



Observing the Transit of Venus

by night being therefore impossible, and twilight observations being rarely successful, no other way remains but to make the attempt in full daylight, in the continual presence of the sun, and through an atmosphere constantly illuminated. Certain trials made in 1881 persuaded me that it would be possible not only to see the markings on Mercury in full daylight, but also to obtain a series of sufficiently connected and continuous observations of these spots. In the beginning of 1882 I determined to make a regular study of the planet; and in the eight following years I have had the telescope directed upon Mercury several hundreds of times, usually to little purpose, and with the loss of much time; sometimes on account of atmospheric disturbance, which during the day is often very great (especially in the summer months); and again on account of insufficient transparency of the air. Nevertheless, by employing the necessary patience, I succeeded in seeing the spots on the planet with greater or less precision on more than one hundred and fifty occasions, and also in making at such times some rather satisfactory drawings. For this purpose I used at first the smaller telescope of our observatory, made by Merz, which was often found to be inadequate for observations so difficult as these. But in the mean time the new great equatorial refractor had been installed in the observatory of Milan. It may be called the most perfect work which has yet come from the workshops of Munich. By its aid I was enabled to pursue the work with greater success, and to attain more complete and more certain results. And in regard to this refractor I can not recall without lively emotions of gratitude the warm interest shown by your Majesties, now eleven years ago, when it was a question of providing that noble instrument for the Milan Observatory. Nor is it possible for me to forget the generous eagerness with which this academy, and Quintius Sella of glorious memory at the head of it, supported the proposition with an authoritative vote, and the large majority by which it was honoured in both branches of Parliament; The new facts concerning the planet Mercury which this telescope has revealed, I consider as the most important and most precious results, which have been so far obtained by its aid; so that to give the first account of these new things at this time and in this place seems to me the

2. "On the Mechanical Energies of the Solar System," "Transactions of the Royal Society of Edinburgh," April, 1854, and "Philosophical Magazine," December, 1854.

3. "Mechanical Energies of the Solar System."

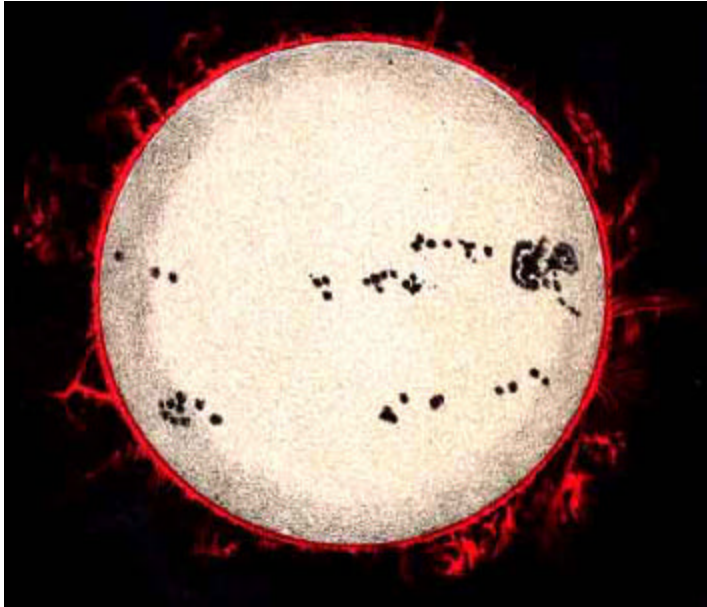
4. The "specific heat" of a homogeneous body is the quantity of heat that a unit of its substance must acquire or must part with, to rise or to fall by 1° in temperature. The mean specific heat of a heterogeneous mass, or of a mass of homogeneous substance, under different pressures in different parts, is the quantity of heat which the whole body takes or gives in rising or in falling 1° in temperature, divided by the number of units in its mass. The expression, "mean specific heat" of the sun, in the text, signifies the total amount of heat actually radiated away from the sun, divided by his mass, during any time in which the average temperature of his mass sinks by 1° , whatever physical or chemical changes any part of his substance may experience.

5. The "expansibility in volume," or the "cubical expansibility," of a body, is an expression technically used to denote the proportion which the increase or diminution of its bulk, accompanying a rise or fall of 1° in its temperature, bears to its whole bulk at some stated temperature. The expression, "the sun's expansibility," used in the text, may be taken as signifying the ratio which the actual contraction, during a lowering of his mean temperature by 1°C. , bears to his present volume.

6. One horse power in mechanics is a technical expression (following Watt's estimate) used to denote a rate of working in which energy is involved at the rate of 33,000 foot pounds per minute. This, according to Joule's determination of the dynamical value of heat, would, if spent wholly in heat, be sufficient to raise the temperature of $23\frac{3}{4}$ pounds of water by 1°C. per minute.

7. "Mechanical Energies of the Solar System." Note, p. 351.

focus-toward the upper focus. Now, these two foci being distant from each other not less than one fifth of the whole diameter of the orbit of Mercury, the libration of the planet is very great; and that point of Mercury which receives the solar rays vertically is projected on the surface of the planet, and oscillates along its equator in an arc which has an amplitude of forty-seven degrees—that is, more than an eighth of the whole circumference of the equator itself. The complete period of going and returning is equal to the time employed by Mercury in moving around its orbit—that is, almost eighty-eight terrestrial days. Mercury, therefore, is continually oriented to the sun as a magnetic needle to a piece of iron; but it does not point thither so constantly as not to permit of a certain oscillatory motion of the planet eastward and westward, similar to the moon's oscillation with respect to the earth. This oscillatory motion is of the greatest importance in respect to the physical condition of the planet. Let us suppose for a moment that this motion did not exist in fact, and that Mercury always presented the same hemisphere to the light and heat of the sun, the other hemisphere remaining wrapped in perpetual night. That point of the planet's surface which lies at the central pole of the illuminated hemisphere would eternally have the sun vertically above it; all other places upon Mercury which are reached by the sun's rays would always see the sun above the same point of the horizon, at the same altitude, without any apparent motion or sensible change of place whatever. Therefore such places would have no alternation of day and night, and no vicissitude of seasons. Remaining thus perpetually in presence of the sun, with the stars always invisible, Mercury having no moon, it is difficult to understand how the dwellers in the regions of perpetual day could make any determinations of time (or have any chronology). Upon Mercury things are nearly in this case, but not entirely so. The oscillating motion to which we have seen the body of the planet is subjected with respect to the sun would be attributed by an observer on the planet to the sun itself, just as we are used to attribute to the sun the diurnal motion of rotation which actually belongs to the earth. While, therefore, to us the sun seems to revolve continually from east to west, and thus determines the period of night and day to be



The Sun – ca 1890



Earth's Shadow

believe that all theories of complete, or nearly complete, contemporaneous meteoric compensation must be rejected; but we may still hold that "meteoric action ... is ... not only proved to exist as a cause of solar heat, but it is the only one of all conceivable causes which we know to exist from independent evidence." 7. The form of meteoric theory which now seems most probable, and which was first discussed on true thermodynamic principles by Helmholtz, 8. consists in supposing the sun and his heat to have originated in a coalition of smaller bodies, falling together by mutual gravitation, and generating, as they must do according to the great law demonstrated by Joule, an exact equivalent of heat for the motion lost in collision. That some form of the meteoric theory is certainly the true and complete explanation of solar heat can scarcely be doubted, when the following reasons are considered:

1. No other natural explanation, except by chemical action, can be conceived,
2. The chemical theory is quite insufficient, because the most energetic chemical action we know, taking place between substances amounting to the whole sun's mass, would only generate about 3,000 years' heat. 9.
3. There is no difficulty in accounting for 20,000,000 years' heat by the meteoric theory.

