

Moving Through Curved Spacetime

A Search and Discovery piece by Steven K. Blau (PHYSICS TODAY, June 2003, page 21) discusses Jack Wisdom's work showing that the position of an object can be changed when that object modifies its shape by extending and retracting across a Schwarzschild metric. Although this result may be new to theorists, it is already known to rocket scientists.

In a paper presented in 1990, I showed that by changing the length of

a tether in a gravitational gradient—that is, in curved spacetime—one can modify the orbit, even to the extent of making the object climb away from the planet without expenditure of reaction mass.¹ In 1987, Manuel Martinez-Sanchez and Sarah Gavit had calculated similar results.² One can't push on flat spacetime, but in a region of curved space—or, if you prefer, tidal forces—one can use the difference in force to push against gravity.

References

1. G. A. Landis, *Acta Astronautica* **26**, 307 (1992).

2. M. Martinez-Sanchez, S. A. Gavit, *J. Guid. Control Dyn.* **10**, 233 (1987).

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Blau replies: This letter speaks to issues considered by Jack Wisdom, so we contacted him for a response.

Wisdom comments: Geoffrey Landis is correct that, in Newtonian gravity, cyclic changes in the shape of an extended body can work against the gravity gradient to effect certain changes in the orbital parameters. For example, tidally induced shape changes of a synchronously rotating natural satellite can damp the orbital eccentricity of the satellite. However, he is incorrect in identifying that effect with swimming in spacetime.

Cyclic changes in the shape of a body in the curved spacetime of Schwarzschild geometry can lead to net translation of the body. The swimming effect depends on curvature; it does not occur in the flat space of Newtonian gravity. It is a geometric effect: The amount of the translation does not depend on how fast the shape cycle is executed. In the Newtonian effect that Landis cites, there is no translation of the center of mass for fast cycles. That the swimming effect is a relativistic one is apparent in its dependence on the speed of light.

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More on Early LEDs

In their article "The Promise and Challenge of Solid-State Lighting" (PHYSICS TODAY, December 2001, page 42), Arpad Bergh, George Craford, Anil Duggal, and Roland Haitz show a graph (page 43) of performance of light-emitting diodes as a function of time. The graph obscures the early history by suggesting that GaP:Zn,O devices first appeared in 1968, whereas by that time a number of manufacturers had them on the market. The breakthrough in gallium phosphide came in 1962 when Jerzy Starkiewicz and I discovered that good red emission required both zinc and oxygen to be present, and we mapped the appropriate concentration ranges.¹ That work allowed for the development of devices (we called them "crystal lamps") with sufficient reproducibility for manufacture. They were

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