Questions and Answers

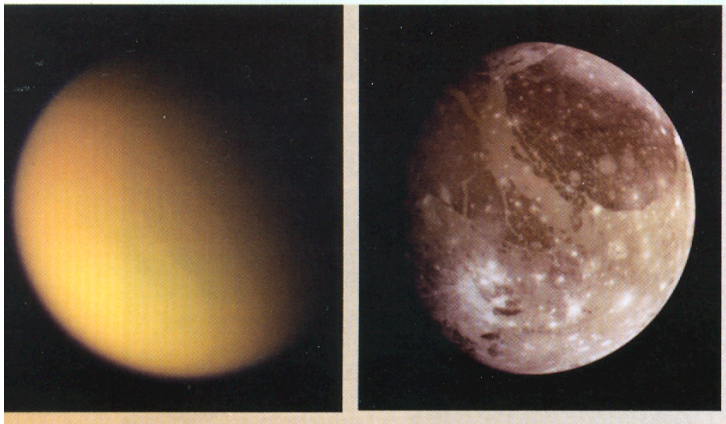
How did Titan retain such a thick atmosphere while other large moons in the outer solar system—such as Ganymede—did not?
—William V. Stine
Fairfax, Virginia

Scientists are still wrestling with the "origin of atmospheres" question, but observations by *Galileo, Cassini,* and *Huygens* have provided important insights. We believe that in Titan's distant past, an atmosphere of nitrogen was formed by the action of the Sun's ultraviolet photons on ammonia. The planetesimals that formed Titan also delivered ammonia to Saturn's largest moon.

On the other hand, unlike Titan, Ganymede may not even have acquired ammonia, or other volatiles needed to form an atmosphere in the first place. This is because the planetesimals that formed Ganymede were warmer, being close to the Sun. Laboratory measurements show that at those temperatures, planetesimals do not trap ammonia efficiently.

There is another significant factor in this retention story. Even if some atmosphere began to form on Ganymede, it must have been quickly stripped away by high-energy charged particles. That's because Ganymede lies well within Jupiter's powerful magnetosphere. Again, Titan lucked out, as it finds itself only occasionally inside Saturn's magnetosphere. But even then, the removal of the atmosphere from Titan would be minimal because Saturn's magnetosphere is relatively benign compared with Jupiter's.

—SUSHIL ATREYA,
University of Michigan



As Cassini approached Titan (far left) on August 21, 2005, it captured this natural-color view of the smog-enshrouded Saturnian moon. The images that went into making this natural-color view of Jupiter's moon Ganymede (left) were taken by Galileo on June 26, 1996. Although Titan and Ganymede are both large moons, many factors—such as chemistry, temperatures, and their parent planets' magnetic fields—are responsible for the fact that Titan has a thick atmosphere and Ganymede does not.
Images: NASA/JPL/Space Sciences Institute and NASA/JPL

I understand that Io has significantly less ice than the other Galilean satellites. Could that be due to the heat of its constantly erupting volcanoes?
—Allison Durney
San Francisco, California

Io is indeed very different from the other Galilean satellites because it lacks water—something we knew from telescopic observations before any spacecraft ever visited the Jovian moon. And Io's rate of eruptive activity is so prodigious that the moon could have recycled itself tens of times over the age of the solar system. The key question for this moon's dryness is whether water was present at all when Io formed, or if the satellite's active volcanism drove the water out after some time.

Infrared observations of Io show a weak absorption feature at the 3.15-micron wavelength that might be due to tiny quantities of hydrated minerals, hydroxides, or even water. According to Bob Carlson, principal investigator of *Galileo*'s Near-Infrared Mapping Spectrometer (NIMS) team, if the absorption is due to water, it is at an abundance of 4 parts per million or lower. In comparison, the other Galilean satellites are water-rich worlds.

An important result of spacecraft and ground-based observations is the discovery of progressive enrichment of water in the Galilean satellites as they move out from Io (which is closest to Jupiter) to Europa, Ganymede, and Callisto. This has prompted solar system modelers to assume that there was a temperature gradient in the subnebula surrounding Jupiter, from which the satellites formed.

In 1982, Jonathan Lunine of the University of Arizona and David Stevenson of the California Institute of Technology (Caltech) put forth a model of the Jovian system in which water does not condense at Io's distance from Jupiter. According to this model (and other theories), Io most likely formed in a region depleted of water. Therefore, current thinking favors the view that Io has always been a "dry" world.

—ROSALY M. LOPES,
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