It would extend this article to too great a length, and would require something of mathematical calculation, to explain fully the principles on which this last estimate is founded. It is enough to say that bodies, all much smaller than the sun, falling together from a state of relative rest, at mutual distances all large in comparison with their diameters, and forming a globe of uniform density equal in mass and diameter to the sun, would generate an amount of heat which, accurately calculated according to Joule's principles and experimental results, is found to be just 20,000,000 times Pouillet's estimate of the annual amount of solar radiation. The sun's density must, in all probability,

cold. The presence of such an atmosphere upon Mercury was conjectured by Schroeter a century ago; in my observations I find more evident indications of it, which concur in making the probability of its existence almost a certainty. One of the first proofs springs from the continually observed fact that the markings on the planet, visible for the most part when they are found in the central regions of the disk, are less visible or even disappear as they approach its circular borders. I have been able to convince myself that this does not occur simply from the greater obliquity of the line of sight due to perspective, but from the fact that in that perimetral position there is actually a greater hindrance to the vision, and this seems to be due to nothing else but the greater length of the path which the visual rays coming from the non-central spot must pass through in the atmosphere of Mercury to reach the eye. And from this I conclude that the atmosphere of Mercury is less transparent than that of Mars, and that it more nearly resembles, in that regard, that of the earth. In addition to this, the circular border of the planet, where the spots become less visible, always appears more luminous than the rest of the disk. It is often irregularly luminous, in certain parts more so, in others less; and sometimes along this edge rather brilliant white areas may be seen which remain visible for several consecutive days, but which nevertheless are, in general, changeable, now in one portion and now in another. I attribute this fact to condensations in the interior of the atmosphere of Mercury, which must reflect the solar rays outward toward celestial space, and more strongly as they become more opaque. Such white areas are also often seen in the more central parts of the disk, but in that case they are not so brilliant as upon the border. But there is still more. The dark spots of the planet, although permanent in form and arrangement, are not always equally apparent, but are sometimes more intense and sometimes more faint; and it also happens that some of these markings occasionally become entirely invisible. This I can not attribute to any more obvious cause than to atmospheric condensations similar to our terrestrial clouds, which prevent more or less completely any view of the true surface of Mercury in any portion. The clouded regions of the earth must present an absolutely

(as we shall see in the third part of this article), could not have raised his mass at any time to this temperature, unless his specific heat were less than 10,000 times that of water. We may therefore consider it as rendered highly probable that the sun's specific heat is more than ten times, and less than 10,000 times, that of liquid water. From this it would follow with certainty that his temperature sinks 100° C. in some time from 700 years to 700,000 years. What, then, are we to think of such geological estimates as 300,000,000 years for the "denudation of the Weald"? Whether is it more probable that the physical conditions of the sun's matter differ 1,000 times more than dynamics compel us to suppose they differ from those of matter in our laboratories; or that a stormy sea, with possibly Channel tides of extreme violence, should encroach on a chalk cliff 1,000 times more rapidly than Mr. Darwin's estimate of one inch per century?

II. THE PRESENT TEMPERATURE OF THE SUN,

-At his surface the sun's temperature can not, as we have many reasons for believing, be incomparably higher than temperatures attainable artificially in our terrestrial laboratories, Among other reasons it may be mentioned that the sun radiates out heat from every square foot of his surface at only about 7,000 horse power.⁶ Coal, burning at a rate of a little less than a pound per two seconds, would generate the same amount; and it is estimated (Rankine, "Prime Movers," p. 285, edition 1852) that, in the furnaces of locomotive engines, coal burns at from one pound in thirty seconds to one pound in ninety seconds per square foot of grate-bars. Hence heat is radiated from the sun at a rate not more than from fifteen to forty-five times as high as that at which heat is generated on the grate-bars of a locomotive furnace, per equal areas. The interior temperature of the sun is probably far higher than that at his surface, because direct conduction can play no sensible part in the transference of heat between the inner and outer portions of his mass, and there must be an approximate convective equilibrium of heat throughout the whole,

conclusive argument to the contrary could be advanced. And as those spots are not grouped in great masses, but are dispersed about in areas and zones of no great width, much ramified, and alternated with clear spaces with some uniformity, it might be concluded that no vast oceans and great continents exist upon Mercury, but that the liquid and solid areas mingle with each other in reciprocal ways and with frequent vicissitudes, thus giving rise to a condition of things very different from that which exists upon the earth, and one which perhaps we might envy. At any rate, we have in the case of Mercury (as in Mars), a world which is sufficiently diverse from our own; which receives light and heat from the sun, not only in a greater amount but in a different manner than the earth; and where life, if so be life exists there, finds conditions so different from those to which we are accustomed that we can scarcely imagine them. The perpetual presence of the sun almost vertically above certain regions, and its perpetual absence from other regions, appears to us to be something intolerable. But we must recollect that such a contrast should produce an atmospheric circulation which is at the same time stronger, more rapid, and more regular than that which sows the elements of life on the earth; and ' that on this account it may come about that an equilibrium of temperature is produced quite as complete as ours, and possibly even more so. Mercury is conspicuously distinguished from the other planets by the manner of its revolution around the sun, turning always the same face toward it. All the other planets (at least so far as is ascertained in the cases which it has been possible to determine) revolve rapidly around their axes in the space of a few hours. Mercury's manner of revolution, however, which is unique among the planets, seems, on the other hand, quite usual for the satellites; such at least is true in all the cases where it has been possible to investigate the rotation motion of a satellite. That our own satellite has always in the memory of man shown to the earth the same hemisphere, is certain also from historical testimony, because Dante speaks of "Cain and the Thorns, " and among the smaller works of Plutarch there is one entitled "Of the Face to be seen In the Disk of the Moon." That the satellites of Jupiter show always the same face to their chief planet is probable as to the first three, and for

heat 4. of the sun's whole substance is less, and very certain that it can not be much greater, than that of water. If it were equal to the specific heat of water we should only have to divide the preceding number (6×10^{30}), derived from Herschel's and Pouillet's observations, by the number of pounds (4.3×10^{30}) in the sun's mass, to find 1.4^0 C. for the present annual rate of cooling. It might therefore seem probable that the sun cools more, and almost certain that he does not cool less, than a centigrade degree and four tenths annually. But, if this estimate were well founded, it would be equally just to assume that the sun's expansibility 5. with heat does not differ greatly from that of some average terrestrial body. If, for instance, it were the same as that of solid glass, which is about $1/40000$ on bulk, or $1/120000$ on diameter, per 1^0 C. (and for most terrestrial liquids, especially at high temperatures, the expansibility is much more), and if the specific heat were the same as that of liquid water, there would be in 860 years a contraction of one per cent on the sun's diameter, which could scarcely have escaped detection by astronomical observation. There is, however, a far stronger reason than this for believing that no such amount of contraction could have taken place, and therefore for suspecting that the physical circumstances of the sun's mass render the condition of the substances of which it is composed, as to expansibility and specific heat, very different from that of the same substances when experimented on in our terrestrial laboratories. Mutual gravitation between the different parts of the sun's contracting mass must do an amount of work, which can not be calculated with certainty, only because the law of the sun's interior density is not known. The amount of work performed on a contraction of one tenth per cent of the diameter, if the density remained uniform throughout the interior, would, as Helmholtz showed, be equal to 20,000 times the mechanical equivalent of the amount of heat which Pouillet estimated to be radiated, from the sun in a year. But in reality the sun's density must increase very much toward his centre, and probably in varying proportions, as the temperature becomes lower and the whole mass contracts. We can not, therefore, say whether the work actually done by mutual gravitation during a contraction of one

motionless at their posts. It was concluded rightly from this that they must occupy the poles of rotation of the planet, or at least must be found very near to them. Consequently they were given the name of polar caps or spots. And not without reason is it conjectured that these represent upon Mars that immense mass of snow and ice which still today prevents navigators from reaching the poles of the earth. We are led to this conclusion not only by the analogy of aspect and of place, but also by another important observation. As things stand, it is manifest that if the above-mentioned white polar spots of Mars represent snow and ice they should continue to decrease in size with the approach of summer in those places and increase during the winter. Now this very fact is observed in the most evident manner. In the second half of the year 1892 the southern polar cap was in full view; during that interval, and especially in the months of July and August, its rapid diminution from week to week was very evident to those observing with common telescopes. This snow (for we may well call it so), which in the beginning reached as far as latitude 70° , and formed a cap of over 2,000 kilometres (1,200 miles) in diameter, progressively diminished, so that two or three months later little more of it remained than an area of perhaps 300 kilometres (180 miles) at the most, and still less was seen in the last days of 1892. In these months the southern hemisphere of Mars had its summer, the summer solstice occurring upon October 13th. Correspondingly the mass of snow surrounding the northern pole should have increased; but this fact was not observable, since that pole was situated in the hemisphere of Mars which was opposite to that facing the earth. The melting of the northern snow was seen in its turn in the years 1882, 1884, and 1886. These observations of the alternate increase and decrease of the polar snows are easily made even with telescopes of moderate power, but they become much more interesting and instructive when we can follow assiduously the changes in their more minute particulars, using larger instruments. The snowy regions are then seen to be successively notched at their edges; black holes and huge fissures are formed in their interiors; great isolated pieces many miles in extent stand out from the principal mass and, dissolving, disappear a little later. In short, the same divisions and movements of

