The Surprising Molecular and Isotopic Content of Planetary Nebulae

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Abstract

Planetary nebulae (PNe) were once thought to merely be the realm of atomic material, as any molecules remaining from the AGB stage were expected to be rapidly photodissociated. Recently, however, polyatomic molecules of increasing complexity have been detected in PN envelopes, with structures as large as C60 and C70 having been identified in their ejecta. As PNe provide _˜85% of their mass to the surrounding interstellar medium (ISM), elucidation of their chemical makeup is vital for understanding their contribution to diffuse clouds. Several recent surveys by Schmidt & Ziurys probing the molecular content of a set of PNe spanning a wide range of ages, sizes, and morphologies uncovered the presence of HCN, HCO+, HNC, and CCH in most of the observed nebulae, showing, strikingly, that polyatomic molecules are a common constituent of PN envelopes. Further, these works revealed that (1) the abundances of each molecule do not vary significantly with kinematic age, in contrast to the predictions of nebular models, and (2) the abundances of these molecules are approximately 1-2 orders of magnitude greater than those measured for the diffuse ISM, indicating that the molecular material from PNe disperses and seeds the surrounding ISM. Detections of HCO+, H2CO, HCN, HNC, CCH, and c-C3H2 at numerous positions across the Helix Nebula show that this material is well-mixed in the PN envelope. Targeted searches of several PNe revealed an even greater wealth of molecules. In particular, recent observations of the young PN K4-47 using the ARO 12-M and SMT and the IRAM 30-M Telescope uncovered the presence of a surprising array of molecular transitions, including several singly and doubly 13C-substituted isotopologues of HC3N and HC15N. Estimations of the 12C/13C ratio for K4-47 as well as several other PNe ranged from _˜1-10, implying that these nebulae may have J-type progenitor stars. Furthermore, the 14N/15N ratio measured for K4-47 is an astounding 9, the largest enrichment of 15N yet observed, suggesting that J-type stars could be a significant source of 15N in the Galaxy. The results of the aforementioned works, as well as their implications for nucleosynthetic processes and the role that PNe play in providing the ISM with molecular material, will be presented. Additionally, recent CO, HCN, and HCO+ ALMA images of several PNe will be shown.

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