Beyond the Dawes Limit: Observing Saturn's Ring Divisions

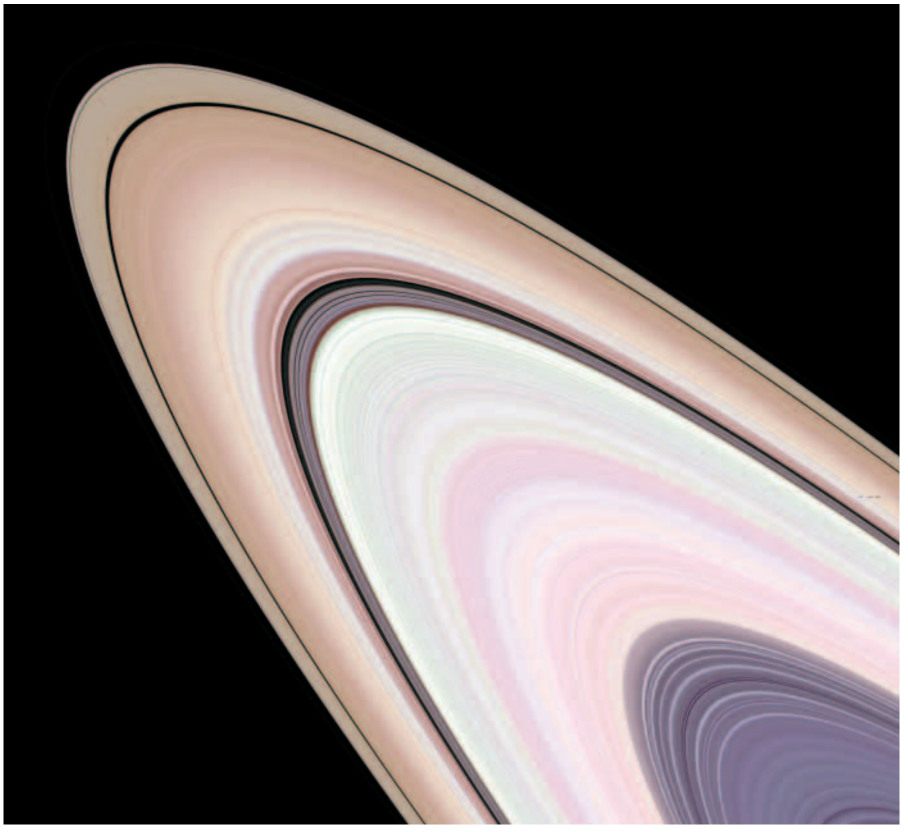
In theory it can't be done, yet under optimal seeing conditions you might discern delicate ring structures through surprisingly small telescopes. | **By Thomas Dobbins and William Sheehan**

A century ago a heated debate was raging about the network of canals crisscrossing the globe of Mars, first reported by the Italian astronomer Giovanni Schiaparelli in 1877. Percival Lowell, the most fervent and eloquent advocate that the canals were real and not some sort of optical illusion, described them as "little gossamer filaments only . . . but threads to draw your mind across the millions of miles of intervening void."

One of the arguments advanced by skeptics was that the canals — at least in the form of the exceedingly fine lines described by Lowell — were far too narrow to be resolved by his telescope. Some cited the oft-quoted Dawes limit, which states that the resolving power of a telescope in arcseconds can be calculated by dividing 4.56 by the telescope's aperture expressed in inches. This empirical formula was derived in the 1860s by a keen-eyed British amateur, William Rutter Dawes, following an extensive series of observations of double stars of similar brightness through a variety of modest but optically excellent refractors.

Lowell and his allies countered that this was a case of comparing apples and oranges. Granted, the Dawes limit might be valid for point sources of light seen against a dark background (like double stars), but the eye's ability to resolve linear objects against a bright background is far greater. Lowell conducted experiments on the threshold visibility of telegraph wires with the naked eye and determined that they could be glimpsed when their apparent diameter was only 0.7 arcsecond — 1⁄30 the Dawes limit. The Harvard astronomer William H. Pickering found that he could detect a human hair through an 11-inch telescope at a distance of nearly a quarter mile, when its apparent width was reduced to only 0.03 arcsecond — 1⁄14 the Dawes limit — even when handicapped by moderate atmospheric turbulence.

