

CARMA CO($J = 2 - 1$) Observations of the Circumstellar Envelope of Betelgeuse

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We report radio interferometric observations of the $^{12}\text{C}^{16}\text{O}$ 1.3 mm $J = 2 - 1$ emission line in the circumstellar envelope of the M supergiant α Ori and have detected and separated both the S1 and S2 flow components for the first time. Observations were made with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) interferometer in the C, D, and E antenna configurations. We obtain good $u - v$ coverage (5–280 k λ) by combining data from all three configurations allowing us to trace spatial scales as small as $0''.9$ over a $32''$ field of view. The high spectral and spatial resolution C configuration line profile shows that the inner S1 flow has slightly asymmetric outflow velocities ranging from -9.0 km s^{-1} to $+10.6 \text{ km s}^{-1}$ with respect to the stellar rest frame. We find little evidence for the outer S2 flow in this configuration because the majority of this emission has been spatially-filtered (resolved out) by the array. We also report a SOFIA-GREAT CO($J = 12 - 11$) emission line profile which we associate with this inner higher excitation S1 flow. The outer S2 flow appears in the D and E configuration maps and its outflow velocity is found to be in good agreement with high resolution optical spectroscopy of K I obtained at the McDonald Observatory. We image both S1 and S2 in the multi-configuration maps and see a gradual change in the angular size of the emission in the high absolute velocity maps. We assign an outer radius of $4''$ to S1 and propose that S2 extends beyond CARMA’s field of view ($32''$ at 1.3 mm) out to a radius of $17''$ which is larger than recent single-dish observations have indicated. When azimuthally averaged, the intensity fall-off for both flows is found to be proportional to R^{-1} , where R is the projected radius, indicating optically thin winds with $\rho \propto R^{-2}$.

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