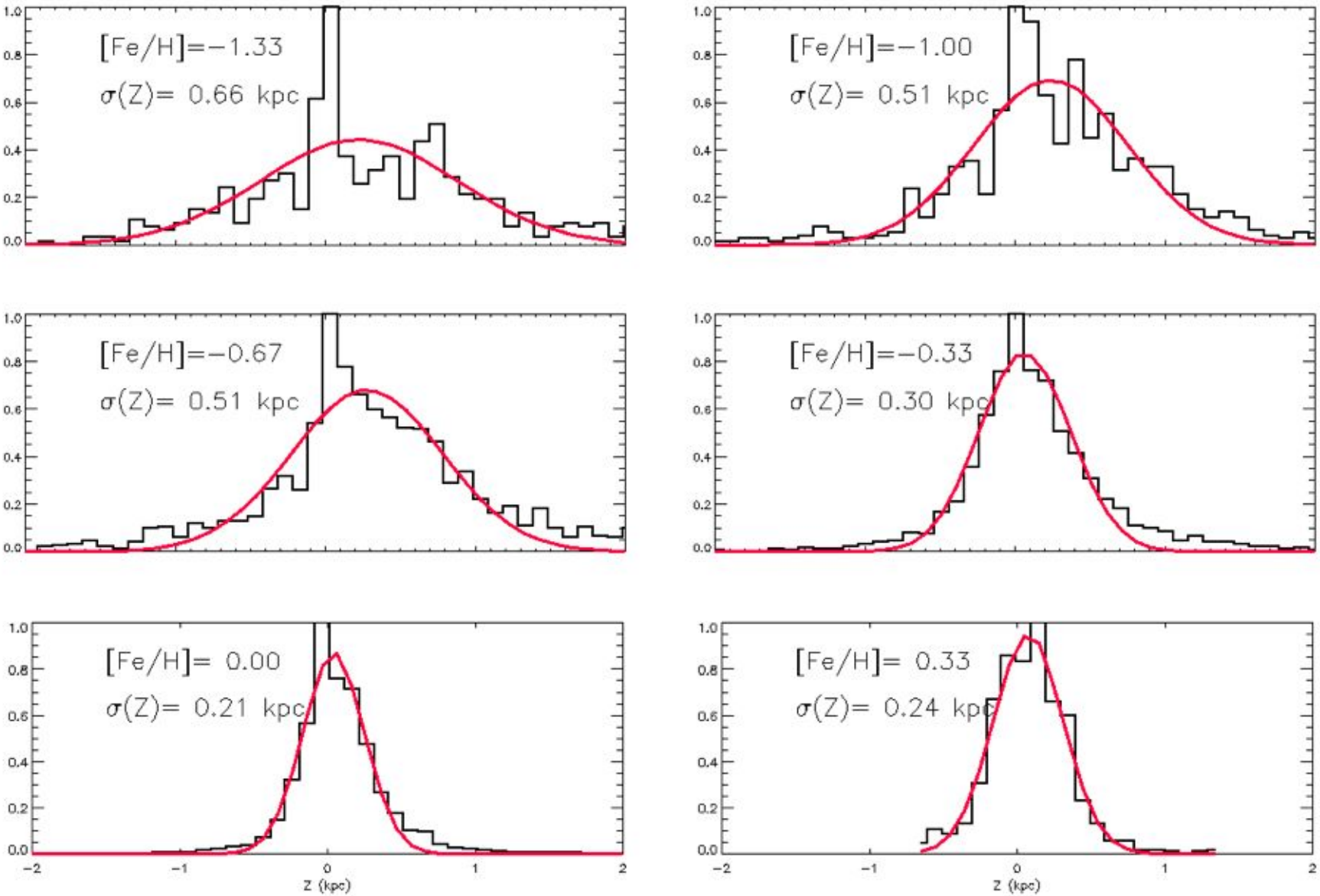
distances


APOGEE current best 20k spectra
APOGEE's giants
Probe distances of up to ~ **100 kpc**
logg
distance (kpc)
0
1
2
3
4
5
0.01
0.10
1.00
10.00
100.00
1000.00

