Effects of the variation of fundamental constants on Pop III stellar evolution

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The equivalence principle is a cornerstone of metric theories of gravitation and in particular of General Relativity. This principle, including the universality of free fall, the local position and Lorentz invariances, postulates that the values of the dimensionless constants, such as the fine structure constant, must remain fixed. It follows that by testing the constancy of fundamental constants one actually performs a test of General Relativity, that can be extended on astrophysical and cosmological scales. We have considered the very first generation of stars which are thought to have been formed a few $10^8$ years after the big bang, at a redshift of $z \sim 10^{-15}$, and with zero initial metallicity. A variation of the fundamental constants is expected to affect the thermonuclear rates important for stellar nucleosynthesis. In particular, the triple-alpha process is very sensitive to the position of a resonance corresponding to the "Hoyle state"[1] in $^{12}\text{C}$. In order to analyze its variation with the nuclear interaction, we have used a nuclear microscopic cluster model to calculate the energy of the $^8\text{Be}$ ground state, of the Hoyle level and the binding energy of deuterium. This latter quantity can be related (model dependently) to the more fundamental parameters[2]. We followed the evolution of 15 and 60 $\text{M}_\odot$ stars, zero metallicity stellar models, up to the end of core helium burning. These stars are assumed to be representative of the first Population III stars. The requirement that some $^{12}\text{C}$ and $^{16}\text{O}$ be present at the end of the helium burning phase allows, for the first time, to limit the variation of the nucleon-nucleon interaction, at a cosmological redshift of $z \sim 10^{-15}$[3]. Depending on models, this can be related to limits on the variations of the fine structure constant.

