LETTERS

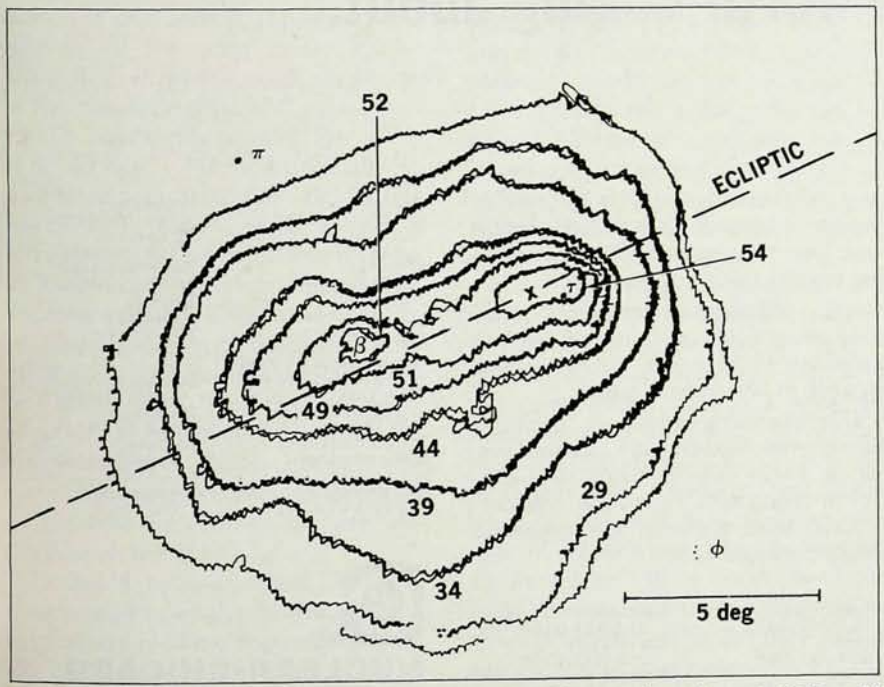
Doubt about libration clouds

We read with interest the article "Dust Cloud Moons of the Earth" by J. W. Simpson in the February issue of PHYSICS TODAY since Simpson for a number of years has been the most assiduous American observer seeking earth-moon libration-cloud phenomena. However, a substantial amount of investigation of the triangular libration points done both at the department of astronomy and the aerospace engineering department here at the University of Texas, leads us to rather different conclusions.

Photographic observations made at the McDonald Observatory on 12 March by one us (Roosen)[1] confirm that the patchy appearance of the background skylight on the night from McDonald was essentially the same as seen by Simpson over 1000 miles away and 2 hours later (figure). But it is neither necessary, nor to us even probable, that the features seen were libration clouds orbiting the earth.

The observational problem is that of detecting a cloud of dust particles at a libration point against a background brightness arising from a large and bright zodiacal "cloud" of particles distributed throughout the solar system. This cloud causes the zodiacal light, probably also the gegenschein, and in fact produces diffuse brightness over the entire sky.[2] There is no reason to expect that this zodiacal cloud will be completely homogeneous; bright patches of the size that have been observed might be seen as a result of several causes. Although much more work must be done on this subject, we suggest as one possibility that, when seen "end on," the orbits of many old comets may still contain enough diffuse matter to produce enhanced sky brightness. Also interaction of the interplanetary gas and dust grains with the filamentary solar wind might produce observable effects. In this connection isophotes very similar to those shown in our figure, but due only to the gegenschein, have been observed photoelectrically.[3]

From the theoretical point of view,



ISOPHOTOMETER TRACING of composite from photographs taken at McDonald Observatory 12 March 1966. Tau and phi Leonis and beta and pi Virginis are identified. Numbers are relative densities of the isophotes. x marks the antisolar point.

