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Planetary and cometary astronomy at the Collegio Romano

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Abstract

Jesuit astronomers working at the Collegio Romano Observatory have given many contributions in the field of planetary astronomy: De Vico and Dumouchel studied Halley's comet, while Secchi was a pioneer in cometary spectroscopy, studied the surface of the Moon, Saturn's shape, and Mars' surface; he discovered a comet in 1853, and in 1869 he was the first to observe the spectrum of Uranus.

1. Introduction

The Collegio Romano can be considered one of the places where modern science was born. Since its foundation³, astronomical observations have been carried out there, first with naked eye and later with optical instruments.

The first telescopic planetary observations date back to 1611, when Cardinal Roberto Bellarmino (1542-1621) asked his Jesuit confreres to verify Galileo's observations. Under the supervision of Christopher Clavius (1538-1612), they built a Galilean telescope and confirmed the conclusions of the Pisan scientist.

However, the establishment of a true observatory at the College dates back to the year 1787, when abbot Giuseppe Calandrelli (1749-1827) built a tower in the south-east corner of the roof of the palace, in order to house astronomical instrumentation.

The tower still exists today and is even now used for meteorological observations with the instrumentation placed on its top. Inside the tower there is a sundial, and in the same room there are two marble commemorative plaques: one concerns the construction of the tower in 1787, the other one the visit of Pope Pius VII together with the King of Sardinia, Vittorio Emanuele I, on the occasion of the solar eclipse of 11 February 1804 (Buffoni et al. 2001).

Fig. 1 A gravure of the Collegio Romano with the Calandrelli Tower (from *Opuscoli astronomici* by G. Calandrelli and A. Conti, 1803)

Calandrelli was called to the chair of mathematics in 1773, when Pope Clemens XIV ordered the suppression of the Society of Jesus and entrusted the College to the secular clergy.

After the reconstitution of the Society of Jesus in 1824, the directorship of the astronomical observatory was held first by Etienne Dumouchel (1773-1840), who was director until 1838, and then by Francesco De Vico (1805-1848) from 1839 to 1848.

Dumouchel strove to equip the Observatory with new instruments; in particular in 1825, thanks to the financial support of the General Superior of the Society of Jesus Luigi Fortis (1749-1829), he purchased a Cauchoix achromatic refractor telescope of excellent construction.

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³ The Collegio Romano was established by Ignatius of Loyola (1491-1556) a few years after the foundation of the Society of Jesus for the purpose of training young people from elementary school to university. At the order of Pope Gregorio XIII, between 1582 and 1584 a large building was erected to host the sessions; after the fall of Rome in 1870, it was expropriated by the Italian State. Its cultural tradition was later passed on to the Università Gregoriana.

Fig. 2 The Cauchoix telescope with the old altazimuth mounting (De Vico, 1840c)

This instrument had a long operational life. After Secchi became director in 1850, it was installed on a new equatorial mount and moved to the new Observatory of the Collegio Romano, built by Secchi above the church of St. Ignatius. It was later used by Pietro Tacchini (1838-1905) and Giuseppe Armellini (1887-1958) until it was finally moved to the Monte Mario Observatory, where it was still used for both scientific and educational purposes until the end of the 1980s.

In 1851, under the direction of Angelo Secchi (1818-1878), the Observatory was completely renewed. Only the meteorological instruments remained at the Calandrelli Tower, while the astronomical instruments, especially those dedicated to astrophysics studies, were located in the new rooms and installed above the sturdy pillars that had been designed to support a large dome that was never built.

After Secchi's death, the Observatory passed to the Italian State and it was annexed to the newly established Ufficio Centrale di Meteorologia, directed by Pietro Tacchini. Astronomical observations continued until the early 1900s under the guidance of Tacchini himself and Elia Millosevich (1848-1919).

Finally, in 1923 the Observatory of the Collegio Romano was merged with the Observatory of the Campidoglio under the direction of Giuseppe Armellini and became the founding nucleus of the Astronomical Observatory of Rome, whose headquarters were located in the ancient Villa Mellini in Monte Mario in 1938.

2. Planetary observations in Italy before the 19th century

After the observations made at the time of Galileo, the Jesuits continued to study the Solar System, not only at the Collegio Romano.

