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A Nineteenth-century Coronal Transient

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Summary. The remarkable coronal transients seen in white light by the coronagraph on Skylab suggest a search for such features in past eclipse records. An unusual feature observed in the corona during the 1860 total solar eclipse appears to be a very likely predecessor. Sketches and firsthand reports reveal the circumstances of its development, motion, and physical characteristics and indicate that it was a relatively subtle feature to the naked eye. Unlike the events seen with present orbital coronagraphs, the 1860 event occurred at solar maximum.

Key words: solar corona — coronal transients — eclipse

I. Introduction

A remarkable accomplishment of the HAO White Light Coronagraph on the NASA Skylab mission has been the detailed photography of numerous transient disturbances in the solar electron corona. These appear in broad-band visible light as blobs or loops, some as large as the solar disk, which move radially outward at velocities of several hundred km/s. An example is shown in Fig. 1. White-light transients were first noted by the NRL coronagraph on OSO-7 (Tousey, 1973) and are generally taken to be associated with one or more of the other known forms of coronal activity, including ascending prominences, transient events in the green line, K-coronameter "depletions", and moving Type IV radio bursts (Hansen *et al.*, 1971; Sheridan *et al.*, 1972; DeMastus *et al.*, 1973; Riddle *et al.*, 1974; Koomen *et al.*, 1974; Gergeley and Kundu, 1974). The Skylab coronagraph, with nearly continuous photographic coverage of high spatial and temporal resolution, has defined typical forms, motions, and lifetimes for scores of these white-light events. During only the first four months of Skylab coverage, more than 24 transients were observed, or an average of at least one each 120 h (MacQueen *et al.*, 1974).

Why have we not seen these spectacular white-light features at eclipse? The coronal form has been recorded at nearly every total eclipse for well more than a century, and at almost every one attempts have been made—with little success—to detect possible short-term change. In fact, the now apparent nature of transients and their statistics of occurrence make eclipse detection unlikely.

At the round-number rate of one major coronal transient per 100 h we can expect only about one chance per century to capture one at eclipse. Moreover, a disturbance which moves at hundreds of km/s (about one solar diameter per hour) will show barely perceptible movement during the allotted minutes of totality, and would likely be detected only as a possibly anomalous coronal structure. Finally it may be true that these apparently spectacular events, especially when they occur in the outer corona, are not a high-contrast object when seen with the eye or unfiltered camera. The externally occulted coronagraph on Skylab is characterized by a strong vignetting function which suppresses the inner field radiance, serving to enhance subtle, outer-corona features. Moreover, the orbital coronagraph enjoys a lower level of background light than do observers at eclipse, by virtue of the negligible radiance of the sky and the perfection of the coronagraph optical system.

Eclipse observations of a white-light coronal transient might answer several questions which lie beyond the scope of the present coronagraph data. Are these features peculiar to the declining or minimum phase of solar activity in which all the orbital data were taken? What is their color? As suggested by MacQueen *et al.* (1974), could the recently-observed transients be partly Hα emission—a line which is included in the passband of both OSO and Skylab coronagraphs? Finally, aesthetically, how would a bubble transient appear to the eye?

In a cursory survey of historical coronal records we find one case which stands out as a clear candidate

