Astronomers Try to Put Mauna Kea "into Space"

The rapidly improving technology of adaptive optics may soon bring space-like clarity to many telescopes on the ground

Mauna Kea, Hawaii

FOR ASTRONOMERS, a journey to the bleak, lava-strewn summit of Hawaii's Mauna Kea is the next best thing to leaving the atmosphere entirely. Not only is the 4200-meter summit home to the highest major observatory in the world, but its crystalline air lets starlight through to the telescopes with minimal damage from turbulence and convection. Images of galaxies and nebulas taken here will often show twice as much detail as typical images taken at lower altitudes.

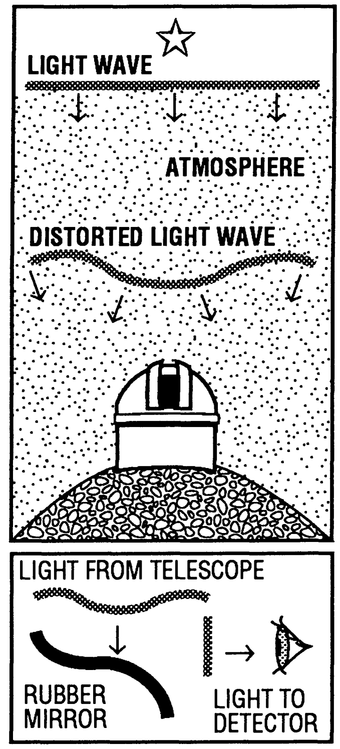
But then, for some people, "the next best thing" to space isn't quite good enough. At the University of Hawaii's Institute for Astronomy in Honolulu, where the astronomers have observing rights at every telescope on the mountain, scientists and engineers are developing a new "adaptive optics" system that could correct enough atmospheric distortion to make Mauna Kea almost the equal of space. If all goes well, in fact, the telescopes on Mauna Kea (and elsewhere) should one day be able to achieve just as much image clarity in some regions of the spectrum as the Hubble Space Telescope will—even after its optical flaw is fixed.

Adaptive optics certainly won't make Space Telescope obsolete, cautions institute director Donald N. Hall. The technology promises to be most useful in the infrared, where atmospheric distortion tends to be least severe. Hubble should still be unsurpassed at most visible wavelengths. And in the ultraviolet it will actually have the field to itself because all this short-wavelength radiation gets absorbed in the atmosphere. Also, Hubble will have an advantage in imaging big objects such as extended nebulas, since adaptive optics can only correct for atmospheric distortion over a fairly small angular scale—about one arc minute on Mauna Kea, and a few arc seconds at most other sites. Nonetheless, says Hall, "Adaptive optics will sharply narrow the areas in which Space Telescope has an advantage over the ground."

Hawaii is hardly alone in its pursuit of adaptive optics. Indeed, the field has emerged within the past 2 years as one of the hottest technology development efforts in astronomy, with European researchers in the lead and several U.S. university teams pushing hard to catch up. Of these, the Hawaii team led by Francois Roddier is considered one of the most innovative.

The problem, says Roddier, is that the stars ought to look like bright little points in a telescope. And yet, even on Mauna Kea, they actually look like blurry, jittery blobs roughly one-half to one arc second across. What's happening is that the light waves from each star have to pass through a constantly changing obstacle course of fine-grain atmospheric turbulence. By the time the waves actually reach the telescope, they look like the fender of a car that has gone through a demolition derby. Adaptive optics, Roddier says, is basically just an attempt to pound those light waves back into shape before they reach the detector.

This is simple enough in principle, he says: just bounce the crumpled waves into the detector with a "rubber mirror," a small reflective surface that can rapidly be deformed into a pattern of bumps and valleys that just cancels out the aberration. The problem, however, is that you first have to find out what the deformation in the light wave is—and the deformation is changing on a time scale of hundredths of a second.



Optical body work. *Damage done by the air (top) can be undone by a rubber mirror (bottom).*

The conventional approach to meeting this challenge, which is being followed by the Europeans and most U.S. groups, is to electronically monitor the distortions of a bright star lying close to the object you are really interested in. The electronic signals representing atmospheric distortion are then converted into a computer program to bend the rubber mirror; with any luck the corrections to the star's aberrations will also unscramble the real object.

A prototype of such a system, developed by the European Southern Observatory (ESO), recently produced 0.18–arc second images at ESO's 3.5-meter telescope at La Silla in the Chilean Andes. That is Hubble-class resolution already. However, there are some severe drawbacks of the ESO approach, Roddier says. Perhaps the most notable is the fact that not every interesting object is going to have a bright reference star sitting right next to it. (The ESO prototype required a fifth magnitude star, which is like a searchlight by astronomical standards, although more advanced versions should get by with fainter stars.)

Roddier and his colleagues at the Institute for Astronomy are therefore exploring an alternative, unconventional approach—"a new kind of sensor that would be faster, cheaper, and more sensitive," he says. Instead of relying on reference stars, Roddier and his team propose to equip their system with internal optics that form an image of the telescope's starlit primary mirror. This is more or less the image you would see if you were looking down on the primary mirror with your naked eye. If this "pupil image," as it is known, is rapidly taken in and out of focus, it acquires a pattern of light and dark that maps the distortion directly; this pattern can be electronically monitored to produce instructions for the rubber mirror.

The virtue of this approach, says Roddier, is that it would make very efficient use of the available photons and could, therefore, be used to look at almost any object in the sky. However, it remains to be seen whether the technique can be made to work in practice. Thus far, the Hawaii group has only demonstrated the principles of its scheme in benchtop tests. "It's a very exciting approach," says ESO's Jacques Beckers, "but we don't yet know what its capabilities are."

Still, Roddier is optimistic. "We hope to have a laboratory demonstration by the end of the year," he says. And if all goes well, a fully operational system could be installed in a telescope in 2 or 3 years. If so, by the time Hubble's blurry vision is corrected, astronomers on the ground could already be seeing at least some objects with space-like clarity.

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