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A few aspects of Schiaparelli's studies.

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Abstract. A description of selected studies and professional achievements of G.V.Schiaparelli reveals the vast fields of interest of the historian and scientist. His researche in Oriental languages, especially Cuneiform and Arabic, was parallel to an always deeper knowledge of mathematical and applied Astronomy with results that are valid even at present. The discovery of asteroid 69 Hesperia is also commented.

Key words. History of Astronomy - Stars - Mars - Asteroids

1. Introduction

On January 1st, 1855 Schiaparelli, just in his twenties, began a collection of writings for a history of Mathematics; it was to be composed of 10 parts and 109 books, and obviously included Physics and Astronomy. This work, however, was never accomplished, but in 1901 Schiaparelli put the basis for a history of Ancient Astronomy, for which he wrote essays on many other subjects that in 1926 were collected in "Scritti sulla Storia dell' Astronomia antica", and that we have reprinted in Milan in Schiaparelli (1998).

The three volumes include a total of 1197 pages that by themselves alone testify the daily commitment of the scientist, and are to be added to the direction of the Brera Observatory, thousands of observations [1], calculations, and to the papers written for international journals, besides the unpublished works that cover a wide range of subjects, always with new discoveries or considerations.

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[1] He mentions, for example 11000 double star observations from 1875 to 1898 (ms."Note e scritti di vario argomento" at Brera Archive)

I have selected a few aspects of Schiaparelli's works that involve discoveries, computations or details not much known, but that however presented points of scientific novelty; also I shall briefly update some items that I covered in the Seminar held at the Brera Observatory on 12 May 1997.

2. Oriental studies

Two Main lines directed the studies of Schiaparelli: the history of ancient records and Astronomy. I believe, that the history of Astronomy conceived by Schiaparelli is the classical ΙΣΤΟΡΙΗΣ ΑΠΟΔΕΙΞΙΣ, the public display of proofs, as Herodotus called it, integrated by the careful computing of data to confirm or reject previous interpretations. That is, to support his statements by the power of numbers. A way followed, for example, by Delambre, Wolf, Bailly, and especially Otto Neugebauer and B. van der Waerden.

This methodology requires full command of theoretical and observational astronomy, besides the direct study of sources; and to this purpose Schiaparelli started to teach himself Greek, Arabic, Cuneiform, as well as basics of

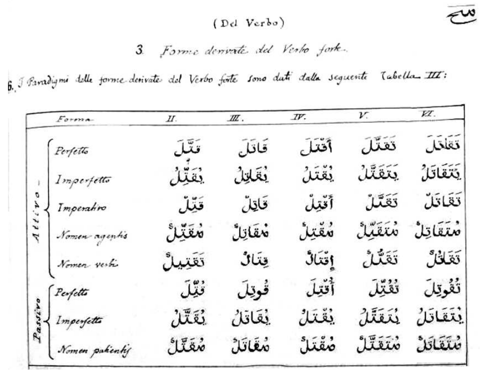


Fig. 1. A page from an Arabic grammar "di mano di G.V. Schiaparelli".

Egyptian and Hebrew, in addition to the several European languages of which he had full command. Fig. 1 is an example.

Incidentally, it is to note the important astronomical comment by Schiaparelli to the fundamental work of Carlo Nallino on Al Battani Opus Astronomicum (Nallino 1903) with translation from Arabic to Latin. This follows his systematic approach: the Brera archive preserves neatly ordered notes on carefully cut sheets of paper, line translations of original texts, and notes on meanings; also, almost a forerunner of ecology, he never wasted paper: he wrote on the back of invitations, Senate notices, even of family letters. Other manuscripts were bound in books. Thus it is interesting to have an inside look at his methodology that requires the research of texts, descriptions, previous studies, and goes in depth even of details.

An example will show his ability: Fig 2-left shows Craig's careful copy of the British Museum tablet Rm 105 (Obverse and Reverse) Virolleaud (1908). Fig. 2-right is the copy, transliteration and translation of tablet Rm 105, obverse, by Schiaparelli.

