Through a Lens, Deeply

SEATTLE—Pacific Northwest winter skies cleared for 4 days in early January, welcoming more than 2000 astronomers to their biannual meeting.

Photographers and astronomers love their zoom lenses. Now, a new camera on the Hubble Space Telescope has looked through the best natural lens in space with unprecedented clarity in search of baby galaxies—and has found far fewer than expected.

The view comes by means of a "gravitational lens," which arises when light from a distant source passes by a massive object in direct line of sight to Earth. The intervening object's gravity bends and magnifies the source's light. The strongest known lens is Abell 1689, a cluster of galaxies that crams hundreds of times the mass of the Milky Way into a small volume of space more than 2 billion light-years away. Light goes through funhouse-mirror distortions as it traverses the cluster's gravitational dips and bumps. Hubble's recently installed Advanced Camera for Surveys (ACS) targeted Abell 1689 for 13 hours in June 2002, creating an extraordinary map of its eerie arcs and blobs—the imprints of remote galaxies behind Abell 1689.

Warped. Abell 1689, the most powerful gravitational lens, magnifies remote galaxies into distorted blobs and crisp arcs.

The result, which dazzled viewers at the meeting, is "the deepest view of the universe so far," says astronomer Narciso Benitez of Johns Hopkins University in Baltimore, Maryland. The lens amplifies light from a few galaxies at least 13 billion light-years away—ordinarily beyond Hubble's vision. Judging by the number of slightly closer galaxies, astronomers had expected to see 25 to 30 such remote objects with Abell 1689's boosted view. Instead, the ACS images captured just three, Benitez reported. Most galaxies that existed less than a billion years after the big bang might not have grown bright enough for the lens to expose, he speculates.

Because even a powerful gravitational lens zooms in on only tiny patches of sky, Benitez and colleagues plan to bolster their statistics by using ACS to explore a half-dozen more lenses. Rich cradles of baby galaxies probably won't appear, an ongoing survey suggests. A team led by astronomer Richard Ellis of the California Institute of Technology in Pasadena has found only a dozen primitive galaxies in eight gravitational lenses examined by another Hubble camera with less sensitivity. "We may be hitting the wall when we can no longer see these feeble little glowworms," says Ellis, whose team has not yet reported its findings.

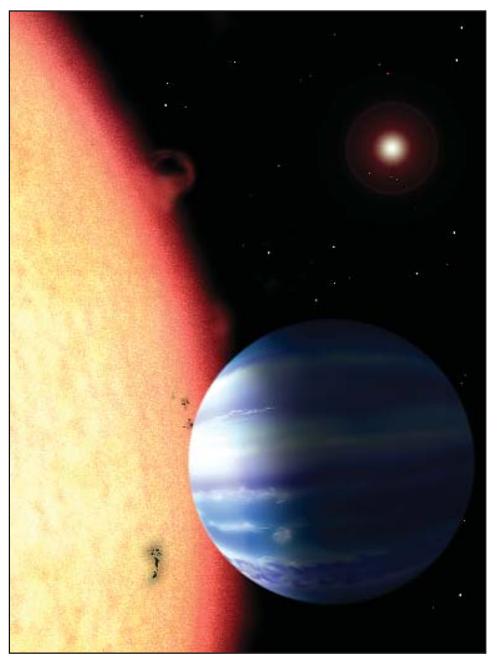
Most light from infant galaxies may have been absorbed by the remnants of neutral hydrogen gas that filled space before the first stars and quasars shone—the so-called dark ages of the universe. Alternatively, the first gasps of star birth in the tiny galaxies may have snuffed out further star formation by heating up gas so much that it could no longer collapse into stars. That process, Ellis says, would have left the galaxies too dim to see until they grew larger as the universe aged.

However, other ACS images shown at the meeting reveal remote galaxies freckling the sky, a discrepancy that astronomers are hotly debating. Graduate student Haojing Yan of Arizona State University in Tempe and his colleagues found about two dozen extremely faint galaxies in a patch of sky just 1/10th the width of the full moon, revealed by a 7-hour-long ACS exposure. "We think these were the significant contributors to ending the dark ages," Yan says. Radiation from vigorous star birth in the young galaxies should have ionized the last of the neutral hydrogen, he says, allowing light to stream freely through the universe.

