Reports

Mercury: Anomalous Absence from the 3.4-Millimeter Radio Emission of Variation with Phase

Abstract. *Radio observations of Mercury at 3.4 millimeters from July to October 1965 showed, contrary to expectation, brightness temperatures of only about 200°K, even when major fractions of Mercury's illuminated hemisphere were observed. There was no significant variation with phase.*

The dark-side brightness temperature of 220° ± 35°K recorded at 3.4 mm (88 Ghz) during the April 1965 inferior conjunction of Mercury (*1*), and the brightness temperatures recorded at longer wavelengths, including the preliminary results at 8 mm (*2*), led us to expect great variation with phase in the 3-mm emission of Mercury. This expectation was based on the assumption that Mercury's surface layers behave as do those of Moon. [If Moon were moved to Mercury's distance from Sun, its 3-mm emission would show variation with phase of approximately ± 200°K about a mean temperature of ≈350°K (*3*)].

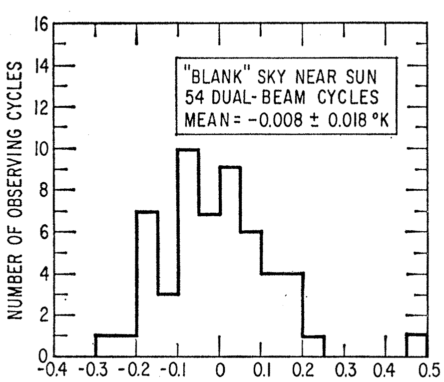

Fig. 1. Histogram of the antenna temperatures recorded during 54 18-minute dual-beam observing cycles while tracking "blank" sky (that is, away from known radio sources) within 3° to 5° of Sun and within a few beamwidths of Mercury (and moving with it). The histogram is centered about zero and has a width in good agreement with the width predicted on the basis of short-term noise fluctuations of the radiometer; it thus indicates absence of deleterious solar effects in the Mercury data.

During observations of Mercury from 16 July through 17 October 1965 at 3.4 mm with the 15-foot (4.57-m) antenna of the Space Radio Systems Facility of Aerospace Corporation, no significant variation with phase was recorded, even though the observations covered almost a complex revolution of Mercury.

The antenna is equipped with two 3′ (minutes of arc) beams; one is aligned on the electrical axis and the other is 12′ off the electrical axis (the *E*-field vectors of both beams are parallel with a line of constant declination). This configuration allowed me to use the dual-beam observing mode (*4*) to cancel the effects of variations in atmospheric emission; in this mode the recorded quantity was the difference between the antenna temperatures "seen" by the on-axis and off-axis beams. When one moved the antenna back and forth 12′, Mercury was alternately observed (at 60-second intervals) in the on- and off-axis beams. (Note that the dual-beam mode allowed me to record the emission from Mercury during 100 percent of the observing time.) The brightness temperature was derived from the difference between the readings taken during these alternate observations.

Primary calibration of the antenna temperature scale was made by taking the 3.4-mm brightness temperature of Sun as 6650°K and using the 15-foot antenna's theoretical diffractive efficiency of 78 ± 5 percent. Secondary calibration was made with a neon discharge tube. The antenna gain value was estimated to be 70.0 ± 0.5 db at 3.4 mm, based on theoretical computations and on measurements with a transmitter in the far field of the antenna (*5*). Ephemeris tracking of Mercury was provided by an SDS 920 computer; the tracking was checked at least once daily with the aid of an independently prepared ephemeris. The radio-frequency pointing (*6*) and atmospheric attenuation [by use of the "average temperature" method (*6*)] were checked hourly by solar observations. Corrections of the measured antenna temperatures for pointing errors (typically, 5 to 10 seconds of arc) amounted to only 2 or 3 percent. The corrections for atmospheric attenuation ranged from 20 to 65 percent, averaging about 35 percent.

Ability of my system to detect weak signals at large angular separations from Sun has been demonstrated (*4*, fig. 2). The results of observations

Table 1. Planetary brightness temperatures, T_B, at 3.4 mm. The daily number of cycles of observation, in parentheses, follows the date. Each cycle of observation lasted 18 minutes; $\Delta T_a e^{\tau \sec z}$ is the observed antenna temperature corrected for atmospheric attenuation.

