H_2 Kinematics in Planetary Nebulae

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The evolution of planetary nebulae is controlled largely by hardening of the radiation field from the central star and by hydrodynamic interactions between the "fast wind" and the slower red giant wind. These processes also result in the heating and dissociation of H_2 and in the production of H_2 vibration–rotation lines in the near-infrared. Both mechanisms tend to produce high gas temperatures and, at high densities, a thermal population of states. Kinematic studies provide vital information on the geometry and expansion of the nebulae and offer a discriminant between shocked and photodissociated regions.

We mapped the velocity fields of seven PN and proto-PN in the H_2 1–0 S(1) line at $\lambda = 2.121$ μm and four also in the [Fe II] 1.644 μm line using the NASA Infrared Telescope Facility on Mauna Kea. H_2 and [Fe II] velocities and line widths provide evidence for expanding bubbles, collimated outflows, shock fronts, photodissociation regions, and in the case of AFGL 2688, for an expanding, rotating equatorial ring. The data are being analyzed in conjunction with near-infrared imaging and spectral data to understand the geometry and evolution of the nebulae and to constrain shock and photodissociation models for the nebulae.

One of our more interesting targets is the proto-PN AFGL 618. An east-west slit was placed along the major axis of the bipolar nebula, and longslit spectra were taken of the H_2 and [Fe II] lines. Both lines show very large velocity widths (190 km s^{-1} for H_2 and 140 km s^{-1} for [Fe II], FWZI). These velocities are remarkable in that shock velocities of 30-50 km s^{-1} are sufficient to dissociate H_2. The high velocity H_2 emission is very smooth, with no evidence for clumping. Most of the H_2 emission is at low velocities, where it appears to decelerate with increasing distance from the nucleus. The high velocity gas appears to accelerate somewhat as it moves away from the nucleus. However, very high velocities appear at small radii, arguing against a smooth acceleration of the gas. The H_2 must have formed out of the post-shock gas. The [Fe II] emission lies just outside of the H_2 emitting region. It seems that the high velocity outflow is encountering the outer edge of the lobe and terminating in a shock that destroys the H_2 and forms a high velocity dispersion, thin region of [Fe II] emission. There is no evidence for [Fe II] emission from the sides of the lobe at smaller projected radii, indicating that the outflow is probably highly collimated.

Detailed results of this work are presented in papers by Kelly et al. (1997) and by Latter et al. (1997). This program will be continued with observations of additional sources and with complementary HST observations. This work has been supported in part by NSF grant AST94-53354.

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