Space Telescope (I): Implications for Astronomy

Quite aside from the science it will do, Space Telescope will have a major impact on the way astronomers work

On 15 June the Space Telescope Science Institute officially dedicated its brand-new home, a graceful brick building nestled in a leafy enclave of Johns Hopkins University in Baltimore. Astronomers and other guests were there by the hundreds, and director Riccardo Giacconi welcomed them in style. There were symposiums, tours, speeches, a reception, even a live string ensemble. The 2-year-old science institute—which, as its name suggests, will manage the scientific research on the National Aeronautics and Space Administration/European Space Agency Space Telescope—was at last embodied in a physical *place*.

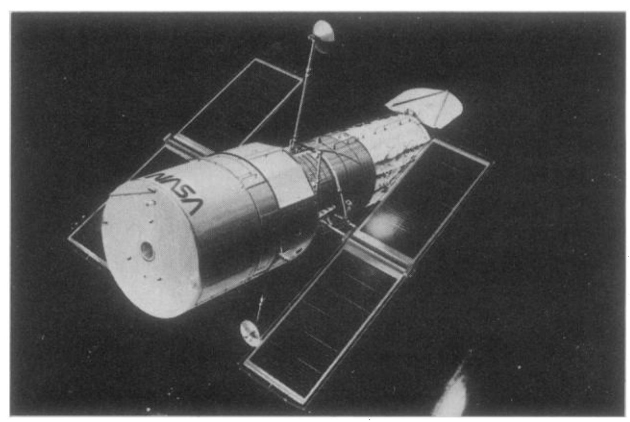
The symbolism was apt. The dedication comes as astronomers are talking less and less about Space Telescope as a marvelous abstraction—"the instrument of the century," for example, or "the most momentous step since Galileo"—and are starting to come to grips with it as a real piece of astronomical hardware. At Baltimore, in fact, the visitors often seemed less interested in the science Space Telescope could do than in such unglamorous essentials as the procedures for proposals, time allocation, and data processing.

In listening to it all, however, one did get a sense of just how profound an impact Space Telescope will have on the way astronomers work and think.

Space Telescope will be unique in many ways, but the first and most important is the fact that its "seeing" will be unaffected by absorption and scattering in the earth's atmosphere. Its 2.4-meter mirror will thus achieve an angular resolution of 0.1 arcsecond, an order of magnitude better than anything on the ground. Moreover, because it puts more photons into a smaller spot on the focal plane, and because it does not have to contend with nearly as much background light, Space Telescope will be able to see sources 50 times fainter than its ground-based counterparts. Its wavelength coverage, meanwhile, will extend from roughly 1000 angstroms in the ultraviolet to 10 micrometers in the infrared, much of which is absorbed on the way to the ground.

To exploit this power, Space Telescope will carry five instruments: two cameras, two spectrographs, and one photometer, each with its own science team and principal investigator. In addition, the telescope's fine guidance sensors can be used for very high precision astrometry, the measurement of the positions of stars. [The fine guidance sensors are currently the most famous of the Space Telescope instruments. Their main task is to hold the telescope steady within 0.007 arcsecond by sighting off stars at the edge of the field of view. Trouble with their development is a major reason that Space Telescope's launch has been delayed from the spring of 1985 until late 1986 (*Science*, 8 April, p. 172).]

The science produced by this armamentarium should be every bit as exciting as enthusiasts say (see page 250). However, it is also important to recognize that Space Telescope cannot do everything. Its 2.4-meter mirror is quite modest by terrestrial standards, for example, which means in turn that its light-gathering power is relatively limited. This poses a distinct constraint on such photon-hungry activities as high-resolution spectroscopy. Its angular resolution is still a long way from forming direct images of, say, the active core of a quasar. Its wavelength coverage, wide as it is, still misses out on the x-ray and gamma-ray spectrum at one end and the far infrared and radio bands at the other.



Space Telescope

Not just an abstraction but a real piece of astronomical hardware.

