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## THE CANALS OF MARS

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Many attempts have been made to photograph those difficult markings, the canals of Mars. Although interesting pictures have been obtained, no photograph has shown the fine details described by visual observers. With the increased optical power and improved photographic techniques now available it may seem strange that better photographs have not been made. The explanation that large apertures are not adaptable to the problem, because seeing conditions are *almost* never good enough, is commonly accepted. Whether the word in italics offers any hope of success is now to be considered. My experience in observing the canals at the favorable opposition of 1939 is described here, not in any attempt to add to the already extensive literature on Martian canals, but to lay a basis of procedure for photographing them.

Largely as a matter of self-education, I began early in 1939 a series of drawings of the planet with a 6-inch Clark refractor in Pasadena to verify, if possible, the well-known seasonal changes. After examining the planet carefully at the oppositions of 1907 and 1909 and casually in 1924 and 1926, I had arrived at the conclusion that the canals, if not largely chimerical, could be seen only with an eye of special adaptation and that my eyes were of the great majority which could not see them. Certainly I had no thought of ever seeing them with a 6-inch refractor.

By midsummer of 1939 a small collection of drawings had been obtained. If such sketches of the planet were in color, the polar caps and certain temporary spots would be white, the shaded areas green, and the remainder of the planetary disk a

brick red. Early in the morning of July 6 (civil date) the seeing was about 3–4 on a scale of 7, but by the time an outline sketch had been made, it improved to 5–6. Plate I, *a*, shows the planet as it appeared about 1:25 A.M., P.S.T. I was not satisfied with it, however, and was trying to make out the character of the narrow equatorial boundary *AC* of the large elliptical eyelike marking and had centered my attention on the section *AB*, when suddenly a canal appeared to descend from *A* to the green boundary of the north (lower) polar cap (apparently wriggling as it proceeded, then becoming steady) and then almost simultaneously another descended from *D*. Within a few seconds the canal connecting *B* with the north polar region was observed as shown in Plate I, *b*. This was at 1:30 A.M. By 3:30 A.M. an additional canal had been observed, and at times the four were seen simultaneously (Plate I, *c*). At this time the objective dewed over and the ocean fog covered the sky. It seemed that critical focusing was necessary, and that spectacles somewhat improved visibility of the canals. My left eye, which is best adapted to other observational work, seemed best for seeing the canal structure. These observations were made with a power of 243. The canals could be seen with difficulty with 141 power, but there was not time to try other powers. Having seen canals for the first time, I decided not to examine drawings or maps made by others until the 1939 opposition was past, thinking that complete ignorance of canal details observed by others would make my drawings of more value. No comparisons were actually made until the present paper was prepared.

On succeeding nights the definition was not so good, but, knowing what to look for, the previously observed canals and some additional ones were found as the planetary markings retrograded toward the east limb (as seen in the sky) from night to night, since the Martian day is 37<sup>m</sup> longer than the earth's.

On July 10 the drawing in Plate I, *d*, was made at 1:30 A.M. with the 6-inch Clark, and the following day I went up Mount Wilson to attempt similar observations with the 20-inch reflector, which was used in Cassegrain form with a power of 377.

On July 12 at 1:30 A.M., when the seeing again reached 6–7, drawing I, *e*, was obtained. This drawing represents four and

one-half hours at the telescope. At times the whole pattern of canals became visible and the canals appeared green. Because each canal was located on the sketch and identified three times before being put in the final drawing, I think there were many canals not plotted. The following night, drawing I, *f*, was obtained with the 20-inch at 12:20 A.M. After returning to Pasadena I obtained drawings I, *g*, and I, *h*, with the 6-inch on July 15 and 21. The canal which touches the NW limb (as seen in the sky) was observed on July 23, but has been added to the original drawing of July 21 for the sake of compactness. I again returned to Mount Wilson and obtained the drawing I, *i*, with the 20-inch on July 25.

