Atomic Data to Trace the Chemical History of the Galaxy

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The first stars formed in the Universe were massive and short-lived, creating the heavier elements we know today and contributing them to the Galaxy in supernovae. Their influence can be studied through the elemental abundances of metal-poor stars found in the Galactic halo. The abundance patterns in these stars are quite different to the Sun and mounting evidence suggests that the lighter iron-group elements, Sc, Ti and V, were formed in a different way to the other iron-group elements in these stars [1]. This evidence relies on high quality laboratory wavelengths, oscillator strengths and hyperfine structure constants for many lines in both neutral and singly-ionized elements. The analysis of large numbers of spectral lines in metal-poor stars reduces the sensitivity of the analysis to the model atmosphere and indicates possible deviations from local thermodynamic equilibrium. Since the spectra of metal-poor stars are quite different to the spectrum of the Sun, different sets of lines are required for abundance measurements, and accurate atomic data are thus crucial.

Groups at the National Institute of Standards and Technology (NIST), Imperial College London (ICL), and the University of Wisconsin-Madison (UW) have been active in the measurement of these atomic data for many decades. Wavelengths, energy levels, and hyperfine structure constants are measured using high-resolution Fourier transform (FT) and grating spectrometers at NIST and ICL. Oscillator strengths combine a measurement of atomic lifetimes at UW with branching fractions measured using NIST and ICL FT spectrometers, with weaker branches measured using a high-resolution echelle spectrometer at UW. The uncertainties in these oscillator strength measurements are now dominated by the branching fractions rather than the lifetimes. This is particularly the case when lines used for abundance measurements are widely separated in wavelength from the dominant lines from the upper level of the transition and require more than one standard lamp for radiometric calibration.

I shall present our current work on measurements of atomic data for neutral and singly-ionized iron-group elements. I shall illustrate some of the problems in measuring branching fractions using a recent study of Sc II [2], where the correction of previous oscillator strengths of the visible lines most widely used for abundance determinations has resulted in an increase in the transition probabilities of over 20% for some lines, several times the estimated uncertainty.

References

[1] C. Sneden, J. J. Cowan, C. Kobayashi, M. Pignatari, J. E. Lawler, E. A. Den Hartog, M. P. Wood, Astrophys. J. **817**, 53 2016.
[2] J. E. Lawler, Hala, C. Sneden, G. Nave, M. P. Wood, J. J. Cowan, Astrophys. J. Suppl. Ser. (in press).