Cultural Heritage and Modern Technologies **2024**, 2, 184-205

Cultural Heritage & Modern Technologies

www.aaatec.org ***ISSN** 2837-0759*

DOI: 10.24412/2837-0759-2024-2184205
UDC: [930.2+523.46]

Was the northern hexagon of Saturn seen from Earth before Voyager 1? Further researches.

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Abstract

Saturn's atmospheric boreal hexagon, discovered by the Voyager 1 probe in 1981, has such dimensions – sides km. 13800; total extension in length almost km. 30000; latitude 78°N; major angular diameter 4″; smaller angular diameter 1.3″ – to make it visible from Earth with common telescopes. Nowadays it is photographed with instruments with a diameter of 36 cm (Celestron C14) and digital image processing. We therefore wondered in the recent past if it had ever been reproduced in telescopic images prior to 1981. A systematic archive research conducted by us (Walter Ferreri, Mario Codebò, Barbara Bubbi 2021a; 2021b) in the two-year period 2020-2021 allowed us to find old drawings, performed starting from 1898 by the astronomers E.E. Barnard and E.M. Antoniadi with various refractors, in which the hexagon was reproduced although never mentioned in the writings. In the summer of 2022 Henry de Santis then found a drawing by the Italian astronomer Luigi Taffara from 1929 which presents the same reproduction of the hexagon. Two facts are noteworthy: 1) all the reproductions found so far have been copied from images obtained with refractor telescopes of various diameters, but never with reflectors; 2) the dates on the drawings show that the hexagon has persisted on Saturn's north pole since at least 1898. Further research in the archives of the Lowell Observatory, carried out by Laura Citernesi, demonstrated that professional photographs, taken in the first half of the 20th century, consistently did not have sufficient resolving power to show the hexagon. In this article we present and discuss all the images found to date.

Keywords: Saturn, Boreal Hexagon, Voyager 1, old astronomical drawings, telescopic images, archive research.

1. How this research was born

In 2019 Barbara Bubbi told Mario Codebò that amateur astronomers familiar with her, such as Damian Peach, are able to photograph Saturn's hexagon with small to medium sized amateur instruments, such as the 355 mm Schmidt-Cassegrain C14 (fig. 1).

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[4] Archeoastronomia Ligustica; ALSSA; SIA.
[5] Magazine «Cosmo».

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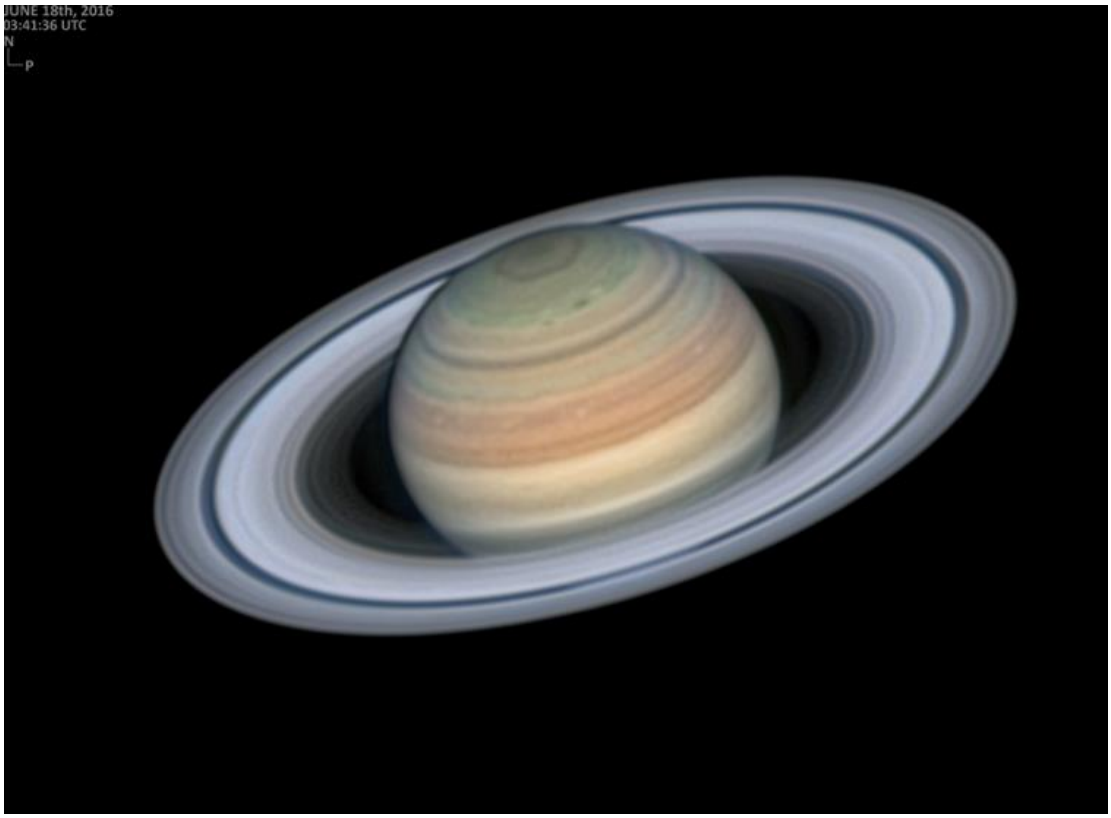

Figure 1. Saturn photographed (<…near perfect seeing conditions…>) by Damian Peach on 18 June 2016 in Barbados Islands, using his reflector C14 (diameter 355 mm) and digital processings[6].

These are naturally digital photographs, obtained by superimposing a large number of images and then treating them with special softwares. The news, accompanied by images easily available on the Web, made Mario Codebò think that, if a «small» and amateur telescope was enough to distinguish the hexagon, even more so the large professional telescopes of the past – such as, for example, those of Yerkes and M. Palomar – should have allowed one to see the hexagon directly, if the seeing conditions were good or excellent.

The question remained on standby until, in the spring of 2020, Mario Codebò found himself observing some images of Saturn printed in Gino Cecchini's book *Il Cielo*, UTET, 1969, vol. I, pp. 501-505, one of which reproduces a drawing by E.E. Barnard, made on the night of July 7, 1898 with the 101 cm refractor by Yerkes, in which the three sides and the two included angles of a polygonal structure are clearly reproduced.

Involved in the research was the professional astronomer Walter Ferreri (of the INAF - Astronomical Observatory of Turin and Pino Torinese, Italy), who assumed the coordination of the research. Also thanks to the lock-down caused by the Sars – Covid19 pandemic, the original group of researchers – Ferreri, Codebò and Bubbi – consulted some archives online and found other drawings of Saturn which bore more or less distinct traces of polygonal structures on the North Pole of the planet.

The results of this first research were published in Italian in the Giornale di Astronomia, which is an official magazine of Italian Society of Astronomy S.A.It. (Ferreri, Codebò, Bubbi 2021a); in English in the Journal of Archaeoastronomy and Ancient Technologies (AaATec (Ferreri, Codebò,

[6] https://www.damianpeach.com/barbados16b.htm

Bubbi 2021b) and again in Italian in the Bulletin of the U.P.S. Astronomical Observatory of Genoa (Ferreri, Codebò, Bubbi 2022). In 2022 Henry de Santis found two other drawings (one of which by the Italian astronomer Luigi Taffara) which we published in the Giornale di Astronomia 2023 (Codebò, De Santis 2023).

Finally, Laura Citernesi, after having participated in the ALSSA 2023 Seminar, brought her contribution to the research by consulting the archive of the Lowell Observatory in Flagstaff, Arizona, USA, which contains many photographs taken in the first half of the 20th century and which demonstrate how the chemical photographic techniques on film or plate, in use at the time, did not have a degree of sharpness that would show any detail of Saturn's North Pole, with the exception of color. And in fact we expected this default from chemical photography compared to the human eye, as we expect it from reflectors compared to refractors[7].

2. Analysis of the first images found

In 1981 the Voyager 1 probe, flying over Saturn, sent exceptional images of that planet to Earth. Among the many discoveries, the presence of a hexagonal formation near the north pole emerged. The findings of the Cassini probe then made it possible to ascertain that it is a structure of atmospheric waves that rotates together with the planet without altering its shape. It seems that it extends up to over 300 km in altitude and that each layer of the hexagon is about 10 – 15 km thick. But, since the aims of our work are not to study and explain the existence of this formation but rather to analyze why it was not discovered with telescopes from Earth, although potentially visible, we will not waste time discussing its physical characteristics. Let's look at the observational ones instead!

This hexagonal formation is located at a latitude of 78° and has sides of 13800 km; that is, each side has a length greater than the diameter of the Earth. These dimensions imply a global extension of the hexagon of almost 30000 km in maximum length, which, seen from Earth, translates into: an angular diameter of 4″[8] as the largest extension and 1.3″ as the smallest; a modest value but enough to be within the reach of common telescopes. This formation was then photographed in a wonderful way by the Cassini probe, but it has also recently been possible to highlight it from Earth with instruments of the C14 level, i.e. a 36 cm diameter Schmidt-Cassegrain[9].

In light of these facts, we wondered why a formation clearly within the resolving power of 19th century telescopes was not discovered from Earth, but we had to wait for the arrival of Voyager to highlight it. And, furthermore: is it true that it has never been spotted before?

3. Ancient observations

To answer these questions, we went in search of observations made before the Voyager mission. In this research we only considered the periods in which Saturn's pole was well inclined towards the Sun (and therefore towards the Earth) and, with the exception of the Herschel, Schroeder and Lord Rosse investigations, we began to examine the observations from second half of the 19th century. This is above all because the previous instruments were almost all modest in size and inefficient in relation to the fact that the hexagon for our view is located in a very foreshortened position and, above all. also very dark. On a visual scale in which the brightest part of the Saturn

[7] Indeed, all the ancient pictures/drawings showing the hexagon we found until today, were made using refractors – with small or large diameter – but always refractors and never reflectors.

[8] Seconds of arc.

[9] Please, see figure no 1 and its caption.

system (the edge of the B ring bordering the Cassini division) has a value of 1 and the background of the sky 10, the polar region with the hexagon has a rating between 6 and 6,5. By way of comparison, keep in mind that the shadow of the globe on the rings has a value of 8,5. Therefore, to highlight it with visual observation it was imperative to use apertures above a certain minimum value, which we estimated in the order of 20 cm for lens telescopes and 25-30 for 19th century mirror telescopes. Another negative aspect for its observation is the fact that Saturn turns its north pole towards us when it is in the region of the sky where the ecliptic is around its most southern position. And the largest telescopes until the first half of the 20th century were mostly located in the Northern Hemisphere.