The Jesuit Giovanni Battista Riccioli (1598-1671), who lived in Bologna, produced a detailed map of the visible part of the Moon and created the nomenclature of craters and seas which is still used today. He was also among the first astronomers to deepen the study of the libration of the Moon, manifested by an oscillation of the visible lunar disk. This means that, even if the Moon turns the same face to the Earth, the visible surface of our satellite during the year is greater than half of its total surface. These studies were carried out with the contribution of another Jesuit, Francesco Grimaldi (1618-1663), who is also famous for the discovery of the light diffraction.

In addition, Riccioli observed and described the five planets known at the time (Mercury, Venus, Mars, Jupiter and Saturn) and noted the variations in the shape and position of the Jupiter's bands.

Fig. 3 The drawing of the Moon by Giovanni Battista Riccioli and Francesco Grimaldi (Riccioli 1665).

Francesco Bianchini (1662-1729), maker of the famous meridian line in Santa Maria degli Angeli church in Rome, made systematic observations of Venus. He determined its rotation period to be 24 days, which is very far from the real value (Bianchini 1728). Indeed, due to the dense atmosphere that covers the planet's surface, the period of rotation of Venus remained an enigma until the twentieth century, when it was possible to perform radar observations in frequencies where the planet's atmosphere is transparent.

Bianchini drew a map of the planet and constructed a globe of Venus which is now kept at the Museo della Specola in Bologna. His observations were conducted from various places in Rome and from Albano using telescopes made by Giuseppe Campani (1635-1715) with a focal length more than 10 meters long. Campani had his optics laboratory in the centre of Rome, not far from the Collegio Romano, and made planetary observations by himself, in particular of Saturn, drawing the unequivocal shape of the rings (Campani 1664).

Eustachio Divini (1610-1685) is the other famous instrument maker operating in Rome in the 17th Century. His telescopes were provided with wooden tubes whose focal length could exceed 15 meters; with them he observed the Moon, Jupiter and Saturn and those of their satellites that were known at the time (Divini 1660).

The Jesuit Gille François de Cottignies (1630-1689) observed the atmosphere of Jupiter, as well as the great comets of 1664, 1665 and 1668. Assisted by Brother Salvatore Serra, de Cottignies observed Mars from 27 to 30 March 1666 with a telescope by Divini of “25 palms”⁴ and with a second telescope of “45 palms”. By measuring the changes of the position of some formations on the Martian surface, they hypothesized a rotation period around the axis of the planet of about 13 hours (Cassini 1666), very far from the true rate⁵.

Giuseppe Maria Asclepi (1706-1776) observed the 1761 transit of Venus across the Solar disk from the Collegio Romano. He also made measurements of the diameters of Venus and Mars, and conducted observations of Mercury and of the comet of 1769 (Asclepi 1761, 1765, 1767, 1770).

Finally, it is worthwhile mentioning that Ruggero Giuseppe Boscovich (1711-1787) SJ observed the transit of Mercury in 1737 in Rome. He laid the foundations of geodesy through the first measurement of the geodetic base along the Appia Antica. His work was interrupted because of the Napoleonic occupation and subsequently resumed by Secchi in 1854-55, as reported in a plaque placed along the ancient street near Capo di Bove (Aebischer 2012).

3. Comets’ observations at the Collegio Romano Observatory

Giuseppe Calandrelli and his assistant Andrea Conti (1777-1840) described the observations of planets and other celestial bodies in the eight volumes of *Opuscoli astronomici* of the Collegio Romano published from 1803 to 1824. They calculated the orbits of planets and comets and provided detailed tables of the parallax of the Moon. Later, in 1816 they were joined by canon Giacomo Ricchebach (1776-1841). A few decades later, Angelo Secchi declared that the scientific value of the work of these astronomers far exceeded the poverty of the instruments they had used at the Collegio Romano.

In the *Opuscoli astronomici* of the year 1808, Calandrelli reported the observations of the comet of September 1807. In the same issue Andrea Conti published the orbital elements of the comet⁶. Similarly, the 1813 issue reports the observations and orbital elements of the great comet that appeared in 1811. This comet was visible to the naked eye for about 250 days and was mentioned by Lev Tolstoj in *War and Peace*.