ACS is the prime tool to resolve the debate, says instrument chief Holland Ford of Johns Hopkins. The camera is 10% to 15% more sensitive than hoped, he notes. However, the electronic pixels in its largest detector are suffering a higher rate of irreparable radiation damage than projected. Astronomer Adam Riess of the Space Telescope Science Institute in Baltimore says the damage—which will knock out about 2% of the camera's imaging surface within 3 years—is "a potential annoyance that will have little scientific impact." Still, Ford's team will take the most demanding ACS images sooner rather than later.

A Tsunami of Hot Jupiters?

Astronomers have found about 100 planets beyond our solar system, so new ones must smash records to get noticed. The latest, announced at the meeting and scheduled for publication in the 30 January issue of *Nature*, sets three standards: farthest from Earth, tiniest orbit, and the first to be revealed by a technique that could expose thousands more like it. "This is the beginning of a new wave of extrasolar planets," says astronomer Sara Seager of the



Swifter than Mercury. In this artist's conception, planet OGLE-TR-56b roasts just 3 million kilometers from its star.

CREDITS: (TOP) NASA, N. BENITEZ (JHU), T. BROADHURST (THE HEBREW UNIVERSITY), H. FORD (JHU), M. CLAMPIN AND G. HARTIG (STSCI), G. ILLINGWORTH (UCO/LICK OBSERVATORY), THE ACS SCIENCE TEAM AND ESA; (BOTTOM) DAVID A. AGUILAR/HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

Carnegie Institution of Washington, D.C. "It's a big step forward."

All previous planets were inferred by the back-and-forth gravitational tugs they exert on their parent stars. For several years, many teams have tried a more direct method by looking for planetary "transits." A planet crossing the face of its star, as seen from Earth, will block a bit of the star's light at regular intervals. Astronomers have watched repeated transits by one Jupiter-size body since 1999, but that planet was first detected by means of the wobbling of its star.

The new object, dubbed OGLE-TR-56b, marks the first time a transit led to a planetary discovery. Its name comes from the Optical Gravitational Lensing Experiment, a survey of light variations in thousands of stars, conducted in Chile by astronomers at Warsaw University in Poland. Astronomer Maciej Konacki of the California Institute of Technology in Pasadena and colleagues used several large telescopes to scrutinize 59 stars that OGLE singled out for a closer look by noting subtle dips in their brightnesses.

Nearly all candidates had binary star partners rather than planets, a "false alarm" problem that complicates transit searches. The 56th star, however, harbored a surprising companion: a planet that dashes around the star once every 29 hours. That puts the planet in a scorching orbit just 1/14th as far from its star as Mercury is from our sun—by far the tightest orbit ever seen. Moreover, the star is about 5000 light-years away, more than 30 times farther than any other sunlike star with a planet. By peering so deeply into space at millions of stars, researchers should unleash "a tsunami of transit discoveries" within several years, predicts team leader Dimitar Sasselov of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

"It's awfully nice to see good evidence for another transiting planet instead of all false alarms," comments astronomer Timothy Brown of the National Center for Atmospheric Research in Boulder, Colorado. "It reassures us that we'll discover things with transits that would elude any other technique."

Brown's optimism is justified, says astronomer Keith Horne of the University of St. Andrews, U.K. Horne's assessment of more than 20 current transit programs foresees that the planetary discovery rate will soon soar by a factor of 10 to 100. Most objects will be gas giants that orbit their stars in 10 days or less, called "hot Jupiters." The real quarry for future searches will be planets the size of Earth, but stellar eclipses by such bodies are so slight that astronomers can't measure them reliably from the ground. Two planned satellites—NASA's Kepler and the European Space Agency's Eddington—should spy other Earths by decade's end, Horne says.

Stars Behaving Badly

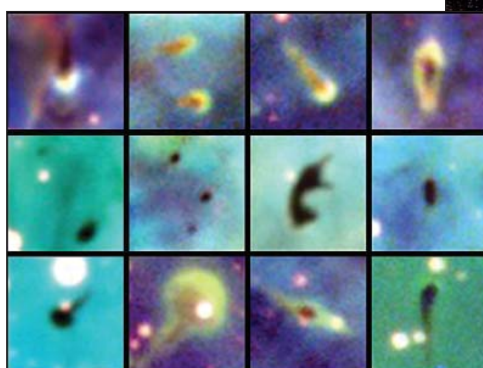
Supernovas may grab the spotlight, but the massive stars that give rise to them put on flashy shows long before they blow up. Violent pulsations blast gas and dust into space for thousands of years in prologues to the stars' explosive deaths. Two observations described at the meeting cast light on these unstable phases—and the dramatic effects they can have on nearby stars.