Among William Herschel's observations, the one made on April 18, 1805 with the 25 cm 300x reflector (Herschel 1805, p. 274), in which the north pole was inclined towards us, remained famous. The peculiarity of this observation is the square shape of the globe (Herschel 1805, plate IX), but in correspondence with the visible pole the great astronomer did not indicate anything, leaving this part of the drawing blank. However, even where Herschel indicated something at the pole, he limited himself to a shading, although, for this, he sometimes used his large 1.2 meter telescope.

In the case of the German Johann Schroeder, who used mirror instruments of the same power as those of Herschel (about half a meter in diameter), there is no useful indication in this regard. Here it should also be added that many of the results of this German astronomer were unfortunately lost during the destruction of his observatory in 1813 by a Napoleonic army.

In the records of Lord Rosse, who began using his large 1,8 meter telescope in 1845, there is no mention of any hexagonal formation at Saturn's north pole. It is also worth pointing out that he, unlike the Herschels, was more of a designer and builder than an observer; the time he dedicated to observation was modest overall.

Even the large telescope of the English Lassell observatory, 1,2 meters in diameter, installed in Malta, did not give results in this sense; with the observations made with this instrument there is no annotation of this characteristic on Saturn.

Around the middle of the 19th century, refractors of good diameter began to come into use, more suitable for observing planets than the reflectors of the time equipped with metal mirrors. One of these was the «large» 38 cm diameter Harvard refractor, which was also used intensively for the study of planets. The work on Saturn highlighted several interesting aspects, including the discovery of the veil-ring or «C», but no reference to a hexagonal shape around the north pole (Cranch Bond W. et alii 1857, pp. 1 -136).

Starting from the second half of the 19th century, suitable instruments and planetary observatories became numerous and it is certainly impossible to take them all into consideration. Our research was therefore limited to the most famous ones, whose results were more widespread. Examining the notes of these observatories and the related drawings we find much detailed information relating to the rings, satellites and the globe but none concerning the existence of a hexagon formation at the pole, despite many authors reporting in detail variations in the extension and color of the polar caps, to which they evidently paid some attention. And this even considering the more skilled observers who used the larger instruments. In this context, the American observatories stand out as they had the largest refracting telescopes at their disposal and in Europe the Antoniadi used the 83 cm of Meudon (France).

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The first image that attracted our attention was the drawing (fig. 2 and 2_bis)[10] made by Barnard on 7 July 1898 (Cecchini 1969, volume I, fig. 309) through the 1 m Yerkes refractor, in which three of the six sides can be recognized (fig. 3).

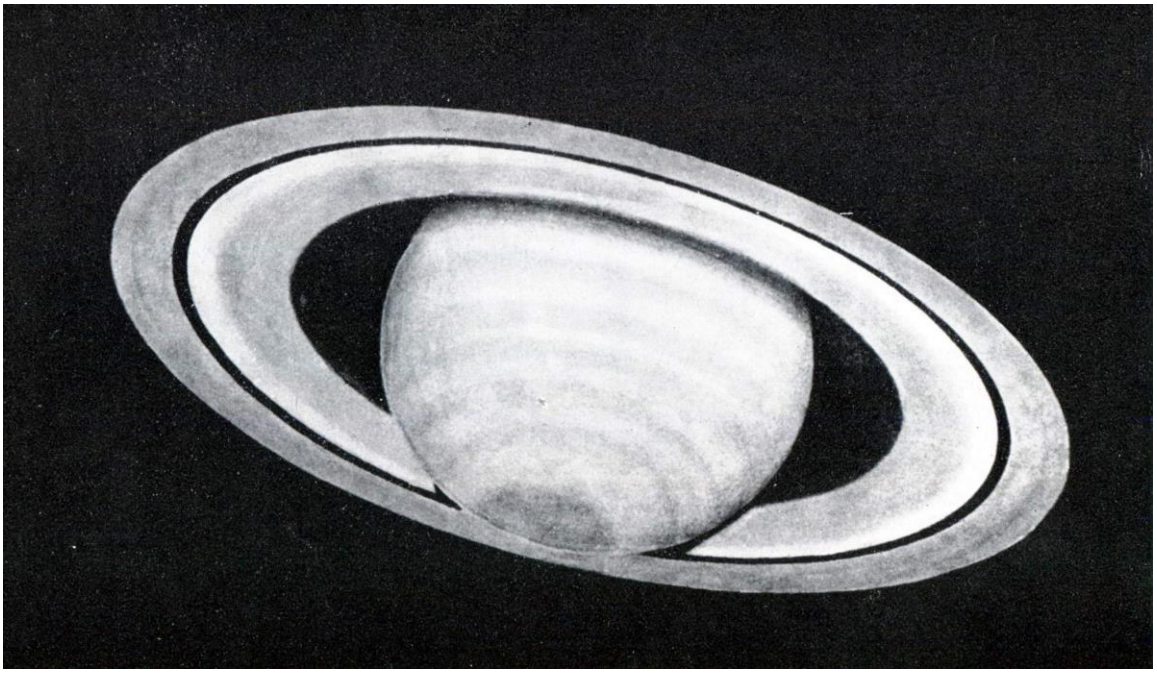

Figure 2. Barnard's drawing dated 07/07/1898 at the Yerkes refractor (the north pole is at the bottom). Credits: ADS.

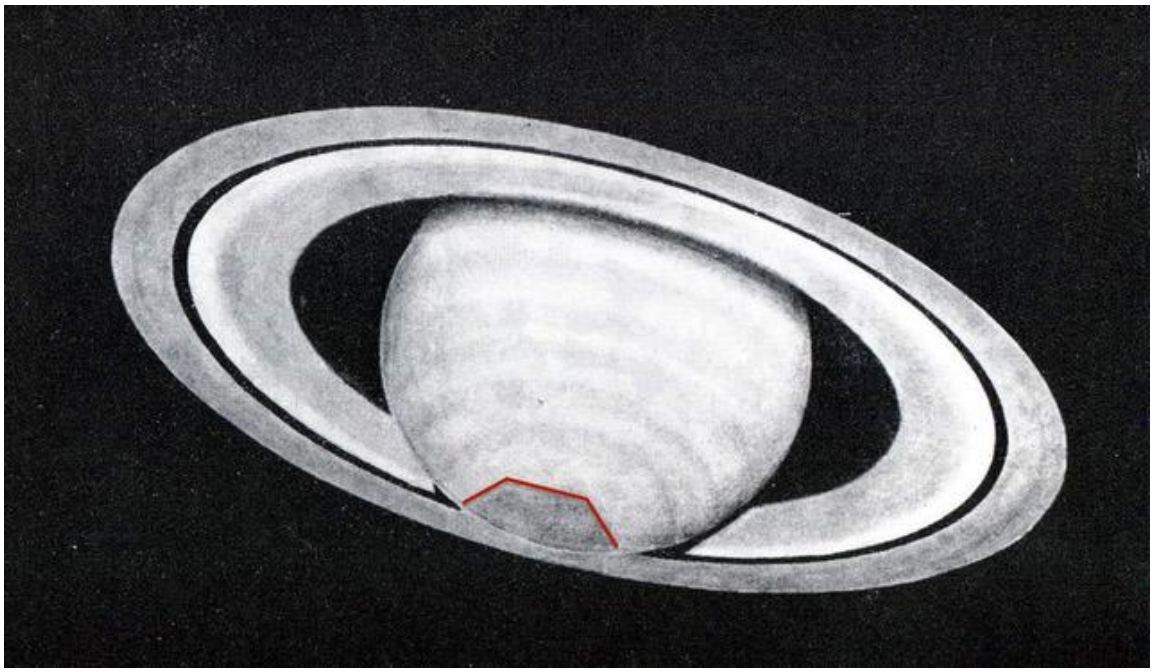

Figure 2_bis. The drawing made by Barnard on 07/07/1898 with the three sides of the hexagon and two corners highlighted for us in red by courtesy of Dr. Caterina Avanzino.

[10] The number of each figure, followed «by _bis» indicates the same photo number with the sides of the hexagon highlighted in red colour for us by Dr. Caterina Avanzino of the Associazione Ligure Astrofili Polaris (Ligurian Association of Amateur Astronomers Polaris, Italy).

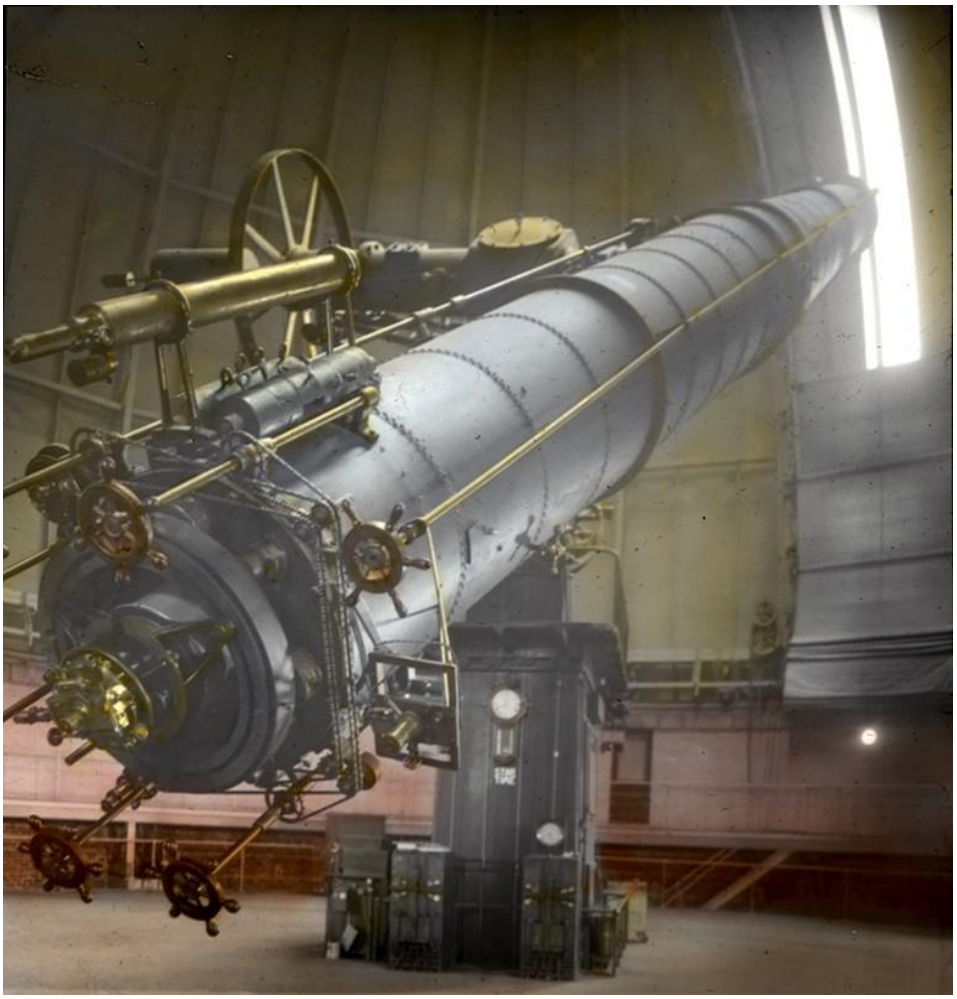

Figure 3. The 101.6 cm «Clark» refractor, with a focal length of 19,4 m, of the Yerkes Observatory, in Wisconsin, USA (Ferreri 1989, pp. 199 and 202). Still the largest refractor in the world in operation today.

