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# Yet Another Snapshot of Foundational Attitudes Toward Quantum Mechanics

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# Yet Another Snapshot of Foundational Attitudes Toward Quantum Mechanics

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## Abstract

A survey probing respondents' views on various foundational issues in quantum mechanics was recently created by Schlosshauer, Kofler, and Zeilinger and then given to 33 participants at a quantum foundations conference. Here we report the results of giving this same survey to the attendees at another recent quantum foundations conference. While it is rather difficult to conclude anything of scientific significance from the poll, the results do strongly suggest several interesting cultural facts – for example, that there exist, within the broad field of “quantum foundations”, sub-communities with quite different views, and that (relatedly) there is probably even significantly more controversy about several fundamental issues than the already-significant amount revealed in the earlier poll.

## 1 Introduction

The “snapshot of foundational attitudes toward quantum mechanics” taken by Schlosshauer, Kofler, and Zeilinger (SKZ) and shared in Ref.[1] attracted a surprising amount of attention in both the scientific and popular media. [2, 3, 4, 5, 6, 7] Apparently many people regard it as interesting and perhaps surprising that simple, seemingly elementary questions about the meaning and implications of the (now-almost-100-years-old) quantum theory could remain unresolved and indeed hotly contested. Actually, though, our feeling upon examining the results was that SKZ's survey did not even come close to revealing the true nature and extent of the controversy surrounding certain key issues.

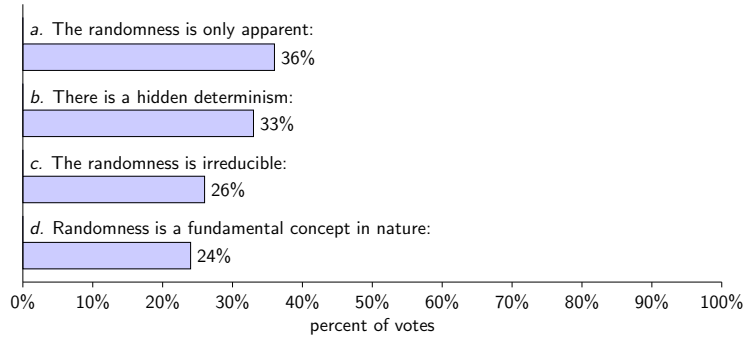
So with the hope, not so much of finding a “truly representative sample” but rather simply of demonstrating the existence (and prevalence) of different viewpoints, not well represented in the original survey, we arranged to give the same poll to the attendees at another recent quantum foundations conference: “Quantum Theory Without Observers III” held in Bielefeld, Germany in late April (2013). [8] It was decided that, although a number of the questions (and/or answers) from SKZ's poll seemed less than ideal, it would be better to pose exactly the same set of questions so that the answer-statistics could at least be meaningfully compared between the two conferences. As was done by SKZ in the original poll, the attendees were told that their participation was optional and also that they need not necessarily pick just one and only one answer on each question: multiple answers as well as write-ins were allowed. Seventy-six people (of the roughly 100 who were in attendance) filled out the survey in Bielefeld.

In the following section we present the results of the survey without commentary. A few brief thoughts are then elaborated in the subsequent section, focusing especially on the points of most significant difference between our results and those of SKZ.

## 2 Results

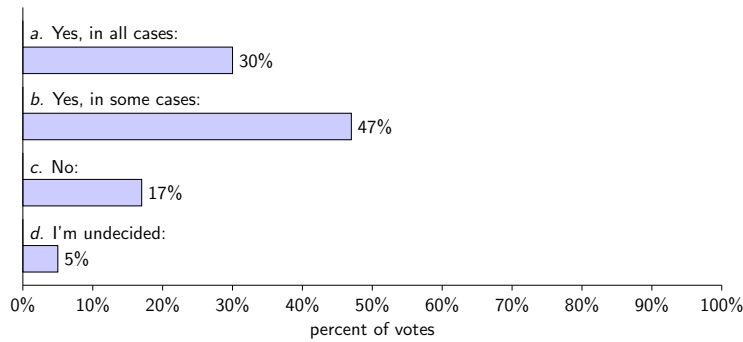
For each question, the bar graph indicates the percentage of respondents who endorsed the given options. Afterwards we indicate the fraction of respondents who made comments in the margin (which is perhaps some kind of measure of how problematic people found the question and/or the proposed answers to be) and quote any particularly interesting or noteworthy or common comments and write-ins.