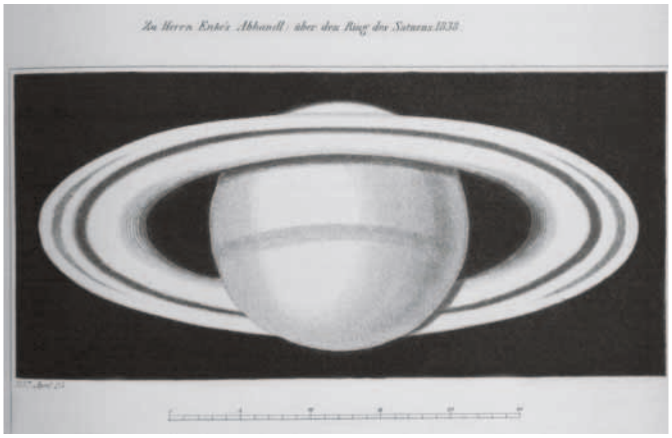
So it turns out that had there actually been canals on Mars, they could have been resolved through surprisingly modest telescopes. And there are very real "little gossamer filaments" to be seen elsewhere in the solar system — the divisions in the rings of Saturn. Like the Martian canals, the reality of many of these elusive features was the subject of controversy for many years. Right now, with Saturn riding high in the sky and the rings tilted open as much as 24°, backyard astronomers are challenged to coax the utmost in resolution from their telescopes.

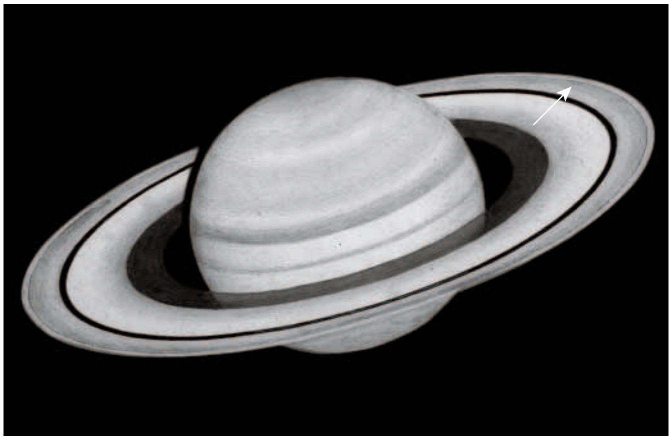


This spectacular false-color image of Saturn's ring system was created by A. Tayfun Oner using images snapped by Voyager 2 on August 23, 1981. Several of the lesser-known dark ring divisions seen here are within reach of ordinary amateur telescopes.

The Cassini Division

Discovered by Gian Domenico Cassini in 1675 with an unwieldy nonachromatic refractor of about 2.5 inches aperture and a focal length of 20 feet that magnified 90×, the most prominent division in the rings is 4,700 kilometers wide. At the mean opposition distance of Saturn, it subtends a span of only 0.7 arcsecond, so Cassini managed to achieve a 2.6-fold improvement over the Dawes limit.





Left: **This 1837 drawing of the rings of Saturn by Johann Franz Encke depicts the broad, dusky feature in the middle of ring A that he saw through Berlin Observatory's 9.6-inch Fraunhofer refractor, the telescope used to discover the planet Neptune nine years later. Note the closely spaced divisions that he recorded near the inner edge of ring B. From *Mathematische Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin,* 1838. *Right:* James Keeler's drawing of Saturn through the 36-inch Lick refractor shows the hairline void (arrowed) that now bears the name Encke Division. Exhibited at the Chicago World's Fair in 1893, today this famous rendering hangs in the foyer of Allegheny Observatory in Pittsburgh, where Keeler served as director from 1891 to 1898.**

Cassini's instrument was one of the monster "aerial" telescopes for which the 17th century was notorious. Despite its small aperture, its very long focal length no doubt made the telescope difficult to use for protracted observations. Nevertheless, its optical quality must have been far better than is generally assumed.

