REPORT ON MARS, No. 9.

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This Report will be devoted, not like its predecessors, to a description of observations and changes noted upon the planet, but instead to suggestions to amateur and professional observers, with regard to the coming opposition. The best scale for the drawings of Mars is three millimetres (1/8 of an inch) to the second of arc. This will be found more convenient than to make them all on the same scale. The drawings are, for ready comparison, all placed on the right hand page of the record book, and below each should be entered the times, magnification, and quality of the seeing. Beneath is left a space for the insertion of the computed angular diameter, central meridian, latitude of the center, and martian date. Three or more circles of the proper size are prepared beforehand by means of the *American Ephemeris* or *Nautical Almanac*, the polar and phase axes inserted, and the phase arc drawn. This latter can be done with sufficient accuracy with dividers, using a larger radius than for the circumference of the disc when the phase is large, and finishing by hand.

It is the writer's custom to orient his drawings either by means of the north polar cap, or, when that is not available, by a spider-line set at the proper computed angle in the eye-piece. The north polar cap is first drawn, care being taken to get it of just the right size. Next we put in any conspicuous detail that may happen to be near the center of the disk, and then whatever is on the limb and nearly opposite to the polar cap. The limb is next spaced off by the eye, and other limb detail drawn. After this whatever is left can be inserted without large error. After the main features are completed, the outlines of the minuter details are drawn, beginning on the preceding side of the disk, so as to lose as little detail as possible by the rotation of the planet. The drawing of the outlines usually requires from ten to twenty minutes. The mean of the times of beginning and end gives the longitude of the central meridian.

The shading is next done, which occupies about ten minutes, and then a careful comparison of the drawing is made with the planet, and any defects that are detected are remedied. We next insert a low power eye-piece (0.6 in. focus), giving a magnification of 330, and search for any faint contrasts, particularly in the more uniformly illuminated regions both bright and dark. We then record the colors visible with this eye-piece, and often the brightness of the different areas, making if necessary a supplementary drawing copied hastily from the first one. Finally we again insert the higher power and confirm these colors, again recording the time. The low power seldom shows any detail that has not been detected by the higher one, but if the contrast is slight, it shows it to better advantage. It also brings out the colors in the larger surfaces more clearly, because of the increased light. It is in this study of color, as we shall presently see, that we most feel the need of a large aperture, that is we need more light. As far as definition is concerned most of the detail that we have seen at this past opposition would have been visible had the aperture been reduced to 5 inches, and several of the canals notably Nilosyrtis, Thoth, Eunostos, Lethes, and Cerberus were recorded as clearly visible in our 3-inch finder, when using a magnification of 180.

For comparison of the quality of the seeing at different stations, or on different nights at the same station, the so-called Standard Scale is recommended. Indeed it is the only method by which these comparisons can be made with any certainty, and is of universal application. This description of it is copied with one or two slight modifications from the *Harvard Annals* **61**, 29. The objective must be a good one. and in perfect adjustment, that is the diffraction rings must be complete circles, not mere arcs. A bright star, preferably of the first or second magnitude should be examined, using a ¼-inch eye-piece. This gives a magnification of about 60 to the inch of aperture.

As adapted to a 5-inch telescope the scale is as follows:—

1. Image about twice the usual size. That is twice the diameter of the third diffraction ring.
2. Image occasionally twice the usual size.
3. Image of about the usual size, and brighter at the center.
4. Disk often visible, short arcs occasionally seen.
5. Disk always visible, short arcs seen about half the time.
6. Disk always visible, short arcs constantly seen.
7. Disk sometimes sharply defined.
8. Disk always sharply defined. Rings all in motion.
9. Rings. Inner one stationary.
10. Rings. All stationary, or in slow motion.

If we double the aperture of the telescope we must add two units to the scale. For a 7-inch telescope perfect seeing would be 11, for a 10-inch it is 12, for a 14-inch 13, etc.

It is of little use to observe Mars when the seeing is below 6, or when its altitude is below 30°. When the seeing is really good on Mars, the last three units of the scale, the amount of fine detail visible remains just about the same. The chief difference that we have noticed is that with good seeing one can draw faster, as one does not have to wait for clearer glimpses, between intervals when all is blurred. On account of the rapid rotation of the planet, greater accuracy is secured by rapid drawing. Also, with good seeing, the observer has more time to carefully compare and criticize his work.

