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Multi-transitional SHAPEMOL modelling of M1-92: the discovery of a shock excited hot molecular component.

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Abstract

M1–92 is a well-studied pre-planetary nebula characterized by a bipolar appearance with a high degree of axial symmetry. It consists of a thick equatorial structure dividing the two emptied lobes. The nebula is rich in molecular gas and dust, with a total mass $\sim 1\,M_\odot$, except for two knots in the middle of the lobes where there is ionized gas as a result of shocks, as proved by the detection of optically forbidden lines and vibrationally excited H_2. We present the most complete and detailed modelling of M1–92, using ^{13}CO, $C^{17}O$, and $C^{18}O$ J=2–1 NOEMA maps with 0.″7 resolution, and single-dish data for ^{12}CO J=1–0, J=2–1, J=3–2, J=5–4, J=7–6, and J=9–8, and for ^{13}CO, $C^{17}O$, and $C^{18}O$ J=1–0 and J=2–1 (from IRAM 30m, CSO, and HSO/HIFI). The modelling is performed using `SHAPE+shapemol`, computing the excitation of CO using the LVG approximation and solving the radiative transfer problem via ray tracing. We have derived the nebular structure, the density and temperature distributions of the different molecule-rich components, and the $^{12}C/^{13}C$ and $^{16}O/^{17}O/^{18}O$ ratios. These ratios confirm the hypothesis that the nebula is the result of a 1200 yr old sudden mass-loss event, leading to the premature end of the AGB phase of the central star (probably as a consequence of a common-envelope event).
The fitting of the high-J lines of CO requires a new molecular component that is relatively hot, 700–900 K, in striking contrast with the rest of the molecular gas. There are no maps of these transitions: we suggest that this component could be the molecular counterpart of the shocked knots seen in optical forbidden lines and vibrationally excited H_2.

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