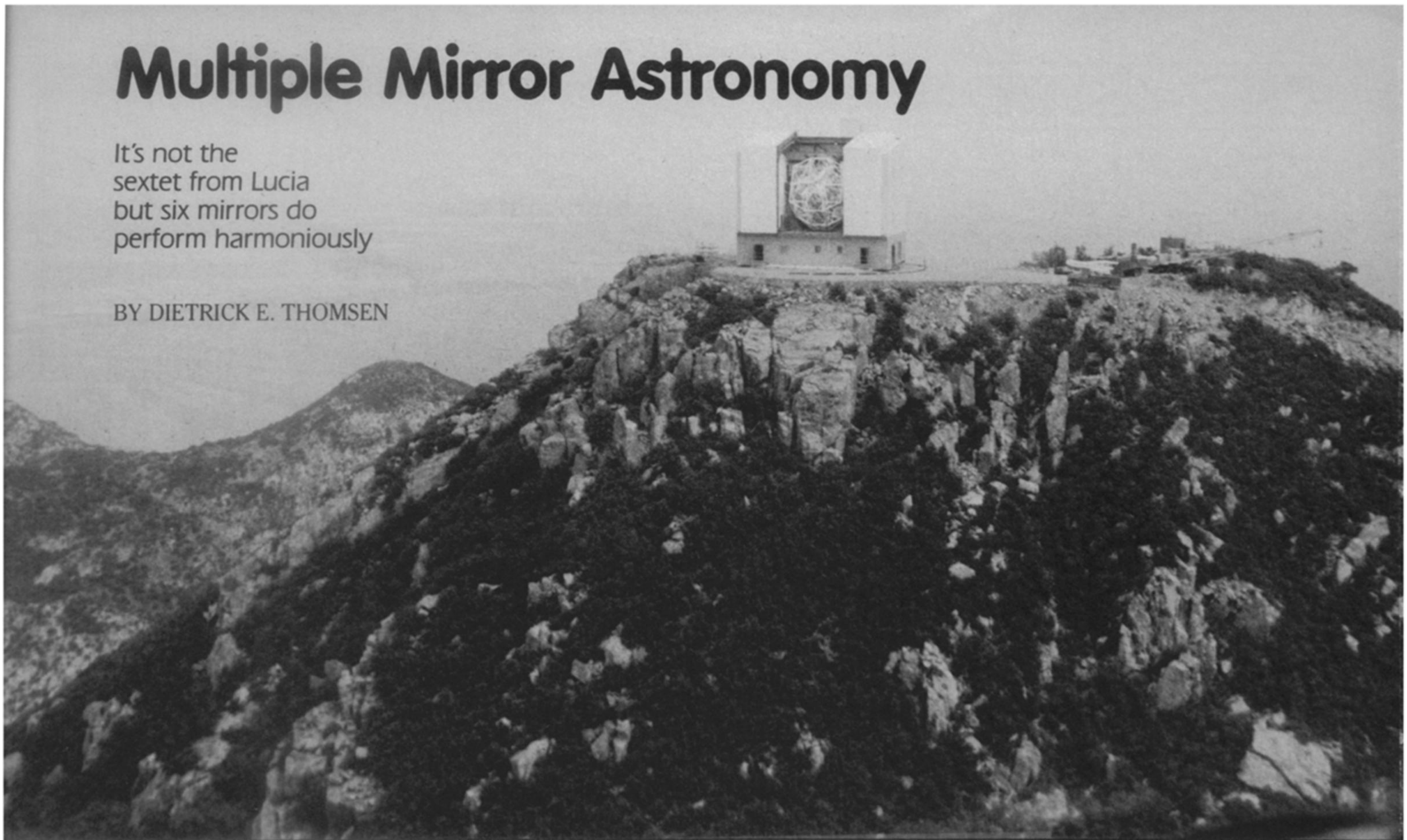
Multiple Mirror Astronomy

It's not the sextet from Lucia but six mirrors do perform harmoniously

BY DIETRICK E. THOMSEN



Multiple Mirror Telescope Observatory

"The MMT was having its gorgeous seeing as usual." The remark is by Richard Green of the University of Arizona at the meeting of the Astronomical Society of the Pacific in Tucson last month. It means that the telescope sees the sky with minimal interference from atmospheric turbulence. The phrase, or something equivalent, comes up repeatedly when astronomers who have worked with the new Multiple Mirror Telescope (MMT) describe their experience.