Nebraska amateur David Knisely has found that it is difficult to surpass Cassini's feat, even with modern telescopes. Curious about the minimum aperture required to discern the Cassini Division, on a night of steady seeing Knisely experimented with a series of off-axis aperture stops fitted over the tube of his 10-inch Newtonian reflector. Holding the magnification constant at 141×, he gradually reduced the aperture in 10-millimeter increments from 80 mm to 50 mm. With a 60-mm (2.4-inch) aperture, he could detect the Cassini Division only in the ansae (tips) of the rings, but with the aperture reduced to 50 mm he could no longer make it out with certainty.

In 1851 William Stephen Jacob, while observing in India, reported that the Cassini Division appeared slate-colored through Madras Observatory's 6.2-inch refractor at 365×, and that he was able to trace the jet-black shadow cast across it by Saturn's globe. A half century later the French astronomer Camille Flammarion found that during moments of very steady seeing his 10.2-inch refractor showed the Cassini Division as dark gray, causing him to speculate that "there is probably some matter in it." This surmise was verified by Pioneer 11 in 1979. Then the Voyager spacecraft revealed the presence of narrow ringlets composed of 10-meter-diameter boulders of dirty ice revolving within the Cassini Division. These difficult and varied observations are well worth attempting to repeat in the weeks before and after opposition when the shadow of the globe is prominent.

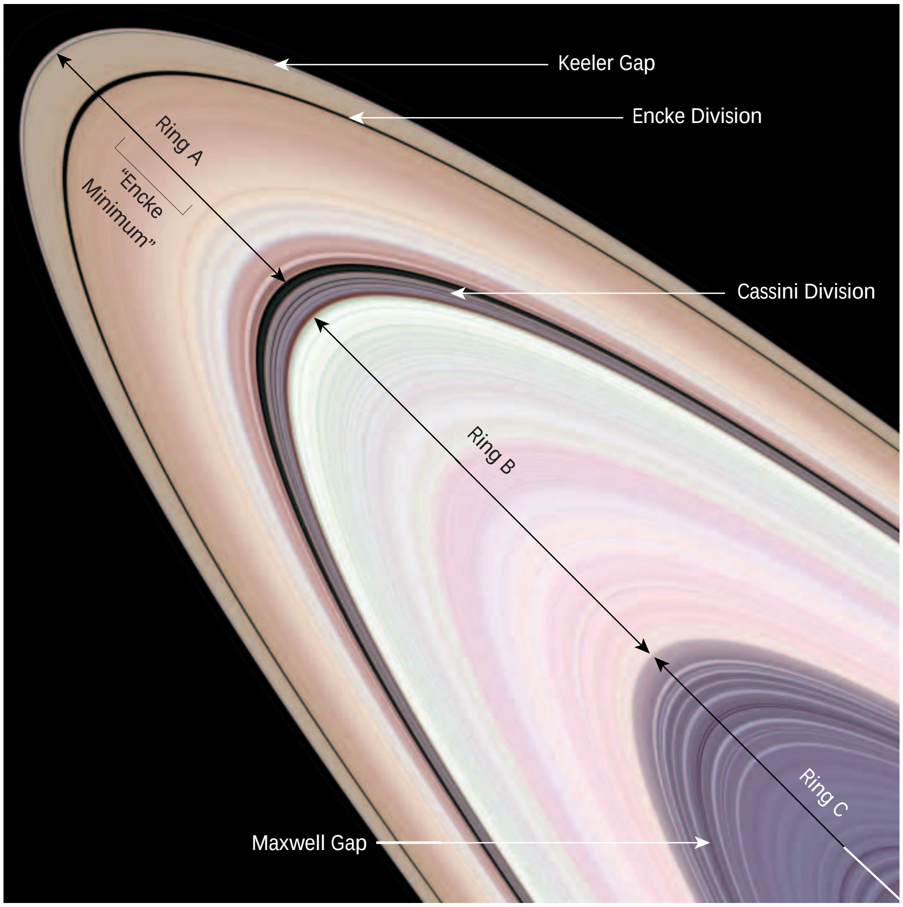
Confusing Nomenclature

Known as ring A in modern parlance, the ring exterior to the Cassini Division is 14,600 kilometers wide and has a steel gray hue reminiscent of the bluing on a rifle barrel. As early as the middle of the 18th century, the Scottish optician James Short thought he saw ring A divided by several dark lines, but no other observer could confirm his suspicion until well into the following century. In 1823 the Belgian astronomer Lambert Adolphe Quetelet was able to see the outer ring "divided in two" through a 10-inch refractor at Paris Observatory. Two years later, the British amateur Henry Kater's 6-inch Newtonian reflector at a magnification of 280× revealed three "dark divisions, extremely close, one stronger than the rest dividing the ring about equally," flanked by narrower divisions on either side, one of which was close to the outer edge of the ring. Kater never again succeeded in catching more than uncertain glimpses of these delicate markings and concluded that they were probably not permanent features.

