In search of cosmic water

Water in the Solar System

Maria I. Błęcka has been involved in space experiments for about 20 years, studying planetary atmospheric and surface composition (gas, dust, and aerosols)

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Water is ubiquitous in the Solar System, being present in gaseous form in all planetary and cometary atmospheres, as well as in the form of ice on the surface, subsurface or interior of Mars, comets, and most planetary satellites

The planet Earth, where water exists in all three forms - solid, liquid and gas - is unique in our Solar System. Life cannot exist without liquid water. Liquid water has been found in every form of life on Earth, and conversely, whatever liquid water exists on Earth, life has also been found. The fact that there are other places in our Solar System where water exists is particularly exciting because of the possibility of life also existing there. What are the origins of the Solar System's water?

History of planetary water

When the Solar System formed about 4.5 billion years ago, there was initially a cloud of gas around the Sun. The cloud was hot in the center, and colder towards the outside. The inner planets formed in a hot environment, and so they are made of compounds that condense at very high temperatures, like various kinds of rocks. Going further outwards, we reach the point where ice can condense. Once it starts to condense, it accumulates much faster, and the planets get larger. Gas is also accumulated, making them even larger. For this reason there is an abundance of ice and water in the outer part of the Solar System. But there is also water present in the inner Solar System - Earth being a good example. What is the source of this water? As we know, comets are mainly made of water. In the initial period when material was accumulating into planets, comets, which had formed in the cold edges of the Solar System, were strewn around by the gravity of the larger planets, and may have delivered a large amount of water to the inner part of the Solar System.

The Earth may not be the only place in our Solar System that contains so much water. On February 20, 1997 the Galileo spacecraft orbiting the planet Jupiter flew by Europa, one of Jupiter's moons, at a distance of 587 km, giving us the best images of Europa. These pictures showed a red-colored sea with a thick crust of ice. Europa has most likely had, at some point in its recent geologic history, an ocean of water underneath its surface of frozen water ice. Scientists believe that this ocean could be as much as about 100 kilometers deep. If this is true, then Europa may have twice as much water on it than is present on the entire Earth.

Water is present on our Moon, too. The Lunar Prospector spacecraft, which mapped the chemical composition of the Moon's surface, discovered water in its polar regions. It was important to investigate the chances of finding water there, since comets that collided with the moon may have brought water to this quite dry environment. Such water might still remain at the poles, in the form of ice mixed with the soil to a depth of a few

