Mars, our most Earth-like planetary neighbour, beckons. Its pristine and diverse surface, equal in area to Earth's land surface, displays a long and fascinating history, punctuated by impact events, volcanism, tectonics, and aeolian, fluvial and glacial erosion. A century ago, astronomers believed they were witnessing the last attempts of a dying martian civilisation to cope with the devastating effects of climate change. The notion of an intelligently inhabited Mars was later dispelled, but the expectation that simple life forms could have survived persisted. Today, after sending robotic missions to Mars, our view of the planet retains some striking similarities to those earlier romantic conjectures.

We know from orbiting spacecraft that Mars has undergone dramatic climatic and geologic changes. Water coursing over its surface in the distant past left dramatic evidence in deeply carved channels and fluvial networks. Yet today we find the planet is cold and dry. There is no evidence so far that life exists there now, but primitive life during Mars' warmer, wetter past is a real possibility. So, mysteries remain: how did our Earth-like neighbour arrive at its present parched, cold and almost airless state? Did life evolve and then die out? Did it leave a fossil record? Last but not least, can the changes experienced by Mars teach us something about the dramatic changes being predicted for our own planet?

These and other questions have spurred scientists and engineers to meet the enormous challenge of sending missions to Mars. A Mars-bound spacecraft must survive journeys of more than 6 months, approach the planet from just the right angle and at the right speed to enter orbit, and then operate successfully to return valuable observations. Some missions have failed, but the successes have more than repaid the effort and risk. Our knowledge about Mars has grown dramatically with every successful visit. Four decades of space-based observations have produced more information and knowledge than earlier astronomers with Earth-bound telescopes could have imagined.

Europe joins Mars exploration

Since the Greeks of more than 2000 years ago, many Europeans have made important observations of Mars with the naked eye and through ground-based telescopes, including Nicolaus Copernicus, Tycho Brahe, Johannes Kepler, Galileo Galilei, Christian Huygens, Giovanni Cassini, William Herschel, Giovanni Schiaparelli and Eugene Antoniadi. Europeans have also contributed their fair share of speculation and fantasy about the planet in a fine tradition beginning in 1897 with the publication of *The War of the Worlds* by H.G. Wells, in which hostile martians invade Earth.

The Soyuz launcher and its precious cargo are transported to the launch pad on 29 May 2003.

**Mars from 5.5 million km, imaged by the High Resolution Stereo Camera (HRSC). The dark features at top are part of the northern lowlands, where oceans possibly existed billions of years ago.
(ESA/DLR/FU Berlin; G. Neukum)**

Europe, however, never sent its own spacecraft to Mars – until now. The European Space Agency (ESA) launched the Mars Express orbiter and its small Beagle 2 lander in 2003 on Europe's first mission to any planet. Research institutes throughout Europe provided the instruments onboard the orbiter, some of them first developed for the ill-fated Russian Mars-96 spacecraft. Now upgraded, they provide remote sensing of the atmosphere, surface, subsurface and space environment of Mars to a degree of accuracy never before achieved. The information being gleaned is helping to answer many outstanding questions about the planet.

The mission

Mars Express was successfully launched on 2 June 2003 from Baikonur, Kazakhstan, by a Russian Soyuz rocket. Following a cruise of almost 7 months, the main spacecraft was captured into orbit on 25 December 2003 and soon established a highly elliptical polar orbit with a closest approach to the surface of about 270 km and a period of about 6.75 h. The fate of the Beagle 2 lander, aimed to land in Isidis Planitia, remains unknown. In addition to global studies of the surface, subsurface and atmosphere at unprecedented spatial and spectral resolutions, the unifying theme of the mission is the search for water with all the instruments in its various states everywhere on the planet.