**Question 1: What is your opinion about the randomness of individual quantum events (such as the decay of a radioactive atom)?**



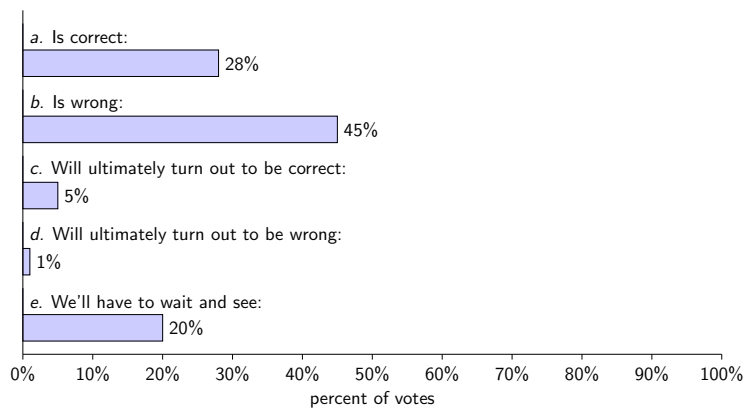
15% made marginal comments, e.g., “stupid answers”, “don’t know”, “I’m undecided”.

**Question 2: Do you believe that physical objects have their properties well defined prior to and independent of measurement?**



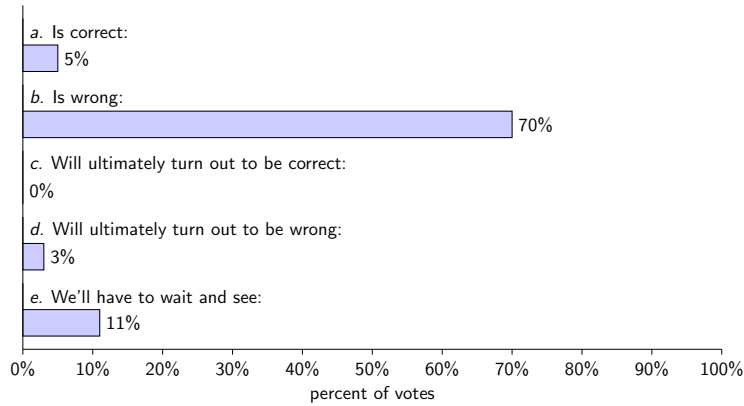
7% made marginal comments, e.g., “formulation too unclear”, “Give me a definition of ‘property’.”

**Question 3: Einstein’s view of quantum mechanics**



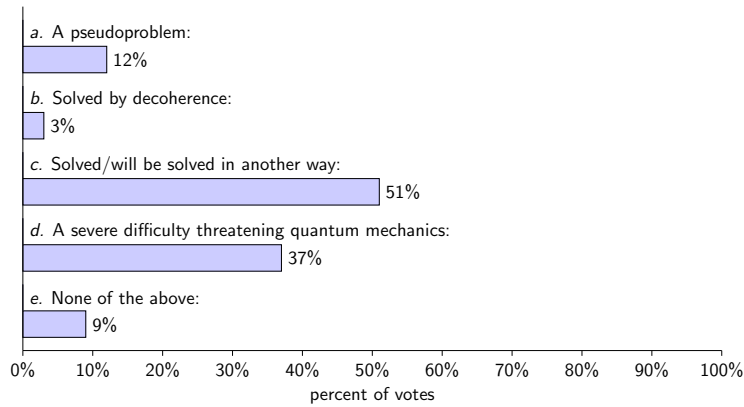
18% made marginal comments, e.g., “what the heck is meant exactly?”, “can striving for a deeper understanding be considered correct or incorrect?”, “partly right, partly wrong”.

