

ENCKE'S MINIMA AND ENCKE'S DIVISION IN SATURN'S A-RING

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When viewed with the aid of a good quality telescope Saturn is undoubtedly one of the most spectacular objects in the sky. Many amateur astronomers (including the author) say that their first observation of Saturn turned them on to astronomy.

Saturn's rings are easily visible with a good 60 mm refractor at 50x. The 3D appearance of this planet is what makes it so interesting. Details in the rings can be seen during moments of good seeing. The Cassini division (between ring A and B) is easily visible with moderate apertures. The Encke minima and Encke division are more difficult to observe and require large apertures and telescopes of excellent optical quality.

These two features can be observed in Saturn's A-Ring. The Encke minima consists of a broad, low contrast feature located about halfway out in the middle of the A-Ring. The Encke division is a narrow, high contrast feature located near the outer edge of the A-Ring. Unlike the Encke minima, the Encke division is an actual division of the ring (Figure 1).

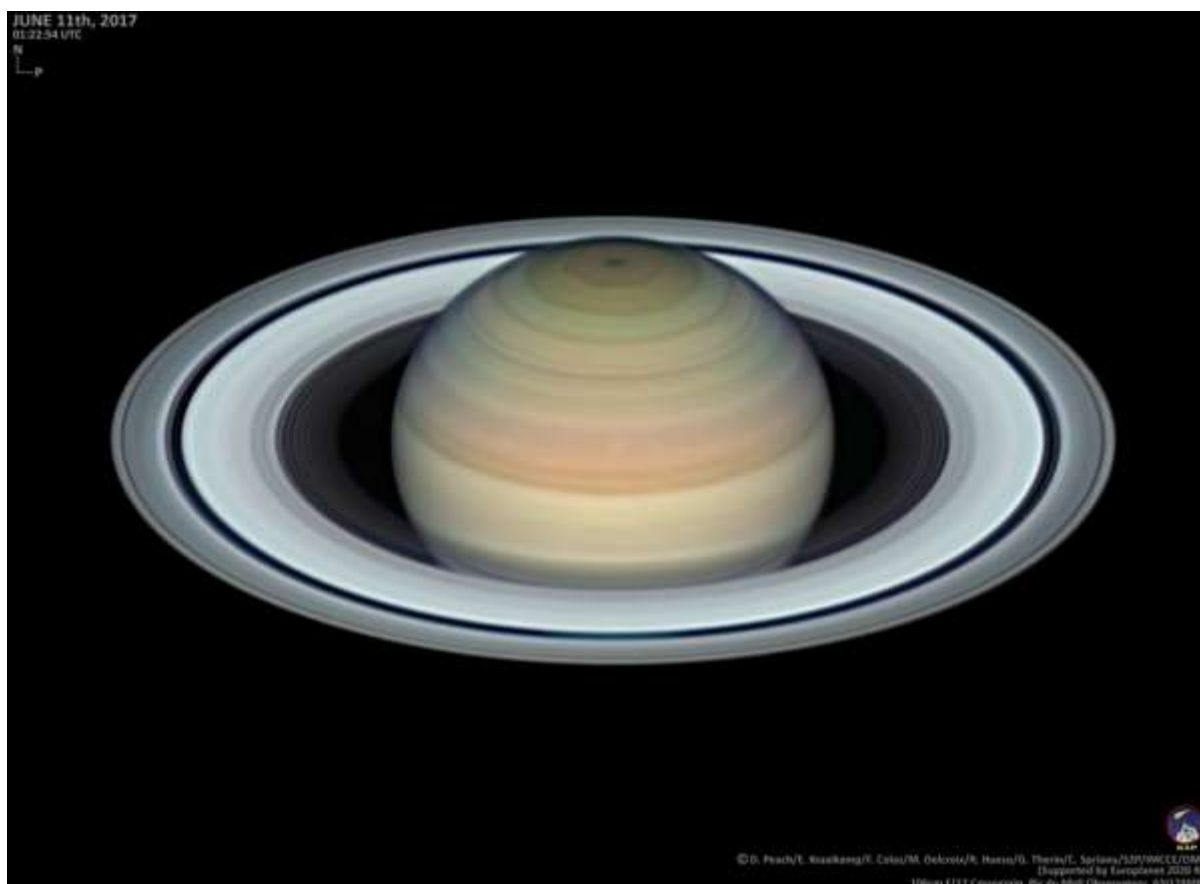


Figure 1- Saturn near Opposition on June 11, 2017. D. Peach, E. Kraaikamp, F. Colas, M. Delcroix, R. Hueso, G. Thérin, C. Sprianu, S2P, IMCCE, OMP. The Encke division is visible around the entire outer A ring. Astronomy Picture of the Day (20170617) <https://apod.nasa.gov/apod/ap170617.html>

Galileo Galilei observed the disk Saturn for the first time using one of his largest refractor. With a magnification of only 32x, this first observation was made in July 1610 when the ring was only narrowly open (Figure 2). Galilei announced his discovery to Belisario Vinta (counsellor and secretary of state to the Grand Duke of Tuscany) in a confidential letter (July 30, 1610):

I have discovered a most extraordinary marvel, which I want to make known to Their Highnesses and to Your Lordship, but I want it kept secret until it is published in the work which I am going to have printed. But I wanted to announce it to Their Most Serene Highnesses so that, if someone else should discover it, they would know that no one observed it before I did. Yet I believe that no one will see it before I inform him. The fact is that the planet Saturn is not one alone, but is composed of three, which almost touch one another and never move nor change with respect to one another. They are arranged in a line parallel to the zodiac, and the middle one is about three times the size of the lateral ones (...)

