Mem. S.A.It. Vol. 82, 358

Memorie della

A figure in the carpet: Giovanni Schiaparelli's classic observations of Mercury reconsidered in the light of modern CCD images

W. Sheehan[1], J. Boudreau[2], and A. Manara[3]

[1] Lowell Observatory– 1400 W Mars Hill Road, Flagstaff, Arizona, USA
e-mail: sheehan41@charter.net
[2] Association of Lunar and Planetary Observers – P.O. Box 13456, Springfield, Illinois 62791-3456, USA, e-mail: jeboud@comcast.net
[3] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Brera, Via Brera 28, 20121 Milano, Italy, e-mail: alessandro.manara@brera.inaf.it

Abstract. Though best known for his observations of Mars, Giovanni Virginio Schiaparelli also undertook a prolonged series of observations of Mercury leading to a rotation period for the planet that was repeatedly confirmed by later astronomers and would remain the standard for almost seven decades. In 1965, his result was shown to be mistaken. This study of Schiaparelli's drawings and notes in his observing log books in the light of CCD images allows a comprehensive understanding of how Schiaparelli reached the conclusions he did and provides insights into the difficulties of planetary studies in the visual era.

Key words. Astronomy: history – Schiaparelli – Planets: Mercury – Mercury: visual observations – Mercury: rotation

1. Introduction

Giovanni Virginio Schiaparelli was arguably the most skillful visual planetary observer of the nineteenth century, but he came to this branch of the science relatively late. Before 1877, he had hardly any experience with planetary observations at all. Then, on the night of August 23, while watching an eclipse of the Moon, he turned his 22 centimeter Merz refractor toward Mars as a diversion. It was then brilliant in the sky and just weeks away from a highly favorable (perihelic) opposition. "I desired", he afterward recalled, "only to experiment to see whether our refractor . . . possessed the necessary optical qualities to allow for the study of the surfaces of the planets. I wished also to verify for myself what was said in books of descriptive astronomy about the surface of Mars, its spots, and its atmosphere" (Schiaparelli 1878).

On first examining the planet, Schiaparelli felt disoriented and confused. "I must confess", he wrote, "on comparing the aspects of the planet with the maps that had been most recently published, my first attempt did not seem very encouraging". He entered in his log book a rude sketch. He observed Mars again on August 28. Gradually the markings fell into more definite and recognizable shapes. Never one to let pass an opportunity, he decided–on September 12, 1877, already a week after the date of opposition–to commence a full-fledged observational campaign that he would keep up until the following March. He was thus (with the French astronomer E.L. Trouvelot) the first student of Mars to study it so far from opposition.

A certain marked style characterized everything that Schiaparelli did. He had very little tolerance for ambiguity, allowed nothing vague or indistinct to enter into his work. His obsession was with detail, with precision. Accordingly, he drew up a map based not only on "dead reckoning" with the eye but on careful micrometrically determined positions of the Martian features—effectively adapting methods learned during his student days at Pulkovo Observatory for double-star observations to the mapping of the surface of the planet. (Years later, on the verge of retirement, he advised younger astronomers to make their work "precise measures! The thing most necessary and at the same time the most difficult".) Finding so many new features for which there were no counterparts on existing maps, he improvised—out of his immense store of knowledge of biblical and classical literature and geography– a new system of nomenclature, which quickly replaced the prior schemes offered by the English author Richard Proctor and the French astronomer Camille Flammarion. (With modifications needed to accommodate modern spacecraft results, it still serves as the basis of that in use today, and will no doubt remain in place as long as humans study Mars.) His map also first revealed to the world a system of sharp, groove-like markings on the Martian surface—the *canali*—and in doing so furnished the nidus around which Percival Lowell's provocative (and at the time plausible) theory of artificial canals and intelligent life crystallized in the last decade of the nineteenth and first decades of the twentieth century.

Schiaparelli kept Mars under intensive observation at the oppositions of 1879, 1882, 1884, 1886, 1888, 1890, and published a series of dense, highly technical memoirs, which showed his penchant for systematizing both in its discussion of the observations and in his meticulous, highly detailed maps. The celebrated Greco-French observer E. M. Antoniadi, who at first confirmed but later grew skeptical of the canal network in the form depicted by Schiaparelli, summed up in 1910 that "the verdict of science will probably be that . . . the discovery of the 'canals' by the unrivalled acuteness of the Italian observer meant the discovery, under a symbolic, geometric form, of the minor irregular shadings variegating the Martian surface" (Antoniadi 1910). In other words, Schiaparelli realized *that* something was there; he could not, however, entirely succeed in making out the more difficult problem of determining *what* it was.

