Center for Adaptive Optics

Volume 1 , Issue 2

Sharper Image with Adaptive Optics

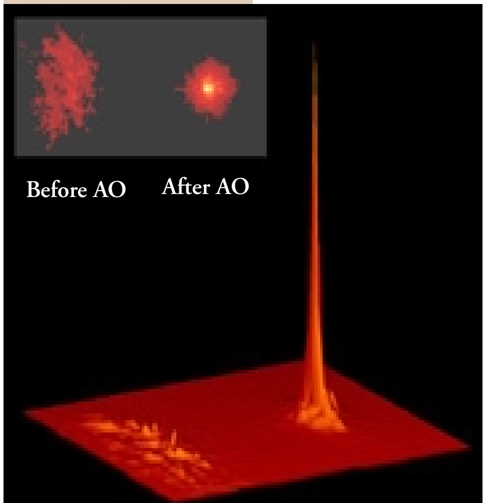


Image credited to UC Berkley UC Santa Cruz and Lawrence Livermore National Laboratory

Stars are so far away that they would appear as "points" of light in a telescope, if it weren't for the effects of distortion in the earth's atmosphere. In the figure on the left, the inset (in the upper left hand corner) shows an uncorrected and an adaptive optics image of a star, taken on Lick Observatory's 3 meter telescope. The white color represents the highest intensities, and orange-red the lowest intensities. The uncorrected image shows the deleterious effects of atmospheric blurring which are to a large extent removed by adaptive optics. The larger surface plot (lower image) contains the same information as the "picture", but now the height of the "peaks" represents the intensity of the light at each point on the detector.

The surface plot is useful because it shows that adaptive optics not only makes images smaller, it also greatly increases their peak intensity because all the light is now falling on a very small area of the detector.

The National Science Foundation Science and Technology Center for Adaptive Optics, University of California, Santa Cruz, CA 95060
Phone: (831) 459 5592
Fax: (831) 459 5717
email: cfao@ucolick.org

Low Cost Wavefront Correctors for Vision Science Adaptive Optics

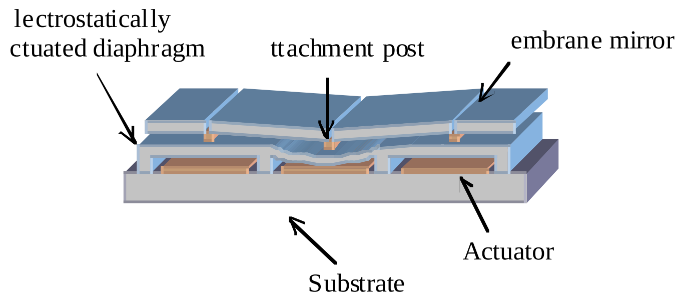
Nathan Doble and David Williams - Center for Visual Science, University of Rochester

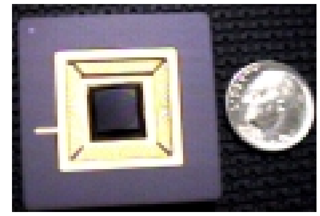
Adaptive optics (AO) for astronomy has been an established discipline for a couple of decades. The last five or so years has seen successful application of this technology to imaging the human eye. Current vision AO systems have generally used the low volume, high cost AO components found on telescopes. The mirrors alone are expensive ($1000 per channel), physically large and lack the necessary stroke required for correcting the aberrations of many eyes. Through CfAO, a collaboration is underway between the University of Rochester, Lawrence Livermore National Laboratory (LLNL), BostonMicroMachines Corporation (BMC), UC Berkeley and Lucent Technologies to investigate alternative low cost wavefront correctors for the next generation of ophthalmic instrumentation.

NSF Science and Technology Center for Adaptive Optics

Various mirror designs are being explored but for a commercial instrument the mirror would need a corrective range greater than 1um, require over 100 channels and be small, ideally comparable to the pupil diameter (7mm). As a first step, a BMC MEMS mirror has been incorporated into the current Rochester AO testbed and a system containing a Hamamatsu liquid crystal spatial light modulator (LC-SLM) has been built by LLNL for delivery to UC Davis. *(Continued Page 2 - Vision Science AO)*