By a comparison with the spider line in the eye-piece, it was found at this last opposition, that the breadth of an average canal was about the same as that of Cassini's division at the ansae in Saturn's ring, the canal was however very much fainter. Encke's division cannot be distinguished when the seeing is below 7. It is much narrower than most of the canals.

The writer does not consider that in the case of an astronomical drawing any attempt should be made to shade the object exactly as it appears to the eye, but only to produce an approximation to the truth. We can never obtain on paper the extreme range of illumination usually visible in the telescope. It is therefore impossible to represent objects as they really appear. Hence contrasts which are of no consequence should be reduced, in order that contrasts more important for our purposes may be increased. If drawn exactly as it appears to the eye, the surface of Mars would be represented much darker than the polar caps, and the more faintly marked contrasts of the surface would not be visible at all, or at least seen only by means of special diagrams. Therefore small contrasts are always exaggerated. The power to do this constitutes one of the chief advantages of a drawing over a photograph, where such selective exaggeration is impossible, and in consequence much is lost. This difficulty may be partially overcome by printing in colors, but the added expense of the process is at present prohibitive for most purposes.

The breadth of the canals and diameters of the lakes may be measured, and their densities determined, by a scale of canals or lakes attached to the outside of the tube of the telescope, near the objective, as described in Report No. 7. The brightness of the surface features can be recorded on a scale of 10, similar to that employed by selenographers for the moon, as described in Report No. 4. On this scale the polar snows are marked 10, the polar clouds generally 8, the deserts 6 to 7, most of the *maria* 3, and the blackest lakes 1.

The colors of the surface are most important, but some persons find difficulty in properly describing them, perhaps because their eyes are not suited for this kind of work. The *maria* are sometimes green and sometimes grey. The clouds are sometimes yellow and sometimes white. Occasionally an intense vivid green, which seems to be subjective, appears on the limb, or in the polar areas. The marshes are sometimes a deep intense blue but when near the limb the blues are usually very light. This leads us to believe that the atmosphere of Mars is sufficiently dense to reflect a considerable amount of sunlight. The deserts vary from yellow to orange red, the latter color in the case of observations made by daylight.

Before attempting to represent the colors seen through the telescope there are a few points which we must consider, and which should be kept clearly in mind. The first of these is that *the source of light illuminating the paper should be, if possible, of the same color as the sun, as seen from the distant body.* But a few years ago there were only two practicable methods of illuminating the paper in our studies of color at the telescope, the oil lamp and daylight. Latterly we have had the carbon filament, the color of which however is but little whiter than that of the oil lamp. At the last opposition we were successful in having some tungsten lamps of only 2 and 5 c. p. made to order for us. These threw much light on the color phenomena of the planet, and it is expected that at the coming opposition by transmitting their light through pale blue glass, we shall be able to render the illumination of our paper of very nearly the same color as the illumination of the surface of Mars by the sun. Sunlight, while much bluer than the unprotected tungsten filament, is at the same time decidedly more yellow than the ordinary daylight illumination of our sky.

The color of the illumination if it is white enough to show the blues at all, affects our studies of them, and of the greens far less than it does that of the reds and yellows. By the yellow light of the carbon filament the tendency is to paint the greens and blues rather too intense, but we paint the reds and yellows much too pale. Indeed, plain white paper sometimes appears redder than the planet itself. This is doubtless due to martian cloud or haze, and was recorded three times during the past opposition. By the light of an oil lamp it is difficult to distinguish crimson lake from golden yellow, and either will at times match the planet. By the unprotected tungsten light the center of the disk can usually be matched by yellow ochre. By the magnesium light, which is our bluest source of illumination next to sunlight and the vacuum tube, the color of the disk has been matched with dragon's blood. This is pretty near its true color.

