A new model grid expanding on the BoOST project

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Chemically Homogeneous Evolution

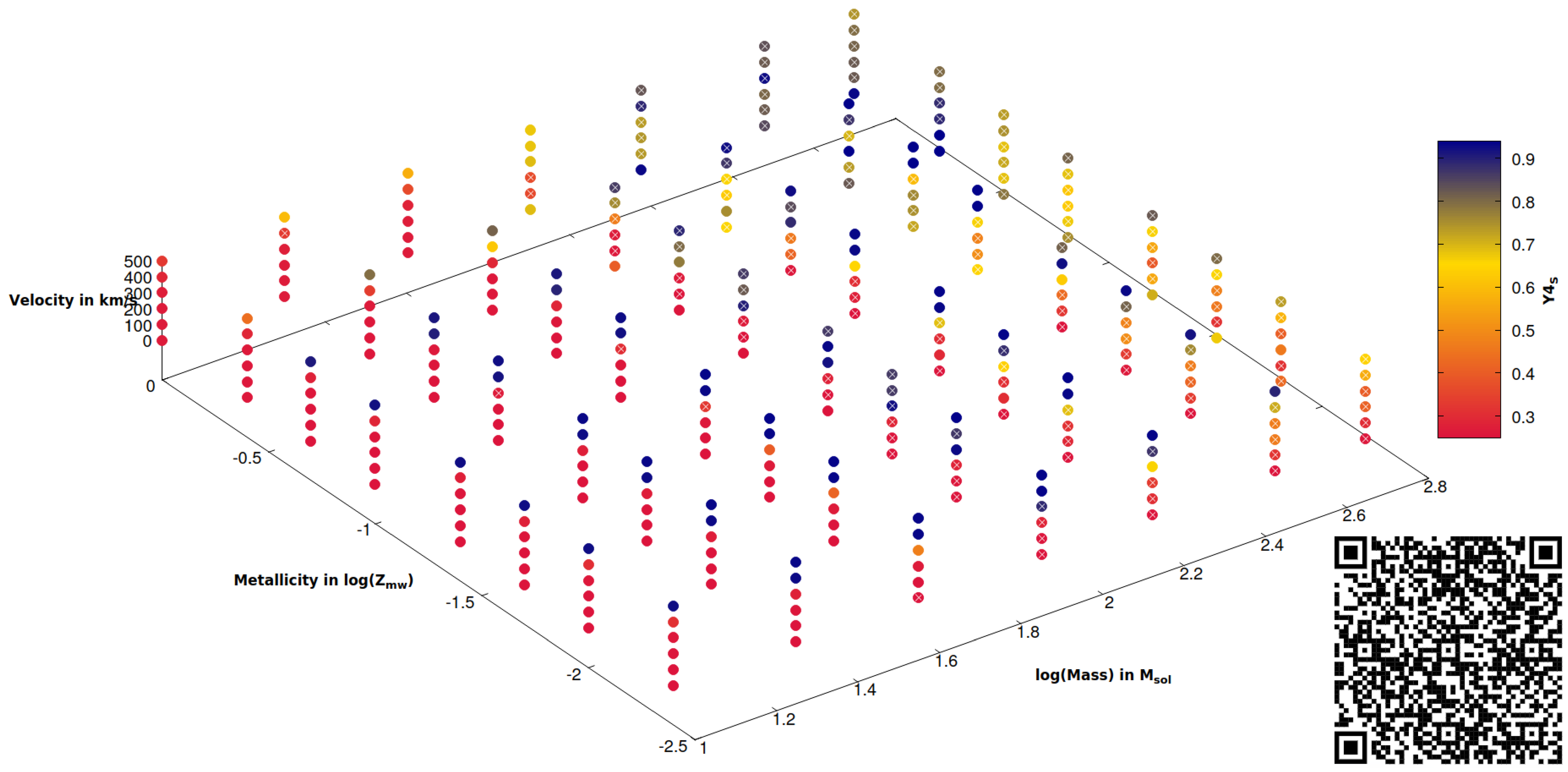
In contrast to the 'normal' evolution of stars (with core-envelope structure) in our vicinity, models show that a different kind of evolution is possible: Chemically homogeneous evolution [1]. Rotation enhances mixing in massive stars. This facilitates longer lifetimes and different surface abundances, and in extreme cases may lead to (complete or partial) chemically homogeneous evolution. For example Szécsi, Langer, et al. (2015) [2] showed (by means of models with metallicity of the metal-poor dwarf galaxy I Zwicky 18) that this evolutionary behavior is more likely for higher masses and velocities.

