tion on 16 October 1964; this ratio fits the decay curve in Fig. 1 excellently.

Harley *et al.* (*17*) have measured the weapon yields for Ce^{144} and Sr^{90} at 46,900 and 35,000 atoms per 10^6 fissions, respectively. From these determinations and the mean ratios in Table 2, the weapon yield of Eu^{155} is calculated at $1400/10^6$ (atoms/fissions). As 1 kton of fission corresponds to 1.45×10^{23} fissions (*17*), production of Eu^{155} by nuclear weapons is estimated at 72.6 kc per megaton of fission. The total fission yield of the 1961–62 test series was 101 Mtons (*18*), so that the total production of Eu^{155} in these tests was 7.3 Mc.

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6 March 1967

Photography of the Earth's Cloud Satellites from an Aircraft

Abstract. *Under astronomically favorable circumstances, photographs do not reveal excess light near the triangular libration points of the earth–moon system. We find that the visible surface brightness of anomalous dust populations, if these populations do exist, is less than 10^{-9} candela per square centimeter.*

Kordylewski (*1*) successfully recorded on film, on two different nights, cloud-like objects in the vicinity of the libration points, L4 and L5, of the earth-moon system. These points are also sometimes called the Lagrangian equilibrium points as a result of the early mathematical treatment of the restricted three-body problem by Lagrange. Recently Steg and DeVries (*2*) have reviewed the theory of the earth-moon libration regions and Simpson (*3*), the history of photographic attempts. As of late 1965, there had been no other available photographs in spite of several serious and lengthy observing efforts by others. For example E. Morris, U.S. Geological Survey, conducted a photographic investigation of the libration regions from Mt. Chacaltaya, Bolivia, in 1962–3 and was unable to obtain conclusive results. More recently R. G. Roosen (*4*) reported his attempts and concluded that in March 1966 the L5 position was empty to the limit of photographic detection. While visual observations are also important, photographs suitable for even crude photometry would be a more fruitful way of confirming the existence of these clouds and also of providing some potential data as to particle size distribution.

Table 1. Circumstances of observations. All observations were made in 1966; time is universal time.

Time	Zenith angle of field center	Mean location	Objective
1120–1220 1 March	43°	27°N 124°W	L4 region
1130–1240 2 March	61°	26° 125°	L4 region
0420–0530 10 March	31°	23° 125°	L5 region
0515–0620 12 March	43°	24° 125°	L5 region

We here report an attempt to photograph these clouds from the NASA Convair-990 jet laboratory operating at an altitude of 12,000 meters over the

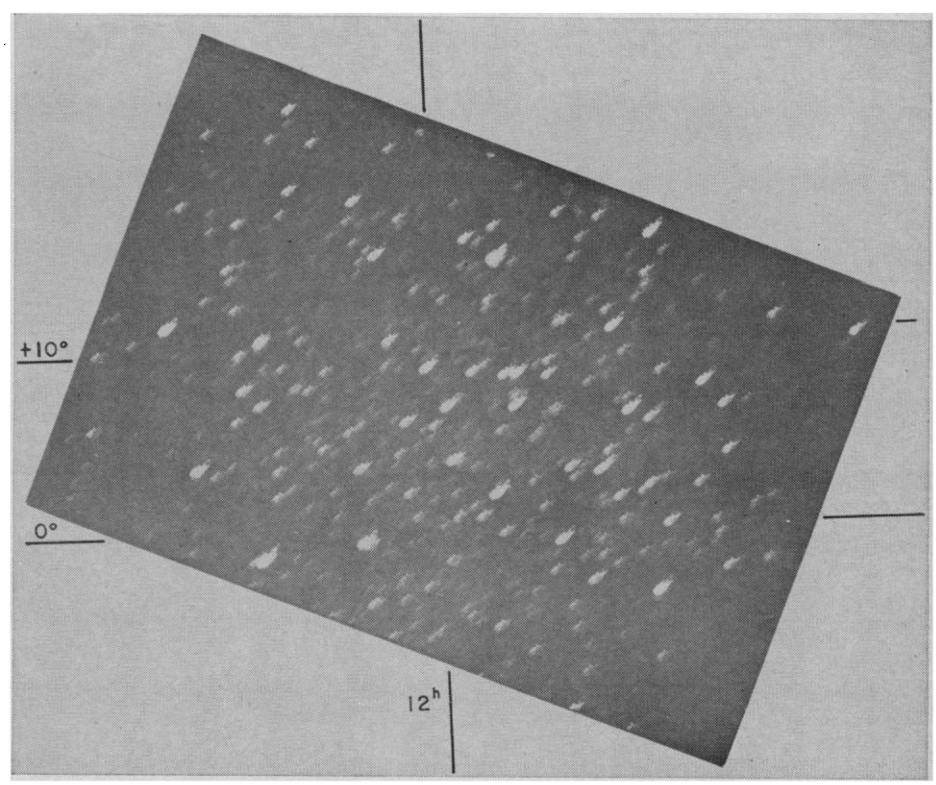

Fig. 1. Three-minute exposure containing the L5 point, beginning at 0616 universal time on 12 March 1966. The approximate right ascension, declination, and scale are indicated.

