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SPACE

Mercury up close

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When MESSENGER, launched by NASA, began orbiting Mercury on March 18, it became the first spacecraft to do so.



The deep, terraced crater Camoes, named after the Portuguese poet Luiz Vaz de Camoes.

THE planet Mercury has been somewhat neglected during the exploration of the solar system. It is the only planet within three billion kilometres of the earth not to have been orbited by a spacecraft until recently, and with good reason, for Mercury is a tricky place for a spacecraft to visit. The main stumbling block is that reaching Mercury requires a complex trajectory designed to decelerate a spacecraft. Until now, the only spacecraft to have achieved this feat, which was a monument to human ingenuity, was Mariner 10. It flew past Mercury three times between March

1974 and March 1975. Orbital mechanics meant that each time the same hemisphere was on view, and so only 45 per cent of Mercury's surface has been studied up close. Mariner 10 may have laid the foundations, but the complete mapping of Mercury and a full understanding of the planet's past remains an unfinished project.

The workhorse for this endeavour is a spacecraft named MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging). Launched by the National Aeronautics and Space Administration (NASA) of the United States in August 2004, MESSENGER lowered its velocity using a close fly-by of the earth followed by two of Venus and is currently orbiting around Mercury. MESSENGER started orbiting Mercury on March 18, 2011. But before that, the spacecraft needed to modify its trajectory using three fly-bys of the planet, which occurred on January 14, 2008, October 6, 2008, and September 29, 2009. Aside from enabling MESSENGER to be on target for its rendezvous with Mercury on March 18, these intricate fly-bys were a perfect prologue to the orbital mission and provided scientists an opportunity to observe regions of the planet not seen by Mariner 10. "Roughly 50 per cent of the planet was seen by MESSENGER during the first fly-by, and of that there was about a 25 per cent overlap with the Mariner 10 hemisphere," said Mark Robinson, a MESSENGER science team member at Arizona State University. "So we will see about 25 per cent of Mercury that is completely new; combined with Mariner 10, we will then have seen about 70 per cent of Mercury."

PICTURES:

BY

SPECIAL

ARRANGEMENT

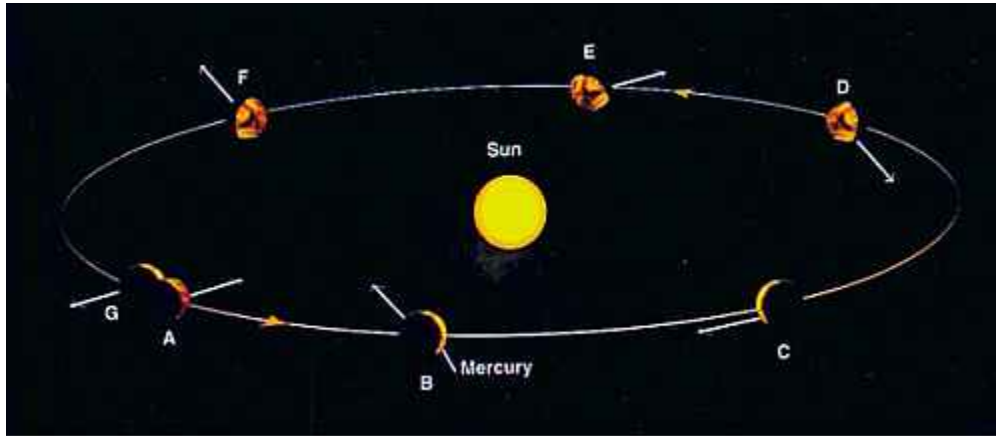


The orbiting messenger and its sunshade, without which the spacecraft would be roasted.

Mercury is the innermost planet of the solar system and until very recently has been one of the least understood. Mercury is a small world, with just over 5 per cent the volume and mass of the earth and virtually no atmosphere. Before the space age, telescopic observers knew little about the planet. Since we on the earth are outside Mercury's orbit looking in at it, Mercury always appears close to the sun in the sky. At times it rises just before sunrise and at times it sets just after sunset, but it is never up when the sky is really dark.

