



Director's Introduction

Taft Armandroff, Director, WMKO



Welcome to the first Keck Observers' Newsletter of the new decade.

One of the first astronomy events of the year is the winter meeting of the American Astronomical Society. Keck Observatory science results were well represented at the meeting, including special sessions, media releases, and resulting stories in the national and international media. I would like to share some of the highlights with you.

The first announcement was of six new extrasolar planets, five of which were the first discovered via transit observations from the [Kepler space telescope](#) and then verified and studied in depth with precision radial velocities from the Keck I telescope and its High Resolution Echelle Spectrometer (HIRES). The new planets are about the size of Jupiter or larger and tend to be quite hot. In a separate meeting session, Geoff Marcy, who was involved with the Kepler findings, and his team, led by Andrew Howard of the University of California, Berkeley, [announced finding the second smallest exoplanet to date](#). This planet is roughly four times the mass of Earth and is one of the new class of so-called "super-Earths." It was also discovered using Keck I with HIRES.

Another news item was that the Keck telescopes have found evidence of "[waltzing black holes](#)." Berkeley astronomer Julia Comerford and her colleagues [identified 33 dancing black hole pairs](#) using the Keck II telescope and the Deep Imaging Multi-Object Spectrograph (DEIMOS). The discovery has profound implications for understanding the merger history of galaxies, as well as the evolution of supermassive black holes.

Raja GuhaThakurta of the University of California, Santa Cruz, also announced that [the nearest spiral galaxy, Andromeda, has two additional, previously unseen tidal streams of stars](#). The findings indicate that M31 has been consuming several neighboring dwarf galaxies over the last one to two billion years.

Turning from the latest science news to practical matters at Keck Observatory, this Newsletter contains the latest information that you should be aware of when preparing your observing proposals for semester 2010B. I particularly draw your attention to the articles on the [LRIS-Red upgrade](#) and on the [new laser guide star adaptive optics system for Keck I](#). Teams have been working on both of these projects for a number of years to enable new observing capabilities which exceed any of our "classic" capabilities. The LRIS-Red upgrade was commissioned successfully in June 2009 and resulted in dramatically improved performance at far red wavelengths. However, as the article describes, we have had problems with both of the CCDs since September, and plans are underway to find a permanent solution. As regards laser guide star adaptive optics on

Keck I, we are pleased to report that we had first on-sky propagation with the new laser from Lockheed Martin Coherent Technologies in late January. This is an important milestone on the road to the commissioning and testing of the new adaptive optics system. «

Keck I Laser Achieves First On-Sky Propagation

Randy Campbell, Support Astronomer, WMKO

Jason Chin, Senior Electronics Engineer, WMKO

Driven by the high demand for laser guide star adaptive optics (LGS-AO) observing time on Keck II and our desire to use the LGS-AO system with the Keck Interferometer, commissioning a laser guide star system on Keck I to provide us with two LGS-enabled telescopes has been a top priority at Keck for several years. As reported in previous issues of this newsletter (see [Summer 2008](#) and [Summer 2009](#) issues), the three key goals of the project are to achieve high reliability via a solid-state laser, to produce a more circular guide "star" by using a center-mounted laser launch telescope, and to yield a more visible guide star image with a brighter, more focused beam.

The Keck I laser system was assembled in the labs of Lockheed Martin Coherent Technologies (LMCT) and passed its acceptance tests in July 2009. The laser arrived at WMKO headquarters on September 7, 2009 to undergo eight weeks of integration and testing. The testing phase at HQ was valuable; Keck personnel gained experience and LMCT personnel furthered the development of this new device during the system's two months in Waimea.

This integration and testing phase also allowed us to debug remaining interface, environmental, and infrastructure issues before taking the system to the summit. Tests at HQ demonstrated that the new laser has excellent stability once properly aligned at its operating temperature. As part of the testing, the system ran unattended for over two days to capture performance data in several key areas: power, spectral content, wavefront quality, and stability. The laser and remaining subsystems reached the summit on November 16, 2009. The laser is now installed within the Laser Service Enclosure beside HIRES on the Keck I right Nasmyth platform. The tweaks and adjustments are of course all the more difficult in the summit environment, working within the boundaries of an operational telescope.