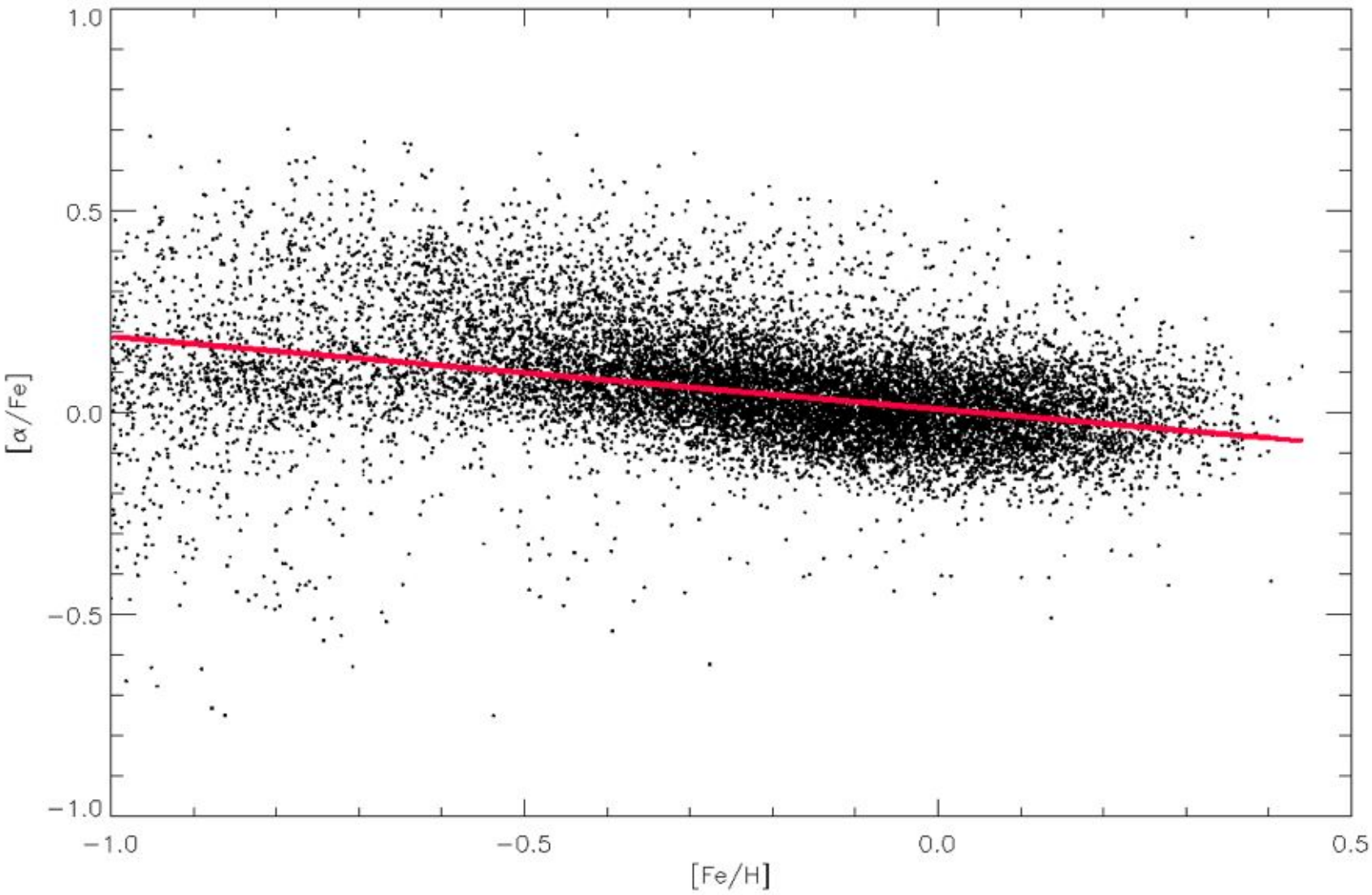
Sample distributions



