**Erratum: Self-interacting dark matter and cosmology
of a light scalar mediator
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The true exclusion constraint from the invisible Z -decay width is less constraining than the one shown in Fig. 4 of Ref. [1]. We present a corrected version of the calculations and the figure below [2]. The invisible Z -boson decay width is

$$\Gamma_{Z \rightarrow \text{inv}} = \Gamma_{Z \rightarrow \nu_e \nu_e} + \Gamma_{Z \rightarrow \nu_\tau \nu_\tau} + \Gamma_{Z \rightarrow \nu_\mu \nu_\mu} + \Gamma_{Z \rightarrow NN}. \quad (1)$$

Let us denote the decay width of Z to one relativistic fermion by $\Gamma_{Z \rightarrow \nu\nu}$. If, for example, N mixes only with a τ neutrino, then

$$\begin{aligned} \Gamma_{Z \rightarrow \nu_e \nu_e} &= \Gamma_{Z \rightarrow \nu_\mu \nu_\mu} = \Gamma_{Z \rightarrow \nu\nu}, \\ \Gamma_{Z \rightarrow \nu_\tau \nu_\tau} &= \cos^2 \theta \Gamma_{Z \rightarrow \nu\nu}, \\ \Gamma_{Z \rightarrow NN} &= \sin^2 \theta \Gamma_{Z \rightarrow \nu\nu} \left(1 - \frac{m_N^2}{m_Z^2}\right) \left(1 - \frac{4m_N^2}{m_Z^2}\right)^{\frac{1}{2}}. \end{aligned} \quad (2)$$

Now for $m_N \ll m_Z$, the invisible decay width of Z is $\Gamma_{Z \rightarrow \text{inv}} = 3\Gamma_{Z \rightarrow \nu\nu}$, as in the standard model. This decay width is in agreement with the experimental value given by Eq. (4.5) of the original paper. The mixing modifies $\Gamma_{Z \rightarrow \text{inv}}$ only at $m_N \gtrsim m_Z/2$, as shown in Fig. 1.

In addition, our CMB constraint on sterile neutrinos with $m_N \lesssim 1$ MeV was too weak; we only required that such neutrinos decay before CMB formation. But this is not enough: Since N 's decay only to neutrinos, their late decay could lead to a significant increase in the neutrino energy density, potentially in conflict with the existing bounds on the amount of dark radiation [3]. We therefore require that N energy density does not exceed that of one-half an equivalent neutrino degree of freedom at the time of their decay. Assuming that the freeze-out of sterile neutrinos occurred before the QCD phase transition ($T_{\text{fo}} > T_{\text{QCD}}$), we find that at $T < m_e$

FIG. 1. We show the excluded regions in the sterile N parameters due to the Z -decay width (red area), the BBN (blue area), and the CMB (green area). In the rightmost shaded region (yellow area), S is too heavy to provide a sufficiently strong self-interaction for ψ .

$$\rho_N = m_N n_N = m_N \frac{g_{\text{eff}}(T)}{g_{\text{eff}}(T_{\text{fo}})} \frac{3\zeta(3)}{2\pi^2} T^3 \approx 0.008 m_N T^3, \quad (3)$$

which, relative to the relativistic neutrinos, is

$$\frac{\rho_N}{\rho_\nu} = \frac{0.008 m_N T^3}{\frac{7\pi^2}{120} \left(\frac{4}{11}\right)^{4/3} T^4} \approx 0.05 \frac{m_N}{T}. \quad (4)$$

We then must require that N decays at the latest at $T = m_N/10$. The N decay width relative to the Hubble expansion rate is given by [using Eq. (4.8) of the original paper for decay width $\Gamma_{N \rightarrow 3\nu}$]

$$\left. \frac{\Gamma_{N \rightarrow 3\nu}}{H} \right|_{10T=m_N} \approx 0.03 \left(\frac{m_N}{\text{MeV}} \right)^3 \sin^2 \theta, \quad (5)$$

which gives

$$m_N (\sin \theta)^{2/3} > 3 \text{ MeV}. \quad (6)$$

This excludes the gray region in Fig. 4 of the original paper. Hence, the ultimate lower bound for the mass of N at given $\sin^2 \theta$ comes from the requirement that N decays before BBN. Figure 1 shows a corrected version of Fig. 4 of the original paper.

[1] K. Kainulainen, K. Tuominen, and V. Vaskonen, *Phys. Rev. D* **93**, 015016 (2016).

[2] We thank J. M. Cline for bringing this error to our attention.

[3] G. Rossi, C. Yèche, N. Palanque-Delabrouille, and J. Lesgourgues, *Phys. Rev. D* **92**, 063505 (2015).