DOUBLE SUPPLEMENT: SATURN AND THE SOLAR SYSTEM

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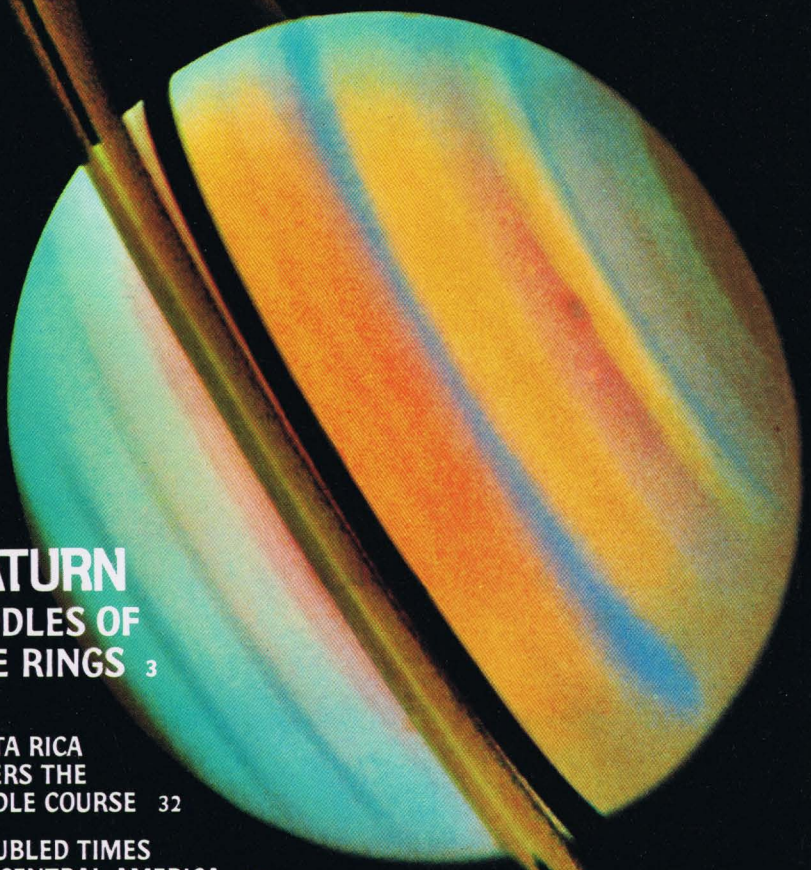

