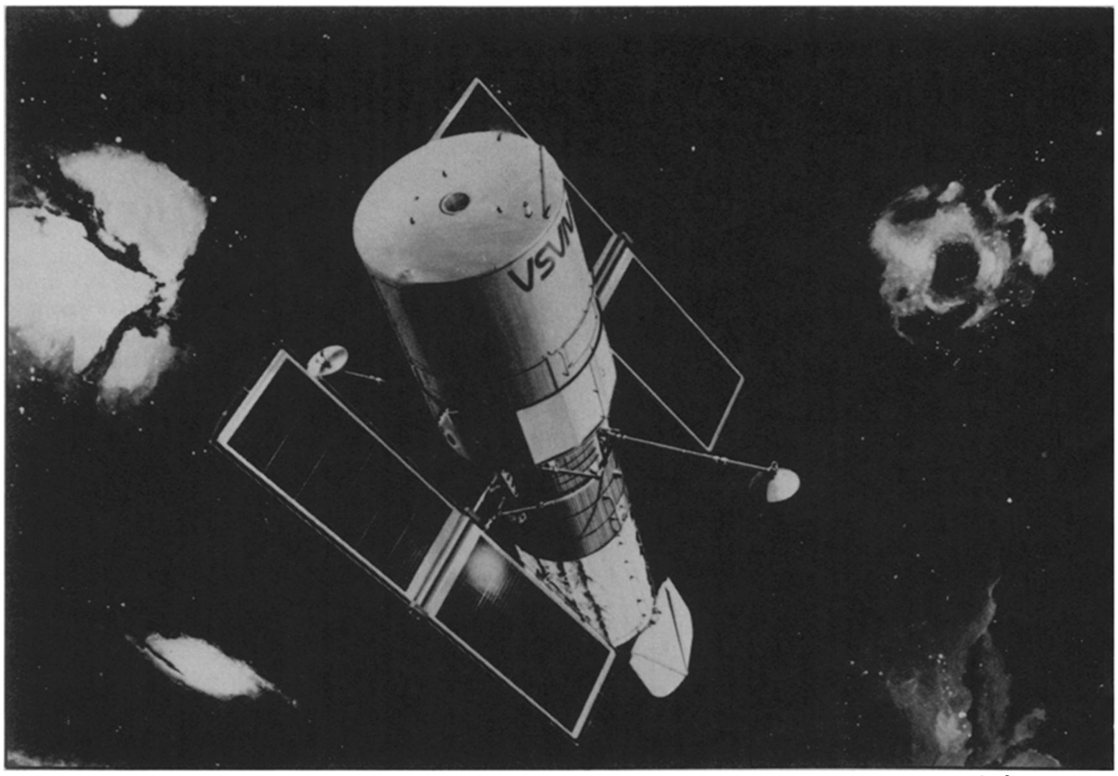
WILL ASTRONOMY



NASA

As the age of telescopes in space dawns, astronomers ask whether any of their science will stay on the ground

BY DIETRICK E. THOMSEN

The 310-mile orbit of the Space Shuttle Telescope, which may be launched as soon as 1983, is about 307 miles farther from sea level than the top of Mauna Kea. Will astronomy rush to move to this side of the atmosphere?

"Astronomy has been very exciting in the last two decades," Joseph Wampler of the Lick Observatory reminded the recent meeting in Tucson of the Astronomical Society of the Pacific. "If you think the '60s and '70s were exciting, you ain't seen nothing yet." The question before the symposium was where the coming excitement would mostly get its fuel, on mountain tops or in orbit. Putting it another way: Is there life for ground-based astronomy after the birth of the Space Telescope?

By all means, says John Hardy of Itek Corp. One reason he cites goes right to the breadbasket: The cost per pound of a radio telescope is as much as hamburger. That of an optical telescope is equivalent to caviar. A space telescope costs as much per pound as gold (without necessarily following the rather wild daily fluctuations).

Wampler had a few words about where the poundage is, however. The dome (unnecessary in space) is half the cost of a ground-based telescope. And "it is possible with new design to make telescopes lighter." In his opinion the ST wins handily.

It may be unfair to try to compare ground-based and space telescopes as if they represented equal poundage, but at any weight an instrument worth its weight in gold had better be versatile and efficiently used, and so should any that costs like caviar. (Chopped-meat astronomy was not really in this discussion; the ST would be an instrument for optical and infrared work.)

"Ground-based observations are going to be a very viable field for decades to come," says Don Hall of Kitt Peak National Observatory.