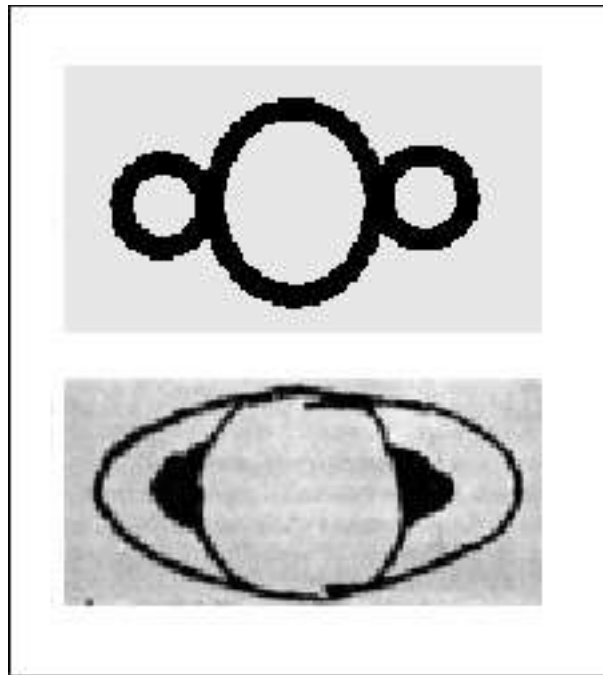


Figure 2- Galileo's drawings of Saturn, 1610 (top) 1916 (bottom)

The Dutch mathematician and scientist Christiaan Huygens proposed for the first time that Saturn was surrounded by a solid ring in 1655: *a thin, flat ring, nowhere touching, and inclined to the ecliptic* (Figure 3). Huygens also discovered Titan, the brightest Saturn's moon.

A few years later, in 1675, Jean Dominique Cassini, an Italian-French astronomer, discovered a narrow gap in the ring system that has since been known as "Cassini division" (Figure 4).

Cassini described this gap in 1676:

(...) the breadth of the ring was divided into two parts (dividebatur bifarium) by a dark line, apparently elliptical but in reality circular, as if into two concentric rings, the inner of which was brighter than the outer one. This aspect I saw immediately after Saturn's emersion from the Sun's rays and through the whole year till immersion...

J.D. Cassini used a 35-foot long telescope and a smaller 20-foot telescope for these first observations.

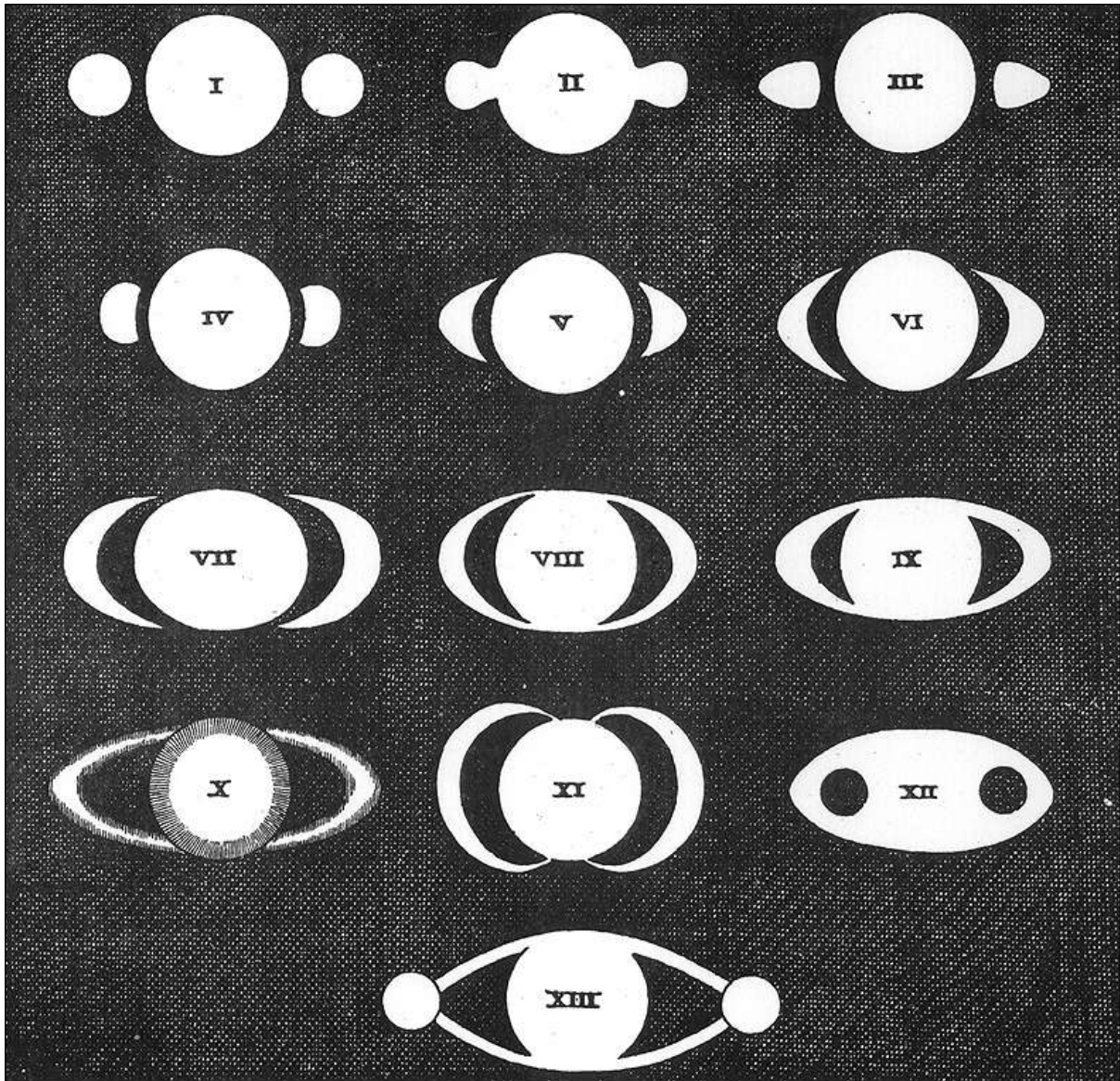


Figure 3- Early drawings of Saturn (from *Systema Saturnium*, 1659 by C. Huygens): I Galileo (1610); II Scheiner (1614); III Riccioli (1641 or 1643); IV-VII Hevel (theoretical forms); VIII. IX Riccioli (1648-50); X Divini (1646-48); XI Fontana (1636); XII Biancani (1616), Gassendi (1638-39); XIII Fontana *et al.*(1644-45).