SATURN
RIDDLES OF THE RINGS 3

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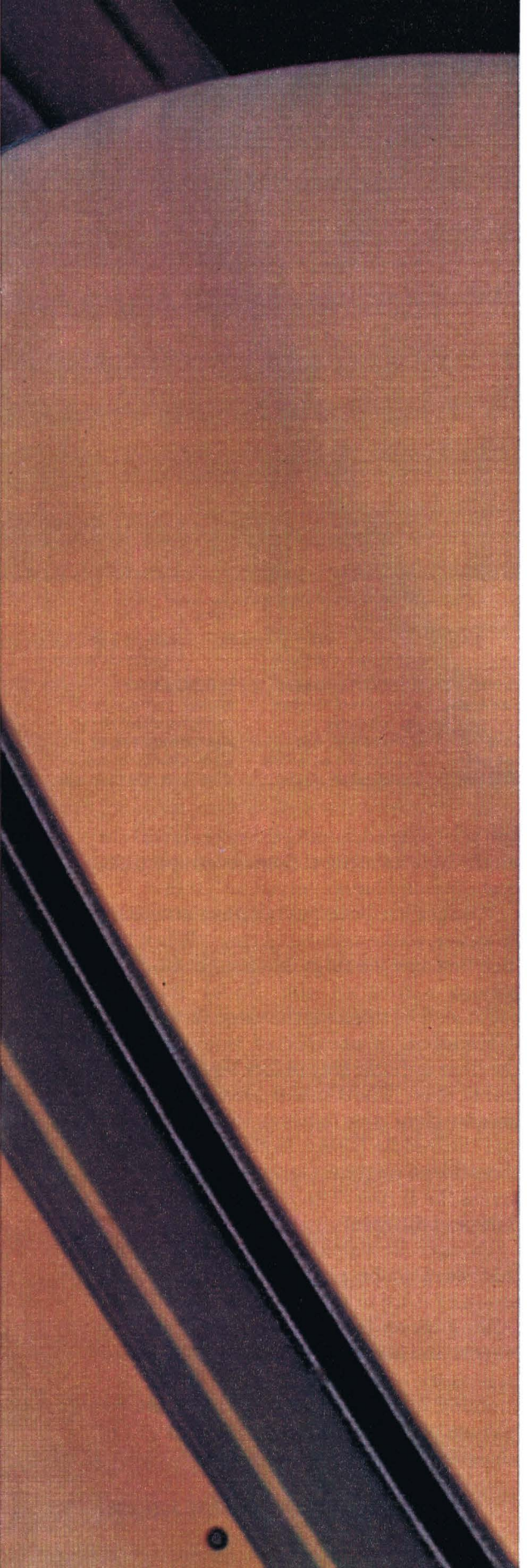
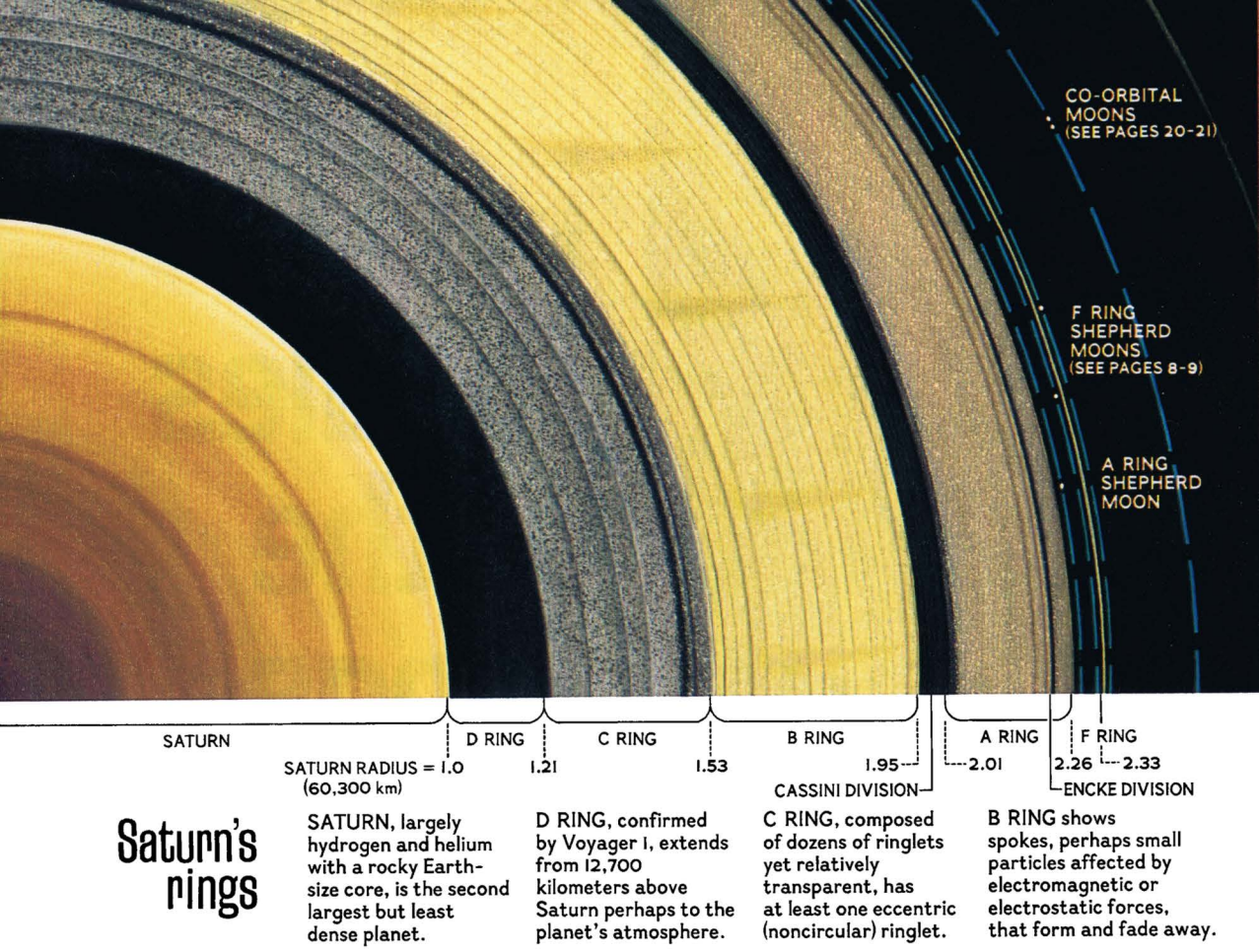


VOYAGER 1 AT SATURN

Riddles of the Rings

Still 13 million kilometers away, Voyager 1 takes a portrait of Saturn and two of its moons, one casting its shadow on the cloud tops below the rings. Shortly, Voyager would find the bizarre reality—puzzles in the rings and enigmas on the moons. With worlds yet to reveal, the unmanned Voyager spacecraft have proved themselves instruments of wonder on the frontier that forever recedes.

By RICK GORE
NATIONAL GEOGRAPHIC SENIOR WRITER
Photographs by NASA



Saturn's rings

SATURN, largely hydrogen and helium with a rocky Earth-size core, is the second largest but least dense planet.

D RING, confirmed by Voyager 1, extends from 12,700 kilometers above Saturn perhaps to the planet's atmosphere.

C RING, composed of dozens of ringlets yet relatively transparent, has at least one eccentric (noncircular) ringlet.

B RING shows spokes, perhaps small particles affected by electromagnetic or electrostatic forces, that form and fade away.

