the VLA and ATCA to derive a detailed three-dimensional trajectory for the probe through Jupiter's atmosphere. Such a trajectory would allow them to better understand energy and momentum transfer in Jupiter's atmosphere. It also may be possible to extract more quantitative information on nitrogen abundances from the attenuation of the probe's signal caused by ammonia.

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. . . And Io Yields Still More Surprises

Almost four centuries after Galileo's telescope revealed moons orbiting Jupiter, those same moons are revealing their secrets to the Galileo spacecraft—starting with Io's differentiated structure and magnetic properties.

Researchers have come to expect spectacular surprises from Io, the innermost of Jupiter's Galilean satellites. The Voyager missions revealed Io to be the most volcanically active object in the Solar System. Voyager also revealed the importance of Io's interactions with Jupiter's magnetosphere, which generate a potential of 400 kV across the moon's diameter and currents of over a million amperes between Io and Jupiter's ionosphere. As a result of this past performance, researchers eagerly waited for Galileo to pass within 900 km of Io, a factor of 20 closer than any of Voyager's flyby's. Initial analysis of the data indicates that, once again, Io has not disappointed.

Probing Io to the core

Problems with Galileo's tape recorder limited the amount of information researchers could gather about Io. In part because Voyager's images had already revealed a great deal of information about Io's surface, the highest priority was given to measurements that might reveal something about the moon's internal structure and dynamics, specifically its gravitational and magnetic fields.

The mass within a body determines its gravitational field; thus, the precise shape of the field, especially very near the body, reveals information about the distribution of mass therein. Using the Doppler shift of Galileo's 2.3 GHz signal to determine the gravitational acceleration experienced by the spacecraft, John Anderson and W. Sjogren of Jet Propulsion Laboratory in Pasadena, California, and Gerald Schubert of University of California, Los Angeles, were able to measure the precise shape of Io's gravitational field, from which they calculated the moon's moment of inertia.[1]

Because Io's moment of inertia was substantially smaller than would be expected for an equivalent uniform mass distribution, Anderson, Sjogren and Schubert concluded that Io has a heavy core—probably a mixture of iron and iron sulfide—surrounded by a mostly silicate mantle. The core would have a radius of 651 ± 79 km, (about 36% of Io's radius of 1821.3 km) if it were composed of pure iron, or 942 ± 118 km (52% of Io's radius) if it were composed of a eutectic (minimum-melting-point) mixture of iron and iron sulfide. Given the preponderance of sulfur involved in Io's volcanism, the second number is probably a better guess.

The existence of a heavy Fe–FeS core within Io, surrounded by a lighter predominantly silicate mantle would explain why magmas on Io tend to be silica rich and iron poor. It also indicates that, at some point in its history, the moon was sufficiently hot and molten that differentiation could occur between its heavy and light components. In this respect, Io's history may be similar to that of the terrestrial planets. Measurements of Jupiter's magnetic field in the vicinity of Io indicate that there may be other similarities that are even more profound.

A magnetic moon?

Although Galileo has only recently returned all of the data it took during the Io flyby on particle fluxes and electromagnetic fields, the spacecraft previously returned one-minute averages of its magnetometer readings. These data indicate that near Io, Jupiter's magnetic field drops about 38% from its unperturbed value of 1860 nanotesla. At the Spring meeting of the American Geophysical Union in May, Margaret Kivelson of UCLA[2] suggested that this large drop could arise from the acceleration of large numbers of ions from Io in the vicinity of the spacecraft or from a magnetic field generated by Io itself. After showing that even generous upper limits on the contributions of ion fluxes cannot account for the magnitude of the field perturbation at Io, Kivelson argued that an intrinsic field of Io—probably generated by a dynamo mechanism similar to that of Earth and Mercury—is necessary to explain the results. If this explanation stands up when the detailed analyses of particle fluxes and fields become available, Io would be the first moon found to generate its own magnetic field. However, given the importance of tidal heating in Io's energetics and the possibility that the moon's core might remain liquid right to the center, "the resulting fluid flow structure and dynamo generation would both be quite different from what we think is happening in Earth's core," says Gary Glatzmaier (Los Alamos National Laboratory). (See PHYSICS TODAY January, page 17.)

Other Galilean moons

Although Io's opening act will be tough to follow, Galileo is poised to answer many of the questions raised by the Voyager missions about the other Galilean satellites—Europa, Ganymede and Callisto. In sharp contrast to Io's young, rocky and volcanically sculpted surface, Callisto, the farthest of the Galilean satellites from Jupiter, has a largely static, ancient and icy surface, marked by some of the largest and oldest impact structures in the solar system. Europa and Ganymede seem to be transitional between these two extremes. Researchers hope Galileo will help them to better understand the compositions of these moons and to quantify the importance of tidal forces, volcanism, tectonic activity and cratering on each of the moons.

By the nominal end of its mission in December 1997, Galileo will have returned images of Europa, Ganymede and Callisto with resolutions as fine as 12 m/pixel, 10 m/pixel and 29 m/pixel, respectively, as well as data on their spectroscopy, and gravitational and magnetic fields. All of this will surely keep researchers busy, but many will also be hoping for another trip to Io in 1998.

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