Vision Science AO



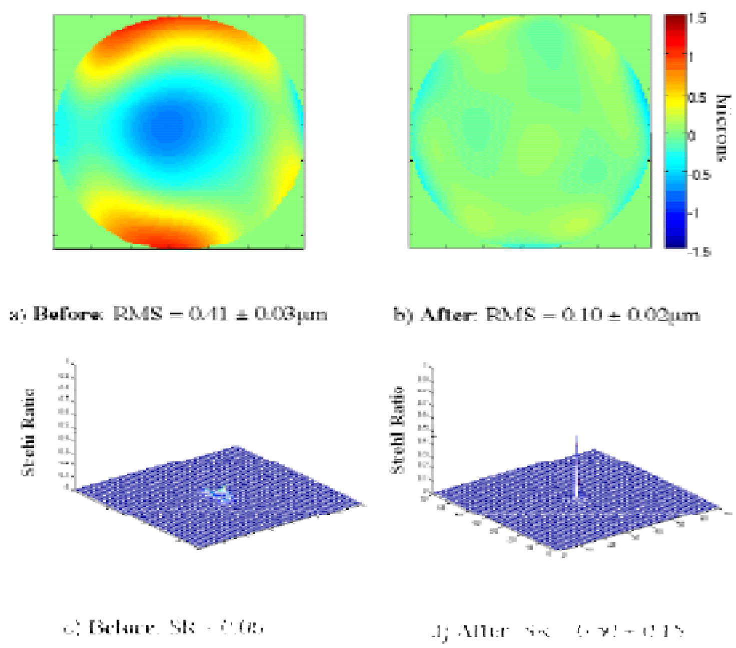


The BMC MEMS mirror: 144 actuators defined under a 3.3mm² active area with a mirror stroke of 2um. Photograph BMC.

MEMS technology is appealing because the devices are very small (see comparison to the dime above) and would eventually allow high volume, low cost manufacture. One area that needs further development is the mirror stroke. Several CfAO groups have designs for higher stroke devices, including Lucent and UC Berkeley. The BSAC team at Berkeley has a segmented mirror design with over 10um of stroke operating at a low voltage (70-80 volts). Initial results with the BMC MEMS have been very promising. For the first time, the AO loop was closed with a MEMS device instead of a conventional mirror. The results before and after correction are shown for a subject with a 4.6mm pupil.

AO *promises to provide new tools for the diagnosis of eye disease, as well as improving corrections to vision*

The system built by LLNL for UC Davis uses an optically



Before and after AO results for a 4.6mm pupil with the BMC MEMS mirror as the corrective element

Vision Science AO

addressed Liquid Crystal Spatial Light Modulator (LC-SLM) to provide the wavefront correction. It avoids the need for large stroke due to the fact that it is segmented and can be phase wrapped. A photo of the UC Davis system is shown at right. The LC-SLM can be seen in the back right of the breadboard.

A low cost AO system for vision science would be very useful in earlier diagnosis and monitoring of treatments for many retinal diseases. In addition, such a system could be used as a means of showing patients the benefits of a vision correction procedure, such as LASIK or contact lenses. The ongoing research described here will eventually lead to several prototype AO equipped phoropters. These devices will be tested at several CfAO nodes with a view to commercialization.■

The Liquid Crystal Spatial Light Modulator (LC-SLM) AO system designed by LLNL for delivery to UC Davis. Photograph Scot Olivier, LLNL

Creating and Detecting Rayleigh Laser Guide Stars

Laird Thompson, Astronomy Department, University of Illinois

Adaptive optics systems on large telescopes have limited sky coverage if natural stars are the only sources used to monitor atmospheric irregularities. To extend sky coverage for adaptive optics, artificial laser guide stars must be incorporated into the system. The art of creating and detecting laser guide stars is a challenge, to say the least.

Two separate specialties have developed during the 20-year history of this research endeavor. One centers on the elegant process of exciting sodium atoms that float in a tenuous layer some 95 km above the surface of the Earth. The other specialty — the topic of this article — is more "brute force" in character and relies on laser illumination of both molecules and dust particles in the Earth's atmosphere at somewhat lower altitudes than the sodium layer. In the jargon of adaptive optics, the first type of artificial star is called a "sodium guide star" and the second a "Rayleigh guide star".

The first Rayleigh guide star system was developed at Starfire Optics Range (Kirtland Air Force Base) under the direction of Dr. Robert Fugate and was in full operation during an 8-year period in the early to mid 1990's. The Starfire system used a powerful copper vapor laser emitting light at green wavelengths. It was focused at the relatively low altitude of 10 km.

The second Rayleigh guide star system is now in place at the Mt. Wilson 2.5-m telescope. It was developed at the University of Illinois with NSF funds from the Advanced Technology and Instrumentation Program. The full system — adaptive optics, Rayleigh laser guide star, and science cameras — is called UnISIS: University of Illinois Seeing Improvement System. The author's primary collaborator in the UnISIS development is Prof. Scott Teare from New Mexico Tech.