In 1837 Johann Franz Encke, director of Berlin Observatory, repeatedly saw a broad, low-contrast marking in the middle of ring A through the observatory's 9.6-inch Fraunhofer refractor, and he was even able to measure the position of the feature with a filar micrometer. The inner boundary was located about one-third of the distance from the outer edge of the Cassini Division to the outer edge of ring A.

Dawes was one of the first observers to confirm the feature reported by Encke. Observing with a 9-inch Newtonian reflector owned by his friend William Lassell on a hazy but exquisitely steady night in September 1843, Dawes found "the outline of the planet was very hard and sharply defined with power 450," affording "by far the finest view of Saturn that I was ever favored with." The dark division was "pretty obvious." He estimated its width as one-third that of the Cassini Division and its location as "rather outside the middle" of ring A.

Observing from Malta with a 24-inch reflector nine years later, Lassell also saw ring A much as Encke had depicted it: "No division, properly so called . . . but there was an evident shade in the middle of its breadth and occupying about one-third of it." At the close of the 19th century the renowned planetary observer Eugène M. Antoniadi characterized the division as "a zone of a rarefication of particles" and took pains to depict it as a diffuse shading. This appearance is within the grasp of a first-rate 5-inch telescope on a very steady night and should



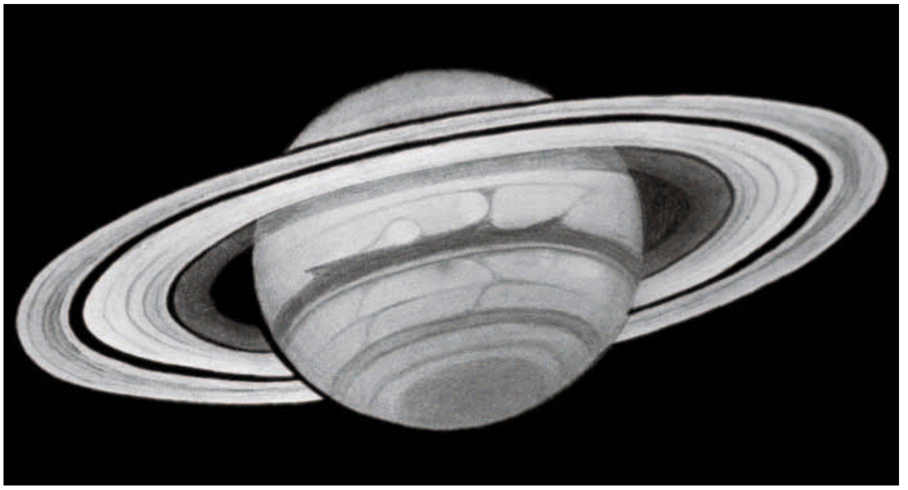
The principal components of Saturn's ring system are shown in this illustration based on Voyager images. The narrow gap in ring A that was described by Keeler has been named for Encke, and the broad, diffuse shading that Encke actually saw is now informally referred to as the "Encke Minimum." Note the four ringlets within the Cassini Division, each measuring about 500 kilometers across.

