CO IN PLANETARY NEBULAE

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ABSTRACT. We report the first detection of millimeter CO emission in two highly evolved planetary nebulae: NGC 6720 and NGC 7293. The CO is a useful probe of the structure and kinematics of the molecular gas in the nebulae, and provides an estimate of the mass of material which remains un-ionized by the central star.

Millimeter emission from CO has been the single most useful probe of the kinematics and masses of the dense neutral circumstellar envelopes around the coolest giant stars. Since these objects are generally believed to be the direct precursors of planetary nebulae, observations of CO in the remnant neutral shells of the nebulae are of considerable diagnostic potential for understanding the evolutionary sequence. However, despite repeated searches, very few have so far proved to have detectable CO emission (cf. Knapp 1985). Here we report on the first results of an observational program to re-evaluate the question of CO in planetary nebulae.

The observations were made with the NRAO 12-m telescope at Kitt Peak in the CO (2-1) line at 230 GHz, where the beamsize is 30 arc seconds (FWHM). This telescope-frequency combination offers a considerable improvement in sensitivity to small scale, optically thin emission than was available for previous searches. Among the nebulae in the program are the Ring (NGC 6720, PK 63 +13.1) and the Helix (NGC 7293, PK 36 -57.1), and CO has been detected in both.

The CO emission from the Ring nebula has a peak temperature of 0.2 K and the line is centered at a radial velocity of 1 km/s (with respect to the local standard of rest), with a total velocity extent of 48 km/s. The kinematics are similar to those found from studies of optical lines. Very limited mapping indicates a CO source size which is comparable to that of the optical nebula, whose diameter is about 70 arc seconds. The CO molecules probably reside in the dense filaments seen, e.g., in OI images of the nebula.

The angular size of the Helix nebula (about 12 arc minutes in diameter) is much larger than the telescope beamsize and allows the CO distribution to be examined in more detail. Limited mapping

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indicates that the CO emission closely corresponds to the two ring structures seen in optical images, and several positions have CO line temperatures in excess of 1 K. The line widths at each position are typically a few km/s, and the velocities vary systematically with position angle in the nebula. Two distinct kinematic components are seen, which correspond to the two optical rings, and the systematic velocity variations can be reproduced quite closely with a simple model of two expanding rings; complex helical models which have previously been proposed are not required to explain the CO kinematics. The radial velocity of the nebula is -23 km/s.

In addition to the structure and kinematics of the neutral gas in the nebulae, the observations can be used to estimate the mass of molecular material, using simplifying assumptions on the opacity, excitation, distribution, and abundance of the CO. The results indicate that the mass ratio of molecular to ionized matter is approximately 0.1 for both the Ring and the Helix.

The few previous detections of CO in bona fide planetaries include the young objects NGC 7027 and CRL 618 (cf. Knapp 1985 and references therein). Both have very small ionized masses and thick neutral envelopes, with mass ratios of molecular to ionized matter greater than 100, much larger than found here for the evolved nebulae. Thus for the nebulae in which CO has been detected, the observed trend is for lower molecular to ionized masses for the more evolved nebulae. This is in accord with the work of Pottasch (1980), who has shown statistically that the ionized masses of planetary nebulae increase with radius, and interprets this as indicating a reservoir of neutral material which becomes ionized as the nebulae expand. The results described here provide support for the picture in which the formation and evolution of planetary nebulae are directly controlled by the ionization of circumstellar material commonly seen around their red giant precursors.

Further details of this work can be found in Huggins and Healy (1986a, and 1986b).

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REFERENCES

Huggins, P. J., and Healy, A. P. 1986a, Ap. J.(Letters), 305, L29.
Huggins, P. J., and Healy, A. P. 1986b, M.N.R.A.S., 220, 33p.
Knapp, G. R. 1985, in "Mass Loss from Red Giants", eds. M. Morris and B. Zuckerman (Dordrecht: Reidel), p171.
Pottasch, S. R. 1980, Astr. Ap., 89, 336.