Comment on arXiv:2312.04495 by M. I. Eremets and coauthors

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In the recently posted arXiv:2312.04495v3 [1], its authors used a computer code written by me supplied to them by the authors of Ref. [2], and claimed that the results that they obtained invalidate the results and conclusions presented in the paper J. Supercond. Nov. Mag. 35, 3141-3145 (2022) by F. Marsiglio and myself [2]. Here I point out that the authors' claim (i) resulted from improper unauthorized use of my computer code, (ii) is wrong, and (iii) is misleading to the scientific community.

I. INTRODUCTION

In Ref. [2], F. Marsiglio and I analyzed experimental results on trapped magnetic flux in hydrides under pressure published in Ref. [3] by Minkov, Ksenofontov, Bud'ko, Talantsev and Eremets, and we concluded from our analysis that the experimental results indicated that the residual magnetic moment measured after the external magnetic field was turned off under zero field cooling (ZFC) conditions did not originate in superconducting currents [2], hence did not provide proof that the materials were superconducting, contradicting the claims of Ref. [3].

At a scientific meeting in the Summer of 2023, one of the authors of Ref. [3] expressed their disagreement with our conclusions in Ref. [2], and their interest to study the computer codes that we had used for our analysis presented in Ref. [2]. On September 18, 2023, that author requested by email to F. Marsiglio and myself that we provide the codes used to generate the curves presented in the figures in our paper Ref. [2]. In their email request the author wrote *"I am confident that together we will reach a consensus."*

The figures shown in Ref. [2] were generated using computer codes written independently by the two authors of Ref. [2], that were based on the model defined in Ref. [2], that yielded identical results. On September 19, 2023, we sent this author one of my computer codes, named *cylinder.f*. I did not include specific instructions on how to use my code, expecting that the author would contact us if questions arose. At no point did we give that author nor anybody else permission to publish neither my computer code nor results derived from my computer code.

On December 7, 2023, that author together with four coauthors, posted arXiv:2312.04495v1, Ref. [4]. In it, the authors E.F. Talantsev, V.S. Minkov, V. Ksenofontov, S.L. Bud'ko and M.I. Eremets showed results that they obtained using my computer code, claiming that the results of my computer code proved our conclusions of Ref. [2] wrong. On December 8, 2023, we sent an email to all the authors of Ref. [4], with subject "To authors of arXiv:2312.04495v1" informing them that they had drawn incorrect conclusions from using my code, resulting in statements and figures in their paper that are wrong and misleading to the scientific community. We also pointed out to the authors that we had not authorized them to publish results obtained using my code. None of the authors responded. In the ensuing days, they posted new versions of their paper [1, 5] that did not correct the problem.

Our email of December 8 to the authors was copied to arXiv moderation. In addition, we wrote to arXiv moderation and to arXiv's scientific Director Steinn Sigurdsson also on December 8, informing that Ref. [4] had posted results obtained from my code that were incorrect and profoundly misleading to readers, and that at no point did we grant permission for publication by others of results obtained using my code, and requesting that arXiv withdraws arXiv:2312.04495v1.

Arxiv responded on December 11, 2023 that it would take no action, and has taken no action as of today, December 18, 2023. That is the reason for this Comment.

II. THE PHYSICS AND THE COMPUTER CODE

In Ref. [2], we modeled what the trapped magnetic field in a hard superconductor would be when a magnetic field H_M is applied at low temperatures and subsequently removed, i.e. zero field cooling (ZFC) protocol. We used the well-known Bean model, that assumes a critical current independent of magnetic field.

The model has two important parameters: (1) The threshold magnetic field H_p, below which the applied magnetic field does not penetrate and hence cannot be trapped, and the field H^*: for applied magnetic field $H_M = H^*$, the applied field reaches the center of the sample. H^* is proportional to the critical current density. The threshold magnetic field H_p is the lower critical field H_{c1} if the sample is a long cylinder, and for other sample shapes it is the lower critical field H_{c1} corrected for demagnetization. In any case, for applied magnetic field $H_M < H_p$ the applied magnetic field does not penetrate the sample, hence cannot be trapped, hence when the external magnetic field is removed the resulting magnetic moment is exactly zero.

All the figures shown in our paper Ref. [2] that show results of our model, namely Fig. 3, Fig 4 and Fig. 5, and their insets, show that the trapped magnetic moment predicted by our model for $H_M < H_p$ is exactly *zero*.

