

Erratum: Non-Gaussian entanglement swapping between three-mode spontaneous parametric down-conversion and three qubits [Phys. Rev. A 105, 022401 (2022)]

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An error has been found in the derivation of the genuine multipartite entanglement witnesses of Eqs. (6) and (7) in the numbering of the original text. For clarity, we repeat their definitions with consistent notation here and provide them with new numberings:

$$G_{CV} = |\langle a_1 a_2 a_3 \rangle| - \max_{\substack{i,j,k=1,2,3 \\ i \neq j \neq k \neq i}} \sqrt{\langle a_i^\dagger a_i \rangle \langle a_j^\dagger a_j a_k^\dagger a_k \rangle}, \quad (1)$$

$$G_{DV} = |\langle \sigma_1^- \sigma_2^- \sigma_3^- \rangle| - \max_{\substack{i,j,k=1,2,3 \\ i \neq j \neq k \neq i}} \sqrt{\langle \sigma_i^+ \sigma_i^- \rangle \langle \sigma_j^+ \sigma_j^- \sigma_k^+ \sigma_k^- \rangle}. \quad (2)$$

In the original paper we claimed that their derivation followed from using a convex inequality tighter than the triangle inequality used in a closely related witness introduced in Ref. [1]. Again, we repeat the definition of this correct witness in order to better discuss the flaw in Eqs. (1) and (2):

$$G'_{CV} = |\langle a_1 a_2 a_3 \rangle| - \sum_{\substack{i,j,k=1,2,3 \\ i \neq j \neq k \neq i}} \sqrt{\langle a_i^\dagger a_i \rangle \langle a_j^\dagger a_j a_k^\dagger a_k \rangle}. \quad (3)$$

During the proof of G'_{CV} in Ref. [1], we followed a common route when designing witnesses: we assumed to have a state with no genuine entanglement and derived bounds it had to follow. Namely, we derived bounds for states of the form

$$\rho = P_1 \rho_{1-23} + P_2 \rho_{2-13} + P_3 \rho_{3-12}. \quad (4)$$

Violating those bounds is then proof of genuine entanglement. Crucially, we used the triangle inequality on some expectation values, as stated in Eq. (7) of Ref. [1]:

$$|\langle abc \rangle_\rho| \leq P_1 |\langle abv \rangle_{\rho_{1-23}}| + P_2 |\langle abv \rangle_{\rho_{2-13}}| + P_3 |\langle abv \rangle_{\rho_{3-12}}|. \quad (5)$$

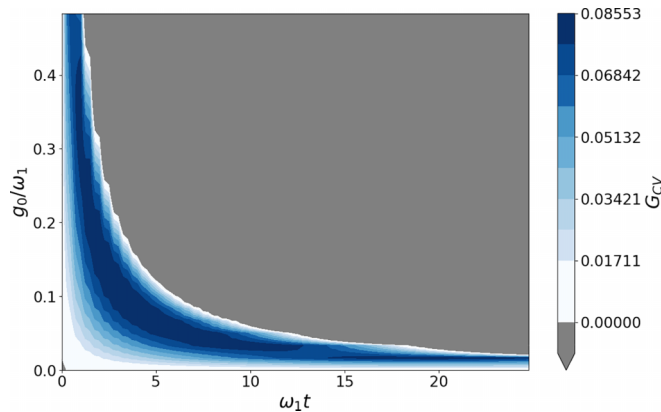


FIG. 1. Genuine multipartite witness from Eq. (3) as a function of both the coupling between the modes in units of the lowest mode g_0/ω_1 and time in units of that same frequency $\omega_1 t$. A positive value certifies genuine entanglement between the photonic modes. When compared to the figures of the original article, the parameter regime of the positive witness is smaller, as expected coming from a loosened bound in the witness derivation.

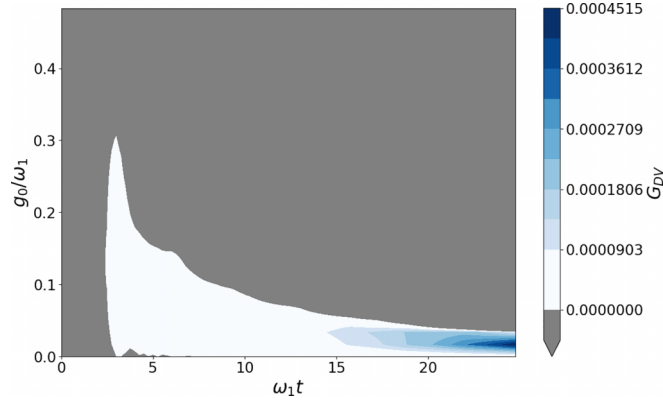


FIG. 2. Genuine multipartite witness from Eq. (3) but applied to the qubits and represented on the same parameter regime as Fig. 1.

Then, in the article this erratum amends, we said that a tighter bound holds if one takes into account the fact that the expectation values are taken over a convex sum, not some general addition. That is technically correct and the following bound holds:

$$|\langle abc \rangle_\rho| \leq \max_{\substack{i,j,k=1,2,3 \\ i \neq j \neq k \neq i}} |\langle abv \rangle_{\rho_{i-jk}}|. \quad (6)$$

However, we must note the new bound makes no reference to any P_i . Then, it is not possible, to our knowledge, to bound each $|\langle abc \rangle_{\rho_{i-jk}}|$ with some expectation value over the experiment's state ρ .

We conclude that Eqs. (1) and (2) are not genuine entanglement witnesses. Nevertheless, most conclusions from the article to amend still hold if analysis is carried out with the witness in Eq. (3). The genuine entanglement detected is still of non-Gaussian nature and the parameter regimes in which that entanglement is present are reproduced in Figs. 1 and 2.

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- [1] A. Agustí, C. S. Chang, F. Quijandría, G. Johansson, C. Wilson, and C. Sabín, Tripartite genuine non-Gaussian entanglement in three-mode spontaneous parametric down-conversion, *Phys. Rev. Lett.* **125**, 020502 (2020).