REPORT ON MARS, NO. 38.

By WILLIAM H. PICKERING.

THE DOUBLE CANALS, IMAGINED AND REAL.
THE NARROW DOUBLES.

In my last Report I gave what seemed to me to be the best explanation available of the three kinds of canals visible upon Mars. In the present one I shall deal with the question of the reality of the double ones. These canals were divided by Lowell into two classes, the wide and the narrow. The division was placed by him at a width of 5°.5 measured on the planet, or about 200 miles. I should place it at 10°, or 370. It should be noted with regard to this subject that there are two distinct questions involved, which should by no means be confused. The first is as to the reality of the appearance, and the second is as to its explanation.

With regard to the first there can hardly be any doubt. The appearance has been seen by a score of practiced Martian observers, among whom may be named Schiaparelli, Perrotin, Terby, Molesworth, Lowell, Douglass, the two Sliphers, Antoniadi, Jarry-Desloges, the two Fourniers, Maggini, Hamilton, Wilson, and the writer, and all of their descriptions of the phenomenon coincide. The observation is a difficult one, and can only be seen under very favorable circumstances, and even then only at brief intervals, "by flashes of revelation" (Lowell Bulletin **15**, 97). With regard to the second question on the other hand, the explanation of the phenomenon, there is a marked difference of opinion among the observers, and they, by the way, are the only persons who have any right to express any independent opinion on the subject at all.

All the earlier observers, and all those who have been connected with the Lowell Observatory, with the exception of Professor Douglass, believed or believe that the phenomenon is real, and due to two actual Martian canals, parallel, and located 75 to 200 miles apart. See an interesting discussion in the Lowell Bulletin, above mentioned. The writer has always felt hitherto that with our present means of observation it was impossible to settle the question, when the separation of the canals amounted to less than 0″.5. Few canals have exceeded this figure. Two alternative explanations were proposed by him, one that the appearance was due to a contrast effect (Report No. **5**) the other that it was due to an occasional brief regular vibration due to our atmospheric waves (Report No. **16**).

The duplication of the canals, as stated by Schiaparelli (Memoria **6**, 106) and confirmed by Lowell, is most marked at three of our months before the summer solstice of the northern hemisphere of the planet, and again five months after it. These dates correspond to ⊙ 50° and

165°, the corresponding Martian Dates being April 50 and September 10. The recent apparitions that were most favorable from the standpoint of duplications were those of 1916 and 1922, whose oppositions occurred on February 10 and June 10. Those apparitions occurring in June are much the more favorable of the two, since the planet then appears to be nearly fifty per cent larger than it does in February. This difference is of exceptional importance in studying a phenomenon of this sort. On the other hand the planet is much farther south in June.

In Table I is given a description of all the narrow doubles that I have observed. Their number is rather small, because I have always held that any features which were so difficult that I could not hold them in steady vision were too uncertain to make it worth while to devote much time to them. That is to say I felt that my time could be better spent in a study of those features that I could see more clearly. I therefore

TABLE I.

Narrow Double Canals Observed in Jamaica.

No.	Date	☉ °	M. D.	Diam. ″	Canal	Arc ″	Deg. °	Miles
1	1914 Feb. 24	40	Apr. 28	10.3	Thoth	0.27	2.9	110
2	1916 Mar. 3	62	May 21	12.7	Protonilus	....	...	...
3	1916 Mar. 5	63	May 23	12.5	Gehon	.50	4.5	170
4	1916 Mar. 5	63	May 23	12.5	Deuteronilus	.25	2.2	85
5	1916 Apr. 7	78	May 56	9.5	Gehon	.26	2.9	110
6	1916 Apr. 7	78	May 56	9.5	Deuteronilus	.20	2.3	90
7	1922 July 8	187	Sept. 49	19.3	Gehon	1.12	6.5	245

merely recorded what doubles I saw or suspected, but never hunted for them. Neither have I ever entered any of these narrow doubles upon my drawings, because I doubted if they were real. This was in part because I have always noticed that no matter how near the planet, nor whatever the size of the aperture employed by other observers, they have always described the duplication as being at the extreme limit of visibility.

The first double that I recorded, Thoth, was seen as the result of an examination of some drawings kindly sent me, at my request, by Dr. Lowell. They exhibited several doubles, but Thoth was the only one I could verify at all. The following remarks were made at the time, February 18. "By looking at Thoth with magnification 300 I can get the effect, but certainly should not have thought of it as real. It is at best merely a suspicion. With magnification 660 it is less clear. Lowell's drawings were all made with powers less than 400. I should strongly doubt any fine doubles made with so low a power. Seeing 10." February 24. "Thoth still presents the double effect, but it was more marked when central. I doubt if it is really double however. Seeing 8."

Numbers 2, 3, and 4. March 3. "Protonilus and Deuteronilus perfectly straight and narrow. 8-inch aperture. Protonilus looked double, but I could not be sure of it. Seeing 8. Aryn pretty certainly there.

I believe Gehon is really double, but still not sure of it. It is seen best with the 8-inch aperture and magnification 430. I could be sure if the canals were darker, but they are exceedingly faint. Gehon has twice the separation of Deuteronilus." March 5. "I doubt if Gehon is really double yet. It is broad and rather hazy. I think both sides of it developed (*i.e.* became more distinct) tonight. Seeing 10."

Numbers 5 and 6. April 7. "Deuteronilus appears as a possible double. Gehon is wider, but more difficult. Magnification 660 is better than 850 or 430. Light yellow glass interferes rather than helps, by cutting off the light. If double, the components are extremely faint. As single bands both canals are obviously perfectly straight, and not difficult. Seeing 10. Being so narrow they clearly cannot properly be doubled, but this is as near, and perhaps nearer to seeing a duplication than anything I have heretofore detected."

