and more sharply marked than those produced by the currents acting at a greater distance from the mirror."

Mandeville, Jamaica, B. W. I., April 1, 1925.

REPORT ON MARS, NO. 30.

By WILLIAM H. PICKERING.

The White Spot of 1922. Formation of the Canals.

The most conspicuous and striking single event of this apparition was undoubtedly the formation of the large white spot just to the south of Margaritifer on July 9. Its appearance on that evening when fully developed is shown in Figure 6 of our last Report. At 8:02 E. S. T., a drawing of the region was made, and a round dark area of unusual appearance and some 400 miles in diameter was recorded and sketched near the sunrise terminator, near longitude 15°, latitude —25°. The central meridian of the planet at the time was 331°, ⊙ 187°.8, corresponding to the Martian Date September 49, or 13 days after the equinox. The spot was appreciably darker than its surroundings, being marked 4, while the latter were 5 on our scale of brightness. The average maria are marked 3, and the deserts 7. A straight dark band 100 miles in width, and of the same darkness as the spot, led northerly from it, connecting it with Margaritifer.

The drawing was finished at 8:47, but the spot unfortunately was not again examined until 10:15, since I was busy at the time in proving that the brilliantly blue surface of the Syrtis, which was near the limb, did not give out any polarized light, and therefore was not liquid. It was then at once seen, however, that during the intervening 90 minutes the spot had suffered a great change. It had notably increased in size, and now measured 1100 miles in longitude by 900 in latitude. It had also changed its position, its center having moved fully 300 miles to the north in the meantime. It is certain that this result could not have been due to the spread of vegetation. The simplest and only obvious explanation is that the change of size and position was caused by the thawing of frozen ground to the east, west, and north of the original area, as the morning sun rose higher and higher upon this portion of the planet's surface. It thus appears that ground that is thawed by the sun will produce the effect of dark areas, and also of dark bands or canals.

The interesting feature that had now developed however was a large white spot located slightly to the south of the center of the dark area, and measuring 700 miles in longitude by 550 in latitude. It was therefore considerably larger than the dark spot when the latter was first seen. Its brightness was 7, or about that of the desert regions, and the canal or band was still visible through its middle. The width of the canal was 70 miles. Its center was located in longitude 23°.5, latitude —13°.4, and it did not coincide with any known canal seen before or since that time. By 11:05 the spot had brightened to 8, and was as bright as the northern polar cap. When at maximum brightness the polar caps are marked 10. The edges of both the spot and the canal were very sharp, but in spite of that fact, and the straightness and uniformity of the canal, there would seem to be but little doubt but that the white spot consisted simply of two clouds.

The next night, July 10, it is recorded at 8:31 that there was no elevation on the sunrise terminator in the place of the spot. The region was clouded, but there certainly was no high cloud there. The whole sunset limb also was heavily clouded, showing that there was much moisture in the planet's atmosphere. By 11:00 the white spot had separated itself from the cloud on the terminator, and was distinctly yellowish and ill defined, indicating that it was now certainly cloud or fog. The canal had disappeared. The spot had elongated itself towards the northwest, was somewhat crescent-shaped and convex towards the west. It measured 1200 miles in this direction, by 500 miles at its maximum width. The southern border had moved northerly 200 miles and its northwestern point 900, crossing the equator to latitude +15°. In longitude its eastern edge was unchanged, but its western edge near its northern extremity had advanced about 550 miles. In 25 hours its center therefore had advanced 550 miles north, and 250 miles west. While the advance of a cloud does not necessarily mean the same thing as the distance traversed by the wind, yet this southeasterly wind of 24 miles per hour is about what we find in direction and speed over the oceans at the same season in the same latitude in our own torrid zone. At this time the southern polar cap, while still large, was melting rapidly, and the northern cap depositing, showing a rapid transfer of moisture from pole to pole.

