Issue 16 — Winter 2014

Director's Introduction

Taft Armandroff, Director, WMKO

It has been a great honor and an enormous privilege to lead Keck Observatory since June 2006. I am going to be leaving Keck Observatory in May, after almost eight years as Director. I have accepted an appointment as Director of McDonald Observatory and Professor of Astronomy at the University of Texas at Austin that will begin on June 1.

The aggregate scientific discoveries from Keck Observatory since first light are humbling. And I am so proud of what the Keck Staff and the broader Keck astronomy community have accomplished.

The hallmarks of my period as Director include delivering to the Keck observer community new advanced instrumentation as well as upgraded observing capabilities. A prime achievement was the development and commissioning of our unique MOSFIRE instrument, delivering unprecedented sensitivity and multiplexing for near-infrared multi-object spectroscopy. Another important innovation was the upgrade of the CCD system in the red channel of our LRIS spectrograph, delivering extraordinary efficiency for spectroscopy at the far red end of the optical window, a formerly neglected region of the spectrum that our observers are now exploiting enthusiastically. We have advanced our adaptive optics (AO) systems in several fundamental ways. New wavefront controllers have yielded enhanced performance, and the Keck I AO system has been upgraded from limited use to a full laser AO system. We are completing the installation and commissioning of the center launch laser on the Keck II AO system and near-infrared tip-tilt sensing on the Keck I AO system, both of which will improve performance. We have embarked on an upgrade to increase the sensitivity of our OSRIS instrument, both for integral-field spectroscopy and imaging. Under construction are our next breakthrough instrument, the Keck Cosmic Web Imager—which will yield unique optical integral-field spectroscopy of extended sources—and a new advanced laser for the Keck II AO system.

Our Keck team has also addressed infrastructure, which is undoubtedly aging since the Observatory celebrated in 2013 the 20-year anniversary of the first scientific observations from Keck I. A major upgrade of our telescope control system is underway. We are also undertaking a fundamental refurbishment of our primary mirror segments and how they are bonded to their mechanical supports. In addition to more mundane items such as pumps and cooling systems, we have replaced several legacy guiding and acquisition cameras with more capable MAGIQ systems.

Keck Observatory's scientific productivity has remained excellent over this period. We set new records in refereed publications per telescope per year (321 in 2012) and citations per telescope per year. Keck continues to lead observatories worldwide in both of these widely accepted performance metrics. The Observatory's role in graduate education remains strong, and the tally of students who have earned their Ph.D. based on data from Keck Observatory has reached 287 over the observatory's lifetime. Keck Observatory's contributions to blockbuster science at the frontiers are stronger than ever, with recent widely recognized results on exoplanets, the black hole at the Galactic Center, the high-redshift universe, and the intergalactic medium.

While Keck Observatory's ties with its founding partners, Caltech and the University of California (UC), remain as strong as ever, the engagement of other partners in the Observatory has increased over my term as Director. Swinburne University of Technology, Yale University, and the Australian National University all have entered into partnerships for Keck observing access. The University of Hawaii has deepened its partnership in WMKO. In addition, over the past seven and a half years, NASA has twice reviewed its participation in WMKO as a 1/6 partner and renewed enthusiastically both times. The expansion of the Keck Observatory Archive has also increased WMKO's importance to the national astronomy system. Finally, we have broadened our communications mechanisms, such as this Observers' Newsletter and the participation in our Science Steering Committee and planning meetings, in order to enhance contact with our now larger and more diverse scientific community.

We have significantly expanded our partnerships with federal and philanthropic funding partners to achieve new observing capabilities. From the National Science Foundation (NSF), we have received significant support from all their major established programs (ATI, TSIP and MRI), and we have a proposal pending with the new Mid-Scale Innovations Program for WMKO's Next Generation Adaptive Optics System. WMKO's Advancement program has been very successful in sharing our science with the philanthropic community and inviting donor participation. Since 2006, we have attracted almost 800 donors and raised over $13 million of philanthropic contributions.

It takes a world-class team to achieve world-class results. I will always be grateful for the inspired contributions of the Keck Observatory Staff, our Board of Directors, our Science Steering Committee, NASA, NSF, our philanthropic contributors, the instrument and AO teams at Caltech and UC, and the Keck observer community.

