

# GYRE Pulsation Code

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## Running GYRE

GYRE is packaged with MESA, so you don't need to download any new code to run GYRE. The source code lives in `mesa/gyre`. GYRE documentation can be found at <https://bitbucket.org/rhdtownsend/gyre/wiki/Home>.

Users are encouraged to post questions to the GYRE forum:

<http://www.astro.wisc.edu/~townsend/gyre-forums/>

This tutorial loosely follows the instructions found under the Tutorials section of the GYRE wiki.

To run GYRE, you should first store the path to GYRE as an environment variable. Add a line in your `.profile` or `.cshrc` or `.bashrc` file, right below your path to MESA, which should look something like

```
export GYRE_DIR=$MESA_DIR/gyre/gyre
```

or

```
setenv GYRE_DIR $MESA_DIR/gyre/gyre
```

depending on which operating system you are running. This should work as long as you have set `$MESA_DIR` as instructed in the MESA installation instructions. My `.bashrc` file looks like this:

```
export MESASDK_ROOT=~/.mesasdk
```

```
source $MESASDK_ROOT/bin/mesasdk_init.sh
```

```
export MESA_DIR=~/.mesa
```

```
export OMP_NUM_THREADS=4
```

```
export GYRE_DIR=$MESA_DIR/gyre/gyre
```

Remember to open a new terminal after making the changes so that they can take effect.

Although GYRE is compiled when MESA is installed, we need to make it again (this may change with future releases). Go into your GYRE directory:

```
cd $GYRE_DIR
```

and then type

```
make
```

Compilation should only a few seconds. If it fails, flag down a TA to track down the problem.

Create a work folder in your GYRE directory with

```
mkdir work
```

Next, lets copy one of the included stellar models into our work directory:

```
cp $GYRE_DIR/models/mesa/spb/spb.mesa $GYRE_DIR/work/
```

The next step is to create a namelist file that gives GYRE instructions on what kind of run to do. This is very similar to a MESA inlist file. Look on the MESA summer school for a file called `gyre_ad.in` which will be our namelist. This file is slightly different than the current version on the GYRE wiki, but should work with the version of GYRE packaged with the current version of MESA. Save this file into `$GYRE_DIR/work/gyre_ad.in`

We are now ready to run GYRE! From your work directory, type

```
../bin/gyre_ad gyre_ad.in
```

This will run the adiabatic version of the code. As the code runs, you should see data being printed on the screen. You'll also notice that your work directory is now full of files labeled something like `mode-00001.txt`. These files contain information on the oscillation mode eigenfunctions, and are similar to the profile files created when you run MESA. There will also be a file called `summary.txt` which contains info on each mode calculated, similar to the history file created by MESA. There are many options available for the data presented in these files, consult the GYRE wiki for possibilities.

Next, let's try to run the non-adiabatic version of the code. First we create a new namelist called `gyre_nad.in` or something similar. It's easiest to copy your adiabatic namelist:

```
cp gyre_ad.in gyre_nad.in
```

The non-adiabatic code is less stable than the adiabatic code. In order to get it to run correctly, you'll likely need to replace the `&num` section of the namelist with

&num

```
ivp_solver_type = 'MAGNUS_GL2' ! 2nd-order Magnus solver
```

/

To run the non-adiabatic code, type

```
../bin/gyre_nad gyre_nad.in
```

You will see the code repeat the adiabatic code calculations, the results of which it will use to perform the non-adiabatic calculations.

Look at the columns labeled  $\text{Re}(\omega)$  and  $\text{Im}(\omega)$  in the output from your run. The real part of  $\omega$  is the oscillation mode frequency (by default presented in units of the dynamical frequency of the star), while the imaginary part is the mode damping rate. Look through the values of  $\text{Im}(\omega)$ . Are they positive or negative? What is the meaning of a negative damping rate? Can you explain why a spb (slowly pulsating B-type) star pulsates?

We can use MESA to create a stellar model compatible with GYRE. Luckily, MESA is configured to output GYRE-compatible stellar models. To do this, all you need to do is add the following lines to the &controls section of your inlist:

```
write_pulse_info_with_profile = .true.
```

```
pulse_info_format = 'GYRE'
```

The GYRE-compatible stellar models will be output in your LOGS folder, with names like `profile1.data.GYRE`.

Create a Sun-like star using MESA by the method of your choosing. Include the lines above to generate GYRE-ready models. Copy a Sun-like GYRE model into your GYRE work directory, naming it whatever you like, e.g., `solar.mesa`. Now modify your non-adiabatic code to run on this model by replacing the &model section of the namelist with

&model

```
model_type = 'EVOL' ! Obtain stellar structure from an evolutionary model
```

```
file = 'solar.mesa' ! File name of the evolutionary model
```

```
file_format = 'MESA' ! File format of the evolutionary model
```

/

Let's calculate pressure modes by replacing the &scan section of the namelist with

```
&scan  
  
    grid_type = 'LINEAR' ! Scan for modes using a uniform-in-frequency grid; best for p-modes  
    freq_units = 'NONE'  ! Interpret freq_min and freq_max as being dimensionless  
  
    freq_min = 3.         ! Minimum frequency to scan from  
  
    freq_max = 100.       ! Maximum frequency to scan to  
  
    n_freq = 250          ! Number of frequency points in scan  
  
/
```

Run the non-adiabatic code. You may need to switch back to `ivp_solver_type = 'MAGNUS_GL4'` in your namelist in order for it to converge. Look at the damping rates of the modes. Are any of the solar p-modes overstable?