

# Window To The Stars: A Guide

October 19, 2006

## 1 Introduction

We present *Window To The Stars* (*WTTS*), a graphical user interface to the popular *TWIN* single/binary stellar evolution code, for novices, students and professional astrophysicists. It removes the drudgery associated with the traditional approach to running the code, while maintaining the power, output quality and flexibility a modern stellar evolutionist requires. It is currently being used for cutting edge research and interactive teaching.

This guide is for version 0.14 of *WTTS*.

### 1.1 What is a stellar evolution code?

A stellar evolution code makes models of stars and evolves them in time.

### 1.2 What is *TWIN*?

The stellar evolution code used by *WTTS* is a modified version of the *TWIN* stellar evolution code originally developed by Peter Eggleton [1, 2]. It uses an adaptive non-Lagrangian mesh which allows stars to be evolved with only 200 meshpoints in a few minutes on a normal desktop computer. It is written in *FORTRAN*.

The code has three modes of operation: one to calculate the evolution of single stars and two different ways for binaries, *TWIN* and non-*TWIN*. In *TWIN* mode, the two stars are solved for simultaneously by inverting a single matrix, while in non-*TWIN* mode the code evolves both stars individually and alternates between them at regular intervals.

### 1.3 What is *WTTS*?

*WTTS* is a user interface that sits between you and the gory details of what is going on with the *TWIN* stellar evolution code and various other system tools. You probably do not need to know how these work, just how the considerably simpler *WTTS* works. *WTTS* is a Perl script, and so should run on any platform which can run Perl, which includes Linux, Mac OS X, Windows, HP-UX, ... the only modern operating system

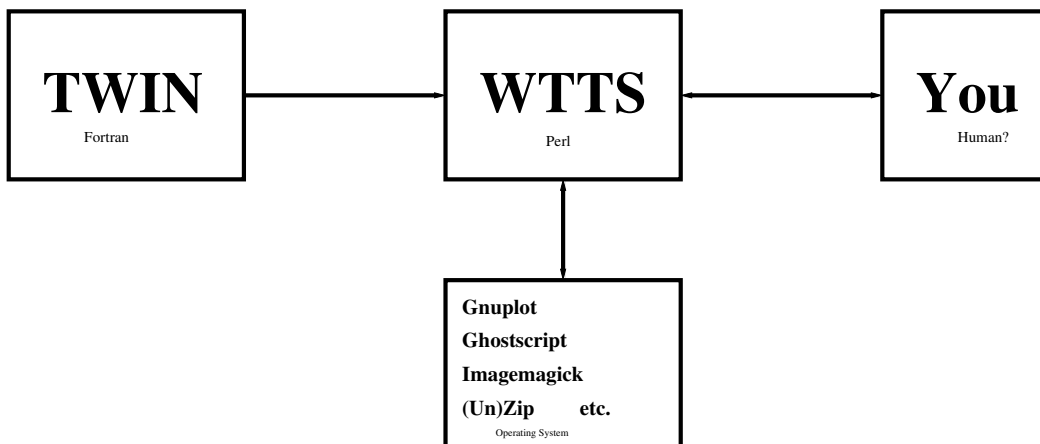


Figure 1: Structure of the *WTTS* and *TWIN* setup. *WTTS* sits between you and *TWIN*, but also isolates you from the details of all the other tools it uses.

I have used which has no Perl is my iPod. Detailed and up-to-date instructions for installation can be found at the *WTTS* website <http://www.astro.uu.nl/~izzard/window/> and below.

The stellar evolution code used by *WTTS* is Peter Eggleton's *TWIN*. This is a separate executable and must be downloaded or built from source. For each piece of software you are required to install, you probably have to download it first, so rather than point you to a specific web page, which is liable to change, I would recommend using your favourite search engine (Google, Yahoo, etc.). Section 2 details how to include *WTTS* and *TWIN*.

The user manual is in section 3. This explains about the various windows and settings which are in *WTTS*.

If you use *WTTS* for work you intend to publish, please cite us – we have a paper coming out soon in *New Astronomy*.

## 2 Installation

I assume you are using a command line interface (“Terminal” on MAC OS X), with a bash shell (type `bash` to get into a bash shell), and you are vaguely familiar with how to make your computer work via this interface. I assume you have *Perl* installed, which should be standard on a decent operating system (otherwise you must get it! Try [www.perl.com](http://www.perl.com)), and also *zip* and *unzip*.

### 2.1 Automated Installer

The automated installer should install most of *WTTS* and *TWIN*, but will not install standard packages such as Gnuplot, Ghostscript, etc. on your machine. You can get the installer from our website and try it, with

```
wget http://www.astro.uu.nl/~izzard/window/installer
```

```
perl installer
```

Please contact us if this does not work. It is difficult to write an installer for every operating system so it may well go wrong on your machine and it is only through your feedback that we can improve *WTTS*. You should now be able to run *WTTS* with this command:

```
wtts
```

## 2.2 Pre-built executables

We have started to experiment with pre-built executables which will, in theory, replace the need for the Perl script. You can get a binary file from <http://www.astro.uu.nl/~izzard/window> but be warned that *these will only work on some systems* (e.g. the systems we have access to). You will need to download both *WTTS* and *TWIN* to the same directory, then just run the *WTTS* executable. You may need to make a subdirectory called *code* and move the *TWIN* executable into it.