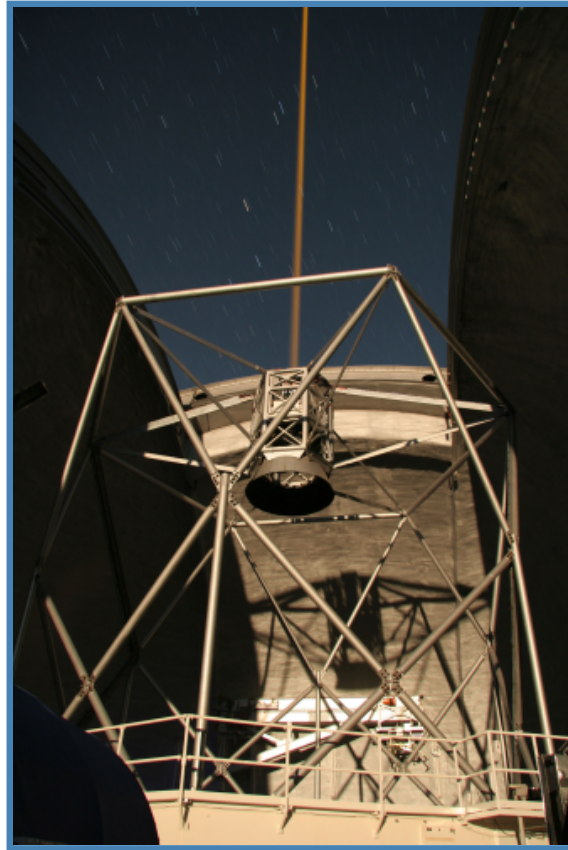


Figure 1. The Keck I laser guide star system employs a center-launched beam (contrast with the [side-mounted design on Keck II](#)) to yield a rounder guide star image. *Photo courtesy Andrew Cooper (WMKO); click to enlarge.*

The quasi-continuous wave power output by the laser was measured at 30 W, exceeding the specification. However, obtaining sufficient power and stability required that LMCT decrease the temporal pulse width and increase the pulse energy of the laser. This prevents the full pulse energy from propagating through the fiber due to [stimulated Raman scattering](#) (SRS).

Despite the SRS limitation, the laser and subsystems achieved “first light” on January 28, 2010. The LGS team’s dedicated work over many years culminated in propagating a laser beam out of the Keck I dome, joining the family of lasers on the Mauna Kea summit (see [Fig. 2](#)). The team is especially proud of having achieved excellent laser performance, precise alignment of the propagation system, and proper operation of the LGS-AO related subsystems. Although the on-sky brightness of the laser guide star is currently insufficient to support science operations, the team will be working in the coming months to understand the issues and increase the guide star brightness.

