A Self-Consistent Photoionization-Dust Continuum-Molecular Line Transfer Model of NGC7027

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A model to simulate the entire spectrum (1000 Å to 1 cm) of the high-excitation young planetary nebula NGC 7027 is presented. The ionized, dust, and molecular components of the object are modeled using geometric parameters obtained from visible, radio, infrared, and CO data. The physical processes considered include recombination lines of H and He, collisional excited lines of metals, bf and ff continuum radiations, two-photon radiation, dust continuum radiation, and molecular rotational and vibrational transitions. The dust component is assumed to be heated by a combination of direct starlight and the line and continuum radiation from the ionized nebula. The molecular component of the nebula is coupled to the dust component through the stimulated absorption of the dust continuum radiation. Specifically, we compare the predicted fluxes of the CO rotational lines and the 179.5 μm water rotational line to those observed by the Infrared Space Observatory satellite (Liu *et al.* 1996, A&A in press).

The model draws upon previous studies of the dust and the ionized region (Hoare, Roche, and Clegg 1992; MNRAS, 258, 257) and of the CO molecular emission (Jaminet *et al.* 1991; ApJ, 380, 461) plus the available information about the central star temperature (Heap and Hintzen 1990, ApJ, 353, 200) and the distance (Masson 1989; ApJ, 336, 294). The combined photoionization/dust radiative transfer solution was constrained mainly by the radio angular size, the radio flux densities at 2mm and 5 GHz, the continuum level at 170 μm and the total infrared flux. The radiation field from these models was then used for the molecular emission modeling.

The observation of the high CO rotational transitions by ISO requires the presence of a thin, high density ($\approx$ 20 times the ionized region density) and high temperature (T $>$ 220 K) shell between the ionized region and the wind region of the molecular shell. This high density shell contains about 10% of the total neutral mass. Once these parameters had been established the H_2O molecular model was run with various H_2O/CO number ratios assuming that the two species are uniformly mixed in the gas. In order to reproduce the observed 179.5 μm H_2O/186.0 μm CO line ratio of 0.61, a water number abundance fraction of $3.2\,10^{-7}$ compared to H_2 is needed. We take the line strength ratio to be uncertain by $\pm 10\%$ thus this water abundance has an uncertainty of about $\pm 35\%$.

We examined the relative contributions of the various layers to the water line and we find that the water abundance may be higher if water is restricted to certain regions of the molecular shell. However it is unlikely that water exists only in the outer parts or only in the high density part of the neutral shell because the required abundances would be large in both cases. We predict that the 108.1 μm water line is the best one to use to deduce a water abundance.