been suggested), stands the fact, that the luminosity of the satellites compare about equally with that of the planet. We can hardly imagine these comparatively small bodies to retain any sensible amount of their supposed original incandescence. They may, however, receive a considerable amount of light from the planet itself. This question is one of great interest, and should be investigated, as it probably will be, on a more accurate and scientific basis.

"IS JUPITER SELF-LUMINOUS?"

By A. B. Biggs.

It is with some diffidence that I submit the following paper, partly because I am doubtful of its being a subject of general interest, and partly from a consciousness that the experiments in the course of my investigation of the subject did not attain the degree of accuracy which I had hoped for. Perhaps, however, the fact that the question which I set myself to solve is intimately connected with that of the physical condition of Jupiter, and inferentially also of all the giant planets may lend an interest to the subject.

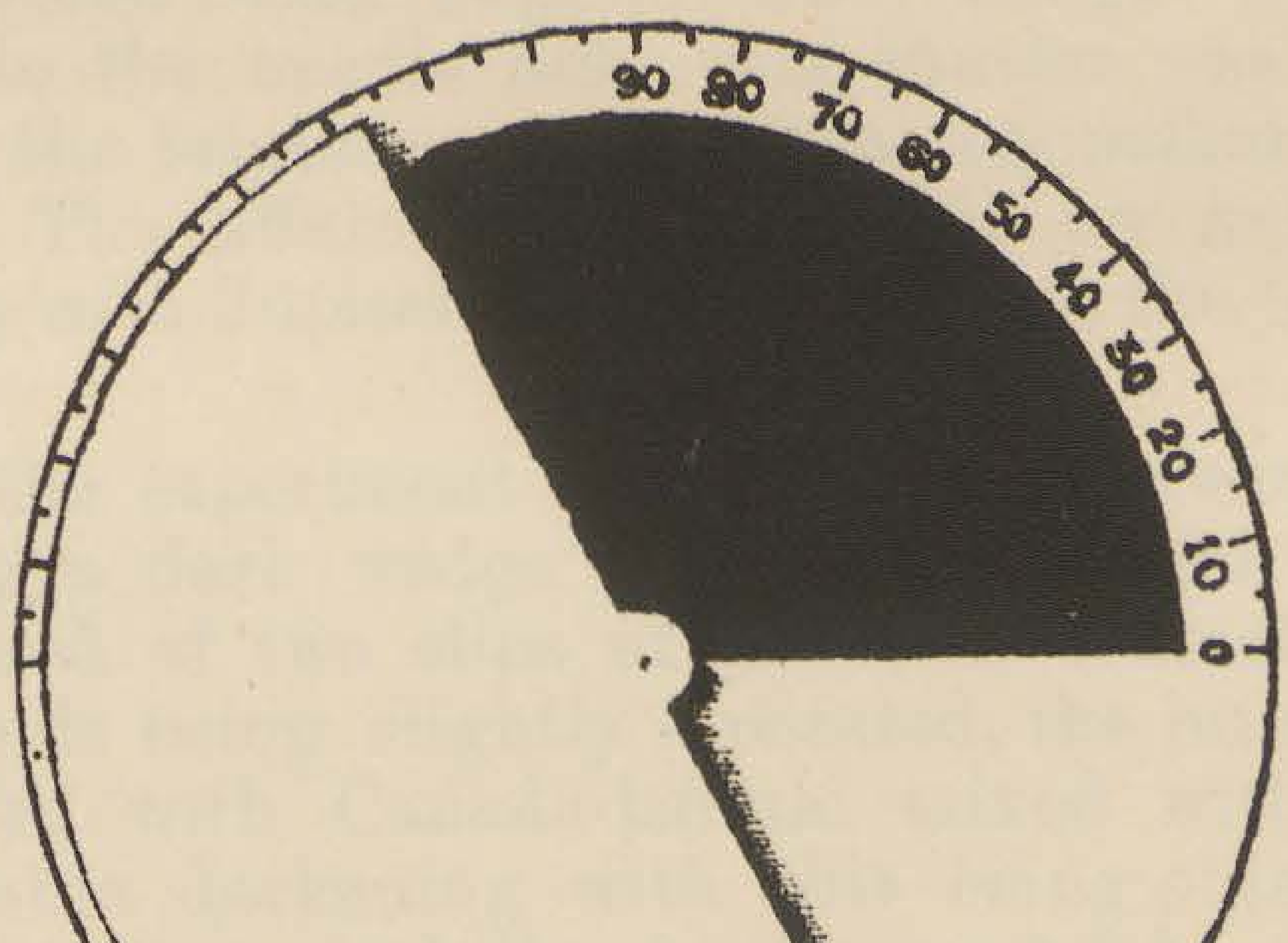
In the concluding part of my paper on the occultation of Jupiter in April last (read 8th June), I referred to the question of Jupiter's intrinsic brilliancy, and expressed the hope that the question would be scientifically investigated. In order to clear the way, I will first state the case. Jupiter is, roughly speaking, about five times the earth's distance from the sun. It is impossible, therefore, that he can receive from that luminary more than $\frac{1}{25}$ (one twenty-fifth) part of the intensity of illumination which reaches the earth; that is, in inverse proportion to the squares of the distances. Now, from the time of my first telescopic acquaintance with Jupiter, I was struck with the impression that his brightness far exceeds what, by the above rule, it ought to be. The question naturally arises, how is this want of accordance with the laws of radiation to be accounted for, presuming it to exist? Some modern astronomical works just refer to this question, but as a rule they pass it over lightly.