NOVEMBER 10, 1980. The Voyager 1 spacecraft is a billion miles and more than three years from home. Deep in the outer solar system, it is rapidly approaching Saturn. In this super-cold, alien domain, where perpetual ring glow has banished night, Voyager is photographing a pale yellow giant, a turbulent ball of primordial gas that more resembles a star than the inner planets we know.

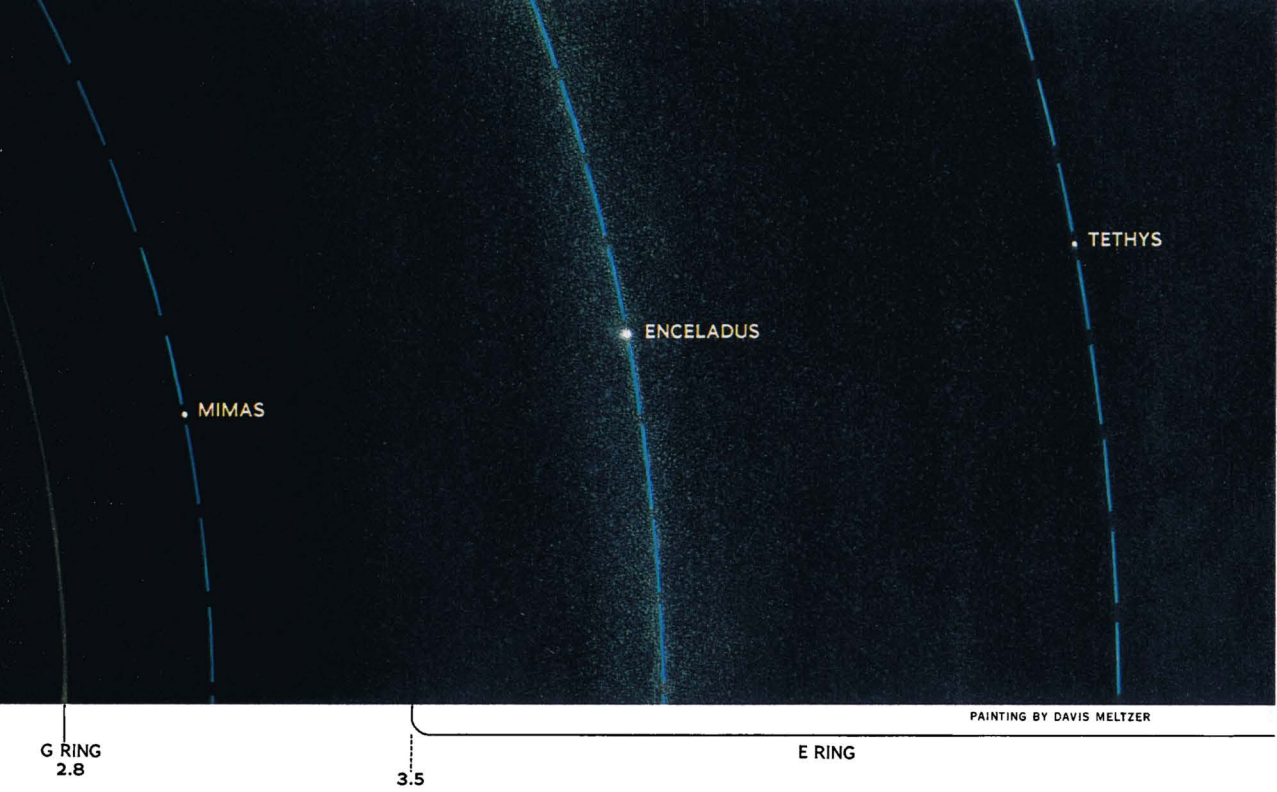
In two days Voyager will fly within 50,000 kilometers (30,000 miles) of those three bright rings that astronomers refer to simply as A, B, and C. It will explore the faint, recently discovered outer rings, E and F, and try to confirm sightings of a tenuous D ring close to the surface of the planet.

Voyager is also ready to unveil Saturn's moons, which range from the size of a small asteroid to mammoth Titan, larger than the planet Mercury. Most of the 15 known are mid-size—200 to 1,500 kilometers across—and made not from sand and stone and ores but from the icy stuff of comets. Big, mysterious Titan is known to have an atmosphere, and scientists are hoping that clouds will not totally hide its surface. Some even speculate that life could have evolved on Titan.

Voyager has been paying most attention, however, to the celebrated rings. When Galileo first saw the rings, he thought God was playing a trick on him. Today scientists could well be thinking the same thing.

Hundreds of unexpected ringlets within the rings are emerging before Voyager's electronic eyes. The Cassini Division, a supposedly clear zone between the outer A ring and the middle B ring, is alive with at least three dozen ringlets. Curious spokes radiate across the B ring. The close-in C ring looks dark and different.

Voyager is watching two small moons that seem to be playing tag as they race around Saturn in almost the same orbit. The trailing moon is traveling faster than the leader, and should catch up with the leader in January 1982 (pages 20-21). The two presumably have been playing this game for billions of years. Through what sleight of physics do they avoid colliding?



CASSINI DIVISION is seen from Earth as an empty space; it contains several evenly spaced bands of ringlets.