The UnISIS Rayleigh guide star light is created with an excimer laser. Excimer lasers are the industry standard for LASIK eye surgery and UV silicon foundry work. Depending on the gas mixture loaded into the laser chamber, excimers will emit pulsed radiation at 6

Rayleigh Laser Guide Stars (continued)

different wavelengths ranging from 157 nm to 351 nm. The UnISIS laser is loaded with xenon and fluorine and thereby works at the longest of these wavelengths, 351 nm. This particular wavelength is very attractive for laser guide star work because the Earth's atmosphere is relatively transparent (but not too transparent!) at 351 nm and Rayleigh scattering is strongest at the short wavelengths. (For LASIK eye surgery, excimer lasers are loaded with krypton and fluorine and thereby emit at 248 nm, a wavelength that is strongly absorbed by the cornea.)

At Mt. Wilson, the laser beam is projected off the full 2.5-m primary mirror and is focused 18 km above the telescope (20 km above sea level). This altitude is high enough to position the artificial laser star above nearly all of the strong layers of atmospheric turbulence, but the fact that the light returning from a laser guide star at 18 km fills a conical volume (rather than a cylindrical volume like the star light) does degrade the adaptive optics performance. In short, the higher the guide star the better the performance. There is no doubt that the newer generation of Rayleigh laser guide stars will move even higher into the atmosphere. With newer and more powerful lasers becoming available, an altitude range of 30 km to 35 km seems most attractive.

30 Watt UnSIS excimer laser with its top removed. Vent hose in foreground removes spent laser gas - xenon and flourine in a neon buffer, all of which are specific to 351 nm laser emision

The primary challenges in building and operating laser guide star systems are: (1) dealing with very high power laser systems at astronomical facilities that have as their primary mission the detection of extremely faint astronomical signals, (2) dealing with the logistics of reliably operating complex laser equipment developed as experimental rather than industrial systems, and (3) satisfying hazard-avoidance both within the observatory building and in the airspace above the telescope. Just a few interesting aspects of these challenges are mentioned here.

Specialized optical systems must be installed to capture the relatively faint Rayleigh laser guide star return signal in the presence of the much brighter low altitude laser light that is scattered by the atmosphere on its up-link path. This problem can be handled gracefully because both the copper vapor laser used at Starfire Optical Range and the excimer laser used with UnISIS are pulsed laser systems. For example, the length of the UnISIS laser pulse is less than 20 nanoseconds. Since the roundtrip light travel time to 18 km is 120 microseconds, there is sufficient time for fast electronic shutters (based on polarized light and a so-called Pockel's cell) first to hide the wave front camera from the burst of low altitude Rayleigh scattered light and then open it a time precisely in sync with the fainter return signal from 18 km.

Laser reliability has been a key factor in nearly all laser systems deployed at telescopes. In a few cases, systems have failed to work because the laser power has been too low, but more commonly the systems will work but only some fraction of the time. Solving this problem becomes a matter of good management. Everyone runs under very tight budget constraints, but having a reliable system is a necessity.

The Federal Aviation Agency (FAA) is well aware that the astronomy community is actively developing and installing laser guide star systems at major observatories. One special beauty of UnISIS is the inability of humans to see 351 nm light. This fact, plus the benign manner in which the excimer light is projected to altitude, made it possible to

Rayleigh Laser Guide Stars (continued)

classify the UnISIS laser guide star system as a Class I laser from the perspective of pilots and the FAA. The time-consuming airplane countermeasures that other laser guide star systems must face are not an issue at Mt. Wilson Observatory. This represents a major simplification in the operation of UnISIS compared to other laser guide star systems.

The future of Rayleigh laser guide star work looks very bright for several reasons. First, the development of industrial-quality laser systems means that robust and powerful laser systems are entering the market every year. One of many possible examples is the new release by Lambda Physik of a system they call "Lambda Steel", an excimer laser designed for LCD manufacturers. Second, Rayleigh guide stars are flexible tools for astronomers because they can be focused and detected at all altitudes up to 35 km.

This last characteristic makes it possible to use Rayleigh laser guide stars to

(1) monitor atmospheric turbulence as a function of altitude above an observatory,

(2) easily correct for ground-layer turbulence, i.e. atmospheric distortions that originate in telescope domes and the atmospheric boundary layer, and

(3) develop the 3D tomography of turbulence for forefront multi-conjugate adaptive optics systems.

There is no shortage of new opportunities! ■

People and Profiles

Financial Analyst - David Ginn - Dave joined the Center in June 2001. He has a MBA and a BA in Political Science, both from from UC Irvine and is also a Russian linguist.

Dave has served in the military and worked in industry before joining the Center

Education Coordinator - Geri Philley. Geri joined the Center in October 2001. She has a bachelor's degree in mathematics, a master's degree in instructional technology, plus a broad range of experiences that are aligned with the specific educational objectives of the CfAO. Geri comes to the Center from the California State University, Monterey Bay (CSUMB) where in addition to teaching, she researched community issues and in collaboration with community members developed appropriate solutions. She has been associated with the Technology Tutors, an undergraduate course designed to fulfill community service requirements at CSUMB, and through this has worked with K-12 teachers and librarians in the low income neighborhoods of Salinas, Castroville, and Watsonville.