Although nothing unusual was noted in this region in August, except the striking size and darkness of Lunae, yet on September 14, Martian Date November 3, a round black spot 500 miles in diameter appeared in apparently exactly the place where the white area had been on July 9. Lunae appeared as a similar spot of the same size, while Ganges was very dark and over 300 miles in width. Moreover the whole of Thaumasia was dark, completely hiding Solis from view. This also occurred in 1892. The canal Issedon showed faintly, but the next night both it and Nilokeras were very dark and wide. The whole of this side of the planet seemed to be transformed, but no bright spot analogous to that of July 9 appeared there. This region remained active and changeable throughout our observations in October and November, Ganges being again particularly wide and dark in the latter month. The rapid changes in the appearance of the chief canals of this region clearly implied the presence of water in the form of moistened soil rather than of vegetation, at this season of the year. Changes somewhat similar, but less marked, were noted in the early Martian September in 1920, but on account of the remoteness of the planet at that time were not well seen. It is of interest to note however that while Ganges frequently appeared broad in 1924, at this same Martian season, yet it was never as conspicuous as in 1922, nor were there any changes in Aurorae and Thaumasia this year at all comparable to those of the previous apparition.

Between June 28 and August 2, ⊙ 181°.5 and 202°.0, corresponding to the Martian late September and early October, Thaumasia increased in length towards the west from longitude 45° to 65° by the disappearance of Aonius. The same phenomenon took place in 1924 during the Martian November. In 1922, from July 5 to the end of the year, Pandora appeared, disappeared, and reappeared in a striking manner, sometimes in the course of twenty-four hours. This must have been due to invisible cloud, or terrestrially speaking haze, since the background was never as bright as the desert regions of the planet.

What is believed to be Amenthes appeared on May 9, ⊙ 154°.1, Martian Date August 46. Nevertheless two hours later on this same date, when on the central meridian, it could not be found although carefully looked for. This illustrates how ephemeral even well marked tropical canals may sometimes be. No Martian clouds were visible in this place at this time. This observation tends to confirm our belief that some of the Martian canals are at times merely shower tracks, which under a hot tropical sun simply dry up. Of course later in the season they may develop vegetation, and become more permanent. At the next presentation, on June 13, ⊙ 173°.0, Martian Date Sept. 24, Amenthes was clearly visible, joining Thoth directly to the Syrtis Minor. This is the first apparition at which it has certainly appeared, although Maggini and others had suspected it in previous years. On the same date Aethiops was seen as a broad dark meridional band, joining Cimmerium to the northern polar cap, and tangent to Elysium at Hephaestus. The next night the northern section had disappeared, although it was then crossing the central meridian, and again no clouds were visible. It was not seen again until the next month, when it was even more conspicuous. The dark border to the southern polar cap, due to the melting snow, appeared for the first time on May 9 corresponding to August 46. The canals bounding Elysium, as we have earlier noticed, nearly disappeared from view during this month, leaving this conspicuous marking almost unrecognizable. At the following presentation in June it appeared as usual.

On June 14, ⊙ 173°.5, Martian Date September 25, clouds crossed the Syrtis when it was within 40° of the central meridian, dividing it in two, as had been the case in 1920 April 20, Martian Date July 41 (Report No. **25**, Figures 19, 33, and 34). This cloud has even been noted on the central meridian itself at the Lowell Observatory, and seems to be a not unusual feature during the late summer and early autumn of the planet. The northern polar cap very greatly increased in extent in June, between the Martian Dates of September 27 and 29. Its rapidly shifting shape and position from night to night left no doubt in our mind that it was due to cloud. The surface still retained a somewhat greenish tint, as if the cloud only partly covered the grass or foliage beneath it. Much cloud was visible on the deserts bordering the southern maria, as has been frequently noticed on other occasions. It appears as if an upward current of air occurred in these places, carrying the moisture with it and precipitating it as cloud. During late May and June, corresponding to September on Mars, Acidalium went through many very remarkable changes of shape, not apparently due wholly to cloud, but which cannot be described here. Still later, August 2, ⊙ 202°.0, when the apparition was well over, and the planet's diameter reduced to 16″.1, the fine canals crossing the desert in the vicinity of longitude 120° came out (see Figure 11). They were extremely faint and difficult, and this is the first apparition at which they have been visible here. The lakes upon them were large, round, and fuzzy, as they have sometimes been drawn by Lowell. An hour later large areas around them had darkened. Unfortunately weather conditions were such that we obtained only one good view of them before the disk had become too small. It certainly appears regretable that with so much that was of interest occurring at this unusual apparition, and so much more that we must necessarily have missed, that no southern observer furnished with a suitable telescope felt enough interest in Martian phenomena to turn it on the planet, even for the few hours required to obtain valuable results.

