Highlights of Astronomy, Vol. 12
International Astronomical Union, 2002
H. Rickman, ed.

Oxygen Abundances: New Results from [O I] Lines

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Abstract. From new high resolution spectra of metal-poor giants we use equivalent widths of [O I], Sc II, and Fe II lines to derive new values of [O/Sc] and [O/Fe]. These results are generally consistent with previous determinations of oxygen abundances from [O I] lines, but the star-to-star scatter is greatly reduced.

1. Introduction

Conti et al. (1967) first suggested that [O/Fe] ratios in metal-poor stars are substantially larger than the Solar System value. To reach this conclusion they analyzed the [O I] 6300,6363 Å lines in a sample of bright giants of mainly the young and old disk. This work led Lambert, Sneden, & Ries (1974) to search for the 6300 Å line in the very metal-poor ([Fe/H] $\sim$ –2.7) giant HD 122563. Their successful detection of the line implied a very high abundance, [O/Fe] $\simeq$ +0.6. Subsequently, Sneden, Lambert, & Whitaker (1979) found large [O/Fe] ratios from analyses of the O I very high excitation (9.15 eV) 7770 Å triplet lines in a number of metal-poor dwarfs. Oxygen abundance studies have continued to the present, and there is unanimous agreement that [O/Fe] $>$ 0 in almost all low metallicity stars. But abundances deduced via LTE analyses of different oxygen-species transitions do not agree in detail. The [O I] lines suggest [O/Fe] $\simeq$ +0.4, essentially independent of metallicity in the range –1.0 $\geq$ [Fe/H] $\geq$ –2.7 (e.g., Gratton et al. 2000 and references therein), and new data for the OH infrared vibration-rotation bands (Balachandran & Carney 1996, Melendez, Barbuy, & Spite 2000) are consistent with that result. But the O I triplet lines and OH near-UV electronic band lines yield increasing oxygen abundances with decreasing metallicity, approaching [O/Fe] $\sim$ +1 at [Fe/H] $\sim$ –3 (Israelian, García-Lopez, & Rebolo 1998; Boesgaard et al. 1999).

Here we make no attempt to solve the oxygen abundance problem in low metallicity stars. Instead, we re-examine the abundances deduced from the [O I] lines in giant stars, using an analytical technique employed by Lambert et al. (1974) and subsequently by, e.g., Gratton & Ortolani (1986), but relatively neglected in recent years: a comparison of the relative strengths of [O I] and Sc II lines.

2. Observations, Reductions, Analyses

The spectra originally were obtained for other projects with the McDonald Observatory 2.7m Smith reflector and the Tull *"2d-coudé"* echelle spectrometer. The spectra have resolving power R $\simeq$ 60,000, and S/N > 100. In the reduction procedures, care was taken in the cancellation (via division by the spectrum of a rapidly rotating hot star) of the telluric O_2 features surrounding the stellar [O I] 6300 Å line. Radial velocity shifts moved the stellar [O I] lines away from the night sky emission lines in all cases. In the top panel of Figure 1 we show examples of program star spectra near the 6300 Å line.

Neighboring lines are also labeled, including the Sc II 6300.67 Å feature. As has been noted in earlier papers, the [O I] and Sc II lines have very similar equivalent widths (EWs) in the Sun and solar metallicity giant stars, so the apparent larger strength of the [O I] line here points to an oxygen overabundance.

We measured the EWs of the [O I] 6300 Å line (and the 6363 Å line when it was strong enough), as many as seven Sc II lines, and as many as six Fe II lines in the yellow-red spectral region of our spectra. Only these transitions were considered, first because several investigations (notably that of Thévenin & Idiart 1999) suggest that neutral species of metals such as Fe I (but not the ionized species) may be subject to substantial departures from LTE in the atmospheres of metal-poor stars. Second, O I has a high ionization potential, and therefore is the majority species of oxygen, as are the ionized species of scandium and iron. The [O I] and Sc II line excitation potentials differ by only $\simeq$1.5 eV, and so the dependence on atmospheric uncertainties in ratios of abundances derived from these transitions is very small (e.g. Lambert et al. 1974).

