Rapidly rotating Population III stellar models

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The first stars in the Universe have inherited their composition from primordial nucleosynthesis, so they have no metals.
Recent studies showed that they might have been fast rotators (Stacy et al. 2013). This has likely interesting consequences for their radiative, mechanical and chemical feedback.

Aim → Considering initially fast rotating Pop III stellar models, we discuss how their evolution differ from non-rotating and moderately rotating ones. We mainly explore the consequences on the production of ^{12}C, ^{13}C, ^{14}N, ^{16}O, ^{19}F and ^{22}Ne.

Methods → We compare grids of Pop III stars with *zero*, *average* (Murphy et al. 2021a), and *high rotation* (this work). All the models have been computed using Geneva code (GENEC) in the mass range of $9M_\odot \leqslant M_{ini} \leqslant 120M_\odot$. Rotational mixing of the chemical elements is mainly due to shear turbulence.

Results → The fast rotating Pop III stellar models do not follow a homogeneous evolution, they never reach the Eddington limit and lose very little mass in case mechanical winds are switched on.
Impact on the ionising flux appears modest when compared to moderately rotating models.
High rotation favours in models, with initial masses above ~20 $M_\odot$, the apparition of a very extended intermediate convective zone around the H-burning shell during the core He-burning phase. This shell has important consequences on the sizes of the He- and CO-cores and thus will impact the final fate of stars. It has also a strong impact on nucleosynthesis boosting the production of ^{13}C, ^{14}N, ^{19}F and ^{22}Ne.

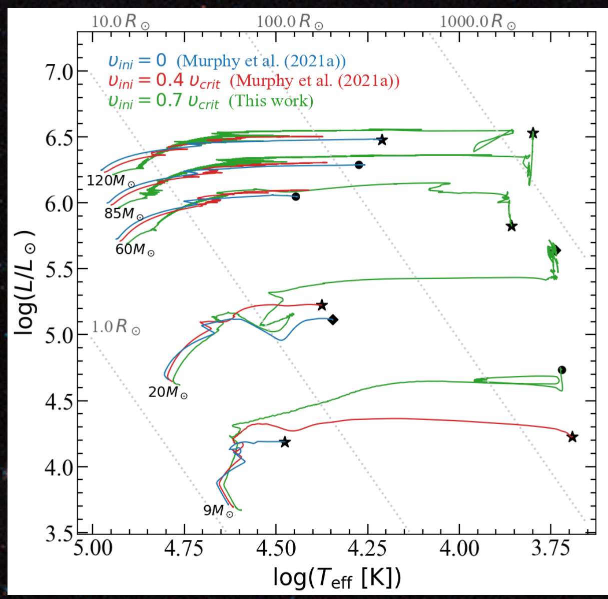

Figure 1: Hertzsprung-Russell diagram (HRD) of the Pop III models from Murphy et al. (2021a) (zero and average initial rotation) and the rapidly-rotating models computed for this work. The symbols drawn at the end of the tracks mark the final evolutionary stage attained: a star for models that have completed the core He-burning phase, a circle for models that are either during the core C-burning phase or at the end of it, and a diamond for models after the core C-burning phase. The models without any symbol were stopped in the core He-burning phase. Iso-radius lines are drawn in dotted grey.

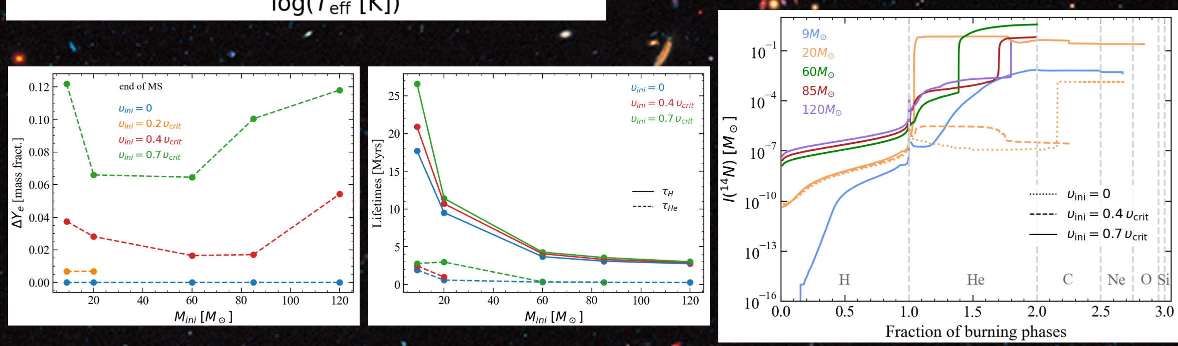

Figure 2: *Left panel:* Surface ^{4}He enrichment at the end of the MS phase as a function of the initial mass for all the Pop III models. *Middle panel:* The lifetimes of each model given the initial mass for all the grids with different initial rotations. The solid lines correspond to the lifetime of the MS (core H-burning phase) and the dashed lines to the lifetime of the core He-burning phase. *Right panel:* The evolution of ^{14}N during the evolution of the models with zero, average and high initial rotation.