Chamber's Astromony devotes but one short paragraph to the question, from which I quote as follows:—"Bond computed that Jupiter actually emits more light than it receives (!); but whether we accept this problematical result, or the more trustworthy one obtained by Zölner, strong indications of inherent luminosity in Jupiter seem to exist; and this points to the conclusion that this planet is itself a *miniature Sun.*" Professor Newcomb says:—"A still more remarkable resemblance to the sun has sometimes been suspected—nothing less in fact, than that Jupiter *shines partly by his own light*," etc. Guillemin asks:—"Does the globe of Jupiter still possess an internal heat considerable enough to raise the temperature of the crust to an extent sufficient to make up for the relative feebleness of the solar heat?" (and *light*, he might have said) "These are questions on which science is still silent." Herschel, Ball, and Webbe, pass the question by in silence. Mr. Proctor, however, argues strongly in favour of the giant planets being more or less self-luminous.

The recent conjunction of Jupiter and Mars (28 June) was looked forward to with interest by me, as furnishing a favourable opportunity for photometric experiments with reference to the relative intrinsic brightness of these two planets; and I commenced my preparations several days before hand. At the risk of being somewhat tedious, I think it will be well to describe in detail the means I adopted, in order that the results may be judged of at just what they are worth, and no more.

I constructed a diaphragm (or shutter), for the telescope ($8\frac{1}{2}$in. reflector), consisting of two half-discs, pivoted at their circular centres, and graduated on their rims in degrees, thus:—

Face p. 34



This enabled me to shut off any proportional part of the aperture of the telescope from one half to the whole.

In order to equalise the conditions, so far as to have equal visual areas in comparison, I covered the field-bar of the eye-pieces used with tinfoil (blackened) leaving open (for finding the object) a segment only, about one-third of the field. In the centre of the tinfoil I pierced a small hole with the point of a fine needle.

In observing, I used a Barlow lens in conjunction with the eye-pieces, so as to enlarge the focal image. I at first employed the sun-prism (the image being viewed by reflection from the first surface of clear glass), thereby getting rid of the greater part of the illumination. This was still further reduced by a 6-inch stop to the telescope. For comparison, a lamp was enclosed in a cupboard having an aperture covered with paper. The image of Mars being brought to the needle hole, the shutter was gradually closed until the brightness of the image equalled that of the lamp-light. The different readings gave an average of 90deg. Dealing with Jupiter in the same way, the average was 29deg.