A difficulty that arises in making daylight studies of the planet, which would otherwise be very satisfactory, is that the illumination of our own atmosphere mixes a certain amount of color with that due to the planet itself. This is well illustrated by viewing a distant landscape through a telescope and attempting to paint it. A bright red brick building seen from a distance of two or three miles is best matched not by red, but by chrome orange, while as we all know the grass on a distant mountain appears light blue instead of green, and darker colored foliage dark blue or grey. Thus it is impossible to represent the true colors by this method. The best we can do is to obtain results from which we may conclude what the true colors really are. If on the other hand this distant foliage is illuminated at night by an arc light, and we view it through the telescope, the grey or blue is replaced by a bright green, which we at once recognize as the true color that we should find if we visited the tree by daylight. From this we conclude that all studies of color should be made at night, and that to get the best results our paper must be illuminated by a light of as nearly the color of direct sunlight as possible.

The simplest method of determining what shade of blue glass we should employ in front of our tungsten light is to reflect sunlight through a very small aperture into a darkened room. We may then compare it directly with the tungsten light by means of a shadow photometer. As high a voltage as practicable should be used, when this can be varied. A method that may sometimes be more convenient is to reflect the sunlight from an adjustable mirror onto four successive plane sheets of glass, arranged so as to throw the light back and forth nearly perpendicular to their surfaces. This may be done out of doors. This will reduce the intensity of the light about ten thousand times, so that we may look directly at the image and compare its color with that of the tungsten filament, whose intensity will also be reduced by looking at it through half a dozen sheets of very pale blue glass. A point of great importance is that the brightness of our paper should equal as nearly as may be the brightness of the planet as seen through the telescope. The blue glass greatly reduces the brightness of the tungsten light, so that even if a high candle power lamp is employed the illumination will be rather faint. In Report No. 7 we found that a sheet of white paper illuminated by a 5 c.p. tungsten light at a distance of 6.5 inches was as bright intrinsically as Mars viewed with the 11-inch aperture and a magnification of 430. With blue glass of such density as to give the color of sunlight, when placed in front of a tungsten lamp, the brightness is reduced to 4.5 per cent. We shall obtain the proper illumination of the paper therefore with blue glass if we use a 10 c. p. light at a distance of 3 inches, and use a magnification of 660 in the telescope. A 25 or 50 c. p. light, possibly with a reflector attached, at a somewhat greater distance would be more convenient in practice. Indeed when the paper is painted red or orange a lamp of this brightness will certainly be necessary. The spectrum of the tungsten light through blue glass gives plenty of red, yellow, and violet rays, and shows no absorption bands. In general effect it is very like the solar spectrum.

We should determine once for all the distance that the lamp should be held from the paper, for each different eyepiece that we employ. A high power always makes the planet appear redder than a low one. This is simply because the illumination is less. But besides this the objective and eye-pieces themselves absorb a perceptible amount of the blue and green rays, so that if we point the telescope by daylight on some distant trees, or on the sky, and look with one eye through the telescope, and the other directly at the object, we shall find that to get the same color effect we should place a piece of light blue glass in front of the eyepiece.

Under faint illumination all colors tend to appear grey, but this is particularly so of blues and greens. If in order to avoid this we diminish the magnification, thus making the planet brighter, the smaller areas may become so small that they fail to show any color at all. We must therefore select our magnification with regard to the size of the object in view. A large aperture is for this reason of the greatest advantage for color studies, and little can be done with very small apertures. It is a good plan to cut a round hole of the proposed size of our drawing of Mars, in a piece of black paper. This we can occasionally lay over the drawing, thereby imitating the effect of contrast with the dark sky.

The blues and greens are seen to best advantage in the night time, but if our own atmosphere is very clear, especially in the early morning, the blues may be seen till near sunrise, and the greens somewhat later. The blues can be detected after the planet is invisible to the naked eye. In March and April 1892 paintings were made by daylight in which the green, yellow, and orange exactly match these colors as applied at night by the carbon filament in December 1914. This would imply a distinct change in the real color of the desert regions of the planet at different seasons.

During his earlier work in past years the writer employed water colors exclusively to record the colors observed. This still seems to be the best plan for the ground work of the disk, the yellow ochre, orange, and reds, but for the greens, blues, and browns he has latterly used colored pencils, and finds the manipulation much quicker, and more adaptable in connection with lead pencils of varying degrees of hardness.

