Searches for the Most Metal-Poor Stars with SDSS/SEGUE

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SDSS

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- Jeffrey Munn (USNO)

Why the Fascination with Large Numbers of MP Stars ?

- Extremely MP stars have recorded the heavy element abundances produced in the first generations of stars
- The shape of the low-metallicity tail of the Metallicity Distribution Function (MDF) will (eventually) show structure that reveals the characteristic abundances of major epochs of star formation in early Galaxy
- Change in the nature of the MDF as a function of distance may reveal the assembly history of the MW
- Determination of the frequency of various elemental abundance signatures, e.g., enhancement of [C/Fe], [alpha/Fe], etc.
- Identification of relatively rare objects amongst MP stars, e.g., r-process / s-process enhanced stars

Previous Efforts to Find Metal-Poor Stars in the Galaxy

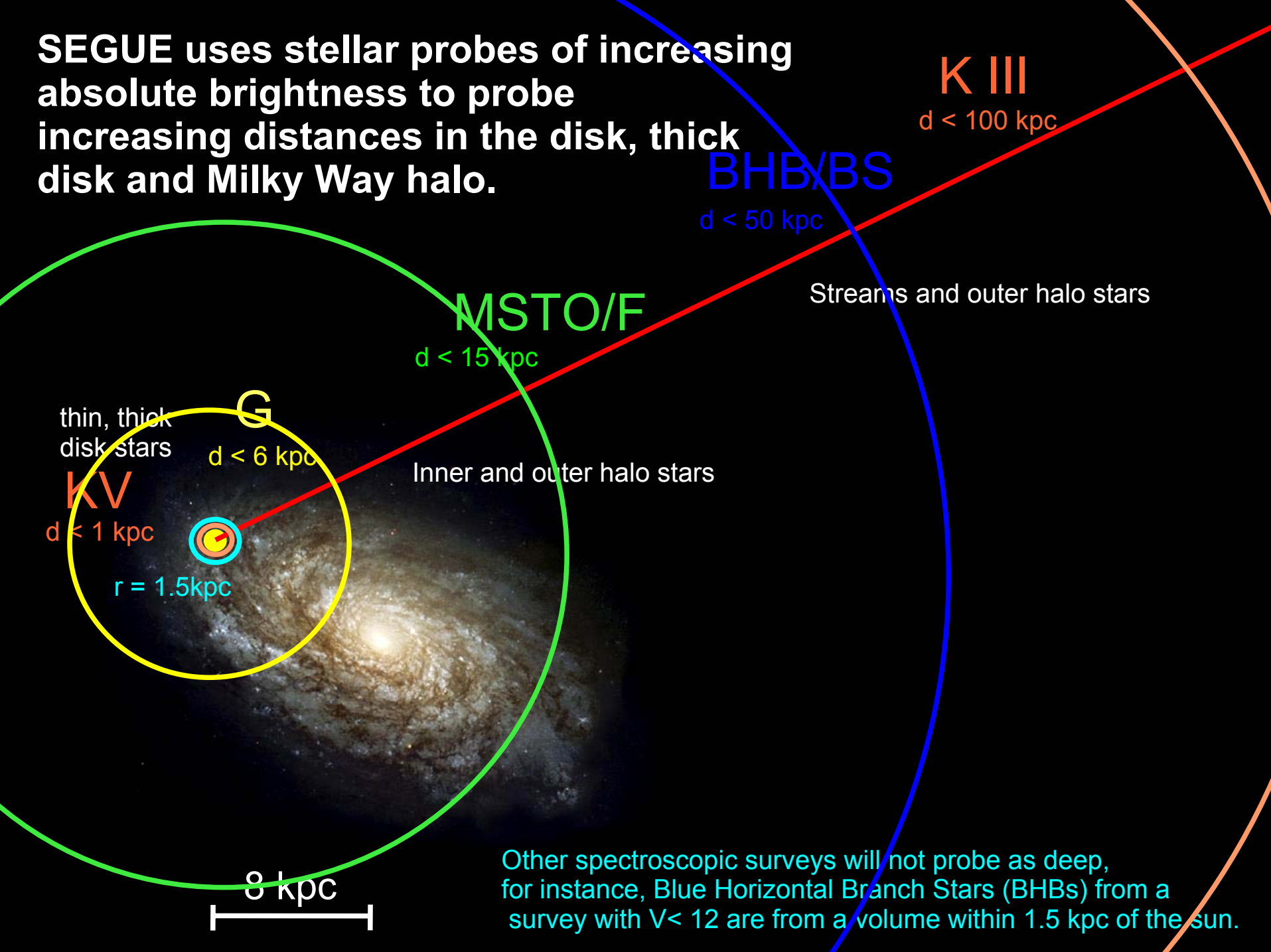
- Concentrated on
  - High proper-motion stars (e.g., Carney et al., Ryan & Norris)
  - In-situ prism surveys (e.g., HK survey, HES)
- In total, such surveys have identified
  - ~ several thousand stars with [Fe/H] < -2.0
  - ~ several hundred stars with [Fe/H] < -3.0
- Inspired numerous several large-scale high-resolution spectroscopic follow-up efforts
  - Cayrel et al. (2004) "First Stars" (VLT/UVES) (~100 stars)
  - Christlieb et al. (2004) "HERES Survey" (VLT/UVES) (~350 stars)
  - Cohen et al (2002) "0Z Survey" (Keck/HIRES) (~100 stars)
  - Aoki et al. (in prog) "UMP Star Survey" (Subaru/VLT) (~ 50 stars)

New Efforts for Finding Very Metal-Poor Stars

- Stellar observations at medium-resolution have been obtained during the course of the Sloan Digital Sky Survey (SDSS)
  - Calibration of spectrophotometry / telluric bands
  - Directed studies (e.g., BHB stars, C-rich stars)
  - “Failed QSO” targets
- New stellar observations being obtained during the course of SDSS extension program SEGUE

SEGUE: The Sloan Extension for Galactic Understanding and Exploration

- Use existing SDSS hardware and software to obtain:
  - 3500 square degrees of additional *ugriz* imaging at lower Galactic latitudes
    - Stripes chosen to complement existing areal coverage; includes several vertical stripes through Galactic plane
- Medium-resolution spectroscopy of 250,000 "optimally selected" stars in the thick disk and halo of the Galaxy
    - 200 "spectroscopic plate" pairs of 45 / 135 min exposures
    - Objects selected to populate distances from 1 to 100 kpc along each line of site
    - Proper motions available (from SDSS) for stars within ~ 5 kpc