The MMT, which is located on the summit of Mt. Hopkins, near Amado, Ariz., is six mirrors (really six whole telescopes) designed to act as one and combine their light in a single image. The rationale is to obtain the light-gathering power of a single large mirror without the expense and trouble of casting the large mirror. The MMT with six 1.8-meter mirrors has a light-gathering power about that of a single 4.5-meter mirror. It thus ranks as one of the world's major telescopes. It is sometimes said that this scheme is the first major innovation in optical telescope design since Isaac Newton started grinding mirrors. Depending on which astronomer is talking, it is either the wave of the future for optical astronomy, a dead end or something in between.

The "extraordinarily good seeing at the MMT" (the words are from Frank Low of the University of Arizona speaking to the ASP meeting) cannot be attributed to location alone. Mt. Hopkins is one of three mountains near Tucson that bear major clusters of telescopes, the other two being Kitt Peak and Mt. Lemmon. On a clear day these mountains can be seen from each other. They are not that different climatologically, yet the others do not consistently enjoy the seeing quality claimed for the MMT.

John McGraw of the University of Arizona, another recent MMT user, attributes the difference to the design of the building that houses the MMT. A single telescope is customarily set in a dome with a slit that is pulled open to expose the aperture to the sky. Six telescopes together require a building in which the whole roof slides open. McGraw feels, and others agree, that this configuration makes for smoother air movements around the telescopes and thus less turbulence.

Nevertheless, Mt. Hopkins seems more remote and primitive than the other two observatory mountains in spite of its location right by the highway between Tucson and Nogales, the main road to Sonora and the rest of western Mexico. Kitt Peak is a tourist attraction; visitors are invited to drive the two-lane tarmac road to the top and wander around. In addition to telescopes Mt. Lemmon has recreation areas and hiking trails. Mt. Hopkins is climbed by a narrow, twisting dirt road totally innocent of guardrails, which is a difficult exercise even for drivers familiar with it. At 8,100 feet the road passes a ridge that bears the older buildings of the Smithsonian Astrophysical Observatory's southwestern station. (The MMT, which is a joint operation of the Smithsonian and the University of Arizona, is actually "a kind of tenant on Mt. Hopkins.") The road goes on across a saddle and up a precipitous spiral to the summit of the mountain, 8,600 feet, where they blew away 25 feet of the peak to give the MMT room to stand. There is just room on this pinnacle for the MMT building and parking for a few vehicles. The whole is surrounded by chain link fences to prevent pedestrians from falling off the mountain.

When a new telescope is opened, there is always the question how well it will work. Usually the designers have followed the accumulated wisdom of the art closely enough in the basics that the questions are matters of degree or of fine points. The MMT is a radical departure in design. Some people questioned whether it would work at all.

Standing under the barrels of the six mirrors Jacques Beckers, the MMT's director, told a group of visiting astronomers just how well it does operate. Basically the operators of the MMT are happy, and they would like to be happier. Six telescopes *can* be made to put their images together coherently and to track a celestial object in fairly stable unison. There is a system by which the coalignment of the telescopes is to be monitored and automatically corrected by laser beams run through the optical system. It is not yet in operation. The coalignment is done by hand.

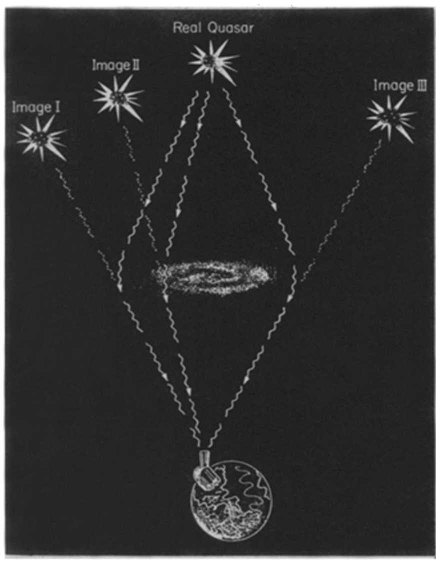
It's a little surprising, Beckers says, that the stability of the structure is such that the coalignment can be done with just the operator sitting there, but it's gratifying, of course. The hand operation does not delay observations unduly. It's a matter of about 30 seconds to accomplish coalignment, he says, and then it's good for 15 or 30 minutes until the earth's rotation changes the relation between the object of observation and the telescope's geometry. An adjustment is then necessary.

