Computational Assignment 2

Rotating Stellar Drs.:
How Rotation Changes Stellar Evolution

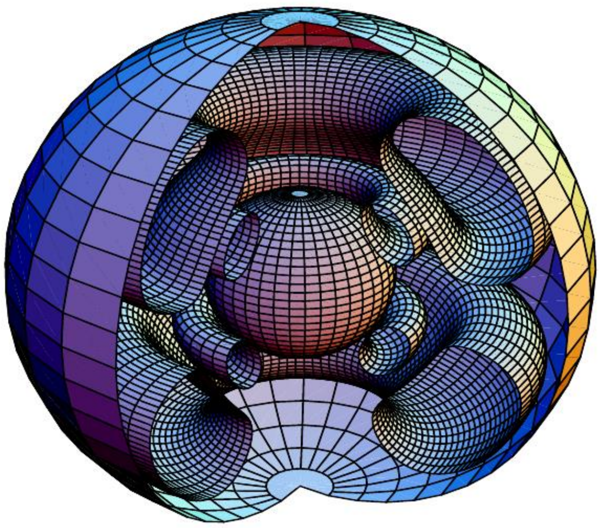

Image credit: Meynet & Maeder 2002

In this assignment, you will repeat the stellar evolution calculation from Assignment 1, but now including **rotation**. Again, you will use the web interface: http://user.astro.wisc.edu/~townsend/static.php?ref=mesa-web
Use the same initial mass and metallicity as before, and compute two initially rotating models:

For both the A and B part of the assignment:
Ω_ZAMS/Ω_crit=0.95

And for the B part of the assignment only

Ω_ZAMS/Ω_crit=0.4 too**.**

There we will also use your non-rotating model from Assignment 1 for comparison. All other assumptions in your rotating models will be the same as in Assignment 1, apart from initial rotation (also I would suggest to allow for **250 profiles**, so that you have enough internal-structure snapshots).

A) Only for the 0.95 model:

1. Angular Momentum Evolution

Using trimmed_history.data, plot the **total angular momentum** as a function of time for the rotating model.

Try different x-axis choices to pick the one that shows the the evolution as clear as possible (i.e. which zooms at the abrupt changes in angular momentum). For example, try

- linear time
- logarithmic time
- or remaining time until the end of the model, |t_max – t|, on a logarithmic axis, and optionally reversed for aesthetic reasons

Check Assignment 1 also for the discussion of this axis. Also decide on the whether the y-axis should be linear or logarithmic

Discuss briefly what we see in the evolution of J_spin

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2. Surface Rotation Evolution

Using trimmed_history.data, plot figures of the time of evolution of

- **V_surf,**
- **Ω_surf,**
- **Ω_crit,**
- **Ω_surf/Ω_crit**
- **Radius** (in log preferably)

Feel free to combine pairs of them together in one plot, adding a second y-axis (so time, as discussed and decided in point 1 above, and y-axes V_surf and Radius together).

Discuss:

- What happens when the star expands or contracts?
- Does the star approach critical rotation at any point and why?
- Is Ω_surf/Ω_crit mainly changing because of Ω_surf, or Ω_crit change, or both?
- Connect the behaviour of the quantities to the main evolutionary phases (changes in nuclear burning, changes in the state of the star, changes in radius, etc)

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3. Internal Rotation and Specific Angular Momentum

Choose three profiles for the rapidly rotating model:

- one during the MS,
- one after TAMS but before helium core burning.
- one at the very end

Plot $\Omega(m)$ and as a 2nd y-axis the specific angular momentum $j(m)$

Discuss:

- Is the star close to solid-body rotation, or differentially rotating? When
- What is happening at the convective regions, do they behave in a similar manner as regions of radiative equilibrium?
- Does the core rotate faster than the envelope?
- Where is most of the angular momentum stored?
- What evidence is there for angular momentum transport?
- How do the slowly and rapidly rotating models compare?

B) Combining the 0.95 model, as well as the 0.4 and the non-rotating one:

4. HR Diagram: With and Without Rotation

Plot the HRD for:

- the non-rotating model from Assignment 1,
- $\Omega_{ZAMS}/\Omega_{crit}=0.40$,
- $\Omega_{ZAMS}/\Omega_{crit}=0.95$.

For each model, report:

- age at TAMS,
- luminosity and effective temperature at TAMS,
- final total mass,
- final helium-core mass.

Discuss:

- Does rotation change the MS lifetime, how and, why?
- Does rotation change the HRD track?
- Does rotation change the final helium-core mass?

- Can rotational mixing explain the differences?

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5. Chemical Mixing Near TAMS

Choose one profile close to TAMS for each of the three models:

Plot the abundance profiles versus mass coordinate, or show the ones from the movie.

Discuss:

- Are the abundance gradients smoother in the rotating models?
- Is there evidence for extra mixing outside the convective core?
- Does the rapidly rotating model show stronger mixing?
- How does the helium-core size compare between the three models?