Line-depth Ratios of Red Giants in APOGEE H-band Spectra: the Metallicity Effect

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INTRODUCTION

Ratios of carefully selected spectral line depths (LDR) can be used to determine $T_{\rm eff}$ in tens of Kelvin. However, the metallicity effect on LDR-$T_{\rm eff}$ relation haven't bee well studied. Here we quantify the metallicity effect using H-band spectra and stellar parameters from APOGEE survey, applying a sample size ~100 times larger than previous study.

DATA & MEASUREMENT

Around 20000 high quality spectra are selected among 163278 in DR12. They spread a wide range of stellar metallicity. Eight line pairs are adopted from the previous study on the same wave band (Fukue et al. 2015), and three new pairs are selected making use of the different coverage of APOGEE. In our measurement, the minimum value of parabola fitting is adopted as the depth, while some weak and bad fitting measurements are rejected.

RESULT

Solar metallicity (within ± 0.1 dex for Fe and ± 0.1 / ± 0.2 dex for elements involved according to each line pairs) sample is first used for deriving the LDR-$T_{\rm eff}$ relation, and compared with the result from Fukue et al. (2015).

Second order parabola fitting

$$T_{\rm eff} = a(r-r_0)^2 + b(r-r_0) + c$$

is used with the line depth ratio $r = \frac{d_{\rm Low}}{d_{\rm High}}$.

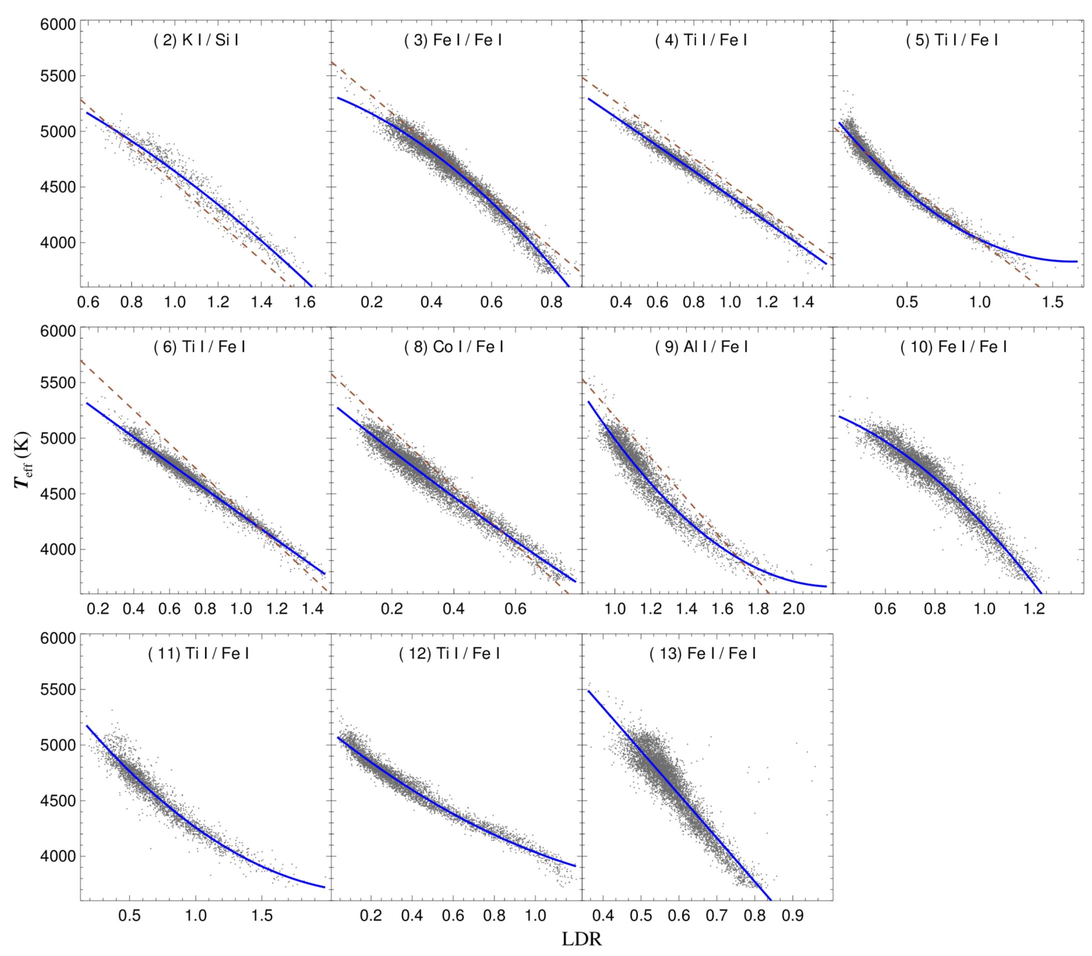

Figure 1 | LDR-$T_{\rm eff}$ relations for solar-metal objects. The fitted curve of relation is indicated in blue, and result of linear fitting from Fukue et al. (2015) is indicated in brown.