Etienne Dumouchel observed the return of Halley's comet with the Cauchoix refractor on 5 August 1835 and he immediately reported it in the periodical *Astronomische Nachrichten*. The credit for this discovery is to be attributed to his young assistant Francesco De Vico, who calculated the comet's orbit on the basis of previous apparitions and identified its expected position, thus allowing its discovery long before other astronomers would notice it.

⁴ 25 palms of focal length correspond to about 5.6 meters. It is probably one of the long focal length telescopes currently on display at the Astronomical and Copernican Museum of the INAF-Astronomical Observatory in Rome.

⁵ “Anno 1666 die 30 Martii bor. 2 n.s. typus Martis cum insignibus maculis Romae visis primum a DD. fratribus Salvatore ed Francisco de Serris tubo Eustachii Divini palmorum 25., ac subinde 60. a die 24. Martii ad 30., qua die in aedibus Ill.mi D. Caesarii Giorii hora praedicta, et ipsomet Illmo D. describente tub. pal. 45. apparuit, ut hic exprimitur, inverso modo nigriore inter alias existente macula orientali, pro situs observata variatione ejusdem planetae circa primum axem revolutionis periodum indicatura, boris nempe circiter 13” (books.google.it/books?id=qmZPeL_r9i4C at the Biblioteca Casanatense).

⁶ This comet was also observed in Palermo by Niccolò Cacciatores (1770-1841) (Cacciatores 1808; Chinnici 2015).

De Vico continued to carry out cometary observations at the Collegio Romano Observatory during his directorate. We just mention the comet of July 1839 which was discovered during the collection of data concerning the constitution of nebulae: as it is written in the *Memorie del Collegio Romano* published on 31 January 1840, the observations were made with the Cauchoix telescope with the assistants Luca Boccabianca (1810-1875) SJ and Benedetto Sestini (1816-1890) SJ. In total, De Vico was given priority in the discovery of seven comets observed at the Collegio Romano in the years from 1839 to 1847, and for his discoveries he was awarded by the King of Denmark.

Questions about the physical structure of the Solar System became more and more of interest during the nineteenth century and they had driven the attention of the astronomers to comets, because cometary orbits were used for determining the masses of the planets with no satellites and in order to understand the composition of the comets themselves.

Angelo Secchi, who succeeded De Vico in the direction of the Observatory, reported in the *Astronomische Nachrichten* on 25 August 1852 the observation of the return of Comet Biela, which splitted into two parts during the previous passage of 1846 (Secchi 1852a; Chinnici 2019).

In the same issue of the German periodical, Secchi communicated data of the asteroid Melpomene observed at the Collegio Romano (Secchi 1852b), which had been discovered just over a month earlier by English astronomer John Russell Hind (1823-1895). In 1853 Secchi himself discovered a new comet (Secchi 1856c; Chinnici 2019).

Secchi mentions observations of numerous other comets between the years 1858 and 1862 and then again in 1874, carried out together with his assistant Enrico Cappelletti (1831-1899) SJ. Cappelletti was a good draftsman and his contribution was of great importance for sketching the drawings of comets and other celestial objects (we will see later in particular those of Mars) that Secchi observed.

Fig. 4 Comet observed by Angelo Secchi in 1861 (INAF-Osservatorio Astronomico di Roma, Historical Archive).

Extensive studies were made for the Comet of 1861, in particular on its nucleus, to show that the tail jets increased as the distance from the Sun decreased. Secchi was also interested in cometary spectra, starting from 1866, when he observed the spectrum of Comet Tempel, and found that the chemical composition of the comets was different from that of nebulae.

The biggest development on the subject came with Schiaparelli's discovery of the correlation between comets and shooting stars, to which Secchi gave space on several occasions in the *Bullettino* he edited (Schiaparelli 1866). In Secchi's words, "these meteors moved accordingly with the orbits of comets, so one of two consequences was inevitable, either that comets were clusters of shooting stars, or that comets were large shooting stars that were tied to the orbits of these bodies"⁷ (Secchi 1877).

Finally, we recall the contribution of Elia Millosevich, who unlike his predecessors was more devoted to celestial mechanics than to astrophysics, turning his attention to calculating the orbits of comets and asteroids. He discovered the asteroids Josephina and Unitas in 1891 and in 1899 was among the first to calculate the highly eccentric orbit of the asteroid Eros with very high accuracy, showing that the trajectory covered by this asteroid periodically brings it close to the Earth. This work, in particular the prediction of the proximity of Eros to the Earth on the occasion of the asteroid's opposition in 1900, was of great use for a more precise determination of the Solar parallax and, consequently, of the astronomical unit.