"For the rest of my career we are going to be doing it [improving the angular resolution of the images of infrared sources] here on the ground. The same goes for optical." Thus Frank Low of the University of Arizona.

"The future of earth-based infrared is bright," says H. P. Larson of the University of Arizona. "The long integration times [necessary to build up useful data] are not acceptable in a space telescope. Even if it were restricted to existing ground-based facilities, the future is good."

"The competition by better space observations is possibly felt more in the solar community than in the stellar," says Jacques Beckers, director of the Multiple Mirror Telescope. "Premise: Any kind of observation can be done better or at least as well from space if dollars are not a consideration."

Of course dollars are a consideration, and outside of solar astronomy, where space techniques have done so many spectacular things, the premise would be disputed. Indeed it is reservations of that sort that account for some of the comments quoted above that seem less favorable to space techniques. Yet the discussion is not categorical or one-sided. Beckers lists a rather long budget of solar observations that can be done well from the ground, even though, failing the development of certain new ground-based techniques, he says, "the big interest will be in space."

Low points out that locating a telescope in space reduces background glow by a factor between a million and ten million compared with a telescope on the ground. This improves infrared sensitivity by a factor of about 1,000.

It also improves optical sensitivity by a large factor, and astronomers who want to see dim and distant things go for the idea of a space telescope in a big way.

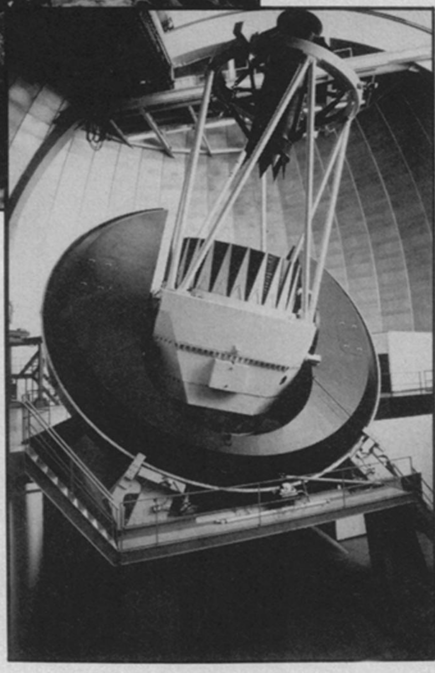
Wampler has a long budget of such things, reflecting his interest in the very far out. He hopes to be able to see the geometry and the evolution of the cosmos, including such things as possible evidence for localized collapse of space-time.

Are there quasars in the nuclei of galaxies? The fuzziness of earth-based pictures is in part responsible for an inability to tell.

A good space telescope — one of Wampler's suggestions is a large space telescope 15 meters in diameter — could "hope to be able to see galactic evolution." It could resolve the wavelengths in the spectrogram of an object of magnitude 20 or 21 to about a part in a thousand. That would enable it to determine the proportions of stars of different spectral classes and different ages and generations

GO INTO ORBIT?

One of the more recently constructed large mirrors is Kitt Peak's 4-meter Mayall Telescope. It orbits a little over a mile above sea level.



Photos: Kitt Peak National Observatory

in those galaxies, and so learn details of how galaxies develop.

The ST could see individual stars in much more distant galaxies than ground-based telescopes can. "The ST could see Cepheids in the Virgo cluster," Wampler says. Cepheids are a class of variable stars with a useful peculiarity. The time period of the variation of a given Cepheid is related to its intrinsic brightness. The astronomer who measures the period of a Cepheid knows its intrinsic brightness. Comparing intrinsic and apparent brightness gives the distance. Cepheids have been used for distance measurements for decades, but only for nearby galaxies.

Virgo cluster galaxies have redshifts substantial enough that a meaningful comparison between distance measurement by Cepheids and by redshift could be made. This might pin down an unequivocal value for the Hubble constant, the proportionality constant between redshift and distance. That could lead to more certain measurements of distance for really far-out objects. From this could follow information on the curvature of the universe and its expansion rate.

Wampler's list goes on from here: Chemical composition of galaxies, the chemical balance of the early universe, the universal blackbody radiation. Everything anybody wants to know about cosmology, galactic astronomy, intergalactic space, quasars, etc., could get startling new contributions from a space telescope, be it only large enough.

Beckers is enthusiastic about the past contributions of space vehicles to his personal specialty of solar astronomy, and he looks to the future for more, the Solar Coronal Explorer in the middle 1980s, and the Advanced Solar Observatory in the early 1990s, which would carry a solar optical telescope into space.