2. A Color-blind astronomer

Schiaparelli possessed several advantages for planetary work. He had learned well the lessons received in his courses on surveying and engineering at the University of Turin, including skill in draftsmanship. Indeed, this training was reputed to have given him the ability "to transcribe quickly onto paper the almost cinematic impressions of the figures observed in the field of the telescope" (Cossavella 1914).

He was also color-blind. This seeming defect, like blindness in jazz musicians or a lack of social skills in mathematicians, was actually an advantage for planetary observations. He had only one good eye—his left; the other, apparently due to uncorrected childhood strabismus, was useless for any but ordinary purposes. The form of color-blindness from which Schiaparelli suffered was the common form involving decreased appreciation of differences in red-green. Though color-vision–an inheritance of our primate ancestry–is an asset when deciphering large complex patterns (such as pieces of fruit in a jungle or canvases by Monet), color-blind individuals are superior to normals at making out fine details and in noting subtle boundaries of light and shade (as is appreciated by radiologists, who routinely employ grey-scale for their readings). Admittedly, in the case of a colorful and subtly featured planet like Mars, color-blindness could be a two-edged sword: at least some astronomers with normal color-vision felt that Schiaparelli caricatured the Martian surface features, rendering them harder and sharper than they really were. Thus the eminent British artist and amateur astronomer Nathaniel Green, a rival of Schiaparelli in the observation of Mars in 1877, wrote that Schiaparelli and others who drew the planet as he did "have not drawn what they have seen, or, in other words, have turned soft and indefinite pieces of shading into clear, sharp lines" (Green 1890).

3. A difficult planet to observe

The fierce debates about Mars were just getting underway when Schiaparelli, in June 1881, decided to extend his reconnaissance to another world. The innermost planet, Mercury, had been almost neglected by earlier observers, who had struggled, usually in vain, to make out any details on the planet during the brief twilight periods when the planet's image was vexed by tremors and disturbed by rushing currents in the Earth's atmosphere. The fact that the planet passed through a cycle of phases like those of the Moon as it traveled around the Sun had already been established in the seventeenth century and lent additional credence to the Copernican theory. But apart from this scrap of information, the planet whose tiny disk never appears more than a paltry 10 arcseconds in diameter–and then does so at inferior conjunction when it unhelpfully presents its night face toward the Earth—jealously guarded its secrets.

William Herschel, the greatest observational astronomer of the 18*th* century, could make out no detail on Mercury. However, his contemporary, the indefatigable German astronomer Johann Hieronymus Schroeter, with a large reflector at his observatory at Lilienthal (near Bremen), was marginally more successful. In 1800, Schroeter noted that the southern cusp appeared blunted compared to the northern–another toehold of factual information about the strange Mercurial world. Schroeter's observation has been confirmed by many observers since. The explanation for the effect he recognized is that the area around the north pole is brighter than that around the south pole owing to the presence there of several rayed impact craters (Dobbins 2009). From the repetition of the same appearance on subsequent nights, Schroeter—or rather his assistant, Karl Harding—worked out a rotation period of 24 hours, 5 minutes. That conclusion must have seemed smugly gratifying at a time when the other planets were still routinely cast in the image of the Earth.

As slender as was the reed of Schroeter's results, they set the standard—the *ne plus ultra*—of Mercury studies for decades. At last, in 1870, the British observers Warren de la Rue and William Huggins reported "markings, like the lunar craters, of a dazzling whiteness and seen as through a veil of mist" (Browning 1870). In retrospect, this was a startlingly prescient insight. Meanwhile, photometric work by the pioneer German astrophysicist Karl Zöllner revealed the planet's very low albedo, from which he deduced the inexorable conclusion: "Mercury is a body the surface condition of which must be nearly the same as that of our Moon, and which, like our Moon, probably does not hold an appreciable atmosphere" (Zöllner 1874). Unfortunately, he published his result in a festschrift for the physicist Johann Christian Poggendorf (the founder of the *Annalen der Physik*), and Schiaparelli probably never saw it, since he was a classical astronomer not a physicist and never favorably disposed to the developing field of astrophysics. In any case, he missed noticing a crucial clue, since Mercury's low albedo proved that it could not have an appreciable, or cloudy, atmosphere.