The relations of Fukue et al. (2015) tend to be offset from the distribution from our measurements. The moderate offsets, 100-200K, are still at the same order of the residuals around the fitted relations which Fukue et al. (2015) found for the eight calibrating stars.

The metallicity range is then expanded to obtain the new fits with metallicity terms:

$$T_{\rm eff} = a(r-r_0)^2 + b(r-r_0) + c + d[{\rm FeH}] + e[{\rm FeH}](r-r_0) + f\,[{\rm X_{low}}/{\rm X_{high}}]$$

For line pairs with ${\rm X_{low}} = {\rm X_{high}}$, the last term is omitted.

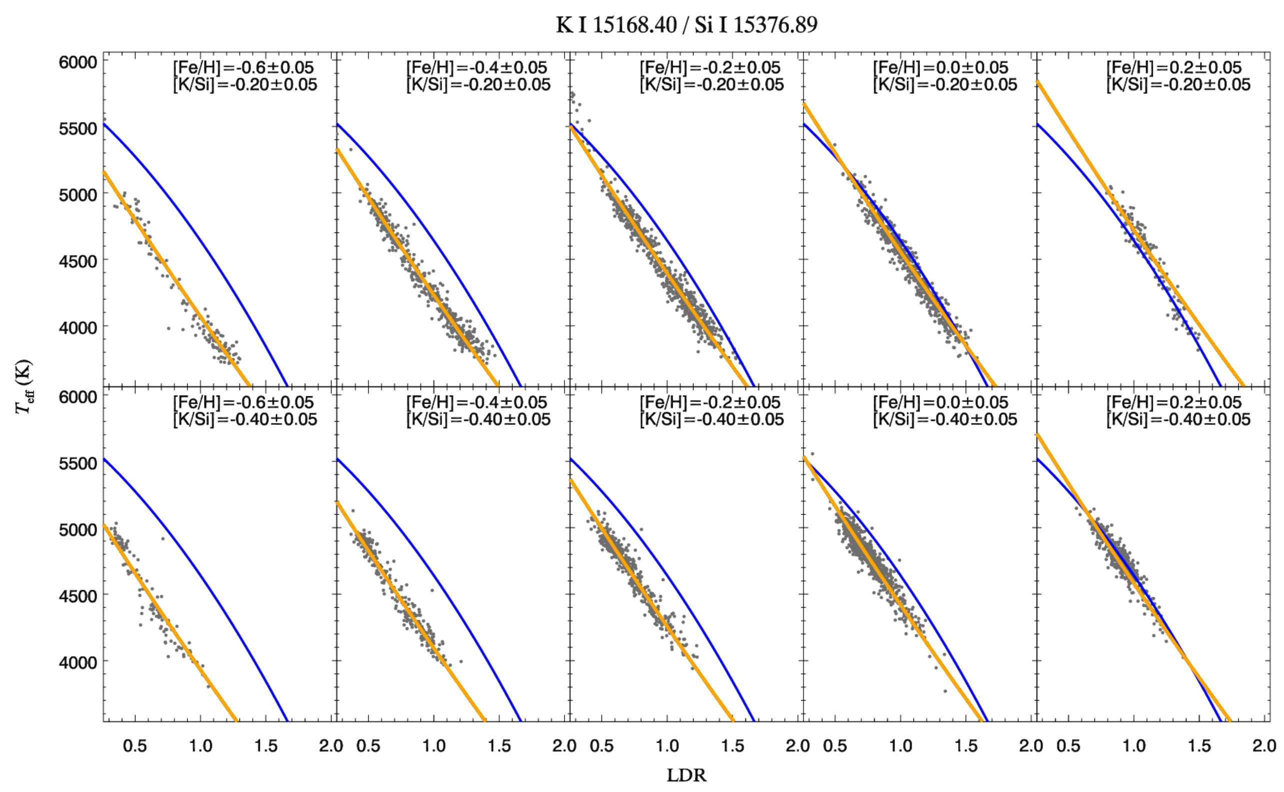

Figure 2 | Panels of relations for samples with difference abundances of line pair 1. Blue curve is the solar-metal result, and orange curves are the fitted curve.