Schiaparelli showed that at his time many cuneiform ideograms were not identified as far as meaning or, if applicable, names of stars or planets were concerned. Hence he was not ashamed to show his methodic approach and indicate his thoughts and doubts, just as Epping (1889) and Kugler (1907) had made in the early assyriological research, when everything had to be proven by tentatives. Novelty is the purpose of scientific papers, and he developed methods and techniques to investigate new ideas or data. A short quotation is in order. In 1996 I discovered that a notebook in the Archive of the Brera Observatory, in "Cartella N.426", entitled "Nomi di stelle e di costellazioni e di pianeti presso i Babilonesi", had never been studied before; perhaps it was believed a simple list copied from elsewhere, although Schiaparelli wrote "Io ho raccolto senza molta fatica più di cento nomi di costellazioni, di gruppi minori di stelle e di stelle particolari isolate" (Schiaparelli 1908) and pointed out the difficulties of identification. However, this is a true example of research in a field in development, such as Assyriology.

While at present some 400-plus names of Babylonian stars are documented (Goessmann 1950; Kurtik 2007), at Schiaparelli's time there were only those published by Epping and Kugler (some 50); he identified 120 stars, directly from the cuneiform names in the texts of Craig (1899), systematically analyzing their position relative to other known bodies or peculiar characteristics mentioned in the texts[2], and, as we showed (De Meis 1999; Hunger 1999), have also at present the meaning and identification that Schiaparelli gave to them.

A few words about the text Rm 105. It concerns the heliacal phenomena of stars in the various months. This phenomenon, now rarely observed, had an enormous importance in Antiquity, for example in matters concerning calendars (seasons), archaeology (orientation of monuments), literature (poems as the Works and days of Hesiod, or the Fasti of Ovid), even commerce (contracts of insurance in Greece for goods shipped before or after the rise of Arcturus as reported by Demosthenes [3].

The first line refers to the heliacal rising of a star MUL DIL.GAN in the month Nissan, now shown to be ASH.GAN2 = IKU. (Kurtik

[2] Craig 1899. These and other 'astrological' texts were indeed a source of many astronomical data for the history of Ancient Astronomy

[3] Demosthenes mentions interests of 22.5% before the rising of Arcturus, 30% after it

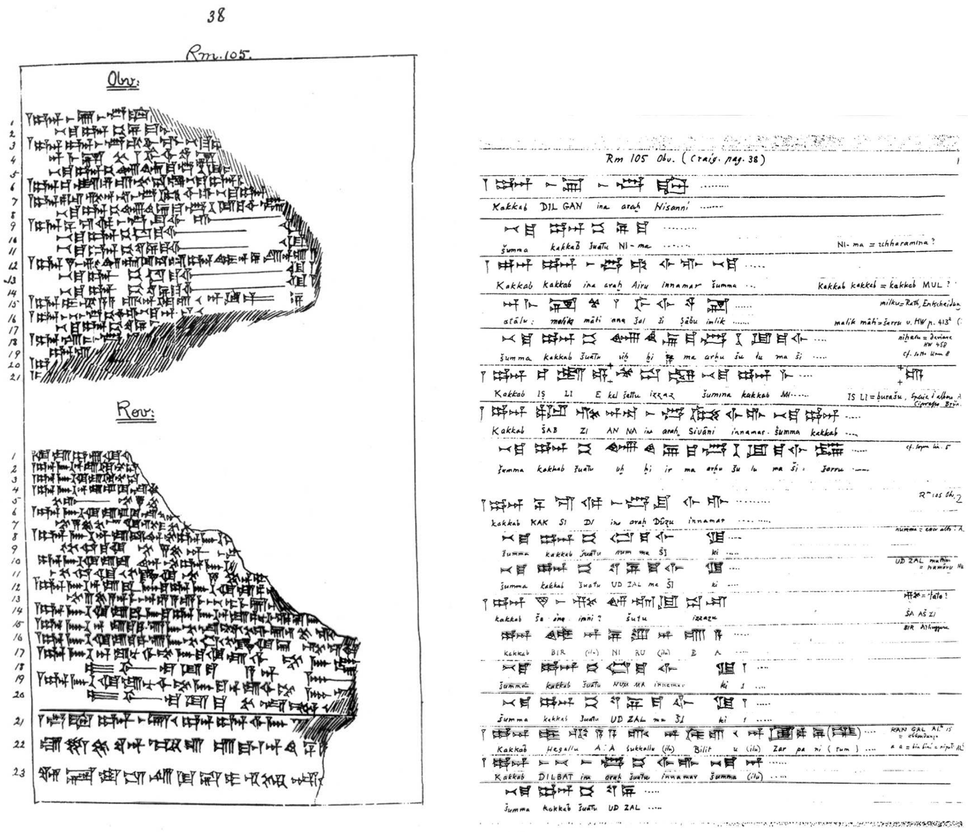


Fig. 2. Left: Cuneiform text of tablet Rm 105, by J.A.Craig. Right: Copy, transliteration and translation of obverse of tablet Rm 105 by Schiaparelli.