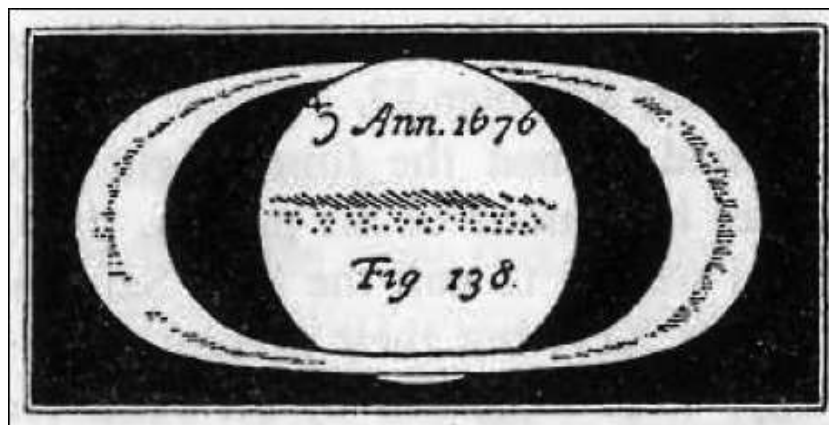


Figure 4- J.D. Cassini sketch of Saturn in 1676 showing the Cassini division in the rings, the first published drawing of the division.

In 1825 Henry Kater, an English amateur astronomer observed three divisions extremely close to each other dividing Ring A into equal parts (Figure 5).

I fancied that I saw the outer ring separated by numerous dark divisions, extremely close, one stronger than the rest dividing the ring about equally... I have little doubt that which has been considered as the outermost ring of Saturn consists of several rings (...) The inner ring decidedly has no such appearance.

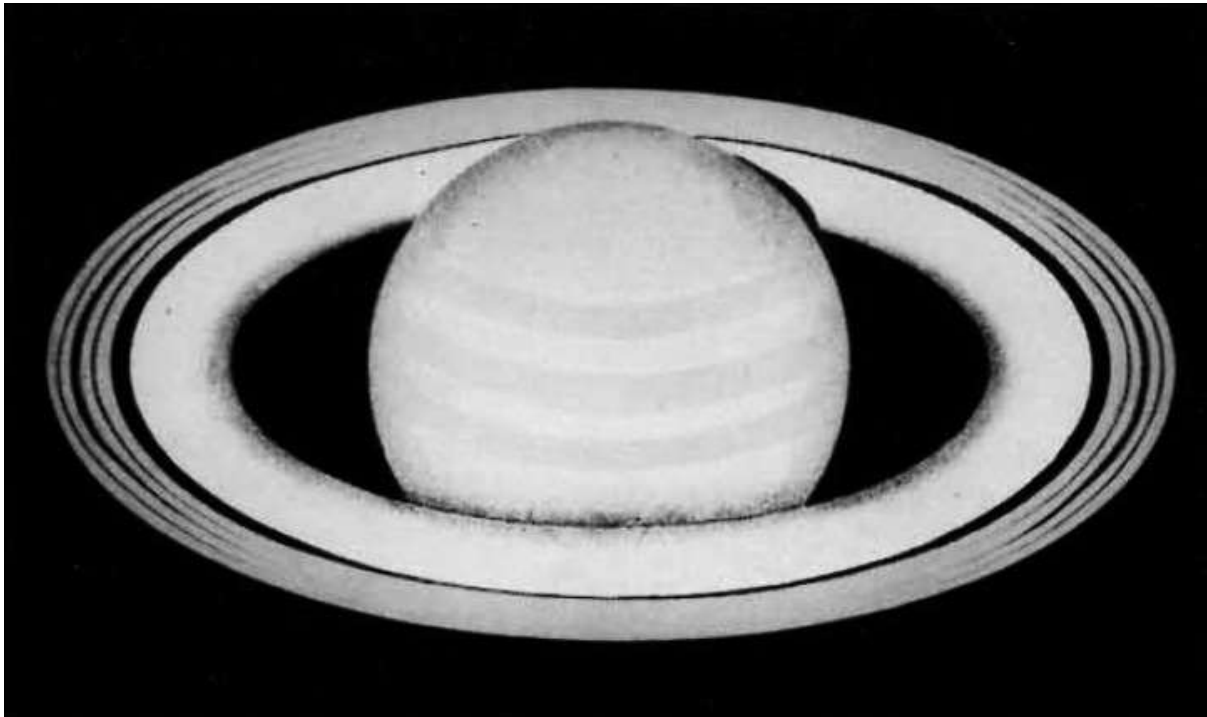


Figure 5- H. Krater drawing of Saturn (December 17, 1825) with a 6 ¼-inch refractor, showing minor “divisions” on the A ring.

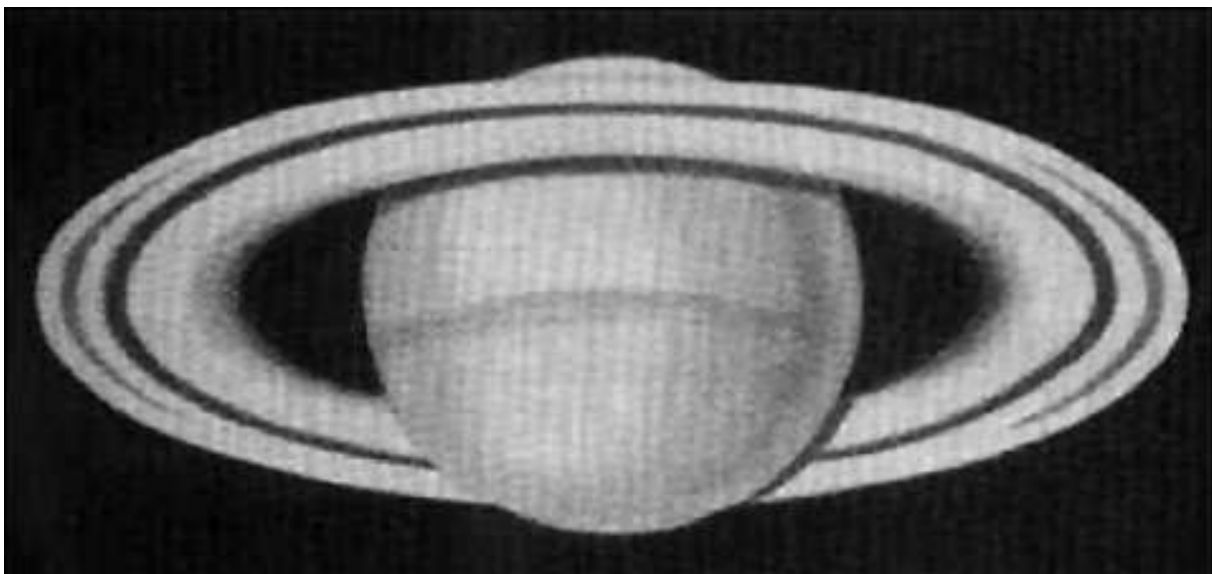


Figure 6- Johann Franz Encke drawing of Saturn in May of 1837, showing the broad, low-contrast feature in the middle of the A ring (Encke minima).