Pressure of the Martian Atmosphere.

It has been universally believed heretofore that the atmospheric pressure at the surface of Mars was materially less than that on the surface of the earth. Ratios of 1/10 to 1/4 were commonly assumed. In Report **19**, *7* a numerical result was obtained, in which it was shown that the minimum pressure could not well be less than one-quarter of that found at the earth's surface. No maximum results however have hitherto been secured. The arguments in favor of a low pressure were fourfold. One depended on the surface gravity, which is 0.38 that of the earth. This indicated that an unobstructed gaseous molecule whose radial velocity exceeded 2.7 miles per second could escape from the planet, whereas on the earth it would have to reach a speed of 7 miles. This argument is however by no means conclusive, since the average speed of oxygen and nitrogen molecules at ordinary temperatures is only 0.2 miles, and we do not know that our atmosphere was ever much more dense than it is at present. If it was not, and if it accordingly has not been losing gases to any appreciable extent, then there is no conclusive evidence that Mars could not also retain as dense an atmosphere as ours is at the present time.

The second argument depends on the brightness of the Martian limb as compared to that of the center of the disk. This assumes that the effect of the planet's atmosphere, like the sun's, or Jupiter's, is wholly absorptive, and therefore must darken the limb. In point of fact the limb of Mars is often brighter than the center, which on that theory would make us see the center of the disk through a greater thickness of atmosphere than we do the limb. It is obvious that the brightness of the limb therefore is due not to lack of absorption, but simply to cloud or haze, so that this argument in favor of a rare atmosphere need not be taken seriously.

The third argument is equally ineffective. It states that the surface detail of the planet, especially near the limb, is so distinct that a dense atmosphere is impossible. A simple mathematical consideration should help us to settle this matter. One can under favorable circumstances just distinguish the maria from the deserts when within 0″.5 of the limb. If we assume that the planet's diameter at this time is 20″, this will correspond to a distance from the center measured on the surface of 71°.8. The ratio of the length of atmosphere traversed by a ray of light coming from this point to the eye, to the length traversed at the center of the disk is as the secant of this angle, or 3.2. The height of our homogeneous atmosphere, that is to say the height our atmosphere would reach if it were of uniform density equal to that at sea level, is 5 miles. Hence if we were outside our atmosphere, looking down on the earth, it would interfere with our vision just as much as the atmosphere does between us and a hill five miles distant at sea level. Consequently, if the Martian atmosphere contained as many molecules over every square foot of surface as does that of the earth, it would interfere with our vision within 0″.5 of the limb just as much as our own atmosphere does in viewing an object 16 miles distant. In the clear dry air of our western plains the interference with vision at such a distance is almost negligible. It is certainly materially less than we find on Mars near the limb. Whence we must conclude either that the Martian atmosphere is less clear than our own under favorable circumstances, or else that it contains more molecules per square foot of surface than that of the earth.

The fourth argument in favor of a rare Martian atmosphere is the simplest of all, and for that reason is probably the one which appeals most directly to the unthinking. They say the earth has a dense atmosphere, the moon has hardly any at all, since Mars in size and mass lies between them, its atmosphere must do the same. In point of fact the reason that the moon has so little atmosphere is on account of its origin as a meteoric ring from the side of the earth, and has nothing whatever to do with its mass.