A RING has at its outer boundary a newly discovered moon.

F RING, bounded by shepherd moons, has an eccentric shape and irregular pattern; two of its strands appear intertwined.

G RING, narrow and diffuse, probably is accounted for by gravitational forces of undiscovered shepherd moons.

E RING is a broad, diffuse band of small particles that may be fed by material escaping from Enceladus.

Voyager has also spotted three "shepherd moons." Two of these moons orbit along the inner and outer edges of the F ring (pages 8-9), which wreathes the three bright main rings like a ribbon. Using odd gravitational tricks, these moons herd back in bounds particles trying to escape the F ring.

These F ring moons, along with a third little moon just 800 kilometers outside the bright A ring, seem to be shepherding the entire main ring system. These unimpressive chunks of ice apparently hold in place countless trillions of ring particles, spanning 63,000 kilometers.

AN AURA OF ASTONISHMENT pervades the Jet Propulsion Laboratory in Pasadena, California. Twenty months earlier this same Voyager had discovered so many marvels at Jupiter—a complex, storm-tossed atmosphere, a thin ring, volcanism on one moon, and evidence of ancient Earth-like crustal movements on another—that its Saturn encounter had threatened to be anticlimactic.*

"We were afraid Voyager's Saturn encounter was going to be a bust," one project scientist confides.

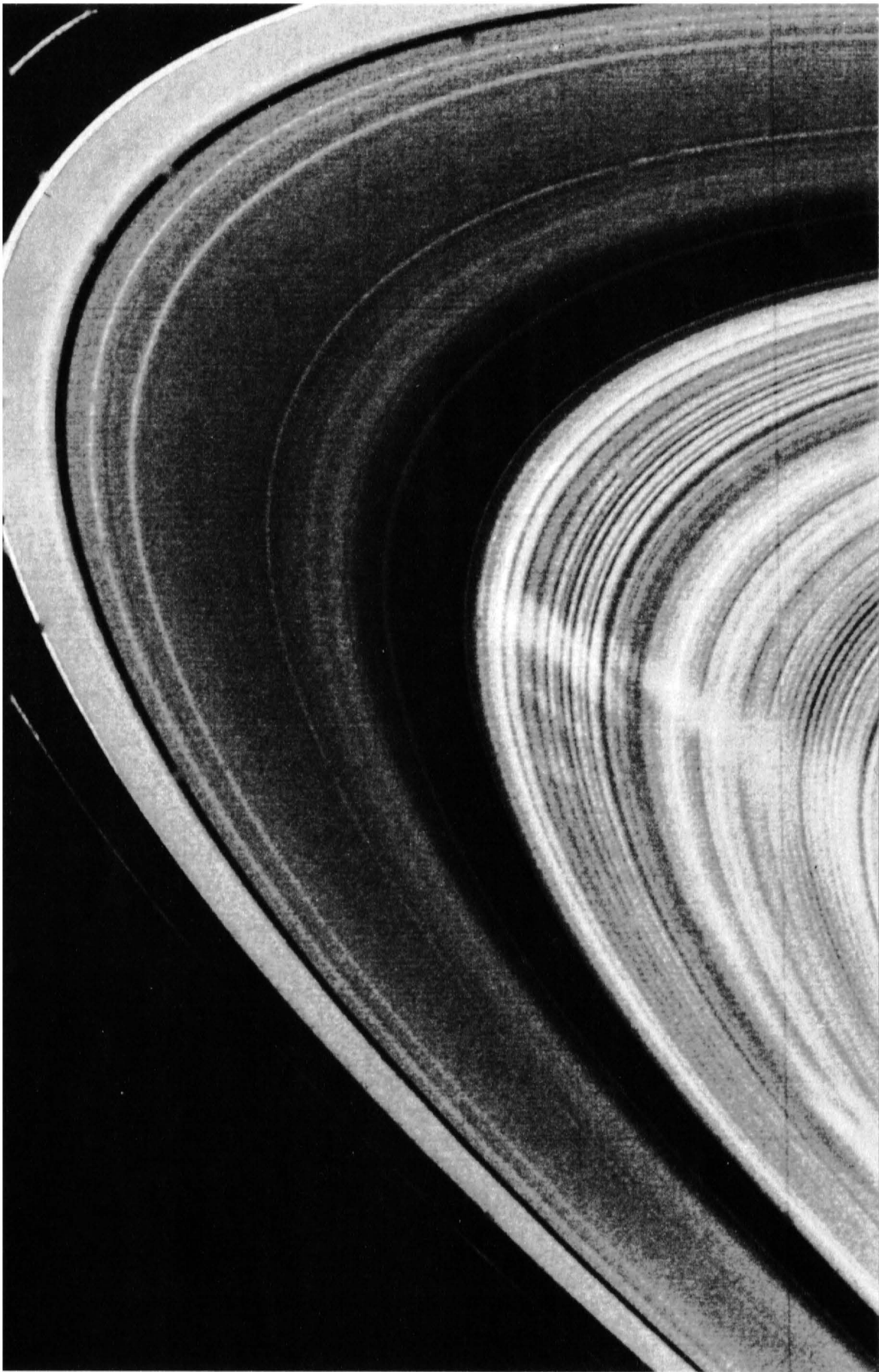
But Saturn is *not* a bust. The JPL pressroom teems with reporters—far more than came for the Jupiter encounter. This space mission has clearly excited the public. Why? For one thing, the flawless performance of this little-spacecraft-that-could is a national pride. Space exploration is something the United States is very good at.