## 2.3 Build It Yourself

In true Unix-fashion, the best way to use *WTTS* is to build the *TWIN* code and install the Perl modules yourself. In this section we outline the general procedure, which of course may need to be modified for your system.

### 2.3.1 Build TWIN

You should download the *TWIN* code distribution from our website, currently <http://www.astro.uu.nl/~izzard/window/TWIN.zip>. You must have a Fortran compiler! We use *ifort*, from Intel, on Linux, and *g95* from GNU on Linux and MAC OS X. So, make a directory, download *TWIN.zip* to that directory, and unzip the *TWIN* file e.g.

```
mkdir ~/wtts
cd ~/wtts
wget http://www.astro.uu.nl/~izzard/window/TWIN.zip
unzip TWIN.zip
```

Build it with

```
make
```

(which assumes you have GNU *make* as your default *make* - if this fails try *gmake* instead). If you are *not* using *ifort*, you should change the default Fortran compiler via the environment variable *FORT*. E.g., to use *g95* instead, type

```
export FORT=g95
make
```

Wait a little while until the build is finished.

### 2.3.2 Get required standard Perl modules

Here is where it gets tricky. *WTTS* requires some (quite standard) Perl modules. You can either get packages for these modules which are specific for your system (e.g. RPMs for Redhat/Fedora Linux (see [www.pbone.net](http://www.pbone.net)), .deb for Debian etc. or perhaps Fink packages for OS X) or install from downloaded source files from CPAN at [www.cpan.org](http://www.cpan.org). You need to install *at least* the following Perl modules:

- ExtUtils-Depends-0.205
- ExtUtils-PkgConfig-1.07
- File-Tail-0.99.3
- Glib-1.102
- Gtk2-1.102

For Gtk2-perl and Glib-perl you must have the Glib and Gtk2 libraries already installed on your system. You can get these as packages (e.g. RPM packages) or by going to [www.gtk.org](http://www.gtk.org).

### 2.3.3 Packages?

If you want to try the package route, which you probably should, then you are on your own because it is different for each system. If you are very lucky then you are using a system with a proper administrator, and if you are really lucky indeed then he will read this and install everything for you!

With RPM packages (e.g. on Redhat or Fedora Linux) you should download the required packages, log in as root (with `su`) and issue the command

```
rpm --install <package name>
```

for each package.

### 2.3.4 CPAN

CPAN has a search facility, [search.cpan.org](http://search.cpan.org), where you can simply search for the Perl modules listed above. For example, to get the Perl Gtk2 module, type `gtk2` into the search box. This gives you the search results – the first one is Gtk2. Click on the “Gtk2”, which brings you to a description of the module and a link to Download. Click on that, and save the file `Gtk2-xxxx.tar.gz` (where `xxxx` is the module version, which should not be too important) to a temporary directory, e.g. `~/src`, then issue these commands

```
tar -xvzf Gtk2-xxxx.tar.gz
cd Gtk2 (the directory name may differ slightly)
perl Makefile.PL
```

```
make
make install
```

where the final command should be *as root*. Note: these are quite basic procedures for anyone experienced with a UNIX operating system. If in doubt *get help* or email us!

### 2.3.5 Get Rob's Perl modules

You need Rob's custom Perl modules as well. These are similar to those from CPAN but Rob wrote them himself. In a temporary directory, e.g. `~/src/modules`, download the modules and build them. If you are *root*:

```
wget http://www.astro.uu.nl/~izzard/window/rob_misc_perl_module.zip
wget http://www.astro.uu.nl/~izzard/window/STARS_perl_module.zip
mkdir rob
cd rob
unzip rob_misc_perl_module.zip
perl Makefile.PL
make
(as root) make install
cd ..
mkdir STARS
cd STARS
unzip STARS_perl_module.zip
perl Makefile.PL
make
(as root) make install
```

Rob's Perl modules should now be installed. You *can* install the modules without being root, by putting a line in your shell options file (e.g. `.bashrc`)

```
export PERL5LIB=$HOME/lib/perl/lib/perl5/site_perl/5.8.5
```

where the 5.8.5 is your version of Perl (run `perl -v` to find out). Then, before the `perl Makefile.PL` steps above, type

```
PREFIX=$HOME/lib/perl
```

and continue as before.

### 2.3.6 Other required software

For plotting, *WTTS* uses Gnuplot, but also uses ImageMagick (for its *convert* utility) and/or Ghostscript, and perhaps the *sed* utility (preferably GNU *sed*). These should be available in package form for your operating system, or are available in source form for you to build. On any decent distribution these *are installed by default*. (What a definition of decent!) Use your favourite search engine to find these (very useful) tools.