Whenever Mercury is visible, its light has to pass obliquely through the earth's atmosphere to reach us. Since we are looking close to the horizon, along a long path through turbulent air, our

view is blurred. Thus, astronomers have never gotten a really good view of Mercury from the earth even with the largest telescopes. Many people have never seen it at all. It is said that Copernicus' deathbed regret was that he had never seen Mercury in his lifetime.



FOLLOW THE ARROW that starts facing rightward towards the sun in the image of Mercury at the left of the illustration (A), as Mercury revolves along the line. Mercury, and thus the arrow, rotates once with respect to the stars in 59 days, when it has moved only two-thirds of the way around the sun (E). Note that after one full revolution of Mercury around the sun, the arrow faces away from the sun (G). It takes another full revolution, a second 88 days, for the arrow to face the sun again. Thus, the rotation period with respect to the sun is twice 88, or 176, days.

Rotation of Mercury

From studying drawings and photographs, astronomers of the first half of the 20th century did the best they could to describe Mercury's surface. A few features could, it seemed, barely be distinguished, and astronomers watched to see how long those features took to rotate around the planet. From these observations they decided that Mercury rotated in the same amount of time that it took to revolve around the sun. Thus, they thought that one side always faced the sun and the other side always faced away from the sun. This conclusion led to the fascinating further conclusion that Mercury could be both the hottest planet and the coldest planet in the solar system. Such a match of periods is called synchronous rotation, which implies that the periods of rotation and revolution are equal, and so the less massive body will always keep the same face toward the more massive body. The moon is in synchronous rotation.



The 305-metre-diameter radio telescope at Arecibo in Puerto Rico was used to determine Mercury's rate of rotation.

Later, it became possible not only to receive radio signals emitted by Mercury but also to transmit radio signals from the earth and detect the echo. This technique is called radar. In the 1960s, the 305-metre-diameter radio telescope at Arecibo in Puerto Rico was used to determine Mercury's rate of rotation, and it was detected that scientists had for a long time been wrong about the period of Mercury's rotation. It actually rotates in 58.6441 days. Mercury's 59-day period of rotation is exactly $\frac{2}{3}$ of the 88-day period of revolution that scientists had originally equated with its rotation period. Thus, Mercury rotates three times for each two times it revolves around the sun.

The rotation period is measured with respect to the stars; that is, the period is one mercurian sidereal day, the interval between successive returns of the stars to the same position in the sky. Mercury's rotation and revolution combine to give a value for the rotation of Mercury relative to the sun (that is, a mercurian solar day) that is neither the 59-day sidereal rotation period nor the 88-day period of revolution. As can be seen from careful analysis of the combination, if we lived on Mercury, we would measure each day and each night to be 88 earth days long. We would alternately be fried and frozen for 88 earth days at a time. Mercury's solar rotation period is thus 176 days long, twice the period of Mercury's revolution.

Mariner 10

In 1974, much more was learned about Mercury in a brief time. Mariner 10, launched by the U.S., flew right by Mercury. First, Mariner 10 passed by Venus and then had its orbit changed by Venus's gravity to direct it to Mercury. The 475-kilogram Mariner 10 spacecraft had a variety of instruments on board. One was a device to measure the magnetic field in space and near the two planets. Another measured the infrared emission of the planets and from that information deduced their temperatures. The other instruments – a pair of television cameras – generated not only the greatest popular interest but also much important data.



MESSENGER photographed the bright, rayed crater Hokusai (named after the Japanese artist Katsushika Hokusai).

When Mariner 10 flew by Mercury the first time, it took 1,800 photographs, which were transmitted to the earth. It came as close as 750 km to Mercury's surface. The most striking overall impression obtained was that Mercury was heavily cratered. On its second visit, in September 1974, Mariner 10 was able to study the south pole and the region around it for the first time. This pass was devoted to photographic studies. The spacecraft came within 48,000 km of Mercury.

On its third visit, in March 1975, it had the closest encounter – only 300 km above the surface. Thus, it was able to photograph a part of the surface with a high resolution of 50 m. In total, Mariner 10 sent back images of 45 per cent of Mercury's surface, with an average resolution of 1 km.

The MESSENGER spacecraft approached Mercury on January 14, 2008, at about 7 p.m. GMT. Within a quarter of an hour, it had skimmed above the crater-blasted surface at an altitude of just 200 km before racing away at a velocity of 25,000 km/hour relative to Mercury. During its fly-by visit, MESSENGER snapped hundreds of pictures of regions of the planet never seen before and at a resolution far beyond what Mariner 10's cameras could achieve. As the spacecraft approached Mercury, it recorded its approach with its Mercury Dual Imaging System (MDIS).