I. THE SECULAR COOLING OF THE SUN.-How much the sun is actually cooled from year to year, if at all, we have no means of ascertaining, or scarcely even of estimating in the roughest manner. In the first place we do not know that he is losing heat at all. For it is quite certain that some heat is generated in his atmosphere by the influx of meteoric matter; and it is possible that the amount of heat so generated from year to year is sufficient to compensate the loss by radiation. It is, however, also possible that the sun is now an incandescent liquid mass, radiating away heat, either primitively created in his substance, or, what seems far more probable, generated by the falling in of meteors in past times, with no sensible compensation by a continuance of meteoric action. It has been shown 2. that, if the former supposition were true, the meteors by which the sun's heat would have been produced during the last 2,000 or 3,000 years must have been all that time much within the earth's distance from the sun, and must therefore have approached the central body in very gradual spirals; because, if enough of matter to produce the supposed thermal effect fell in from space outside the earth's orbit, the length of the year would have been very sensibly shortened by the additions to the sun's mass which must have been made. The quantity of matter annually falling in must, on that supposition, have amounted to $1/47$ of the earth's mass, or to $1/15000000$ of the sun's; and therefore it would be necessary to suppose "the zodiacal light" to amount to at least $1/5000$ of the sun's mass, to account in the same way for a future supply of 3,000 years' sun-heat. When these conclusions were first published it was pointed out that disturbances in the motions of visible planets "should be looked for, as affording us means for estimating the possible amount of matter in the zodiacal light; and it was conjectured that it could not be nearly enough to give a supply of 30,000 years' heat at the present rate. These anticipations have been to some extent fulfilled in Le Verrier's great researches on the motion of the planet Mercury, which have recently given evidence of a sensible influence attributable to matter circulating, as a great number of small planets, within his orbit round the sun. But the amount of matter thus indicated is very small; and, therefore, if the meteoric influx taking place at present is enough to

And it is to be remembered as a very probable thing that the flowing of this melted snow is the cause which determines principally the hydrographic state of the planet and the variations that are periodically observed in its aspect. Something similar would not be seen upon the earth if one of our poles came to be located suddenly in the centre of Asia or of Africa. As things stand at present, we may find a miniature image of these conditions in the flooding that is observed in our streams at the melting of the Alpine snows. Travellers in the arctic regions have frequent occasion to observe how the state of the polar ice at the beginning of the summer, and even at the beginning of July, is always very unfavourable to their progress. The best season for exploration is in the month of August, and September is the month in which the trouble from the ice is the least. Thus in September our Alps are usually more practicable than at any other season. And the reason for it is clear—the melting of the snow requires time; a high temperature is not sufficient; it is necessary that it should continue, and its effect will be so much the greater, as it is the more prolonged. Thus, if we could slow down the course of our season so that each month should last sixty days instead of thirty, in the summer, in such a lengthened condition, the melting of the ice would progress much further, and perhaps it would not be an exaggeration to say that the "polar cap at the end of the warm season would be entirely destroyed. But one can not doubt, in any case, that the fixed portion of such a cap would be reduced to much smaller size than we see it to-day. Now, this is exactly what happens on Mars. The long year, nearly double our own, permits the ice to accumulate during the polar night of ten or twelve months, so as to descend in the form of a continuous layer as far as parallel 70° , or even farther. But in the day which follows, of twelve or ten months, the sun has time to melt all, or nearly all, of the snow of recent formation, reducing it to such a small area that it seems to us no more than a very white point. And perhaps this snow is entirely destroyed; but of this there is at present no satisfactory observation. Other white spots of a transitory character and of a less regular arrangement are formed in the southern hemisphere upon the islands near the pole, and also in the opposite hemisphere whitish

planet's interior. Rather may we see in a planet such as Eros a portion of the primeval solar nebula unused in the formation either of Mars or of the earth. The minor planets are probably no fragments of a larger planet previously existing, but the fragments that might have helped to form a larger planet had it not been for the influence of the mighty globe of Jupiter. We may see in them one more instance of the effect of that process of tidal action which Professor Darwin has of late so wonderfully applied to show how the matter of the moon may, in bygone time, have been disrupted from the then viscous earth, in the form of a succession of lumps broken off by centrifugal effect from the summits of great tidal waves—a hypothesis which is found to be of ever-widening application, as, for instance, to the genesis of double stars, and to the temporary outburst of such stars as that which Kepler saw in 1572 in Cassiopeia. The attraction of the globe of Jupiter, as the solar nebula contracted within his orbit, may well have produced such tides in its mass as, in place of allowing a greater quantity of matter or a nebulous ring to be more quietly detached at some subsequent epoch, so as to form another large globe, may have caused many and many a smaller portion to have been broken off and left behind. These portions we may now see in the hundreds of minor planets which have so far been discovered. After a while, it may be supposed that the influence of Jupiter was so far left behind by the continued contraction of the solar nebula that the formation of larger globes, such as those of Mars and the earth, Venus and Mercury, began again. However this may be, let us hope that in the succession of celestial photographs now being continuously secured other similar fragments may ere long be revealed whose orbits may be as interesting as that of Eros, whether they may revolve within, or, like it, outside of the orbit of the earth. Let us hope that some of them may approach the earth even more closely than Eros. If so, they will be still more useful rewards of the unwearied industry of observers and computers, and of the skill displayed in astronomical photography.

moment Nature brings forth an infinite variety in its operations. Of the greatest influence must be different arrangement of the seas and the continents upon Mars and upon the earth, regarding which a glance at the map will say more than would be possible in many words. We have already emphasized the fact of the extraordinary periodical flood, which at every revolution of Mars inundates the northern polar region at the melting of the snow. Let us now add that this inundation is spread out to a great distance by means of a network of canals, perhaps constituting the principal mechanism (if not the only one) by which water (and with it organic life) may be diffused over the arid surface of the planet. Because on Mars it rains very rarely, or perhaps even it does not rain at all. And this is the proof. Let us carry ourselves in imagination into celestial space, to a point so distant from the earth that we may embrace it all at a single glance. He would be greatly in error who had expected to see reproduced there upon a great scale the image of our continents with their gulfs and islands and with the seas that surround them which are seen upon our artificial globes. Then without doubt the known forms or part of them would be seen to appear under a vaporous veil, but a great part (perhaps one half) of the surface would be rendered invisible by the immense fields of cloud, continually varying in density, in form, and in extent. Such a hindrance, most frequent and continuous in the polar regions, would still impede nearly half the time the view of the temperate zones, distributing itself in capricious and ever-varying configurations. The seas of the torrid zone would be seen to be arranged in long parallel layers, corresponding to the zone of equatorial and tropical calms. For an observer placed upon the moon the study of our geography would not be so simple an undertaking as one might at first imagine. There is nothing of this sort in Mars. In every climate and under every zone its atmosphere is nearly perpetually clear and sufficiently transparent to permit one to recognise at any moment whatever the contours of the seas and continents and, more than that, even the minor configurations. Not, indeed, that vapours of a certain degree of opacity are lacking, but they offer very little impediment to the study of the topography of the planet. Here and there we see appear from time to time a few