Number 7. July 8. "I have been able to imagine the doubling, and the separation is easy in this case, but the lines are, as always, at the limit of vision."

Referring to the Table, we find that among the seven duplications described, Gehon was recorded three times, and Deuteronilus twice. Thoth was the most doubtful one. Excluding it, since I did not discover it independently, it will be noted that during the seven apparitions which I have observed from Jamaica, nearly completing the planet's year, in only two of them has any duplication been independently suspected. During these two the planet was near the solar longitudes picked out by Schiaparelli and Lowell as being the most favorable to seeing duplications, namely 50° and 165° (compare with column 3 of the Table). The duplication, even when narrow, (see column 7) applied only to these particular canals. In many cases the canal was noted as being remarkably straight when the duplication was seen, a characteristic often mentioned by Schiaparelli. On the other hand the most convincing of the duplications occurred when the planet was most remote, diameter 9″.5, and the separation very narrow, 0″.26 and 0″.20.

By observing two parallel dark lines drawn on white paper at a distance of 1100 feet, with the 15-inch refractor at Harvard, it was found that under the most favorable conditions, with excellent seeing owing to the short distance, the closest pair we could separate was at a distance of 0″.42. With fainter or less strongly illumined lines, this number increased very rapidly (Harvard Annals **32**, 149). It is therefore more than doubtful if so small a separation would apply to Mars. Assuming it however, with our 11-inch aperture we should have been able to separate an actual double only when the distance between the middles of its components reached 0″.57. Only the last double recorded in the Table exceeded this figure.

In order to obtain perfect seeing, and to eliminate all optical difficulties due to the use of a large telescope, thus obtaining the most favorable possible conditions, this experiment has been recently repeated

here on a small scale employing a very short distance. As was to be expected, we found that by so doing this limiting distance was reduced, but only by a comparatively small amount. Since Lowell rarely used an aperture exceeding 16 inches, and usually between that and 12, I assumed that the doubles seen by him and by myself were observed with a mean aperture of 12.5 inches, or 32 cm., that we employed a magnification of 400, and that the average double seen had a separation of 0″.3. Let us now reduce the scale of our observations 32 times. Our aperture will then be one centimeter, our magnification 12.5, and the separation of the double 9″.6. Two fine ink lines were ruled on paper 0.7 mm. apart. In order to obtain the proper separation they were placed at a distance of 15 meters or 50 feet from the objective of the telescope. They then appeared simply as a uniform blur, without any detail whatever, and could only be separated when they were brought within 40 feet of the telescope, giving a separation of 12″.0. *This angle may be taken as a constant for an aperture of one centimeter.*

Reducing this back to the 15-inch refractor, we find that even under these extremely favorable circumstances, observed out of doors in broad daylight, in order to separate a real double the separation must be 0″.32, as compared with the result obtained with the telescope, itself under especially favorable practical conditions of 0.″42. For three quarters of Lowell's canals the separation lay between 0″.30 and 0″.17. I therefore conclude that for these canals, even if they were really double, and of the width stated, with our present instruments, used under the most favorable conceivable conditions, observers could not see the components nor recognize the fact. Furthermore, no telescope unless its aperture exceeds 15 inches, can perceive a real duplication unless the separation from middle to middle exceeds 0″.40. Atmospheric difficulties, as we have seen in Report No. **35**, affect larger apertures adversely for planetary observation. We may therefore place 0″.40 as a minimum value for any telescope,—a distance eight times as great as that discernible as an elongation for a double star. We may perhaps say that separations recorded between 0″.40 and 0″.60 are doubtful to possible, and that those exceeding 0″.60 if made under favorable conditions should be accepted. No close duplication recorded however should be admitted, unless the aperture of the telescope used at the time is also stated.

Since the rods and cones in the retinas of all human eyes are of about the same size, all persons having reasonably good eyesight can separate parallel lines at about the same angular distance apart. Thus, if we draw two parallel ink lines separated by one millimeter, and view them from a distance of three meters or ten feet, we shall find them to be at about the limit of resolution. Their angular separation is then 69″. Twelve feet would certainly be the maximum distance. I tried this experiment when visiting Dr. Maggini, and later with Hamilton, both of whom are experts in seeing close double canals, and it was found as

was to be expected, that we all obtained practically identical results. Dividing our constant 12″ by 69″, we find that the equivalent diameter of the pupil of the eye in a brightly lighted room is 0.17 cm.—a result checking the constant fairly well.

The narrowest double measured on the planet by Lowell in 1903, out of 34 in all, and called by him Djihoun, had a mean width of 2°.2 or 85 miles. The narrowest one that I observed, number 4 of the Table, had the same width. This width is by no means that of a narrow canal, indeed it is rather a wide one, the distance between whose edges is clearly seen, and is readily susceptible of measurement on a drawing. This comparison of our results shows pretty clearly that we saw the same phenomenon. If one side of the canal were darker than the other, that too would be detected. What Schiaparelli, Lowell, and others failed to see however, was that by introducing two narrow canals, one on each side of the broad band, these would interfere with one another to such an extent in our vision that the whole band would merely be darkened uniformly, in case the two narrow canals were equal. If one member of the real double is darker than the other, then that side of the band will appear darker. That is the *only* effect produced. Lowell's measurements of Euphrates, Hiddekel, and Gehon, which he doubled with a 6-inch telescope, and gave respectively as 0″.27, 0″.26, and 0″.28 (Lowell Bulletin No. **5**) are absolutely impossible.