Krater could not see any divisions in the A ring in January 1826 and wrote: *I am, therefore, the more persuaded that they are not permanent.*

Adolphe Quetelet, director of the Brussels observatory using a 250 mm refractor thought that he had seen ring A divided into two rings in 1823. In 1826 John Herschel and Wilhelm Struve could not see any subdivision in the rings, though observing with larger aperture telescopes.

In 1837 Johann Franz Encke, director of the Berlin observatory, using a 246 mm refractor observed a dark “minimum” of intensity on the northern face of ring A and obtained micrometre measures of its position (Figure 6).

William Lassell and William Dawes (1843) observed the Encke minima with a 9-inch refractor and another division near the edge of ring A (Figure 7). Dawes described these observations:

Having obtained a fine adjustment of the focus, I presently perceived the outer ring to be divided into two. This coincided with the impression Mr. Lassell had previously received (...) With 400x the secondary division was perceptible during occasional best views of the planet. occasionally, for several seconds together, I had by far the finest view of Saturn that I was ever favoured with. The outline of the planet was very hard and sharply defined with power 450x and the primary (Cassini's) division very black and steadily seen all round the southern side. When this was most satisfactorily observed, a dark line was pretty obvious on the outer ring. I was not only perfectly satisfied of its existence, but had time during the best views carefully to estimate its breadth, in comparison with that of the division ordinarily seen (...) It is certainly rather outside the middle of the outer ring, and is broadest at the major axis, being in this respect precisely similar to the primary division. It was equally visible at both ends of the ring.

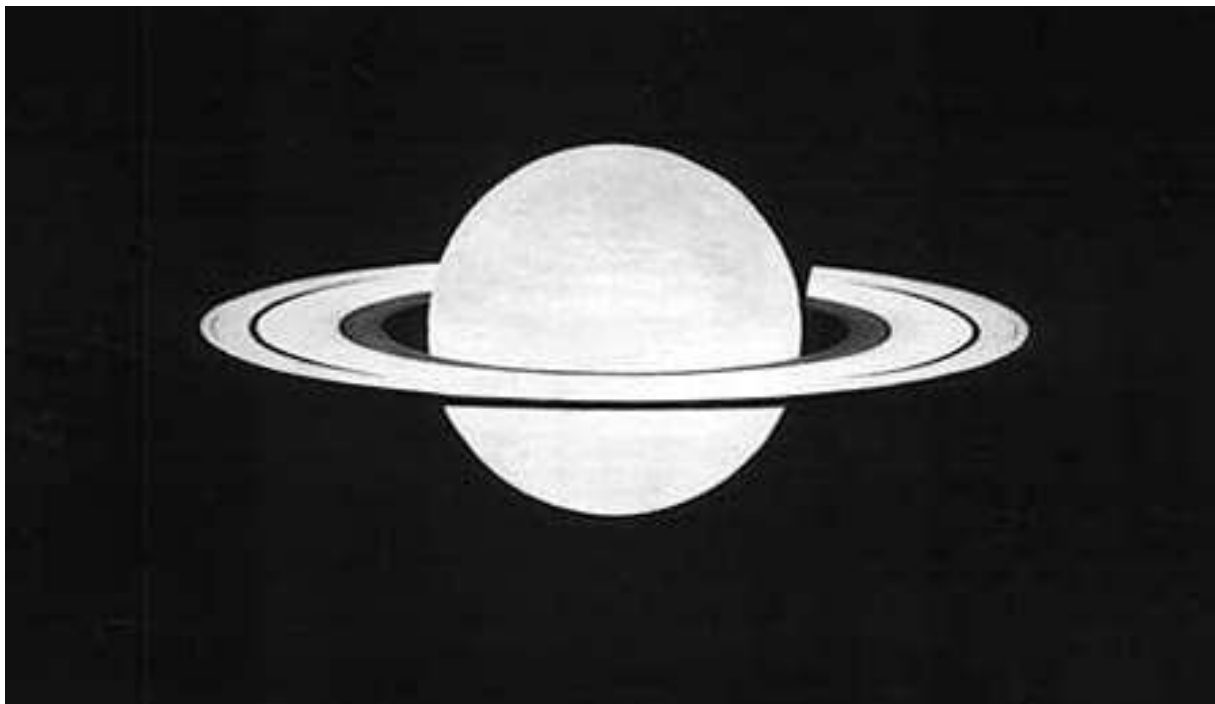


Figure 7- Dawes' drawing of the Encke division (1850)

Phillip Sidney Coolidge an American amateur using a 380mm refractor saw “three of four lines or divisions” on ring A (1854/1855) (Figure 8).

There is certainly one division in the outer half of ring A, and I cannot be positive that that there is not a second one. If so, it is outside of the first division." On December 27th using a magnification of 401x he noted "There are two (and at times I suspect three) divisions in ring A."