I next varied the experiment by removing the sun-prism, and substituting a dark wedge (a make-shift affair for the occasion, composed of two slips of glass, in contact at one end, the other ends being slightly separated, the intervening space being filled with Canada-balsam mixed with lamp-black). A suitable darkening with this being obtained, it was retained in position, and the shutter used for equalising the illumination.

In this experiment each image was reduced to the minimum of visibility. The averages of the readings were 102deg. for Jupiter, and 146deg. for Mars.

Between these two sets of measures there is considerable discordance; but they both agree in making Jupiter's surface much the brighter of the two; in the first set as 90 to 29, or nearly three times; and in the second as 146 to 102, or nearly $1\frac{1}{2}$. Taking the mean we have as 118 to 65, or nearly double.

Their relative distances from the sun at that date were as 15,747 to 54,561. The proportion of the squares of these numbers is almost exactly as 1 to 12; Jupiter, then, instead of being $\frac{1}{12}$ the brightness of Mars, is by the above measure nearly double, or about 22 times as bright as he ought to be by the laws of radiation.

The near conjunction of Jupiter and the Moon, on 7th July, furnished opportunity for comparison between these bodies. On this occasion the readings averaged 180deg. for

Jupiter, and 80deg, for the Moon. Their relative distances from the Sun were :—

As.	1·0155 to 5·4562
Theoretical illumination (as squares)	1 to 28·8
As measured	4 to 9, or 1 to 2·25
Actual exceeds *theoretical* ...	$\frac{28 \cdot 8}{2 \cdot 25}$ = 12·7 times.

I had not yet done with the question. In my experiments I had, by various means, stopped back all but the smallest fraction of the light received. The inquiry arose, did this small amount represent *equal percentages* from both bodies ? I settled this question at home thus :—A small hole $\frac{1}{10}$ inch in diameter was pierced in a bit of sheet metal, and covered with tracing paper. This, with a flame behind it, made a capital artificial planet. I improvised a small telescope out of a short focus photo. combination, using the same eye-pieces as before, and the dark wedge. To this arrangement I adapted a graduated shutter as before described. The light—a small gas flame—was enclosed in a magic lantern, the lenses being removed, Measures were then taken of the intensity of light as received upon the spot of tracing paper, the flame being at 1, 2, 3, 4, and 5 feet distant respectively. The average of a series of readings for these several distances in order was 180, 110, 61, 31 and 6 degrees.

Theoretically they should have been 175, 112, 63, 28 and 7 degrees.

This was, I think, sufficiently near to show the general correctness of the principle.

To sum up then—as compared with Mars, I make Jupiter's surface brightness to be 22 times as great as it ought to be—and as compared with the Moon 12·7 times.

These comparisons, of course, go on the assumption that the surfaces to be compared are equally reflective, that is, of equal whiteness. That they are really *not* so may be considered as certain. But even supposing Jupiter's surface to be of the *whiteness of snow*, we have at the poles of Mars planetary snow with which to compare it, and illuminated with 12 times the intensity of Jupiter's sunshine; yet, even this comparison, I judge to be in favour of Jupiter. As compared with the Moon, the vaporous envelope of Jupiter (whatever its nature) is probably more reflective than the bare and broken lunar surface. There *must*, however, remain a vast amount of illumination to be accounted for in some other way.

I must say that the result of my measures appears incredible even to myself. I, therefore, look for some corroboration. According to Mr. G. P. Bond's estimate, the light we receive from Jupiter amounts (at a mean) to $\frac{1}{6430}$ of that of full moonlight. Jupiter's visual disc (mean) is $\frac{1}{2553}$

of the Full Moon. My estimate of his surface brightness $= \frac{4}{9}$ that of the Moon. The product of these fractions is $\frac{1}{5744}$ — ; not far from Bond's estimate.