⁷ "...queste meteore andavano di conseguenza con le orbite delle comete, onde era inevitabile una delle due conseguenze, o che le comete erano ammassi di stelle cadenti, o che le comete erano stelle cadenti maggiori che camminano di conserva con le catene di questi corpuscoli" (Secchi 1877).

4. Planetary observations during the directorates of Giuseppe Calandrelli and Francesco De Vico

From the *Opuscoli astronomici* edited by Giuseppe Calandrelli, we know that Andrea Conti, friend and pupil of Calandrelli, observed the transit of Mercury on 8 November 1802 from the tower built by Calandrelli himself on the roof of the College (Conti 1803). Conti wrote that the observations of the phenomenon were disturbed by the frequent passage of clouds. However, he did not lose heart and completed the mathematical study of the phenomenon. In his analysis he also used observational data provided by Giuseppe Cassella (1755-1808), director and founder of the Astronomical Observatory of Naples at the ancient monastery of San Gaudioso in Caponapoli; by the Viennese astronomer Franz de Paula Triesnecker (1745-1817); and by the French Joseph Jérôme Lefrançois de Lalande (1732-1807), who sent him the data taken by Joseph Thulis (1768-1810) director of the Observatory of Marseille.

Observations of Uranus and Jupiter on the occasion of their oppositions of 1819 are reported in the *Opuscoli astronomici* of the year 1822 (Conti 1822). Conti wrote that the measurements of the position of Uranus were made with the transit instrument and the mural quadrant, and with the transit instrument and the Reichenbach multiplier circle for Jupiter. He used as reference points the positions of the fixed stars from the Piazzi's catalogue, published in 1814. From them, Conti calculated the times of the oppositions of the two planets and also proposed new tables of Uranus, with correction of the old tables by Barnaba Oriani (1752-1832) and Jean Baptiste Delambre (1749-1822).

Conti was assisted by Ignazio Calandrelli (1792-1866) in calculating the elements of Uranus' orbit. Ignazio was nephew of Giuseppe Calandrelli and director of the Astronomical Observatory of the Campidoglio after 1848. Ignazio Calandrelli renovated this observatory, obtaining funds from Pio IX for improving the instrumentation, which was increased with an Ertel meridian circle and an equatorial refracting Merz telescope.

Back at the Collegio Romano, in the *Opuscoli* of 1824 we also find tables to calculate the annual parallaxes of Jupiter and Saturn, by Conti (Conti 1824a). In addition, he calculated new tables of Mercury (Conti 1824b) starting from the data of the planet's transit over the solar disk which was observed in November 1822 in Parramatta (New Wales, Australia) by Georg Friedrich Wilhelm Rümker (1832-1900).

We have already mentioned Francesco De Vico in the section dedicated to comets, in particular for his precise calculation of the ephemeris of Halley's comet, which made it possible to observe the return of the comet at the Collegio Romano in 1835 before any other observers.

His skill was not limited to calculation; he was also a keen observer. In 1838 De Vico was able to observe the satellites of Saturn, Mimas and Enceladus, with the Cauchoix telescope. From a series of very accurate observations he calculated the period of revolution of both, and the ephemeris of Mimas (De Vico 1838b). Due to the proximity of these satellites to the planet, only the discoverer William Herschel (1738-1822) had seen them before De Vico did, and that only on a few occasions.

De Vico attempted to study the divisions of Saturn's rings; to facilitate these observations he introduced a small opaque metal sheet into the focus of the eyepiece to hide the planet, whose brightness interfered with seeing the objects closest to it (De Vico 1842a). He tried to measure the supposed eccentricity of the rings with respect to the position of Saturn and to verify the rotation time of the rings themselves, in both cases without success.

Fig. 5 Saturn and its satellites observed by Francesco De Vico (De Vico 1840b).