Post Doctoral Researcher - Eric Steinbring Eric completed his PhD studies at the University of Victoria in Canada. He joined the Center in the Fall of 2000. His research is studying extremely faint, distant galaxies, and the AO at Keck has been used to obtain high-resolution near-infrared images of these objects. He is currently working on methods of characterizing and enhancing AO image quality, especially for laser guide stars. As part of the Center's outreach activities, he is building AO teaching demonstrators for vision-science and astronomy.

Eric Steinbring

Jerry Nelson

From the Director

The Center for Adaptive has just completed its second year as a National Science Foundation Science and Technology Center. This was a year in which we reviewed and revised our research, implementing a change to theme oriented research programs. There is now an increased emphasis on technology relative to science, resulting in a subtle but significant redistribution of effort. Our four theme areas are:

Theme 1: Education and Human Resources

Theme 2: AO for Extremely Large Telescopes

Theme 3: Extreme Adaptive Optics (eXAO) Enabling Ultra-High-Contrast Astronomical Observations

Theme 4: Compact Vision Science Instrumentation for Clinical and Scientific Use

While some areas of research were negatively impacted, we believe that in the longer term, the Center will be better positioned to maximize its impact on the field of Adaptive Optics. Our two external committees - the Program Advisory Committee and the External Advisory Board, have endorsed the new theme approach, as did the NSF Site Visit Committee. We are now working hard to implement our collective vision for the Center.

In addition to the changes in our research agenda, we have aligned our Educational activities closely to the Center's research. The Center's "Stars, Sight and Science" summer program for talented High School students offered through the University of California Santa Cruz's COSMOS program is one such example. The enthusiastic participation of post docs and grad students as instructors played a major role in its success.

While all Center researchers are expected to participate in Educational activities, our post docs and graduate students are in the unusual position of partaking as BOTH contributors and beneficiaries. The Center sponsored a Professional Development workshop in Kona Hawaii, that was directed at helping graduate students and post docs improve their teaching skills and also their background knowledge in Adaptive Optics - the latter by visiting the Observatories on Mauna Kea. The success of the "Stars, Sights and Science" program was to a significant measure the result of the application by the instructors of the lessons learned at Kona.

Our Year 3 has started with a gathering of all our researchers and educational experts for a Fall Science Retreat in Monterey. The meeting was held in an informal setting and attendees were encouraged to actively participate in discussions.

In summation, last year was one of transition from a goal to a theme mode for managing our research. We have made a good start to year 3 and look forward to a fruitful and rewarding year for the Center. ■

Year 2 - NSF Site Visit a week after Sept 11

The Center for Adaptive Optics (CfAO) as a Science and Technology Center (STC) funded by the National Science Foundation (NSF) is evaluated on an annual basis by a visiting committee of researchers and technologists. Last year this was scheduled for September 19th to 21st, 2001. The tragic events of September 11th intervened and after extensive discussions, it was decided, because of potential difficulties in travel, to proceed with a "virtual" site visit. It was agreed that only in-state site visitors would assemble at Santa Cruz, the others

Site Visit (continued)

including the NSF officers in Washington, would participate via video-conference or tele-conference links.

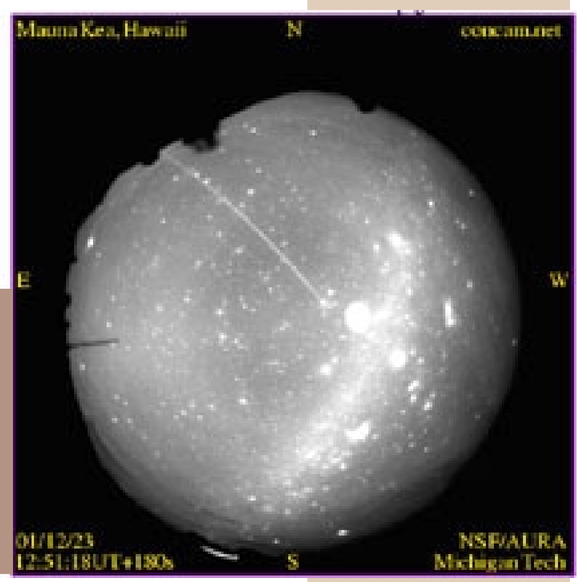
Over a five day period speakers were informed of the decision to proceed. Slides were prepared and presentations reviewed, discussed and edited via tele-conference and email. The final versions of slides to be used were placed in a "secure" location on the Center web-site. This enabled participants to download presentations onto their terminals while watching or listening to the speaker located at another site. Our presenters were at geographically diverse locations ranging all the way from London to Honolulu. Consequently, time zones were taken into account when preparing the schedules. In the main, despite the potential for catastrophe and a few technical glitches that occurred, the "virtual site visit" went extremely well. Irrespective of their location, Center presenters were there ready and waiting when called upon. In all cases they stayed within their allocated time periods and no difficulties were experienced in maintaining the schedule. The subsequent panel report was complimentary of the enormous effort spent in the past year refocusing the Center's efforts from research goals to themes that are more technology oriented and also commented on the relative smoothness of the "virtual site visit". There had been some concern as to the efficacy of this communication mode for transferring information and encouraging discussion. A "wrap-up" evaluation by the NSF staffers and the site visit committee concluded that overall the information exchange was good and probably ninety per cent as effective as that for an actual on-site visit.

