The computations have been made by the usual formulæ, applied from station to station, and the different altitudes thus deduced for the same place in ascending and descending, furnish the following checks upon the accuracy of the work:

Nicolosi	ascending,	2,337 feet.
	descending,	2,378 feet.
Casa Ferentina..	ascending,	4,928 feet.
	descending,	4,986 feet.

In closing, permit me to express to you, sir, my appreciation of the official and personal courtesy which has rendered the expedition a most pleasant one to me.

I am, sir, very respectfully, your obedient servant,

HENRY L. ABBOT,
Major of Engineers and Brevet Brigadier-General.

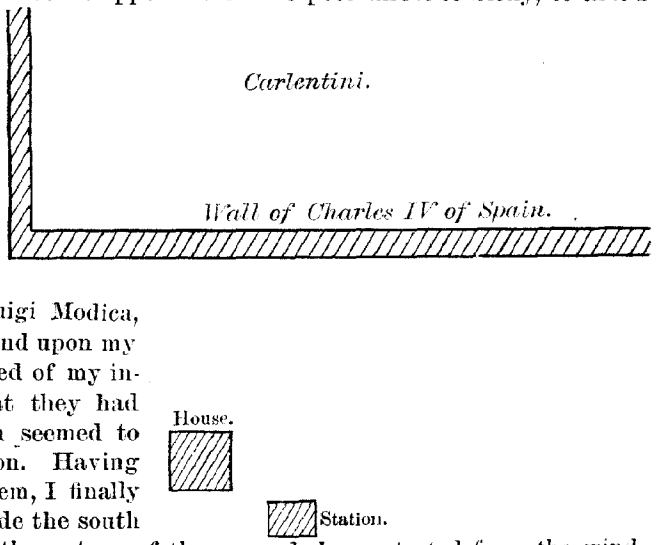
Professor BENJAMIN PEIRCE, *in charge of Solar Eclipse Expedition.*

REPORT OF OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF DECEMBER 22, 1870, MADE AT CARLENTINI, SICILY, BY JAMES C. WATSON, PH. D., DIRECTOR OF THE OBSERVATORY AT ANN ARBOR, MICHIGAN.

ANN ARBOR, *March*, 1871.

DEAR SIR: Having received an invitation from you to join your party in Sicily to observe the solar eclipse of December 22, 1870, I have the honor to transmit to you the following report of my observations:

I left Ann Arbor the latter part of October and proceeded via England and the continent, reaching Catania on the 17th of December. After consultation with you and with Dr. Peters, I finally, with your approval, selected the village of Carlentini, twenty-one miles south of Catania, and very near the central line of the eclipse, as my observing-station; but on account of the reputed unhealthiness of this village to a person not acclimated, I did not go there until the day of the eclipse. My telescope and stand had been shipped from Liverpool direct to Sicily, so that I found them in Catania upon my arrival there, and having decided upon observing simply the phenomena presented by the corona, it was not necessary for me to convey other instruments to Carlentini. Accompanied by your courier as a general assistant, I left Catania early on the morning of December 22 by special conveyance, and reached Carlentini at 11 o'clock. I had been provided with a letter of introduction to MM. Alfio and Luigi Modica, prominent citizens of the place, and I found upon my arrival that they had already been advised of my intended visit and of its object, and that they had already selected various positions which seemed to them convenient as stations for observation. Having examined the localities suggested by them, I finally decided to observe from a point just outside the south wall of the town, where I would, from the nature of the ground, be protected from the wind, which was blowing quite briskly. There was no opportunity during my stay in Carlentini to determine the geographical position of my station; but it may be easily determined from the data of the trigonometrical survey of the island in the possession of the Italian government. The station was 200 feet south of the south wall known as the wall of Charles IV of Spain, and 100 feet east of its southwest corner, as shown by the above diagram.