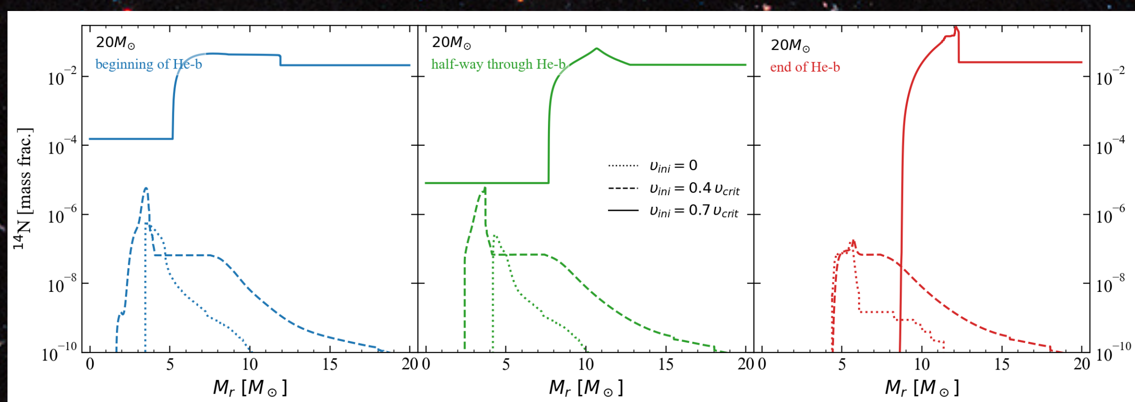

Figure 3: The abundance of ^{14}N as a function of the lagrangian mass coordinate during different stages of the core He-burning phase for the 20 $M_\odot$ model with different initial rotations, zero (dotted lines), average (dashed lines), and high (solid lines).

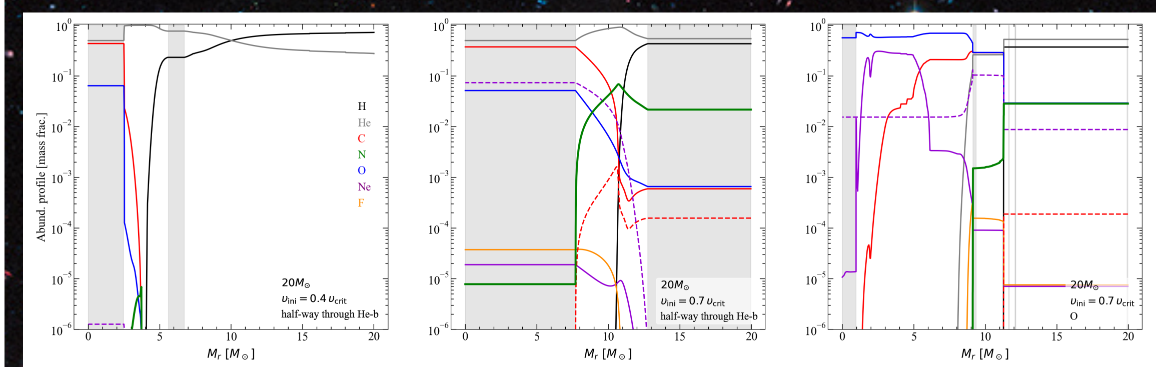

Figure 4: The chemical structures as a function of the lagrangian mass coordinate in the interior of 20 $M_\odot$ Pop III with average initial rotation (*Left panel*) and high one (*Middle and Right panel*). Each coloured line represents a different element, as it is noted on the upper left plot. The light brown zones are the convective areas of each model.

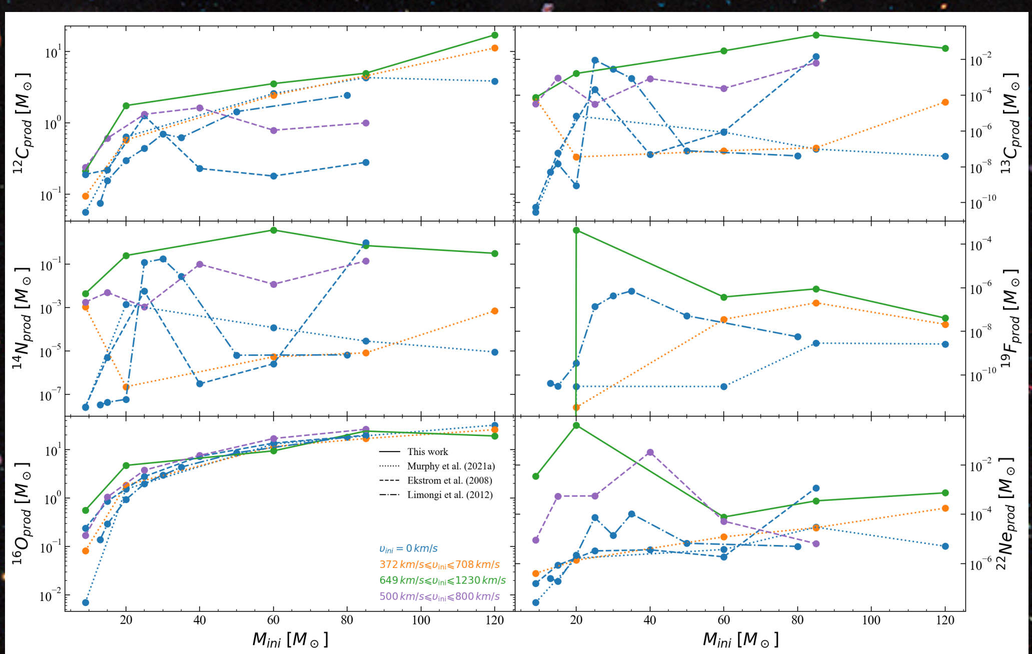

Figure 5: The stellar yields Pop III grids with and without rotation. The dotted-lines are grids from Murphy et al. (2021a), the dashed-lines from Ekström et al. (2008), and the dash-dot-lines from Limongi & Chieffi (2012). Different colour correspond to different initial rotations as it is indicated on the bottom left plot.

High initial rotation impacts significantly the chemical feedbacks of Pop III stars.

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