Astronomers prepare to launch the long-awaited Space Infrared Telescope Facility, the last of NASA's four Great Observatories

Sensing the Hidden Heat of The Universe

SUNNYVALE, CALIFORNIA—For a telescope known as a "Great Observatory," the Space Infrared Telescope Facility (SIRTF) seems rather small. It stands 4 meters tall in a cavernous clean room here at Lockheed Martin Space Systems, dwarfed by scaffolds that 2 decades ago embraced the Hubble Space Telescope in this same room. Many small colleges own telescopes with mirrors that rival the 0.85-meter reflector inside the Thermos-like tube of SIRTF. Perched on its testing platform, SIRTF gleams but doesn't overwhelm.

Yet this compact machine carries the hopes of dozens of astronomers who have devoted their careers to making it fly. Their dreams of peering at faint traces of heat from the cosmos will become real on 15 April, when SIRTF is scheduled for launch at the Kennedy Space Center in Florida. The launch had been set for 29 January, but on the eve of Thanksgiving, NASA postponed it to make way for a military satellite damaged in a launch pad crane accident in October. However, the latest delay doesn't faze a team that has weathered 20 years of development, two severe redesigns, and two cancellations.

"People almost forgot about us," says Giovanni Fazio of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who leads one of SIRTF's three instrument teams. "Now, I think we'll have to convince them that it's really going to go off."

Fazio needn't fret: Astronomers working within and beyond the confines of infrared wavelengths say SIRTF has their attention. The observatory will sense the thermal glows of normal stars in remote galaxies, cocoons of star birth in nearby galaxies and in our Milky Way, and planet-forming whorls of gas and dust around young stars. Infrared radiation pierces dust, opening vistas that are frustratingly shrouded in Hubble's iconic images. Other satellites have examined the infrared heavens—notably the European Space Agency's Infrared Space Observatory (ISO), which set the standard in the field from 1995 to 1998. But with its modern detectors scanning the heavens from a frigid perch millions of kilometers from Earth, SIRTF will trump ISO's sensitivity by factors of 10 to 1000.

"Using infrared light to look inside places where stars and planets are forming and at distant galaxies will be two of the dominant prongs of astrophysics for the next 50 years," says optical astronomer Alan Dressler of the Carnegie Observatories in Pasadena, California. "A lot of that will involve cold telescopes, and here's the first one. It's a triumph that it finally got built."

A descoped scope

SIRTF's awkward acronym dates from the early 1980s, when the "S" stood for Shuttle, not Space. The facility ('80s NASA-speak for a reusable payload) was supposed to hitch rides on the space shuttle to soar above the infrared-absorbing water vapor in Earth's atmosphere. In 1985, however, a test flight of a small cryogenically cooled telescope showed that the shuttle was a lousy setting, because heat from the spacecraft dazzled the instrument's sensors.

Just chill. SIRTF's silver and black coatings will reflect solar heat and radiate the telescope's heat, respectively. (Solar panels are not shown.)

The goal shifted to a grand, free-flying orbiter to fill out NASA's suite of powerful eyes at different wavelengths: Hubble, the Compton Gamma-Ray Observatory, and the Chandra X-ray Observatory. A national panel of astronomers led by John Bahcall of Princeton University dubbed the 1990s the "Decade of the Infrared" and declared SIRTF its top priority. Planners envisioned a $2 billion titan lugging 3800 liters of superfluid helium, aptly launched aboard a massive Titan rocket.

Then, NASA's budget roof caved in, forcing not just one but two total redesigns—or "descopings"—of SIRTF by 1995. The telescope was axed for about a year and wiped from the books a second time by a clerical error in Congress. The saga became painful. "There was a time when SIRTF was not mentioned in polite company," says project scientist Michael Werner of NASA's Jet Propulsion Laboratory in Pasadena. "Only the imprimatur of the Bahcall report allowed us to rise from the ashes."

Loyal backing from colleagues helped, but the savior was a radically overhauled concept. "In the old days, you'd build a big infrared telescope and an even bigger Thermos to drop it into," says Michael Bicay, director of SIRTF's Legacy Science Program. In the new design, a tiny vat of helium—just 360 liters—insulates only the observing instruments, not the entire assembly. The mirror and telescope tube, shielded from the sun, will cool to about 35 kelvin in space. Then, boiled-off helium vapor will course along the tube like dry-ice fumes cascading down the sides of a cauldron in a high school play, chilling the optics to 5 kelvin.