an excellent test as to whether the light received from it varies exactly as the inverse square of its distance from us, or meets with any hindrance, or absorbing medium, in its passage. The comparison of its light with the phases of its little disk corresponding to its positions relatively to the earth and the sun will also be instructive. The discovery of Eros has afforded a most important proof of the value of stellar photographs carefully kept and preserved. For the more accurate determination of the elements of its orbit it was very desirable to obtain, if possible, records of its exact position in previous years. Very careful search was therefore made among the many plates preserved at the Harvard College Observatory, in America, in order to see if its faint trace could be found upon some of those which had been exposed in 1896. It seemed almost impossible to detect it. But at last success rewarded a search which proved most trying to the eyes. Mrs. Fleming, well known for her splendid work in connection with stellar spectra in the Harvard Observatory, detected the trail upon a plate dated the 5th of June, 1896. It was soon found upon other plates of that year, as its probable position could not be more precisely calculated; then on others of 1893 and 1894; upon thirteen plates in all. Its orbit is consequently known at the present time with great accuracy. There is no reason to suppose that Eros is a body recently drawn, by the attraction of the earth, into its present orbit. Its near approach to the earth is by no means near enough for such an event as that to have occurred. It has doubtless escaped previous observation because its light has only exceeded that of an eighth-magnitude star (or, for the purpose of photography, as it seems to be wanting in violet rays, that of a ninth-magnitude star) for about two months in the last eleven years. On the comparatively rare occasions of its very nearest approach it will be barely within the range of visibility to the naked eye. In conclusion, it may be noticed that the proximity of the orbit of this little neighbour to that of the earth may afford one more argument against the hypothesis put forward by Olbers's of the supposed origin of the minor planets by the explosion of a larger planet, a hypothesis which for a while met with much acceptance. When only four minor planets had been discovered, three at least of

while the Cimmerium, the Sirenum, and the Solis Lacus are connected with it only by means of narrow canals. We shall notice in the first four a parallel arrangement, which certainly is not accidental, as also not without reason is the corresponding position of the peninsulas of Ausonia, Hesperia, and Atlantis. The colour of the seas of Mars is generally brown, mixed with gray, but not always of equal intensity in all places, nor is it the same in the same place at all times. From an absolute black it may descend to a light gray or to an ash colour. Such a diversity of colours may have its origin in various causes, and is not without analogy also upon the earth, where it is noted that the seas of the warm zone are usually much darker than those nearer the pole. The water of the Baltic, for example, has a light, muddy colour that is not observed in the Mediterranean. And thus in the seas of Mars we see the colour become darker when the sun approaches their zenith, and summer begins to rule in that region. All of the remainder of the planet, as far as the north pole, is occupied by the mass of the continents, in which, save in a few areas of relatively small extent, an orange colour predominates, which sometimes reaches a dark-red tint, and in others descends to yellow and white. The variety in this colouring is in part of meteorological origin, in part it may depend on the diverse nature of the soil, but in its real cause it is not as yet possible to frame any very well grounded hypothesis. Nevertheless, the cause of this predominance of the red and yellow tints upon the surface of ancient Pyrois is well known. Some have thought to attribute this colouring to the atmosphere of Mars, through which the surface of the planet might be seen coloured, as any terrestrial object becomes red when seen through red glass. But many facts are opposed to this idea, among others that the polar snows appear always of the purest white, although the rays of light derived from them traverse twice the atmosphere of Mars under great obliquity. We must then conclude that the Aerean continents appear red and yellow because they are so in fact. Besides these dark and light regions, which we have described as seas and continents, and of whose nature there is at present scarcely left any room for doubt, some others exist, truly of small extent, of an amphibious nature, which sometimes appear yellowish like the

altering the apparent direction in which the planet would be seen as if he were looking at it one moment from Jamaica, and then were suddenly transported to see it from Aden. The difference in the directions in which the planet is seen from two such standpoints, as compared with the positions of the stars around it, which are so distant that no change is produced in their apparent places, is in such cases large enough to be capable of very accurate measurement, and will be so much the larger and more easily measurable the nearer any planet employed is to the earth. It was a few years ago supposed that the diurnal method would prove to be the most satisfactory possible, because in it the same observer and the same instrument can be employed for all the observations. We are inclined to think that this may ultimately prove to be the case if an observatory suitably equipped, and situated near to, the equator, can be employed. Dr. Gill has, however, introduced such improvements into the other method that it has been chiefly used under his superintendence for the last published and most accurate result that has yet been obtained-viz., from observations of the minor planets Victoria, Sappho, and Iris, made in 1888 and 1889 at the Cape of Good Hope, and at Yale, Leipsic, Gottingen, Bamberg, and Oxford (Radcliffe) Observatories. But it is very interesting that it is also found that observations (nearly 3,500 in number) made at the same time by the diurnal method upon the planet Victoria at the Cape, although that observatory is unfavourably situated for the use of this method, in a latitude thirty-four degrees south of the equator, gave almost precisely the same result-a value of very nearly 92,875,000 miles as the distance of the sun from the earth. This is a very trustworthy value, but it nevertheless involves an uncertainty of about 50,000 miles, or possibly somewhat more. It was obtained by the observation of planets selected for their suitability of position and because their orbits were very accurately known, which did not, however, come within a distance equal to six times that of the nearest approach which Eros may make to the earth. There is every reason, therefore, to hope that our future observations of Eros may give us this all-important unit for all our celestial measurements-the distance of the earth from the sun-with an accuracy six times greater than any which

the continuity was only seen to be broken once for a short time in 1888. Other smaller dark spots are found here and there in the continental area which we may designate as lakes, but they are certainly not permanent lakes like ours, but are variable in appearance and size according to the seasons, to the point of wholly disappearing under certain circumstances. Ismenius Lacus, Lunae Lacus, Trivium Charontis, and Propontis are the most conspicuous and durable ones. There are also smaller ones, such as Lacus Moeris and Fons Juventae, which at their maximum size do not exceed 100 to 150 kilometres (60 to 90 miles) in diameter, and are among the most difficult objects upon the planet. All the vast extent of the continents is furrowed upon every side by a network of numerous lines or fine stripes of a more or less pronounced dark colour, whose aspect is very variable. These traverse the planet for long distances in regular lines that do not at all resemble the winding courses of our streams. Some of the shorter ones do not reach 500 kilometres (300 miles), others, on the other hand, extend for many thousands, occupying a quarter or some-times even a third of a circumference of the planet. Some of these are very easy to see, especially that one which is near the extreme left-hand limit of our map, and is designated by the name of Nilosyrtris. Others in turn are extremely difficult, and resemble the finest thread of spider's web drawn across the disk. They are subject also to great variations in their breadth, which may reach 200 or even 300 kilometres (120 to 180 miles) for the Nilosyrtris, while some are scarcely 30 kilometres (18 miles) broad. These lines or stripes are the famous canals of Mars, of which so much has been said. As far as we have been able to observe them hitherto, they are certainly fixed configurations upon the planet. The Nilosyrtris has been seen in that place for nearly one hundred years, and some of the others for at least thirty years. Their length and arrangement are constant, or vary only between very narrow limits. Each of them always begins and ends between the same regions. But their appearance and their degree of visibility vary greatly, for all of them, from one opposition to another, and even from one week to another, and these variations do not take place simultaneously and according to the same laws for all, but in