As the metallicity ([Fe/H] and [K/Si] in Figure 2) increases, the distribution in the LDR- $T_{\rm eff}$ plots shifts from the lower left to the upper right side. That is, for a given LDR value, the $T_{\rm LDR}$ increase as the metallicity increase. This is also true for other line pairs, but with different size of the shift (200-750 K dex^{-1}).

ACCURACY

We compare the averaged temperature derived by LDR-$T_{\rm eff}$ relations, $T_{\rm LDR}$, and those from APOGEE catalog, $T_{\rm APOGEE}$. The difference is almost negligible as constant against $T_{\rm eff}$ and [Fe/H], but small deviations are seen in the lowest and highest $T_{\rm eff}$.

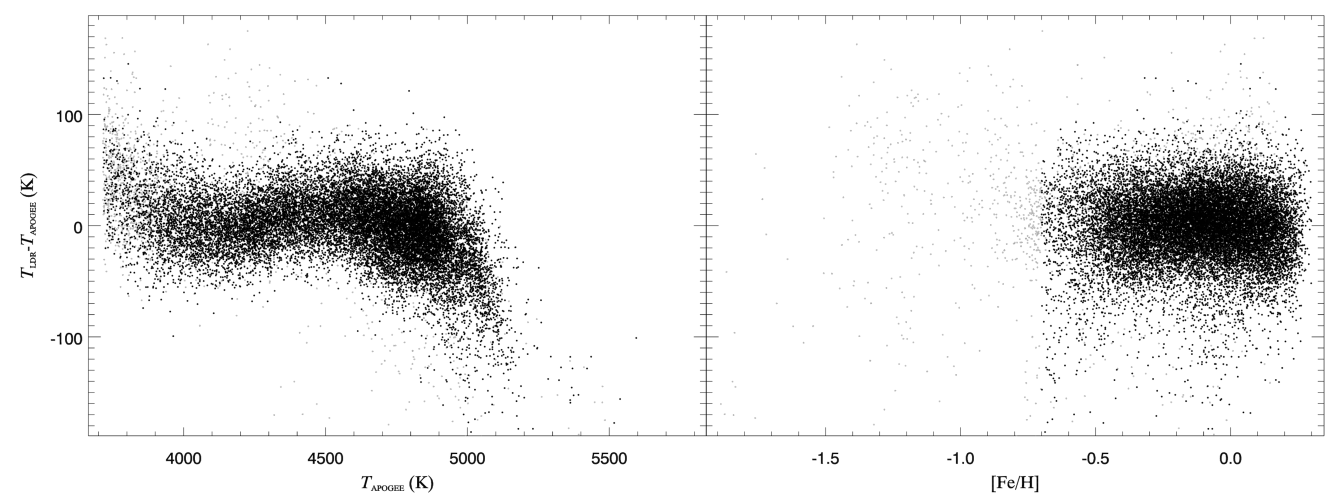

Figure 3 | Plotted against the $T_{\rm APOGEE}$ and [Fe/H] in the APOGEE catalogue, is the difference of temperature from the LDR method ($T_{\rm LDR}$) and $T_{\rm APOGEE}$. Stars with extreme low or high metallicity are plotted in grey.

For the scatter, the value of 35K is smaller than the uncertainty given by Fukue et al. (2015).

CAUSE OF LINE SATURATION

We've found that Line saturation can explain the metallicity effect on the LDR-$T_{\rm eff}$ relations. We use MOOG (Sneden et al. 2012) to predict line depths in a much wider [Fe/H] range and see if the curve of depth deviates from linear region (where the metallicity effect can be eliminated by dividing the depths).

