thereafter considerably overbalance the gravitational pull. This happens when the temperature-time coefficient $d\theta/dt$ is negative. When the latter is positive, gravitation and the radiant forces coöperate. It is seen, moreover, that the higher exhaustions (a few tenths mm. and less), are (like the plenum) favorable to strong radiant forces; whereas in moderate exhaustions (a few millimeters) the radiant forces tend to a minimum, so that the night observations become more and more trustworthy. This may be inferred from the gradual simplification of the F, R curves between Aug. 1 and August 14. In corroboration, the apparatus was again exhausted on Aug. 14 and tested about 12 hours later on the morning of Aug. 15. It is seen that the strong radiant forces have reappeared.

* Advance note from a report to the Carnegie Institution of Washington, D. C.

FURTHER MEASUREMENTS OF STELLAR TEMPERATURES AND PLANETARY RADIATION

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1. *Introductory Statement.*—In a previous communication[1] estimates were given of the temperatures of 16 stars as determined from their spectral energy distribution which was determined by means of a new spectral radiometer, consisting of a series of transmission screens and a vacuum thermocouple.

By means of these screens, which, either singly or in combination, had a uniformly high transmission over a fairly narrow region of the spectrum and terminating abruptly to complete opacity in the rest of the spectrum, it was possible to obtain the radiation intensity in the complete stellar spectrum as transmitted by our atmosphere.

Not being equipped at that time for making radiometric measurements on the Sun, the effective temperature of which is known with some degree of accuracy, and hence could be used as a standard, an estimate of the effective temperature of a star was obtained by two methods, one of which consisted in using a solar type star (α Aurigae, Class G o) as a standard. This seemed permissible in view of the fact that the observed temperature (6000° K) of α Aurigae was found to be in close agreement with that assigned to the Sun.

The object of the present communication is to report a verification of the above-mentioned stellar radiation measurements, by similar measurements recently made on the Sun; also to give some measurements of the radiation from the major planets.

2. *Apparatus and Procedure.*—The apparatus used in this work consisted of the 40-inch reflector of the Lowell Observatory, to which was attached a special radiometer mentioned in a previous issue of these PROCEEDINGS,[1] and fully described elsewhere.[2] The thermocouples were new and were made of fine bismuth wire, with receivers 0.2 mm. in diameter.

The crucial part of this investigation consisted in obtaining an exact measurement of the water cell transmission of the direct sunlight. For this purpose, the great reflecting mirror and the end of the telescope tube were covered. Parallel light, entering a small opening in the cover of the telescope tube, fell upon a small, plane, silvered mirror, placed in the axis of the tube, and from thence reflected upon the diagonal mirror to a thermopile which was especially constructed for these measurements.

3. *Experimental Data.*—The solar radiation data are given in table 1, in which column 1 gives the spectral range, and columns 2 and 4 give the spectral radiation components (A.M. and P.M.) of the Sun (also of α Aurigae, column 6) corrected for all losses except atmospheric absorption. The corresponding temperatures are given in columns 3, 5 and 7.

TABLE 1

SPECTRAL RADIATION COMPONENT OF THE SUN AND OF α AURIGAE IN PER CENT OF THE TOTAL

	SUN				α AURIGAE	
	A.M.		P.M.			
Spectral range. μ = 0.001 mm.	Spectral radiation component	Temperature °K	Spectral radiation component	Temperature °K	Spectral radiation component	Temperature °K
0.30μ to 0.43μ	25.0%	5670	25.6%	5750	18.4%	5000?
0.43μ to 0.60μ	22.1	6500	19.0	5760	18.2	5800
0.60μ to 1.40μ	31.8	5860	35.0	5050?	30.6	6000
1.40μ to 4.10μ	20.6	6060	20.1	6140	26.4	5200?
4.10μ to 10.00μ	0.5	....	0.8	....	6.4	....
Average		6000° K		5900° K		5900° K

These data are interesting in showing a close agreement between the spectral radiation components of the Sun and α Aurigae in the visible spectrum (0.43μ to 0.6μ) which is in agreement with the visual and photographic observations. However, in the ultra-violet the radiation component of α Aurigae is less, and in the infra-red it is greater (owing partly to the low-temperature radiation from the companion star), than that of the Sun. The lower value in the ultra-violet might be owing, in part, to the larger air mass traversed and hence to the greater amount of scattering of the incoming radiations. But this does not explain, and is inconsistent with, the higher values observed in the infra-red, in many of the stars previously measured, in spite of the greater air mass traversed.

