Why the 'Venus rainbow' is actually a glory

The first sighting of the light spectacle on another planet reveals properties of the mysterious Venusian clouds.

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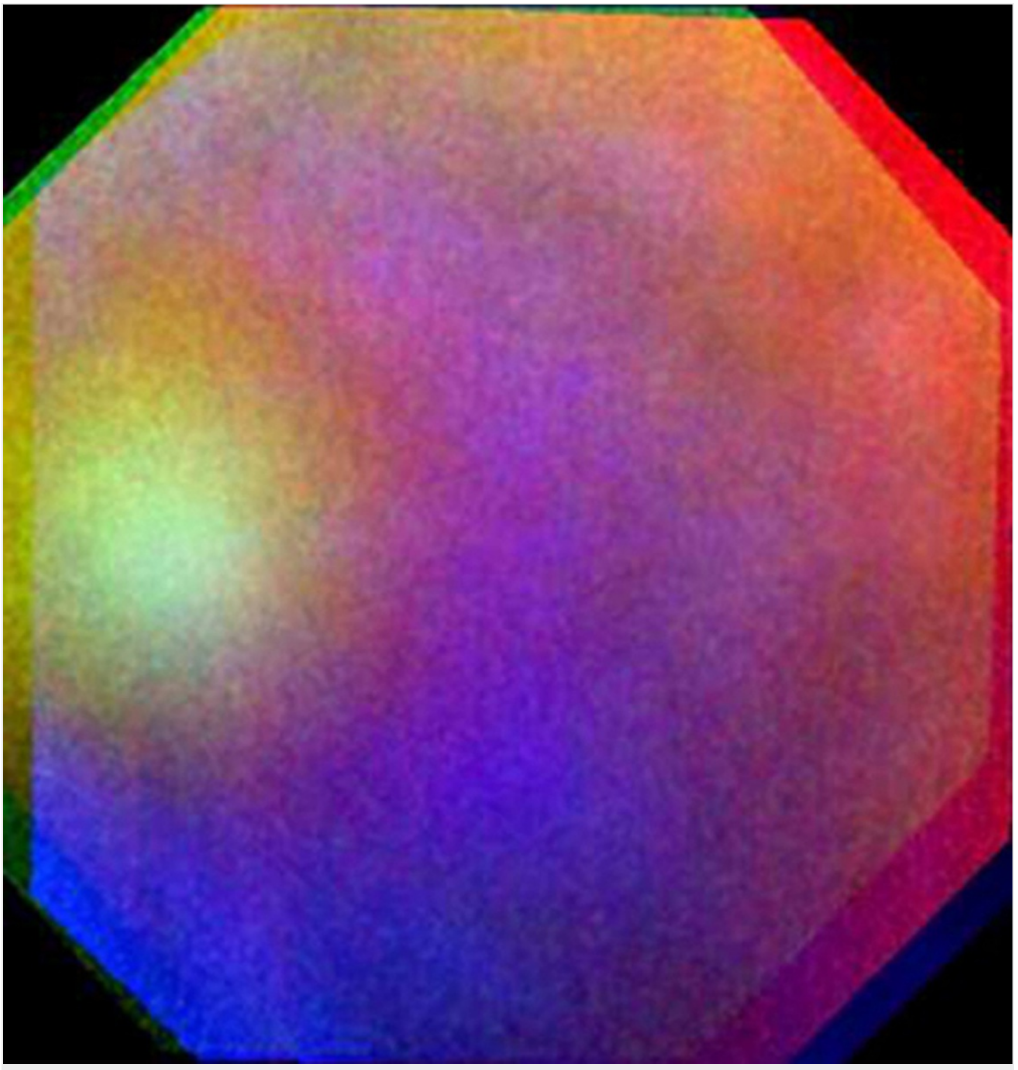
14 March 2014 | Corrected: 03 April 2014



ESA/MPS/DLR/IDA

An optical effect called a glory seen by the Venus Express probe from an altitude of 6,000 kilometres. The false-colour image is composed of images at ultraviolet, visible, and near-infrared wavelengths taken ten seconds apart, so that they do not overlap perfectly.

If you look out of the window of an aeroplane and see its shadow on the cloud tops, you might be lucky enough to also see a 'glory': a bull's-eye pattern resembling a small, circular, pastel-coloured rainbow surrounding the shadow. The European Space Agency's Venus Express space probe has now taken the first picture of the same phenomenon on another planet. The image was captured on 24 July 2011 and released this week. *Nature* explores how glories occur, how they differ from rainbows, and what this discovery means.

What causes a glory?