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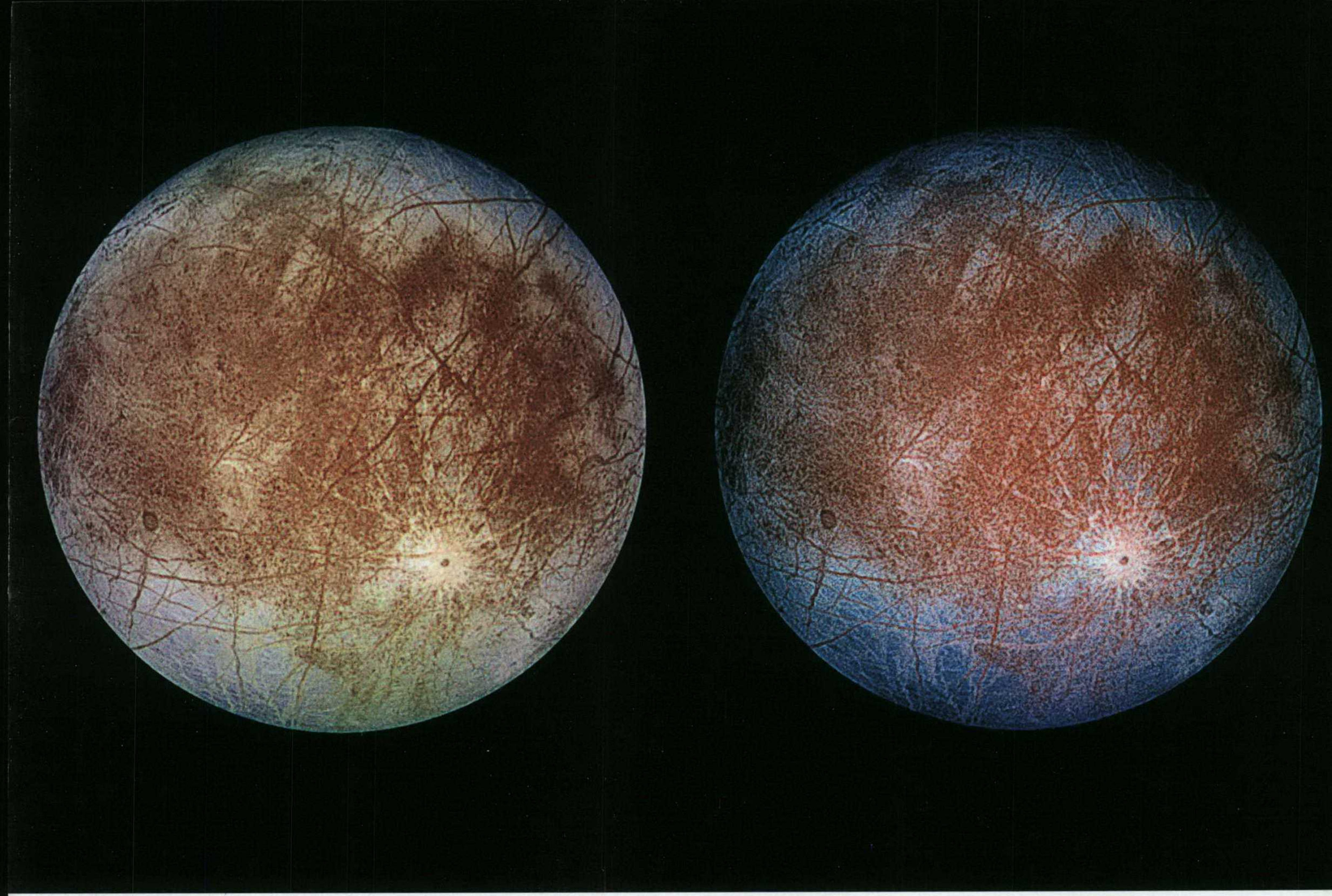
From a distance, Martian valley networks resemble river valleys on Earth



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meters. Water on the Moon could be useful as a key resource in the on-going exploration of the rest of the Solar System - especially of the planet closest to Earth, Mars.

Mars – the closest neighboring planet

Until very recently, planetary scientists had thought that while Mars is a cold, dry planet today, it hasn't always been so. Then in the summer of 2000, NASA released MGS (Mars Global Surveyor) images showing fascinating evidence of very recent seepage of ground water from crater and valley slopes in the southern hemisphere. It seems that substantial reservoirs of water that once ran so copiously on the surface may still exist. Exploration of Mars is nowadays proceeding very intensively. The Red Planet is being observed by the Hubble Space Telescope, NASA's Mars Global Surveyor, Odyssey and the ESA's (European Space Agency) orbiter Mars Express. Scientists from the Space Research Centre (SRC) in Warszawa are participating in this last mission.

Mars Express scientific goals

The scientific objectives of the Mars Express Orbiter are to obtain global high-resolution photo-geology (10m resolution), mineralogical mapping (100m resolution), mapping of the atmospheric composition, and to study the global atmospheric circulation and the subsurface structure, and then the interaction between the atmosphere and the surface, and between the atmosphere and the interplanetary medium.

The Planetary Fourier Spectrometer (PFS) experiment onboard the Mars Express Orbiter is an infrared spectrometer optimized for atmospheric studies. The instrument is able to cover a wavelength range from 1.2 to 45 μm, divided into two channels with a boundary at 5 μm. The instrument field of view is about 2 degrees for the Short Wavelength channel and 4 degrees for the Long Wavelength channel. This corresponds to a spatial resolution of 10 and 20 km when Mars is observed from a height of 300 km (the nominal height of the pericentre). PFS may yield unique data necessary to improve our knowledge not only of the atmospheric properties but also about the mineralogical composition of the surface and the surface-atmosphere interaction.