Because of this hand operation, Beckers describes the MMT as "operating but not finished." He will not consider it finished until the laser system operates and an alternate automatic coalignment system is developed, one that uses the image of a guide star selected from the field that happens to be in view.

Nevertheless, Tom Riley, one of the MMT staff, is satisfied that "this telescope has answered the question: Can you make an active optical system [one that senses its own imperfections and corrects them]? Yes." But he is also satisfied that this is not the way to do it. Active optics are too cumbersome for large installations. "The next one will not use laser beams. It will use TV cameras and a computer [to combine the images electronically]." The next one is more than just a speculative glimmer. Astronomers connected with the MMT like it so well that they are already proposing an MMT II, an array of eight 5-meter mirrors.

MMT I, operating as it does, gave about 70 percent of its time during June to scientific observation, the rest to engineering. In the fall it is expected to do 75 percent research in spite of not being "finished."

Beckers puts numbers on the "very good seeing" of the MMT that other astronomers celebrate. Seeing is measured by the smallest detail of the image that can



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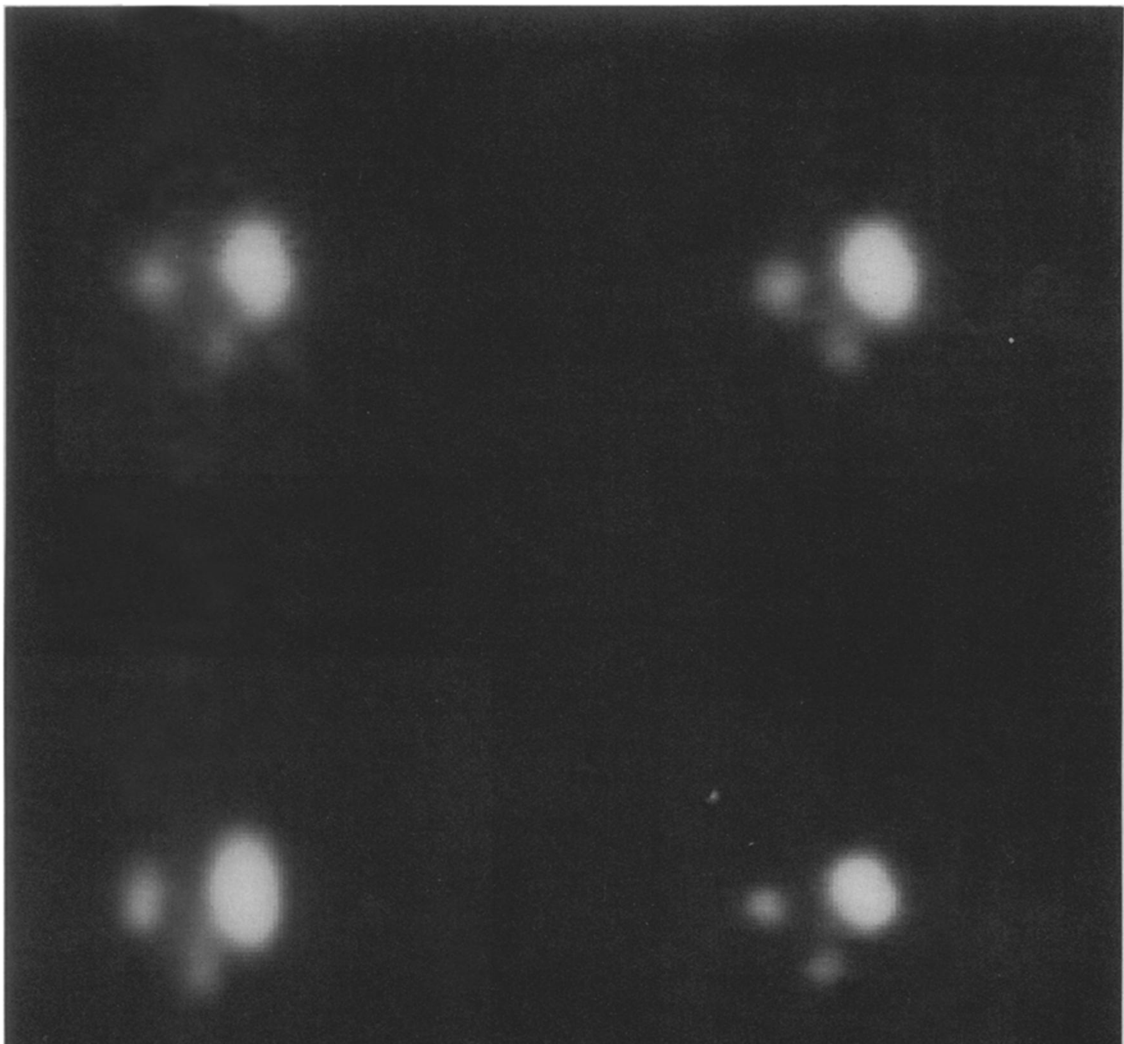
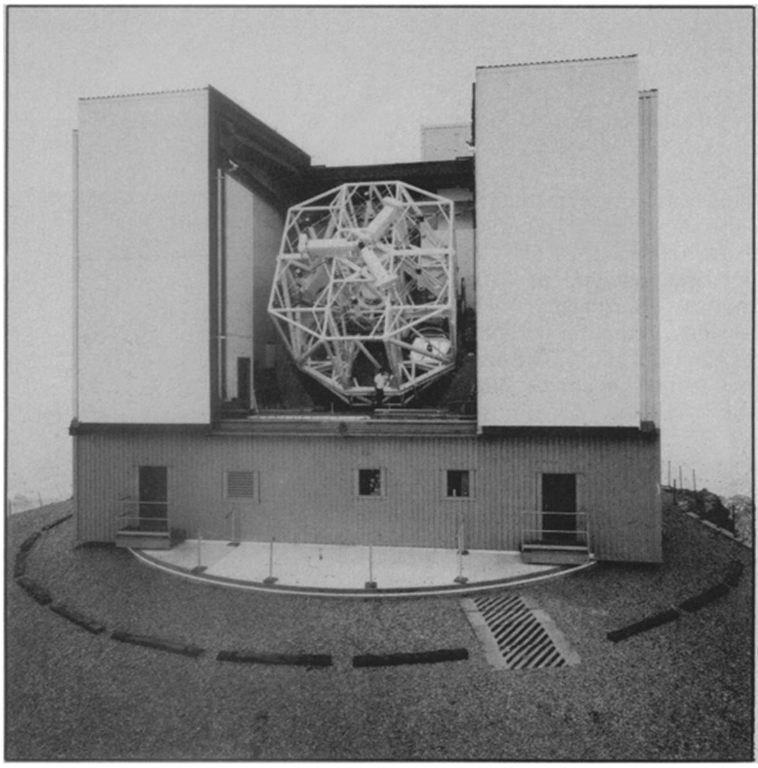


