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► **To cite this version:**

Michael E. Tobar, Peter Wolf, Paul L. Stanwix. Comment on “Test of constancy of speed of light with rotating cryogenic optical resonators”. *Physical Review A*, 2005, 72, pp.66101. 10.1103/PhysRevA.72.066101 . hal-03733187

HAL Id: hal-03733187

<https://hal.science/hal-03733187>

Submitted on 29 Jul 2022

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Comment on “Test of constancy of speed of light with rotating cryogenic optical resonators”

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(Received 4 July 2005; published 19 December 2005)

A recent experiment by Antonini *et al.* [Phys. Rev. A **71**, 050101 (2005)] set new limits on Lorentz violating parameters in the framework of the photon sector of the standard model extension, $\tilde{\kappa}_{e-}^{ZZ}$, and the Robertson–Mansouri–Sexl framework, $\beta - \delta - 1/2$. The experiment had significant systematic effects caused by the rotation of the apparatus which was only partly analyzed and taken into account. We show that this is insufficient to put a bound on $\tilde{\kappa}_{e-}^{ZZ}$, and that the bound on $\beta - \delta - 1/2$ represents a fivefold, not tenfold, improvement as claimed.

DOI: [10.1103/PhysRevA.72.066101](https://doi.org/10.1103/PhysRevA.72.066101)

PACS number(s): 03.30.+p, 12.60.-i, 07.60.-j

Nonrotating experiments that test Lorentz invariance are not sensitive to the standard model extension (SME) parameter $\tilde{\kappa}_{e-}^{ZZ}$ [1–6]. To determine this parameter one requires active rotation with a nonzero signal expected to occur at twice the rotation frequency, $2\omega_R$ [7–9]. Thus, it is important to control and minimize systematic signals at this harmonic. If systematics dominate over statistical uncertainties, care must be taken when analyzing the data as it is difficult to distinguish the systematic signal from an actual nonzero value of $\tilde{\kappa}_{e-}^{ZZ}$. One way to do this is to characterize the systematic and subtract it from the data, which can be a difficult process as the amplitude may not necessarily be stationary over the period of data collection. Nevertheless, if one is careful it is a valid process and Antonini *et al.* [7] did effectively account for part of the unknown systematics in their experiment by subtracting the frequency modulation of the resonators induced by tilt. However, they were still left with a statistically significant amplitude at $2\omega_R$, which led to a positive signal for Lorentz violation of $\tilde{\kappa}_{e-}^{ZZ} = (-2.0 \pm 0.2 \times 10^{-14})$. They state that this is likely due to a (nonaccounted) systematic effect and thus claim an upper bound of $|\tilde{\kappa}_{e-}^{ZZ}| < 2 \times 10^{-14}$.

Since the suspected systematic is uncharacterized there is no way to know if the measured amplitude is due to a systematic or a true nonzero value of $\tilde{\kappa}_{e-}^{ZZ}$. Furthermore, one cannot rule out that the uncharacterized systematic is actually canceling (partly or completely, depending on its phase) a larger nonzero value of $\tilde{\kappa}_{e-}^{ZZ}$, so one cannot set a valid upper limit simply equal to the measured value. One way to set a bound amongst the systematic is to include more than one independent set of data (i.e., $n > 1$ where n is the number of data sets). A bound can then be set by treating the amplitude of $\tilde{\kappa}_{e-}^{ZZ}$ as a statistic. This is possible because the phase of the

systematic depends on the initial experimental conditions (i.e., phase with respect to the frame of reference of the test), and is likely to be random across the n data sets [8,9]. If we take the mean of the n $\tilde{\kappa}_{e-}^{ZZ}$ amplitudes, the systematic signal will cancel if the phase is random, but the possible Lorentz violating signal will not. Thus a limit can be set by taking the mean and standard deviation of the amplitude over the n data sets. Therefore, unless more than one data set is analyzed a bound on the value of $\tilde{\kappa}_{e-}^{ZZ}$ cannot be given in the presence of an unknown systematic. Since Antonini *et al.* [7] only gave statistics for one data set of 76 h duration ($n=1$), it is not possible to quote a bound on $\tilde{\kappa}_{e-}^{ZZ}$ from the analysis of this data.

In our recent rotating experiment we determined a value of $\tilde{\kappa}_{e-}^{ZZ}$ of $4.1(0.5) \times 10^{-15}$ by fitting the amplitude over five data sets [8,9]. However, we did not use this result to claim an upper limit on the value of $\tilde{\kappa}_{e-}^{ZZ}$. Instead we followed the approach suggested above and took the mean and standard deviation of the amplitudes obtained from the individual data sets. This allowed us to determine $\tilde{\kappa}_{e-}^{ZZ} = 2.1(5.7) \times 10^{-14}$, the uncertainty being dominated by the variation of the systematic over the data sets.

Antonini *et al.* also claim a tenfold improvement in the Robertson–Mansouri–Sexl (RMS) [10,11] parameter $\beta - \delta - 1/2$ [7], which is determined to be $(+0.5 \pm 3 \pm 0.7) \times 10^{-10}$, in comparison to the previous best result of $(-2.2 \pm 1.5) \times 10^{-9}$ [2]. Comparing the uncertainties this is no more than a factor of 5 improvement and has been overstated by a factor of 2. Our recent concurrent work obtained a value of $(+0.9 \pm 2) \times 10^{-10}$, which is a factor of 7.5 improvement [8].

This work was funded by the Australian Research Council.

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