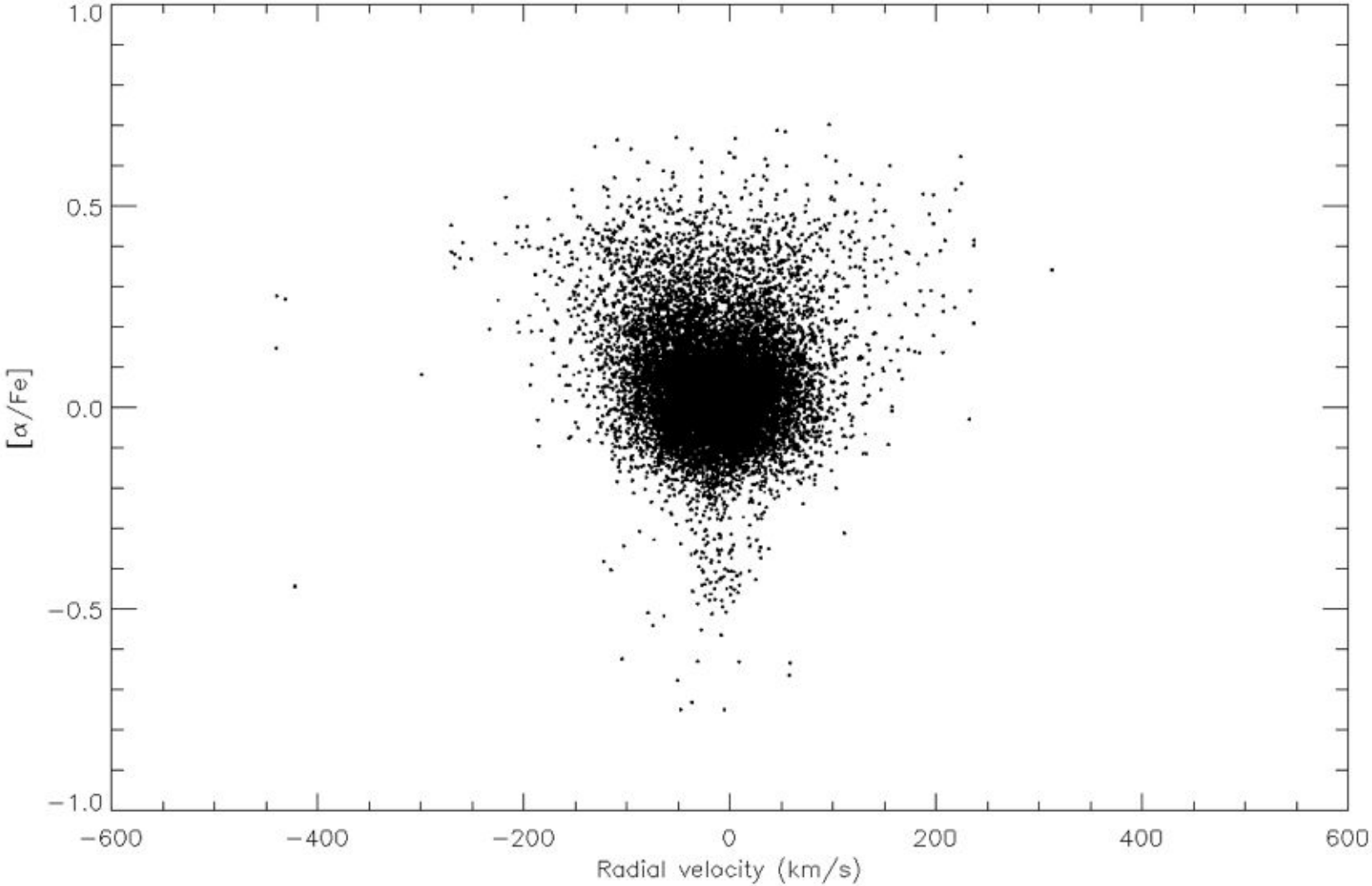
Scale height



α/Fe (OH + Mg)