De Vico and his assistants Clemente Palomba (1819-1891) and Benedetto Sestini conducted numerous observations of Venus with the aim of calculating the rotation period of the planet. However, he was misled by the presence of a dense atmosphere on Venus, which was unknown at the time, that did not

allow to observe its surface. In the *Memorie del Collegio Romano* we find a detailed description of the attempts to see the spots on the surface of Venus and to follow their movements as long as possible, even in broad daylight.

Using the Cauchoix telescope with a string micrometer applied on it, he concluded that a full revolution of Venus on its axis occurred in between 23 and 24 hours (De Vico 1840c). De Vico also wrote that he could not believe that Bianchini had made such a gross mistake by declaring a rotation of 24 days. Today we know that both were wrong; in fact, the rotation period of Venus is very slow, equal to about 243 Earth days, and retrograde.

5. Planetary observations during the directorate of Angelo Secchi

When Secchi took over the directorate of the Observatory of the Collegio Romano he found himself having to work with instruments located in a tall tower that lacked the necessary stability for accurate observations. As it has been previously mentioned, he started the construction of a new observatory located on the pillars of the church of St. Ignatius and commissioned new instrumentation, including the Merz equatorial refractor. The first improvement he made concerned the Cauchoix telescope, which was equipped with a new equatorial mount, making it more suitable for observations of comets and minor planets. Among others, Secchi studied asteroid Massalia (Secchi 1852), discovered in September 1852 by Annibale de Gasparis (1819-1892) at the Astronomical Observatory of Capodimonte, and at the same time by the French astronomer Jean Chacornac (1823-1873), who first communicated the discovery.

It is well known that Secchi was more interested in the study of the physical nature of celestial bodies, rather than in their motions, and this is evident in the planetary observations he conducted. From the beginning, his studies included spectroscopic observations of the planets and these became more extensive from the end of the 1860s.

5.1 The Moon and the photography

The eclectic nature of Secchi's interests led him to experiment with all kinds of new techniques in astronomical observations, including photography. In fact, together with the pharmacist and photographer Francesco Barelli, in 1858 he created the first photographic atlas of the Moon (Secchi 1858a, 1858b). Using the wet collodion technique, they obtained eight different detailed images of the satellite during the crescent phases. Moreover, Secchi made an extremely detailed drawing of Crater Copernicus, the result of a study that lasted more than two years starting in 1855. Secchi also photographed the planets Jupiter and Saturn, "in the first [Jupiter] the bands, in the second [Saturn] the ring with its shadow were very clear"⁸ (Secchi 1858c).

His photographs of the Moon have survived to our time, but not those of the planets. Secchi tells us that the latter were overexposed. From the exposure times he deduced that the absolute brightness of Jupiter exceeded that of Saturn, which far exceeded that of the Moon; and referring to the latter he ironically noted that his conclusion "may seem strange to those who hear so much praise of [the Moon's] silvery splendor"⁹.

Fig. 6 Picture of the Moon in the 6th day by Angelo Secchi and Francesco Barelli (Secchi 1858a).

5.2 Mercury

⁸ "...nel primo si ebbero nettissime le fasce, nel secondo l'anello fino colla sua ombra" (Secchi 1858c).

⁹ "...conclusione che potrà parere strana a chi tanto sente decantare l'argenteo suo splendore" (Secchi 1858c).

Secchi mentions numerous observations of Mercury. He noticed spots and structures on its surface, but he did not systematically study it, probably due to the difficulty of observing the planet as it is always immersed in twilight.

5.3 Venus

With Benedetto Sestini, Secchi observed Venus several times, both on the occasion of its transit in front of the solar disk and during inferior conjunctions. In particular, during the inferior conjunction of 1857, Secchi was convinced that the planet had a dense atmosphere. He also mentioned the presence of possible surface structures, which he believed to be solid. Today we know that in reality the very opaque atmosphere prevents observation of the surface of Venus. At that time one issue was therefore to determine the exact period of rotation of the planet, which remained unanswered until the 1960s, when radar observations in radio wavelengths were able to penetrate the dense atmosphere.

Secchi himself realized that some of the features he observed changed their shape and that consequently they could not be associated with the surface of the planet but with its atmosphere. From the observations of the spectral lines Secchi noticed a certain similarity between the atmospheres of Venus, Mars and the Earth (Secchi 1874b).