ESA provided the launcher, orbiter and operations, while the instruments were provided by scientific institutions through their own funding. The ground segment includes the ESA station at Perth, Australia, and the mission operations centre at ESOC in Germany. The Mars Express prime contractor was Astrium in Toulouse, France, and a large number of European companies were involved as subcontractors. The ESA engineering and scientific teams are located at ESTEC in The Netherlands. International collaboration, through participation either in instrument hardware or data analysis, is important for diversifying the scope of the mission and improving its scientific return. Collaboration with the NASA Mars Exploration Rovers plays an important role because of the complementary science goals.

Following spacecraft commissioning in January 2004, most instruments began their own calibration and testing, in the process acquiring scientific data. This phase lasted until June 2004, when all the instruments but one began routine operations after the payload commissioning review. The deployment of the MARSIS radar antennas, however, was postponed. The late deployment was initially planned to maximise daylight operations of the other instruments before the pericentre naturally drifts to southern latitudes, which coincides with the nightime conditions required for subsurface sounding by MARSIS. The nominal lifetime of the orbiter is a martian year (687 days), with a potential extension by another martian year to complete global coverage and observe all seasons twice over.

Early science results

The High Resolution Stereo Camera (HRSC) has provided breathtaking views of the planet, in particular of karstic regions near the Valles Marineris canyon (pointing to liquid water as the erosional agent responsible for modifying tectonic and impact features in the area) and of several large volcanoes (the Olympus Mons caldera and glaciation features surrounding Hecates Tholus). The OMEGA IR mineralogical mapping spectrometer has provided unprecedented maps of water-ice and carbon dioxide-ice occurrence at the south pole, showing where the two ices mix and where they do not. The Planetary Fourier Spectrometer (PFS) has measured atmospheric carbon monoxide variations in each hemisphere and confirmed the presence of methane for the first time, which would indicate current volcanic activity and/or biological processes. The SPICAM UV/IR atmospheric spectrometer has provided the first complete vertical profile of carbon dioxide density and temperature, and has simultaneously measured the distribution of water vapour and ozone. The ASPERA energetic neutral atoms analyser has identified the solar wind interaction with the upper atmosphere and has measured the properties of the planetary wind in Mars' magnetic tail. Finally, the MaRS radio science experiment has measured for the first time surface roughness by pointing the spacecraft high-gain antenna towards the planet, reflecting the signal to Earth. Also, the martian interior is being probed by studying the gravity anomalies affecting the orbit owing to mass variations of the crust.

Water is the unifying theme of the mission, studied by all instruments using different techniques. Geological evidence, such as dry riverbeds, sediments and eroded features, indicates that water has played a major role in the early history of the planet. It is assumed that liquid water was present on the surface up to about 3.8 billion years ago, when the planet had a thicker atmosphere and a warmer climate. Afterwards, the atmosphere became much thinner and the climate much colder, the planet losing much of its water in the process; liquid water cannot be sustained on the surface under present conditions. Mars Express aims to reveal why this drastic change occurred and where the water went. A precise inventory of existing water on the planet (in ice or liquid form, mostly below ground) is important given its implications for the potential evolution of life on Mars; the 3.8 billion-year age is precisely when life appeared on Earth, which harboured similar conditions to Mars at that time. Thus, it is not unreasonable to imagine that life may also have emerged on Mars and possibly survived the intense UV solar radiation by remaining underground. The discovery of methane in the atmosphere could indicate just that or the presence of active volcanism. From previous orbital imagery, volcanoes on Mars were assumed to have been dormant for hundreds of millions of years. This idea needs a fresh look as the implications of currently active volcanism are profound in terms of thermal vents providing niches for potential ecosystems, as well as for the thermal history of the planet with the largest volcanoes in the Solar System. Mars Express is already hinting at a quantum leap in our understanding of the planet's geological evolution, complemented by the ground truth being provided by NASA's rovers.

