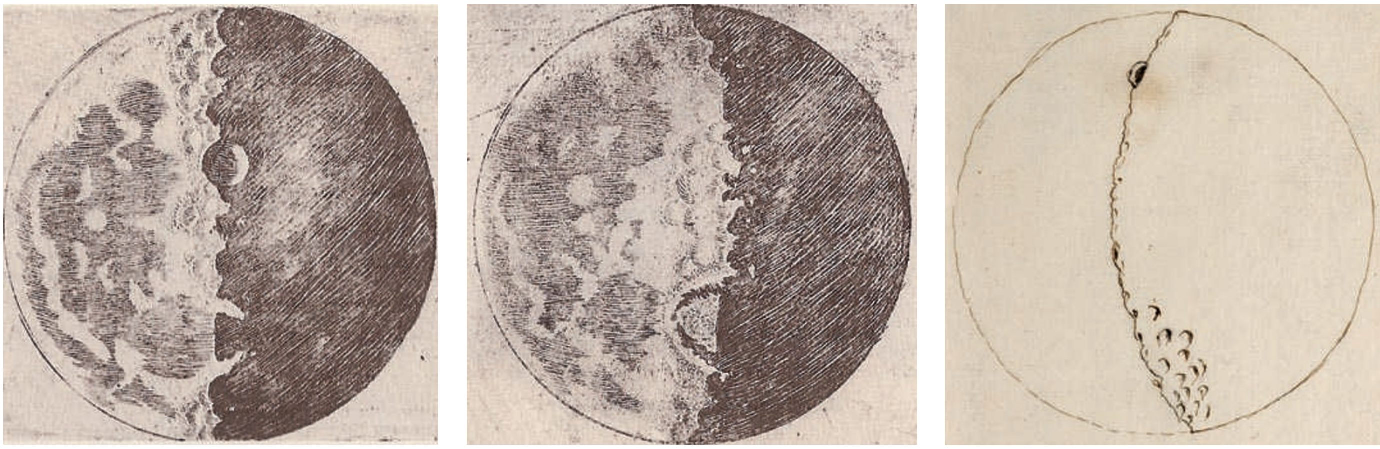

Galileo's sketches (left and centre) conveyed the mountainous lunar landscape; Thomas Harriot's Moon map (right) lacked relief.

RIGHT: M. ALEXANDER/LORD EGREMONT/SPL

IN RETROSPECT

The celestial message

John Heilbron reflects on the first telescopic survey of the sky, published 400 years ago.

The inventory of the heavens swelled in March 1610 with the publication of Galileo Galilei's *Sidereus nuncius* (The Celestial Message, or Messenger). The first survey of the sky using a telescope increased the number of visible stars by more than a factor of ten and resolved the Milky Way into starlets. The tally of known satellites rose five-fold with the discovery of the four moons of Jupiter, and the count of Earth-like bodies doubled with the detection of mountains on our Moon.

Galileo's little book — which occupies just 60 pages in the 1989 English translation by Albert van Helden — caused a sensation among the learned of Europe. Galileo initially aimed his manuscript at a local audience and began his record of observations in Italian. When he found the starlets around Jupiter, however, he recognized it as a discovery of world and historical importance, and switched to Latin. His plan to reissue the book in the vernacular later on, filled with commissioned accolades, foundered under the pressure of his ongoing discoveries — the phases of Venus, bumps on the edges of Saturn (prefiguring its rings), splotches on the Sun — and because of career moves abetted by his new-found fame.

Galileo's matter-of-fact account carried conviction of his wonders well before other astronomers had telescopes to confirm them. That took time because he gave the first instruments he made to princes and prelates, from whom he anticipated admiration and gifts, rather than to his peers, from whom he expected the usual academic scepticism. Among the first of Galileo's contemporaries to celebrate his marvels were poets. Seizing on the analogy closest to hand, they extolled Galileo as a greater Christopher Columbus — as superior to the original as the heavens are to Earth.

The new Columbus was a professor of mathematics at the University of Padua, a man admired for his wit and literary talent, fond of wine and women, yet inclined to melancholy and hypochondria. He was sometimes cutting and querulous, but usually cautious and circumspect, as was fitting for an expatriate professor from Florence without tenure. He was further constrained by debt, an ageing mistress and three illegitimate children. Yet Galileo had many friends and patrons, particularly among priests, artists, astrologers and philosophers.

Sidereus nuncius (The Celestial Messenger)
GALILEO GALILEI
First published 1610

In 1609 one of these friends, the notorious anti-Jesuit monk Paolo Sarpi, had drawn Galileo's attention to the military and commercial potential of a gadget invented in the Netherlands that brought distant objects closer. Galileo maintained a workshop for making mathematical instruments and assembling eyeglasses for sale. With supplies from the shop, some inspired tinkering and the expert advice of Sarpi, Galileo turned the Dutch gadget, which magnified three-fold, into a telescope that magnified by 20 times.

Galileo was perfectly, perhaps uniquely, equipped to be the first to explore the heavens by telescope. In addition to his experience with instruments, his industry and his open-mindedness about astronomical systems, he had excellent vision, a good imagination and an ability to draw in perspective (see *Nature* **452,** 289; 2008). Galileo's painterly portrait of the mountains and valleys of the Moon contrasts with the flatter sketch by Thomas Harriot (see *Nature* **460,** 957; 2009), a mathematician and surveyor who had mapped the New World for Walter Raleigh. Harriot's Moon, as viewed through a telescope he had invented independently of Galileo, depicts the boundary between the bright and dark sides of the Moon as a coastline and the rest without relief. Galileo's cratered landscape mirrored the romantic description of the Moon in his favourite poem, Ludovico Ariosto's *Orlando furioso* (1532).