The Models

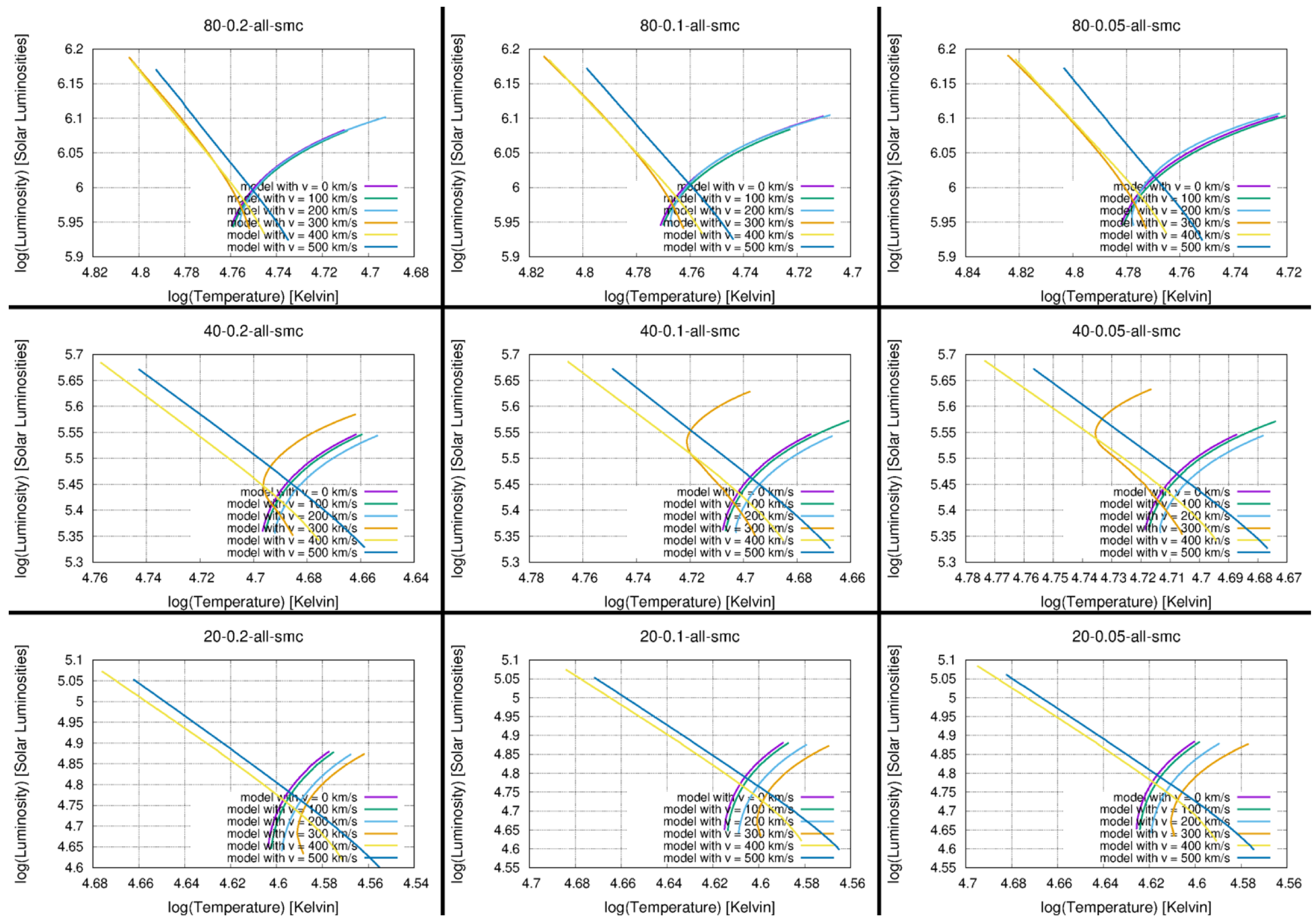
The models I created cover the initial masses **10**, **20**, **40**, **80**, **150**, **300** and **500** $\boldsymbol{M_\odot}$ (massive stars), initial rotational velocities of **0**, **100**, **200**, **300**, **400** and **500** $\boldsymbol{km/s}$ and initial metallicities of the Milky way (Z_{MW}), the Large Magellanic Cloud (Z_{LMC}) and multiple fractions of that of the Small Magellanic Cloud (**1**, **0.5**, **0.2**, **0.1**, **0.05** and $\mathbf{0.02 \cdot Z_{SMC}}$), together summing up to 336 model sequences.
The ranges for masses and metallicities were chosen because of the BoOST project (Bonn Optimized Stellar Tracks) [3], which is a publication of 9 stellar model grids computed with the so-called Bonn-Code. It employed a similar set of initial values, on which I wanted to expand on the velocity variation. The goal was a set of grids including low metallicity environments with a smooth distribution that can then be used in e.g. chemical evolution studies.

