Academia Sinica Press Release

Rare Carbon Molecule Detected in Dying Star Gives Glimpse of Stellar Evolution

(Release time: Taiwan time March 5, 2013, 9:00 am)

An international research team led by Dr. Masaaki Otsuka, a Postdoctoral Fellow of the Institute of Astronomy and Astrophysics (ASIAA) recently detected a rare carbon molecule C_{60} in a dying star. The result was obtained with state-of-the-art ground-based and space telescopes, including the Subaru Telescope. This disclosure propels research of evolved star. These results were published in *The Astrophysical Journal* on January 28, 2013.

To understand the stellar evolution and the chemical evolution of galaxies, it is important to investigate the amount and composition of the dust produced by dying stars and the subsequent return of this dust to interstellar space. A large fraction of this dust is in the form of carbonaceous dust grains, thus the investigation of carbonaceous dust may provide the basis for research into the evolution of galaxies. The C_{60} fullerene is an aggregate consisting of 60 carbon atoms, with a geometry that is the same as the pattern of seams on a soccer ball. The first detection of C_{60} in space was reported in July 2010, using infrared spectroscopy obtained with the NASA Spitzer Space Telescope. So far, C_{60} has been found in about 20 objects, most of which planetary nebulae (a class of dying stars). Dr. Otsuka and his team tried to analyze the physical condition of C_{60} in these objects with the aim to establish their evolutionary state.

Dr. Otsuka and his collaborators analyzed spectroscopic data from over 300 planetary nebulae taken by the Spitzer telescope. They carefully checked for the presence of C_{60} infrared resonances and identified C_{60} in several planetary nebulae, among which, they detected C_{60} resonances in the dying star named M1-11 for the first time. In M1-11, two C_{60} resonances were found at 17.3 and 18.9 microns. Dr. Otsuka also found C_{60} emission at 8.5 microns in the archived spectra of M1-11 taken by Europe Southern Observatories. Using the intensities of the detected C_{60} lines, he was successful in estimating the total amount and the temperature of C_{60} in M1-11. Using data obtained with Spitzer, and with the Japanese infrared satellite telescope AKARI, Otsuka and his team also investigated the dust grain composition in M1-11 and derived the amount in each component. It turns out that although M1-11 is rich in

amorphous carbon grains and polycyclic aromatic hydrocarbons (PAHs), the total amount of C_{60} makes up only 0.01 percent of the total dust mass. Thus, it can be concluded that C_{60} is very rare in the interstellar medium.

Furthermore, to characterize the physical conditions in environments that contain C_{60}, The team used HDS (The High Dispersion Spectrograph) on the Subaru 8.2-m telescope and ISLE on the NAOJ Okayama 1.88-m telescope. HDS and ISLE are high-dispersion and high-sensitivity spectrographs that operate in the ultraviolet/optical and near-infrared respectively, so that the team could measure the intensities of target lines exactly. Detailed analysis of the spectra in the range from 0.36 to 2.3 microns revealed the abundances of 11 elements. The team found that M1-11 is a very young planetary nebula, which formed from material ejected by the star ~1000 years ago, and that it evolved from a star 50% more massive than the Sun. The derived physical parameters including the C_{60} mass and temperature, the elemental composition of the gas in the nebula, the mass of the progenitor star, and the evolutionally status are very similar to those seen in other planetary nebulae containing C_{60}. Thus, C_{60} tends to be formed in carbon-rich dusty objects, such as M1-11. As the spatial distribution of C_{60} and PAHs in the nebula is similar, it could be a basis to explore the origin of life and relevant science by understanding the spatial distribution of C_{60}. The team intends to challenge such topics in future research.

The full paper is entitled “The detection of C_{60} in the well-characterized planetary Nebula M1-11”. The complete list of authors is: Masaaki Otsuka, F. Kemper, S. Hyung, B. A. Sargent, M. Meixner, A. Tajitsu, and K. Yanagisawa.

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