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Improving Astrophysical Nuclear Rates with New Many-Body and Fewer-Body Reaction Models

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Nuclear and particle astrophysics has long relied on relatively crude models of nuclear reaction rates, because computational methods are lacking for systems of more than two particles and because empirical constraints on simplified models are scarce. *Ab initio* methods, which model nuclei using a quantitatively accurate nucleon-nucleon interaction and reasonably complete model spaces, now offer alternatives to the traditional reaction-by-reaction or systematics-based phenomenology. Particularly at $A < 12$, there are now theoretical cross sections grounded directly in nucleon-level physics. I will give a quick overview of this work to date, emphasizing the significant further investments in each *ab initio* approach that are needed to produce accurate results with quantified errors. I will then argue that in the long run, these methods are unlikely to deliver astrophysical rates of the desired precision without inputs beyond the nucleon-nucleon interaction: rates are too sensitive to "finely tuned" numbers like threshold and resonance energies. It is therefore urgent to develop methods that can consistently incorporate complementary information from both *ab initio* and empirical data into "fewer-body" models like the empirical R-matrix or halo effective field theory (EFT), particularly in combination with Bayesian methods to provide quantified errors. I will illustrate this point with applications of halo EFT to rates in the solar pp-chain.

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