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Images of the Saturn Hexagon before Voyager 1

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Abstract[1]

In 1981 the Voyager 1 probe photographed – and later the Cassini probe confirmed – a hexagonal vortex on Saturn's North pole. This cloud features extends for about 30,000 km keeping its shape unchanged as it rotates with the planet. But, since we see it very foreshortened, it appears to us with the greater extension of 4" and the smaller one of 1.3": this makes it virtually visible from Earth with telescopes. And in fact, after the first images of Voyager 1, many amateur astronomers managed to photograph it even with modest instruments of a few tens of centimeters in diameter, but using digital photography techniques. We therefore wondered if the hexagon had been seen by astronomers of the past mainly using their professional telescopes. Our research gave positive results: E.E. Barnard (with the Yerkes' refractor) and E.M. Antoniadi (earlier with Juvisy's and later with Meudon's refractors) pictured it since the end of the 19th century, but they never mentioned it in their writings, probably because it was at the limit of visibility and it was impossible to explain the hexagon with the knowledge of that time. These pictures prove that the hexagon has been present and active for at least 124 years on the North Pole of Saturn, similar to the (longer-lived) red spot of Jupiter.

Keywords: Saturn, Exagon, Voyager 1, Barnard, Antoniadi, Planetary observations, Refractors.

Introduction

In 1981, the Voyager 1 probe flew over Saturn, sending back to Earth exceptional images of the planet. One of the many discoveries was the presence of a hexagonal formation near the North Pole. Surveys by the Cassini probe later revealed that it is an atmospheric wave structure that rotates with the planet without altering its shape. It appears to extend to an altitude of over 300 km and each layer of the hexagon is about 10-15 km thick. However, since the aims of our work are not to study and explain the existence of this formation, but rather to analyze why it has not been discovered with telescopes from Earth, we will not dwell on discussing its physical characteristics. Instead, let us look at the observational ones.

[1] This article in Italian was printed in the *Giornale di Astronomia*, vol. 48, No. 3, September 2021, Fabrizio Serra Publisher, Pisa, Italy, that is one of the two official organs of the Società Astronomica Italiana S.A.It. (Italian Astronomical Society).

This hexagonal formation lies at a latitude of 78° N and has sides of 13,800 km, i.e. each side is longer than the diameter of the Earth. These dimensions result in a global extension of the hexagon of about 30,000 km in maximum length, which, when viewed from Earth, is equivalent to an angular diameter of 4" as the greatest extension and 1.3" as the smallest: a modest value but one that is within the reach of ordinary telescopes. This formation was then photographed in a wonderful way by the Cassini probe, but also from Earth it has recently been possible to highlight it with instruments of the level of the C14[2], i.e. a 36 cm diameter Schmidt-Cassegrain.

In the light of these facts, we wondered why a formation within the resolving power of 19th century telescopes was not discovered from Earth, but had to wait for the arrival of Voyager to highlight it. And is it true that it has never been seen before[3]?

Ancient observations

To answer these questions we went in search of observations made before the Voyager mission. In this research we considered only the periods when Saturn's North Pole was well inclined towards the Sun (and therefore towards the Earth) and, with the exception of the investigations of Herschel, Schroeder and Lord Rosse, we started examining observations from the second half of the 19th century[4]. This is mainly because the previous instruments were almost all of modest size and inefficient in relation to the fact that the hexagon, seen from the Earth, is situated in a very foreshortened and, moreover, very dark position. On a visual scale in which the brightest part of the Saturn system (the edge of the B ring, bordering the Cassini division) has a value of 1 and the bottom of the sky 10, the polar region with the hexagon has a grade between 6 and 6.5. By way of comparison, it should be noted that the globe's shadow 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 refractors and 25-30 for reflectors of the 19th century. Another negative aspect for its observation is the fact that Saturn turns its North Pole towards Earth when it is in the region of the sky where the ecliptic is around its most austral position. And the major 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 18 April 1805 with the 25 cm reflector and 300x (Herschel, 1805, p. 274), in which the North Pole was inclined towards Earth, remains famous. The peculiarity of this observation is the square shape of the globe (Herschel, 1805, table IX), but in correspondence with the visible pole the great astronomer did not indicate anything, leaving this part of the picture blank. However, even where Herschel indicated

[2] Numerous astronomers are now able to photograph the hexagon using digital methods. One of them is Damian Peach who used a C14 Schmidt-Cassegrain.