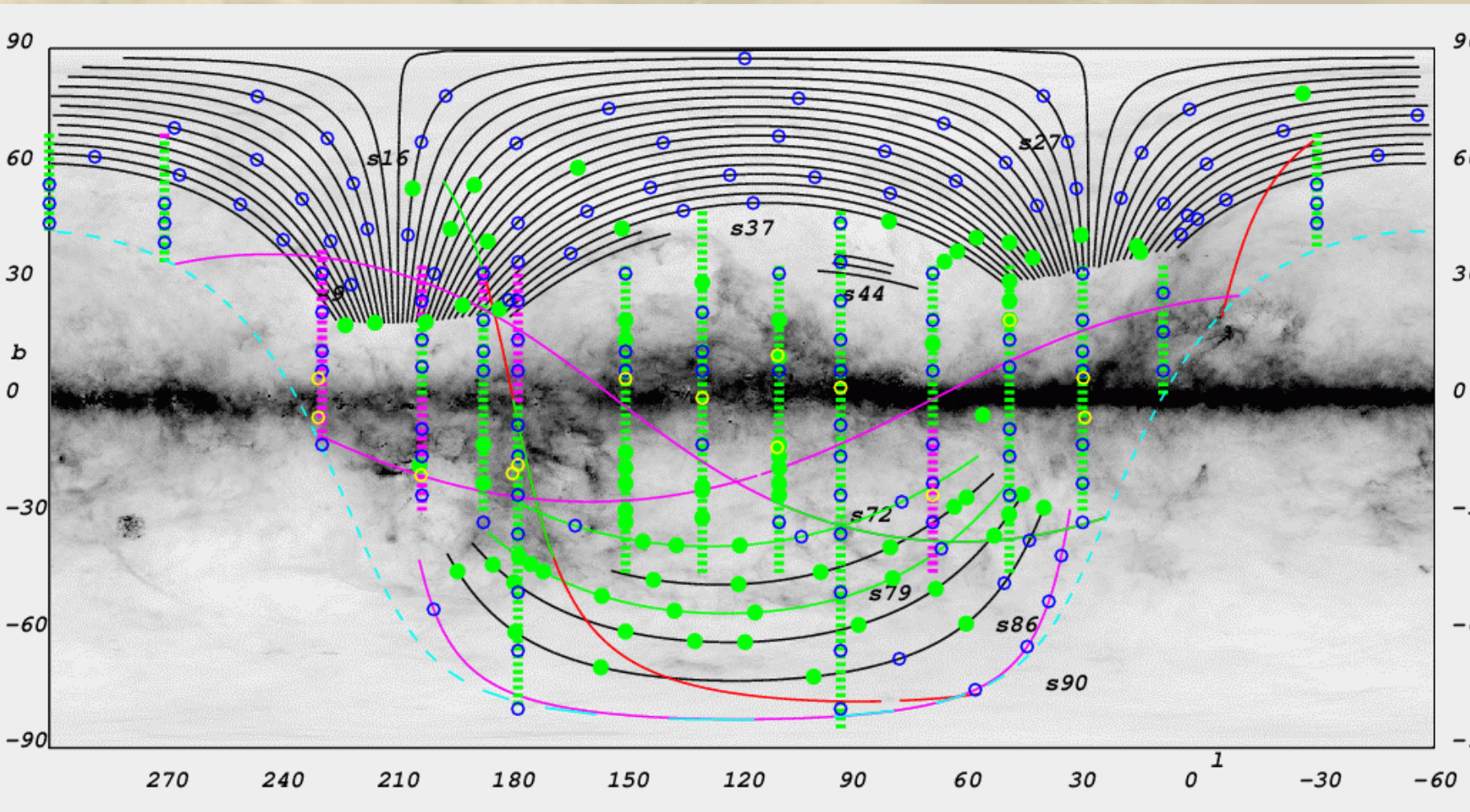

SEGUE uses stellar probes of increasing absolute brightness to probe increasing distances in the disk, thick disk and Milky Way halo.
K III
d < 100 kpc
BHB/BS
d < 50 kpc
Streams and outer halo stars
MSTO/F
d < 15 kpc
Inner and outer halo stars
G
d < 6 kpc
thin, thick disk stars
KV
d < 1 kpc
r = 1.5kpc
8 kpc
Other spectroscopic surveys will not probe as deep, for instance, Blue Horizontal Branch Stars (BHBs) from a survey with V< 12 are from a volume within 1.5 kpc of the sun.

Likely (?) Numbers of Detected MP Stars from SEGUE

- Actual numbers will depend on the shape of the halo Metallicity Distribution Function

–	[Fe/H] < -2.0	**~ 20,000 (VMP)**
–	[Fe/H] < -3.0	**~ 2,000 (EMP)**
–	[Fe/H] < -4.0	**~ 200 ? (UMP)**
–	[Fe/H] < -5.0	**~ 20 ? (HMP)**
–	[Fe/H] < -6.0	**~ 2 ? (MMP)**

SEGUE observing plan and status as of May 2007



SDSS Imaging scan

Planned SEGUE scan (3500 sq deg)

Sgr stream planned scan

Completed SEGUE imaging

Declination = -20 degrees

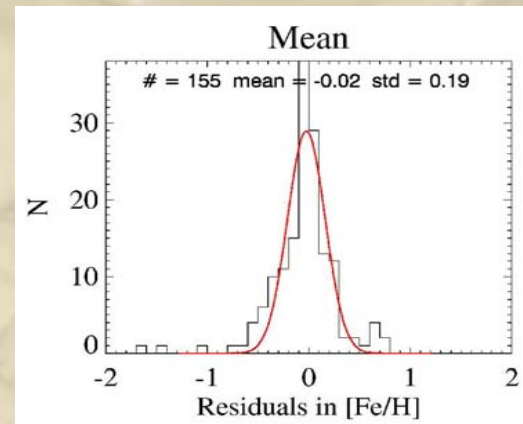
Planned SEGUE grid pointings (200)

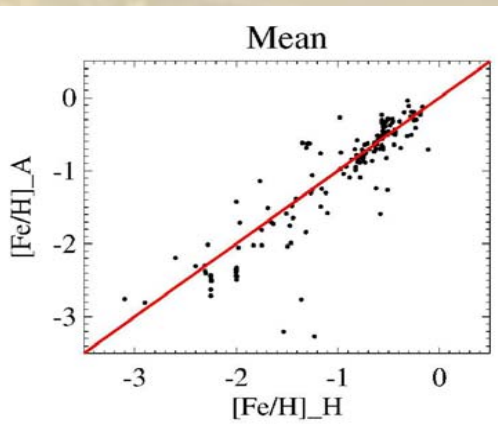
Planned targeted SEGUE pointings(60)

