Dark Matter in Pop III stars:
The effect of a hypothetical object over another

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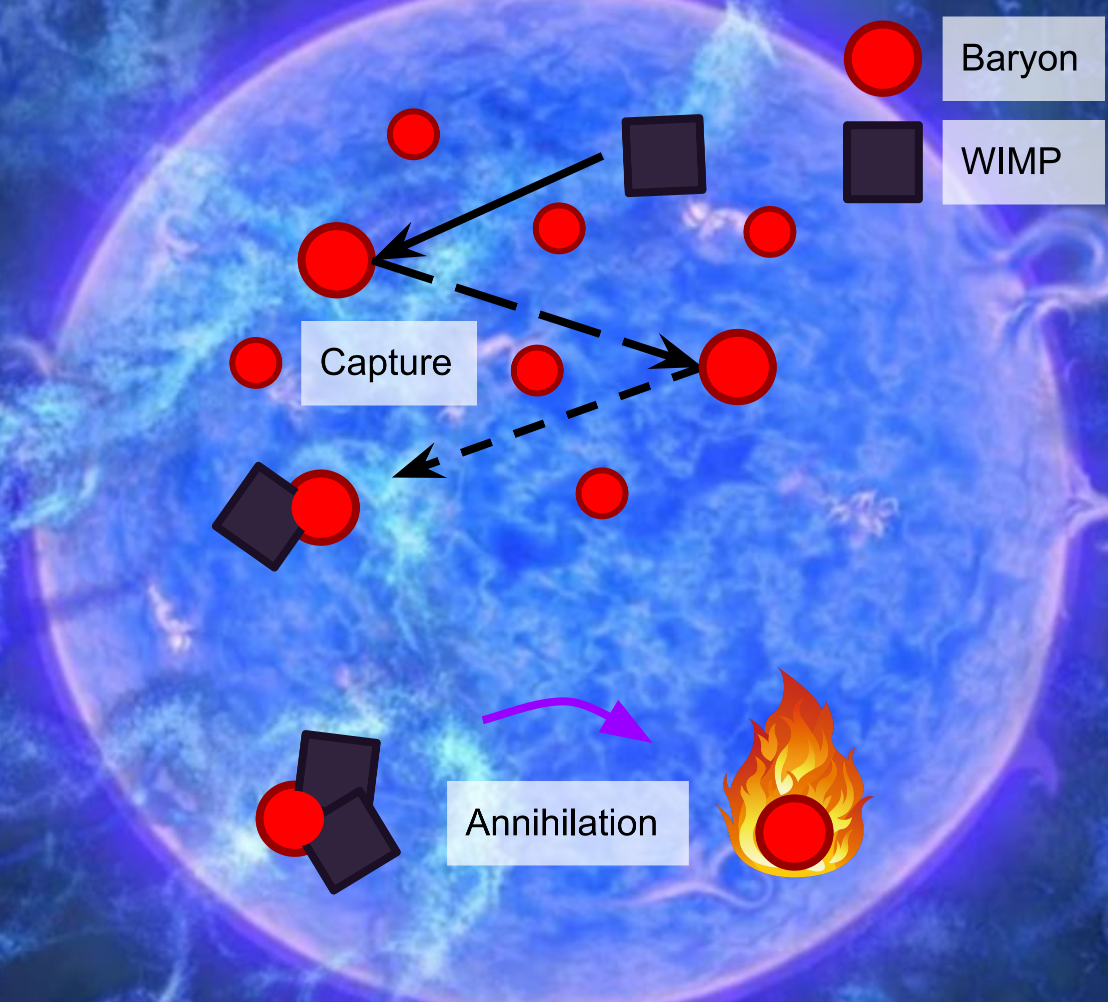
Introduction

Population III stars are the **first supplier of light and metal of the universe.** As formed in dense **Dark Matter (DM) halos**, their formation and evolution can be strongly affected by the **capture and annihilation of Weakly Interacting Massive Particles (WIMPs)** a DM candidate.
In this work we run models of 20 $M_\odot$ with **different WIMPs densities and rotation velocities**, thanks to the stellar evolutionary code GENEC (observatoire de Genève), and analyse their effects on the structure, lifetime and chemical composition of the star along its evolution (*Pauchet et al. 2026*).

Baryon–DM interaction

DM can interact with baryonic matter through two main mechanisms:
Capture: a WIMP passing by the star will scattered by baryons until it loses enough momentum and is captured by one of them.
Annihilation: as WIMPs are their own antiparticle they can annihilate themselves which bring energy to the star.