The researchers and engineers from SRC in Warszawa are very actively involved in the PFS experiment. Some blocs of the

The trailing hemisphere of Jupiter's ice-covered satellite, Europa, in real (left) and enchanced (right) colors. The long, dark lines are fractures in the predominantly water-ice crust. Europa's cratered surface is mostly water ice, and there is strong evidence that it may be covering an ocean or water or slushy ice. If so, Europa may have twice as much water on it than is present on the entire Earth

instruments and software for its testing were developed by our group. Now, using our numerical simulation of the transmittance of atmosphere loaded with the gases and dust and of the Martian surface (its emissivity and reflectance), we are working on the real data obtained from Mars.

The pictures from Hubble Space Telescope and from other spacecraft measurements show white clouds and white caps near both poles. The white clouds are composed of water ice, as are clouds on Earth. Both polar caps contain frozen carbon dioxide (dry ice), but the north cap, also includes a large deposit of frozen water. The latest measurements of PFS and OMEGA spectrometer, both on board Mars Express, also show the presence of H_2O ice above the south cap.

Mars probably had a lot of liquid water on it at some time in the past. Large outflow channels, each of which could only have been formed by the massive release of water over a short period of time, scar four regions: Chryse-Acidalia, Elysium Planitia, the eastern Hellas Basin and the Amazonis Planitia. Several of these channels drain into the northern plains, lending support to the existence of an ancient ocean over most of the northern hemisphere. However, there is other evidence for flowing water in earlier times.

Valley networks that must also have been formed by water cross the Martian southern highlands. From a distance, the valley networks resemble river valleys on Earth, but the camera on NASA's MGS is revealing some notable differences. The valleys tend to start and end up with the same width and shape and they have few small tributaries up-stream. This argues for an underground source of water rather than run-off after rainfall. Once on the surface, though, the water must have remained for a long time to carve out the valleys, some of which are more than 200 km long. That could only have happened if Mars was warm and wet when they formed more than 3.8 billion year ago.

There are also impact craters, formed when meteorites smashed into the Martian surface. Most of the degraded craters are large. Some large, ancient craters are the sources of channels, and some are partly filled by layers of easily eroded material, suggesting that the craters once contained lakes. Most of the fresh-looking craters are smaller. Craters formed in soft, probably water-logged ground. Many craters on Mars, especially at latitudes greater than 45°, are surrounded by lobed patterns suggesting that the impacting object struck wet or icy ground. The latest images from the HRSC instrument on Mars Express display wonderful examples of such craters.

Most of the large channels start in the Martian highlands and end in low plains

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Kasaei Vallis is the largest outflow channel on Mars. It was possibly created by glacial erosion or water outflows from subglacial lakes. This picture was taken by the High Resolution Stereo Camera (HRSC) onboard ESA's Mars Express orbiter

