PERSPECTIVES: PLANETARY SCIENCE

# The Night Side of Venus

David Crisp

On 20 November 1999, Slanger *et al.* (*1*) pointed the giant, 10-meter-diameter, Keck I telescope at the night side of Venus, our closest planetary neighbor. Venus has been scrutinized for 35 years by ground based telescopes and an armada of spacecraft, but it took just eight minutes of exposure for the high-resolution spectra to yield an important discovery, namely the first evidence for atomic oxygen on the night side of Venus. The telltale sign was the 557.7 nm atomic oxygen green line in the airglow—the light emitted by atmospheric photochemical processes—on the night side of Venus. This type of emission is prominent in Earth's aurora and diffuse background nighttime airglow, but its appearance in the spectrum of the Venus night sky is surprising for several reasons.

Unlike Earth's atmosphere, where molecular oxygen ($O_2$) is a major constituent, the dense, predominately carbon dioxide ($CO_2$) atmosphere of Venus contains less than ~0.1 part per million of free oxygen, atomic or molecular, above the planet-encircling sulfuric acid clouds (*2*). Atomic oxygen (O) may be produced on the day side of Venus through photo-dissociation of $CO_2$ molecules by ultraviolet sunlight. To produce the observed nightglow, these O atoms must first be transported from the day to the night side of the planet by the prevailing winds. Once there, they must acquire around 4 eV excess energy to be excited into the $^1S$ state. The green line emission is then produced as the excited O atoms each emit a 557.7 photon and relax to the ground state.

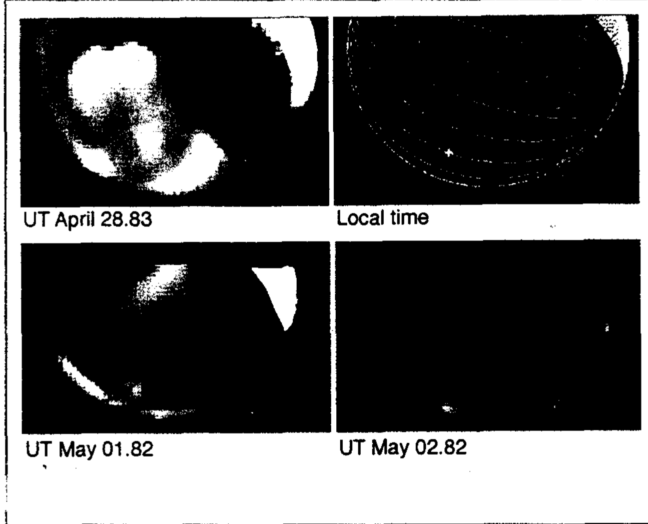
In Earth's atmosphere, O atoms gain the required energy through collisions with energetic electrons from the solar wind or with highly excited $O_2$ molecules. Neither of these two excitation mechanisms were expected to be very effective on the night side of Venus because Venus has no detectable permanent magnetic field to transport solar wind electrons to the night side and excited $O_2$ was expected to be much less abundant. Slanger *et al.*'s measurements indicate, however, that the green line volume emission rates from the Venus night side are comparable to the ambient nightglow emission rates observed in Earth's oxygen-rich atmosphere (*3*).

The author is with the New Millennium Program, Jet Propulsion Lab, NASA, Pasadena California. Email: dc@cripsy.jpl.nasa.gov

The green line intensities measured by Slanger *et al.* are far too dim to account for the so-called "ashen light" observed by amateur and professional astronomers since well before the space age, but the new observations should help to unravel the unusual oxygen chemistry and dynamics of the upper atmosphere of Venus. In particular, they may provide additional insight into the processes responsible for the much more intense and variable infrared $O_2$ airglow (*4*, *5*) (see the figure). This airglow is produced as atomic oxygen recombines in the upper atmosphere of Venus, producing $O_2$ in a particular excited state, $^1\Delta_g$. These molecules then emit a photon at wavelengths near 1.27 μm as they relax to their ground state. As in the case of the green line emission, the observed $O_2$ emission rates indicate that despite much lower concentrations of ground state $O_2$ on Venus than on Earth, the two atmospheres appear to have similar concentrations of $O_2$ in this particular excited state. Surprisingly, however, the Venus atmosphere appears to produce only $O_2$ ($^1\Delta_g$), whereas atomic oxygen recombination in Earth's atmosphere produces $O_2$ molecules in a variety of excited states.

The physical and chemical processes responsible for the high spatial and temporal variability in the $O_2$ ($^1\Delta_g$) airglow (*5*) are not well understood, but this variability may help to explain a puzzling aspect of the green line emission discovered by Slanger *et al.* Spacecraft observations of the night side of Venus at visible wavelengths in 1975 revealed no evidence of atomic oxygen green and red lines (*6*), but both the new measurements and the earlier spacecraft observations detected comparable airglow intensities from the $O_2$ Herzberg II bands. The latter occupy the same wavelength range as the atomic oxygen green line and have comparable intensities. These results suggest that the green line emission is spatially and/or temporally variable. Could these variations be associated with the $O_2(^1\Delta_g)$ variability? Unfortunately, even this simple question cannot yet be answered because there are no simultaneous measurements of the atomic oxygen green line and the $O_2(^1\Delta_g)$ airglow.

Oxygen green line emission from Earth's upper atmosphere has been studied extensively from the ground and from Earth-orbiting satellites. These observations have been analyzed to produce global maps of winds, temperatures, and atmospheric waves at altitudes between 90 and 120 km in Earth's upper mesosphere and lower thermosphere (*7*-*9*). Similar information may eventually be derived from remote sensing observations of the green line and $O_2(^1\Delta_g)$ emission from Venus, greatly advancing our understanding of upper atmospheric processes on our closest planetary relative.




References

1. T. G. Slanger, P. C. Cosby, D. L. Huestis, T. A. Bida, *Science* **290**, XXX (2000).
2. J. T. Trauger, J. I. Lunine, *Icarus* **55**, 272 (1983).
3. For both planets, the green line volume emission rates are ~150 Rayleighs, where 1 Rayleigh is $10^6$ photons per square centimeter per second.
4. J. L. Phillips, C. T. Russell, *Sky and Telescope* **75**, 250 (1988).
5. V. A. Krasnopol'sky, A. A. Krysko, V. N. Rogachev, V. A. Parshev, *Cosmic Res.* **14**, 789 (1976).
6. P. Connes, J. F. Noxon, W. A. Traub, N. P. Carleton, *Astrophys. J.* **233**, L29 (1979).
7. D. Crisp *et al.*, *J. Geophys. Res.* **101**, 4577 (1996).
8. U. B. Makhlouf, R. H. Picard, M. J. Taylor, J. R. Winick, *Adv. Space Res.* **19**, 583 (1997).
9. D. Y. Wang, W. E. Ward, G. G. Sheperd, D. L. Wu, *J. Atmos. Sci.* **57**, 1906 (2000).
10. W. E. Ward, G. H. Solheim, G. G. Shepherd, *Geophys. Res. Lett.* **24**, 1127 (1997).

**Mysterious oxygen emission.** Spatial and temporal variations in $O_2$ ($^1\Delta_g$) emission intensity from the night side of Venus (*4*). The upper right-hand panel shows the orientation of the planet. North is to the lower right, and the illuminated crescent is at the top. The other three images show the airglow distribution on 28

April, 1 May and 2 May 1993.