2007). A most interesting example, moreover, is the ideogram MUL.MUL that was still to be fully identified; it is composed of the repeated word MUL (star), so that the meaning was "the star-star", "the star par excellence", or the plural of "star", and was eventually recognized as the Pleiades. In this case, Schiaparelli made a list of details to help the search (De Meis 1999; Hunger 1999), such as the month of rising (Airu), the position with respect to the ecliptic (the text said "it follows and precedes the Moon", then the star was close to the ecliptic) or the vicinity to another star. To identify the correspondence of stars in modern astronomy, it is necessary to compute the date for the location wanted, to guess the star's coordinates, its arcus visionis, the status of the air and other parameters. The best approach to the solution is to have more data, such as the simultaneous rising (or setting) with another star. Lists of this type of phenomena are in the MUL.APIN (List II), the astronomical compendium in cuneiform, as Pingree and Hunger have called it (Hunger 1999); they write (MUL.APIN, p.140) that this is "the most secure data that we have for identifying the constellations".

To confirm Schiaparelli's care, he also lists the texts that were published by Thompson (1900) (The reports in this book have been commented and compared to the more recent Hunger (1992), as well as in De Meis (1998)), Brunnow, Delitzsch, and the astronomical data that he found in Craig.

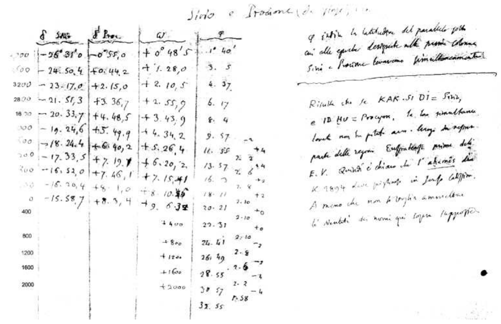


Fig. 3. Sirius and Procyon: simultaneous rising

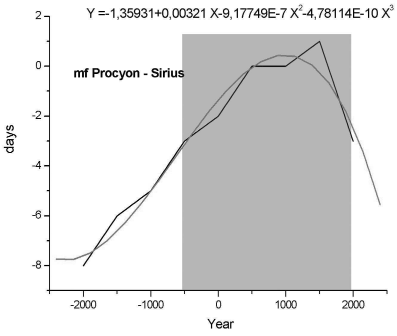


Fig. 4. Syrius and Procyon simultaneous rising from -500 to +2000.

An interesting further calculation is found in his notes: tablet K 2894 (K means from Kuyounjik) mentions that Sirius and another star, that Schiaparelli thought to be Procyon, rise simultaneously (ahamesh), hence he wanted to compute the latitude where in given epochs such phenomenon could happen. To solve the problem he developed a set of formulae (an algorithm we would say today) that follows Ptolemy and is rather simple. He computed (Schiaparelli, Cartella 426/001) the coordinates of the stars from -4000 to +2000, applied his formulae and found that the phenomenon could not occur in any region of the Euphrates, before our Era. Hence it was not an observation.

His manuscript reads: It results that KAK.SI.DI = Sirius and ID.HU = Procyon. Their simultaneous rising could not have happened in places of the region of Euphrates before Era Vulgaris. Then it is clear that the ahamesh of tablet K 2894 must be taken in a very large sense. Unless one would not admit the identity of the names proposed above.

However, if the ahamesh is referred not to the daily rise, but to the yearly heliacal rise, for the latitude of Babylon one gets that in the period -500 to +2000, the difference varies within less than three days, and as Schiaparelli clarified in his papers on parapegmata, the variation of a phase might reach two or more days, depending on the atmosphere, the local conditions, the visual acuity of the observers, the azimuth difference between the star and the Sun.

A clarification is in order. The authoritative CAD, the Chicago Assyrian Dictionary, lists many variations of the meaning of ahamesh, that range from "together", "side by side", "at the same time".