The tight constraints forced everyone on SIRTF to adapt. "Our original instrument designs were not quite as big as the Hubble phone booths, but they were as big as phone booths for dwarfs," recalls George Rieke of the University of Arizona, Tucson, another instrument team leader. Squeezing into oversize shoeboxes meant that some versatility had to go, Rieke says. Still, the delays gave the teams time to create sensitive new detectors with far more pixels than previous infrared missions had.

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This reimagined mission costs $720 million, including launch on an economical Delta rocket. A gentle nudge will propel SIRTF to a unique outpost: trailing far behind Earth in the same orbit and drifting about 15 million kilometers farther away each year, like a dog on a running track

Small but sensitive. SIRTF's instruments (*above*) and mirror (*right*).

trailing its owner on a progressively longer leash. "We don't really care where it goes, as long as we know where it is," Bicay jokes. Toward the end of the mission, NASA will need the largest antennas in its Deep Space Network to download data from the distant spacecraft once or twice daily.

With Earth's hulking globe out of the way, SIRTF will observe nonstop until the coolant gurgles away. "In principle, the mission will last at least 5 years with careful management of the helium, which is our lifeblood," says Werner. The team won't know how quickly the telescope consumes its helium until 2 or 3 months after launch.

Cool science

Several factors dictate the research within reach of SIRTF. On the down side, its small mirror won't collect nearly as much infrared light as do ground-based telescopes, which can peer from mountaintops or the arid South Pole through infrared "windows" in the atmosphere. However, SIRTF's new detectors pick up the barest hints of heat, and its deep freeze means that virtually no stray warmth will muddle the weak cosmic signals. "It adds up to an enormous gain in sensitivity," says B. Thomas Soifer, director of the SIRTF Science Center at the California Institute of Technology (Caltech) in Pasadena. "We can't reach back to where galaxies begin to form, but we can reach back to their early childhood."

Indeed, galaxies in many guises are high on SIRTF's list of targets. Today, astronomers know distant galaxies only by the light of their hottest, youngest stars. These objects blaze in ultraviolet light, which gets stretched by the expansion of the universe into visible and near-infrared light by the time it reaches us. Such "redshifting" also lengthens the visible light of distant, ordinary stars such as our sun—which compose the bulk of stellar mass in galaxies—to wavelengths that are right in SIRTF's range. This inexorable bit of cosmic physics makes SIRTF the first tool with the power to see older, long-lived stars that dominated the universe's galaxies as they matured.

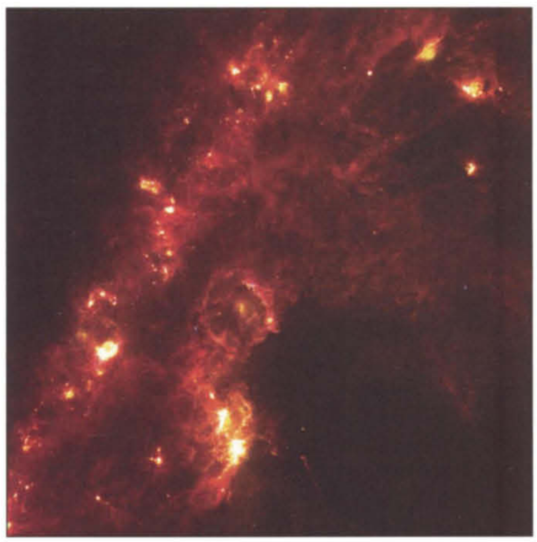
SIRTF's Legacy Science Program will capitalize on that strength by devoting chunks of observing time to major galaxy surveys. "We want a census of the stellar-mass assembly history of galaxies," says astronomer Mark Dickinson of the Space Telescope Science Institute in Baltimore, Maryland. Such a census will include a better grasp of star formation in distant galaxies, much of which is veiled by dust. "That energy has to come out somewhere, and SIRTF will see it," Dickinson says.

One survey, which Dickinson directs, overlaps the most penetrating views of the universe ever taken. The spark was the now-famous "Hubble Deep Field," in which the Hubble telescope stared at a minuscule patch of sky for 10 days in 1995 and exposed thousands of galaxies. "That became a magnet for other observations. Everyone pointed everything they had at that same patch," says Dickinson—including the Chandra X-ray Observatory. Now, SIRTF will follow suit with detailed images of a swath 30 times bigger, enveloping the original Deep Field, plus it will make a similar scan of the Southern Hemisphere skies. Hubble is covering the same territory with its new Advanced Camera for Surveys. With all telescopes working in concert, says Dickinson, astronomers will have more tools for deciphering the nature of each remote fleck.