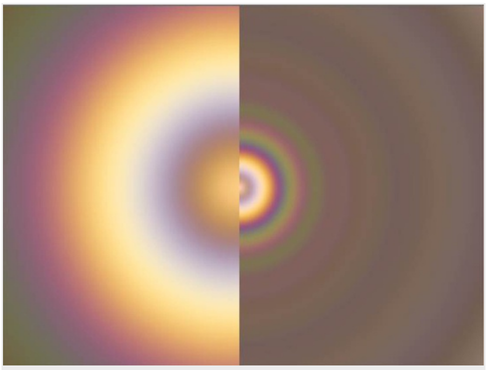
Like a rainbow, a glory is essentially a highly distorted image of the Sun reflected off water droplets or other aerosols in the atmosphere[1]. The way it is formed, however, differs in important details from the prism effect that produces the wider arc of a rainbow, and the physics is surprisingly subtle. Optical theorists' attempts to fully understand how glories work were unsuccessful until the 1980s, when physicist Moysés Nussenzveig at the Federal University of Rio de Janeiro in Brazil showed that the main cause is a process known as wave tunnelling[2, 3]. This is caused when rays of sunlight reflected by a droplet do not actually hit the droplet — as in the case of rainbows — but merely pass near it. They nonetheless stir up electromagnetic waves within the droplet. Those waves rattle around inside the droplet and eventually tunnel back out, sending light rays back in the direction from which they came. The way waves resonate within the droplet is wavelength-dependent, thus splitting white light into the spectrum of colours.

When can you see a glory?

To see a glory, you have stand with your back to the Sun, so that the reflected rays return along your line of sight. A good viewing site, apart from an aeroplane window, is a mountain peak that rises above clouds or fog (see picture). The bull's-eye pattern will surround the shadow cast by your head — giving you the appearance of a saint in Christian iconography. In fact, admirers of the phenomenon speculate that all those halos you see around saints' and mystics' heads are really depictions of atmospheric glories. Samuel Taylor Coleridge described the aura in the poem “Constancy to an Ideal Object.” Because of the precise visual alignment required, each person will see the glory around his or her own head, but not around anyone else's.

What have scientists now observed?

Venus Express, which has been orbiting Earth's sister planet since 2006, observed glories in April and July 2011. When the orbiter had the Sun behind it, it looked straight down at the Venusian clouds and saw the characteristic bull's-eye pattern, about 1,200 kilometres across. Wojciech Markiewicz at the Max Planck Institute for Solar System Research in Göttingen, Germany, and his colleagues report the discovery in a forthcoming paper in *Icarus*[4]. Although the Pioneer Venus mission of the late 1970s and 80s observed cloudbows, which are yet another type of phenomenon[5–7], this is the first sighting of a full extraterrestrial glory.



C. Wilson/P. Laven/ESA

This simulated view shows how a glory would appear on Venus (left) versus Earth (right).

Does the discovery serve some broader purpose, or is it just a pretty sight?

The glory is a sensitive marker for conditions in the Venusian clouds, which, made of sulphuric acid and completely enveloping the planet, have long held a special fascination for planetary scientists. The clouds contribute to the runaway greenhouse effect that makes the planet so hellish. Some substance in the clouds accounts for half of the solar energy absorbed by Venus and gives the planet its yellowish colour[8]. Yet researchers do not know what that substance is.

The mere fact that a glory can form at all suggests that the cloud droplets are spherical in shape and uniform in size. The position of the concentric rings indicates that the droplets are 2.4 micrometres in diameter, and the relative brightness of different rings indicates that the refractive index of the droplet fluid exceeds that of sulphuric acid, according to Markiewicz's team. The simulated image at left shows how the smaller particle size in Venusian cloud tops (compared to a typical 10 to 40 micrometres in terrestrial ones) causes the coloured fringes to spread further apart than they would appear on Earth. Markiewicz and his co-authors suggest that the droplets either have a core of iron chloride or an outer coating of elemental sulphur. Both substances were suggested in the early 1980s as candidates for the mysterious absorber, and both are interesting for the broader story of the planet[8]. Sulphur is tied up with volcanism and greenhouse warming; iron chloride poses the problem of what would have launched iron compounds 70 kilometres up into the sky[9, 10].

TomBean/Corbis

A hiker captured an image of an Earthly glory around his own shadow at the Colorado National Monument, a national park.

Nature | doi:10.1038/nature.2014.14869

Corrections

Corrected:A previous version of this article stated that the researchers estimated the Venusian droplets to be 1.2 micrometres in diameter; however, that figure referred to the droplets' radius. Also, the wording was changed to reflect the fact that the rays of sunlight do enter the droplets (via tunneling) even though they do not hit the droplet directly.

References

1. Bryant, H. C. & Jarmie, N. *Sci. Am.* **231**, 60–71 (1974).
2. Nussenzveig, H. M. & Wiscombe, W. J. *Phys. Rev. Lett.* **59**, 1667–1670 (1987).
3. Nussenzveig, H. M. *Optics Lett.* **27**, 1379–1381 (2002).
4. Markiewicz, W. J. *et al. Icarus* http://dx.doi.org/10.1016/j.icarus.2014.01.030 (2014).
5. Coffeen, D. L. *J. Opt. Soc. Am.* **69**, 1051–1064 (1979).
6. Kawabata, K. *et al. J. Geophys. Res.* **85**, 8129–8140 (1980).
7. Makoto, S., Travis, L. D. & Kawabata, K. *Icarus* **124**, 569–585 (1996).
8. Titov, D. V. *et al.* in *Exploring Venus as a Terrestrial Planet* (eds Esposito, L. W., Stofan, E. R. & Cravens, T. E.) (AGU, 2013); http://dx.doi.org/10.1029/176GM08.
9. Zasova, L. V., Krasnopolsky, V. A. & Moroz, V. I. *Adv. Space Res.* **1**, 13–16 (1981).
10. Toon, O. B., Turco, R. P. & Pollack, J. B. *Icarus* **51**, 358–373 (1982).