First Light for Keck Laser Guide Star

The "first-light" for the Keck laser was a complete success with the laser guide star being propagated for the first time at 11:42 UT, December 23 2001. CfAO researchers Claire Max and Dee Pennington were present .

Operators were very satisfied with the brightness of the laser guide star spot at the 100-km altitude of the sodium layer and the fact that the low-altitude laser beam emission (due to Rayleigh scattering) was at the low level predicted. It was not easily visible from the Gemini Observatory 600 meters distance from the Keck Observatory. The laser guide "star" was on the autoguider for the first run

The team present at the summit included: Joel Aycock, Michael Bray, Curtis Brown, Jason Chin, Pam Danforth, Bill Healy, Hilton Lewis, David Lynn, Claire Max, Craig Nance, Dee Pennington, Paul Stomski, Doug Summers, and Peter Wizinowich.



The image is from the ConCam all-sky camera on Mauna Kea. In this three-minute exposure, the narrow white line at the 10 o'clock position is the laser beam. The Milky Way can be seen as the broad diagonal band. Plans to further optimize the laser and to fully integrate the laser guide star with the Keck II adaptive optics system are proceeding.

ASTRONOMERS OBSERVE DISTANT GALAXIES MORE CLEARLY

Using the unprecedented power of adaptive optics combined with the 10-meter (400 inch) Keck II telescope, UCLA astronomers and Center for Adaptive Optics (CfAO membersTiffany Glassman and Dr. James Larkin are peering into the distant universe to discover what our own Milky Way galaxy might have been like at the time our sun was forming.

The observations are an important step forward in the process of understanding how galaxies formed and how they evolved into the wide variety seen today.

"For the first time, we're able to get very detailed images in a survey of distant galaxies in the infrared," said Larkin, associate professor of astronomy at UCLA speaking at the annual meeting of the American Astronomical Society. "These new measurements will help pin down the details of galaxy evolution, and they show that adaptive optics will play an important role in understanding galaxy formation billions of years ago."

The ten galaxies observed are about 5 billion light years from earth (redshift of about 0.5), a period when the universe was about two-thirds of its present age. This time span represents a significant portion of the lifetime of a galaxy and is far enough back to begin to discriminate between different theories of galaxy formation.

"This is an important first step in gaining much more information about galaxies in the early universe," said Glassman, graduate student in astronomy at UCLA. "Though our current sample is small and the results preliminary, our only clue towards an understanding of how galaxies - like our own Milky Way - form is to look further and further into the past, and adaptive optics promises to be one of the best ways to do that."

Galaxies are among the largest cohesive structures in the universe, often consisting of more than 100 billion stars. At great distances, however, even these vast structures appear as only small smudges through the world's largest ground-based telescopes.

Adaptive optics (AO) allows astronomers to remove much of the blurring effects of the earth's atmosphere and achieve sharper images than any previously taken. These sharper images allow the sizes of galaxies, as well as the properties of smaller components that make up each galaxy, to be studied.

Glassman and Larkin observed galaxies whose dominant components are a large, flattened disk and a central, spherical bulge, similar to the Milky Way and other nearby spiral galaxies. With AO the same basic properties (size and brightness of the disks and bulges) can be measured for the distant galaxies they observed and for local galaxies.

The astronomers can now compare these properties to see how the galaxies have changed over billions of years. They found that as a group the disks of the distant galaxies are 2.5 times brighter at their center and 20% smaller than local disks. A less quantitative analysis of the galaxies' bulges showed that their central brightness also fades by about a factor of 2 but their size stays relatively constant.

