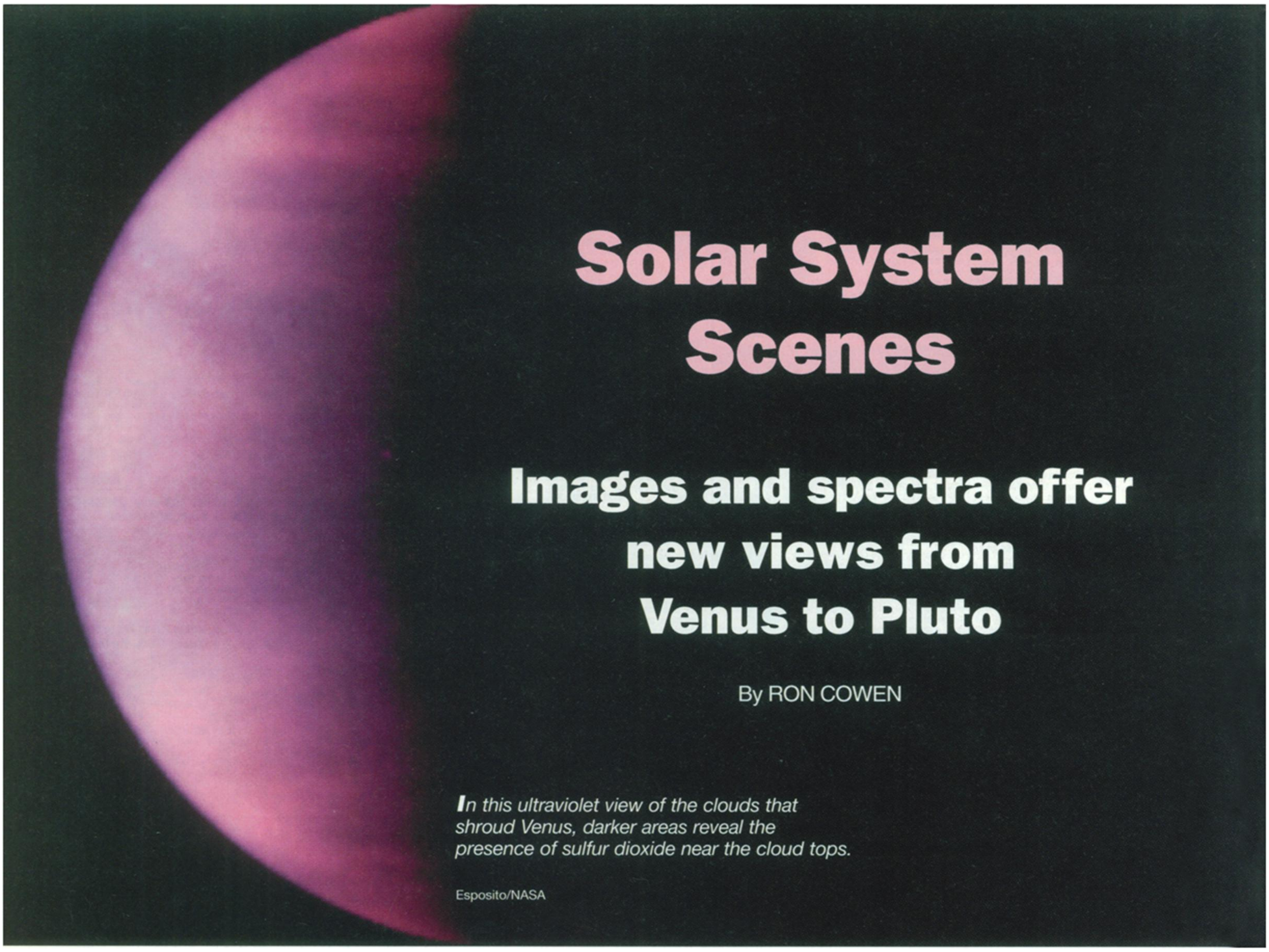


Solar System Scenes

Images and spectra offer new views from Venus to Pluto

By RON COWEN

In this ultraviolet view of the clouds that shroud Venus, darker areas reveal the presence of sulfur dioxide near the cloud tops.

Esposito/NASA

Think of the Hubble Space Telescope and the mind conjures up images of distant galaxies and faraway quasars. But Hubble also gazes at celestial bodies right in our own solar system.