It has been pointed out by him that when Gehon doubles it is very wide, often stretching from the preceding to the following bay of the Furca, and moreover that there is no question but that these two bays are easily separable. This was quite true during the apparitions of 1922 and 1924. According to our measures made during the five apparitions from 1914 to 1922 the distance between the northern extremities of these two bays was just one-fifteenth the diameter of the planet, 7°.6 or 280 miles. Measures made from four drawings secured on July 8 and 9, 1922, when the canal was suspected of doubling (Plate III, Figure 2) gave, as we see by the last line of the Table, a somewhat smaller figure, 6°.5. Had the canals been dark, there would have been no question whatever about the duplication, because the separation, 1″.12, was obvious, and also theoretically possible to be seen. The real question however was, were there any canals there at all on either side of the wide gray streak.

When a sharply defined broad dark area on Mars lies in contact with a bright one, Hamilton and Maggini both frequently see a dark canal bounding the dark region, where the writer sees nothing but a sharply defined edge. This perhaps gives us a clew to the explanation. We can readily understand that, if the dark area is long and now becomes extremely narrow, they would see a double canal, that is one canal bounding it on each side, where the writer would see simply a single dark uniform band. The faintness of the components in every case that I observed, relatively to that of the space between them was very strik-

ing. When the canals were dark the space was dark. The difficulty in detecting the phenomenon, as it appeared to me, was not due in the least to any difficulty in the apparent separation, which latter was easily seen with such broad canals, and must necessarily have been so had there been no interference effect. The real difficulty that I found was due *only* to the lack of contrast of their darkness with that of the space between them.

Schiaparelli's description of the appearance as given in Flammarion's "Mars" leaves one with the impression that the doubling is obvious, and can hardly be missed. We have seen here, and in Arequipa, markings of which Schiaparelli never dreamed, yet we consider the duplication very near the border line of the imagination. M. Jarry-Desloges wrote me recently that in all the years that he had studied the planet, under most favorable conditions, he had personally never seen but one double. That the duplication cannot be explained simply and solely as due to the imagination however I feel quite sure. Too many practical observers have seen it. Moreover it appears clearly only at certain specified seasons, and does not affect all the canals. A characteristic of all the doubles that I have seen, was their straightness and artificial appearance. This characteristic, as we have before mentioned, was noticed also by Schiaparelli. There seems to be something peculiar about these particular canals that causes them to present the double appearance, convincingly to some observers, unconvincingly to others. This we shall now consider.

Since the actual duplication of the canal appears to be ruled out, it would seem that the surest way to discover the true explanation of the effect is to produce it artificially, and experiment with it. Unfortunately it is so fleeting an impression, or, as Lowell puts it, is such a matter of mere "flashes of revelation," that the imagination is liable to influence one's opinions too strongly to secure reliable results. I tried to imitate the phenomenon with my one centimeter aperture, by viewing narrow light gray bands of 1.0 and 1.2 millimeters in width, drawn with a number 3 pencil, at varying distances. Knowing just what to look for, I had hoped that I might be able to see them bounded by faint narrow dark lines. I cannot say that I succeeded, although several times by using a certain amount of imagination I thought that I could glimpse something of the sort. It is possible that a more practiced, or a more imaginative observer of doubles would have been more successful.

Undoubtedly the easiest celestial double canals to see are on the moon. I am not referring now to the well-known divergent double found in Aristillus, but to the extremely narrow parallel doubles located within many of what I have called the snow craterlets. These craterlets are very numerous, and when the sun is near their meridians they are intensely brilliant, like Aristarchus. A few days previous to this, a narrow black line descends their northwestern interior walls, and later disappears. With really good seeing this line in many cases appears to

PLATE III

FIG. 1
June 30, 58° Sept. 40

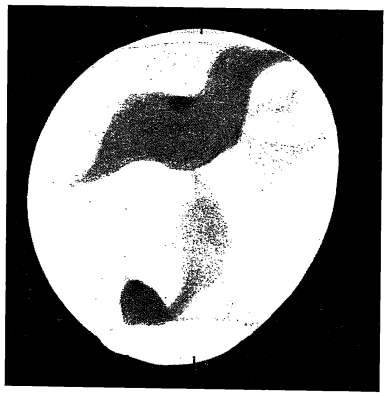


FIG. 4
Aug. 8, 57° Oct. 22

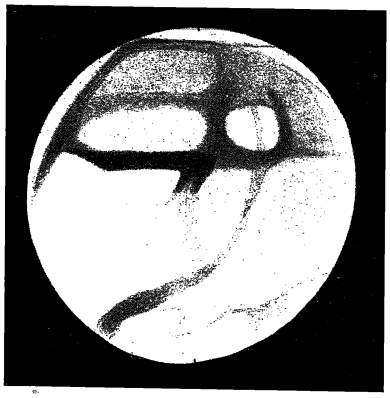


FIG. 2
July 9, 3° Sept. 49

FIG. 5
Aug. 8, 85° Oct. 22

FIG. 3
July 13, 294° Sept. 53

FIG. 6
Aug. 9, 49° Oct. 23

DRAWINGS OF MARS.

POPULAR ASTRONOMY, No. 342.