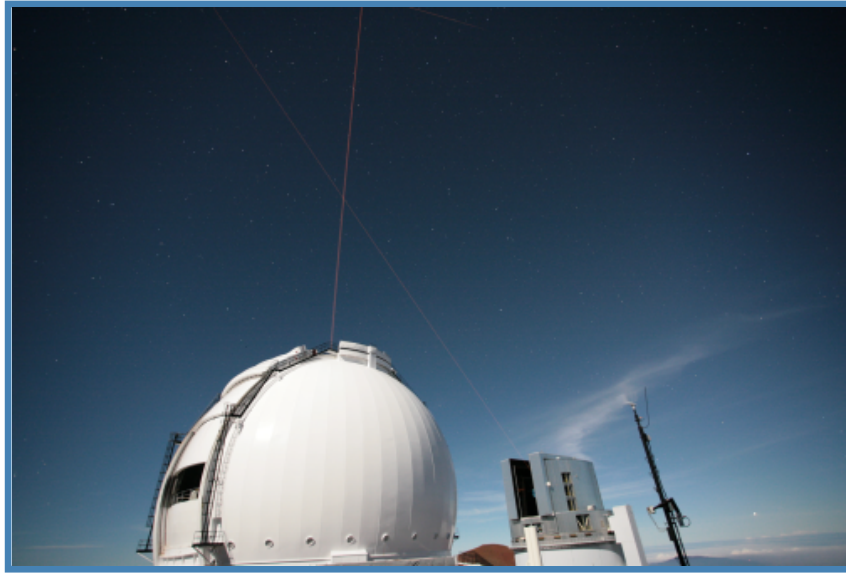


Figure 2. “First light” with the Keck I laser guide star system was achieved on January 28, 2010 under full-moon conditions. The Subaru telescope and its laser are visible in the background, and the Gemini laser can be seen entering the top of the frame. *Photo courtesy Don Holdener (WMKO); [click to enlarge](#).*

System testing using the AO engineering camera, SHARC, provided by James Larkin and Shelley Wright of UCLA, will continue through semester 2010A and into 2010B. The science operation plan is to move another James Larkin instrument, OSIRIS, from Keck II to Keck I when the new LGS-AO system is ready. The current plan calls for moving OSIRIS in mid-December 2010, followed by at least a month of integration and testing before it returns to science operations. OSIRIS will thus remain available in its current configuration on Keck II for most of semester 2010B before being removed from service for a few months. «

The Return of Segment Exchange

Barbara Schaefer, Observing Support Coordinator, WMKO

After completing primary mirror segment recoatings and exchanges in 2005 (Keck II) and 2006 (Keck I), our team discovered cracks in some of the segments (see the [Summer 2008 Observers' Newsletter](#)). Subsequently, we found the cracks to be somewhat more widespread than originally thought. Accordingly, we suspended segment recoatings and exchanges in order to study the causes of the cracks, repair the worst of them, and to prevent additional damage to the mirrors.

In July of 2009 a dedicated outside review team consisting of Maxime Boccas (Optical Group Leader, Gemini), Peter Gray (Deputy Project Manager, TMT), Jerry Nelson (Keck Telescope Project Scientist and current TMT Project Scientist, UCSC), and Steve Bauman (Operations Mechanical Engineering Manager, CFHT) conducted a thorough review of segment handling procedures with assistance from the internal WMKO review team and other WMKO specialists. Subsequent to the paper review, we held an on-mountain review, a dry run with a mock segment, and a continuing review during the first segment exchange at the end of August 2009. The reviewers made many excellent suggestions leading to revisions in our procedures. With new procedures in hand and a recently refurbished aluminizing chamber (see the [Summer 2009 Observers' Newsletter](#)), the WMKO segment exchange team was ready to embark on recoating and exchanging the mirror segments in the Keck II telescope. The team still had many things to learn and

relearn as well as new team members to train. For the first time in several years, segment exchange was proceeding, but at a slightly slower, more deliberate pace than in past years.

Quality control is crucial to the coating process. To improve the aluminizing process we installed a water deionization plant to enable a final, critical rinse of the segments before coating, and we installed a HEPA filtration system in the coatings lab to significantly decrease the occurrence of pinholes. These changes enabled the coating team to produce some of the best coatings seen at Keck in years. The team is now routinely inspecting and testing all coatings to insure minimum pinholes and maximum adhesion and reflectivity. The vacuum chamber equipment ensures the coatings are the proper thickness and evenness.

As of January 2010, 11 of the 36 segments on Keck II have been exchanged, as detailed in [Table 1](#) and [Fig. 3](#). AO observers have noted the increased reflectivity of the recoated segments as indicated by the brighter regions on [Fig. 4](#) below.

Dates	Segment Positions
31 August - 1 September, 2009	13, 27
29 - 30 September, 2009	4, 15, 32
28 - 29 October, 2009	24, 25
2 - 3 December, 2009	5, 9, 14, 22

Table 1. Dates of recent Keck II segment exchanges and corresponding segment positions which were exchanged.

