Observations of Near-Infrared H_2 Emission in Planetary Nebulae

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We report the results of a near-infrared (mostly K-band) spectroscopic survey of planetary nebulae at McDonald Observatory during the period 1986-1993. These observations were made with a grating spectrometer based on a 1×32-element InSb array. Most of the K-band observations were taken with spectral resolving power $R = \lambda/\Delta\lambda = 600$ in order to resolve the v=1-0 S(1) 2.121 μm H_2 line from the adjacent recombination line of He I at 2.113 μm. We also simultaneously measured the strengths of H I Br γ and He II 2.189 μm. The typical limiting line flux detected in our 3.8" beam was 1 - 3 $\times 10^{-14}$ erg cm^{-2} s^{-1}, corresponding to a surface brightness of 3×10^{-5} to 1×10^{-4} erg cm^{-2} s^{-1} $ster^{-1}$. An early result of this study was the first conclusive proof that the UV-pumping or "fluorescence" mechanism, rather than thermal (shock) excitation, is responsible for the H_2 emission in a planetary nebula, Hubble 12 (Dinerstein *et al.* 1988, ApJ, 327, L27). This was also one of the first demonstrated cases of UV-pumped H_2 emission in any astronomical source, and Hubble 12 has become a template for the study of this emission mechanism.

We report here observations of an additional 15 planetary nebulae, in 8 of which we detected H_2 emission. We mapped 6 of these objects, observed another 5 at several positions, and observed the rest at only one or two positions. Because the instrument had only a linear array, mapping had to be carried out by a sequence of observations at different positions on the sky. We searched for the presence and peak of the H_2 emission by stepping the single aperture along $E - W$ and $N - S$ axes cutting through the central star, at intervals of 3". Our goal was to isolate the H_2 emission by placing the aperture at a position which effectively excluded the bright central star and the ionized gas, both of which produce strong continuum emission and also strong line emission; many of the central stars have strong winds and give rise to strong, broad emission lines such as He II 2.113 μm. The H_2 emission tends to peak just outside the brightest part of the ionized gas, as expected for photodissociation regions. Some of the non-detections are interesting: for example, no H_2 emission was seen from IC 418 despite intensive mapping. IC 418 is known to have a massive H I envelope seen at 21 cm (Gussie, Taylor, & Goss 1989, ApJ, 340, 932), and shows strong infrared [O I] and [C II] line emission (Dinerstein *et al.* 1995, in Airborne Astronomy Symposium, ASP Conf. Ser. 99, 387, and this conference). We suggest that IC 418 belongs to a class of PN which have large amounts of neutral atomic but little or no molecular material (Dinerstein, Sneden, & Uglum 1995, ApJ, 447, 262). For a few of the detected objects, additional observations were obtained in the J and H bands and with a longer-wavelength setting in the K-band that included the 1-0 S(0) 2.223 μm and 2-1 S(1) 2.247 μm lines. The intensity ratios range from those characteristic of "pure fluorescence" to values typical of thermally-excited or thermalized emission, with the planetary nebula BD+30^o 3639 representing an intermediate case.