The Organic Refractory Material in the Diffuse Interstellar Medium: Mid-IR Spectroscopic Constraints

Y. J. Pendleton and L. J. Allamandola
Space Science Division, NASA Ames Research Center

We present an analysis of the 4000 to 1000 cm^{-1} (2.5 to 10 micron) region of the spectrum of diffuse interstellar medium (DISM) dust compared with the spectra of thirteen chemical entities produced in the laboratory which serve as analogs to the interstellar material. The organic signatures of extragalactic dust, carbonaceous chondritic material, and E. coli bacteria are also presented because these have been discussed in the literature as relevant to the diffuse interstellar medium. Spectral analysis of the DISM allows us to place significant constraints on the applicability of proposed candidate materials. The spectra of candidate materials are evaluated using four spectral characteristics based on the interstellar data: i) comparisons of the profile and sub-peak positions of the 2940 cm^{-1} (3.4 micron) aliphatic CH stretching-mode band, ii) the ratio of the optical depth (O.D.) of the aliphatic CH stretch to the O.D. of the OH stretch near 3200 cm^{-1} (3.1 micron), iii) the ratio of the O.D. of the aliphatic CH stretch to the O.D. of the carbonyl band near 1700 cm^{-1} (5.9 micron), and iv) the ratio of the O.D. of the aliphatic CH stretch feature to the O.D. of the CH deformation modes near 1470 cm^{-1} (6.8 micron) and 1370 cm^{-1} (7.25 micron).

We conclude that the organic refractory material in the diffuse interstellar medium is predominantly hydrocarbon in nature, possessing little nitrogen or oxygen, with the carbon distributed between the aromatic and aliphatic forms. Long alkane chains $H_3C–$ $(CH_2)_n–$ with n much greater than 4 or 5 are not major constituents of this material. Comparisons to laboratory analogs indicate the DISM organic material resembles plasma processed pure hydrocarbon residues much more so than energetically processed ice residues. This result is consistent with a birthsite for the carrier of the 3.4 micron band in the outflow region of evolved carbon stars. The organic material extracted from the Murchison carbonaceous meteorite and the spectrum of E. coli bacteria reveal spectral features in the 5-10 micron region that are absent in the DISM. Although the presence of unaltered circumstellar components in the Murchison meteorite has been established through several lines of evidence, it is unclear whether or not the aliphatic component which gives rise to the 3.4 micron band is in that category. Considering the complete 2-10 micron wavelength region, there is no spectral evidence for a biological origin of the 3.4 micron interstellar absorption band. The similarity of the aliphatic CH stretch region of dust from our own galaxy compared with that of distant galaxies suggests that the organic component of the ISM is widespread and may be an important universal reservoir of prebiotic organic carbon.