Mr. Modica informed me that the house near which I observed is 400 yards due south from the pillar erected near the north entrance to the town for the trigonometrical survey. It is quite probable that the position of the southwest corner of the wall is recorded in the results of the survey. The town is situated on a hill about 500 feet in height, it being the ridge separating the valley of Catania from that of Agosta and Syracuse. The telescope which I used was an excellent one, constructed by Alvan Clark & Sons, and belonging to the high school at Grand Rapids, Michigan. Its aperture is $3\frac{3}{4}$ inches, and tests under a great variety of circumstances have convinced me that its optical performance cannot be excelled by any instrument of its size. My experience in the case of the total eclipse of the sun in 1869 admonished me that the interval of totality would quickly pass; much more so than one actively engaged in observing would suspect, and that if I attempted too much I should fail in all. I therefore determined to observe with a power of about 40, which gave me a sufficiently extended field and the most perfect definition. Although I had determined to observe chiefly the phenomena of the corona at the time of totality, yet there was of course opportunity, without interfering with my plan, to observe the first and last contacts, and to make observations of the cusps and of other phenomena as the eclipse progressed.

When I left Catania, in the morning, it was raining, and the prospect for clear weather was anything but favorable. About 9 o'clock the clouds broke up, and shortly afterward the sky was quite clear in all directions, except in the immediate neighborhood of Mount Etna, around which the low clouds seemed to hover. From my station, at 12 o'clock, the prospect for clear weather during the remainder of the day was good.

The first contact was observed at—

$18^h\ 4^m\ 13^s.0$ chronometer time.

The moon's limb bisected the umbra of the first two spots at—

$18^h\ 27^m\ 17^s.0$.

And it bisected the umbra of the second spot at—

$18^h\ 33^m\ 13^s.0$.

It also bisected the nucleus of a smaller spot, near the sun's center, at—

$18^h\ 38^m\ 27^s.0$.

During the progress of the eclipse I watched the cusps attentively, and they remained constantly sharp at the extremities, there being no blunting whatever. The atmosphere was remarkably steady and the definition excellent. At about $18^h\ 50^m$, chronometer time, a bank of clouds appeared in the west rising rapidly, and in a few minutes the sky was entirely overcast. I sent the courier to the top of the wall to report as to the prospects around us, and he reported dense clouds in all directions, with a rain storm in the neighborhood of Catania.

The high expectations created by the favorable beginning, gave place to an indescribable anxiety at the prospect now before me. It seemed the very greatest misfortune that my long journey was to be without any scientific reward. It gave me some consolation, however, to know that my distress was sympathetically shared by the gentlemen present, and it is but just to say that the enthusiasm at the *denouement* was as strikingly manifested. While all appeared thus hopeless, suddenly a ray of promise gleamed through a small break in the great cloud which covered the sun; by degrees this became wider and wider, until at last, just four minutes before totality was to begin, the cloud parted, one part passing to the northward in the valley south of Etna, and the other passing to the south, so that during the whole of totality, and afterwards, with only a single interruption, until near the time of the last contact, I had the good fortune to observe in the clearest and purest sky imaginable.

The moments for observing the corona during the totality being so precious, I did not venture to observe the time of the second contact; but Mr. Modica observed it with a small refractor, power about 50, at

$19^h\ 27^m\ 10^s.0$ chronometer time.

The third contract was not observed, since the gentlemen present were so struck by the grandeur of the scene that they remained, as it were, spell-bound until the light had again burst forth. I had requested MM. Modica, whom I found to be an accomplished gentlemen, and well versed in solar physics, to make sketches of the corona for me, and I had prepared sheets for them, with refer-

ence-points marked on them; but when the totality had passed, in answer to my question as to what they had recorded, they showed me the sheets without any additional trace, and with a shrug of the shoulders and a gesticulation of sublimity, they said it had passed so soon that they could not "think to make one mark."

Before proceeding to state particularly the results of my observations during the totality, I will complete in this connection the statement of the results as to the times of the contacts. I observed the last contact through a bank of thin clouds, at

$20^h\ 47^m\ 41^s$ chronometer time.

The times were noted by a pocket-chronometer made by the National Watch Company of Elgin, Illinois. It had maintained its rate well during the long journey from Ann Arbor to Catania, and hence it was relied upon for these observations. It was compared with the standard chronometers at the observing station of Mr. Schott, in the Benedictine Garden at Catania, on the days preceding and following that of the eclipse. The comparisons gave the following results:

1870, December 21, $21^h\ 42^m$ chronometer time. Hornby 1107, chronometer $6^h\ 32^m\ 18.^s0$.
21 50 chronometer time. Kessels 1287, chronometer 18 24 57.5

The errors of Hornby and Kessels, for these instants, were determined by Mr. Schott, as follows:

Hornby 1107, $22^s.0$ slow on Catania mean time.
Kessels 1287, $6^h\ 7^m\ 40^s.3$ slow on Catania sidereal time.

