Ca and Dust in Planetary Nebulae

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Under nebular conditions it is expected that the [CaII] lines at 7291.470 and 7323.880 Å should be among the strongest emission lines in the red part of the optical spectrum unless the nebula is matter bounded. The lines are observed in novae, supernovae and some symbiotic systems but the only observation of these lines in planetary nebulae (PN) is for AFGL 618 where the lines are thought to be shock-excited. While higher ionization states of Ca do produce some lines observed in a few high-excitation PN, from which gas-phase Ca abundances averaging to about 5% of solar are found, the CaII lines are not observed even in PN with massive neutral envelopes such as NGC 7027. If the Ca is depleted onto dust grains it would explain the absence of the CaII lines. However it is thought that the dust is destroyed with time in the ionized region. Any observation of the CaII lines would produce better abundance estimates and would test the extent of dust destruction that is taking place in the outer parts of the PN.

We have observed 21 PN using the echelle spectrograph on the 2.7-m telescope at McDonald Observatory (Tull *et al.* 1995; PASP, 107, 251). The wavelength region of the CaII lines and four commonly observed [OII] lines (7318.847, 7319.917, 7329.634, and 7330.704 Å) is covered in one echelle order. For 15 of the 21 objects the OII lines were detected. In no case was either CaII line detected. As the photoionization models predict that OII and CaII will exist in nearly the same volume of the PN we have looked at these 15 spectra to obtain approximate Ca/O abundance limits from CLOUDY photoionization models. For each PN we use specific stellar temperatures and nebular densities based on values in the literature to calculate an expected line ratio 7323.88/7321.91 for a solar Ca/O abundance ratio. Comparison with the upper limit line ratio gives a lower limit Ca/O depletion estimate. These values range from 5 to 1170 depending upon the OII line S/N and the nebular parameters. The average upper limit depletion is 260, much higher than the previous depletion estimate of about 20 (Khromov 1989; A&A, 138, 10). Nebulae with large derived depletions include NGC 2440, IC 418, and NGC 40.

It appears that there is not much, if any, dust destruction in these PN except in the inner regions of high-excitation PN where the conditions are extremely hostile. The only alternative explanation would be that the photoionization codes have bad parameters for CaII, which seems unlikely when these lines in other types of objects can be explained by the codes. If there is a decrease in the dust fraction of the ionized region as PN evolve these results suggest that the dust grains are ejected from the ionized region, possibly by radiation pressure, rather than being destroyed by the plasma.

Othe PN have also been observed with the spectrograph on other runs and we have not yet looked at all the data in detail. So far no CaII lines have been seen.

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