Scope of this publication

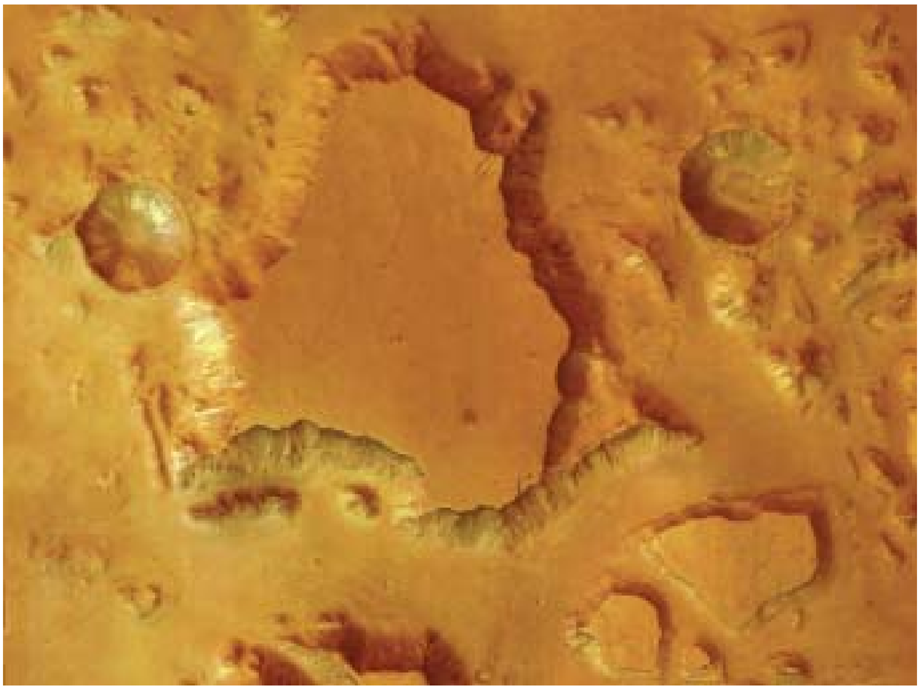
This ESA Special Publication focuses on the Mars Express scientific instrumentation and its state about a year after launch in order to include some initial scientific discoveries. In spite of the Beagle 2 failure, the lander's payload is also thoroughly described here because it is of the highest scientific value. Furthermore, the orbiter instruments are looking specifically for possible evidence of past or present life. No other mission to Mars since NASA's Viking missions in the 1970s has made exobiology so central to its scientific goals. For further details, both in terms of science results and public outreach, see http://sci.esa.int/marsexpress/