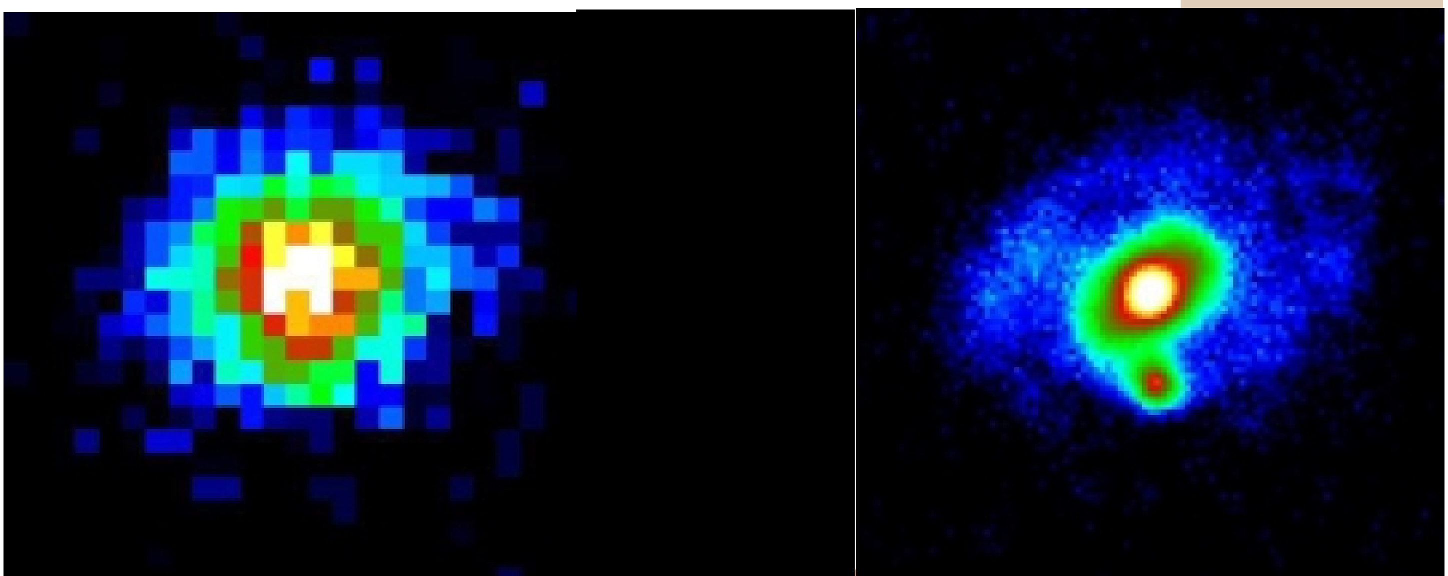
The results produced by Glassman and Larkin support other observations and theories that indicate that large galaxies were primarily assembled more than 10 billion years ago and are slowly fading as a group as the rate of new star formation declines.

To continue their research, Glassman and Larkin are building a much larger sample of galaxies including many at significantly greater

Distant Galaxies (Continued)

distances. This survey is possible because of a new camera for the Keck Telescope's Adaptive Optics system called NIRC2 (Near Infrared Camera 2) which has been available to the researchers since July through the cooperation of the camera team led by Keith Matthews of Caltech.

NIRC2 has a much larger field of view and is significantly more sensitive than the earlier cameras and greatly improves the quality of the data available to Glassman and Larkin. "This new sample should allow for more detailed comparisons between local and distant galaxies, but perhaps more importantly it will contain a small number of galaxies seen just after their initial formation," said Glassman. "Detailed images like these, of galaxies in their infancy, will give astronomers the best handle on how galaxies first assembled."



Shown above are two, false-color images of the same galaxy, both taken with the 10-meter Keck Telescope by UCLA astronomers Tiffany Glassman and Dr. James Larkin. The image on the left was taken without Adaptive Optics and shows the usual limit on the detail that can be seen with ground-based telescopes. The image on the right was taken with the Keck Adaptive Optics system and shows the vast improvement in the sharpness of the image and the detail than can be seen. This galaxy, located in the constellation Pegasus, is 4 billion light years from Earth (redshift of 0.37). A basic disk and bulge structure can be seen, as well as a central bar, a smaller point source that might be a satellite galaxy, and the hint of spiral arms in the disk. With detailed images of distant galaxies like this one, astronomers can learn more about what the universe was like billions of years ago. This material was presented to the American Astronomical Society meeting in Washington, DC on January 7, 2002. PHOTO CREDIT: UCLA, Department of Physics and Astronomy: T. Glassman & J. Larkin.

Education and Human Resource Activities

There has been considerable restructuring of the CfAO's Education outreach programs in this past year. The changes have aligned the educational programs more closely with the Center's research activities and increased focus on the recruitment and retention of underrepresented sectors of the population in the disciplines of science and engineering. The activity focus is on students ranging from high school level to the graduate level.

The programs offered in Year Two related directly to the stated objectives. These included the Stars, Sight and Science Summer Program, the ALU LIKE Traineeship program and the Annual Professional Development Conference.

