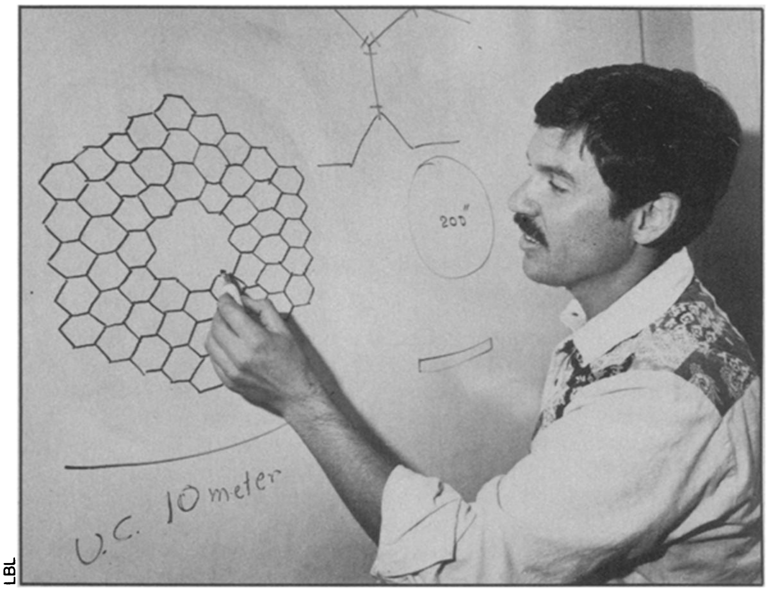
# Reflections on a 10-Meter Mirror

**University of California astronomers are making plans for a superlative telescope with which to see superlative things. To get it they will need superlative support. Does Nob Hill still harbor nabobs?**

BY DIETRICK E. THOMSEN

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*Jerry Nelson of Lawrence Berkeley Laboratory sketches the honeycomb pattern of mirror segments favored by him and his collaborators.*

If a single photon of light from the most distant object in the universe should enter the aperture of a telescope and strike the telescope's mirror, that photon might find its way to its proper location in the image formed at the telescope's focal plane. But nobody will see it there. Increasing the aperture of the telescope is likely to catch more and more photons from this hypothetical most distant object until enough of them are brought to the focal point for the object's existence to be detected.

Nobody knows how big a telescope it might take to discover that hypothetical most distant object in the universe, but there are plenty of objects already discovered from which astronomers would be overjoyed to be able to collect more photons, whether it is a question of seeing more detail or of studying a spectrum that cannot now be studied. And, as always, with more photons, new objects may appear in the field of view, things too faint to have been seen before. Most of these are likely to fall into astrophysical categories that are already familiar, but who knows?

Therefore, the astronomers of the University of California are deciding that they want to build a new telescope, probably a single mirror ten meters in diameter. If they do it, they will have the world's largest optical telescope. It will be almost twice the diameter of the largest existing single mirror (six meters), which is at the Crimean Astrophysical Observatory in the USSR. It is proper to say "the astronomers of the university." They are working through a committee that represents all of them with the official endorsement of the university president.

As Leonard Kuhi of the university's Berkeley faculty puts it, "There are as many or more astronomers in the university system than at Caltech. We have one three-meter telescope, and they have half a dozen that are larger than 28 inches. The needs are there." So the astronomers began talking up a new telescope, and it quickly escalated from two or three meters to ten (twice the diameter of the largest the Caltech astronomers have, the five-meter or 200-inch on Palomar Mountain). "Our President [David] Saxon became quite excited and provided seed money to get a study started," Kuhi says. The study is being done by a committee chaired by Donald E. Osterbrock, director of the Lick Observatory.

It is a California committee, and they want to make their telescope a California project. When a big and expensive piece of equipment like this is proposed — and it could cost upwards of $50 million before it is finished and inflation is finished with it — a reporter's first question is "Have you talked to the National Science Foundation?" They are talking to the NSF, but they are talking California money up front. "The University of California has a long tradition of research in astronomy," says Osterbrock. "To build a large telescope as a California telescope means getting a large part of the money from California."