In Report No. 8 are given four plates showing Mars in six different positions, as seen by five different observers. These six positions indicated as A, B, C, D, etc., are drawn with martian longitudes 0°, 60°, 120°, 180°, 240°, and 300° central, and give therefore a complete representation of the appearance of the planet at this last opposition. It is hoped to continue this publication next year. In order that drawings by different observers, executed at different times, may be fully comparable, it is very desirable that the planet should be as nearly as possible in the same position. It is therefore recommended to other observers that they should adopt these same positions as far as practicable for making their drawings, and should therefore compute beforehand the hours at which their observations should be made. It is not by any means intended to discourage drawings made at other times, as for instance might be necessary between passing clouds, but merely to suggest that drawings should be made by all observers, when equally convenient to do so, in these six positions.

To find the hour on a given date when the particular martian longitude is central at any place upon the earth's surface, let l equal the martian longitude selected, m the martian Central Meridian given in the Ephemeris for the date in question, and r the number of degrees rotated by Mars in one hour, as seen from the earth. For ordinary purposes this last may be taken as $14^\circ.62$.

Let T equal the difference in the time used by the observer and at Greenwich. Then t will equal the required number of hours to be added to Greenwich Mean Noon or Midnight.

For west longitude we have $t = \frac{l - m}{14.62} - T$, and for east longitude $t = \frac{l - m}{14.62} + T$. When necessary add 360° to l, and 24^h to $\frac{l - m}{14.62}$. The same meridian is central about 37^m later on successive nights. To find on what night at any given hour a selected longitude will be central on Mars, solve with regard to m and look up the date in the *Ephemeris*. To find what meridian is central on any given drawing solve with regard to l.

For 1915 the *American Ephemeris* uses Washington Mean Noon. To correct to Greenwich Midnight add $100^\circ.3$ to m. For 1916 it uses Greenwich Mean Noon. It is to be hoped that later it will finally adopt Greenwich Midnight, as it has done in the case of the Moon, and as is now in use by the *British Nautical Almanac* for both of these quantities. This plan would render interpolation more accurate, and would show at a glance what is visible here in the early evening.

In the question of identification of the lakes and canals, on martian drawings there is always liable to be an element of uncertainty, particularly if they are far removed from the assured detail. This is due in part to errors of drawing, and in part to the shifting of the canals themselves over the surface, both laterally and in position angle. Thus Tartarus may change to Trais (Lowell), and Pactolus to Hephaestus.

There are two independent methods of identification when in doubt, one by the configuration of the surrounding surface, and the other by the latitude and longitude. When they differ the observer must use his judgment which to employ. The former is in most cases the better but if the marking is far from any certainly known feature, and is near the center of the disk, the latter is sometimes to be preferred. This is particularly true of a lake. When a very faint canal is seen one night standing out by itself, and a few nights later another very faint canal in nearly the same place, also standing by itself, the question at once arises are they really two different canals, or is it a case of an error in drawing? Since very faint canals are so easily concealed by martian clouds, the writer prefers in most cases not to go back of the observations, but to identify them as two distinct canals. If, however, one of them has never been observed before, he would usually consider that an error had been made in the drawing.

Again a canal may be so broad as to cover two parallel canals, or may lie just between them. This was the case early in 1914 with the canals Galaxias of Schiaparelli, and Achelaus of Lowell, between Elysium and the southern *maria*. It does not seem desirable under these circumstances to give the canal another name, and usually the earlier name is preferred. In that particular instance however the configuration agreed better with Achelaus, so that that name was adopted.

Another difficulty is to decide when a marking may properly be called a canal. Thus Cerberus on November 17 was 310 miles in width by 800 miles in length. The question might properly be raised could such a marking be designated as a canal? Yet in January and February it had narrowed to but half its former breadth. Nilosyrtis November 7 was 330 miles in breadth and 1500 miles in length. By February 24 it had narrowed to 50 miles. It was then certainly a canal. A more puzzling case was that where the whole triangular area bounded by Jamuna, Ganges, and Nilokeras on January 5 was darkened, uniform and sharply defined. Could it properly be said that these three canals were visible, or should we wait until a lighter spot appeared within the dark region? If we are discussing vegetation, they certainly had appeared, if we are discussing topography, perhaps not. Again should we say that Hydraotes which crosses the center of this region and extends beyond it, had also appeared? Since it is certain that for much of the time many of the canals are broad markings, the writer has decided to record a canal as having appeared, regardless of its shape, when its position is correctly indicated, and the region it crosses is dark. If only one side is visible it might be indicated thus:—Ganges /2, but if neither side were visible it would not be recorded at all. Therefore on January 5 we should record as visible Jamuna /2, Ganges /2, and Nilokeras /2, but not Hydraotes.

