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Erratum: Lightest sterile neutrino abundance within the ν MSM

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The following corrections should be implemented in the formulae. In eq. (3.6), the two factors $\frac{3}{4}$ should be replaced with $\frac{1}{2}$. In table 1, the factor $\frac{9}{4}$ should be replaced with $\frac{3}{2}$, and the factor $-\frac{3}{4}$ with $-\frac{1}{2}$. In addition, in eqs. (3.7) and (3.8), one should switch $a_L \leftrightarrow a_R$, which implies $b \rightarrow -b$, $d \rightarrow -d$. The numerical effect of these corrections on $\text{Im } \Sigma$ can be up to $\sim 25\%$ at $T < 20$ MeV for $\alpha = 1$, but is only on the few percent level at $T > 100$ MeV. The effect on the right-handed neutrino production rate is thus much smaller than hadronic uncertainties at $T > 100$ MeV.

The reason for the last correction is subtle. Given that weak interactions of Standard Model neutrinos take place through vertices with the Dirac structure $\sim \gamma^\mu a_L$, where $a_L \equiv (1 - \gamma_5)/2$ is a chiral projector, their inverse propagator is of the form [52]

$$S^{-1}(Q) = a_R (Q + \not{Z}) a_L . \quad (1)$$

Because of the chiral projectors, the (retarded) self-energy can be expressed as

$$\not{Z} = a \not{Q} + b \not{\mu} , \quad (2)$$

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where a, b are complex functions. With this form, the left-handed neutrino propagator reads [52]

$$S(Q) = a_L \frac{(1+a) \not{Q} + b \not{u}}{[(1+a)Q + bu]^2} a_R. \quad (3)$$

It is this propagator which plays a role in our expressions. However, the imaginary parts of a, b originate at 2-loop level and then \not{Z} has a chiral structure which is *not* trivially of the form in eq. (2). For instance, hadronic effects contain a phase space integral (cf. eq. (3.4))

$$\begin{aligned} \text{Im } \not{Z} &\propto \int d\Omega_{2 \rightarrow 2} \gamma^\mu \not{P}_1 \gamma^\nu \text{Tr} \left[\not{P}_2 \gamma_\mu \not{P}_3 \gamma_\nu a_L \right] \\ &= 8 \int d\Omega_{2 \rightarrow 2} \left(P_1 \cdot P_2 \not{P}_3 a_R + P_1 \cdot P_3 \not{P}_2 a_L \right), \end{aligned} \quad (4)$$

where $d\Omega_{2 \rightarrow 2}$ denotes a phase space measure including appropriate initial or final state Fermi distributions, and P_1, P_2 and P_3 are four-momenta of the associated particles. Now, when considered in the context of eq. (1), the part containing a_R gets projected out. In contrast, if the full \not{Z} were inserted into the numerator of eq. (3) (which is inconsistent), the part containing a_L would get projected out. In order to get correct results, it is important to *first* take the projection that sets the self-energy in the form of eqs. (1), (2).

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