→ take place in the **densest part i.e. the stellar core**
WIMPs annihilation produces a **new source of energy throttling nuclear burning** ⇒ the star is sustained without using its Hydrogen fuel ⇒ **extended Main Sequence** (MS) (see *Figure 1*)



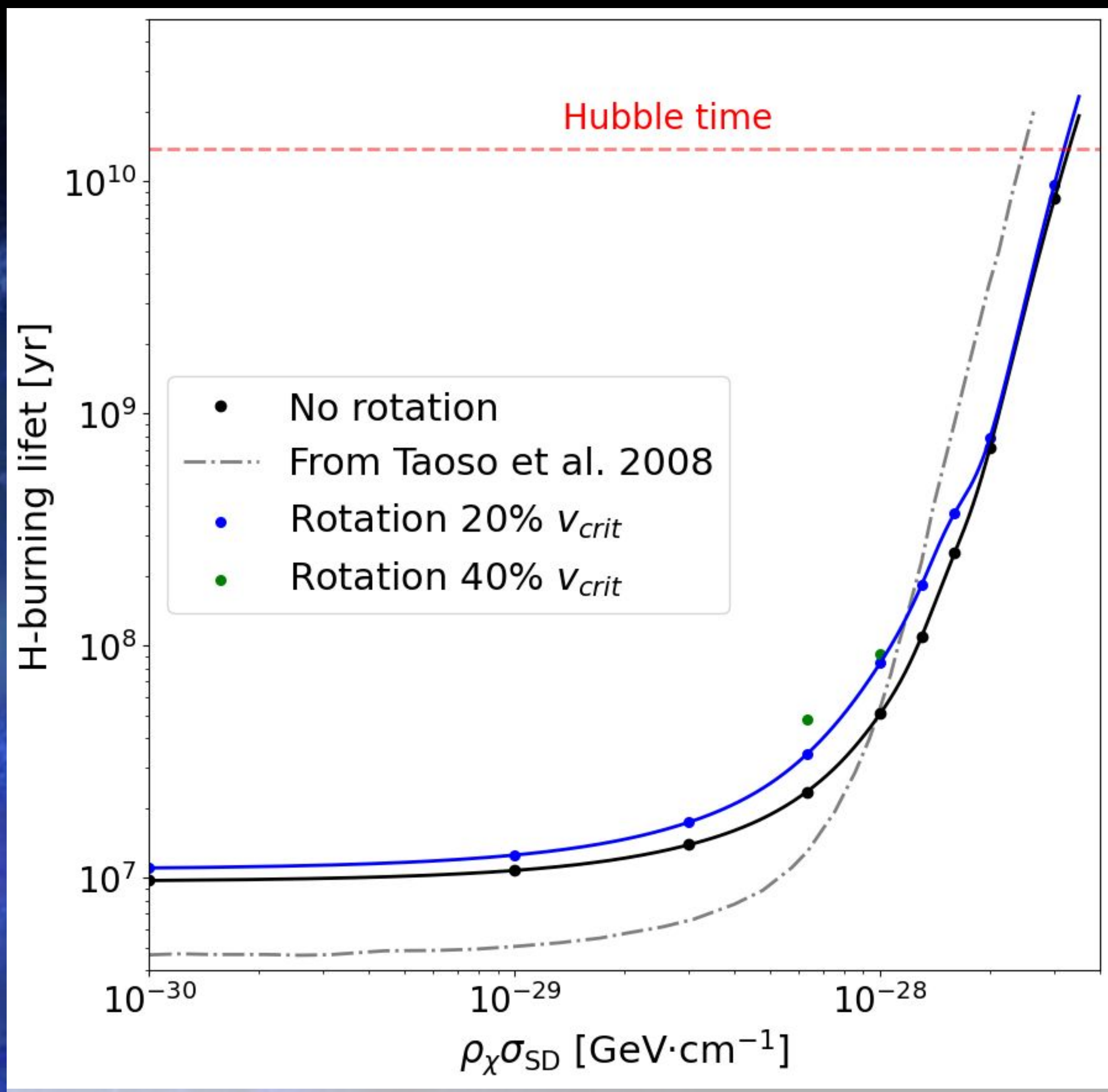


Figure 1: MS duration for a 20 $M_\odot$ stars as a function of the WIMPs density surrounding the star $(\sigma_{SD} = 10^{-40}\ cm^{-2})$. Blue and green dots describe rotating stars at 20% and 40% of the critical velocity (v_{crit}).