The Center's "Stars, Sight and Science" summer program for talented high school students was offered in collaboration with the University of California Santa Cruz's California State Summer School for Mathematics and Science (COSMOS) program. The four-week summer immersion experience included three coordinated courses on vision science, astronomy and science communication developed by the CfAO. High school students were recruited by the CfAO from three area high schools — Watsonville, Overfelt and North Salinas high schools — all of which have large underrepresented student populations. Cynthia Mendoza, from Watsonville High School, was awarded a scholarship of $1000 to attend any university; $2000 to attend an institution within the University of California system and $4000 if she attends the University of California Santa Cruz. The scholarship was for academic achievement, attitude and overall excellence during the summer session. CfAO faculty, graduate students, research scientists, and postdocs played a pivotal role as instructors and mentors to the high school students and their enthusiastic participation contributed much to the success of the program. Watsonville High science teacher Burnne Yew was part of the instructional team, assisting the CfAO instructors in delivering material that was engaging and appropriate for high school students.

Making a Bubble Tower - An exercise in Inquiry Based Learning

The island of Hawaii is home to many of the world's largest observatories on Mauna Kea. Unfortunately these employ few Native Hawaiians in technical or professional roles as there is a lack of training facilities on the islands. In an effort to overcome this, the CfAO is cooperating with educational establishments in Hawaii to identify and develop new programs that will increase the participation of Native Hawaiians in CfAO related research and technology. As part of this effort the CfAO is collaborating with the ALU LIKE organization and with LLNL to provide traineeships on the mainland for native Hawaiian Community College and recent high school graduates. See Issue 1 of this newsletter for more details.

Last year the CfAO sponsored the first of its annual Professional Development Conference series for graduate students and postdocs. This

Education and Human Resource Activities, cont'd

provided 25 CfAO graduate students and postdoctoral researchers an opportunity for experience in inquiry-based teaching, for developing interdisciplinary ties, and to establish contacts for future collaborations. The conference was held on the Big Island of Hawaii and attendees visited the Gemini and Keck observatories on Mauna Kea. Attendees spent an intensive two days in a workshop on inquiry-based learning developed and delivered by Doris Ash (Education Dept., UC Santa Cruz) and Barry Kluger-Bell (Exploratorium), and presented non-technical posters to local high school teachers. The subsequent evaluation of the conference conducted by Dr. Barbara Goza (Director, Research and Evaluation, Educational Partnership Center, UCSC) indicated that the initial participant responses were extremely positive. The second annual conference will be held in Maui, May 15-18, 2002.

A Mini-Grant Project was launched Year 2, and gained momentum at the Kona Conference. Graduate students and postdoctoral researchers were invited to submit one-page proposals outlining a visit to a collaborating CfAO site. These visits are designed for students to gain experience in a discipline different to their own, for example astronomers visiting vision science sites, or projects in education. Mini-grants were awarded to UCSC graduate student Lynne Raschke to visit the University of Rochester and Peter Kurczynski, a postdoctoral researcher at Bell Labs. .

The Second Annual Summer School on Adaptive Optics held in July 2001 provided all professionals interested in adaptive optics a six-day workshop aimed at both astronomy and vision science researchers. Of the approximate 96 people that attended the workshop, eighty percent were CfAO graduate students and post docs. The major focus of the workshop was on MEMS technology and image processing techniques. Computer lab sessions were held to introduce participants to the programs used for image enhancement.

Austin Roorda - a CfAO Principal Investigator, speaks to students at the SACNAS conference

The CfAO was represented and participated extensively in the SACNAS (Society for Advancement of Chicanos and Native Americans in Science) conference in 2001. This conference combines science, professional development and culture. It attracts approximately 2000 participants each year, most of whom are underrepresented undergraduates. CfAO Associate Director, Claire Max chaired a scientific symposium on adaptive optics. Panel members included Austin Roorda (University of Houston), and Gabriella Canalizo (Lawrence Livermore National Laboratory). The CfAO sponsored a booth to provide an extended opportunity for students to learn about the CfAO. Fernando Romero (University of Houston), Shuleen Chau-Martin (UC Berkeley), and Lisa Hunter (UC Santa Cruz) joined the CfAO speakers at the booth and other conference activities. Three CfAO undergraduate interns were awarded full travel awards and were selected to present posters. They included Carmen Kunz and Tammi Floyd, who last summer completed projects at UCO Lick Observatory Shops, at UC Santa Cruz.

In Year Three, EHR will further refine educational projects. The activities will focus on inquiry-based teaching, clustered mentoring, and the development of instructional materials that bring CfAO research into the classroom and public arena.

Education and Human Resources Notices

CfAO Undergraduate Internships
The CfAO will cover the costs of 18 undergraduate students this summer with a Research Experience for Undergraduates (REU) supplement provided by the NSF.
We need:

- CfAO people/places to host students (CfAO covers all costs)
- Underrepresented student applicants (emphasis is on community college students)

For information contact Geri Philley.