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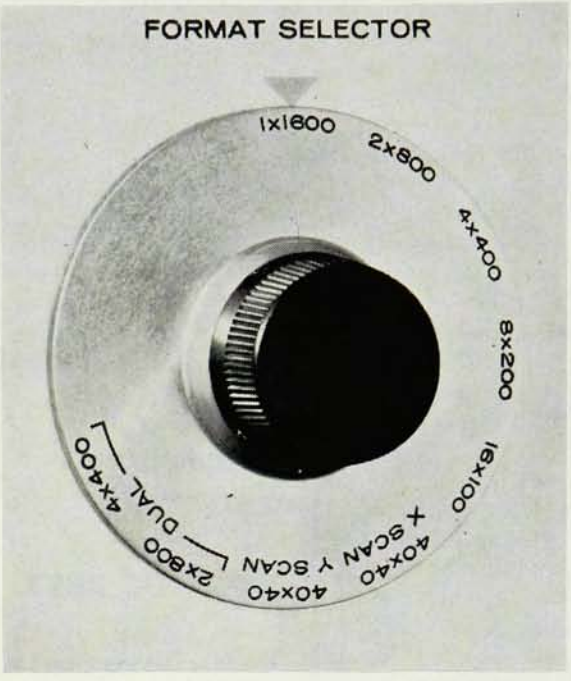

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some remarks should be made concerning libration-point stability. Insofar as the restricted three-body problem goes, there is absolute stability in the mathematical sense that if a particle is put close enough to L/4 or L/5 with small velocity, it will remain in the vicinity of the libration point *forever*, as has been shown by A. M. Leontovich[4] and more generally by A. Deprit[5] using powerful new theorems due to Kolmogoroff, Arnold and Moser. The libration points are even stable (for a set of initial conditions of positive measure) in the three-dimensional elliptic case, a fact that follows from these theorems and the work of J. M. Danby.[6]

However, one cannot directly apply this over-simplified theory to the interpretation of observations of bright patches near the predicted triangular libration points of the earth-moon system. The restricted three-body problem is a poor model of the actual situation, primarily because of the two-fold effect of solar perturbations. First, the sun produces an oscillation of the actual libration point perpendicular to the earth-moon plane with a period equal to the synodic period and an amplitude, as seen at the earth, of about 1/4 deg; second, it produces oscillations of the point in the earth-moon plane that have small amplitude in the radial direction but a total amplitude rotationally around the earth of 45–50 deg.[7] Material originally at a libration point would not rigidly follow these oscillations in the potential surface; instead, particles would move in long extended orbits around the libration points. This behavior has been amply demonstrated by numerical-integration experiments performed here by Schutz.[8] Thus the integrated effect of the sun would be to smear any material into bands lying *in the plane* of the moon's orbit. (Kordylewski has recently claimed to have observed such bands.[9])

It should be emphasized that the observations have shown that the interplanetary medium does exhibit patchy brightness—an important result in itself. However, the interpretation of this phenomenon is by no means settled.

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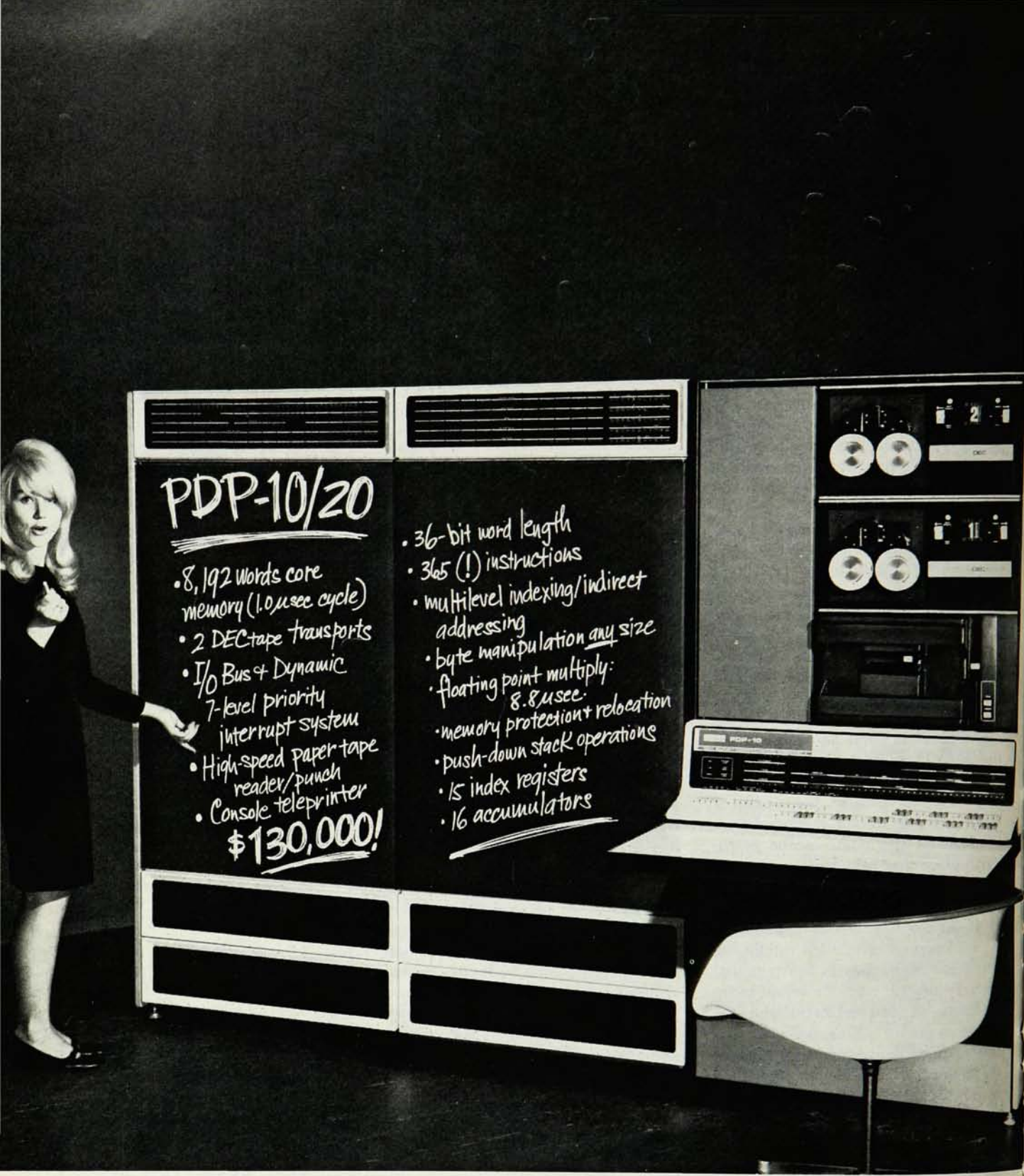
R. G. Roosen
R. S. Harrington
W. H. Jefferys
University of Texas