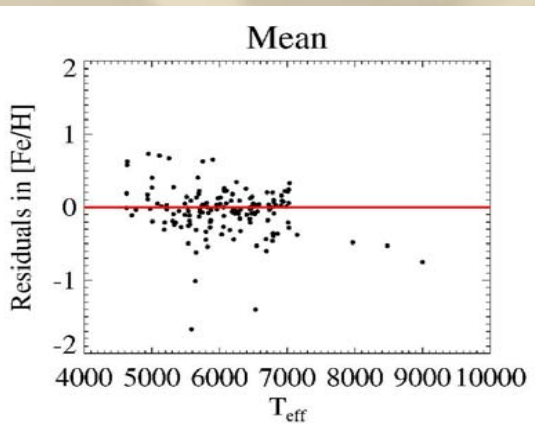
Completed SEGUE plate pointing

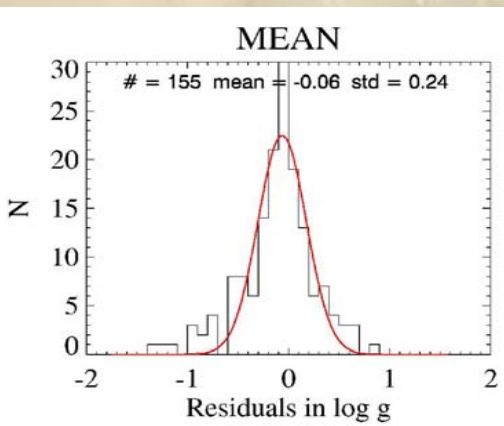
High-Res Observations To Date

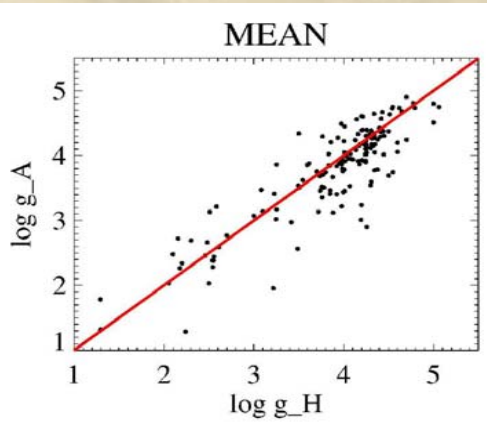
Telescope	Instrument	Resolution $R=\lambda/\Delta\lambda$	Wavelength Coverage Å	No. stars
HET	HRS	15000	4500 - 7000	112
Keck	HIRES	45000	3000-10000	24
Keck	ESI	6000	3000-10000	27
Subaru	HDS	45000	3000-5800	11

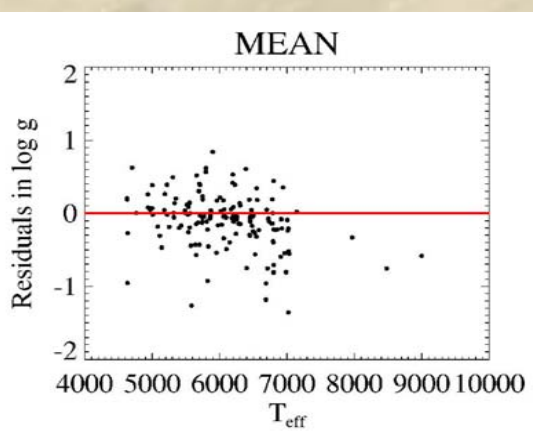

Mean
= 155 mean = -0.02 std = 0.19
N
Residuals in [Fe/H]