4. Mercury by day, Mars by night

Schiaparelli decided that, instead of opportunistically seizing on the brief periods in which Mercury was visible low in the sky during the unfavorable twilight periods, as previous observers had done, he would try to study it during the daytime. He tested the idea on several occasions in June 1881, using the setting circles of the Merz refractor's equatorial mounting to flush the planet from its hiding place in the midday sky. With a magnification of 200x, Mercury appeared about two-thirds the size of the Moon seen with the naked eye, a tantalizing tiny pale-rose orb swimming in the bright blue circle of the eyepiece that all but disappeared whenever haze or a layer of cirrus clouds were present. There were markings, but they were delicate. Nonetheless, he was convinced "that it would be possible not only to see the markings on Mercury in full daylight, but also to obtain a series of sufficiently connected and continuous observations of these spots" (Schiaparelli 1889).

In January of 1882, he commenced a systematic study that would last for the next seven years. A perusal of his observing log books shows that, as in everything he undertook, he was extremely diligent and persevering—one has the impression he must have virtually lived at the observatory. Before long he was on such intimate terms with the planet of his predilection that he referred to it in a note as *l'amico* $\Sigma\ \tau\ \iota\ \lambda\ \beta\ o\ \eta$—his *friend* Stilbon (Stilbon, the "Twinkling One", was the ancient Greek name for Mercury). He noted that when viewed during twilight periods, when subject to disturbances and unequal refraction in the lowest atmospheric strata, Mercury showed an "uncertain and flaming" appearance in the telescope, but as seen higher in the sky during the daylight periods, Stilbon often became fairly still. Sometimes the tremors ceased altogether in a miraculous "momento stupendo!" allowing the markings to stand forth with all the clarity of a proverbial steel engraving.

From the first, Schiaparelli's main object was to determine the rotation period of the planet. Though he took great care in doggedly sketching the surface markings day after day, he tried to refrain from prematurely guessing what the observations were telling him. The drawings and notes in his log book were clearly meant as raw data. Accordingly his notes seem aseptically clinical. They refer blandly, not to say tediously, to the various spots shown in the drawings, which are carefully labeled with arabic letters.

Though observing in broad daylight conferred advantages in the steadiness of the images and the duration of time in which they could be studied, there are always trade-offs, and contrast suffered. Under these conditions, the markings usually appeared washed out, as "pale indefinite streaks against a rosy-colored background"; soft and only slightly nuanced, they were difficult to distinguish, and apt to vanish during tremors of the atmosphere or whenever the transparency of the sky was poor. No doubt Schiaparelli's acute-eye, his ability to detect delicate nuanced details, and his skill in transcribing what he saw helped him. Most of the time—as his notebooks make clear—his problem was not to see but to sketch accurately what was seen. He was seldom satisfied with the sketches he did produce. As he later summed up: "It is most difficult to give a satisfactory graphic representation of such vague and diffused forms or bands especially from the want of fixity of the edges which always leaves room for a certain choice" (Schiaparelli 1889).

5. The testimony of observing logs

Apart from terrestrial factors, such as atmospheric seeing and the reduced contrast afforded by an image viewed in the daylight sky, the appearance of surface features on Mercury is also sensitive to a number of extraterrestrial factors: the position of the subsolar point (where features are experiencing high noon), the distance of features from the line of the terminator, and the geometry of the planet's orbital position relative to the Earth. The complicated interplay of all these variables makes the planet an extremely problematic object for visual telescopic observers. In principle, Schiaparelli understood the interaction of these variables, but in practice they were difficult for him to control for. In the present attempt to reconstruct Schiaparelli's 1880s study in the light of CCD images, we realized that useful comparisons were only possible if the planet were imaged under nearly the same conditions as those obtaining in Schiaparelli's sketches of the planet.

