Space News Update
— April 2, 2019 —

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New findings have emerged about five tiny moons nestled in and near Saturn’s rings. The closest-ever flybys by NASA’s Cassini spacecraft reveal that the surfaces of these unusual moons are covered with material from the planet’s rings — and from icy particles blasting out of Saturn’s larger moon Enceladus. The work paints a picture of the competing processes shaping these mini-moons.

"The daring, close flybys of these odd little moons let us peer into how they interact with Saturn’s rings," said Bonnie Buratti of NASA’s Jet Propulsion Laboratory in Pasadena, California. Buratti led a team of 35 co-authors that published their work in the journal Science on March 28. "We’re seeing more evidence of how extremely active and dynamic the Saturn ring and moon system is."

The new research, from data gathered by six of Cassini’s instruments before its mission ended in 2017, is a clear confirmation that dust and ice from the rings accretes onto the moons embedded within and near the rings. Scientists also found the moon surfaces to be highly porous, further confirming that they were formed in multiple stages as ring material settled onto denser cores that might be remnants of a larger object that broke apart. The porosity also helps explain their shape: Rather than being spherical, they are blobby and ravioli-like, with material stuck around their equators.

"We found these moons are scooping up particles of ice and dust from the rings to form the little skirts around their equators," Buratti said. "A denser body would be more ball-shaped because gravity would pull the material in."

"Perhaps this process is going on throughout the rings, and the largest ring particles are also accreting ring material around them. Detailed views of these tiny ring moons may tell us more about the behavior of the ring particles themselves," said Cassini Project Scientist Linda Spilker, also at JPL.

Of the satellites studied, the surfaces of those closest to Saturn — Daphnis and Pan — are the most altered by ring materials. The surfaces of the moons Atlas, Prometheus and Pandora, farther out from Saturn, have ring material as well — but they’re also coated with the bright icy particles and water vapor from the plume spraying out of Enceladus.

This graphic shows the ring moons inspected by NASA’s Cassini spacecraft in super-close flybys. The rings and moons depicted are not to scale. Credits: NASA/JPL-Caltech
Enceladus. (A broad outer ring of Saturn, known as the E ring, is formed by the icy material that fans out from Enceladus’ plume.)

This montage of views from NASA’s Cassini spacecraft shows three of the small, ring moons inspected during close flybys: Atlas, Daphnis and Pan. They’re shown here at the same scale. Credits: NASA/JPL-Caltech/Space Science Institute

The key puzzle piece was a data set from Cassini’s Visible and Infrared Mapping Spectrometer (VIMS), which collected light visible to the human eye and also infrared light of longer wavelengths. It was the first time Cassini was close enough to create a spectral map of the surface of the innermost moon Pan. By analyzing the spectra, VIMS was able to learn about the composition of materials on all five moons.

VIMS saw that the ring moons closest to Saturn appear the reddest, similar to the color of the main rings. Scientists don’t yet know the exact composition of the material that appears red, but they believe it’s likely a mix of organics and iron.

The moons just outside the main rings, on the other hand, appear more blue, similar to the light from Enceladus’ icy plumes.

The six uber-close flybys of the ring moons, performed between December 2016 and April 2017, engaged all of Cassini’s optical remote sensing instruments that study the electromagnetic spectrum. They worked alongside the instruments that examined the dust, plasma and magnetic fields and how those elements interact with the moons.

Questions remain, including what triggered the moons to form. Scientists will use the new data to model scenarios and could apply the insights to small moons around other planets and possibly even to asteroids. "Do any of the moons of the ice giant planets Uranus and Neptune interact with their thinner rings to form features similar to those on Saturn's ring moons?" Buratti asked. "These are questions to be answered by future missions."

Cassini’s mission ended in September 2017, when it was low on fuel. Mission controllers deliberately plunged Cassini into Saturn’s atmosphere rather than risk crashing the spacecraft into the planet’s moons. More science from the last orbits, known as the Grand Finale, will be published in the coming months.