You could try the following websites

- [www.gnuplot.info](http://www.gnuplot.info)
- [www.cs.wisc.edu/~ghost/](http://www.cs.wisc.edu/~ghost/)
- [www.imagemagick.org](http://www.imagemagick.org)
- [www.gnu.org/software/sed/](http://www.gnu.org/software/sed/)

### 2.3.7 Running WTTS

Now everything should be in place, you can download and run Window To The Stars, like this

```
cd ~/wtts
wget http://www.astro.uu.nl/~izzard/window/stars.experimental.perlscript
mv stars.experimental.perlscript wtts
chmod 755 wtts
./wtts
```

Of course you can change the name from `wtts` to whatever you like.

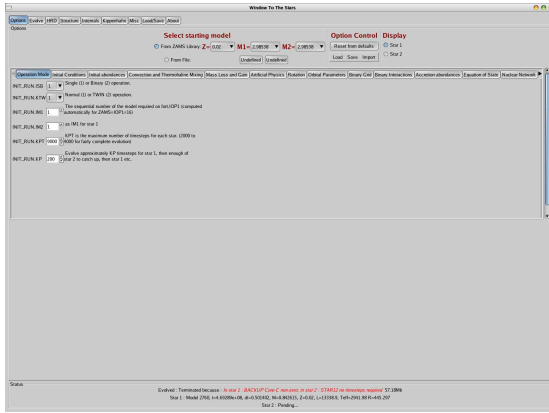
If there are any problems, please feel free to email us (see the website for our email address).

## 3 Using Window To The Stars

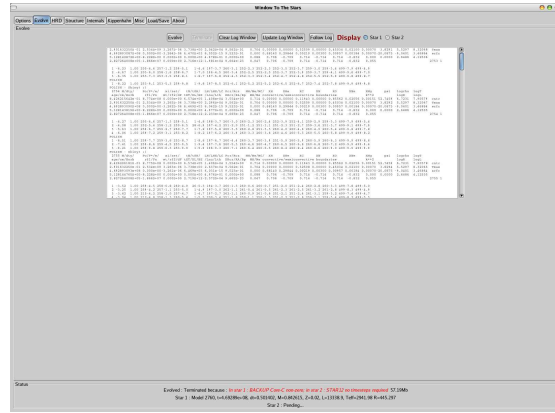
*Window To The Stars*, is laid out in a logical progression of *tabbed windows*, starting with the choice of physics, through the stellar evolution, to analysis of the results. We shall describe each in turn and corresponding screenshots from the evolution of a  $3M_{\odot}$  star can be found in Fig. 2.

In addition to the main tab window, a status bar is visible at all times, informing the user of the current status (e.g. “Evolving” or “Stopped”) and the physical state of the primary and secondary star.

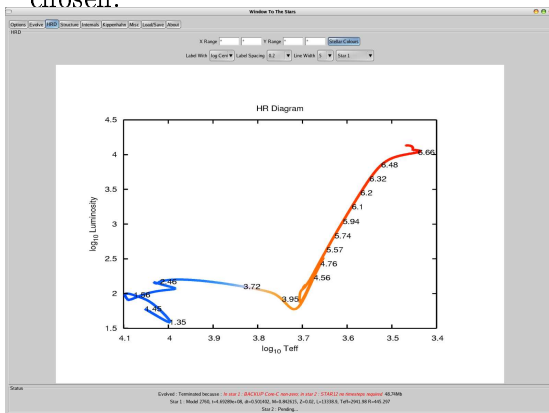
All images can be saved as either PNG, suitable for web-based projects, or Postscript for publications and talks. Animations are saved as animated GIFs, also compatible with web browsers.



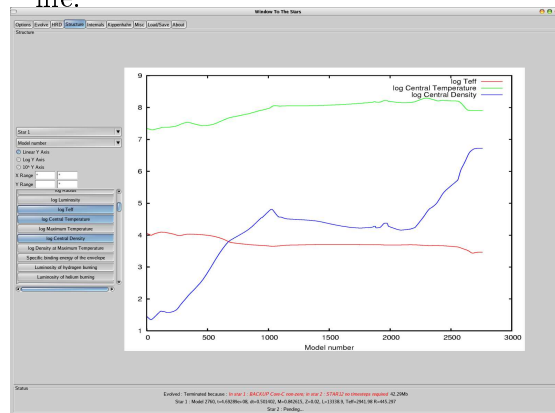
The *Options* tab where physical input is chosen.