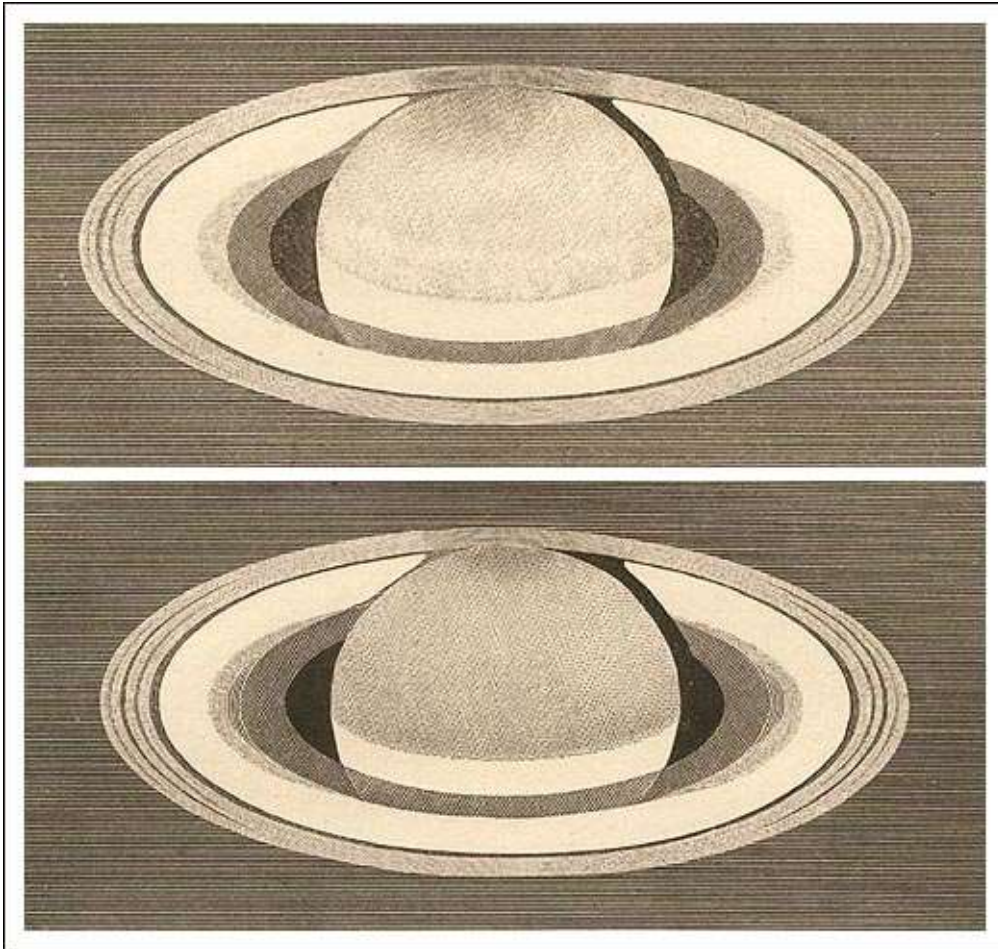


Figure 8- Coolidge drawings of Saturn in December 27, 1854 (top) and January 9, 1855 (bottom) using a Merz & Mahler 15-inch F/16 refractor.

In 1888 (January 7th), James Keeler using the 910 mm Lick Observatory refractor observed the Encke division and the Encke minima clearly.

(...) beyond doubt the greatest telescopic spectacle ever beheld by man. The giant planet, with its wonderful rings, its belts, its satellites, shone with a splendor and distinctness never before equalled. Not only was he shining with the brilliancy due to the great size of the objective, but the minutest detail of his surface were visible with wonderful distinctness.

Keeler saw a thin black division (*a mere spider's thread*) close to the edge of the A-Ring, a little less than 1/5 of the ring from its outer edge. Keeler's drawing of Saturn shows these two features (Figure 9).

The Encke division was observed again on March 2, 1889 with the same instrument at 1000x. Edward E. Barnard joined Keeler at the eyepiece and they noticed a diffuse shading which began at about 1/3 of the ring width starting from the edge, precisely in the position estimated by Dawes and Lassell during an observation made in 1843: it was probably the Encke minimum, still not separated by the division. But by switching from 400 to 1000x they saw the narrow line discovered by Keeler the year before to form just the outer edge of the Encke minimum:

“This line marked the beginning of a dark shade which extended inward, diminishing in intensity, nearly to the great black division”.

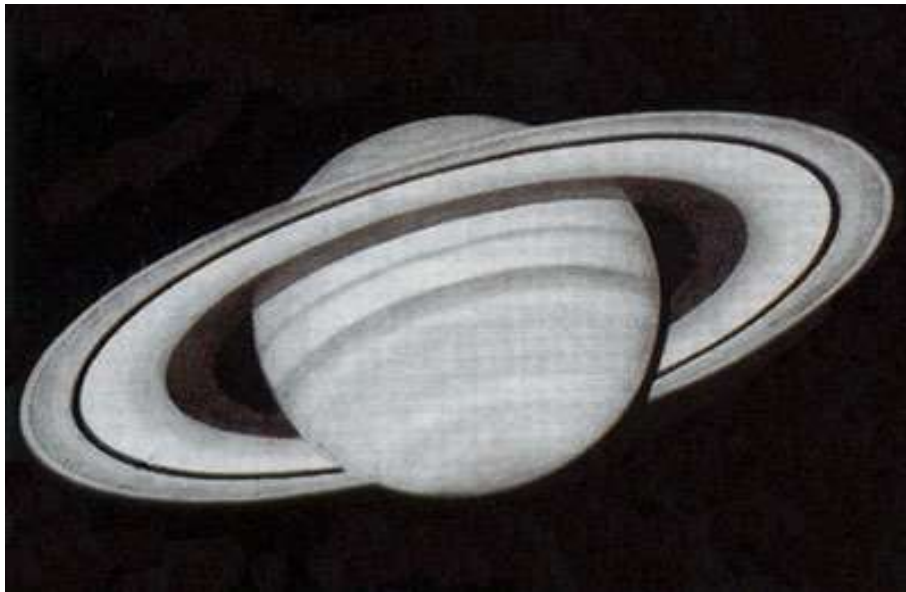


Figure 9- Drawing by James Keeler made in January 1888 using the Lick 36" refractor showing the high contrast feature at the edge of the A-Ring that is now called the Encke division on the northern face of Saturn's A-Ring.

Giovanni Schiaparelli, director of Brera observatory in Milan (Italy) used the 490mm Merz-Repsold refractor at 830x in March 1890. The Keeler “line” was clearly observed at 1/6 of the ring width starting from the edge. He also noted that: *the shadow [minimum] of Encke is contiguous [to the division] and ends in it.*