[3] The origin of this research started by chance in 2019, when Barbara Bubbi showed Mario Codebò some digital pictures of Saturn taken by her correspondent Damian Peach, in which the boreal hexagon was clearly visible. About a year later Mario Codebò, who since then had been convinced that the hexagon could be even more within the reach of the great telescopes of the past and especially of refractors, observing in Cecchini 1969 the picture of Saturn made by Barnard in 1898 with the large refractor of Yerkes (102 cm diameter), recognized the boreal hexagon. This initiated the research project, coordinated by Walter Ferreri, whose results are described in this article.

[4] As the archives of the observatories were inaccessible due to the SARS-Cov-2 epidemic prevention measures, literature searches were mainly carried out online. The two main sources consulted were:

1) the SAO/NASA Astrophysics Data System https://ui.adsabs.harvard.edu
2) the Société Astronomique de France.

something at the pole, he limited himself to shading, although he sometimes used his large 1.2-meters telescope for this.

In the case of the German observer Johann Schroeder, who used mirror instruments of the same power as Herschel's (about half a meter in diameter), there is no useful indication in this respect. Here we should also add 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 started using his large 1.8 meters telescope in 1845, there is no mention of any hexagonal formation at Saturn's North Pole. It should also be pointed out that, unlike the Herschel family, he was more of a designer and builder than an observer, and the time he devoted to observation was modest.

Even the large telescope of the English observer Lassell, with a diameter of 1.2 meters, installed in Malta, did not give any results in this respect: with the observations made with this instrument there is no record of this feature on Saturn.

Around the middle of the 19th century, refractors with good diameters began to come into use, which were more suitable for planetary observation than the reflectors of the time equipped with metal mirrors[5].

One of these was the "large" 38 cm diameter Harvard refractor, which was also used intensively for the study of the planets. The works on Saturn highlight several interesting aspects, including the discovery of the veil or "C ring", but no reference to a hexagonal shape around the North Pole (Bond, 1857).

Starting in the second half of the 19th century, suitable instruments and planetary observers became numerous and it is certainly impossible to take them all into account. Our research has therefore been limited to the most famous ones, whose results have been most widely disseminated[6].

Examining the notes of these observers and their pictures we find a lot of circumstantial information about the rings, satellites and the globe but none about the existence of a hexagonal formation at the North Pole, despite the fact that many authors report in detail variations in the extent and color of the polar caps, to which they clearly paid some attention. And this is true even when considering the most skilled observers using the largest instruments (for instance: Hall, 1891). In this respect, the American observers with the largest refracting telescopes and E.M. Antoniadi in Europe using the 83 cm Meudon (France) stand out.

As mentioned in footnote 3, the first image that attracted our attention was the picture (fig. 1)[7] made by Barnard on 7 July 1898 through the Yerkes 102 cm refractor (Cecchini, 1969, fig. 309), in which three of the six sides can be recognized[8].

[5] It should be noted that all images of the Saturn hexagon prior to the Voyager 1 mission that we found were obtained with refractors.

[6] Despite the need to focus our attention only on the works of the most famous astronomers, in the ASD we searched, downloaded and consulted all the articles from 1800 to 1981 that answered to the keyword "Saturn", limiting ourselves to those whose title made explicit reference to the body of the planet and to general observations (thus excluding articles explicitly dedicated to satellites and rings). In particular, we looked at the articles written by the Section for the Observation of Saturn, later renamed Saturn Section and still active today.