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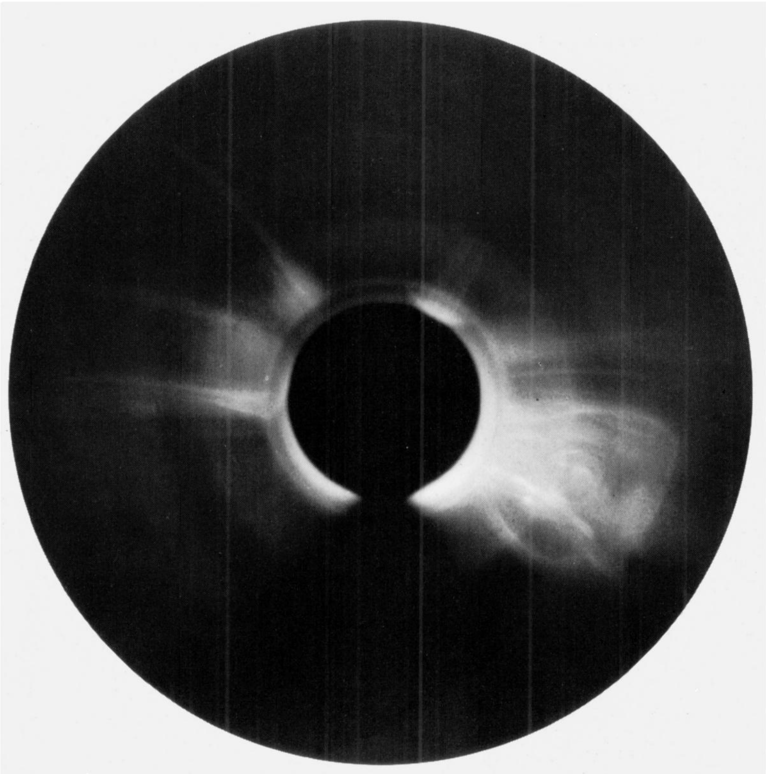

Fig. 1. Coronal photograph taken 0954 UT 10 June 1973 (11 min after Fig. 2 of MacQueen *et al.*, 1974) by HAO White Light Coronagraph Experiment on first NASA Skylab mission. Diameter of occulting disk is about 1.5 R_0. Transient feature at lower right (in northeast quadrant) was observed for about 30 min and moved outward with an apparent velocity of 450 km/s

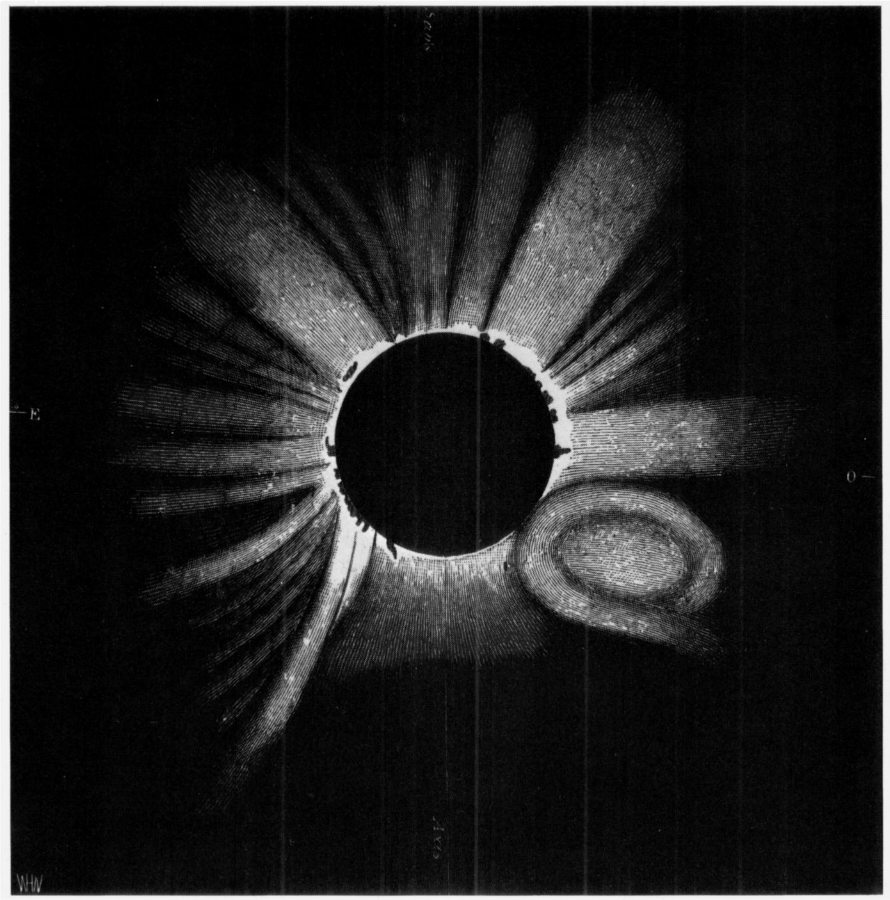

Fig. 2. Drawing of the corona as it appeared to Tempel at Torreblanca, Spain during the total solar eclipse of 18 July 1860 (Ranyard, 1879). South is at bottom, west at right

