High-Resolution Molecular Spectroscopy for Millimeter and Sub-millimeter Astronomy:From Chemistry to Nucleosynthesis

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During the past twenty-five years in which molecular astrophysics has existed, over one hundred different chemical species have been identified in interstellar gas. The identification of these molecules has primarily been the work of radio, millimeter, and sub-mm astronomy, including both ground-based and airborne observations. The detection of such species and their subsequent use as tracers of the dense interstellar medium has lead to significant advances in our understanding of star formation, galactic structure, evolved stars, and even cosmology, as well as causing a significant revision of chemical thinking and creation of a new discipline of chemistry. An overwhelming factor in the success of molecular astrophysics has been the ability to unambiguously identify a given species, which for the most part has occurred through astronomical observations of its pure rotational spectrum, which provides a unique, fingerprint pattern. Such a spectrum can only be accurately known from high-resolution laboratory measurements, which typically have a precision of 1 part in 10^8.

Molecular astrophysics has thus relied heavily on the progress of high-resolution laboratory spectroscopy of potential interstellar species. Several groups have been active in this area of research, employing a variety of experimental techniques, including mm/sub-mm direct absorption methods, Fourier transform microwave spectroscopy, and laser-induced fluorescence. Many molecules of interest are short-lived species that require exotic synthetic methods, such as laser ablation, use of Broida-type ovens and d.c. discharges. Recently, considerable progress has been made in laboratory studies of small carbon clusters and metal-bearing species. For example, a number of new carbon chains have been found in the lab and subsequently detected in molecular clouds and in circumstellar envelopes. (e.g. McCarthy et al 1997). Also, laboratory investigations have lead to the detection of several new metal-bearing molecules towards circumstellar shells, such as MgNC and MgNC (Kawaguchi et al 1993, Ziurys et al 1995). Observations of the magnesium isotopomers of MgNC in fact have put useful constraints on nucleosynthesis in late-type stars (Guélin et al 1995). These recent laboratory results and their implications for astrophysics will be discussed, as well as future directions.

References:

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