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Erratum: Improved constraints on the variation of the weak scale from Big Bang nucleosynthesis

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After publication, we noticed that we did not take into account correctly how the backwards reaction $d + \gamma \to n + p$ is influenced by a change in the deuteron binding energy. Because of the so-called "deuterium bottleneck", the rate of this reaction defines the beginning of Big Bang nucleosynthesis and has therefore a sizeable impact especially on the Helium-4 abundance. The reaction rate for $d+\gamma \to n+p$ is derived from the rate for $n+p \to d+\gamma$ through a detailed balance relation (see e.g. eq. (2.18) of [1]) which can be parameterized in terms of

$$\langle \sigma(d + \gamma \to n + p)v \rangle = \alpha T_9^{\beta} \exp(\kappa/T_9) \langle \sigma(n + p \to d + \gamma)v \rangle ,$$

where T_9 is the photon temperature in units of 10^9 K. The parameter α depends on the deuteron mass (and hence on the deuteron binding energy) and the neutron and proton mass through

$$\alpha \propto \left(\frac{m_n m_p}{m_d} \right)^{3/2} ,$$

while the parameter κ corresponds to the reaction Q-value and is, for this reaction, directly proportional to the deuteron binding energy $\kappa \propto B_d$. When making changes to the deuteron binding energy (and hence its mass) and the nucleon mass, this needs to be taken into account. Of course, changing the deuteron binding energy will affect the parameters α and κ also in other reactions involving the deuteron. However, as we know the dependence of the binding energies of the other nuclei on the Higgs VEV only approximately or not at

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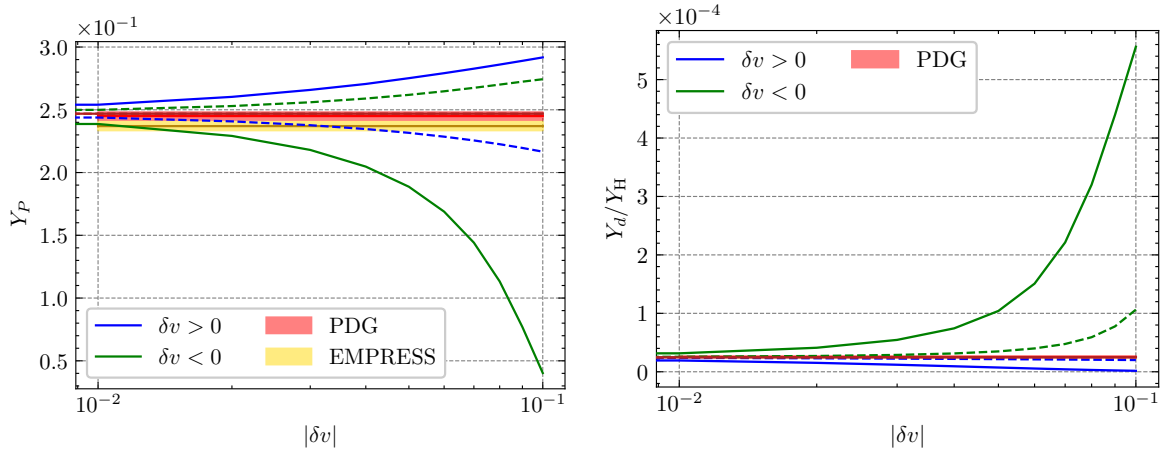

Figure 1. ^{4}He (left) and d (right) abundance as a function of $\delta v/v$. The dashed lines are the previous result shown in figure 8 of the original work, the straight lines the new, corrected ones.

	^{4}He	d
PDG	$\delta v/v \in [-0.0069, 0.0039]$	$\delta v/v \in [-0.0007, -0.0002]$
EMPRESS	$\delta v/v \in [-0.0138, -0.0030]$	

Table 1. Constraints on the Higgs VEV variation $\delta v/v$ derived from 2σ bounds of the observed values given in the PDG [2] and by the EMPRESS collaboration [3] for the abundances of ^{4}He and deuterium.

all, it would seem incomplete to include only the change in the deuteron binding energy for the parameters of these reactions. Because the effects of changing the detailed balance parameters for other rates will be minor compared to changing the $d + \gamma \to n + p$ rate that defines the deuterium bottleneck, we are restricting changes to this reaction only. Having implemented these corrections into the `PRyMordial` code [1], we find that the Helium-4 and deuterium abundance dependence on the Higgs VEV is altered significantly. The new results are displayed in figure 1. As one can see, the effect on the Helium-4 abundance is huge, even changing the sign of the Higgs VEV dependence. The deuteron abundance varies even more drastically as before. From this, one can derive new constraints on the Higgs VEV variation, which are listed in table 1. The bound on the Higgs VEV variation from the deuterium abundance is even more stringent than what was found before.

Data Availability Statement. This article has no associated data or the data will not be deposited.

Code Availability Statement. This article has no associated code or the code will not be deposited.

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