Then again, the pictures coming across the monitors speak directly to the imagination. Not fiery, chaotic, and psychedelic like those of Jupiter, they look cool, ethereal, and from a distance orderly enough to have been drawn with a celestial compass.

"Saturn *is* astronomy to many people," notes Reta Beebe, a mission scientist. "Through even a small telescope, it's the most beautiful thing in the sky."

Right now, to Brad Smith, the leader of Voyager's *(Continued on page 10)*

*The author described what Voyager saw in Jupiter's dazzling realm in the January 1980 GEOGRAPHIC.



The rings: spoked, tilted, and eccentric

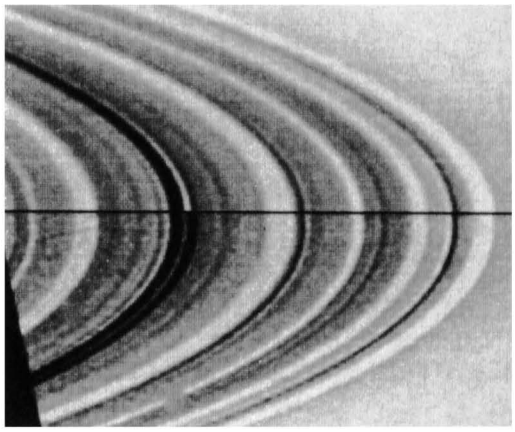
*CAROUSEL OF TRILLIONS of particles from smaller than dust to larger than cathedrals courses around Saturn as its ring system. Voyager 1 found it to be full of structure and puzzles—such as spokes, one seen as a light streak (**left**) across the bright B ring. Spokes may be very fine particles lifted out of the ring plane by electrostatic forces.*

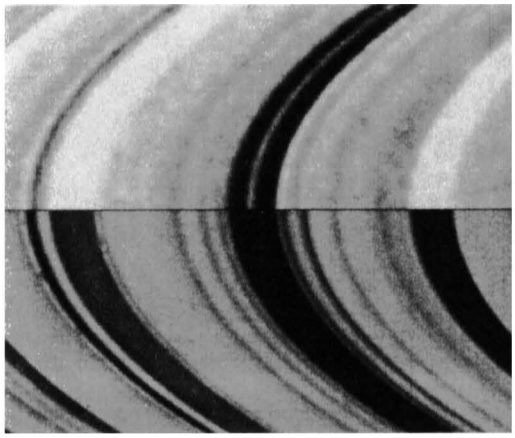
Seen farther out in the grayish part of the A ring are two bright, narrow ringlets close together. Between them is a faint ringlet that begins as white in the upper right-hand corner. When followed counterclockwise, the ringlet turns dark, perhaps because it is somewhat tilted out of the ring plane.

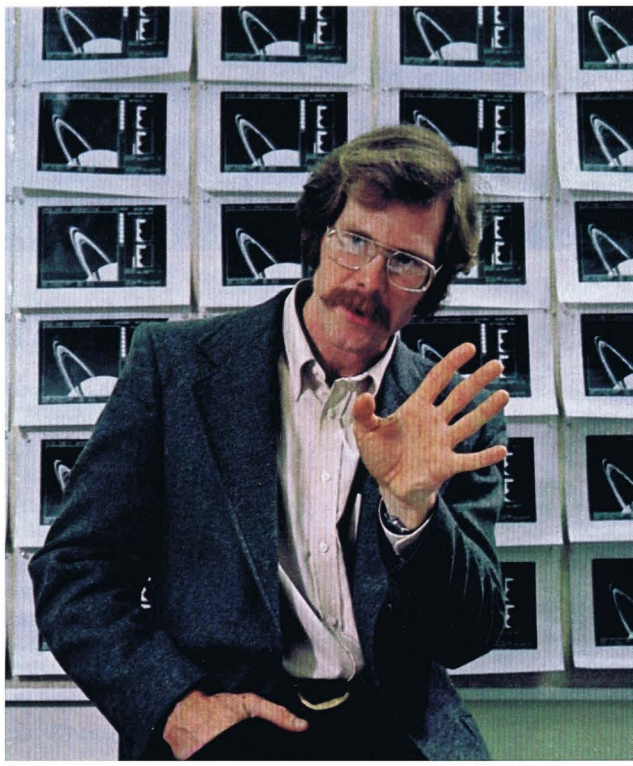
*The density of rings can be roughly determined by the play of light upon them. In this composite view (**right, middle**) the upper, or sunlit, half was taken as Voyager 1 approached. Regions thick with material reflect light and thus appear bright. Regions void of material appear dark. The lower, or shaded, half of the image was taken from beneath the rings. Regions that are bright both above and below indicate particles that reflect light, but also, because of low density, allow some light to pass through. Regions bright from above but dark below indicate density so great that no light can pass through. Regions dark both above and below are void of particles.*