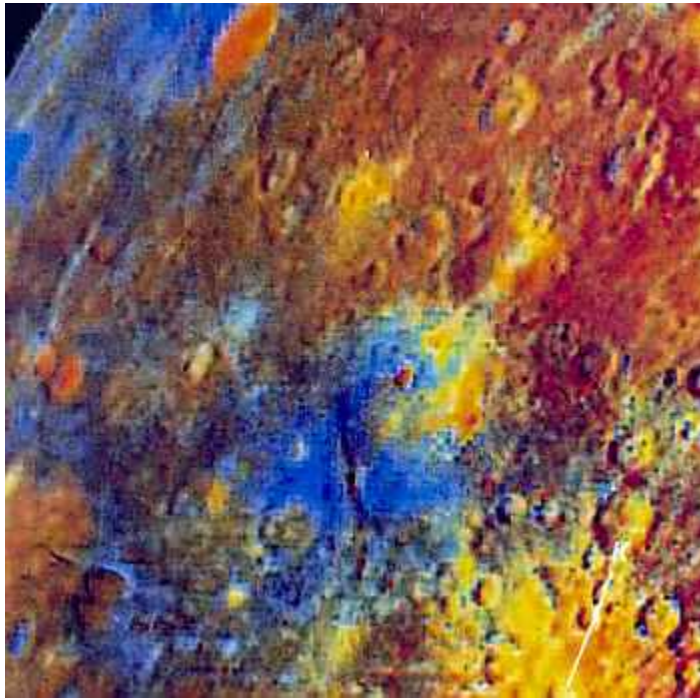


The crater-strewn surface of Mercury, photographed for the first time by Mariner 10.

The MDIS showed the previously mapped section of Mercury's surface at a higher resolution than what was recorded by Mariner 10, while the spacecraft's other instruments were also kept busy. The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) investigated the abundance of species of atmospheric gases in the space over the planet. Other instruments such as the magnetometer, the X-ray spectrometer and the gamma-ray and neutron spectrometer investigated Mercury's magnetic field and made an attempt to measure the bulk composition of the planet's crust. MESSENGER then raced into Mercury's shadow and swept past the unlit hemisphere at an altitude of just 200 km. Here, MESSENGER's Mercury Laser Altimeter (MLA) began measuring the planet's topography. After emerging into the sunlight, MDIS had fantastic views of Mercury in a gibbous phase displaying a swathe of unseen surface, a slice of the Mariner 10 hemisphere towards the limb, and the 1,300-km diameter Caloris impact basin basking in the blazing sun.