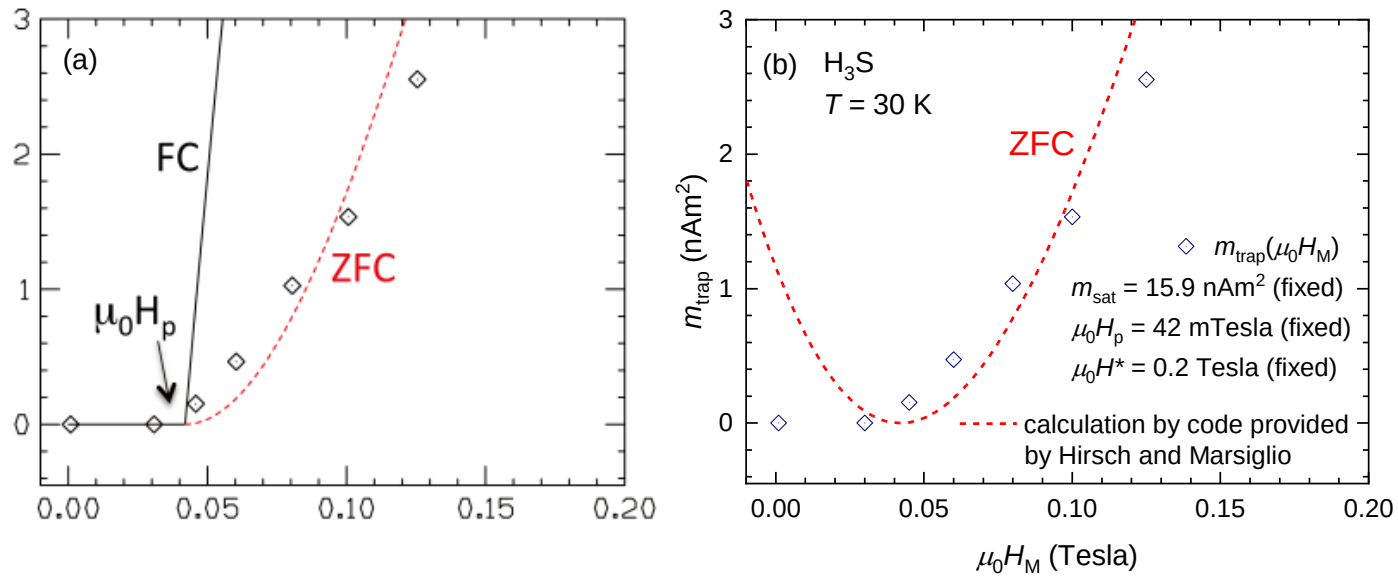

FIG. 1: Panels (a) and (b) of Fig. 2 of Refs. [1, 4, 5]. The figure caption of Refs. [1, 4, 5], as it refers to these panels, reads *"Experimental ZFC $m(B_{appl}, T = 30K)$ dataset measured in highly compressed H_3S, together with reproduced simulations and standard data fitting. (a) The original Figure 5 from Ref.1; (b) the reproduced full simulation curve utilizing the original simulation code, the reported fixed $\mu_0 H_p, \mu_0 H^*, m_{sat}$, and $\mu_0 H_{max}$ parameters and the aforementioned authors´ manipulations demonstrating the unphysical anomaly within the Meissner state...Open rhombuses represent experimental data, black and red curves represent simulation and fitting curves."* Here, Ref. 1 is Ref. [3] and "the aforementioned authors" are the authors of Ref. [2].

In their paper arXiv:2312.04495v1,v2,v3 [1, 4, 5] the authors show in their Fig. 2 the two panels shown in Fig. 1 here. The left panel of Fig. 1 shows the inset of Fig. 5 of our paper Ref. [2], the red dashed curve on the left panel of Fig. 1 shows the prediction of our model for zero field cooling (ZFC), as published in our paper Ref. [2]. The red curve reaches zero at magnetic field $H_M = H_p = 0.042T$ and does not continue for $H_M < H_p$ because in that range there cannot be a trapped moment under ZFC since the applied field never penetrated the sample, as explained above.

The right panel of Fig. 1 show what the authors of Refs. [1, 4, 5] obtained when they ran the computer code *cylinder.f* provided by us to them and plotted the numbers that the computer code printed in unit 12. Those numbers joined by a smooth line result in the dashed red line on the right panel of Fig. 1.

It can be seen that the dashed red curves are identical on the left and right panels of Fig. 1 in the field range $H_M \geq H_p$, with $H_p = 0.042T$. Instead, for $H_M < H_p$ there is no dashed red curve on the left panel, while on the right panel there is a dashed red curve that rises as H_M becomes lower.