We now come to a distinct turning point in our views regarding the surface conditions upon the ruddy planet. It has been known for many years to planetary astronomers that the temperature of the Martian surface does not differ very greatly from that of our earth, and that the polar summers indeed are warmer. But while we have no reason to change our views regarding the temperature of the Martian surface, there are now five very excellent reasons, just developed, why we should change our opinion regarding the pressure of the Martian atmosphere. The first of these has been already referred to in our Report No. **29**, 8. It is there recorded that limb clouds were observed rising over the southern polar cap, and reaching an altitude on two days of 50 and 55 miles. Our own analogous thunder storm clouds have occasionally been known to reach an altitude of 7 miles. If the surface gravity on Mars were increased 2.6 times, so as to equal that of the earth, its atmosphere would be condensed in this same ratio, and we should not expect its clouds to rise higher than 20 miles. But if our clouds were to rise to a height of 20 miles, the pressure upon them would be only 1/15 of what it is at 7 miles, and could only equal it in case there were 15 times as many molecules in our atmosphere as at present. Is it possible that the Martian and terrestrial clouds rise till they reach the same atmospheric pressure? If so, there are then 15 times as many molecules in the Martian atmosphere per square foot of surface as there are in our own, and this implies that the pressure at the surface is 6 times as great as it is on our earth! This figure may of course be modified, increased or lowered, by the molecular weights of the gases concerned, and also by the temperature at the point of condensation of the cloud, but neither of these modifications can change our result very materially. We may therefore take 6 times our atmospheric pressure as a maximum probable figure, and say that the indications are that the pressure is at least likely to be somewhat greater than it is at the surface of the earth.

The second argument that we shall mention in favor of a dense Martian atmosphere is due to Mr. Wright. By photographing the planet by blue, and also by infra-red light, he found that the former gave an image indicating a radius 120 miles greater than the latter. The photographs were taken with a reflector, and all allowance made for chromatic aberration, irradiation, etc., in the path of the rays after passing the focus. He considers the blue image to be that of the planet's atmosphere, and the red that of the planet's surface (*Pub. Astr. Soc. Pacific,* 124, **36**, 246). For reasons presently to be given, I cannot accept the view that the blue image is of the planet's permanent atmosphere, but hold rather that it is of haze supported in the permanent atmosphere. If our own planet were photographed from a distance in the same manner, we might find that the blue image showed haze and thin cirrus cloud, rising in some places to 7 miles above the terrestrial surface, as indicated by the diameter of the red image. Our visual observations of the Martian limb clouds indicate that they rose 8 times higher than our cumulus. Mr. Wright's photographic measures indicate a ratio as compared to our cirrus of 17. He states however that he does not insist on the accuracy of his measures, but perhaps he would be unwilling to reduce the distance he found by one-half. Personally I think his infra-red diameters may be a little too small, since he states that they agree with the Ephemeris, which is based on the measures of Hartwig, made in 1877.

In 1892 a series of micrometric measurements were made at Arequipa of the polar and equatorial diameters. These measures extended from July 24 to August 18, or during the period when the planet's diameter exceeded 24″. From 14 measures of the polar diameter, after reducing to unit distance, and correcting for refraction and phase, the writer obtained 9″.52 ± 0″.05. From 13 similar measures Professor Douglass obtained 9″.54 ± 0″.07. For the equatorial diameter, from 12 measures by each, we obtained 9″.65 ± 0″.05 and 9″.66 ± 0″.05 respectively. These figures are slightly larger than Hartwig's determination, which is now generally accepted, and which gives 9″.30 for the polar diameter and 9″.42 for the equatorial. We found a polar flattening of 1/76, Hartwig found it 1/78. At the next apparition in 1894, between October 12 and November 21, Dr. Lowell, Professor Douglass, and the writer made at Flagstaff a quite extensive series of measurements, 464 in all, of which over eighty percent were made by Professor Douglass. Dr. Lowell gives the results in his Annals **1**, 75. He makes a correction for irradiation of the disk, which would be doubtless desirable if we were sure of its amount. He considers its value to be 0″.125. In order to compare his results with those of other observers, who make no such correction, we must add this to his published figures, and obtain for the polar diameter 9″.45, and for the equatorial 9″.50. Since both the seeing and instrumental equipment at Arequipa and at Flagstaff were superior to those of all previous observers, it seems likely that Hartwig's value is too small.

In 1892 Mars was in the same portion of its orbit as in 1877 and in 1924. The southern polar cap was melting rapidly, many clouds were seen, and the atmosphere was full of moisture. On the other hand, while the measures in 1894 were in progress the polar cap had entirely disappeared, and the planet's atmosphere should have been dry and clear. This is further indicated by the similarity in the values of the polar and equatorial diameters, giving the theoretical ellipticity of 1/190, which would lead us to believe that the measures referred to the disk itself, and not to the haze in its atmosphere. Taking the difference in the equatorial diameters in the two years, we find that this amounts to 0″.16. The difference between the polar diameters is 0″.08. Their difference divided by 2, expressed lineally is 18 miles, which leads us to believe, if only an equatorial belt of haze existed, that the maximum height to which the haze rose in 1892 in the planet's atmosphere did not exceed this figure. This is 2.5 times that of our cirrus.