*A composite image of two separate sections of the C ring (**right, top**) shows one ringlet whose track doesn't match up, thus establishing it as an eccentric (out-of-round) ringlet that varies in width. It may be subject to perturbation by small, embedded moonlets.*

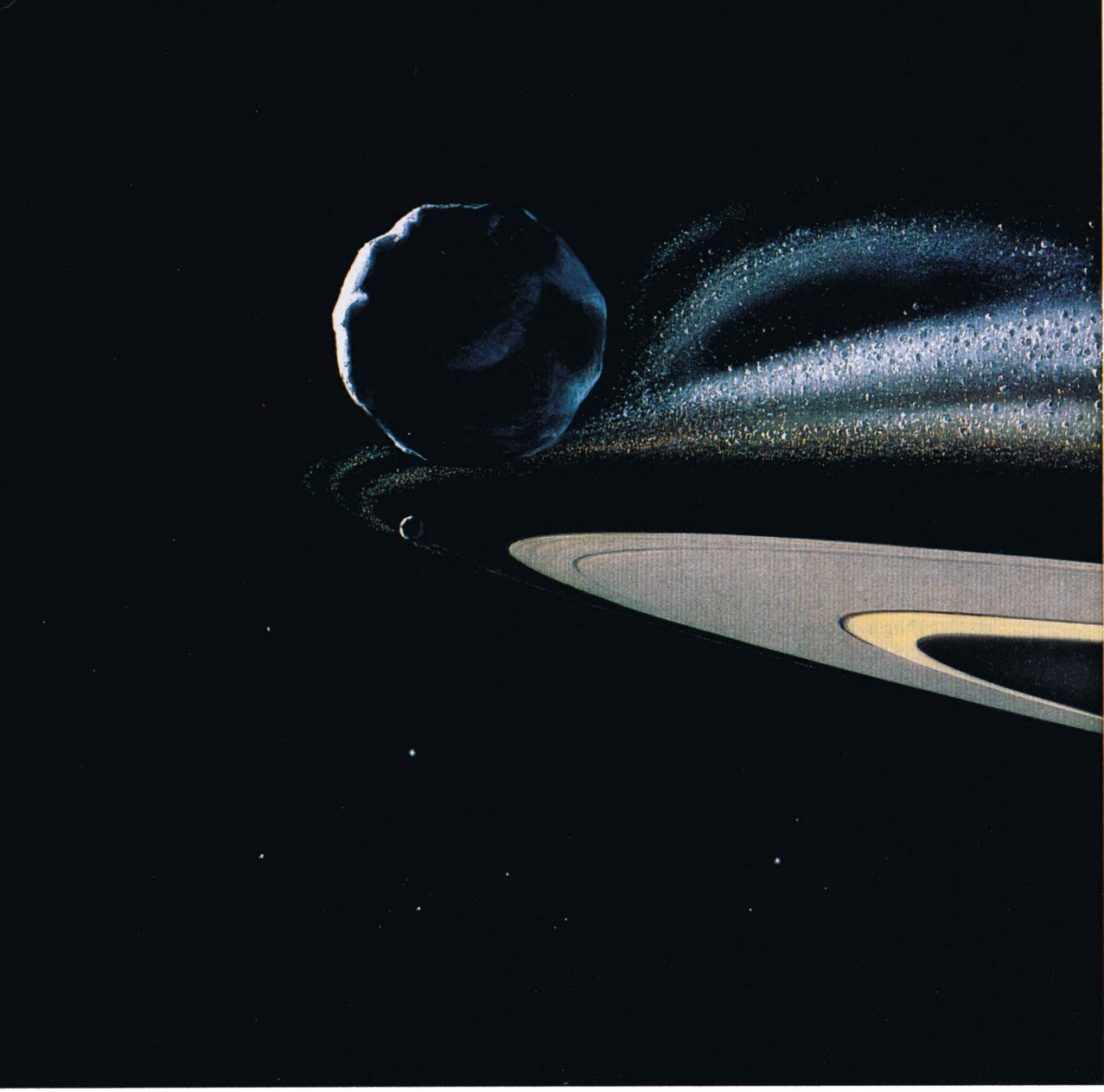
*The complex structure and features of the rings have turned out to be anything but obvious. As mission scientist Jeffrey Cuzzi (**right**) points out: "Understanding the structure is going to take a lot more work. It's not something that just clicks into place."*