The Board of Directors of the W. M. Keck Observatory has named Hilton Lewis Interim Director of the Observatory effective mid-May. Lewis has been an integral part of the development team for the Observatory since its inception in the 1980s, and has served as Deputy Director since 2002. Our Board Chair, Ed Stolper, who is the Provost and Interim President of Caltech, stated "We have great confidence that under Hilton's leadership the Keck Observatory will continue at its current high level of performance with no interruption of new and exciting scientific breakthroughs." Please join me in congratulating Hilton on his important new role.

In closing, the opportunities for major scientific advances from Keck Observatory remain rich and profound. ✶

Recent Grant Funding Successes

Taft Armandroff, Director, WMKO

Keck Observatory (WMKO) relies on grants from federal and private sources to develop new observing capabilities and to upgrade existing instruments, all in the service of addressing important astrophysical issues. The past year has been a very successful one for attracting new funding for priority programs.

A more robust implementation of time-domain astronomy at WMKO was one of the goals of the Observatory's Scientific Strategic Plan. In parallel, the Astronomy and Astrophysics Decadal Survey identified time-domain astronomy as a priority for this decade nationally. The National Science Foundation (NSF) Major Research Instrumentation Program (MRI) has funded our proposal to build a new tertiary mirror and its mount for the Keck I telescope to make its full instrumental capabilities available for time-sensitive scientific programs. In contrast to the existing tertiary mirror and mount, the device will rapidly deploy and rotate the mirror to any instrument at a Nasmyth focus or, as desired, stow the mirror out of the light path to permit observations at the Cassegrain focus. Thus, the new deployable tertiary mirror will enable observations with any of the instruments mounted on Keck I on any given night, and at any given time. The PI for this grant is Xavier Prochaska (University of California Observatories [UCO]), and the Co-PIs are Taft Armandroff (WMKO) and Jerry Nelson (UCO). The NSF-MRI award was made in September 2013 for $1.479M. Design work is currently underway at UCO and WMKO.

While OSIRIS, WMKO's integral-field spectrograph, has been a productive instrument, its performance is limited by the performance of the spectrograph's Hawaii-2 science detector. In addition, the detector manufacturer has informed us that design flaws will eventually cause the existing detector to fail catastrophically. Therefore, we proposed to NSF's Advanced Technologies and Instrumentation (ATI) program to upgrade the OSIRIS spectrograph's science detector from a Hawaii-2 to a Hawaii-2RG, providing higher sensitivity and a significant reduction in detector artifacts, and to perform related electronics and software upgrades. The PI for this proposal is James Larkin (UCLA), and the Co-PIs are Richard Ellis (Caltech) and Sean Adkins (WMKO). The NSF-ATI proposal was successful, and the award was made in September 2013 in the amount of $968k. The upgrade will more than double the sensitivity of the spectrograph at many wavelengths and will mitigate the risk of detector failure.

OSIRIS also includes an imager channel with a Hawaii-1 infrared array. The OSIRIS imager did not see much use as a scientific tool coupled with the Keck II telescope since Keck II also offers the more capable NIRC2. However, with the move of OSIRIS to Keck I, the community desires an adaptive optics imaging capability for use interspersed with integral-field spectroscopy. Andrea Ghez and Michael Fitzgerald (UCLA) have attracted funding from the Gordon and Betty Moore Foundation to upgrade the OSIRIS imager to a Hawaii-2RG science detector and to add improved camera optics. This upgrade will significantly enhance the imaging performance of OSIRIS, improving field of view, sensitivity, and distortion. The OSIRIS imager upgrade will be performed alongside the spectrograph detector upgrade and will yield a fully revitalized instrument.

NSF-ATI made a grant of $1.716M to WMKO for "Near-Infrared Tip-Tilt Sensor for Laser Guide Star Adaptive Optics" which commenced on August 1, 2010. Peter Wizinowich (WMKO) serves as PI for this initiative. WMKO has attracted $150k of supplemental funding from NSF-ATI and $250k of funding from the Gordon and Betty Moore Foundation to make infrared tip-tilt sensing available to the user community on the Keck I adaptive optics system and to extend its functionality. These grants were both awarded in the fall of 2013.

With these awards, WMKO's batting average for grant notifications in 2013 is 100%. Given the intense competition for resources, we feel particularly fortunate to receive this vital funding. The success of these proposals reflects community endorsement of the high scientific productivity of Keck Observatory and the importance of new instrumentation to maintaining this productivity.