#### Question 4: Bohr's view of quantum mechanics



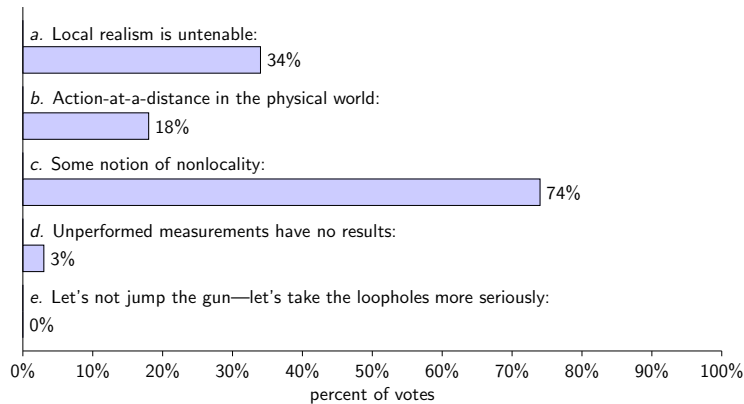
12% made marginal comments, e.g., “don't know”, “none of the above”, “I like some aspects of it, but there is some bad philosophy related to it”, “partly fruitful, partly obstructive (regressive)”.

#### Question 5: The measurement problem



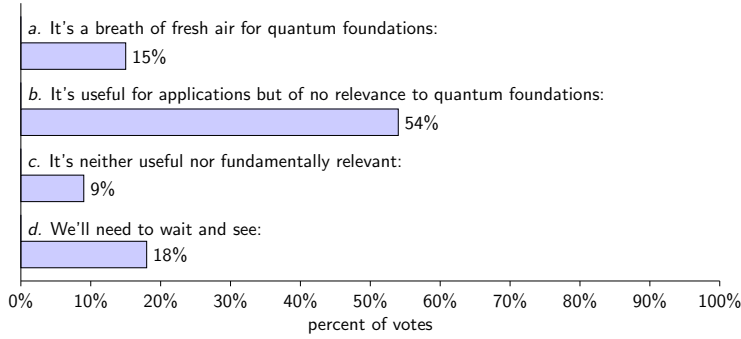
8% made marginal comments, e.g., “solved with a conceptual clarification (see Primitive Ontology)”.

#### Question 6: What is the message of the observed violations of Bell's inequalities?



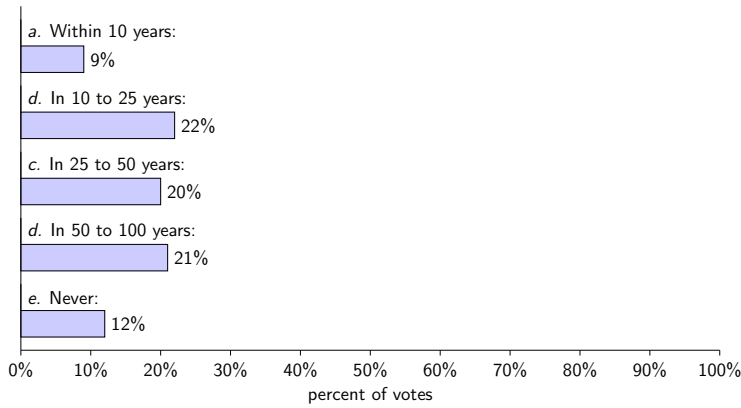
3% made marginal comments, e.g., “no strong opinion”.

**Question 7: What about quantum information?**



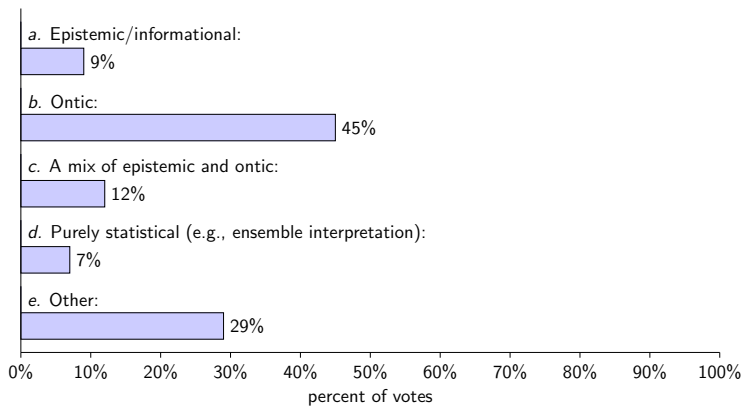
5% made marginal comments, e.g., “don’t know”, “(e) some relevance to quantum foundations”.

