Venus

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Abstract
On 8 June 2004 Venus will pass in front of the Sun as seen from the Earth. Many people will watch the small dark dot cross the solar disk, but will they stop to think about Venus as a real place? In this article we discuss what we know about Venus, what it looks like from orbit, what you might see if you were on the surface and future plans for further exploration of the planet.

Introduction

On 8 June 2004 a transit of Venus will occur, as Venus passes in front of the Sun as seen from the Earth. This is an extremely rare event—no living person has ever seen this happen! Venus will appear as small dark dot on the solar disk, visible from most of Europe, Africa and Asia, and will take about six hours to complete the transit. Many people (weather permitting!) will watch the small dark dot cross the solar disk, but will they stop to think about Venus as a real place? What does Venus look like from orbit? What would you see if you were on the surface? In this article we begin with a brief summary of planetary data for Venus, followed by an introduction to the atmosphere and surface features, and end with a look at plans for future exploration.

Venus: planetary data

Venus is the second planet from the Sun, orbiting at a distance of about 108 200 000 km. The orbit of Venus is the most nearly circular of that of any planet, with an eccentricity of less than 1%. The mean radius of Venus is 6052 km (Earth's is 6378 km). Venus has no satellite.

The rotation of Venus is somewhat unusual in a number of ways. Firstly, it is very, very slow: one Venus day is equivalent to 243 Earth days. Since it only takes Venus approximately 225 Earth days to complete one orbit of the Sun, one Venus day is actually longer than one Venus year! Secondly, it is retrograde: Venus rotates in a clockwise direction when viewed from above the north pole. (The north pole of Venus is the one on the same side of the ecliptic as the Earth's north pole.) Most planets and satellites have prograde rotation (i.e. they rotate in a counterclockwise direction when viewed from above their north pole). Finally, the period of rotation of Venus and the period of its orbit are synchronized such that it always presents the same face toward Earth when the two planets are at their closest approach. It is not known whether this is a resonance effect or merely a coincidence.

Venus is sometimes referred to as the sister planet of Earth. This is because, despite the unusual rotational properties of Venus, the two planets have some clear similarities. They are approximately the same size and have approximately the same density and chemical composition. For many years, because of these similarities, it was thought that below its dense clouds Venus might be very similar to Earth. The interior of Venus is probably very similar to that of Earth: an iron core about 3000 km in radius, a molten rocky mantle comprising the majority of the planet. It was even thought for many years that Venus might harbour life. However, more detailed studies of Venus in more recent times have

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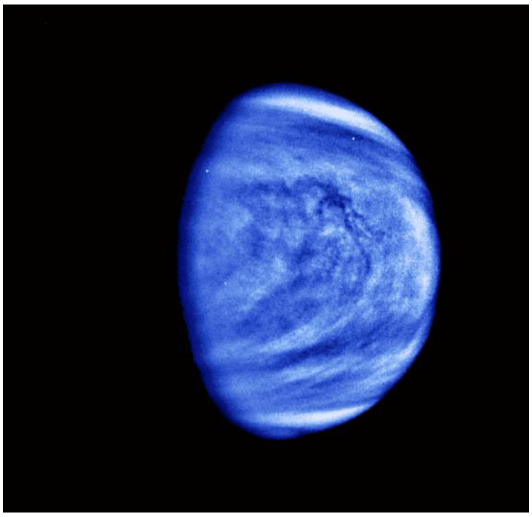

Figure 1. Venus cloud patterns (colourized and filtered) imaged by the Galileo spacecraft. Courtesy NASA/JPL-Caltech.

shown that Venus is very different from the Earth in many important ways. For example, Venus has a swelteringly hot surface and does not have a magnetic field. The hot surface is due to a greenhouse effect, while the lack of a magnetic field may be because of the slow rotation of the planet, or because no inner core has yet begun to form. Why Venus does not have a magnetic field is one of the many fascinating questions that we still do not have the answer for—yet! These similarities and differences between Venus and Earth lead us to study our sister planet further, in the hope that it can help us to understand how Earth-like, habitable planets form.

