German Aerospace Center

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Out of orbit and in the lab – On the track of Venus's secrets

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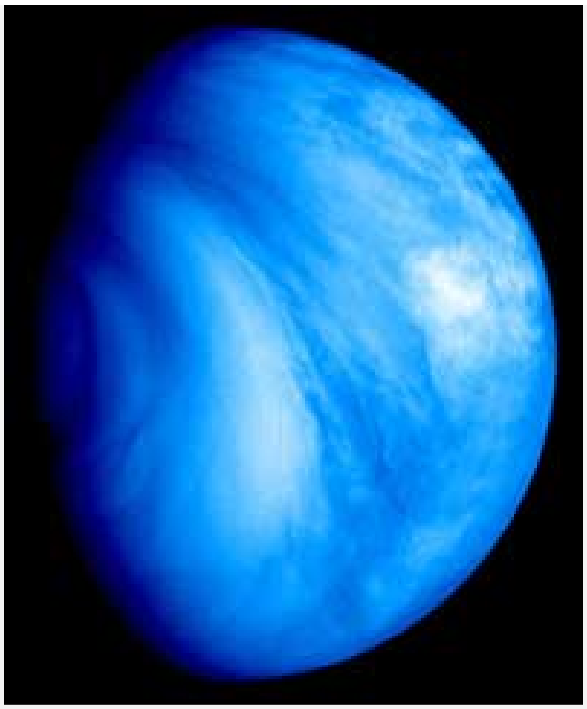


The southern hemisphere of Venus in ultraviolet

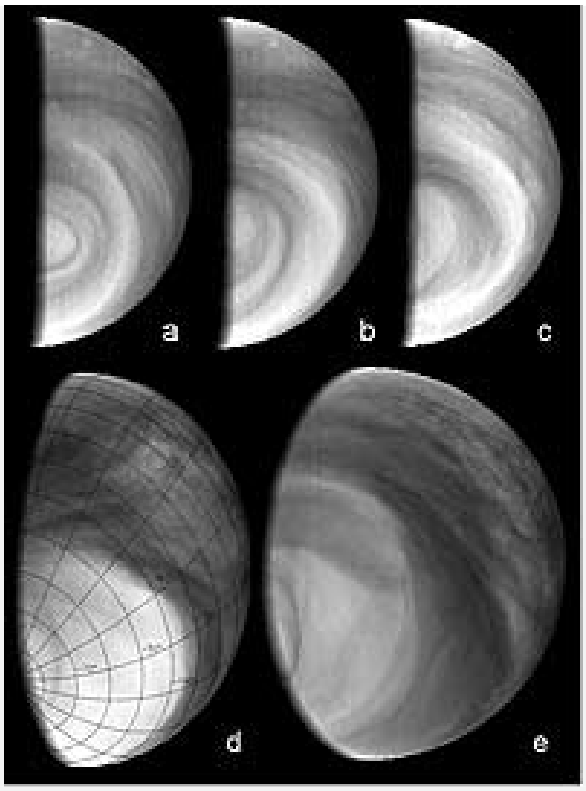
It will probably be many years yet before the first piece of Venus's surface is actually examined in a laboratory on Earth. But even today laboratory tests on volcanic rocks from Earth are a great help in analysing the surface of Venus that is marked by thousands of volcanoes. Scientists from DLR (the German Aerospace Center) are finding out about the mineral and chemical composition of Venus's surface by investigating both the spectral properties of Earth's volcanic rocks and measurements from the European Space Agency (ESA) space probe Venus Express. "With the VIRTIS spectrometer onboard Venus Express we can look at the surface of the planet through the thick cloud cover in some near infrared wavelengths," explained Dr. Jörn Helbert from the DLR Institute for Planet Research in Berlin

Newly published in the scientific magazine, *Nature*, with DLR participation

Venus Express has been in orbit around Earth's near neighbour since 11 April 2006 and circles the planet once every 24 hours. "We compare the spectra recorded with measurements from rocks from volcanoes in Southern Italy and by the comparison with Earth we can better estimate what sort of rocks there are on Venus," said Helbert. At a press conference on 28 November 2007, ESA reported on this and other scientific results that were obtained with the mission. They will be published in the current issue of the scientific magazine, Nature, devoted to the Venus Express mission, which comes out on 29 November 2007. The DLR planet researchers have also collaborated on three of the nine scientific articles. As it is a member of the ESA, Germany also has a financial interest in the Venus Express mission through DLR's space agency.