We deeply appreciate the support of the NSF and the Moore Foundation. Many thanks to the PIs, Co-PIs, contributors to the scientific cases, project teams, internal reviewers, and the financial and grant experts who supported these proposals, all of whom made these successes possible! ✶

News From Observing Support

Bob Goodrich, Observing Support Manager, and the Support Astronomer team, WMKO

In December we were delighted to have Support Astronomer Scott Dahm return to our team, after spending a year in Afghanistan. Scott is rapidly coming back up to speed on observer support and his other duties at the Observatory.

Several improvements in observing tools have been made over the past months, including a new electronic log facility, deployment of a new slitmask alignment tool on DEIMOS, and a redesigned “PIG.”

The recently developed electronic observing logs are now fully functional and in regular use. Observers’ feedback has been mainly positive. The logs can currently be accessed from any computer connected to our internal network. At the end of the night, they can be printed to a PDF file or exported as an HTML page, which can then easily be imported into an excel spreadsheet. In the near future, we will integrate the observing logs with the observer login page; once that is done, observers will be able to access the logs for any nights for which they were the PI.

We have good news for DEIMOS observers: the Slitmask Alignment Tool (SAT) is now available for use on DEIMOS after several years of successful operation on LRIS and, more recently, on MOSFIRE. We designed the SAT to eliminate common procedural errors we have seen over many years of watching observers complete the complicated alignment process. Observers and support staff have come to appreciate the great convenience of using the SAT to efficiently align slitmasks on sky (see our previous description). During commissioning tests on DEIMOS, we have found that the SAT predicts star positions with accuracy comparable to the DSIMULATOR software used for slitmask design. To minimize the possibility of difficulties, we advise observing teams to continue using Dan Magee’s finder chart generator as a backup method. Your support astronomer will be glad to assist you in using the SAT.

The “PIG” (Program Identification GUI) is designed to allow users on split nights to easily and clearly change programs, hence properly identifying and segregating the data for the separate programs. This is important, because it helps the Keck Observatory Archive (KOA) to properly assign each file to the correct PI. The PIG contains buttons to switch between programs, designated by the program ID and PI listed on the telescope schedule. The OBSERVER keyword is also filled in by default from the telescope schedule’s OBSERVER field, although observers can now edit that keyword if they wish. Different directories are used for different programs, and just the push of a button on the GUI will allow an observer to switch to their program. It is in the interests of observers to properly use this GUI so that their data get properly assigned to them.

A new twist that we are experimenting with is the addition of programs to observe “targets of opportunity” (ToOs). These programs (for example, a nearby supernova, or interesting activity in the Galactic Center) are not regularly scheduled, but instead will be called in to interrupt the scheduled observing for some relatively quick observations of the transient phenomenon. With a list of approved ToO programs from the time allocation committees, we will have part of the GUI that will expand to allow selection of one of these programs should an interrupt be triggered. Again, this will easily and clearly allow ToO data to be assigned to the proper PI, and properly separated into a new directory.

In other news, KOA has finished ingesting data (including all legacy data) from all eight of the active WMKO instruments. Still to do are the legacy data from NIRC and LWS. LRIS and MOSFIRE data have started going public, respecting all approved proprietary period extensions, of course.

The Observatory is phasing out the auto DVD writer sometimes used by observers for data backups. Although there is no time line for its removal, we will no longer troubleshoot or maintain the DVD writer. Because KOA now hosts all raw data from every instrument at the observatory, observers are encouraged to use KOA to retrieve a copy of the data following your observing sessions. (KOA is testing a UNIX script to translate archive file names to original file names. Ask your SA for a copy if you would like to use this script before official deployment on KOA.) Instructions and links to possible methods of data backup including KOA, scp, and rsync are found at: BackingUp.

Some of you will have already been asked to fill out a TSR (*Assurance Regarding Technology and Software Under Restriction*) form. This is part of our export control policy. Because some of the information that observers can access on our computers is under export control restrictions, non-U.S. persons working at foreign institutions are requested to fill out one of these forms to acknowledge that they will not take controlled information out of the U.S. For a small number of countries, the restrictions are even more stringent, possibly requiring supervision during observing.

Finally, we want to thank observers for continuing to fill out the new Post-Observing Comment forms. The response to the reminders has been excellent; we have been seeing four times as many POC reports as we did before the reminder system was put in place. These reports are invaluable to us in understanding and tracking observing issues, and in prioritizing our resources. We thought we would share some statistics collected to date. There have been over 100 POC forms since mid-August, when the new form was released. The plots below show the rankings for all of these forms, in the six categories used on the form. 5 is the most favorable ranking, while 1 is the least favorable.