The first sketch in Schiaparelli's observing log was entered on January 27, 1882. The planet was then a small gibbous approaching a February 6 elongation east of the Sun (evening apparition). He continued his series until February 10, making 30 sketches in all during this observing window. In the first few

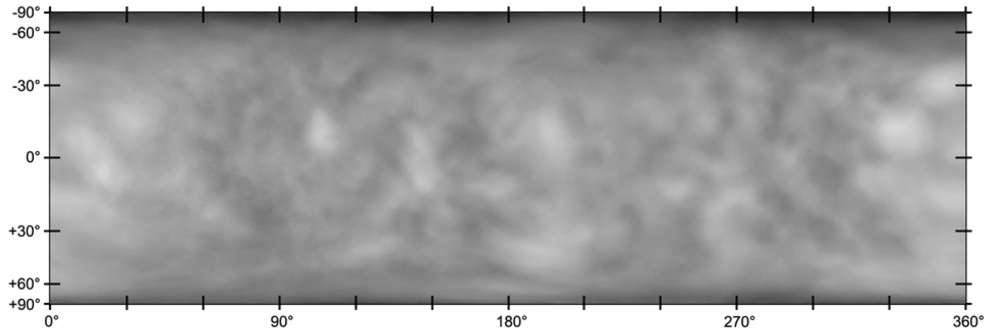

Fig. 1. A cylindrical projection composed of video-based CCD images taken from 2007 to 2010 by John Boudreau.

sketches, the markings are rather vague and indistinct. The Central Meridian (CM) of the features he studied (calculated according to the modern coordinate system based on the 58.65 day rotation period) ranged from 43 and 85 degrees of longitude.

CCD imaging of Mercury utilized in this study began in 2007 by John Boudreau using a Celestron-11 (Boudreau 2009). As shown in Fig. 1, the cylindrical projection based on this imagery shows the Mercurial surface generally consists of little more than a nondescript mottling of vague brightish patches appearing against a general backdrop of halftones. There was certainly no clear reference point such as the Syrtis Major or the Meridiani Sinus of Mars, or the Great Red Spot of Jupiter. Nevertheless, Schiaparelli at once detected a gradual drift of the markings from one day to the next, in a direction that was consistent with a period of rotation of somewhat less than 24 hours (in fact, as we can now see, he was noting the actual slow rotation of the planet!). To settle the matter, he followed the features over a period of several hours. As they showed no appreciable change in position, there could be no doubt: the rotation period was much slower than Schroeter's period, and might even be equal to its period of revolution around the Sun.

On February 6—as the planet reached its greatest elongation, and the disk resembled a small half-Moon—Schiaparelli's attention was seized by something less amorphous than usual (see Fig. 2).

He sketched a pattern of spots resembling the arabic numeral 5, and continued to note its presence over the next several days. This figure-of-5 lay in the illuminated region west of longitude 90 degrees (according to modern reckoning). It was at least a definite form—a "figure in the carpet" more regular and well-defined than anything he had seen so far. It gave him a reference point. Crucially, his later observations of the planet whenever it ran east of the Sun would be haunted by this hallmark figure.

Precisely here another aspect of Schiaparelli's work may have proved decisive. From his student days in Turin, Schiaparelli had excelled not only in the study of mathematical subjects but in languages, and had

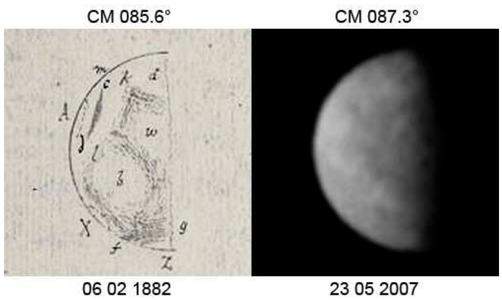

Fig. 2. Schiaparelli's February 6, 1882 drawing compared to Boudreau's CCD image of May 23, 2007.

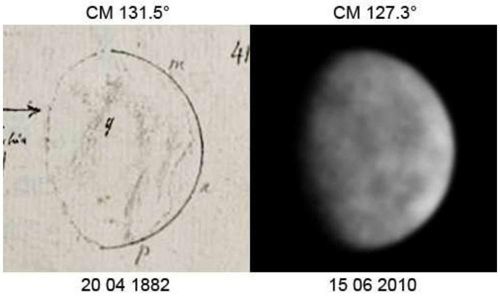

Fig. 3. Schiaparelli's April 20, 1882 drawing compared to Boudreau's CCD image of June 15, 2010.

