`StarStruc.jl`: Stellar structure in Julia

Asher Wasserman

1 Introduction

This document presents a description of a static stellar structure model implemented in `Julia`, a high-performance dynamical programming language. The accompanying code can be found at `https://github.com/adwasser/StarStruc.jl`. For carefully considered initial guesses as to the boundary values, the code should converge on a structure model on the order of a few minutes.

2 Background

Stars are fearsome beasts, so we tame them by introducing some simplifying assumptions. We model stars as non-rotating, time-independent, uniform composition, spherically symmetric cows. Such domesticated animals still can pose numerical dangers to reckless star-cow wranglers, however.

We assume that the star is a fully ionized ideal gas, so its equation of state is

$$P(\rho, T) = \frac{\rho}{\mu m_H} kT$$

where

$$\mu = \frac{1}{1 + 3X + Y/2}$$

is the dimensionless mean molecular weight for hydrogen mass fraction, X, and helium mass fraction, Y. With this equation of state, our simple equations of stellar structure are

$$\frac{\partial r}{\partial m} = \frac{1}{4\pi r^2 \rho}$$
$$\frac{\partial \ell}{\partial m} = \epsilon_n$$
$$\frac{\partial P}{\partial m} = -\frac{Gm}{4\pi r^4}$$
$$\frac{\partial T}{\partial m} = -\frac{GmT}{4\pi r^4 P}\nabla$$

Here, ϵ_n is the nuclear burning luminosity per unit mass, a quantity that is dependent on temperature, density and composition,

$$\nabla = \frac{T}{P}\frac{\partial T}{\partial P} = \begin{cases} \nabla_{\text{ad}} & \nabla_{\text{rad}} \geq \nabla_{\text{ad}} \\ \nabla_{\text{rad}} & \nabla_{\text{rad}} < \nabla_{\text{ad}} \end{cases}$$

For our assumed ideal gas, ∇_{ad}, and from a diffusive radiative transport model,

$$\nabla_{\text{rad}} = \frac{3}{16\pi a c G}\frac{\kappa \ell P}{m T^4}$$

3 Methods

4 Results

5 Conclusions