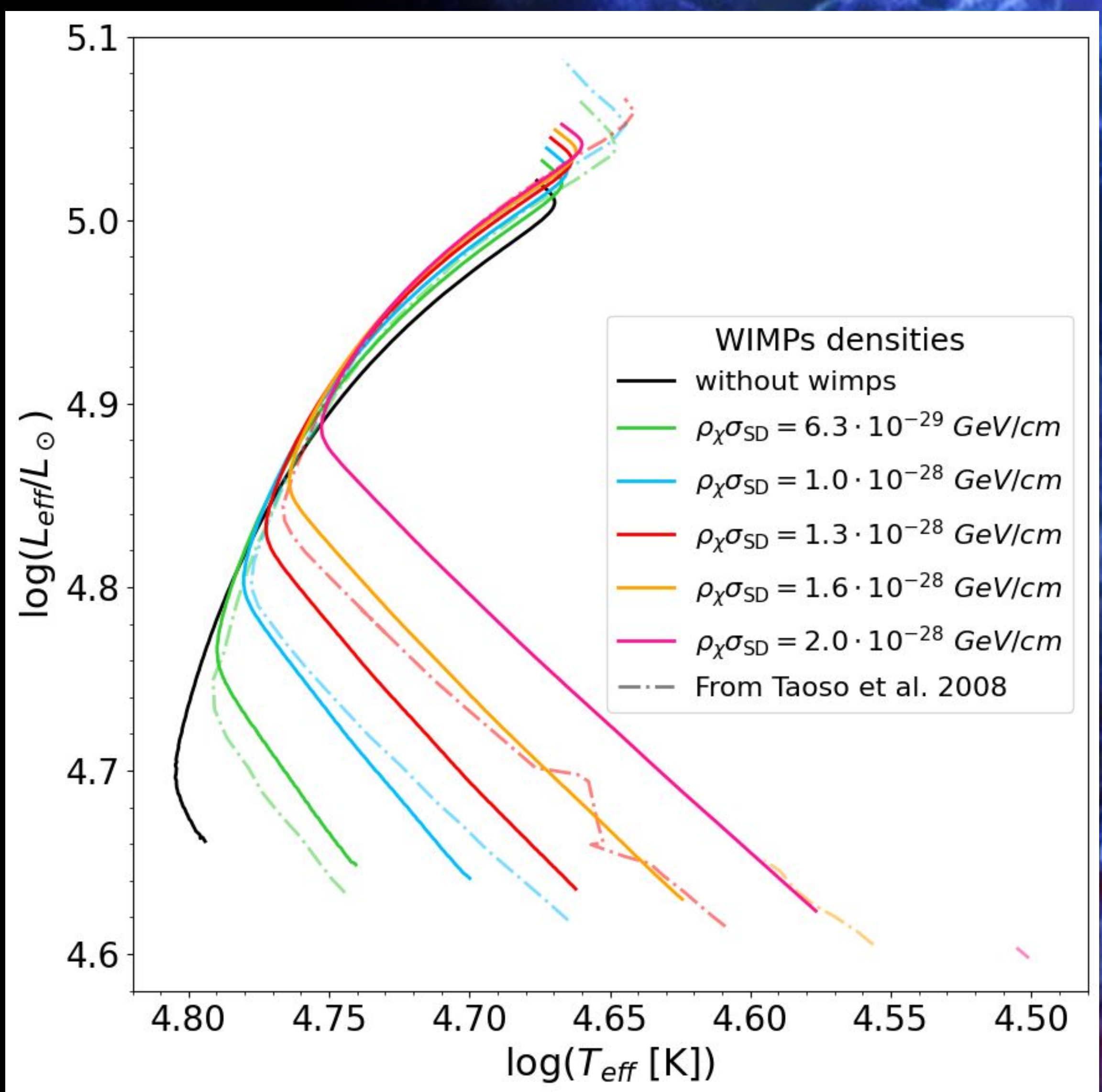


Figure 2: Hertzsprung-Russel Diagram for a 20 $M_\odot$ stars within a halo of different WIMPs densities