Source: NASA
2. Laser Blasts Show Asteroid Bombardment, Hydrogen Make Great Recipe for Life on Mars

A portion of the experimental setup Rafael Navarro-González, an astrobiologist at the Institute of Nuclear Sciences of the National Autonomous University of Mexico in Mexico City and a co-investigator with the SAM instrument, and his team of researchers used to simulate asteroid impacts in the early Martian atmosphere. The flask (center) contains a composition of carbon dioxide, nitrogen and hydrogen gases. A high-intensity infrared laser is focused into the flask from a lens (left), to simulate the high energy shockwaves produced by asteroids entering the Martian atmosphere. The gas is then evacuated from the flask and analyzed to determine the composition and levels of nitrogen fixation. Credits: Rafael Navarro-González

A new study reveals asteroid impacts on ancient Mars could have produced key ingredients for life if the Martian atmosphere was rich in hydrogen. An early hydrogen-rich atmosphere on Mars could also explain how the planet remained habitable after its atmosphere thinned. The study used data from NASA’s Curiosity rover on Mars and was conducted by researchers on Curiosity’s Sample Analysis at Mars (SAM) instrument team and international colleagues.

These key ingredients are nitrites (NO$_2^-$) and nitrates (NO$_3^-$), fixed forms of nitrogen that are important for the establishment and sustainability of life as we know it. Curiosity discovered them in soil and rock samples it took as it traversed within Gale Crater, the site of ancient lakes and groundwater systems on Mars.

To understand how fixed nitrogen may have been deposited in the crater, researchers needed to recreate the early Martian atmosphere here on Earth. The study, led by Dr. Rafael Navarro-González and his team of scientists at the Institute of Nuclear Sciences of the National Autonomous University of Mexico in Mexico City, used a combination of theoretical models and experimental data to investigate the role hydrogen plays in altering nitrogen into nitrites and nitrates using energy from asteroid impacts. The paper was published in January in the Journal of Geophysical Research: Planets.

In the lab, the group used infrared laser beam pulses to simulate the high-energy shockwaves created by asteroids slamming into the atmosphere. The pulses were focused into a flask containing mixtures of hydrogen, nitrogen and carbon dioxide gases, representing the early Martian atmosphere. After the laser
blasts, the resulting concoction was analyzed to determine the amount of nitrates formed. The results were surprising, to say the least.

“The big surprise was that the yield of nitrate increased when hydrogen was included in the laser-shocked experiments that simulated asteroid impacts,” said Navarro-González. “This was counter-intuitive as hydrogen leads to an oxygen-deficient environment while the formation of nitrate requires oxygen. However, the presence of hydrogen led to a faster cooling of the shock-heated gas, trapping nitric oxide, the precursor of nitrate, at elevated temperatures where its yield was higher.”

Although these experiments were conducted in a controlled lab environment millions of miles from the Red Planet, the researchers wanted to simulate the results obtained from Curiosity using the SAM instrument on the rover. SAM takes samples drilled from rock or scooped up from the surface by the rover’s mechanical arm and bakes them to look at the chemical fingerprints of the released gases.

“SAM on Curiosity was the first instrument to detect nitrate on Mars,” said Christopher McKay, a co-author of the paper at NASA’s Ames Research Center in California’s Silicon Valley. “Because of the low levels of nitrogen gas in the atmosphere, nitrate is the only biologically useful form of nitrogen on Mars. Thus, its presence in the soil is of major astrobiological significance. This paper helps us understand the possible sources of that nitrate.”

Why were the effects of hydrogen so fascinating? Although the surface of Mars is cold and inhospitable today, scientists think that a thicker atmosphere enriched in greenhouse gases such as carbon dioxide and water vapor may have warmed the planet in the past. Some climate models show that the addition of hydrogen in the atmosphere may have been necessary to raise temperatures enough to have liquid water at the surface.

“Having more hydrogen as a greenhouse gas in the atmosphere is interesting both for the sake of the climate history of Mars and for habitability,” said Jennifer Stern, a planetary geochemist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and one of the co-investigators of the study. “If you have a link between two things that are good for habitability – a potentially warmer climate with liquid water on the surface and an increase in the production of nitrates, which are necessary for life – it’s very exciting. The results of this study suggest that these two things, which are important for life, fit together and one enhances the presence of the other.”

