National Aeronautics and
Space Administration

"Frame-Dragging" in Local Spacetime

Gravity ProBe

In 1918, just two years after Einstein presented his theory of general relativity to the world, two other physicists, Josef Lense and Hans Thirring, predicted that masses in spacetime could deform spacetime in more than one way. Masses will not only "curve" the structure of spacetime around them, but also they will "twist" local spacetime if the mass is rotating.

This predicted effect was called "frame-dragging" to illustrate how a rotating planet will "twist" the local frame of reference around it. This "twisting" would alter measurements of distance, time, and direction in local spacetime.

One way to visualize this effect is to place a small ball—a super ball or a racquet ball—it in a bowl of a viscous liquid, such as honey. Add a few drops of food coloring to enhance the effect.

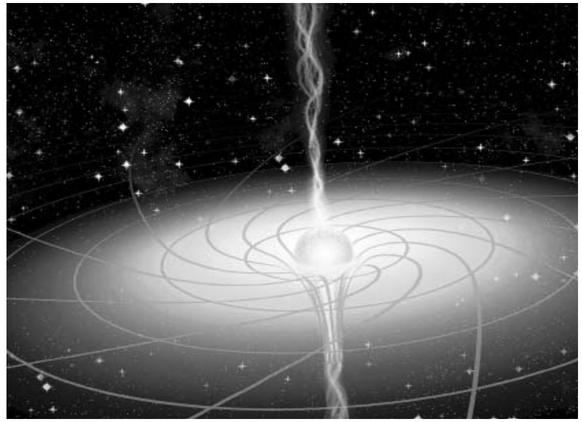
Now, spin the ball, and notice that the honey tends to turn with it. The honey that is closer to the ball is pulled around more than the honey that is farther away from the ball. Notice also that the food coloring, or anything else floating in the honey, is pulled around, as well.

Our rotating Earth is like the ball and spacetime is like the honey. According to the predictions of Lense and Thirring, as our Earth rotates, it should drag the framework of local spactime around with it. This frame-dragging effect should be most noticeable close to our rotating Earth, fading away almost completely as we move farther away.

The predicted frame dragging effect around a planet with the mass and size of our Earth, as measured by the Gravity Probe B gyroscopes, is very, very small—only 42 milliarc-seconds of angle over the course of a year.

How small an angle is 42 milliarc-seconds? One milliarc-second is 1/1,000 of an arc-second, and there are 3,600 arc-seconds in a single angular degree. 42 milliarc-seconds is approximately equivalent to the width of a human hair as seen from 1/4 mile away! It takes an extremely precise instrument to measure such a tiny angle—which is why the frame dragging effect has never been measured before.

The Earth is an rather small body in the scale of the universe, so frame-dragging is but a whisper in this realm. However, in the vicinity of black holes and other massive bodies, scientists believe that the effects of frame dragging are enormous, and that frame dragging may be responsible for the power generation in some of the most explosive objects in the universe.



In this hypothetical illustration, a rotating black hole drags spacetime around with it. Ultra-powerful jets of energy shoot out above and below the spinning black hole along its spin axis. Scientists believe that frame-dragging may be responsible for this phenomenon. While the energy jets have not been seen in black holes, they have been spotted emerging from distant quasars.

For more information, comments or questions, contact GP-B at www@relgyro.stanford.edu or visit http://einstein.stanford.edu/

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