Scientific session of the General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (26–27 November 1980)

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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on November 26 and 27, 1980 at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following papers were delivered:

November 26

1. *M. D. Kislik, Yu. F. Kolyuka, V. A. Kotel'nikov, G. M. Petrov, and V. F. Tikhonov,* A Unified Relativistic Theory of the Motion of the Inner Planets of the Solar System. Relativistic Effects in Determination of the Orbits of the Planets from Radar Observations.

2. *Yu. N. Pariĭskiĭ,* Preliminary Results of an Extreme-Depth Sky Survey at 7.6 cm.

3. *I. D. Karachentsev,* Motion of Binary Galaxies from BTA Data.

27 November

4. *G. A. Smolenskiĭ, V. V. Lemanov, A. B. Sherman, A. A. Dobrovol'skiĭ, Yu. M. Gal'perin, and V. P. Kozub,* Acoustoelectronic Interaction in a Piezoelectric-Secondary Electron System.

5. *A. A. Kaplyanskiĭ,* Optical Studies of High-frequency (10^{12} Hz) Acoustic Phonons in Crystals.

We publish below brief contents of four of these papers.

M. D. Kislik, Yu. F. Kolyuka, V. A. Kotel'nikov, G. M. Petrov, and V. F. Tikhonov. *A Unified Relativistic Theory of the Motion of the Inner Planets of the Solar System. Relativistic Effects in Determination of the Orbits of the Planets from Radar Observations.* Radar observations of Mercury, Venus, and Mars made in the Soviet Union in 1980 with an improved planetary radar[1] have provided important supplements to the results of earlier observations, especially in the cases of Mercury and Mars. A realistic basis has been created for a unified theory of the motion of the inner planets, i.e., for simultaneous determination of the orbital elements of Mercury, Venus, and Earth, and Mars from the entire aggregate of available observations. A procedure for the derivation of such a theory has been elaborated for this purpose and programmed for computer use. The principal distinctive features of this procedure as compared to that used in Refs. 2 and 3 reduce to the following. The Schwartzschilt terms governed by the sun were included in the right-hand sides of the differential equations of motion of the inner planets and in the calculated values of the return-signal delay time. Coordinated time, which is linearly related to the natural time of a terrestrial observer (atomic time) was used as an independent variable. Neptune was added to the list of attracting bodies. The equations of motion of the major planets and the Moon were integrated jointly.

This procedure was used to derive a unified relativistic theory of the motion of the inner planets. A total of 3768 radar measurements of reflected-signal delay time and 7193 optical (angle) measurements distributed over the interval from 1960 to 1980 were processed. The astronomical unit, the equatorial radius of Mars, and the radii of Mercury and Venus (for a total of 28 unknowns) were determined in addition to the elements of the planetary orbits. The results were reported in Ref. 4. Analysis of the nature and magnitude of the derivations of the measured distances and angles from their theoretical values in accordance with the derived theory showed that these deviations were distributed nearly normally over the 20-year measurement interval, with practically zero mean value. The standard deviations of the distances vary from 0.9 to 9 km, depending on the time of the observations and the target planet; the standard deviations of the angles are $0''.6 - 1''.2$. The agreement between the measured and calculated distances deteriorated noticeably when the same data were processed without allowance for the relativistic perturbations. Systematic deviations ranging up to 390 km for Mercury, 8 km for Venus, and 12 km for Mars appeared on certain segments of the twenty-year interval. It is therefore in advisable to use Newtonian mechanics in solving this problem.[1)]

The good agreement obtained between observational and calculated data in deriving a unified relativistic

[1)]However, this does not preclude its use in the derivation of limited-time-scale theories of the motion of Venus, the Earth, and Mars (as was shown, for example, in Refs. 2 and 3).

theory of the motion of the inner planets can be regarded as an experimental verification of the general theory of relativity by astonomical methods. Radar observations of Venus were also used as a basis for experimental verification of the relativistic effect that arises in determining the orbit of the Earth and the target planet from the measured distances when a Newtonian model is used. This effect consists of a synchronous retardation of the predicted motion of the Earth and the planet around the sun. Its existence and approximate magnitude were predicted by analytic modeling of the orbit-determining processes. For circular coplanar motion, and on the assumption that equally accurate distance measurements are concentrated in the neighborhoods of two inferior conjunctions (oppositions) of the planet, the secular variation in longitude over 100 years, $\Delta u_s^{(100)}$, which is the same for the Earth and the target planet, is given by[5]

$$\Delta u_{B}^{(100)} = -\frac{6\pi\mu k^{5/2}\ln k}{a_1(k^{5/2}-1)} \times\left[1+\frac{k(k+k^{1/2}+1)^2}{(2k^2+k^{3/2}+2k+k^{1/2}+2)(2k^2+4k^{3/2}+5k+4k^{1/2}+2)}\right]\cdot 100, \quad (1)$$

where $k=a_1/a_2$, a_1 and a_2 are the radii of the orbits of the Earth and the planet, respectively, and $\mu = 1.477$ km is the sun's gravitational radius. Relation (1) is represented graphically in the figure. For the Earth-Venus pair, $\Delta u_s^{(100)} = -2''.31$.

To predict the secular variations that correspond to the aggregate of all real radar observations of Venus distributed over the interval from 1962 to 1980 with allowance for their error characteristics, the orbit-determining process was modeled numerically. The variations $\Delta u_s^{(100)}$ for the Earth and Venus were $-2''.13$, and $-2''.10$, respectively, i.e., they came quite close to the results of the analytic modeling. To obtain ex-

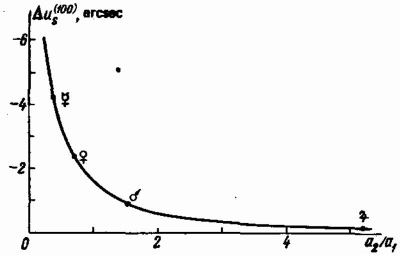

FIG. 1. Secular drift in longitude versus distance of target planet from the sun (in astronomical units).

perimental verification of the relativistic effect, the orbits of the Earth and Venus were determined twice from actual data—using the Newtonian and relativistic models. The secular variations $\Delta u_s^{(100)}$ for each of the planets were determined from the difference between the sidereal periods obtained for the Newtonian and relativistic models. They were found equal to $-2''.10$ for the Earth and $-2''.07$ for Venus. Thus, the relativistic-effect magnitude predicted theoretically by numerical modeling was confirmed accurate to 1.5% for both the Earth and Venus.

[1] V. A. Kotel'nikov, Pravda, October 20, 1980.

[2] M. D. Kislik, Yu. F. Kolyuka, V. A. Kotel'nikov, G. M. Petrov, and V. F. Tikhonov, Dokl. Akad. Nauk SSSR **241**, 1046 (1978) [Sov. Phys. Dokl. **23**, 526 (1978)].

[3] M. D. Kislik, Yu. F. Kolyuka, V. A. Kotel'nikov, G. M. Petrov, and V. F. Tikhonov, *ibid.* **249**, 78 (1979) [**24**, 870 (1979)].

[4] M. D. Kislik, Yu. F. Kolyuka, V. A. Kotel'nikov, G. M. Petrov, and V. F. Tikhonov, *ibid.* **255**, 545 (1980) [**25**, 867 (1980)].

[5] M. D. Kislik, Pis'ma Astron. Zh. **7**, 56 (1981) [Sov. Astron. Lett. **7**, 31 (1981)].