N39a Refining Parameters and Assessing Predictive Capability in Müller's Model

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Understanding whether massive stars can undergo supernova explosions is crucial for predicting stellar endpoints, tracing heavy-element synthesis and distribution, and assessing the role of supernova feedback in galaxy evolution. Although detailed explosion models have succeeded under specific conditions, simplified models are often needed for large-scale parameter studies or rapid evaluation of progenitor structures. This work examines the approximate framework proposed by Müller et al. (2014, 2016) as a tool to analyze the link between progenitor structure and explosion characteristics. The model incorporates multidimensional effects without full-scale simulations by introducing key parameters such as the turbulent pressure correction $\alpha_{\rm turb}$, neutron star cooling timescale $\tau_{1.5}$, and gravitational-to-neutrino conversion efficiency ζ, allowing approximate predictions of explosion energy and remnant type. We applied this model to a series of progenitors to study explosion criteria and energies, and compared results with 3D simulations from Burrows et al. (2024). Through this comparison, we identified the optimal parameter settings and discussed their physical significance. We revised the value of $\tau_{1.5}$ to 2.0, consistent with the detailed neutrino transport results of Hüdepohl (2014). Furthermore, incorporating Takahashi's (2023) diagnostic $M_{\rm ff}$, we found that $\alpha_{\rm turb}$ can be approximated as a bivariate function of $M_{\rm ff}$. Our revised expression improves agreement with the results of the 3D simulation, especially for progenitors in the 9–11 $M_\odot$ range. These results provide a foundation for evaluating explosion outcomes in future massive star models.