[7] In pictures Nos 1; 2 ;3; 4 the North pole is at the bottom, because the telescopes turn the images upside down. In pictures No 5 and 6 the North Pole is up because the images have been straightened. The picture No 7 (which is a photography by Cassini probe) correctly shows the North Pole at the up.

[8] In all the pictures, the straight sides of the hexagon are most evident when looking at the images in digital format. Printing, and especially enlarging it, makes the image less sharp and tends to make the straightness of the sides disappear.

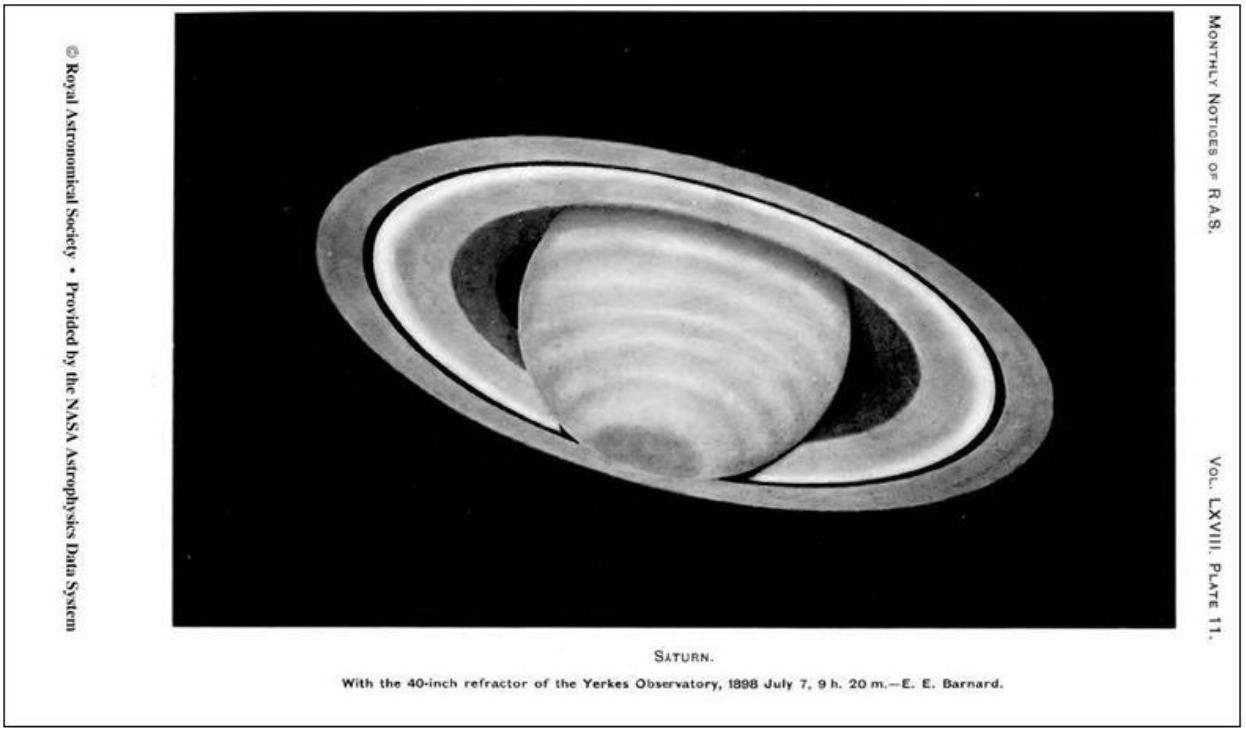

Figure 1. Barnard 1908 (Credit: ADS).

