Iron and Alpha in Individual Red Giants from Medium Resolution Spectra

Evan Kirby¹, Puragra Guhathakurta¹, Chris Sneden²
1) UC Santa Cruz, 2) UT Austin

ABSTRACT. We present a technique to determine [Fe/H] and [α/Fe] from individual iron and alpha element lines in medium resolution spectra from the DEIMOS spectrometer (R ~ 6,000) on the Keck II telescope. The moderate dispersion and multiplexing drastically increase the accessibility of halo and dSph stars not only in the Milky Way, but also M31. Using a grid of spectral syntheses of stellar atmospheres in local thermodynamic equilibrium, we have measured elemental abundances from the metal lines in DEIMOS spectra of individual red giants in well-studied Milky Way globular clusters. The abundances are consistent with high resolution studies over a wide range of [Fe/H].

I. Synthetic Spectra

Line list

Demonstration of line list accuracy. Black points: High resolution spectra of the Sun and Arcturus (Hinkle & Wallace 2005) smoothed to σ = 1 Å. Red lines: Spectra synthesized with MOOG (Sneden 1973, 2007) using the solar and Arcturus (Peterson, Dalle Ore, & Kurucz 1993) atmospheric parameters and elemental abundances.

The syntheses include lines from the Vienna Atomic Line Database (VALD, Kupka et al. 2000) which satisfy

6300 Å < λ < 9100 Å
excitation potential < 10 eV
log (gf) > −5
neutral or singly ionized

• 71 atomic species
• 3 molecular species (CN, C₂, MgH)
• 30873 atomic lines
• 2810 oscillator strengths modified to match Sun and Arcturus simultaneously
• 17345 molecular lines

Grid of syntheses

We synthesize a grid of spectra using MOOG and Castelli & Kurucz (2004) atmospheres in local thermodynamic equilibrium.

\begin{align*}
4000 \text{ K} < T_{\text{eff}} < 5500 \text{ K} & \quad @ 100 \text{ K} & 16 \\
0.0 < \log g < 3.0 & \quad @ 0.5 & 7 \\
-3.6 < [\text{Fe/H}] < 0.0 & \quad @ 0.1 & 37 \\
-0.6 < [\alpha/\text{Fe}] < +0.6 & \quad @ 0.1 & 13 \\
\log (v_t - 1.51 \text{ km/s}) = 0.38 - 0.40 \log g & \quad \text{total syntheses} & 53,872 \\
\end{align*}

II. Atmospheric Parameter Determination

• remove telluric absorption using a hot star observed with DEIMOS
• determine continuum: smooth the spectrum with a Gaussian (σ = 10 Å) kernel, ignoring spectral regions known to have absorption lines
• determine radial velocity by cross-correlation with a synthetic template
• mask regions that are poorly modeled or saturated with telluric absorption
• find the synthetic spectrum with the minimum \( \chi^2 \) using Levenberg-Marquardt optimization and linear interpolation between grid points

III. Globular Cluster Diagnostics

We estimate [α/Fe] by varying the ratios of Mg, Si, S, Ar, Ca, and Ti together with respect to Fe. Despite masking the spectral regions around the strongest and most poorly modeled α element lines (Ca I 8498, 8542, 8662 and Mg I 8807), we recover not only the expected plateau value of [α/Fe] ~ +0.3, but also the trend for more metal-rich systems to have lower [α/Fe] (e.g., Venn et al. 2004).

The DEIMOS \( T_{\text{eff}} \) for individual stars agree fairly well with the high resolution \( T_{\text{eff}} \). This method has room to improve for hotter stars (not observed in high resolution) whose lines are weaker. Such stars are susceptible to degeneracy between \( T_{\text{eff}} \) and [Fe/H].

IV. Future Applications

We intend to apply this technique to existing DEIMOS spectra of Milky Way dwarf spheroidal galaxies, which are too faint to allow high resolution spectra or more than a few stars each. We also intend to measure elemental abundances in M31 halo and satellite galaxy stars. Because these stars are so faint, we will coadd spectra based on photometric properties.

These measurements will test theories of hierarchical structure formation, which make predictions for [Fe/H] and [α/Fe] for different galactic components (e.g., Font et al. 2006).

Hinkle, K., & Wallace, L. 2005, Cosmic Abundances as Records of Stellar Evolution and Nucleosynthesis, 336, 321

This work is supported by NSF grants AST-0607852 and AST-0607078 and an NSF Graduate Research Fellowship.