plate with the hope of obtaining upon it the trail of another previously known minor planet. He succeeded, but upon the plate there was also a second, fainter trail-faint and of unusual length because of the rapidity with which the planet had moved. This indicated an unusual orbit. Further observations were at once made. From them Herr Berberich calculated what proved to be a most surprising orbit. The path of Mars up to this time had practically formed the boundary beyond which minor planets had hardly transgressed. This new planet came 45,000,000 miles within the mean distance of Mars. With the exception of the moon it is by far the nearest celestial neighbour of the earth, the nearest approach even of Venus to the earth being not much less than twice as great. But let us now ask, Why should the near approach of Eros to the earth attach an extraordinary value to our acquaintance with it? Is it because we may hope to see the details of its surface, or: to set up some communication between it and the earth? By no means. If we may judge by the amount of light which it reflects to us, we may conclude that its diameter is probably less than twenty miles. The largest telescope, therefore, will barely reveal in it any disk of measurable breadth. On the contrary, the great value of this little Eros depends upon its enabling us to measure the scale upon which the whole universe around us is constructed with an accuracy much surpassing any that has been previously attained. Our estimate, for instance, of the distance of any star, or of the size of the orbits of any pair of double stars, in fact, all our measurements in the celestial spaces, depend upon our knowledge of the distance of the earth from the sun. To determine that distance a direct trigonometrical method, such as is used in surveying, and such as may be applied to find the distance of the moon from the earth, can not be used, as no instruments can be constructed of the necessary delicacy. But there is a remarkable proportion connected with the movements of the planets in their orbits, discovered by Kepler and more fully investigated by the genius of Newton, which enables us at once to determine the distance of the sun, if only we can measure the distance of anyone of the other planets from the earth. It was at one time hoped that this might be accurately determined in the case of Venus by observations made on

lines called canals are truly great furrows or depressions in the surface of the planet, destined for the passage of the liquid mass and constituting for it a true hydrographic system, is demonstrated by the phenomena which are observed during the melting of the northern snows. We have already remarked that at the time of melting they appeared surrounded by a dark zone, forming a species of temporary sea. At that time the canals of the surrounding region become blacker and wider, increasing to the point of converting at a certain time all of the yellow region comprised between the edge of the snow and the parallel of 60° north latitude into numerous islands of small extent. Such a state of things does not cease until the snow, reduced to its minimum area, ceases to melt. Then the breadth of the canals diminishes, the temporary sea disappears, and the yellow region again returns to its former area. The different phases of these vast phenomena are renewed at each return of the seasons, and we were able to observe them in all their particulars very easily during the oppositions of 1882, 1884, and 1886, when the planet presented its northern pole to terrestrial spectators. The most natural and the most simple interpretation is that to which we have referred, of a great inundation produced by the melting of the snows; it is entirely logical and is sustained by evident analogy with terrestrial phenomena. We conclude, therefore, that the canals are such in fact and not only in name. The network formed by these was probably determined in its origin in the geological state of the planet, and has come to be slowly elaborated in the course of centuries. It is not necessary to suppose them the work of intelligent beings, and, notwithstanding the almost geometrical appearance of all of their system, we are now inclined to believe them to be produced by the evolution of the planet, just as on the earth we have the English Channel and the channel of Mozambique. It would be a problem not less curious than complicated and difficult to study the system of this immense stream of water, upon which perhaps depends principally the organic life upon the planet, if organic life is found there. The variations of their appearance demonstrated that this system is not constant. When they become displaced, or their outlines become doubtful and ill defined, it is fair to suppose that the water is getting

important problems of astronomy. In order to appreciate the method of its discovery, and the reasons which make that discovery so important, it will be well briefly to recall what had been previously achieved in the same line of research. Copernicus had proved and Kepler and others had drawn attention to the greatness of the gap between the orbits of Mars and Jupiter. Then, in 1781, Sir William Herschel detected the planet Uranus at a distance from the sun agreeing with the next term of a series which Titius and Bode had noticed as almost exactly representing the distances of the other planets, except that for one term, between those which corresponded with Mars and Jupiter, there was no planet known. While twenty-four astronomers were arranging a search for such a missing member of the solar system, Piazzi (who was not one of them) unexpectedly detected at Palermo, on the 1st of January, 1801, a little planet, afterward named Ceres. Three more were found by two out of the twenty-four astronomers in the course of the next six years. A fifth was found in 1845, after an interval of thirty-eight years; then the progress became rapid. Since 1846 no year has passed without such a discovery. In 1868 the total reached 100; in 1879, 200; in 1890, 300; in 1895, 400; and now it is nearly 450. After a few of the brighter ones had been detected the search for others became a wearisome process. New star charts had to be constructed, with great labour, so as to include the fainter stars. If a small star was noticed with the telescope which could not be found in them, it was carefully watched, and if it exhibited an orbital movement it was entered on the list of planets, and the various elements of its orbit were calculated and recorded. But when many astronomers were inclined to look upon all this work as well-nigh profitless, and too wearisome to be continued, photography with startling suddenness did away with all need of star charts and of any comparison of observations with them. Upon a photographic plate suitably exposed, Herr Max Wolf, of Heidelberg, found that a little planet had recorded its place on the 22d of December, 1891. There was no need to compare the plate with any chart of stars. The planet had asserted its right to the name of Wanderer by moving on a little way in its orbit among the stars during the exposure of the plate. The stars left their traces in

miles), up to more than 100 kilometres (60 miles). The colour of the two lines varies from black to a light red, which can hardly be distinguished from the general yellow background of the continental surface. The space between is for the most part yellow, but in many cases appears whitish. The gemination is not necessarily confined only to the canals, but tends to be produced also in the lakes. Often one of these is seen transformed into two short, broad dark lines parallel to one another and traversed by a yellow line. In these cases the gemination is naturally short and does not exceed the limits of the original lake. The gemination is not shown by all at the same time, but when the season is at hand it begins to be produced here and there, in an isolated, irregular manner, or at least without any easily recognisable order. In many canals (such as the Nilosyrtris, for example) the gemination is lacking entirely, or is scarcely visible. After having lasted for some months, the markings fade out gradually and disappear until another season equally favourable for their formation. Thus it happens that in certain other seasons (especially near the southern solstice of the planet) few are seen, or even none at all. In different oppositions the gemination of the same canal may present different appearances as to width, intensity, and arrangement of the two stripes; also in some cases the direction of the lines may vary, although by the smallest quantity, but still deviating by a small amount from the canal with which they are directly associated. From this important fact it is immediately understood that the gemination can not be a fixed formation upon the surface of Mars and of a geographical character like the canals. The second of our maps will give an approximate idea of the appearance which these singular formations present. It contains all the geminations observed since 1882 up to the present time. In examining it it is necessary to bear in mind that not all of these appearances were simultaneous, and consequently that the map does not represent the condition of Mars at any given period; it is only a sort of topographical register of the observations made of this phenomenon at different times. 3. The observation of the geminations is one of the greatest difficulty, and can only be made by an eye well practised in such work, added to a telescope of accurate construction and of great power. This explains

said to have a surface at all. As the changes due to the gradual cooling and contraction proceed, life in its simpler forms becomes possible, and in course of time a state is reached like that of this globe at present, in which the conditions for highly organized life are at their best. Assuming this, the question of fact becomes, is there any other planet or satellite in the system in which this state of maximum habitability, if we may so call it, now exists? We can say with great confidence that it does not on Jupiter and Saturn; that the chances are much against it on Uranus and Neptune; that Venus and Mercury are probably still too young for it; but that there is a reasonable probability for it on Mars, though this planet seems to be passing into the decline, the steps of which we do not clearly understand, but of which we see perhaps the final result in the torn, scarred, and desolate surface of our own satellite. With regard to the satellites of the great planets, we have absolutely to suspend judgment. As the period of habitability is probably less than that of development, though of this we are far from certain, the chances are perhaps against any particular one of them being in that state just now; but as they number at least seventeen altogether, the probability that some one of them may be habitable is not so inconsiderable. As to the satellites of Mars, and the swarm of asteroids, they seem to be too small to retain an atmosphere sufficient for the support of beings like ourselves. If they had a course to run, it has probably been concluded long ago. In speaking of the natural life and development of the planets, we are, of course, looking at the matter merely from a scientific point of view. Of course, most Christians believe that long before the natural life of this earth would be concluded, it will suffer a final catastrophe which will at least close the history of the human race on it as it exists now. Such catastrophes may, of course, occur to any planet by natural as well as supernatural causes; by collision with some other body, for instance; or to the whole planetary system, by some large body striking on the sun. One thing which we may perhaps look forward to is a time when, after the death or destruction of all the planets, the sun itself ceasing to be a luminary and furnace for bodies circulating round it, may itself become the great seat and

