CSI 661 / ASTR 530 Spring 2009
Astrophysics

Project: Numerical Modeling of Stellar Structure and Evolution

Assignment date: April 6, 2009
Due date: April 29, 2009

1. Introduction

The structure and evolution of a star can be understood from a combination of physical laws we know, including mechanics, thermodynamics, thermal statistic, atomic physics and nuclear physics. The mathematic solution can be obtained from a set of equations that describe these laws. We have experienced with various exact analytic solutions, but with certain assumptions, some of which are unrealistic. In order to obtain a realistic model of a star, numerical solution is needed to solve a set of coupled differential equations. In this project, you are asked to solve numerical models to study the structure of a star and its evolution with time.

2. Description

(a) Paczynski Numerical Model

The Paczynski model is a well-established numerical model of stellar structure and evolution. It is implemented in FORTRAN, a computer language widely used in scientific community. The codes are provided in the CD-ROM attached with the textbook. It is in the directory "PACZYNSKI". For a description of the codes, please refer to the file "readme.txt". Basically, it has three modules, and you need to compile and run the code in each of these modules.

(1) Module 1 – k02. The code is in "k02.f". It makes a table of an envelope model for fixed X (Hydrogen mass fraction) and Z (metal mass fraction). The default output file is "envopa".

(2) Module 2 – s02. The code is "so3.f". It constructs a ZAMS model using the fitting method (described in Chap. 7). The default output file is "mod0000.h03"

(3) Module 3 – h03. The code is "h03.f". It calculates the evolution of a star. The default output file is "evol.h03".

Since the Paczynski model treats only hydrogen burning, the evolution starts from the ZAMS and ends before the helium burning. As a result, the later stages, e.g., the Red Giant stages and white dwarfs are not included.

(b) Tasks

You are asked to model a star with a particular mass and composition, determined by M, X and Z as the input to the codes. The mass shall be some number between one and ten.

Each person in the class should choose a different mass to start with.

The run of the codes depends on the successful run of an earlier module. Therefore, you should start from k02, then s02 and finally h03. You need to look into the numeric codes, in particular, the head instruction part in order to understand what exactly the codes are doing, and what physics are involved. There is no need to modify the codes unless necessary.

You need to compile the code, run the code, input the required parameter, get the output and analyze the results. First, you need to analyze “mod000.h03” for the purpose of understanding the result of the ZAMS model. Secondly, you need to analyze “evol.03” in order to understand the evolution.

(c) Resources

There are various online resources for using FORTRAN. You may consult any of them to get the job done. Here is a small list to start your adventure. The version of compiler you need is “f77”. The latest versions are “f90” and “f95”, which may not be necessary.

(1) The FORTUNE company: http://www.fortran.com/
(2) One F77 Tutorial: http://www.stanford.edu/class/me200c/tutorial_77/

The basic command line operations in LINUX (or UNIX) are
%f77 –o myexecutable mycode.f
%./myexecutable

To analyze the output and make the required plots, you may use “excel”, “IDL” or other tools to visualize the data.

3. Requirement

This is an individual project. However, since it involves practical issues of compiling and running the FORTUNE code, a team effort is encourage. Nevertheless, each person shall deal with a model of different stellar mass from others. The following is the specific requirement.

(A) A research paper. No more than 5 pages including Figures. The paper shall (a) demonstrate your understanding of stellar structure and evolution, e.g, a list of governing physical equations and brief explanations, (b) summarize the work you have done with the PACZYNSKI model. To explain the results of your model calculation, you should at least make the following two figures: (1) the temperature profile from the center to the surface of your ZAMS star, with at least 15 radius points, (2) the variation of the luminosity of your star with time, with at least 5 points.

(B) In-class presentation. You need to prepare a 5-minute-or-so PPT presentation to show your results. Cross-comparison with other students’ results of various masses will be conducted in class. The presentation will be on April 29.