What is the reason for this discrepancy? On the left panel there is no dashed red curve for $H_M < H_p$ because there can be no trapped magnetic moment if the magnetic field didn't penetrate, as explained above. On the right panel there is a dashed red curve for $H_M < H_p$ because the authors of Refs. [1, 4, 5] took the numbers from the output of the computer code *cylinder.f* in the region $H_p < H_M$ and plotted them and connected them with a dashed red line.

However, those numbers don't have any physical meaning and should not be interpreted as having any physical meaning. Anybody that understands the computer code *cylinder.f* and how to use it, and understands the physics of the model used in our Ref. [2] to describe trapped flux in hard superconductors, knows this. The authors of Refs. [1, 4, 5], because they ran a computer code that did not belong to them, and used it without checking with the authors of the code how the code should be used and how the numbers printed out by the code should be interpreted, apparently don't know this.

From the upturn in the dashed red curve seen on the right panel of Fig. 1 for field $H_M < H_p$, and similar upturns shown in Figs. 1(a), (1b) of Refs. [1, 4, 5] also for $H_M < H_p$, the authors of Refs. [1, 4, 5] concluded that:

- *"Significantly, the Hirsch-Marsiglio model does not describe the Meissner regime"*,
- *"the model predicts a significant positive magnetic moment for ZFC"*,
- *"This feature of the proposed model was not discussed by the authors and obviously contradicts the physics for the trapped magnetic flux in superconductors"*,
- *"they simulated the $m(B_{appl})$ curves by implementing the following step-by-step procedure... manually*

hide/delete all simulated points within the Meissner state, i.e. for $B_{appl} \leq \mu_0 H_p$

- *"we conclude that the authors in their Figures 3-5 hid/deleted (without reporting this) parts of their simulated datasets that disagree with the Meissner state. This potentially allowed them to conceal the issue that their model and computer code do not adequately describe the Meissner state."*
- *"The simulations conducted by the authors involve ... and unjustifiably deleting parts of the simulation dataset."*
- Caption of Fig. 2: *"...the aforementioned authors´ manipulations demonstrating the unphysical anomaly within the Meissner state"*
- Abstract: *"Hirsch and Marsiglio, in their recent publication (J. Supercond. Nov. Mag. 35, 3141–3145, 2022), assert that experimental data on the trapping of magnetic flux by hydrogen-rich compounds clearly demonstrate the absence of superconductivity in hydrides at high pressures. We argue that this assertion is incorrect, as it relies on the wrong model coupled with selective manipulations (hide/delete) of calculated datasets..."*.

These conclusions of Refs. [1, 4, 5] are (i) wrong, (ii) misleading to the scientific community, and (iii) were obtained using a computer code that did not belong to the authors of Refs. [1, 4, 5], in a way that was incorrect and inconsistent with the way the computer code was designed to be used, without authorization from the code's authors, and without checking with the code authors whether the code was used properly.

III. SUMMARY AND DISCUSSION

In summary, Refs. [1, 4, 5] used in an incorrect way a computer code written by me supplied by F. Marsiglio and me to one of the authors of Ref. [3] responding to their request, and drew incorrect conclusions from it. Namely, the incorrect conclusion that the model used in Ref. [2] yields the unphysical conclusion that a trapped magnetic moment appears when a magnetic field smaller than the lower critical field is applied to the sample and then removed. The authors of Refs. [1, 4, 5] did not request nor receive permission from us to publish results derived from the code that we sent them, nor did they send us their paper in advance of posting it (nor thereafter) to request our comments. When we notified them more than 10 days ago that they had used our computer code incorrectly and asked that they replace the paper they had posted correcting the error, they did not respond, ignored our request, and posted two subsequent versions of their paper [1, 5] with essentially the same content. All of this is in violation of normal scientific practice.

In a separate paper, F. Marsiglio and I will address other issues about our paper Ref. [2] that were raised in arXiv:2312.04495.

Now about the bigger picture: in 2015, Mikhail Eremets and coauthors announced that they had discovered conventional superconductivity in sulfur hydride under high pressure [6] at a temperature that was a factor of 5 higher than the previously known highest T_c conventional superconductor, MgB_2. An enormous breakthrough, deserving of a Nobel prize, if real. Since then, many other hydrides under high pressure have been claimed to be similarly high or even higher temperature superconductors [7]. However, eight years after the original announcement, there is still no confirmation that superconductivity at high temperatures in any hydride under high pressure is real [8–10]. Two papers making such claims have been recently retracted [11, 12] and an "Expression of Concern" has been published about a third one [13].

