"Frame-Dragging" in Local Spacetime

In 1918, just two years after Einstein presented his general theory of 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 "drag" the local frame of reference around it. This "twisting" would alter measurements of distance, time, and direction in local spacetime.

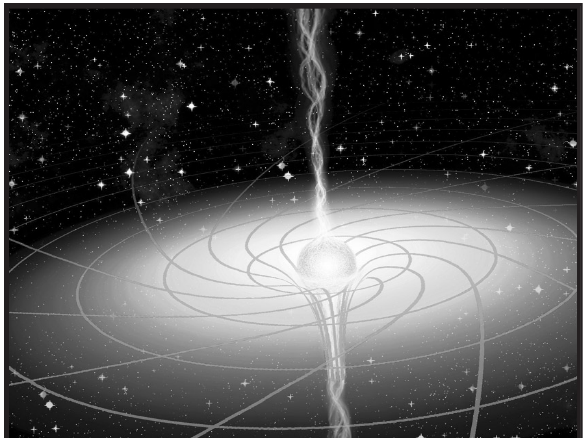
One way to visualize this effect is to place a small ball in a bowl of honey. Add a drop of food coloring near the ball. Now, spin the ball quickly and notice that the honey turns with it. The honey that is closer to the ball is pulled around more than the honey that is farther away from the ball. Notice also that the food coloring, or anything else floating in the honey, is pulled around, as well.

The spinning ball represents our Earth and the honey represents spacetime. According to the predictions of Lense and Thirring, as our Earth rotates, it should drag 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 milliarcseconds of angle over the course of a year.

How small an angle is 42 milliarcseconds? One milliarcsecond is 1/1,000 of an arcsecond, and there are 3,600 arcseconds in a single angular degree. 42 milliarcseconds 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.



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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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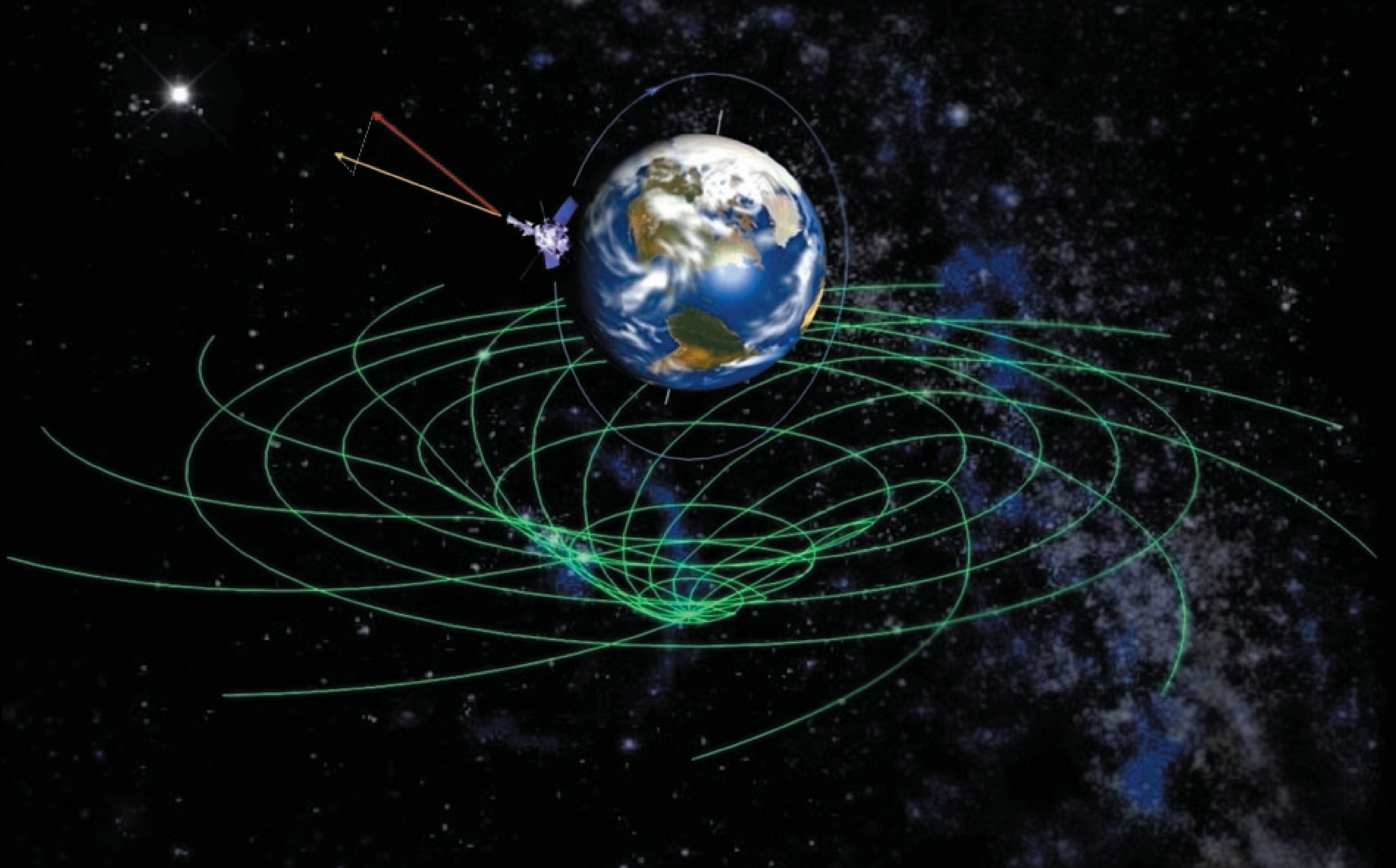
Gravity ProBe



c. James Overduin, Pancho & Evelyn Eekels and Katherine Stephenson