In the text of the original article (Barnard 1908, plate 11 and p. 367) Barnard simply says: «The polar cap was darker than the darkest part of the ball». At the end of the note relating to that 7 July 1898, he adds: «The definition was superb. I have never seen the planet better, nor have I seen so much detail upon it before... ». It is easy to conclude that the resolving power of the large instrument, combined with exceptional seeing, accomplished the «miracle» of making the hexagon «visible». However, there is no trace of the hexagon in the drawing he made on 31 March 1895 of Lick's «smaller» (91 cm) refractor (Barnard 1895, p. 381).

A second group of images (figure 4, 5, 6 and 4_bis; 5_bis; 6_bis), more or less distinctly reproducing the straight sides of the hexagon, are those published in Antoniadi's 1930 article, namely his figures n. 1 of 12 July 1926 (p.1); n. 7 of 18 July 1927 (p. 8); no. 8 – 11, respectively of 22 June, 29 June, 2 August 1927 and 26 August 1929 (p. 9). This article is particularly interesting because the author also published some images of the south pole – figs. 3; 4 and 84 drawn between 1909 and 1913 – in which there is no trace of rectilinear features, demonstrating that he actually perceived and drew (but did not describe!) the northern pole as a polygonal formation and not circular like the southern pole. All the drawings reproduced in the 1930 article were made on Meudon's 83 cm refractor (fig. 7).

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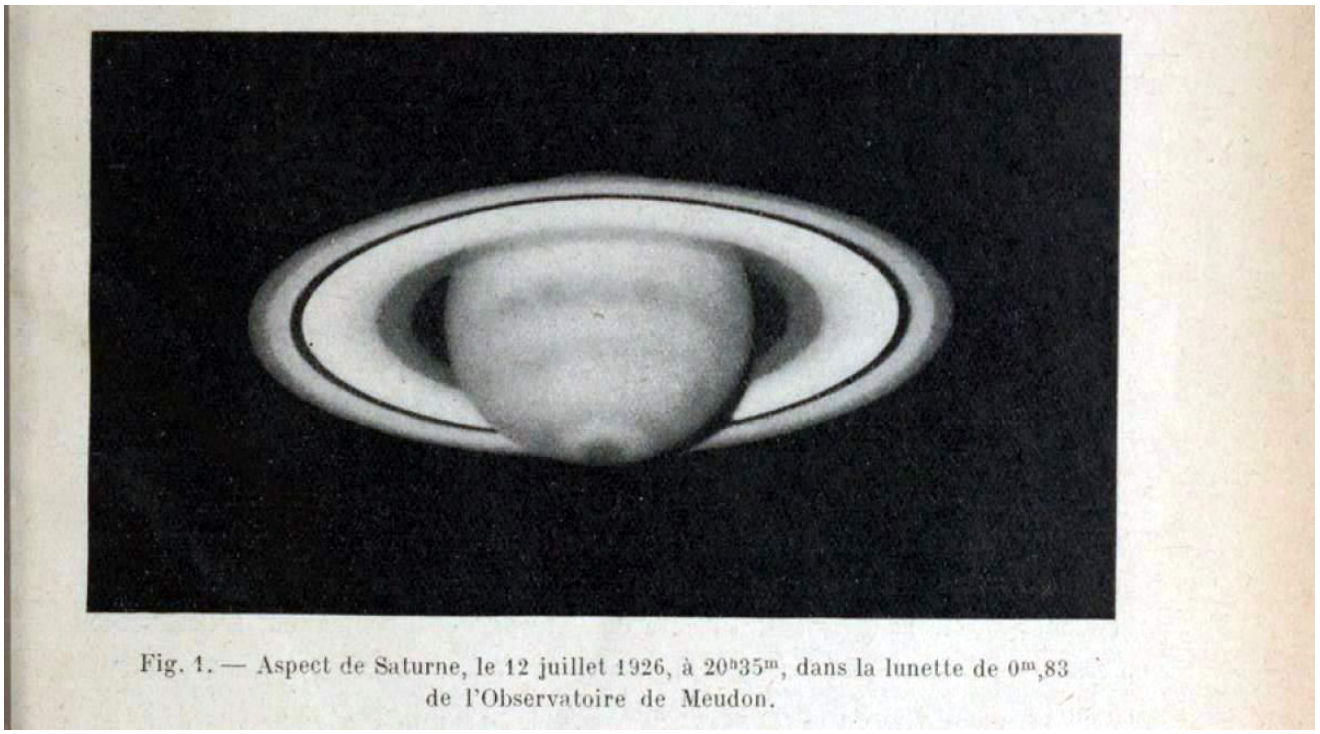

Fig. 1. — Aspect de Saturne, le 12 juillet 1926, à 20h35m, dans la lunette de 0m,83 de l'Observatoire de Meudon.

Figure 4. Antoniadi 1930 (12 July 1926). Credits: BNF Gallica - S.N.F.

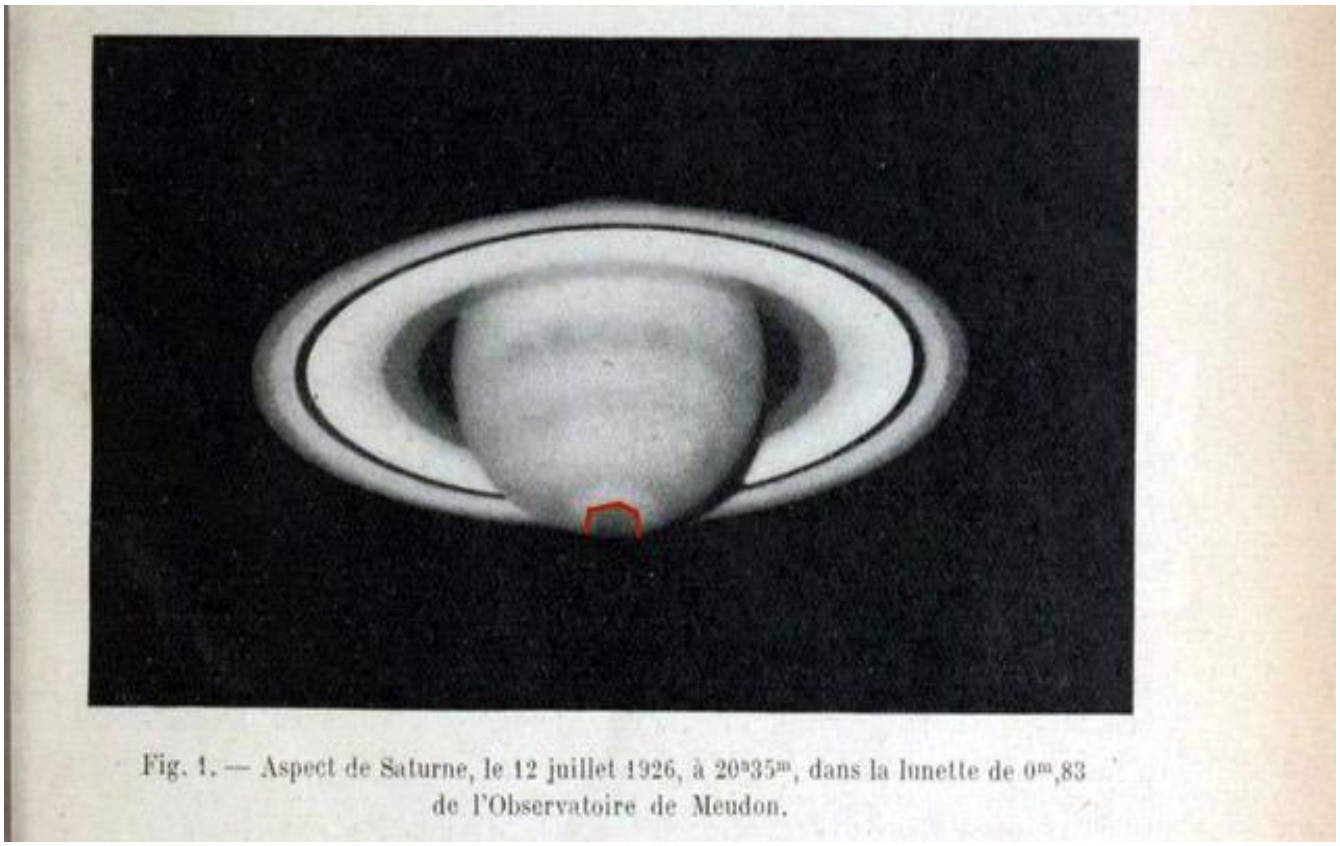

Fig. 1. — Aspect de Saturne, le 12 juillet 1926, à 20h35m, dans la lunette de 0m,83 de l'Observatoire de Meudon.

Figure 4_bis. The drawing made by Antoniadi on 07/12/1926 with four sides and three corners of the hexagon highlighted by us in red (by courtesy of Caterina Avanzino).