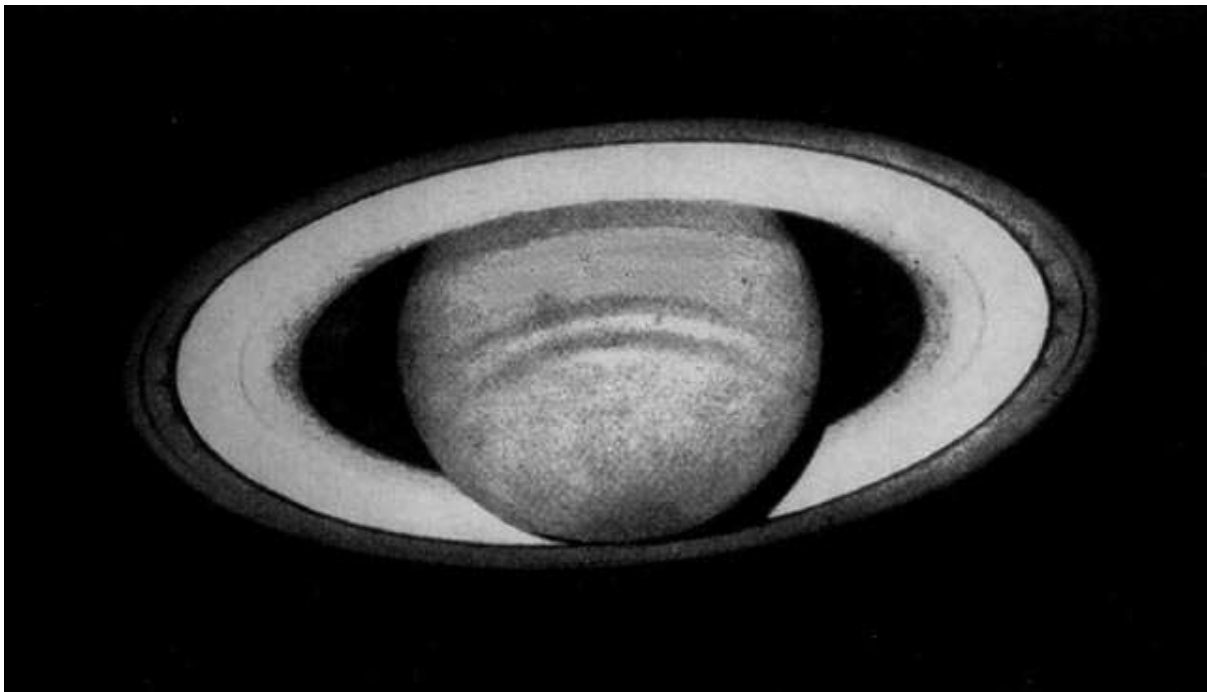


Figure 10- E.M. Antoniadi's drawing of Saturn (10 ¼-inch refractor at Juvisy observatory) on July 30 1899, showing Encke's division (ring A) and a faint linear marking on Ring B.

Camille Flammarion report on Saturn rings in 1899 refers that the Encke division was only seen on July 30, the best night of the observing season (Figure 10):

it was perfectly visible on both ansae. An easier feature of ring A was a series of dusky indentations emerging from the Cassini division. The outer edge of A was in no wise sharply defined, but seemed to shade off rather gently into space. Cassini's division could be traced easily all round the ring, even under very poor seeing; it was dark grey, not black, and seemed tangential to Saturn's north limb.

Bernard Lyot observed Saturn during from 1943 to 1945 with the 600 mm refractor at Pic du Midi. Audoiu Dollfus made a photometric profile of the rings using several photographs (1950/1960) (Figures 11 and 12).

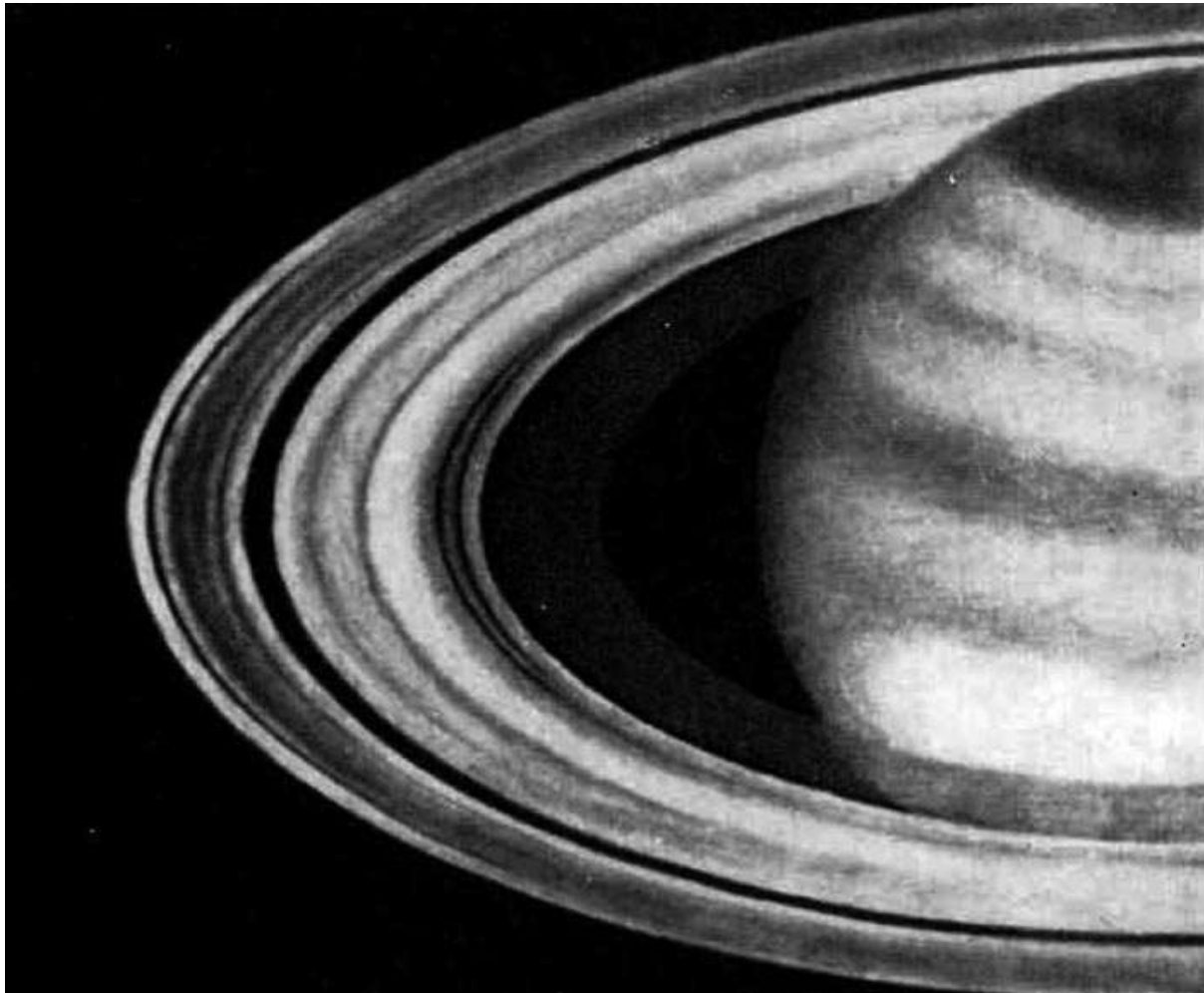


Figure 11- Lyot's diagram of Saturn's belts and markings (600 mm Pic du Midi refractor, 1943).