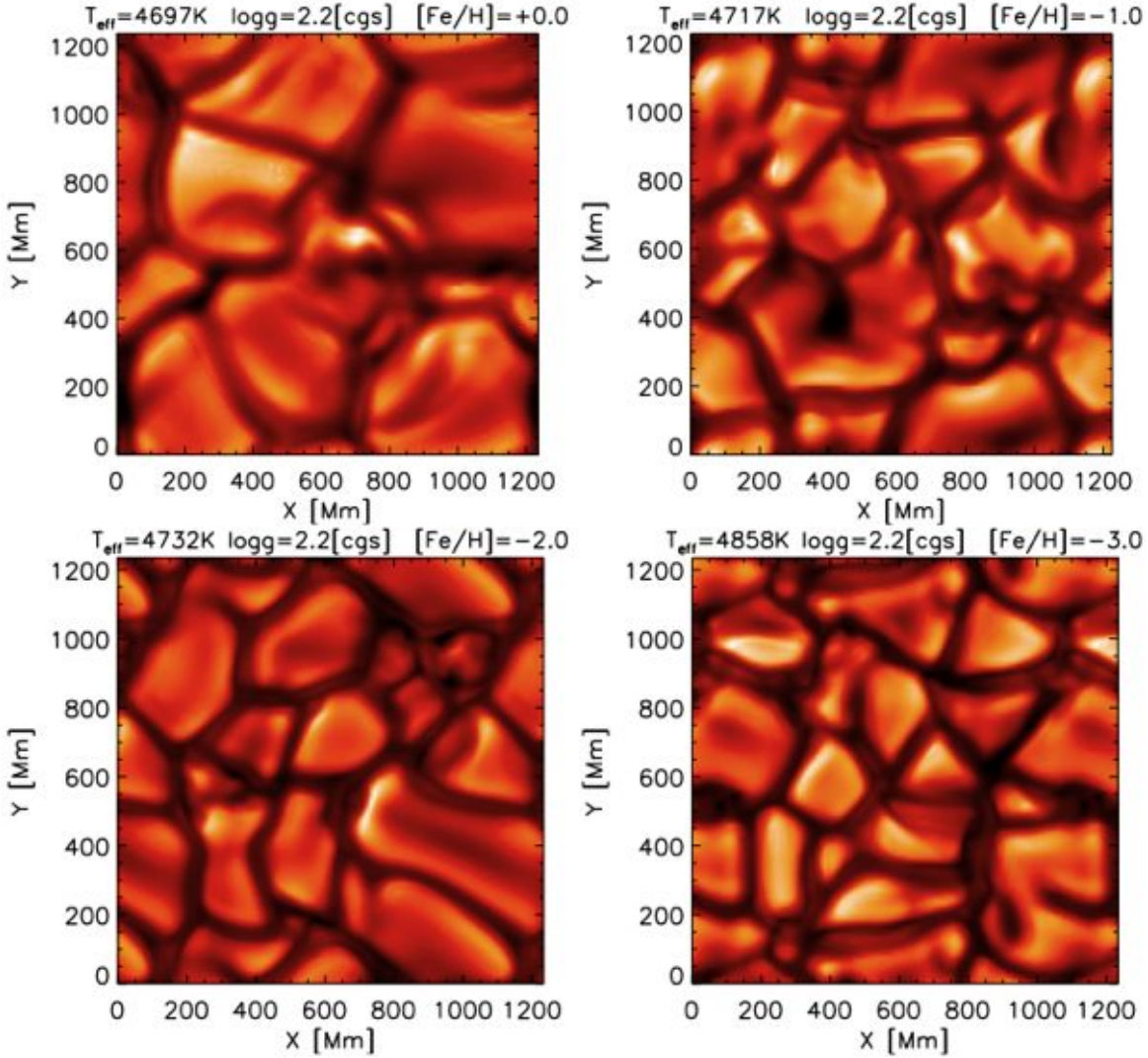
Chemistry + kinematics



Systematic errors on abundances?