Spectacular views

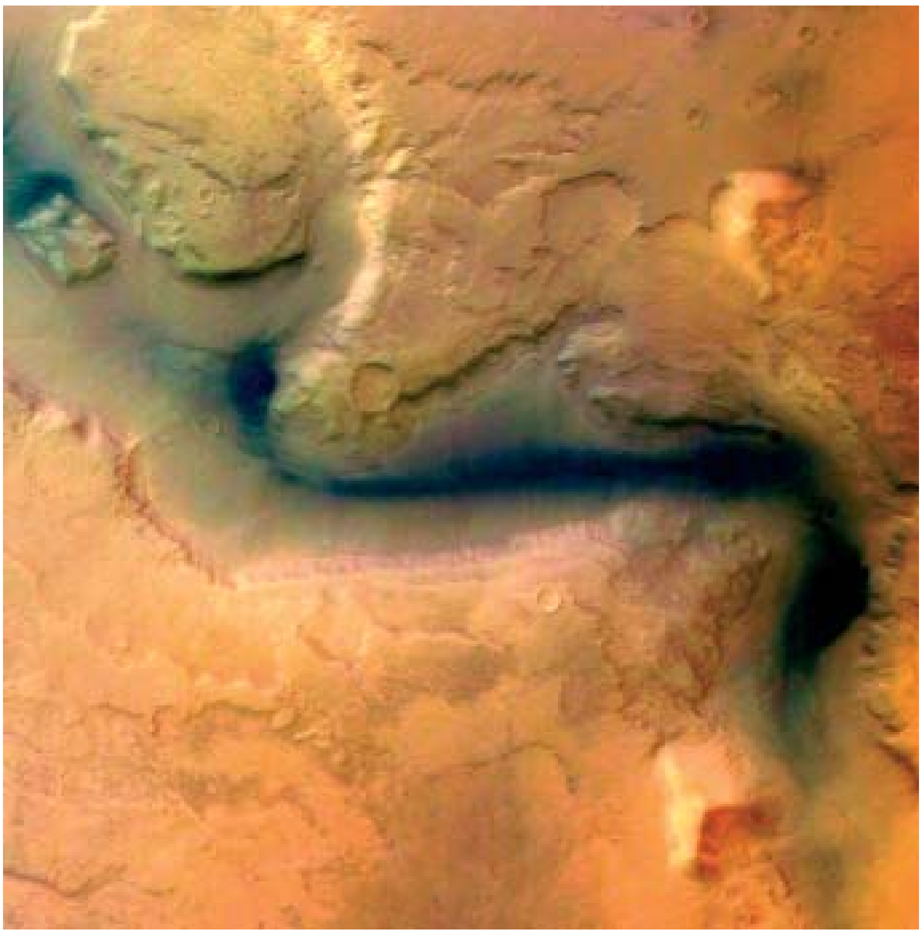
A few spectacular initial results are shown in the next few pages, selected in view of their wide public appeal rather than their intrinsic scientific value. All the scientists involved in Mars Express are now busy submitting papers that include important scientific results, and even a few breakthroughs at this early phase of the mission. The purpose here is to give a visual impression of this early science data.

