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Filling the gaps in the map of Mercury: first results from the MESSENGER flyby

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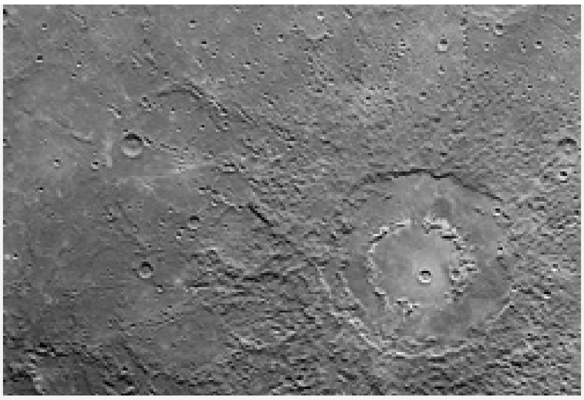
Mercurial mosaic

On 14 January 2008, the American spacecraft MESSENGER passed by planet Mercury at a distance of just 200 kilometres. The seven instruments on board the probe recorded gigabytes of data. Eagerly the planetary scientists waited for what they would see on the 1213 images returned: MESSENGER turned its two camera eyes on areas never photographed before by a space probe at such a close distance. In a first evaluation the MESSENGER team – with two participating scientists from DLR (German Aerospace Center) – concluded that Mercury does not resemble Earth’s Moon as close as had been thought before. MESSENGER (**ME**rcury **S**urface, **S**pace **EN**vironment, **GE**ochemistry and **R**anging) is a mission of NASA’s ‘Discovery Program‘, providing science with low-cost opportunities for innovative missions to solve the mysteries of the Solar System.

“We’re able to present some surprising results”, reports Jürgen Oberst from DLR’s Institute of Planetary Research in Berlin and a professor for planetary geodesy at Technical University Berlin, MESSENGER participating scientist. “Many things on Mercury seem to be quite different from what we expected.” Dr. Jörn Helbert, a colleague and another participating scientist from DLR who joined the MESSENGER science team for two weeks in the US, confirms: “It was fascinating to see the new data coming in every day – and almost each time our ideas about Mercury changed a little bit.” The scientist from DLR is focusing on the evaluation of spectrometer data that can lead to evidence about the surface composition of Mercury.

Unique MESSENGER images shed new light on Mercury



Dual ring crater on Mercury

The innermost, and smallest, of the eight planets in the Solar System has, until now, been visited by one single spacecraft. During three fly-bys in the years 1974 and 1975, NASA’s *Mariner 10* mission was only able to image approximately 45 per cent of Mercury’s surface. “More than half of the planet is unknown - ‘terra incognita’ in a way. But now we will be able to fill in the gaps on the maps in Mercury’s atlas with new data. It’s a little bit like a first expedition in the interior of a continent not yet explored in detail”, Jürgen Oberst states happily. The geophysicist from DLR is working intensively on geodetic and mapping aspects regarding Mercury.

“The first MESSENGER flyby of Mercury not only provided us with a ‘gold mine’ of data, it was near perfect also from the perspectives of spacecraft performance and manoeuver accuracy”, added Professor Sean Solomon from the Carnegie Institution of Washington, the Principal Investigator of the mission. The target area for the probe’s fly-by was reached with high precision, allowing the spacecraft to continue its journey through the inner Solar System on the calculated path. This will lead MESSENGER to its second rendezvous with the planet in October 2008, and once more in September 2009.

Finally, the probe will travel on a route very close to Mercury’s own orbit about the Sun and then will be able to enter into orbit around the planet in 2011.

The probe has been designed and built by the Applied Physics Laboratory (APL) of the Johns Hopkins University in Laurel, Maryland (USA). The APL is also controlling the space probe and provides a centre for the science teams’ research.

Since it is so close to the Sun’s tremendous gravitational pull, this planet is very difficult to navigate to. MESSENGER after its lift-off on 3 August 2004, has therefore been directed on a complicated spiral tour some three and a half billion kilometres through the inner Solar System before the first encounter with its prime target was possible. Another challenge for mission designers is the protection of the instruments and satellite components from the heat of the Sun which is between fifty and sixty million kilometres away.