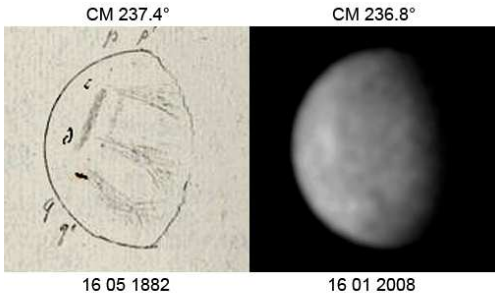

Fig. 4. Schiaparelli's May 16, 1882 drawing compared to Boudreau's CCD image of January 16, 2008.

devoted a great deal of effort in learning not only modern languages but ancient languages including Latin, Greek, Hebrew, Arabic, even Babylonian cuneiform. His transcriptions of ancient texts are remarkable—works of sheer calligraphic beauty which bear witness to a remarkable ability to absorb and deploy symbols. Now the problem of the visual planetary observer is a difficult one: even under excellent conditions of seeing, details of the surface are glimpses only in flashes (similar to tachistoscope stimulus exposures), and after each such glimpse, the art of sketching the planet consists of recording the image before it fades from short-term or working memory (Sheehan 1988). The limited scope and fallibility of short-term memory can be partly circumvented by resorting (as a kind of mnemonic device) to a shorthand of symbols and codes. This is what Schiaparelli did: he approached the surface detail of Mercury as he might an ancient and corrupt text he wished to transcribe, and so the numeral 5 entered in as a shorthand and code.

Schiaparelli resumed his observations as soon as the planet's thin sickle emerged from the Sun after inferior conjunction on March 10, 1882. Following it as it moved from day to day along its arc west of the Sun, he continued to observe it until April 27, making 16 sketches during this western apparition. The most prominent feature was a dusky spot, centered on about longitude 135 degrees. He labeled it "q", as shown in Fig. 3.

Observations around the next eastern elongation (June 1) were kept up during the whole period between May 5 and June 5, 14 sketches in all. The reason for the decreased output had nothing to do with flagging dedication or interest. Schiaparelli's observations of Mercury had begun in the winter, when the air over Milan was generally pure and steady, and they had continued during the spring when conditions were good in the early morning hours. Now the seeing began to deteriorate with the arrival of the hot Milanese summer, when sometimes the cupola on the roof of the Brera Palace became "infernally hot" and the air was in a continual boil. Still, he saw—or seemed to see–the figure-of-5 again as shown in Fig. 4.

Since the planet was again at an elongation east of the Sun, he naturally supposed he was seeing the same features as those noted under similar conditions of phase in February.

Here, however, Schiaparelli had taken a sharp wrong turn, for he was now examining a different part of the planet. The CM during the period of his observations in May and June ranged from 192.5 degrees to 333.8 degrees, but in January and February from 43.3 degrees to 80.6 degrees. Thus he was seeing a figure-of-5 in positions on almost opposite sides of Mercury (at about longitudes of 60 degrees and 240 degrees) but identifying them as the same feature. This is an example of what can be referred to as a "bottom-up" influence on perception: figure-completion.

No hint of what was going on in Schiaparelli's mind at this stage is recorded in his notebooks; the pages therein are a bland register of "facts". One has to turn elsewhere for clues as to how Schiaparelli's thinking was converging on the conclusion that the planet's rotation was synchronous.

In fact, in addition to the "bottom-up" influence on perception just described, a "top-down" influence was also involved. Only a few years earlier, in 1877, the British astronomer George Howard Darwin, son of the famous naturalist, had published an exhaustive mathematical study demonstrating how tides raised by the Earth on the primordial Moon had gradually slowed our satellite's spin until it turned on its axis in the same period of time that it takes to complete one orbit around the Earth. Darwin himself had coined the terms "tidal friction" and "captured rotation" to describe this mechanism and its consequence. It was reasonable to suppose that the same mechanism might have been at work on Mercury, and that the immense tides raised by the Sun should have braked its rotation until it became equal to its year of 88 days.

No doubt such thoughts were playing at the back of Schiaparelli's mind as he continued his observations of Mercury through the summer of 1882. In early August he heroically chased it to within a few days of superior conjunction and to only 3 $1/2^{o}$ of the Sun. These observations seared his eyeball, and (as he later maintained) produced a "weakening" of his eyesight that would force his early retirement from visual observing in the 1890s.

Just as soon as it emerged from superior conjunction, Mercury began gliding toward its next Eastern elongation in September. That month, Schiaparelli made 10 sketches, for which the corresponding CMs range from 74 to 222. Once more his drawings show a figure-of-5. The "5" at the beginning of the month was the one at 60 degrees, but as the planet rotated, it slowly crept westward (with the planet's rotation) out to 180 degrees.