In the text (Barnard, 1908, table 11 and p. 367) Barnard merely says: "*The polar cap was darker than the darkest part of the ball*". At the end of his note on 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 an exceptional seeing, made the "miracle" of making the hexagon "visible". On the other hand, there is no trace of the hexagon in the picture he made on 31 March 1895 with 91 cm Lick's refractor (Barnard, 1895, p. 381).

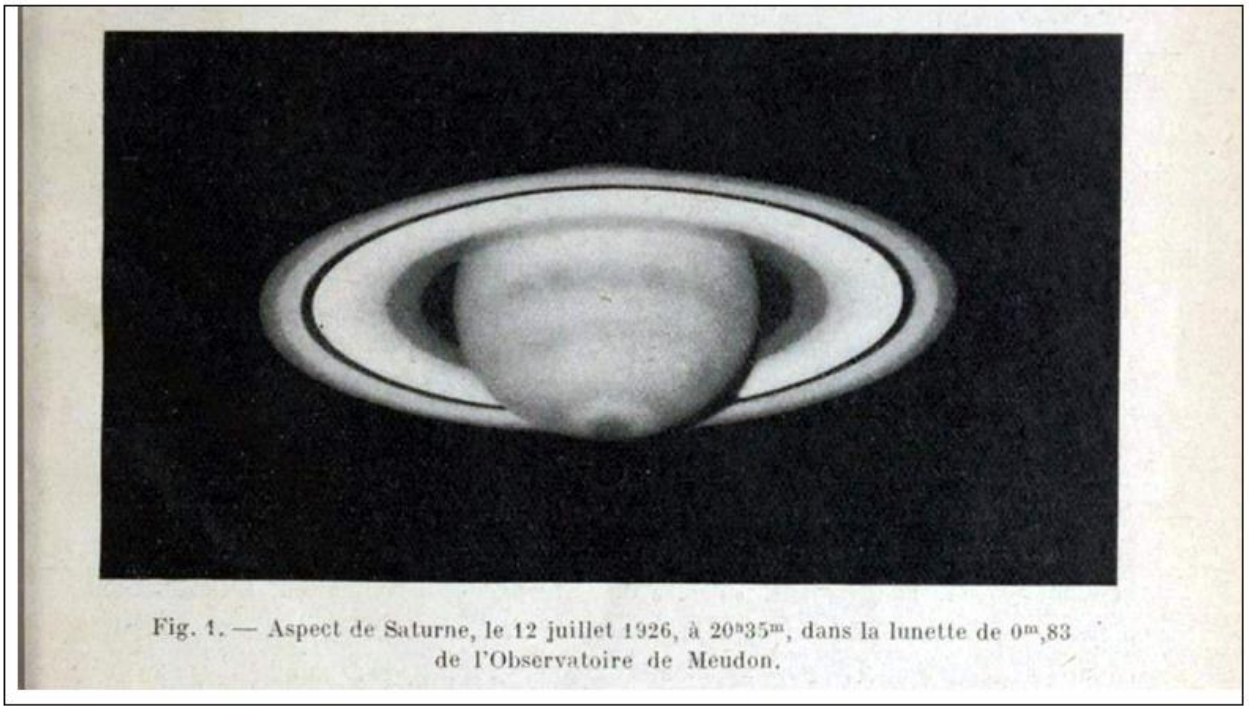

Figure 2. Antoniadi 1930 (Credit: BNF Gallica – S.A.F.).

A second group of images (figs. 2; 3; 4) reproducing more or less distinctly the rectilinear sides of the hexagon, are those reproduced in Antoniadi's 1930 article, namely his figures Nos. 1 of 12 July 1926 (p. 1); 7 of 18 July 1927 (p. 8); Nos. from 8 to 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 pictured between 1909 and 1913 – in which there is no trace of straight lines, thus demonstrating that he actually perceived (and pictured, but did not described!) the boreal pole as a polygonal formation and not as circular as the austral pole. All the images reproduced in the 1930 article were taken with Meudon's 83 cm refractor.