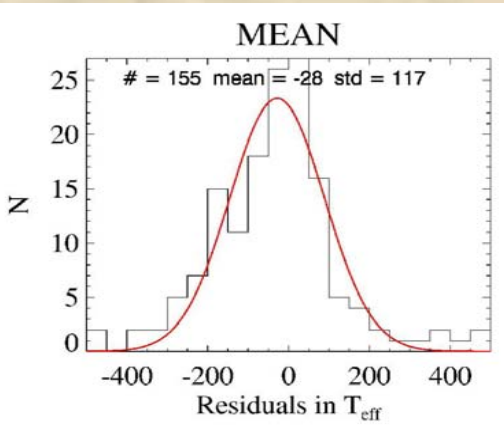

Mean
[Fe/H]_A
[Fe/H]_H

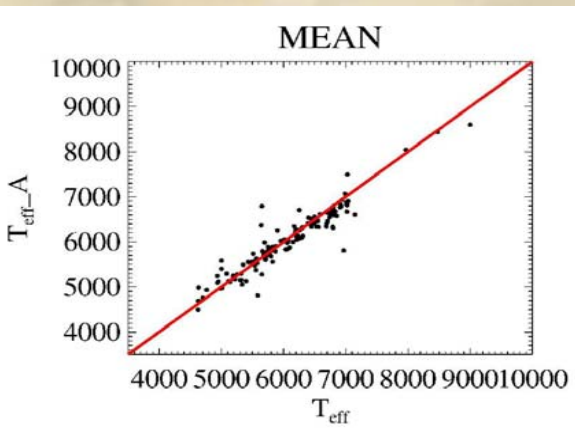

Mean
Residuals in [Fe/H]
T_eff

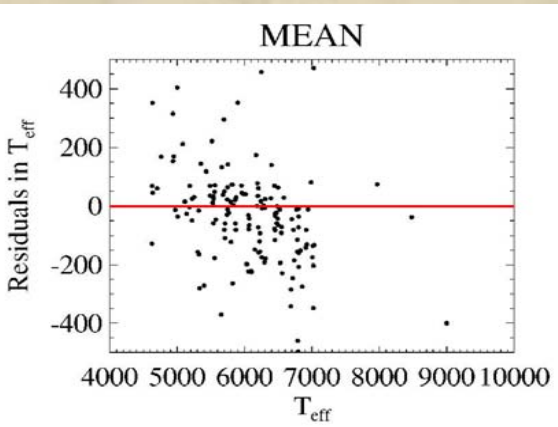

MEAN
= 155 mean = -0.06 std = 0.24
N
Residuals in log g


MEAN
log g_A
log g_H

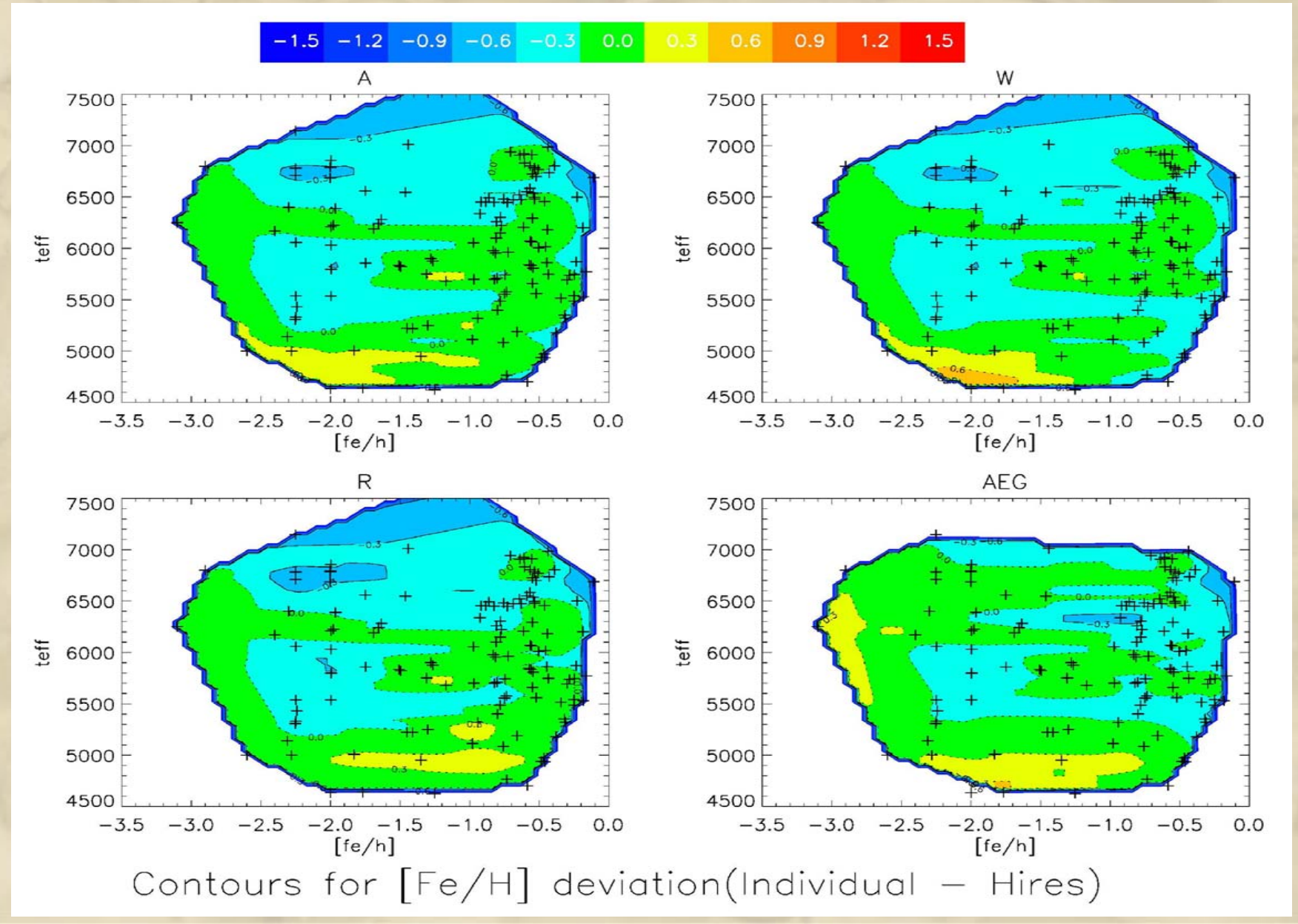

MEAN
