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MOLECULAR ENVELOPES OF PLANETARY NEBULAE AND PROTO-PLANETARY NEBULAE

SUN KWOK
Dept. of Physics & Astronomy, U. of Calgary, Calgary, Canada T2N 1N4

INTRODUCTION

As stars evolve up the asymptotic giant branch (AGB), they begin to lose mass at a high rate, and in the process they create extended circumstellar molecular envelopes. Since the transition from AGB to planetary nebula stages is of the order of 1000 yr, the remnant of such molecular envelopes should still be observable in proto-planetary nebulae (PPN) and planetary nebulae (PN). Recent ground-based survey of cool IRAS sources have discovered ~30 candidates of PPN (Kwok 1992). These sources show the characteristic "double-peak" energy distribution. The cool component is due to the remnant of the AGB dust envelope, and the hot component represents the reddened photosphere. The fact that the two components are clearly separated suggests that the dust envelope is well detached from the photosphere. Radiative transfer model fits to the spectral energy distributions of PPN suggest a typical separation of ~1 arc sec between the dust envelope and the photosphere, and such "hole-in-the-middle" structure can be mapped by millimeter interferometry in CO.

CO IN PLANETARY NEBULAE AND PROTO-PLANETARY NEBULAE

The picture that the molecular envelope is detached can also be tested by the profiles of the CO emission. Figure 1 shows the JCMT CO J=3→2 spectrum of the compact planetary nebula IC 5117 (Kwok & Woodsworth 1993). The profile shows two strong wings and a dip in the center. This is consistent with CO emission originating from a shell of inner radius of 10.4 arc sec and an outer radius of 16 arc sec. In comparison, the radio continuum map of IC 5117 shows an angular radius of ~1 arc sec (Aaquist & Kwok 1991).

IC 5117 is known to be a very young PN from its energy distribution (Zhang & Kwok 1991). Most of the observed energy from the object is in the infrared from the dust envelope. This suggests that the molecular envelope is still intact, and the strong infrared excess is consistent with the strong CO emission observed.

THE FUTURE

The evolution from AGB to PPN to PN can be traced not only in the infrared (Kwok 1990) but also from the change in the CO profiles. As the molecular envelope expands away from the photosphere, the CO line will change from a flat top to a double-peaked profile. Future millimeter wave interferometry will allow imaging of the molecular envelope and provide direct observation of the nebular expansion during this previously poorly-understood phase of stellar evolution.

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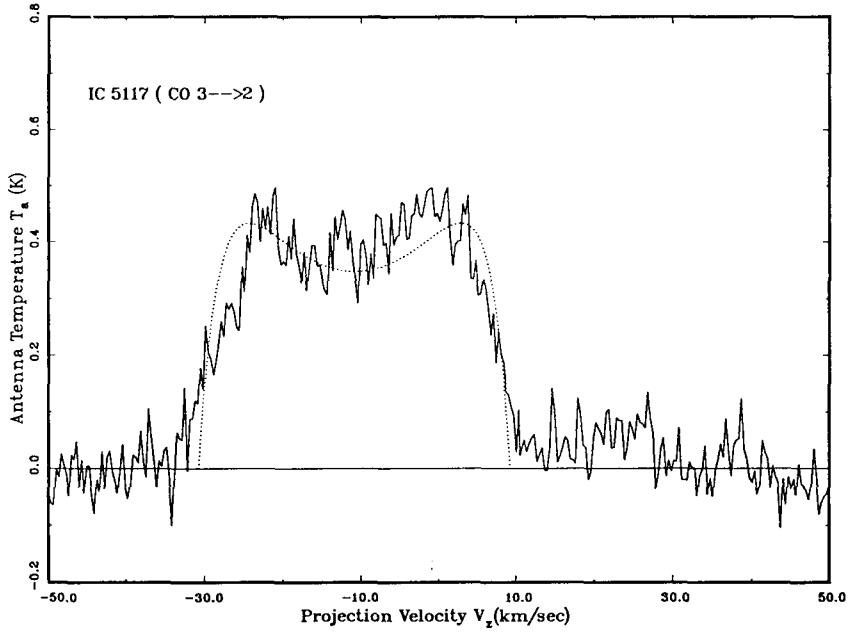

Fig. 1. CO (J=3-2) spectrum of IC 5117. The FWHM beamsize is 16 arc sec. The dotted line is the model curve used to derived the outer and inner radii.

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