PLATE IV

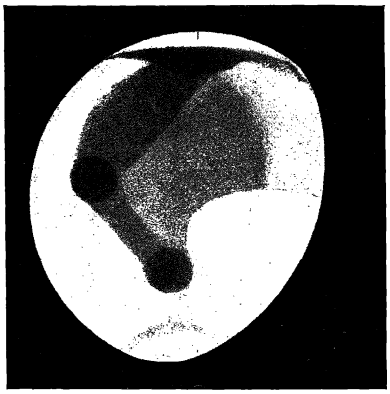


FIG. 7
Sept. 14, 77° Nov. 3

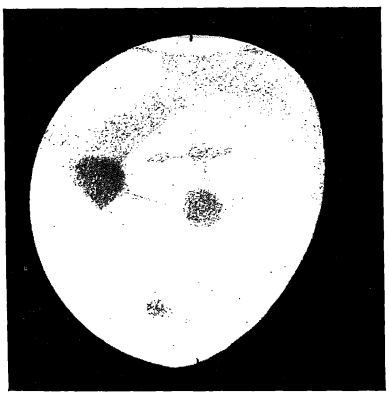


FIG. 10
Oct. 19, 86° Nov. 37

FIG. 8
Sept. 15, 56° Nov. 4

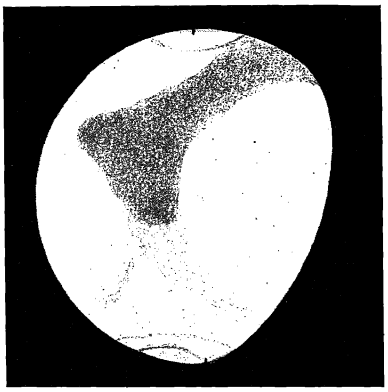


FIG. 11
Oct. 21, 68° Nov. 39

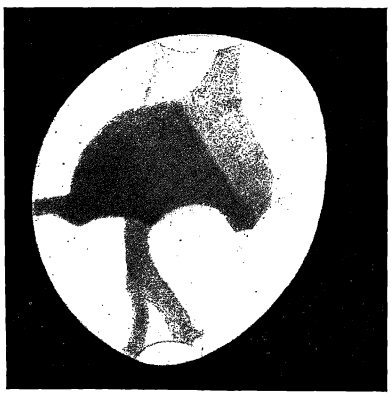


FIG. 9
Sept. 16, 43° Nov. 5

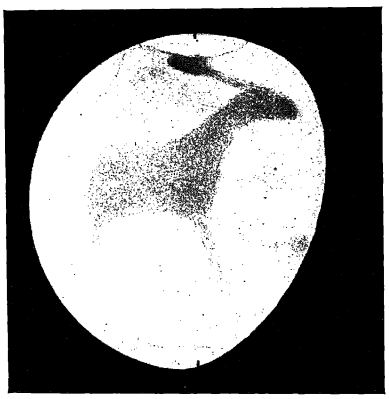


FIG. 12
Oct. 22, 58° Nov. 40

DRAWINGS OF MARS.

POPULAR ASTRONOMY, No. 342.

be double. The most convincing case that I have found lies in a small craterlet situated on the northwestern rim of Posidonius, indicated on Wilkins' 2nd edition map of 1924 by the letter B. It is perhaps 6 miles in diameter. The canal appears as early as colongitude 43°, and has been seen as late as 112°. The separation is about 0″.56, or 3400 feet. Mösting A, near the center of the moon, shows a similar double. but more difficult. It is visible between colongitudes 70° and 90°. There are many more on the moon of varying degrees of difficulty. I cannot say that any of these would be convincing to me, were it not for the one on the rim of Posidonius, which seems real, and is certainly far easier to see than any of the narrow Martian doubles. The contrast between the dazzling interior of the crater and the black canal is of course very marked. Indeed it is so strong that it might almost be compared to the case of a double star reversed, that is to say black for white. Consequently in its case the advantages secured by a large aperture should become effective, and it is possible that with exceptionally good seeing some of the great telescopes in the north could definitely settle the question whether the lunar canals are really double, or whether the effect is due merely to contrast, the bright background causing the edges of the canal to appear darker than the middle.

As a general result of my observations I may say that I believe that in order to produce the effect, a canal must be not only (*a*) fairly wide, but must be (*b*) of the proper density, and (*c*) of a preferably straight, clean cut, and artificial appearance, with (*d*) very sharply defined edges, so as to give *a full effect of contrast.* We can readily understand that, since the canals gradually change with the seasons, it will be only at certain times of the year that the proper conditions will be fulfilled. Furthermore we may say that as long as the effect is not due to a real duplication, and can probably never be clearly seen, nor accurately studied, it is not a matter of very great importance as to just why these four conditions, with the proper spice of imagination thrown in, will produce this double appearance. Possibly the snow craters on the moon may give us further information, since they at all events show it more clearly than the canals of Mars. Undoubtedly some Martian observers are much more influenced by contrast than others, and they as we have seen are the ones that see the doubles. It is hoped that this brief description may be of some use to other observers who may wish, and are trying to see this double effect, by informing them exactly what they are to look for.

Schiaparelli made comparatively few mistakes in dealing with Mars, and his name rightly carries great weight with all thoughtful Martian astronomers. Several well-known and skillful observers fully believe at the present time that these narrow canals are really double markings. I have therefore gone into the matter at some length, and described what I have seen with care. Doubtless the majority of my readers have little faith in the doubles, and some may think that much of what I

have said was merely knocking down a man of straw. I hope that this is not really the case.

The Wide Doubles.