Venus: atmosphere

Venus has a very dense atmosphere that is mostly made up of carbon dioxide. There are several layers of clouds of that are many kilometres thick and composed in part of sulfuric acid, which completely obscure our view of the surface. Strong winds blow at about 350 km h^{-1} at the cloud tops (figure 1), but winds at the surface are very slow and blow at no more than a few km h^{-1}. The pressure of this dense atmosphere at the surface is 90 atmospheres, which is about the same as the pressure at a depth of 1 km in Earth's oceans. This dense atmosphere also produces a runaway greenhouse effect that raises the surface temperature of Venus by about 400 K to over 740 K. This is more than hot enough to melt lead. In fact, the surface of Venus is actually hotter than that of Mercury, even though Venus is nearly twice as far away from the Sun. The greenhouse probably formed relatively early in the history of Venus. The current hot surface temperatures preclude the presence of liquid water on the surface, although some interpretations of the atmospheric chemistry of Venus suggest that there might have once been oceans.

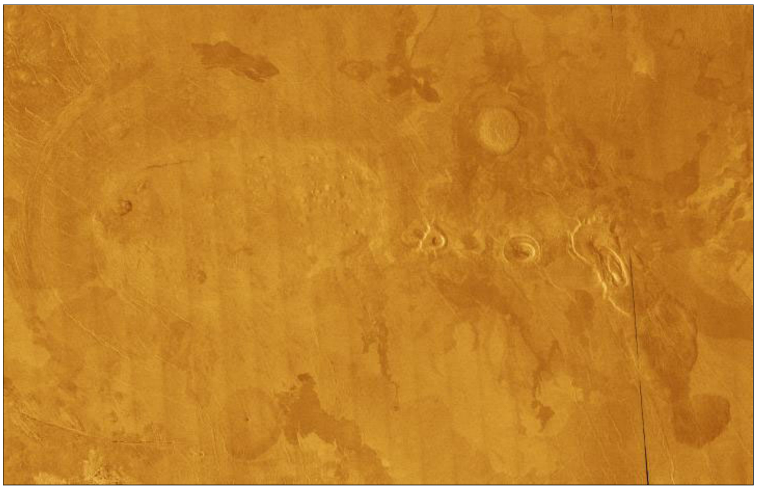

Figure 2. An image of the volcanic plains of Venus. The area covered is 490 km long by 310 km wide. The plains appear mottled because of different roughness of each solidified lava flow. The rougher the terrain the brighter it appears in the radar image. The small, bright bumps clustered in the centre-left of the image are a grouping of small volcanoes called a shield field. Courtesy NASA/JPL-Caltech.

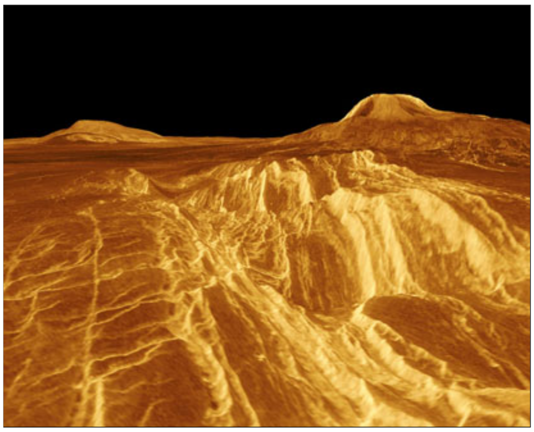

Figure 3. A three-dimensional, computer-generated, false colour, perspective view of Sif and Gula Montes on the surface of Venus. The viewpoint is at an elevation of 1.2 km at a location 700 km southeast of Gula Mons, the volcano on the right horizon. Gula Mons reaches 3 km high, whereas Sif Mons, the volcano on the left horizon, has a height of only 2 km. Courtesy NASA/JPL-Caltech.

Venus: surface

Venus has a solid surface that you could stand and walk on, assuming that you could withstand the 90 atmospheres of pressure and the ~700 K temperature. Most of the surface consists of relatively smooth plains that have little relief (figure 2). Even though there is relatively little relief in the plains, there are still plenty of things to look at.

A large proportion of the surface of Venus is covered by lava flows. There are many clusters of small volcanic shield volcanoes, called shield fields (figure 2). There are also several large shield volcanoes, similar to Mauna Loa on the Big Island of Hawaii or Olympus Mons on Mars, such as Sif Mons and Gula Mons (figure 3).

