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Heliophysics and General Relativity Investigation with MESSENGER

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The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft was equipped with an onboard radio frequency (RF) telecommunication subsystem that enabled precise Doppler and range observations for navigation and radio science.

The Doppler data allow the precise determination of Mercury's gravity field, orientation, and tides, since these measurements provide information on the orbit dynamics of the spacecraft. The range data, with a precision of $\sim$3 m, enable the high-accuracy estimation of Mercury's ephemeris.

Due to Mercury's proximity to the Sun, relativistic gravitational forces significantly perturb the planet's heliocentric orbit. A precise measurement of the precession of Mercury's perihelion using MESSENGER data constrains the general relativity Parameterized Post-Newtonian (PPN) coefficients γ and β, the gravitational parameter (*GM*) and the flattening (J_2) of the Sun, and the gravitomagnetic Lense-Thirring effect. In general relativity, the Lense-Thirring precession is due to the distortion of space-time around a rotating body, so it scales with the angular momentum of the Sun (S).

We analyzed MESSENGER Doppler and range data from the three Mercury flybys (January and September 2008 and September 2009) and the full orbital mission (from March 2011 to April 2015) in order to simultaneously estimate Mercury-related (gravity, orientation, and tides), heliophysics (*GM*, J_2, S), and relativistic parameters (γ, β). For this reason, we modified our orbit determination software, NASA Goddard Space Flight Center's GEODYN II, to integrate the trajectories of both MESSENGER and the planet Mercury. The co-adjustment of Mercury's ephemeris leads to significant improvements in the estimation of Mercury's gravity field and orientation. Results for these geophysical parameters include updates for all of these quantities.

We will discuss results of the estimation of γ and β, which were previously determined by the Cassini solar conjunction experiment and lunar laser ranging, respectively, and the Sun's J_2 and S, which will be compared with values from helioseismology.