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CfAO to host 2nd Annual NSF Research Center Education Workshop
This workshop brings together education directors from Science and Technology Centers (STC's), Engineering Research Centers (ERC's), and Materials Research and Science Engineering Centers (MRSEC's). Tentative dates: October 26-28, 2002.
For information contact Lisa Hunter.

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Mini-Grants
CfAO graduate students and postdocs are invited to apply for Mini-Grants. Use this opportunity to develop new skills, get exposure to new disciplines, and develop new collaborations. Interested in policy and management? Apply to attend the CfAO External Advisory Board meeting or other events…
For information contact Lisa Hunter.

Professional Development Conference
The date and place for the 2002 Professional Development Conference has been set: May 15-18, Maui, Hawaii. This conference is for CfAO graduate students and postdocs and will focus on developing inquiry-based educational activities and exploring professional opportunities in Hawaii. Details and registration will be posted on the web in February.
For information contact Lisa Hunter.

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2002 Summer School for AO - Aug 4-9 2002
The 3rd annual Summer School on AO will be held on the campus of the University of California in Santa Cruz. The school will include system components, and general adaptive optics concepts relevant to both astronomy and vision science. The course level will be appropriate for graduate students, postdocs, and researchers who are not experts in the field.
Cost of Attendance:
Graduate students and Post-docs : $200 Conference fee includes all Board and Lodging. US based students are also eligible for travel support within designated limits.
All Others: Conference fee $200; Board and Lodging (includes 3 meals a day) $100 per night (single occupancy), $80 per night (double occupancy).
For Information contact Paula Towle.

Contact Information:

Lisa Hunter - Email: hunter@ucolick. Phone: 831-459-2416
Geri Philley - Email: geri@ucolick.org Phone: 831-459-4688
Paula Towle - Email cfao@ucolock org. Phone: 831-459-5592
More information on Year Three CfAO projects may be obtained at the web site : (http://cfao.ucolick.org/EO/ProjectsComing/index.shtml).

Upcoming AO Related Conferences

"Engineering the Eye" June 13-15, 2002 Symposium. at the Center for Vision Science University of Rochester.
Topics include the study of eye movements to perceptual constancy, information coding and applications of Adaptive Optics to advanced instrumentation for eye disease diagnostics and vision correction.
For more info. see
http://www.cvs.rochester.edu/Symposium.html

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Call for Papers
The International Society for Optical Engineering - Astronomical Telescopes and Instrumentation is holding a conference on the 22-28 August 2002, at the Hilton Waikoloa Village Hotel, Hawaii
General Chair: J. Roger P. Angel, Steward Observatory/Univ. of Arizona
Deputy General Chair: James B. Breckinridge, National Science Foundation
Sessions will feature:
Astronomy with Large Telescopes
UVOIR Ground Instruments
Astronomy Information Technologies
Space Telescopes and Instruments
Millimeter and Submillimeter Detectors
Astronomy Outside the EM Spectrum
Astrobiology
http://spie.org/Conferences/calls/02/as/

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CfAO visits the USAF's Advanced Electro-Optical System site at Maui and Gemini Observatory – January 2002.

Technical Sergeant USAF, Rob Medrano speaks to site visitors from left Dr. Scot Olivier (CfAO) Lisa Hunter, (CfAO) Dr. Morris Aizenman (NSF) Dr. Julian Christou (CfAO), Dr Joseph Janni (Air Force Maui Optical and Supercomputing Site), Dr Kent Miller (AFOSR), Mrs J. Agee, Mrs. K. Miller.

Dr. Jean-Rene Roy (Gemini North Observatory), meets with site visitors Dr. Morris Aizenman (NSF) Major Paul Bellaire Jr. (AFOSR) and Dr. James Beckinridge (NSF)

Center for Adaptive Optics

Laser Guide Star, First Light at Keck Observatory

A very faint beam from the Keck sodium laser appears in this 20-minute exposure. The laser creates a “virtual” star high above the Earth’s surface, which is not visible to the human eye, but is bright enough to guide high resolution adaptive optics at Keck. This photo was taken from 600 meters away. Hazard lights from an automobile mark the steep descent path of the summit, and the motion of the Earth has created star trails in the sky. Photo by John McDonald from Canada France Hawaii Telescope (CFHT)

Extract from CfAO's Mission statement

"Our purpose is to advance and disseminate the technology of adaptive optics to serve science, health care, industry, and education."

The National Science Foundation Science and Technology Center for Adaptive Optics,
University of CA 95060
Santa Cruz, California
Phone: (831) 459 5592
Fax: (831) 459 5717
email: cfao@ucolick.org