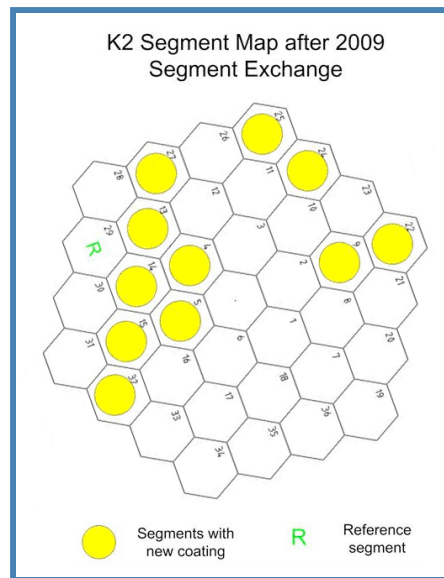


Figure 3. The segment map for Keck II indicates which segments were recoated in 2009. [Click image to enlarge.](#)

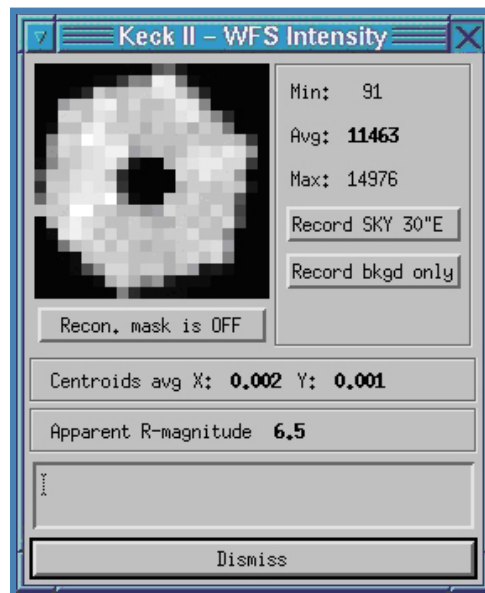


Figure 4. Keck II AO wavefront sensor map. Note higher reflectivity of recoated segments. The segments in this figure are shown at the same orientation as in the previous figure.

Quantitative measurements and analysis by WMKO Optics Engineer Sergey Pantelev (see [Fig. 5](#)) indicate an increase in reflectivity of 16%–17% on the freshly aluminized segments, confirming the qualitative visual wavefront sensor evidence.

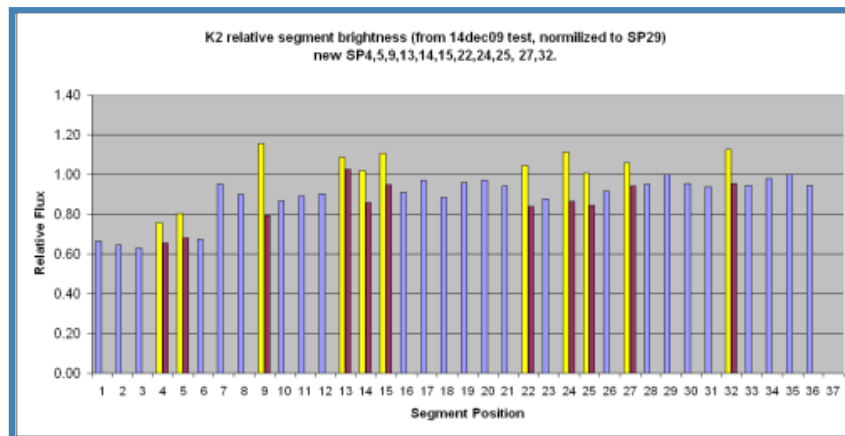


Figure 5. Relative brightness of primary mirror segments on Keck II measured in December 2009. Yellow bars indicate improvement over old coating (red). Note that the relative brightness of the inner ring of segments (segment positions 1–6) is lower than the others because of partial vignetting by the tertiary tower. *Click image to enlarge.*

While plans include completing the exchange of most of the Keck II segments by the end of August 2010, five segments currently in the telescope should not be handled until our segment crack repair procedures are in place. We are planning a review of the crack repair procedures in April 2010 and aim to begin repairs before the end of year. We anticipate resuming segment exchanges on Keck I shortly after the Keck II exchanges in August. «

OSIRIS Status: Fourth OSIRIS Service is the Charm!