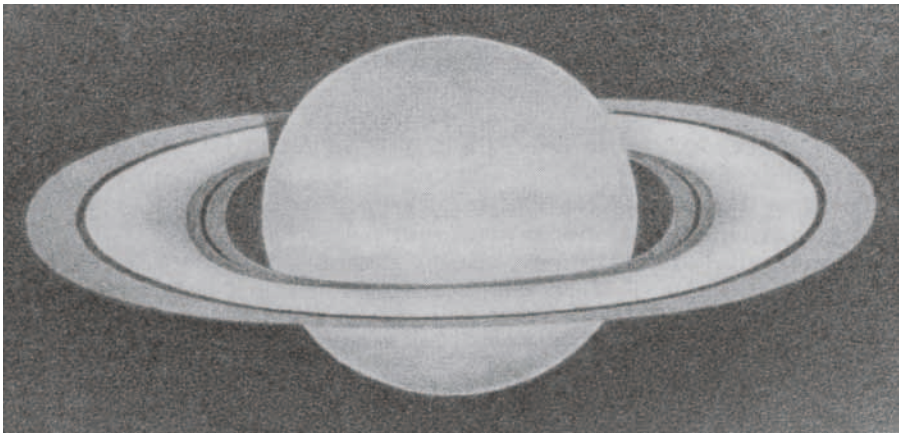
prove fairly easy through a decent 8-inch instrument. The key is to use a sufficiently high magnification; even the eagle-eyed Dawes remarked that he was hard-pressed to see it at less than 323×.

In 1850 Dawes reported a further division in ring A, but this one was "extremely narrow" and situated near the ring's outer edge. It was reminiscent of one of the features glimpsed by Kater in 1823. Confirmation of this division came on January 7, 1888, the night of first light through the Lick Observatory's new 36-inch Clark refractor. As luck would have it, the seeing was superb, permitting crisply defined views even at 1,000×. Studying the image carefully, James Keeler was able to discern a very narrow black line beyond the outer edge of Encke's fuzzy shading. He described it as "a mere spider's thread" and estimated its position as "a little less than one-fifth of the width of the [A] ring from its outer edge." Keeler's colleague Edward Emerson Barnard estimated the feature's width as only 1⁄50 that of the Cassini Division.

Far more challenging than the feature described and measured by Encke, this division has been spotted by quite a few amateurs through 10-inch and larger telescopes, and the fact that Dawes made it out with a 6.3-inch refractor certainly lends credence to modern claims that it can be glimpsed through similar apertures under ideal conditions. Once again, sufficiently high magnifications (400× or more) are necessary. At most observing sites the use of such high magnifications requires keeping long vigils at the eyepiece, waiting patiently for those fleeting moments when the atmosphere steadies for a second or two and delicate planetary markings flash out in what Percival Lowell so aptly described as "revelation peeps."

When the feature glimpsed by Dawes and unambiguously described by Keeler was imaged by the Voyager spacecraft, it proved to be a 325-km-wide gap located precisely where Keeler had estimated its position. By then astronomers had fallen





Top: **This exceptionally detailed drawing of Saturn's rings was made by Charles Giffen on June 14, 1962, with the 15.6-inch Clark refractor at the University of Wisconsin's Washburn Observatory at powers of 423× to 705×. Note the impression of multiple divisions within both the A and B rings.** ***Bottom:*** **Compare the C ring in Giffen's drawing with its aspect in this 1851 sketch by the elder Otto Struve. The dark feature coincides precisely with the location of the Maxwell Gap.**

into the habit of calling this the Encke Gap. Belatedly, they came to appreciate not only that it was Keeler who made the first definitive observation of this feature but also that Encke never saw it! (The feature that Encke actually did see is now often referred to as the "Encke Minimum" to distinguish it from an actual gap.) Despite a very persuasive attempt by astronomers Donald Osterbrock and Dale Cruikshank to correct the error (see "Keeler's Gap in Saturn's A Ring," *Sky & Telescope*, August 1982, page 123), the International Astronomical Union officially adopted the flawed nomenclature. Adding insult to injury, the name Keeler Gap has been assigned to a division only 35 km wide located 270 km inside the outer edge of ring A — a feature that Keeler never saw and that is beyond the grasp of any ground-based telescope. The result is a hopeless muddle that is utterly inconsistent with the extensive historical record.

Rings Within Rings

Even through a 4-inch telescope it is obvious that the brightness of the 25,500-km-wide ring B is not uniform. Just inside the Cassini Division its brilliant outer portion is snowy white, while the dusky inner regions appear tawny or beige and have been likened to the color of raw wool.