How to get a large part of the money from California? Kuhi concedes that talk on this point began before the passage of Proposition 13, but he insists that Proposition 13 has not cut off sources of money for the state and that the state still has money it can spend if it wants to. Private money seems possible, too. "One chance is to find a wealthy individual or individuals," Osterbrock says. Kuhi speaks of finding another James Lick. Lick was a San Francisco sugar merchant who financed the Lick Observatory and became so emotionally involved in it that he had himself buried at the foot of one of its telescopes.

If they can do it that way, and maybe because they are in California they seem to think that such fortunes are still around, it will be a California telescope administered by the university's astronomers. That is not to say that visiting observers will not be welcome. Such a welcome is traditional, but the university's astronomers will nevertheless have an instrument of their own to relieve their own pressure for observing time.

It has been argued that the way to provide a lot of viewing time for a lot of University of California astronomers is to provide several telescopes. After all, that is what the Caltech astronomers have at Mt. Wilson and Palomar. The several telescopes could be separate installations or they could be an array that would work together on occasion and simulate a larger telescope. But committee members maintain that a single 10-meter instrument would benefit everybody.

First among the beneficiaries are those who want to do observations that only a ten-meter telescope could do. (It will gather four times as much light as the five-meter and so see much farther into the universe.) At the University of California the number of such people is not small, and their voice is influential. But as Sandra Faber of Lick, who chairs the science subcommittee, stresses, most others would benefit too.

In addition to the observations that are impossible without the four-fold increase in light gathering power, Faber points out that the 10-meter telescope would make feasible observations that are so time consuming as to be difficult to schedule now. "The politics of astronomical time assignments are such that the difference of a factor of four in time may mean doing or not doing."

And in any case, the line of people waiting to observe will go all the faster. And they do mean line. E. Joseph Wampler of Lick, who is cited by his colleagues as the

*E. Joseph Wampler*

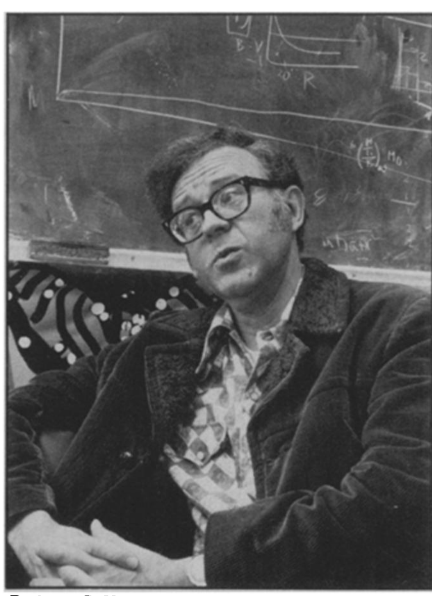
Lick Observatory

*Donald E. Osterbrock*

Lick Observatory

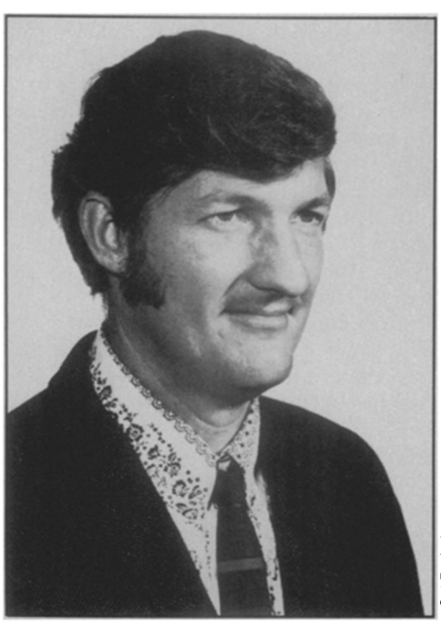
*Sandra Faber*

John Douglas



*Robert P. Kraft*

John Douglas



*William J. Welch*

UCal Berkeley

*Leonard Kuhi*

UCal Berkeley

*There's always a committee. This one is composed of very individual astronomers. This selection of its members includes the over-all chairman, Osterbrock, the chairwoman of the science committee, Faber (Nelson is chairman of the technical committee), and a few of the members whose contributions are considered by their colleagues to be significant or insistent.*

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great pusher for a single large telescope and who does not deny the ascription, points out that there will most likely be "split nights." Traditionally the use of a telescope is assigned to a given observer for one night or even for a few nights. At the ten-meter telescope it may well be that one group would be observing in the early part of the night while another group sat in the anteroom with their sensing equipment in their laps waiting until 2:00 a.m., say, when it became their turn to plug in.