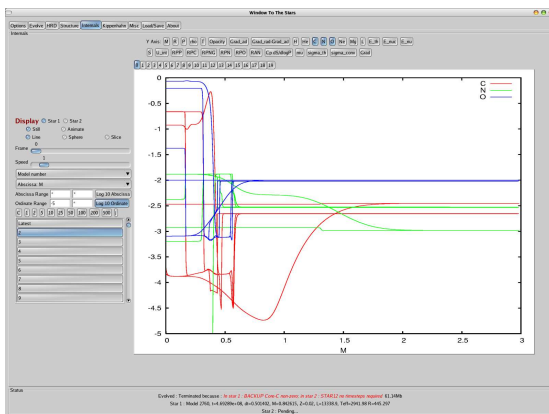
The *Evolve* tab follows the *TWIN* log file.



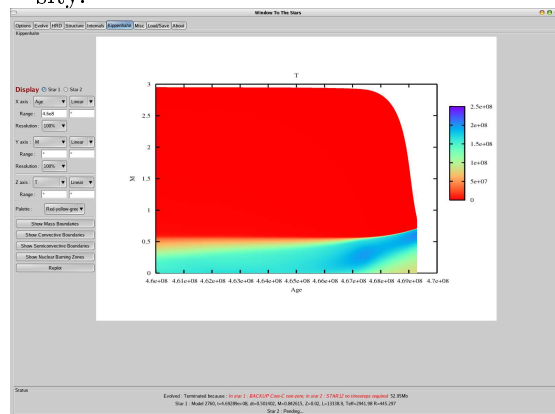
The *HRD* tab, labelled by log central density.



The *Structure* tab showing surface and central temperature, and central density.



The *Internals* tab showing CNO abundances for one in every 500 models.



The *Kippenhahn* diagram tab showing temperature as a function of mass coordinate and age.

Figure 2: Example screenshots of the various tabbed windows showing the evolution of a  $3 M_{\odot}$  solar metallicity star (a total of 2760 stellar models).

## 3.1 Options Tab

The first steps in creating a series of stellar evolution models are the choices of input parameters and physics. We provide a selection of initial mass(es) from a library of zero-age main sequence (ZAMS) stellar models with a range of metallicities (typically  $10^{-4} \leq Z \leq 0.03$ ). It is also possible to load pre-calculated models as the starting model (see *Internal* below for details on saving models). The physics and initial conditions for stellar evolution are then selected in a series of tabbed menus. These provide the user with the original variable name, an input box or menu, and a description of what the parameter means with a suggested default parameter. In this way every aspect of the stellar evolution run can be controlled. We have added the ability to load or save a complete set of *WTTS* options, and also to import the original `init.dat` files from the *TWIN* code distribution.

### 3.1.1 Select Starting Model

You must choose whether to start from a zero-age main sequence (ZAMS) model, or one of your own (previously saved) models. If you are running *WTTS* for the first time, then leave this setting at the default ZAMS library. You can, however, choose a metallicity  $Z$ , and masses for the primary and secondary star. If you are only planning on evolving a single star, the secondary mass becomes irrelevant.

### 3.1.2 Option Control

If you press *Reset from defaults* then *all* the options will be reset to a default value (which is usually suitable for basic, single-star evolution). You can also *Load* and *Save* a whole set of options by clicking on Load and Save. You can import a TWIN `init.dat` file into your options by selecting *Import->init.dat*.

The *plugins* menu is for operations which are in some way special or automated. At present (version 0.13) there are two plugins:

- *Import TWIN init.dat* This allows you to import an original TWIN `init.dat` file into the current options set. This can be useful for running, say, binaries using Peter's `init.dat` files which come with the TWIN distribution.
- *Remesher* This plugin takes the selected starting model and changes the number of mesh points in it. Note that the *TWIN* code has a maximum number of meshpoints (usually 5000) which is set in the source file `mesh.f`.

### 3.1.3 Display

Here you can choose either star 1 or star 2. This is the (global) control for the later plotting screens, and enables you to display either star 1 or star 2. This will probably be removed at a later date.



### **3.1.4 The Options**

Most of the screen is taken up by the series of sub-tabs denoting evolution options. They are grouped logically, e.g. initial conditions are all together. Each option comes with a short help description. Sometimes you can enter a number in a box, sometimes you have a limited choice. Remember, the choice is limited for a reason!

Detailed descriptions of what the options do, and how they affect your stellar evolution runs, can be found in Peter's writeup file, which is distributed with the *TWIN* code. On the other hand, the help given here might be enough for you.

## **3.2 Evolve Tab**

This is where the bulk of the stellar evolution is done. There are buttons to start and stop the evolutionary sequence. The *TWIN* log file is also shown and updated automatically during the evolutionary run.

### **3.2.1 Evolve**

Click on this to start the stellar evolution.

### **3.2.2 Terminate**

Click on this to end the stellar evolution (if it does not end itself).

### **3.2.3 Clear Log Window**

This clears the log window of its contents.

### **3.2.4 Update Log Window**

This updates the log window with the current output from *TWIN*.

### **3.2.5 Follow Log**

This can be toggled – when it is on the log is continuously updated, and the cursor is sent to the bottom so you can always see the latest activity. This is annoying if you want to read something that happened some time ago... so you can also turn it off.

