Erratum: Constraints on dark photon dark matter using data from LIGO's and Virgo's third observing run [Phys. Rev. D 105, 063030 (2022)]

R. Abbott *et al.*[*]

(LIGO Scientific Collaboration, Virgo Collaboration, and KAGRA Collaboration)

(Received 8 January 2024; published 15 April 2024)

DOI: 10.1103/PhysRevD.109.089902

An oversight in the analysis presented in the original article led to an overly optimistic estimate of the sensitivity of the cross-correlation search to a dark photon dark matter signal. Specifically, the overlap reduction function (ORF) used for the contribution of the finite light speed effect ("common-mode" mirror motion within either interferometer arm leading to an apparent differential strain) [1] was taken to be the same as the ORF for the true differential-mode mirror motion. As reported in [2], the ORF for the finite speed effect (-0.18) is, instead, significantly smaller than that for true differential motion (-0.9). Since the ORF values are squared in computing the coupling strength ϵ^2, the sensitivity reduction of the cross-correlation results depicted in Fig. 3 in the original article is substantial. Hence, we include here a revised Fig. 3 to supersede that in the original article. Because the relative importance of the finite speed contribution is larger at higher frequencies, the sensitivity degradation is greater at higher frequencies. The results from the BSD analysis, which does not rely upon cross-correlation, are unchanged from those shown in the original article and now provide more constraining upper limits on the coupling strength of dark matter to baryons across most of the frequency range.

Following the same notations in the original article, the square root of the amplitude ratio of the cross-correlation for two signal channels in the frequency domain is given by

$$\sqrt{\left|\frac{\langle h^*_{C,I}(f)h_{C,J}(f')\rangle}{\langle h^*_{D,I}(f)h_{D,J}(f')\rangle}\right|} \simeq \frac{\sqrt{3}}{2}\frac{2\pi f L}{v_0}\alpha_{IJ}, \tag{1}$$

where $v_0 \simeq 220$ km/s is the velocity of dark matter orbiting around the galaxy center, L is the arm length of the interferometer, I, J are the detector indices, α_{IJ} is the factor effectively taking into account the ratio of ORFs between the two signal channels, which is given by

$$\alpha_{IJ} = \sqrt{\frac{\delta_{ab}(\hat{X}^a_I - \hat{Y}^a_I)(\hat{X}^b_J - \hat{Y}^b_J)}{\delta_{ac}\delta_{bd}(\hat{X}^a_I\hat{X}^b_I - \hat{Y}^a_I\hat{Y}^b_I)(\hat{X}^c_J\hat{X}^d_J - \hat{Y}^c_J\hat{Y}^d_J)}}, \qquad a,b,c,d = 1,2,3, \tag{2}$$

where $\hat{X}^a_I(\hat{Y}^a_I)$ is the a component of the unit vector of the x arm (y arm) of the interferometer I. For the LIGO-Hanford (H1) and LIGO-Livingston (L1) detectors,

$$\delta_{ab}(\hat{X}^a_{\mathrm{H1}} - \hat{Y}^a_{\mathrm{H1}})(\hat{X}^b_{\mathrm{L1}} - \hat{Y}^b_{\mathrm{L1}}) \simeq -0.059, \tag{3}$$

$$\delta_{ac}\delta_{bd}(\hat{X}^a_{\mathrm{H1}}\hat{X}^b_{\mathrm{H1}} - \hat{Y}^a_{\mathrm{H1}}\hat{Y}^b_{\mathrm{H1}})(\hat{X}^c_{\mathrm{L1}}\hat{X}^d_{\mathrm{L1}} - \hat{Y}^c_{\mathrm{L1}}\hat{Y}^d_{\mathrm{L1}}) \simeq -1.8, \tag{4}$$

and thus,

$$\alpha_{\mathrm{H1L1}} \simeq 0.18. \tag{5}$$

[*]Full author list given at the end of the original article.

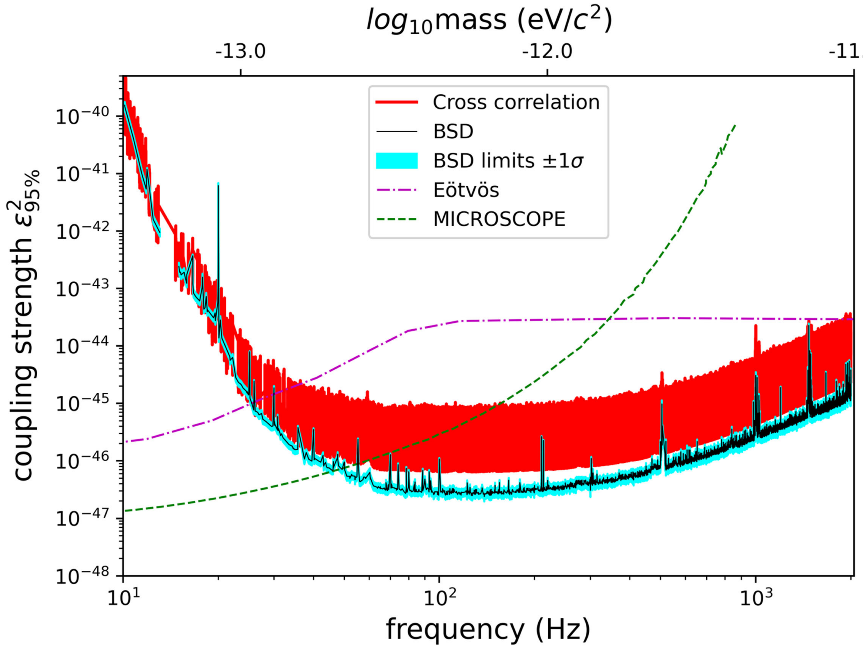

FIG. 1. Updated Fig. 3 of the original article, showing the effect of the reduced ORF on the cross-correlation upper limits (BSD limits remain the same). Even though the fast Fourier transform length $T_{\rm FFT}$ is lower (compared to that of cross correlation) at higher frequencies, the improvement factor resulting from the finite time correction is orders of magnitude larger than the reduction in sensitivity due to a shorter $T_{\rm FFT}$.

