Einstein and Gravity Probe B

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Organization of the Talk

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- General Theory of Relativity

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- Remarks

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the frame dragging precession due to spinning of the earth.

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2. Riemannian geometry and
3. Gravity.

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Instantaneous communications are out and space and time merge into the single entity called space-time.

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A rotating observer will measure the geometry to be non-Euclidean due to the length contraction effects.

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GTR: Matter moves in a curved Riemannian manifold whose geometry is determined by the matter distribution.

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A small spinning body would precess due to curvature near a massive body and an additional precession if the body is rotating (Being tested!).

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If the distant stars rotated and not the bucket, would the surface be curved?

May be notions of inertia, dynamics be such that with either view, the surface should be curved – Mach

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This entails space-time being not only curved, but also dragged by a rotating body.

It is hard to rotate the whole universe or go very close to a rotating black hole, but we can just watch a spinning gyroscope falling freely around the rotating earth.

This is just what Gravity Probe B Experiment is.

Basic Equation for Spin precession

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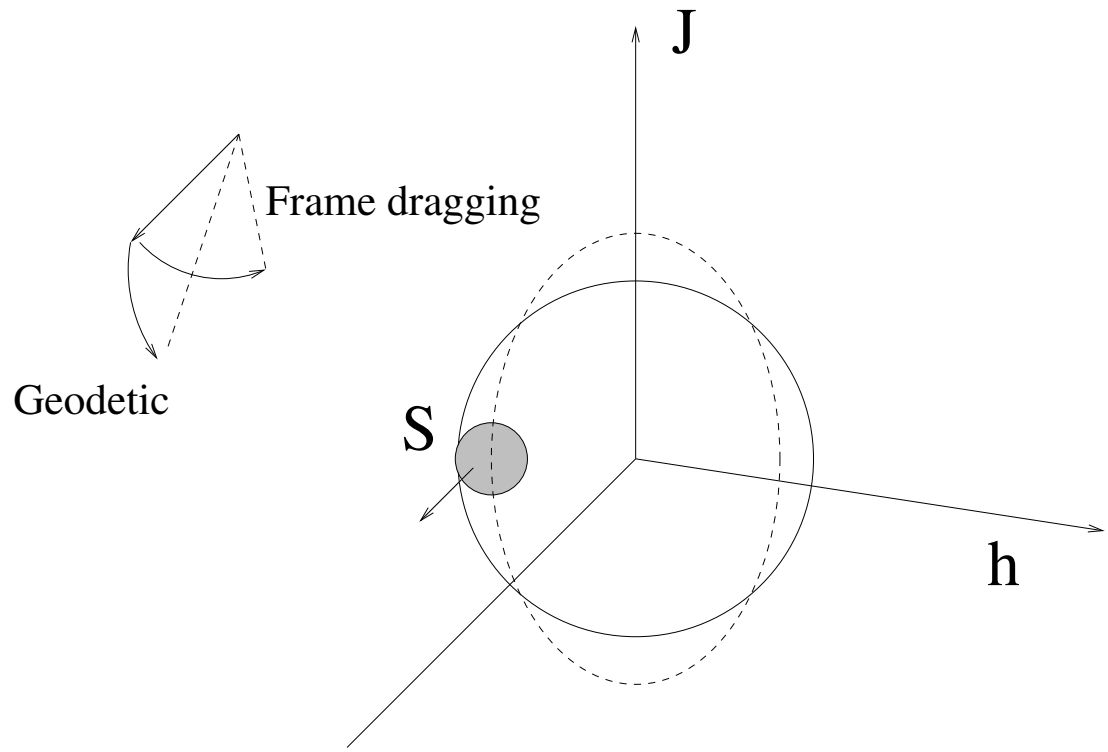

$$\frac{d\vec{S}}{dt} = \langle\vec{\Omega}\rangle \times \vec{S} \ ,$$

$$\langle\vec{\Omega}\rangle = \frac{G}{2r^3}\left[\vec{J}_E - \hat{h}(\hat{h}\cdot\vec{J}_E)\right] + \frac{3(GM_E)^{3/2}}{2r^{5/2}}\hat{h}$$

Basic details and Estimates

- Polar circular orbit with $r \sim 400$ miles;
- Duration of experiment $\sim 12 - 14$ months;
- Estimated Geodetic precession rate ~ 6.6 arcsec/yr;
- Estimated Frame-dragging precession rate ~ 40.9 milliarcsec/yr;

Experimental Requirements

Basically, all sources which could induce precession must do so with amount less than the estimate and since the change is so minute, the detection of the changes must be extremely precise.

