Galileo Hits a Strange Spot on Jupiter

The first probe to enter a gas giant planet plunged through a rare hole in the clouds to return a plethora of observations that have researchers in a dither

No planet gives up its secrets easily, but Jupiter may be the most miserly of the lot. Last 7 December, after 20 years of preparation and a seemingly endless string of crises ranging from the Challenger explosion to a balky tape recorder, the Galileo spacecraft's free-flying probe smashed into Jupiter's upper atmosphere like a meteor, slowed, and dropped below the level of the planet's uppermost clouds. In the 58 minutes between opening its parachute and being seared by the planet's fierce heat, the probe returned observations that at times were so offbeat that researchers scrambled to see if their instruments had run amok. The set of three predicted cloud layers was nowhere to be seen, and preliminary data suggested that Jupiter—or at least the spot the probe happened to hit—is far drier than expected.

Indeed, when Galileo probe investigators reported their first public results at a press conference held on 22 January, they were still a bit befuddled. "Whenever you have an influx of new data," said Galileo project scientist Torrence Johnson of the Jet Propulsion Laboratory (JPL) in Pasadena, California, "it usually doesn't fit existing models very well. There's always a sense of humility at this point." But there may also be a mundane explanation for why at least some of the new observations were so puzzling.

By chance, the probe had entered the Jovian atmosphere at one of its driest, most cloud-sparse spots—the Sahara of Jupiter. And that has complicated planetary scientists' original plans to see Jovian weather up close and get a representative sample of the planet's ingredients—a chemical Rosetta stone they could use to understand the formation of that planet and of the whole solar system. As planetary scientist Jonathan Lunine of the University of Arizona puts it: "There's only one Rosetta stone, and it's in the British Museum."

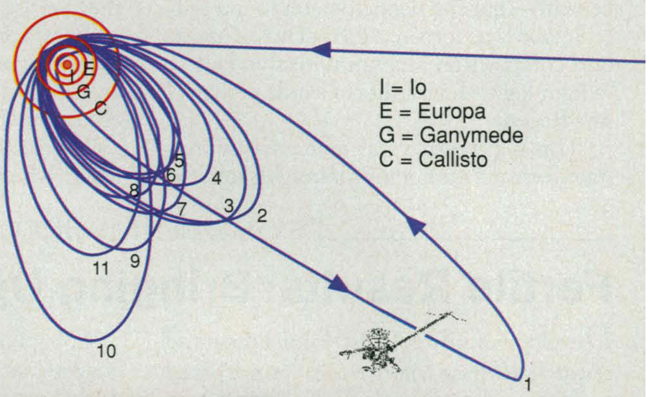
Still, the probe did deliver some answers. It seems to have finally settled the debate over whether Jupiter's winds run deep or are confined to a shallow layer: Deep wins out, suggesting to some scientists that the planet's ferocious winds are driven by heat emanating from deep within the planet. And it has yielded some tantalizing hints about how Jupiter condensed from primordial gas and dust.

Hitting a Jovian desert was a bit of bad luck, plain and simple, explains Galileo team member Glen Orton of JPL. The cloud-free spots form in regions where the Jovian atmosphere—having lost much of its water and other condensable gases by rising and forming clouds elsewhere—sinks and heats up, in the same process that creates deserts on Earth. Earth-based infrared observations show that these hot spots cover only about 1% of the planet, so the odds certainly favored a more typical impact site for the Galileo probe. In fact, the hot spot it hit only began forming in September, says Orton, 2 months after the probe separated from the orbiter, which is now circling the planet. Unfortunately, he adds, this spot "may be drier than any [other] place on the planet."

That may help explain why the probe's neutral mass spectrometer revealed half the water that was expected. And the uncertainty about how much water was lost where the probe came down means, says Arizona's Lunine, that "it's going to be a bit hard to interpret the water data." Researchers had hoped to use the water abundance, along with the levels of ammonia and methane, to gain insights into how Jupiter formed 4.5 billion years ago from the cloud of gas and dust that preceded the solar system.

In one scenario for the planet's assembly, a core of ice and rock might have formed first and then pulled in gas and much more ice and rock—the infall of solids continuing even after the gas was gone and boosting the abundance of ice-borne gases, such as methane, in the upper Jovian atmosphere. Measurements of Jupiter's gravity field by the two Voyager spacecraft supported this picture by hinting at the presence of a dense, rocky core, and the abundance of water and methane remotely sensed from the Voyagers and Earth suggested plenty of methane-laden ice had fallen into the young planet. But theorists haven't ruled out another possibility: that Jupiter formed the way stars are made when gas, rocky dust, and ice collapsed all at once under their own gravity.

