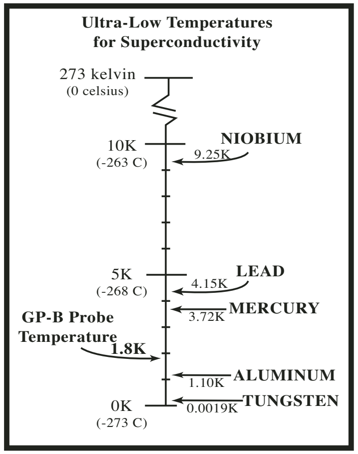
# Using Superconductivity to "See" a Spin Axis



Gravity Probe B's ultraspherical spinning gyroscope acts as a pointer floating in spacetime. The gyroscope's spin axis is aligned with a distant star at the beginning of the mission. After one year of orbit, scientists predict that the gyroscope, floating freely above the Earth, will turn slightly as local spacetime twists slightly (see "Frame-Dragging" card). The predicted amount of turn is extremely small (< 0.002% of a degree), which means that the gyroscope must be extremely stable while it is spinning (~$10^{-12}$ degrees of drift per hour).

Given this need for an ultra-stable spin, how could GP-B measure—to 0.1 milliarcseconds—the orientation of the spin axis of this perfect unmarked sphere, and do so without disturbing its perfectly balanced rotation?

The answer came from an unexpected source: **superconductivity**. When some metals are supercooled **near absolute zero** (0 kelvin, -273.15° celsius), they have the remarkable ability to conduct electricity without resistance; i.e., they become "superconductors". Another unique property of these superconducting metals is that they produce a magnetic field when the metal is spinning. The central axis of this magnetic field is exactly aligned with the spin axis of the rotating metal. This phenomenom is known as **the "London moment,"** named after Fritz London who predicted its existence in 1948. This prediction was experimentally verified by three independent groups (including one at Stanford University) in 1963.




Gravity Probe B applied the London moment phenomenon to its experiment by coating its four fused quartz gyroscopes with a sliver-thin layer of niobium (1270 nanometers thick), a superconducting metal. When one of these gyroscopes is spinning, the superconducting niobium layer generates a magnetic field around it. Within the niobium layer, the metal's positive charges spin with the gyroscope, but its electrons are "slippery" and lag behind. This creates a charge difference, which in turn, creates the magnetic field. The axis of this magnetic field is exactly aligned with the spin axis of the gyroscope.

To know which direction the gyroscope is pointing, GP-B simply monitors the orientation of this magnetic field. A thin superconducting metal loop which is connected to an external **SQUID** (a Superconducting QUantum Interference Device) encircles the gyroscope. If and when the gyro tilts, the magnetic field tilts with it, minutely changing the orientation of the magnetic field. The magnetic field affects the current in the superconducting loop which the SQUID senses. The SQUID is so sensitive that it can detect a field change of 5 x $10^{-14}$ gauss (1/10,000,000,000,000 of the Earth's magnetic field), corresponding to a gyro tilt of 0.1 milliarc-second.

National Aeronautics and Space Administration

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