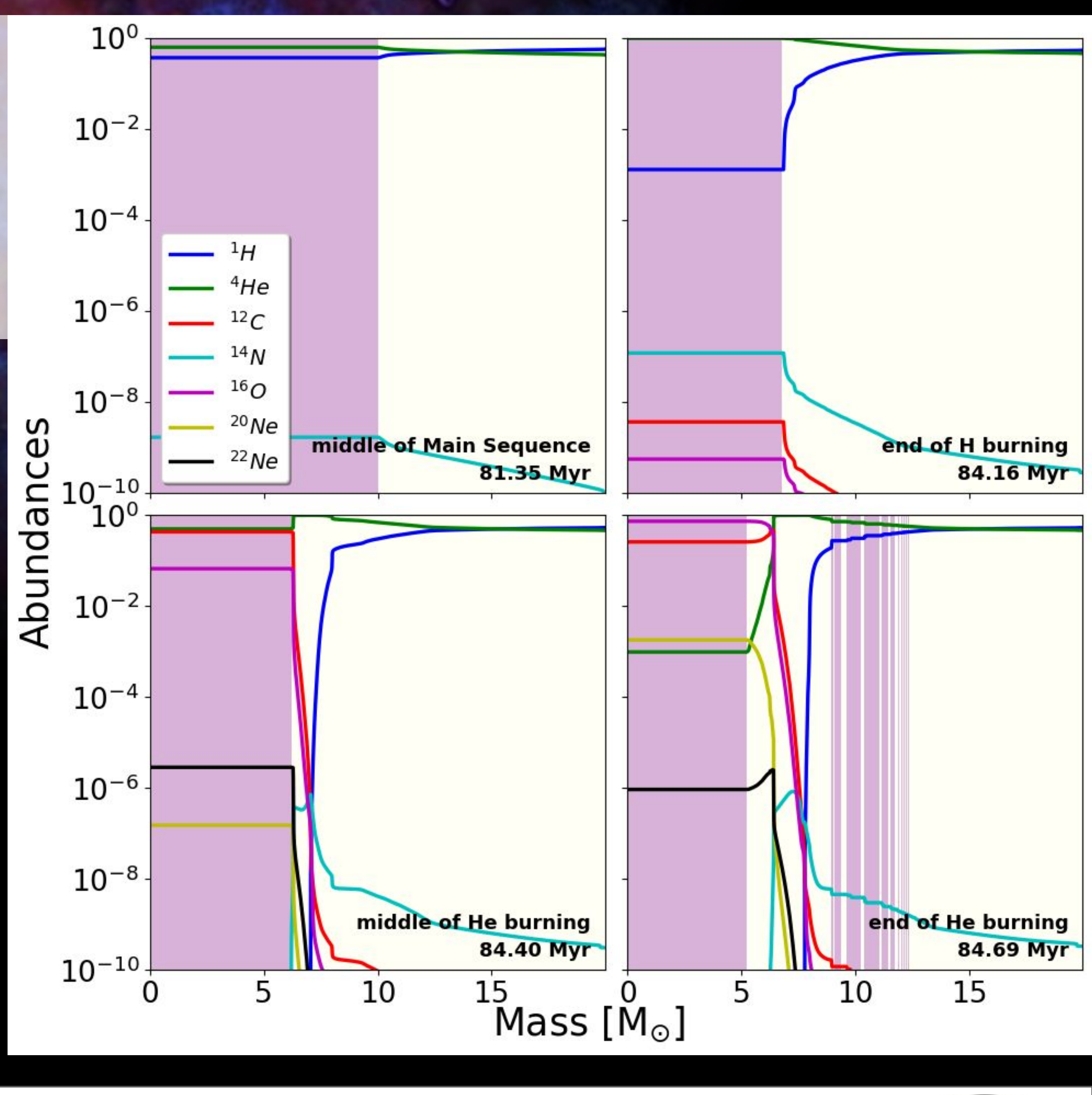
Effect on the star structure

At the ZAMS: additional energy injection from WIMPs annihilation in the stellar core **inflates the star → larger radius (cooler Teff)**.
⇒ **energy output is dominated by WIMP annihilation rather than nuclear fusion**, the star undergoes only minimal H-burning during MS.
As evolution proceeds, the **DM energy input gradually becomes less dominant**. Once a significant amount of H is converted into He in the core, the **WIMP capture rate drops** → nuclear energy production steadily increases and **the star resumes a more conventional MS evolution** (see *Figure 2*).

Rotating stars

Adding rotation to the system, **even a relative low rotation velocity i.e. 20% of** v_{crit} is enough to show an **extended mixing of chemicals and heat transport towards the surface**. This leads to hotter and more luminous stars even when H-burning becomes dominant again.

Figure 3: Chemical abundances as a function of the mass enclosed inside a specific radius of a 20 $M_\odot$ star at 20% of v_{crit} with DM. Each plot shows a different star evolution stage. The pink area describes the helium core area.



Chemical mixing and SuperNova (SN) yields

Surface abundances: For a DM-star with 0.2 v_{crit}, H surface abundance is lowered to ~0.53 while He increases to Y~0.47 in comparison to X~0.75 and Y~0.25 for a DM-free star, **values generally reached for DM-free stars at much larger spin > 0.5** v_{crit}. The same model also leads to **extreme CNO yields, i.e. 50 times higher surface abundances**.

SN yields: The integrated masses, from the He core to the surface **are 45% poorer in H and 33% richer in He for the DM + rotation model**. Additionally the same model gives SN yields **5 and 8 times more massive for N and O, respectively.**

Conclusion

- ***lifetime***: extension of MS which can reach billions of years.
- ***stellar structure***: At the ZAMS the static WIMP model is 26% cooler and 55% larger compared to the DM–free model.
- ***mixing***: rotation + extended lifetime → surface abundances richer in metals and poorer in H.
- ***SN yields***: rotating model with WIMPs = most promising model as it exhibits an ↗ in He, N and O, while ↘ for H.

Stars formed in a DM halo could be **the progenitors of massive black holes in the center of galaxies**. The challenge is **how to detect them?** With this work we hope to open the research on those fascinating objects.

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