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Spin dynamics of terrestrial planets – high precision estimation by Earth-based radar

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A promising new way to obtain information about the interiors of terrestrial planets is by estimating of their spin dynamics through the radar speckle displacement interferometry (RSDI) technique (Holin, 1988, 1992, 2004). RSDI is an optimized Earth-based technique to measure the instantaneous transverse (orthogonal to the Earth-Mercury line-of-sight) spin vector Ω of planetary mantles with minimum errors caused by thermal noise in radiotelescopes. The approach uses monochromatic radar transmission and relies on the maximizing the Gaussian functional

$\ln L = -0.5 \int\int\int\int W(\mathbf{r}_1, t_1; \mathbf{r}_2, t_2)\, y(\mathbf{r}_1, t_1)\, y(\mathbf{r}_2, t_2)\, d\mathbf{r}_1 d\mathbf{r}_2 dt_1 dt_2 + \text{const}$, (1)

where integration is over the Earth surface through the observation time T, y($\mathbf{r}$, t) is the input mixture of the radar echo field with noise, and function W is determined by the space-time correlation function of the input mixture. The limiting rms (root mean square), $\sigma_\eta^{-2} = - \partial^2 \ln L/\partial\eta^2$ and $\sigma_\Omega^{-2} = - \Omega^2 \partial^2 \ln L/\partial\Omega^2$, of joint estimates of the orientation η (in radians) and magnitude Ω (relative rms) of Ω for nearly symmetrical objects like Mercury, Venus, and Mars are

$\sigma = \sigma_\eta = \sigma_\Omega = l\, v / \pi\, q\, b\, \Omega\, d$, (2)

where l is the speckle diameter, v the velocity of speckle displacement, q the output amplitude signal-to-noise ratio, b the interferometer baselength, d the Earth-planet distance. One-shot accuracy Eq. (2) for the today's Goldstone / Green-Bank radar interferometer (USA) is of an order of 10^{-5} for Mercury and Mars and 10^{-6} for Venus. Further improvements in accuracy by an order or two of magnitude can be obtained with a new radar transmitter to be constructed in, e.g. Euro-Asia or the north of Africa, that works with a variety of European radiotelescopes.