for following the seasonal changes in the polar cap and in the blue-green areas.

September 22, 1924.

RADIATION MEASURES ON THE PLANET MARS

By Edison Pettit and Seth B. Nicholson

Observations of the radiation from *Mars* have been made with the vacuum thermocouple attached to the 100-inch telescope on eleven days since November, 1923. Two thermocouples have been employed, No. 36 having receivers 0.8 mm. in diameter which was used to measure the integrated radiation from the planet, and No. 42 having receivers 0.40 by 0.20 mm. used for observations on planetary markings, drift curves, etc. Both of these couples have rock salt windows.

Three screens, a water cell 1 cm. thick, a glass plate 0.165 mm. thick and a fluorite plate 4 mm. thick are so mounted that each in turn can be thrown into the beam of light from the mirror of the telescope. By this means regions in the spectrum, 0.3 to 1.3μ, 1.3 to 5.5μ, 8 to 11μ, and 11 to 14μ can be isolated when combined with the transmission of the atmosphere. Transmission curves for the atmosphere and these screens will be found in these *Publications,* **35,** 195, 1923. The method of making the observations has been described in *Astronomical Journal,* **56,** 343, 1922. The D'Arsonval galvanometer and registering device were used throughout.

The radiometric magnitude of *Mars* (magnitude of an A0 star from which we receive the same amount of radiation) was determined by measuring the radiation from stars in the same region of the sky. The radiometric magnitudes of these stars have been determined by a considerable number of direct comparisons, and the atmospheric absorption factors to reduce the observations to the zenith have been determined for both the stars and the planet. Since the image of the planet at opposition is twice the diameter of the receivers on couple No. 36 it is necessary to make a correction for the amount which does not fall upon the receivers. This correction factor was obtained by integrating the drift curves made with couple No. 42 and its value is —0.78 magnitudes. This correction when applied to the radiometric magnitude determined with the junction placed centrally upon the planet gives —3.92 for the radiometric magnitude of *Mars* at the present opposition, and this would be the maximum value. The radiometric magnitude of the dark side of *Venus* at inferior conjunction is nearly one magnitude brighter, namely, —4.84. The radiometric magnitude of *Sirius* is only —1.29, more than two nad a half magnitudes fainter.

The distribution of energy in the planet's spectrum has been determined by use of the transmission screens as indicated above. The method of isolating the various regions in the spectrum has already been indicated (these *Publications,* **35,** 195, 1923). Table I shows the distribution of the energy in the spectrum of various features on *Mars* determined with couple No. 42 compared with that from the Moon, *Mercury* and the Sun.

TABLE I.

	Reflected Light			Planetary Radiation		
	I	II	III	IV	V	VI
	0.3—1.3μ	1.3—5.5μ	1.3—5.5μ	8—11μ	11—14μ	8—14μ
Mars: Center disk	28.2	13.6	6.8	17.2	34.3	51.5
Mars: Pole-Cap	33.6	16.2	13.3	6.7	30.3	37.0
Mars: Integrated	29.9	14.4	4.5	13.9	37.1	51.0
Moon (Center, full phase)	9.5	4.6	6.2	31.2	48.5	79.7
Mercury	6.5	3.2	20.2	37.6	32.5	70.1
Sun	67.5	32.5	0	0	0	0

An inspection of the table shows that *Mars* is much like *Mercury* and the Moon in that a large percentage of the radiation which it emits is transmitted by our atmosphere through the band between 8 and 1μ4. This radiation is emitted by the heated surface of the planet and we shall call it *planetary radiation.* Some planetary radiation is also transmitted by our atmosphere between 1.3 and 5.5μ. *Jupiter, Saturn,* and *Venus* at full phase emit only about 8 per cent of planetary radiation.

We may estimate the temperature of a point on *Mars* by two methods. First, we may attempt to make the data in Table I to fit a black body radiation curve after applying the atmospheric transmission to it, or we may employ the principle of the total radiation formula (fourth power law). In using the data given in Table I it must be remembered that the values given in columns II and III are computed from the values in columns I and VI, assuming that the sunlight is unaltered in quality upon reflection. This indeed is not true, as the color of *Mars* testifies, and therefore these transmissions have not been used in computing temperatures for this planet. The values in columns IV, V and VI can be used with more confidence, but here again we are confronted with only a general knowledge of the atmospheric transmission in this region. This criticism also applies with equal force to the method of total radiation.

The temperatures of *Mars* obtained by the two methods are indicated in Table II.

TABLE II.

	Temperature Absolute		
	From Spectrum	From 4th Power Law	Average
Center, full phase	285°C	275°C	280°C
Limb	......	260	260
Pole-Cap	170	240	205
Integrated Disk	240	260	250

The radiation from the disk as a whole comes from regions of considerably different temperatures. In computing the temperature from the integrated radiation of the disk we have used atmospheric corrections for the temperature for which a black body curve best fits the observations. Since the atmospheric correction curve is very steep at these temperatures, we can use the integrated disk observations only for a general check upon the results. In all temperature calculations an emissivity of unity has been assumed for all wave-lengths. This assumption is much more likely to be in error for the pole-cap than for the surface of the planet so that the temperatures assigned to the former are probably more uncertain than those assigned to the other regions.

From these results we may conclude that the radiation temperature of the center of the illuminated hemisphere of *Mars* is a little above freezing, and that the mean temperature of the pole cap is about —70° centigrade. The measures on the limb give the mean value over a region extending inward to about one-fourth of the radius toward the center, and this is about

—13° C. The actual temperature at the limb must be much lower than this.

Drift curves taken across the planet from east to west near the time of opposition are symmetrical and show that the distribution of radiation follows the sine law, with no displacement of the point of maximum radiation from the center, which might be caused by rotation as on the Earth. The forms of the drift curves taken both without and with the transmission cells are very much like similar curves taken across the Moon. These results point to a rare atmosphere. This is confirmed by the large percentage of radiation between 8$^{\mu}$ and 14$^{\mu}$ and its spectral distribution, which is similar to that of the Moon and *Mercury.*

Mount Wilson Observatory, Sept. 15, 1924.

RADIOMETRIC MEASUREMENTS ON MARS

By W. W. Coblentz and C. O. Lampland

Preliminary reports of radiometric observations of the planets carried on at the Lowell Observatory the past months have appeared in these *Publications*[1] and were also presented at the Hanover meeting of the American Astronomical Society. With the further progress of the measurements it is now possible to give more complete results, especially for the planets *Mars* and *Venus.*

The main problem in this year's radiometric program was the measurement of the radiation of *Mars,* but *Venus, Jupiter, Saturn, Uranus,* and the Moon were also observed, particular attention being given to *Venus* and the Moon.

The present work is a continuation of the planetary radiation measurements of 1922, which were carried out in preparation for the present opposition of *Mars,* with the equipment suitably adapted for the problems in hand. The radiometer was used with the 40-inch Lowell reflector, with focal lengths of 220 inches and 480 inches. The receivers of the several sets of thermocouples used were of different sizes, with diameters sufficiently large to intercept the whole planetary disk, and also

[1] *Publ. A. S. P.,* **36,** 220, 1924.