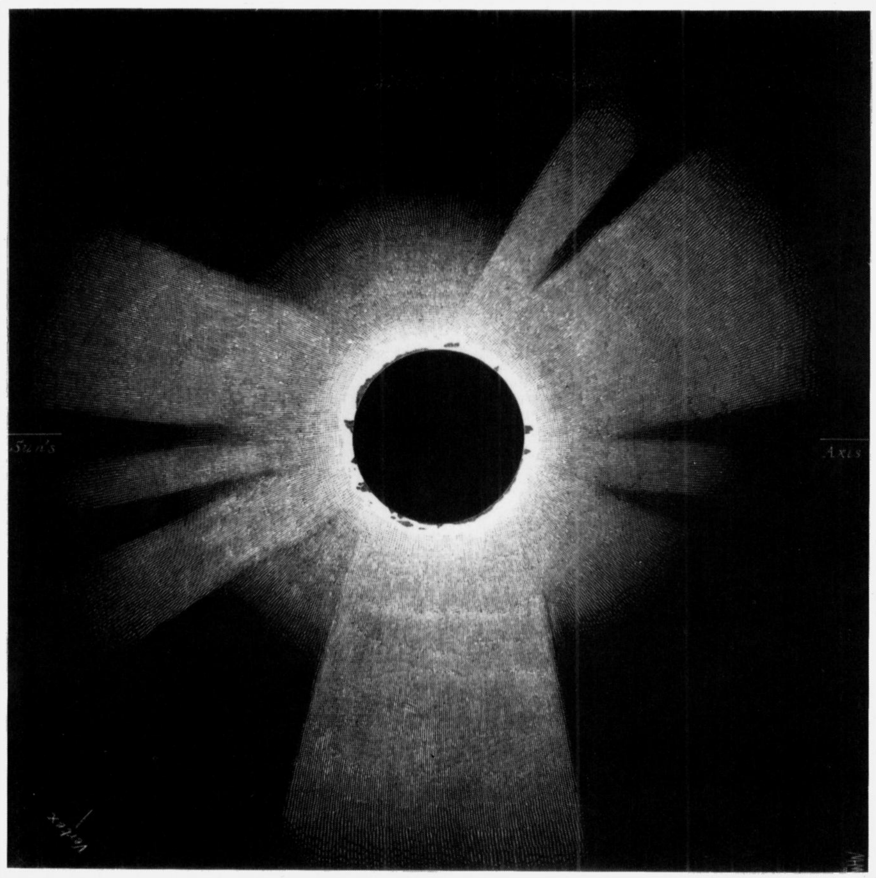

Fig. 3. Drawing of the corona as it appeared to Secchi at Desierto do las Palmas, Spain during the 1860 eclipse, at the same time that Tempel's drawing was made (Ranyard, 1879)

for an early, unrecognized event: a spectacular feature recorded in a drawing by the Italian astronomer Guglielmo Tempel at the Spanish eclipse of July 18, 1860. We see it in Fig. 2, and note an almost uncanny resemblance to the June 10, 1973 feature portrayed in Fig. 1.

Can we trust the sketch of a single observer? Astronomical photography was still new in 1860, and the eclipse of that year was not well recorded other than in drawings. The most widely published of these, by Secchi (1860; 1875) (Fig. 3) does not show Tempel's peculiar feature, although it is likely that Secchi's eye was dazzled by light from the inner corona and chromosphere, which were the objects of his primary interest. To resolve the question we can seek confirmation in other 1860 coronal drawings, many of which were collected together in Ranyard's eclipse compendium of 1879.