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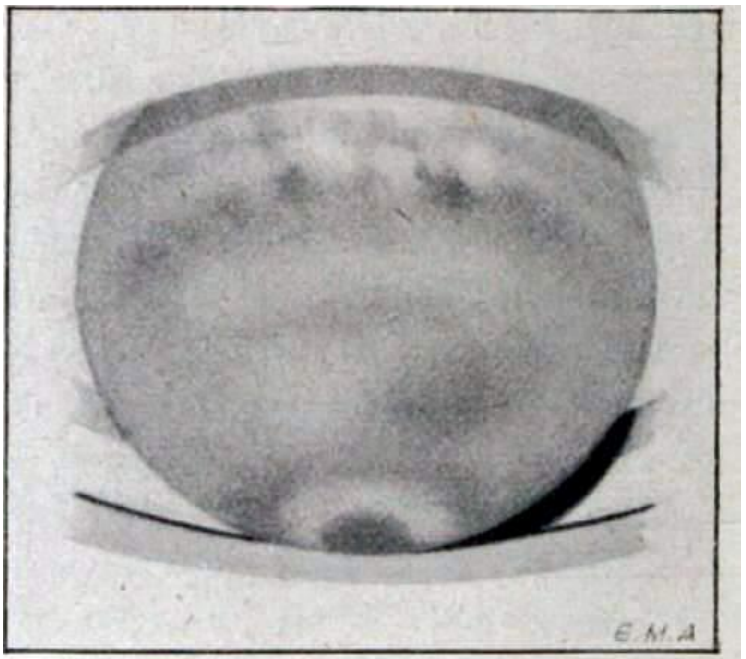

Fig. 7. — Grande ombre irrégulière dans les régions tempérées nord de Saturne, le 18 juillet 1927 à 21h6m (Lunette de 0m,83).

Figure 5. Antoniadi 1930 (18 July 1927). Credits BNF Gallica - S.N.F.

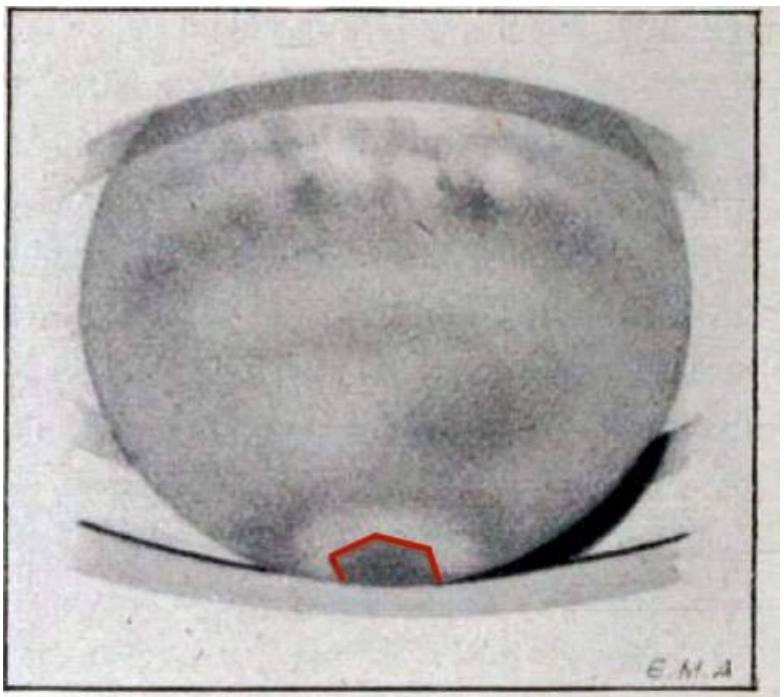

Fig. 7. — Grande ombre irrégulière dans les régions tempérées nord de Saturne, le 18 juillet 1927 à 21h6m (Lunette de 0m,83).

Figure 5_bis. Antoniadi 1930 (18 July 1927). Four sides and the three included angles higthlighted in red colour (by courtesy of Caterina Avanzino).

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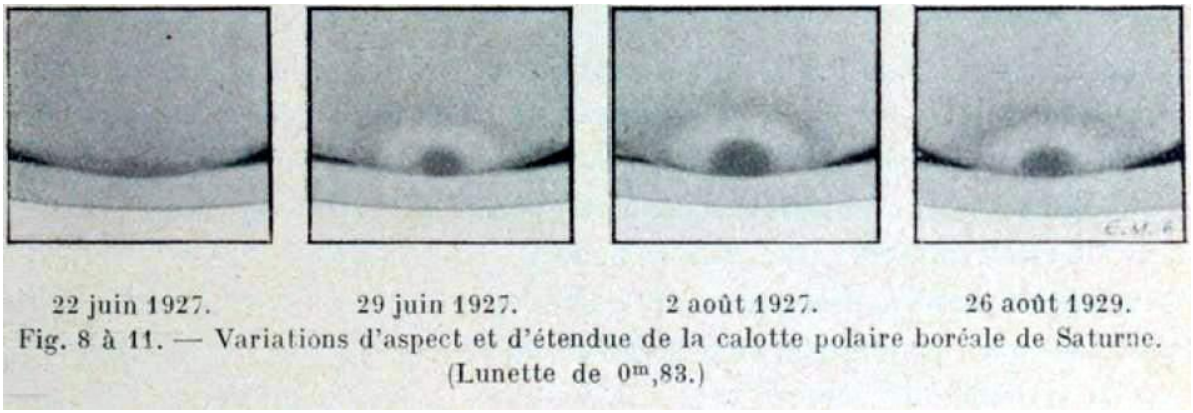

Figure 6. Antoniadi 1930 (1927 – 1929). Credits: BNF Gallica - S.N.F.

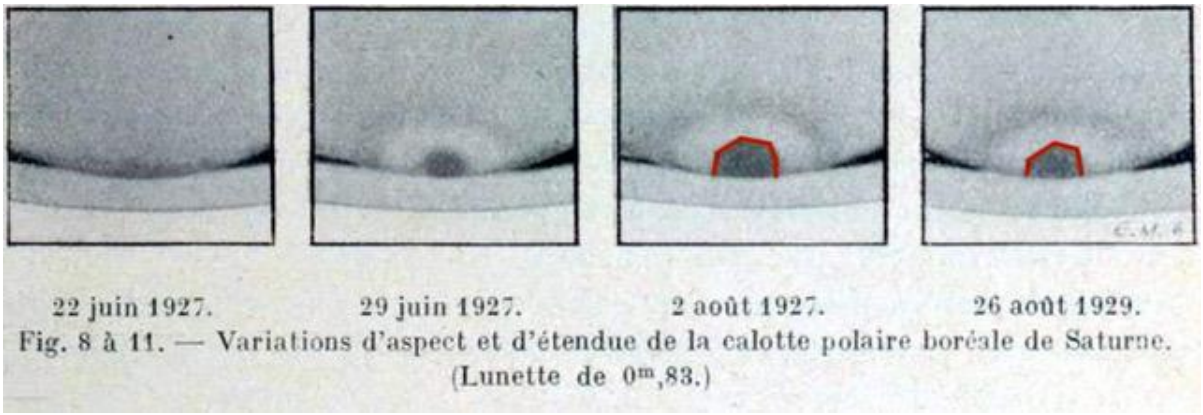

Figure 6 bis. Drawings made by Antoniadi between 1927 and 1929: in those of 02 August 1927 and 26 August 1929 we have highlighted in red four sides and three corners of the hexagon (by courtesy of Caterina Avanzino). In our opinion, some polygonal traces can also be seen in the drawing dated 29 June 1927, but they are completely absent in the drawing dated 22 June 1927.

Please note that in the images from June – August 1927 and August 1929 Antoniadi expressly speaks of «Variations ... of extension of the north polar cap of Saturn». These variations in extension are even more evident if we compare all the drawings by Antoniadi and Taffara, made in the 1920s with those by Antoniadi himself in 1899 and by Barnard in 1898. Evidently the hexagon changed in size, becoming smaller from the end of the 19th century to the first half of the 20th.

Here is what Antoniadi wrote then about the polar ice caps:

<**Calotte polaire sud** – En 1852, Lassel, Dawes et Secchi, observérent une étendue claire, verdâtre, au pôle austral de Saturne, mais, en 1855, Lassel y notait, au contraire, une tache tres foncée, que de La Rue peignait en bleu l'année suivante. En 1880, Hall y voyait une teinte verdâtre, en 1884 et 1887, du gris sombre; les fréres Henry notaient du gris en 1884. Cette calotte apparut enorme à Terby en 1887, lorsque Elger y distinguait du gris bleu. En 1908, Barnard voyait une tache sombre ici; et, l'annéesuivante, nous notions avec la lunette de 0m,83 de Meudon une calotte foncée d'un gris bleu si intence (Bulletin de la Société, t. 24, 1910, p. 374)[11] qu'au premier abord, nous avons cru avoir affaire en partie à un produit de spectre secondaire (fig. 3).

[11] In the original article the bibliographic quotation is a foot note and its reference in the text is no. 6.

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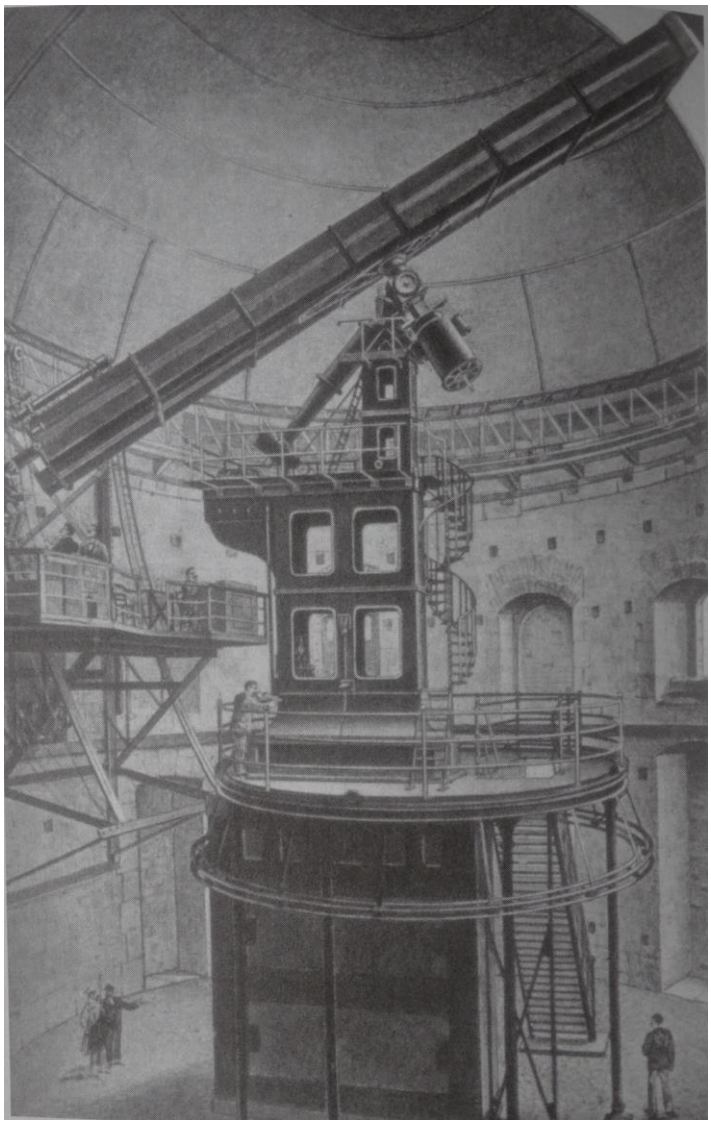

Figure 7. The Meudon refractor (named La Grand Lunette) which has a diameter of 83 cm and a focal length of 16,2 m. It is part of the Paris Astronomical Observatory (France) and it is the largest refractor in Europe (Ferreri 1989, p. 198).