TelescopeScore		
5:	(73)	68.2%
4:	(23)	21.5%
3:	(6)	5.6%
2:	(5)	4.7%
1:	(0)	0.0%
InstrumentScore		
5:	(69)	62.2%
4:	(33)	29.7%
3:	(5)	4.5%
2:	(4)	3.6%
1:	(0)	0.0%
StaffScore		
5:	(99)	86.1%
4:	(13)	11.3%
3:	(2)	1.7%
2:	(1)	0.9%
1:	(0)	0.0%
ObservingScore		
5:	(70)	62.5%
4:	(33)	29.5%
3:	(9)	8.0%
2:	(0)	0.0%
1:	(0)	0.0%
NetworkScore		
5:	(80)	71.4%
4:	(27)	24.1%
3:	(5)	4.5%
2:	(0)	0.0%
1:	(0)	0.0%
AccomodationsScore		
5:	(80)	80.0%
4:	(15)	15.0%
3:	(5)	5.0%
2:	(0)	0.0%
1:	(0)	0.0%

Figure 1. Summary rankings for over 100 submitted POC forms. ✶

A New Near Infrared Tip-Tilt Sensor For Keck I LGSAO

Peter Wizinowich, Optical Systems Manager, WMKO
Randy Campbell, Jim Lyke, Support Astronomers, WMKO

Have your Laser Guide Star (LGS) Adaptive Optics (AO) science observations been limited by the quality of tip-tilt (a.k.a. image motion) correction? Perhaps you haven't been able to find a suitable tip-tilt star? Starting in semester 14B you can expect a performance improvement when observing with OSIRIS.

A near-infrared tip-tilt sensor called TRICK (for Tilt Removal with IR Compensation at Keck) is currently being commissioned with the Keck I LGS AO system and is expected to be available for shared risk science in semester 2014B. The concept is simple; instead of measuring the tip-tilt error using a seeing limited image in the visible with the current sensor—STRAP—the sensing is performed in the near-infrared where the image is partially AO corrected. In addition, typical lower main sequence stars have *V*–*H* colors ranging from 1 to 5, thus the average tip-tilt star will be significantly brighter in the near-infrared.

Although the concept is relatively simple, the technology and implementation is rather complicated. The TRICK sensor, a Teledyne H2RG, has a fixed field of view that will make guide stars available up to ~60 arcsec from the science target. The approach relies on using multiple nondestructive reads of a small field (2×2 pixels up to 16×16 pixels) around the selected guide star location to reduce the read noise, as demonstrated by Roger Smith for the TMT. Based on this approach WMKO received an NSF Advanced Technologies and Instrumentation award (P.I. Peter Wizinowich) to build and field the first-ever near-infrared tip-tilt sensor for AO. The camera was built at Caltech, the modifications to the existing real-time controller were made by Microgate, and WMKO staff have implemented the required modifications and additions to the Keck I AO bench and to the controls and operations software.

The on-sky performance of this system will be measured over the next few months and will be made available to the community for planning purposes via the LGS AO web page. When using TRICK, a choice of dichroic beamsplitter is placed in the beam before OSIRIS such that tip-tilt sensing can be done in the *H* or *Ks* bands. The wavelengths not being used for tip-tilt pass through to the science instrument. The new sensor can be used for all OSIRIS modes except for *K*-band imaging. A single star down to a faintness of approximately 16th *H* or *K*-magnitude can be used for tip-tilt sensing. Observers will be able to switch between the existing visible and new near-infrared tip-tilt sensors during the night.

Observers can start planning for possible infrared tip-tilt guide stars using a new version of the AO Guide Star tool found at the "Manage your target lists HERE" link on the Observer Login Page. This tool includes the 2MASS catalogue, designates whether the guide star is intended for a visible or IR sensor, and shows the unvignetted field of regard for TRICK. The new tool also has other improvements for star list management in general and since it's still under development, feedback is encouraged.

A number of improvements to TRICK are already envisioned for semesters 2015A and 2015B thanks to a recent grant from the Gordon and Betty Moore Foundation. Depending on TRICK's measured performance these may include the ability to use multiple tip-tilt stars to reduce tilt anisoplanatism, the use of a correlation instead of a centroid algorithm, simultaneous usage of TRICK and STRAP, and improved operations and planning tools.

