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# Djehuty: a Code for Modeling Whole Stars in Three Dimensions[1]

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**Abstract.** The DJEHUTY project is an intensive effort at the Lawrence Livermore National Laboratory (LLNL) to produce a general purpose 3-D stellar structure and evolution code to study dynamic processes in whole stars.

## 1. Introduction

Stellar models in 1-D work remarkably well for most stars. However, stars are three dimensional objects and the computing power is now at a point where we can do better than 1-D models for modeling the large array of physical processes occurring in stars for which spherical symmetry is no longer a valid approximation. With a 3-D stellar code one can tackle the problems linked to rotation, turbulent motions and convection, magnetism, binarity, and explosive phases of stellar evolution in a consistent and physically meaningful way.

The DJEHUTY code is an evolution of a radiation hydrodynamics code developed over decades at LLNL. It is our goal to provide the astrophysical community with the first general purpose 3-D stellar structure and evolution code suitable to study the whole gamut of dynamical processes occurring in stars.

## 2. The DJEHUTY code

At the heart of DJEHUTY is an Arbitrary Lagrangian-Eulerian (ALE; Barton, 1985) code for radiation hydrodynamics which treats radiation transport in the diffusion approximation. Microscopic physics appropriate for stars has been added. The opacities used are those of OPAL (Iglesias & Rogers, 1996) for high temperatures and Alexander (Alexander & Ferguson, 1994) for low temperatures. A set of Planck opacities computed from the OP data (Seaton et al., 1994) is being used within the hydro code to couple the radiation to the matter.

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An improved version of the EFF equation of state (Eggleton et al., 1973) is implemented. Full nonaxisymmetric gravity will be implemented shortly using a Heine boundary solver combined with Djehuty radiation diffusion solvers being used for solving Poisson's equation. Finally, a general nuclear network (Dearborn, 1992) is operational. Eventually, a chemical network may be added and a more general calculation for opacities should be implemented.

The star is divided in seven logical cubes. Six of the cubes are arranged and deformed into a spherical (or spheroidal in the general case) shell around a central cube. The central cube is subdivided in $N^3$ elements and the outer cubes are subdivided in $N^2\times$ an arbitrary number of radial elements, typically $2N$ in calculations done so far. This mesh structure was chosen to avoid singularities and poles. As the numerical scheme is currently explicit, time steps are limited by the Courant condition but an implicit method is being investigated.

The starting model for computations is a 1-D model mapped on the 3-D grid. Since the 3-D mapping does not result in a perfect hydrostatic 3-D star, the model readjusts itself. Tests show that a new equilibrium is attained quickly. As the star evolves, convection and other hydrodynamical processes will establish themselves naturally.

A complete paper detailing the physics and numerics of the code is in preparation.

## 3. First results and future science

Apart from test problems, the code has so far been applied to a 4 $M_\odot$ star on the main sequence in the goal of studying core convection and overshoot. This issue is well suited to the code as it stands now, as our maximum spatial resolution is achieved in the stellar core. It is also one of the more fundamental theoretical problems in modern astrophysics. Preliminary results show the start of convective motions which do extend outside the limit of the convective cores that are typical of 1-D models. Some models with rotation have been computed but the results are too preliminary so far to draw any conclusion on the interaction of convection and rotation.

Close binaries will be the subject of our efforts in the near future. Current plans call for a point-like secondary as a first effort, followed by calculations where both members of the system are in the computational domain, including dynamics in both stars as well as mass transfer.

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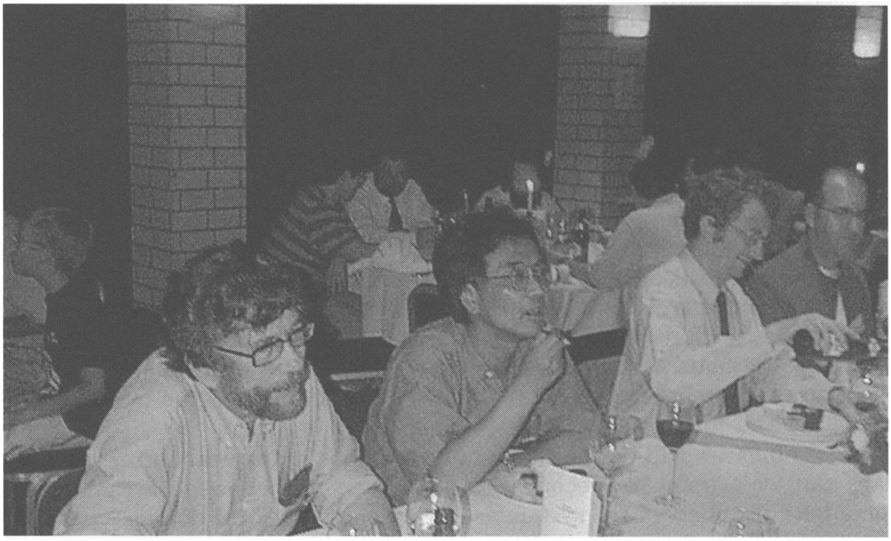

Jean-Paul Zahn, Hideyuki Saio and Geert Molenberghs (= Mr. Aerts, the fortunate husband of the LOC chairwoman) are eating their desert, as anybody else in the room, except for the SOC chairman (3rd from the left) who clearly prefers yet another drink first ...

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