Once four times as much light is gathered, something has to be done with it. Astronomers in recent years have become very happy with light sensing instruments called CCD's (charge coupled devices), which register the light on an array of solid state elements and transmute it to electrical pulses that can be registered in a computer memory. One argument for an array of smaller telescopes is that CCD's that can cover the area of a 10-meter telescope don't exist, and therefore an array of smaller telescopes for which there are CCD's to fit would be better. Faber characterizes that argument as "specious." "You have the same number of pixels, nevertheless," she points out. Pixels, short for picture elements, are the divisions of the CCD in which light is recorded. The more pixels in a recording screen of a given area, the finer is the detail that can be distinguished. Multiplying telescopes does not increase that if all the CCD's have the same graininess. Also, CCD technology is progressing, so who's to say that eventually, maybe by the time a 10-meter telescope was completed, there would not be CCD's capable of covering its field of view?

It is that field of view that Wampler stresses in his arguments for a single monolithic ten-meter mirror. A wide field of view has been traditional for optical telescopes. It is the way you see things you didn't intend to see and the way you compare things with one another. An astronomer studying the edges of the visible universe wants to be able to count high-redshift quasars or high-redshift galaxies and compare them with one another. There aren't that many of them to see, but the ten-meter mirror is likely to pick up more than ever before. Faber expects "a breakthrough" in studies of redshifted galaxies "in order to examine questions of galaxy evolution."

Wampler is interested in galaxy evolution, too. He is especially curious about the question of whether quasars are a stage in galaxy evolution. He says that the light gathering ability and resolution of the ten-meter telescope, along with its field of view, would be ideal for seeing whether there are faint, nebulous, protogalactic hazes around quasars. It has been suggested that such nebulosities would be galaxies in the process of development around quasars. Faber points out that the ability to see numbers of galaxies out to a redshift of one means that astronomers would see them "in a substantially different state [of evolution] from what they are now."

"You've got to have superior resolution to isolate parts of extended objects," adds Robert P. Kraft, a Lick astronomer who also chairs the Santa Cruz astronomy department. These include galaxies, the collections of globular clusters of stars that surround galaxies, the haloes of galaxies and the regions in which new stars form. Resolution includes spectrographic resolution —the ability to separate closely lying lines in a spectrum. Faber points out that studies of the composition of unevolved stars, K giants for instance, which are all jumbled up and not well layered like most stars, will be possible with a ten-meter telescope. They "can't be done now." Kraft adds faint stars such as K and M dwarfs and searches for other planetary systems: "what the odds are on planetary masses as a function of the mass of the principal stellar component." Many of the things that would be done would be "modular extensions or generalizations of what's going on now," Kraft adds.

For all these reasons it seems pretty generally agreed among the committee that an array of telescopes is out of the running. The discussion is between a 10-meter monolithic mirror — that is, one made from a single piece of glass — or a segmented one. There are partisans for both. Jerry Nelson of the university's Lawrence Berkeley Laboratory, who chairs the technical subcommittee, is well along with a tentative design for a segmented mirror. It consists of 54 hexagonal pieces (a centerpiece surrounded by three rings of hexagons) which go to make up the paraboloid shape of the mirror.

Each segment would be supported separately and would be moved by an "actuator" in such a way that together the segments maintained the paraboloid shape. The positions and orientations of the segments would be monitored from the rear, thus avoiding any protrusions on the surface of the mirror or any probing laser beams in the telescope's optical pathways to interfere with the astronomical light. Position data from 288 points would be fed to a computer that would command the necessary adjustments. The computing turns out to be easier than might at first be thought, Nelson says, because in any instance a number of segments will have to do the same thing.

