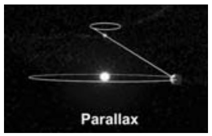
National Aeronautics and
Space Administration

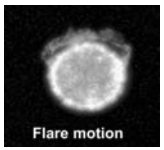
Focusing On the Guide Star

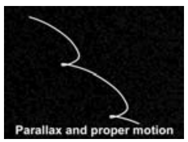
While the stars in the sky may appear to be fixed points of light, they are anything but stable objects. They wander around the sky relative to other objects, and as their light travels to Earth, it diffracts, or scatters, as it passes through the universe.

This instability and fuzziness creates significant problems for Gravity Probe B. For the experiment to work, GP-B must have an extremely stable, distant reference point at which to aim its telescope and gyroscope. If the guide star that we choose moves more than 0.1 milliarcsecond, GP-B cannot trust the star to be steady enough to measure the minute effects of local spacetime on the GP-B gyroscope.

Gravity Probe B examined many stars as possible candidates before settling on IM Pegasi as the most stable star they could use. But even IM Pegasi is not very still. This star has four unsettling motions: its proper motion, orbit perturbations from a binary star, annual parallax from the Earth's orbit, and star flares.

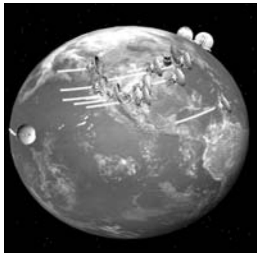

Parallax


Flare motion

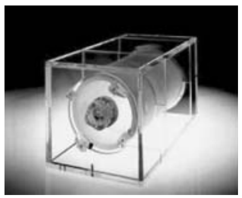

Parallax and proper motion


All four motions combined

To account for all these motions, IM Pegasi is monitored by a sophisticated worldwide system of radio telescopes operating in conjunction with each other. Telescopes from New Mexico to Australia to Germany focus on the guide star and map its movements as if one telescope the size of the Earth was focused on the star. In addition, the motions of the guide star are compared to an extremely distant quasar, an exceptionally still and "loud" object in the sky. The quasar emits powerful radio waves which make it easier to pinpoint in the sky.

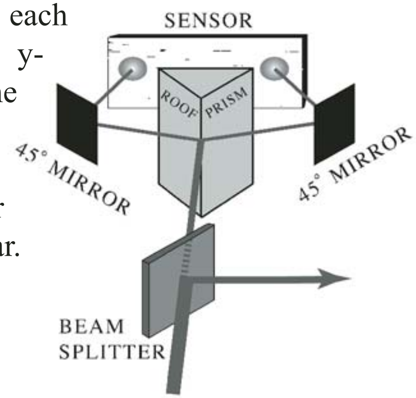


The second issue is finding the exact center of a star whose light is widely diffracted. GP-B solves this by using a sophisticated optical telescope only fourteen inches long. Diffraction spreads the star's image to a diameter of 1,400 milliarcseconds, corresponding to a focused image 0.001 inch across. Locating the star's center to 0.1 milliarcseconds means finding the image's optical center to one ten-millionth of an inch -- a formidable task.



GP-B accomplishes this task by focusing the starlight in the "lightbox" at the telescope's front end, and passing it through a beam-splitter (a half-silvered mirror). The beam-splitter forms two separate images, each of which falls on a roof-prism (a prism shaped like a peaked rooftop). The prism slices the star's image into two half-disks, which are directed to hit opposite ends of a tiny sensor.

On the sensor, the light signals of each half-disk are converted to electrical signals and then compared. If the signals are not precisely equal, this means that the roof-prism is not splitting the image precisely in half. The telescope is then adjusted until the signals are equal and the image is split right down the middle. When this is accomplished in both sensors for each axis (x- and y-axes), then the telescope is focused on the exact center of the guide star.



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

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