In another survey, astronomer Carol Lonsdale of Caltech and her colleagues will take an opposite tack: a sweeping roundup of millions of closer galaxies in 63 square degrees of the sky, the size of a decent constellation. SIRTF is ideal for identifying dusty star-forming galaxies that suffused space during the universe's adolescence, Lonsdale says. By casting such a wide net, the survey should expose how galaxies grew up in different environments. For example, astronomers assume that galaxies assembled more quickly in matter-rich clusters than in sparse voids, but they have very little evidence for this theory.

Other SIRTF legacy programs are confined to just one galaxy, our Milky Way. The birth pangs and rowdy youths of stars and planets are the quarries. "We're specifically looking at sunlike stars as analogs to our own, to help us put our solar system in context," says astronomer Michael R. Meyer of the University of Arizona.

Meyer's survey team will examine more than 300 relatively nearby stars, ranging in age from 3 million years to 3 billion years. Although SIRTF will not spy individual planets, infrared patterns from the stars will reveal whether they are swaddled in dusty or gas-rich disks. As planets condense within those disks, they should carve out gaps around the stars in the shapes of thick Hula-Hoops. SIRTF would detect infrared radiation from warm dust inside such a gap and from cooler dust on the far side, but none in between. That telltale temperature dropout will yield indirect but strong evidence about the architectures of planetary systems elsewhere, Meyer says.



Star children. SIRTF will examine stellar birthplaces in Perseus (upper right) and Orion (lower center).

SIRTF also will examine how rough-and-tumble dustups in emerging planetary systems enrich those infrared signals. "Once objects grow to the size of Volkswagens and start crashing together, they generate their own secondary dust," Meyer says. In our solar system, such debris arises mainly from

CREDITS: (TOP TO BOTTOM) BALL AEROSPACE; NASA JPL; INFRARED PROCESSING AND ANALYSIS CENTER/CALTECH/JPL the asteroid belt between Mars and Jupiter—the source of the twilight sky's "zodiacal light"—and from the extended Kuiper belt of cold, primitive objects beyond Neptune. SIRTF will spot faint wisps from such tenuous bands even around stars nearly as old as our sun, Meyer notes.

Meanwhile, another team led by astronomer Neal Evans of the University of Texas, Austin, will use SIRTF to examine newborn stars still tucked in their dusty nests or just fledging from them. Out to a distance of about 1000 light-years from Earth, says Evans, "we'll see anything forming a star, as well as substellar objects," such as brown dwarfs. "However the energy is getting out, we'll be able to study very small amounts of it."

Resolving the controversial origins of brown dwarfs (*Science*, 4 January, p. 64) is one aim of the survey, Evans says. The other key goal is to learn how long the gas and fluff girdling a new star remain available for planet formation. Planetary scientists disagree over the time scales and mechanisms needed for objects such as Jupiter to arise (*Science*, 29 November, p. 1698). By tracing the waxings and wanings of infrared patterns around a range of ordinary stars, SIRTF might steer that debate.

Some of SIRTF's science will hit closer to home. With part of its guaranteed observing time, Rieke's instrument team at Arizona will scrutinize scores of objects in the Kuiper belt. Astronomers have a poor grasp of the sizes of these icy bodies, because they must make assumptions about how much sunlight the objects reflect. SIRTF will detect their heat emissions directly; when combined with optical images, the data will pin down the objects' sizes and hint at their compositions. Leaders of a proposed mission to Pluto and the Kuiper belt will fine-tune their observing strategies based on SIRTF's results.

Observations from the telescope's major legacy programs will flow directly into a public archive after the SIRTF Science Center processes the data. In that way, astronomers may analyze images as they see fit, perhaps finding surprises that mission planners couldn't envision. This rapid public access—an aspect of SIRTF that all of the project's astronomers praise—will help scientists devise follow-up studies quickly enough to be conducted during the mission's second year in flight. After SIRTF's first 9 months in space, most of the observing time will be open to peer-reviewed proposals from all U.S. astronomers.

