SIMPLIFYING NUCLEAR REACTION NETWORKS WITH PARTIAL EQUILIBRIA

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One of the principal difficulties in performing nucleosynthesis calculations beyond carbon burning is the computational cost and memory footprint of large nuclear networks. This problem is exacerbated in the multidimensional simulations that are coming to dominate our understanding of the many astrophysical locales where nucleosynthesis occurs. Our understanding of Quasi-Equilibrium (QSE) and other partial equilibria open the possibility of reducing the size of the nucleosynthesis calculation without reducing its accuracy or sensitivity to the temperature, density, or degree of neutronization. To evolve the abundances of every member of an equilibrium group, it is sufficient to evolve the abundance of any one member along with the abundances of the free nucleons. One can thereby calculate the abundances of all members of an equilibrium group and the resultant reaction rates, but one need evolve a much smaller set, resulting in a more computationally efficient method that still retains the accuracy of the full network and yields abundances for all nuclei found in the full network. The first application of this method is a QSE-reduced α-network.[4,5] Application of QSE results in a network that is twice as fast and has half the memory requirements of the minimal α-chain network it replaces, without significantly affecting the nuclear evolution. Development of a more complete QSE-reduced network proceeds. Preliminary results[6] indicate decreases of factors of 3–5 in computational cost. Future work will refine this method and extend it to other partial equilibria; for example, the $(n,\gamma)(\gamma,n)$ equilibrium present during the r-process. We also plan to apply this method to the many places where nucleosynthesis occurs with temperatures sufficient for partial equilibrium.

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