# LETTERS TO THE EDITOR

## ASTRONOMY

### Instability of Motion at the Lagrangian Triangular Point in the Earth–Moon System

I wish to comment on the communication by Dr. E. T. Benedikt[1] on the "Exact Determination of the Lunar Mass by means of a Selenoid Satellite".

(*a*) If we write the equation of motion of a particle referred to a well-defined sextile configuration of the Earth–Moon system, it is easy to show that the selenoid satellite proposed by Benedikt is very unstable. The motion of a satellite, even in a small region around a sextile point, resembles the motion of a non-linear vibrational, time-dependent system without friction, very close to resonant and sub-resonant conditions. The main effect of the Sun may be considered a periodic perturbation with a period of one-half of the lunar period, rather than a period of the order of one year, as given by Benedikt. A crude numerical evaluation which I have made in the last months is confirmed by numerical integrations made by the Space Science Laboratory of the General Electric Co., Philadelphia, Pa., for the U.S. Air Force Rome Air Development Center, Rome, New York.

(*b*) To place a satellite in orbit around the Moon would be both technically simpler and theoretically more advantageous for the precise determination of the mass of the Moon and of its gravitational field, than to place a satellite in a sextile point with the required velocity.

(*c*) If we suppose that Kordylewski clouds are condensations of meteoric particles, it follows from (*a*) that these clouds are very unstable. The objects which Kordylewski reported last spring may no longer be visible, or at best may no longer be of the same dimensions nor, consequently, of the same density. In any event, I fail to see how observations of these large and rapidly changing objects could be useful in determining precisely the lunar mass. Studying the General Electric computations, one would conclude that such a cloud of particles, originally covering a few degrees of the sky, would expand to cover a region larger than 20° along the lunar orbit in about six months.

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[1] Benedikt, E. T., *Nature*, **192**, 442 (1961).

The kinematic stability of a planetoid orbiting in permanent sextile configuration with two other attracting centres, for which the ratio of the larger to the smaller mass exceeds 25, is well established. Indeed, the Trojan asteroids, the elongation from their theoretical libration points of which is sometimes considerable, do certainly not appear to exhibit the catastrophic instability predicted by Colombo's non-linear model.

The question of instability resulting from the inclusion of non-linear terms in the expansion of the equations of motion about the libration points was indeed considered by me[1]; absolute stability of the artificial or natural selenoid satellite was not postulated (as explicitly expressed in my original publication) in the proposed method of measurement of the lunar mass; however, it was deemed justified to expect a sufficient permanence of the motion of such satellites to carry out the required measurements. L. Sehnal[2] predicts also (on the basis of an approximate model) an instability of a selenoid in the Earth–Moon–Sun system, but similarly concludes that in spite of this instability the satellite will remain in the vicinity of the libration point for a long time.

The instability of selenoid satellites cannot be regarded as demonstrated on the basis of the result of automatic computations unless the latter are supplemented by rigorous error analysis. Indeed, in a long-term computation, such an apparent instability could possibly result from accumulation of error. Also, the disappearance of the clouds observed by Kordylewski has not been as yet announced.

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[1] Benedikt, E. T., paper presented at the First Intern. Symp. Analyt. Astrodynamics, Los Angeles (June 1961).

[2] Sehnal, L., *Bull. Astron. Inst. Czechoslovakia*, **11**, No. 4.

## RADIOPHYSICS

### Remote Phase Control of Radio Station *WWVL*

The standard very-low-frequency 20-kc. emission from the National Bureau of Standards radio station *WWVL* at Sunset, Colorado, has been synchronized with the frequency of a working atomic standard located at the National Bureau of Standards Laboratories in Boulder, Colorado, eleven miles from the transmitter site. The phase-lock loop for this purpose uses a servosystem similar to that described by Looney[1], with the system elements necessarily divided between the two locations. At Boulder Laboratories is located a 20-kc./s. receiver, phase detector, atomic standard and a 50 Mc./s. F.M. auxiliary transmitter for returning error and reference phase signals, by means of duplexing, to a 400 c.p.s. two-phase servo-motor with gear reduction which drives a resolver at the transmitter site. The resolver, which is located electrically between the local crystal oscillator and transmitter input, thus corrects the transmitter input phase so as to maintain the transmitted output phase, as received at Boulder Laboratories, in synchronism with the phase of the controlling atomic oscillator. This system therefore corrects for frequency drift of the transmitter control oscillator as well as for changes in phase which in general are known to occur in the transmitter and antenna system (ref. 2 and Watt, A. D., private communication). Comparisons made on a very-low-frequency monitor between the phase of the received 20-kc./s. signal at