THE AUTHOR REPLIES: We have read with interest the letter by Roosen, Harrington and Jefferys and are replying so that your readers may evaluate for themselves the worthiness of their critique.

In paragraph two, they refer to Roosen's observations at McDonald. Simpson spent several hours with Roosen at the International Symposium on the Zodiacal Light and Interplanetary Media at Honolulu on 31 Jan. During the evening discussion, Roosen seemed to accept the validity of our work, especially with material shown him that could not be presented, due to time limitations in the symposium. He appears to have changed his attitude. Simpson discussed Roosen's photographic efforts[1] and agreed that Roosen's photographs covered the same basic area, including the gegenschein, that was observed from the NASA Convair 990 Flying Science Laboratory. The airborne observations were made a few hours later, on the same date, from an altitude of 40 000 feet. In the PHYSICS TODAY article[2] will be found one of our basic constraints, namely, *proximity to the gegenschein. This has been one of our governing parameters controlling our window selection.* From earth-based observing sites we would probably not have tried to observe on the



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morning of 12 March as he did. In view of our continued experience, during the past five and a half years, we might attempt to do so in some cases, but practical experience would dictate our window determination.

In our airborne observations we observed L/4 on 1 and 2 March. The L/5 clouds were observed on 10 and 12 March. The scheduled observation period for 11 March was cancelled because all NASA 990 scientists felt that the L/5 clouds would be submerged in the gegenschein, as would have been true. (See predicted position for L/5 on 11 March in figure 4 of reference 2.) On 12 March the smaller L/5 cloud (L/5B) was observed to be adequately displaced from the gegenschein. The larger cloud (L/5A) was close to the gegenschein and was located for two reasons. First, the gegenschein, shown in figure 4 of reference 2, during the first hour was smaller because of its low altitude and partial atmospheric extinction. One hour later, being higher in the sky, the gegenschein appeared larger, but we had located the L/5A cloud during the first hour's observation. Second our altitude of 40 000 feet placed us above 85% of the earth's atmosphere. Roosen did not have either the advantage of this altitude or the benefit of experienced observers as we did–both NASA and Lockheed.

In the Honolulu discussion, Simpson pointed out to Roosen that he would not choose the 103-0 film, which Roosen used in his photographic efforts. In addition, Simpson pointed out that he would not expose the film for the 40-min periods that Roosen used. Eastman Kodak Co. lists the 103-0 emulsion as having moderately low resolving power and as displaying moderately coarse granularity.[3] Both Kazimierz Kordylewski and Simpson used considerably shorter exposures. Long exposures introduce sky fog and increase film density. The result, according to Roosen's statement, was that his negatives were quite dense. We use Eastman Plus-X Pan film, which is noted for its unusually extended latitude. It is specifically recommended for situations involving photography of subject matter under illumination extremes. It is capable of a luminance range of a million to one, roughly five thousand times the brightness range in an average pictorial scene. We previously used this film unsuccessfully with normal development. However, with our development enhancement we were successful; a combination of the inherent capabilities of this emulsion and our film-speed enhancement gave us minimal grain size.

