MEETINGS AND CONFERENCES

Scientific Session of the Division of General Physics and Astronomy and the Division of Nuclear Physics, Academy of Sciences of the USSR (28–29 March 1984)

Usp. Fiz. Nauk **145**, 137–146 (January 1985)

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 March 28 and 29, 1984 at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences. The following reports were presented.

March 28

1. *M. D. Kislik.* Experimental check of the general theory of relativity and the oblateness of the sun.

2. *G. E. Kocharov.* Gamma quanta and neutrons from solar flares.

March 29

3. *A. A. Bykov, I. M. Dremin, and A. V. Leonidov,* Quark atoms and their spectroscopy.

4. *M. B. Voloshin.* Heavy quarkonium outside the potential model.

5. *V. A. Khoze,* Heavy quarks and perturbation theory in quantum chromodynamics.

The brief contents of four of the reports are published below.

M. D. Kislik. *Experimental check of the general theory of relativity and the oblateness of the sun.* The possibilities for checking Einstein's general theory of relativity (GTR) experimentally by astronomical methods have increased markedly in recent years with the advent of new astrometrical techniques and extensive use of computers for processing the observational data. The high accuracy of the measurements and the expansion of the set of measured parameters, achieved with the help of planetary radar, have enabled the observation of a number of new relativistic effects created by the sun's Schwarzschild field and previously not accessible to observations.[1,2] The main check of the GTR, however, is the good agreement between the experimental and computed data, which has been achieved with the construction of relativistic theories of the motion of the inner planets.[3–5] This check is of a global character, i.e., it encompasses all possible relativistic effects created by the Schwarzschild field in the post-Newtonian approximation, including also the classical effect of the secular shift of the perihelions of the orbits. The lack of reliable data on the value of the dynamic coefficient of solar oblateness J_2 cannot cast doubt on the results, because neglecting J_2 has practically no effect on the actual accuracy achieved to date in the determination of the orbits of the inner planets.[6] This can be shown by estimating the range of possible values of J_2 and the limiting magnitude of the discrepancies appearing in the theories of motion of the planets neglecting the solar oblateness.

Assuming that the sun rotates as a rigid body with the angular velocity of sidereal rotation of points on the equator, while its density is a nonincreasing function of distance from the center, from the theory of the shapes of celestial bodies we obtain[6]

$$J_2^{\min}=0<J_2<1{,}08\cdot 10^{-5}=J_2^{\max}. \tag{1}$$

The corresponding limits for the geometrical oblateness of the sun α will be $1.08\cdot 10^{-5}<\alpha<2.69\cdot 10^{-5}$. Inequalities analogous to (1) hold for all large planets with known values of J_2 (Table I); for the giant planets the ratio $J_2/J_2^{\max}$ is appreciably smaller than for the Earth and Mars. The values of J_2 for the sun, based on data from a number of studies performed in recent years,[3,7,9] are presented in Table II. The rotation of the interior layers (the "core") of the sun with a velocity greater than the rotational velocity of the photosphere[8–11] (if it exists, which a number of authors[12,13] deny), according to data obtained by supporters of this hypothesis,[8,9] does not lead to a violation of the inequalities (1).

To estimate the discrepancies in the parameters being determined and measured, corresponding to $J_2=J_2^{\max}$, it is

TABLE I.

Planet	$J_2^{\max}\cdot 10^2$	$J_2\cdot 10^2$	$J_2/J_2^{\max}$
Earth	0,174	0,108	0,62
Mars	0.257	0.196	0,76
Jupiter	4.74	1,48	0,31
Saturn	9,1	1,65	0,18
Uranus	3,4	1,2	0,35
Neptune	1,4	0,4	0,29

TABLE II.

Author	$J_2\cdot 10^6$	$J_2/J_2^{\max}$
Anderson *et al.*[3]	$2{,}4\pm 1{,}7$	0,22
Hill *et al.*[7]	$5{,}5\pm 1{,}3$	0.51
Gough[8]	3,6	0,33
Campbell *et al.*[9]	1,6—5,0	0.15—0,46

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TABLE III.

Tracked planet	i	Deviations $\Delta A_i = -\Delta a_{1i}$, km	Discrepancies $\delta A_{(\mu\nu)} = -\delta a_{1(\mu\nu)}$, km	Drift over 100 years $\delta u_{1i} = \delta u_i$
Mercury	2	0.131	$\delta A_{(2,3)} = A_2 - A_3 = 0{,}067$	0″, 170
Venus	3	0.064	$\delta A_{(3,4)} = A_3 - A_4 = 0.060$	0″, 083
Mars	4	0.004	$\delta A_{(4,2)} = A_4 - A_2 = -0{,}127$	0″, 006

sufficient to use a simple analytic model of the process of determining the orbit from the measured distances for the case of coplanar motion of the earth and the planet being tracked in the sun's equatorial plane.[6,14] Analyzing separately the observations for two planets ($i = \mu, \nu$) and comparing the values of the astronomical unit A_i and the long semiaxis of the earth's orbit a_{1i}, we obtain the discrepancies in the observed parameters: $\delta A_{(\mu\nu)} = A_\mu - A_\nu$, $\delta a_{1(\mu\nu)} = a_{1\mu} - a_{1\nu}$. The deviations of the long semiaxes of the earth's orbit Δa_{1i} and of the planet's orbit Δa_i from their true values will give rise to discrepancies in the measured parameters—the secular longitudinal shifts δu_{1i} and δu_i—in comparisons of the computed longitudes of the earth $u_{1i}^{(c)}$ and of the planet $u_i^{(c)}$ with the actual longitudes $u_1^{(a)}$ and $u_i^{(a)}$, obtained from optical observations: $\delta u_{1i} = u_{1i}^{(c)} - u_1^{(c)}$, $\delta u_i = u_i^{(c)} - u_i^{(a)}$ (Table III). Based on the data in Tables I and II it may be assumed that the ratio J_2/J_2^{max} for the sun is unlikely to be greater than 0.5, i.e., that the discrepancies in Table III are too high by a factor of approximately two. Even without this assumption, however, the discrepancies are too small to be reliably separated from the background noise in processing the observational data for the inner planets. Noise means in this case the totality of all discrepancies appearing in the theories of motion of planets for different reasons—unknown or known, but unavoidable for the time being. At the same time, relativistic perturbations in the motion of the planets and in the propagation of light, if they are ignored, lead to discrepancies (relativistic effects) which exceed this noise level manyfold. For example, in constructing a unified theory of the motion of the inner planets in the Newtonian variant the discrepancy between the measured and computed ranges in a measuring interval of 20 years attains 390 km for Mercury, which exceeds by approximately two orders of magnitude the discrepancies in the relativistic theory.[4]

In conclusion we note that in the age of radar astronomy and interplanetary cosmonautics the relativistic secular shift of the perihelion of Mercury's orbit, with which, because of a lack of knowledge of the solar oblateness, doubts in the validity of GTR in weak gravitational fields were usually associated ("drama of ideas"), can no longer be regarded as the principal or, especially, the only criterion in the experimental check of GTR. All the experience gained in recent years from the successful practical application of relativistic celestial mechanics points to the validity of GTR.

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