Jim Lyke, Support Astronomer, WMKO

After a difficult 2009 that saw three servicing missions fail to fix a thermal problem with OSIRIS, the fourth servicing mission was a success and OSIRIS is again operating normally. We found the OSIRIS cold head was working at low efficiency due to a poor thermal contact between the cold head and the internal copper block. During the October 2009 service, we took great care in mating the cold head to the copper block using sheets of indium. We now have a procedure that will ensure proper thermal connection between the cold head and the copper block for any future service. We are grateful to OSIRIS PI James Larkin for his tireless assistance in tracking down and fixing this problem.

The OSIRIS team continues to work on improving the wavelength solution and rectification matrices needed for the OSIRIS data reduction pipeline. We thank those observers who dealt with a sub-optimal OSIRIS for their patience as we update the calibrations. Please continue to check the [OSIRIS News Page](#) for updates. «

LRIS Red CCD Charge Transfer Problem Stabilized*Marc Kassis, Support Astronomer, WMKO*

In mid-2009, the red arm of our workhorse multi-object spectrometer, [LRIS](#), received a new dewar with a highly-sensitive detector mosaic that substantially improved the instrument's red-side throughput (see the [Summer 2009 issue](#)). The CCD array operated well for several months, but then began deteriorating; images showed pronounced "smearing" in the serial direction as shown in [Fig. 6](#). This charge-transfer efficiency (CTE) problem was originally isolated to a single amplifier; however, in the following months a second and then a third amplifier also began exhibiting the same symptoms, leaving only one of the original four amplifiers still working well. At present, the only remaining "good" amplifier is the one on which the longslit spectrum falls in dual-amplifier readout mode; i.e., the nominal "slitb" position.

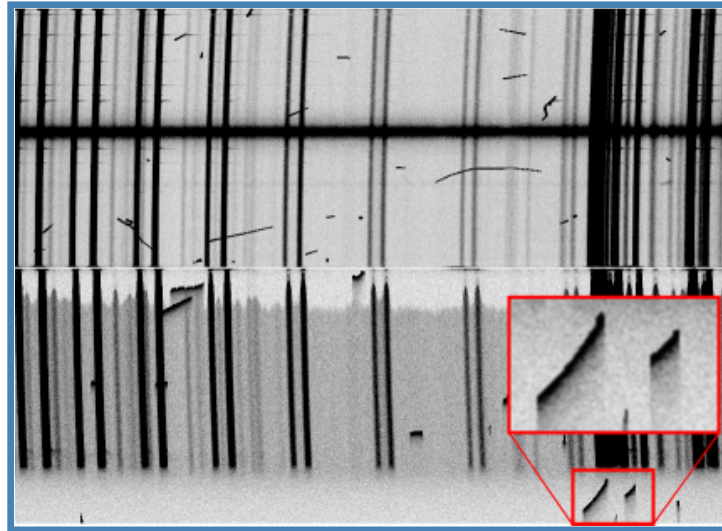


Figure 6. Sample LRIS red image showing "good" area at top and "bad" area at bottom. Note the vertical "smearing" of cosmic rays in the affected region, as highlighted in the inset. The amount of signal lost in the smearing may be as much as 20% of the total light. *Click image to enlarge.*

Based on extensive thermal modeling of the CCD package design, UCO/Lick staff concluded that thermal cycling of the CCDs might have caused the CTE problem. Thermal cycling occurs when LRIS is installed or removed from the telescope as part of the

observatory's regular instrument switching procedures. When we turn power to LRIS off during the normal instrument changeout process, the dewar temperature monitoring system stops, causing the CCD temperature to drop from an operating temperature of -140 C to as low as liquid nitrogen temperatures (-196 C). The new Lick thermal models suggest that excessive mechanical stress may occur if the LRIS-R mosaic gets colder than -150 C .

To stabilize the CCD temperature, WMKO and UCO/Lick staff have added new electronics to LRIS to maintain power during instrument changeouts and new software that will supply a steady heater current, ensuring that the CCD temperature remains at or above the operating temperature during this process. With these additions in place, we hope to maintain the current operational state of the LRIS red CCDs; however, this will not recover the three degraded amplifiers, which remain unusable for science. Before using LRIS, observers should review the [LRIS news](#) to check whether these stabilizing measures have been successful.

