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FINAL REPORT - 28 February 1983

Millimeter-Wave Studies of the Surfaces of Mercury and Mars and the Atmosphere of Venus

Contract: NASW-3255

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I. OBJECTIVES

A. Mercury. 1) Continue 3.3-mm observations with the Aerospace 4.6-m radio telescope begun under NASA Contract NASW-2868. Because the Aerospace telescope is the only facility in the world suitably equipped with a short millimeter wavelength continuum receiver and available for use on a year-round basis, this is unique work in that these are the shortest wavelength extensive radio observations of Mercury possible. The data are approximately four times more precise than previous 3-mm data. 2) Search the data for periodicities which correlate with phase angle, hermocentric longitude, and beat frequencies produced by modulations of various celestial mechanical parameters.

B. Venus. Spectral-line observations with the NRAO 11-m radio telescope of the total CO content and the CO vertical profile, and their variability, and searches for other molecules in Venus' stratosphere.

C. Mars. Reduction and analysis of 3-mm Mars data obtained with the NRAO 11-m telescope during the favorable early 1978 opposition to determine longitudinal variations and, from comparison with infrared and radio observations, deduce information about large-scale thermophysical properties of the surface.

(NASA-CR-169867) MILLIMETER-WAVE STUDIES OF THE SURFACES OF MERCURY AND MARS AND THE ATMOSPHERE OF VENUS Final Report (Aerospace Corp., Los Angeles, Calif.) 9 p
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II. SUMMARY AND CONCLUSIONS

A. Mercury. Disk-average brightness temperatures were obtained on a total of 108 days; corrections for contamination due to antenna sidelobe pickup of solar radiation ("imaginary Mercury" observations) were necessary for 44 of those days and required measurements on an additional 63 days. Five of the 108 values were discarded because of either equipment problems or obvious discordancy with proximate data. The one-harmonic least-squares best fit to the disk-average brightness temperature as a function of phase angle ϕ is

$$T_B(\text{Mercury, 3.3 mm}) = \underset{\pm 4}{352} + \underset{\pm 10}{142} \cos (\phi + \underset{\pm 3}{20°}) \text{ K}, \quad (1)$$

The standard deviation of the residuals is 41 K. A five-parameter fit involving the sub-earth hermocentric longitude ℓ is

$$T_B(\text{Mercury, 3.3 mm}) = \underset{\pm 4}{349} + \underset{\pm 9}{141} \cos (\phi + \underset{\pm 3}{21°}) + \underset{\pm 6}{21} \cos (2\ell + \underset{\pm 16}{2°}) \text{K} \quad (2)$$

the standard deviation of the residuals is 39 K. (For comparison, the standard deviation of the residuals of the five-parameter fit to the 1967/68 data was 93 K.) Equal weight was assigned to all the data in making the above fits. The following are the fits with the data weighted as the reciprocal of the square of the standard error of the individual data points:

$$T_B(\text{Mercury, 3.3 mm}) = \underset{\pm 3}{343} + \underset{\pm 8}{128} \cos (\phi + \underset{\pm 2}{21°}) \text{ K}; \quad (3)$$

the standard deviation of the residuals is 30 K.

$$T_B(\text{Mercury, 3.3 mm}) = \underset{\pm 3}{342} + \underset{\pm 9}{128} \cos (\phi + \underset{\pm 3}{22°}) + \underset{\pm 6}{7} \cos (2\ell + \underset{\pm 36}{7°}) \text{ K}; \quad (4)$$

the standard deviation of the residuals is 30 K.

The statistically significant dependence upon hermocentric longitude in the unweighted fit was expected on the basis both of extensive lower

signal-to-noise observations obtained in 1967/1968 and the combination of the eccentricity of Mercury's orbit and the 2:3 synchronicity between Mercury's orbital and rotational periods. What was not expected was the negligible reduction in the standard deviation of the residuals when the physically more complete analytic 5-parameter expression was used.

A systematic search for periodicities between 3 and 400 days was made by using a two-term unweighted Fourier series. As expected, there was a clear indication of a periodicity of 115.5 days, which is close to the synodic period of 115.9 days and corresponds to the phase angle periodicity. There were also slight indications of periods at 60 and 83 days, corresponding to the rotational (59) and orbital (88 days) periods. The 115.5-day period fit yields an average standard deviation of the residuals of 46.2 K; this period is well determined because varying it by only ±1.0 day increases the average standard deviation of residuals by 8%. The 46.2 K value could be reduced by fitting a higher order Fourier series to the data; however, the coefficients of the higher order terms were not statistically significant.

