An Introduction to Webnucleo: A Webgate for the Masses

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Abstract

In this paper, we introduce Webnucleo.org

Introduction

Numerical tools have been the bread and butter for conceptual understanding and order of magnitude estimates for scientists since the 50s. With advancements in processing power, memory management, and internet access, numerical tools and programming languages proliferated the scientific community. Each subfield in scientific community has a niche set of algorithms and codes to work with. With accessibility and ease of use in mind, the Webnucleo team, based in the department of physics and astronomy at Clemson university, has built a webgate of codes that focus on applications in astrophysics that can be found at www.webnucleo.org. Specifically, our applications focus on nuclear astrophysics, nucleosynthesis, stellar evolution, astronomy, and cosmochemistry. We are producing a number of products that researchers, educators, and students may find useful in studying the aforementioned topics of interest. These products include open-source codes, Docker images, and Jupyter notebooks.

To be a true webgate for the masses, we house the codes themselves in GitHub repositories controlled by the authors and are published under GPL-3.0 licenses. They are open source and contributions to the codes can be done through GitHub. Webnucleo.org itself is hosted on Read The Docs, a platform which is easy to navigate. Interested groups may contribute any developed tools in the field to the webgate by simply submitting a ticket through webnucleo.org.

The codes added to the webgate are all self-contained within their respective environments. Simply put, there is no elaborate package and library management required. Should the tool you are looking at requires any particular package, either explicit documentation is provided or the tool will automatically handle the installation. The remainder of the paper highlights the Jupyter notebooks currently available, which are categorized as nucleosynthesis, stellar structure, and webnucleo XML building.

Nucleosynthesis

Since its postulation by Eddington in 1920, nucleosynthesis has expanded beyond simple nuclear fusion to include a plethora of capture and decay processes, whose prevalence is determined by the thermodynamic properties of the environment. The Webnucleo team is primarily a thermonuclear astrophysics group, so naturally understanding mainline stellar nucleosynthesis is foundational to understand energy production in stars. The first notebook describes precisely that. It utilizes a simplistic temperature and density model to help describe core nuclear fusion in stars. It illustrates core burning in all mass ranges, covering all the way from Hydrogen to Silicon burning.

Nuclear fusion however, is insufficient to create nuclei heavier than iron. For that, other capture processes are required. Within the lifetime of the star, one such process occurs. The slow neutron capture process, s-process, occurs during thermal pulsations in the asymptotic giant branch of low and intermediate mass stars, and in the shells of massive stars beyond Hydrogen burning. The process itself is slow since in the time between neutron captures, β- decay may occur, creating heavier species. Multiple notebooks have been devloped to analyze

Stellar Structure

Understanding the environment in which nucleosynthesis occurs helps put things in context. Stellar modeling in and of itself is quite an intricate undertaking. Building a code that solves the coupled stucture equations, determines the appropriate opacity, calculates the thermodynamics, and handles the nuclear network is quite the challenge.

Webnucleo XML

To study different effects on nucleosynthesis, the webnucleo team uses libnucnet. It is an in-house network developed by Prof. Bradley S. Meyer over the years. The network itself uses the JINA reaction rates and can run s and r-process calculations after setting the appropriate initial conditions. The code itself utilizes XML format for data structuring and allows users to vary rates and abundances easily by simply using their own XML files as input for the network.

To create such XML files, a series of notebooks have been written to easily illustrate their construction, and another to visualize the newly created XMLs.

Final Remarks

At the time of writing, the webgate seems rather limited. Notebooks and other packages are constantly being polished and added to the webnucleo.org. As

mentioned, the use for these packages are not strictly for research, but can also be utilized in the classroom as visual aids, or for students and enthusiasts alike to test and tweak parameters in a simple environment that does require much experience in programming. This accessibility allows anyone with sufficient background to understand these involved subjects and have read-to-use tools at their finger tips.