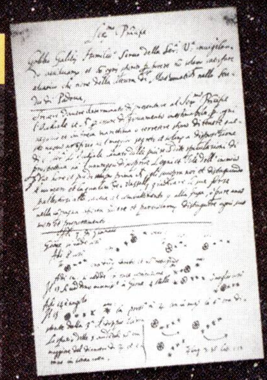
Astronomy's Greatest Hits

When Galileo first pointed his telescope at the moon in 1609, the light from some of the discoveries mentioned in these pages was just passing the Pleiades star cluster, some 400 light-years from Earth. (The moon's light took about 1.25 seconds to reach Galileo's telescope.) During those 400 years, astronomers learned to capture light from ever-greater distances, revealing a universe that became (and continues to become) ever larger and stranger. Here is a sampler of what we've learned from 4 centuries of harvesting photons.

–TIM FOLGER

1600s

1609: Between 30 November and 19 December, Galileo trained his telescope on the moon and saw mountains, valleys, and "seas." His drawings of the moon appeared in *Sidereus Nuncius*, or "Starry Messenger," which Galileo published in Venice in 1610.

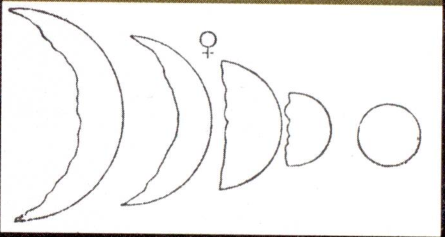


1610: A page from Galileo's journal with sketches of Jupiter and its moons. By 15 January, 3 months before the publication of *Sidereus Nuncius*, Galileo realized that four "stars" he had been tracking near Jupiter were in fact moons of the giant planet.

1610: On 30 July, Galileo wrote to his patron, Cosimo Medici, "I have discovered another very strange wonder. ... Saturn is not a single star, but is a composite of three." Galileo sketched Saturn's rings without knowing what they were. In 1659, Christian Huygens proposed that a ring surrounded Saturn, but he believed the ring was a solid object.

1610: In December, Thomas Harriot, an English polymath, made the first observations of sunspots.

1610: Galileo's drawings of the phases of Venus, which he observed in December. The discovery proved that Venus orbited the sun, not Earth.



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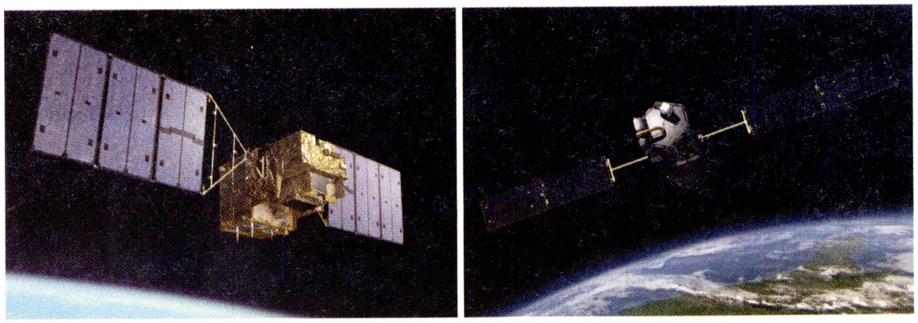
EARTH OBSERVATION

Tracking CO_2's Comings and Goings From Space

Climate scientists trying to better understand Earth's carbon cycles have long been hampered by tunnel vision. Ground-based carbon dioxide (CO_2) monitoring is precise, but the 100-odd stations across the globe provide insufficient coverage, particularly in developing countries and over the oceans. Soon, however, there will be two eyes in the sky with all-encompassing views of this worrisome greenhouse gas. In the next few weeks, Japan and the United States plan to launch satellites to observe CO_2 from space.



Parallel views. Japan's GOSAT (*left*) and NASA's OCO will provide the first global views of CO_2.

The view from on high should lead to more accurate predictions of how rising CO_2 levels might affect global temperatures and climate change. "This will also contribute to political decisions on [acceptable levels] of CO_2 emissions," says Tatsuya Yokota, who heads the satellite observation office of Japan's National Institute for Environmental Studies (NIES) in Tsukuba. In addition, patchy data have been a "barrier to coloring in the maps of CO_2 sources and sinks," says Peter Reyner, a climate modeler at the Laboratoire des Sciences du Climat et de l'Environnement near Paris. "There are large parts of the globe where this will be our first look [at CO_2 data]."