Residuals in log g
T_eff

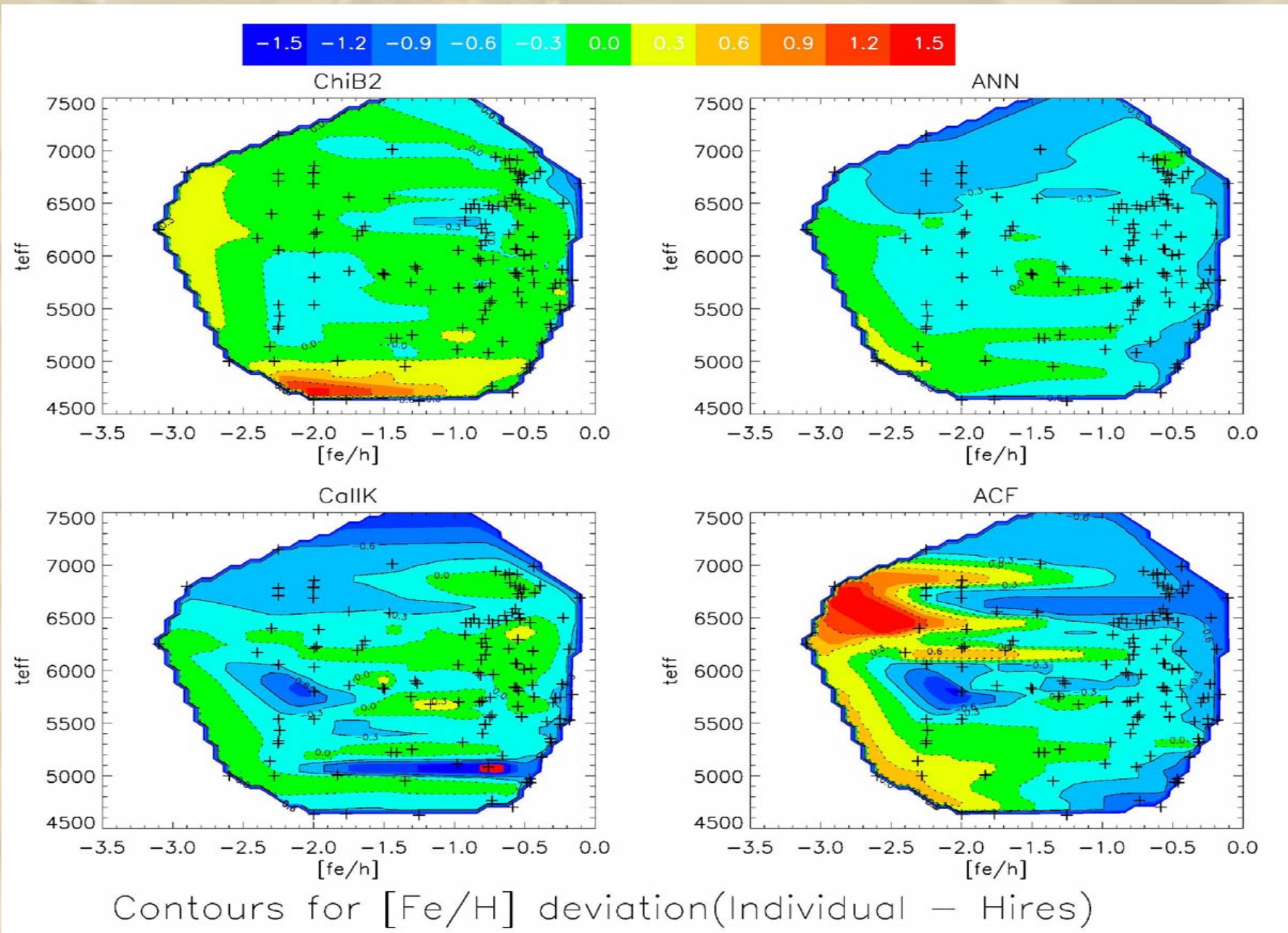

MEAN
= 155 mean = -28 std = 117
N
Residuals in T_eff

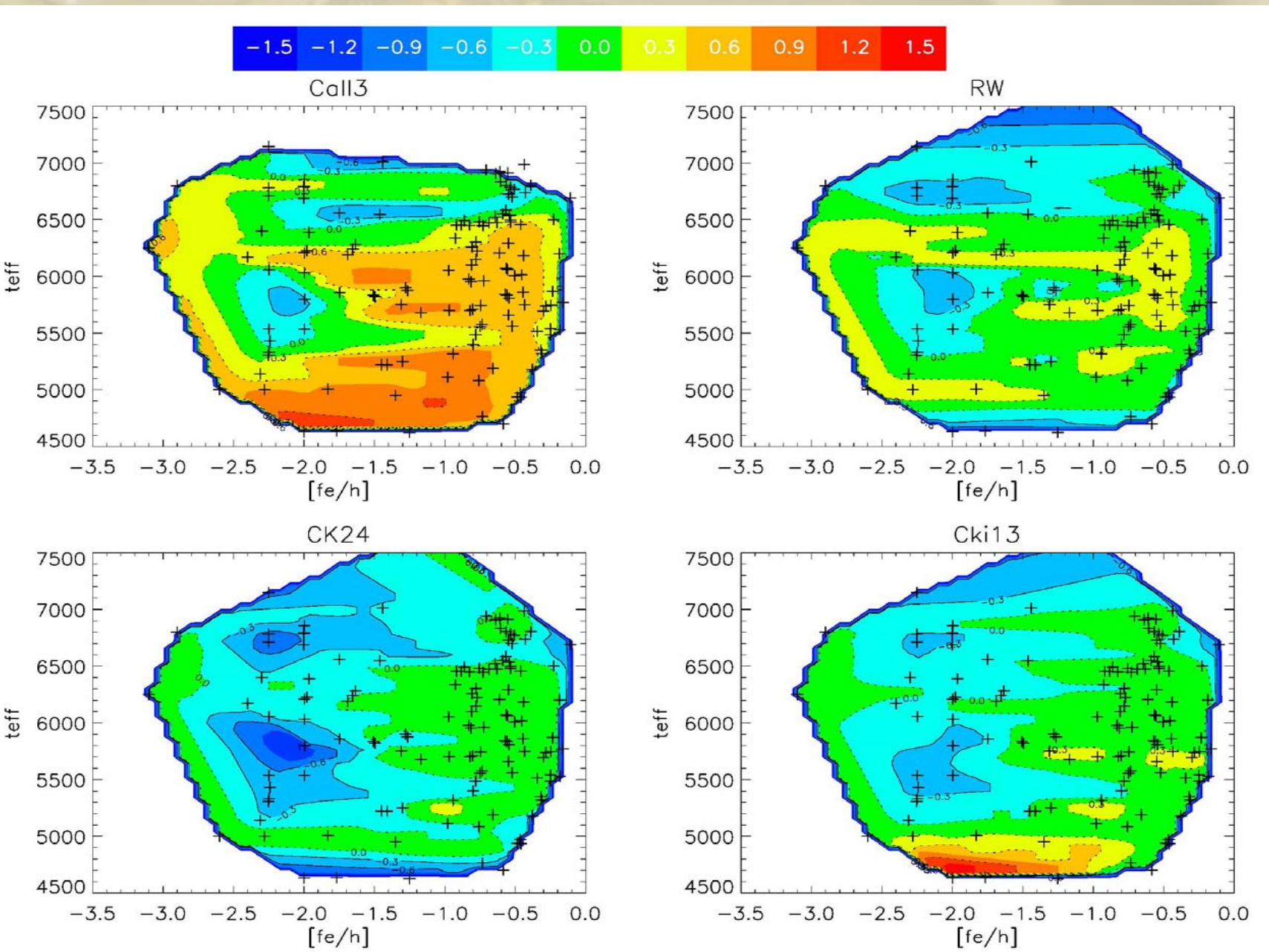

MEAN
T_eff_A
T_eff


MEAN
Residuals in T_eff
T_eff

Recalibration of Individual Techniques

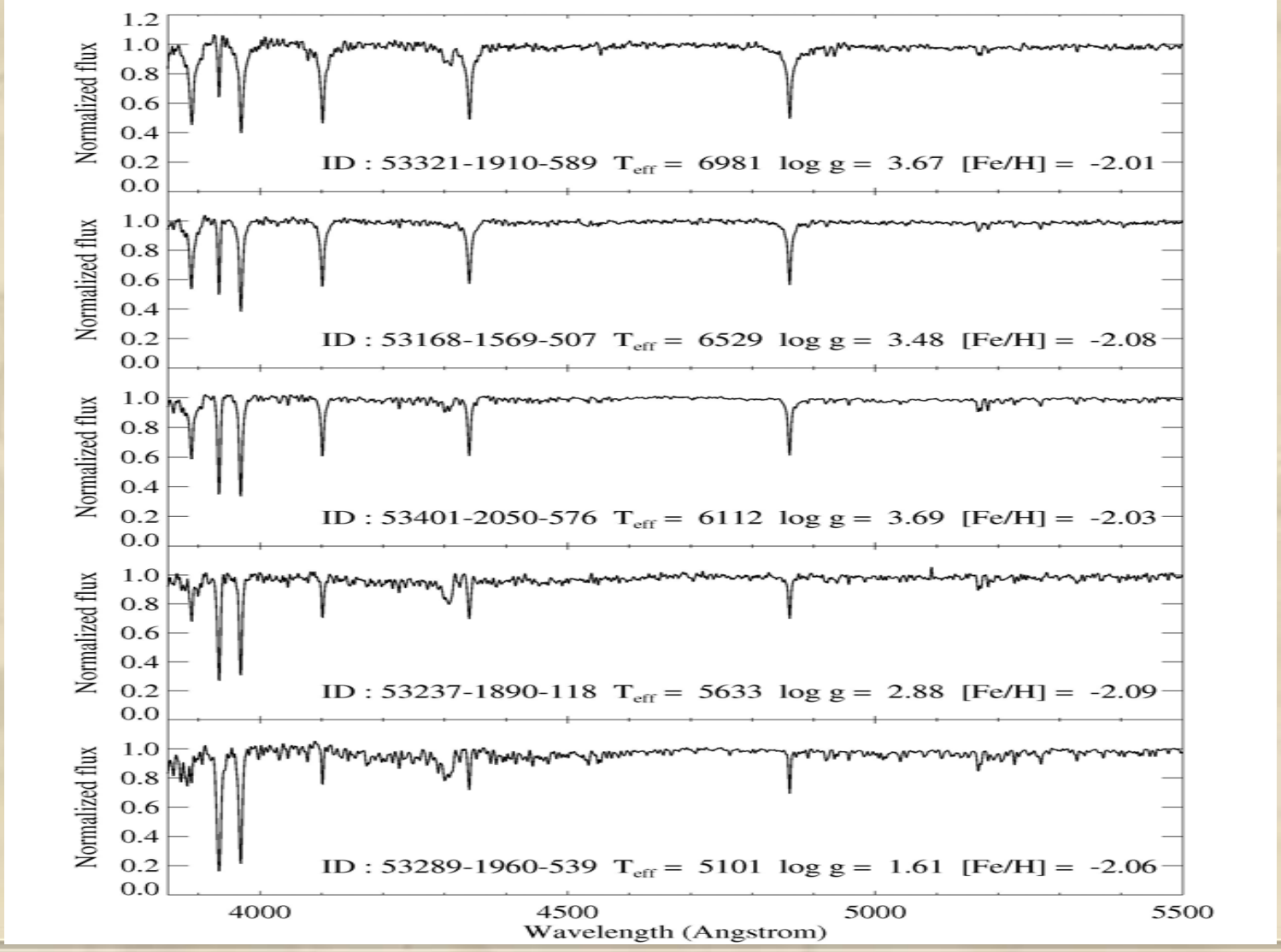



