controlling the precise size and shape of inorganic nanoparticles. One of these can be gleaned from the analogy between colloidal and molecular crystals. Molecules, which always have lower symmetry than spheres, follow the closest packing principle of 12 nearest neighbors but crystallize in lower symmetry (typically monoclinic or triclinic) structures (*6*). The rich variety of molecular crystal structures suggests that something more interesting than cannonball packings may be awaiting colloids of uniform but nonspherical size and shape.

There is also an interesting analogy between the synthesis of asymmetric nanoparticles in polymer molds and the biological synthesis of nanocrystals. The size and shape of the latter are determined by controlled nucleation and growth within bilayer vesicles (*7*). The functional materials (such as sea shells, bones, and teeth) that incorporate these nanocrystals do not have a macroscopic shape that reflects the unit cell of the underlying inorganic material; rather, the nanocrystals are stitched together into hierarchical structures that are programmed by their shape and by their crystal-face–specific interactions with biological macromolecules (*8*).

Much progress has been made in mimicking the process of biomineralization in the laboratory. Furthermore, colloidal nanoparticles can now be made in various symmetric shapes, such as cylinders, prisms, cubes (*9*), and tetrapods (*10*). What we lack, however, is a means of producing nanoparticles with arbitrary asymmetric shapes that might be used to make interlocking structural materials, nanoscale machines, or nanocircuits through self-assembly and colloidal crystallization.

The principles of this kind of assembly are now well established for millimeter-scale objects (hexagons and other shapes), the surfaces of which are derivatized with hydrophilic and hydrophobic materials. When stirred at the interface of two immiscible liquids, these shapes form two-dimensional patterns that minimize the total interfacial free energy (*11*). A similar strategy has been used to direct the growth of three-dimensional crystals from asymmetrically derivatized truncated octahedra (*12*). Noncovalent assembly of this type is likely to scale to nanometer dimensions, as protein assemblies such as flagellar motors and photosynthetic reaction centers demonstrate. It remains to be seen whether the replication of readily available nanoscale objects can be used to fabricate, stretch, and twist molds into the right shape for this kind of synthesis, but the method of Jiang *et al.* is a good start.

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PERSPECTIVES: PLANETARY SCIENCE

The Nightside of Venus

David Crisp

On 20 November 1999, Slanger *et al.* (*1*) pointed the giant, 10-m-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 8 min of exposure time for the high-resolution Keck spectra to yield an important discovery, namely the first evidence for atomic oxygen airglow (*2*) at visible wavelengths on the nightside of Venus. The telltale sign of this airglow was a diffusive emission from the upper atmosphere in the 557.7-nm atomic oxygen green line. 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.

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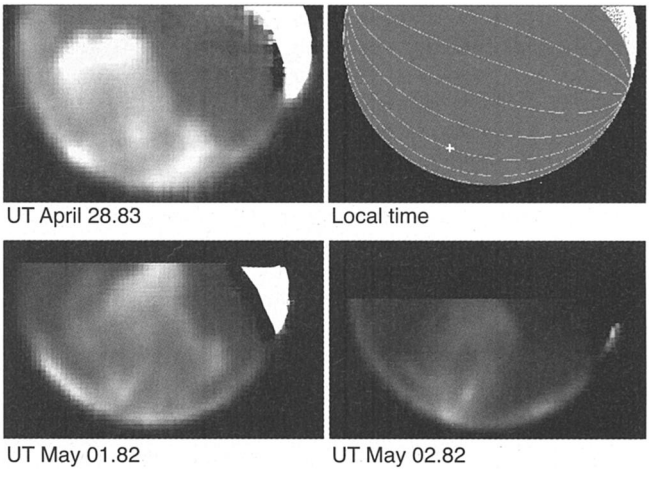
Venus was once thought to be Earth's twin because of its similar size and position in the solar system, but closer examination has shown that the two planets differ in just about every aspect, from atmospheric composition to planetary rotation. Unlike Earth's atmosphere, where molecular oxygen (O_2) 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 (*3*). Atomic oxygen (O) may be produced on the dayside of Venus through photodissociation of CO_2 molecules by ultraviolet sunlight. To produce the observed nightglow, these O atoms must first be transported from the day to the nightside of the planet by the prevailing winds. Once there, they must acquire around 4 eV of 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-nm photon and relax to the ^1D 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 nightside of Venus because Venus has no de-



Mysterious oxygen emission. Spatial and temporal variations in O_2 ($^1\Delta_g$) emission intensity from the nightside of Venus (*8*). 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.

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tectable permanent magnetic field to transport solar wind electrons to the nightside 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 nightside are comparable to the ambient nightglow emission rates observed in Earth's oxygen-rich atmosphere (*4*).

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 (*5*), 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 (*6–8*) (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 (*6*) 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 nightside of Venus at visible wavelengths in 1975 revealed no evidence of atomic oxygen green and red lines (*7*), 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 (*9–11*). The chemistry, thermal structure and dynamics of the atmosphere of Venus at levels within and above the clouds have puzzled planetary scientists for decades. Additional observations and analyses of the O green line and O_2 ($^1\Delta_g$) airglow from the nightside of Venus may help to identify some of the mysterious processes operating in the upper atmosphere of our closest planetary neighbor.

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PERSPECTIVES: IMMUNOLOGY

Giving Inhibitory Receptors a Boost

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For more than half a century, patients with antibody deficiencies have been treated with intravenous injections of immunoglobulin (IVIG). IVIG is prepared from pooled serum and its major component is immunoglobulin G (IgG), the most abundant class of antibody in serum (*1*). IVIG is similar to other replacement therapies involving, for example, administration of coagulation factors to hemophiliacs or red blood cells to patients with various forms of anemia. Because antibodies are one of the principal weapons that the immune system uses to combat microorganisms, IVIG is also given as a treatment for septic shock caused by certain bacteria.

More recently, some autoimmune disorders have been treated with high concentrations of IVIG and the results have been encouraging (*2*). These disorders are characterized by the presence of autoantibodies (antibodies against normal components of the human body) that cause inflammation and the consequent destruction of target cells or tissues. For example, autoantibodies that recognize antigens on platelets cause immune thrombocytopenia; anti-erythrocyte autoantibodies result in autoimmune hemolytic anemia; acute demyelinating polyneuropathy (Guillain-Barré syndrome) and myasthenia gravis are caused by autoantibodies that attack nerves and muscles, respectively. The ability of IVIG to reduce inflammation in patients with autoimmune disease remains unexplained.

According to Samuelsson *et al.* (*3*) on page 484 of this issue, the surprising key player that mediates the therapeutic benefits of IVIG is the Fc inhibitory receptor for IgG, FcγRIIB. In a murine model of immune thrombocytopenia—in which platelets bound by circulating anti-platelet antibodies are destroyed by macrophages (see the figure)—the authors showed that IVIG protected the mice from developing the disease. The protective effect of IVIG was unexpectedly abolished if the activity of FcγRIIB was blocked by antibody or if the receptor itself was deleted through genetic engineering. Treating mice with IVIG led to an increase in the number of macrophages expressing FcγRIIB, implying that this receptor could be responsible for the inhibition of platelet destruction.

How does IVIG induce macrophages to express more FcγRIIB? An increase in the surface expression of FcγRIIB does not seem to require that existing FcγRIIB receptors on macrophages are cross-linked by antibody. Administering the Fc fragment of antibody—the "stalk" without the antigen-binding portion (which is essential for cross-linking) that binds to the Fc receptor—is as effective as IVIG at prevent-

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