Lecture Notes

NRAO Lecture Program - Summer 1964

Review of

# DATA ON PLANETS AND PLANETARY RADIO EMISSION

by

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| | Mass ($M_⊕$) | Mean Radius ($R_⊕$) | Visual Albedo A | $T_M$ (°K) | $T_A$ (°K) | $D_M$ (arc sec) |
|---|---|---|---|---|---|---|
| Mercury | .0543 | 0.38 | 0.058 | 625 | ... | 10 |
| Venus | .8136 | 0.961 | 0.76 | 324 | 229 | 70 |
| Earth | 1.000 | 1.000 | 0.39 | 349 | 246 | ... |
| Mars | 0.1069 | 0.523 | 0.148 | 307 | 217 | 10 |
| Jupiter | 318.35 | 10.97 | 0.51 | 145 | 102 | 50 |
| Saturn | 95.3 | 9.03 | 0.50 | 107 | 76 | 20 |
| Uranus | 14.54 | 3.72 | 0.66 | 69 | 49 | 4 |
| Neptune | 17.2 | 3.38 | 0.62 | 56 | 40 | 2 |
| Pluto | 0.033 (?) | 0.45 | 0.16 | 60 | 42 | 0.1 |
| .... | | | | | | |
| Moon | 0.0123 | 0.273 | .072 | 387 | 274 | 1800 |

References (25) and (26)

Where $D_M$ is the approximate maximum angular diameter of the planet as seen from earth, and

$$T_M = \left( \frac{S_\odot}{r_\odot^2} (1-A) \right)^{1/4} \qquad T_A = \frac{T_M}{\sqrt{2}}$$

where $S_{\odot}$ = the solar constant

$r_{\odot}$ = mean distance of planet from the sun in A.U.

$\sigma$ = the Stefan-Boltzmann constant

$T_M$ is the equilibrium temperature of a perfectly insulating gray surface at a distance $r_{\odot}$ from the sun, and is the highest temperature of a solid body of albedo A can attain as a result of solar radiation.

$T_a$ is the equilibrium temperature of a perfectly conducting gray sphere at a distance $r_{\odot}$ from the sun, where the heat input is solar heating alone.

Most Recent Observed Infra-red Temperatures ($\lambda$ = 8-14 $\mu$)

| | |
|---|---|
| Mercury | 613°K† (1) |
| Venus | 215°K* (2)   235°K* (3) |
| Mars | Varies during Martian day between about 205°K and 290°K (4) |
| Jupiter | 128°K (2) |
| Saturn | 93°K (5) |
| Moon | ~395°K at "noon" to < 125°K at "midnight" (6) |

(Numbers in parentheses refer to the reference number.)

* This temperature refers to the center of the disk. The average temperature over the disk would be ~10° lower for Venus and ~3° lower for Jupiter.

† Pettit did not have available modern interference filters for the isolation of the 8-14$\mu$ region. The filtering materials used, plus the atmosphere,

transmit between about 3 and 14μ. This temperature is the "noon" temperature on Mercury and refers to a phase angle of zero.

## Radio Wavelength Data

### Mercury

| λ | $T_B$ | Reference |
|---|---|---|
| 3.45 and 3.75 cm | ~550 ± 100°K | (7) |

The above data refers to the range of phase angle between 60° and 110°, and it is not obvious from the data that the brightness temperature is a function of phase angle. However, the brightness temperature is much higher at this phase than the infra-red data gives, and might imply that at 3.5 cm the "noon" temperature reaches ~1100°K.

### Venus

| λ | $T_B$ | Reference |
|---|---|---|
| .8 cm | 315 ± 70°K | (8) |
| .86 | 410 ± 160 | (9) |
| 3.15 | 595 ± 55 | (10) |
| 3.37 | 575 ± 58 | (11) |
| 3.4 | 575 ± 60 | (12) |
| 3.75 | 585 ± 7 | (13) |
| 9.4 | 580 ± 160 | (10) |
| 10.2 | 600 ± 65 | (14) and (12) |
| 21 | 520 ± 33 | (15) |
| 40 | 400 ± 57 | (15) |

Besides the "roll-off" in the spectrum near 1.5 cm, Venus also exhibits a brightness temperature which is a function of phase angle, with the minimum brightness temperature occurring near inferior conjunction, but evidently not at inferior conjunction. The most accurate measure of this "phase effect" is probably that of Drake (15) at 10.0 cm, which gives

$$T_B = 622 + 41 \cos [i \pm 21°]°K$$

where the + (-) is used after (before) inferior conjunction. (This plus-minus sign convention is due to the fact that the phase angle increases too, and reaches 180° at inferior conjunction, but decreases from 180° after inferior conjunction.)

Mars

| λ | $T_B$ | Reference |
|---|---|---|
| 3 cm | 218 ± 50°K | (10) |
| 3.14 | 211 ± 20°K | (16) |
| 10 | 177 ± 17°K | (15) |

The observations indicate that Mars behaves like a perfectly ordinary, perhaps slightly rough, black-body.

Jupiter

| λ | $T_B$ A | $T_B$ B | Reference |
|---|---|---|---|
| 9.4 cm | A + 1/2 B = 658 ± 58°K | | (17) |
| 10.0 | 635 ± 4 | 106 ± 30 | (18) |

continued --

| $\lambda$ | $T_B$ A | B | Reference |
|---|---|---|---|
| 10.6 | A + 1/2 B = 800 $\pm$ 100 | | (19) |
| 22 | 2296 | 1465 | (20) |
| 22 | A + 1/2 B = 3380 $\pm$ 50 | | (21) |
| 31 | A + 1/2 B = 5500 $\pm$ 740 | | (21) |

Jupiter has a distinctly non-thermal spectrum, as may be seen above, and, because of the fact that its brightness temperature is so high at long wavelengths, was the first planet detected by radio astronomers. In fact, over the radio region, the flux from Jupiter appears independently of wavelength, which gives a $\lambda^2$ increase of brightness temperature with wavelength. When Jupiter is observed with a linearly polarized antenna in the decimeter wavelength region, its brightness temperature is a function of rotational phase. This changing brightness temperature can be separated into an A component, which is independent of rotational phase, and a B component, which is the amplitude of the variable term.

In the decameter wavelength region, Jupiter has been observed to give bursts of radiation which, although they are most common near 18 Mc/s, have been observed between 4.8 Mc/s and 43 Mc/s. These bursts occur most frequently when certain longitudes are on the central meridian.

The origin of the decimeter radiation is evidently in synchrotron radiation from radiation belts surrounding Jupiter, which belts are like the Earth's Van Allen belts. The origin of the decameter radiation is not known.

Saturn

| $\lambda$ | $T_B$ | Reference |
|---|---|---|
| 3.45 cm | $106 \pm 21°K$ | (22) |
| 10.0 | $196 \pm 44$ | (23) |
| 9.4 | $141 \pm 20$ $\vec{E}$ parallel to rot eq. | (24) |
| | $213 \pm 18$ $\vec{E}$ perpendicular to rot. eq. | |

The earlier observations at 3.45 cm and 10.0 cm were interpreted as indicating that Saturn was a black-body radiator; however, the recent observations at 9.4 cm by the NRL group indicate the presence of non-thermal radiation, and show the rather surprising result that Saturn is brightest when the antenna E-vector is aligned with the rotational axis.

Neptune, Uranus, and Pluto have not been detected by radio astronomers -- which is not surprising -- because if they are black-body radiators they would give antenna temperatures of less than .002°K on the 300-foot antenna at 20 cm.

## Review Articles

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