Agustin Chicarro
Project Scientist, Mars Express
ESTEC, June 2004

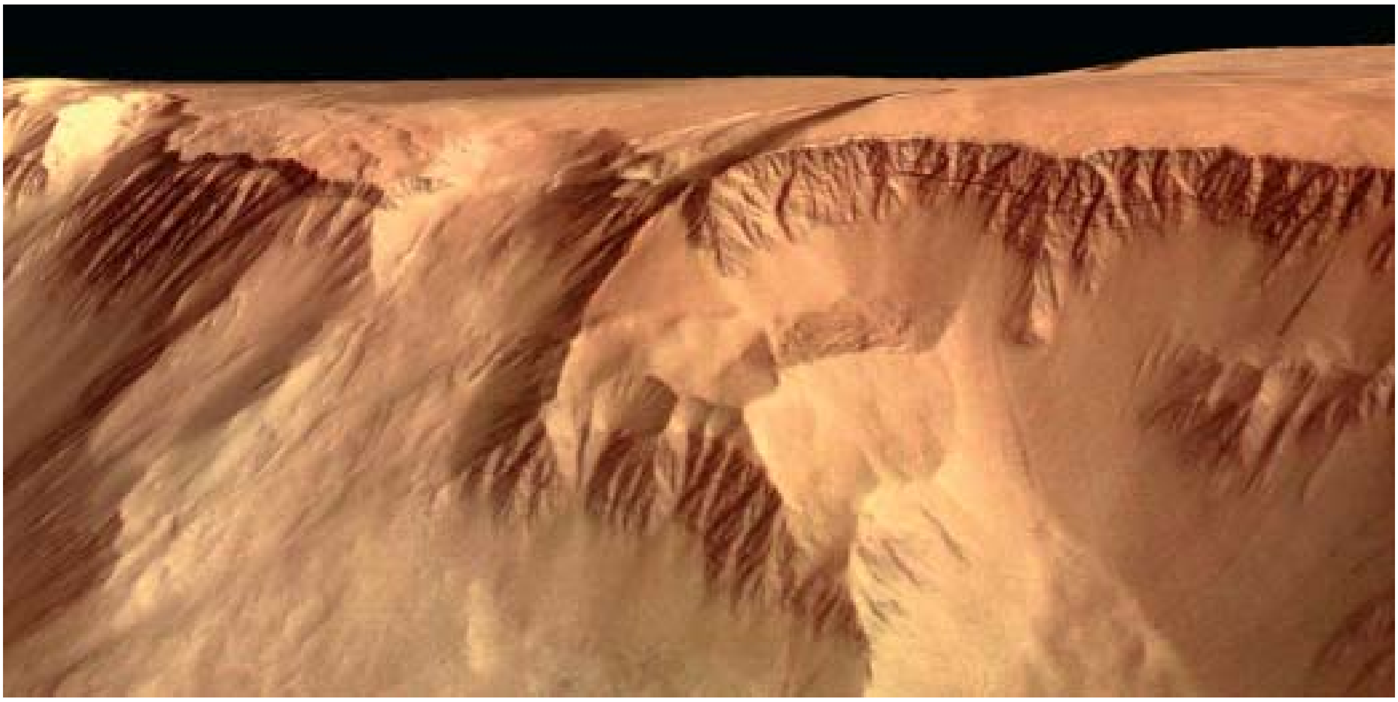
This HRSC image was recorded on 14 January 2004. It shows a portion of a 1700 km-long and 65 km-wide swath taken in the south-to-north direction across the huge Valles Marineris canyon. It is the first Mars image of this size at high resolution (12 m pix^{-1}), in colour and in 3-D. (ESA/DLR/FU Berlin; G. Neukum)



