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Celestial Map Helps GPS Stay on Target

December 7, 2009

GPS technology helps us find our way around on Earth. But what helps GPS satellites find their own locations?

"For GPS to work, the orbital position, or ephemeris, of the satellites has to be known very precisely," says Dr. Chopo Ma of NASA's Goddard Space Flight Center in Greenbelt, Md. "In order to know where the satellites are, you have to know the orientation of the Earth very precisely."

This is not as obvious as simply looking at the Earth, since space isn't conveniently marked with lines to determine our planet's position. Worse yet, "everything is always moving," says Ma. The Earth wobbles as it rotates due to the gravitational pull (tides) from the Moon and the Sun. Even apparently minor things like shifts in air and ocean currents and motions in the Earth's molten core all influence our planet's orientation.

Fortunately, just as people can use landmarks to find their place in a strange city, astronomers can rely on landmarks in space to position the Earth. Stars seem the obvious candidate, since they've been used throughout history for navigation on Earth. "However, for the extremely precise measurements needed for things like GPS, stars won't work, because they are moving, too," says Ma.

What's needed are objects so remote that their motion isn't detectable. Only a couple classes of objects fit the bill, because they also need to be bright enough to be seen over incredible distances. Things like quasars, which are typically brighter than a billion suns, can be used. Many scientists believe these objects are powered by giant black holes feeding on nearby gas. Gas trapped in the black hole's powerful gravity is compressed and heated to millions of degrees, giving off intense light and/or radio energy.

A collection of remote quasars, whose positions in the sky are precisely known, forms a map of celestial landmarks in which to orient the Earth. The first such map, called the International Celestial Reference Frame (ICRF), was completed in 1995. It was made over the course of four years, using painstaking analysis of observations on the positions of some 600 objects.

Ma led a three-year effort to update and improve the precision of the ICRF map. Called ICRF2, the updated map uses observations of approximately 3,000 quasars. ICRF2 was officially recognized as the fundamental reference system for astronomy by the IAU last August.

Making such a map isn't easy. Despite the brilliance of quasars, their extreme distance makes them too faint to be located accurately with a conventional telescope that uses optical light. Instead, a special network of radio telescopes, called a Very Long Baseline Interferometer (VLBI), is used. VLBI networks can span continents, giving them the resolving power of a telescope thousands of miles in diameter. For ICRF2, the analysis of the VLBI observations reduced uncertainties in position to angles as small as 40 microarcseconds, about the thickness of a 0.7 millimeter mechanical pencil lead in Los Angeles when viewed from Washington, D.C.

The next update to the ICRF may be done in space. The European Space Agency plans to launch a satellite in 2012—Gaia—that will observe about a half-million quasars. Gaia uses an optical telescope, but because it is above the atmosphere, the satellite will be able to clearly see faint objects and precisely locate them in the sky.

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