### **3.2.6 Display**

You can follow the log of star 1 or star 2, use these buttons to select which one.

### 3.3 HRD Tab

The Hertzsprung-Russell diagram (HRD), which shows  $\log L/L_{\odot}$  vs  $\log T_{\text{eff}}/K$ , is the primary diagnostic tool of stellar evolution. It is displayed for each star individually or for both stars, and updates as the evolution progresses. The tracks can be labelled with a third variable, such as central temperature or core mass, and coloured according to the effective temperature.

#### 3.3.1 X Range and Y Range

Here you can enter the ranges of the X ( $L$ ) and Y ( $T_{\text{eff}}$ ) axes, from minimum to maximum. Enter a \* to have *WTTS* automatically calculate a range for you.

#### 3.3.2 Stellar Colours

Switch this on to label the colours in your HRD with the “true” stellar colours. You can adjust the colour settings (e.g. hue, contrast) in the Misc tab.

#### 3.3.3 Label with

You can label the curve in the HRD with a third variable, e.g. age or mass. Use this to select which third variable.

#### 3.3.4 Label spacing

The labels are automatically designed to not overlap, but you can override the spacing with the menu given here. 0.1 is the default and is usually good enough. On the other hand, if you zoom in you will need to make the number smaller.

#### 3.3.5 Line width

The width of the line in the HRD

#### 3.3.6 Star 1, Star 2, Stars 1 and 2

You can plot either star 1 or star 2 or both with this menu

### 3.4 Structure Tab

In this tab structural variables such as age, model number, total mass, core mass, luminosity, radius and abundances, are plotted against one another. The plot automatically updates throughout the evolution and many variables can be plotted at once, with the option of logging the axes and choosing data ranges.

#### 3.4.1 Star menu

Here you can choose whether to plot star 1, star 2 or both stars on your graph.

### 3.4.2 $x$ -Variable

Below this is the variable menu, where you choose which variable to plot on the  $x$  axis.

### 3.4.3 Y-axis control

With the three buttons “Linear Y Axis”, “Log Y Axis” and “ $10^Y$  Axis” you can plot either  $y$ ,  $\log_{10} y$  or  $10^y$ , where  $y$  is the variable in question.

### 3.4.4 X range and Y range

Here you can choose the range of the  $x$  and  $y$  axes by selecting a minimum and maximum value. As usual, a \* means *WTTS* automatically scales the axis.

### 3.4.5 $y$ -Variable

This is the list of toggle buttons controlling the variables which should be plotted on the  $y$ -axis.

## 3.5 Internals Tab

It is often desirable to examine the internal details of each stellar model individually or plot the results from a few models in one graph. Plots are made of a selection of internal variables vs one other internal variable (usually the mass coordinate) for a selection of models. It is possible to overlay the results of successive models, or make an animated sequence. There is also a sphere rendering mode, which shows a spherical star with a slice removed so the internal details are visible. There are twenty sub-tabs in this tab, so it is possible to work on multiple images at the same time. There is an option to always look at the latest model, so internal details are followed during a model sequence run. Each model can be saved and later used as a starting model for a new evolutionary run (see the *Options* tab description).

### 3.5.1 Y Axis

You can choose to plot many different variables on the  $y$  axis, just click on the buttons

### 3.5.2 Display

As usual, choose to plot either star 1 or star 2.

### 3.5.3 Still/Animate

You can either plot a series of models as a still image, in which case they will be overlaid, or as an animation.

### 3.5.4 Frame

This gives the current frame number of the animation.

### 3.5.5 Speed

This changes the speed of the animation, which is usually limited by your CPU! (This goes to 11.)

### 3.5.6 Ranges

You can change the  $x$  and  $y$  axis ranges here

### 3.5.7 C 1 2 5 ...

Each of these buttons affects the model list (see below). C clears the list, 1 selects every model, 2 every 2nd model, 5 every 5th etc. | (pipe) logical ORs the entire list (so selected becomes deselected, and vice versa).

### 3.5.8 Model List

Click on a model number to plot it. You can select as many as you like. If you select a model, hold shift, then select another, the range will be selected. If you select a model, hold the control key, then select another, the range will be unselected.

### 3.5.9 Image Tabs

You can plot 20 different images, each has its own tab.

## 3.6 Kippenhahn Tab

The traditional Kippenhahn plot shows convective regions as a function of mass coordinate and time. We expand on this idea by plotting a mapped 3D surface of any of the stellar evolutionary variables, which includes convection, as a function of any two others. The map is in greyscale or colour, with a selection of palettes. In the case of mass-coordinate used as an ordinate, the core mass(es), convective boundaries and nuclear burning zones can be over-plotted.

### 3.6.1 Axis, range, resolution

Each axis has its own range selector, much like the other tabs, and can be plotted as a linear, log or  $10^y$  plot. Choose a low resolution (e.g. 10%) to experiment with your plot, as this will be faster. 100% resolution should be used for publication-quality plots.