Unless researchers can show that the probe's mass spectrometer worked long enough to get below the dry hot spot, the ambiguous water data won't help theorists choose between those possibilities. The probe's methane data might, however, as methane should be unaffected by the hot spot. The preliminary abundance estimate is low, less than half that measured from Earth and the Voyagers, which might seem to favor a starlike origin for Jupiter. However, the data discrepancy raises doubts about the new mass spectrometer results, says planetary physicist David Stevenson of the California Institute of Technology: "It's a tricky business. The history of planetary exploration has been one in which mass spectrometer data changes, or the interpretation changes, over a year or more."



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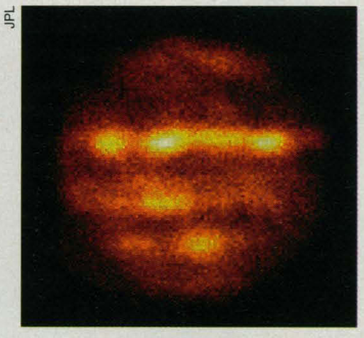


Dry landing. The probe hit a warm spot (*upper-right infrared bright spot*) after release from Galileo, which is now in the first of 11 orbits of Jupiter.

But even if the probe hasn't immediately shed light on Jupiter's origin, it is offering a clue to the planet's history since then. The probe's helium abundance detector, which was built by Ulf von Zahn of the University of Rostock, Germany, confirmed earlier Voyager data indicating that the outermost regions of Jupiter now contain much less helium than the planet started with, a figure calculated from the helium-to-hydrogen ratio in the sun. A reduced helium content is in keeping with a suggestion made 20 years ago that Jupiter's helium is now condensing into droplets under the deep interior's megabar pressures; the droplets then fall even deeper into the planet. So the gravitational energy released as heat by the fall of helium raindrops must in fact be fueling Jupiter's infrared "glow," which is brighter than anything the solar energy reaching the planet could account for. "Jupiter is clearly a planet that is evolving compositionally," says Stevenson, "and it derives a large part of its energy output from helium raining into the interior."

Galileo team members with a bit more immediate interests—figuring out what makes Jovian weather tick—had some frustrations of their own. In keeping with its reputation as a Jovian Sahara, the hot spot's atmosphere was "relatively clear," says Boris Ragent of the San Jose State University Foundation, principal investigator of the cloud-sensing nephelometer instrument. Theorists had expected the probe would penetrate three dense cloud layers—the ammonia clouds obvious from Earth and ammonium hydrosulfide and water clouds beneath—but the nephelometer found only one cloud layer for sure, and that was of uncertain composition and unimpressive bulk—"a light fog with visibility of a mile perhaps," says Ragent.

This fair weather has momentarily frustrated researchers hoping for insights into the heat-driven, vertical circulation of Jupiter's atmosphere. Just as a towering thunderhead on Earth traces a column of rising air, planetary meteorologists hoped the Jovian cloud structure would deliver clues to how convection works on Jupiter. Pulling together observations from several atmospheric instruments besides the nephelometer should help, but one feature of the Jovian weather has already come through clearly: the vertical extent of the fierce winds that shape Jupiter's distinctive globe-girdling bands.

Before Galileo's arrival, some planetary meteorologists thought that the winds are most likely driven by solar energy absorbed by the clouds, which implies that they peter out not far below the cloud layers. Others preferred the idea that the winds are probably driven by a combination of heat left over from Jupiter's formation and the heat generated by the helium rain, in which case they persist deep into the interior.

By tracking the Doppler shift in the frequency of the probe's radio carrier signal as it fell through the atmosphere, David Atkinson of the University of Idaho and his colleagues clocked the powerful westerly winds, which blew at 360 kilometers per hour at the cloud tops. "There was no evidence the winds were decaying toward zero" at greater depths, he says.

"If that's right, it simplifies things a good deal," says planetary meteorologist Peter Gierasch of Cornell University, a probe team member. "It says the meteorology is deep, which rules out [the shallow-wind] hypotheses." How deep is "deep" remains to be seen, but rotating fluid-filled spheres—a laboratory model for stars and the largely fluid Jupiter—suggest that if the winds are driven by internal heating, they could extend as deep as the rocky core of the planet. The heat source driving the winds is also uncertain; even Galileo team members have yet to agree whether the observed winds require or merely suggest a deep energy source.

