ing-out may arise from two causes: stirring of the regolith and preponderance of micrometeorites in the meteorite influx (*11, 1*). Whichever of these factors is dominant, the spatial constancy of the meteoritic component suggests that the influx rate derived from our Apollo 11 data, $3.8 \times 10^{-9}$ g $cm^{-2}$ $yr^{-1}$ (*1*), is a meaningful average for the entire moon.

We have not calculated a separate influx rate from our Apollo 12 data because the thickness of the regolith is not accurately known. It is supposed to be slightly less than at the Apollo 11 site (*12*), as might be expected from the slightly younger Rb-Sr age of the Apollo 12 rocks (*5*).

The two AB rocks that were analyzed are similar enough to their Apollo 11 counterparts to leave our conclusions (*1*) unaffected. However, sample 12028,66 raises problems. If it represents a major stratigraphic unit, and if the high Bi,Cd content of our sample is typical of that unit, then the moon's depletion in volatile metals cannot be as great as inferred from the Apollo 11 and Apollo 12 basalts. This in turn undermines all our conclusions based on such depletion (*1, 2*).

At the moment we do not have enough evidence to settle this question conclusively. However, there are two lines of evidence suggesting that material of high Bi,Cd content is uncommon. The lack of a Bi,Cd enrichment in surface soil (12070,69) or deeper layers of core 12028 suggests that Bi,Cd–rich material was deposited only once and was not stirred appreciably. One-time deposition might be expected for material of shallow but localized, or deep-seated but wide-spread, occurrence. Either would be exposed only infrequently. Lack of stirring requires that the deposit be of very recent origin.

From Gault's data (*13*), the "turnover time" of the lunar surface layer to a depth of 13 cm seems to be very short: Two turnovers would be expected in $10^6$ years and $1.5 \times 10^4$ turnovers in $10^9$ years. Much of the turning-over is done by infrequent large impacts, and thus the actual survival time of a discrete layer may be longer in some patches. Moreover, it is possible that Gault's times were somewhat too low. Nonetheless, since the 13-cm layer was not even slightly dispersed, much less turned over, it is probably no older than a few million years. This tends to speak against a Copernican origin, as the age of Copernicus, estimated as $10^9$ years from crater counts (*14*), is not likely to be 2 to 3 orders of magnitude shorter.

We are therefore inclined to believe that the light gray material typified by sample 12028,66 may be quite rare. An alternative possibility is that this material is common but normally quite poor in Bi and Cd. Our sample may have accidentally contained a grain of a Bi,Cd–rich mineral. In any event, sample 12028,66 raises some interesting questions about statistical problems in lunar sample collection or lunar geochemistry, or both.

R. GANAPATHY
REID R. KEAYS*
EDWARD ANDERS
*Enrico Fermi Institute* and *Department of Chemistry, University of Chicago, Chicago, Illinois 60637*

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* Present address: School of Geology, University of Melbourne, Parkville, Victoria, 3052 Australia.

30 June 1970

## Mercury: The Dark-Side Temperature

Abstract. *The planet Mercury was observed before, during, and after the inferior conjunctions of 29 September 1969 and 9 May 1970 at wavelengths of 3.75, 4.75, 8.6, and 12 microns. The average dark-side temperature is 111° ± 3°K. The thermal inertia of the surface required to fit this temperature is close to that for the moon and indicates that Mercury and the moon have very similar top surface layers.*

Radar measurements have shown that the mercurian day is two orbital periods long. When Mercury is new, the center of the dark hemisphere presented to the earth is at the midnight temperature, and 88 days have elapsed since noon for this point. The noontime temperature at the mean distance of the planet from the sun is about 620°K. A measurement of the midnight temperature will establish the average temperature of the planet, as well as the thermal inertia of the surface. In order to establish the dark-side temperature it is necessary either to observe with sufficient resolution to put one photometer beam on the cold disk without including any of the crescent, or to fill the photometer beam with the planet when the planet is near inferior conjunction and the contribution of scattered light and thermal emission from the crescent can be reduced indefinitely. Murray attempted to measure the dark-side temperature by the first method (*1*), using the 200-inch (508-cm) telescope at Mount Palomar. No signal was observed, and Murray concluded from this that the temperature must be less than 150°K.

We used the second method of observing the entire planet near its new phase. This method has the disadvantage of requiring observations at very small elongation angles from the sun. Fortunately, this can be accomplished much more easily in the infrared region than in the visible, and in September 1969 we observed down to an elongation angle of 3°. Solar heating of the mirror resulting in defocusing can cause a reduction in signal from the planet when observations are made with beam sizes only slightly larger than the apparent angular diameter of the planet. As shown below, it appears that this effect was small although not negligible.