The measured EWs were employed in a standard LTE abundance analysis (e.g., Westin et al. 1999), the results of which are summarized in the lower panel of Figure 1. A dashed straight line has been drawn by hand to represent the mean trend of the abundances. The residual scatter about this line is small, with $\sigma \simeq 0.1$. A similar plot could be shown of the [O/Fe] trend with [Fe/H], but the results would look quite similar to that shown for [Sc/Fe], since our derived [Sc/Fe] do not differ significantly from zero.

The abundances are very consistent with previous [O I] studies in the metallicity regime [Fe/H] > −2, and shows evidence for a small upward trend at lower metallicities. But the oxygen abundances even at the lowest [Fe/H] values of our sample remain incompatible with the much larger abundances derived from the O I triplet and UV OH transitions.

Acknowledgments. We gratefully acknowledge research support through NSF grant AST-9987162.

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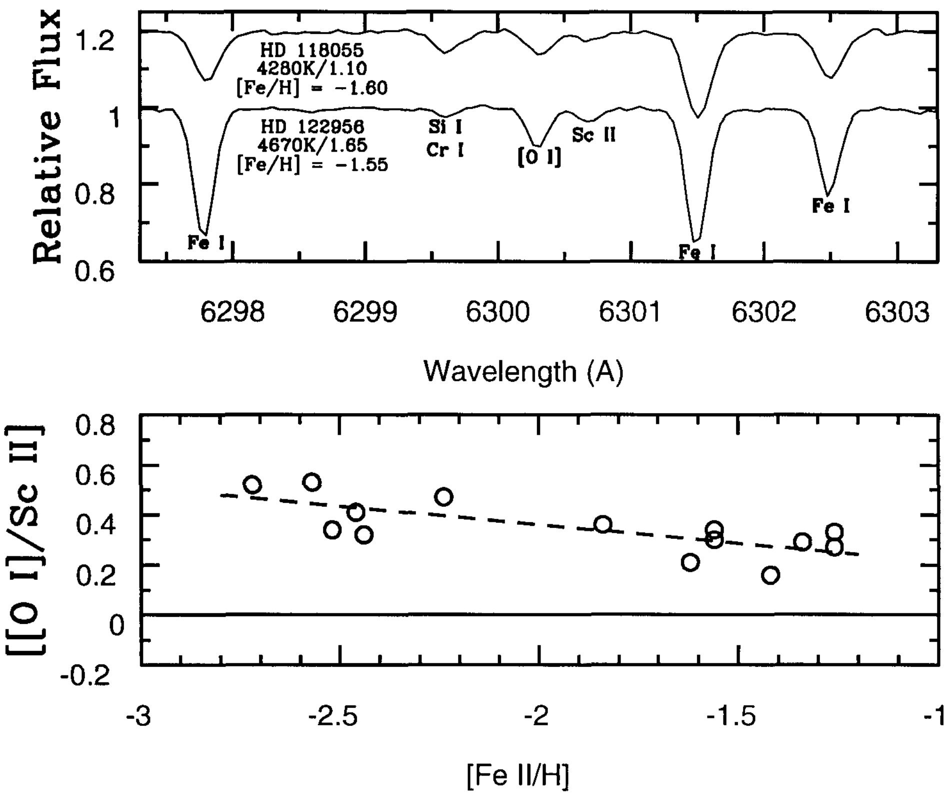

Figure 1. Upper panel: sample spectra of two of the program stars. The relative flux is correct for HD 122956, and the spectrum of HD 118055 is shifted vertically for display purposes. Bottom panel: [O/Sc] values correlated with [Fe/H]. The axis labels explicitly state the transitions used for these abundances. The dashed line is a hand-drawn linear best fit to the data.

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https://doi.org/10.1017/S1539299600013927 Published online by Cambridge University Press