Even though the composition of the early Martian atmosphere remains a mystery, these results may provide more pieces for solving this climate puzzle.

This self-portrait of NASA’s Curiosity Mars rover shows the vehicle on Vera Rubin Ridge in Gale crater on Mars. North is on the left and west is on the right, with Gale crater’s rim on the horizon of both edges. This mosaic was assembled from dozens of images taken by Curiosity’s Mars Hands Lens Imager (MAHLI). They were all taken on Jan. 23, 2018, during Sol 1943. Credits: NASA/JPL-Caltech/MSSS

Source: NASA
A small asteroid has been caught in the process of spinning so fast it’s throwing off material, according to new data from NASA’s Hubble Space Telescope and other observatories.

Images from Hubble show two narrow, comet-like tails of dusty debris streaming from the asteroid (6478) Gault. Each tail represents an episode in which the asteroid gently shed its material — key evidence that Gault is beginning to come apart.

Discovered in 1988, the 2.5-mile-wide (4-kilometer-wide) asteroid has been observed repeatedly, but the debris tails are the first evidence of disintegration. Gault is located 214 million miles (344 million kilometers) from the Sun. Of the roughly 800,000 known asteroids between Mars and Jupiter, astronomers estimate that this type of event in the asteroid belt is rare, occurring roughly once a year.

Watching an asteroid become unglued gives astronomers the opportunity to study the makeup of these space rocks without sending a spacecraft to sample them.

“We didn’t have to go to Gault,” explained Olivier Hainaut of the European Southern Observatory in Germany, a member of the Gault observing team. “We just had to look at the image of the streamers, and we can see all of the dust grains well-sorted by size. All the large grains (about the size of sand particles) are close to the object and the smallest grains (about the size of flour grains) are the farthest away because they are being pushed fastest by pressure from sunlight.”
Gault is only the second asteroid whose disintegration has been strongly linked to a process known as a YORP effect. (YORP stands for “Yarkovsky–O'Keefe–Radzievskii–Paddack,” the names of four scientists who contributed to the concept.) When sunlight heats an asteroid, infrared radiation escaping from its warmed surface carries off angular momentum as well as heat. This process creates a tiny torque that can cause the asteroid to continually spin faster. When the resulting centrifugal force starts to overcome gravity, the asteroid’s surface becomes unstable, and landslides may send dust and rubble drifting into space at a couple miles per hour, or the speed of a strolling human. The researchers estimate that Gault could have been slowly spinning up for more than 100 million years.

Piecing together Gault’s recent activity is an astronomical forensics investigation involving telescopes and astronomers around the world. All-sky surveys, ground-based telescopes, and space-based facilities like the Hubble Space Telescope pooled their efforts to make this discovery possible.

The initial clue was the fortuitous detection of the first debris tail, observed on Jan. 5, 2019, by the NASA-funded Asteroid Terrestrial-Impact Last Alert System (ATLAS) telescope in Hawaii. The tail also turned up in archival data from December 2018 from ATLAS and the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) telescopes in Hawaii. In mid-January, a second shorter tail was spied by the Canada–France–Hawaii Telescope in Hawaii and the Isaac Newton Telescope in Spain, as well as by other observers. An analysis of both tails suggests the two dust events occurred around Oct. 28 and Dec. 30, 2018.

Follow-up observations with the William Herschel Telescope and ESA’s (European Space Agency) Optical Ground Station in La Palma and Tenerife, Spain, and the Himalayan Chandra Telescope in India measured a two-hour rotation period for the object, close to the critical speed at which a loose “rubble-pile” asteroid begins to break up.

“Gault is the best ‘smoking gun’ example of a fast rotator right at the two-hour limit,” said team member Jan Kleyna of the University of Hawaii in Honolulu.

An analysis of the asteroid’s surrounding environment by Hubble revealed no signs of more widely distributed debris, which rules out the possibility of a collision with another asteroid causing the outbursts.

The asteroid’s narrow streamers suggest that the dust was released in short bursts, lasting anywhere from a few hours to a few days. These sudden events puffed away enough debris to make a “dirt ball” approximately 500 feet (150 meters) across if compacted together. The tails will begin fading away in a few months as the dust disperses into interplanetary space.