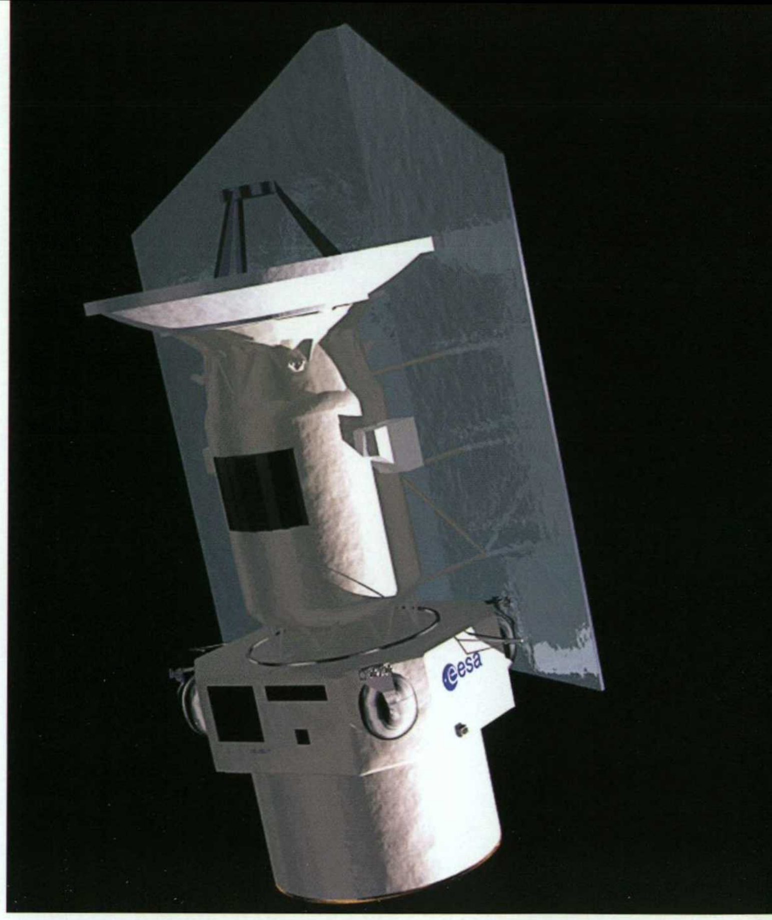
that may once have held an ocean several kilometers deep. Altitude measurements from orbit show that these northern plains are incredibly flat - flatter than any terrain on Earth except deep ocean basins. There is also a narrow line of steep slopes that surrounds the northern plains, everywhere at the same altitude. Some investigators have suggested that this line was eroded by the waves of an ancient Martian ocean.

The soil of Mars contains around 1% water, and some of the Martian meteorites contain small amounts of water-bearing minerals. A substantial fraction of Mars' water could be in these surface materials, depending on the thickness of the planet-wide soil layer. Most of the water that once flowed on Mars, though, is probably trapped underground.

Which kinds of minerals could be connected with the presence of water on Mars? First and foremost, various carbonates (calcite for example), but also some ferric oxides (for example hematite), which are often associated with the presence of water on Earth. About 3% of the surface mapped by the Thermal Emission Spectrometer on Mars Global Surveyor probably contains coarse-grained crystalline hematite. The presence of this mineral can be a good confirmation of the presence of water in this region in the past.

Discussion is still open about the presence of minerals connected with water on Mars. Images of the planet clearly show the signatures of past bodies of standing water, where the accumulation of sedimentary deposits should have occurred. On the other hand, the apparent absence of carbonates in the homogeneous fines covering the Martian surface raises the question: Where might carbonates be hiding now? Researchers from SRC in Warszawa who are interpreting the PFS data are very actively involved in this discussion.

We have demonstrated that a proposed destruction mechanism, the photodecomposition caused by UV radiation, cannot alone account for the "missing" carbonates. By means of simulations, we have shown that the difficulties in detecting the carbonates can be ascribed to the low temperatures of the emitting zones so far observed.



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Herschel Space Observatory is slated for launch in 2007. A group from the Space Research Center in Warszawa is very actively involved in Herschel's HIFI spectrometer experiment, which is focused on the subject of water in the Solar System

Future mission

The exploration of Europa, Mars, and our own Moon are all realities happening today, making for an exciting future of potential explorations and discoveries based on the existence of water. Such a new possibility will be offered, in the nearest future, by the Herschel Space Observatory - a planned infrared and sub-millimeter satellite. The satellite is slated for launch in 2007. The key scientific topics to be addressed by Herschel will also cover cometary and planetary atmospheres in our Solar System. A group from the Space Research Center in Warszawa is very actively involved in Herschel's HIFI spectrometer experiment, which is also focused on the subject of water in the Solar System.

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Further reading:

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