The determination of star names in Babylonian astronomy, for certain ideograms, is still debated. One item is just the identification of Procyon, that currently is listed in the CAD, in the Concise Dictionary, in Goessmann 1950 and in Kurtik 2007. The interpretation of ID.HU as Procyon given by Schiaparelli can be considered valid also in this case; the alternative proposal, Altair, is not acceptable, as the heliacal rising between Sirius and Altair is about six months apart, hence there is no ahamesh. Kugler (1913) made a systematic search of stars setting or rising together, (see p. 17), as we shall see in a moment.

It is to note that the rising of Sirius was connected in Babylonian astronomy to the dates of the equinoxes, and lists are found in tablet BM 36731 (Neugebauerb 1967), but only at present, by the study of the Babylonian Diaries by Sachs and Hunger, it can be stated that the linear scheme used to compute equinoxes is not faithful, whereas the observations preserved are more reliable (Hunger 1999; Neugebauer 1975 at pp. 363 and 707). Therefore it is important that Schiaparelli anticipated the unreliability of some cuneiform texts for what concerns observations versus theories. Delambre (1819) had developed similar formulae using ecliptical coordinates, and had shown that, contrary to the initial opinions of the discoverers[4], the bas-relief of the Dendera zodiac does not represent actual observations of simultaneous heliacal phenomena of alpha Tau and alpha UMa, as these would have occurred at Thebes only in +1667, not in Ancient Egyptian epochs[5]

Schiaparelli had gone a step forward, because his algorithm gave directly the latitude at which the phenomenon could happen, and for Sirius and Procyon indeed we obtain 35.1°. Nineveh was at about 36°. The conclusion of Kugler was that "this research was perhaps the most difficult in the field of investigations of the Babylonian celestial topography", though most fruitful. But Schiaparelli was not scared by the difficulties of identification that he endeavoured to solve, with good results; and the history of mathematical astronomy is based on such type of calculations of specific events, besides the study of ancient theories.

Sirius, of course, has always attracted the attention of learned people (see Panaino 1990), and Schiaparelli also paid his tribute when translating in a very elegant way the verses of Hesiod about that star, or in "Rubra canicula" (Schiaparelli 1998), an excursus on the color of the star from Hesiod, Aratos, Homer and the Egyptians too. Thus, amongst the many duties, he observed intensely, double stars especially, gave lectures, published essays, always with a line of thought on the subjects that he was collecting for the theory and use of the history of Astronomy.

Just a further note: Fig. 5 shows the transcription, transliteration and translation of a part of the tablets later called "of Ammizaduqa", where the motion and phases of the planet Venus are described. Schiaparelli wrote an important essay, Sui fenomeni del pianeta Venere, reprinted in Schiaparelli (1998), III. This tablet is still studied by assyriologists,

Fig. 5. Part of the Tablets of Ammizaduqa, after Schiaparelli.

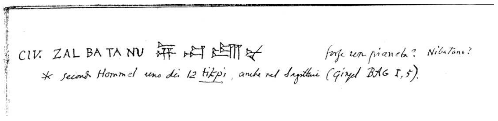


Fig. 6. ZAL.BAT.ANU

with various interpretations, still debated, because they might mark the epoch of the first Assyrian dynasty, even if from 20 to 40 percent of the data are wrong, as Huber (1999) has shown.

One more topic about Assyrian-Babylonian astronomy. In his paper "Le opposizioni di Marte secondo gli osservatori babilonesi",Schiaparelli (1908) deals again with the tablet K 2894, published by Bezold (1888); the star-planet was attributed by some Assyriologists to be either Mercury or Mars or even Sirius. Babylonians already called the planet Mars "kakkab la minati", the star that cannot be computed, Plinius (nh 2,15 7) added "maxime inobservabilis cursus", and Needham (1959) reports that as Sima Qien wrote, the planet's irregular path and visibility increased its study. In Babylonia Mars had a special importance, as the letters of scholars testify (Parpola 1993). Years before, Schiaparelli listed in his "Notebook": "Is it maybe a planet? Nibatanu?"

Now he clearly states that it is Mars. It is well known that the oppositions of Mars were fundamental to determine its orbit, from Babylonians to Ptolemy and, especially, Kepler, and also at present celestial bodies, as-

[4] Especially Letronne, Biot and others that suggested years from -2000 to +500. A summary in Boll (1903) and Gundel (1992).