Based on observations by the Canada–France–Hawaii Telescope, the astronomers estimate that the longer tail stretches over half a million miles (800,000 kilometers) and is roughly 3,000 miles (4,800 kilometers) wide. The shorter tail is about a quarter as long.

Only a couple of dozen active asteroids have been found so far. Astronomers may now have the capability to detect many more of them because of the enhanced survey capabilities of observatories such as Pan-STARRS and ATLAS, which scan the entire sky. “Asteroids such as Gault cannot escape detection anymore,” Hainaut said. “That means that all these asteroids that start misbehaving get caught.”

The researchers hope to monitor Gault for more dust events.

The team’s results have been accepted for publication by The Astrophysical Journal Letters.
The Night Sky

**Tuesday, April 2**

- Bright Capella shines high in the northwest after dusk. Its pale-yellow color matches that of the Sun, meaning they're both about the same temperature. But otherwise Capella is very different. It consists of two yellow giant stars, larger and brighter than the Sun, orbiting each other every 104 days.

Moreover, for telescope users, it's accompanied by a distant, tight pair of red dwarfs: Capella H and L, magnitudes 10 and 13. [Article and finder charts](https://example.com).

**Wednesday, April 3**

- In this dark-of-the-Moon time, explore springtime galaxies for your small scope using a sky atlas and the Deep-Sky Wonders article in the April *Sky & Telescope*, page 54. And for much tougher dark-sky challenges, try for big, dim *galactic cirrus clouds* using the Going Deep article and charts on page 57.

**Thursday, April 4**

- This evening, you'll find that Mars is right on the line between Aldebaran and the Pleiades.

**Friday, April 5**

- Shortly after the end of twilight at this time of year, Arcturus, the bright Spring Star climbing in the east, stands just as high as Sirius, the brighter Winter Star descending in the southwest (for viewers at mid-northern latitudes).

These are the two brightest stars in the sky at the time. But Capella is a very close runner-up to Arcturus! Spot it high in the northwest.

- New Moon (exact at 3:50 a.m. on this date EDT).

**Saturday, April 6**

- The asteroid 2 Pallas is at opposition and detectable in good binoculars at magnitude 7.9, the same brightness as Neptune. It's only 4° from Arcturus tonight, on its way to passing very close by Eta Bootis on the evening of April 10th.

And, smaller 7 Iris is also about at opposition. It's farther south in Corvus and only magnitude 9.4. See Bob King's [Pop In on Pallas and Iris Tonight](https://example.com), with finder charts.

Source: *Sky and Telescope*  

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# ISS Sighting Opportunities (from Denver)

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Sighting information for other cities can be found at [NASA’s Satellite Sighting Information](https://www.nasa.gov/iss).

## NASA-TV Highlights (all times Eastern Time Zone)

### April 2, Tuesday
- 10 a.m. – Administrator Jim Bridenstine testifies before the House Committee on Science, Space and Technology on the FY2020 budget request (All Channels)
- 2 p.m. – International Space Station Expedition 59 Spacewalk Preview Briefing (All Channels)

### April 4, Thursday
- 6:45 a.m. – Coverage of the launch of the Progress 72 Cargo Ship to the International Space Station; launch scheduled at 7:01 a.m. EDT (All channels)
- 9:45 a.m. – Coverage of the rendezvous and Docking of the Progress 72 Cargo Ship to the International Space Station; docking scheduled at 10:25 a.m. EDT (All Channels)
- 2:30 p.m. – RS-25 Engine Test

### April 5, Friday
- 12 p.m. – International space Station In-Flight Event for the Canadian Space Agency with Flight Engineer David Saint-Jacques of CSA (All Channels)

Watch NASA TV online by going to the [NASA website](https://www.nasa.gov/).
Space Calendar