The Kordylewski photographs in some cases were taken when the libration clouds were within the boundaries of the gegenschein. In a letter dated 20 April 1966, R. S. Harrington stated to us, "We have looked a little more closely at the reported sightings of Kordylewski and have found good reason to question their reliability. He was so troubled by vignetting that to call any of the humps in the isophotes of his plates anything but emulsion noise is wishful thinking at best. He may very well have seen the clouds, if in fact such clouds exist, but we are sure he never photographed them." Roosen's photograph[2,5] was taken under almost the same conditions as the Kordylewski photographs referred to in the Harrington letter. To use a photograph of the same libration-cloud–gegenschein relation, of which they are so critical, as a basis for their conclusions is not a valid basis for a critique. This comment is especially true of the Simpson photographs, which were taken when the gegenschein was not even on the film (more than 40 deg removed). The photographic technique used by Simpson was markedly different from that used by the Texas group and that of Kordylewski.

The "rather different conclusions" presented by the Texas group appear to be not so different after all and concur with the previously developed theory of Kordylewski concerning particle distribution in or near the lunar path about the earth. Apparently many scientists studying the near-earth environment agree with this theory. As the Texas group further develop their particular version of this theory, however, they may very well come to the same conclusion that others in the field, such as Boeing Air-

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craft, Kordylewski, and us, have arrived at before them. This theory provides that even though the band of debris does exist in the lunar plane, the probability that the null areas (L/4 and L/5) would tend to concentrate particles about their nominal locations is significant. To deny the concentrations of particles at or near the null points, moving in conjunction with the lunar motion or libration clouds, is a departure from accepted observational fact. This assertion is further supported by the evidence presented by W. H. Allen at the Honolulu symposium.

Allen stated, "The observations were a combination of the most experienced observers with a good knowledge of the night sky and young men with good vision but naive with respect to the sky. The groups varied from four to eight, with at least one experienced observer aboard each flight. The search for the L/4 cloud was made on 28 Feb.–1 March and on 1–2 March. On the first flight, the nebulosity was seen by both inexperienced and experienced observers. On the next flight we again saw the nebulosity about 5 deg north of the predicted position. *On the second flight we checked the area where the nebulosity had been seen on the first flight and we found nothing.* The search for the L/5 cloud was made on the nights of 9–10 March and 11–12 March. On these flights, we saw nebulosity about 5 deg south of the predicted positions." The plotted observations of both NASA and Lockheed personnel agreed very closely as to the shape, position and daily motion.

This statement is further substantiated by the recent work of Kordylewski and ten scientists working for two months in Africa. Kordylewski states, "I could, through observations in the tropics, determine most assuredly that the earth has not only the libration clouds as satellites but also dust-particle formations distributed around the moon's orbit."

Apparently the Texas-group investigation covers areas of "patchy brightness" over the "entire sky." Our own investigation is concerned only with those areas of "patchy brightness" in or near the plane of the lunar orbit, at or near the libration points, moving at a rate approximating that of the moon. In the cases of Kordylewski, his ten scientist associates, the writers and NASA personnel, the clouds have been observed with their expected departure from their predicted position. In numerous cases we have observed their movement from night to night at a daily rate closely approximating the daily motion of the moon when it occupied that portion of its orbit during the same revolution. Air-glow patches and loosely distributed material along the lunar path would hardly be expected to have this daily motion, which we have all observed for the libration clouds. Whether they are called "nebulosity," "patches" or any other name, the fact that they occupy the positions in the moon's orbit defined by the libration areas L/4 and L/5 is sufficient for us to call them "libration clouds."

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J. W. Simpson
R. G. Miller
Lockheed Missiles and Space Co.

Teapot means Coanda

In September 1956 you published an article of mine on "The Teapot Effect." To my great surprise I find now from an article by Imants Reba in the June 1966 issue of *Scientific American* that the effect has been known, evidently only to a limited number of scientists, as "the Coanda effect" since 1910.

Markus Reiner
Technion–Israel Institute of Technology □