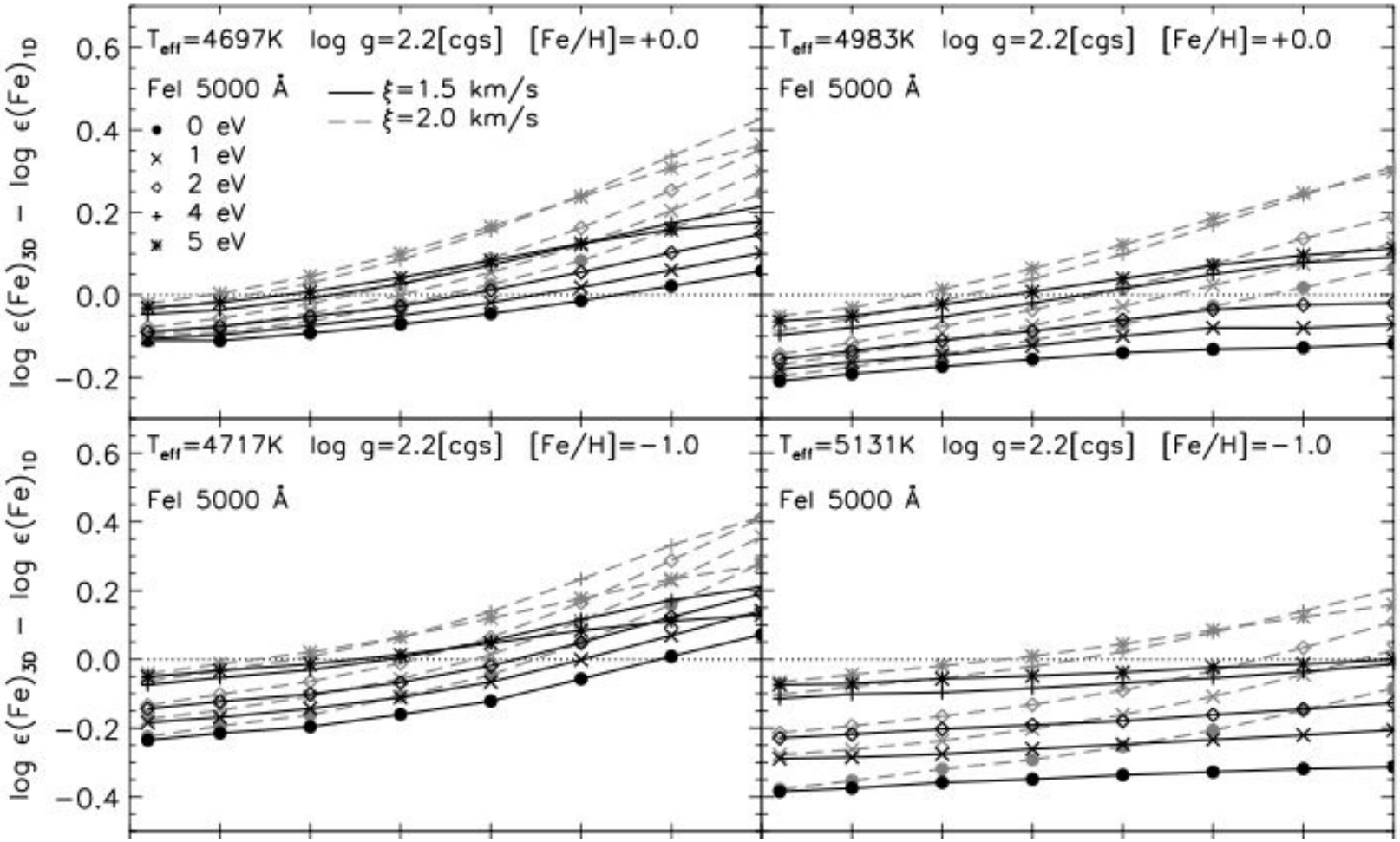
- APOGEE heavily relies on a conventional LTE-1D analysis
- At ~ 1.6 μ balance between H^- bound-free and free-free opacity, i.e. mimimum opacity and therefore spectrum formed at deeper optical depth than optical. This typically implies less vulnerability to departures from LTE
- Important to check for 3D effects

Red Giant Simulations



(Collet, Asplund & Trampedach 2007)

Fe I in the optical



20 30 40 50 60 70 mA (equivalent width)

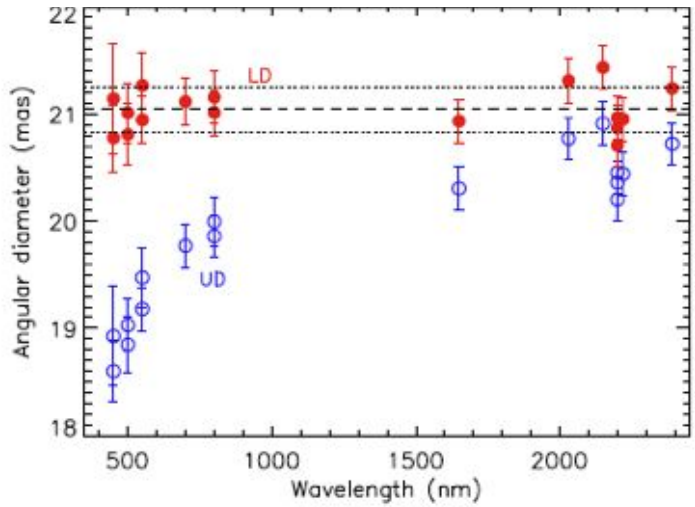
(Collet, Asplund & Trampedach 2007)

3D effects (optical/UV)

- Weak Fe I lines in the optical for -1<[Fe/H]<0 get stronger in 3D with abundance corrections of order -0.1 to -0.2 dex.
- Corrections reduce and then change sign for stronger lines
- Similar situation for Mg I lines, without reversing the sign of corrections for strongest features
- -0.1 to -0.2 dex corrections as well for CO or OH transitions at around solar metallicity