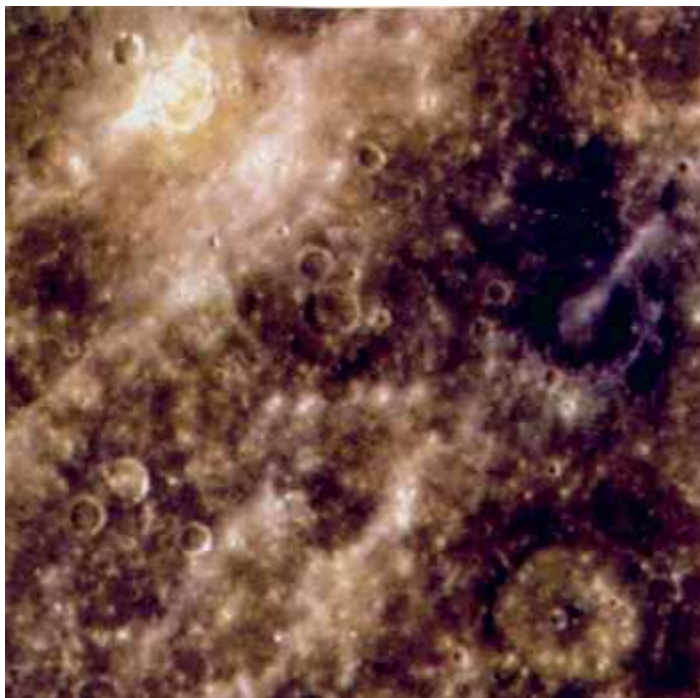
Entering mercury's orbit

After the fly-by, MESSENGER travelled at 224,000 km/hour, becoming the fastest spacecraft ever. With the three fly-bys under its belt, MESSENGER settled into Mercury's orbit on March 18. The spacecraft has been looping around Mercury at an inclination of 80° in an elliptical orbit varying between 200 km and 15,193 km. At its lowest point, MESSENGER is able to resolve surface features a mere 18 m across. MESSENGER is to complete two orbits every 24 hours, but it will still be six months before the MDIS has images of the entire surface and another six months before global models of Mercury's surface chemistry, magnetic field and gravity field are completed. MESSENGER's mission will last for only two mercurian solar days, that is, for 2×176 earth days, and as such during the spacecraft's 12 earth months of orbital observations, it will experience just two mercurian solar days. All the new data will help answer key questions about the planet already raised by earth-based observations. It is expected that the mystery behind Mercury's surprisingly dense core that produces a magnetic field that interacts with the solar wind may also be solved.



An enhanced false-colour map of a part of Mercury observed by the Mariner 10 mission. The colours show regions in which different minerals are dominant.

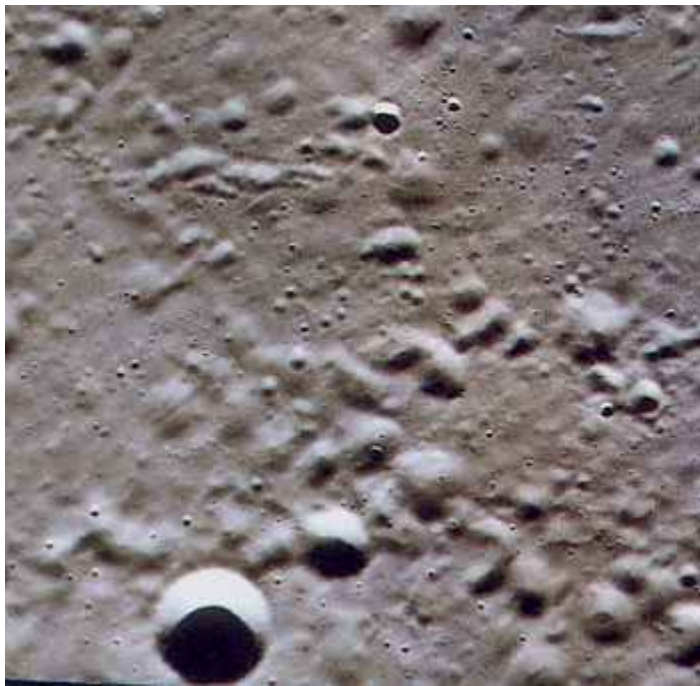
As MESSENGER arcs around Mercury, the craft is protected from the relentless heat by a large sunshade. Without this precaution the spacecraft would be roasted to the same maximum temperature as the planet below, a staggering 450° Celsius.



ONE OF THE first colour images of Mercury received from MESSENGER.

There are areas on the planet that are indicative of the lava flows that once ran across the surface of a young Mercury but cooled and solidified long ago. Similar lava flows can be seen on the moon: those dark “seas” that are called maria. But on Mercury the lava flows are not dark in appearance as on the moon, so spotting them requires a little extra effort. Key to understanding the history of Mercury's surface are the “lobate scarps”, first imaged by Mariner 10 and seen in superb detail through MESSENGER. These are cliff-like features that crisscross the surface in the vague shape of lobes (hence “lobate”) and are thought to have formed when the interior of Mercury began to cool and shrink, forcing the surface to crumple and contract.

With MESSENGER, scientists hope to understand the sequence of events that led to Mercury looking like it does today. What is clear just from the initial batch of MESSENGER images is that there were different periods of contraction, lava flows, and then more contraction as the different features overlaid themselves on top of one another. Now, with the mass of information from MESSENGER's exploration to be accumulated and analysed, it is clear that Mercury may hold important clues to the violent birth of other planets and of the earth itself.



One of the highest resolution pictures ever taken by MESSENGER of the planet's surface. The picture has a resolution as small as 16 m a pixel.

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