A fourth reason for believing in a high density for the Martian atmosphere depends on the recent thermopile observations of the temperature of its surface, which we shall presently briefly describe. These prove that the equatorial temperature of that planet is something like 100° F higher than we should expect it to be, based on the equatorial temperature of our earth. Such a great difference, while doubtless partly explicable by other causes, implies very distinctly a much denser, not a rarer atmosphere than our own.

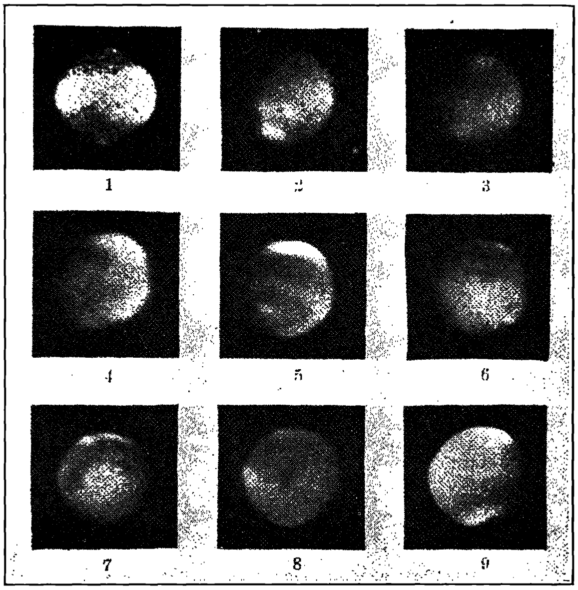
Finally we have a fifth, but at present only qualitative method of determining the density of the Martian atmosphere. We speak of our clouds as white, although they are by no means as white as snow. On Mars the clouds are distinctly yellow, as has been noted by many observers. Dr. Lowell even went so far as to describe them as dust clouds. Nevertheless they are of all grades of whitish yellow and yellowish white. On rather rare occasions they appear as white as our own. The polar caps never appear as white as snow near at hand, although whiter than the snow upon distant mountains. For those observers who live within sight of snow peaks, which we do not, it is suggested that we have here a fifth method of determining the density of the Martian atmosphere, by means of a comparison of this sort. This suggestion is particularly recommended to Swiss observers.

For these five reasons, based on observations and investigations favoring a dense atmosphere, and for the four reasons previously given, showing the inadequate support of the view favoring a rare atmosphere on Mars, I believe it is now time for planetary astronomers to change their views with regard to surface conditions on that planet, and adopt the position that not merely its temperature, but also its atmospheric pressure, closely resembles that found on the earth. Heretofore we have doubtless all felt that it was possible that it supported animal as well as vegetable life, and even that intelligent life, if not proved, was not impossible. Now however we may perhaps say that with similar conditions to those found on the earth, and vegetable life assured, animal life is almost certain. Furthermore if it, and if intelligent life exist there, as the straight and narrow canals seem to imply, then the evidence now adduced indicates that it need not be so very unlike ourselves as we have heretofore been led to surmise.

Let us now turn to certain other interesting statements made by Mr. Wright. Regarding the photographs secured with the blue rays, he says "all contrast relating to permanent markings is lost." Doubtless this statement was entirely correct for this apparition, but it is nevertheless by no means always the case, for in 1890 before the color sensitizing process was in general use, or was indeed even well known, we obtained a number of photographs on ordinary plates, showing surface detail which is now better exhibited by means of plates which have been rendered sensitive to color.

In Plate XXIV nine photographs are shown, taken for a study of Martian meteorology (Harvard Annals, **53**, Part 8). On three of these, 6, 7, and 8, surface detail is visible, showing that at times the atmosphere of Mars is quite transparent to the blue rays. The Furca end of Sabaeus is central in No. 6, Sabaeus and the Syrtis are shown in No. 7, while the Syrtis itself is central in No. 8. The instrument used was a 13-inch Clark refractor, and the first photograph was taken at Cambridge, Mass. The remaining eight were taken from Mt. Wilson,

PLATE XXIV.