This work has been described in detail by Epstein and Schneider (1983).

B. Venus. In February and April 1977 observations of CO absorption spectra at 2.6 mm were made with the NRAO 11-m antenna. The two spectra are significantly different, with the April spectrum (phase angle = 170°) being narrower and deeper than the one obtained in February (phase angle = 100°). Numerical inversion calculations show that the CO mixing ratio increases by a factor of 100 between 78 and 100 km and that the CO abundance above 100 km is greatest on the night-side hemisphere. These conclusions are in qualitative agreement with theoretical models.

Additional observations were made in November 1975, November 1978, and January 1979 to search for other molecules. Upper limits were established for the abundances of O_3, OCS, SO_2, H_2CO, N_2O, SO, CS, and HCN.

This work has been described in detail by Wilson et al. (1981).

C. Mars. Observations were made with the NRAO 11-m antenna at 3.5 mm in early and late January and February 1978. Great difficulties were encountered in reducing the data -- the repeatability and internal self-consistency were

poor. Mechanical measurements of the 11-m reflector in early 1981 revealed that it was unstable, thus explaining the difficulties. This instability is the chief source of noise in the results.

The 131 values of the disk-average 3.5-mm Mars brightness temperatures are plotted against Central Meridian Longitude in Fig. 1. The circled symbols represent data for which Saturn, not Jupiter, served as the reference. The same data, but grouped into longitude bins of equal width, are shown in Fig. 2. A one-harmonic least-squares fit to the unbinned data, with equal weights assumed for all 131 points (it is not possible to assign reliable weights to the points), yields

$$T_B(\text{Mars, 3.5 mm}) = \underset{\pm 1}{198} + \underset{\pm 2}{10} \cos (\text{CML} + \underset{\pm 12}{42^\circ})\text{K} \qquad (5)$$

the standard deviation of the residuals is 8.6 K. A two-harmonic fit yields

$$T_B(\text{Mars, 3.5 mm}) = \underset{\pm 1}{198} + \underset{\pm 2}{12} \cos (\text{CML} + \underset{\pm 12}{48^\circ}) - \underset{\pm 3}{4} \cos(2\,\text{CML} - \underset{\pm 20}{76^\circ})\text{K}; \qquad (6)$$

because the standard deviation of the residuals reduces only to 8.3 K and because the amplitude of the second harmonic term is not statistically significant, this two-harmonic fit is not meaningful. The one-harmonic fit is shown in Fig. 2.

These results indicate that if Mars is to be used as a calibration source at 3 mm, the CML at the time of observation must be taken into account if precision to better than $\approx \pm 5\%$ is sought.

For comparison, Doherty *et al.* (1979) obtained the following two-harmonic fit to their 1978 opposition 2.8-cm data:

$$T_B(\text{Mars, 2.8 cm}) = \underset{\pm 0.4}{191.5} + \underset{\pm 0.8}{1.1} \cos (\text{CML} - \underset{\pm 38}{37^\circ}) + \underset{\pm 0.8}{1.6} (2\,\text{CML} - \underset{\pm 18}{134^\circ})\ \text{K}. \qquad (7)$$

The similarity of the 3.5-mm behavior to that at 2.8 cm is not too surprising considering that 3.5 mm is at the long end of the wavelength range

where the cross-over between infrared and radio variations with longitude might occur. This result argues that the surface of Mars is relatively smooth globally at ~3 mm scale because a rough surface would result in values for δ/λ , where δ is the thermal penetration skin depth, which are small enough that the behavior would not be like that seen at longer wavelengths. It would be of much interest to measure rotational curves at wavelengths near 1 mm or smaller to learn more about the global nature of the Mars surface.

The details of the observations and extensive discussion appear in Epstein et al., (1983).

BIBLIOGRAPHY

Doherty, L. H., Andrew, B. H., Briggs, F. H. (1979). Confirmation of the longitudinal dependence of the radio brightness of Mars. Astrophys. J. (Letters) 233, L165-L168.

Epstein, E.E., Andrew, B. H., Briggs, F. H., Jakosky, B. M., and Palluconi, F. D. (1983). Mars: observed longitudinal variation of the 3.5-mm brightness temperature and implications for thermal and electrical skin depths and surface roughness. Submitted to Icarus.