Figure 2. Installing the stage for the dichroic beamsplitters on the AO bench just in front of OSIRIS. ✶

TBAD, A Transponder-based Aircraft Detection System For LGSAO

Paul Stomski, AO/Optics Engineer, WMKO
Randy Campbell, Support Astronomer, WMKO

Lasers propagated into the navigable airspace as part of laser guide star (LGS) adaptive optics (AO) operations can pose a safety risk to passing aircraft. Observatories propagating lasers into the sky where aircraft may be present need to implement safety systems to protect those aircraft from illumination by the lasers.

For the first eight years of LGSAO science operation on Keck II, 2005–2013, laser avoidance of aircraft was achieved using safety spotters: personnel situated outside the dome ready to shutter the laser for any aircraft that enters the laser-affected airspace. As of October 2013, laser operation on Keck II is no longer required to use safety spotters.

WMKO applied for and received a determination of no-objection from the Federal Aviation Administration (FAA) for our automated aircraft protection system. This is the first automated system approved by the FAA for use at an astronomical laser guide star system. WMKO's system, named AIRSAFE, uses transponder-based aircraft detection, TBAD, to replace spotters. TBAD is a passive array of antennas mounted to the telescope (Fig. 3) and tuned to the frequency of aircraft transponder squawks, 1090 MHz. The ratio of signal strength from narrow-field and wide-field antennas will trigger a laser shutter when an aircraft is within 12 degrees of the laser beam, as shown in Figure 4. TBAD was developed by Bill Coles and Tom Murphy (Coles and Murphy 2012) of UCSD for use on Apache Point lunar laser-ranging measurement (Murphy 2008) of the Earth-Moon separation for experiments in gravitational physics, etc. WMKO and UCSD partnered in 2010 to further advance the testing, characterization, and FAA approval process. That partnership led to a very involved testing, administrative, and documentation process that eventually proved successful for use on Mauna Kea.

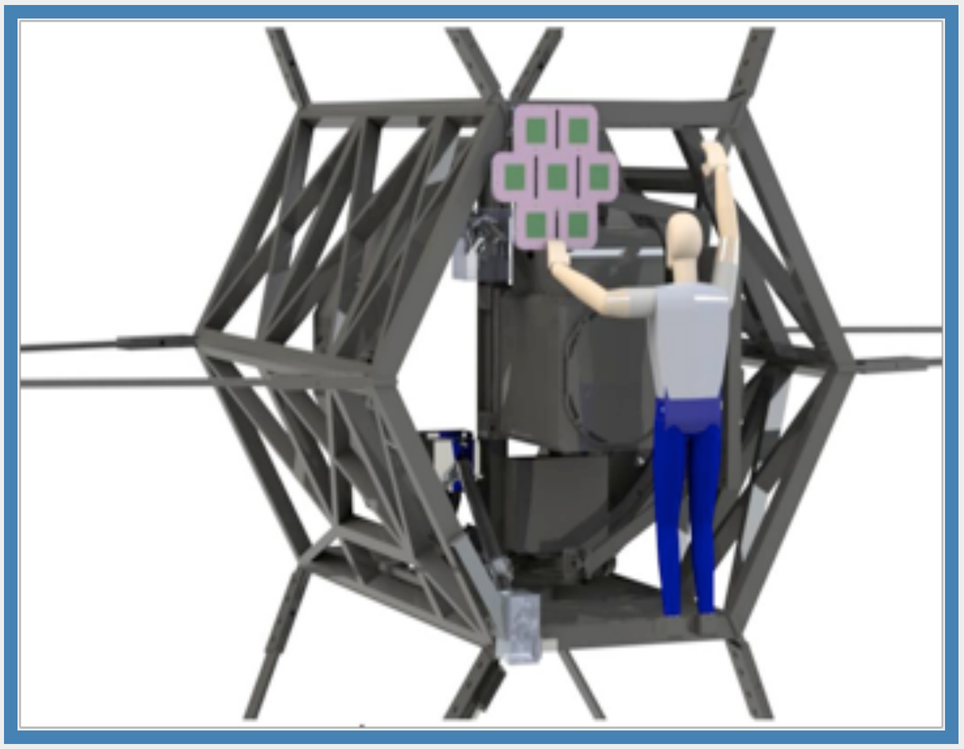

Figure 3. Model of TBAD as mounted on the sky side of the Keck II secondary module. TBAD is a phased array of patch antennas tuned to 1090 MHz, the frequency of aircraft transponder squawks.