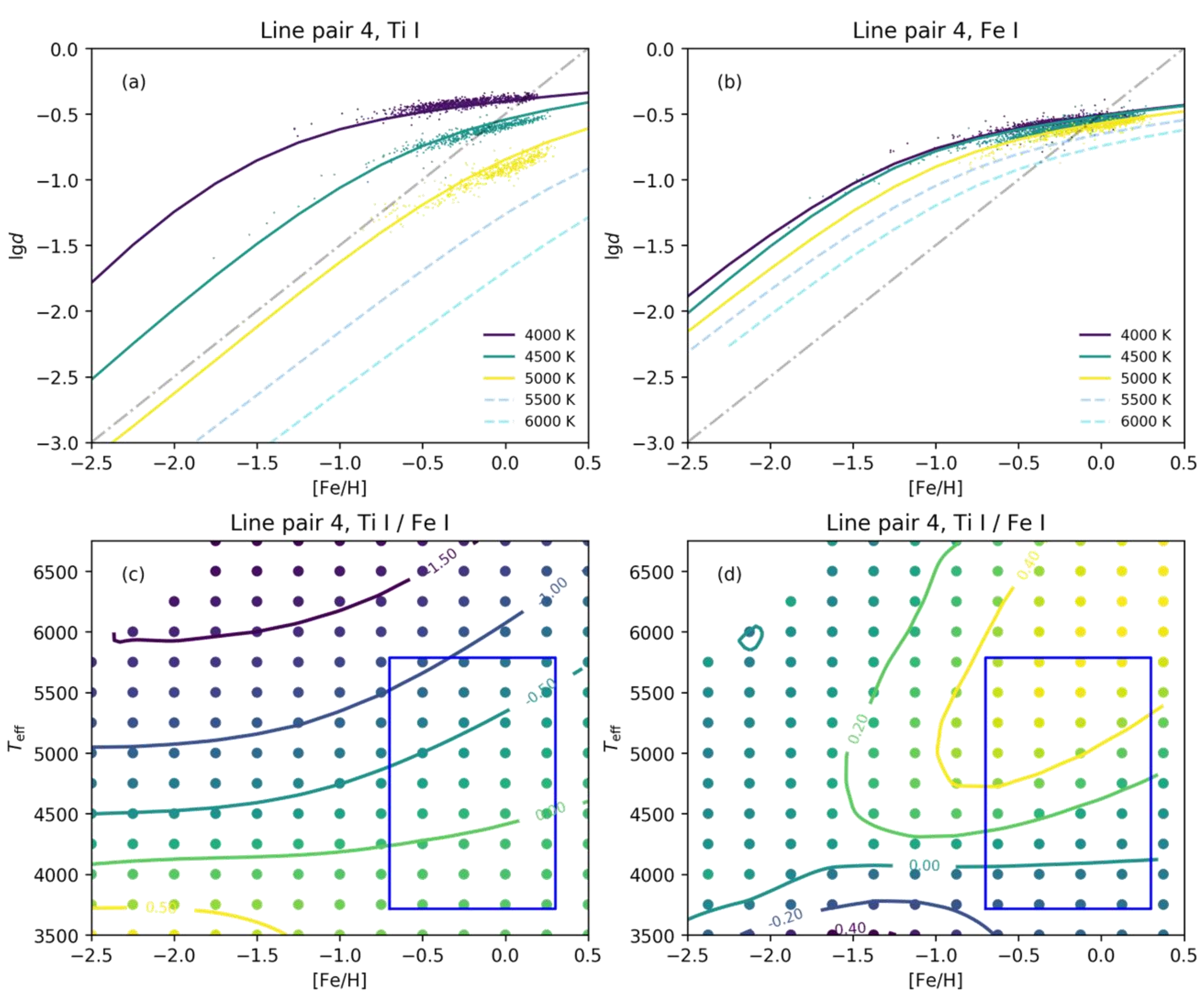

Figure 4 | CoG and LDR-[Fe/H] dependence of line pair 4. (a, b): observed (points) and model (lines) CoGs of low and high EP. line; (c): LDR scatter and histogram plot of various [Fe/H] and Teff; (d): $\frac{\partial {\rm LDR}}{\partial [{\rm Fe/H}]}$ scatter and histogram plot of various [Fe/H] and Teff. Metallicity range used for deriving the relation is indicated by a blue box.

Only curves in relative high [Fe/H] and low $T_{\rm eff}$ are not linear for low excitation line, while all the curves deviate from linear in high [Fe/H] region for high excitation line. As illustrated in the contour map in Fig. 4(c) and (d), such a deviation from the linear line explains the metallicity effect.

CONCLUSION & FURUTE PLAN

- Eleven line pairs (three newly found) are used based on 20000 spectra to derive LDR-$T_{\rm eff}$ relations with metallicity terms
- Metallicity effects on the LDR-$T_{\rm eff}$ relations are confirmed
- Saturation is the reason causing metallicity effect

Taniguchi et al. (2017) have found ~100 LDR- $T_{\rm eff}$ relations in J band. We are planning a J-band spectroscopic observation on a homogeneously distributed sample in $T_{\rm eff}$-metallicity space. Better characterization of the metallicity effect can be achieved using this dataset.