### 3.6.2 Palette

Here you can choose from a series of colour palettes. There is one greyscale palette, suitable for black and white printing.

### 3.6.3 Boundaries

You can attempt to show the core-mass /surface boundaries, convective boundaries, and nuclear burning zones.

### 3.6.4 Replot

You must click on Replot to draw the graph. Drawing is quite time consuming, as the data must be extracted and then plotted, and there is a *lot* of data involved.

## 3.7 Miscellaneous Tab

Other options can be changed here, such as image size, HRD colour contrast, font type and size, plot type (postscript or PNG) etc.

## 3.8 Load/Save Tab

Here you can load or save a *complete set of models* ! The files are zipped, because they are necessarily quite big.

## 4 WTTS API

As of version 0.13 *WTTS* has used a crude application programming interface (API) in the *STARS* perl module in an attempt to abstract the details of the stellar evolution code from *WTTS* so that at some point in the future *WTTS* can be used with *any* stellar evolution code. As of version 0.13 this is still experimental.

Note that a complete overhaul of the variable setting procedure (which is crude, archaic, rubbish, hacked together etc ...) and associated API is planned for 0.15.

### 4.1 API Implementation

The API in the *STARS.pm* module is the default *TWIN* function set. In order to load a different set of functions then a different module should be loaded instead of *STARS.pm*. At present this must be done manually, but there is no reason why it cannot be automated in the future. (However, right now there is only the *STARS.pm* module!)

### 4.2 TWIN specific stuff

Because *WTTS* was designed to work with *TWIN* it uses the output files from *TWIN* to function properly. I would suggest that the easiest way to adapt *WTTS* to a different stellar evolution code is to simply output the same information as *TWIN* does to similarly

named files from the different code. These are the *.mdl1*, *.mdl2*, *.out1*, *.out2*, *.plt1*, *.plt2* and *.mod* files.

The following descriptions are taken from the STARS wiki at <http://www.phys.uu.nl/~glebbeek/twiki/bin/view/Main/TwinCode> which will contain the most up to date documentation. This is correct as of *WTTS* V0.14 and the current *TWIN* code.

#### 4.2.1 *.mdl* files

This file contains stellar structure at different ages written for plotting purposes. Apart from the first line this file consists of blocks of stellar structure.

##### **First Line**

1. number of grid points = number of lines of one block of stellar structure
2. number of variables = number of columns (may be different from the number of variables listed below)
3. Convective overshoot parameter

##### **Blocks of stellar structure**

Each block starts with a header containing

1. Model number
2. Model Age (yr)

The columns with the actual stellar structure follow, one line for each mesh point. The first line is the interior of the star. The first 21 variables are described in the IO manual. Check it for units and please add them to this wiki. The columns 22 and further are missing in this manual.

1. Mass coordinate, in solar units
2. Radius Coordinate, in solar units
3. Pressure [dyn/cm<sup>2</sup>]
4. Density [g/cm<sup>3</sup>]
5. Temperature [K]
6. Opacity [cm<sup>2</sup>/g]
7. Adiabatic Temperature Gradient [-]
8. Radiative - Adiabatic Temperature Gradient [-] !!! Wrong in IO manual
9. XH

10. XHe
11. XC
12. XN
13. XO
14. XNe
15. XMg
16. Total Luminosity, in solar units
17. Energy generation by contraction [erg / g / s]
18. Energy generation by nuclear reactions [erg / g / s]
19. Energy generation in neutrinos [erg / g / s]
20. Entropy [erg / g / K]
21. Internal Energy [erg / g]
22. Reaction rate RPP: pp chain: effective  $2p \rightarrow 1/2 \text{ He4}$
23. Reaction rate RPC: effective  $\text{C12} + 2 p \rightarrow \text{N14}$
24. Reaction rate RPNG: effective  $\text{N14} + 2p \rightarrow \text{O16}$
25. Reaction rate RPN: effective  $\text{N14} + 2p \rightarrow \text{C12} + \text{He4}$
26. Reaction rate RPO: effective  $\text{O16} + 2p \rightarrow \text{N14} + \text{He4}$
27. Reaction rate RAN: effective  $\text{N14} + 3/2 \text{ He4} \rightarrow \text{Ne20}$
28.  $C_p \frac{dS}{dP}$
29. Mean Molecular Weight, in atomic mass units
30. Mixing coefficient for thermohaline mixing (or unused)
31. Mixing coefficient for convective mixing (convective velocity \* mixing length)
32. Actual temperature gradient  $d \log T / d \log P$
33. homology invariant:  $d \log \rho / d \log P$  (or unused)
34. homology invariant:  $U_{\text{hom}}: d \log R / d \log P$  (or unused)
35. homology invariant:  $V_{\text{hom}}: d \log M / d \log P$  (or unused)

### 4.2.2 .mod files

These are only used for saving models, so you do not need to know the format. You should, however, know the equivalent format for your stellar evolution code and have an appropriate *extract\_model()* function.