(Collet, Asplund & Trampedach 2007)

Arcturus

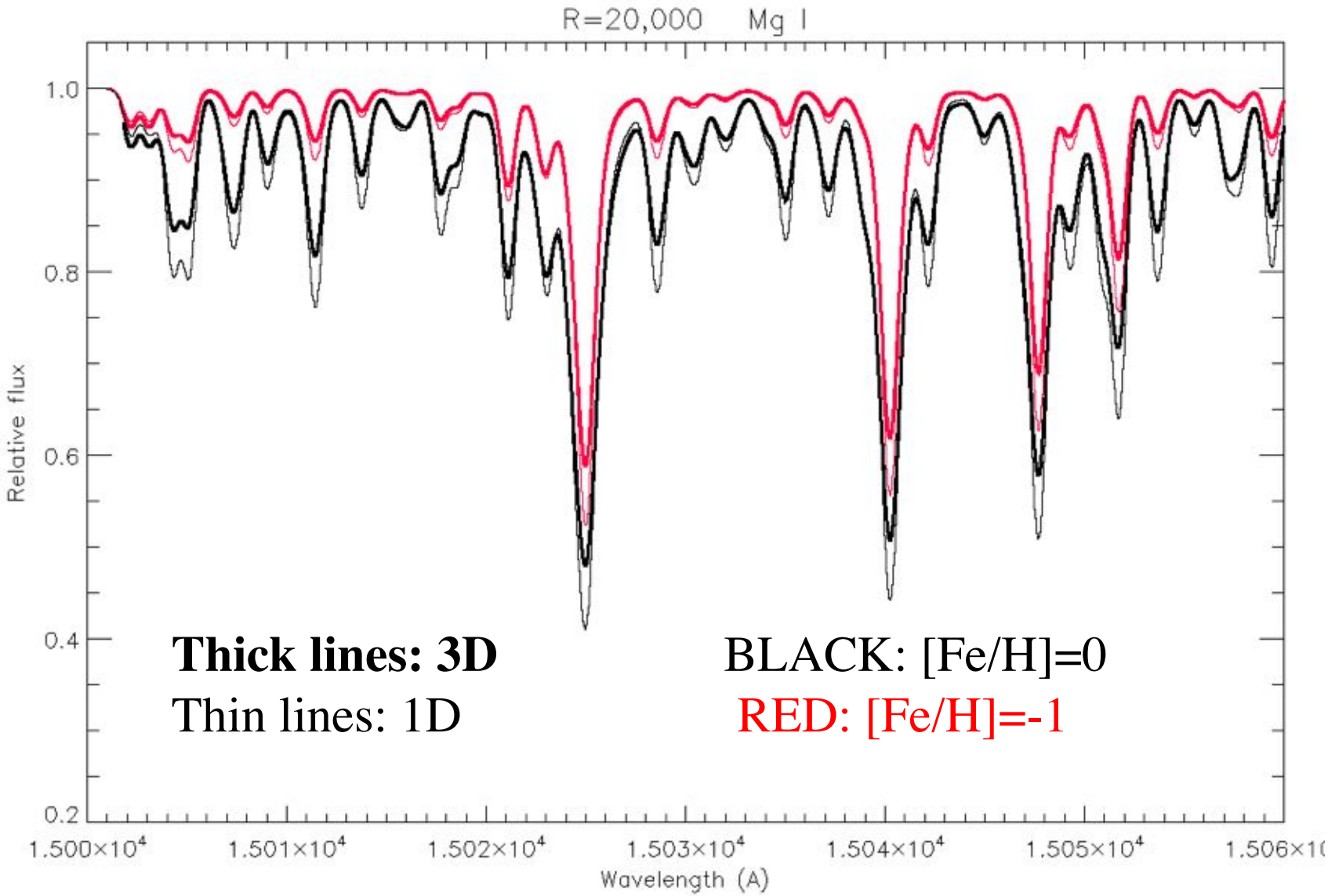


- Nice standard star: nearby (11 pc), bright (V=-0.05 mag), well-observed (parallaxes, angular diameter, absolute fluxes available), prototypical thick-disk (7 Gyr old)
- Atmospheric parameters are tightly constrained: Teff=4286 ±30 K, logg=1.66 ±0.05 dex , [Fe/H] =-0.52 ±0.04 dex, [α/Fe]~+0.4
- FeI/FeII ionization balance not satisfied (0.12 dex discrepancy) for iron in LTE/1D (Ramirez & Allende Prieto 2012)