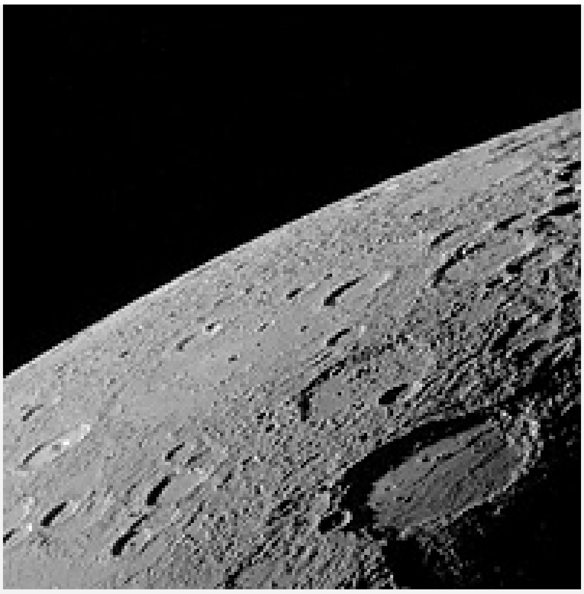
Preparing the future – Europe will follow the US to Mercury

Mercury's Long Cliffs

The findings that the two DLR scientists will make with MESSENGER's data will help to prepare for another mission to Mercury. Europe's space agency, ESA, last week signed a contract with industrial partners to start the construction of the *BepiColombo* project, scheduled to lift off in 2013 and reaching Mercury in 2019. DLR will provide two instruments, a laser altimeter and a spectrometer alongside scientific contributions to the mission. "*BepiColombo* will complement perfectly the MESSENGER mission and build on the results", says Dr Oberst.

"I have returned with many new ideas from the US that we want to test in our laboratory", Dr Helbert explains in his plans. DLR operates a "Planetary Emissivity Laboratory" (PEL), a testing facility for the spectroscopic investigation of rocks that are similar to those occurring on the planets Mercury and Venus. In this facility, the rocks are heated to temperatures above 400 degrees Celsius – quite common on both these celestial bodies. The intensity of the reflections of light in wavelengths of the visible and near-infrared are then measured and evaluated. With these analyses Helbert hopes to be able first to support the MESSENGER team, "and then in the combination of PEL data and data received from Mercury we might be able to obtain important clues that help us in the preparation for the spectrometer experiment we're planning for *BepiColombo*".

Mercury's surface: many impact craters, high scarps – and possibly volcanic plains



Krater Sholem Aleichem crater on Mercury's horizon

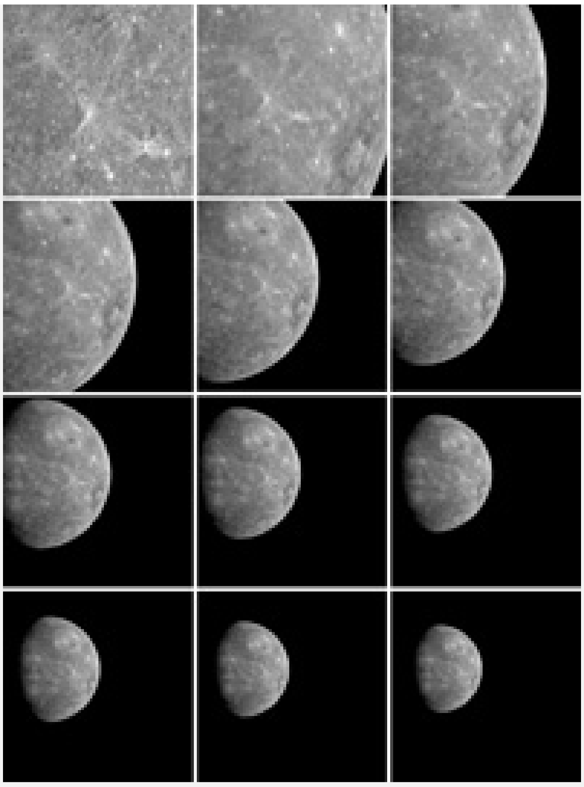
Eyecatching in the images returned by the 'Mercury Dual Imaging System' (MDIS) are the myriads of impact craters on the planets' surface – reminiscent of the far side of Earth's Moon. Due to the higher gravitational pull on Mercury the pattern of material ejected and re-deposited on the surface is different to what we observe on the Moon. This makes estimates of the ages of the geological units on Mercury more difficult, since the method of age estimation is based on a statistical evaluation of the frequency of different-size primary impact craters on a planet's surface. There is agreement among planetary scientists, though, that most of what can be seen on Mercury should be older than three billion years. Like all the other planets in the Solar System, Mercury was formed about 4.5 billion years ago. For the first time, MESSENGER's camera system was able to provide a complete view of the Caloris impact basin; Mariner 10 imaged only half of that structure. It turns out that Caloris has a diameter of 1550 kilometres, about a fifth larger in size than previously estimated. The basin is the result of a collision of an asteroid with Mercury three to four billion years ago. Interestingly, the plains inside the basin's rims are smoother and have a higher reflectivity, or 'albedo', than the scattered areas outside Caloris.

