

Could the combination of general relativity and quantum mechanics lead to spintronics?

March 3 2011, By Miranda Marquit

(PhysOrg.com) -- In the early 20th century, two famous discoveries about spin were made. One of them, discovered by Albert Einstein and Wander Johannes de Haas, explains a relationship between the spin of elementary particles. They found a relationship between magnetism and angular momentum. (Around that time, Einstein also put forth his theory of general relativity.) A little more than a decade later, Paul Dirac unveiled his equation dealing with a relativistic quantum mechanical wave, providing an explanation of electrons as elementary spin-1/2 particles.

Even though both of these discoveries have existed for nearly century, Sadamichi Maekawa tells *PhysOrg.com*, no one thought about combining them. “For nearly 100 years, people did not study putting these together. We decided to combine different ideas to come up with a fundamental Hamiltonian to investigate mechanical rotations in the Dirac equation.”

Maekawa, a scientist working with the Japan Atomic Energy Agency, as well as the Japan Science and Technology Agency, worked with scientists associated with Kyoto University and Tohoku University, to come up with a new model of spin that could be helpful in the development of [spintronics](#). Mamoru Matsuo, Jun’ichi Ieda and Eiji Saitoh were all involved in creating the new model, which is published in *Physical Review Letters*: “Effects of Mechanical Rotation on Spin Currents.”

“The Einstein-de Haas effect is brought about by the [angular momentum](#)

conservation between magnetism and rotational motion,” Maekawa explains. “Quantum mechanics tells us that the origin of magnetism is electron spin. Recent progress in nanotechnology enables us to manipulate the flow of electron spins, or ‘spin current’”. He points out that the relationship between spin current and magnets has been studied for nanodevice applications, but there has been little attention paid to the way rotational motion can be used to control spin current.

In Japan, Maekawa and his colleagues decided that studying how to use mechanical rotation to direct spin current could be advantageous in the development of spintronic devices that scientists think could eventually replace silicon-based electronics. “We found that we needed to add general relativity to the equation,” Maekawa says. “Dirac included special relativity, but general relativity was needed as well. We combined the two Einstein theories, and added them to the theory of [quantum mechanics](#). This way, we added mechanical rotation to the quantum equation.”

Part of this new model includes extending the physical system into a noninertial frame from its present inertial frame. Maekawa and his fellows relied on the fact that the dynamics of spin currents is closely related to the spin-orbit interaction, resulting from using the low energy limit of the Dirac equation. “We tried to combine general relativity and spin current, even though general relativity is not so popular in condensed matter physics right now,” he explains. The result, Maekawa points out, is that it should be possible to control [spin current](#) using mechanical means.

For now, the model is theory. “We formulated an equation, and in the future we hope to try the theory,” Maekawa says. He believes that, “this theory will give birth to nanoscale motor and dynamo,” providing a practical way to realize spintronics in the future.

More information: Mamoru Matsuo, Jun'ichi Ieda, Eiji Saitoh, and Sadamichi Maekawa, “Effects of Mechanical Rotation on Spin Currents,” *Physical Review Letters* (2011). Available online: link.aps.org/doi/10.1103/PhysRevLett.106.076601

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