Or, il n'en était rien; et cette calotte bleue si vive est devenue, l'année suivante, la grand curiosité que l'on montrait à l'Observatoire du Mount – Wilson dans le télescope de $1^{m},52$ aux astronomes venus des divers pays à l'occasion du congrès solaire. Puis, en 1913, la lunette de $0^{m},83$ nous la montra agrandie (fig. 4), grise, et avec un e teinte bleue très légère. Ainsi cette calotte polaire change d'étendue et de couleur. M. W. R. Wood photographia Saturne en 1915 avec de la lumière violette et obtint une vaste région sombre autour du pôle méridional.> (Antoniadi 1930, pp.4 – 5).

<**Calotte polaire nord** – Le zone polaire était jaunâtre pour Barnard en 1904 et elle nous apparut grise bleûatre sur 35° de rayon autour de pôle en 1927; puis elle était verdâtre en 1928, et semblait plus verte encore en 1929. La calotte sombre, variable elle mème (fig. 8 à 11), était entourée dans le $0^{m},83$ d'une zone claire en 1926 et 1927; le 2 juillet 1928, cette zone avait disparu, pour réapparaitre le 11 et rester visible encore en 1929. En 1793, Herschel trouva la calotte polaire blanchâtre et pâle; en 1806, elle lui apparut plus enfumée. Browning l'à vue bleuâtre; Barnard cendrée, puis très petite et foncée en 1894, très sombre en 1895; Stanley Williams et nous – même

l'observâmes grise en 1895 et 1896. Une teinte bleuâtre réapparut en 1897 selon Barnard, qui trouvait la calotte curieusement inexistante en 1901. A Meudon, elle se montra grise en 1924, ardoise en 1926, bleuâtre, un peu verdâtre en 1927, simplement grise en 1928, et de nouveau ardoise en 1929. On ne la voyait point le 22 juin 1927. Elle était diminuée le 13 juillet 1926, s'était étalée un an plus tard, et elle fut observée petite en 1928 et 1929.> (Antoniadi 1930, p. 9).

Paradoxically, however, among all the drawings we have examined, the one that perhaps bears the most convincing traces of a hexagon at the north pole is the one that Antoniadi made on 30 July 1899 with the 26 cm refractor of the Observatory «Juvisy – sur – Orge» or «Camille Flammarion Observatory» (France). Here, with our awareness, it is possible to recognize three sides of the hexagon even if the observer does not mention it in his report. In this regard, let's see his drawing, both original (fig. 8) and with the sides highlighted by us (fig. 8_bis).

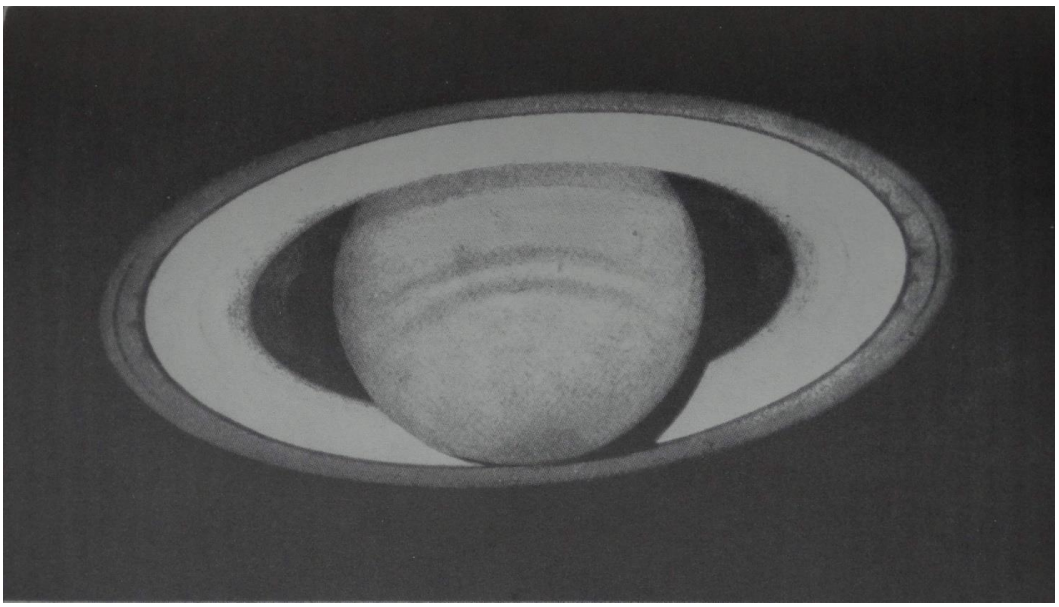

Figure 8. (DSC05498) Antoniadi, 30 July 1899. Credits: «Monthly Notices of the Royal Astronomical Society», vol. 60, table 12.

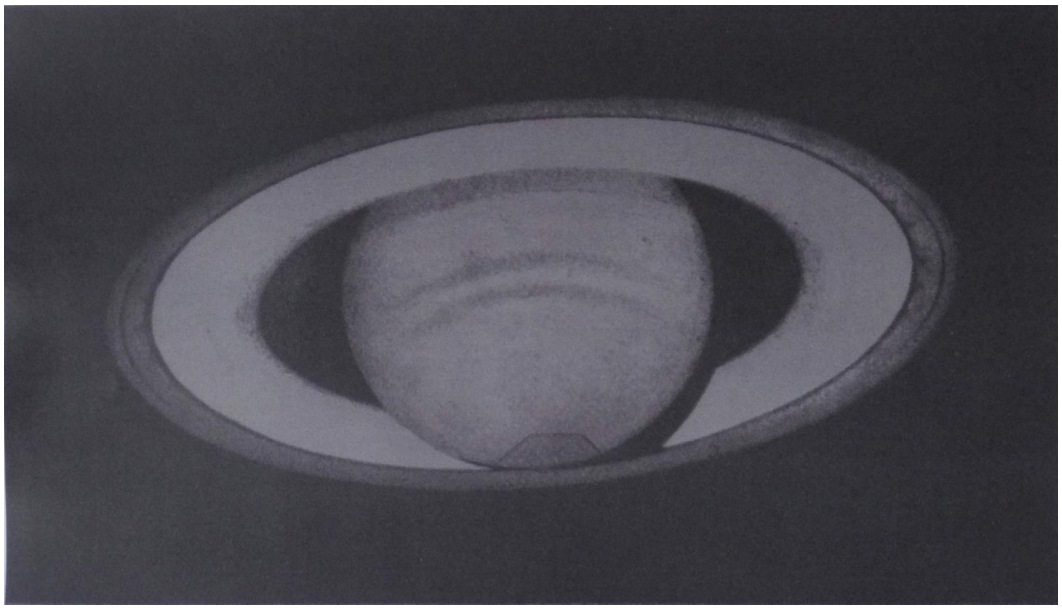

Figure 8_bis. Highlighting in black of three sides and two corners of the hexagon by Walter Ferreri.

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4. The new acquisitions

In the summer of 2022 one of us (Henry de Santis) found another drawing (fig. 9 and fig. 9_bis) made by Luigi Taffara on the night of 4 June 1929 on the 33 cm refractor of the Royal Astrophysical Observatory of Catania, which the author inserted, with three other drawings of subsequent dates, not only in the 1938 Yearbook of the Observatory, but also in a rare extract, entitled «The planet Saturn», published in 1937 by the Scuola Salesiana del Libro[12], Catania, Barriera Locality, Italy, and kindly sent to us in digital copy by the Library of the INAF Astronomical Observatory of Brera.

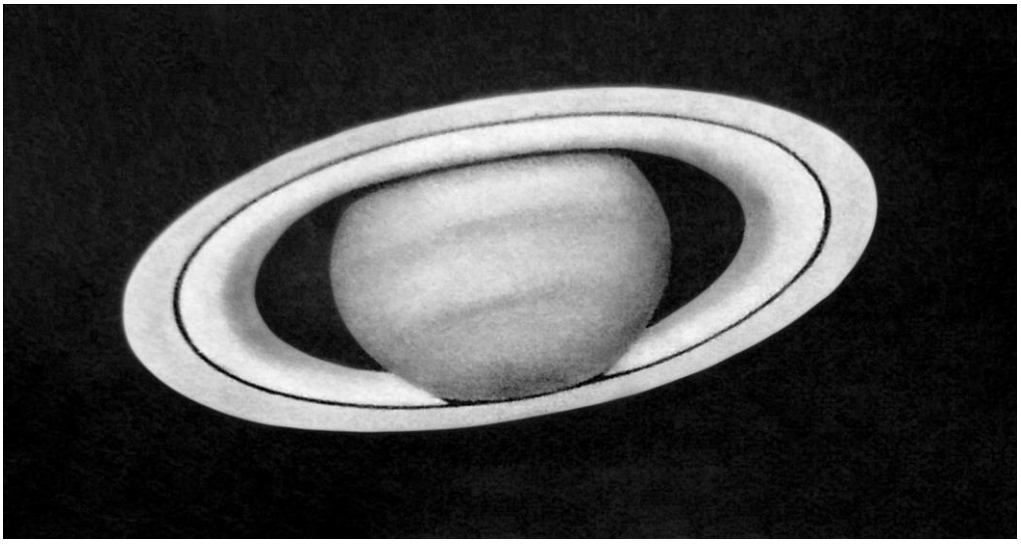

Figure 9. Taffara 1929. Credits: INAF-Astrophysical Observatory of Catania and INAF-Astrophysical Observatory of Brera (photo retouched for us to improve contrast by professional photographer Mauro Repetto).