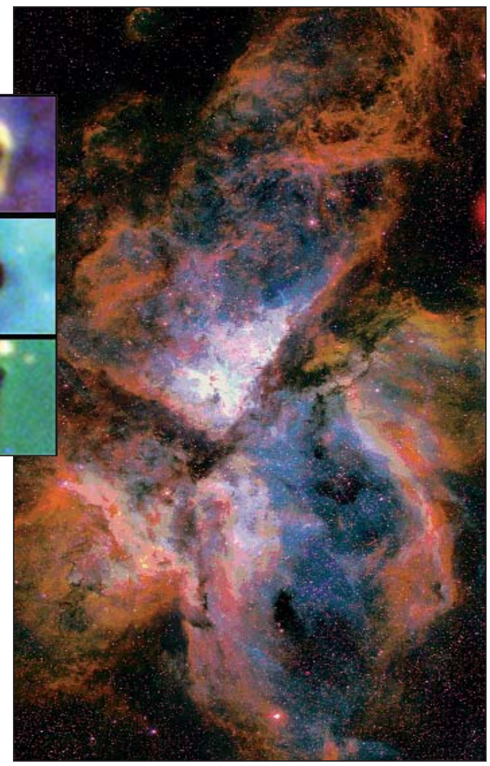
In one event, the supergiant star Rho Cassiopeiae shed more mass than any other stellar eruption witnessed with modern instruments. A team led by astronomer Alex Lobel of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, used five telescopes in the United States and Europe to monitor the star for a decade. During its latest eruption, a 200-day outburst that peaked in fall 2000, the star brightened and then dimmed dramatically as an ejected shell expanded at supersonic speeds. Temperatures in the star's distended atmosphere plummeted to an unusually chilly 4000 kelvin, allowing molecules such as titanium oxide to form. Analysis of the light absorbed by those molecules shows that the ejected shell contains about 10,000 times the mass of Earth, Lobel says.

The team's analysis suggests that Rho Cassiopeiae swelled to 700 times the sun's size during its outburst, making it one of the biggest stars known. "At those low temperatures and densities, the atmosphere is extremely elastic," says astronomer Andrea Dupree, Lobel's CfA colleague. "A perturbation anywhere in the star creates enormous movements." The team will keep watching the star's fits as it staggers toward a supernova death—a fate less than 50,000 years away, Dupree estimates.

If such outbursts occur in a stellar nursery, they can influence a whole slew of emerging stars. A prime example is Eta Carinae, a supermassive star whose shell of expelled dust from a 19th century eruption marks the heart of the Carina Nebula. Surprising new images of the nebula have exposed possible homes for nascent planetary systems amid the harsh onslaught of energy and ultraviolet (UV) light from Eta Carinae and its neighbors.

Earlier Hubble images of the Orion Nebula had revealed scores of dusty cocoons called protoplanetary disks, or "proplyds" (*Science*, 8 December 2000, p. 1884). But the Carina Nebula is a more violent setting. It hosts about 60 gigantic stars, each as powerful as the single star that irradiates most of Orion. Despite the radiation bath, proplyds dot Carina in large numbers, according to images from a 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. "This is an extremely threatening environment to dusty disks, but they somehow survive," says astronomer Nathan Smith of the University of Colorado, Boulder.





Windy cities. Giant disks of gas and dust (*inset*) in the Carina Nebula survive intense radiation from dozens of hot young stars.

CREDITS: NATHAN SMITH, UNIVERSITY OF COLORADO/NOAO/AURA/NSF

Smith's team doesn't yet know whether the disks last long enough to make planets, because they clearly get baked by pulses of radiation. Some blobs display cometlike tails pointing away from Eta Carinae, suggesting that the star blasts the nebula most intensely. However, Smith has identified a few dark proplyds that aren't being lit up today. The thick shroud spat out by Eta Carinae during its eruption in the 1840s blocks its worst radiation for now, he believes. "It's as if we had a UV light bulb that suddenly turned off," Smith says—giving the proplyds a brief respite from their inevitable erosion.

–ROBERT IRION