The hallmark figure-of-5 was now molding his perceptions and shaping the tentative model of the planet he would elaborate over the next several years. Significantly, when in November 1882, the English astronomer W.F. Denning sent Schiaparelli a description of his own observations of the planet in the early morning twilight, and suggested that the general appearance was similar to that of Mars, Schiaparelli replied: "You are right in saying that Mercury ... resembles Mars... It has some spots which become partially obscured and sometimes completely so; it also has some brilliant spots in a variable position" (Denning 1891).

By then, Schiaparelli was confiding even more interesting things to his closest astronomical colleague, Francois Terby of the University of Louvain. On October 20, 1882, he wrote: "I believe that my researches ... are advanced enough to give you a first idea of my findings. If I should happen to die before I publish them, I pray you will do so, so that this beautiful result will not be lost to science" (Schiaparelli 1963). And what was the beautiful result? In the tradition of earlier astronomers, Schiaparelli communicated it in a Latin verse which reads in translation:

Cyllenius, turning on its axis after the manner of Cynthia,
Eternal night sustains and also day:
The one face is burned by perpetual heat,
The other part, hidden, is deprived of the sun.
Be not Ceylon by you more admired,
Which Titan, fiery potent, oppresses with his rays,
Nor by you the Riphaean mountains, paralyzed with cold,
Nor Thule, buried in the night of the Bears' heaven.
Luna, to be sure, in her great changes is scorched and freezes,
For she calls "days" what you measure as "months".
But the wretched star that revolves in the first circle
By greater flame, by greater ice, is touched.

More prosaically stated, Schiaparelli believed he had confirmed the result anticipated on the basis of Darwin's theory of tidal friction: the planet's period of revolution and rotation were the same, at 88 terrestrial days.

Schiaparelli's observations continued unabated during 1883. By then he had kept the planet under observation through a full seven synodic periods. In November, when he wrote once more to Terby to account for a long and uncharacteristic lapse in communication, he attributed it to "the unhappy combination of heavy work with a decrease of health and vigor, obliging me to lay aside my correspondence as well as several other works to which I attach interest. Must I confess to you that for several months I have done little more with Mercury?" (Schiaparelli 1963).

He was coming to realize that there were times when the characteristic features of the planet's evening and morning faces, the figure-of-5 and the "q", were difficult to identify or altogether absent when they should have been visible. Some of the variations could be explained by changes in the transparency of the Earth's own atmosphere; others by the effects of Mercury's expected libration–as the planet's velocity varied along its eccentric orbit, the rotation will get out of step with its orbital motion, as noted in the case of the Moon. In Mercury's case, because of its highly eccentric orbit, the effect was extreme, and supposed to produce a "twilight zone" of sunrise and sunset comprising about a quarter of the planet's surface. Thus a good deal of the difference in the location and the appearance of the markings at various times could be accounted for. But not all.

By now, he had no doubts about the synchronous rotation–"it is a thing completely secure, about which I have not the least hesitation", he told Terby. That being so, he was forced to introduce additional constraints upon his model. "The appearance of the planet is subject to very considerable variations", he explained, "in part theoretically justifiable by the laws of photometry and by the nature of the reflecting surface of the planet; the other part . . . depends on the transparency of the atmosphere [of the Earth], changes which are sometimes very obvious to the eye. [But] sometimes the sky [here] is of the purest blue and yet the surface features are [still] unclear; other times one sees the planet well except for certain areas which seem to be covered by a dense veil". He decided that the only explanation was that Mercury must be surrounded by a dense atmosphere containing opaque clouds, "analogous to what the Earth would show from a similar distance". These clouds altered the appearance of the features, and sometimes veiled them altogether.

Still he procrastinated. He refrained from publishing until he could confirm his work with the 49 centimeter Merz-Repsold refractor which, delivered in 1886, joined its smaller companion in an adjacent, but much larger, cupola on the roof of Brera. However, the views he obtained were not appreciably better than those he had obtained with the Merz; perhaps because the air over Milan was deteriorating with the growing industrialization of the city, perhaps because his eyesight was no longer as keen as once.

