

The *real* scandal of quantum mechanics is that so many physicists still insist on thinking about quantum phenomena with classical ideas. Art Hobson<sup>1</sup> advised us that the universe “is made of” quantized fields, preferring that to “manifestations of a wave function,” used by Kampen<sup>2</sup> in his letter. The wave function is merely an intellectual tool used by physicists, and the notion that anything is “manifestations of wave functions” is just as incorrect as the notion that electrons are particles. The trouble with the terms “particle” and “wave function” is that each of these has a well-defined meaning, and experiment shows that nothing is made of either of them. In contrast, “quantized fields” has no meaning at all, and hence is invulnerable to criticism. But, Hobson claimed that he has found what the universe “is made of!”

It seems that almost everyone feels that the universe must be “made of” *something*, and wants to know *what*. Another outstanding example of this urge of the human mind is the paper<sup>3</sup> by President Bush’s OSTP Director, John H. Marburger III, which I have referenced in my essay, “The mental universe<sup>4</sup>.” It is fine how marvelously Marburger disposes of both “waves” and “particles.”

*“The wave is not in the underlying stuff, it is in the spatial pattern of detector clicks. We do not – cannot – measure waves in the underlying stuff. We can only measure detector clicks. But when we hear the click we say “there’s an electron!” We cannot help but think of the clicks as caused by little localized pieces of stuff that we might as well call particles. This is where the particle language comes from. It does not come from the underlying stuff, but from our psychological predisposition to associate localized phenomena with particles.”*

Excellent! However, you will have noticed that, just like Hobson, Marburger *does* demand that the universe be “made of” *something*: in Marburger’s case, “underlying stuff.” (I was present for Jack’s talk, and he even pronounced it as German “Stoff.”) But, we also are quite aware that Marburger did *not* advise President Bush to institute a National Science Foundation program to characterize the “underlying stuff,” even though this is supposed to be fundamentally what the universe is made of!

Sorry folks—*stuff and nonsense!* We know for a fact that the universe is not “made of” anything. Get it through your heads, physicists! It is sometimes said that the only thing that is real are the observations, but even *that* is not true: observations are not real either. They, and everything else, are purely mental.

You *are* making observations, *right now*. But let’s get more sophisticated about it, and carefully make some observations of a certain kind. We find (in the circumstances that we have selected) that we typically *only* measure values  $\hbar/2$  and  $\hbar$ . We understand these results completely, since we have quantum mechanics! It is true that we also have in our minds the notion of a three-dimensional object or “thing,” and that we know from quantum mechanics that any such *thing*, should it exist, cannot<sup>5</sup> have spin angular momentum less than  $\hbar$ , so we know *for sure* that our observations of *half* that value cannot possibly be of things. And, while the observed values that are  $\hbar$  in principle could be of “things” (photons totally flattened in the direction of motion by special relativity), Occam’s razor tells us that, since such a notion adds nothing, and is *ruled out* for our *other observations* (the  $\hbar/2$  measurements), we should not even consider the notion, which is valueless, or, rather, worse than valueless.

Now, let's make some more observations, but in a different way. We find, now, that we often get values  $9.1 \times 10^{-28}$  g. Again, because we have quantum mechanics, we are quite justifiably certain that we are observing one eigenvalue of some operator. In fact, the current central task of physics is to find that operator! It is curious that the job is completely done for angular momentum, but is *not yet* done for mass-energy.

Why have we made *these two particular* sets of observations, and not others? It is because Emmy Noether taught us that symmetries lead to conservation laws, and our universe (the set of all of our observations—hey, THAT is all we know about the universe) turns out to have various symmetries (for unknown reasons) that result in conserved quantities.

It is no fun to make measurements of quantities that are *not* conserved, because they are evanescent. But, it seems to be very dangerous to make observations of quantities that *are* conserved because they stay the same, and so they start us thinking, again, about “things” (which by definition also stay the same).

Gröblacher et al.<sup>6</sup> put the final end to reality: I quote the first and final sentences of their abstract: “Most working scientists hold fast to the concept of ‘realism’—a viewpoint according to which an external reality exists independent of observations.” How true! But, then ... “Our result suggests that giving up the concept of locality is not sufficient to be consistent with quantum experiments, unless certain intuitive features of realism are abandoned.” Aspect<sup>7</sup> captures this as “... it implies renouncing the kind of realism I would have liked.” *Finis!*

Let's review all of our candidates for “what the universe is made of:”

“Particle, wave, and wave function” are wrong by experiment.

“Quantized fields and underlying stuff” are wrong simply because they are meaningless.

“Mental” is correct, which you verify with complete certainty automatically through the very process of thinking about it.

<sup>1</sup> A. Hobson, “Response to ‘The Scandal of Quantum Mechanics, [Am. J. Phys. **76**, 989-990 (2008)],” Am. J. Phys. **77**, 293 (2009).

<sup>2</sup> N. G. van Kampen, “The scandal of quantum mechanics,” Am. J. Phys. **76**, 989-990 (2008).

<sup>3</sup> J. Marburger, “On the Copenhagen interpretation of quantum mechanics,” in *Symposium on The Copenhagen Interpretation: Science and History on Stage*, National Museum of Natural History of the Smithsonian Institution, 2 March 2002; Marburger's excellent paper is no longer available at the OSTP web site, so I make it available at <http://henry.pha.jhu.edu/Marburger.pdf>

<sup>4</sup> R. C. Henry, “The mental universe,” Nature (London) **436**, 29 (2005).

<sup>5</sup> R. Shankar, *Principles of Quantum Mechanics* 2<sup>nd</sup> ed. (Plenum, New York, 1994), p. 324.

<sup>6</sup> S. Gröblacher et al., “An experimental test of non-local realism,” Nature (London), **446**, 871 (2007)

<sup>7</sup> A. Aspect, “To be or not to be local,” Nature (London), **446**, 866 (2007)

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My Letter, above, will be immediately followed by a response from Art Hobson—who slices me, dices me—hey, I'm chopped liver! Hobson lets us know that things are made of quantized fields. (But Art does not tell us what quantized fields are made of.)