### 4.2.3 .plt files

This file contains global properties for the output of the evolution calculation. Each calculated structure model occupies one line.

#### **First Line**

The first line contains the number of columns in the output. This may be less than what is listed here.

#### **Subsequent lines**

1. Model number
2. Age of the model [yr]
3. Mass, in solar units
4. Helium (Hydrogen exhausted) core mass, in solar units
5. Carbon-Oxygen (Helium exhausted) core mass, in solar units
6. Oxygen-Neon (Carbon exhausted) core mass, in solar units
7. log radius, in solar units
8. log luminosity, in solar units
9. log effective temperature [K]
10. log central temperature [K]
11. log maximum temperature [K]
12. log central density [g/cm<sup>3</sup>]
13. log density at maximum temperature [g/cm<sup>3</sup>]
14. Binding energy of envelope [erg / solar mass]
15. Luminosity by Hydrogen burning, in solar units
16. Luminosity by Helium burning, in solar units
17. Luminosity by Carbon burning, in solar units
18. Luminosity carried by neutrinos, in solar units



19. Luminosity by release of excess thermal energy, in solar units
20. Rotation period, in days
21.  $k^2 = I/MR^2$ , basically the axis of gyration or moment of inertia  $I$ .
22. Base of the convective envelope, in units of the stellar radius
23. Thickness of the convective envelope, in units of the stellar radius

### 4.3 Function List

The following is a list of functions which are currently in the API (V0.14). This is liable to change as the code is cleaned up, added to and trimmed. The names are also likely to change.

#### 4.3.1 analyse\_evcode\_log\_for\_termination\_reason

Usage: `analyse_evcode_log_for_termination_reason()`

Check the stellar evolution code's log file to determine why it failed and return a string containing an error message.

#### 4.3.2 check\_for\_evcode\_error

Usage: `check_for_evcode_error()`

This checks for an error in the evolution code log file, if one is detected sets the status bar and stops the evolution run.

#### 4.3.3 clear\_evcode\_caches

Usage: `clear_evcode_caches()`

Clears up any cached variables and data and close file handles in the API module. This should be called from `clear_global_caches` in *WTTS*.

#### 4.3.4 emergency\_exit

Usage: `emergency_exit()`

In an emergency, e.g. when you use too much memory, try to shut down the evolution code. This should try to stop the code in a nice way, then *kill* it.

#### 4.3.5 evcode\_colour\_log\_text

Usage: `evcode_colour_log_text(Gtk::textbuffer buffer, int n)`

Given the text buffer which contains the log output, colour it. If  $n$  is given then only colour the last  $n$  lines. If  $n$  is undefined then colour the whole text buffer (this is very slow).

#### 4.3.6 `evcode_eval`

Usage: `evcode_eval(string s)`

Evaluates the string *s* in the context of the API module, rather than in *WTTS* main program context.

#### 4.3.7 `evcode_plugin_menu`

Usage: `evcode_plugin_menu(menubar menubar)`

Given the widget *menubar* from *WTTS*, adds evolution-code specific plugins. Returns the *menubar* widget, modified. Copy then *STARS.pm* version and hack it.

#### 4.3.8 `evcode_value_from_hash`

Usage: `evcode_value_from_hash(string file, string key)`

Returns the element *key* of the hash called *file* (so-called because the hashes are named after the files they represent).

#### 4.3.9 `evcode_variable_settings`

Usage: `evcode_variable_settings()`

This function is called to set default evolution code settings, and set up (arrays of) variables used by the evolution code API. Some of the variables it sets are in the *main::* context, some are not.

#### 4.3.10 `extract_model`

Usage: `extract_model(string filename, array pointer models)`

Alternative model extraction routine. This will be removed in future to make way for `extract_evcode_model` but it is currently used with *TWIN* to get models for a *.mod* file (which `extract_evcode_model` cannot do yet). The *.mod* file is given in *filename*, and the (pointer to an) array `@models` contains the numbers of the models for extraction. An array containing the model data is returned.

#### 4.3.11 `extract_evcode_model(int nmod)`

Usage: `extract_evcode_model(int nmod)`

Extracts model *nmod* and returns the data as a string. In *TWIN* context this extracts model *nmod* from the *.mdl* file by calling `random_extract_model`.

#### 4.3.12 `get_available_models`

Usage: `get_available_models()`

Returns a list of model numbers which are available for us to play with. In *TWIN* context this function calls `get_TWIN_model_list` on the *.mdl* files.

#### 4.3.13 has\_evcode\_terminated

Usage: `has_evcode_terminated()`

Returns 0 if the evolution code is running, 1 if it is not running and 2 if it is running and/or has crashed. In the TWIN version this first checks if the `main::running_pid` variable is set, then checks if a `kill 0` can be performed on the pid. How the check is performed may depend on the specific evolution code.

#### 4.3.14 load\_evcode\_defaults

Usage: `load_evcode_defaults()`

Loads and sets the variable hashes with their default values. Redundant???