Except for very small planetocentric phase angles, the infrared radiation in the 3.5- to 12-$\mu$ region is produced by thermal emission from the illuminated part of the disk, and thermal emission exceeds scattered sunlight by a large factor, even at the shortest wavelength. As Mercury approaches its new phase, the effective brightness temperature of the crescent drops and sunlight scattered from the crescent finally exceeds the thermal emission from the crescent at 3.75 $\mu$. At the longer wavelengths, the thermal emission from the dark side of Mercury exceeds the thermal radiation from the crescent when the fraction illuminated ($k$) becomes less than 0.01.

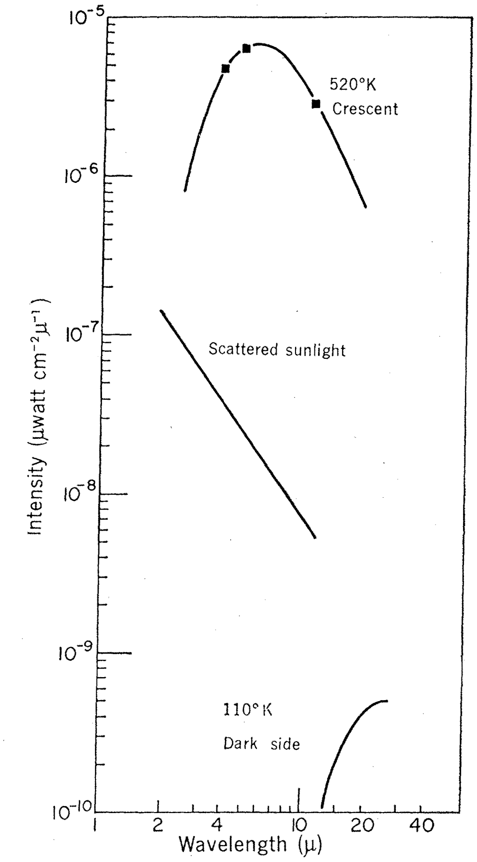


Fig. 1. Measured intensities from Mercury at 3.75, 4.8, and 11.3 $\mu$ on 8 August 1969. At this time $k$ was 0.853.

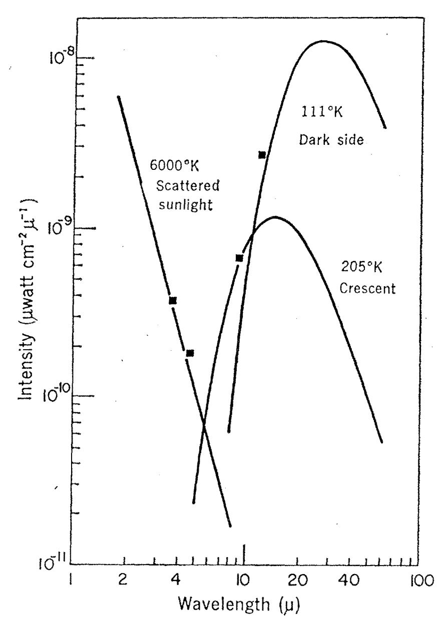


Fig. 2. Corrected intensities from Mercury at 3.9, 4.8, 8.6, and 11.8 $\mu$ on 29 September 1969. At this time $k$ was 0.004.



Mercury was observed six times between 21 September and 3 October 1969 and three times between 4 May and 17 May 1970, including the two days nearest inferior conjunction in September. The 1969 observations were made with a four-filter, broadband infrared system which had effective wavelengths of 3.75, 4.75, 8.6, and 12 $\mu$. The 1970 observations were made with an eight-filter, broadband system with effective wavelengths of 2.3, 3.6, 3.75, 4.75, 8.6, 10.6, 12.2, and 20 $\mu$. The angular diameter of beam projected on the sky by the 30-inch telescope at the O'Brien Observatory, University of Minnesota, was 12 seconds of arc with the four-filter system and 26 seconds of arc with the eight-filter system. The apparent angular diameter of Mercury at the September conjunction was 10 seconds of arc so that the planet nearly filled the beam, thus producing the best possible signal-to-noise ratio. Complete sky cancellation was obtained with both systems by switching the beam to a position one beam diameter away at 10 cycle/sec. The noise level was determined at the short wavelengths by the bolometer detector and at the long wavelengths by sky noise.