II. Observations

The 1860 eclipse initiated a series of important eclipses of the nineteenth century, at a time of growing interest in the physical sun and its outer atmosphere. The shadow crossed Canada, Spain, and northern Africa and, like nearly every one since, the eclipse was subsequently reported as "more thoroughly observed than any other that ever occurred" (Anonymous, 1860). Because of the proximity of good sites in Spain, most European observers, including Secchi and Tempel, saw it there, where totality lasted about three minutes. Tempel's station was on the Spanish Mediterranean coast at Torreblanca, where totality began at about 15:02 local time; Father Secchi, at nearby Desierto de las Palmas, saw a nearly simultaneous eclipse.

Just over two hours earlier, Gilliss, an experienced eclipse observer for the U.S. Coast Survey, had watched the sun rise partly eclipsed at Steilacoom, near present-day Tacoma on the Puget Sound. During the ensuing totality he observed the corona and described it as "composed of radial beams or streamers, having slightly darker interstices" (Gilliss, 1860). He described each prominence, as was the custom, but made no mention of any curved or otherwise anomalous coronal feature. We may assume that the coronal disturbance, if real, was not in conspicuous progress two hours before Tempel reported it.

About an hour later another professional astronomer, Ashe, R.N., caught sight of the corona momentarily

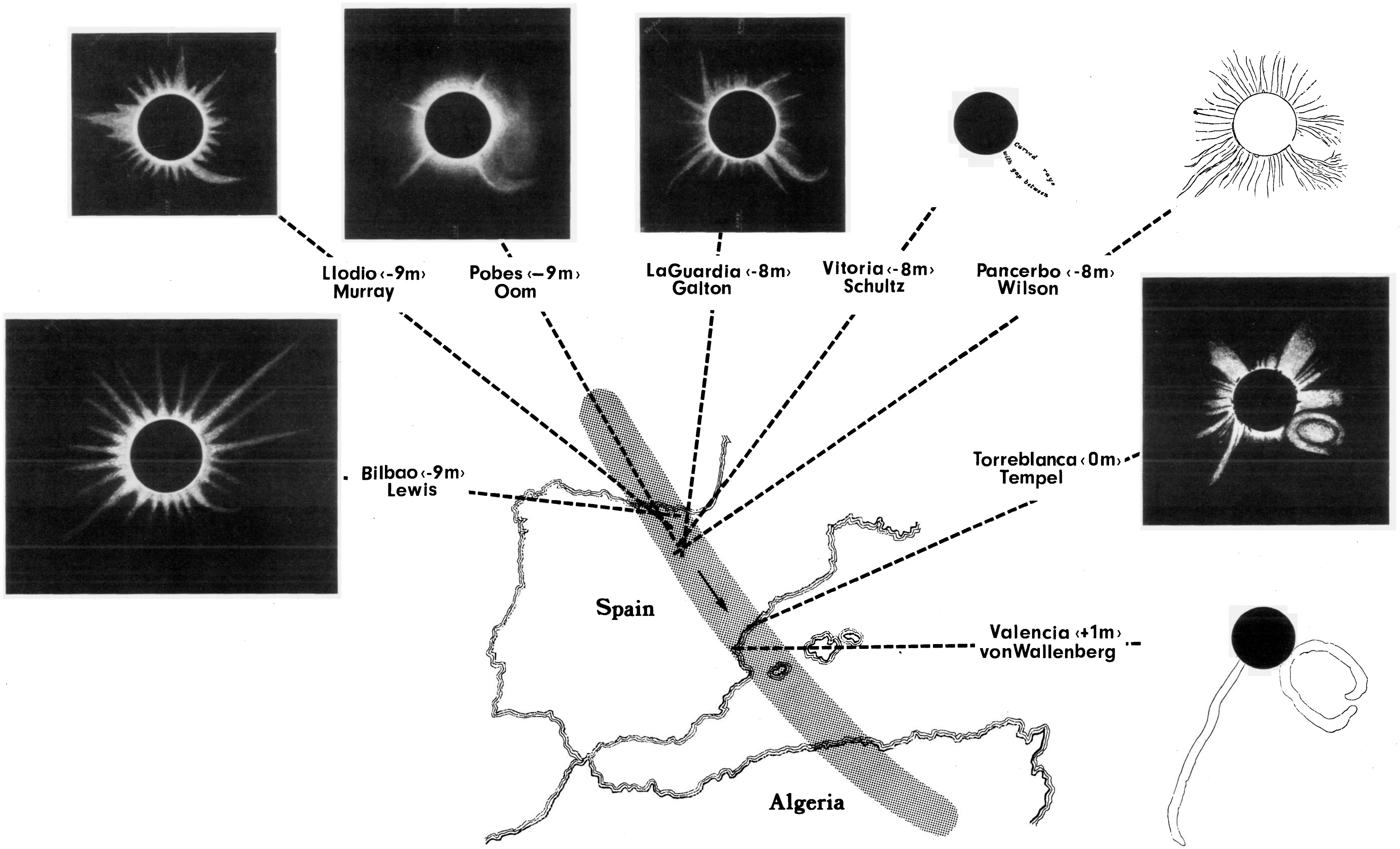

Fig. 4. Selected drawings of the corona (from Ranyard, 1879), made by different observers along the path of totality in Spain during the 1860 eclipse. Times are relative to mid-totality at Tempel's station at Torreblanca

through broken clouds on Ungava Bay in Labrador. Ashe observed with a 3 in. telescope and described the corona as a bright halo about the moon; then, in the same southwest quadrant where Tempel later reported the anomaly, he reported "a white flame, shooting up to a considerable distance" (Ashe, 1861). A dense cloud then passed over the sun and prevented further observation. This tantalizing observation, made under poor conditions, is of course of very limited value; still, it may be a real record of the early phase of a coronal disturbance which developed during the next hour as the shadow swept across the North Atlantic.