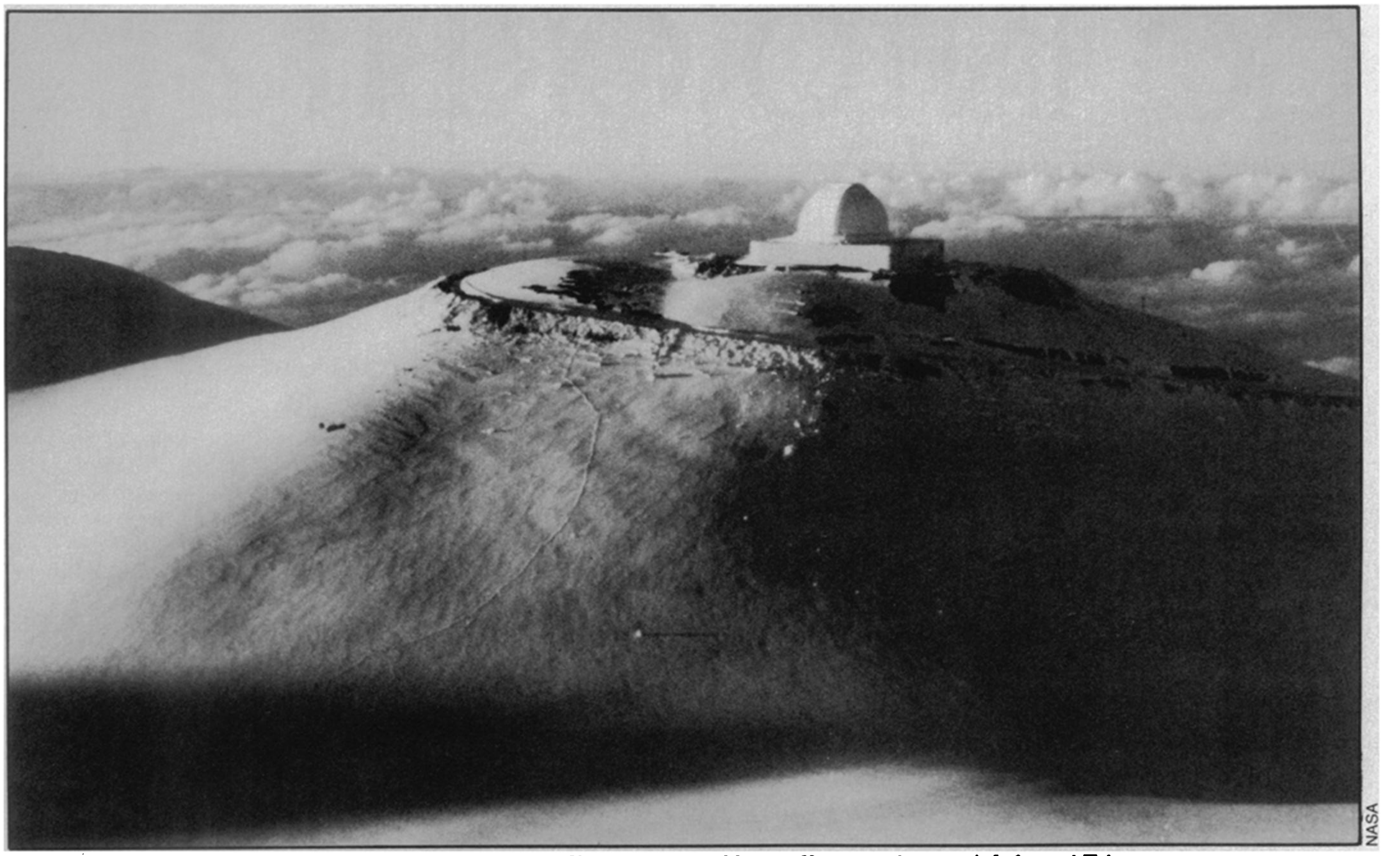
These operations will concentrate largely on the dynamics of the sun's outermost layers, such things as sunspots, flares, coronal disturbances, magnetic fields. When these things are up, "how does it affect the ground-based solar effort?" he asks. It doesn't destroy it. Ground-based cooperation will still be necessary. "Ground will be needed," he says. "You will never get all wavelengths or field of view in space."

