IAUS-REG-NUMBER: IAUS-151
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TITLE: ALMA Imaging of Planetary Nebulae
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ABSTRACT:
Planetary nebulae (PNe) were historically considered to be hostile environments for molecules, with chemical models predicting that their abundances would be notably depleted within the first ~1000 years. However, observations over the last couple of decades have shown that not only can molecules survive these harsh conditions, but their abundances remain relatively constant over the lifetime of the PN. These species are primarily identified through measurements of their rotational transitions at millimeter and sub-millimeter wavelengths. Given the large beam sizes and comparatively small angular sizes of the PNe, spatial information about the distribution of these molecules is unavailable from single-dish observations alone. Thus, we have imaged five bipolar/quadrupolar nebulae (K3-45, K3-58, M1-7, M2-48, and M3-28) in CO using the Atacama Large Millimeter Array (ALMA). A subset of these nebulae (M1-7, M2-48, and M3-28) were also imaged in HCN and HCO+. These observations indicate that the molecular distributions are strikingly different from their optical counterparts; specifically, it appears that they are concentrated in a smaller region near the PN's center. Analysis suggests that this molecular material may play an important role in PN shaping. In particular, a roughly spherical molecular distribution may have been disrupted by bipolar/multipolar outflows generated at the central star, allowing ionized matter to be blown through the remnant molecular material.