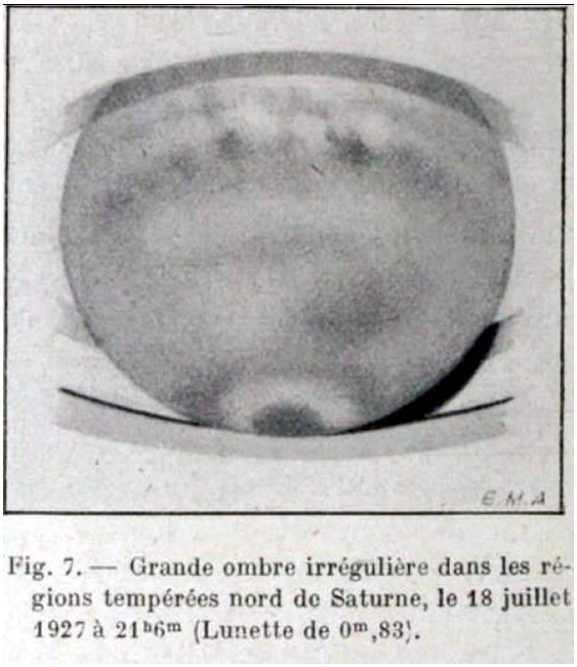

Fig. 7. — Grande ombre irrégulière dans les régions tempérées nord de Saturne, le 18 juillet 1927 à 21h6m (Lunette de 0m,83).

Figure 3. Antoniadi 1930 (Credit: BNF Gallica – S.A.F.).

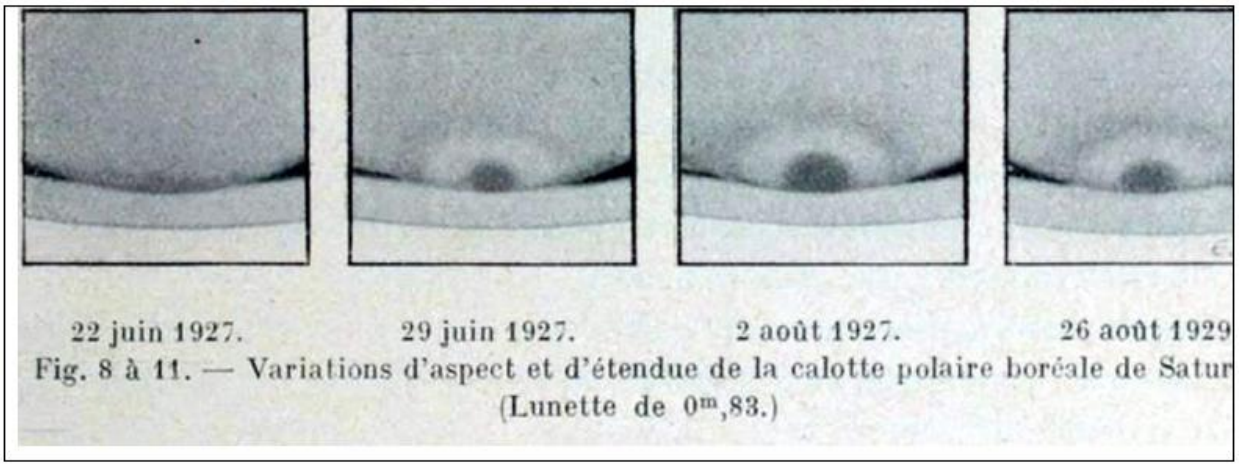

Fig. 8 à 11. — Variations d'aspect et d'étendue de la calotte polaire boréale de Satur
(Lunette de 0m,83.)

Figure 4. Antoniadi 1930 (Credit: BNF Gallica – S.A.F.).