There are a number of broad depressions in the surface, including Atalanta Planitia, Guinevere Planitia and Lavinia Planitia, and two large highland areas: Aphrodite Terra and Ishtar Terra. Aphrodite Terra is located along the equator of Venus, and is about the same size as South America. Ishtar Terra is about the same size as Australia, and is located in the northern hemisphere of Venus. The main feature of Ishtar Terra is a high plateau called Lakshmi Planum, which is surrounded by the enormous Maxwell Montes (figure 4). The Maxwell Montes are the highest mountain range on Venus, which rise up

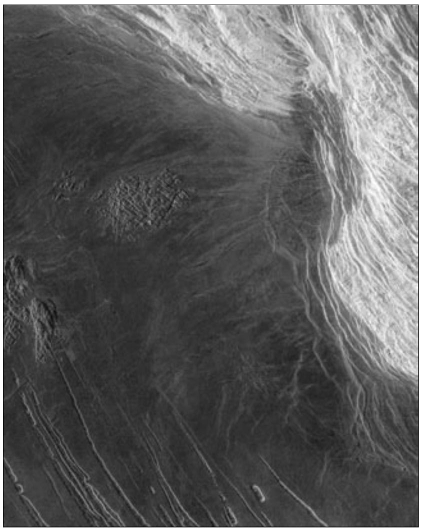

Figure 4. The eastern edge of Lakshmi Planum and the western edge of the Maxwell Montes. To the bottom left of the image are the plains of Lakshmi, which are made up of radar-dark, smooth lava flows. To the top right of the image are the Maxwell Montes, which are made up of radar-bright parallel ridges that are separated by distances of 2–7 km. The image is 300 km wide. Courtesy NASA/JPL-Caltech.

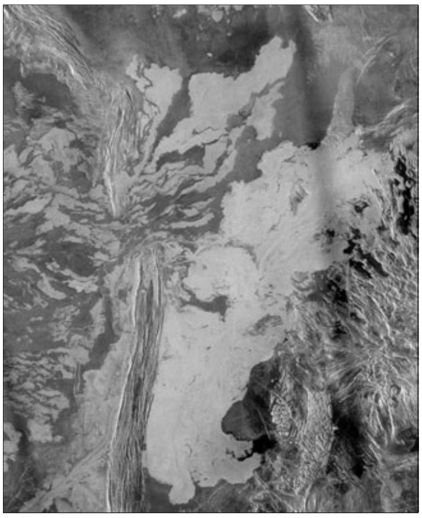

Figure 5. Radar image mosaic of the Lada region of Venus. The scene is approximately 550 km east–west by 630 km north–south. The mosaic shows a system of east-trending radar-bright and dark lava flows encountering and breaching a north-trending ridge belt (left of centre). Upon breaching the ridge belt, the lavas pool in a vast, radar-bright deposit, which covers ~100 000 km^2 (right side of image). The source of the lava flow is a caldera that is ~300 km west of the scene. North is at the top of the image. Courtesy NASA/JPL-Caltech.

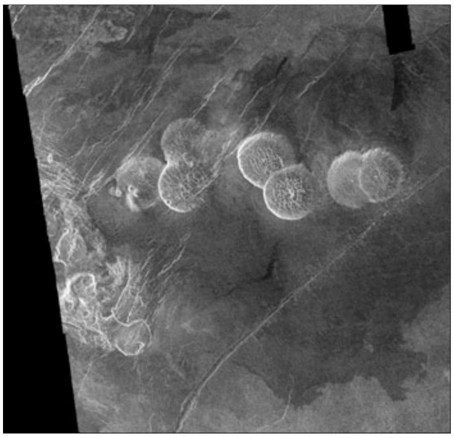

Figure 6. Seven circular, dome-like hills at the eastern edge of Alpha Regio, Venus, averaging 25 km in diameter with maximum heights of 750 m. The prominent black area in the northeast corner of the image is a data gap. North is at the top of the image. Courtesy NASA/JPL-Caltech.

Figure 7. Atete Corona, which is 600 km by 450 km. Coronae are roughly circular features that are thought to form over thermal upwellings and are often associated with volcanism. The black rectangles that form a dashed line across this image are simply data gaps, i.e. places for which no data were retrieved from the spacecraft. Courtesy NASA/JPL-Caltech.

to 11 km above the mean planetary radius—they would be a great place to practise the ultimate in extreme sports!

Tectonism is seen at all scales on Venus, from the very large such as the Maxwell Montes, through an extensive system of fracture belts that circle the planet, down to relatively small fractures that are found throughout the volcanic plains. The interplay between tectonic and volcanic features is often complex, and suggests that the surface has been very geologically active (figure 5).

