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Modeling the circumstellar structure of Water Fountain evolved stars

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Abstract

"Water Fountain" (WF) sources are late asymptotic giant branch (AGB) and post-AGB stars with high-velocity water maser emission ($> 50\,\mathrm{km/s}$) that traces the earliest known manifestation of collimated mass ejection in evolved stars. Optical and mid-infrared observations with high angular resolution toward these sources typically reveal a bipolar structure, with a dark equatorial waist that might correspond to a torus. These features are surrounded by an extended and optically thick dusty envelope, whose emission dominates the far infrared wavelength range. However, the presence of either a disk or a torus could be better traced at mm and submm wavelengths where the envelope is optically thin and, therefore, one can probe the innermost regions.
There are 14 WF sources identified to date. We report 1.2 mm observations, carried out with the IRAM 30 m telescope, of eight WF sources. We also report 3 mm and 3.3 mm observations, carried out with the Australia Telescope Compact Array (ATCA), of five WF sources. Using these data, together with observations at shorter wavelengths taken from literature, we built the spectral energy distribution (SED) between 0.8 and 3300 μm of the sources observed at mm wavelengths. We fitted the broad band SEDs with radiative transfer models that include a star, a circumstellar disk or torus, and an expanding shell. The modeling of the sources allows us to estimate physical parameters of the components, such as masses, sizes, dust grain properties, and geometry. Our radiative transfer models indicate that, in order to fit the SED at IR wavelengths a massive envelope ($\sim 2\,\mathrm{M}_\odot$) is requiered, while to fit the data at longer wavelengths, a very massive disk ($>>2\,\mathrm{M}_\odot$) is needed. Thus the availability of data over a wide wavelength range has allowed us to trace structures that we would be missing otherwise. Considering that post-AGB stars evolve from progenitors of $0.8 - 8\,\mathrm{M}_\odot$, our results suggest that progenitors of WFs are relatively massive ($> 4\,\mathrm{M}_\odot$) within that range. This is consistent with WFs being the precursors of bipolar planetary nebulae.