Turning now to the question of the wide doubles, we have here something definite to study, something that we can clearly see, and something that is certainly singular, unexpected, and that cannot be explained as due to mere accident. In my observations they do not merge into the narrow ones, as far as their width is concerned, and their appearance and duration are entirely different. Lowell considered the duplications a permanent feature of the planet, their visibility varying however with the seasons. I find the duplications to be sometimes extremely brief. The separation according to my measures is never less than 10°, or 368 miles. They show plenty of contrast with the space between them, and while only seven in number, there are three other features of a similar character which indicate that duplication is a distinct attribute of Mars. Table II is arranged like Table I except that a last column is added giving the length of the canal. The first one in the table is due to Schiaparelli, although he did not describe it as a double, but gave each component a separate name. Still as shown by his map these components are certainly strikingly parallel for a surprisingly long distance. He gives no measures at all, and we can only obtain his results from

TABLE II.

Wide Double Canals.

No.	Date	☉ °	M.D.	Diam. ″	Canal	Arc ″	Deg. °	Mi.	Len.
1	1882	...		....	Gehon Indus	....	12	450	1500
2	1903	125	July 45	11.1	Nilokeras	0.91	9.8	360	1000
3	1922 July 26	198	Oct. 9	17.1	Boreas	1.52	12.0	440	800
4	1922 Aug. 9	206	Oct. 23	15.3	Nilokeras	2.55	19.1	700	700
5	1922 Aug. 8	206	Oct. 23	15.4	Ganges	1.46	10.9	400	600
6	1924 Aug. Sept.	234	Nov. 11	23.7	Strymon Achates	4.88	23.6	870	800
7	1924 Aug. Sept.	234	Nov. 11	23.7	Aethiops Amenthes	4.31	20.9	770	1200
8	1858, '62 Jun.Sep.	...		....	Margaritifer	....	20.5	760	750
9	1864 Nov. Dec.	...		....	Margaritifer	....	13.3	490	750
10	....	...		....	Furca	....	7.7	280	300
11	1913 Dec. 17	8	Mar. 17	14.5	Castorius, Propontis	2.07	16.4	600	1100

his maps. The following canals he also represents as fairly wide doubles: Euphrates 9°, Jamuna and Typhonius 8°, Titan and Phison 7°. He indicates in addition 25 more doubles ranging from 6° to 4°. I feel doubtful if any of these should be accepted as real duplications. The diameter of his objective was only 8.5 inches, or only a little more than half the aperture usually used by Lowell. The latter twenty years later records Euphrates as 4°.2, Jamuna sometimes 4°.5, but generally single, Typhonius and Titan single, and Phison 3°.5. His widths are about half those of Schiaparelli, which is perhaps suggestive of his larger aperture, and, if his measures are correct, these duplications if unchanged could not have been visible to Schiaparelli at all.

The second double mentioned in the Table is due to Lowell, while the writer is responsible for the third, fourth, and fifth. It is of interest that in the second duplication of Nilokeras, the canal is linearly twice as wide as in the first. The considerable angular widths, 0″.91 and 2″.55, makes the difference undoubted. It is proposed to discuss the third double in another Report. The measures of the sixth and seventh pair give the mean results of the four observers mentioned in Report No. **34**, Hamilton, Wilson, Trumpler, and the writer. The fourth column gives the mean date of their drawings. The parallelism of these two doubles is surprising, and cannot be due to accident, although I do not believe them to be artificial. If we turn to Reports Nos. **34** and **35**, and examine Figures 17, 18, 19, and 20 of the former, and Figure 41 of the latter, we shall find representations of each of them drawn by five different observers. Among the ten, the only drawings showing an appreciable lack of parallelism are numbers 17 and 20, of the northern double. In the former, this double is slightly narrower at the north, and in the latter at the south.

The eighth and ninth lines refer to the duplication of Margaritifer as observed by Secchi in 1858, Lockyer in 1862, and Kaiser and Dawes in 1864. This duplication probably disappeared between 1871 and 1873, although it may have appeared for brief intervals a little later, as seen by Dreyer in 1877 (Report No. **14**). The well-known Furca, whose duplication was discovered by Dawes in 1864, doubles regularly soon after the autumnal equinox of the northern hemisphere, M. D. September 23, and remains double until well into the following October, or sometimes even early January. The Martian dates on which the duplication was first detected in 1920, 1922, and 1924 were September 25, 46, and 38, corresponding to ⊙ 174.0, 186°.0, and 181°.1. On the other hand in 1892 at Arequipa, it only first appeared double between ⊙ 209°.6 and 212°.1, the latter number corresponding to October 32. The very early longitude in 1920, 174°.0, is a little doubtful, since the planet was rather remote, diameter 9″.2, and the duplication, 0″.6, was only suspected rather than seen. In any case, the first appearance of Aryn, ranging over about one Martian month or eight weeks, appears to be one of the most regular features of the planet's year. Since the duplication is believed to be due to a dense cloud dividing the two so-called bays, it is possible that thin wisps of cloud may produce a very faintly marked doubling at other times as has been suspected by several other observers and once by the writer himself. These two bays are about 8° degrees long at their longest.

The Castorius, Propontis bays seem to have been better seen by us in Jamaica for some reason than by other observers. The latter bay was first noticed on December 16, 1913. The other appeared the next night, and the pair are shown in Report No. **8**, Figure 14. They are very much foreshortened on account of their high latitude, but are nevertheless a very striking feature of the planet. They were seen on

six nights in December, and on four in the January presentation. There is considerable evidence that, as they lengthened, they also travelled slowly towards the west, between 200 and 300 miles in five weeks (see map in Report No. **4**). These bays were seen also by Douglass and Wilson during the apparitions of 1916 and 1918 (Reports Nos. **17** and **21**).