Images of Venus have revealed a wide variety of interesting features, some of which, including pancake volcanoes (figure 6) and coronae (figure 7), are unique to Venus. Pancake or steep-sided volcanoes are dome-like hills that may be interpreted as very thick lava flows that came from an opening or vent on relatively level ground, allowing the lava to flow in an even pattern outward from the opening. The complex fractures on top of the domes may indicate that a cooled outer layer formed that was later stretched when further lava flowed into the interior of the dome. Alternatively, the domes may be the result of molten rock or magma in the interior pushing the surface layer upward for a time, then withdrawing, causing the collapse and fracturing of the dome surface. Coronae are typically circular features that are characterized by an annulus of ridges, fractures and troughs. They have a variety of topographic forms including domes, plateaus, depressions and rimmed depressions, and are often associated with volcanism, and are thought to form over thermal upwellings.

Similarly to Earth, there are very few impact craters on Venus, indicating that the surface is relatively young: extensive volcanism has wiped out or covered up older surfaces, including any large craters from early in Venus's history. There are no small craters on Venus, because small meteoroids burn up in the dense atmosphere of the planet before reaching the surface. Craters on Venus are sometimes clustered, indicating that large meteoroids that do reach the surface can be broken up in the atmosphere (figure 8). Scientists who study Venus are not sure whether the extensive volcanism that resurfaced Venus occurred rapidly, or at a slower pace over the last 700 million years.

The study of the surface of Venus is ongoing, and is providing us with some clues as to why Venus and Earth have evolved so differently. It is hoped that future missions will provide data that will help us to understand the formation and evolution of the atmosphere, surface and interior of Venus, and help us to understand better why Earth is apparently unique in our solar system in its ability to sustain life.

Venus: future exploration

The first spacecraft to visit Venus was Mariner 2 in 1962 (figure 9). Since then it has been visited by many others, including the Soviet spacecrafts Venera 7, which was the first spacecraft to land on

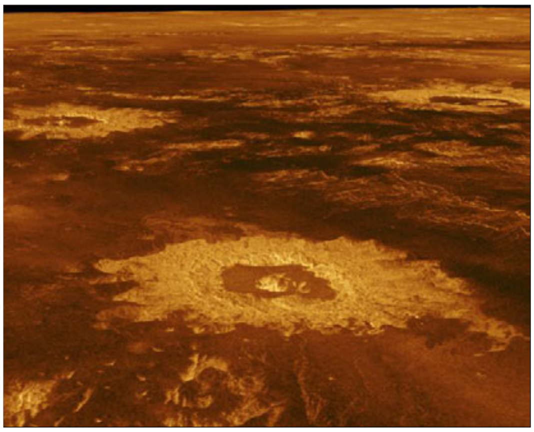

Figure 8. A three-dimensional, computer-generated, false colour, perspective view of three impact craters on the surface of Venus. The viewpoint is located southwest of Howe Crater, which appears in the bottom-centre of the image and has a diameter of 37.3 km. Danilova crater, with a diameter of 47.6 km, is in the top-left of the image. Aglaonice crater, with a diameter of 62.7 km, is in the top-right. Courtesy NASA/JPL-Caltech.

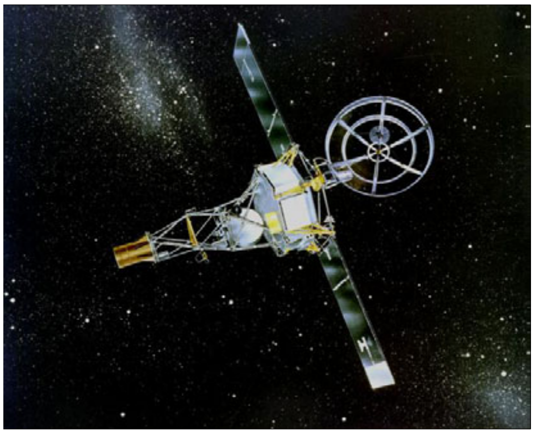

Figure 9. Mariner 2—the world's first successful interplanetary spacecraft. It was launched on 27 August 1962, and passed within about 34 000 km of Venus. It collected, and sent back to Earth, valuable information about interplanetary space and the atmosphere of Venus. Courtesy NASA/JPL-Caltech.

another planet, and Venera 9, which returned the first photographs of the surface (figure 10). Most recently, the orbiting US spacecraft Magellan produced stunningly detailed images of the surface of Venus using radar (figure 11).

Designing missions to Venus presents a number of challenges. All images of the surface from the Magellan mission are produced by

Figure 10. Venera 9 Lander image of the surface of Venus. Courtesy NASA/JPL-Caltech.

radar which, unlike instruments using visible wavelengths, can penetrate the clouds and return images of the surface. If you want to land on the surface you need to design a craft that can withstand the intense pressures and temperatures for as long as possible. Eventually, this challenge comes down to a simple choice: would you prefer to try to dissipate as much heat as possible, and eventually burn up from the outside inwards, or would you prefer to try to insulate your spacecraft as much as possible, and eventually burn up from the inside outwards?