Date (1965)	$\Delta T_a e^{\tau \sec z}$ (°K)	T_B (°K)
Jupiter: weighted average, 145 ± 23 (SE); estimated total SE, ± 30		
July 23 (4)	2.29	154
24 (5)	1.46	98
28 (5)	2.19	147
29 (4)	2.90	195
30 (4)	2.42	157
Sept. 4 (5)	2.56	141
8 (6)	2.77	149
9 (5)	2.87	154
10 (7)	2.64	141
11 (5)	2.56	136
12 (7)	2.70	142
Venus: weighted average, 295 ± 37 (SE); estimated total SE, ± 40		
Aug. 19 (3)	0.78	329
21 (2)	.60	248
21–22 (3)	.84	343
22–23 (5)	.66	268
26–27 (3)	.79	308
20–21 (3)	.82	240
Sept.		
21–22 (4)	1.09	313
22–23 (3)	1.11	316
24 (2)	1.12	315
24–25 (4)	1.15	319
25–26 (3)	1.13	308
26–27 (4)	0.91	247

made by me at small angular separations from Sun (3° to 6°), away from known radio sources, while tracking on a course several beamwidths away from Mercury (and moving with it), appear in Fig. 1. This histogram of the antenna temperatures recorded during the 54 18-minute observing cycles resembles a Gaussian distribution, is centered about zero (the mean antenna temperature is $-0.008° \pm 0.018$°K SE), and has a width commensurate with the short-term noise fluctuations of the radiometer. These facts indicate that my Mercury data, which were obtained at distances greater than 3° from Sun, were not affected by solar emission received by the antenna sidelobes.

From 4 to 15 18-minute cycles of observation were obtained each day, the average being ten. Brightness temperatures were determined from data taken each day in July and August. Data from 2 to 4 days were combined to determine the brightness temperatures near superior conjunction (September and October) because of the low signal strength. The daily (or combined) average antenna temperatures of Mercury ranged from $\approx$ 0.02°K (superior conjunction) to $\approx$ 0.3°K (inferior conjunction); the statistical standard errors of the average antenna temperatures ranged from 15 to 50 percent, the mean being about 25 percent. Systematic errors in the derived brightness temperatures were estimated to be about 15 percent. Corrections to adjust the brightness temperatures to the mean distance from Sun were computed (on the assumption of no phase lag) but were not used because they were consistently less than 11 percent, which is much less than the scatter in the data.

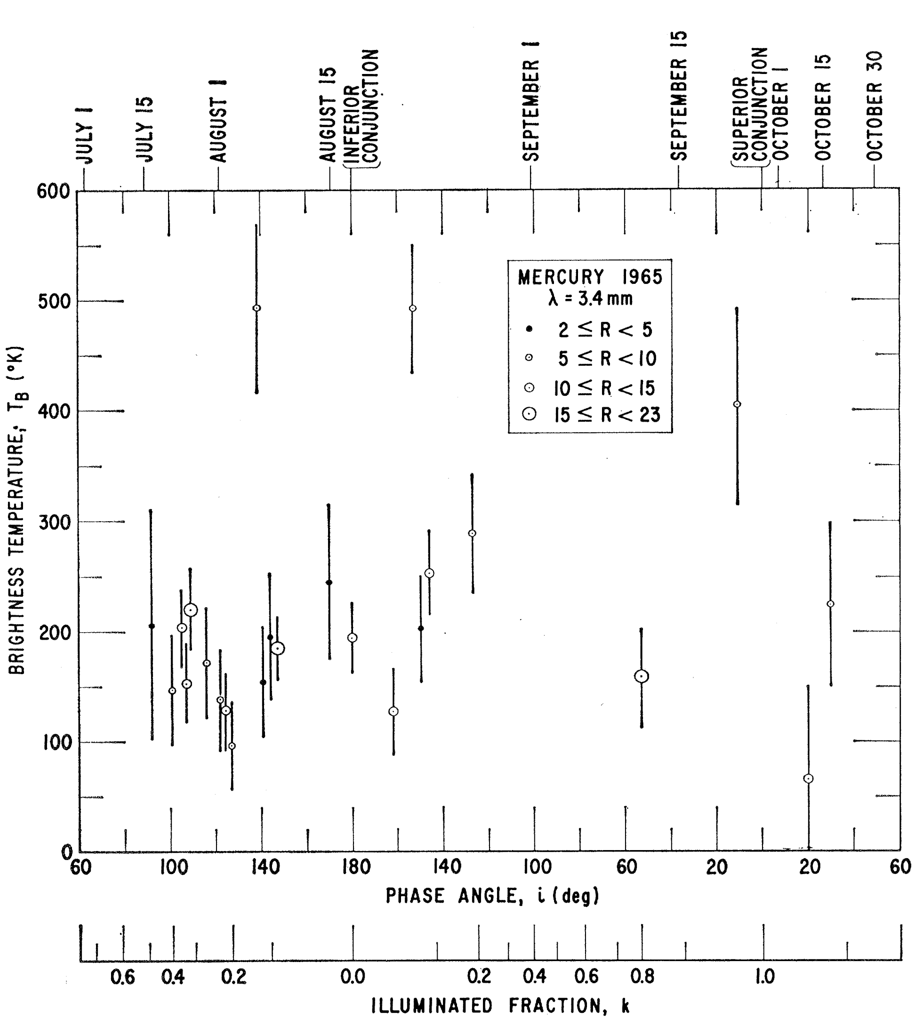

Fig. 2. Brightness temperature, T_B, plotted against both phase angle, i, and illuminated fraction, k, for Mercury at $\lambda = 3.4$ mm. The relative weight, R, is proportional to the product of the solid angle subtended by Mercury, the atmospheric transmissivity, and the inverse square of the statistical standard error. Error bars represent the statistical standard errors.