**Question 8: When will we have a working and useful quantum computer?**



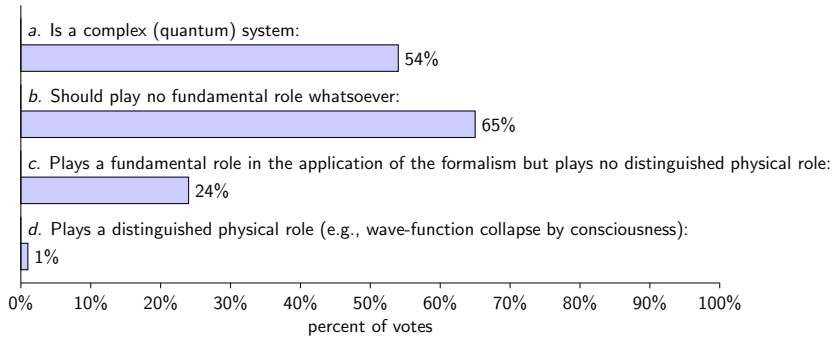
13% made marginal comments, e.g., “?”, “don’t know”, “what is ‘useful’?”

**Question 9: What interpretation of quantum states do you prefer?**



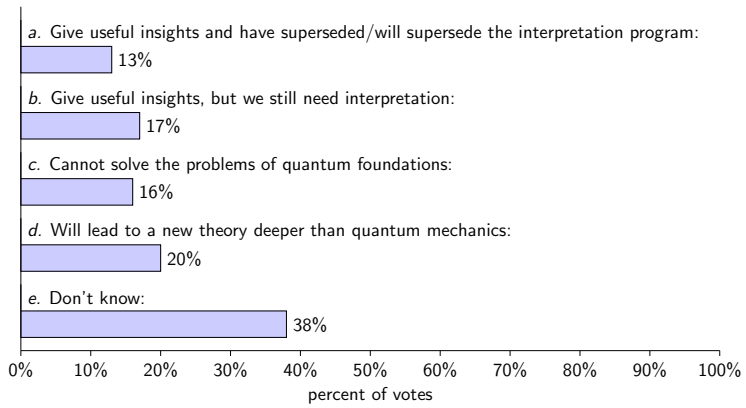
5% made marginal comments, e.g., “stupid question”, “no strong opinion”, “define quantum state”.

### Question 10: The observer



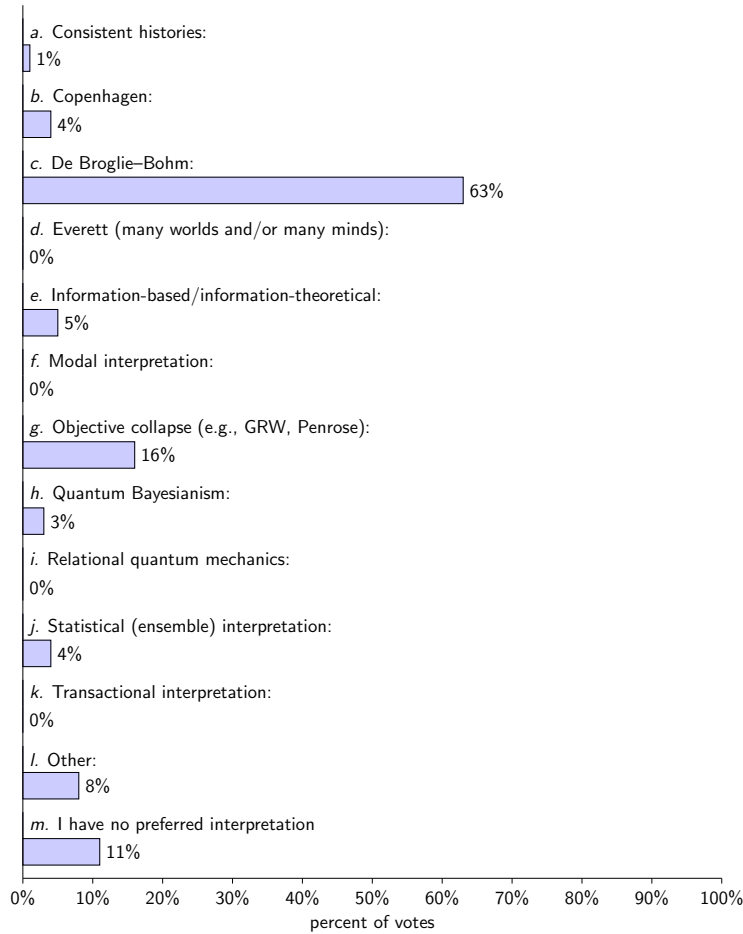
8% made marginal comments, e.g., “none of the above”.