The next spacecraft planned for launch to Venus is the European Space Agency's Venus Express, which is due to be launched in November 2005 and does not include a landing module. Venus Express will carry an impressive suite of instruments, many of which are based on the designs originally used for the Mars Express mission, which successfully entered Mars orbit in January 2004. Venus Express is designed to answer the following questions:

- How does the atmosphere circulate?
- How does the composition of the atmosphere change with depth?
- How does the atmosphere interact with the surface?
- How does the upper atmosphere interact with the solar wind?

NASA is also looking to return to Venus, and has asked for proposals for lander missions to the planet. We look forward to rising to these challenges, discovering some of the answers to these questions and developing new questions for future missions to Venus.

Acknowledgments

All images in this article are courtesy NASA/JPL-Caltech and can be found in the NASA Planetary Photojournal, an excellent resource bank containing thousands of images complete with their original release captions [1].

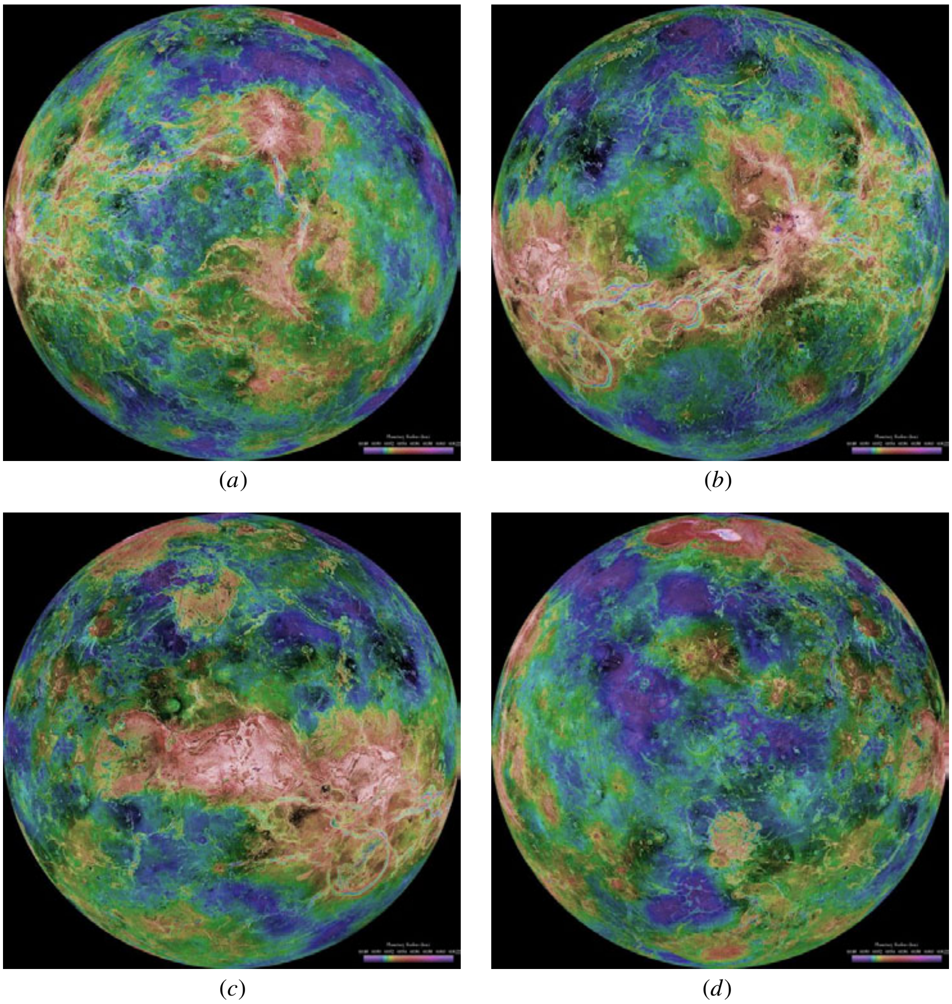

Figure 11. Hemispheric views of Venus, as revealed by radar: (*a*) centred at 270° east latitude; (*b*) centred at 180° east latitude; (*c*) centred at 90° east latitude; (*d*) centred at 0° east latitude. These composite images have been processed to improve contrast and to emphasize small features. They are colour-coded to represent elevation: blue is low, green is intermediate, red is high, white is extremely high. Courtesy NASA/JPL-Caltech.

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