Pacific Ocean at least 1000 km west of Baja California—a sufficient distance to eliminate all interference from artificial lighting. Natural irregular backgrounds due to possible airglow inhomogeneities are effectively smeared out in our photographs as a result of the 600-knot speed of the aircraft and the multiminute exposure times. The flights took place in March 1966, as shown in Table 1.

Having chosen the late winter for practical reasons, the observing times in March were selected to minimize the interference caused by the gegenschein and the variable surface brightness of the Milky Way. In this note we report on the better set of observations, those of L5, which were taken closer to the zenith and for which a more complete set of comparison photographs is available.

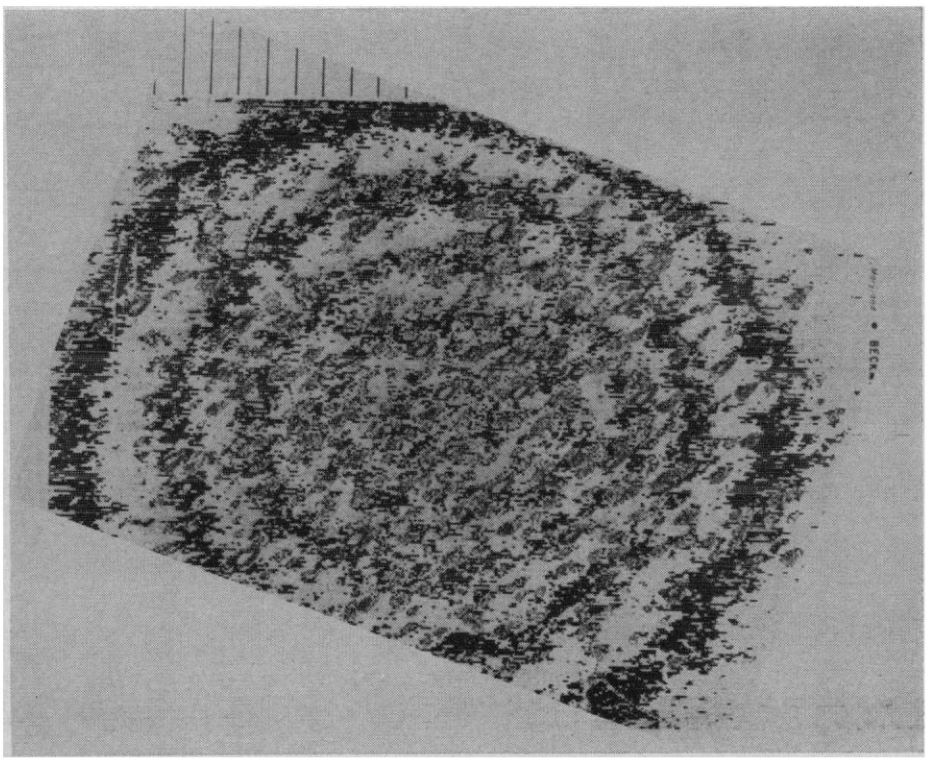

Fig. 2. Isodensity plot of Fig. 1. The vignetting function of the lens is easily seen.