- Apr 02 - **Mercury** Passes 0.4 Degrees From **Neptune**
- Apr 02 - **Apollo Asteroid 2019 FT2** Near-Earth Flyby (0.006 AU)
- Apr 02 - **Apollo Asteroid 2019 FN1** Near-Earth Flyby (0.022 AU)
- Apr 02 - **Aten Asteroid 2018 PK21** Near-Earth Flyby (0.088 AU)
- Apr 02 - 60th Anniversary (1959), Selection Of The **Mercury 7 Astronauts**
- Apr 02 - Apr 04 - **Paris Space Week**, Paris, France
- Apr 02 - Apr 04 - **Microwave Technology and Techniques Workshop (MTT)**, Noordwijk, The Netherlands
- Apr 02 - Apr 04 - **Geospatial World Forum**, Amsterdam, Netherlands
- Apr 03 - Apr 05 - **Aten Asteroid 2011 FK1** Near-Earth Flyby (0.076 AU)
- Apr 03 - Apr 05 - **Seminar: Assessing the Habitability Potential of Mars and Beyond Through Mission Data Analysis, Numerical Modeling and Laboratory Experiments - Implications for Instrument Development**, Houston, Texas
- Apr 03 - Apr 05 - **Lecture: Artists in Space - The Early Years**, London, United Kingdom
- Apr 03 - Apr 05 - **Lecture: Where Did We Come From - A Tale About Galaxies Far, Far Away**, Kamuela, Hawaii
- Apr 03 - Apr 05 - **SKA History Conference**, Manchester, United Kingdom
- Apr 03 - Apr 05 - **5th CEAS Conference on Guidance Navigation and Control (2019 EuroGNC)**, Milan, Italy
- Apr 03 - Apr 05 - **Workshop: The Dark Side of Black Holes**, Brussels, Belgium
- Apr 03 - Apr 05 - **UniVersum 2019 Meeting: Tracing a Communal Path for the Italian Cosmology Community**, Milan, Italy
- Apr 03 - Apr 05 - **Meeting: Review of Progress Toward Implementing the Decadal Survey - Solar and Space Physics - A Science for a Technological Society**, Boulder, Colorado
- Apr 04 - **Progress MS-11** Soyuz-2.1a Launch (International Space Station 72P)
- Apr 04 - **Beresheet**, Moon Orbit Insertion
- Apr 04 - **Parker Solar Probe**, 2nd Perihelion
- Apr 04 - **Apollo Asteroid 2016 GE1** Near-Earth Flyby (0.010 AU)
- Apr 04 - **Amor Asteroid 2019 FW1** Near-Earth Flyby (0.043 AU)
- Apr 04 - **DORIS Analysis Working Group meeting (AWG) of the International DORIS Service**, Munich, Germany
- Apr 04 - **Colloquium: Massive Black Hole Binaries in the Cosmos**, Princeton, New Jersey
- Apr 04 - **Lecture: Clues about the Early Martian Climate from the Phyllosilicate Record - How Warm is Warm?**, Knoxville, Tennessee
- Apr 04 - **Seminar: Apollo Zircons - A New Perspective on Lunar Crustal Evolution**, Houston, Texas
- Apr 04 - **Lecture: A Brief History of Branes**, Trieste, Italy
- Apr 04 - **Seminar: The Internal Structure of Open Clusters - The Case of NGC 2682 (M67)**, Barcelona, Spain
- Apr 04-05 - **Science Talk '19 Conference**, Portland, Oregon
- Apr 04-06 - **2nd International Conference On Astronomy, Astrophysics & Astrobiology**, Auckland, New Zealand
- Apr 05 - **8th New England String Meeting**, Providence, Rhode Island
- Apr 05 - **Lecture: A Two-Higgs-Doublet-Model for Muon g-2 and Dark Matter**, Barcelona, Spain

Source: **JPL Space Calendar**

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A team of scientists has proposed a powerful new test for inflation, the theory that the universe dramatically expanded in size in a fleeting fraction of a second right after the Big Bang. Their goal is to give insight into a long-standing question: what was the universe like before the Big Bang?

Although cosmic inflation is well known for resolving some important mysteries about the structure and evolution of the universe, other very different theories can also explain these mysteries. In some of these theories, the state of the universe preceding the Big Bang — the so-called primordial universe — was contracting instead of expanding, and the Big Bang was thus a part of a Big Bounce.