The Models - Y_S

The bifurcation of the evolutionary paths can also be displayed by plotting the surface helium mass fraction of the models at the end of the main sequence (as dots) or the end of their current lifetime if the main sequence was not yet completed (as crossed dots) of each model (in a color diagram for all the initial parameters, from different perspectives for better accessibility).
The evolutionary pathway heavily impacts the helium levels; Chemically homogeneous evolution leads to high helium abundances (up to 0.95, blue in the above figure), whereas a normal evolution leaves the helium abundance more or less untouched at initial values (around 0.25, red in the above figure). When plotting it against the initial parameters, one therefore can see the tendencies for such behaviors depending on the initial parameters.



The Models - HRD



Here the Hertzsprung-Russell diagrams of **80** to **20** $\boldsymbol{M_\odot}$ and metallicities from **0.2** to **0.05** of that of the Small Magellanic Cloud are depicted. The velocities are plotted in the same graph with various colors, ranging from purple (**0** $\boldsymbol{km/s}$) to dark blue (**500** $\boldsymbol{km/s}$).
In the Hertzsprung-Russell diagrams you can see the bifurcation of the sequences evolving red- and rightward (towards cool temperatures) with a "normal" evolution, and blue- and leftward (towards hot temperatures) with a chemically homogeneous evolution. Additionally transitional modes are presented for some sequences (cf. for example the orange line of the **40** $\boldsymbol{M_\odot}$, $\mathbf{0.1 \cdot Z_{SMC}}$ sequence).

References

[1] Yoon, S.C., Langer, N., "Evolution of rapidly rotating metal-poor massive stars towards gamma-ray bursts", A&A
[2] Szécsi, D. et al., "Low-metallicity massive single stars with rotation. Evolutionary models applicable to I Zwicky 18", A&A
[3] Szécsi, D. et al., "Bonn Optimized Stellar Tracks (BoOST). Simulated Populations of Massive and Very Massive Stars for Astrophysical Applications", A&A
[4] Da Costa, G.S. (1997), "Abundance Anomalies in Globular Clusters", In: Bedding, T.R. et al., "Fundamental Stellar Properties: The Interaction Between Observation and Theory" (International Astronomical Union / Union Astronomique Internationale), vol. 189
[5] Cameron, A. G. W., Fowler, W. A., "Lithium and the s-process in red-giant stars", Astrophys. J.