Hence the error of my chronometer was the following:

1870, December 21, $4^h\ 18^m$ Catania mean time. Correction to chronometer $= + 6^h\ 32^m\ 39^s.8$.

The comparisons in the forenoon of the day after the eclipse gave:

1870, December 22, $15^h\ 20^m$ chronometer time. Kessels 1287, chronometer $18^h\ 31^m\ 45^s.0$.
15 49 chronometer time. Hornby 1107, chronometer 6 32 22 .3.

And for these instants Mr. Schott gave me the following corrections:

Kessels 1287, $6^h\ 7^m\ 39^s.2$ slow on Catania sidereal time.
Hornby 1107, 0 15 .5 slow on Catania mean time.

Hence the error of my chronometer is found to be:

1870, December 22, $22^h\ 8^m$ Catania mean time. Correction to chronometer $= + 6^h\ 32^m\ 37^s.3$.

The observed contacts at Carlentini are therefore the following:

	Catania mean time.			Observer.
	h.	*m.*	*s.*	
First contact	0	36	51.6	Watson.
Bisection of first spot	0	59	55.6	Watson.
Bisection of second spot	1	5	51.6	Watson.
Bisection of third spot	1	11	5.6	Watson.
Beginning of totality	1	59	48.5	Modica.
Last contact	3	20	19.4	Watson.

The difference of longitude between my station and the American station in the Benedictine Garden at Catania, may be obtained from the data given by the trigonometrical survey of the island of Sicily, and then these times may be reduced to Carlentini mean time.

As already stated, a few minutes before the totality began the cloud broke and gave us perfectly clear sky in the neighborhood of the sun. Just before the second contact I noticed the formation of Baily's beads, but only such appearances as would result from the irregularities of the moon's limb. I also noticed one bright prominence near the south point of the limb about fifteen seconds before the total obscuration. The corona was also visible at the same time. As soon as the last rays of the photosphere disappeared, I immediately sketched, with the naked eye, the outline of the bright corona, and having completed its trace I compared the sketch with the sun in order to be assured of its accuracy. Then, without loss of time, I placed my eye at the telescope already adjusted for sharp definition. In the first place I moved the telescope around

the limb of the moon to see whether the outline and extent of the corona agreed with the sketch already made, and having assured myself of this fact, I then sketched the places of the principal prominences as reference points for the positions of remarkable indentations in the corona which were conspicuous in passing round it. Having sketched the places and the form of these indentations, I then studied carefully, for a few moments, its structure, and sought to notice particularly whether any changes whatever took place. As soon as I saw that the totality was about to end, I again traced the outline of the corona as visible to the naked eye, and the total phase, lasting one hundred and ten seconds, had passed. Fully sensible of the impossibility of sketching more than outlines during the short period of totality, I did not attempt more, and I was thus enabled to devote attention to details of structure and to other phenomena which would otherwise have passed unnoticed. The sketches were made in my note-book with pencil; but as soon as the totality had passed, I sat down and wrote out full explanations of the meaning of the marks made, as well as full descriptions of the phenomena which I observed. Upon returning to Catania, I spent the greater portion of the next three days in making, from these sketches—while everything connected with the appearance of the corona was vivid in my mind, and before I could be influenced in my judgment by any reports of what was seen by others—two crayon drawings, which I send you with this report, the first showing the corona as it appeared to the naked eye, the other showing it as it appeared in the telescope. But, before proceeding further with statements in regard to these drawings, I will mention particularly some of the phenomena which I observed. As seen by the naked eye there was a bright band of light, about one-third the solar radius in extent, completely surrounding the sun. The outline of its exterior portion was well defined, but irregular; and near the lower limb, and to the right, was a conspicuous indentation, while on the eastern limb, where the width of the corona was on the average a maximum, there were fainter indentations. Immediately outside of this bright corona was a second or fainter one extending out until it faded away at perhaps a distance from the moon's limb equal to the sun's radius, although I recorded it as being distinctly seen at a distance of only two-thirds of the solar radius. From the beginning to the end of the total phase the bright solar corona, so far as I could see, was absolutely constant both in form and in brilliancy, but I noticed that the exterior or faint corona was first brighter and more extensive on the eastern limb at the beginning of totality, and then perceptibly brighter on the western side as the total eclipse ended. This change of brilliancy of the exterior faint corona led me to think at the time that this portion of the corona is non-solar, and that it was due to the illumination of our atmosphere by the bright light of the inner or solar corona, and I see no reason yet to change the opinion thus formed, although possibly it might have been due in part to particles of matter in the neighborhood of the sun, but not connected with it directly.