To take advantage of the one remaining good amplifier, observers acquiring data in longslit mode should select dual-amp readout mode to save readout time. Observers acquiring imaging or multislit data should select single-amp readout mode with the right-side amplifiers to obtain good images over 1/2 of the mosaic at the expense of doubling the readout time to 3 minutes per exposure. We have updated the [Xpose](#) GUI for the red side to include the option of reading out the mosaic in single-amp mode using the right-side amplifiers. Staff from UCO/Lick Observatory have updated the ds9 image display tool so that it will display images in the same orientation regardless of the readout mode.

Observers planning to use slitmasks must design their masks to place slits on the "good" region on the red side. This [example Autoslit slitmask design](#) shows where slits may be placed to land on the "good" side, which is opposite to the side with pickoff mirrors when in use. Highest-priority objects for red-side observations should be placed on the "good" side, but slits for blue-side science may be placed anywhere on the slitmask.

Longer term, we intend to identify replacements for the current LRIS red CCDs with assistance from UCO/Lick staff; options include both $2\text{K} \times 4\text{K}$ and $4\text{K} \times 4\text{K}$ devices. The UCO/Lick detector team is currently characterizing candidate $2\text{K} \times 4\text{K}$ CCDs which have a different packaging than the devices currently in use with LRIS. The second replacement option is a monolithic LBNL $4\text{K} \times 4\text{K}$ detector, which would also represent an upgrade to the current mosaic. «

Integral Field Spectroscopy Comes to ESI

Gregory D. Wirth, Support Astronomer, WMKO

The ESI Integral Field Unit (IFU) has completed its commissioning phase, providing a new ESI observing mode which offers medium-resolution spectroscopy for extended targets. Developed at UCO/Lick by Andy Sheinis and Joe Miller, the unit employs an image slicer arrangement to reimage a contiguous 4.0×5.7 arcsec field of view into 5 separate spectra covering 20 arcsec of slit length with a slit width of 1.13 arcsec. The resulting echellette-mode spectra cover the normal ESI wavelength range of $0.37\text{--}1.0\mu\text{m}$ at a resolution of $R=3500$.

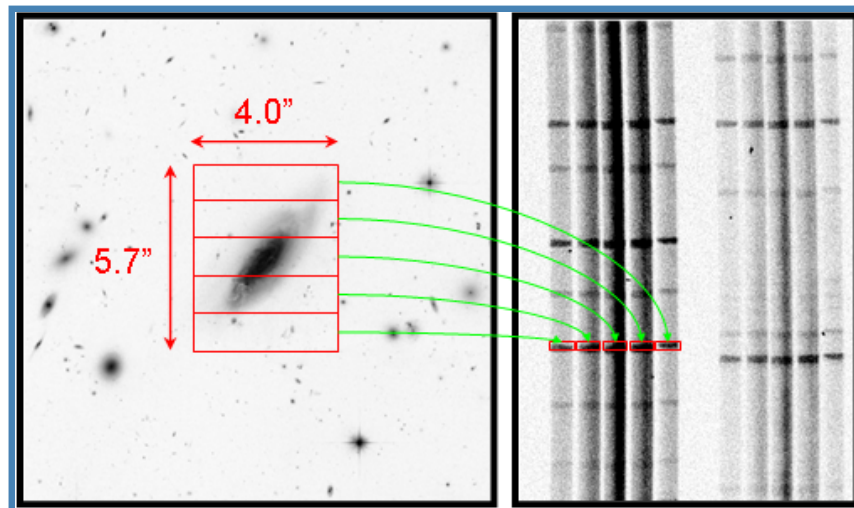


Figure 7. *Left:* Simulation of a possible target for the ESI Integral Field Unit (IFU), a galaxy much wider than the typical ESI slit. The red boxes indicate the 5 slitlets in the IFU. *Right:* Small section of the corresponding ESI spectrum consisting of 5 individual spectra corresponding to the 5 slitlets in the IFU.