Wilson, W. J., Klein, M. J., Kakar, R. K., Gulkis, S., Olsen, E. T., and Ho, P. T. P. (1981). Venus. I. Carbon monoxide distribution and molecular-line searches. Icarus 45, 624-637.

Epstein, E. E., and Schneider, E. (1983). Mercury: Millimeter-wave thermal emission. I. 3.3-mm observations. Submitted to Icarus.

FIGURE CAPTIONS

Figure 1 Disk-average 3.5-mm Martian brightness temperatures vs. Central Meridian Longitude. The circled symbols represent data for which Saturn served as the reference; Jupiter served as the reference for all other data.

Figure 2 The same data as in Fig. 1, but grouped into longitude interval bins of uniform width. The statistical standard errors of the bin averages are indicated. The numerals represent the number of data points in the bin average. The curve shown is the unweighted least-squares one-harmonic best fit to the 131 individual data points: T_B(Mars, 3.5 mm) = 198 + 10 cos (CML + 42°) K.

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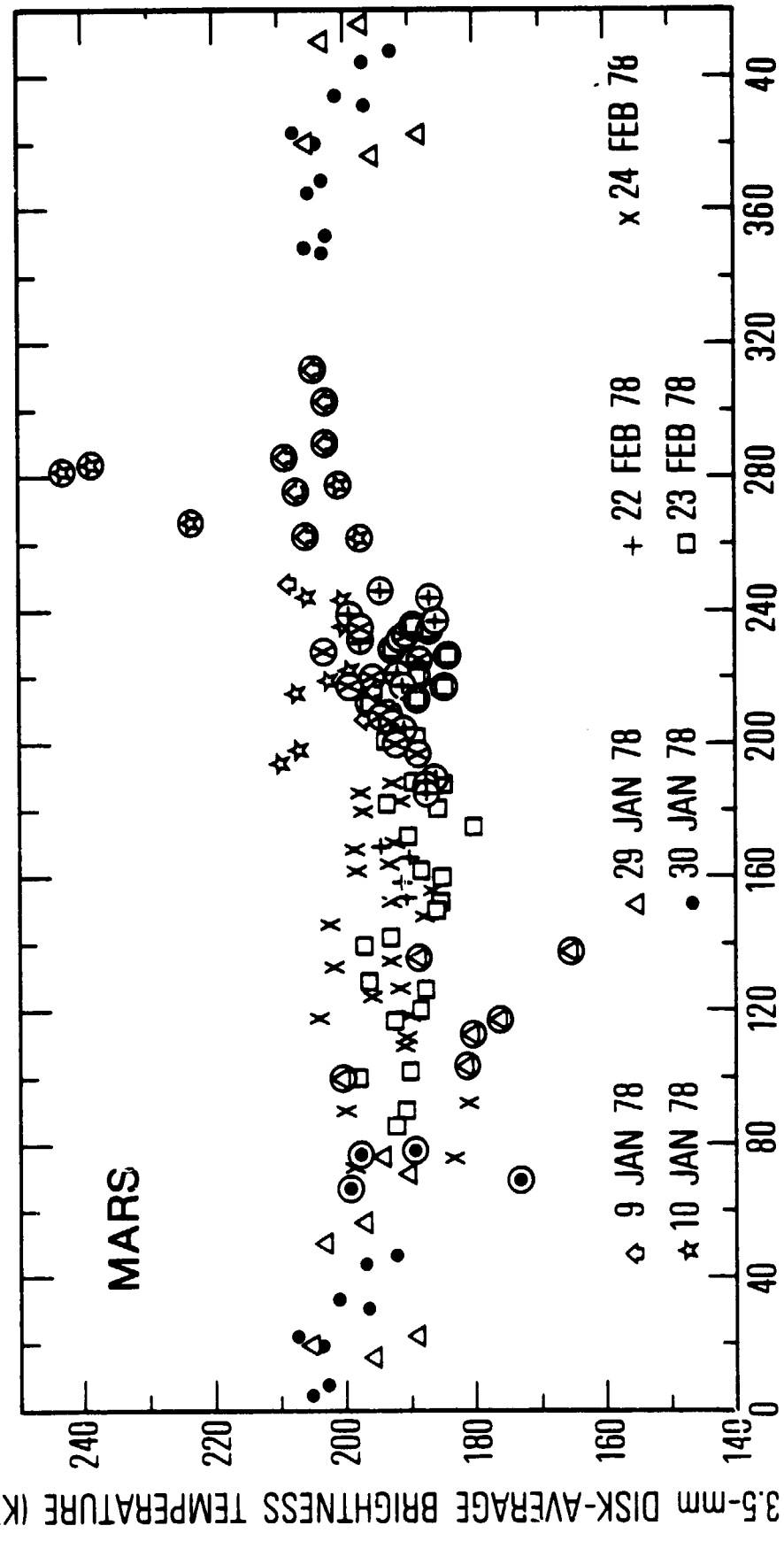