The advantages of the segmented mirror lie in cost and mechanics. The segments would be small, rigid and independently supported. The difficulty, as Nelson points out, is that "we have never made a segmented mirror. Can you make the segments?" The segments are off-axis paraboloids. Talk to a conventional optician about that and he "sort of gets the cold shudders." New techniques of grinding and shaping mirrors would have to be developed.

Avoid this possibly fatal complication, Wampler advises. Opticians already know how to make a monolithic on-axis paraboloid. If it has to be ten meters across, that's a formidable task, but it's an extension of techniques they already know. Such a monolith could not be rigid. It would slump under its own weight and so would require supports capable of holding its shape.

Existing large mirrors have a form of "passive" support, in which pressures generated by counterweights are applied at various points to maintain the shape. This could be extended to a ten-meter monolith, Wampler believes. Such a technique could hold the weight of a ten-meter monolith six inches thick, he proposes.

Wampler's other reason for wanting a monolith is that he believes segmentation will necessarily degrade some of the optical quality of the telescope. Nelson argues that either a monolith or a segmented mirror could be built to the basic optical specifications set out by the committee, a resolution capability of one-quarter of a second of arc. (This means that the telescope's performance would be limited by the state of the atmosphere, which even in the best times and places rarely permits better than one-half a second.)

Nelson doubts that passive supports could achieve as much as Wampler alleges they can. Others are also dubious. "Optics may be possible by a passive support technique," says William J. Welch, a Berkeley radio astronomer, "but what happens when a little bit of wind blows on it? At that point you have to give up and add active support." That could be something like the "actuators" Nelson is designing for his segments. He and his co-workers have already built the central part of one.

Active or passive support, a ten-meter telescope would be a big heavy object, and could not be hung on the optical astronomers' traditional equatorial mounting, in which the axis of the mirror is aligned with the poles of the earth and the plane of the mirror is parallel to the earth's equatorial plane. A ten-meter telescope would have to be hung in an alt-azimuth mounting, with the telescope axis vertical and the plane of the mirror horizontal.

The equatorial mounting makes it easier for astronomers to find and track celestial objects. It takes out most of the rotation of the earth during the night. Traditionally, says Welch, "if you wanted to study a group of stars, you would calculate in advance the precession from some standard catalog position, then go to the telescope with your tables, and they tell you how to follow" — by hand controlling the telescope.

Now the following is done by computer. It has to be with an alt-azimuth mount. The computations involve too much extra arithmetic, and the control involves too many manipulations. That's one reason Welch is on the committee, he says. Radio astronomers have used heavy telescopes with alt-azimuth mounts and computer controls for decades. They're experts in these techniques.

Whatever balance is struck in the technical and scientific requirements of the instrument there is one further delicate question: the site. The biggest telescope in the world should have the best possible site, says Osterbrock. Wampler interjects that that is the Atacama Desert in Chile where seeing is the best in the world. Osterbrock is not sure that a southern hemisphere site is as desirable from the point of view of what can be seen from there as it might have been a few decades ago when there were no large southern telescopes. Politics might make it desirable to have a site for a California telescope in California, and there are two such under consideration, Junipero Serra Peak and White Mountain. Logistics might make Mauna Kea in Hawaii seem desirable, and the possibilities for infrared observations (which require high altitude) could point to that volcano or White Mountain.

Wherever the telescope might be built, it would be remote, high (maybe above 14,000 feet) and automated. This prompts Kuhi to suggest a radical departure in observing procedures. He points out that most astronomers are not experts in the manipulation of the new sensing devices. Furthermore, it takes them time to get used to the night shift and to the altitude. Why not train a new class of high-level astronomical technicians who would work at the telescope every night and become experts in using the equipment? These people would do the actual observing according to prescriptions sent up by the astronomers and then send the data back down to the astronomers in the valley. Astronomers tend to take a highly participatory attitude toward their research, and Kuhi admits he's having trouble selling the idea. The younger astronomers will think about it, but the older generation resist. Their attitude is: "I've just got to get my hands on a telescope."

That could be any astronomer's cry. There are more astronomical research projects around than telescope time, and that has been steadily true for years and is likely to be true indefinitely. The University of California astronomers are exceptional only in that they belong to a single institution, and their needs added up together come to an impressive total. So does the collective ability for design and management of such a project. Given money they could push ahead with it. Given money. □