Plate II (*a* to *g*) shows a nearly complete rotation of the planet from drawings made during July and early August 1939. Drawing II, *e'*, which was made on August 24 (25 U.T.), is at the same aspect as II, *e*, above it, made on July 26. Here the Martian season has advanced until the south temperate zone has turned from green to brown, exposing two intersecting canals not previously seen. Plate II, *a'*, which was drawn on September 17 (18 U.T.) when the planet had the same aspect as in II, *a*, on July 12, also shows the effects of the advance in season.

The drawings in Plate II, which were copied from notebook sketches made on specific nights, have now been compared with drawings and maps of other observers. About 40 canals are indicated in Plate II. Plate III shows Schiaparelli's maps <sup>1,2</sup> from his observations over the period 1877 to 1888. The aspect of the left-hand map is about the same as that of Plate II, *a*, in which Sabaeus Sinus is near the center, and the aspect of the right-hand map is approximately that of Plate II, *d*, in which Trivium Charontis, the spot from which long canals extend in spider fashion, is a prominent feature in latitude north 18° and longitude 195°.

The two longest canals extending from Trivium Charontis, shown in Plate II, *d* and *c*, extend over more than 100° of longi-

<sup>1</sup>*Le Opera Di G. V. Schiaparelli*, II, 56, 1930.

<sup>2</sup>*Pop. Astr.*, 2, 1, 1894. C. Flammarion, *La Planète Mars*, I, 296, Paris, 1892.

tude. The five canals leaving Sabaeus Sinus, not shown in Schiaparelli's map, are on maps by Percival Lowell<sup>3</sup> and by R. J. Trumpler.<sup>4</sup> The isolated spot on the border of Mare Cimmerium in south latitude  $25^\circ$ , longitude  $190^\circ$ , shown in Plate II, *d*, from which a long slanting canal extends, is on neither Schiaparelli's, Lowell's, nor Trumpler's maps. However, Geddes' map<sup>5</sup> which was made in New Zealand during the opposition of 1939 shows it.

The only twin canal I saw was probably Thoth, in longitude  $260^\circ$ . It shows in Plate II, *e*, *f*, and *e'*. Although it is single in Schiaparelli's map reproduced here, he drew it much as it appears in Plate II in a map of canals that geminate.<sup>1</sup> Lowell seemed to consider Thoth strongly curved,<sup>3,6</sup> and this opinion was apparently shared by others at Flagstaff. Trumpler's map of 1924 shows it completely shaded over, and Geddes' map of 1939 shows the space between the canals shaded so that they appear as one wide marking. Of the parallel canals in the north central position in Plate II, *g*, the right-hand member cannot be accounted for on the maps of others, unless it has been drawn too far from its neighbor, in which case this canal is a gemination; it appears so on Lowell's map. Although on three nights I have drawn the right-hand canal as shown in Plate II, *g*, it is at best a doubtful feature.

At times the boundary of the south polar cap appeared darker than the neighboring green area and on June 13 both polar caps seemed to show this effect.

Besides the canals and dark polar boundary, the other important features, seen on eight nights during the 1939 opposition, were white areas on the east and west limbs, which sometimes showed as large arcs, Plate II, *d*. These certainly had a frosty appearance.

Features observed by others but not seen by me were: (1) roughness of the terminator, although the observations were

<sup>3</sup> *Mars and Its Canals*, p. 384, 1906.

<sup>4</sup> *Lick Obs. Bull.*, 13, 36, 1927.

<sup>5</sup> *Pop. Astr.*, 49, 9, 1941.

<sup>6</sup> *Mars and Its Canals*, p. 208, 1906.

continued one month past November 15, the date of maximum phase-angle,  $44^{\circ}5$ ; (2) clouds or dust storms; (3) definite oases at canal intersections, except in four places, one of which is shown in Plate II, *a*; (4) canals in the green areas, although the presence of intersecting canals in the southern hemisphere in Plate II, *e'*, which appeared after the green area turned brown with the advance in season is an indication that they may have been present.