The astronomy community, in fact, would like to see Space Telescope serve as the prototype for a whole series of space-borne observatories (*Science*, 10 December 1982, p. 1101). "Space Telescope is the first major investment in space astronomy, but not the last," says science institute director Giacconi, who is himself one of the founders of x-ray astronomy. And because it is the first, he says, "we'll be testing out the whole system: launch and servicing by the shuttle, remote observing, the data transmission hardware, data processing here on the ground, and even the sociology of the institute."

For example, the spacecraft subsystems and the scientific instruments on Space Telescope are designed for easy access by shuttle astronauts' spacesuits. The hardware can thus be repaired and maintained on a regular basis (although with launch schedules so tight it is not clear how quickly a shuttle could reach Space Telescope in an emergency). Eventually, the existing instruments will be replaced by new ones, just as at a ground-based observatory.

In addition, Space Telescope will be linked to the ground by NASA's new Tracking and Data Relay Satellite System (TDRSS). So instead of sending data home in spurts to a scattered series of ground stations, as previous astronomical satellites have done, Space Telescope will send home data in a near-continuous stream.

For NASA, these activities give Space Telescope an importance that goes well beyond science. By providing a major rationale for TDRSS, Space Telescope helped the agency sell what it sees as a key element in all its future space endeavors. (The first TDRSS satellite was launched by the space shuttle Challenger in April, although it only recently limped into its intended spot in geosynchronous orbit.) Moreover, the satellite servicing to be demonstrated on Space Telescope was one of the original rationales of the space shuttle—and is now being put forward as a rationale for a permanent manned space station (*Science*, 10 September 1982, p. 1018).

For astronomers, however, the significance is that Space Telescope will not be just another satellite. It will be a full-fledged space observatory. Its lifetime will be measured not in months but in decades. Its capabilities will grow and change as the instrumentation technology changes. Users will even have the option of real time, interactive observing. It was this image of Space Telescope as observatory that, as much as anything else, led NASA to entrust it to a permanent science institute instead of to a single, principal-investigator-led science team as the agency had on most previous astronomical missions.

In the institute "sociology" that Giacconi mentions, there is no issue more sensitive than that of time allocation. "Of all the things Space Telescope *can* do, time only permits it to do a fraction," says Princeton University's Jeremiah Ostriker, who headed the science institute's outside advisory committee on personnel. "So the question of what it *will* do is of the utmost importance."

In space the heavens are always clear and black, so at first one might think that Space Telescope could observe 24 hours a day. Alas, no. To avoid stray light and thermal problems it must point at least 50° from the sun, 15° from the moon, and 70° from the bright limb of the earth. Moreover, it will turn from source to source just a bit more slowly than the minute hand on a clock—roughly 15 minutes for a rotation of 90°—and once pointed it will take about 3 minutes to lock onto its guide stars. Factoring all the constraints together, Space Telescope will actually spend only a third of its time collecting photons. This is roughly the same duty cycle as, for example, Kitt Peak National Observatory's 4-meter Mayall telescope, which has to contend with daylight, moonlight, and clouds—and which can accommodate about a quarter of the observers who want to use it.

On Space Telescope the problem will only be that much worse, because there are so many things that Space Telescope alone can do. Giacconi intends to screen the proposals by the usual process of peer review, of course, but the implications actually go far beyond that.

For example, Malcolm S. Longair, Astronomer Royal of Scotland and Space Telescope multidisciplinary scientist, points out that astronomers very rarely see something that makes them shout Eureka! Historically, the fundamental advances have more often come out of the tedious, painstaking slog of survey work. Witness the Cambridge University radio surveys, which led to the discovery of quasars, or Edwin Hubble's survey of galactic redshifts, which led to the discovery of the expansion of the universe. "I would like to make a plea that such large-scale programs of observations be undertaken in a systematic way [on Space Telescope]," he says.