The apparent similarity between some of the smaller lunar and the larger Martian formations has been frequently mentioned in these Reports. In Plate III, Figure 3, drawn on July 13, 1922, we have an example of a divergent double closely resembling the Aristillus canal upon the moon. On account of the foreshortening due to its high latitude it is really much less divergent than it appears. It extends between latitudes —66°.1 and —30°.5 over a distance of 1300 miles. The components diverge at an angle of 10°.1, and their maximum separation from middle to middle is 6°.5 of a great circle, or 240 miles, a

TABLE III.

FUNDAMENTAL DATA OF THE FIGURES.

Fig.	1922	Magn.	Seeing	Long. °	Lat. °	Diam. ″	⊙ °	M.D.
1	June 30	430	9	58	+ 9	20.0	182.6	Sept. 40
2	July 9	430	9	3	+10	19.2	187.8	Sept. 49
3	July 13	430	10, 9	294	+10	18.7	190.1	Sept. 53
4	Aug. 8	430, 330	10	57	+ 8	15.4	205.7	Oct. 22
5	Aug. 8	430, 330	8	85	+ 8	15.4	205.7	Oct. 22
6	Aug. 9	430	7, 9	49	+ 8	15.3	206.3	Oct. 23
7	Sept. 14	430	9	77	+ 1	11.6	228.6	Nov. 3
8	Sept. 15	430	9	56	0	11.5	229.2	Nov. 4
9	Sept. 16	430	10	43	0	11.5	229.9	Nov. 5
10	Oct. 19	430	10	86	— 9	9.2	250.8	Nov. 37
11	Oct. 21	430	9	68	—10	9.1	252.0	Nov. 39
12	Oct. 22	430	11	58	—10	9.0	252.7	Nov. 40

trifle less than that of the Furca, which is 280. Lowell once recorded Arnon near the north pole similarly divergent as it approached a lower latitude. The canal is interesting because whether natural or artificial the components are here obviously related to one another, and appear to be distributing the water, from the polar cap by means of gravity, during the spring of the year (for the southern hemisphere), M. D. September 53, from a common source in the south. One component leads towards Euxinus in the Syrtis major, the other towards Sabaeus. These are frequently the two darkest areas on the planet, and were so at this time.

The remaining figures all refer to the same region. In Figure 4 we recognize Solis on the right near the western, or sunrise terminator, Aurorae and Lunae on the central meridian, and Acidalium carrying a little elongated lake, to the south of the northern polar cap. On the eastern side of the cap we notice one of those high polar clouds, referred to in several previous Reports. Ganges is clearly shown connecting Lunae with Aurorae. It is of interest because it will be noted

that it is distinctly narrower towards the southern end. Another drawing not shown was made an hour later. It differs but little from the previous one, save that Ganges has widened somewhat near Aurorae, and Nilokeras, joining Acidalium to Lunae, is also wider. On the same date, just two hours after Figure 4 was drawn, we secured another drawing, Figure 5. Lunae it will be seen, owing to the rotation of the planet, has moved towards the left, and it is noon there now. Regions to the east, or to the left of it, have faded out under the dense mists of the limb, while regions towards the sunrise terminator have appeared that were not recorded before. Ganges is seen to have doubled.

That it was carefully drawn in the two previous representations is shown both by its unusual shape, and by its gradual widening in the second drawing. The process of duplication has always been considered mysterious by those who have recorded it, and it has been suspected of being sudden. Schiaparelli has mentioned cases where it developed in the course of twenty-four hours, but his remarks applied merely to the narrow doubles. A real duplication of a wide double, separated by an interval of 1″.46, as shown in Table II, occurring within an hour is believed to be a record. Of course it is possible that this was due to the clearing away of invisible cloud, and just before Figure 5 was drawn it was recorded that a cloud was seen preceding Lunae. This fact may have some bearing on the phenomenon. The eastern canal in this case was the fainter. The western denser one formed by the side of it. In the drawing showing the duplication the seeing was 8, while in the earlier one it was 10, so there can be no doubt but that the change actually took place.

That the duplication was not permanent we see by Figure 6, taken on the next day, about half an hour earlier in the morning than Figure 4. Ganges is again hazy and indistinct, the southern end now being wider than the northern. An hour later however the duplication again formed as on the previous day, but this time the two components were not parallel. At Lunae they were the same distance apart as before, but only 0.6 as wide at Aurorae. Moreover the duplication was now apparently carried down the whole length of Lunae, and stopped when it got to the end of it. Here the canals were perfectly parallel and straight, a bend occurring in the eastern canal but none in the western. This drawing is not shown because it is incomplete. A thin haze was prevailing, which prevented our seeing clearly the fainter detail. When clear the duplication was certain, although faint. The varying coloration of the various regions was rather marked. Lunae was brownish gray, the maria green, Tithonius and Acidalium gray, the southern snow yellowish white, and the northern "snow white."

It appears that on both of these dates in August the duplication did not appear until towards Martian noon. We have unfortunately no means of knowing how late in the afternoon the duplication lasted, since we had bad weather on the previous nights, but in any case

it would have probably disappeared before the canal reached the limb. The only other drawing that we possess showing the duplication of Ganges was made a month later on September 15, Figure 8. This time it occurred well before the Martian noon, and the width was clearly less, only 0".7, or about 260 miles. The previous night, Figure 7, there had been recorded the effect of a heavy Martian storm, darkening the soil of all the deserts in that vicinity. Lunae is shown as a perfectly round dark spot, just past the central meridian. The other spot is located on the coast line, between Aurorae and Margaritifer. The dark band connecting them is Ganges. When the deserts had dried off, Ganges doubled, and the other canals appeared. Diameter of Mars 11".5, seeing 9.