Repaired late in 1993, Hubble has now cast its keener eye on objects as nearby as Venus and as distant as Pluto. The new observations provide the first detailed images of several solar system residents and reveal surprising new aspects of some of our better-known neighbors.

Orbiting in the deep freeze of the outer solar system, Pluto may be cold, but it's no featureless ice ball. Astronomers have known that the intensity of sunlight reflected from the tiny planet varies dramatically. Its brightness waxes and wanes as much as 30 percent every 6.4 days, the time it takes Pluto to make one complete rotation. Only one other large solar system body, Saturn's moon Iapetus, shows greater brightness fluctuations.

The marked variation strongly suggests that a patchwork of materials, some far more reflective than others, paves Pluto's surface. Partial eclipses of Pluto by its moon, Charon, a few years ago provided some observational support for this idea (SN: 6/6/92, p.379). But astronomers still lacked compelling proof of the cause of Pluto's variability. Until now.

Viewing for the first time features on Pluto only about 600 kilometers across, Hubble's faint-object camera has definitively revealed a panoply of light and dark regions on the frigid body.

"These are the best images we've ever had of Pluto," says Alan Stern of the Boulder, Colo., office of the Southwest Research Institute. "We see features galore." He unveiled the pictures last month at the annual Lunar and Planetary Science Conference in Houston.

For their observations, Stern and his colleagues chose Hubble's faint-object camera because it records images in both visible light and the ultraviolet. Rock typically appears bright in visible light but dark in the ultraviolet, while ices stay bright in both. This dual sensitivity enabled the researchers to discriminate between the two types of material.

At this early stage of analysis, Stern, Marc W. Buie of Lowell Observatory in Flagstaff, Ariz., Laurence M. Trafton of the University of Texas at Austin, and Brian C. Flynn of the Southwest Research Institute describe their work only in qualitative terms. But some surface features stand out clearly. For instance, Hubble's images reveal a cap of icy material at Pluto's north pole. The ice cap may consist of frozen nitrogen, methane, carbon monoxide, and carbon dioxide.

Whether ices cover Pluto's south pole, previously a matter of debate, remains unclear. "We haven't decided what is at the south pole," Stern says. The ambiguity may stem simply from geometry. Pluto's north pole now tips toward Earth, making it easier to see an ice cap there, while the south pole leans away.

Visible and ultraviolet images reveal that the rock-to-ice ratio on Pluto varies from place to place. And although the images can't resolve features on Charon, the team hopes that the pictures will provide new insight into the reflectivity and perhaps the composition of Pluto's moon.

For years, planetary scientists have believed that the dust storms that engulf Mars every 2 years are the key factor in understanding the climate of the Red Planet. As long as a significant amount of dust stays in the atmosphere, it keeps the atmosphere warm by absorbing sunlight and radiating it as heat.

But dust has less influence on the Martian climate than many researchers believe, asserts R. Todd Clancy of the Space Science Institute in Boulder. He maintains that the particles kicked up by the dust storms, which typically occur when Mars is near perihelion, or closest to the sun, don't usually remain in the atmosphere for more than 6 months. For at least 6 additional months, the atmosphere of the Red Planet is colder, and water vapor easily condenses to form low-lying ice clouds.

This emerging picture, suggested by radio wave measurements of the temperature of the Martian atmosphere and the distribution of water vapor, has gained new support from Hubble images and spectra. The most recent Hubble images, taken with the wide-field and planetary camera, show that "clouds are everywhere, [in] a belt across the mid- and low-latitude regions and over volcanoes," notes Clancy.

His colleagues, Hubble principal investigator Philip B. James of the University of Toledo in Ohio and Steven W. Lee of the University of Colorado at Boulder, presented the latest Hubble images at a March 21 press conference.

Clancy says that the Viking spacecraft caught Mars out of character during the late 1970s. During that era, residual dust in the atmosphere kept average temperatures relatively warm, so water vapor never froze at low altitudes — even when Mars was far from the sun, near aphelion. But when the atmosphere contains little or no dust near aphelion — the more typical state of affairs, he asserts — water vapor easily condenses into ice crystals, forming low-lying clouds in abundance.