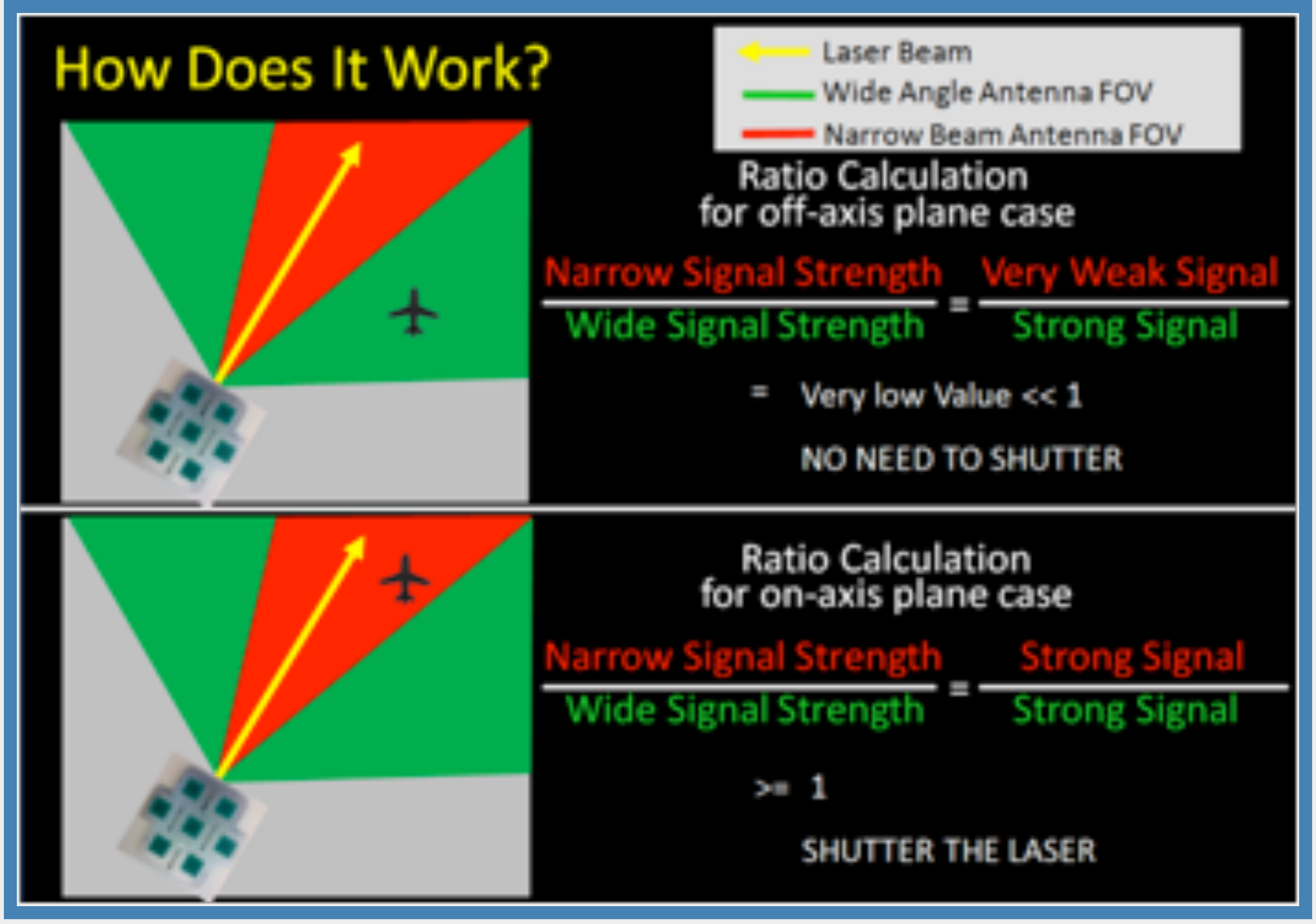

Figure 4. Schematic view of TBAD operation. The ratio of signal strength in two antennas, one wide field and one narrow field, will trigger a laser shutter when the rdio source is within 12 degrees of the laser beam.

The Keck aircraft protection system is made up of components that detect aircraft (such as TBAD and spotters), a PLC, a laser shutter with redundant position feedback, spotter packs, emergency e-stop circuits, bypass key switches, user interfaces, performance monitors and loggers, characterization of site-specific environmental and operational considerations, operating and maintenance procedures and various computer hardware and software infrastructure to support it all.