In this context, in order to provide further evidence for superconductivity in hydrides, Eremets and coauthors wrote and posted Refs. [1, 4, 5], where they argued that the arguments presented in Ref. [2], casting doubt on the interpretation that trapped flux measurements in hydrides [3] indicate superconductivity, can be proven wrong by improperly and unauthorizedly using a computer code (*cylinder.f*) supplied to Eremets and coauthors upon their request made under the pretense that *"together we will reach a consensus"*. Eremets and coauthors may not have known that they used the computer code *cylinder.f* incorrectly since they did not write the code themselves nor did they ask the authors of the code to explain how to use the code and how not to use it. But they certainly did know that they used that code and published results [1, 4, 5] that they obtained using that code without the authorization of the code authors. The motivation and reasoning behind this action by the authors of Refs. [1, 4, 5] needs to be clarified.

A simple way to provide strong evidence for superconductivity in hydrides and strongly undermine the doubts about hydride superconductivity raised in Refs. [8–10] and elsewhere would be for Mikhail Eremets and coauthors to supply their measured underlying data from which their published results on magnetic screening in hydride superconductors in Ref. [14] were derived. Ref. [14] would be the strongest evidence in favor of superconductivity in hydrides to date, *provided* that the underlying data support the published data. I have requested one year ago and repeatedly thereafter that those underlying data be made public, but the authors of Ref. [14] V. S. Minkov, S. L. Bud'ko, F. F. Balakirev, V. B. Prakapenka, S. Chariton, R. J. Husband, H. P. Liermann and M. I. Eremets, have declined to do so. It should also be noted that in Refs. [15–17] evidence was presented indicating that the data published in Ref. [14] do not derive from the measured data in the way described by the authors in Ref. [14] and its "Author Correction" Ref. [18]. The authors of Ref. [14] have been repeatedly in-

vited by editors of the journal Physica C to submit a Reply to a Comment on Ref. [14] published in Physica C [17], that claimed that it can be shown mathematically that the data published in Ref. [14] could not have been derived from the measured data in the way described in Refs. [14] and [18]. The authors have not published nor posted a Reply to date.

[1] E.F. Talantsev, V.S. Minkov, V. Ksenofontov, S.L. Bud'ko and M.I. Eremets, "Is MgB2 a superconductor? Comment on "Evidence Against Superconductivity in Flux Trapping Experiments on Hydrides Under High Pressure" [J. E. Hirsch and F. Marsiglio in J. Supercond. Nov. Mag. 35, 3141–3145 (2022)]", arXiv:2312.04495v3, December 13, 2023.

[2] J. E. Hirsch and F. Marsiglio, "Evidence Against Superconductivity in Flux Trapping Experiments on Hydrides Under High Pressure", J Supercond Nov Magn 2022; 35: 3141–3145.

[3] V. S. Minkov, V. Ksenofontov, S. L. Bud'ko, E. F. Talantsev and M. I. Eremets, "Magnetic flux trapping in hydrogen-rich high-temperature superconductors", Nat. Phys. (2023).

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[5] E.F. Talantsev, V.S. Minkov, V. Ksenofontov, S.L. Bud'ko and M.I. Eremets, "Is MgB2 a superconductor? Comment on "Evidence Against Superconductivity in Flux Trapping Experiments on Hydrides Under High Pressure" [J. E. Hirsch and F. Marsiglio in J. Supercond. Nov. Mag. 35, 3141–3145 (2022)]", arXiv:2312.04495v2, December 10, 2023.

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[10] J. E. Hirsch, "Are hydrides under high pressure high temperature superconductors?", National Science Review, nwad174 (2023) and references therein.

[11] E. Snider et al, "Retraction Note: Room-temperature superconductivity in a carbonaceous sulfur hydride", Nature 610, 804 (2022).

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[13] E. Snider et al, "Expression of Concern: Synthesis of Yttrium Superhydride Superconductor with a Transition Temperature up to 262 K by Catalytic Hydrogenation at High Pressures [Phys. Rev. Lett. 126, 117003 (2021)]", Phys. Rev. Lett. 131, 239902 (2023).

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[18] V. S. Minkov, S. L. Bud'ko, F. F. Balakirev, V. B. Prakapenka, S. Chariton, R. J. Husband, H. P. Liermann and M. I. Eremets, "Author Correction: Magnetic field screening in hydrogen-rich high-temperature superconductors", Nat Commun 14, 5322 (2023).