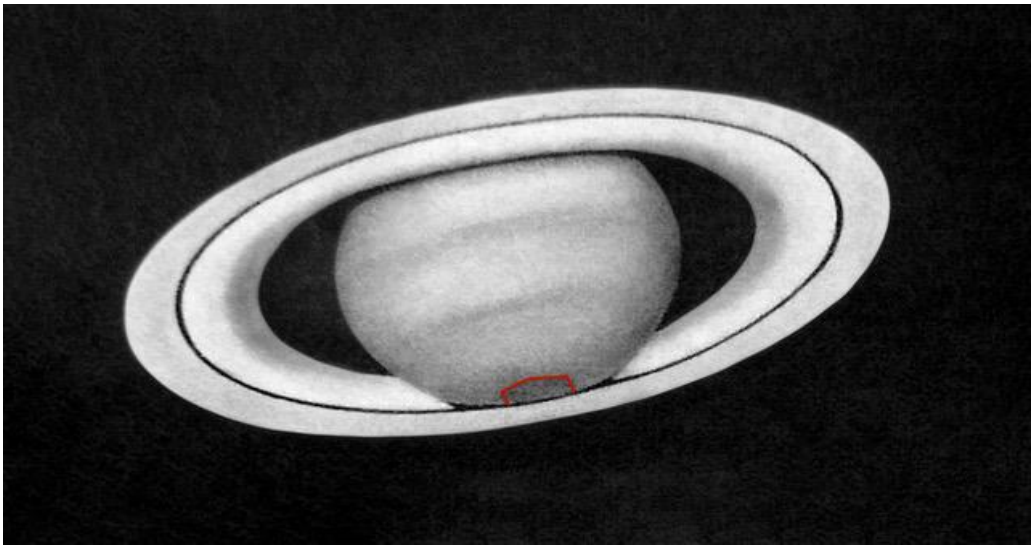

Figure 9_bis. drawing made by Luigi Taffara in 1929 in which we highlighted four sides and three corners of the hexagon in red (courtesy of Dr. Caterina Avanzino).

[12] Salesian School of the Book. Salesians are priests and lay people of the «Salesian Society of Saint Giovanni Bosco» (in latin: Societas Sancti Franciscii Salesii; abbreviation: S.D.B.), a male religious institute of pontifical right founded in 1859 and dedicated above all to the scholastic education of children and young people and to the press.

In Taffara's drawing one can clearly see a small dark polygonal structure (of which four sides and three corners can be distinguished) at the North Pole of the planet. Please, compare it with the drawing made by Antoniadi on 08/26/1929. Like Barnard and Antoniadi, Taffara also does not make the slightest mention of the hexagon in his text (which is rather informative). Taffara's four drawings also appeared, but graphically less clear, in two books by Giuseppe Armellini: *Astronomia e Geodesia*, Bompiani, Italy, 1941 and *I fondamenti scientifici dell'astrofisica*, Hoepli, Milan, Italy, 1953.

Figure 10. The front cover of the Hoeply manual 1945 «Gravitazione».

In April 2023 de Santis found another drawing (fig. 10) which very clearly reproduces a hexagon in the pole of Saturn facing the Earth: this is the front cover of the second edition, 1945, edited by L. Gabba , of the Hoepli manual «Gravitazione» by G. B. Airy, already published and translated by F. Porro in the first edition in 1893, but with an unillustrated hard cover.

Unfortunately, this second 1945 edition does not contain any data on who, where and when made this drawing of the planet. According to Walter Ferreri, it is an artistic drawing, not made with a telescope, but created by an artist, who, however, must have used some original drawings from telescopic observatories, while reinterpreting them quite freely. The fact remains that this artistic drawing, created no later than 1945, clearly shows a polar hexagon. These two images were the subject of another of our publications (Codebò, De Santis 2023, pp. 52 – 53).

5. Photographs from the Lowell Archives

Research carried out by Laura Citernesi on photographs of the Lowell Observatory in Flagstaff in Arizona, USA, taken in the first half of the 20th century by the USA astronomer E.C. Slipher, generally with the historic 61 cm Clark refractor (Fig. 11), demonstrated that the chemical emulsion of the films and plates used at the time were not capable of reproducing the hexagon despite the large aperture of the refractor objective, the strong magnification (1500x) and the almost constant use of colored filters.

Figure 11. The historic 61 cm «Clark» refractor of the Lowell Observatory in Flagstaff, Arizona, USA, systematically used by founder Percival Lowell (photo by W. Ferreri).

Slipher himself (Slipher 1964, pp. V-XVI) informs us about these data and the exposure times used: 20-30 seconds in the first times, then reduced to 1.5-3 seconds in the last twenty-five years

of observation, thanks to improvement of techniques and materials for photographic shooting. Slipher also experimented, perhaps first time, the technique of obtaining a single, best image by superimposing more than one (which has become very common in modern digital photography). On the minor, albeit objective, power of photography to distinguish almost evanescent details he himself wrote: «The eye can record the occasion at moments of superb seeing, but photographs can rarely catch such brief intervals» (Slipher 1964, p. VI).

On May 6, 2023, following the presentation of the report «Images of the Saturn hexagon before Voyager 1», at the XXV Archaeoastronomy seminar A.L.S.S.A.[13] at the Astronomical Observatory of Genoa, Laura Citernesi sent M. Codebò a pdf containing a table from the Lowell Observatory (Flagstaff, Arizona) showing the ring system of Saturn, found in the 1979 Catalog of the Universe (Murdin, Allen 1981), published in Italy in April 1981 (fig. 12).

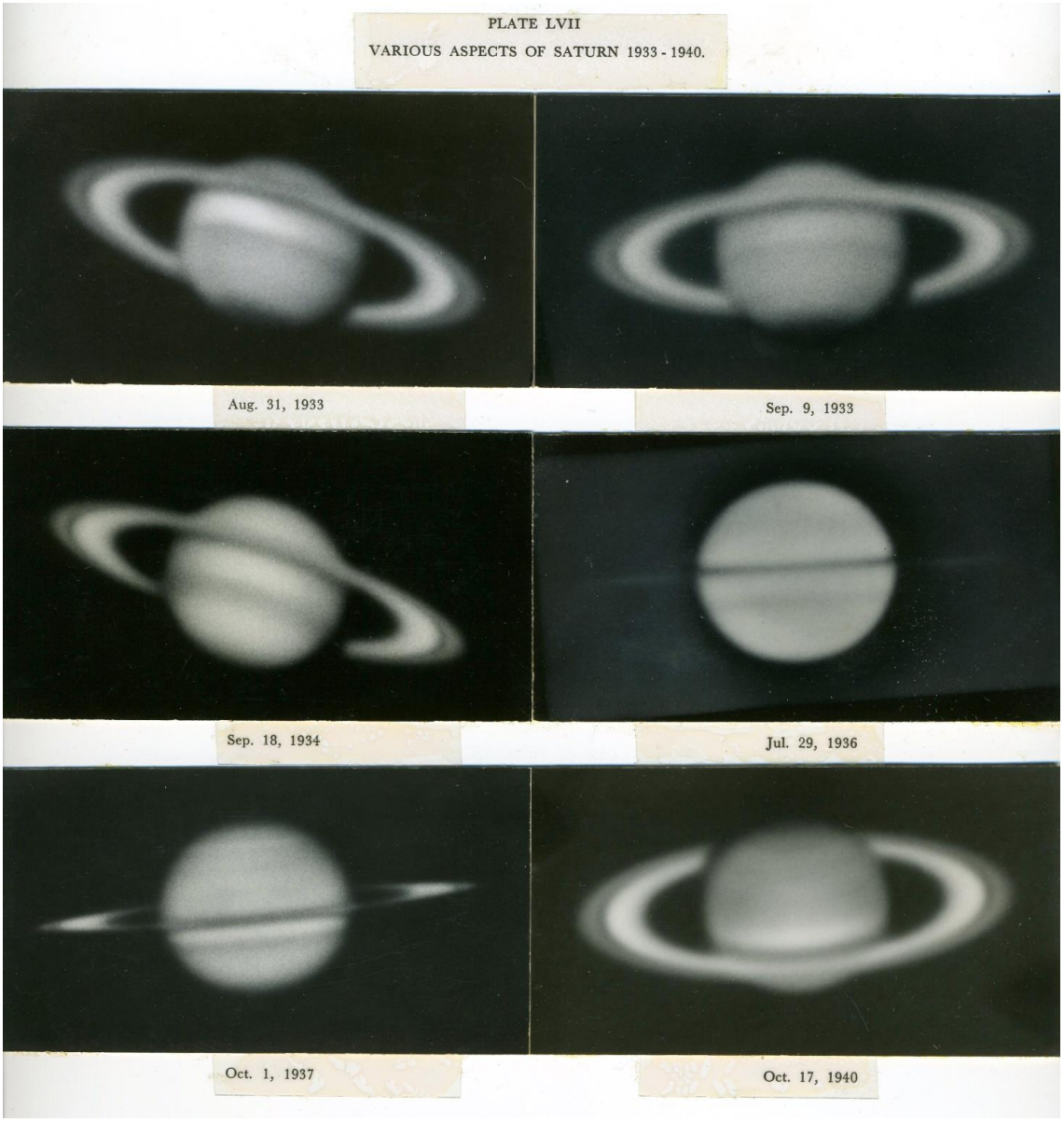

Figure 12. The table of Saturn from Murdin and Allen 1981.

[13] A.L.S.S.A.: Assciazione Ligure per lo Sviluppo degli Studi Archeoastronomici (Ligurian Association for the Developments of the Archaeoastronomical Researches).

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Through the archivist of the Lowell Observatory it was possible to trace the author, E.C. Slipher[14], but not the exact date of each individual image. The photos were taken over several decades, between approximately 1910 and 1955. Through the Stellarium software, the time interval in which Saturn's north pole was visible from Earth was identified: from 1924 until the early 1930s.

Later, Laura Citernesi and Mario Codebò found the photographic book *A Photographic Study of the Brighter Planets* by E.C. Slipher. In figure 13, coming from Slipher's book, it is possible to observe the northern pole of Saturn. We invite readers to carefully compare this photo of Slipher with the drawing of Antoniadi (fig. 6 and fig. 6_bis), both from 1929: one immediately notices the greater clarity of the drawing made by Antoniadi on 26 August 1929, and the great blur and the total absence of the sides of the hexagon in the photo taken by Slipher on 14 September 1929 (i. e. only twenty days after Antoniadi's drawing), in which the North Pole of Saturn is reduced to a circular and somewhat shapeless dark spot.