This is what he wrote at the time about the polar caps:

> **Calotte polaire sud** – En 1852, Lassel, Dawes et Secchi, observèrent 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 frères 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'année suivante, nous notions avec la lunette de 0^m,83 de Meudon une calotte foncée d'un gris bleu si intence (Bulletin de la Société, t. 24, 1910, p. 374)[9] qu'au premier abord, nous avons cru avoir affaire en partie à un produit de spectre secondaire (fig. 3). 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 une 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 bleuâtre 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 bears the most convincing traces of a hexagon at the North Pole is the one that Antoniadi made on July 30, 1899 with the 26 cm refractor in Juvisy (France). Here, with our awareness, it is possible to recognise three sides of the hexagon even if the observer does not mention them in his report. Let us see, in this regard, his drawing, both original (fig. 5) and with the sides we have highlighted (fig. 6).

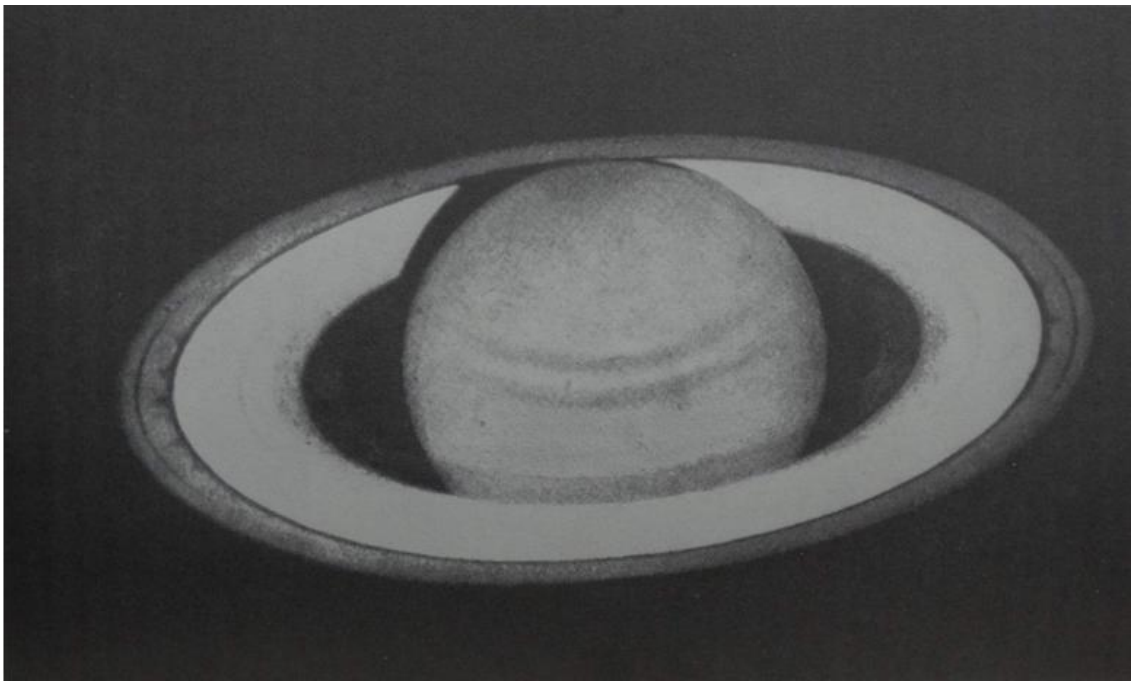

Figure 5. (DSC05498) Antoniadi, 30 July 1899, Juvisy Obs., 26 cm Refractor. (Credit: Montly Notices of the Royal Astronomical Society, vol. 60, Plate 12).

[9] In the original article the bibliographic quotation is in a footnote named No 6 in the text.