This is a striking difference to the Moon, where the large impact basins are filled with dark volcanic rocks low in silica - the so-called basalts. The geologists in the MESSENGER team have two theories at hand:

First, the smooth plains could have formed when the tremendous energy of the impact melted Mercury's crust to some depth, forming a 'lake' of impact melt in the Caloris depression that the impact caused. The molten rock solidified, forming smooth plains.

Alternatively there is another scenario, as is the case for many impact basins on the Moon. Some time after the impact, volcanism set in, again filling the depression with lava. The brighter appearance of these plains on Mercury could be the result of a different mineralogy than on the Moon.

Another contrast to the Moon is the existence of huge cliffs, or scarps, stretching for hundreds of kilometres over the surface. These 'rupes' are remnants of tectonic processes, like compression of Mercury's crust. Possibly they formed when the young hot planet cooled and shrank to its present size. The process could be compared to some extent with the wrinkles that form when grapes are sun-dried to raisins – with no liquids being involved in Mercury's case.



MESSENGER-Images from the fly-by

Precise measurements of shape and axis-orientation

When working with the first MESSENGER data from Mercury, one of the focuses of DLR is the mapping of the planet's surface and the determination of 'geodetic parameters'. That is, the exact measurement of the precise shape of the planetary body and the orientation of its rotational axis. In addition, with the images, the results of the Mariner 10 mission can be confirmed – or corrected. In a first simplified model, Mercury has been seen as a perfectly spherical body, with its rotational axis perpendicular to the plane of its orbital motion. “But now we’re able to determine the size of the planet and its ellipsoidal shape with higher accuracy”, explains Dr. Oberst. “The existing values for the radius have uncertainties that are larger than one kilometre.”

An important method to accomplish this task is to measure the limb of the planet using the complete darkness of the space behind as background. With these measurements, the curvature of the planetary disk, and hence, its radius, can be determined with high accuracy. Also, of particular interest is the measurement of periodic variations in the planets’ rotation called ‘librations’. This value tells scientists something about the inner structure of the planet, be it completely solid, or partially molten – and to which extent molten. Before Dr. Oberst digs into the fly-by data he will have a look at all the images that MESSENGER recorded while approaching the planet. This helps to quantify the geometrical calibration of the camera optics and the measurements, and hence improve the data evaluation itself.

For the first time since launch, MESSENGER’s laser altimeter fulfilled its dedicated task: During the fly-by, many point-measurements of the distance between the spacecraft and the surface of the planet have been made, resulting in a 2000 kilometre-long profile along the flight path. These data can be used to measure the albedo of Mercury’s surface materials. The highpoint for the laser altimeter, though, will come when the probe enters its orbit around Mercury. Then systematic mapping of the planet's topography will begin.

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