Figure 13. The Norther Pole of Saturn on 14 September 1929 by Slypher 1964. Credits: Lowell Observatory Archives.

From the author's preface it is clear that the photographic book was created in two editions: a classic one with chiaroscuro images, another limited and made available for those who deal with planetology. This turns out to be quite interesting because from the Lowell archive website, dedicated to the Slipher brothers, in addition to the images of the planets it is possible to see a couple of drawings of Saturn probably also taken from the book. However, neither the browsable version nor the paper version purchased by M. Codebò contain any drawings of the gas giant. The images were made over a period of approximately 60 years in order to be able to record any

[14] E.C. Slipher was a pioneer in planetary photography and made some of the best images of planets of his time. Most of these are present in his two books: *The Photographic Story of Mars* (1962) and *Photographic Study of the Brighter Planets* (1964);
http://collectionlowellobservatory.omeka.net/show/slipherbrothers/homepage-e-c

changes in the characteristics of the planets. According to Slipher, photography is the most effective way to «measure» motions and changes in planetary details.

His photos were taken in Flagsteff but also in South Africa: with the 24 inch (61 m) «Clark» refractor of Flagstaff (fig. 11); with the 42-inch (1,05 m) John S. Hale reflector in Ritchey-Chretien configuration; with the South African Lamont-Mussy 27,5 inch (70 cm) refractor, using corrective lenses (far IR, blue and violet), color filters for the Jupiter and Saturn bands and photographic emulsions for yellow, green, orange and red (Slipher 1964, p. VI).

We are not sure whether the images of Saturn were also made in Africa. The photos, as usual, are all arranged with the south pole at the top. The author explains that detail was sacrificed to improve grain. This confirms to us once again the limits of photography of the time. Another important fact could concern the characteristics of the northern hexagon: according to the astronomer and astrophotographer Peter Lawrence[15], between 2012 and 2016 the hexagon changed its blue hue to a golden shade (Lawrence 2020). We wonder if this could have happened in the past too[16].

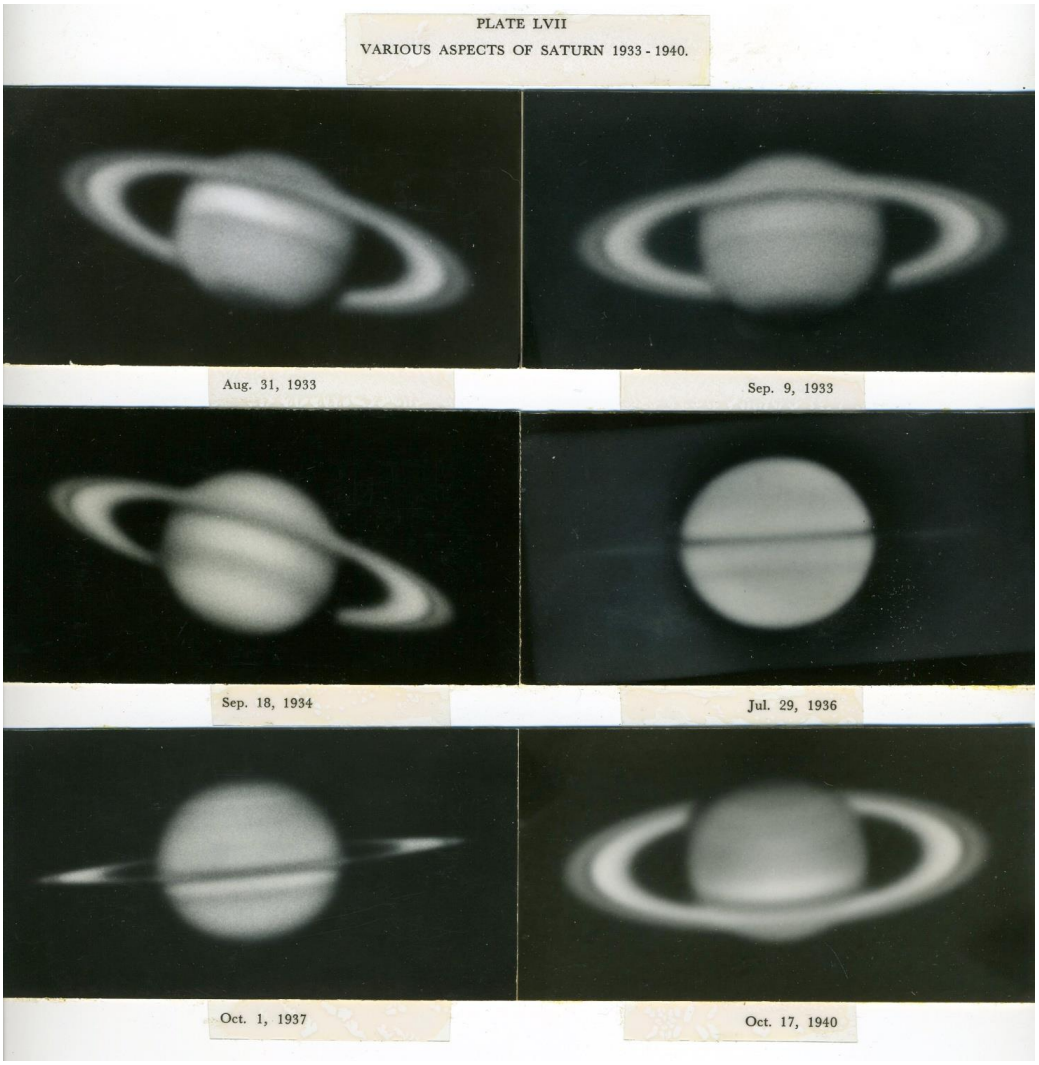

Figure 14. E.C. Slipher 1964: Plate no. LVII. Saturn from 1933 to 1940. Credit: Lowell Observatory Archives.

[15] Staff-Fellow of the BBC magazine *Sky at Night*.

[16] Indeed, many 19th century authors – notably A.Hall in his 1891 article – reported colour changes in the polar ice caps.

Again using the virtual planetarium «Stellarium» it was possible to go back to the sky of Flagstaff and see which pole of Saturn was visible from Earth on the dates indicated in the photographs. It emerged that only the first three images of the table that goes from the year 1933 to the year 1940 (fig. 14) show the northern pole of Saturn without clearly showing the hexagon. There are images in which the north pole can be glimpsed, which is only mentioned in table LIV, when reference is made to a brighter area towards the northern pole. The other tables are dedicated to the description of the ring system, the variation of the white spots and the dark cap of the south pole.

6. Modern hypotheses

The hypothesis that the surprising north-polar hexagon of Saturn could also be visible in the 19th century, using adequate instruments, is strengthened by recent studies based on observations from the Cassini probe. These studies, in fact, suggest that the formation is particularly persistent and deep, and that it could have been present for thousands of years. A study published in Nature Communications by scientists from the University of the Basque Country (*Multilayer hazes over Saturn's hexagon from Cassini ISS limb images* https://www.nature.com/articles/s41467-020-16110-1) reveals that the hexagon is overlain by a system composed of at least seven regularly spaced layers of haze, extending from the tops of the clouds to an altitude of more than 300 km above them. Previously, images from the Cassini probe had made it possible to identify the presence of a north-polar vortex that forms in Saturn's upper atmosphere as the summer season approaches. The vortex is located hundreds of kilometers above the clouds, in the planet's stratosphere, and its edges are hexagonal, almost coinciding with the well-known hexagonal cyclone observed deeper in the atmosphere. It therefore seems that the famous hexagon immortalized by the Voyager 1 probe in the early 1980s is actually a towering structure that rises vertically for many hundreds of kilometers.

This could explain the vastness (the hexagonal vortex extends for over 30 thousand kilometers) and persistence of the formation: we knew for sure that it has characterized the planet for at least forty years but by now we can say: <For one hundred and twenty years>! remaining almost static, almost identical during the rotation of the planet, despite the raging winds exceeding 400 kilometers per hour.

But how is it possible that such an unusual and vast system has remained unchanged until now? The longevity of the hexagon makes it somehow special, so much so that scientists have conducted studies and experiments to identify possible explanations. A recent study, published in Proceedings of the National Academy of Sciences and carried out by scientists from Harvard University (*Deep rotating convection generates the polar hexagon on Saturn* https://www.pnas.org/content/117/25/13991) provides a possible explanation of the formation of the hexagon, using three-dimensional models. The new study suggests the storm penetrates thousands of kilometers deep, well below the planet's cloud cover.

According to the researchers, such a polygonal atmospheric structure forms when deep atmospheric flows within a gaseous planet like Saturn create large and small vortices. Similar vortices surround an immense horizontal jet stream flowing eastward near Saturn's north pole. The current is characterized within it by a series of further cyclones, which interact with the larger system, compressing it in some points and confining it. This compression process would give the jet stream a hexagonal shape. A phenomenon called «deep thermal convection» would be the basis of the entire complex mechanism. According to the authors, in such a scenario the hexagonal shape

of the jet stream is supported by six large adjacent vortices, which are hidden by the chaotic convection processes taking place in the shallower layers. Since these phenomena originate in the depths of the planet, they are able to make the general structure of the vortex particularly persistent and deep (fig. 15).