Japan will launch its Greenhouse Gases Observing Satellite (GOSAT) on 21 January. NASA's Orbiting Carbon Observatory (OCO) will follow on 23 February. Both intend to answer a fundamental question: Where is CO_2 generated by human activities coming from and going to? Each year, humans dump about 9 billion tons of carbon into the atmosphere, but only half stays there, says David Crisp, principal investigator for the $270 million OCO at NASA's Jet Propulsion Laboratory in Pasadena, California. Of CO_2 recycled from the atmosphere, about one-quarter is absorbed by land vegetation and another quarter is somehow drawn into the oceans. "We don't know where the other half is going," Crisp says.

How these carbon sinks might evolve as climate shifts in response to rising CO_2 levels is also unclear. And scientists can't begin to fathom the missing sinks until they've been located.

There are other mysteries, such as large variations in atmospheric CO_2 concentrations from year to year. In 1973, virtually all of the 5 billion tons of carbon put into the atmosphere stayed there; but the following year, 4 billion out of 5 billion tons that were emitted got absorbed by sinks, Crisp says. In another riddle, in 1993, a major El Niño coincided with high rates of CO_2 absorption; the link and mechanism are unclear. GOSAT, a $500 million joint effort of Japan's space and environment agencies and NIES, has a mission lifetime of 5 years (versus OCO's 2 years) because scientists want "to detect annual variations in CO_2 [resulting from] El Niño, La Niña, and other weather phenomena," Yokota says.

GOSAT will also measure methane, a greenhouse gas for which there is even less data. Both missions might also contribute to understanding localized problems by helping pinpoint pollution sources.

The satellites grew out of ongoing Earth-observation programs. Crisp says that the CO_2 data gap was long recognized but that improved detection was beyond standard remote-sensing techniques. Previous satellite sensors for ozone worked at thermal or ultraviolet wavelengths, but thermal wavelengths don't work well for CO_2. The new satellites will observe in near-infrared. "The measurement technique is one of the real innovations that OCO and GOSAT have had to make in order to move forward," says Crisp.

The two satellites will observe in different patterns; OCO will be more sensitive to fortnightly or monthly rhythms, whereas GOSAT will be better able to correlate CO_2 levels with changing weather patterns. "The data will be highly complementary," says Yokota. That kind of stereovision might be just what it takes to spot those missing carbon sinks.

–DENNIS NORMILE

CDC have made statements that meant nothing [to us]. Julie really tried to connect CDC with the average person," says Michael Osterholm, director of the Center for Infectious Disease Research and Policy at the University of Minnesota, Minneapolis, and a longtime supporter of Gerberding— and, he hastens to note, of Barack Obama.

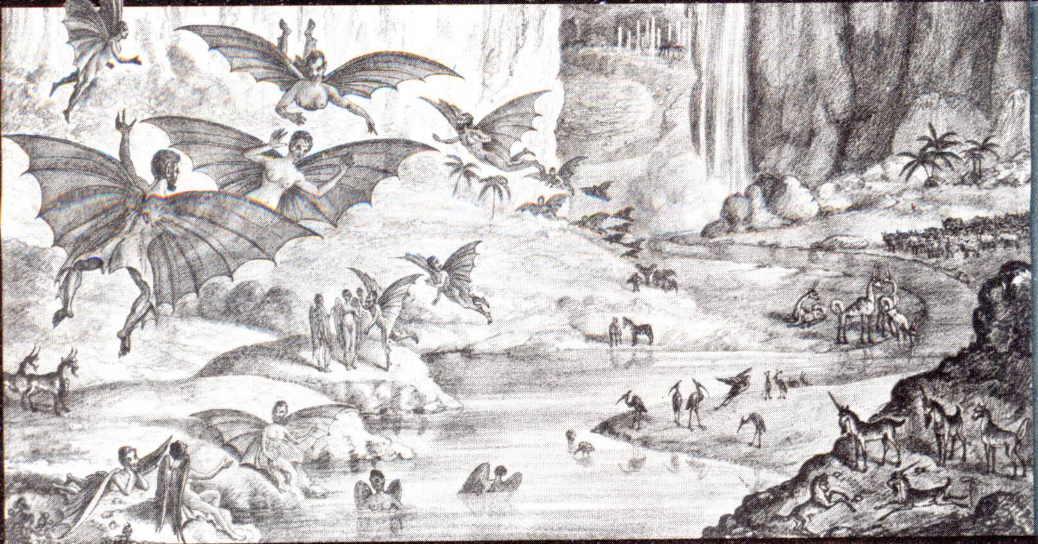
Saying goodbye. Julie Gerberding is leaving CDC to make way for an Obama appointment.

