PHYSICAL BACKGROUNDS TO MEASURE INSTANTANEOUS SPIN COMPONENTS OF TERRESTRIAL PLANETS FROM EARTH WITH ARCSECOND ACCURACY I. V. Holin, Space research institute, Moscow, holin@mail.cnt.ru

Introduction: Precise measurement of rotational dynamics of terrestrial planets may give a bulk of information about their interiors, histories of formation and evolution. E. g. an arcsecond or better accuracy is desirable in obliquity and especially in physical librations of Mercury to place significant constraints on size and state of its core [1]. Earth-based techniques now in use have low accuracy and can not measure variations in rotational components. In this work a new for astronomy radiophysical effect is considered allowing precise measurement by Earth-based radar of instantaneous transverse spin vectors of terrestrial planets and their variations with time [2-7]. I show that the effect is classical because it follows immediately from the Huygens-Fresnel principle [2-4].

The effect of far coherence: We may not know exact hights and positions of roughnesses over a planetary surface and a reasonable approach here is to consider it to be randomly rough. As a consequence scattered radar fields can be treated as randomly speckled. Space-time properties of such fields are characterized by the correlation function (matrix in general) [4]

$$K(\boldsymbol{\rho}_1,\boldsymbol{\rho}_2;\tau) = \exp\{jkP(\boldsymbol{\rho}_1,\boldsymbol{\rho}_2;\tau)\}$$

$$\iint I(\mathbf{r}) \exp\{jk\mathbf{r}_t\cdot(\boldsymbol{\rho}-\mathbf{v}\tau)/R\}d\mathbf{r}_t$$

$$\exp\{jkr_r(\rho_2^2-\rho_1^2)/4R^2\}dr_r \qquad (1)$$

where $P(\boldsymbol{\rho}_1,\boldsymbol{\rho}_2;\tau) = |\mathbf{R}+\mathbf{V}\tau| + |\mathbf{R}+\mathbf{V}\tau-\boldsymbol{\rho}_2| - R - |\mathbf{R}-\boldsymbol{\rho}_1|$ does not depend on planetary rotation, $I(\mathbf{r})$ is the power distribution over the scattering surface, $\mathbf{r}_t$ и r_r are the Descartes coordinates of $\mathbf{r}$ (r_r along with and $\mathbf{r}_t$ orthogonal to $\mathbf{R}$), $\boldsymbol{\rho}_1$,0 and $\boldsymbol{\rho}_2$,τ are space-time observation points, $\boldsymbol{\rho} = \boldsymbol{\rho}_2 - \boldsymbol{\rho}_1$, · denotes dot-product, $k = 2\pi/\lambda$, λ is the transmitted wavelength, **v** is the velosity of speckle pattern displacement [2]

$$\mathbf{v} \sim 2\mathbf{R}\times\boldsymbol{\Omega} + 2\mathbf{V}_t \qquad (2)$$

$\mathbf{V}_t$ is the transversal component of **V** with respect to **R**. The first (fast) exponent inside the integral (1) presents the effect of speckle displacement and the last (slow) one causes speckle decorrelation [2-4]. Due to the fast exponent the reflected speckle pattern "runs" in a transversal plane near the surface of Earth in a "frozen" state at the velocity **v** (2). For Mercury v ~ 200-300 km s^{-1}. The slow exponent destroys the "frozen" state of a speckle pattern. The length over which a speckle pattern remains "frozen" is much larger than the diameter of Earth and we can say about far coherence of radar fields scattered from inner planets. Indeed the correlation radius of a radar field scattered from Mercury is only l ~ 3 km (near coherence) [3,4] but due to the effect of far coherence (speckle displacement) radar echoes are highly correlated over thousands kms if the receiving baseline is colinear with **v**. We may use this fact to measure presisely instantaneous transversal spin-vectors of terrestrial planets [3-7]. Far coherence has a global character and possible baselines are transAtlantic (Europe-USA), transPacific (Japan-USA), and transcontinental (Europe-Japan).

From (1) the degree of far coherence can be estimated for a number of interferometers [4]. E. g. for the Goldstone – Green Bank radar interferometer (baselength b ~ 3000 km) the degree of far mutual coherence of the radar echoes from Mercury near its inferior conjunction with Earth is ~ 0.999987 (1.0 maximum), for Goldstone – Arecibo, b ~ 4000 km (Goldstone transmits at 13 cm) it is ~ 0.999985, for Arecibo – Goldstone (Arecibo transmits) ~ 0.999976, and for Goldstone – Utsuda (Japan), b ~ 8000 km it is ~ 0.99984. In any case the loss in correlation (decorrelation) is less or compared to 10^{-4} and radar techniques based on the effect of far coherence should work very perfectly and reliably.

Limiting accuracy: It was shown in [5] that one should use the effect of far coherence and the corresponding RSDI-technique (radar speckle displacement interferometry) [3-7] to reach in instantaneous spin components the limiting accuracy (monochromatic illumination)

$$\sigma = \frac{l}{qb}\cdot\frac{v}{v_\Omega} \sim 4.5\cdot 10^{-6} \qquad (3)$$

where the numerical value corresponds to the Goldstone – Green Bank interferometer for Mercury [3], v_Ω is a part of v caused by rotation, $q = Q^{0.5}$, Q is the signal-to-noise ratio. The limiting RSDI-accuracy for Mars and Venus is comparable with an arcsecond level too.

It was a pleasure to discuss here another wonderful consequence from the Huygens-Fresnel principle.

References: [1] Peale S. J. et al. (2002) *Meteoritics & Planet. Sci., 37,* 1269-1285 [2] Holin I. V. (1988) *Izvestiya VUZov: Radiofizika, 31,* 515-518. [3] Holin I. V. (2002) *Solar system research, 36,* 206-213 [4] Holin I. V. (2004) Forthcoming [5] Holin I. V. (1992) *Izvestiya VUZov: Radiofizika, 35,* 433-439 [6] Holin I. V. (2003) *Meteoritics & Planet. Sci., 38,* A9 [7] Holin I. V. (2003) *LPS XXXIV,* Abstract #1109.