This HRSC image was recorded during revolution 18 on 14 January 2004. It shows a vertical view of a mesa in the true colours of Mars. The summit plateau stands about 3 km above the surrounding terrain. Only isolated mesas remain intact after the original surface was dissected by erosion. The large crater has a diameter of 7.6 km. (ESA/DLR/FU Berlin; G. Neukum)

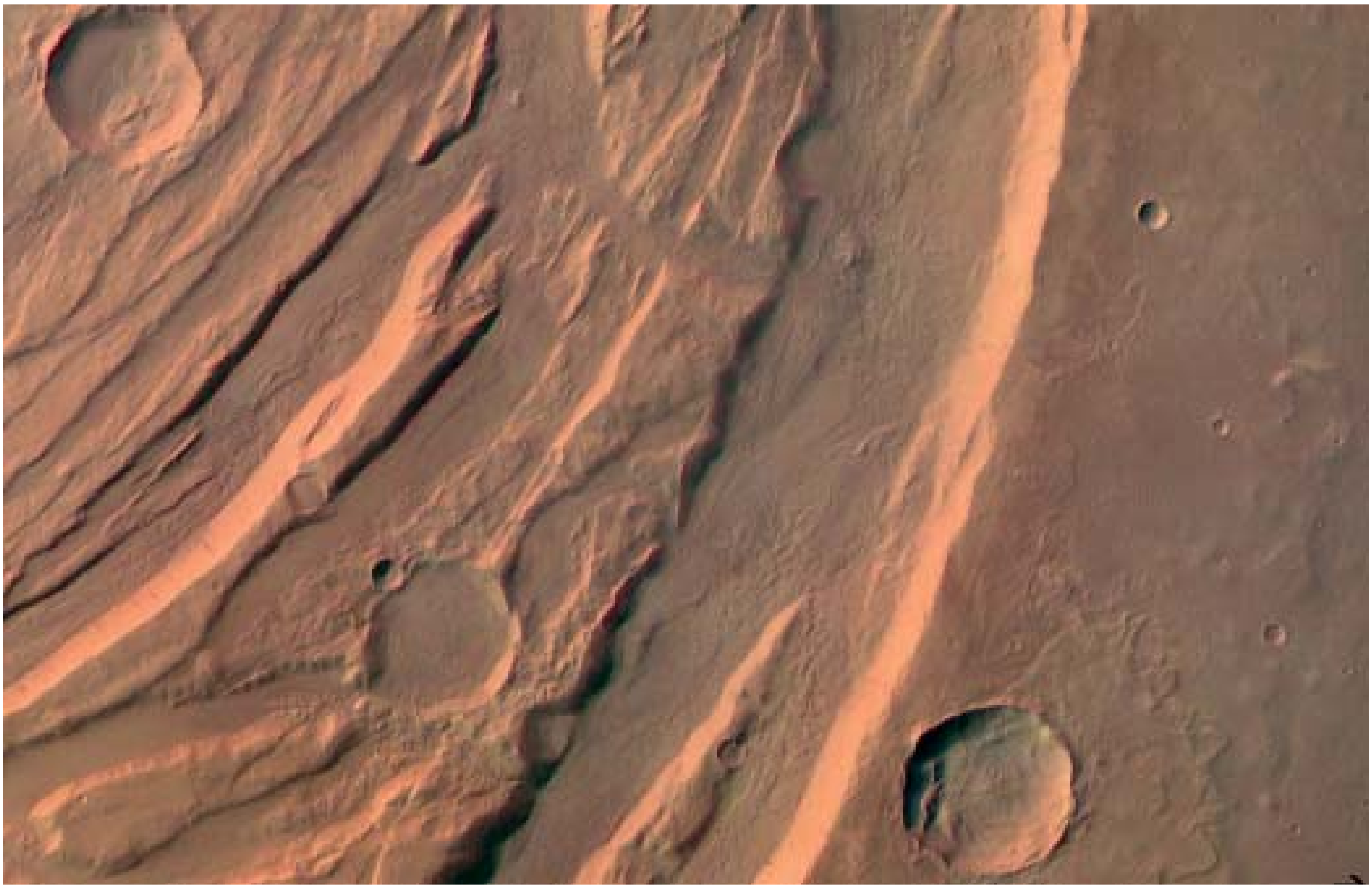


This HRSC image was recorded during revolution 18 on 15 January 2004 from a height of 273 km, east of the Hellas basin at 41°S/101°E. The area is 100 km across, with a resolution of 12 m per pixel. It shows the Reull Vallis, formed by flowing water. North is at top. (ESA/DLR/FU Berlin; G. Neukum)