But Gerberding's leadership of CDC was also marked by tension and sharp criticism, especially after she launched an extensive reorganization of the agency. Morale among CDC scientists reportedly plunged, and five former CDC directors wrote Gerberding a letter 3 years ago expressing "great concern" about the departure of top scientists from the agency. In a sometimes testy interview with *Science* in late 2006, Gerberding defended the changes and expressed confidence that they were needed to help CDC tackle large-scale health threats (*Science*, 13 October 2006, p. 246).

The agency is "clearly at a crossroads" now, says James LeDuc, who spent 14 years at CDC before leaving at the end of 2006 to join the University of Texas Medical Branch at Galveston. Whoever takes over next will have to ensure that young, talented scientists come and stay. And, adds Curran, they must prove adept at another critical task— communicating with Congress and the White House.

–JENNIFER COUZIN

CREDITS: (LEFT TO RIGHT) JAXA; NASA; (BOTTOM) JAMES GATHANY/CDC



1835: Man-bats on the moon! In August, *The New York Sun* falsely reported that John Herschel (William Herschel's son) had discovered life on the moon, including herds of bison, biped beavers, and humanoid bat-winged creatures.

(He also made the first telescopic drawings of the moon a month or so before Galileo's sketches but never published them.)

1639: A 20-year-old English astronomer named Jeremiah Horrocks became the first person to observe the transit of Venus. Horrocks, who died only 2 years after observing the transit, was also the first to hypothesize that the moon's orbit was elliptical.

1687: Isaac Newton published *Philosophiae Naturalis Principia Mathematica* (The Mathematical Principles of Natural Philosophy). The *Principia*, arguably the most important scientific work ever written, presented Newton's laws of motion and his theory of gravity, giving birth to modern physics and astronomy.

1700s

1705: Edmund Halley published *Synopsis of Cometary Astronomy* in 1705, which described the orbits of comets and predicted the periodic return of the comet now named for him.

1781: William Herschel discovered Uranus and wanted to name the new planet after King George III.

1785: William Herschel and his sister Carolyn mapped the entire sky, proving that the Milky Way is a giant disk of stars with a central bulge.

1800s

1846: Neptune, the first planet whose existence was predicted on the basis of mathematical calculations, was discovered on 23 September.

1877: The Italian astronomer Giovanni Schiaparelli reported seeing *canali* (channels) on the surface of Mars. Percival Lowell, an American astronomer, later popularized the notion that intelligent beings on Mars had constructed an elaborate network of canals.

1900s

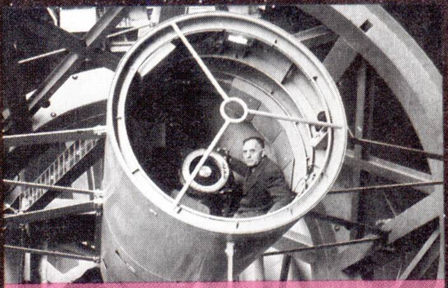
1908: Henrietta Swan Leavitt discovered that Cepheid variable stars can be used as "standard candles" to measure interstellar distances with great accuracy.

1919: Arthur Eddington led an expedition to Principe, an island off the west coast of Africa, to observe a total solar eclipse. Eddington's observations confirmed Einstein's prediction that massive bodies can warp spacetime and bend light.

1930: Clyde Tombaugh discovered Pluto while working at Lowell Observatory in Flagstaff, Arizona.

1932: Karl Jansky invented radio astronomy with the discovery that the center of the Milky Way emits radio waves. His rotating antenna was mounted on wheels from an old Model T automobile.

1951–1953: James Van Allen launched a



Late 1920s: Edwin Hubble discovered the first galaxies outside the Milky Way. He also found something even more startling: The galaxies were all rushing away from us, proof that the universe is expanding.

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