−1.5 −1.2 −0.9 −0.6 −0.3 0.0 0.3 0.6 0.9 1.2 1.5
ChiB2
ANN
CaIIK
ACF
teff
[fe/h]
7500
7000
6500
6000
5500
5000
4500
−3.5 −3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.0
Contours for [Fe/H] deviation(Individual − Hires)

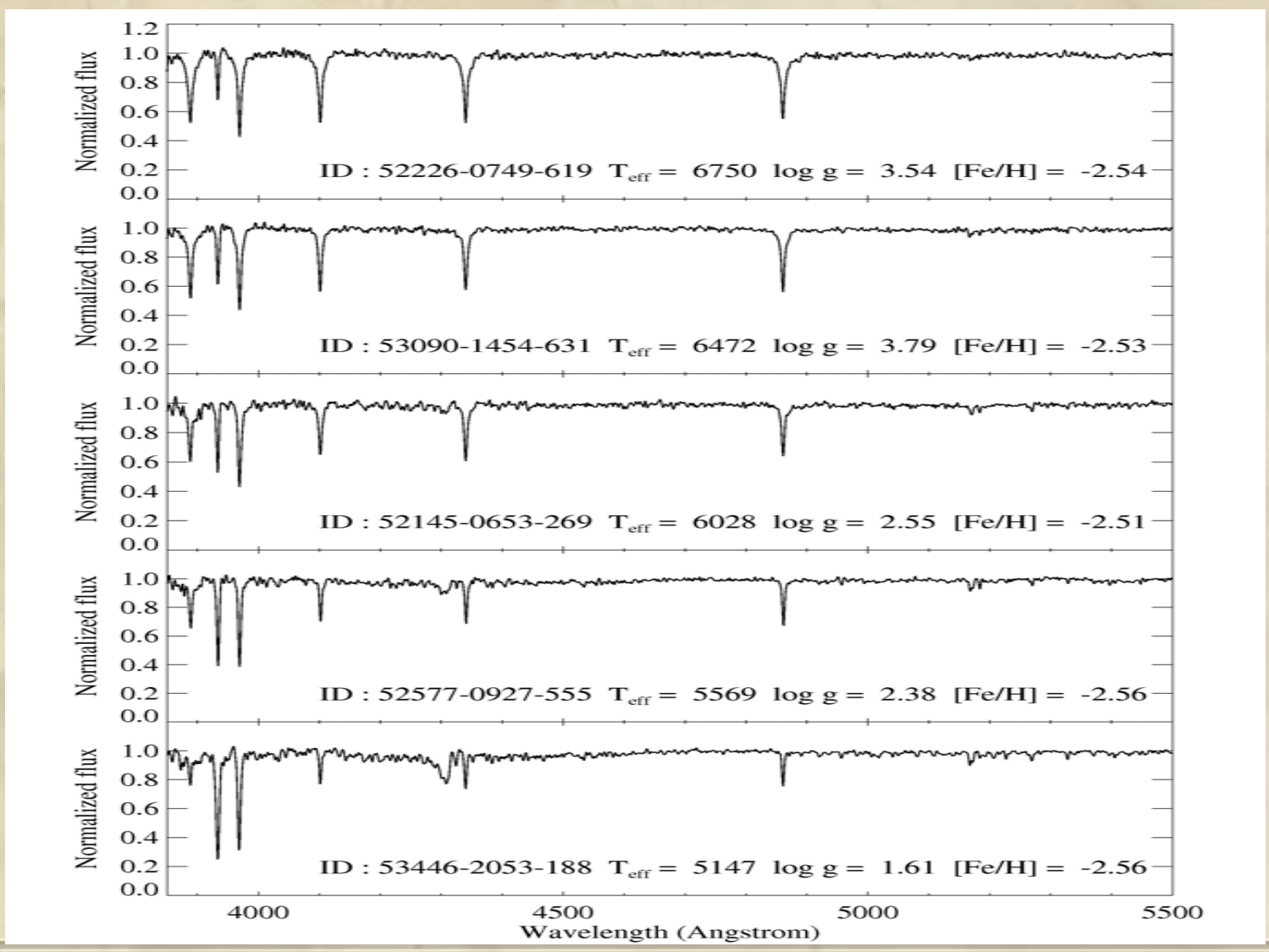


Contours for [Fe/H] deviation(Individual − Hires)