If, then, we may take it as proved that *solar illumination* is vastly insufficient to account for Jupiter's brightness, how is the excess to be accounted for? Prof. Newcomb says (hesitatingly) :—" A still more remarkable resemblance to the sun has sometimes been suspected—nothing less, in fact, than that Jupiter shines partly by his own light. It was at one time supposed that he actually emitted more light than fell upon him from the sun; and if this were proved, it would show conclusively that he was *self-luminous*." Mr. Proctor favours this opinion, and indeed accepts it as a necessary fact. I think we can come to no other conclusion. The greatest difficulty in the way of this theory is, I think, the relative brightness of Jupiter's satellites. As I suggested in my former paper, they may derive a small portion of their light from their primary, but this, of course, would be apparent to us only in the farther portion of their orbits. On this question, Newcomb says:—" If we assume that the planet emits any great amount of light, we are met by the fact that *the satellites would shine by this light when in the shadow of the planet.* As these bodies totally disappear in this position, the quantity of light emitted by Jupiter must be quite small." If these satellites were seen *in a dark sky* when in shadow, I, too, think they would be visible. By a rough process of calculation (which it would take too long to describe), and taking my own estimate of Jupiter's brightness, I find that his first satellite would receive from him about 50 times the light which our new Moon receives from earth shine, or about $\frac{1}{846}$ of our sunshine, obtained thus :—

Full moonlight to sunlight (mean of several		Sun.
observers)	=	550·000
Earthlight to Moon...	=	13
		Moon.
Jupiter to Satellite I, at $\frac{4}{9}$ Moon brightness ..	=	50
		Earth.

$$\therefore \quad \frac{13 \times 50}{550{\cdot}000} = \frac{1}{846} \quad ;—$$

(assuming equally reflective surfaces) as between Earth and Moon. This is about equal to the sunshine received by the satellite of Neptune. But it must be remembered that when Jupiter's satellites enter his shadow, they are in such close proximity to the limb of the planet that such feeble illumination would be totally overpowered by his glare.

The evidence of the satellites appears still further hostile when we consider that they sometimes appear (the third especially) as *bright* spots when entering upon his surface in transit, as I have myself observed; but this is only for a short distance within the limb. As they advance upon the face of the planet they become *dark* by contrast—sometimes as black as their shadows. This is accounted for by the vast difference of brightness between the centre and the edge of the planet's disc. This last is, I think, compatible with the supposition of a *glowing ball*, whose surface lies far within the confines of the vaporous envelope, which alone is visible to us. As to the satellites, we cannot argue anything definitely or positively from them with regard to the question under discussion, as we know next to nothing of their physical condition; their *variable brightness*, if nothing else, compels us to rank them among the many unsolved mysteries of astronomy.

The subject deserves, and I trust will receive, more precise and thorough investigation.

TASMANIAN MOSSES.

By R. A. Bastow, F.L.S.

The illustrated key, accompanying this paper, is prepared chiefly for the use of students, residing in our country districts, who have not at all times access to the many valuable Botanical works in the Royal Society's Library.

The illustrations are, for the most part, drawn from nature; or, where specimens of the mosses have not been available, the drawings have been taken from standard works on the subject, namely:—"Flora of Tasmania," "Flora of New Zealand," and "Flora of the Antarctic Islands," by Dr. J. D. Hooker, F.R.S.; "Bryologia Britannica," by William Wilson, Esq.; and "Musci Exotici," by William Jackson Hooker, F.R.A. & L.S., and in the accompanying description of species the following works have also been freely used:— "Bridel, Bryologia Universa;" "Hooker's Handbook of the New Zealand Flora;" "Fragmenta Phytographiæ Australiæ," by Baron von Mueller; "Musci Austro-Americani," by Mitten; "Australian Mosses," by Baron von Mueller; "Mitten's Catalogue of Australian Mosses;" and MSS. from Mr. H. Boswell, of Oxford.

The genera are all arranged on one large sheet so that the whole may be presented at one view. The drawings on the upper half of the sheet are so placed that