The 19th-century Jesuit astronomer Angelo Secchi saw this gradual diminution in brightness in the form of "steplike concentric bands of shading" through the 9-inch refractor of the College of Rome. With a 7.5-inch Clark refractor, Dawes found ring B "decidedly in stripes . . . about one-fifth of its breadth from the outer edge very bright; then a lightly shaded narrow stripe; then a lighter stripe; next a considerably darker stripe, then a much darker one extending nearly to the interior edge." His friend Lassell compared these concentric and deepening bands of shade to the steps of an amphitheater and related that "during some rare glimpses" the dusky innermost band "appeared to me as if it were constructed in narrow concentric circles."

On October 20, 1851, Charles W. Tuttle enjoyed a truly remarkable view of Saturn through the 15-inch refractor at Harvard College Observatory at 861×. Ring B was "minutely subdivided into a great number of narrow rings" that commenced close to its inner edge. "The divisions were not unlike a series of waves," he later recalled, "the depressions corresponding to the spaces between the rings, while the summits represented the narrow bright rings themselves." Five years later, his colleague Sidney Coolidge noted four or five divisions on ring B "giving its shaded part a wavy appearance." It is this innermost region of ring B that should be carefully scrutinized at the highest magnification the seeing will bear.

Ring C was independently discovered in November 1850 by Dawes in England and by William Cranch Bond and his son, George, at Harvard College Observatory ("Saturn's Enigmatic Crepe Ring," *S&T*, September 1998, page 116). Within days the elder Bond suspected the presence of a division separating the outer edge of the faint new ring from the inner edge of the bright B ring. Dawes detected this feature during the following January. It was independently rediscovered in 1887 by the Belgian astronomer François Terby and in 1897 by the eccentric (and not entirely trustworthy) Serbian astronomer Leo Brenner, who christened it the "Manora Division" after his wife.

However, the Voyagers found a rather different situation. A distinct clearing does exist, but it is less than 300 km wide and located some 4,500 km inside the B-C boundary. This feature has been named the Maxwell Gap in honor of James Clerk Maxwell, who demonstrated in 1857 that the rings of Saturn must be composed of countless tiny satellites. The gap's narrowness, combined with the low surface brightness of ring C, make it challenging if not impossible to spot. Nevertheless, it may have been glimpsed in 1851 by the elder Otto Struve, using the 15-inch refractor of Pulkovo Observatory. Conversely, as noted, a gap was discerned right at the B-C boundary by Dawes and Brenner with 6.3- and 7-inch refractors, respectively, and by Terby using an 8-inch Newtonian reflector.

An Observing Tip from a Master

These century-and-a-half-old eyepiece impressions are remarkably accurate in the light of the images provided by the Voyager encounters of 1980–81. Yet, despite the many descriptions of minor divisions in the rings of Saturn by a host of skilled observers, at the dawn of the Space Age the very existence of these features was still widely questioned. In 1954 the eminent planetary observer Gerard Kuiper carefully examined Saturn through the 200-inch Palomar reflector at a magnification of 1,170× on a "nearly perfect night." He reported that the Cassini Division was the only genuine gap in the ring system; all the other reported divisions were either mere "intensity ripples" that coincided with abrupt boundaries of shading or were simply nonexistent. Kuiper's status as a leading professional, combined with his use of what was then the world's largest telescope, resulted in many accepting his pronouncement as authoritative until the Voyager space probes revealed the presence of literally thousands of "phonograph groove" gaps and ringlets.

How was Kuiper deceived? The French astronomer Audouin Dollfus has made a convincing case that the key lies in the timing of Kuiper's observation, only days from the date of opposition. The rings appear to brighten dramatically at this time because ring particles appear to cover the shadows they cast on more distant particles. Dollfus notes that this surge in brightness is disproportionately pronounced in the tenuous regions of the rings, so it is accompanied by a reduction in their contrast with their surroundings. Surprisingly, the best opportunities to observe delicate details in Saturn's rings occur at least several weeks before and after the date of opposition, not when the planet is at its closest. During the 2000–01 apparition, Saturn reaches opposition on November 19th, so the best times to search for these minor ring divisions occur in October and from mid-December onward. Under steady seeing conditions, you may be rewarded by glimpses of features first seen by some of the giants of visual astronomy.

Thomas Dobbins *and* William Sheehan *are accomplished authors who combine a detailed knowledge of the history of observational astronomy with decades of experience at the eyepiece. Their most recent article, "Mesmerized by Mercury," appeared in the June issue.*