R03a Volume density structure of the NGC 253 CMZ through ALCHEMI excitation analysis

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We report a spatially-resolved excitation analysis for the central molecular zone (CMZ) of the starburst galaxy NGC 253 with the ALMA Large program ALCHEMI, whereby we explore parameters distinguishing NGC 253 from the quiescent Milky Way's Galactic Center (GC). Non-LTE analyses employing a hierarchical Bayesian framework are applied to Band 3–7 transitions to delineate the position–position–velocity distributions of column density ($N_{\rm H_2}$), volume density ($n_{\rm H_2}$), and temperature ($T_{\rm kin}$) at 27 pc resolution. Two distinct components are detected: a low-density component ($n_{\rm H_2} \sim 10^{3.3}$ cm^{-3}) and a high-density component with ($n_{\rm H_2} \sim 10^{4.4}$ cm^{-3}), separated at $n_{\rm H_2} \sim 10^{3.8}$ cm^{-3}. NGC 253 has ∼10 times the high-density gas mass and ∼3 times the dense-gas mass fraction of the GC. These properties is consistent with the HCN/CO ratio but cannot alone explain the factor of ∼30 difference in their star formation efficiencies (SFEs), contradicting the dense-gas mass to star formation rate scaling law. The $n_{\rm H_2}$ histogram toward NGC 253 exhibits a shallow declining slope up to $n_{\rm H_2} \sim 10^6$ cm^{-3}, while that of the GC steeply drops in $n_{\rm H_2} \gtrsim 10^{4.5}$ cm^{-3}. Their dense-gas mass fraction ratio becomes consistent with their SFEs when the threshold $n_{\rm H_2}$ for the dense gas is taken at $\sim 10^{4.2–4.6}$ cm^{-3}. The rich abundance of gas above this density range in the NGC 253 CMZ, or its scarcity in the GC, is likely to be the critical difference characterizing the contrasting star formation in two galactic centers.