Dollfus' profile (Figure 12) shows most of the features that can be observed using large aperture telescopes: the Encke division the Encke minima and several markings on Ring B.

Dollfus in 1957 using the 82-inch McDonald reflector (stopped down to 25-inches) was able to make a careful study of the minima of light on the northern face of Saturn's rings. He found almost the same results as in Lyot's drawing of the southern face. There were no gaps except Cassini's division, but several minima of light, or narrow shadings of low contrast, in excellent agreement with Lyot's observations.

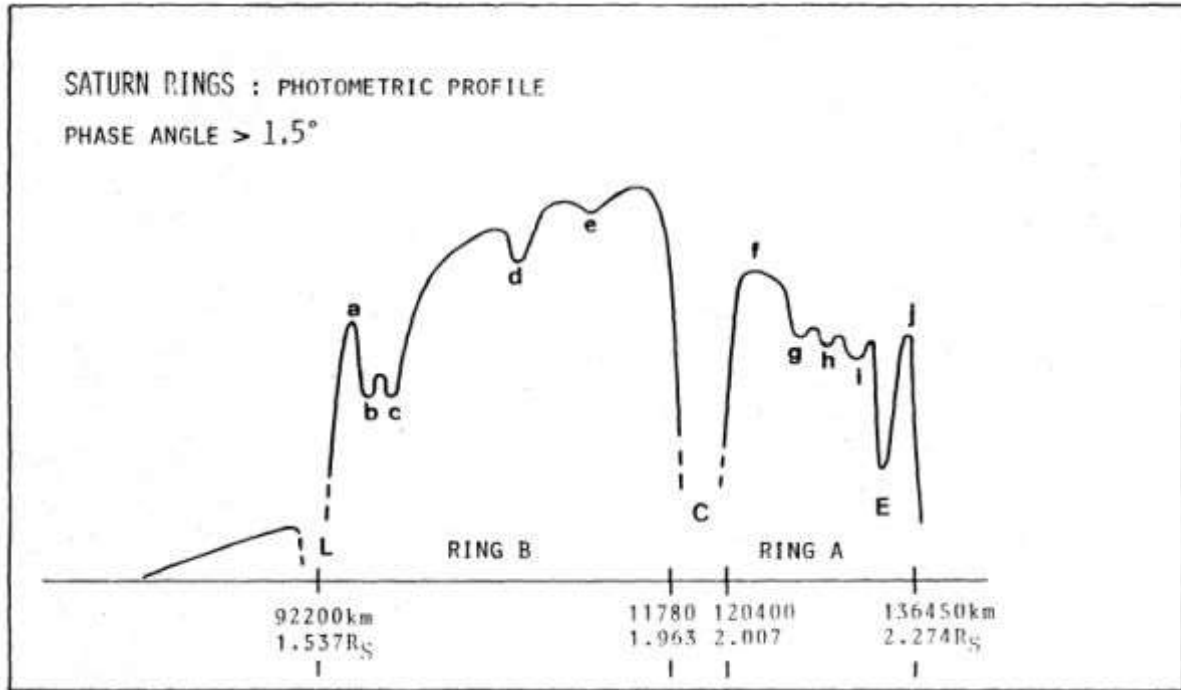


Figure 12- Photometric diagram of the northern face of Saturn's rings based on observations at the McDonald and Pic-du-Midi Observatories, 1957 and 1958 (A. Dollfus).

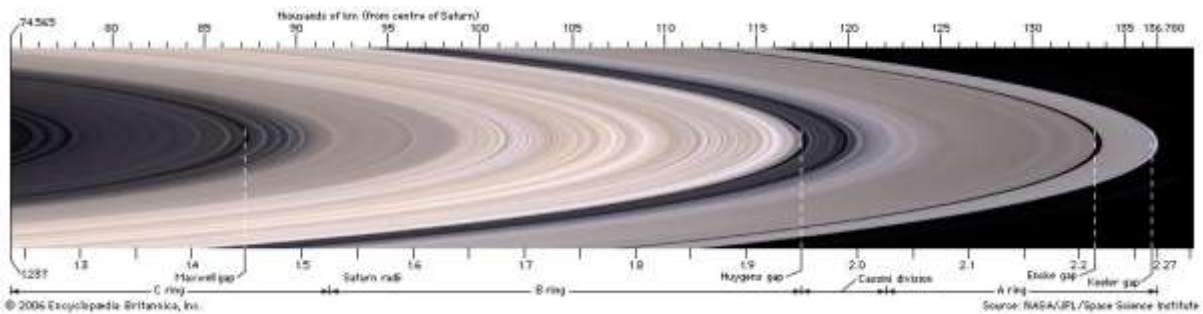


Figure 13- Details of Saturn's three main rings, in a natural-colour composite of six images obtained by the Cassini spacecraft on December 12, 2004. The view is from below the ring plane, with the rings tilted at an angle of about 4° <https://www.britannica.com/topic/Keeler-gap>

Many amateur astronomers produce excellent images of Saturn rings using the lucky imaging technique. The recent advent of CCD cameras that can be operated in a video mode, taking 100 or more images per second for periods of up to a few minutes, can be used with excellent results for high-resolution imaging. Image processing software can then be used to stack and align the best frames to produce a low noise high-resolution image. Individual frames of the video are analysed and the sharpest frames selected using dedicated software. These good frames (less affected by the seeing) are stacked together to produce a high-resolution image in the form of a single still picture. The composite images have less noise, higher contrast and better resolution than a single exposure.

The remarkably sharp image of Saturn obtained with the 1-meter telescope at Pic du Midi (Figure 1) is the best image obtained so far with ground based instruments. This image was obtained on June 11, 2017, 5 days before Saturn's opposition. In this image, North is at the top with the giant planet's north polar storm and curious hexagon clearly seen bathed in sunlight. Saturn's spectacular ring system is also shown in stunning detail. The narrow Encke division is visible around the entire outer A ring, small ringlets can be traced within the fainter inner C ring, and Saturn's southern hemisphere can be

glimpsed through the wider Cassini division. Near opposition Saturn's rings also appear exceptionally bright, known as the opposition surge or Seeliger Effect. Directly illuminated from Earth's perspective, the ring's icy particles cast no shadows and strongly backscatter sunlight creating the dramatic increase in brightness. Still, the best views of the ringed planet are currently from the Saturn-orbiting Cassini spacecraft. Diving close, Cassini's Grand Finale orbit number 9 is in progress. The Hubble Space telescope also produced excellent Saturn images (Figures 14, 15 and 16).

