

# The Implementation of the Enhanced C&O Opacity Tables in the Eggleton Stellar Evolution Code.

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## 1 Construction.

The tables are based on the tables supplied by the OPAL collaboration. We currently use the tables of Alexander and Ferguson at low temperatures. Full details can be found in our paper in MNRAS or astro-ph/0310255. There are 265 tables that range from  $-8$  to  $+7$  (in steps of 0.5) in  $\log R$  (not  $\rho$ ,  $R = \frac{\rho}{T^3}$ ) and from 3 to 10 (in steps of 0.05) in  $\log T$ . These tables are split into 5 main batches according to hydrogen composition,  $X=0.0,0.03,0.1,0.35,0.7$ . The number of tables at each abundance varies, to simplify the implementation and interpolation each group is regrid onto 61 tables at each  $X$  abundance, producing 305 tables in all.

Each table is scaled so that when interpolating in the 2D C&O space the coordinates go to 0.0 to 1.0. At 0.0 there is no extra carbon above that included in the initial  $Z$  of the star. While at 1.0 the extra carbon or oxygen abundance is  $(1 - X - Z)$  while the total carbon or oxygen abundance would be  $(1 - X - Z + Z_{C/O})$ . Where  $Z_{C/O}$  is the carbon or oxygen mass fraction included in the base metallicity.

## 2 Implementation in code.

Three routines must be altered to implement the new tables. This also includes adding new COMMON statements to hold the new tables and required information for interpolation.

1. PRINTA.F : this must be modified to load in the tables from the file “COtables”. Then also to create the splines for interpolation later. This process increases the memory requirements for the code to around 170Mb. We have not included linear interpolation at this time. Since we have not smoothed the tables in construction the inclusion of the splines ensures smoothness when used in models.
2. STATEF.F : just to include the new 5D interpolation routine. The routines could possibly be shortened and made neater but it works!
3. XOPAC.F : a new routines added to perform the interpolation. Copied from older spline routines but formatted for the new table orientation.

## 3 How to use them.

1. First select the correct table to use. The names are “COtables.X.gz” where the metallicity of the model will be 0.X. Copy this file onto “COtables” which is the file the program looks for. You will still also need the old “phys02.dat” for the other nuclear and neutrino data.
2. Then open “data” and alter the IOP value the list is now as follows:
  - 0: Old tables, linear interpolation.
  - 1: Old tables, spline interpolation.
  - 2: Only interpolate in R,T and X. So enhanced C&O are not considered.
  - 3: Interpolate in R,T,X,C and O.
  - 4: NA
  - 5: As in 3, although every element heavier than oxygen included in that abundance.
  - 6: NA

unless there are special circumstances use 5. (Note: molecular opacities not yet fully working and are not included in this version of the code.)

9. Final thing, set the  $Z$  in data to the required metallicity. Make sure the C&O and O&O are also correct since these are used to set the base levels of carbon and oxygen above which the composition is considered to be ‘enhanced’.

When stepping between opacity tables the best models to use are proto-stars in which there are no nuclear reactions, ie the central core temperature is below  $10^6 K$ . Although usually you can step up or down on level in metallicity with the supplied range of tables.

If you need a metallicity that is not included in the tables I provide then use linear interpolation in the basic tables, not those I created by interpolation myself.

## 4 Future plans.

- Include enhanced molecular opacities at low temperatures.
- Look at the total CNO abundance, splitting any extra N into the C&O abundance.
- If the table exceeds the dimensions of the grid in density to extrapolate linearly. This only occurs for Wolf-Rayet stars.

## 5 Appendix

List of the ‘real’ tables that were created:  $z = 0.0, 0.001, 0.004, 0.01, 0.02, 0.03, 0.1$ . Therefore the tables created by interpolation:  $z = 10^{-5}, 10^{-4}, 0.04, 0.05$ .

The points used are for the C&O compositions were: 0.00, 0.01, 0.03, 0.10, 0.20, 0.40, 0.60, 1.00. These closely resembled the arrangement used by the OPAL collaboration. The arrangement 61 C&O compositions are listed in the tables in the following order: These are repeated for the 5 hydrogen compositions in the order  $X=0.0, 0.03,$

C	O(from)	O(to)
0.00	0.00	1.00
0.01	0.00	1.00
0.03	0.00	1.00
0.10	0.00	1.00
0.20	0.00	1.00
0.40	0.00	1.00
0.60	0.00	0.60
1.00	0.00	0.40

0.1, 0.35, 0.7. Each table is formatted with 32 numbers per row, The first is the temperature in  $\log_{10}(T)$  then 31 opacities, the first is  $R = -8, -7.5, -7, \dots, 6, 6.5, 7$ . There are 141 such rows per table. They are separated by three numbers with the metallicity of the table.

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