

gestions have invoked mixing due to rotational effects. However, we know from seismological measurements of the Sun that its core is essentially in solid-body rotation. This precludes rotational mixing as an important process at some distant time in the future when the Sun evolves into a giant star.

The elegant new insight provided by Eggleton *et al.* is that the distribution of ^3He itself plays a key role in driving this additional mixing by establishing a distribution of ^3He in the star that is susceptible to a Rayleigh-Taylor instability. This is similar to the well-known instability in everyday life where a dense fluid on top of a lighter fluid leads to the mixing of the two fluids. Even though the unstable gradient produced by ^3He is tiny, the authors demonstrate, using three-dimensional, hydrodynamic stellar calculations, that this leads to rapid mixing and the destruction of ^3He .

These calculations are some of the first results of an ambitious project led by Eggleton and Dearborn at the Lawrence Livermore National Laboratory (LLNL) to realistically model stars in three dimensions using a computer code named “Djehuty.” The important difference between Djehuty and all other stellar evolution codes is the inclusion of three-dimensional hydrodynamics, which can account self-consistently for mixing and non-spherical effects. This is a step requiring a

great deal of effort in both code development and computational brute force.

These results highlight the importance of improving the underlying physics in stellar models, especially because the driving physics in this particular case would be easy to ignore; this apparently minor consideration can be seen to have very important results.

Djehuty is still a work in progress: Impressive though their work already is, to model binary stars they will require an aspherical gravitational potential and will need to increase the number of hydrodynamic mesh points they use in the simulation by four orders of magnitude (3). Even the addition of rotation will cross another interesting threshold.

Stars cannot yet be genuinely evolved through their lifetimes with Djehuty, even with the computing resources at LLNL; in fact, the calculations presented by Eggleton *et al.* contain less than a day’s worth of stellar evolution. To put this in perspective, for Eggleton’s one-dimensional stellar evolution code, “an evolutionary sequence requires about 60 min from the main sequence to the helium flash”—and that was in 1971 (4). It will be a very long time before three-dimensional stellar evolution calculations can be done as rapidly and routinely as today’s one-dimensional codes.

The example of the ^3He problem and its resolution illustrates that, to understand the origin and evolution of the universe, we need to understand stars, and vice versa. In particular, the predictions of Big Bang nucleosynthesis have pointed to a problem in stellar modeling. On the other hand, there are many examples where an understanding of stars in the local universe would lead to a better understanding of the evolution of the universe and its constituents on the large scale. Besides the ^3He problem, there is also a ^7Li problem. The Big Bang prediction of the ^7Li is at least a factor of 2 higher than is observed in metal-poor stars (5), and in this case extra mixing cannot provide a simple explanation. Undoubtedly, the resolution of this puzzle will provide new insights into the physics of stars, the Big Bang, or even both.

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CHEMISTRY

Pulling Strings

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Computing devices, like the information they process, are embodied in a material substrate constrained by the laws of physics (1). The design of modern computing devices has nevertheless succeeded to a remarkable extent in separating hardware from software and questions specific to physics from questions specific to computation. In such a setting, abstract formalisms of the kind envisioned by Turing (2) can justifiably ignore the nature of materials and issues such as energy dissipation and material stability.

However, this separation between hardware and software—and hence physics and computation—breaks down when device features approach atomic scales or when the devices that process information are of the

same class as the information itself. How, then, can we realize computation in the world of molecules and their chemical reactions? On page 1585 of this issue, Seelig *et al.* (3) provide an answer to this question.

One way to formally express computation is in terms of rules that rewrite words. Molecules, like words, are combinatorial structures, and chemical reactions can provide the required rules, if we can program chemistry. To exert the necessary control over chemistry, we must be able to specify which components in a mixture of molecules interact when, and where. This control can be achieved by designing appropriate single-stranded DNA (or RNA) sequences that bind to each other like Velcro’s hook and loop fasteners, but in an addressable manner. Based on this idea, Seelig *et al.* exploit a simple principle—strand displacement—to implement not just logic gates, but also a toolkit of devices for building molecular circuits of a digital kind.

A toolkit of DNA-based devices can be used for computational circuits.

In the past decade, DNA (or RNA) sequences have been used to find solutions to combinatorial problems by self-assembly (4), to encode complete decision trees for simple games like tic-tac-toe (5), and to build programmable sensors of cellular states (6). DNA has also been used to build nanostructures and nanomechanical devices (7, 8), as well as two-dimensional grids that can function as frames of reference for placing such devices at specific locations (9). For example, Seeman and co-workers (10) have developed a rotary device that consists of two DNA strands woven into two pairs of helices, with a flexible hinge region in between. This device can act as a programmable, molecular-scale robot arm. On page 1583 of this issue, Ding and Seeman (11) report the deliberate, function-preserving placement of such a device in a two-dimensional array of DNA tiles.

There are two reasons for the versatility of

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