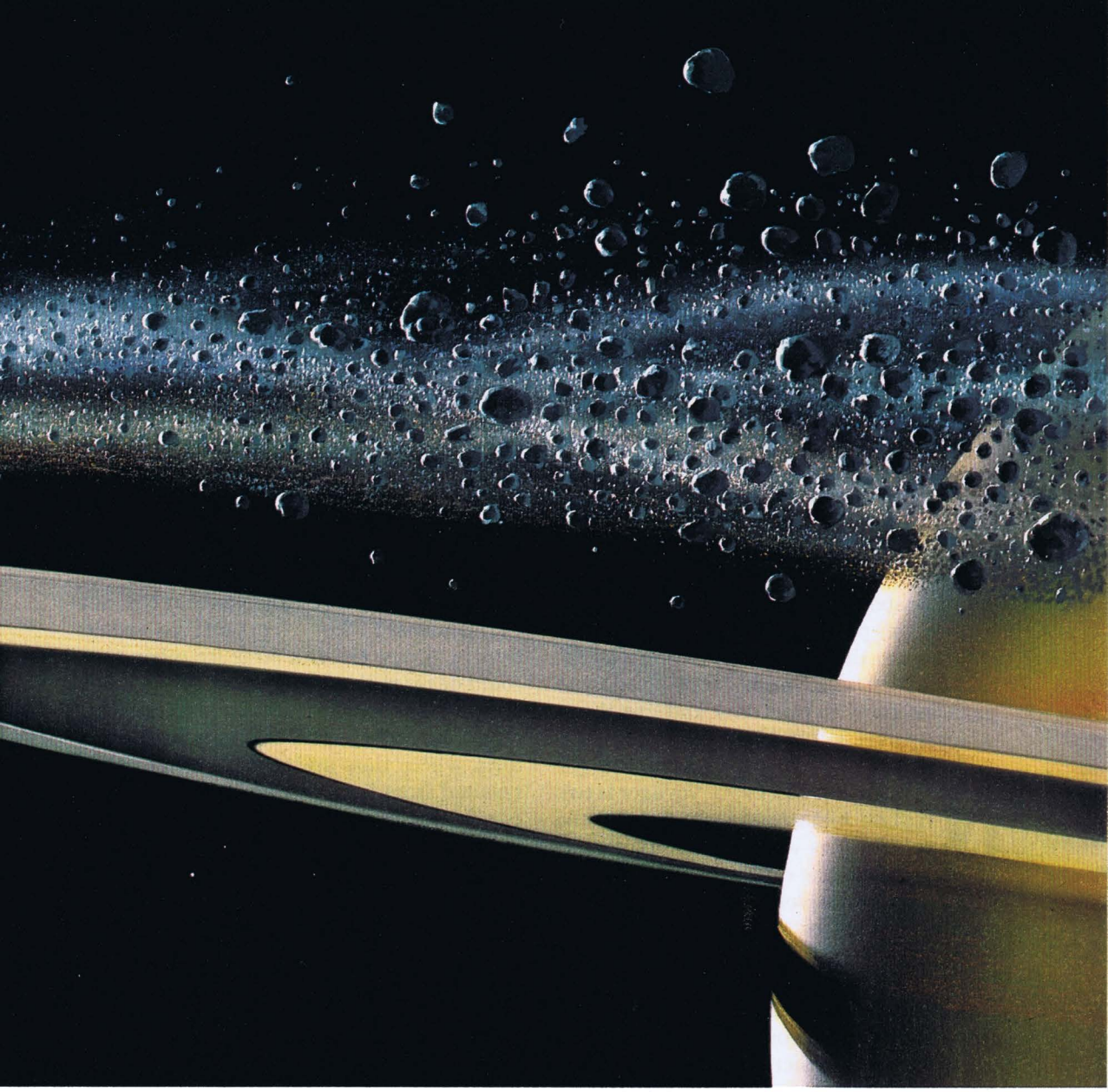


JAMES A. SUGAR

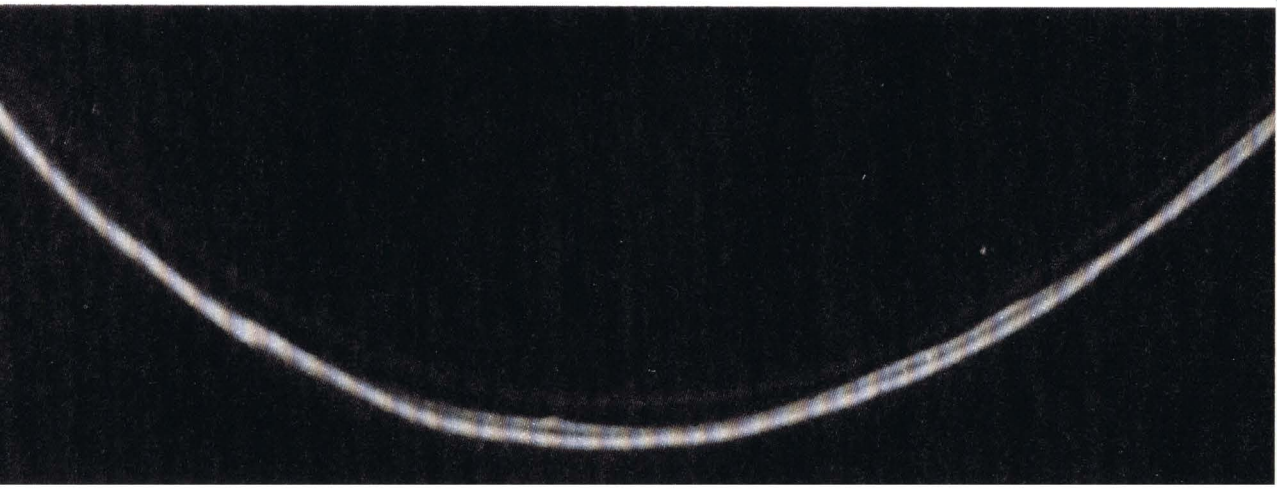


Shepherd moons

IF PACKED snowball fashion, about a fourth of Antarctica's ice could make up the two newly discovered shepherd moons ***(above)*** *that confine the diffuse and twisted F ring, many of whose particles are microscopic. As seen by Voyager 1* ***(right)****, two of its three strands appear intertwined and kinked, and its material gathered in clumps. Why is the ring so disorderly? The moons' gravity plays a major role, yet their gravity is so weak that astronauts could high jump a hundred meters on them. Both moons have eccentric orbits, as do the ring particles. The inner shepherd, rear, travels faster and repeatedly laps the outer, so the angles and intensities of gravitational pull keep changing. Electromagnetic forces may also play a role. In August 1981, Voyager 2 will take a more detailed look to try to unravel the mystery.*



PAINTING BY WILLIAM H. BOND, NATIONAL GEOGRAPHIC ART DIVISION



imaging team, Saturn is also the most bedeviling thing in the sky. Today he is most baffled by those odd spokes, or fingerlike projections, that are slightly darker than the rings themselves and that stretch across the B ring.

"We've never been confused for so long about anything so obvious," he says, swatting rolled-up paper against his palm. "It's just so damned frustrating professionally. We first saw them three weeks ago, and we still don't have any good ideas."

These spokes emerge from the shaded side of Saturn, sometimes in bursts of five or so, and revolve with the rings. Gradually they fade away. Theoretically each particle that makes up the spokes should behave like a mini-satellite. Those closer to Saturn should be moving much faster than those farther out. The spokes should tear apart. Yet they seem to stay perfectly aligned.

"How do they form in the first place?" asks the frustrated Smith. "How do all those particles know to turn dark and line themselves up over 25,000 kilometers?"

NOVEMBER 11, 1980. Voyager is two million kilometers from Saturn and tonight flies within 4,000 kilometers of Titan. More ring close-ups have come in. Life grows no simpler for Brad Smith.

"The mystery of the rings keeps getting deeper and deeper, until we think it's a bottomless pit," he says at a press briefing. "The thing I least expected to see was an eccentric ring—and we have found two."

He flashes on a picture of one ringlet dramatically fatter on one side of Saturn than on the other (page 7).