Figure 1

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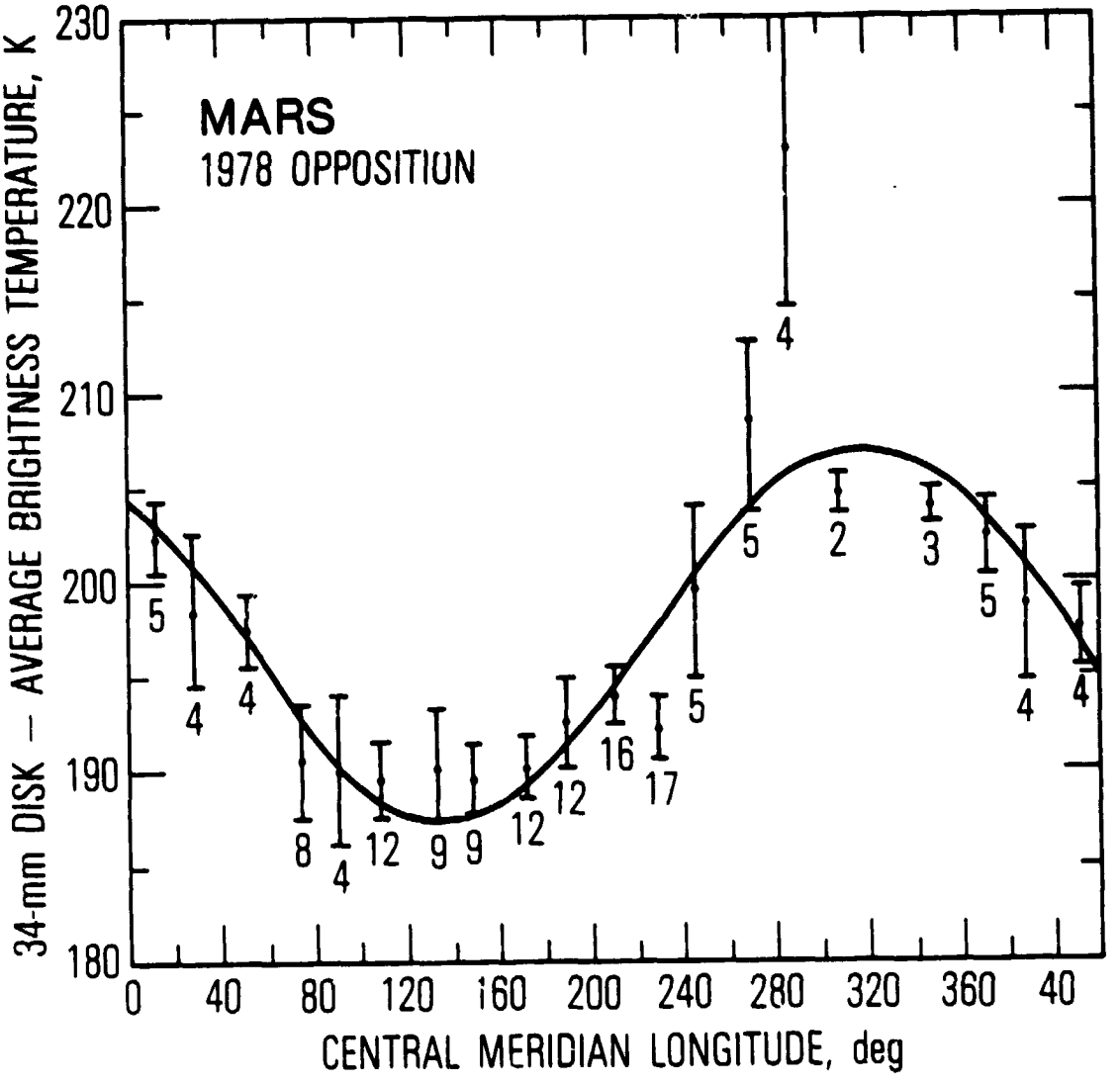

Figure 2