How do you trust but verify hydride superconductivity?

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I discuss the sharp dissonance between the recent Nature Materials Editorial "Trust but verify" [1] and the publication, in the same journal issue, of the Feature Comment by M. I. Eremets and coauthors on hydride superconductivity [2].

In its January 2024 Editorial, Nature Materials urges their readers to "Trust but verify", emphasizing that reproducibility of reported scientific results is key to the advancement of science. It cites an earlier Nature Materials Editorial [3] that focuses on the need for authors to share their underlying data to aid reproducibility and increase transparency, and decries the fact that *"in the vast majority of cases data have remained locked up in the authors' drawers, and allowed to see the light only 'upon request'."*

If only. The reality is starkly different from what the above depicts. In reality, Dr. Chris Graf, Research Integrity Director of Springer Nature, the Publisher of Nature Materials, stated in a recent letter to this author that *"while we would always encourage authors to share data with interested readers, we recognize the right of the authors to not share the data with you"* [4].

The data in question referred to in Graf's letter are data from Minkov, Eremets and coauthors underlying their publication on magnetic screening in hydride superconductors, Ref. [5]. I requested those data from the authors on January 11, 2023, and many times thereafter, after spotting anomalies [7] in the results published in Ref. [5]. The underlying data remain hidden to me and to the rest of the world to this date. Eremets and coauthors refuse to release them, and Nature Communications, in behavior endorsed by its publisher Springer Nature [4], has declined to enforce the "Data availability" statement attached to the paper, and in addition has declined to inform readers that there are restrictions on data availability.

Why are those data important? Ref. [5] reports how hydride materials under high pressure screen applied magnetic fields. Those experimental results are of utmost importance to the field of hydride superconductivity, given the dearth of magnetic data available for those materials. However what Eremets et al publish in Ref. [5] are processed data, not measured data. The measured data can potentially determine whether the materials are superconductors or not, adjudicating conflicting claims in the literature [6]. The published processed data [5] show behavior compatible with what is expected for the magnetic behavior of superconductors. However, because the processed data were derived from the measured data by a set of transformations and *"linear manipulations"*, as disclosed by the authors of Ref. [5] in a recent "Author Correction" [8] published in response to Ref. [7], it is impossible for readers to make their own judgement about the significance of the published processed data in relation with the physical reality they purport to reflect. The authors of Ref. [5] claim for themselves the exclusive right to know and judge whether their data "manipulation" [8] is or is not in conformance with accepted scientific practice.

There is a precedent to this situation in the contentious field of hydride superconductivity. In October 2020, Ranga Dias and coauthors published in Nature a paper claiming room temperature superconductivity in a hydride under pressure [9]. Immediately thereafter, having spotted anomalies in the paper [10], I requested from the authors and the journal the release of certain underlying data. For over a year, Ranga Dias and coauthors refused to supply those data, claiming that they *"don't trust Hirsch to appraise the data fairly"* [11] . When the underlying data were finally released [12], more than a year after I had requested them, serious problems of incompatibility between published data and measured data became apparent [13], and the paper was subsequently retracted [14]. Those problems would not have come to light if the underlying data had not been released. The possibility that the same scenario would play out when the underlying data of Ref. [5] are released can certainly not be ruled out until those data 'see the light'.

In fact, analysis of the data published in Ref. [5] has already conclusively shown [15–18] that the transformations used to go from measured to published data are *not* exclusively linear, contrary to what Ref. [8] claims, which invalidates the conclusions derived from those data in Ref. [5]. In particular, Ref. [16] was reviewed by 7 anonymous independent reviewers as well as the editor in Chief of the journal, some of which independently carried out an analysis that went beyond that contained in the paper and confirmed its findings. Eremets and coauthors were invited by the Editor of the journal to submit a reply to Ref. [16] but have not done so.

Given this situation, it appears remarkably tone-deaf that in the very same issue where Nature Materials encourages readers to "Trust but verify" [1], it features an article by Eremets and coauthors, Ref. [2], that claims that their experimental results on hydride superconductors are valid and reproducible, listing Ref. [5] (with its measured data kept under wraps) as supporting their claim. The Nature Materials Editorial advertises the Eremets featured article by stating *"In contentious fields with reproducibility issues, it is wise to see what results are on solid ground. In a Feature, by*

Mikhail Eremets and colleagues, this is done for the field of high-pressure superconductivity, where superhydrides formed at high pressures (of order 100 GPa) can exhibit superconductivity at temperatures up to 250 K."