[5] Kugler (1913) made systematical calculations for tablet BM 86378 (MUL.APIN). My computing, made differently, gives good agreement,e.g for eps Cyg and alp Aql the date is Darius I 21 IX 15 = -500 Dec 10; with Schiaparelli's formula the latitude is 23.1° (that is 1.4° less than Babylon).

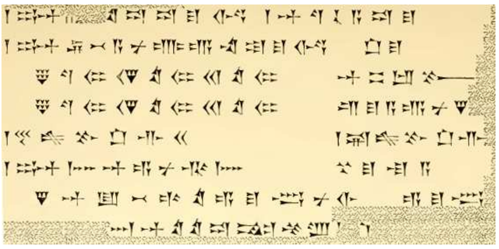


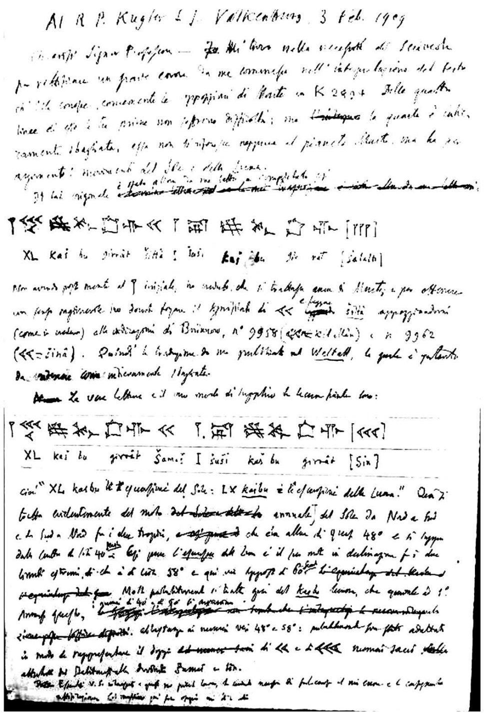
Fig. 7. Motion of Mars, tablet K 2894.

teroids especially, are observed to this purpose at oppositions.

The tablet mentions the word then transliterated NI BAT A NU, NI BE A NU, or ZAL BAT A NU. Schiaparelli maintains that it is Mars and shows why, also because he quotes that Mars has the largest variations of magnitude . He translates the lines 15-18:*[when] the star of Mars becomes powerful, its brightness increases 7 days, 14 days, 21 days this planet rises shining 7 days, 14 days, 21 days goes back, then completes its prescribed path 40 kaspu the two runs, 60 kaspu the [three] runs* . It refers to the retrogradation of the planet, even if the numbers seem too exact, at first.

Actually, Schiaparelli remarks that these data change at every opposition, and as a mean value of the path of retrogradation considers the "runs" as in the figure he draws, where the parts AB, BC, CD are equally extended in longitude. Moreover the planet cannot be Mercury or Venus, that while retrograding have a very weak light . He used Mueller's formula to compute the magnitudes. The conclusion of Schiaparelli is correct, although for readers of "Scritti" an update is in order.

It was in a letter to Kugler, then considered the "number one" in Assyriology, (3 Feb 1909, the draft in Italian is in the Brera Archive) that Schiaparelli informed him that having overlooked a separation sign (a vertical wedge of many meanings), he had not noticed that the new paragraph was not about Mars, but referred to Sun and Moon. Indeed, as in many cuneiform ideograms, there are several homophones to which various meanings are related, and in this case the sign can be read "di", unity (1 or 60), "ana, umma" (if), or the beginning of a new sentence . However this "error" was not



Al R. P. Kugler S. J. Valkenburg 3 Feb. 1909

XL kaš bu girrât Šamši I šuši kaš bu girrât [Sin]

Fig. 8. Letter of Schiaparelli to F.X. Kugler(3 Feb 1909).

infrequent. Kugler (1913), at p. 17, quotes that the same error was made by E.Weidner, with similar references to Sun and Moon. Therefore the error of referring the "kaspu" to Mars can be eliminated.

After one hundred years, the knowledge of cuneiform is very much improved, and one can immediately say that "Ṣalbatanu" (as it is now transliterated) is certainly Mars, as it is confirmed in many tablets.