As seen in the telescope the phenomena presented to the naked eye were more distinct. The extent and the outline of the inner bright corona were the same, but the faint indentations which were visible to the naked eye here appeared to extend down to the limb of the moon, giving the appearance of a cusp quite deeply shaded at the point and gradually becoming brighter and brighter, until at the limit of the corona it was somewhat brighter than the external halo. This external halo seemed thus to envelope the inner corona like a veil. The positions of these cusps were carefully noted by reference to neighboring prominences. They were bounded by regular curved outlines with opposing convexities. The points were sharp, and I noticed particularly that the moon in passing along occulted them precisely as it did the prominences. There were three of these cusps on the eastern limbs and one on the lower limb, and a little to the right, as seen by direct vision.

The positions of these cusps measured from the vertex of the sun toward the east were approximately as follows:

First cusp	26°
Second cusp	93°
Third cusp	142°
Fourth cusp	220°

These angles, it must be understood, are not the results of exact measurements, but simply the mean of the results obtained by estimation from two independent sketches of their relative

positions. Their position in reference to neighboring prominences are correctly shown on the drawings, and when the exact places of these prominences shall have been determined, we may thus derive more exact values. The first three of these cusps were more distinct as seen in the telescope than the fourth, but not quite so large. An examination of the coronal parts between these apparent indentations, which I have called cusps, showed that for a distance of perhaps one minute from the limb it was of intense uniform brilliancy, then passing outward were streams of luminous matter, extending to near the outer extremity of the corona, where they were again blended together into a bright even band which marked the limit of what appeared to be the real solar corona. These radiating streams were separated by more faintly illuminated interstices, and thus gave indications at some points of an apparent radial structure of the corona. In the vicinity of the cusps these lines were curved conformably to the cusp, the curvature becoming less and less receding from the cusp, until, at a point midway between two cusps, the lines or streams were radial. This structural form was most distinct on the eastern limb, and in the immediate vicinity of the cusps. The fine definition of the telescope was shown during these observations by a view of Saturn which I obtained in sweeping round the contour of the corona.

I thought at first that I could see an apparent connection between the distribution of the prominences and the divisions in the corona, but the brief period of observation did not permit me to determine anything definitely on that point. I did not venture to attempt to sketch more than the principal prominences as sure points of reference, and I think it quite possible that when the places of all the prominences then visible are known, some connection of this kind will be evident. It was apparent to me that the extent of the corona was directly connected with the prominences, and after my drawing, showing its outline, was completed, I was informed by Mr. Seabrooke, of the English party, that he had mapped all the prominences on the day of the eclipse and not long before its commencement by means of the spectroscope. We subsequently compared his map with my drawing, and the intimate relation which I had suspected was completely shown. Where, by his map, there were high prominences, there was shown in my drawing a corresponding extension of the corona, and where there were no prominences my drawing showed the corona at its minimum.

The drawings, which I send you herewith, were made with crayons, from the outlines traced and descriptions recorded at the time of the eclipse as already stated. For facilities in this work I am indebted to Mr. Darwin, of the English party, who had intended to sketch the corona from the cone of Mount Etna, but having been so unfortunate, after ascending nearly 6,000 feet, as to be in a terrific snow-storm during the whole of the eclipse, he was not permitted to realize his plan, and hence he very kindly turned over to me the paper and the crayons. Having been thus provided with means of completing the delineations which I had sketched, I determined to make the drawings before I left Catania, while everything connected with the observations was vividly impressed upon my mind, although I had taken the precaution to write out full descriptions of the phenomena observed and explanations of the marks which I traced in my pencil sketches in my note-book, to be available for the completion of the drawings at any subsequent time. Not being skilled in crayon drawings I found great difficulty in attempting to delineate what I saw. I send you the drawings as I made them at Catania, fearing that if I attempt to improve them I may interfere in some way with the evidence which they afford. I will therefore endeavor to state wherein they do not convey precisely the idea which I wish to communicate.

