the cosmological constant. According to Sabbata and Siravan, the introduction of torsion could also resolve the deep incompatibility that exists between gravitational theories and quantum mechanics. Einstein recognized very early that torsion could represent spin; with Elie Cartan, he developed the so-called Einstein–Cartan theory,[2] which is a viable alternative to the theory of general relativity. This theory is indeed interesting; for instance, the electromagnetic fields do not couple to the torsion. As far as we know, the Einstein–Cartan theory has not been disproved by any experimental evidence.

A key question to ask is whether the geometrical character of spacetime endowed with torsion is amenable to experimental testing. Our answer is yes! The Einstein–Cartan theory predicts new physical phenomena, as explained by Sabbata and Sivaran.

References

1. V. de Sabbata, C. Sivaran, *Spin and Torsion in Gravitation*, World Scientific, Singapore (1994).
2. For a thorough account, based mainly on cosmological consequences, see A. K. Raychaudhuri, *Theoretical Cosmology*, Oxford U.P., Oxford (1978).

MARCELO S. BERMAN
RUBENS M. MARINHO JR
Technological Institute of Aeronautics
Saõ José dos Campos, Brazil

More on Schwinger's Views on Cold Fusion

The splendid commemorative article on Julian Schwinger by Paul Martin and Sheldon Glashow (October 1995, page 40) provides a remarkably human picture of one of the more brilliant physicists of our time. It is wonderful to learn not only of Julian Schwinger's many accomplishments but also of his legacy.

I believe it is fitting, and consistent with Schwinger's concern for accuracy and truthfulness, to present some additional facts concerning his involvement in cold fusion.

First, not only did Schwinger believe in the phenomenon of cold fusion, but he resigned from the American Physical Society in 1990 as a direct consequence of the manner in which an APS journal's editorial board had dealt with the subject.[1]

Second, Schwinger observed quite correctly that it is entirely possible (contrary to the situation in free space) for unexpected modes of energy transfer to occur within a solid when a region that is macroscopically small but microscopically large "attains a state of such uniformity that it can function collectively in absorbing . . . energy."[1] (Collective motion and interaction of precisely this nature lie at the heart of the modern theory of conductivity in solids and are responsible, for example, for our understanding of electron holes and their application in modern semiconductor technology.)

Third, although Schwinger did not believe cold fusion and sonoluminescence to be directly linked, he found it helpful to use sonoluminescence to draw attention to the fact that, through coherent phenomena, it is possible to transfer energy between entities (atoms and nuclei) that possess characteristic energies that are vastly different.[1]

In addition, it is worthwhile noting that Schwinger recognized that the attainment of high loadings of deuterium (D) into palladium deuteride (PdD), approaching the limit of $x \to 1$ in PdD_x, could be expected to provide the environment in which the kinds of collective phenomena suggested by his theory would apply. Published information in peer-reviewed journals[2] and conference proceedings[3] exists that not only illustrates the reality of anomalously large heating effects in heavily deuterated PdD but also provides documentation that a necessary condition for achieving the heating phenomenon is that these kinds of loadings ($x \to 1$ in PdD_x) of D into PdD take place. It is also worthwhile noting that these kinds of conditions are both difficult to obtain (because nonequilibrium chemistry is required) and clearly were not obtained in a large proportion of the early experiments. For this reason, a large majority of early attempts to identify the anomalous heating effect were unsuccessful.

Because of Schwinger's pioneering insight into the theoretical underpinnings of much of modern solid-state physics, nuclear and high-energy physics and statistical physics, it is clear that he had great scientific vision. It is also becoming clear, as a result of the unfolding experimental situation, that this vision may have included the elucidation of a number of the factors responsible for initiating cold fusion–related phenomena. Was Schwinger correct? Time will provide the answer.

References

1. J. Schwinger, Trans. Fusion Technol. **26**, xiii (1994).
2. See issues of the American Nuclear Society's journal *Fusion Technology* published since 1990.
3. See, for example, Trans. Fusion Technol. **26** (1994), which contains the pro-

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