This is exactly equivalent to a judge appointing the defendant as jury of their own actions. Ref. [2] does not present any new evidence for superconductivity in hydrides, it just repeats contested claims. Several of the references that Ref. [2] cites as independently confirming hydride superconductivity have been analyzed and challenged in peer-reviewed journals [6]. In particular, a careful analysis of measured raw data supplied by the authors of Ref. [19] and Ref. [20] to this author and coworkers has shown [21, 22] that the relation between measured and published data raises substantial doubts on the validity of the conclusions of Refs. [19] and [20]. None of this is mentioned in Ref. [2].

In order to "Trust but verify", as Nature Materials urges readers to do [1], it is indispensable that journals, research institutions and granting agencies enforce data availability statements and regulations, particularly in situations where authors refuse to release their underlying data invoking loopholes in the existing regulations, such as that data requests are not a "reasonable request", as the authors of Ref. [5] have done [4]. In such cases, the reasons the authors invoke to justify their refusal to supply the data should be scrutinized by expert independent peer review, and ruled invalid if appropriate, instead of accepting them at face value. That is *not* currently being done [4, 23], to the detriment of scientific progress.

[1] Nature Materials Editorial, "Trust but verify", Nature Materials 23, 1 (2024).

[2] M. I. Eremets, V. S. Minkov, A. P. Drozdov and P. P. Kong, "The characterization of superconductivity under high pressure", Nat. Mater. 23, 26–27 (2024).

[3] Nature Materials Editorial, "Data take centre stage", Nature Materials 19, 1 (2020).

[4] Letter from Chris Graf to the author, September 29, 2023.

[5] 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, "Magnetic field screening in hydrogen-rich high-temperature superconductors", Nat Commun 13, 3194 (2022).

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

[7] J. E. Hirsch and F. Marsiglio, "On Magnetic Field Screening and Expulsion in Hydride Superconductors", J Supercond Nov Magn 36, 1257 (2023).

[8] 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).

[9] E. Snider et al., 'Room-temperature superconductivity in a carbonaceous sulfur hydride', Nature 586, 373 (2020).

[10] J. E. Hirsch, "About the Pressure-Induced Superconducting State of Europium Metal at Low Temperatures", arXiv:2012.07537v1 (2020), Physica C 583, 1353805 (2021).

[11] Robert F. Service, "Breakthrough or bust? Claim of room-temperature superconductivity draws fire", Science 374, 520 (2021).

[12] Ranga P. Dias and Ashkan Salamat, "Standard Superconductivity in Carbonaceous Sulfur Hydride", arXiv:2111.15017, Dec. 28, 2021.

[13] J. E. Hirsch and D. van der Marel, "Incompatibility of published ac magnetic susceptibility of a room temperature superconductor with measured raw data", Matter and Radiation at Extremes 7, 048401 (2022).

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

[15] J. E. Hirsch and F. Marsiglio, "On magnetic field screening and trapping in hydrogen-rich high-temperature superconductors: unpulling the wool over readers' eyes", arXiv:2309.02683 (2023), J Supercond Nov Magn 36, 1813 (2023).

[16] J. E. Hirsch, "Can linear transformations bend a straight line? Comment on Author Correction to Magnetic field screening in hydrogen-rich high-temperature superconductors", Physica C 616, 1354400) (2024).

[17] J. E. Hirsch, "Hysteresis loops in measurements of the magnetic moment of hydrides under high pressure: Implications for superconductivity", Physica C 617, 1354449 (2024).

[18] J. E. Hirsch, "On the Author Correction to "Magnetic field screening in hydride superconductors" ", OSF Preprints https://doi.org/10.31219/osf.io/h289v (2023).

[19] X. Huang, X. Wang, D. Duan et al, "High-temperature superconductivity in sulfur hydride evidenced by alternating-current magnetic susceptibility", Nat. Sci. Rev. 6, 713 (2019).

[20] F. Capitani et al, "Spectroscopic evidence of a new energy scale for superconductivity in H_3S", Nat. Phys. 13, 859 (2017).

[21] J. E. Hirsch, "Faulty evidence for superconductivity in ac magnetic susceptibility of sulfur hydride under pressure", National Science Review, 9, nwac086 (2022) and arXiv:2109.08517 (2021).

[22] J. E. Hirsch and F. Marsiglio, "Absence of evidence of superconductivity in sulfur hydride in optical reflectance experiments", Nat. Phys. 18, 1033 (2022).

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