Lunae it will be seen had now extended 500 miles to the east, at a speed of 20 miles per hour, the slightly curved canal extending it further is first shown in Figure 4, but is now much more strongly marked, and is joined to the polar cap on the north, and to Margaritifer on the south, by broad bands. The next night, September 16, Figure 9, still further changes occurred. Lunae being on the terminator is not recorded, while Ganges, joining it to Aurorae, appears as a single and rather narrow canal. Again its duplication appears to be of a very temporary character unlike the narrow doubles of Schiaparelli and Lowell. The changes in the appearance of Ganges on the three successive September nights are certainly striking, and rather suggestive.

The only drawing that we have of Nilokeras as a double was made on August 9, Figure 6. None of the three drawings made the previous night, except for their continuous widening of the canal, suggest anything of the sort. The duplication it will be noticed, like that of Ganges in September, occurred in the early morning. It was very wide, the outer edges of the canal being tangent to the circumference of the circular Lunae. The western member is a little darker towards the polar cap. Each member is about one quarter of the width of the canal as measured from middle to middle of each component. They are each about 170 miles wide, and the western member in this case coincides with the original canal of Figures 4 and 5. Proceeding from Acidalium to Thymiamata, which lies between Furca and Margaritifer, we see a long straight meridional band, of about the same width and density as Nilokeras, but without its bounding canals. Since this band was really straight and very wide, as appears on a drawing made August 11, it is evident that in this figure it should have been curved, and nearly parallel to the limb. Under the rather unfavorable conditions of lighting, position, seeing, clouds, etc., under which all drawings at the telescope are made, such accidental errors are occasionally almost unavoidable. The important fact to note however is that this band has no bounding canals. It appeared again in September, but is best shown in Figure 9, where it is much narrower and darker. At the June, July presentation of this region, which preceded the August one,

Ganges was a narrow, clearly defined, single canal. Nilokeras was occasionally sharp, but sometimes broad and faint, Figure 1. The curious shape of Acidalium is noticeable. On October 21, Figure 11, Jamuna was broad with a well defined component on its western side, but with none on the other. The western side of all these canals is the darker. Figures 1, 4, 8, and 12 were drawn at successive presentations of the planet, and all have practically the same central meridian. Still another drawing was made of the region on November 24, M. D. December 17, central meridian 64°. In this a dark area is shown over Aurorae much like that in Figure 10, except that it is nearly twice the size. Ganges is decidedly wider, much as it was in Figure 7, only now it reaches the polar cap, instead of stopping at Lunae.

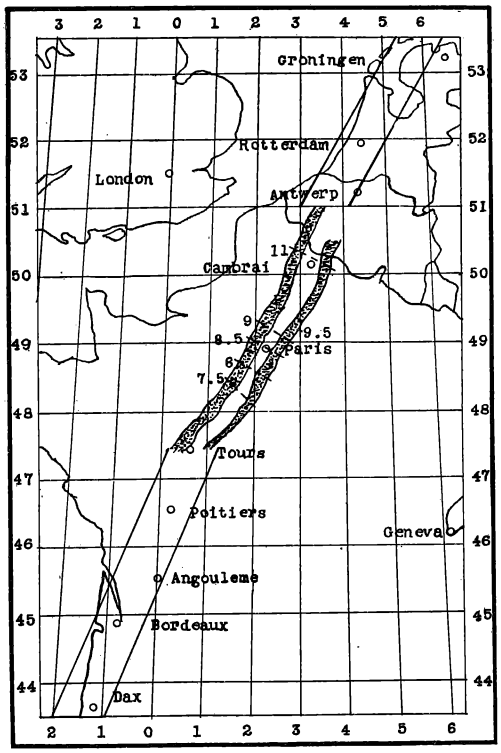
These are all the facts that we have learned in connection with the double canals. The suddenness with which the duplication forms, and the shortness of its duration, in some cases, should aid us somewhat in its interpretation. The fact that one appeared in connection with a cloud, and another immediately after a general surface darkening, which we have interpreted as indicating the result of a wide-spread rain storm, implies the darkening of a desert region by rain, rather than by vegetation. Why the lines should be duplicated it is not easy to see, but we may recall that even in this matter we have some terrestrial analogies. Accompanying our cyclonic storms in the west, we sometimes find a group of tornadoes which move in straight, narrow, parallel lines, although often they may be many miles apart. An instance still more to the point occurred nearly one hundred and fifty years ago in France, in connection with a shower of hail. That a hail storm occurring so long ago as that could in any way throw any light on what we see at the present time occurring on a neighboring planet, certainly appears at first sight a little surprising. Fortunately this storm was so thoroughly and accurately observed, that it might well serve as a model of observation for similar occurrences at the present day.

The Great Storm of July 13, 1788.

This storm swept over the most populous portions of France, and caused the people such severe losses, chiefly through the hail that accompanied it, that it has been noted as one of the contributing causes to the French revolution. It is described in two articles in the "Memoires de l'Academie des Sciences" for 1789 and 1790 by Messrs. Leroi, Buache, and Tessier. Hailstones as large as hen's eggs were not uncommon, and a few were found measuring nearly three inches in diameter. Some weighed half a pound. In places they were swept by the accompanying wind into drifts over two feet in depth. The noise made by their fall was terrifying, and prevented one from hearing the accompanying thunder. The clouds from which they fell were very low, extremely black, and advanced with frightful speed. The rain was very heavy, but the hail only lasted seven or eight minutes. Partridges,

rabbits, and sheep were killed, but no human beings, although a number of the latter were badly bruised.