The relation between the cross-correlation for two signal channels and the coupling strength ϵ is

$$\begin{aligned}\langle h^*_{{\rm tot},I} h_{{\rm tot},J}\rangle &= \langle h^*_{C,I}(f) h_{C,J}(f')\rangle + \langle h^*_{D,I}(f) h_{D,J}(f')\rangle \\ &\simeq \gamma_{D,IJ}\left[6.58\times10^{-26}\alpha^2_{IJ} + 6.56\times10^{-27}\left(\frac{100\ {\rm Hz}}{f}\right)\right]^2\left(\frac{\epsilon}{10^{-23}}\right)^2, \end{aligned} \tag{6}$$

where $\gamma_{D,{\rm H1L1}} = -0.9$ is the ORF of the differential-mode signal for the LIGO-H1 and LIGO-L1 detector pair.

We see here that the reduced ORF, i.e., $\gamma_{D,{\rm H1L1}} \times \alpha^2_{\rm H1L1} \sim 0.03\gamma_{D,{\rm H1L1}}$ instead of $\gamma_{D,{\rm H1L1}}$ for the ORF of the common-mode signal, implies a larger upper limit on ϵ^2—see Fig. 1 in this Erratum.

We thank Yusuke Manita for drawing our attention to the original oversight and for helpful discussions.

This material is based upon work supported by NSF's LIGO Laboratory, which is a major facility fully funded by the National Science Foundation. The authors also gratefully acknowledge the support of the Science and Technology Facilities Council (STFC) of the United Kingdom, the Max-Planck-Society (MPS), and the State of Niedersachsen/Germany for support of the construction of Advanced LIGO and construction and operation of the GEO600 detector. Additional support for Advanced LIGO was provided by the Australian Research Council. The authors gratefully acknowledge the Italian Istituto Nazionale di Fisica Nucleare (INFN), the French Centre National de la Recherche Scientifique (CNRS) and the Netherlands Organization for Scientific Research, for the construction and operation of the Virgo detector and the creation and support of the EGO consortium. The authors also gratefully acknowledge research support from these agencies as well as by the Council of Scientific and Industrial Research of India, the Department of Science and Technology, India, the Science and Engineering Research Board (SERB), India, the Ministry of Human Resource Development, India, the Spanish Agencia Estatal de Investigación, the Vicepresidència i Conselleria d'Innovació, Recerca i Turisme and the Conselleria d'Educació i Universitat del Govern de les Illes Balears, the Conselleria d'Innovació, Universitats, Ciència i Societat Digital de la Generalitat Valenciana and the CERCA Programme Generalitat de Catalunya, Spain, the National Science Centre of Poland and the Foundation for Polish Science (FNP), the Swiss National Science Foundation (SNSF), the Russian Foundation for Basic Research, the Russian Science Foundation, the European Commission, the European Regional Development Funds (ERDF), the Royal Society, the Scottish Funding Council, the Scottish Universities Physics Alliance, the Hungarian Scientific Research Fund (OTKA), the French Lyon Institute of Origins (LIO), the Belgian Fonds de la

Recherche Scientifique (FRS-FNRS), Actions de Recherche Concertées (ARC) and Fonds Wetenschappelijk Onderzoek—Vlaanderen (FWO), Belgium, the Paris Île-de-France Region, the National Research, Development and Innovation Office Hungary (NKFIH), the National Research Foundation of Korea, the Natural Science and Engineering Research Council Canada, Canadian Foundation for Innovation (CFI), the Brazilian Ministry of Science, Technology, and Innovations, the International Center for Theoretical Physics South American Institute for Fundamental Research (ICTP-SAIFR), the Research Grants Council of Hong Kong, the National Natural Science Foundation of China (NSFC), the Leverhulme Trust, the Research Corporation, the Ministry of Science and Technology (MOST), Taiwan, the United States Department of Energy, and the Kavli Foundation. The authors gratefully acknowledge the support of the NSF, STFC, INFN, and CNRS for provision of computational resources. This work was supported by MEXT, JSPS Leading-edge Research Infrastructure Program, JSPS Grant-in-Aid for Specially Promoted Research Grant No. 26000005, JSPS Grant-in-Aid for Scientific Research on Innovative Areas 2905: Grants No. JP17H06358, No. JP17H06361, and No. JP17H06364, JSPS Core-to-Core Program A. Advanced Research Networks, JSPS Grant-in-Aid for Scientific Research (S) Grant No. 17H06133, the joint research program of the Institute for Cosmic Ray Research, University of Tokyo, National Research Foundation (NRF) and Computing Infrastructure Project of KISTI-GSDC in Korea, Academia Sinica (AS), AS Grid Center (ASGC) and the Ministry of Science and Technology (MoST) in Taiwan under grants including Grant No. AS-CDA-105-M06, Advanced Technology Center (ATC) of NAOJ, and Mechanical Engineering Center of KEK.

[1] S. Morisaki, T. Fujita, Y. Michimura, H. Nakatsuka, and I. Obata, Phys. Rev. D **103**, L051702 (2021).
[2] Y. Manita, H. Takeda, K. Aoki, T. Fujita, and S. Mukohyama, arXiv:2310.10646.