5.4 Mars

Mars was the planet most continuously observed by Secchi. In 1859 Secchi published 18 detailed drawings of the red planet and two representations of the view of its lower and upper poles (Secchi 1859a). This was the result of observations carried out from June to August of the previous year, at the time of the opposition of the planet, drawn with great accuracy by the hand of Cappelletti. The result was noteworthy, most likely thanks to the favourable conditions given by the planet's position in the sky and by the excellent quality of the Merz telescope of 24-cm aperture and 4.35-meters focal length.

Several years later - in 1877 - Secchi described his work on Mars, writing that “the most important discovery is that of two permanent blue channels between the two great red equatorial continents, which was confirmed by subsequent observations since the planet has been re-observed in recent years almost under the same aspect”.¹⁰ (Secchi 1877). About the polar caps, he went on saying that “their extreme variability was proved; which leads us to believe them to be clusters of clouds rather than snow or ice”¹¹. He concluded by saying that “many of these latter drawings are unpublished”¹², as if to demonstrate an awareness of the value and uniqueness of his work, or perhaps a certain humility in not considering the result of his observations sufficiently confirmed by other studies.

Fig. 7 Drawing of Mars in colours by Angelo Secchi and Enrico Cappelletti (*Osservazioni all'Equatoriale dal 23 giugno 1858 al 24 febbraio 1859*, INAF-Osservatorio Astronomico di Roma, Historical Archive, Inv. 43, n.158).

We also know from Secchi's words that a few of these drawings were sent to Francois Terby (1846-1911), who was also interested in studying the planet. From these drawings and his writings it is possible to note that Secchi observed and documented some Martian sandstorms (McKim 1999).

A significant landmark in the study of this planet in the years to come was the use by Secchi of the word “*canali*”, which should be translated as “channels”, to indicate the regular structures that seemed to be present on the surface of the planet. This usage anticipated and perhaps generated the great

¹⁰ “...la scoperta più importante è quella di due canali azzurri permanenti tra i due grandi continenti equatoriali di color rosso, che è stata confermata dalle osservazioni posteriori essendosi il pianeta riosservato negli ultimi anni quasi sotto lo stesso aspetto” (Secchi 1877).

¹¹ “...si provò la loro estrema variabilità; il che fa credere piuttosto ammassi di nubi che di nevi o ghiacci” (Secchi 1877).

¹² “...molte di queste figure ultime sono inedite” (Secchi 1877).

attention towards the red planet that would be unleashed just over a decade, when the word “*canali*” was taken up by Giovanni Virginio Schiaparelli (1835-1910) who began observing Mars at the Brera Observatory starting in 1877.

It is worth remembering the great mutual esteem between the two scientists, which is well attested by the note written by Schiaparelli in the register of observations of 26 February 1878, the day of the death of Angelo Secchi.

Fig. 8 Pages of the register of observations by Giovanni Virginio Schiaparelli of 26 February 1878 with the annotation of the death of Angelo Secchi (INAF-Osservatorio Astronomico di Brera, Historical Archive).

Concerning spectroscopic observations, Secchi observed few absorption bands in Mars and from this he deduced that the Martian atmosphere should be thinner than the atmospheres of the other planets and in particular of the outer giant planets and that its chemical composition is rather similar to that of the Earth's atmosphere.

5.5 Jupiter

Secchi made a large number of drawings of Jupiter and noticed that the planet's appearance rapidly changed. He was convinced that phenomena similar to our storms occurred in its atmosphere. The Jesuit also studied the satellites of Jupiter and in particular their rotation inferred from the observation of spots on their surfaces (Secchi 1856b).

Regarding spectroscopic observations, Secchi observed some peculiar absorption lines that only in the Twentieth Century have been explained to be due to the high-pressure condition of the gas. In addition, the existence of lines of water vapour was highlighted, being their presence first denied and then confirmed by other astronomers. However, in the light of modern knowledge it is now understood that these bands are due to the Earth's atmosphere.

In general, the outer planets showed very different spectra from that of the Earth's atmosphere and this led Secchi to believe that the atmospheres of the gas giants were in a primordial stage and composed of unknown gases.

FIG. 9 Drawing of Jupiter dated 23 January 1859 (*Osservazioni all'Equatoriale dal 23 giugno 1858 al 24 febbraio 1859*, INAF-Osservatorio Astronomico di Roma, Historical Archive, Env. 43, n.158)

5.6 Saturn

Saturn was the first planet to be observed by Secchi, as early as 1850, initially with the Cauchoix telescope at the old observatory (the Calandrelli Tower) and later in the new observatory with the Merz telescope.