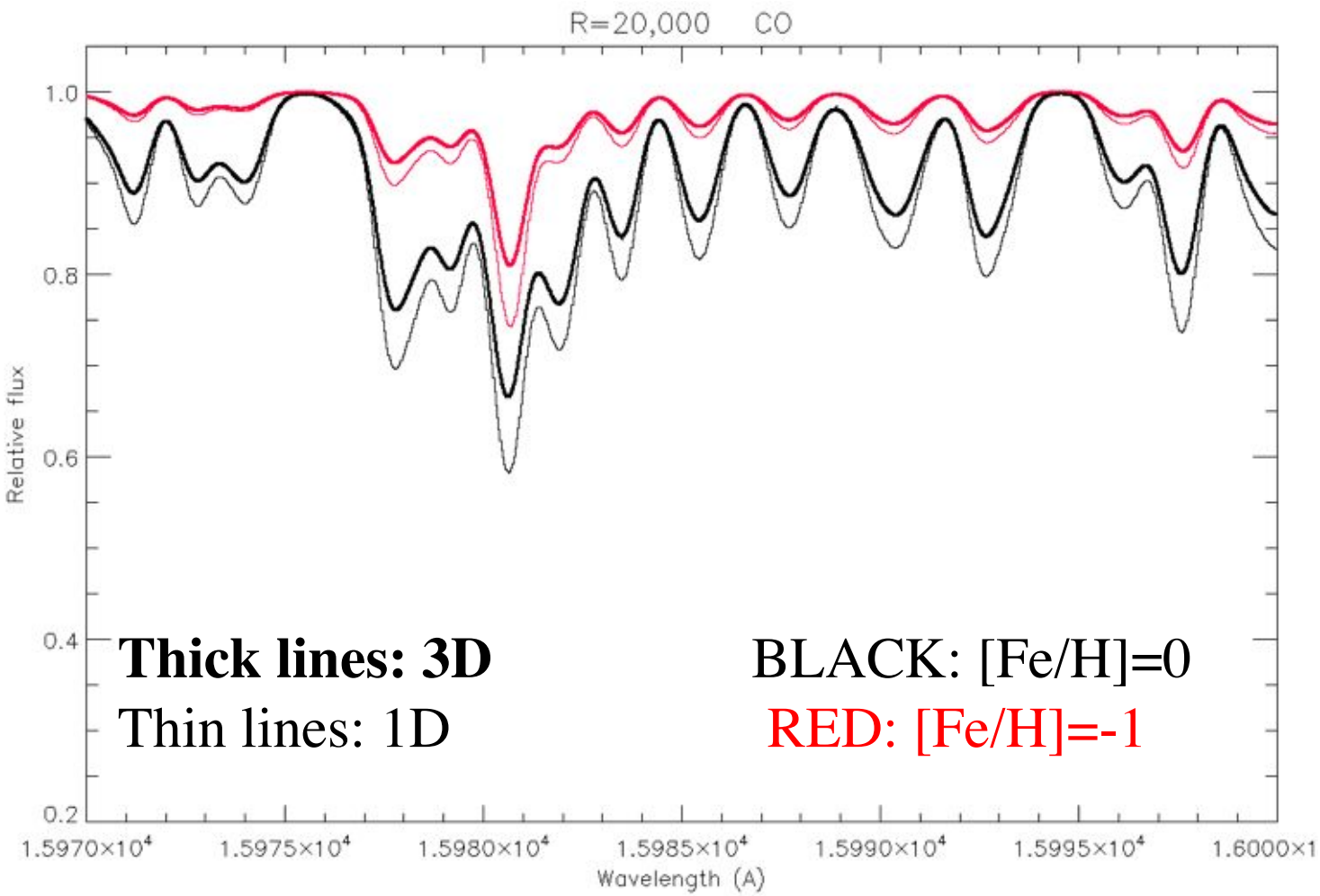
Arcturus

- ‘Arcturus’ 3D hydrodynamical simulations performed by Remo Collet. New simulation with appropriate Teff/logg (cooler than earlier simulations) bracketing the metallicity of Arcturus: [Fe/H]=-1 and 0
- 3D LTE spectral synthesis (including scattering) done with ASSET by Lars Koesterke. Radiative transfer on ~1000 snapshots (240^3 datapoints each)
- 1D LTE calculations performed with ASSET as well: differential study with the same Kurucz models used for the APOGEE pipeline and the APOGEE linelist

