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High Spectral and Spatial Resolution Observations of H_2 Emission in Planetary Nebulae with IGRINS

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Near-infrared emission lines from vibrationally-excited H_2 were first detected in a planetary nebula (PN), NGC 7027, four decades ago. The PN environment hosts multiple potential excitation mechanisms for these transitions: shocks at the interfaces of differentially expanding nebular layers, and a strong UV radiation field from the hot central star that can drive radiative excitation. The first PN in which a "pure fluorescent" H_2 spectrum (Black & van Dishoeck 1987) was detected was Hubble 12 (Dinerstein et al. 1988). Other PNe display H_2 spectra with thermal (collisionally-dominated) spectra or line ratios intermediate between fluorescent and thermal cases. Departures from pure fluorescent line ratios in a radiatively-excited gas can result from collisional modification at high densities (Sternberg & Dalgarno 1989), superposition of fluorescent and collisional components (Davis et al. 2003), a hard UV radiation field, and/or advective effects (Henney et al. 2007), but it is often difficult to determine which of these are relevant. Here we present observations of H_2 emission in PNe obtained with the high-spectral resolution (R = 40,000) IGRINS spectrometer, which covers the entire H and K bands simultaneously (Park et al. 2014). We measure over 100 individual H_2 emission lines in the original fluorescent PN Hubble 12, and also observed the PN M 1-11, which displays two distinct H_2 components: a highly fluorescent H_2 ring expanding at $\pm$10 km/s; and two compact blobs expanding at $\pm$30 km/s. The latter are seen only in the v = 1-0 lines, emit a thermal spectrum with $T_{rot} \sim 1000\ K$, and resemble "molecular bullets" seen in CO in the PN BD+30°3639 (Bachiller et al. 2000). Our observations demonstrate the ability of instruments with high spectral resolution and broad spectral grasp to resolve H_2 components with different excitation, as well as to reveal hidden spatio-kinematical structure within complex sources by utilizing velocity information.

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