with the present argument. Having regard, then, for the principle that in the explanation of natural phenomena it is universally agreed to begin with the simplest suppositions, the first hypotheses of the nature and cause of the geminations have for the most part put in operation only the laws of inorganic Nature. Thus, the gemination is supposed to be due either to the effects of light in the atmosphere of Mars, or to optical illusions produced by vapours in various manners, or to glacial phenomena of a perpetual winter, to which it is known all the planets will be condemned, or to double cracks in its surface, or to single cracks of which the images are doubled by the effect of smoke issuing in long lines and blown laterally by the wind. The examination of these ingenious suppositions leads us to conclude that none of them seem to correspond entirely with the observed facts, either in whole or in part. Some of these hypotheses would not have been proposed had their authors been able to examine the geminations with their own eyes. Since some of these may ask me directly: "Can you suggest anything better?" I must reply candidly, "No." It would be far more easy if we were willing to introduce the forces pertaining to organic Nature. Here the field of plausible supposition is immense, being capable of making an infinite number of combinations capable of satisfying the appearances even with the smallest and simplest means. Changes of vegetation over a vast area, and the production of animals, also very small, but in enormous multitudes, may well be rendered visible at such a distance. An observer placed in the moon would be able to see such an appearance at the times in which agricultural operations are carried out upon one vast plain-the seed- time and the gathering of the harvest. In such a manner also would the flowers of the plants of the great steppes of Europe and Asia be rendered visible at the distance of Mars-by a variety of colouring. A similar system of operations produced in that planet may thus certainly be rendered visible to us. But how difficult for the Lunarians and the Areans to be able to imagine the true causes of such changes of appearance without having first at least some superficial knowledge of terrestrial nature! So also for us, who know so little of the physical state of Mars, and nothing of its organic world, the great liberty of possible supposition renders

soul; nor does it seem to me that the mere size of these planets makes them much more remarkable, or requires more reason for their formation, than if they were only a few feet in diameter. The technical study of astronomy, no doubt, has the effect of reducing the impression made by mere magnitude on the mind; whether this is a delusion or the removal of a delusion, of course I can not say. That the mere size of a body itself does not require inhabitants for it, seems plain from the generally confessed impossibility of inhabiting the sun, the surface of which far exceeds that of all the planets put together—that is to say, that it does not require them at every moment; but it may be, if you will, that it does require that at some time or other it should be used for such a purpose. The general belief is, we may say, an argument for the fact. And, of course, the argument for the plurality of worlds is strengthened if, besides size or standing-room, as we may say, we see some other conditions indicating conveniences for life, though they be imperfect or incomplete. If we see a house with only its framework up, we say, "Nobody lives there now, but it is being built for some one"; and if we see a house in ruins, we say, "Somebody lived there once." Now, this is certainly very plausible; and I think that the history of our own earth, so far as it can be learned from science, increases the probability of the opinion that the planets, and perhaps even the sun itself, were made to be inhabited at some time or other. The teaching of geology is that our own earth was for a long time uninhabitable; that it subsequently became fitted to be the abode of the inferior and simpler forms of life, and finally became ready for the reception of man; and we can hardly shut our eyes, either, to the scientific conclusion that, from the operation of natural causes alone, it would at some time in the distant future become uninhabitable again, though in a different way; that it would become, simply from the changes which must come from the gradual progress of cooling necessarily going on in the solar system, no longer a building which its Creator is forming, but a cold and desolate ruin like the moon. The history of this earth is probably the history of the other planets, if they are to be allowed to develop in a natural way. Some, like the moon, seem to have passed farther along the road than our own planet. This is probably the case with

the region referred to being that in which the central branch of the fork of the Y appeared. Since no such branch was conspicuously visible this year, it would therefore seem from the above that it was the opposition of 1892 that was peculiar, and not the present one.-TRANSLATOR.

3. This map may be found in "La Planete Mars," by Flammarion, page 440.-TRANSLATOR.

MARS

by W. F. Denning

AT intervals of about two years a bright red star becomes conspicuously visible in the firmament throughout the night, and remains thus favourably in view for several months together. Then, setting earlier each time it falls to the horizon, and gradually becoming less brilliant, it is seen for a portion of the night only until, after the lapse of a few more months, it may scarcely be discerned at all, for now, immersed in the twilight and setting in the early evening, the nocturnal sky loses one of its brightest ornaments. This is the planet Mars, which, arriving at opposition to the sun once in little more than two years (or, more exactly, 780 days) attains considerable brilliancy, and becomes noticeable as a singularly interesting object in his bright ruddy splendour. But in different years the appearance of Mars, as seen by

diameters; or, to use another illustration, the ball of the planet would look about three and a half times the diameter of the moon, and the rings nearly nine times that diameter. We come next, in our inward course, to the planet Mars. Here, for the first time, we begin to see positive signs, instead of mere negative possibilities, of what we have been looking for. We have noticed, as we passed this planet on our way outward from the sun, the similarity of its surface to that of the earth, the permanent configurations on it of what we have a good right to assume to be land and water. We have seen its polar ice-caps, its green seas, and red earth; and we know that it has an atmosphere which, though not as dense as our own, is still enough, as it would seem, for life. We know that it has a day almost exactly the same as ours, and not only this, but seasons substantially like our own, as far as the varying angle is concerned at which the sun's rays strike its surface, though it is true that these are a good deal interfered with by the considerable variation in the sun's heat, depending on the eccentricity of its orbit; still this would not amount to so very much. In this latitude, for instance, on the earth, we receive more than three times the heat from the sun in one day in the middle of June than we get in the middle of December, on any given " area, say a square mile or a square yard, owing to the combined influence of the greater height of the sun above the horizon and the greater length of the daylight. About the same would be the case in the same latitude on Mars. The effect of the eccentricity would be quite considerable, making the sun's heat once and a half as great at the nearest point as at the farthest; still, if we can sustain the three-fold multiplication, a half as much again might be added, without the variation becoming intolerable. Moreover, this great variation would only occur when the summer solstice of one of the hemispheres coincided with the point of nearest approach to the sun. During half the time, the eccentricity would tend to moderate, instead of to accentuate, the seasons, as it does with us here in the northern hemisphere now. Mars is certainly the most favourable case for those who would believe the planets to be habitable. It really seems that it might be inhabited by men like ourselves. As remarked on a previous occasion, its climate seems, from the small size of the polar ice-caps, to be warmer than that of

not with equal distinctness. This arises simply from the fact that they are not seen under precisely similar conditions. When the planet is in that part of his orbit nearest to the earth his apparent diameter is greatest, and obviously the markings on his disc will be exhibited very favourably for inspection. Again, our own atmosphere will occasionally allow very excellent views of celestial objects, while at other times little or nothing can be seen through its moisture-laden strata. More-over, the inclination of the planet's axis originates apparent changes in the forms of the markings at different oppositions. Sometimes the southern hemisphere is chiefly presented to view, and sometimes the northern. The true figure of a marking cannot be distinguished unless it is seen at the centre of the apparent disc. Spots near the margin are contracted by the effects of foreshortening. Such differences, therefore, as are observable in the aerographic appearance of Mars are in no way attributable to changes on his surface, but have their origin in his varying distance, and in atmospheric causes. The dark and light objects which diversify his disc are really permanent features existing on his globe, and though they may often be a little dimmed by atmospheric interference (just as we may imagine that, to an observer on Mars, the continents and seas of the earth are partially shrouded by the clouds in our own atmosphere), yet they invariably reappear with former distinctness, exhibiting precisely similar shapes to those depicted in past years. Figs. 1 and 2 are views 1 of Mars selected from a large number of sketches made by Mr. Nathaniel Green in 1873, with a reflecting telescope of 9 inches aperture, and magnifying powers of from 200 to 400. In Fig. 1, that prominent marking, the Kaiser Sea (connected with Dawes Ocean in the southern hemisphere, and projecting towards the Delambre Sea in the northern hemisphere) is well shown as a latitudinal hand tapering at its northern extremity, and curling up as it turns eastwards. In Fig. 2 the planet's rotation has carried the Kaiser Sea to the western margin of the disc, and another conspicuous though more diffused shading has entered well into view. This is the Knobel Sea, and on the southern limb that dark irregular marking, the De la Rue Ocean, is very distinctly marked. The character of the spots on Mars gives the impression of land and

