Comment on "Indirect Evidence for Quantum Gravity"

The paper by Page and Geilker[1] does not provide any evidence of quantum phenomena, but only illustrates the need for a consistent interpretation of a statistical theory. The authors performed a sequence of measurements of the gravitational field of two lead balls. In each measurement these balls were placed in one of two possible configurations, according to a decision procedure whose details are unimportant. The individual measurements of the gravitational field were found to correlate strongly with the individual mass configurations, and not with the average mass distribution over the entire set of possible configurations. A less surprising experimental result has seldom, if ever, been published!

Compare that experiment with an epistemologically isomorphic experiment whose interpretation involves only statistical mechanics. Consider an Ising-type ferromagnet in which spins may point in either of two directions with equal probability. At low temperatures the macroscopic magnetization can have essentially only two values, $+M$ or $-M$, but because of the symmetry the ensemble magnetization $\langle M\rangle$ is zero at all temperatures. Now one could perform a sequence of measurements of the magnetic field to determine whether its source is the actual magnetization $\pm M$ in an individual case or the ensemble average, $\langle M\rangle=0$, over the whole sequence. I take it to be uncontroversial that the former alternative would be confirmed. The experiment of Page and Geilker has merely demonstrated the same truism for the gravitational field.

The authors correctly point out that their result falsifies the Moller-Rosenfeld equation,

$$G_{\mu\nu}=8\pi\langle T_{\mu\nu}\rangle, \quad (1)$$

in which the quantum mechanical average of the stress-energy tensor is taken to be the source of the gravitational field. This is exactly parallel to the ferromagnet case because quantum mechanics is a statistical theory and strictly speaking, the quantum state describes not an individual physical system but an ensemble.[2] It is clearly inconsistent to suppose that the source of the gravitational field in an individual case is the average of the stress-energy tensor for an ensemble of such cases. Equation (1) is valid only as an approximation when the fluctuations described by the quantum state are negligible.[3] If there is any lesson to be learned from this episode it is that the statistical interpretation of quantum mechanics must be applied consistently.

However, it is logically incorrect to claim that the failure of (1) provides even indirect evidence for quantum gravity if by quantum gravity we mean that the metric tensor $g_{\mu\nu}$ is subject to typical quantum dynamics, with its components represented by noncommuting operators, or some other equivalent mathematical formulation of quantum theory. To do so would be to imitate the creationists, who argue that any inadequacy in Darwin's original formulation of the theory of evolution provides evidence in favor of creation. In fact the experiment of Page and Geilker is compatible with a nondynamic Newtonian gravity field carried rigidly by each lump of matter. This crude theory is no doubt falsifiable, but since their experiment does not contradict it they cannot validly claim to have produced any evidence for a dynamical gravitational field, much less for a quantum dynamical field.

Leslie E. Ballentine
Physics Department, Simon Fraser University
Burnaby, British Columbia V5A 1S6, Canada

Received 17 November 1981
PACS numbers: 04.60.+n

[1] D. N. Page and C. D. Geilker, Phys. Rev. Lett. 47, 979–982 (1981).

[2] L. E. Ballentine, Rev. Mod. Phys. 42, 358–381 (1970).

[3] Perhaps the proponents of Eq. (1) hoped that the fluctuations within the quantum state would always be microscopic. This is not the case; indeed it is the nature of the measurement process to produce components in the state function that describe macroscopically distinct configurations (see Ref. 2).

