CORE–MANTLE INTERPLAY FROM SPIN VARIATION OF MERCURY'S CRUST. I. V. Holin (Kravchenko str. 12-244, Moscow 119331 Russia, holin@mail.cnt.ru).

Introduction: Scientific revolutions are based on discovering new phenomena. One of such phenomena, long range coherence (LRC) of scattered fields, was shown to follow from the Huygens-Fresnel principle and then tested with the Goldstone – Green Bank (GGB) radar system ([1] and references there in). LRC reads that the radar echoes from, e.g., Mercury can be highly correlated over thousands kms in USA and Europe or Europe and Asia while earlier they were considered to be correlated within ~ kms only. Rotation of planets initiates displacement of speckled scattered radar fields in a "frozen" state in a global Earth scale allowing cross-correlation of the echoes over a very long baseline to measure the instantaneous spin-vector of a planet with high efficiency and to high precision. An LRC-based technique, HSDI (speckle displacement interferometry as proposed by Holin [2]), has the limiting accuracy or the Holin limit (HL) 3 to 4 orders of magnitude better than all previous Earth-based techniques in use. HSDI helps to estimate the 88-day libration amplitude (LA) of the crust φ, obliquity θ, and possible deviation from the Cassini state ξ [4],[5] and convinces that spin dynamics and related deep interior properties of Earth-like planets and the Moon can be studied by Earth-based radar to a very high precision [3]. In the current projects, a Mercury lander which was originally proposed to measure φ, θ, ξ [6] can be replaced by Earth-based radar. HSDI GGB measurements of Mercury's spin-vector orientation (pole position) and instantaneous rotation rate to ~ 3% and ~ 10% of HL respectively led to a ~ 2 orders of magnitude improvement and estimation of φ to ± 5% (± 15 to 20 meters on the surface) [4].

History: LRC-based HSDI was developed in 1984 –7 out of Russian academy of sciences (RAS). In 1989, during my presentation at RAS, it was strongly rejected by the group of academician Kotelnikov (Rziga, Aleksandrov, IRE RAS) and declined by Kotelnikov himself in 1995 (after his talk with Rziga). Further discussions in Russia and outside resulted in nothing until in April 2001 I described to S. Peale (UCSB) that Earth-based radar can measure φ, θ, ξ and translated for him the paper [7] where it was discussed in detail how to perform HSDI measurements of these parameters. Peale did not exclude that HSDI can really measure φ, θ, ξ and in May 2001 passed the paper [7] to Slade (JPL) and Margot (UCLA) who at that time were developing the repeat orbit radar interferometry (RORI) to measure φ, θ, ξ [5],[8]. As a result, RORI was left off and HSDI was applied with the GGB system to ± 5% in φ and θ [4] which could be helpful in together with the gravity measurements by an orbiter [5]. In October 2001, I manufactured a laser device to demonstrate LRC-effects and asked J. Head (BrU) to pass it to Peale but the device was confiscated at the airport because of tragic events on Sept. 11, 2001. In 2007 HSDI measurements of φ, θ, ξ gave an argument that the core of Mercury had not yet solidified completely [4]. For the part of Russia, in 2009 academician Zelenyi (SRI/IKI RAS) excluded HSDI from the official science. HSDI history clearly shows how official scientific organizations, such as RAS, can be very harmful to the world science throughout decades.

Summing up, in its home country (Russia) HSDI was turned down. In USA during the past 10 years, HSDI has been applied in its main features. Departures from the oridinal proposal [2] may still prevent from approaching HL and starting investigations of state 2 (see below) with the GGB system. Therefore, the values for φ, θ, ξ can be moved again. Other countries restrict to investigations by spacecrafts and telescopes which can not now compete with Earth-based radar in instantaneous-spin-vector-studies. It is for these reasons that the deep interior properties of Mercury, such as the real state of its core, related to high precision spin dynamics of the crust must remain out of reach in any observable future.

HL in Instantaneous Spin-Vector: HSDI potentials relate to its very high accuracy in instantaneous spin-vector. For independent decorrelation and thermal noises, HL (the limiting rms) can be written as

$$\sigma = (2m/\pi)d/qb, \quad (1)$$

where m for Mercury is ~ 1.2, d is the speckle diameter, b the baseline, q the output snr,

$$q = q_1 q_2/(q_1^2+q_2^2)^{0.5}, \quad (2)$$

where q_1 and q_2 are the decorrelation and thermal snrs respectively [1]. It was taken into account in (1) that for Mercury rmss in the two orthogonal projections are 2/π times smaller. Due to better averaging of independent speckle patterns, many-frequency transmission leads to q ~ q_2 and a new transmitter in EAA (Euro-Afro-Asia) may give σ as small as a few parts in 10^7 in a single experiment [1]. Repetition of the experiments daily and yearly (Y) with multiple (M) baselines leads to HL_{MY} in regular spin dynamics between 10^{-8} to 10^{-9}. These limits lead to further studies of Mercury's deep interior by Earth-based radar.