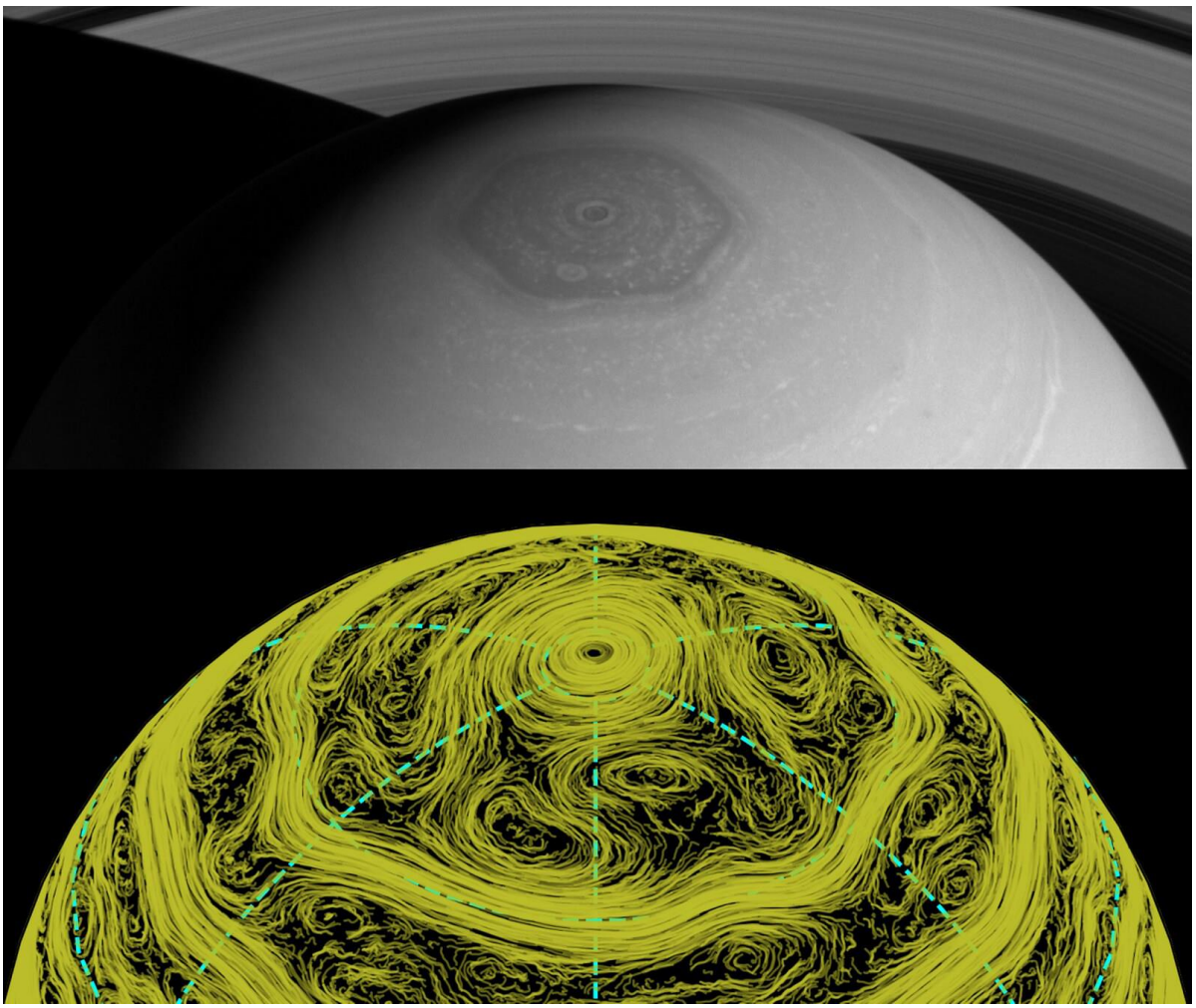

Figure 15. Above, the northern hexagon photographed by the Cassini probe. Below is an image taken from the computer simulation created by Harvard researchers (Credits: NASA/JPL – CALTECH/Space Science Institute/Rakesh K. Yadav).

7. Conclusions

It is impossible not to wonder why a technically visible (even if limited) and actually designed structure has never been recognized. In our opinion there are two explanations:

1). An enormous hexagonal structure must have been – and still is! – very difficult to explain. The photographs of Voyager 1 made its existence indisputable. But in a period in which the image was only telescopic and moreover at the limits of visibility – as demonstrated by the fact that the majority of observers did not reproduce it – it must have been too difficult to support its existence, both from a physical and psychological point of view. We would have found ourselves in the position of claiming the existence of something impossible to prove and explain. It is therefore more prudent to consider it a sort of optical illusion. An examination of the images obtained by the Hubble Space Telescope also reveals how the hexagon, seen from a certain perspective from Earth orbit, is not easily recognizable. This aspect, combined with the low brightness of the polar region, in our opinion provides a further reason why it was not possible to recognize it from Earth.

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2). So far we do not know that any photographic image (fig. 16) has ever captured traces of a polygonal structure at the northern pole of Saturn.

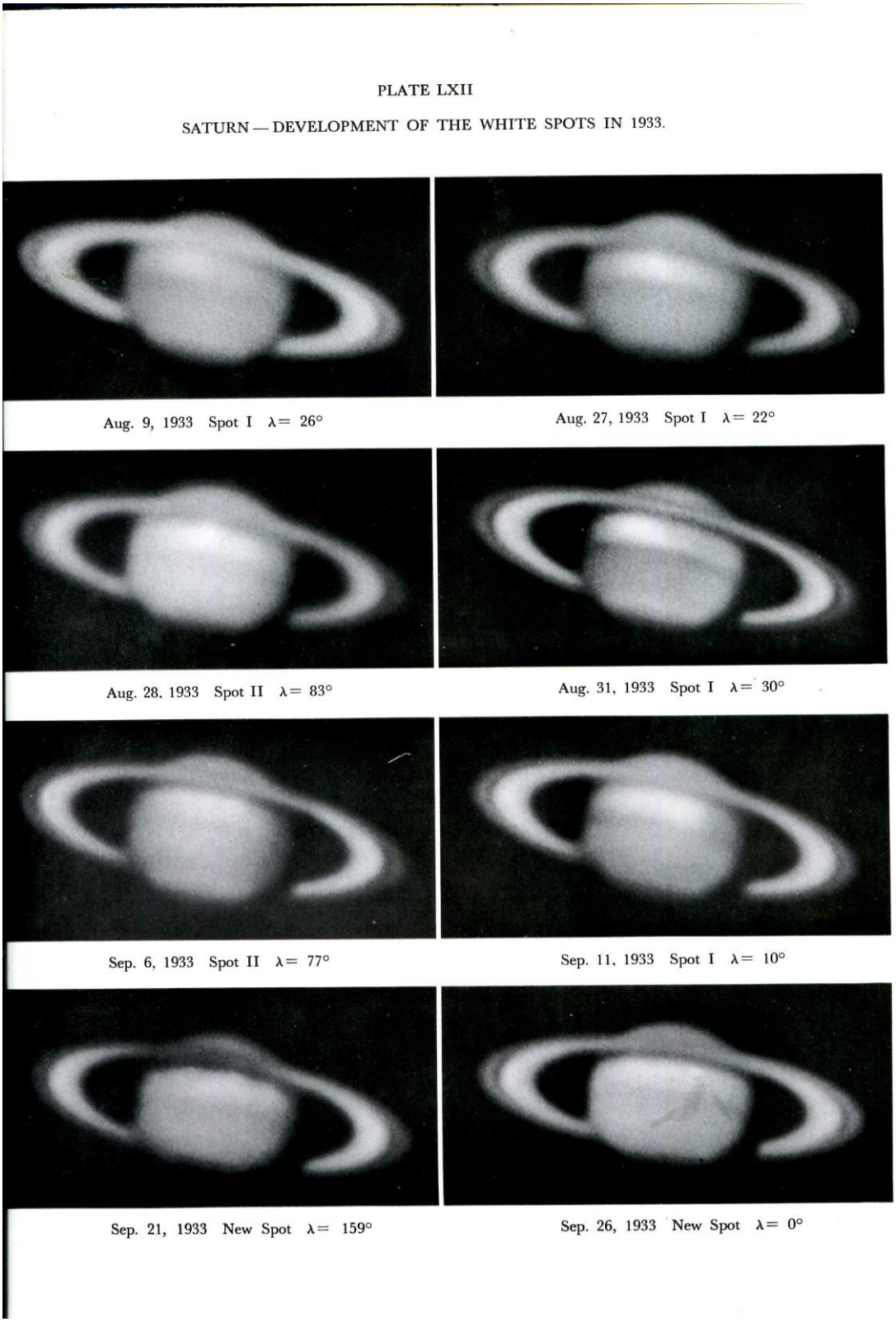

Figure 16. E.C. Slipher 1964. Plate no. LXII: Saturn and its North Pole during 1933, ever without traces of the Hexagon. Credit: Lowell Observatory Archives.

The vision of the human eye, although better than the photographic emulsions of that time, as Slipher himself wrote, is subjective while photography is objective. Therefore, not being able to objectify the hexagon photographically, it became impossible to «prove» its existence.

Paradoxically, what happened with the canals of Mars happened in the same period but in reverse: the latter did not exist but their existence was claimed without being able to demonstrate it; the hexagon was there – and it was designed! – but no one recognized it or, if they recognized it, dared to support its existence. Curiously, Antoniadi proved to be a good prophet and excellent observer by rightly denying the existence of the canals of Mars and similarly drawing the hexagon on Saturn.

Certainly more important than the reason why the hexagon was not recognized is the fact that the drawings shown above demonstrate how it has existed on the north pole of Saturn for at least one hundred and twenty-five years, despite having varied in size and color in the meantime.

8. Acknowlwdgments

Dr. Lauren Amundson, archivist of the Lowell Observatory, who liaised with Laura Citernesi and signed, in July 2023, the Permission to Public Request of the Lowell Observatory Library and Archives.

Mister Morgan Aronson, librarian of the US Naval Observatory Library, who kindly sent us Asaph Hall's 1891 article;

Dr. Caterina Avanzino, member of the board of the «Associazione Ligure Astrofili Polaris», Genova, Italia (Ligurian Association Amateur Astronomers «Polaris» of Genoa, Italy), who highlighted for us the perimeter of the northern hexagon of almost all the photos.

Monsieur Jean-Claude Berçu, librarian of the Société Astronomique de France, who kindly sent us Antoniadi's 1930 article;

Dr. Daniela Domina, of the Astrophysical Observatory – INAF of Catania, Italy, who provided us with the Taffara material contained in the observatory's yearbook;

Ship Commander Agostino Frosini, amateur astronomer.

Lowell Observatory in Flagstaff, Arizona, USA, which granted us free reproduction of the images contained in its archive.

Dr. Agnese Mandrino, of the Astronomical Observatory – INAF of Brera – Merate, Milan, Italy, who sent us the rare publication by Taffara;

Mr. Damian Peach, amateur astronomer and astrophotographer, who allowed us to use his photographs published on his web site http://www.damikanpeach.com/ .

Mr. Mauro Repetto, professional photographer who, to improve its sharpness, retouched the digital image of Taffara's drawing presented above.

Dr. Luigia Maria Concetta Santagati, of the Astrophysical Observatory – INAF of Catania, Italy, who provided us with the Taffara material contained in the observatory's yearbook.

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