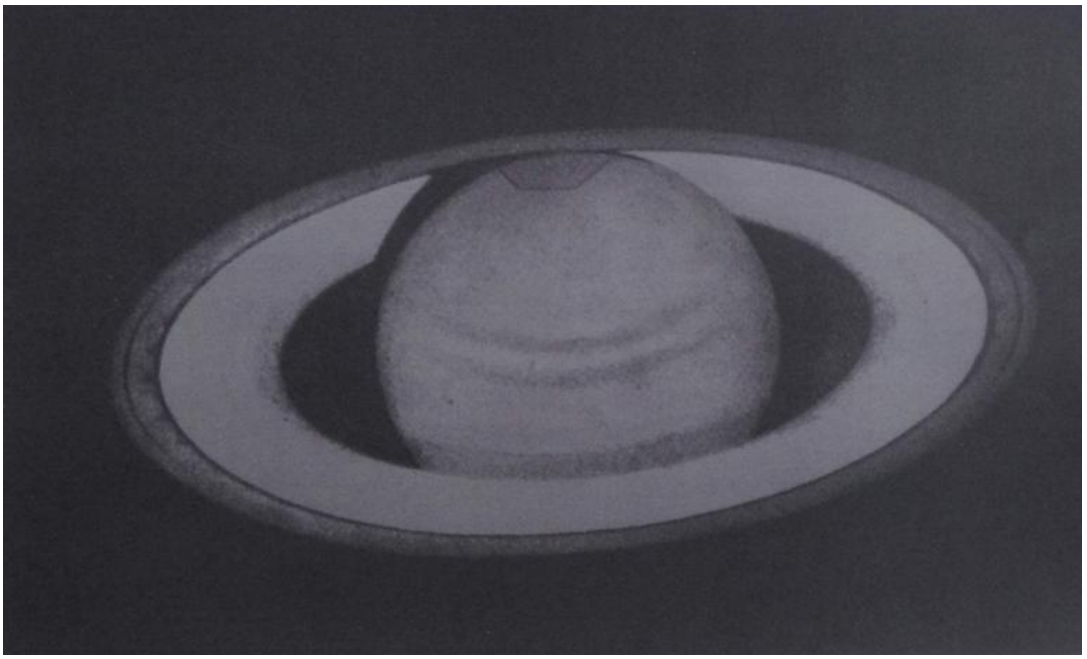

Figure 6. (DSC05501) Still the same as image N 5, but with the sides of the hexagon highlighted.

The following observatories, including the Italian observer Guido Ruggieri, who in 1958 had also used the largest Italian refractor for this purpose (the 49 cm Merz, at the Merate Observatory) did not lead to any results: in none of the publications we examined, limited to the observers considered to be the most experienced and able to access large instruments, could we find any mention of its existence.

At this point one has to ask why a technically visible (albeit borderline) and actually designed structure was never recognized. In our opinion, there are two explanations:

1) An enormous hexagonal structure must have been – and still is! – very difficult to explain. The Voyager I pictures made its existence indisputable; but at a time when the image was only telescopic and moreover at the limits of visibility – as shown by the fact that most observers did not reproduce it – it must have been too difficult to sustain its existence both physically and psychologically. That is, one would have been in the position of supporting the existence of something impossible to prove and very difficult to explain. It was therefore better to consider it as a kind of optical illusion.

2) An examination of the Hubble's images reveals that the hexagon, seen very close up 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 could not be recognized from Earth.

Modern assumptions

The hypothesis that Saturn's striking north – polar hexagon could have been visible even in the 19th century, using appropriate instruments, is reinforced by recent studies based on observations by the Cassini probe. These studies, in fact, suggest that the formation is particularly persistent and deep, and may have been present for thousands of years. A study published in *Nature Communications* by scientists from the University of the Basque Country (Sánchez-Lavega, García-Muñoz, del Río-Gaztelurrutia et al., 2020) reveals that the hexagon is topped by a system of at least seven regularly spaced layers of haze, extending from the top of the clouds to an altitude of more than 300 km above them. Previously, images from the Cassini probe had revealed the presence of a north – polar vortex that forms in Saturn's upper

atmosphere as the summer season approaches. The vortex is 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. So it seems that the famous hexagon immortalized by the Voyager spacecraft in the early 1980s is actually a towering structure rising vertically for many hundreds of kilometers.