Throughput for the unit itself is only 45%-55%, reducing the advantage of the greater field of view, but for certain programs this new capability for ESI may yield greater observing efficiency. For further information on the IFU, please refer to the [ESI IFU documentation](#) and the corresponding [astro-ph article](#) by Andrew Sheinis. If you plan to use the IFU for an upcoming ESI run, please contact your support astronomer in advance. «

Keck Interferometer Offers Improved Performance and New ASTRA Mode

Sam Ragland, Interferometer Operations Manager, WMKO

Julien Woillez, Interferometer Scientist, WMKO

The Keck Interferometer (KI) combines the two Keck telescopes as a long baseline interferometer, providing several high-angular-resolution observing modes in the near- and mid-infrared. KI has been used to study a variety of scientific phenomena including young stellar object disks, young binary stars, debris disks, and active galactic nuclei (AGN). About seven KI science nights are awarded each semester through the various time allocation committees. The *H*- and *K*-band visibility amplitude modes, the most sensitive in the world, have been offered for several years now. The Keck Interferometer team has recently improved the performance of angle tracking in the *H*-band, enabling *K*-band interferometric observations of a sample of bright AGN for the first time as reported in a recent article by [Kishimoto et al.](#)

The nuller instrument, operating in the mid-infrared, continues to be available for science in 2010B but future availability will be determined on a semester-by-semester basis. The high-spectral-resolution mode (V2-SPR), offered for shared-risk science during previous semesters, will transition into a facility-class capability in semester 2010B. The *L*-band (V2-L) and simultaneous *K/L* (V2-DFPR) visibility modes continue to be available for shared-risk observing in 2010B.

On the ASTRA project front, the 2009B semester was dedicated to commissioning the dual-field subsystems located at the focus of the Keck I and Keck II adaptive optics modules. These systems are responsible for selecting a bright reference object up to 30 arcsec away from a faint object of interest in order to perform an observation similar to natural guide star AO. The interferometer team achieved first fringes on a bright star pair

three days before the new year. We hope to obtain the first faint phase-referenced observations in the 2010A semester with the expectation of reaching a *K*-band magnitude of at least 13. Development of the astrometric mode continues and we aim to complete the first astrometric engineering nights this summer.

All Keck users are eligible to propose for science-observations with the Keck Interferometer. Observations are currently taken in service observing mode and may be scheduled in campaign mode. More details of KI sensitivity and observing parameters may be found on the [NExScI web pages](#). «

Novel Techniques Developed for Adaptive Optics

Al Conrad, Support Astronomer, WMKO

Jim Lyke, Support Astronomer, WMKO

Several exciting studies carried out recently with adaptive optics (AO) have motivated WMKO support astronomers and engineers to develop new capabilities for that system. These new observing modes may be applicable beyond the specific program for which we developed them; for example, expanded wavelength coverage for NIRSPA0, motivated by a project to study methane on Mars, will permit high-spatial-resolution spectroscopy of targets in the infrared *K*, *L* and *M* bands.

Differential Tracking

Since its inception, a key limitation of the Keck II laser guide star (LGS) system for studying solar system targets has been the need for the tip-tilt reference object (whether a star or a moon) to be moving at the same rate as the target. Thanks to a recent software upgrade, the system can now accommodate differential motion between the science target and its tip-tilt reference beacon, allowing us to use AO on moving objects. This mode has been applied both in regimes with strong scattered light (e.g., Jupiter and Mars) and for programs where scattered light is not a factor (e.g., Kuiper belt objects).

For Jupiter and Mars, scattered light presents a challenge. For these programs, the tip-tilt reference (moon or appulse star) must be approximately 10th magnitude or brighter. On the other hand, KBO studies have shown that the LGS differential tracking mode can be used for programs unaffected by scattered light with no restrictions beyond the standard specifications for LGS-AO guide stars (for example, $R < 18$).

