Maxilab

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For the Maxilab, we're going to create our own target values to fit. MESA allows you to add these by defining `my_var1`, `my_var2` or `my_var3` in `run_star_extras.f` and specifying target values and uncertainties in `inlist_astero_search_controls`. We will use weighted mean large and small separations (denoted $\Delta\nu$ and $\delta\nu$, respectively) derived directly from the mode frequencies. We'll define the large separation by

$$\Delta\nu_{n,0} = \nu_{n,0} - \nu_{n-1,0} \tag{1}$$

and the small separation by

$$\delta\nu_{n,02} = \nu_{n,0} - \nu_{n-1,2} \tag{2}$$

These definitions are for a given radial order whereas we want an average. To keep things smooth, let's define an average large separation by

$$\langle\Delta\nu\rangle = \sum_n e^{-\frac{1}{2}\left(\frac{\nu_{n-1/2,0}-\nu_{\max}}{\Delta\nu_{\rm as}}\right)^2} (\nu_{n,0} - \nu_{n-1,0}) \tag{3}$$

where $\Delta\nu_{\rm as}$ is the asymptotic large frequency separation and I've used the shorthand $\nu_{n-1/2,0} = (\nu_{n,0} - \nu_{n-1,0})/2$. (You can defined any other weight you like for the average.)

We can define an average small separation by

$$\langle\delta\nu\rangle = \sum_n e^{-\frac{1}{2}\left(\frac{\nu_{n,0}-\nu_{\max}}{\Delta\nu_{\rm as}}\right)^2} (\nu_{n,0} - \nu_{n-1,2}) \tag{4}$$

1 Setting up

The `run_star_extras.f` in the lab materials is already set up to call GYRE to compute the frequencies.[1]

- In case you forgot earlier, copy the file `extras_support.f` from the lab materials to `$MESA_DIR/star/astero/src`.[2]
- Copy `run_star_extras.f` from the lab materials to the `src/` subdirectory of your working directory.

[1] If you think you're skilled enough, I encourage you to try to implement this yourself from scratch. It doesn't require that much code but you'll need to look through the available functions and subroutines in `$MESA_DIR/star/astero/src/` to determine what to call.

[2] This fixes a minor bug that prevents us adding data to the history files.

- Modify `run_star_extras.f` to apply the weight function defined above to `small_sep` and `large_sep`.[3]
- Add these two items to the history by changing `how_many_extra_history_columns` and `data_for_extra_history_columns`. You'll need to import the data for the history columns with something like `use astero_data, only: my_var1, my_var2`.
- Determine the observed values of $\langle \Delta\nu \rangle$ and $\langle \delta\nu \rangle$ and add them to `inlist_astero_search_controls`.[4]
- The `my_var*` values are treated as part of $\chi^2_{\rm spectro}$, so we don't need $\chi^2_{\rm seismo}$ anymore. Change `chi2_seismo_fraction` appropriately.
- Finally, you can tweak `gyre.in` to control the frequency range to be tested.

2 Running

You're now ready to run again! As before, start with `search_type = 'use_first_values'` before you get carried away. If that works, go ahead and start an iterative run. Also, because `astero` isn't using the full $\chi^2_{\rm spectro} \rightarrow \Delta\nu \rightarrow \nu_{n,0} \rightarrow \nu_{n,\ell}$ logic, you may have to tweak your timestep controls in `inlist_astero_search_controls`.

3 Plotting

Now that your run is ready, we can clean up the plots again.

- Because it isn't doing anything, switch off the echelle diagram.
- Use the `History_Track1` plot in PGSTAR to plot the large separation against the small separation.[5]
- Add a target box to the $\Delta\nu$–$\delta\nu$ diagram.

4 Bringing it all together

You now have two different ways of fitting the asteroseismic data: either using the individual frequencies or the averaged information. Let your iterative methods evaluate a few models and see how the parameters in the two cases compare.

[3] If you're struggling, you can skip this step but the large and small separations won't be smooth functions.

[4] These don't need to be exactly correct: after all, you don't know exactly what $\Delta\nu_{\rm as}$ and $\nu_{\rm max}$ are but you can estimate them closely enough from the data.

[5] This is sometimes referred to as a *JCD diagram* or *asteroseismic HR diagram*.