This could explain the vastness (the hexagonal vortex extends for about 30,000 kilometers) and persistence of the formation: we know for certain that it has characterized the planet for at least forty years – but we can now say: for one hundred and twenty years! – remaining almost static, almost identical during the planet's rotation, despite the raging winds of over 400 kilometers per hour.

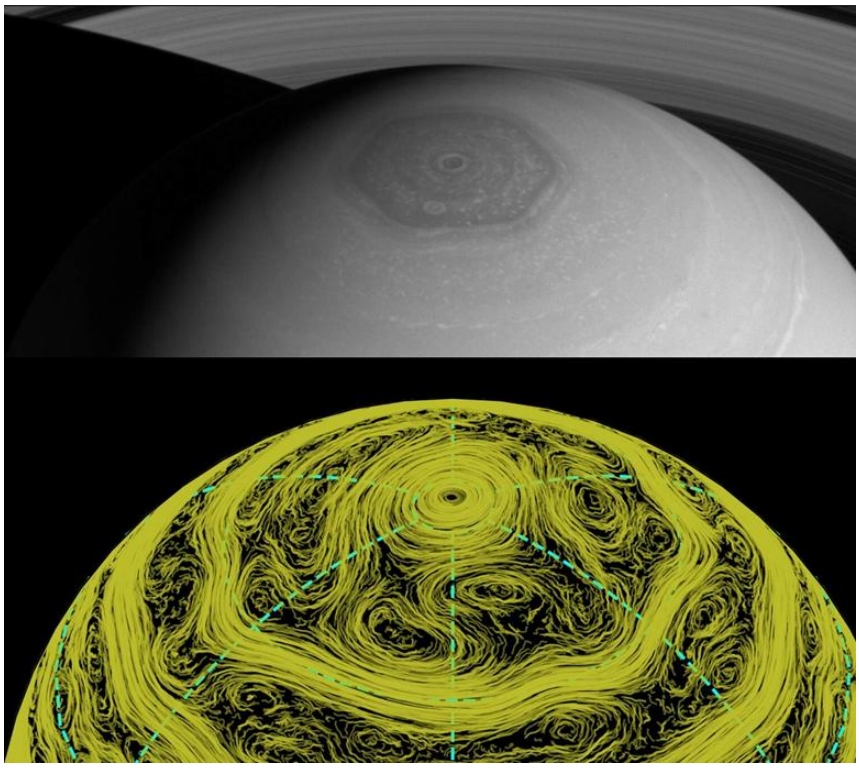

Figure 7. Top: The hexagon at Saturn's North Pole observed by the Cassini spacecraft. Bottom: An image taken from a computer simulation created by Harvard researchers (Credits: NASA/JPL-Caltech/Space Science Institute/Rakesh K. Yadav).

But how is it possible that such an unusual and vast system has remained unchanged until now? The longevity of the hexagon makes it somewhat special, so much so that scientists are conducting studies and experiments to find possible explanations. A recent study, published in the *Proceedings of the National Academy of Sciences* and carried out by scientists at Harvard University (Yadav, Bloxham, 2020) provides a possible explanation for the formation of the hexagon, using three-dimensional models. The new study suggests that 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. Such vortices surround an immense horizontal jet stream flowing eastward near Saturn's North Pole. The current has a number of additional cyclones within it, which interact with the larger system, compressing it in some places and confining it. This compression process would give the jet stream a hexagonal shape. A phenomenon called deep thermal convection would underlie the

whole 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 overall structure of the vortex particularly persistent and deep (fig. 7).

Acknowledgements

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[10] The Bibliographical Code, abbreviated to BibCode, is the unique identification code assigned by the ADS to each article. We thought it would be useful to mention it in order to facilitate readers who might be interested in searching the ADS database.