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The Extreme Chemical Environments Associated with Dying Stars

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Mass loss from dying stars is the main avenue by which material enters the interstellar medium, and eventually forms solar systems and planets. When stars consume all the hydrogen burning in their core, they start to burn helium, first in their centers, and then in a surrounding shell. During these phases, the so-called “giant branches,” large instabilities are created, and stars begin to shed their outer atmospheres, producing so-called circumstellar envelopes. Molecules form readily in these envelopes, in part by LTE chemistry at the base of the stellar photosphere, and also by radical reactions in the outer regions. Eventually most stars shed almost all their mass, creating “planetary nebulae,” which consist of a hot, ultraviolet-emitting white dwarf surrounded by the remnant stellar material. The environs in such nebulae are not conducive to chemical synthesis; yet molecular gas exits. The ejecta from these nebulae then flows into the interstellar medium, becoming the starting material for diffuse clouds, which subsequently collapse into dense clouds and then stars. This molecular “life cycle” is repeated many times in the course of the evolution of our Galaxy. We have been investigating the interstellar molecular life cycle, in particular the chemical environments of circumstellar shells and planetary nebulae, through both observational and laboratory studies. Using the facilities of the Arizona Radio Observatory (ARO), we have conducted broad-band spectral-line surveys to characterize the contrasting chemical and physical properties of carbon (IRC+10216) vs. oxygen-rich envelopes (VY CMa and NML Cyg). The carbon-rich types are clearly more complex in terms of numbers of chemical compounds, but the O-rich variety appear to have more energetic, shocked material. We have also been conducting surveys of polyatomic molecules towards planetary nebulae. Species such as HCN, HCO^+, HNC, CCH, and H_2CO appear to be common constituents of these objects, and their abundances do not appear to vary with age. These results contradict the predictions of all chemical models. We have also been using millimeter-wave and Fourier transform microwave methods to measure rotational spectra of potential new interstellar molecules to complete the chemical inventories. The current results of these studies will be presented.