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THERE ARE NO PARTICLES, AND THERE ARE NO FIELDS

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LETTERS TO THE EDITOR

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THERE ARE NO PARTICLES, AND THERE ARE NO FIELDS

Art Hobson[1] has done an admirable job of analyzing the particle versus field question and bringing it up to date. He lucidly traces the history of this discussion and shows how Quantum Field Theory (QFT) introduces quanta as countable excitations and interactions of fields. He finds no support for a particle concept in QFT, even in some extended sense. Hobson forcefully argues the conclusion that "There are no particles, there are only fields."

By extending some of Hobson's ideas, I arrive at the conclusion that in addition to there being no particles, there are not even fields!

The fields of QFT are *operators*. The system state is an abstract vector in Hilbert or Fock space, not described by a field but instead by a "bra" or "ket" vector; simply a label. The field operators describe *interactions* by which the system evolves in Fock space.

In this view, the QFT construct is a most useful *calculational model*, but does little or nothing to identify a model for the ontological reality (particle, field, wave, or whatever) of the entity being described.

Perhaps there is no useful conceptual model to describe ultimate reality in human terms—and perhaps there is no need for one.

[1]A. Hobson, "There are no particles, there are only fields," Am. J. Phys. **81**, 211–223 (2013).

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HOBSON RESPONDS

I thank R. J. Sciamanda for the nice comments, but must disagree with his views about realism. It is an important topic, because too many physicists, disheartened by the apparent conundrums of standard quantum physics, are giving up on science's endeavor to describe the real world.

There is no reason to regard quantum fields as less real than rocks. Indeed, rocks are made of them. Are electrons and photons not real? If they are, then quantum fields are real because electrons and photons are field quanta.

To discuss this issue, it is sufficient to look only at the non-relativistic limit of the quantized Dirac equation, namely the Schrodinger equation. Here, the issue comes down to the reality of the Schrodinger field (the "wavefunction"). Is it only a calculational tool having nothing to do with reality? I think not. In the double-slit experiment, for example, a real electron comes through one or the other or both slits. As argued in my paper, this electron is an extended wave in a quantum field, as described by the Schrodinger equation.

The conundrums of wave-particle duality, quantum randomness, macroscopic superpositions, non-locality, measurement, and collapse of the state function are not a sign that quantum physics fails to describe the real world. None are true paradoxes. All have consistent explanations in terms of the counter-intuitive behavior of field quanta. Reality does not fade from existence once one reaches some small distance scale, whether it be a millimeter or an angstrom or the distances probed at the LHC.

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