Terby was now becoming impatient. Having learned Schiaparelli's main result as far back as 1882, and finding it still unpublished five years later, he scolded his friend: "Could anyone, in bringing together all the results the photograph and the spectroscope have so far achieved, arrive at anything as marvelous as you have achieved by direct observation? No, a thousand times no. . . . One could hardly add to the beautiful monument that posterity will erect to you" (Schiaparelli 1963). Only now did Schiaparelli at long last relent. In November 1889 he finally published his great memoir, *Sulla Rotazione e Sulla Constituzione Fisica del Pianeta Mercurio* (On the Rotation and Physical Constitution of the Planet Mercury), of the classic works of the visual era of planetary observation, together with his celebrated planisphere shown in Fig. 5 (Schiaparelli 1889).

On December 8 he followed up with a lecture before the Royal Academy of the Lincei in the Quirinal Palace in Rome—King Umberto I and Queen Margherite were in attendance—suggesting that despite Merucry's synchronous rotation relative to the Sun, the rapid circulation of the atmosphere might moderate the temperature all around the planet. Thus this "wretched star" touched, like one of the damned souls of Dante's hell, by "flame" and "ice" might even be inhabited.

6. Retrospectives and conclusions

Following the publication of Schiaparelli's memoir, astronomers of comparable skill, including E. M. Antoniadi and Audouin Dollfus, confirmed his result. In fact, right up until 1965, there was probably no datum in plane-

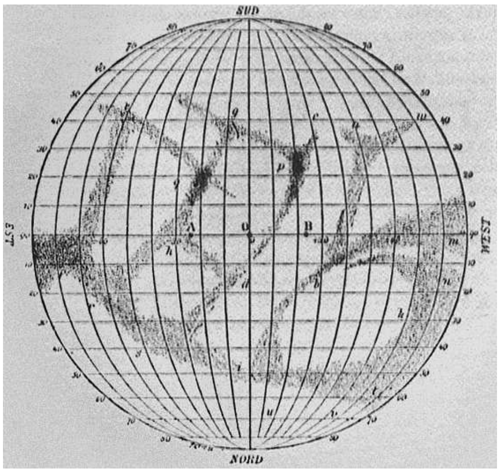

Fig. 5. Schiaparelli's1889 planisphere. The figure of 5 appears as the major western hemisphere feature.

tary astronomy that seemed more secure than the rotation period of this planet.

Then, in 1965, Schiaparelli's legacy absorbed two tremendous shocks: the American spacecraft Mariner 4 flew past Mars, sweeping away the legendary canals and showing the planet to be a stark world of ubiquitous craters, while radio astronomers at Arecibo, Puerto Rico proved that Mercury's rotation period was not in fact equal to its year; instead it was 58.65 days. As noted by the great Italian dynamicist Giuseppe Colombo, this was exactly 2/3rds of the 88-day period of revolution, and a striking example of the phenomenon now referred to as spin-orbit coupling (Colombo 1965; Colombo & Shapiro 1966; Manara 2002).

Stock in visual planetary observations generally, and in Schiaparelli's in particular, dropped to unprecedented lows. For a time, it seemed that Schiaparelli and other observers must have been chasing chimeras!

Fortunately, it wasn't quite as bad as all that. Mercury's surface markings are, after all, exasperatingly indefinite and vague. Schiaparelli himself, as noted, had mentioned the "want of fixity of the edges" that left "room for a certain choice" in their depiction.

Schiaparelli's logbooks show that the features he recorded shifted from day to day. He supposed that this was an effect of the planet's librations, even though inspection of his notebooks shows the direction of the shift was always in the same direction. They were never observed to lurch back the other way. Even allowing for wide-ranging librations, he could not reconcile all the observations. Sometimes markings that ought to be present were fragmentary or missing. But the idea of frequent and obscuring clouds, presumably suggested by analogy to Mars or even the Earth, gave him a convenient fudge factor that would keep him from ever recognizing that different parts of the planet were drifting into view.