For a better understanding, Fig. 9 shows Mars' oppositions in the Babylonian period, from -700 to -685. The figure shows the dates of oppositions at the corresponding heliocentric longitudes, the minimum distance Mars-Earth reached, and the apparent diameter of the planet. Using Mueller's formula $m = -1.30 + 5 \log r\Delta + 0.01486\, i$, where $i = \mathrm{acs}\,(r^2+\Delta^2+R^2)/(2r\Delta)$, I have computed the magnitudes of the planet for the perihelic opposition of -696 July 16, at 7, 14 and 21 days before and after the

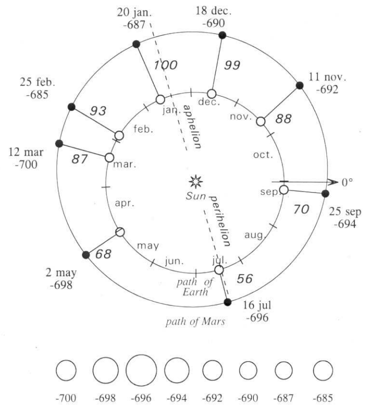


Fig. 9. Mars' oppositions from -700 to -685.

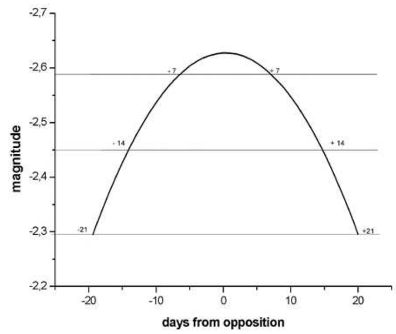


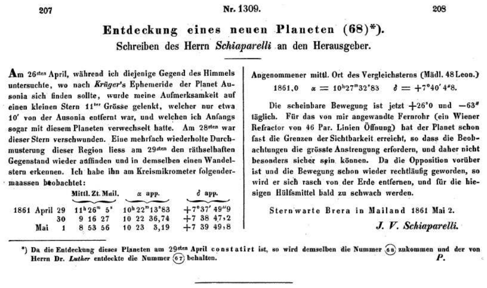
Fig. 10. Mars' magnitude at opposition of -696 July 16.

opposition, and one can see that the change of magnitude follows at its maximum a quasi parabola (better, a sinusoid).

Moreover, enlarging the part of maximum brightness, we obtain the relation mentioned by the Babylonian text. The same occurs as a mean value of other cases of perihelic oppositions.

All this to consider the difficulties of the early assyriologists, and how Schiaparelli used various methods to get once again correct results a century ago.

To conclude on Schiaparelli's knowledge of ancient astronomy, it is remarkable his



207 Nr. 1309. 208

Entdeckung eines neuen Planeten (68)*).

Schreiben des Herrn *Schiaparelli* an den Herausgeber.

Am 26sten April, während ich diejenige Gegend des Himmels untersuchte, wo nach *Krüger*'s Ephemeride der Planet Ausonia sich finden sollte, wurde meine Aufmerksamkeit auf einen kleinen Stern 11ter Grösse gelenkt, welcher nur etwa 10′ von der Ausonia entfernt war, und welchen ich Anfangs sogar mit diesem Planeten verwechselt hatte. Am 28sten war dieser Stern verschwunden. Eine mehrfach wiederholte Durchmusterung dieser Region liess am 29sten den räthselhaften Gegenstand wieder auffinden und in demselben einen Wandelstern erkennen. Ich habe ihn am Kreismikrometer folgendermaassen beobachtet:

	Mittl. Zt. Mail.	α app.	δ app.
1861 April 29	$11^h 26^m 5^s$	$10^h 22^m 13^s 83$	$+7° 37′ 49″9$
30	9 16 27	10 22 36,74	+7 38 47,2
Mai 1	8 53 56	10 23 3,19	+7 39 49,8

Angenommener mittl. Ort des Vergleichsterns (Mädl. 48 Leon.)

1861,0 $\alpha = 10^h 27^m 32^s 83$ $\delta = +7° 40′ 4″8$.

Die scheinbare Bewegung ist jetzt $+26^s0$ und $-63″$ täglich. Für das von mir angewandte Fernrohr (ein Wiener Refractor von 46 Par. Linien Öffnung) hat der Planet schon fast die Grenzen der Sichtbarkeit erreicht, so dass die Beobachtungen die grösste Anstrengung erfordern, und daher nicht besonders sicher sein können. Da die Opposition vorüber ist und die Bewegung schon wieder rechtläufig geworden, so wird er sich rasch von der Erde entfernen, und für die hiesigen Hülfsmittel bald zu schwach werden.