Unfortunately, the pressures for access to a government facility such as Space Telescope all run the other way. "In general, we've not been very successful at supporting long-term programs at the national observatories," says Arthur D. Code of the University of Wisconsin, Madison, director of the science institute during its organizational phase in 1981. The national observatories are committed to serving as broad a community as possible, he says, which in practice puts the pressure on the users: winning proposals tend to be short, sure-fire projects that can be completed in only a few nights of observing. If there are clouds, or a glitch in the apparatus . . . too bad. "The big surveys have been done at private or university-run observatories like Palomar or Cambridge," says Code. "You have more control there."

Thus, there are many voices urging the science institute to defy the pressure and set aside substantial blocks of time on Space Telescope for survey work. "My personal hope is that large bodies of astronomers will . . . form consortia

Eye on the Universe

The conventional wisdom on the matter is almost a tautology: Space Telescope's most exciting discoveries will be the things that no one has thought of yet. But that has not stopped astronomers from holding innumerable symposiums on what Space Telescope will do. Some highlights:

• The age and size of the universe. Astrometric measurements with Space Telescope will improve the precision of parallaxes by a factor of 10. This is the only direct measure of stellar distances. It is also the first and most important calibration for an interlocking chain of "standard candles"—Cepheid variable stars, for example, or bright elliptical galaxies—that eventually lead to a determination of the distances of the galaxies, to the Hubble parameter linking distance with expansion velocity, and finally, to the age of the universe. Not incidentally, Space Telescope will also extend by a factor of 10 the distance over which we can see those standard candles.

• The origin and evolution of galaxies. Space Telescope will be able to see and classify distant galaxies as they appeared a few billion years after the Big Bang. This should settle a number of contentious questions about when and how they formed. A study of how these galaxies cluster would settle some equally contentious questions about large-scale structure in the universe (*Science*, 4 March, p. 1050).

• Active galactic nuclei and quasars. Most of the known ultrahigh energy phenomena in the universe—such as Seyfert galaxies, BL Lac objects, N galaxies, and quasars—can be explained as the accretion of interstellar gas onto massive black holes in the cores of otherwise normal galaxies. The trick is to prove it. Space Telescope will image few of the central powerhouses directly, but even in more distant objects its studies of matter close to the center still could be very illuminating. Space Telescope *will* be able to see the galaxies around (some) quasars, if they are really there. Perhaps this will help us understand why there were lots of quasars when the universe was young, and none today.

• Star formation and the interstellar medium. During the last 10 years this has emerged as one of the most fertile areas of astronomy. Molecular clouds, OB associations, bipolar outflows, planetary nebulas, supernovae remnants—Space Telescope's resolution and wavelength coverage will help everywhere.

• Solar system astronomy. Space Telescope can do high-resolution imagery and ultraviolet spectroscopy of comets, inventory the solar system for new faint satellites and rings, and monitor "weather" on the giant planets and dust storms on Mars. (It will image Jupiter and Saturn roughly as well as Voyager did.) In a related study, Space Telescope can use its astrometric precision to search for wobbling in the courses of nearby stars, which would indicate the presence of planets. It is also just barely conceivable that Space Telescope could image such planets.—M.W.

who will enable these projects to be carried out," says Longair. Ostriker echoes his point: "It is important that *groups* be able to submit proposals for large blocks of time. It's going to require a change of style. Astronomers will have to change their mode of operation from that of 'one lone scientist' to that of working in large teams, like the physicists who work on the big accelerators."

Ironically, there is another time allocation issue, just the inverse of the first. It would be very easy to get Space Telescope locked up heel and toe with absolutely first-rate projects—all based on the conventional wisdom. But occasionally, astronomers *do* shout Eureka! So how does one allow for serendipity?

As a partial answer, Giacconi intends to reserve some small amount of Space Telescope's time for the director's discretion. The time would mostly be used for unscheduled events such as a comet or supernova. In fact, says Giacconi, the institute plans to prepare standard observing sequences for such events, so that the staff could implement them quickly and automatically. But this time could also give leeway for offbeat ideas that otherwise might never make it past peer review.