So much has been evident for quite sometime, but until now it has not been possible to completely reconstruct Schiaparelli's study in detail. As soon as we began to compare Schiaparelli's drawings in the logbooks with Boudreau's images under similar conditions, we realized that it was the apparent repetition of the figure-of-5 in what were actually different zones of the planet that led him astray. One can hardly blame him. Look again at our cylindrical projection of Mercury's features as recorded in the CCD images: among such ambiguous markings, it was easy to eke out a bit here and piece out a bit there into something conforming to expectation. As Sheehan wrote in *Planets and Perception*: "Once a definite expectation is established, it is inevitable that one will see something of what one expects; this reinforces and refines one's expectations in a continuing process until finally one is seeing an exact and detailed—but ultimately fictitious—picture. Schiaparelli's work is a remarkable case study in autosuggestion" (Sheehan 1988). As soon as we produce a cylindrical projection of several of Schiaparelli's best drawings as shown in Fig. 6, we do find that the features he recorded were real enough—only, by mistakenly thinking that the feature at about 60° was the same as that at 240°, he effectively truncated his map into the one-hemisphere planisphere he published in 1889.

The case of the rotation of Mercury serves as a classic reminder of the fallibility—but also, ultimately, the self-correcting nature –of science. Schiaparelli had been entranced by a kind of "figure in the carpet". We must not

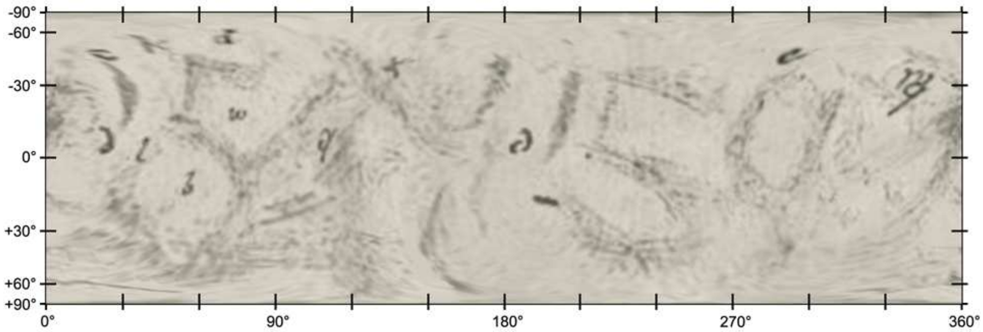

Fig. 6. A cylindrical projection composed of drawings made by Schiaparelli in 1882 and 1883

yield to the temptation to condescend to the visual observers who struggled against great odds and ended up sometimes in by-ways and dead-ends. Humility suggests that perhaps some of our own cherished ideas will prove to be similar cases and that we too may be spell-bound by our own particular "figures in the carpet".

Acknowledgements. The authors wish to thank John Westfall of the Association of Lunar and Planetary Observers for his computations of Mercury data used in this investigation, Michael Armstrong for his translation of Schiaparelli's Latin hexameters to Terby, Salvo de Meis for comments on Schiaparelli's skill in transcribing characters of ancient texts, and Giovanni Berlucchi for his ideas about visual physiology and planetary observations, and Ginevra Trincheri for help with editing.

References

Antoniadi, E.M., 1934: Mars Section: Sixth Interim Report, JBAA, 20, p. 191

Boudreau, J., 2009: Imaging elusive Mercury, Sky & Tel, 118, p. 70

Browning J., 1870: Student and Intellectual Observer, p. 5

Colombo, G., 1965: On the rotational period of the planet Mercury. Nature, 208, 574

Colombo, G., Shapiro Irwin, 1966: The rotation of the planet Mercury. Ap J, Vol. 145, p. 296

Cossavella, G, 1914: L'Astronomo Giovanni Schiaparelli (Turino), p. 10

Denning, W, 1891: Telescopic Work for Starlight Evenings (London), pp. 141-142

Dobbins, T, 2009: Messenger and Memories, Sky & Tel, 118, 72

Green, N, 1890: Report of the Meeting . . . held Dec. 31, 1890, JBAA 1 (1890), 112

Manara A, 2002: Atti XXII congresso di Storia della Fisica e dell'Astronomia Genova, 6-8 giugno, pp. 482-495.

Schiaparelli, G, 1878: Osservazioni astronomiche e fisiche sull'asse di rotazione e sulla topographia del pianeta Marte, Atti della R. Acccademia dei Lincei, Mem. I, ser. 3, vol. 2.

Schiaparelli, G, 1889: Sulla rotazione di Mercurio, AN 2944

Schiaparelli, G, 1963: Corrispondenza su Marte, vol. 1 (Pisa)

Sheehan, W, 1988: Planets and Perception (Tucson), p. 85

Zöllner, KF, 1874: Photometrische Untersuchungen ueber die physiche Beschaffenheit des Planeten Merkur; Poggendorf's Jubelband.