### Question 11: Reconstructions of quantum theory



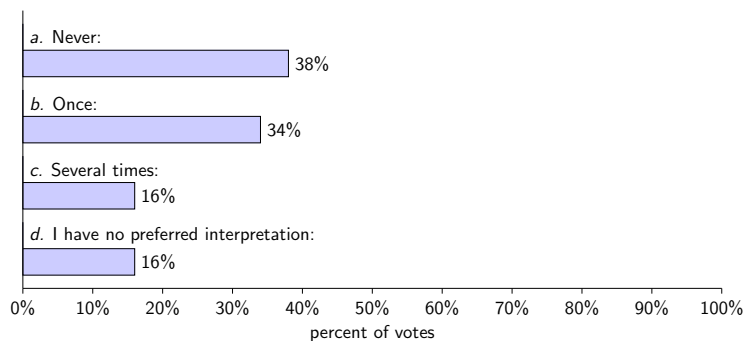
9% made marginal comments, e.g., “??”

**Question 12: What is your favorite interpretation of quantum mechanics?**



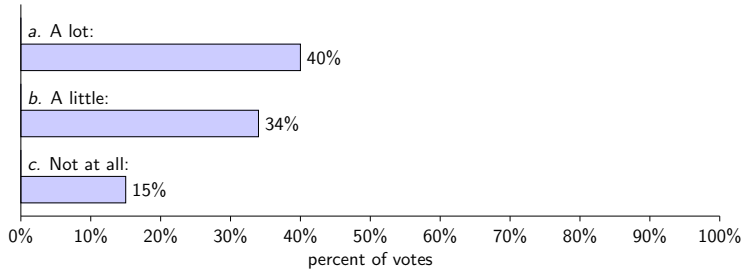
4% made marginal comments, e.g., “iff [option c] means Bohmian Mechanics”.

**Question 13: How often have you switched to a different interpretation?**



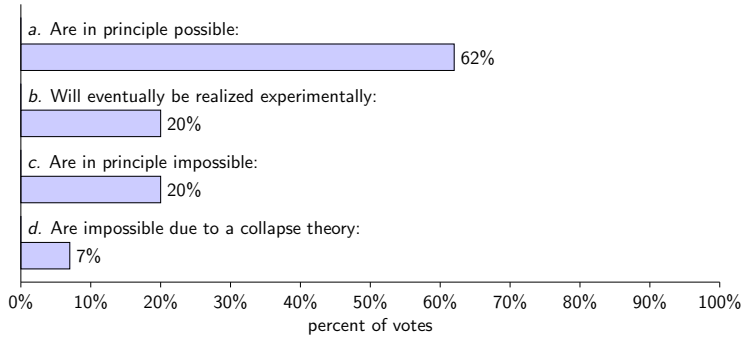
5% made marginal comments, e.g., “can’t decide if switching from ‘not thinking about it’ to ‘Bohm’ should count as switching to a different interpretation”, “before I was only confused”, “I’m just trying to improve my understanding of quantum physics. It’s good to have all the consistent theories (interpretations) on the table.”