To help decide between inflation and these other ideas, the issue of falsifiability — that is, whether a theory can be tested to potentially show it is false — has inevitably arisen. Some researchers, including Avi Loeb of the Center for Astrophysics | Harvard & Smithsonian (CfA) in Cambridge, Mass., have raised concerns about inflation, suggesting that its seemingly endless adaptability makes it all but impossible to properly test.

"Falsifiability should be a hallmark of any scientific theory. The current situation for inflation is that it’s such a flexible idea, it cannot be falsified experimentally," Loeb said. "No matter what value people measure for some observable attribute, there are always some models of inflation that can explain it."

Now, a team of scientists led by the CfA's Xingang Chen, along with Loeb, and Zhong-Zhi Xianyu of the Physics Department of Harvard University, have applied an idea they call a "primordial standard clock" to the non-inflationary theories, and laid out a method that may be used to falsify inflation experimentally. The study will appear in Physical Review Letters as an Editors' Suggestion.
In an effort to find some characteristic that can separate inflation from other theories, the team began by identifying the defining property of the various theories – the evolution of the size of the primordial universe.

"For example, during inflation, the size of the universe grows exponentially," Xianyu said. "In some alternative theories, the size of the universe contracts. Some do it very slowly, while others do it very fast.

"The attributes people have proposed so far to measure usually have trouble distinguishing between the different theories because they are not directly related to the evolution of the size of the primordial universe," he continued. "So, we wanted to find what the observable attributes are that can be directly linked to that defining property."

The signals generated by the primordial standard clock can serve such a purpose. That clock is any type of heavy elementary particle in the primordial universe. Such particles should exist in any theory and their positions should oscillate at some regular frequency, much like the ticking of a clock's pendulum.

The primordial universe was not entirely uniform. There were tiny irregularities in density on minuscule scales that became the seeds of the large-scale structure observed in today's universe. This is the primary source of information physicists rely on to learn about what happened before the Big Bang. The ticks of the standard clock generated signals that were imprinted into the structure of those irregularities. Standard clocks in different theories of the primordial universe predict different patterns of signals, because the evolutionary histories of the universe are different.

"If we imagine all of the information we learned so far about what happened before the Big Bang is in a roll of film frames, then the standard clock tells us how these frames should be played," Chen explained. "Without any clock information, we don't know if the film should be played forward or backward, fast or slow, just like we are not sure if the primordial universe was inflating or contracting, and how fast it did so. This is where the problem lies. The standard clock put time stamps on each of these frames when the film was shot before the Big Bang, and tells us how to play the film."

The team calculated how these standard clock signals should look in non-inflationary theories, and suggested how they should be searched for in astrophysical observations. "If a pattern of signals representing a contracting universe were found, it would falsify the entire inflationary theory," Xianyu said.

The success of this idea lies with experimentation. "These signals will be very subtle to detect," Chen said, "and so we may have to search in many different places. The cosmic microwave background radiation is one such place, and the distribution of galaxies is another. We have already started to search for these signals and there are some interesting candidates already, but we need more data."

Many future galaxy surveys, such as US-lead LSST, European's Euclid and the newly approved project by NASA, SphereX, are expected to provide high quality data that can be used toward the goal.

The preprint of this paper is available in: https://arxiv.org/abs/1809.02603. A related previous work can be found in: https://arxiv.org/abs/1509.03930.

Headquartered in Cambridge, Mass., the Center for Astrophysics | Harvard & Smithsonian (CfA) is a collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

Source: Center for Astrophysics | Harvard & Smithsonian

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Explanation: Across the heart of the Virgo Cluster of Galaxies lies a striking string of galaxies known as Markarian's Chain. The chain, pictured here, is highlighted on the right with two large but featureless lenticular galaxies, M84 and M86. Prominent to their lower left is a pair of interacting galaxies known as The Eyes.

The home Virgo Cluster is the nearest cluster of galaxies, contains over 2000 galaxies, and has a noticeable gravitational pull on the galaxies of the Local Group of Galaxies surrounding our Milky Way Galaxy. The center of the Virgo Cluster is located about 70 million light years away toward the constellation of Virgo. At least seven galaxies in the chain appear to move coherently, although others appear to be superposed by chance.