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## THE CHEMISTRY OF DENSE INTERSTELLAR CLOUDS

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The basic theme of this program is the study of molecular complexity and evolution in interstellar and circumstellar clouds incorporating the biogenic elements. The dense interstellar clouds are the formation sites for stars and presumably for planetary systems. Understanding the molecular composition of these clouds provides probes of physical conditions and evolution by allowing the measurement of local temperature, density and motions; and also provides a means for studying the chemistry in these environments which are so different from those normally encountered in the terrestrial laboratory. Some ninety interstellar molecular species have been identified, the majority of which are organic. The processes producing this chemistry are becoming increasingly well understood, although major questions remain which are being investigated by the observations undertaken as part of this grant.

Recent results include the identification of a new astronomical carbon-chain molecule,  $C_4Si$ . This species was detected in the envelope expelled from the evolved star IRC+10216 in observations at the Nobeyama Radio Observatory in Japan.  $C_4Si$  is the carrier of six unidentified lines which had previously been observed. This detection reveals the existence of a new series of carbon-chain molecules,  $C_nSi$  ( $n = 1, 2, 4$ ). Such molecules may well be formed from the reaction of  $Si^+$  with acetylene and acetylene derivatives. Other recent research has concentrated on the chemical composition of the cold, dark interstellar clouds, the nearest dense molecular clouds to the solar system. Such regions have very low kinetic temperatures, on the order of 10 K, and are known to be formation sites for solar-type stars. We have recently identified for the first time in such regions the species  $H_2S$ ,  $NO$ ,  $HCOOH$  (formic acid). The  $H_2S$  abundance appears to exceed that predicted by gas-phase models of ion-molecule chemistry, perhaps suggesting the importance of synthesis on grain surfaces. Additional observations in dark clouds have studied the ratio of ortho- to para-thioformaldehyde. Since this ratio is expected to be unaffected by both radiative and ordinary collisional processes in the cloud, it may well reflect the formation conditions for this molecule. The ratio is observed to depart from that expected under conditions of chemical equilibrium at formation, perhaps reflecting efficient interchange between cold dust grains in the gas phase.