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3. Stable reference to a Guide Star;
4. Trust worthy Guide Star;

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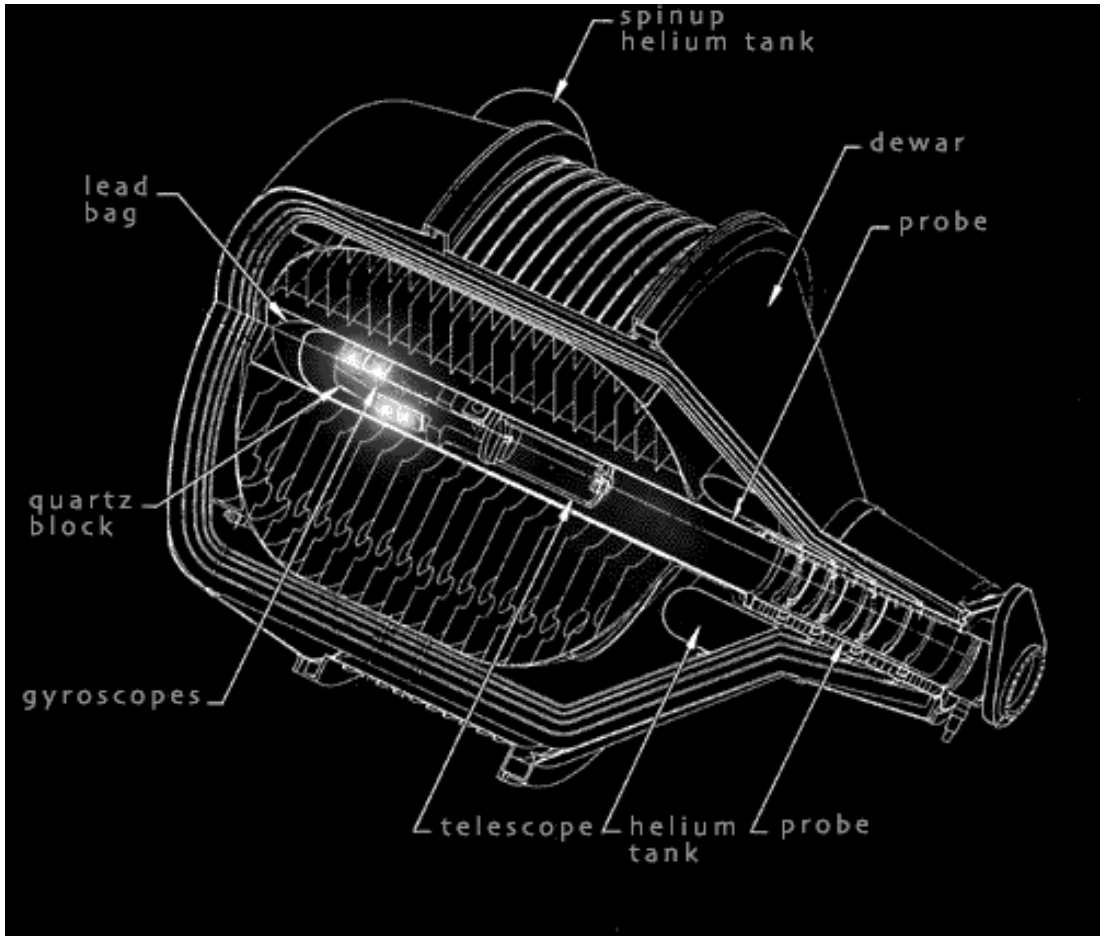
1. Gyroscopes must be stable and drag-free;
2. Method to read the spin direction without disturbance;
3. Stable reference to a Guide Star;
4. Trust worthy Guide Star;
5. Isolating Relativity Effects;
6. Calibration Scheme.

The arrangement



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- Coated with Niobium, suspended electrically in its housing with a clearance of 10^{-3} inches, remains centered within 10^{-6} inches. Spin rate up to 10000 RPM;

- Detecting spin direction: London moment induced in the rotating super-conductor. Read by a SQUID with sensitivity of 10^{-14} gauss. Cut earth's magnetic field by 10^{-13} by enclosing in lead bags;

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- Spin-up is achieved by evaporating super-fluid Helium passing around the gyroscope.

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- convenient position in the sky – IM Pegasi;

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- 5.6 inch diameter, 4 inch length, made up from quartz elements with optical contact.

Near Zeros

Temperature	1.8^0 K
Pressure	$< 10^{-11}$ Torr
Gravitational Acceleration	$< 10^{-10}$ g
material homogeneity	$< 3\ 10^{-6}$
mechanical sphericity	$< 3\ 10^{-7}$ inch
electrical sphericity	$< 5\ 10^{-7}$
Magnetic field	$< 10^{-6}$ Gauss

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- Even for a universally believed theory, there is a qualitatively distinct prediction, which is yet to be confirmed and is being tested;
- The predicted deviations are tiny making the tests very much harder calling for tremendous sophistication;
- Yet, it is worthwhile to devise experiments, even if only to test very esoteric ideas, since they spur new technological developments.

Thank You