He conducted detailed observations of the structure of the rings, revealing their irregularities and confirming the previous observations made by De Vico and other astronomers (Secchi 1856b p. 112). In particular, he observed the very thin third ring, in addition to the first two rings already known from the times of Cassini and Campani. Moreover, he was able to see two subtle divisions of the outermost ring. One of these divisions had been earlier discovered in Berlin by Johann Franz Encke (1791-1865). From these observations Secchi was convinced that the divisions must be real empty spaces that separate the rings (Secchi 1863c).

Secchi's hypotheses were confirmed by Étienne Léopold Trouvelot (1827-1895) who had repeated the same observations with the large American refractors in Cambridge and Washington observatories.

This research continued until 1862, at which time the position of the planet was no longer favourable to observations; and perhaps by then Secchi's interests were directed elsewhere.

5.7 Uranus and Neptune

The two outer planets were observed several times without seeing any spots or structures on their surface. In 1869 Secchi was the first to observe the spectrum of Uranus, which was very bright and characterized by the presence of two dark bands. The first was located in the green region of the visible spectrum and the second in the violet. The spectrum of the planet also showed a wide empty interval in the yellow region and a weak emission in the red. Secchi noted differences with respect to the spectra of Jupiter and Saturn, and also with respect to the spectrum of the Sun, from which he deduced that the peculiarities of the spectrum of Uranus, compared to the reflected light of the Sun, had to be introduced by the planet's atmosphere (Secchi 1869).

Fig. 10 The spectrum of Uranus, as observed by Angelo Secchi (Secchi 1869).

5. Conclusion

As we have seen, the study of planetary astronomy has been a regular part of the work at the Collegio Romano since its foundation, and this has been conducted by Jesuit astronomers and other scholars over the centuries.

These activities continued until the beginning of the twentieth century. In fact, planetary observations were carried out by Pietro Tacchini and Elia Millosevich, who took over the Observatory from the Jesuits after the unification of Italy.

In 1880 they used the 24-cm aperture Merz refracting telescope to observe Uranus and the minor planets Juno, Ceres, Hebe, Diana and Nemausa (Tacchini 1880). Later, further observations were made with the new 39-cm aperture Steinheil-Cavignato refractor, which in the meantime had been installed to replace the Merz telescope (Millosevich 1904).

After that time, the study of the planets continued at the Astronomical Observatory of Rome in Monte Mario under the direction of Giuseppe Armellini. His main field of study was celestial mechanics, and therefore his planetary research was of a theoretical nature. In particular, he conducted in-depth studies on the motion of Uranus and the perturbations of Triton, the largest satellite of Neptune, which made him suspect the existence of other satellites. This intuition was later verified in 1948 when a fifth satellite of Uranus (Miranda) was discovered, and again in 1949 with the discovery of a second satellite of Neptune (Nereid), both by Gerard Kuiper (1905-1973).

Armellini also studied the perturbations of the orbit of Hungaria, an asteroid of the main belt discovered in 1898 by the German astronomer Max Wolf (1863-1932).

Lines of research concerning the planets are still active today in the two INAF institutes of the Roman area. At the Astronomical Observatory of Rome, located in Monte Porzio Catone, this activity is focused on the study of the minor bodies of the Solar System, based on the analysis of data collected by telescopes both on the ground and orbiting in space. Since its foundation, the Institute of Astrophysics and Space Planetology, in Frascati, has been the seat of advanced planetary research, both observational and theoretical, which is still on-going through the participation in important space missions.

Planetary astronomy is also carried out at the Vatican Observatory, concerning both the observation of planets and the laboratory study of meteoritic materials.

The long tradition on planetary research that we have described in this work, together with the astronomical observations that have been conducted since classical antiquity and the founding of stellar

astrophysics in the 19th Century, make Rome a unique place for the history of astronomy. For this reason, it would be worthwhile to further enhance the places and testimonies of this history through dissemination among students, young people in general, and the wide public. This could happen through the frequent organization of events, encouraging public access to places of astronomical interest in the city and the development of museum structures dedicated to science.

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