"This could be a significant contribution to solving the question of how volcanic activity has developed on Venus," explained Helbert.

ESA has now made a film, that will be released soon, about the mission and the work of the Venus researchers comparing phenomena on Venus with volcanoes in Southern Italy. In it, DLR researcher Helbert and others explain volcanic activity on Venus. Tests on the atmosphere lead us to believe that Venus, which is almost as big as Earth, is perhaps much more like Earth than was previously assumed - or at least it was. Today, the gases enveloping the planet consist of 96.5% carbon dioxide that leads to a very strong greenhouse effect and constant temperatures of 457° C which would not support life. These temperatures are much too high for water, which is abundant on Earth, to be stable on Venus. The question is whether there ever has been a significant amount of water on Venus.



Rapid change in the weather in the highest Venus atmosphere

Water vapour fuelled the greenhouse effect on Venus

Water vapour fuelled the greenhouse effect on Venus and in addition Venus Express measurements show increased concentrations of the hydrogen isotope, deuterium. This confirms the hypothesis that "Earth's hot sister" was cooler in its early days and there must have been water on it temporarily.

But it evaporated quickly: The increasing amount of water vapour in the atmosphere increased the greenhouse effect so that it became even hotter on Venus. Solar radiation split the water molecules and the more volatile hydrogen disappeared into outer space - but favoured its lighter isotope so that the heavier hydrogen isotope, deuterium, accumulated in concentrations ten times higher than expected. The free oxygen contributed to the oxidation of the rocks on Venus's surface.

The Venus Monitoring Camera (VMC) on board the Venus Express allowed researchers to study the weather patterns on this planet over long periods for the first time. The VMC was developed and build in a collaborative venture between the Max Planck Institute for Solar System Research in Katlenburg-Lindau, the Institute for Data Technology and Communication Networks at the Technical University of Braunschweig and the DLR Institute for Planet Research with funding from the DLR aerospace agency. From the elliptical orbit it is possible to record the global dynamics mainly in the southern hemisphere and at the same time to study regional atmospheric phenomena high in the equatorial latitudes. Here Venus receives the most solar energy from the Sun which here is vertically overhead.

The weather: super rotation of clouds and a huge cyclone at the south pole

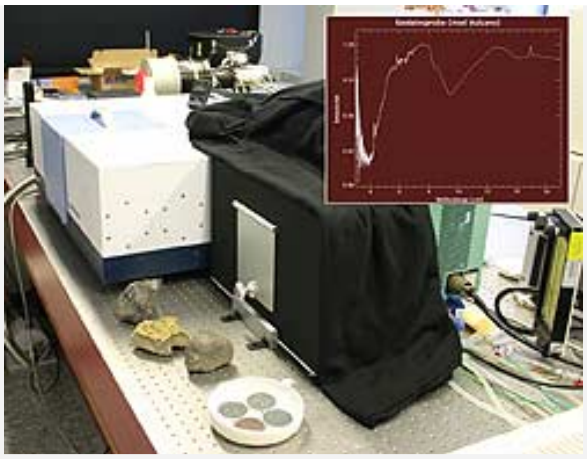
The recordings made by the VMC over a long period helped to answer the question of how the super rotation kept going: Depending on the degree of latitude, the bands of cloud rush round the whole planet in just three to five days at speeds of up to 400 kilometres per hour - much faster than the 243 days it takes for Venus to turn on its own axis and also much faster than winds on Earth. The new observations indicate that the super rotation is kept going by the dynamic dissipation of heat energy to the higher northern and southern latitudes.

The researchers discovered a stable swirl of cloud over the south pole that was strongly reminiscent of hurricanes on Earth but three to four times as big. But the weather changes extremely quickly in the latitudes around the south pole: Thus the VMC recorded changes in the cloud cover over large areas between two subsequent orbits which affected areas from the south pole to a latitude of 35° south. "We suppose that sulphur dioxide rises from the lower layers of the atmosphere, from the mesosphere, and has a massive influence on the weather patterns," said Prof. Ralf Jaumann from the DLR Institute for Planetary Research, who helped to build the VMC and is a member of the VMC scientific team. The DLR Institute for Planetary Research carries out the systematic processing of the VMC image data and creates cartographically accurate mosaics from the individual pictures.

