Transition Probabilities of Intersystem and Forbidden Lines for Astrophysical Diagnostics in the UV

A. Daw[1], W. H. Parkinson[1], P. L. Smith[1], A. G. Calamai[2]
[1] *Harvard-Smithsonian Center for Astrophysics, Cambridge, MA*
[2] *St. Joseph's University, Philadelphia, PA*

In order to improve the accuracy of astrophysical diagnostics, we are continuing a program to measure transition probabilities (A-values) for lines of metastable atomic ions. In astrophysical plasmas, these A-values can be comparable to the rates for collisional excitation and deexcitation. Under such conditions, line intensity ratios can be used to determine electron density, n_e, and electron temperature, T_e. Spectrometers on, for example, the Solar and Heliospheric Observatory (SOHO) and the Hubble Space Telescope are able to measure the UV line intensities required for these diagnostics. The interpretation of the observations requires a model of the equilibrium between the radiative decay of metastable ions and the collisional processes. Thus, accurate n_e and T_e estimates require that the models employ accurate A-values, and our work provides accurate measurements of these A-values. The A-values are also required for interstellar abundance determinations, because the allowed lines of the most abundant ionic species are often saturated. Therefore, column densities are often best determined from measured equivalent widths of the weaker forbidden and intersystem lines.

Although A-values can be calculated theoretically, benchmark measurements are required to asses the accuracy of the calculational methods. The Center for Astrophysics Ion Trap Facility provided the first A-value measurements for many astrophysically important intersystem lines, and these measurements motivated improvements in theoretical calculational methods for intersystem line A-values. We are currently addressing the lack of experimental A-value data for forbidden transitions between different terms in the ground configurations of ions in the second periodic row. These transitions give rise to line-ratio diagnostics, which to date have relied exclusively on theoretical calculations.

We determine A-values by producing a metastable ion population inside a radiofrequency ion trap, and then observing the time dependence of the decay photon rate as the population decays. Metastable levels which decay via intersystem transitions typically have lifetimes from 10^{-4} to 10^{-1} s, while those which decay via forbidden transitions have lifetimes around 1 s. We have recently developed a technique to measure A-values for weaker forbidden lines, by accurately monitoring the total stored ion population to account for trap losses. Using this technique, we have obtained a preliminary A-value measurement for the forbidden lines of the $^1S_0$ metastable level of Ne III. This is the first such measurement for an excited term in the ground configuration of an ion in the second periodic row.

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