

Astro 220A Quarter Project

Basic Instructions for the Calculation of a Stellar Model

(The original famous assignment from Peter Bodenheimer)

- 1) Pick a value for the mass and composition (X, Y, Z). Recall that X (H mass fraction) + Y (He mass fraction) + Z (metals mass fraction) = 1.0

- 2) Find an appropriate opacity table. Write your own interpolation routine to find the opacity at a given temperature and density.

There are at least three sources for data. The first is OPAL:

<http://opalopacity.llnl.gov/>

A variety of already computed tables can be downloaded, and there is a Fortran routine that you can use to help you in designing your program. It can be exceedingly similar to the provided Fortran program, if you choose. You can also have OPAL compute opacities for you, for any mixture. Probably you want “Type 1” tables, which have “standard” abundance ratios for the various metals

The second is the Opacity Project (OP):

<http://cdsweb.u-strasbg.fr/topbase/op.html>

OP allows you to compute opacities, for any mixture, at the OPServer:

<http://opacities.osc.edu/rmos.shtml>

Tables are a bit more customizable, in terms of table format and size.

Note that the OPAL/OP tables only reach down to $\log T = 3.75$. *This may affect your choice of model star mass.* For cooler temperatures see Ferguson et al. (2005), ApJ, 623, 585-596, and their web site here: <http://webs.wichita.edu/physics/opacity/>

- 3) Write your own simple routines for calculation of the rate of energy generation by hydrogen burning, given density, temperature, and composition, and for the equation of state, where you will need the density as a function of pressure, temperature, and composition.

- 4) Set up the inner and outer boundary conditions.

- 5) Read sections 17.0, 17.1, and 17.2 of the “old” Numerical Recipes (Press et al., 1992, 2nd edition). The PDF version of the book can be found online various places, including here: <http://www.nr.com/oldverswitcher.html> (All versions)

We will be using the method of shooting to a fitting point (section 17.2). You can use the routine given there (subroutine shootf) to perform one integration. You will need an overall control program (something like newt, Section 9.7) to do multiple calls to shootf, to calculate corrections to the assumed boundary values, and to eventually obtain a converged solution. Modify the programs for your own purposes. For example, it is generally helpful to take only a fraction of the correction to the unknown parameters that the program calculates.

We have these Numerical Recipes routines readily available. If you login to one of the public machines like mambo, and go to:

`/opt/share/recipes/` you will find Numerical Recipes routines in Fortran or c:

shootf, odeint, lubksb, ludcmp

In Fortran, rk4 and rkqc are also needed, or in c, rkck and rkqs. A number of these routines are already in the IDL language.

- 6) The write-up is as important as obtaining a good solution. A good write-up should include:
 - a) Statement of parameters used
 - b) Statement of the physics problem
 - c) Statement of the numerical method and how well it converged
 - d) Tabular presentation of results
 - e) Graphical presentation of results
 - f) Complete listing of your computer program (Fortran, c, IDL, etc.)
 - g) Comparison of your model with one published in the literature if at all possible
 - h) Conclusion

“To err is human, but to really foul things up requires a computer.”