How a gravitational lens might work is sketched above. The four photos at left show the multiple quasar nicknamed "Mickey Mouse," which seems to be one. They were taken with one of the MMT's six telescopes in four wavebands of light: blue (top l), visual (top r), broadband (bottom l), red (bottom r). Speckle interferometry done June 5 indicates the egg-shaped image is at least a double separated by 0.54 arcseconds. Observers are K. Hege, J.R.P. Angel, R.J. Weymann and G. Hubbard.

Steward Obs.



Close-up of the MMT *before its mirrors were in place*

Multiple Mirror Telescope Observatory

be readily distinguished. Most nights the MMT can resolve details one second of arc across or smaller. "We have seen half an arcsecond," says Beckers.

These numbers pose something of a challenge to the telescope's coalignment system. That system "keeps images together to within one arcsecond," says Beckers. That's not good enough if the seeing is half an arcsecond. They want to improve the coalignment to the level of one tenth of an arcsecond.

Another major advantage is the light-gathering power of the telescope. It gathers as much light as a single mirror 4.5 meters across. This invites people who want to do photometric work with very faint objects, particularly if they want to measure quick and subtle variations in light output. Beckers mentions the cores of planetary nebulas, which are very hot and very blue, and thus difficult to follow as their light pulsates. Similar optical behavior is found in a class of faint pulsating white dwarfs, the so-called ZZ Ceti variables.