The Galileo orbiter's leisurely inspection of the Jovian atmosphere and especially its hot spots during the next 2 years should help put some of the probe's results in better context, but planetary scientists are never ones to think small. They are already talking about how useful another probe mission to Jupiter would be.

–Richard A. Kerr

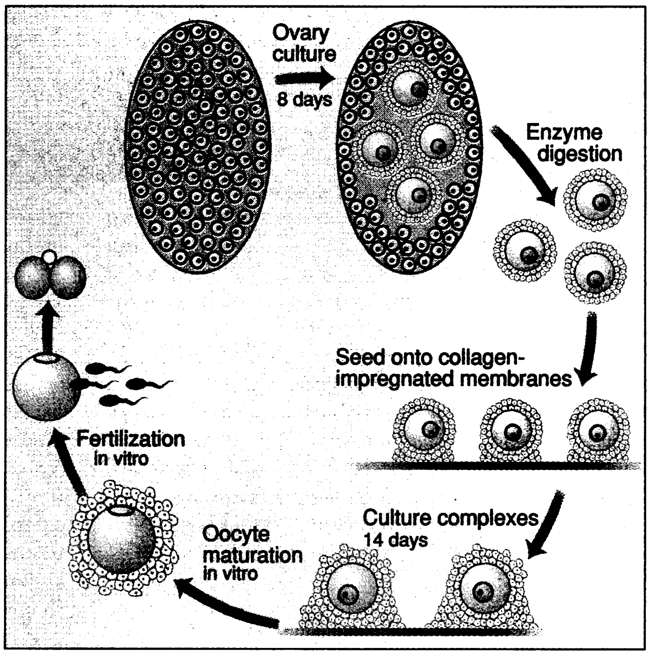
DEVELOPMENTAL BIOLOGY

Fertile Results: Bringing Up Baby (Eggs)

Developmental biologist John Eppig and research assistant Marilyn O'Brien are proud to announce two births: a healthy mouse pup and a new era of reproductive biology. The mouse heralding this new era is the product of an egg grown in vitro, all the way from its primordial precursor to maturity, when it was fertilized. In mice, this process normally takes 3 weeks; biologists have been struggling to replicate it for years.

The birth announcement, in the January issue of *Biology of Reproduction*, explains why. Female mammals are born with thousands of these egg precursors, called oocytes, but only a few at a time mature into eggs. And that limits opportunities for in vitro fertilization (IVF) in humans and other species, as the procedure can only be carried out on mature eggs. Now Eppig and O'Brien, from Jackson Laboratory in Bar Harbor, Maine, have devised a successful two-step "oocyte farming" technique. Not only does the technique promise to open a new window on what governs oocyte development, but because oocytes can be harvested in greater numbers than mature eggs can, it could also revolutionize assisted reproduction in humans and in endangered species.

Eppig's colleagues are handing out verbal equivalents of celebratory cigars. "Beautiful work," says John Biggers, a reproductive biologist at Harvard Medical School. "A tour de force," comments Richard Schultz, a developmental biologist at the University of Pennsylvania. And while the efficiency of the procedure is still low, "just having one mouse born means it is possible," says Joanne Fortune, a reproductive physiologist at Cornell University's College of Veterinary Medicine. "That's the important first step that we all needed to see."



Egg harvest. Egg precursors called oocytes (*pink*) are first grown in organ culture, then isolated; the process yields mature fertilizable eggs.

SOURCE: J. EPPIG/THE JACKSON LABORATORY ILLUSTRATION: K. SUTLIFF

Eppig hit on the technique while investigating the developmental signals passing between mouse oocytes and the so-called "granulosa cells" that surround them. These biochemical conversations begin at birth in female mice and are thought to prepare oocytes to begin growing into fertilizable eggs. Eppig and O'Brien thought they might be able to eavesdrop on these chats if they transferred oocyte-granulosa cell complexes from days-old mice into a culture dish, where they could expose the cell complexes by using collagenase enzymes to digest away surrounding ovary tissue.

Unfortunately, the granulosa cells preferred to walk instead of talk: They kept moving away from the oocytes and attaching themselves to the dish itself. So Eppig began years of what he calls "messing around" with conditions in the culture dishes. And in doing so, Eppig and O'Brien recently found the way to make an oocyte develop. First, they cultured entire newborn mouse ovaries for several days before isolating the oocyte-granulosa cell complexes.