Perhaps a more important approach to serendipity, however, is Space Telescope's ability to operate with at least two instruments simultaneously. While the photometer is taking data, for example, the operators can simply open the shutter of, say, the Wide Field/Planetary Camera and pull in a huge chunk of sky for free. (It is worth noting that on the x-ray satellite Einstein, such wide field exposures led to the serendipitous discovery of a large class of x-ray quasars.) "Many of us think that these will be the most *fun* pictures," says James Westphal of the California Institute of Technology, principal investigator of the Wide Field/Planetary Camera.

Wisconsin's Code imagines this as a new stronghold for the classic lone observer: prowling the Space Telescope archives for unexpected treasures located just to the side of someone else's target. Of course, to prowl the archives one must first *have* the archives, which points up something else about Space Telescope: the science institute is going to be the first observatory to try to keep *all* the data, every binary bit of it.

"It's going to revolutionize the way astronomy is done," says Ostriker, "because right now we throw away 99 percent of the data received on a plate. People end up looking at the same area over and over again because it's easier."

"Archiving and *retrieval*," agrees Code "—it's one of the most exciting new things about Space Telescope." People have been filing away photographic plates in plate vaults for years, he points out, but rarely is there an efficient way for someone else to get at them again. "Then as we started to get digital data with vidicons and CCD's," he says, "the number of bits outstripped the storage facilities. It's only recently that we've had media [high-density magnetic tape and now optical disks] that could store this data in a compact way."

The trick is thus to combine this storage technology with retrieval software that can find the data and get it into a form that someone can use. The problem is not unique to Space Telescope, says Code, but it has been most crucially recognized with Space Telescope. And in this, as in so much else, the Space Telescope Science Institute has taken the lead.—**M. MITCHELL WALDROP**

Next: The Space Telescope Science Institute.

Surviving Heat Shock and Other Stresses

Heat shock genes and their protein products help to protect cells against damage induced by stress and also aid studies of gene control

When fruit flies are exposed to a heat shock they shut off the synthesis of most cellular proteins and turn on the production of a specific constellation of seven heat shock proteins. This response, which appears to protect against the deleterious effects of high temperatures, was once thought to be more or less peculiar to fruit flies. But recent research indicates that it is probably a property of all species. Moreover, many other types of stress also evoke the synthesis of heat shock proteins, suggesting that they may play a more general role in guarding against cell damage.

In addition to shedding light on cells' responses to stresses, studies of the heat shock system are proving valuable for understanding how genes are turned on and off. For example, investigators have identified a nucleotide sequence near the beginning of the genes that is required for the heat shock response.

Although the heat shock response in the fruit fly (*Drosophila*) was discovered some 20 years ago by Feruccio Ritossa at the Laboratoria Internationale Genetica e Biophysica in Naples, current interest in the research began only about 5 years ago. At that time, investigators in several laboratories began to discover that a wide variety of species responded to heat shock in ways that closely resembled the response in the fruit fly.

The organisms displaying the response include the bacterium *Escherichia coli*, unicellular nucleated species such as yeast, the cellular slime mold *Dictyostelium discoideum*, complex plants such as the soybean, and even the cells of mammals and birds. "We recognized that virtually every cell, whatever its source, has a regulatory mechanism at the genetic level that enables it to respond to stresses," says Milton Schlesinger of the Washington University School of Medicine.

Temperatures above 30°C induce a heat shock response in those species, such as the fruit fly and soybean, which normally live at ambient temperatures in the vicinity of 25°C. For the cells of warm-blooded animals temperatures from 42° to 45°C are used to induce the response experimentally.

At roughly the same time that the universality of the heat shock response was becoming apparent, investigators also learned that other types of stresses and agents could evoke the synthesis of heat shock proteins in this whole spectrum of organisms. "We don't think of them so much as heat shock proteins as stress proteins," explains Lawrence Hightower of the University of Connecticut (Storrs), "because there is such a variety of inducers." These inducers include heavy metals, ethyl alcohol, sulfhydryl reagents, amino acid analogs, viral infections, and oxygen deprivation. In mammals, fever may evoke the heat shock response.