**Question 14: How much is the choice of interpretation a matter of personal philosophical prejudice?**



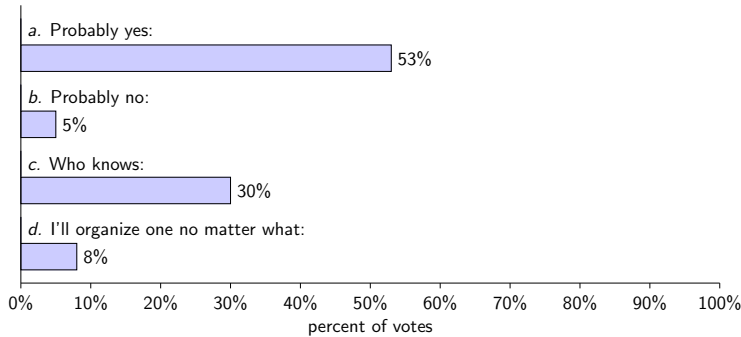
7% made marginal comments, e.g., “stupid question”, “There should be no need for interpretation!”

**Question 15: Superpositions of macroscopically distinct states**



8% made marginal comments, e.g., “?”

**Question 16: In 50 years, will we still have conferences devoted to quantum foundations?**



9% made marginal comments, e.g., “who is ‘we’?”, “I hope not”, “I hope they aren’t necessary anymore!”, “no, we will ask the quantum computer (see Q8) and it will have inherent understanding of what a quantum state is, and will explain it to us”.



### 3 Discussion

In many ways the results of the survey speak for themselves. Of particular interest, though, are the several ways in which our picture differs substantially from the snapshot taken by SKZ. To quantify this, we computed the square of the difference  $d$  in response rate for each given option, and then summed this over all given options for each question. The three questions with the highest  $\Sigma d^2$  were, in decreasing order: Q12, Q7, and Q6. We discuss each of these briefly:

**Question 12: What is your favorite interpretation of quantum mechanics?** In the SKZ results, *b. Copenhagen* (42%) and *e. Information-based/information-theoretical* (24%) received the highest response rates, while *c. de Broglie - Bohm* received zero votes of endorsement. SKZ write explicitly that “the fact that de Broglie - Bohm interpretation did not receive any votes may simply be an artifact of the particular set of participants we polled.” Our results strongly confirm this suspicion. At the Bielefeld conference, choice *c. de Broglie - Bohm* garnered far and away the majority of the votes (63%) while *b. Copenhagen* and *e. information-based / information-theoretical* received a paltry 4% and 5% respectively. It is also interesting to compare results on this question to the older (1997) survey conducted by Max Tegmark. [10] Tegmark, finding that 17% of his respondents endorsed a many-worlds / Everett interpretation, announced this as a “rather striking shift in opinion compared to the old days when the Copenhagen interpretation reigned supreme.” Our results clearly suggest, though, that any such interpretation of these sorts of poll results – as indicating a meaningful temporal shift in attitudes – should be taken with a rather large grain of salt. It is almost certainly not the case, for example, that while a “striking shift” toward many-worlds views occurred in the years prior to 1997, this shift then stalled out between 1997 and 2011 (the response rate endorsing Everett being about the same in the Tegmark and SKZ polls), and then suddenly collapsed (with the majority of quantum foundations workers now embracing the de Broglie - Bohm pilot-wave theory). Instead, the obviously more plausible interpretation of the data is that each poll was given to a very different and highly non-representative group. The snapshots reveal much more about the processes by which it was decided whom should be invited to a given conference, than they reveal about trends in the thinking of the community as a whole. We note finally that insofar as our poll got more than twice as many respondents as the SKZ poll (which those authors had described as “the most comprehensive poll of quantum-foundational views ever conducted”) it is now apparently the case that the de Broglie - Bohm pilot-wave theory is, by an incredibly large margin, the most endorsed interpretation in the most comprehensive poll of quantum-foundational views ever conducted. For the reasons we have just been explaining, this has almost no meaning, significance, or implications, beyond the fact that lots of “Bohmians” were invited to the Bielefeld conference. But it does demonstrate rather strikingly that the earlier conferences (where polls were conducted by Tegmark and SKZ) somehow failed to involve a rather large contingent of the broader foundations community. And similarly, the Bielefeld conference somehow failed to involve the large Everett-supporting contingent of the broader foundations community.