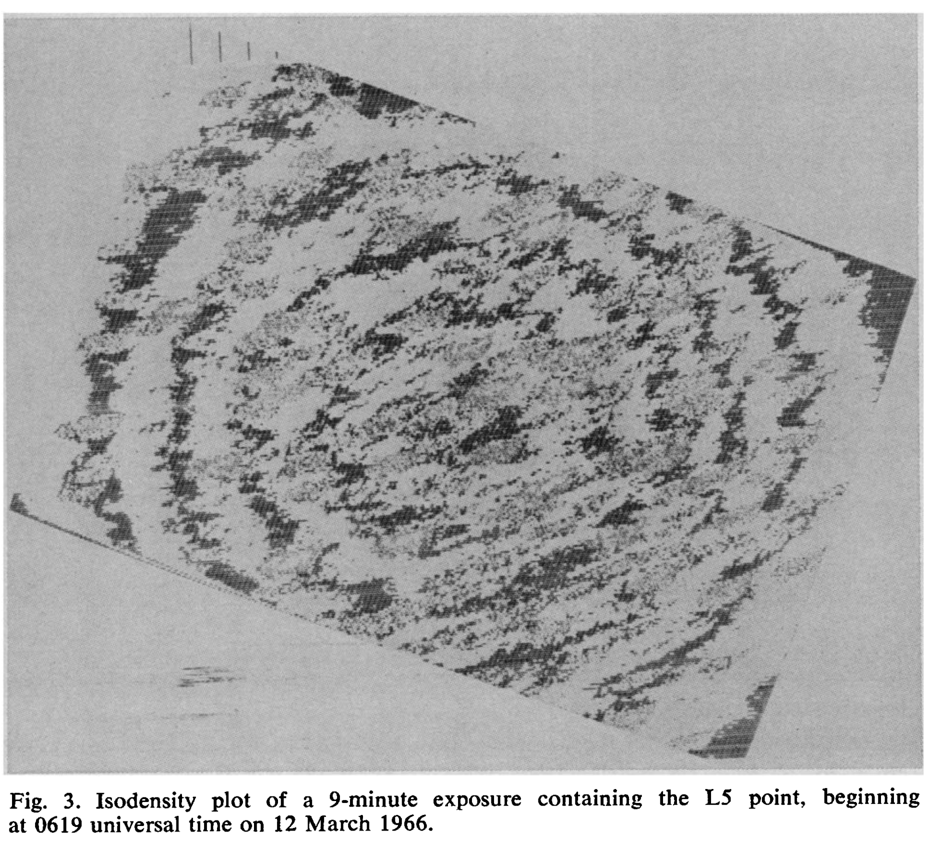

Fig. 3. Isodensity plot of a 9-minute exposure containing the L5 point, beginning at 0619 universal time on 12 March 1966.

Six Nikon cameras were used, each with a 50 mm $f/1.4$ lens mounted in specially designed ports in the aircraft skin; the lens itself was thus the interface between the cabin and the slipstream. The cameras pointed at various fixed angles of elevation to cover the needed angular range of libration cloud positions during the observing period. To keep the lenses clean, a sliding lens cover, operated from inside the aircraft, was provided. Each lens cover was closed while the plane was on the ground and during takeoffs and landings, and opened only for the exposure sequences. Tri-X film was used with exposures of 1, 3, and 9 minutes. These exposures were based on calculations and on the experience of Hennes and Dunkelman (*5*) who used this same type of film, lens, and camera in their rocket photography of night airglow. Exposures were made of those regions where the L5 point was computed to be, and background exposures were also made of the same star fields on other nights when the L-point had moved to another position.

A typical photograph which included the L5 region is shown in Fig. 1. An isodensity contour plot of Fig. 1 is shown in Fig. 2. Figure 3 is an isodensity plot of a longer exposure, better displaying the smoothness of the lens vignetting contour. The small scale irregularities of the contours are primarily a result of star images smeared by aircraft roll. An analysis of all the photographs and corresponding plots led to three conclusions:

(i) There is no positive indication of the libration cloud. (ii) From inspection of the isodensitraces, we can place an upper limit for the surface brightness or luminance of the cloud. This upper limit is 5 percent of the light of the neighboring night sky, about 4×10^{-15} of the sun's surface brightness, or 10^{-9} stilb (cd cm^{-2}). (iii) No cloud would be detectable on our photographs if its angular diameter were less than 2 degrees. This is due to aircraft roll during long exposures.

