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. (A broad outer ring of Saturn, known as the E ring, is formed by the icy material that fans out from Enceladus' plume.)

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.