**Question 7: What about quantum information?** In the SKZ poll, *a. It’s a breath of fresh air for quantum foundations* received an overwhelming majority of votes (76%) and was indeed the most-endorsed answer on the entire poll; a mere 6% of respondents selected *b. It’s useful for applications but of no relevance to quantum foundations*. In our poll the situation was reversed: only 15% of respondents thought quantum information was a breath of fresh air, while 54% thought it was useful for applications but of no relevance to quantum foundations. This dramatic difference again almost certainly does not signal a seismic shift in the field during the year or so between the two polls, but instead arises from the apparently large difference between the two populations polled. In particular, it is not terribly surprising that endorsing the de Broglie - Bohm interpretation correlates positively with endorsing *b.* on this question, and that endorsing either the Copenhagen or information-based interpretations correlates with answering *a.* here. Most people who like the de Broglie - Bohm theory do so precisely because it provides a candidate account of quantum phenomena

in which no reference to anthropocentric notions (like “measurement”, “observation”, “information”, etc.) need appear in the formulation of the theory. This, indeed, was the theme of the Bielefeld conference, literally stated in its title: “Quantum Theory Without Observers”. So it is no surprise that attendees at this particular conference would tend to have more “realist” outlooks, would tend to be attracted to theories like de Broglie - Bohm, and would tend to think that quantum information (whatever its merits and virtues for applications) is not appropriate as an irreducible foundation for understanding the physics of quantum phenomena.

**Question 6: What is the message of the observed violations of Bell’s inequalities?** In the SKZ poll, two different responses – *a. Local realism is untenable* and *d. Unperformed measurements have no results* – both received more than 50% endorsement. (Recall that multiple responses were allowed!) Evidently then a large fraction of SKZ’s respondents believe that both *a.* and *d.* can be concluded from Bell’s theorem and the associated experimental tests. Presumably this reflects the belief that several assumptions – “locality”, “realism”, and the idea that “unperformed measurements *do* have results” – are needed for the derivation of the empirically-excluded Bell inequalities. In our poll, on the other hand, hardly anyone (a mere 3% of respondents) endorsed *d.* A huge majority (74%) selected *c. Some notion of nonlocality*, and the related/overlapping answers *b. Action-at-a-distance in the physical world* and *a. Local realism is untenable* also received significant support (18% and 34% respectively). Note that anybody who believes that the observed violations of Bell’s inequalities implies “some notion of nonlocality” *ipso facto* must also believe that “local realism is untenable”, so the significant overlap there makes sense. Evidently, then, most respondents at the Bielefeld conference believe that only one assumption – “locality” – is needed for the derivation of the empirically-excluded Bell inequalities. In our opinion, it is here on this question that the difference in the responses between the two polls is most interesting and most surprising (or at least should appear most surprising to someone from outside the foundations community). Whereas Questions 12 and 7 ask respondents to assess the merits of a certain interpretation or viewpoint or research program, this Question 6 is essentially asking: what are the premises of a certain mathematical theorem? It is somehow not terribly surprising that different sub-groups within the foundations community would have different background assumptions that lead them to judge different interpretations/programs as “scientifically the best” or “most likely to lead to important future progress” or whatever. But it *is* terribly surprising that different sub-groups could continue, after all these decades, to disagree about what minimal set of assumptions is needed to derive the Bell-type inequalities that (almost) everyone agrees are incompatible with experimental data. If there is an “embarrassment” [4] to be found in any of the poll results, it lies here.

There are several other significant and interesting differences between the results of the two polls, but the above three stand out not only quantitatively but also in terms of the clear centrality and fundamentality of the issues involved. Probably the only thing that can be inferred with statistical confidence from the results is that on these several fundamental questions, the two polled groups were quite different. What explains this? The answer is obvious and has already been alluded to above: each group consisted of a special sub-set of researchers in quantum foundations ... special in that they had been invited to the conference in question.

Several of the organizers of the Bielefeld conference, for example, are prominent proponents of the de Broglie - Bohm pilot-wave theory. And in general the “Quantum Theory Without Observers” series of conferences has been dedicated to furthering the work and ideas of John Bell, whose image for example graced the conference poster. [8] It is thus not terribly surprising that people invited to attend this conference were – by no means exclusively, but, compared to the community at large, unusually – sympathetic to the views developed and endorsed by Bell, including “realism” (meaning here the inappropriateness of anthropocentric concepts like “information” or “measurement” appearing in the formulation of fundamental theories), an extremely high regard for the de Broglie - Bohm pilot-wave theory, and an insistence that it is *locality* (and not some other notion such as “realism” or “determinism”) that is called into question by the experimental tests of Bell’s inequalities. [9] From this point of view, the results of our poll are hardly shocking: they indicate

only that people who are both motivated to and invited to participate in a workshop largely celebrating Bell's continuing influence on the foundations of quantum theory, tend to answer questions similarly to how Bell himself would have answered them.