Where the path of totality next touched land, on the Spanish shore of the Bay of Biscay, several observers saw the anomalous feature in the southwest quadrant. They recorded it in drawings as a pair of rays which curved inwards, forming the outline of a feature very similar to that which Tempel saw a few minutes later. For about eleven minutes, as the eclipse crossed the Spanish peninsula, the corona was under continuous observation. It now appears that a white-light coronal transient was in progress during this interval, and that in this time it developed into a slightly more conspicuous feature.

In Fig. 4 we have assembled a selection of drawings from representative stations along the shadow path in Spain, uniformly oriented and arranged in sequence of actual observation. Together they confirm most of the detail shown by Tempel and leave little doubt that there was indeed an anomalous elliptical feature in the southwest quadrant during the observation of the corona in 1860. Moreover, when put in proper order, they suggest that some evolution was observed and recorded. Other drawings, not included here, further substantiate this conclusion, and statistically at least, establish that it became more visible later in the eclipse period. Of 46 first-hand accounts which were consulted, about half describe the feature; if the sample is restricted to the latter part of the Spanish eclipse, observers reported it in the ratio 2:1.

Verbal descriptions of the corona made by numerous observers in Spain confirm many of the details shown in the sketches. The anomalous feature in the southwest quadrant was described by several as parabolic and crescent-shaped, and by others as shaped like a lyre, a Turkish scimitar, or a stag's horns (Ranyard, 1879). Last descriptions of the event came from observers in Algeria, where at two Saharan sites the corona was seen about 20 min after it was lost from view in Spain. At Batna, where an expedition of French army engineers observed the eclipse, the corona was described as having one feature remarkable for the curvature of its rays, which "donnent l'aspect d'un panache" (Laussedat *et al.*, 1860). At Lambesa, Bulard reported two delicate rays, perfectly white and very distinct, which seemed to emanate from a common point on the solar limb and then diverge, "en forme de feuille de tulipe".