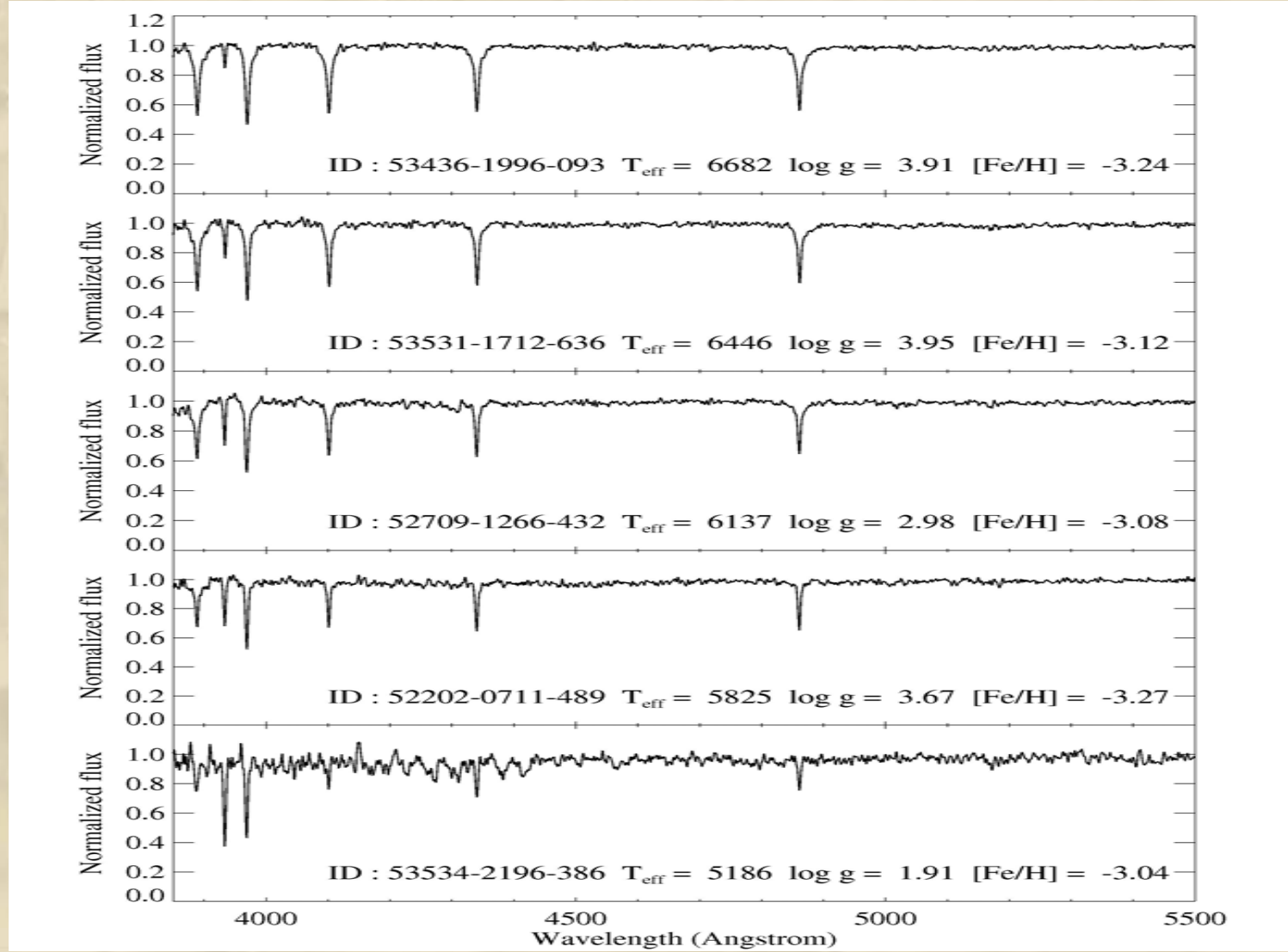
Sample SDSS-I Spectra with [Fe/H] ~ –2.0



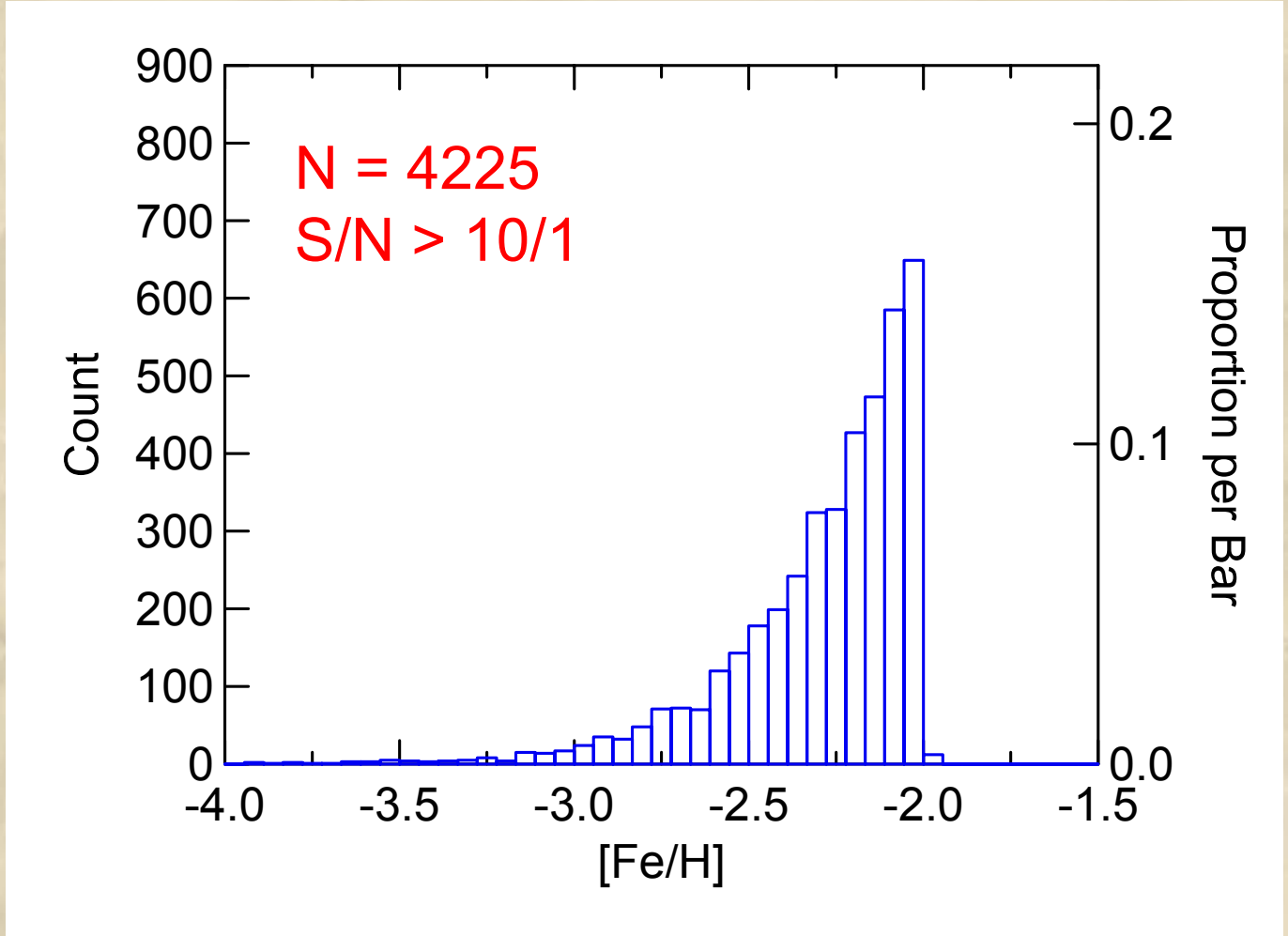
Sample SDSS-I Spectra with [Fe/H] ~ –2.5