however, as we may say, rather negative than positive; we can not give any certain reason why they should not be; but there are really no positive indications to show that they are fit to be the abode of life. The arguments against habitability become much stronger in the case of the two giants of the planetary system, Saturn and Jupiter, which come next in order as we proceed toward the sun. The brilliancy of Jupiter's surface, and the rapidity of the changes which we see there, exceeding what the moderate light and heat which it receives from the sun would be likely to produce, seem to be quite strong arguments that it is still in a condition to emit light and heat to a considerable extent on its own account; and, indeed, that its temperature is still sufficient to keep it in a fluid state. If its surface be indeed in the condition of molten metal, it certainly becomes uninhabitable in the common-sense view of the subject; for in melted metal no organism composed of ordinary chemical elements could possibly subsist. These arguments apply with somewhat diminished force to Saturn. Another, however, which may perhaps be derived from the lightness or small density of all the four great exterior planets of which we have been speaking, is strongest in the case of this one. This lightness may indicate that they have not yet shrunk to their proper dimensions; for it seems reasonable enough to suppose that the chemical constituents throughout the solar system are the same; that all the planets are chips out of the same block; and that when all are reduced to the physical state of the earth they would have about the same density. But this does not seem to amount to much; for though it holds well enough in the cases of Mars and Venus, it notably fails in that of Mercury, if the determinations of the mass of that planet can be considered as trustworthy. The density of Mercury would appear, it will be remembered, to be twice that of the earth; which would prove most undoubtedly that it was made of decidedly heavier materials, unless we maintain that it is very much more solidified than the earth, which would seem to be improbable. When a planet has once become, like the earth, solid on the surface, no further perceptible shrinkage is possible except by a complete breaking up of the crust, which could hardly result except from a collision. But to return to the great planets of which we have been

formation by the Italian observers in 1877 the appearance is remarkably different, consisting of a small triangular patch slightly within the south border of the disc. The delineations of Mars, though agreeing in the main, are yet in some respects strangely dissimilar. The various forms of telescope employed, the different epochs of observation, the differences in vision, and the manner of depicting and interpreting what is seen, all contribute to create discordances ; amongst the results. Yet, as has been said, in the main the general facts are accordant, and observers have at times confirmed each other in an astonishing degree, so that at the present day there can be no doubt as to the form and extent of the principal markings on Mars. Physical changes have been inferred, but none are proved to have occurred. During the last favourable appearance of Mars in 1877, the Italian astronomer Schiaparelli recognised a number of dark, narrow channels or canals intersecting the planet's equatorial zone, and these he had not seen before October in that year, nor had any other observer distinguished them at any previous date. It seems, however, a probable inference that these irregular lines of shading are to be referred to instrumental or visionary errors, for in the more powerful telescopes directed to the planet's disc at the same period, no traces of these remarkable appearances were seen, and it has been adduced in explanation of the observed peculiarities, that minute dusky shadings will, with bad definition, apparently become lines, especially when several lie nearly together. The canals or channels supposed to have been distinguished by the Italians are represented in Fig. 4 (planet in long. 0° , lat. 25° S.). Fig. 4. Suspected Canals on Mars. That Mars has an atmosphere appears extremely probable, for such an envelope is implied in the formation of snow. It is, however; likely to be only moderately dense, and does not originate the intense ruddy tinge of the planet's light as some have believed, for this is most decided in the region about the centre of the disc. Obviously the red colour would be deepest on the margin, were it attributable to the planet's atmosphere. Moreover, it has been ascertained that Mars always looks reddest when his atmosphere is clearest, and the various markings upon his disc come out with great distinctness, and it is a

would this impress us in the case of Neptune. Its distance from the sun is about thirty times ours, and, according to the oft-repeated law of the inverse squares of the distances, the light and heat which it gets from the sun is only one nine-hundredth part of that which receive. But let us not give up the matter as hopeless on this account. One nine-hundredth part of sunlight is not such a faint illumination, after all. It is nearly seven hundred times the light of the full moon, and indeed equal to that given by a large electric arc-lamp at a distance of a few feet. There would be no difficulty about reading by means of it; it would be quite sufficient for all the ordinary practical purposes for which sunlight is used here. And then there is another consideration which is of very great weight. It is this: You know that, as I have said, what astronomers increase the size of telescopes for is to gather more light; rather than to get greater magnifying power. A telescope of two inches diameter, or aperture, as it is technically called, will give four times as much light as one of only one inch; one of ten inches will give twenty-five times as much as the two-inch, or a hundred times as much as the one-inch. The great Lick telescope, of three feet aperture, makes a star look about thirteen hundred times as bright as a one-inch spy-glass, and enables us to see stars about twenty thousand times fainter than any which can be seen with the naked eye. And the same rule would hold for the eye itself. If we should increase the size of the pupil of the eye, we should see fainter objects than we do now; and we indeed actually do this when we go from bright light into a dark room. We can easily see how the pupil dilates to accommodate itself to reduced light, by simply examining another person's eye in these changed conditions, or our own before a looking-glass. The eye of a cat changes much more. If the retina of the cat's eye is as sensitive as our own, she must habitually see stars five or six times fainter than any which we can discern without a glass, and the heavens must present to her a magnificent appearance, if she cares to look at them. Probably she actually uses this increased light rather to discover mice than stars; but her astronomical opportunities are there all the same, though she may not avail herself of them. It is true that this increased light is obtained in the eye at some sacrifice of definition, or sharpness of

positions attentively as they gradually passed across the planet to his western margin, and re-observing them as they came into view on the opposite limb, he was enabled to fix the rotation as performed in 24 hrs. 40 mins., which differs very slightly from the period now adopted, viz.: 24 hrs. 37 mins. 23 secs. But Cassini appears to have been anticipated in these discoveries by Huygens, who approximately discovered the rotation in 1659.

Thus the length of a day on Mars is but slightly in excess of the duration of a terrestrial day, though his year extends over 669 days, and his seasons in the northern hemisphere are unequally distributed in the following proportions :-Spring 192 days, summer 180, autumn 150, and winter 147 days. Mars is only about twice the dimensions of the moon, and little more than half the size of the earth. Fig. 5. Relative Size of Mars and the Earth. In Fig. 5 if the circle E represents the earth, then M is the proportionate size of Mars. Though no satellite had formerly been discovered accompanying Mars in his revolutions, it was conjectured that one might exist, but of such small dimensions as to elude the greatest power of our telescopes. Being a very small planet, it was a natural inference that his satellite must be proportionately minute. That it had never been seen, was not conclusive proof of its non-existence, and it was further argued that the analogies of the solar system strongly suggested that Mars might have a moon, because satellites have been apparently supplied to the planets in increasing numbers, as they recede from the sun; and if the analogy held good in the case of Mars, he must be provided with two satellites, seeing that his orbit lies outside that of the earth, which possesses one moon; yet such bodies, had they any existence, had evaded detection through the long lapse of nearly three centuries since the invention of the telescope. It was hardly to be expected that the old astronomers, with their imperfect and rudely-devised instruments, would ever catch a glimpse of them, but in more recent times it was difficult to see how the gigantic mirrors of Herschel, Rosse, and Lassell, or the large object glasses of Bond in America, and of the eagle-eyed Dawes in England, had failed to render them visible, though the keenest scrutiny had been directed again and again, to the planet's side, with