For approval of Keck's safety system using TBAD, the FAA required WMKO to self-certify compliance with SAE Aerospace Standard 6029A (AS-6029A), *Performance Criteria for Laser Control Measures Used for Aviation Safety*. AS-6029A prescribes performance and administrative criteria for an automated protection system, essentially requiring the system to adequately protect all types of aircraft, traveling at any speed, altitude, distance and direction, reasonably expected in the operating environment. Additional compliance with AS-6029A administrative criteria includes characterization of site-specific air traffic, failure modes, limitations, operating procedures, preventative maintenance procedures, and periodic system test procedures.

The approval of Keck II TBAD affords improvement to the LGSAO operational model and we plan to extend this to Keck I as soon as possible. The night attendants have been relieved from the harsh environment of outside aircraft spotting for Keck II and scheduling constraints have been eased since spotters are not needed on LGSAO nights. TBAD for Keck I has been delivered from USCD and was installed in January 2014. Over the next few months the Keck I system will undergo testing and characterization. Other observatories on Mauna Kea that operate lasers, Gemini and Subaru, are also planning to install TBAD units.

References:

Coles, W. A., Murphy, T. W., et al. , *A Radio System for Avoiding Illuminating Aircraft with a Laser Beam*, 2012, PASP, Volume 124, No. 911

Murphy T. W. , et al., *The Apache Point Observatory Lunar Laser-ranging Operation: Instrument Description and First Detections*, 2008, PASP, Vol. 120, No. 863 ✶

Center Launch System On The Keck II Telescope

Jason Chin, Senior Engineer, WMKO
Jim Lyke, Support Astronomer, WMKO

The side-launched Keck II laser guide star (LGS) reduces the sensitivity of the adaptive optics (AO) system by elongating images on the wavefront sensor. Perspective elongation is reduced significantly by projecting the laser from behind the Keck telescope secondary mirror as is currently done for the Keck I LGS. Laser images with the Keck primary unstacked (Figure 5) shows the difference between Keck I and Keck II. The stacked Keck I LGS as measured on the AO acquisition camera has a FWHM of 1.4″ versus the Keck II LGS FWHM of 1.8″ × 2.2″.