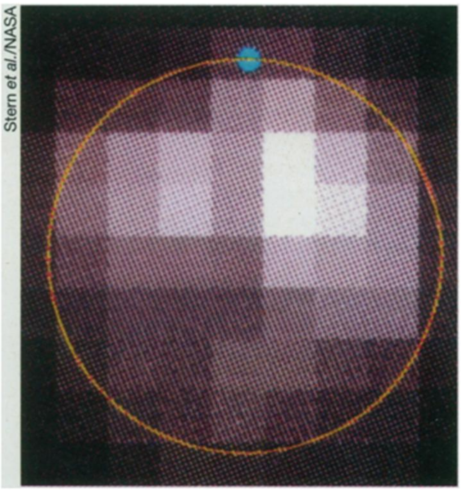
In fact, Mars was near aphelion during the most recent Hubble photo shoot. The myriad low-altitude clouds in these and previous Hubble images suggest that the atmosphere is usually chilly and dust-free at aphelion, Clancy notes

Ultraviolet spectra taken with Hubble's faint-object spectrograph provide another line of evidence for a colder, cloudier Mars, Clancy adds. The spectra show the unmistakable fingerprints of enhanced ozone at mid to low latitudes. That's intriguing because the presence of elevated ozone indicates that these layers of the atmosphere must hold little, if any, water vapor. If they did, the vapor would rapidly deplete ozone by catalyzing its conversion into oxygen.

Clancy believes the ozone finding has a simple explanation: The chilly temperatures in the Martian atmosphere cause water vapor to freeze at low altitudes. In the absence of water vapor, ozone can reside there undisturbed.

These lines of evidence, he adds, may also explain a long-standing puzzle: Why is Mars' north polar cap so much larger than the south cap?

Summer comes to the Martian north pole at aphelion, when the atmosphere is relatively chilly. This means that water vapor subliming from the northern cap can't travel far in the atmosphere before it recondenses into ice crystals. Water vapor circulates from the north pole to the south at an altitude above 5 to 10 km, but very little rises this high before freezing.



Stern et al./NASA

Hubble image of Pluto shows an apparent ice cap at the planet's north pole. The blue dot is an artifact.

In contrast, the south pole has its summer at perihelion, when the atmosphere is warmer. Because of the higher temperature, vapor subliming from the south polar cap resides in significant quantities above the critical range of 5 to 10 km. Thus, water from the south gets pumped northward, but water from the north doesn't circulate south, accounting for the larger ice cap at the north pole, Clancy theorizes.

Ice covers Europa, one of Jupiter's larger moons. Reasoning that where there's water, there should be oxygen, researchers had predicted that this frozen body might have a thin atmosphere of molecular oxygen. Now, Hubble's Goddard high-resolution spectrograph has found evidence to support this. Europa thus joins Earth, Mars, and Venus as the only bodies in the solar system known to have an oxygen-containing atmosphere.

The spectrograph recorded far-ultraviolet emissions from atomic oxygen in Europa's atmosphere. In the Feb. 23 NATURE, Doyle T. Hall of Johns Hopkins University in Baltimore and his colleagues argue that the atomic oxygen most likely comes from molecular oxygen split apart by collisions with electrons.

Several processes may cause Europa's icy surface to deliver small amounts of oxygen to the atmosphere — among them sublimation (the direct change of a solid to a gas) and impacts from micrometeorites breaking up the surface. But Hall and his collaborators say that charged particles from Jupiter's magnetosphere, which strike Europa's surface, probably account for most of the oxygen released into the atmosphere. Europa's oxygen atmosphere is so tenuous that it exerts a surface pressure only 100-billionth that of Earth's.

Late this spring, Hubble will take another look at Europa and two other icy Jovian satellites, Ganymede and Callisto. Hubble will serve as a scout for the Galileo spacecraft, scoping out intriguing features for the craft to investigate during its 2-year Jovian mission.

Because its main antenna remains disabled, Galileo will radio to Earth only a fraction of the images originally planned. Thus, scientists need all the help they can get to decide which features on Jupiter's moons seem most promising to observe, says Keith S. Noll of the Space Telescope Science Institute in Baltimore.

Pioneer-Venus orbited Venus for 15 years, studying its atmosphere and radar mapping some of its cloud-shrouded surface; Magellan then radar mapped its entire surface. So what's left?

Much remains uncertain about the physics and chemistry of Venus' atmosphere, says Larry W. Esposito of the University of Colorado. Using Hubble to take near-ultraviolet images and spectra in late January, he and his colleagues now can measure the concentration of sulfur dioxide at several heights in the planet's cloudy atmosphere.

Spewed by Venusian volcanoes, split apart by sunlight, precipitated as sulfuric acid, and ultimately mixed into the upper atmosphere by diffusion and fierce winds, sulfur dioxide's life cycle embraces many of the elements crucial to understanding Venus' harsh environment.