The phase curve of Mercury appears in Fig. 2. The most significant features are the brightness temperature of only $\approx$ 200°K that was recorded when major fractions of the illuminated hemisphere were visible and the apparent absence of any strong variation with phase. Both features were completely unexpected. Brightness temperatures of $\approx$ 500°K were recorded on 2 days when least expected, that is, near inferior conjunction. None of the parameters of observation were unusual on these 2 days, 5 and 20 August. Subsequent observations of the positions of Mercury on 5 and 20 August indicated no time-constant background radio sources that could have caused spuriously high Mercury temperatures. Moreover, subsequent observations in a range of directions and over the same range of angular separations from Sun ($\approx$ 8°) as that of Mercury on 20 August indicated no spurious enhancements of signal caused by Sun. No similar check was made for 5 August because Mercury was then $\approx$ 19° from Sun.

I can explain failure to record temperatures equal to the expected values ($\sim$ 500°K), well away from the time of inferior conjunction, only by making the unlikely assumption that I had unusually large ($\sim$ 2′) undetected pointing errors, and that these errors decreased near inferior conjunction by just the right amount to cancel out any variation with phase. However, observations of Jupiter and Venus, made with the same procedures and on the same days as many of the Mercury observations, tend to disprove this explanation (see Table 1). The Venus and Jupiter brightness temperatures are internally consistent and are in good agreement with the findings of many other observers, thereby indicating absence of any large systematic errors in my equipment and observational procedures.

One may explain these anomalous results by suggesting that the emissivity of the surface layers of Mercury varies inversely with physical temperature. But, if this were so, the reflectivity would so increase with temperature that the longer-wavelength emission (arising from greater depths than the 3-mm emission) would not yield the high brightness temperatures actually observed away from inferior conjunction. I know no material that exhibits low emissivity at 3 mm only, but perhaps droplets about 3 mm in diameter of molten metal (that thus yield low emissivity and only at radio wavelengths ≲ 3 mm) develop in the surface layers on the hot side, and then on the cold side freeze into a material with normal emissivity; if so, observations 1 and 2 mm also should give an anomalous phase curve. It is difficult to imagine an atmosphere that would strongly absorb the 3-mm emission from the surface, but not the infrared emission, and also remain cold when the surface was hot. Independent confirmation of these results at 3 mm and at nearby wavelengths is obviously desirable.

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References and Notes

1. E. E. Epstein, *Astrophys. J.*, in press; this paper also summarizes previous radio observations of Mercury.
2. B. G. Kutuza, B. Y. Losovskii, A. E. Salomonvich, *Astron. Circ. USSR* (1965), p. 327.
3. Conclusion from an unpublished theoretical investigation by B. Gary, done at my request and based on extensive 3-mm lunar observations [see B. Gary, J. Stacey, F. D. Drake, *Astrophys. J. Suppl. Ser.* **12** (No. 108), 239 (1965)].
4. E. E. Epstein, *Astrophys. J.* **142**, 1285 (1965).
5. E. Jacobs and H. E. King, *IEEE Intern. Conv. Record* **13** (pt. 5), 92 (1965).
6. E. E. Epstein, *Astron. J.* **70**, 721 (1965).
7. C. Sagan, private communication (1965).
8. J. P. Oliver and R. A. Schorn assisted with the observations and with analysis of data. Work supported by USAF contract AF 04(695)-669.