PHOTOGRAPHS OF MARS
taken at Harvard Observatory and the Harvard Station on Mount Wilson in Southern California in 1888 and 1890.

California, where the Solar Observatory is now located. The image was enlarged at the focus of the telescope in the first case to 5″ to the millimeter, in the others to 2″, corresponding to a focal length of 338 feet. In these latter views the exposure ranged from 60 to 90 seconds. The image was again enlarged before printing. The prints in the Annals are poor, and are enlarged too much. The negatives were reprinted on a smaller scale, the same as is here used, in *The Technical World Magazine,* 1906, 460, and in my little book on Mars. A detailed description of the photographs is given in Table I. The third and fourth columns give the longitude and latitude of the center of the disk, and the last two the solar longitude and corresponding Martian Date.

Early Photographs of Mars.

TABLE I.

No.	Date	Long. °	Lat. °	Diam. ″	⊙ °	M. D.
1	'88 Apr. 26	206	+22	15.3	121.0	July 37
2	'90 Apr. 9	133	5	12.8	134.4	Aug. 8
3	" " 10	120	"	"	134.9	" 9
4	" " 15	62	"	13.6	137.4	" 14
5	" May 1	245	6	16.1	145.3	" 29
6	" " 26	357	9	18.9	158.4	" 53
7	" " 31	332	10	19.3	161.0	Sept. 2
8	" June 1	301	11	"	161.6	" 3
9	" " 30	3	14	17.4	177.6	" 32

In these photographs it was shown that clouds may often be photographed on the planet that are wholly invisible to the eye. In 1888, out of 26 plates examined, 54 percent show traces of clouds near the center of the disk, and 15 percent show an equatorial band of cloud or haze. No. 1 in the Plate illustrates the latter, and shows that no surface detail could be photographed through it on such a plate. Nevertheless no such effect is ever seen by the eye. It is clear that this appearance is due to equatorial haze, and not to the Martian atmosphere itself. By the word "haze" as here used is meant an opacity so slight that on the earth we could distinguish through it a hill or mountain 10 to 15 miles distant, but yet could not photograph it on an ordinary dry plate. Probably some haze of this sort covering the whole planet occurred this past year, as is indicated by Mr. Wright's photographs taken by blue light. Indeed we often remarked ourselves that Mars seemed especially lacking in contrast at this apparition. No. 9 in the Plate is taken with practically the same central longitude as No. 6, yet like Mr. Wright's photographs shows no surface detail. The difference between them must be attributed simply to the fact that in No. 9 the Martian atmosphere was full of haze, while in No. 6 it was clear. Undoubtedly in order to study the Martian clouds to the best advantage we must photograph them by blue light, and compare our results with drawings or with photographs upon orthochromatic plates.

In 1890, out of 46 plates, 63 percent showed traces of cloud or haze near the center of the disk, while 52 percent gave evidences of an equatorial band of cloud. This latter is illustrated in No. 5. In No. 2 and 3, taken on successive nights, we note a dispersal of cloud in the northern hemisphere, and the formation of a cloud cap at the southern pole. The increase in this cap five days later, shown in No. 4, is marked. In No. 5, taken two weeks later still, we have what appears from its sharpness and brilliancy to be a deposition there of snow. Since it is near the end of the southern winter, this is what we might naturally expect. The slow and gradual diminution of the snow caps was first noted by Herschel, but this we believe is the first record of their rapid formation. The small bright spot in the northern hemisphere in this figure is located over Elysium, where cloud masses have frequently been noted visually. In No. 7 is given the first record that we have of a limb cloud such as is described in our last report. It must have been very conspicuous visually. Indeed something was vaguely seen there the next night in Cambridge, although the seeing was recorded as very bad. The Martian Date at which it appeared is just 30 days earlier than that of the first projection that we saw in 1922. In our last Report we stated that we were not aware that Limb Projections had been observed elsewhere than in Arequipa and Jamaica, or between 1892 and 1922. We now find that they were also recorded at the observatories of M. Jarry-Desloges at the apparitions of 1911 and 1914, and that one was even seen as late as 1916 (Observations des Surfaces Planétaires **3**, 143, **4**, 90, and **5**, 83). A limb projection was also seen and photographed at the Lowell Observatory in 1911, under the title "Autumnal Frost on Mars" (Bulletin **71**).