No doubt this is owing partly to experimental errors; but some of it may be attributed to the low (selective) infra-red emission of the Sun, the earth's atmosphere being quite transparent to radiations greater than 7μ.

For the purposes of this investigation the agreement between the observed temperatures of α Aurigae and the Sun is considered satisfactory, verifying the previous measurements of stellar temperatures which range from 3000° K for red, class-M stars, to 12,000° K for blue, class-B stars.

Planetary Radiation.—The thermal radiation emitted from a planet as a result of warming by exposure to solar radiation, including heat which may be radiated by virtue of a possible high internal temperature of the planet itself, is essentially of long wave-lengths 7μ to 12μ. Hence, by means of a 1 cm. cell of water, interposed in the path of the total radiation emanating from the planet, this long wave-length radiation can be separated from the reflected solar radiation, and in this manner a measurement obtained of the energy reradiated. If there is planetary radiation, the water cell transmission will be less than that of the direct solar radiation.

The observed transmission of planetary radiation through a cell of water 1 cm. in thickness is given in table 2. This table shows that the

TABLE 2

TRANSMISSION OF PLANETARY RADIATION THROUGH A CELL OF WATER 1 CM. IN THICKNESS; ALSO THE PER CENT OF PLANETARY RADIATION EMITTED

Object	Date June, 1922 MST	No. of sets of measurements	PER CENT TRANSMISSION Deviation from mean	Mean value 1922	Mean value 1914	Planetary radiation in per cent of the total
Sun	17th; 11:30 A.M.	5	1.2%	69.3	....	..
	4:15 P.M.	4	0.5	69.8	....	..
Jupiter						
Central disk	14th; 10:15 P.M.	2	1.4	69.7	65.6	..
Southern hemisphere	10:20 P.M.	2	3.0	66.8	65.8	..
Venus	15th; 8:00 P.M.	2	2.3	66.3	59.0	5
Saturn	14th; 9:00 P.M.	3	1.1	60.0	55	15
Mars	15th; and 18th	.	6.0	50.3	....	30
Moon	....	.	....	....	14.7	80

water cell transmission of the total radiation from Jupiter is practically the same as that of the direct solar radiation. From this it appears that the outer atmosphere of Jupiter does not radiate appreciable energy as the result of warming by solar rays and that the atmosphere is sufficiently thick and opaque to trap all the energy reradiated as the result of warming of its interior by solar radiation, or by internal heating.

The radiometric measurements on Venus, Jupiter and Saturn are in good agreement with similar measurements made at Mt. Hamilton, Calif., in 1914, showing a decidedly lower transmission of radiation through the water cell, in the case of Venus and Saturn.

The intensity of the planetary radiation increases with decrease in the density of the surrounding atmosphere and (as interpreted from the water cell transmissions) in per cent of the total radiation emitted, is as follows: Jupiter (O), Venus (5), Saturn (15), Mars (30) and the Moon (80).

The water cell transmission of the radiations from the southern (50.6%) and northern (53.1%) hemispheres of Mars should be and is higher than that of the radiations emanating from the equatorial (47.3%) region, owing to the depletion of the reradiated energy by the greater air mass. Moreover, the intensity of the planetary radiation from the northern hemisphere of Mars was found to be less than from the southern hemisphere. This is to be expected in view of the observed cloudiness over the northern hemisphere which is usually the brighter and is approaching the winter season, and hence is at a lower superficial temperature.

These data were obtained through the generosity of the Lowell Observatory, Flagstaff, Arizona, who financed this research. Dr. C. O. Lampland again kindly operated the telescope and it is intended to publish the complete results in a joint paper on the measurements of planetary radiation and their astronomical significance.

As already stated, the object of the present note is primarily to place on record a verification of the results, obtained a year ago, on stellar temperatures.

[1] *Proc. Nat. Acad. Sci.*, **8**, 1922 (49–53).
[2] *Bureau of Standards Scientific Paper*, No. **438**, 1922.

PROOF OF A THEOREM DUE TO HEAVISIDE[1]

BY H. A. LORENTZ

HAARLEM, HOLLAND

Communicated August 7, 1922

In the *Electrical Papers*, Vol. 2, p. 412, Heaviside states: "The whole work done by impressed forces suddenly started exceeds the amount representing the waste by Joule-heating at the final rate (when there is any), supposed to start at once, by twice the excess of the electric over the magnetic energy of the steady field set up."

Consider a system of bodies, either conductors or dielectrics, or, for the sake of generality, both at the same time, and denote by **E** the electric force, by **H** the magnetic force, by **D** the dielectric displacement, by **C**