The color of the canals is an important property. On July 12, when the whole pattern was best seen with the 20-inch reflector, and again on August 31 with the 6-inch refractor under nearly as good conditions, the color was very evident and was recorded as olive green. This may explain the difficulty of seeing canals in the green areas, since it is a matter of discriminating between two colors of nearly the same quality. Strong doubt is thrown on this observation by the fact that neither W. H. Pickering,<sup>7</sup> Lowell,<sup>8</sup> nor Schiaparelli<sup>9</sup> saw green color in the canals, which they describe as black or occasionally gray. That he could see no green color in the canals seems to have been a great disappointment to Lowell, for he mentions the color, so far as I know, only in the above reference, where the argument is made that canals are too narrow to show otherwise than black.

The reader can decide for himself whether there is any correspondence between the drawings shown here and other maps, Schiaparelli's for example, bearing in mind that I was entirely ignorant of any specific features of other maps when the drawings were made. In fact, about all I knew concerning the canals was that they were supposed to exist. Although it is doubtful whether photography can help decide the color of canals on Mars, it would be of great importance to photograph the network well enough to decide whether canals are, on the whole, arcs of great circles and whether oases exist at their intersections. Any photograph that will furnish these data will have to show canals nearly as well as we see them, and up to the present time nothing even approaching this goal has come to my attention.

<sup>7</sup> *Pop. Astr.*, **25**, 567, 1917.

<sup>8</sup> *Mars*, p. 167, 1895.

<sup>9</sup> *Le Opera Di G. V. Schiaparelli*, II, 24, 1930.

The optical quality of the atmosphere necessary to make the canal pattern visible is critical in the last degree. The narrowness and low contrast of the canals permit any small disturbance to widen them so much that they disappear. On the best nights in my experience there were four or five periods of a few minutes each during which the pattern would appear and disappear during an interval of a second or two. On only a few occasions was this interval as long as four or five seconds. Photographs that show the canal pattern will, therefore, have to be taken with exposures of not more than about one second, since the pattern cannot be expected to remain visible much longer. A few minutes before the periods when the whole pattern became visible, the canals were seen first singly, then in increasing numbers simultaneously, their disappearance being followed by this process in reverse order. Conditions were never good enough to see the whole canal pattern until after midnight.

Few places are known in the world where the whole pattern of canals has been seen, although there are many places where the canals have been seen occasionally a few at a time. It was nine years after Schiaparelli saw them in 1877 before anyone else saw them. Perrotin in Vienna saw them on April 15, 1886, and in this country H. C. Wilson (late editor of *Popular Astronomy*) saw three of them at Cincinnati on March 6 of the same year.<sup>10</sup> Every astronomer of that time attempted to see canals, but only a few succeeded. Young, Swift, Hall, and Hale, for example, could make nothing of them; W. H. Pickering saw them with difficulty at Harvard, and Keeler had the same experience at Allegheny. The best results at the opposition of 1892 were obtained at the Lick Observatory with the 36-inch by Holden, Campbell, Schaeberle, and Hussey. Barnard is popularly credited with not having seen the canals, although his drawings<sup>11</sup> clearly show them. He observed with the 12-inch and, to a lesser extent, with the 36-inch telescopes. Speaking of a small spot near the Solis Lacus he says,<sup>11</sup> "It is connected with the great sea south by a slender threadlike line. There is a small

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<sup>10</sup> *Sidereal Messenger*, 7, 400, 1888.

<sup>11</sup> *Astronomy and Astrophysics*, 11, 680, 1892.

canal running north from Solis Lacus to a diffused dusky spot which does not appear on Schiaparelli's chart." I think his chief concern was that he never saw the whole pattern at one time. Lowell was probably the first in this country to see the canal pattern, when he began work in 1894. Philip Fox told me thirty years ago that he saw the canals at Flagstaff "stand out like an etching," and this was the experience of others who worked there. It is only with the most favorable atmospheric conditions when the whole pattern appears that we may hope to photograph canals as we can see them, and the exposures must be so short that large reflectors will be required. Special photographic procedures which will probably be necessary will be discussed in a future paper.