In considering what we should look for this year it would be of particular interest to confirm those changes that were seen at the last opposition. It it not expected that they will necessarily occur however, and certainly not upon the same martian dates. At each opposition the martian date, see Report No. 2 where it is referred to as the Equivalent Terrestrial date, falls 42 to 44 days earlier in our calendar year than at the last. That is, their seasons will arrive 44 of our days earlier this year than they did two years ago. At the same time owing to the greater speed of our planet, we shall gradually pass them, so that while in those observations made previous to the martian date of April 24, we shall see Mars less well than formerly, after that martian date which occurs January 2, 1916 of our calendar, we shall see it better. This is illustrated in Figure 1, where the positions that the two planets occupy

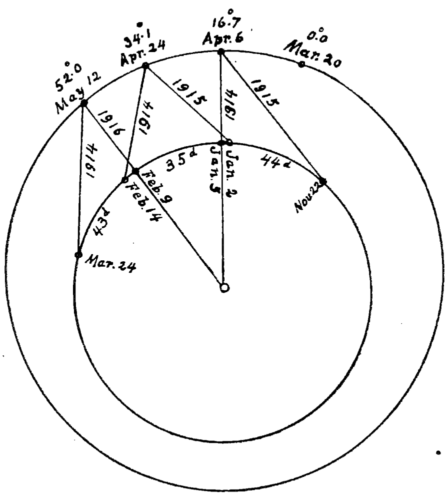

FIGURE 1.

on the same martian date in two different years are joined by lines, the martian and terrestrial dates being given in each case, also the solar longitude ⊙. The two oppositions here considered fall on January 5, 1914, and February 9, 1916. It is hardly worth while to observe the planet before its diameter reaches 6″, which will be seen on September 11. It will then be seen to best advantage just before sunrise, as it transits our meridian at 19^{h} 45^{m}.

At this time we shall expect to see the northern polar cap at about its maximum size, and surrounded by a broad grey band, darker in spots. The southern *maria* should also be grey, not turning green until early in October. About the same time Sabaeus and Margaritifer will develop, and begin to assume their characteristic forms, and a few of the canals connecting the snow cap with the *maria* should become visible as broad bands. By the middle of October some of the great marshes bounding the northern polar cap should have begun to form and should exhibit noticeable changes from night to night, if the planet is well seen, together with a slow but distinct shifting towards the geographical west, i.e. following direction, (Report No. 4.) It will be interesting to note if the twin triangular bays near Propontis, so characteristic of the last opposition again appear. The martian vernal equinox falls on October 19 of our calendar year in 1915. Changes in the Protei Regio may occur about the middle of November, together with the first appearance of Solis Lacus, but they will both be pretty near the limb owing to the high northern latitude of the center of the disk, rendering the southern hemisphere badly seen at this opposition.

The flooding of the Syrtis marsh, described in Report No. 4, occurred last year on January 17. The planet would occupy the same position in its orbit this year December 4, but it is thought that several floods may occur, some perhaps earlier and some later than this, so that we may set this date merely as about the time to look for them. The changes in color and distinctness, as well as in shape and size, of the dark area at the extreme northern end of the Syrtis should be carefully noted each night. Sabaeus should also be watched for a possible blue coloration in February and March. See Report Brit. Astron. Assoc. for 1901. Mem. **11**, 95.

A gradual change in color of the so-called desert regions would be most suggestive if confirmed, and could best be detected by comparison with a sheet of white or lightly tinted paper. On this should be laid a piece of black paper in which was cut a circular hole of about the same apparent size, when held at a convenient distance, as the planet. With a uniform source of light placed at the proper distance from it, comparisons made throughout the opposition might yield interesting results even in a poor climate.

According to Major Molesworth the surface on one side of a faint canal is often slightly darker than on the other. This statement is made not as an explanation of the canals, as proposed many years ago by Green, but as an interesting phenomenon supposed to be associated with them. Molesworth observed in an excellent climate, and his statements deserve high credence. Favorably situated observers should look with care for this appearance at the coming opposition. It is undoubtedly true in some cases, as for instance Triton this past year.