Sternwarte Brera in Mailand 1861 Mai 2.

J. V. Schiaparelli.

*) Da die Entdeckung dieses Planeten am 29sten April constatirt ist, so wird demselben die Nummer (68) zukommen und der von Herrn Dr. *Luther* entdeckte die Nummer (67) behalten. *P.*

Fig. 11. Schiaparelli announces the discovery of asteroid Hesperia

deep study of all the publications available, as we can see from his "Notebook", where he flies from Delitzsch to Craig, to Jensen, to Thompson (for the paranatellonta especially) .

3. Modern astronomy

From Antiquity to modern times, I would like to shortly consider now some professional aspects of our astronomer. An example that is worth quoting, is the discovery of the asteroid Hesperia, and the determination of its orbit. And this is a direct involvement in the history of Science.

As announced in AN 55,(1861), No.1309, 277, Schiaparelli discovered the asteroid on 1861 April 26, while he was looking for the newly 63 Ausonia that A. De Gasparis had discovered at Naples. He saw the two bodies separated by about 10′, and actually the modern computed positions at 19 TT give a distance $0.1398° = 8′23″$. Being concerned that the opposition of Hesperia had already passed and that with his telescope the asteroid was at the limits of visibility, on May 2 he wrote to the Astronomische Nachrichten and to Father Secchi to invite further observations with more powerful instruments (The correspondence lasted until 1878 and included the famous letters with Schiaparelli's theory of comets and meteor streams, see Buffoni, Manara & Tucci 1990a,b).

Thus, observations of Hesperia were made also by Secchi at Rome (May 7-June 26), by Donati at Florence (May 7-June 27), by Respighi at Bologna (May 9-June 27), by Otto

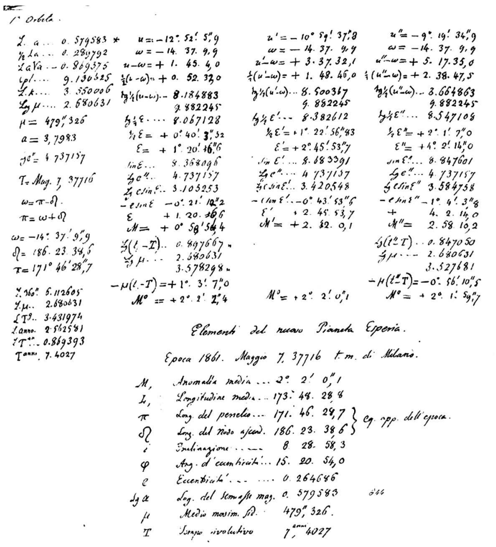


Fig. 12. Orbit calculation of Hesperia by Schiaparelli.

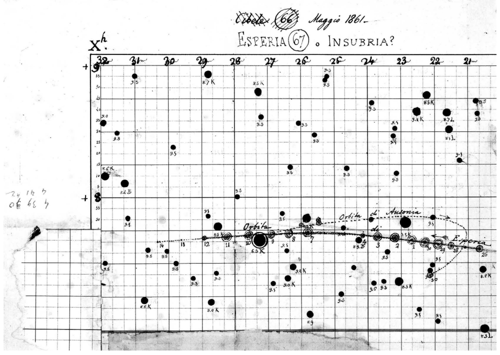


Fig. 13. Path of Hesperia and Ausonia, by Schiaparelli

Struve at Pulkovo (May 9) and by Foerster and Tietjen at Berlin (May 6-June 8). An excellent example of international cooperation of astronomers and of mail (of that time, without Internet).

Fig. 11 from the diary of observations, shows the last page of the preparatory calculation, This copy (Brera Archive, busta 377) was believed to be of an unknown author, but Agnese Mandrino confirms me that it is the authentic writing of the young Schiaparelli.

The above elements were published in AN 55 Nr.1311(1861), 237-238, from Schiaparelli's letter of May 22, with a search ephemeris. The orbit was called "paradoxe Bahn" by the astronomer, who wrote that it needed strong corrections, but believed it useful for an ephemeris to search the "planet", as the asteroids were called at the time.