The inner levels of the sun are now beginning to be revealed by the recently discovered acoustic pulsations, which have periods from a few minutes to a couple of hours. These presumably carry information about interior conditions, and they have aroused much interest. Beckers reviews the techniques of observing them and says, "All that can be pursued from the ground."

He ends with an example of space-ground cooperation, the proposal for a so-called Solar Flasher. This would be a rotating mirror in earth orbit that would flash images of the sun the size of Pennsylvania onto the ground. The idea is to use ground-based instruments in the region on which the image falls (not necessarily Pennsylvania) to examine small parts of the solar surface at very high resolution (figures like 1/20 of a second of arc come up). This idea "combines space and ground-based, professional and amateur astronomy," Beckers says, "and it may be a rather low cost experiment."

In the rest of the solar system we have seen one of the great wonders of our age, the magnificently engineered probes and orbiters that have gone out and touched the planets (and in the case of the moon brought some of it back). Can ground-based observations come anywhere near that?

They have essential things to do, Larson says. He points out that although it was



White, not blue Hawaii. Amid the soft Kona snow on Mauna Kea stands NASA's *Infrared Telescope.*

flybys that discovered the strange bright colors in the upper atmosphere of Jupiter, it was earth-based spectroscopy that identified the trace constituents and determined why those colors were there. Similar cooperation between the local close-ups of the space probes and the global views of earth-based observers continue to be desirable.

Much of this solar system observing is infrared, and the infrared astronomers generally tend to be somewhat less enthusiastic about a space telescope than their optical colleagues. The infrared of interest is mostly wavelengths that do not impress photographic film or phototubes. The recording is done by heat-sensitive elements. The most sensitive of these require temperatures near absolute zero to minimize thermal noise in the sensor itself. Ironically, these are not suitable for deep-space probes because of problems of maintaining the refrigeration for any reasonable lifetime.

"The desire for high spectral resolution always produces large instruments," says Larson. Aircraft and the space shuttle could take them, but the Space Telescope might not be the best place to hang them. Most of them are also "hands-on" instruments that work best for their creators. "A space mission allows an intensive, coordinated study, but few options for change at the last minute."

That touches a professional reflex of astronomers. They like to get their fingers in things. They like to be able to change an observing program in response to what they see. One astronomer, after looking at the Multiple Mirror Telescope for a few minutes, said, "Now I see what's bothering me. There's no eyepiece, no observer's cage." That much automation on a ground-based telescope strikes astronomers as strange; a remotely operated space telescope could give them a very rigid feeling.

Hall makes a distinction similar to Larson's. For photometry and low resolution spectroscopy he recommends a modest instrument, an infrared shuttle telescope. For high resolution spectroscopy "a large ground-based instrument is better than a small space one."

Spectroscopic resolution is how well one wavelength of light can be distinguished from another in a spectrogram after the light from the object has been put through a grating and separated into its component colors. Angular resolution is how well fine details of the object's structure can be distinguished in its image. A space telescope would seem to be ideal for excellent angular resolution. It is outside the earth's atmosphere. Atmospheric turbulence is the main cause of image smearing in ground-based telescopes.

Yet Low speaks of "efforts to achieve breakthroughs in high angular resolution to achieve best possible resolution with existing large instruments." This goes for optical and infrared wavelengths.

One possibility, which would not apply to existing instruments particularly, is Hardy's and Itek's "active mirror." This mirror has actuators behind it to move sections of it in and out. Atmospheric turbulence is not the same over large volumes. It occurs in small patches, and the optical quality of each patch can change as often as 50 times a second. The mirror is divided into segments to correspond to these patches, and a complicated feedback and servo system continually senses the quality of the mirror's image and feeds back instructions to the activators to move their segments so as to keep the image at optimum quality at all times.

The methods Low describes depend mainly on the old but again new technique of Michelson interferometry and the technique called speckle interferometry. Speckle interferometry depends on trying to follow the turbulence changes with high-speed film or other sensors, getting an image (a speckle) for every time the turbulence changes. This produces a pattern of overlapping speckles. Proper computer analysis can construct a sharp image of the object out of this pattern.

So far speckle interferometry has been mainly an optical technique. Low talks of developing it in the infrared by letting infrared speckles fall on different elements of an infrared sensor. Low is quite enthusiastic about using speckle interferometry in both optical and infrared on the Multiple Mirror Telescope (he gives high praise to the optical work already done by Keith Hege). He sees the future development of improvements in angular resolution (by a factor of 10 or 100 or more) on the ground. "If we can learn to use what we have properly." □