McGraw, who is working on the ZZ Ceti stars, says, "I really enjoy using the telescope." The light-gathering power allows high speed photometry, especially in blue light, the most important color for these faint old stars. Integration times (how long it takes to imprint an image with useful information on the sensor) range from a few hundredths to a few tenths of a second. "The real beauty of the MMT is that it's usable with conventional instruments," says McGraw, "but its light-gathering power sees things that others don't."

The ZZ Ceti stars are faint, characteristically magnitude 15. The observer must distinguish pulsations amounting to about 25 percent or even as little as 10 percent of the base brightness. Furthermore, the pulses come fast. The periods are characteristically 5 minutes or 7 minutes—a fact discovered on the MMT, incidentally.

"Our work plus that of others has shown that the ZZ Ceti stars are the best clocks in the sky," McGraw says. Observers can use the stability of the pulsation periods to find out how stars die, how they radiate themselves away through the white dwarf stage. These do it very fast, and so observers may find out more easily "what the white dwarf is made of, what the end product of nuclear burning in stars is like."

McGraw is also doing work on cataclysmic variable novae, pulsating and eclipsing star systems, all of which are characterized by quick small changes in light. "I expect to use the MMT rather frequently," he says.

Possibly the most famous work yet done on the MMT had to do with the multiple quasar, which may or may not be an example of a gravitational lens (SN: 11/10/79, p. 324). This may be three, or it may be five, quasars lying close together in the sky that seem to have identical spectra. The most likely explanation is that these are images of one and the same quasar produced by gravitational bending of light rays by some dark object in the line of sight much as a glass lens of the proper shape can produce multiple images.

The multiple quasar was discovered with the Steward Observatory's 2.3-meter telescope on Kitt Peak, but observations were soon begun on the MMT. Again the great light-gathering power was instrumental in getting spectra of the then-recognized three images that showed a rather close identity. According to Green this was the inaugural run of the MMT spectrometer. The observations did beautifully on faint objects, he says, but an attempt to find out what the object is that does the gravitational lensing was not so successful. Green told the ASP meeting, "The lens is not making its presence very manifest."

The seeing, light-gathering power and the dimensions of the MMT's array are an aid in any kind of interferometric work or even in the formation of ordinary images. The important criterion here is the number of wavelengths of the light being observed contained in the distance between the most widely separated rays reflected into the sensing instruments. In the MMT this distance is 6.9 meters, more than for any single mirror on earth. Beckers says it makes the MMT ideal for any form of interferometry and for infrared observation. The length of infrared waves makes the difference between telescopes in this dimension more critical for infrared than for visible light.

Keith Hege of the University of Arizona has shown something of what can be done by using the MMT for an analysis of the same multiple quasar by the technique called speckle interferometry (which tries to bring out structure not readily visible to the eye). It led him to suggest that the multiple quasar is really four or five images instead of three. With the subarcsecond imaging he has obtained, Hege ask, "How many other QSO's might show structure at this level?"

Low refers to Hege's work as "rather impressive results." Low, who is a prominent infrared astronomer, is enthusiastic about the MMT's possibilities for increasing the definition with which astronomical objects are known. Addressing the same ASP meeting, he mentioned getting down to the domain of one tenth of a second of arc. To do this, work is necessary. Interferometry cannot use the whole 6.9-meter array in the round, only mirrors opposite each other. "Work is necessary to maintain path length equality [among all six light paths]."

One drawback of the MMT that cannot be worked away is its narrow field of view, 45 seconds of arc across. This means the telescope is not really good for studies of extended objects such as nearby galaxies, globular clusters of stars, etc.

Also, the MMT was built on the cheap. The mirrors are second hand, having been made for a NASA project that never got off the ground. Most of the other components were bought off the shelf and had been designed for other purposes. For example, the track on which the MMT building rotates and the motors and wheels that move it are designed for overhead cranes in heavy erecting shops. MMT's operators say that that is not the best way to build a telescope but they concede that it could not have been done otherwise. Its success, they hope, will make it possible to build MMT II with custom components. □