A comparison of the 3.75-$\mu$ intensities taken during the September conjunction with intensities measured in the conjunctions of June 1968 and October 1968 with a beam diameter of 83 arc seconds, and in the conjunctions of May and June 1969 and May 1970 with a beam diameter of 26 seconds shows that defocusing by sunlight heating caused a reduction by a factor of 1.5 in the signal from the planet. This effect also appears at the longer wavelengths. Therefore, all intensities measured during the September 1969 conjunction have been multiplied by a factor of 1.5, with the result that there is a change of 2°K in the average dark-side effective temperature. The mirror was again in equilibrium at the time the calibration measurements were taken.

Figure 1 shows a plot of the surface brightness of Mercury on August 8.8. The infrared radiation was produced by thermal emission from the crescent at a color temperature of 522°K. The solid angle required to make the brightness temperature equal to the color temperature is the solid angle of the illuminated crescent. Also plotted in Fig. 1 are the expected contributions of scattered sunlight and thermal emission from the dark disk.

Figure 2 shows a plot of the surface brightness of Mercury on September 29.8. The infrared radiation was produced by thermal emission from the dark side at 12 $\mu$, thermal emission from both the dark side and the crescent at 8.6 $\mu$, and scattered sunlight at the two shortest wavelengths. We deter-

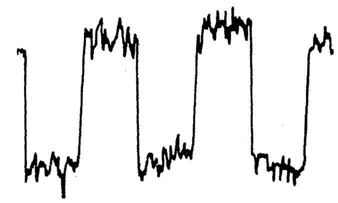

Fig. 3. A reproduction of part of the chart record from 29 September 1969 showing signal and noise at 11.8 $\mu$.

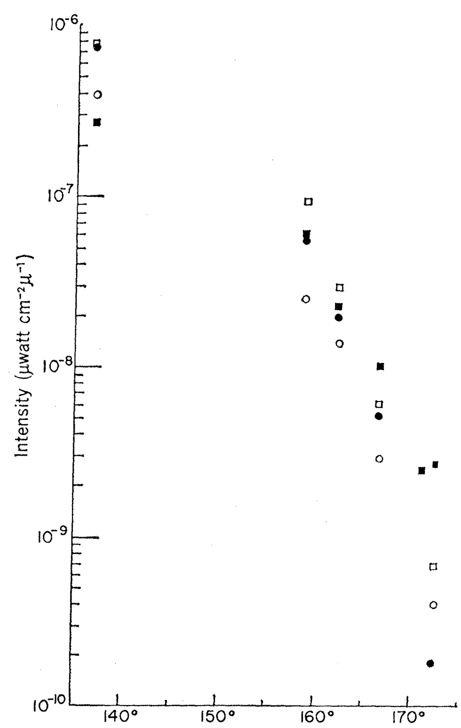


Fig. 4. Corrected intensities at the four infrared wavelengths as a function of planetocentric phase angles for the 1969 conjunction. Open circles, 3.7 $\mu$; solid circles, 4.8 $\mu$; open squares, 8.5 $\mu$; solid squares, 11.5 $\mu$.

mined temperatures by first assuming that all of the 12-$\mu$ radiation was thermal emission from the dark side and that all of the 8.6-$\mu$ radiation was thermal emission from the crescent. A method of successive approximation was then applied. Using intensities uncorrected for mirror defocusing leads to best fit temperatures of 109°K for the dark side and 194°K for the crescent. The corrected average dark-side temperature is 111°K, and the corrected average crescent temperature is 205°K. The dark-side temperature is much better determined than the effective temperature of the crescent. Our value of the dark-side temperature is in agreement with the prediction of Morrison and Sagan (*2*).

The curve for scattered sunlight is drawn through the experimental points (Fig. 2) and gives an albedo for Mercury that is a factor of 2 less than that expected on the basis of an observed visual magnitude of +3.4 and the sun's color index (*3*). This effect could be due either to a real change in Mercury's albedo between visible and infrared wavelengths or to the fact that we were beam-switching against the zodiacal light which should have the same color index as the sunlight scattered from Mercury. Whereas our other measurements were made with a signal-to-noise ratio of up to 5 to 1 (see Fig. 3), our 4.8-$\mu$ measurement was made with a signal-to-noise ratio of 1 to 1 and can properly be called only an upper limit. At an elongation angle of 3° coronal brightness is $1.2 \times 10^{-10}$ the sun's surface brightness (Fig. 4) (*4*). Therefore, for our beam diameter of 13 seconds the intensity of the F corona or zodiacal light at 5 $\mu$ is $9 \times 10^{-12}$ $\mu$watt cm$^{-2}$ $\mu^{-1}$ or about 1/20 of our measured 4.8-$\mu$ intensity (*5*). Under more favorable conditions it may be possible to detect the zodiacal light as an "antisignal."