III. Conclusions

The picture we may now reassemble is that of a major white-light coronal transient, possibly seen from Labrador early in its development as an eruptive prominence or coronal spray and developing into a discernible, apparently detached structure in the next hour. It moved slowly outward to about 2 R_0 during the 11 min that the corona was visible to observers in Spain at a rate consistent with presently-determined values of 200 to 500 km/s (Tousey, 1973; MacQueen *et al.*, 1974). As it developed it became more diffuse on its leading edge and its outer boundaries appeared to open there, giving it a parabolic appearance, apex toward the sun. At the end of the Spanish portion of the eclipse, it had reached about 2 R_0 and appeared to Tempel as elliptical with a diffuse leading edge, and to others as an open parabola. Twenty minutes later, during which time it may have advanced to possibly 3 R_0, its outer boundary appeared to open further while the sunward side pinched closed, so that its form was that of a clipped feather, quill toward the limb, or an inverted tulip leaf.

In color the transient was white, which almost certainly identifies it as due to Thomson scattering by free coronal particles, probably electrons. Were it dominantly Hα emission of a neutral hydrogen cloud it would have appeared reddish, and no observer reported it as any color but white. If we can assume the 1860 case to be typical of the sample recently recorded by orbital coronagraphs, then this historical observation becomes of timely interest.

As is evident by the multi-streamer appearance of the corona in the Secchi and Tempel drawings, the 1860 eclipse occurred at a maximum of solar activity. It fell, in fact, almost precisely at the maximum of the sunspot curve: the monthly mean Wolf number for July 1860 was 94.9, as compared to 41.5, 37.6, 20.4 and 25.6 for the first four months of Skylab coronagraph operation. Thus the two examples come at rather opposite phases of the solar cycle. It does appear, especially in Tempel's drawing (Fig. 2), that the 1860 event occurred in an area of the corona which was noticeably devoid of other major streamers, which in modern terms would be described as an open-field region. In the simplest model one might expect this pattern of occurrence, since transient features in the corona could most easily escape the sun in regions of radial field. Whether there is a true preference of coronal transients for open field regions will surely be answered by the Skylab coronal data sample.

Since some observers described the 1860 feature as spectacular, and a nearly equal number did not see or report it, we may conclude that to the naked eye or simple telescope at eclipse white-light transients may not appear as objects of striking contrast, but instead as rather subtle features of the corona. At eclipse, coronal transients probably fall into a common class of natural features which are obvious and striking only after the eye succeeds in distinguishing them in a nearly equal background. Our chances of detecting another such feature, in future eclipses or in past records, should now be enhanced by a knowledge of what to look for. But it seems true that the orbital, externally occulted coronagraph, with a strong field function and suppressed background radiance, is a better coronal transient detector.

Why didn't astronomers make more of the 1860 feature at the time? Probably because the corona was then still wrapped in so many other unanswered questions. Still pertinent in 1860 was the basic problem of the origin of the corona: was it really solar, or could it be a terrestrial scattering effect? Spectroscopy, and photography of the outer corona were yet to come; the study of coronal structure per se did not begin in earnest until the era of good eclipse photography in the 1890's (Eddy, 1971). Ranyard's compendium of 1879 is a good summary of the state of coronal physics before modern photography and interestingly, in the section on the 1860 eclipse, he included a review of the "synclinal" or curved structure which some had reported at the southwest limb, without any attempt at organization or interpretation. Since not all accounts included the unorthodox structure, its reality was left in doubt, perhaps for future confirmation.

Young displayed both the Secchi and Tempel drawings of the 1860 corona in his classic monograph *The Sun* (1896) to "show how widely observers only a few miles apart will differ in their impressions". It was probably this jocular comparison which led the first editor of the *Astrophysical Journal* to remark soon thereafter that "The experience of previous eclipses has shown that drawings of the corona for the most part serve no useful purpose unless it be to illustrate the personal peculiarities of the draftsman" (Hale, 1900). This opinion, which is surely espoused by most of us today, may need modification in the light of the apparent usefulness and consistency of the collection of historical drawings from the 1860 eclipse. What is more, until the present time anyone who had seen both the Secchi and Tempel drawings of the 1860 corona would have concluded that it was the lesser-known observer who was the less reliable, while in fact it seems to be Secchi who poorly portrayed the corona. In this there is probably a lesson.

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