Electromagnetism is a property of spacetime itself, study finds

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Imagine if we could use strong electromagnetic fields to manipulate the local properties of spacetime—this could have important ramifications in terms of science and engineering.

Electromagnetism has always been a subtle phenomenon. In the 19th century, scholars thought that electromagnetic waves must propagate in some sort of elusive medium, which was called aether. Later, the aether hypothesis was abandoned, and to this day, the classical theory of electromagnetism does not provide us with a clear answer to the question in which medium electric and magnetic fields propagate in vacuum. On the other hand, the theory of gravitation is rather well understood. General relativity explains that energy and mass tell the spacetime how to curve and spacetime tells masses how to move. Many eminent mathematical physicists have tried to understand electromagnetism directly as a consequence of general relativity. The brilliant mathematician Hermann Weyl had especially interesting theories in this regard. The Serbian inventor Nikola Tesla thought that electromagnetism contains essentially everything in our universe. So what is the mutual relationship of electromagnetism and gravitation? We provide one possible explanation to the riddle.

Maxwell's equations and general relativity—what are these all about?

Maxwell's equations are the key linear partial differential equations that describe classical electromagnetism. The equations relate the electromagnetic field to currents and charges. On the other hand, in general relativity, the Einstein field equation is a set of nonlinear partial differential equations describing how the metric of spacetime evolves, given some conditions, such as mass density in the spacetime. Both equations are ultimately of second order, if seen properly.

Therefore, we thought that perhaps we are talking about the same governing equation, which could describe both electromagnetism and gravitation. Indeed, it becomes clear that Maxwell's equations hide inside the Einstein field equations of general relativity. The metric tensor of spacetime tells us how lengths determine in spacetime. The metric tensor also thus determines the curvature properties of spacetime. Curvature is what we feel as "force." In addition, energy and curvature relate to each other through the Einstein field equations. Test particles follow what are called geodesics—the shortest paths in the spacetime.

The missing link

The link between general relativity and electromagnetism becomes clear by assuming that the so-called four-potential of electromagnetism directly determines the metrical properties of the spacetime. In particular, our research shows how electromagnetism is an inherent property of spacetime itself. In a way, spacetime itself is therefore the aether. Electric and magnetic fields represent certain local tensions or twists in the spacetime fabric. Our research shows that the Lagrangian of electrodynamics is just the Einstein-Hilbert action of general relativity; it reveals how Maxwell's equations of electromagnetism are an optimality condition for the metric of spacetime to be sufficiently flat. As Einstein's theory of general relativity provides that the metric is optimal in a sense, electromagnetism is hidden in the nonlinear differential equations of general relativity. On the other hand, this means that general relativity is a generalized theory of nonlinear electromagnetism.

Geometrization of the material world

John Wheeler, the famous physicist, put forward the idea that all of the material world is constructed from the geometry of the spacetime. Our research strongly supports this kind of natural philosophy. It means that the material world always corresponds to some geometric structures of spacetime. Tensions in spacetime manifest themselves as electric and magnetic fields. Moreover, electric charge relates to some compressibility properties of spacetime. Electric current seems to be a re-balancing object, which transports charge in order to keep the spacetime manifold Ricci-flat. This is aesthetically pleasing, as nature seems to strive for harmony, efficiency and simplicity.

Riemann curvature tensor is more than just Ricci curvature—electromagnetic fields stretch and bend the spacetime

Although our theory shows that Maxwell's equations are a condition for the spacetime to be Ricci-flat, electromagnetic fields do seem to cause special curvature in spacetime nevertheless. The relevant curvature is what is known in differential geometry as the Weyl curvature. Weyl curvature in spacetime is the local curving of spacetime in such a way that locally, volumes are preserved. It is a special kind of stretching and bending of spacetime.

Conclusions

We believe that empirical research on this topic is important. This means measuring the local curvature of spacetime when there are strong electromagnetic fields present. Perhaps one could use, e.g., superconducting coils and laser light to measure any deviations in the fabric of spacetime. Artificial modifying of spacetime could have extensive benefits in the field of engineering, for example. Finally, it is worth mentioning that our approach has the benefit of simplicity—we do not need extra dimensions, torsion tensors, asymmetric metric tensors or the like.

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Bio: Jussi Lindgren is finishing his D.Sc. degree at Aalto University, Espoo, Finland and Jukka Liukkonen holds a PhD in applied physics, he works full-time at Nuclear and Radiation Safety Authority, STUK, Helsinki, Finland.