According to our measurements, the average dark-side temperature of Mercury is $111° \pm 3°$K. Comparison of this average temperature with theoretical models requires that the thermal inertia, $(\kappa\rho c)^{\frac{1}{2}}$, (where $\kappa$ is the thermal conductivity, $\rho$ is the density, and $c$ is the specific heat), of the surface be 0.0014. Mercury and the moon therefore appear to have very similar top surface layers (*6*).

T. L. Murdock
E. P. Ney
*School of Physics and Astronomy, University of Minnesota, Minneapolis*

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# Archaeopteryx: Notice of a "New" Specimen

Abstract. *A fourth specimen of* Archaeopteryx *(cf.* lithographica), *the oldest known fossil bird, was recently found in the collections of the Teyler Museum in the Netherlands. Unique preservation of the horny sheaths of the manus claws provides new evidence that may be relevant to the question of the origins of avian flight. Tentative interpretation suggests a cursorial rather than arboreal origin.*

The most persuasive evidence for a reptilian ancestry of birds rests in the few known fossil specimens of *Archaeopteryx* from the Late Jurassic (Middle Kimmeridgian) Solnhofen limestone of Bavaria. If the solitary Solnhofen feather impression noted by von Meyer (*1*), which cannot be assigned with certainty to any taxon, is excluded, only three specimens were known prior to the present discovery: the London specimen initially reported by von Meyer (*2*) in 1861, the Berlin specimen discovered in 1877, and a

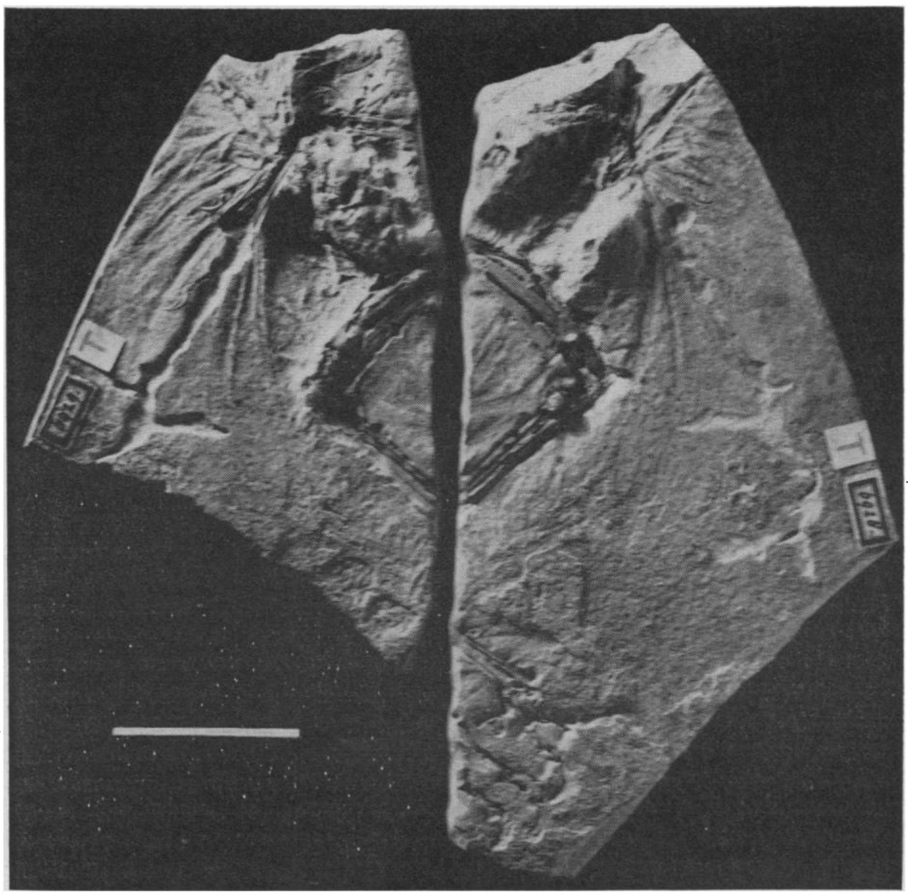

Fig. 1. Part and counterpart slabs that contain impressions and skeletal parts of *Archaeopteryx* cf. *lithographica*. Phalanges and claws of left manus and gastralia are on the left-hand slab. Fragments of both femora, pubes, tibiae, and fibulae show on the right-hand slab. Portions of the feet are at lower right. The scale is 5 cm long.