Schiaparelli remarks that since May 11, 1861 he did not see the asteroid any more; this because of the decreased magnitude (12.0 according to AstDys) and the limitations of his modest instrument,but the third position for the orbit was supplied by Respighi. In his observation logbook Schiaparelli drew maps of Hesperia from 1861 April 26 to May 11 and from May 24 to June 7 that have been displayed at the Exhibition in the Brera National Library this year. The maps still bear the former number 67, and the legend "Esperia or Insubria?". Of course they are very accurate, as we can see. In one also the path of 63 Ausonia is shown.

By numerical integration I have recomputed using Vitagliano (2000) the orbital elements and the position of 69 Hesperia at the epoch of discovery and the most recent ones. The comparison of the osculating elements by Schiaparelli and the modern ones shows that although refinements were needed, the elements were sufficient to compute ephemerides for research observations.

It is also to take into account that Schiaparelli, as astronomers until not much ago, used only 3 observations to compute his first orbit, while for the modern elements many more are used[6] besides the computation of perturbations, hence the results of the old astronomer are excellent indeed. One should note that when the chase for asteroids began, not only powerful instruments were needed but celestial maps as well, that showed stars of high magnitude, in order to locate the new small "planets". And it was for this reason that Gauss (1804) developed a method to find the limits within celestial zones where the new bod-

[6] AstDys numbers 1368 observations up to June 1, 2010, only 78 being discarded to compute the orbital elements.

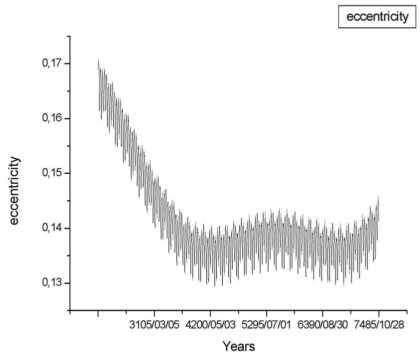


Fig. 14. Variations of the eccentricity of Hesperia

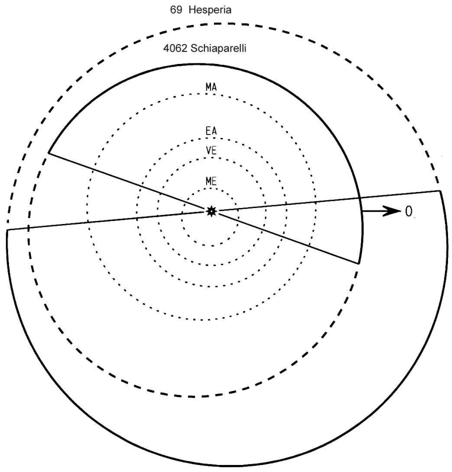


Fig. 15. Orbits of 69 Hesperia and 4062 Schiaparelli.

ies could be found after discovery, thus reducing the research tentatives. Incidentally, both Hesperia and Ausonia rose simultaneously in 1861 at Milan, thus favouring the discovery.

Numerical integration also allows to evaluate and graph the variations of the orbital elements for long time intervals, a type of calculation that was almost impossible in 1861. The evolution of the orbital elements for more than 8000 years shows that the asteroid is very stable, even if there are oscillations of some elements due to perturbations.

Even if with oscillations, the eccentricity decreases; the graph shows the behaviour of e from -52000 to about +7000. Inclination instead increases, with an analog behaviour of peaks and valleys. Concerning apparent angular conjunctions, Schiaparelli was lucky that he could observe Hesperia on 1861 April 26, due to its closeness to Ausonia and a little serendipity. Actually, I calculated the conjunctions Hesperia-Ausonia in longitude, from 1610 to 3000, but the earlier ones are 1701 November 14 separation 0.591° 1861 April 27 0.119°. Next one will occur only on 2363 April 17 with separation 0.051° and will be really very close. Hence, it would have been quite difficult to discover Hesperia at Schiaparelli's time, if the conjunction of 1861 had escaped the Brera astronomer.

Just a note. Asteroid 4062 Schiaparelli, was discovered by the Observatory S. Vittore of Bologna on 1989 Jan 28. Its next opposition will occur on 2011 October 13 at magnitude 15.5, next on 2013 April 5, magnitude 17.1.

Finally, I would like to conclude that as an historian of Science, Astronomy especially, Schiaparelli used his best qualities of astronomer, mathematician, scholar of languages and theories, thus making an optimum use of what we now would call interdisciplinary culture.

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