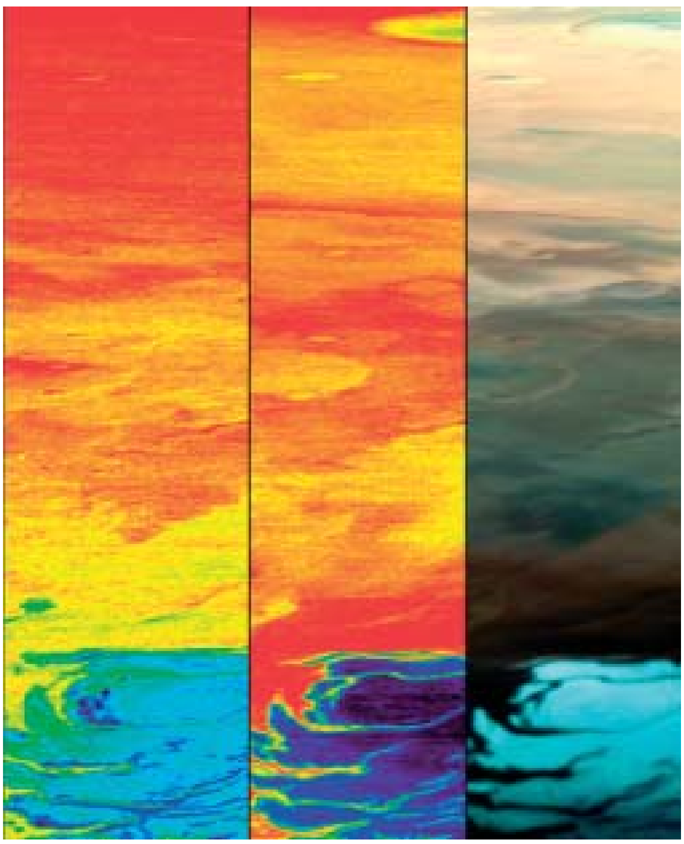


This HRSC image was recorded during revolution 143 from an altitude of 266 km, providing a perspective view of the western flank of the Olympus Mons shield volcano in the western hemisphere. The escarpment rises from surface level to more than 7000 m. Resolution is about 25 m per pixel. The picture is centred at 22°N/222°E; north is to the left. (ESA/DLR/FU Berlin; G. Neukum)

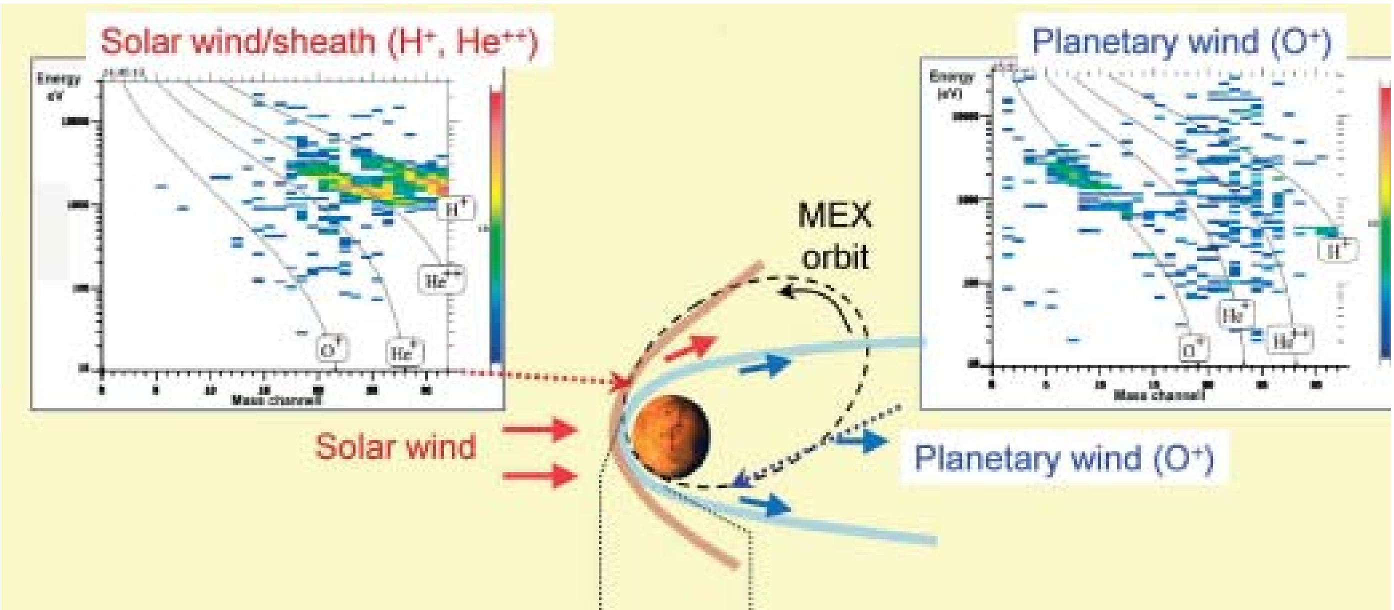
This HRSC vertical view shows the complex caldera at the summit of Olympus Mons, the highest volcano in the Solar System. The average elevation is 22 km; the caldera has a depth of about 3 km. This is the first high-resolution colour image of the complete caldera, taken from a height of 273 km during revolution 37 on 21 January 2004. Centred at 18.3°N/227°E, the image is 102 km across with a resolution of 12 m per pixel; south is at the top. (ESA/DLR/FU Berlin; G. Neukum)