From the Hubble data, Esposito and his collaborators have now determined the change in sulfur dioxide levels since 1992, when Pioneer-Venus fell to its fiery death in Venus' lower atmosphere.

The Hubble observations show that sulfur dioxide levels have declined as predicted since the last Pioneer-Venus measurements and are one-tenth the level seen in 1978. This suggests that a volcano hasn't recently erupted, since it would have spewed more of the gas into the atmosphere.

In addition, tracking sulfur dioxide on Venus may provide new insights for modeling the climate on Earth. "There is a direct parallel to environmental problems on Earth — pollution, the greenhouse effect, and acid rain," Esposito notes.

To search for sulfur dioxide, Esposito's team took advantage of Hubble's ultraviolet sensitivity. In images taken by the wide-field and planetary camera, regions where sulfur dioxide is concentrated are dark because the gas strongly absorbs the sun's ultraviolet light.

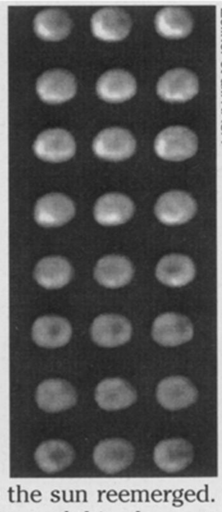
Hubble's Goddard high-resolution spectrograph also measured the gas' vertical distribution, recording the absorption of light at two sets of ultraviolet wavelengths, each characteristic of sulfur dioxide residing at a different atmospheric pressure and temperature.

Obtaining the spectra and images, which Esposito presented at the March 21 press conference, required some unique Hubble maneuvers, as well as some last-minute finagling of its observing schedule.

The problem is that Venus lies at most about 47° from the sun, and ground controllers had never pointed Hubble at any target closer than 50°. This protects its baffles — which prevent spurious light from entering the telescope's main optics — from heating and vaporizing a special coating. If the vapor recondensed on Hubble's detector, it could seriously impair its sensitivity.

In 1992, Esposito received permission to make his observations but then had to wait another year until astronauts refurbished the telescope. On Jan. 9, 1995, Esposito eagerly arrived at the Space Telescope Science Institute to watch Hubble gather data for him. But for unknown reasons, the telescope temporarily went into its "safe mode," stopping all observations. Because of tight scheduling, Esposito would have to wait until April 1996 for Hubble to look at Venus again.

But the telescope's administrators decided to give Esposito a break. On Jan. 24, ground controllers waited until the sun disappeared behind Earth. Then they quickly slewed Hubble to observe Venus while Earth shielded the telescope from the sun's glare. Just as quickly, they slewed Hubble back, before the sun reemerged. After several repetitions of this choreography, Esposito and his team finally got their views of Venus.



Taken late last fall, these 24 images of the asteroid Vesta show bright and dark regions on the rotating body.

Zellner et al./NASA

Ben H. Zellner likes to call the asteroid Vesta the sixth terrestrial planet — after Mercury, Venus, Earth, the moon, and Mars. This rocky body, 540 km in diameter, is one of the largest and most highly reflective asteroids known. But Vesta's spectra also intrigue scientists.

Ground-based observations indicate that Vesta represents the only known parent of a class of stony meteorites called basaltic achondrites. Researchers believe that some pieces chipped from Vesta by collisions with other asteroids ultimately fall to Earth as meteorites of this type.

Basaltic achondrites lack the rounded particles, or chondrules, found inside most stony meteorites. Because they have undergone melting and cooling, these achondrites have a much more diverse composition from crust to core than chondrites. Planetary scientists suspect that Vesta has a similarly diverse makeup.

Late last year, Hubble's wide-field and planetary camera took snapshots of Vesta though several colored filters. The images resolve Vesta's surface into a highly varied mix of dark and bright regions, says Zellner, an astronomer at Georgia Southern University in Statesboro. Analysis of the images over the next year should determine whether the surface variation comes entirely from lava flows or whether debris in the asteroid belt has cracked open Vesta's surface, allowing a peek beneath the crust.

Zellner and his colleagues, Alex Storrs of the Space Telescope Science Institute and Eddie N. Wells of the Computer Sciences Corp. in Baltimore, displayed the images at the Lunar and Planetary Science Conference. They will release more images later this month.

"This is the one place in the solar system where we can see inside an intact, differentiated body," says Zellner. "Now we have a picture that we can hold up and show." □