The southern pole was now turning away from us, concealing the snow, but clouds were forming around the northern one as the autumnal equinox was approached. In No. 9 we have a photograph of one of those striking northern cloud formations which were described in Report **23**, 8, under the name of snow storms. The photograph makes it appear as if the storm had reached its maximum intensity in the afternoon. Most of those observed in 1920 appeared to have occurred at night. The last one detected in that year was on the Martian Date of September 20. What was apparently the first one in 1890 occurred twelve days later in the Martian year.

A more complete description of these observations and early photographs will be found in the volume of the Harvard Annals above mentioned, but we understand the planet so much better now than we did when that description was written, that a brief reference to them here in connection with the more recent photographs taken at the Lick Observatory does not seem out of place. The reason why Mr. Wright obtained no evidence of surface detail with blue light this year, we believe therefore is not due to any peculiar constitution of the Martian atmosphere, differing from our own, but simply that during his observations, owing to the very rapid melting of the southern polar cap, the atmosphere was full of thin haze, penetrable only to rays of long wave length.

The Temperature of Mars.

Besides Mr. Wright's paper, we find in the same publication two others, one by Messrs. Pettit and Nicholson, the other by Messrs. Coblentz and Lampland, both dealing with the temperature of Mars. The former used the 100-inch mirror in California, and the latter the 40-inch at the Lowell Observatory. Both used thermocouples, and their results were in general confirmatory. The former found for the center of the disk a temperature of 45° F, and the latter a result ranging between 45° and 65°. There is nothing surprising in these figures, indeed in Report **23**, 12, it was suggested, based on observations of vegetation and snowfall, that the mean temperature of the equatorial regions of the planet, day and night, might be not far from 40°.

But what is curious and unexpected is that the former found for the polar regions, where the snow was still melting, a temperature of —90°, and the latter state that these regions "emit practically no planetary radiation"! Near the limb the temperature according to the former is only 9°, and at the limb itself "much lower". Further the temperatures were distributed symmetrically on either side of the central meridian, with "no displacement of the point of maximum radiation," such as might be caused by rotation, as on the earth. The latter found "the morning side of the planet at a lower temperature than the afternoon side." How different all this is from what is found on the moon. There when the moon is full "the heat in the circumferential zone differs from that at the center by only about 20 percent" (The distribution of the moon's heat, 36, by F. W. Very). On the earth at sunrise and sunset, as compared with noon, it differs much less than that.

How shall we explain these results? We cannot go back of the observations, which except for the last one are mutually confirmatory, but it is possible that they have not been correctly interpreted. If the diverse observations of Mr. Wright and the writer, both leading to the same result, that Mars has a very dense atmosphere, are correct, and if according to them it has several times as many molecules per square foot of surface as that of the earth, then it is clear that there can be no such range of temperature between the limb and the center of the disk as is suggested in these two papers.

Earlier observations we know showed that the planet Jupiter, like the Martian polar caps, gave out practically no planetary radiation. There can hardly be any doubt in the mind of any living astronomer however that the interior of Jupiter is excessively hot. Were it not for its absorbing atmosphere it might perhaps shine like a sun. Assuming the rotation of the markings in the middle latitudes to give the true time of rotation of the planet, then the equatorial markings are swept along by the wind blowing 250 miles per hour. New spots covering areas nearly as large as the earth sometimes suddenly appear, and then again as suddenly vanish. The red spot has of late years changed its rate of revolution by several seconds. The energy consumed in producing these changes cannot come from the sun at such a distance, and necessarily implies an enormous evolution of internal heat. How dense and how deep an atmosphere is required to conceal the true temperature of this tremendous planet?

