BELLCOMM, INC.

SUBJECT: Recent Measurements of the Solar Oblateness and their Implications for the Einstein Theory of General Relativity - Case 227

DATE: March 17, 1967

FROM: R.W. Newsome

ABSTRACT

A series of high precision measurements of the solar disc were performed in the summer of 1966 by Professor R.H. Dicke and collaborators at Princeton University. These measurements indicate that the equatorial radius of the sun's photosphere subtends 48 ± 7 millisec of arc more than its polar radius.

Dicke claims that the magnitude of the solar mass oblateness, which is inferred from his optical measurements, is such that there is an apparent discrepancy of 8% between observation and the modified Einstein prediction for the motion of the perihelion of Mercury.

If the stated accuracy of these measurements is confirmed, then the photoelectric detection techniques, which were used in this earth-based experiment, may be singularly significant in establishing the relative merit of earth-satellite-based versus earth-based telescope platforms for performing this and possibly related experiments.

It is noted that a zero-drag artificial satellite in an elongated orbit around the sun could in principle make a more direct measurement of a solar mass quadrupole moment, if the satellite could be tracked with sufficient accuracy in the vicinity of the sun.

(NASA-CR-154378) RECENT MEASUREMENTS OF THE SOLAR OBLATENESS AND THEIR IMPLICATIONS FOR THE EINSTEIN THEORY OF GENERAL RELATIVITY (Bellcomm, Inc.) 5 p

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MEMORANDUM FOR FILE

Presentations of the Princeton Measurements and interpretations of the solar oblateness were made by Professor R.H.Dicke at The Relativistic Astrophysics Symposium on January 27, 1967, and at The Annual Richtmyer Lecture of the American Physical Society on January 31, 1967. Both lectures were organized under the auspices of The American Physical Society and were held in New York City. An account of this work has been subsequently published.(8)

The primary data presented by Professor Dicke are summarized in the following equation

$$\frac{\Delta r}{r} = (5.0 \pm 0.7) \times 10^{-5},$$

where r is the equatorial radius and Δr is the difference between the equatorial and polar radii, (i.e., the sun is symmetrically flattened at the poles of its rotation axis). This result was obtained with a specially designed telescope employing quartz mirrors.(8) The telescope was rotated about its axis of symmetry to a new position and an independent measurement was made every minute. The image of the sun was focused on a symmetrically placed circular occulting disc which screened out all light except that from the solar rim. This light was then effectively intensity modulated (as a function of the nonspherical shape of the sun) by subsequently masking it with a well centered rotating disc, in which two diametrically located apertures were cut.(1, 8) The transmitted light was monitored with a photoelectric detection system and its intensity was correlated with the phase angle of the rotating disc. Numerous measurements of intensity versus phase angle were made over relatively short time intervals in order to average out atmospheric distortions.

Due to the 23.5° tilt of the Earth's rotation axis with respect to its orbital plane, the solar rotation axis (which is tilted at 7° with respect to the Earth's orbital plane) appears to shift as the Earth moves about the sun. An important self consistency check of Dicke's data was that it was sensitive (with an accuracy of 2°) to this shift in viewing angle of the solar axis as seen from the Earth.

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In order to relate the observed oblateness in the luminosity of the solar disc to a mass oblateness, it was necessary to assume that there are no appreciable shear stresses in the observed portion of the sun's photosphere, and that equilibrium conditions are such that surfaces in temperature equilibrium coincide with the equipotential surfaces associated with the gravitational field(2). This is a crucial set of assumptions, and although plausible, they are difficult to substantiate quantitatively. Professor Dicke feels that a more direct measurement of the sun's gravitational field would be feasible if a zero-drag(3) artificial satellite could be accurately tracked in the vicinity of the sun.

Two possible explanations for the inferred solar mass quadrupole moment were presented by Professor Dicke. He feels that a possible but rather implausible explanation is that deeply buried and very strong magnetic fields exist inside the sun. His preferred explanation is that the core of the sun is rotating at a rate of about 1 revolution every 1.8 days. The slower rotation rate of the outer solar atmosphere (e.g., the observed rotation period varies from 25.4 days at the equator to 33 days at 75° (North or South) latitude(4)) can be rationalized by considering the external braking torque produced by the solar wind, which is estimated by Dicke to be $\sim 5 \times 10^{29}$ dyne-cm/steradian at the solar equator.

When the deduced mass quadrupole moment (inferred from this measurement) is used to calculate the motion of Mercury's orbit (using Newtonian mechanics), it is found that the anomalous shift in the perihelion of Mercury is reduced from 43.11 ± 0.45 sec of arc per century(5) to 39.6 sec of arc per century. Dicke claims that the original tensor formulation of Einstein's Theory can no longer account for this reduced effect and that a scalar term should be added to the gravitational field equations (as in the Brans-Dicke Theory(6)). This scalar term has the effect of changing the universal gravitational 'constant' into a variable quantity which decreases at a rate of a few parts in 10^{11} per year. It is possible to rationalize some geological and cosmological evidence to support this hypothesis(7), but the present status of this evidence is patently inconclusive.

As a result of this measurement there will probably be a resurgence of interest in the scientific community to make other precision checks of Einstein's General Theory of Relativity. Measurements from future space stations may play a significant role in this endeavor. In this respect, the logical question for the space system engineer is "How much additional accuracy could have been obtained if Dicke's experiment had been performed above the Earth's atmosphere?" This author does not have enough detailed information about this experiment to give a precise answer to this question; however, Professor Dicke did stress his belief that atmospheric turbulence was adequately averaged over, as evidenced by the consistency of his data. He also noted that measurements were discontinued when corrections (due to increased atmospheric refraction of sunlight for low sun angles) were comparable to effects due to the measured solar oblateness(8). As more information becomes available, this experiment should be carefully re-evaluated in order to assess accurately the status and flexibility of the techniques which were used.

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