First, then, in respect to the drawing representing the corona as seen by the naked eye. The outline of the solar corona is perhaps too marked in contrast with the light of the secondary corona, if viewed in close proximity and with a strong light. It conveys best the correct impression if you place it in a moderate light admitted from the side, and view it at a distance of about 15 or 20 feet, so that the contrast between the outer and the inner or solar corona is not too vivid. The color of the moon is too dark; it should be of a deep neutral tint. The corona also should indicate a pearl-white vivid light nearest the limb of the sun, and fainter somewhat at its extremity. There were no prominences visible distinctly to the naked eye as in the case of the total eclipse in 1869, but the effect was apparently to intensify the light of the corona in the places where the telescope revealed them.

The second drawing gives the telescopic view of the corona. The positions and the form of

the cusps are correctly indicated. The streams of light already mentioned are also shown, but I did not succeed, with the crayons which I had at hand, in giving precisely the correct delineation. The form of these streams and their relation to the cusps are indeed clearly indicated, but there was a general effect which, having failed to indicate sufficiently in the drawing, I will attempt to describe.

The appearance in the telescope reminded me of the great comet of 1858, which I observed attentively. There was in the corona first a uniform band of light, pearl-white, as in the case of the bright comets, then streams of luminous matter flowing out, and afterward spreading and uniting, thus forming a shell-like envelope to the sun. It seemed as if the cusps were merely rents in this envelope, and as if I were looking into a partially transparent shell, within which was a brilliant core emitting luminous streams. The manner in which the exterior halo enveloped the solar corona is not exactly shown in my drawing. The cusps were dark at the apex, and quite bright at the extremity of the corona, but not nearly so bright as the other portions of the corona, so that, being of a brilliancy not much in excess of that of the outer halo, the appearance was that of the formation by the latter of a sort of envelope passing down into the indentations of the former. The color of the moon should be of a deep neutral tint, and the prominences should be of a light rosy tint. They were not so red as in 1869, but exhibited a more glowing intensity of light.

In conclusion, permit me to say, that, being fully convinced from these observations that the bright corona whose limit was well defined is really an appendage of the sun, composed of glowing gas, I concluded to observe carefully whether it might not be visible during the partial eclipse, and I was able to see it distinctly, by the visibility of the limb of the moon beyond the limb of the sun. At $20^h\ 38^m$ chronometer time, or only ten minutes before the last contact, I could distinctly trace the limb of the moon to a distance of two minutes of arc from the sun's limb. Hence I venture the prediction that a careful scrutiny will show the corona during any partial eclipse, and I conceive it to be very possible indeed that the Janssen-Lockyer method may be extended so that the corona may be studied at all times, as well as the prominences. If I am not mistaken as to the indications of what I saw and what I have here recorded, the attempt ought to be made.

Thanking you very sincerely for your kind invitation to take part in the expedition, I submit through you to the world this statement of the results of my observations, with the hope that they may be regarded as having some value in perfecting our knowledge of the physical constitution of the sun.

I have the honor to be, sir, yours, very truly,

JAMES C. WATSON.

Professor BENJAMIN PEIRCE,
Superintendent of the United States Coast Survey.

REPORT OF OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF DECEMBER 22, 1870, MADE AT JEREZ DE LA FRONTERA, BY JOSEPH WINLOCK.

SIR: In the autumn of 1870, I undertook at your request the organization and direction of a party to be employed in observing the total solar eclipse of December 22, in the same year.

The place which I selected for the observations was Jerez de la Frontera, in the south of Spain, near Cadiz. The advantages of this station known to me at the time were that it lay near the central line of the eclipse, and was connected by railroad with Cadiz. The climate of the whole of Southern Spain was known to be on the whole favorable to observations, but I could gather no definite information as to the climate of Jerez itself as compared with other Spanish stations. I was gratified to learn, on my arrival there, however, that the chance of clear weather in the southwest of Spain is at least equal, and probably superior, to that at stations farther east. In confirmation of this view, I subjoin a statement compiled from a meteorological record kept between August 15, 1864, and September 30, 1870, at the house of Mr. Richard Davies, in Jerez. A thermometer at a distance from any building would no doubt show a larger range of temperature than is apparent from this record. The thermometer was observed at 8 a. m., 12 m., 3 p. m., 8 p. m.