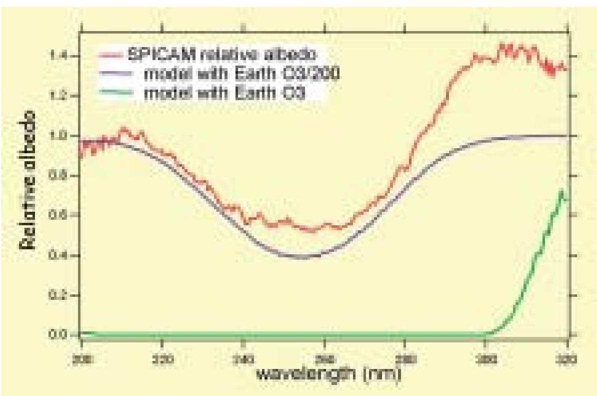
This HRSC image shows the Acheron Fossae region, an area of intense tectonic activity in the past. Acheron Fossae marks the northern edge of the Tharsis plateau; it is part of a network of extensional fractures that radiates from the Tharsis 'bulge', a huge area of regional uplift of intensive volcanic activity. The region is situated at 35-40ºN / 220-230ºE, about 1000 km north of Olympus Mons. (ESA/DLR/FU Berlin; G. Neukum)



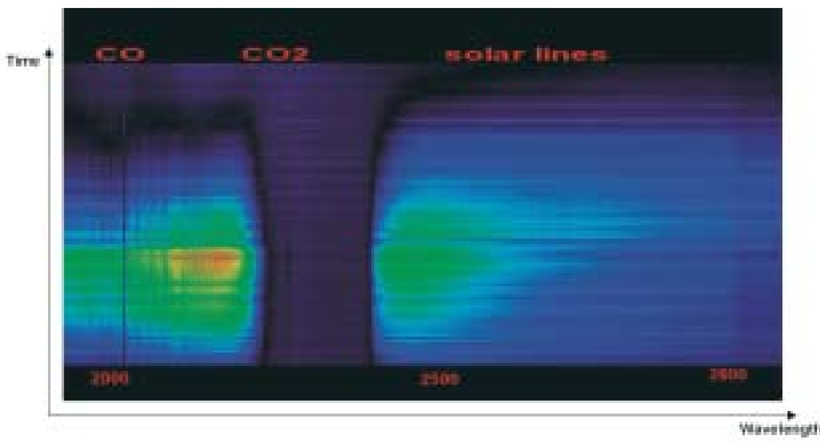
OMEGA observed the southern polar cap of Mars on 18 January 2004, in all three bands. At right is the visible image; in the middle is carbon dioxide ice; at left is water ice. The two types of ice are mixed in some areas but distinct in others. (ESA/IAS, Orsay; J-P. Bibring)



Initial ASPERA results indicate the very different characteristics of two important regions: the impact area of the solar wind with the upper atmosphere and in the Mars tail (planetary wind), confirming the existence of the planetary wind (O^+ and molecular ions). (ESA/RFI Kiruna; R. Lundin)



SPICAM has provided the first complete vertical profile obtained by an orbiter of the density and temperature of carbon dioxide from 10 km to 110 km above the surface. It has also measured the distribution of water vapour and ozone simultaneously for the first time, indicating that where there is more water vapour there is less ozone. (ESA/CNRS Verrières; J.-L. Bertaux)



PFS initial results indicate that the atmospheric distribution of carbon monoxide is different over the northern and southern hemispheres. The presence of atmospheric methane has also been confirmed by PFS, which opens up new possibilities of there being lifeforms on the planet today. Methane is rather short-lived in the martian atmosphere, so the source(s) that replenish it can have only two origins: volcanic or biologic. (ESA/IFSI Frascati; V. Formisano)