According to the experience of Schiaparelli in 1882 this opposition should be a favorable one for detecting the duplication of the canals. The appearance, if dependent on the martian seasons, should be visible throughout December, and should probably be looked for also in January. According to his earlier statements and maps the separation lies between $0''.7$ and $1''.5$ but he later reduced his figures one half when he obtained his larger telescope. The duplication should hardly be visible therefore to anyone unable to detect the duplication of the lunar canal in the interior of Aristillus. This is a divergent double, the separation at the rim being 0″.7. Observers wishing to know if their outfit is adapted to seeing the martian doubles, can readily test it at the proper colongitude upon this lunar canal (POPULAR ASTRONOMY, November 1914.)

Micrometric measurements of clearly defined points on the surface, throughout the opposition, and particularly of the following sides of the northern polar marshes, to show the probable shift of these features are very desirable (Reports Nos. 4 and 5). Determinations of the longitude of Juventae Fons, by transit across the central meridian, should be made when possible.

Especial attention should be made in the case of drawings to the regions of Solis Lacus and Syrtis Major, during the months of October, November, December, and January. In order to facilitate the study of the latter object Table I has been prepared, where the first column gives the terrestrial longitude of the observer, and the second the approximate date at which the Syrtis region, martian longitude 300°, can be favorably observed at the hour indicated at the head of the column. The third column gives the hour at which observations may profitably be begun, which is assumed to be three hours before the planet transits the meridian. On favorable nights observations may occasionally be begun an hour earlier. The remaining four columns are arranged like the second and third. If the dates indicated are cloudy, observations made a day or two later will serve nearly as well. *Observations on as many successive dates as possible should be secured by each observer, should there be any evidence of local*

TABLE I.

DATES WHEN THE SYRTIS MAJOR MAY BE OBSERVED.

Longitude	17^h	Begin	17^h	Begin	17^h	Begin
°		h		h		h
0	Oct. 10	16.0	Nov. 15	14.9	Dec. 23	13.1
30 W	" 12	16.0	" 18	14.8	" 26	12.9
60 "	" 15	15.9	" 21	14.6	" 29	12.7
90 "	" 18	15.8	" 24	14.5	Jan. 2	12.4
120 "	" 21	15.7	" 27	14.4	" 6	12.2
150 "	" 24	15.6	" 30	14.2	" 9	12.0
180	" 27	15.5	Dec. 4	14.1	" 13	11.7
150 E	" 30	15.4	" 7	13.9	" 16	11.4
120 "	Nov. 3	15.3	" 10	13.8	" 19	11.2
90 "	" 6	15.2	" 13	13.6	" 23	10.9
60 "	" 9	15.1	" 16	13.5	" 26	10.6
30 "	" 12	15.0	" 19	13.3	" 29	10.3
0	" 15	14.9	" 23	13.1	Feb. 2	10.0

darkening in the Syrtis (Report No. 4.) In January the planet is visible for a considerable portion of each night, so that the range of favorable dates is materially extended, and we may observe much earlier in the night if more convenient. If we remember that the same meridian is central about 37 minutes later on successive nights, it will be easy to compute the proper hour for observation upon any other date. The writer will be glad to receive any drawings or observations made of the Syrtis region during these four months, and will return them at the end of that time if requested to do so. On account of the inconvenient hours, it is not expected that many observations will be secured, and those received will therefore be of greatly enhanced value.

The table has other uses besides that above specified however. By it we may tell approximately what region of the planet will be visible in any terrestrial longitude, at any date and hour during the period above specified. This is done by interpolating along the horizontal lines. Thus for any station using Central Time, we look along the fourth row, and find that martian longitude 300° was central at 17^h (5 a. m.) on October 18, and again 37 days later November 24. The planet therefore changes by 360° in 37 days. Longitude 280° for instance will therefore be central at the same hour two days later, October 20, and longitude 240° October 24. Since the planet rotates 14°.6 an hour, we may readily compute the longitude that will be central for different hours than that given. The table will therefore serve as a crude substitute for the Nautical Almanac to those amateurs not provided with that useful volume.