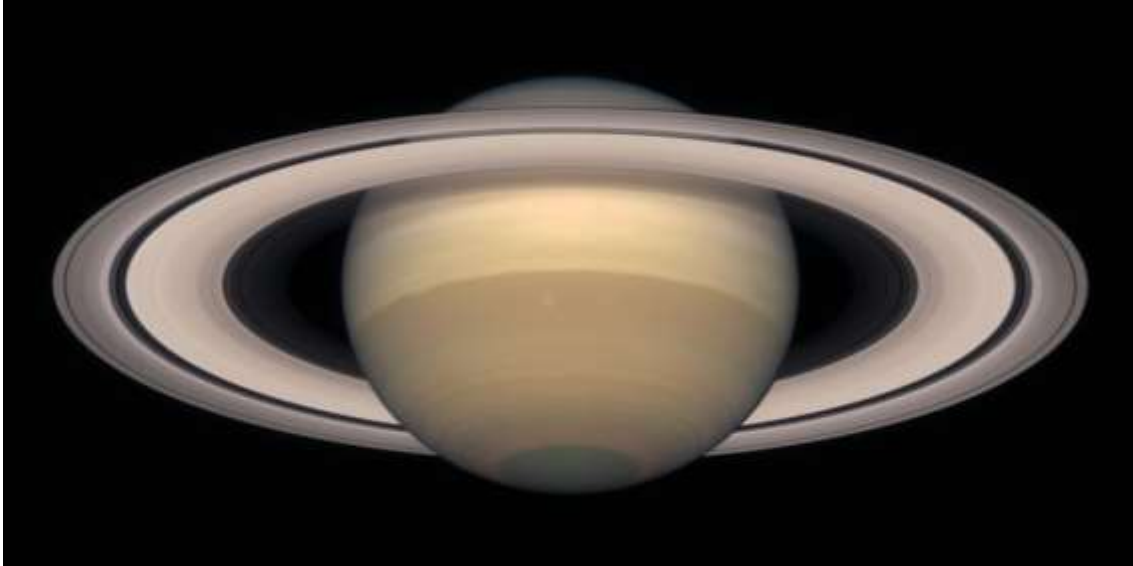


Figure 14- Saturn on November 1999. Hubble Space Telescope. <https://www.spacetelescope.org>

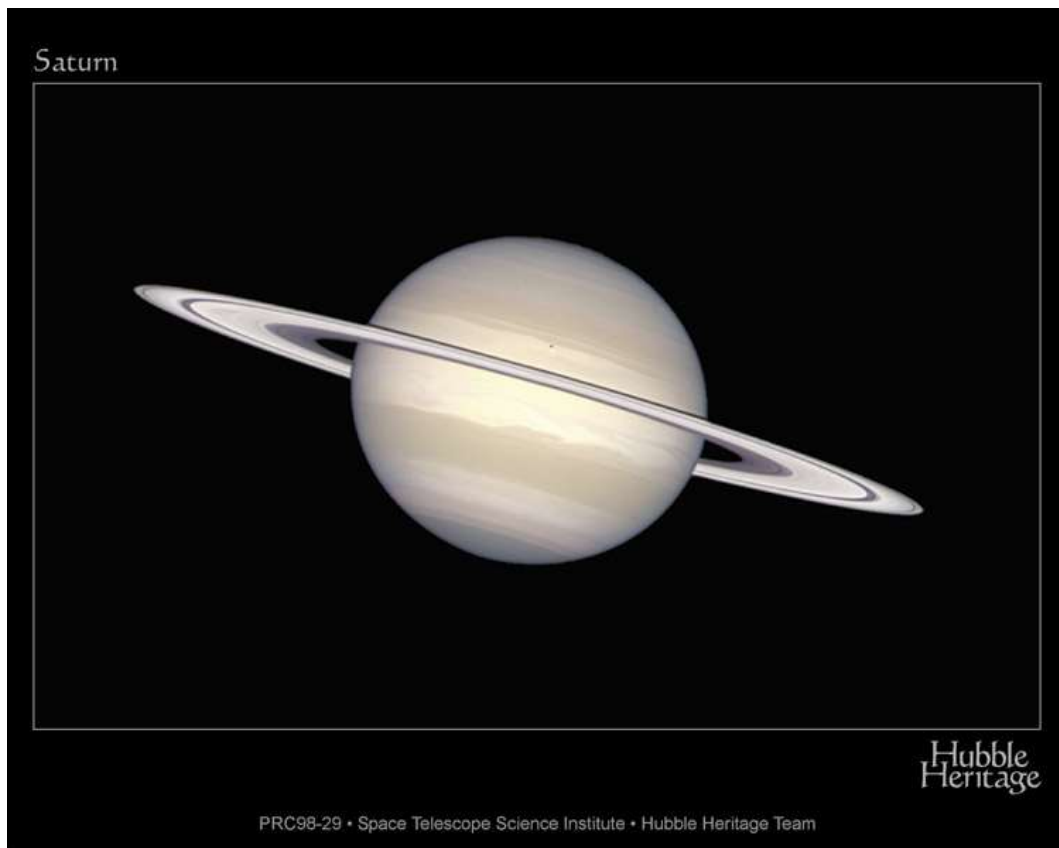


Figure 15- Natural Saturn on the Cassini Cruise. Image processed by the Hubble Heritage project team <http://heritage.stsci.edu/>



Figure 16- Images of Saturn, NASA and the Hubble Heritage Team.

Sources:

- Alexander, A.F.O'D. (1962). The planet Saturn: a history of observation, theory, and discovery. Macmillan, New York.
- The Rings of Saturn. <https://caps.gsfc.nasa.gov/simpson/kingswood/rings/>
- The Encke Minima and Encke Division in Saturn's A-Ring. <http://ejamison.net/encke.html>
- The discovery of Encke division in Saturn's A Ring. <http://www.astrotest.it/historical-notes/the-discovery-of-encke-division-in-saturns-a-ring/>