It can readily be shown mathematically that if the earth had no polar caps, no oceans, and no atmosphere, that at our summer solstice the hottest place on its surface would be the north pole. Owing to these circumstances however, the temperature of the pole is actually lowered to about 50° F below that found on the equator. Now Mars has an atmosphere producing a pressure presumably like our own, very small polar caps at the solstices, and no oceans. It is not likely therefore that the polar temperature is anything like 50° below that at the equator. Moreover the polar regions have sometimes been recorded as a bright vivid green, like young grass in the spring. At the summer solstice in 1924 the polar cap was less than 500 miles in diameter, and was still melting. A temperature of —90° F, or 135° below that at the equator, therefore appears preposterous. But if the Martian atmosphere is of such a density, or of such a nature, as to erroneously indicate such a low temperature at the limb and at the poles, it must also have some effect at the center of the disk. If our reasoning is correct therefore, the results given in the two papers referred to must be considered merely as giving minimum results, and it is possible that, chiefly from the lack of oceans, but also owing to the dense atmosphere, both the Martian equatorial and polar temperatures may be in reality appreciably higher than our own.

It has generally been assumed heretofore that the maria in the southern hemisphere were at a lower level than the deserts in the northern. According to Coblentz and Lampland the difference in their temperature is 15° C or 27° F, the deserts being the colder. On the earth a diminution of 1° F corresponds to an increase of 300 feet in elevation. This would imply that the deserts were on the average 8100 feet higher than the maria. If the densities of the two atmospheres are alike, this same figure might also apply to Mars. This difference in altitude we could hardly detect telescopically by terminator observations, so very likely this difference in elevation is approximately correct. We often see clouds lying on the deserts at the border of the maria, and perhaps we may say that we now know, what we formerly only suspected, that these clouds are lying on the southern slopes of the grand plateau bounding the maria on the north.

It is noticeable that certain portions of the southern maria, particularly between Elysium and the Syrtis, extend considerably farther north at certain times than at others, while other portions, such as that part of Sabaeus south of Edom, appear quite unchangeable. Vegetation will apparently grow only under favorable seasonal conditions in the former region, while it will grow at all times in the latter. The former is therefore presumably more elevated than Sabaeus, or expressed otherwise, the slope from the maria to the deserts north of Sabaeus is more precipitous. We are led to this same conclusion from the fact that this is also the place where the boundary clouds are the most frequent and noticeable upon the planet. Based on this same theory the region south of Sabaeus is also elevated. Sabaeus accordingly lies in a long narrow valley, and possibly the same may be said of Pandora and Cerberus.

If the temperature of the equatorial desert regions fails to rise above the freezing point, or only slightly exceeds it, and drops below freezing every night, we can readily understand why vegetation there is scarce, or non-existent. With a low temperature and high atmospheric pressure, it is now clear how the chief northern canals can exist throughout the day without much evaporation. They are then simply areas of moistened ground, the moisture being deposited from fog at night along the tracks of winds proceeding from the polar caps, and drawn in the course laid down by Ferrel's theory of the winds towards the most marked depressions in the surface of the planet. These new views remove what has always appeared to me to be the main objection to this explanation of the chief canals. The finer straight canals can hardly be due to air currents, and it would seem that they must be laid down on the surface of the soil itself. While these recent observations of the temperature of Mars may not give us all the information that we had formerly hoped for, as to the actual temperature found on the surface of the planet, yet they undoubtedly form a most important contribution to our knowledge, and we must congratulate the four observers on the great skill and success with which they have carried out these exceedingly delicate measurements.

These new ideas with regard to the Martian atmosphere lead us to look on the planet as a much closer facsimile of our own than we had previously believed. While the surface gravity is less than ours, the atmospheric temperature and pressure appear to be much the same. Mars therefore differs mainly from the earth in that our oceans are replaced by elevated deserts. The maria must be very like our continents, and the planet's meteorology like our own, except for the fact that it is that of a desert planet instead of an oceanic one.

Private Observatory, Mandeville, Jamaica, B. W. I.
December 20, 1924.

Note on Dr. Van Biesbroeck's Observation.

In Popular Astronomy for December, 1924, Dr. Van Biesbroeck records an observation of a limb cloud, seen on the evening of October 27, at $14^h\,15^m$ G. M. T. The same cloud was recorded here in a drawing made by Mr. Hamilton on the same evening between $13^h\,15^m$ and $13^h\,37^m$, our eastern longitude accounting for the earlier observation. In this drawing the cloud is about half the length of the one drawn in