VIRTIS (Visible and InfraRed Thermal Imaging Spectrometer) on Venus Express is able to examine the atmosphere of the planet three-dimensionally. This means that VIRTIS can look right into the clouds in near infrared wavelengths which allows us to make conclusions on phenomena at different heights right down to the surface. In two articles for the scientific magazine, Nature, co-authored by Dr. Jörn Helbert, new information on the composition of the upper atmosphere is presented.

With data from VIRTIS now, for example, detailed information on the distribution of oxygen in the gases surrounding Venus can be given. Its concentration increases as the days get longer and decreases again during the night. In addition the dynamics of the clouds in the cyclone system above the south pole have been investigated, not only in the way it is distributed physically and the changes over time but also the different depths. With VIRTIS the lower ridges of the cyclone system can be observed up to a height of 50 kilometres.

A joint effort by spectrometer and camera



The DLR planetary emissivity laboratory: Measurements at 500° Celsius

Data from VIRTIS and the VMC is also suitable for finding out about the composition of the surface of Venus. The spectrometer has taken more than a thousand pictures of the southern hemisphere since April 2006. Unlike the VMC, VIRTIS not only records data for the atmospheric window for the wavelength of 1.02 micrometres (thousandth of a millimetre) available in both instruments but over the whole spectral range up to five micrometres. With this data it is possible to reduce the influence of the clouds on the measuring results and to generate "cloud-free" image maps of the surface temperature.

"We are currently improving this data by removing interfering signals from the atmosphere," explained Nils Müller from the DLR. "We will draw conclusions on the properties and mineralogy of the surface from the minimal deviations between the measured and modelled surface temperatures," continued Müller. Thus it would be possible for the first time to map the different minerals on Venus's surface using its infrared spectrum. Together with colleagues from other scientific institutes the VIRTIS team at the DLR will shortly publish their results.

Venus in the DLR laboratory: Measurements at 500° Celsius

If you want to interpret the data from VIRTIS and the VMC in order to draw conclusions about possible rocks on the surface, a very basic question must be asked: Do the spectral properties of minerals change when the rocks are 500° Celsius, i.e. their reflection behaviour to different wavelengths? DLR is going into this question with its Planetary Emissivity Laboratory (PEL).

The volcanic island of Stromboli: Venus on Earth?

With the PEL the so-called emissivity of minerals and rocks can be measured, which shows how much thermal radiation a material gives off at a certain temperature. This property and particularly its dependency on the wavelength differs from rock to rock and can thus be used for identification. This is also used by a spectrometer experiment on the ESA Mars Express mission that is supported in the PEL by measurements on Mars-related minerals.

"Like so much on Venus, even comparable measurements with this planet are disproportionately more complicated than on Mars," said Dr Alessandro Maturilli, who is carrying out the PEL experiments at DLR. "Firstly the emissivity must be measured in very near infrared: 1.0 micrometres. But here, actually, reflected light dominates the measurements. Therefore, we carry out VIRTIS and VMC measurements on Venus on the night side and in the laboratory too, interfering radiation sources must be eliminated: The rock samples are in total darkness during the measuring procedure."

Secondly there are permanent temperatures of almost 500° Celsius on Venus. At this heat the properties of the rocks may change and this may affect their spectral signatures. "There are hardly any systematic tests on this subject. We are charting unknown territory," said Helbert, the laboratory director. The PEL is currently having a special induction heating system added for this work which will enable samples to be heated to more than 500° Celsius in a shorter time.

Ultimately we need samples that are as close as possible to those on Venus. Some samples like this have been in the DLR laboratory for a short time: They were collected by Dr Jörn Helbert during the filming of a documentary on the Venus Express by ESA on Volcano Island (Italy). Other material is being provided by the Vernadski Institute in Moscow as part of an international co-operation with DLR and the Max Planck Institute for Solar System Research in Katlenburg-Lindau. The close co-operation between data evaluation and accompanying laboratory measurements are the key to understanding the composition of the surface of Venus from the infrared data provided by VIRTIS and the VMC.

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