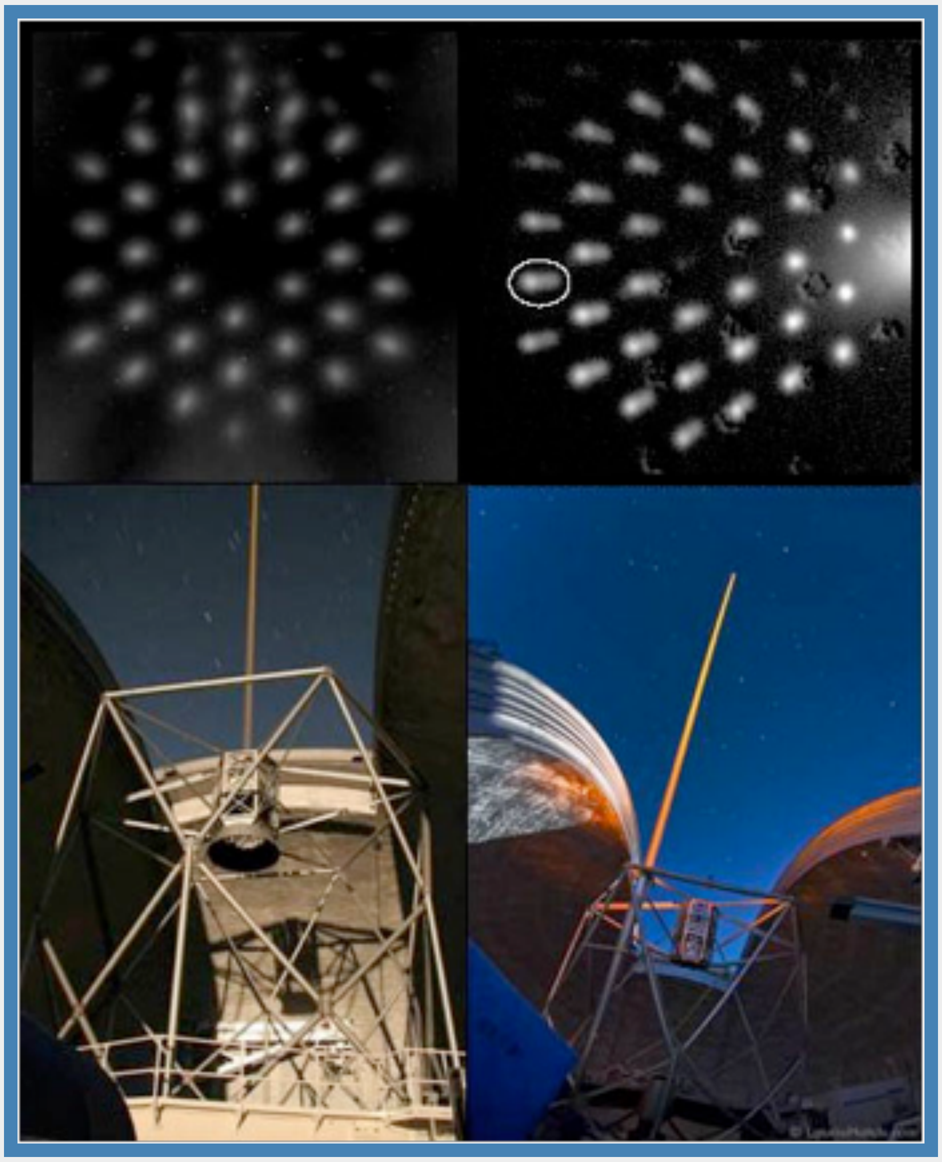

Figure 5. Unstacked primary mirror images of the Keck I (*top left*) and Keck II (*top right*) laser sodium spots. These images demonstrate the decreased spot elongation of the center launch system of Keck I. The smaller spot size and greater pupil symmetry on Keck I should result in improved AO performance. Bottom images contrast the center-launched laser on Keck I (*bottom left*) and the side-launched laser on Keck II (*bottom right*).

Photos: Andrew Cooper (bottom left); Laurie Hatch (bottom right)

Thanks to a grant from the NSF Major Research Instrumentation (MRI) program we have been able to design and implement a center launch system (CLS) for the Keck II telescope. This system will be undergoing on-sky testing and characterization in semester 2014A and is expected to be available for routine science by semester 2014B.

A daytime reconfiguration between side and center launch is currently performed for engineering purposes without impacting the existing operational system. Both configurations can be available during integration and commissioning to minimize operational down time. The CLS, including its launch telescope, has also been designed to accommodate multiple lasers if Keck's next generation AO facility is funded. The launch telescope saw its first light on December 20, 2013 using stars to align it to the Keck II telescope. ✶

Keck Observatory Goes Solar

Greg Doppmann, Support Astronomer, WMKO

Figure 6. Installation of solar panels on the roof of the Keck Observatory headquarters in Waimea. *(Photo: Bob Goodrich)*

In addition to the astronomical photons that Keck Telescopes collect on the summit at night, solar photons are now being harvested at HQ thanks to the recent installation of two photovoltaic systems with a combined capacity of 120 kW. A bank of 696 solar panels now covers much of the SE and SW-facing roofs at HQ and the VSQ (Visiting Scientists' Quarters). Even accounting for the misting rain that frequents Waimea, this system is expected to produce about 500 kWh per day on average throughout the year.

Although this energy generation amounts to only about 20% of the daily electricity consumed at HQ and the VSQ, the cost savings from this grid-tie PV system is pronounced due to the high power rates in Hawaii. At 37 cents per KWh, Keck pays more than 3 times the electric rate of most places on the mainland and elsewhere.

Even before the decision to go solar, Keck had already offset some of its power costs by implementing energy conservation measures at both HQ and on the summit that include more efficient lighting, upgrades to mechanical equipment, and smarter energy management by computer control systems. Yet even with the significant energy savings produced by these conservation efforts, HQ and the VSQ still use about 1.7 megawatt-hours per day, which amounts to $300,000 worth of power annually.

While the total cost of the PV installation was $633,000, completing the project before the end of the 2013 calendar year will allow Keck to collect a 25% tax credit from the State of Hawaii. With the system generating $60,000 worth of electricity at HQ annually, the installation cost will be paid off in 8 years, though probably sooner as power rates will likely continue to climb. As there are no moving parts, the PV system is expected to last well beyond its 20-year warranty.

Besides saving Keck more than a million dollars in utility costs in the coming decades, increasing the amount of renewable power and decreasing our pollution and carbon footprint ensures a more sustainable future for all of us on the island and the planet as we move forward together in the 21st century. ✶

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