Ionized zones and PDRs of planetary nebulae

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Abstract

Planetary nebulae (PNe) are gaseous envelopes thrown off from low- and intermediate-mass stars in advanced evolution stages. Studies of PNe provide understanding about the chemical and physical evolution of the major of stars. PNe are important sources of fresh C, N and s-process heavy elements. Accurate determinations of chemical abundances in PNe are crucial for determining the chemical evolution of galaxies as a whole. In addition, tight limits on the chemical composition constrain the range of dust grain models. An outstanding problem in abundance studies of PNe (and of ionized gaseous nebulae in general) is that the heavy element abundances relative to hydrogen derived from optical recombination lines are systematically higher than those derived from UV and optical collisionally excited forbidden lines, which has been attributed to the presence of significant temperature and/or density fluctuations, yielding apparent lower forbidden line abundances. The physics leading to such large temperature fluctuations is however unknown. The ISO SWS and LWS observations of the mid- and far-IR ionic fine structure lines, which, unlike their counterpart in UV and optical, have excitation energies of less than 1100 K and cover a wide range in critical densities, provide fresh input for a better understanding of this fundamental discrepancy in nebular abundance determinations. A status report on this topic is presented.

Many PNe are surrounded by massive molecular envelopes. Given their relatively simple geometry and well specified radiation fields, PNe are excellent laboratory for the study of the chemistry of dense molecular material exposed to strong radiation fields under various environments (C-rich or N-rich). Many of the key molecules, such as OH, H_2O, CH, CH^+ and HeH^+ have their pure rotational transitions falling within the ISO spectral window. Observations of these lines yield strong constraints on the current PDR theories. An example on this respect is illustrated by the detections of CH^+ and CH in the ISO LWS spectrum of NGC 7027.

Despite the relative low spectral resolution, the LWS grating spectra of a few best observed PNe show a forest of emission lines, many of them remain to be identified. A few of the detected features are known to be spurious, arising from the calibration source Uranus. The majority of the unidentified lines are however likely to be real and probably arise from unknown molecular species. Full identification of these lines requires interaction of a better instrumental calibration, laboratory studies and detailed nebular chemistry modelling.