24 November 1965

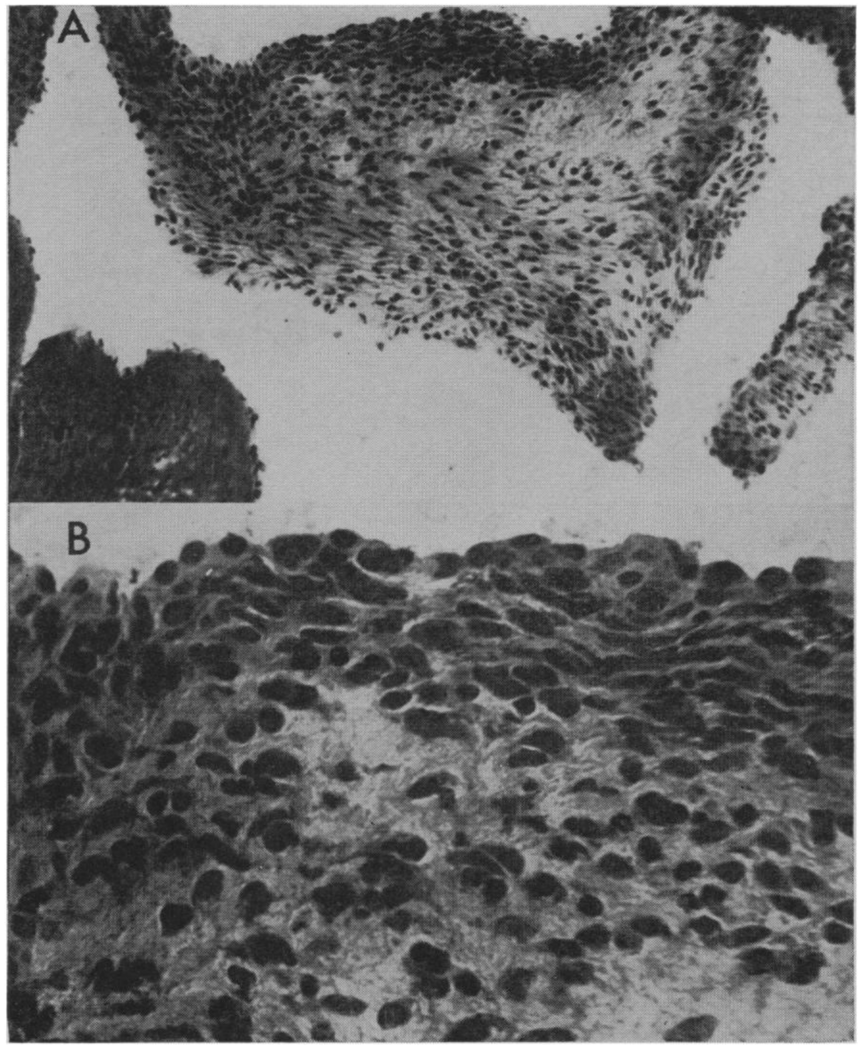

Fig. 1. (*A*) Verrucous lesion on the ventricular surface of the mitral valve of a mouse infected with Coxsackie virus B_4; hematoxylin and eosin staining (about × 110). (*B*) Portion of the lesion (*A*), showing round-cell infiltration, edema, and endothelial proliferation; hematoxylin and eosin staining (about × 440).

Endocarditis in Mice Infected with Coxsackie Virus B_4

Abstract. *Endocarditis has not been generally considered to be a complication of viral infection. We show that mural and valvular endocarditis can be produced in mice infected with Coxsackie virus* B_4. *Because this virus commonly infects man and is highly cardiotropic, it is important to know whether it produces valvular lesions in man similar to those we describe in mice.*

Despite occasional references to viral endocarditis in the medical literature (*1*), cardiologists and pathologists have not considered endocarditis to be a complication of viral disease. Nevertheless, it is well known that B-group Coxsackie viruses produce myocarditis and pericarditis in man (*2*). Detailed studies of the endocardia of patients dying of Coxsackie myocarditis have not been reported. The endocardium has been described as normal in mice having experimental Coxsackie-virus-B_1 myocarditis (*3*). However, endocardial lesions (including valvulitis) have been produced in experimental animals with two other cardiotropic viruses, namely encephalomyocarditis virus (*4*) and virus III (*5*). Recently Lou, Wenner, and Kamitsuka (*6*) found mitral valvulitis in two of nine cynomolgus monkeys infected with Coxsackie virus B_4. Autopsy of two cynomolgus monkeys infected with Coxsackie virus B_4 in our laboratory demonstrated mitral valvulitis in one and aortic valvulitis in the other. These studies prompted reinvestigation of the endocardia of mice infected with Coxsackie virus.

Forty HaM/ICR mice were inoculated intraperitoneally with 0.1 ml of monkey-kidney culture fluid containing Coxsackie virus B_4 (*7*). The mice, varying in age from 2 to 21 days, were killed 2 to 60 days after inoculation. Thirty-six mice, 12 to 20 days old, were inoculated intraperitoneally with 0.1 ml of virus-free monkey-kidney culture fluid; these controls were killed 5 to 20 days after inoculation.

Histologic evidence of valvular endocarditis was found in 55 percent and mural endocarditis in 50 percent of the animals inoculated with the Coxsackie virus B_4. Valves implicated were the tricuspid in 43 percent of the mice, the mitral in 23 percent, the aortic in 10 percent, and the pulmonic in 5 percent. The mural endocarditis affected the right ventricle in 20 percent of the animals, the right atrium in 18 percent, the left ventricle in 3 percent, and the left atrium in 10 percent.