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Progress in Quantitative Atomic Spectroscopy and the Connection to Astrophysics[1]

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Atomic spectroscopy played a central role in the development of quantum mechanics and modern physics. This historical significance may motivate continued teaching of the field, but atomic spectroscopy has lasting significance through its applications in astrophysics. Most of the detailed physical and chemical knowledge humans have now, or may ever learn, about the Universe outside our solar system is from spectroscopy. Databases of atomic and molecular spectroscopic information play an important role in astrophysical research. The origins of the non-primordial elements are an example of a long term research problem in astrophysics that is critically dependent on atomic spectroscopy. Non-primordial here refers to almost the entire periodic table except for H and He produced in the Big Bang. Broadly tunable organic dye lasers created many opportunities to improve spectroscopic parameters including energy levels, wavelengths, and hyperfine structure for atoms and ions. Such data are of value but reasonably accurate atomic transition probabilities are critical to exploring the production of non-primordial elements. The above mentioned organic dye lasers, in combination with a simple and robust atom/ion beam source made radiative lifetime measurements routine for atoms and ions throughout the periodic table. Radiative lifetimes combined with emission branching fractions yield accurate absolute atomic transition probabilities essential for the analysis of stellar spectra. The synthesis of all elements beyond the Fe-group is through n(eutron)-capture because fusion reactions become endothermic beyond the Fe-group. Half of these heavy isotopes are made via s(low)-process n-capture which occurs in AGB stars. The other half are made via r(apid)-process n-capture which occurs in extremely violent events that produce high densities of free neutrons. Recent studies of a binary n(eutron)-star merger first detected by LIGO and FERMI-LAT and observed in great detail by many ground and space based observatories confirmed that n-star mergers do produce r-process n-capture isotopes. There are still many unanswered questions about r-process n-capture sites and about the chemical evolution of the Universe. The role of atomic spectroscopy in studies of the r-process n-capture nucleo-synthesis will be discussed.

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