The 88-day Spin-Variation and Core-Mantle Interaction: A set of Mercury's states is presented in Fig. 1,2 very preliminary, qualitatively, and schematically, where LAs φ, spin variation amplitudes (SVAs) ω, and the instantaneous equivalent inertia moment C_{88}

which determines the crust's spin variation are functions of time t and distance r from Mercury's center-of-mass. In state 1, the core-mantle boundary (CMB) is perfectly liquid and the core is fully separated from the mantle's (m) 88-day libration (for simplicity, in Fig.1,2 the core in state 1 is shown at rest). LA and SVA of the crust are those for the mantle alone $\varphi_{01} = \varphi_m$ (Fig. 2A) and $\omega_{01} = \omega_m$ (Fig.1A) respectively. In state 3 Mercury has solidified completely so the core and the mantle have the same LA φ_{03} and SVA ω_{03}. A core-originating magnetic field and large LA reveal that Mercury is not exactly in state 3. A weak magnetic field and volcanic activity decayed in geological past reveal that Mercury is not exactly in state 1. Therefore, Mercury can be in a transitional state 2 where its crust's spin variation $\omega(t)$ (Fig. 1A) differs from those in states 1,3 due to interaction at a partially solidified CMB. HSDI has potentials to study Mercury in state 2 and determine at what extent it is far from or close to states 1,3, i.e. if SVA of the crust is ω_{01} or ω_{02}, and maybe estimate the difference $\omega_{01} - \omega_{02}$. E.g., for viscous coupling, a force of friction F(t) is proportional to the velocity difference of the layers ~ $\omega(t)$. When ω and F are near zero (Fig. 1A), the acceleration $d\omega/dt$ is near maxima and the behavior of $\omega(t)$ in zero-crossing areas for state 2 should be close to that in state 1. At aphelion (a) or perihelion (p), F is near its maxima which may result in some flattening of $\omega(t)$ and decrease in SVA from ω_{01} to ω_{02}. That should be accompanied by variations in $C_{88}(t)$ (Fig. 1B). It was enough to reach HL ~ 3×10^{-6} with the existing GGB system to constrain ω_{01} (ω_{02}) to a few % in a single experiment because $\omega_{01}(\omega_{02})/\Omega \sim 2\times10^{-4}$ [4], where Ω is the rotation rate of Mercury. That would mean that $\delta = (\omega_{01} - \omega_{02})/\ \omega_{01}$ of several % could be detectable. With a new radar transmitter in EAA, HL_{MY} is 10^{-8} to 10^{-9} which can detect δ and relative variations in $C_{88}(t)$ being as small as ~ 10^{-4}. Asymmetric core (inner core's non-zero SVA ω_{02ic} Fig. 2), displacement (asymmetry) of $\omega(t)$ at aphelion, and other possible effects can be discussed in state 2 as well.

Conclusion: Deep interior properties of Mercury related to its transitional state are within reach of Earth-based radar. A new dedicated radar transmitter in the middle of Euro-Afro-Asia (Iran, Afghanistan), that works with a variety of Euro-Asian radiotelescopes, can improve accuracy by orders of magnitude. International radar astronomy network (IRAN) could be very useful with planetary deep interior, asteroid danger, and other projects in radar astronomy.

References: [1] Holin I.V. (2010) *Icarus, 207,* 545. [2] Kholin I.V. (1992) *Radiophys. Quant. Elec., 35,* 284. [3] Holin I.V. (2010) *LPSC XXXXI,* Abstract # 1038. [4] Margot J.-L. et al. (2007) *Science, 316,* 710. [5] Peale S.J. et. al. (2002) *Meteorit. & Planet. Sci., 37,* 1269. [6] Peale S.J. (1972) *Icarus, 17,* 168. [7] Holin I.V. (1999) *Uspeckhi Sovrem. Radioel., No. 7,* 16-28. [8] Slade M.A. et al. (2001) *Mercury: Space Environ., Surface, and Interior,* Abstract # 8062.

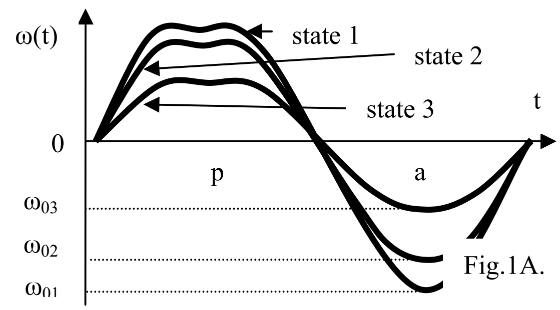

Fig.1A.

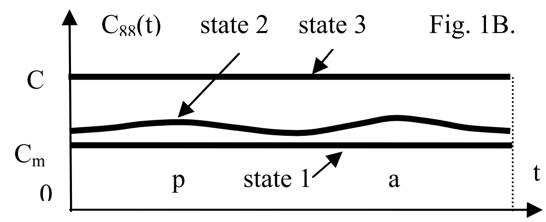

Fig. 1B.

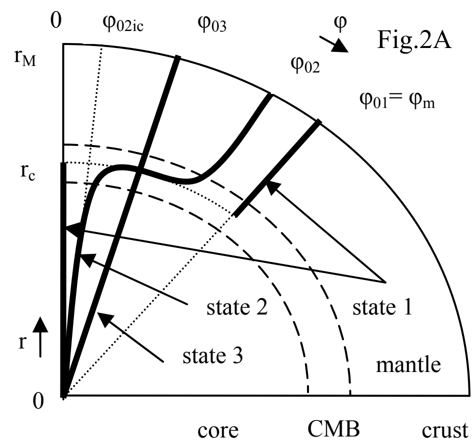

Fig.2A

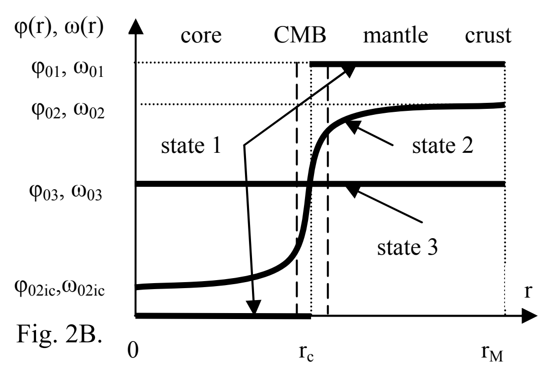

Fig. 2B.