High-flying partners

SIRTF will have an active partner during its third year in 2005: the Stratospheric Observatory for Infrared Astronomy (SOFIA). Based at NASA's Ames Research Center in Mountain View, California, SOFIA consists of a Boeing 747 equipped to carry a 2.5-meter infrared telescope at high altitudes for 10 hours at a time. Chief scientist Eric Becklin of the University of California, Los Angeles, expects SOFIA to follow up on SIRTF's most compelling objects by using its large instruments to measure velocities, temperatures, compositions, and other properties in detail. The European Space Agency plans to launch its own advanced mission into deep space in 2007, a 3.5-meter telescope called Herschel. That instrument will focus on longer wavelengths of infrared light, which penetrate even deeper into dusty clouds.

The SIRTF team realizes that its work sets the stage for two of NASA's highest-profile space endeavors for the next decade: Hubble's successor, called the James Webb Space Telescope, and the Terrestrial Planet Finder. Both observatories will rely heavily on near-infrared vision. In that sense, says Carnegie's Dressler, SIRTF is not so much the denouement of NASA's Great Observatory program as the most logical prologue to the next act—a progression that probably wasn't foreseen when the Infrared Astronomy Satellite first scanned the sky 2 decades ago.

A final transformation awaits SIRTF: After launch, NASA will announce a new and presumably more graceful name, chosen from a national contest. If there's any justice, the name will honor someone as resilient as the oft-threatened telescope itself has been.

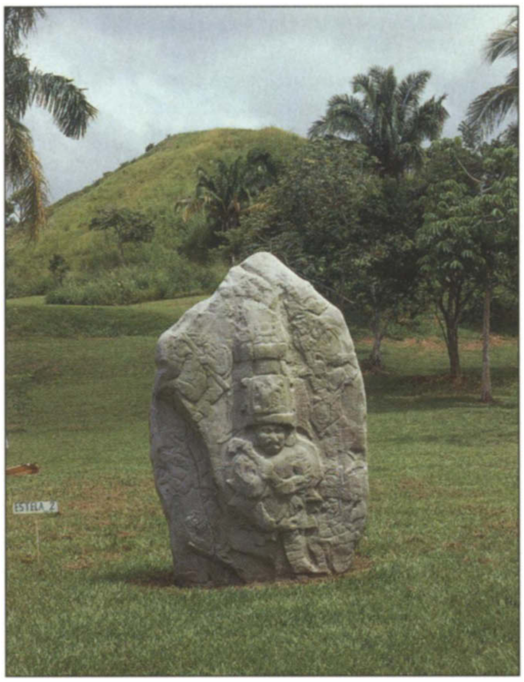
–ROBERT IRION

ARCHAEOLOGY

Oldest New World Writing Suggests Olmec Innovation

Inscribed characters that resemble those used in the later Maya script and calendar suggest that the Olmec were the first American scribes, boosting the theory that they heavily influenced later cultures

In A.D. 738, a minor lord in what is now Guatemala pulled off a staggering victory: Cauac Sky of Quirigua captured a powerful king, known as "18 Rabbit," beheaded him, and overran Copán, a major city in the Maya empire. Chronicled in inscriptions on numerous stone monuments at Quirigua, that upset is just one saga in a sweeping history recorded by the Maya in stone carvings for 7 centuries. Yet despite archaeologists' phenomenal success in deciphering Maya hieroglyphs, a fundamental aspect of this sophisticated civilization and its copious writings has always been a puzzle: their origins.



Think big. The Olmec were the first in Central America to build large cities. Pyramids, such as this one at La Venta, and monuments demonstrated their rulers' power.

CREDIT: CHRISTOPHER VON NAGY

Scarce finds from pre-Maya times have left archaeologists arguing whether key features of Maya civilization, such as writing and the sacred calendar, stemmed from a nearby culture called the Olmec or whether several early cultures contributed. Now on page 1984, a team of archaeologists describes two artifacts that preserve signs of script: fragments of stone plaques and a cylindrical seal that bear symbols known as glyphs. Dated to about 650 B.C., these are potentially the oldest evidence of writing in the Americas. Mary Pohl of Florida State University, Tallahassee, and her co-authors argue that one fragment names a king and a date, indicating that, as with the Maya, early writing was intricately involved with both royalty and the calendar.

For many archaeologists, the discovery, together with findings from new digs in even older Olmec sites, reinforces the notion that the Olmec was a "mother culture" and the primary in-