The star smear due to roll is evident in Figs. 1–3, but it does not displace

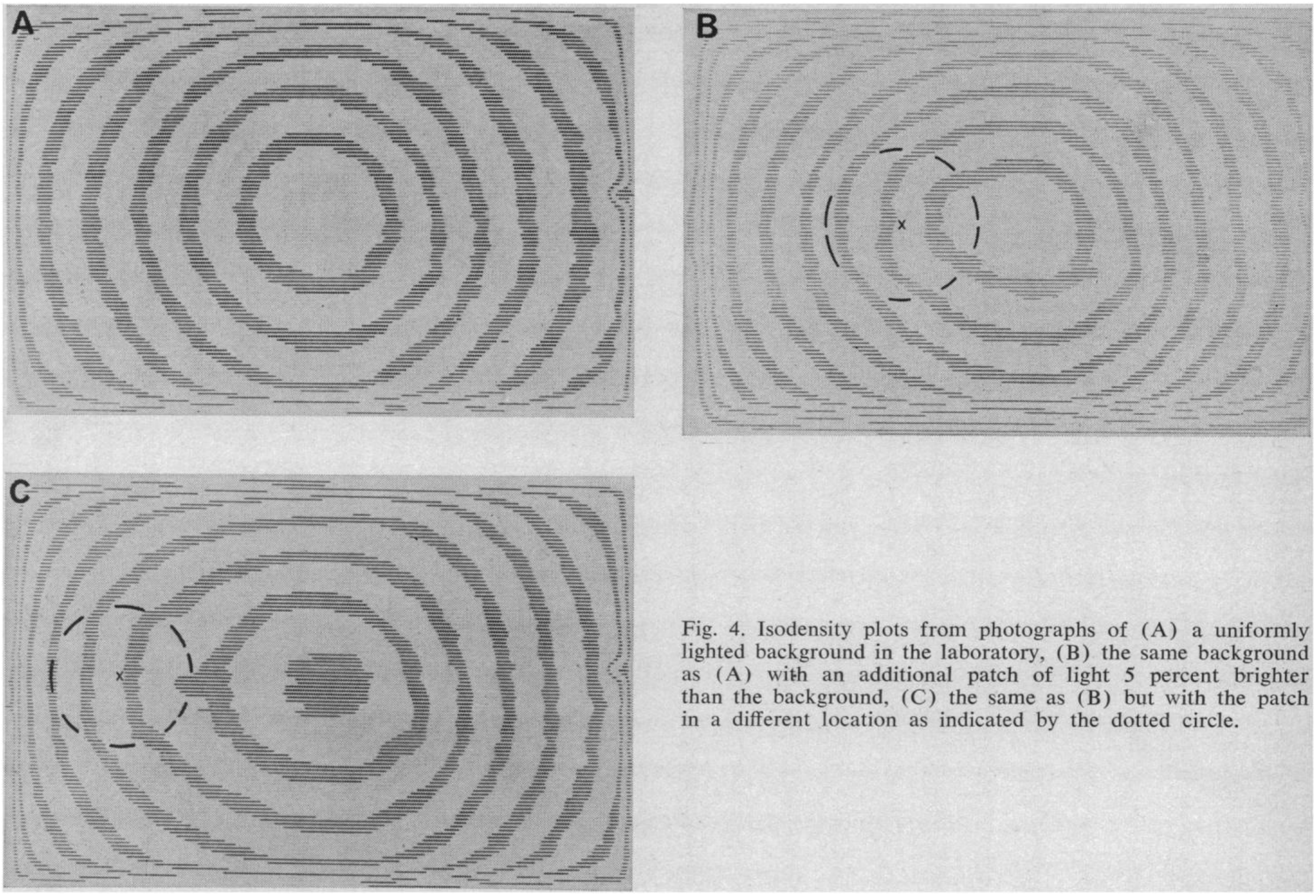

Fig. 4. Isodensity plots from photographs of (A) a uniformly lighted background in the laboratory, (B) the same background as (A) with an additional patch of light 5 percent brighter than the background, (C) the same as (B) but with the patch in a different location as indicated by the dotted circle.

the average position of the contours or prevent their being traced without confusion. The most serious effect of pointing error is to make ambiguous the detection of any feature smaller than the 1- to 2-degree length of the star images.

To further substantiate our estimate that the libration cloud is less than 5 percent of the light of the night sky (integrated starlight, airglow, and zodiacal light) we performed laboratory tests with the 50 mm $f/1.4$ Nikon lens, the results of which are shown in Fig. 4. These are isodensity tracings of photographs of a uniformly illuminated background with and without an additional patch of light whose brightness was adjusted to be 5 percent of the background. Figure 4A shows the uniform background alone; Figs. 4B and 4C show, respectively, the additional patch of light located one-third and two-thirds of the way from the center of the field to the edge. These spots of light 5 percent brighter than the background are easily distinguished as departures from the smooth background contours caused by vignetting. The spots were intentionally left out of focus so that they would not have sharp edges and would more closely resemble the appearance of the suspected astronomical phenomenon.

During the flights a team of visual observers, whose visual thresholds had been calibrated, detected bright areas in the vicinity of the L4 and L5 points through optical quality windows (*6*). The measured thresholds correlated well with the apparent size of the gegenschein that was observed on all flights, that is, the size of the gegenschein as plotted by the observers was proportional to their visual thresholds. These visual observations are not inconsistent with our photographic experience because the visual contrast thresholds are lower than our photographic threshold which established an upper limit of brightness of about 5 percent of the background.

On the basis of visual and photographic results to date, further observations from the aircraft or an attitude controlled rocket are indicated. In either case, the newly available Kodak very high speed film (SO166) should be used; we have recently successfully used it in dim light photography at ASA speeds in excess of 6000. This fast film would require shorter exposures and would reduce star smear in the case of the aircraft and permit short enough exposures to be consistent with the amount of useful rocket time. Finally, the aircraft approach has the advantage that many exposures can be taken, while the rocket, operating well above the bright airglow layer, provides a background less than half that observed from the aircraft.

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