A map was prepared in three sections which I have united in the accompanying figure, changing only the longitudes to the present standard. In the middle and best known section the hail fell in a double band, the space between receiving only a heavy rain, which did good rather than harm. Some rain also fell for a short distance on either side of the double band. The width of the two components varied in different places, but they remained approximately straight and parallel.



The Great Storm of 1788.

The distribution of the hail in the northern and southern sections of the map is unknown. The middle section was 300 miles in length, and averaged 40 miles in width. The total length of the storm as mapped is 800 miles, or 20 times its width. In certain places the time of the coming of the hail was noted, and where these times check one another on the two bands, so as to inspire confidence, cross lines have been drawn, and the Paris time entered on the map. The hail reached the Zuider Zee at $2^h\ 30^m$. In the middle section the hail fell in the morning. The storm advanced from the southeast, and travelled at a fairly uniform speed of 45 miles per hour. In the western band it was accom-

panied by a wind so severe as to break and uproot large trees, and damage houses and churches. There was no evidence of a whirling action, the trees all falling towards the northeast. The western band, it will be noted by the map, was also wider, as in the case of all the Martian doubles.

The double band of hail stones, by its shape and appearance, naturally suggests to our minds an analogy of some sort with the gray double canals of Mars. Had the hail formed at a great elevation, as might have been the case in the dense, extensive Martian atmosphere, and reached the warm surface after a fall of considerable duration, in the form of water, we might well have had two dark parallel bands traced on our own planet. This would have been particularly the case had the soil been barren and parched as in a desert.

But there are other points of interest in this storm. We find that the rain only fell for a short distance on either side of the double band, which gives us a clew to the width of the storm. This width was greater than that of many of the Martian canals, although appreciably less than that of the wide doubles, while its length was a fair average of them. Its direction too was Martian, and quite unlike our usual storms, which generally follow a more or less east and west course. Its straightness, also Martian, was quite remarkable, considering its narrowness and great length. It curved slightly towards the right, which was the proper direction for the northern hemisphere, but had it been in a higher latitude it must have curved more. Its observed radius of curvature was fully 5700 miles. From it we may draw the conclusion that a straight temporary canal on Mars furnishes no argument in favor of artificiality, while a permanent straight canal on the other hand, implying vegetation, may and perhaps does do so.

The Dark Circular Areas.

It has sometimes been suggested that the small lakes on Mars were not really circular as drawn, but only appeared so because they were so small. This argument however does not apply to the larger spots, such as Lunae, which is often perfectly round, as shown in Figures 6 and 7, and Tithonius near the center of Figure 10. Lunae frequently retains its rounded form for weeks at a time, but the other large round spots are only temporary affairs, lasting for but a few days or hours. These latter are quite uncommon, and are undoubtedly the most difficult features to explain of any that are found upon the planet. Perhaps the most interesting one ever recorded was first seen here at 13^h G.M.T., July 9, 1922. It was then central on Pandora, in the immediate vicinity of the Horarum promontory, in latitude —26°.5, longitude 32°.7, and near the terminator. In a couple of hours it had greatly increased in size, had developed a large white spot, presumably cloud, at its center, and had apparently travelled 300 miles towards the north. It was then recorded by several other observers. By the next night the white area

had become irregularly triangular in shape, and had moved in 25 hours 550 miles north and 250 miles west, at a speed of 24 miles an hour. When its location was favorably placed on July 8 there was no trace of it to be seen. On July 11 when Oxia was within 25° of the central meridian no evidence of the spot was visible. It had therefore apparently vanished, and had been visible for less than two days. It is fully described in Report No. **30**. It may be of interest to note that the dark spot shown near the limb in Figure 7 lies near the track, and halfway between the two positions of the white spot above described. It may be the source of the extension of Lunae towards the east, since winds having a component towards the east are almost, if not quite, unknown on Mars. Its approximate position is in longitude 50°, latitude —6°. Should any observer be fortunate enough to see one of these round dark spots in the coming years, it should be watched as carefully and continuously as possible, and its darkness and size, as well as its location, should be most carefully determined for possible motion. Whether in this case the dark spot itself moved, or simply the cloud depositing fresh moisture as it went caused the apparent motion, we cannot say. The latter appears the more probable. That the spot itself really moved 300 miles in a couple of hours when first visible is certainly surprising. The upper air currents, as we found in Report No. **19**, apparently do move at speeds of 100 to 200 miles an hour. Whether this motion ever extends down to the visible clouds we do not know. It is possible that these round spots are due to moisture deposited on the soil at night, but why they should be so accurately circular unless artificial, remains a mystery. Have the Martians on the other hand some means of drawing large supplies of water from the interior of their planet? Can the tapping of submartian water courses explain some of the canals? If so, most of the water is certainly evaporated, and goes into the general atmospheric circulation. Unless that is what they want to do, to dampen their atmosphere, this to terrestrial eyes would appear to be unnecessarily wasteful, but doubtless we should be doing the Martians an injustice to suppose that they were as wasteful as ourselves.

As to the size of these round spots, Lunae on August 9 was 900 miles in diameter. The other spots range from 500 miles down. Three of varying size are shown in Figure 10. Lunae is there quite small, but two days later in Figure 11, and in another drawing not shown, the two southern canals in Figure 10 leading to it, or from it, have widened markedly. Lunae itself has disappeared, and we see that in Figure 12 one of the canals has narrowed again appreciably, as if the moisture had evaporated. Although we are slowly learning, step by step, and find it intensely interesting, we see that we are as yet far from having anything beyond the most elementary meteorological knowledge of our most attractive planetary neighbor.

Private Observatory, Mandeville, Jamaica, B. W. I.,
November 20, 1926.