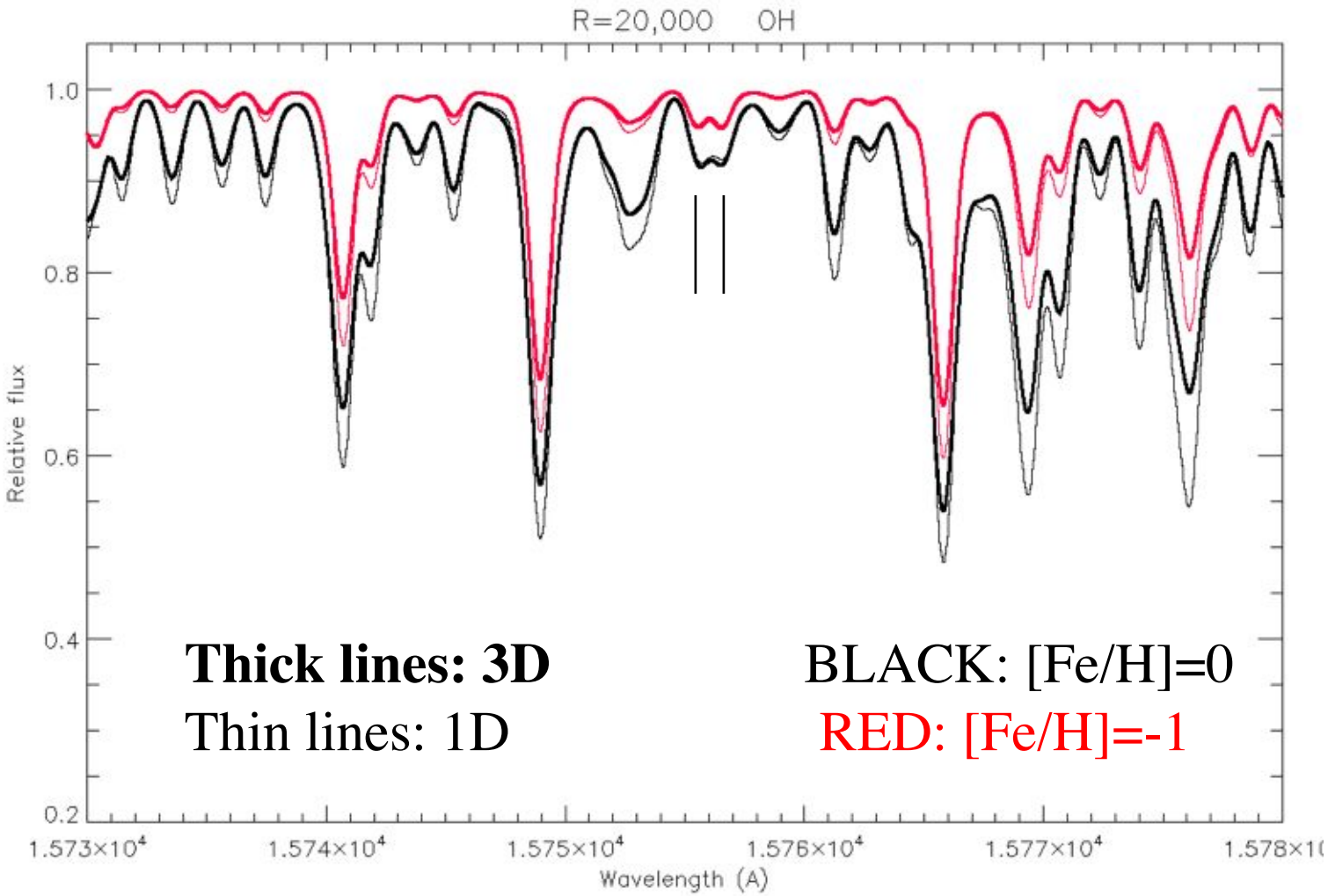
Weaker Fe I and Mg I lines



CO lines get get weaker



Results: OH not affected



Conclusions

- APOGEE has been running for nearly a year since the instrument was taken to the telescope and it has observed over 100,000 spectra
- Pipeline work continues but preliminary results are in hand, so expect soon 3D maps of CNO abundances across the Milky Way disk
- Significant positive 3D abundance corrections are expected for lines of FeI, MgI, CO, while OH not much affected