The different answers given by respondents in the SKZ poll can perhaps be understood similarly – for example, by reference to the fact that Anton Zeilinger, one of the leading proponents of a kind of neo-Copenhagen approach to understanding quantum theory, was one of the organizers [11] or perhaps by reference to the fact that the invitees to the conference at which SKZ's poll was given out were people given a certain kind of grant during a certain period of time by the Templeton Foundation. [12] Presumably the results of another recent survey which used the same set of questions [13] could be understood in a similar way, namely, as telling one more about the biases inherent in the invitation process than it does about what experts in quantum foundations generally think.

With the possible exception of the case discussed in Ref. [11], it is not at all our goal to criticize the existence of bias in the determination of whom should be invited to attend a given conference. “Bias” here simply means that potential attendees are selected in accordance with the extent to which their individual interests and perspectives align with the goals and themes of the conference, and it is entirely reasonable and proper for conference organizers to choose such goals and themes and indeed to aim for a healthy but non-disruptive representation by opposing views. Our point in stressing the role of attendance-bias is instead this: none of these polls, our own very much included, should be taken too seriously as capturing a meaningful snapshot of anything but the views of a small and biased minority.

## Acknowledgements

Thanks to the organizers of Quantum Theory Without Observers III for letting us inflict the survey on the participants, and thanks to the participants who so graciously took the time to fill it out.

## References

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- [2] P. Ball, “Experts still split about what quantum theory means”, *Nature*, January 11, 2013
- [3] C. Moskowitz, “Physicists disagree over meaning of quantum mechanics, poll shows”, January 21, 2013; <http://nbcnews.com>
- [4] B. Plumer, “Why quantum mechanics is an ‘embarrassment’ to science”, February 7, 2013; <http://www.washingtonpost.com/blogs/wonkblog>
- [5] “Poll reveals quantum physicists’ disagreement about the nature of reality”, MIT Technology Review, January 9, 2013; <http://m.technologyreview.com>
- [6] T. Siegfried, “Poll of quantum physicists shows agreement, disagreement and something in between”, *Science News*, February 20, 2013; <http://www.sciencenews.org>
- [7] M. Schlosshauer, “Agreeing to disagree”, *Physics World*, March 2013
- [8] The conference website, which includes a list of participants, is here: <http://www.mathematik.uni-muenchen.de/~bohmmech/bielefeld/index.html>
- [9] For Bell's views on the role of “information”, “measurement”, etc., in fundamental physical theories, see his paper “Against ‘Measurement’.” Almost all of Bell's papers on the foundations of quantum theory involve the de Broglie - Bohm pilot-wave theory in some way; see especially “Quantum Mechanics for Cosmologists” and “On the impossible pilot wave”. For Bell's view on what, exactly, is at stake in regard

to the experimental tests of his famous inequality, see especially “Bertlmann’s socks and the nature of reality” (including the illuminating footnote 10) and “La nouvelle cuisine”. All of these papers are conveniently reprinted in J.S. Bell, *Speakable and Unspeakable in Quantum Mechanics*, Second Edition, Cambridge University Press, 2004.

- [10] M. Tegmark, *Fortschr. Phys.* **46**, 855 (1998); arxiv:quant-ph/9709032
- [11] Interestingly, there seems to be a historical precedent for Zeilinger’s failure to invite, to a relevant conference, people whose views overlap with those of John Bell: see Gerhard Grössing, “Serious Matter: The John Bell Scandal”, [http://www.nonlinearstudies.at/Bell\\_E.php](http://www.nonlinearstudies.at/Bell_E.php)
- [12] See here for the relevant announcement: <http://www.templeton.org/what-we-fund/funding-priorities/quantum-physics-and-the-nature-of-reality>
- [13] C. Sommer, “Another Survey of Foundational Attitudes Towards Quantum Mechanics”, arxiv:1303.2719