UNIVERSIDAD DE GRANADA

FACULTAD DE CIENCIAS

Propuesta TFG. Curso 2024/2025

GRADO: Doble Grado en Física y Matemáticas

CÓDIGO DEL TFG: 295-024-2024/2025

1. DATOS BÁSICOS DEL TFG:

Título: Solving the stiff system of ordinary differential equations in stellar evolution

Descripción general (resumen y metodología):

Stellar evolution is one of the key problems in computational astrophysics as it requires to solve a big set of highly coupled differential equations, namely: (4 + N)xM equations. More specifically, 4 and N are the numbers of equations describing the physical structure and the chemical evolution (one for each isotope), respectively. Note that even with the most advanced supercomputers is still not possible to carry on 3 dimensional simulations of the evolution of a stellar structure through its entire lifetime. Then, spherical symmetry is usually assumed, dividing the star in M radial shells (mesh points). During the late evolution of a star, several hundreds of isotopes are involved in a complex nuclear network made of thousands of nuclear reactions. The coefficients in the differential equations span many orders of magnitude due to the exponential dependence of nuclear reactions with temperature. In practice, for each time step, the numerical problem consists in finding the simultaneous solution of about 10^5-10^6 differential equations.

Implicit numerical solutions are usually preferred. Note that since each isotope is usually connected to its neighbors (i.e., isotopes with not too much different atomic weight and atomic number), the matrix of the coefficients of the system has a band diagonal form, and most of its elements are zero. Thus, the solution of this system of differential equations may be widely speeded up by applying specific algorithm for sparse matrix algebra.

We will compare different solvers, their accuracy and speed for different densities, temperatures and chemical compositions, typical of different stellar masses and evolutionary phases. We will also compare the performance of the various methods using different nuclear networks, with varying number of isotopes and nuclear reactions.

Tipología: Estudio de casos, teóricos o prácticos, relacionados con la temática del Grado.

Objetivos planteados:

The aim of this work is to compare accuracy and computational time consuming of different methods used to solve the stiff system of coupled ordinary differential equations that describe the physical and chemical evolution of stars. This will be done for different nuclear networks and stellar models.

Bibliografía básica:

Kippenhahn, R. and Weigert, A., "Stellar Structure and Evolution", 1990, Springer-Verlag, Astronomy and astrophysics library, isbn 9783540580133.

Chieffi, A., Limongi, M. & Straniero, O., The Astrophysical Journal, Volume 502, Issue 2 (1998). https://ui.adsabs.harvard.edu/abs/1998ApJ...502..737C/abstract

Paxton, B. et al., The Astrophysical Journal Supplement, Volume 192, Issue 1 (2011). https://ui.adsabs.harvard.edu/abs/2011ApJS..192....3P/abstract

Timmes, F., The Astrophysical Journal Supplement Series, Volume 124, Issue 1 (1999).

Recomendaciones y orientaciones para el estudiante:

Plazas: 1

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