conceive of any organized life existing there. It is true that we do not know exactly how much complexity of structure is required in matter as a basis of life; but we can hardly consider life in the proper sense as belonging to a chemical molecule, and everything would indicate that on the surface of the sun matter is reduced to its simply chemical or molecular state. Any structures or organisms which we call alive would instantly be destroyed in that intense flame; even inanimate shapes, like those of crystals, would not survive its action for a moment. But may there not be a cooler region below the sun's surface, protected in some way from the intense heat of the exterior? Such a theory was entertained in the last century and even in this; but it is pretty safe to say that no one now would hold it. That it should have held its ground so long is perhaps, in great measure, to the authority of Sir William Herschel. I do not think it was ever satisfactorily explained just how the interior was protected from the immense radiation of its envelope; certainly it is hard for us to see nowadays, knowing as we do the radiating power of the surface (10,000 horse power per square foot, as we find it to be) how such a blaze as this could even be supposed to be cut off from any point within. To suggest a cool place in the interior of the sun is much as if one should advise a person suffering from the heat of a furnace to wrap himself up well and take a seat inside. Moreover, we know from spectroscopic indications now, particularly from those of oxygen in the sun, that the farther in we go, the hotter it gets; and this also would follow from the only theory which can reasonably account for the formation of the sun, and the maintenance of its heat. We may pretty certainly say, then, that in any common-sense way of using the word, the sun is not habitable. Absolutely speaking, of course, all space is habitable; there is no conclusive reason why an organized being should require nutriment or air, and hence an animal might be conceived as being launched into space as a planet on his own account. But what we mean by a place being habitable is, that it should furnish the requisites and conveniences belonging to a life similar in its principal features to that with which we are acquainted. It is not a thing which can be strictly defined; nevertheless, we know well enough for practical purposes what we are talking about, and we

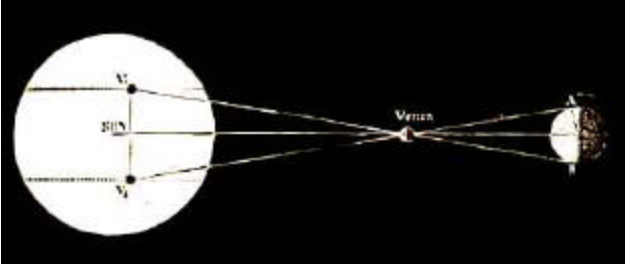
August 20th and 21st, and learnt the secret of its rapidly varying positions. Revolving around Mars in about one-third of the time occupied by the planet in his rotation, its swift orbital motion necessarily carried it from one side of the planet to the other at short intervals, and thus presented a case beyond parallel in the solar system. Subsequently to their discovery in America, the moons were also seen by several observers in different countries. They are marvellously small and minute bodies, but their actual diameters cannot be definitely ascribed with any certainty, because they are mere specks of light incapable of measurement. Undoubtedly, these moons are the smallest heavenly bodies ever discerned by the human eye, and are solely objects for acute vision and large telescopes, and even then will be rarely seen. In the autumn of 1879, Mars being in excellent position, his satellites were glimpsed again, but during the next ten years they will be utterly beyond the reach of the most powerful instruments ever constructed, for the planet is too distant from the earth, and we must await the year 1892 to hear of the re-observation of his moons. The discovery of two satellites attendant on Mars adds another link to the harmony of the solar system, for, so far as our telescopes are capable of revealing, the number of moons furnished to the planets increase accordantly with their distances from the sun. Thus the earth has one satellite, Mars two, Jupiter four, Saturn eight, and if this regular increase is maintained in the cases of the outermost planets, Uranus and Neptune, they must be accompanied by a numerous retinue of such bodies. It appears highly probable that this is the case, as analogy suggests, though hitherto our telescopes have proved inadequate to the task of rendering them visible. Mars does not exhibit phases like the superior planets Mercury and Venus. It is evident that his orbit being exterior to that of the earth, he can never be seen in a crescent shape, though in certain positions he assumes a gibbous appearance, similar to the moon when she is near the full. Galileo recognised this feature in 1610, for on December 30th of that year, he wrote to his friend Castelli, saying: "I dare not affirm that I can observe the phases of Mars; however, if I mistake not, I think I already perceive that he is not perfectly round." The mean distance of Mars from the sun is, in

ARE THE PLANETS HABITABLE

by George M. Searle

HAVING completed our survey of the planetary system in which we live, a question naturally occurs to us, which has occurred to every inquiring mind since the real dimensions of the orbs belonging to it were known. To the great majority of mankind it is, and is rightly, a question of greater interest than anyone with which mathematics or physics has to deal; of greater interest, since life is a much higher and nobler thing than machinery, and the spiritual far above the material. This question is, "Are these planets which, like our earth, move in their appointed paths around the sun, and on which there is certainly ample room for a population far greater than what our globe could support, actually inhabited by beings in any way like ourselves?" Almost every astronomer has probably been asked what his views are on this question, and whether his science has anything to tell us about it. At each successive increase in the size of telescopes, men vaguely hope that with the new optical power it may be possible to discover some signs of sentient, and perhaps even of intelligent, life in the celestial worlds. "How much does this telescope magnify?" is always the interesting question to the popular mind. The professional astronomer perhaps is not looking so much for that. He wants to get more light; to see and to delineate faint nebulae, to follow a comet as far as he can into the darkness of space, in order to determine its orbit as well as possible; but the world in general has comparatively little sympathy with him in this. The discovery of one intelligent being outside this planet of ours would be more interesting to most men here than all the comets which ever have been or ever will be seen. Is it then possible that the power of telescopes will at any time be so increased that any discovery of this kind can be made? That is what people would like to know. Let us answer this question in the first place. The moon is our nearest neighbour. If we can magnify enough

variety of day and night be given, with no intelligent creatures to mark and appreciate the wise and ever-recurring changes. Can we picture to ourselves a planet utterly void of life, where the stillness of death and desolation has absolute supremacy, where in the weird aurora of day-break no beings are aroused to activity, and where the sighing of the wind, amid the rolling of waters, is all that breaks the monotony of time? The undulating contour of hills and valleys is there, but the place is a wreck, and one might think that earthquakes had rent and shattered the rough, uncultured condition of the surface. No vegetation is apparent, and none could subsist in that bleak and rarefied atmosphere, but the most impressive thing of all must be the solitary stillness of the surroundings. The wild character of the landscape, the cold attenuated air encompassing it, the manifest dearth on all around might be endurable, and, perhaps, tolerated for a time, but the absence of living creatures must exercise the most depressing influence of all. An unbearable sensation of loneliness and horror must take possession of a human being could he survey the death-like aspect of a world akin to this, and he would turn shudderingly away from the picture. Such conceptions as these are, however, not only repugnant to our feelings, but in direct opposition to our views of the wisdom of the Creator, who in devising the grand mechanism of the solar system, did not forget to endow the individual parts with many attractive and beneficial details. We must indeed have limited ideas to doubt the extension of life to systems, beyond our own, or to question their adaptability for its suitable maintenance in some form or other. An inhabitant on Mars will see the earth in much the same aspect as we are accustomed to observe Venus. Our planet will appear successively as a morning and evening star of considerable brilliancy, and attended closely by her satellite. Viewed in the telescope we shall exhibit phases, and so will the moon by our side, in which our exact image will be repeated, appearing sometimes as a slender crescent, then increasing until half the disc is enlightened, and finally becoming full. But the most interesting of celestial phenomena to the Martian inhabitants, if any exist, will be that presented by their two satellites, particularly Phobos, which, being less than 4,000 miles distant from the surface



The Transit of Venus



Jupiter – ca 1890