Odd things too are happening out at the thin F ring, the one being shepherded by two little moons. Voyager images now show clumps in the F ring. Could these clumps be satellites trying to form? Are they moonlets being eroded? Do gravitational forces from the shepherding satellites focus ring material into odd-shaped regions? The mission scientists are clearly thinking on their feet.

The F ring is close to what astrophysicists call the Roche limit. Inside this limit the gravitational pull from huge Saturn should keep large satellites from forming.

The Roche limit helps explain why Saturn has rings. Most scientists believe that more than 4.6 billion years ago, when Saturn was forming out of the solar nebula, it was much larger. It collapsed suddenly, then began spinning so rapidly that some of its gases and dust were left in a flat disk around its equator. Hot, young Saturn kept this disk much warmer than the minus 185°C (–300°F) temperatures in the rings today. Heavier materials such as metals and silicates either coalesced into Saturn's forming moons or swirled inward to form its deeply buried Earth-size core, which may be molten.

As the planet shrank further, it cooled, as did the ring region. The water vapor that was left there froze, says a leading theorist, Jim Pollack, and the resulting ice crystals gradually accreted into ring particles thought to be no more than a meter in diameter. At some point a phenomenal blast of solar wind blew away any gas that had not yet condensed. The ring particles would thus be the pieces of a large ice moon that could never pull itself together.

There has long been a competing view, however. Perhaps all those particles did not form where they are today. Perhaps they resulted from some catastrophe. The rings could actually be the end product of a moon, suggests mission geologist Gene Shoemaker. They could be a satellite smashed to pieces by another icy body. Or perhaps such a body, a traveling, homeless moon, was torn apart by Saturn's gravity.

However the rings formed, most astronomers believe they have been choreographed ever since by the laws of orbital mechanics, especially the process called resonance.

Through resonance the gravitational effects of Saturn's moons on parts of the rings are greatly magnified. For instance the moon Mimas and the inner edge of the Cassini Division are in resonance. Mimas takes exactly twice as long to orbit Saturn as do certain Cassini particles. This regularity means that these particles meet a slight gravitational tug from Mimas at precisely the same place every other orbit. Over time that extra tug stretches their circular orbits into ellipses. Eons ago Cassini particles thus started to crash into particles in adjacent orbits. Colliding particles were thrown into other parts of the rings. Gradually a large gap was swept out.

Before Voyager such resonances were