#### 4.3.15 load\_evcode\_hashes

Usage: `load_evcode_hashes()`

Stellar evolution options are stored in hashes where the hash keys are the variable names and the hash values are the values of the variables. This function loads these hashes from input files, so is sometimes useful.

#### 4.3.16 load\_evcode\_options\_from\_zipfile

Usage: `load_evcode_options_from_zipfile(array zip_output)`

The array `zip_output` is the output from the `unzip` command which simply unzips a given file as saved with `save_evcode_options_to_zipfile`. If file names in `zip_output` are recognised to be important then they can be acted upon. The usual way to do this is with a call such as `load_evcode_options_from_zipfile(split(/\n/o, 'unzip -d $cachedir -o $file'))`; where `$file` is the zipped filename

#### 4.3.17 reset\_evcode\_options

Usage: `reset_evcode_options()`

Resets some evolutionary code options. Gets called at the beginning and when the “Reset Options” button is pressed (unlike `evcode_variable_settings` which is called only at the beginning).

#### 4.3.18 reset\_evcode\_options\_to\_defaults

Usage: `reset_evcode_options_to_defaults`

This function sets all options in the *Options* tab to their default values.

#### 4.3.19 run\_evcode

Usage: `run_evcode(Boolean nofork, Boolean startfile)`

This function calls the evolution code. How it does this will depend very strongly on the evolution code. In TWIN context this function looks at the widgets (in the main

program) to determine parameters. It then sets some default values. In most cases *nofork* and *startfile* should be left undefined.

Usually, this function will call *fork* to allow it to both run the evolution code and return control to the user. If *nofork* is set to 1 then *fork* is not called and the function will not return until the evolution code has finished running.

The function checks the main program to see if it should start from an input model which is not part of the ZAMS library. If so, or if *startfile* is set to 1, then the evolution code is started from a user-specified input model.

It is up to this function to update the status bar and log file window as the programmer of the API function sees fit. See the *TWIN* API version for such details.

Returns *TRUE* in the parent fork, the child does not return (it exits with code 0) and returns 0 in the case where *nofork* is set.

#### 4.3.20 save\_evcode\_options

Usage: save\_evcode\_options()

Saves the currently evolution code options to files, usually in preparation for an evolutionary run.

#### 4.3.21 set\_evcode\_options\_list

Usage: set\_evcode\_options\_list()

Set *main::options\_list* with the layout for the options tab. List items should be in this format: '*BLOCK.VAR* in *FILE*' where *BLOCK* is the common block (in capitals!), *VAR* is the variable (in capitals), *FILE* is the filename it is stored in. Structure, i.e. sub-tabs, is introduced with

Label: *label text*

or

Section: *section label*

Note: variables with no options are treated as non-editable!

#### 4.3.22 save\_evcode\_options\_to\_zipfile

Usage: save\_evcode\_options\_to\_zipfile(string *filename*)

Saves the currently evolution code options to a zip file (the name of which is *filename*) so you can load them at a later time.

#### 4.3.23 set\_col\_labels

Usage: set\_col\_labels()

Sets the *main::plt1cols* array. These are the names of the variables in each column of the *plt1* file. Also sets up the *main::plt1cols* hash.

#### 4.3.24 set\_evcode\_start\_model

Usage: set\_evcode\_start\_model(int *n*, filename *f*)  
Sets the starting model for star *n* to the file *f*.

#### 4.3.25 set\_evcode\_var

Usage: set\_evcode\_var(*string* data, *string* blockname, *string* varname, *string* newval)  
Sets the evolution code variable *varname* to *newval* by some circuitous route. In the TWIN module the *data* variable stores the original data file and *blockname* is the name of the FORTRAN common block in which the data is stored. The *set\_evcode\_var* function then searches the *data* for the *blockname* and *varname* and sets what it finds to *newval*. This function is scheduled to be rewritten to remove the *data* and *blockname* as these are horribly programmed.

#### 4.3.26 stop\_evcode

Usage: stop\_evcode()  
Try to stop the evolutionary code, in a nice way. Should call a kill function (*main::pidkill*) just in case it fails.

#### 4.3.27 variable\_help\_array

Usage: variable\_help\_array()  
When called this function returns an array of strings of the format “*VARNAME* Help text...” where *VARNAME* is the name of the variable and the “Help text...” is whatever help text you would like to associate with the given variable.

#### 4.3.28 zams\_ms

Usage: zams\_zs(float *z*)  
Returns a list of masses available in the ZAMS library for a given metallicity *z* (which one of the list returned by *zams\_zs*).

#### 4.3.29 zams\_zs

Usage: zams\_zs()  
Returns a list of metallicities available in the ZAMS library.

## References

- [1] P. P. Eggleton. The evolution of low mass stars. *MNRAS*, 151:351, 1971.
- [2] P. P. Eggleton and L. Kiseleva-Eggleton. The Evolution of Cool Alcols. *The Astrophysical Journal*, 575:461–473, August 2002.