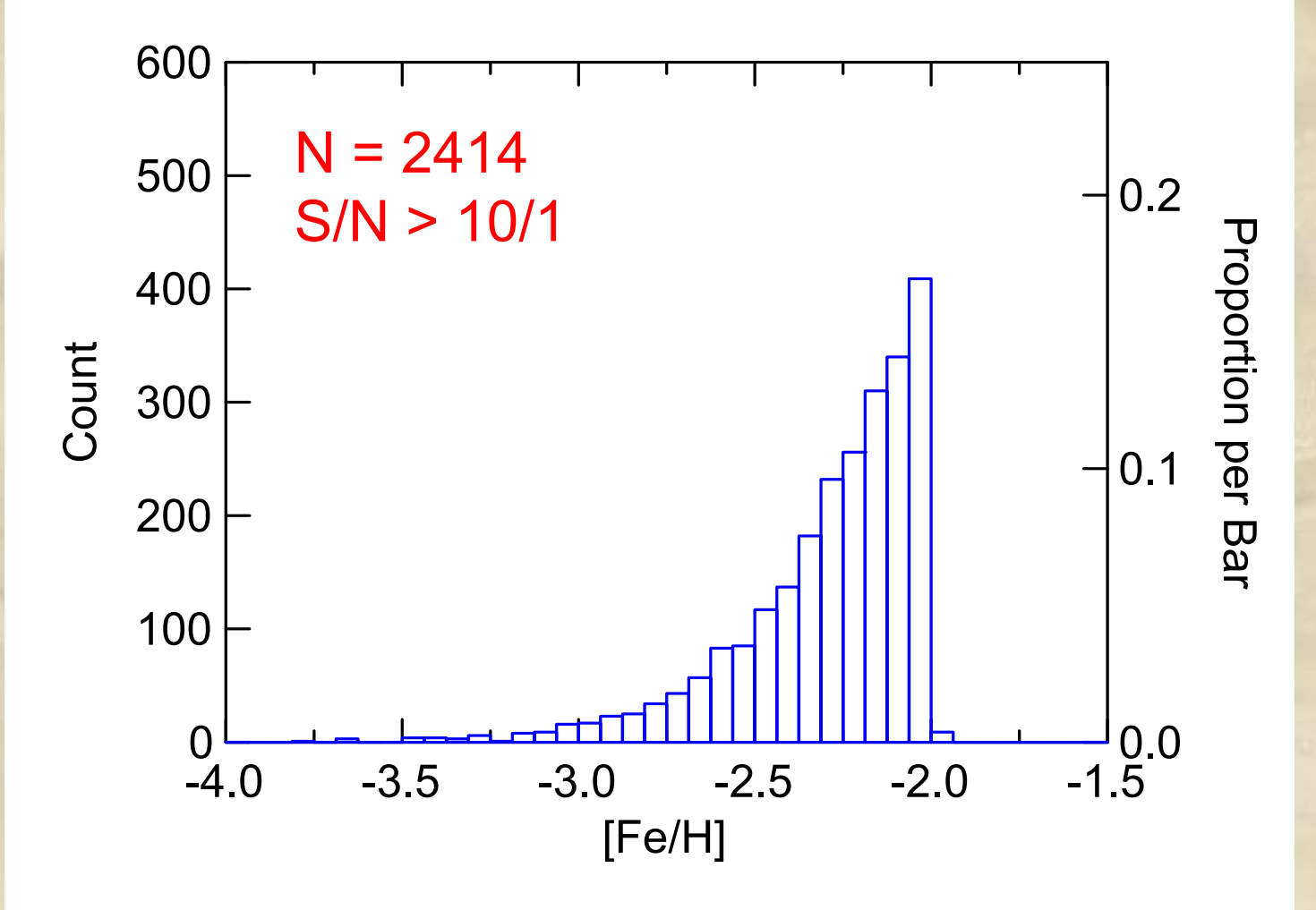
Sample SDSS-I Spectra with [Fe/H] < –3.0



The Low-Metallicity Tail of the Metallicity Distribution Function of SDSS-I Stars



The Low-Metallicity Tail of the Metallicity Distribution Function of SEGUE Stars



What's Next ?

- **One can now** target **outer-halo** stars in order to elucidate their chemical histories **([α/Fe], [C/Fe]),** and possibly their accretion histories
- **One can now** preferentially **SELECT outer-halo** stars based on proper motion cuts in the local volume (SEGUE-II)
- **One can now** take advantage of the lower [Fe/H], in general, of outer-halo stars to find the most metal-poor stars **(all three stars with [Fe/H] < -4.5 have properties consistent with outer halo membership)**
- **One can soon** constrain models for formation / evolution of the Galaxy that take **all of the chemical and kinematic information** into account (e.g., Tumlinson 2006)