Physical Properties of Fullerene-containing Galactic Planetary Nebulae

Masaaki Otsuka (Academia Sinica), Ciska Kemper (Academia Sinica), Jan Cami (University of Western Ontario/SETI Institute), Els Peeters (University of Western Ontario/SETI Institute), and Jeronimo Bernard-Salas (Open University)

We searched the *Spitzer* Space Telescope data archive for Galactic planetary nebulae (PNe), that show the characteristic 17.4 and 18.9 μm features due to C60, also known as buckminsterfullerene. Out of 338 objects with *Spitzer*/IRS data, we found eleven C60-containing PNe, six of which are new detections, not known to contain C60 prior to this work. We analyzed the spectra, along with ancillary data, using the photo-ionization code CLOUDY to establish the atomic line fluxes, and determine the properties of the radiation field, as set by the effective temperature of the central star. In addition, we measured the infrared spectral features due to dust grains. We find that the Polycyclic Aromatic Hydrocarbon (PAH) profile over 6-9 μm in these C60-bearing carbon-rich PNe is of the more chemically-processed class A. The intensity ratio of 3.3 μm to 11.3 μm PAH indicates that the number of C-atoms per PAH in C60-containing PNe is small compared to that in non-C60 PNe. The *Spitzer* spectra also show broad dust features around 11 and 30 μm. Analysis of the 30-μm feature shows that it is strongly correlated with the continuum, and we propose that a single carbon-based carrier is responsible for both the continuum and the feature (See the presentation by Kemper et al. in detail). The strength of the 11-μm feature is correlated to the temperature of the dust, suggesting that it is at least partially due to a solid-state carrier. The chemical abundances of C60-containing PNe can be explained by AGB nucleosynthesis models for initially 1.5-2.5 solar mass stars with the metallicity Z=0.004. We plotted the locations of C60-containing PNe on a face-on map of the Milky Way and we found that most of these PNe are outside the solar circle, consistent with low metallicity values. Their metallicity suggests that the progenitors are an older population.