3D inspired 1D-FASTWIND: The path to solving the mass-discrepancy problem

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Motivation

- Spectroscopic masses are notoriously difficult to calculate and do not agree with dynamical masses consistently. With over all the low mass stars being underestimated, while the high mass stars are overestimated by spectroscopy.

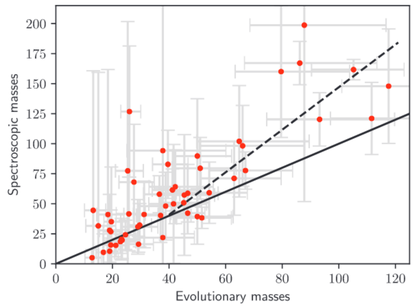


Fig 1

- 1D atmospheres are very different from averages of multi-D radiation hydro-dynamical (RHD) models.
- This difference can be mitigated by the introduction of turbulent pressure

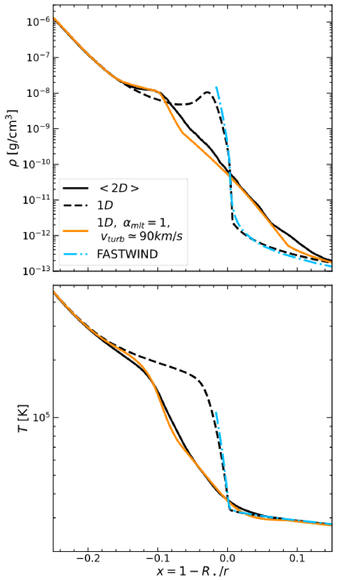


Fig 2

Take-Home Message

By including turbulent pressure in the quasi-hydrostatic calculations of FASTWIND we can solve the mass-discrepancy problem. We show this by retrieving the dynamical mass of a binary through detailed spectral fitting, with a turbulent pressure derived from multi-D radiation hydro-dynamical models.

Methods

- By introducing a turbulent velocity to the effective sound speed, we also add a turbulent pressure.

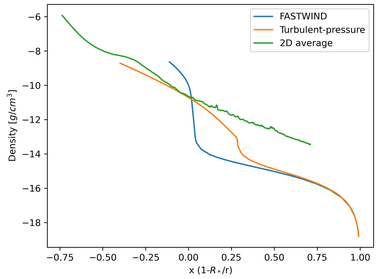
$$a_s^2(r) = \frac{k_B T(r)}{\mu(r) m_H} + v_{turb}^2(r)$$

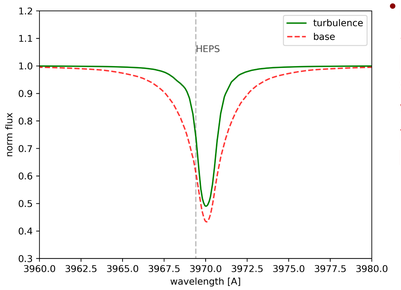
- This new pressure term gets introduced into the hydrostatic equation through the pressure.

$$\frac{dP}{dr} = -\rho(r)\left[g(r) - a_{rad}(r)\right]$$

Induced variation changes on the 1D profile

- The inclusion of turbulent pressure produces a stellar structure a lot closer to the multi-D models
- The line profile of the balmer lines react to the change in scale-height making them narrow





- Due to the multi-D RHD simulations of Moens in prep., we can get an estimate on the turbulent velocity for stars based on their spectroscopic luminosity.

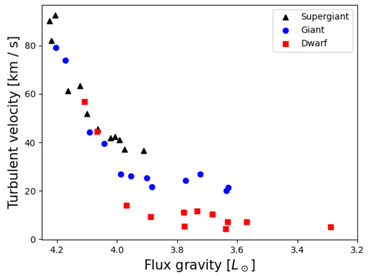
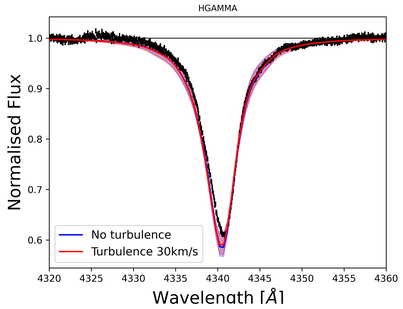
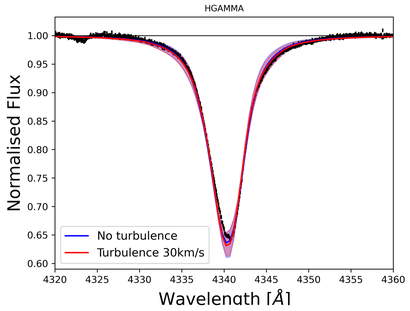


Fig 3

Results

- Logg increases by 0.2 with an error of 0.1
- Fit quality does not change
- Other values such as mass-loss rate and Effective temperature do not change





- Mass increases by almost a factor 2

New spectroscopic mass including turbulence is close to the dynamically derived mass without any fine-tuning of the turbulent pressure

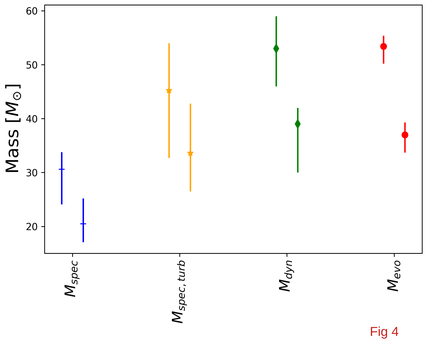


Fig 4

Conclusion:

- **Turbulent velocities are a solution to the mass-discrepancy problem,**
- **The turbulent velocities from the multi-D RHD simulations agree with the real stars.**

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References: Fig1: Bestenlehner et al. 2020
Fig2: Debnath et al. 2024
Fig3: Moens et al. in prep.
Fig4: Dynamical en evolutionary masses from Fabry et al. 2021