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Introduction

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Io is the innermost of the four large Galilean satellites of Jupiter, discovered by Galileo Galilei in 1610. This discovery proved that planetary bodies can orbit something other than Earth and confirmed the Copernican view that the Sun is the center of the Solar System. In 1771 Pierre-Simon Laplace described what is now called the Laplace resonance, in which every time Ganymede orbits Jupiter once, Europa orbits twice, and Io four times. Thus, these large satellites periodically line up with Jupiter. It would take more than 200 years for scientists to appreciate the significance of this observation to Io and Europa.

Prior to *Voyager* spacecraft exploration, there were many clues to the fact that Io was unusual. Fanale *et al.* (1978) wrote: "Observations of line emission from neutral and ionic species in the Io-surrounding cloud, reflectance studies and theoretical considerations suggest Io's surface is unlike that of any other body in the Solar System." They proposed that radiogenic and accretional heat could have transported salt-rich solutions to the surface, leaving behind a layer of evaporite deposits. Recent results have shown this prediction to be remarkably prescient, that is, for Mars (Squyres *et al.* 2004).

Peale *et al.* (1979) realized that the Laplace resonance created a significant forced eccentricity in the orbits of Io and Europa, so these bodies would be deformed periodically while orbiting massive Jupiter, leading to significant internal heating or tidal energy. They predicted that Io would have sufficient heat generation to lead to runaway melting of the interior, and that the *Voyager* spacecraft would observe manifestations of this heat flow. Indeed, shortly after publication of Peale *et al.* (1979), the *Voyager 1* encounter revealed the bizarre volcanic terrains, active plumes, and thermal anomalies ("hot spots"). *Voyager* also revealed mountains more than 10 km high, inconsistent with runaway melting under a thin crust – because the heat is lost primarily via volcanic eruptions rather than conduction through a thin lithosphere.

Io's mean radius and bulk density are similar to the Moon, but whereas the last volcanic eruption on the Moon was more than 1 or 2 billion years ago, Io has hundreds of active volcanic centers. Terrestrial volcanologists say an active volcano is one that has erupted in historic times; each and every volcano that is identifiable on Io's surface may have been active in the past few centuries. Thus, Ionians reserve "active" for a volcano that is erupting lava or pyroclastics and gas in such great quantities that it can be detected in very remote observations, including from Earth. When it comes to our Solar System, Io is by far the most volcanically active, although Mustafer (the lava planet in Star Wars Episode III) seems comparable.

This book contains review chapters by the leading experts in the study of Io. Cruikshank and Nelson begin with a history of Io exploration, from ground-based telescopic studies through the era of spacecraft exploration (*Pioneer*, *Voyager*, and *Galileo*). Much of the rest of the book focuses on the most recent results, primarily from *Galileo*'s tour of the Jovian system from 1995–2003 (Chapter 3) and modeling motivated in part by these results. McKinnon *et al.* discuss the formation of Io in the proto-Jovian nebula and its orbital and thermal evolution. The life history of the terrestrial planets is like that of a mortal person (birth, young and active, declining activity, death), whereas some outer planet satellites have histories more like Buddhist reincarnation, with large fluctuations in tidal heating and internal activity.

Subsequent chapters review current knowledge about Io from the inside out, like an atom of sodium that first resides in Io's interior, rises toward the surface in a convection cell, erupts in an active volcano, then gets sputtered from either the hot lava surface or from a tall plume into the atmosphere and into Jupiter's powerful magnetosphere. Moore *et al.* review the internal structure and tidal heating of Io, which is unique among the silicate planets due to its current heat flow, but may provide insight into processes that operated very early in the histories of the terrestrial planets. Io's geologic activity is the result of how Io transfers heat from the tidally flexed interior to the surface and to space. Moving upward to the crust, Turtle *et al.* review the tectonics of Io, producing impressive but still puzzling features like the mountains and paterae (calderas or volcanic–tectonic depressions).

The most spectacular phenomena on Io are the active volcanic eruptions. Williams and Howell review current knowledge about effusive eruptions of lava on Io, including the discovery of very high-temperature lavas, which may be analogous to ancient terrestrial ultramafic lavas. Io's lavas seemed to get hotter over time from the *Voyager* era through the *Galileo* era, similar to the shrinkage over time in estimates of Pluto's diameter, but both trends are actually due to increasingly accurate measurements. Geissler and Goldstein next review the spectacular volcanic plumes, up to 500 km high, and their surface deposits; they reach the important conclusion that McEwen and Soderblom (1983; my first paper) were not entirely wrong. Carlson *et al.* review the current knowledge about the composition of Io's surface, based in large part on results from the near-infrared mapping spectrometer (NIMS) on *Galileo*.

Moving outward, Lellouch *et al.* review the current thinking about Io's tenuous but dynamic atmosphere, dominated by SO_2 from a combination of volcanic outgassing and sublimation of surface frosts. Next Schneider and Bagenal review the complex interactions between Io and the Jovian magnetosphere.

The final chapter by Marchis *et al.* reviews outstanding questions (there are many) and prospects for future exploration of Io. The Earth-based telescopes keep achieving better observations, and *New Horizons* will provide a glimpse of Io on its way to Pluto/Charon. However, we really need a dedicated Io mission, one that can monitor Io at high spatial and spectral resolution, in order to make major advances. Everyone seems to love Io, but a dedicated mission has not yet been given a high priority in any of the studies or planning documents of NASA or the National Academy of Sciences. Mars, Europa, and Titan are higher priorities in the quest to understand the origin(s) of life, and Io is also a difficult world to explore, deep in Jupiter's harsh radiation environment. But eventually Io's day will come, and it is sure to be a dazzling show.

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