Galileo's discoveries and the praises heaped on them transformed him from an undistinguished mathematician into a courtier and then into a missionary. The telescope enabled him to realize the professorial dream of a position free from teaching. In the autumn of 1610, he moved to Florence as mathematician and philosopher to the Grand Duke of Tuscany, Cosimo II de Medici, keeping a post as chief professor of mathematics at the University of Pisa without the obligation to lecture or reside there. He could devote his time to railing against Aristotelian philosophers and proselytizing for the Copernican cause.

Others were exploring the night sky opened up by *Sidereus nuncius*. A major improvement in instrumentation soon replaced Galileo's telescope design with Johannes Kepler's, which allows a wider field of view and the use of a micrometer to measure angles on the sky. Using this instrument, the Jesuit mathematician Christoph Scheiner produced a thorough and still useful study of sunspots, published in 1630. In the generation after Galileo's death in 1642, Christiaan Huygens showed that the bumps of Saturn were incompletely resolved rings and, with his discovery of Saturn's Titan, added another moon to the cosmos. The number of known satellites grew to eight in the late seventeenth century with the observations of Giovanni Domenico Cassini, another professor of mathematics and seasoned courtier. Together with the six planets then known, Cassini said, the eight satellites made a total of 14 — honouring his royal patron, the Sun King, Louis XIV of France.

By associating planets and moons with flattery of his patron, Cassini continued a game begun by Galileo, who named the four companions of Jupiter the Medici stars. Galileo's discovery and identification of these satellites, and his deduction of accurate values for their periods, were great technical achievements. He recognized that a table of the satellites' eclipses could support a method for finding longitude at sea. He offered to sell the method to the King of Spain and the Estates of Holland, but the technique proved impractical and the terms too dear.

Although technical difficulties undercut the exploitation of the Medici stars for navigation, their application to cosmology was easy. Of all the discoveries that Galileo announced 400 years ago, they provided the strongest argument yet against the geocentric world view. The Jovian system obviously was not centred on the Earth, and Jupiter's ability to retain its satellites during its orbit showed that Earth might move without losing its Moon.

Sidereus nuncius can mean either celestial message or celestial messenger. Galileo intended it to mean 'message' when he applied to the Venetian censors in 1610 for permission to publish his book. Most translators, however, follow Kepler in rendering the meaning of *nuncius* as 'messenger'. In this they have captured the way in which Galileo came to regard himself. His quixotic self-identification as a messenger from heaven or agent of the stars gave him the psychological strength to make *Sidereus nuncius* more than a report of marvels. Whereas Columbus added a new hemisphere to an existing one, Galileo announced his celestial message to his contemporaries as a demand for the replacement of the cosy Christian cosmos by an uncomfortable new world. ■

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EARTH SCIENCE

Fire from the depths

Powerful volcanoes remind us of the fragile boundary between Earth's crust and mantle, finds **Laura Spinney**.

The eruption of the Icelandic volcano Eyjafjallajökull this April, and the month-long havoc it caused in the skies over Europe, was a salutary lesson in how susceptible our global, interconnected society is to natural perturbations. This saga and other spectacular eruptions are explored in the exhibition *Supervolcano* at the Natural History Museum in Geneva, Switzerland.

The highlight is the display of photographs by Geneva's volcanology society. These self-confessed volcano addicts travel the world to record the beauty and devastating impacts of the latest eruptions. The images attest to the many ways that volcanoes can kill you — through flying debris, burns, asphyxiation or being struck by the lightning generated within the columns of charged particles they eject.

Interactive installations convey the volcanic experience. Visitors can feel seismic tremors, listen to a mud volcano and walk through a reconstructed lava tunnel. The destructive power of volcanic ash is revealed in a mock-up of a crushed office: it is the weight of settled ash that causes buildings to cave in.

Other displays explore the wider societal risks of massive eruptions and their historical influence. Eyjafjallajökull was a relatively modest geological event, but volcanologists fear that it might trigger a far more dangerous neighbouring volcano, Katla, now under high surveillance. If Katla blows, the fallout could put April's upset in the shade.

The 1783–84 eruption of Laki, another Icelandic volcano, might have contributed to the French Revolution a few years later. Laki's toxic cloud polluted the atmosphere, lowered temperatures and caused famines across the Northern Hemisphere.

Even more destructive are supervolcanoes — eruptions with the maximum score of eight on the Volcanic Explosivity Index, measured according to the volume of material ejected, among other factors. Eyjafjallajökull qualified as a four. The eighteenth-century Laki eruption and the 1991 eruption of Mount Pinatubo in the Philippines — which spewed out 10 cubic kilometres of debris — both scored a six.

Supervolcano
Natural History Museum, Geneva, Switzerland
Until 4 September 2011

No known supervolcanoes are currently active, although the imploded remains of one lie in Yellowstone National Park in Wyoming. From the size of its caldera, researchers think that it dumped ash across much of the continent about 640,000 years ago. Toba in Sumatra was one of the last supervolcanoes to erupt, 75,000 years ago. Forty kilometres away is Mount Sinabung, which erupted last month after a long period of inactivity. It too is being monitored closely.

This timely exhibition reminds us of our vulnerability to volcanoes; we inhabit Earth's cool, thin crust, but more than 99% of the planet smoulders at temperatures above 1,000 °C. ■

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M. FULLE/STROMBOLI ONLINE

Eyjafjallajökull's billowing ash triggered lightning when particles were charged by friction.