Use of the LGS-AO differential tracking mode could be expanded to other programs. For example, faint asteroids in the main belt, and in the Greek and Trojan swarms at the Jovian L4 and L5 points, frequently pass close to stars brighter than 18th magnitude. In these cases, that star could be used together with LGS-AO differential tracking to acquire diffraction-limited images of these objects, enabling searches for companions and/or studies of the physical properties of the asteroids themselves.

NIRSPA0 Thermal-IR Capability

NIRSPA0 is a NIRSPEC-behind-AO mode that can be used to obtain high-resolution spectra at diffraction-limited spatial resolution. A long-standing restriction has prevented the use of NIRSPA0 at longer wavelengths. The special pupil stop needed for NIRSPEC to work behind AO resided only in the same wheel as the *K*-, *L*-, and *M*-band filters. Until recently, no AO pupil stop existed in the second filter wheel.

During September 2009, a team led by NIRSPEC Instrument Master Jim Lyke successfully installed this second pupil stop during a servicing mission on the warm dewar. NIRSPA0 has since been used to study Mars in the *K* and *L* bands with the AO system (in NGS mode) locked onto features on the Martian surface, initiating a new era of high-resolution

infrared spectroscopy of solar system targets.

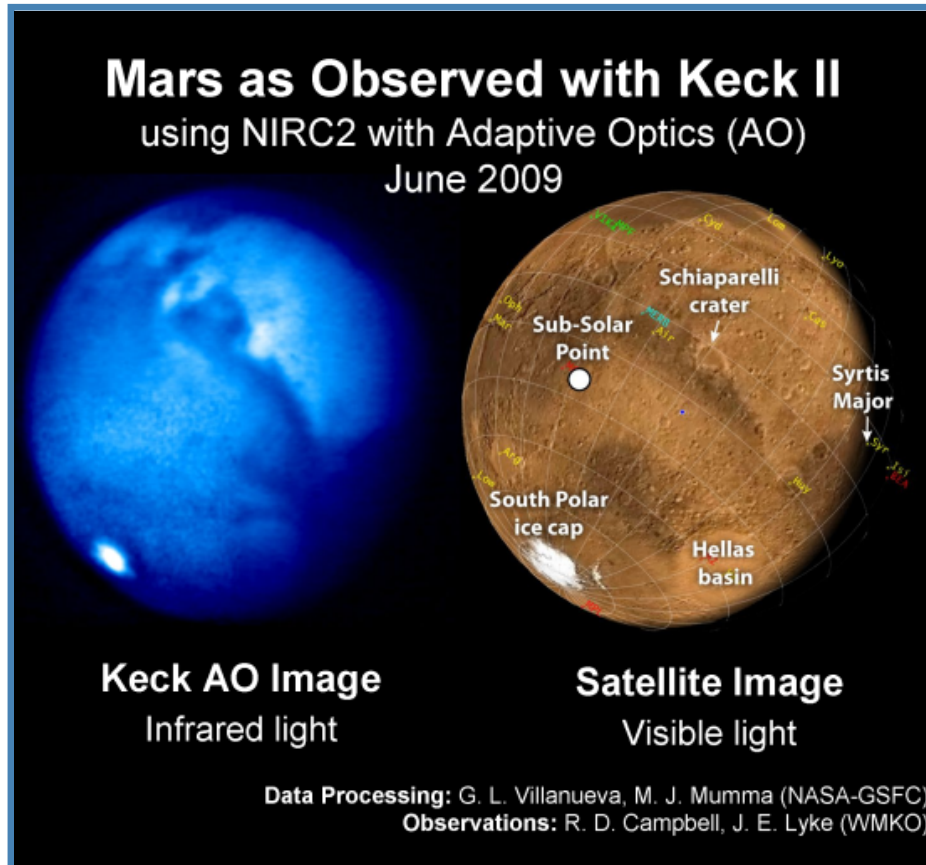


Figure 8. The authors used NIRC2 to image Mars in June 2009 with the Keck II Adaptive Optics system, achieving an angular resolution unprecedented in ground-based astronomy. After processing to improve sharpness, the images easily reveal individual features including Schiaparelli crater. These observations took place during a rare opportunity when Mars was small enough (in apparent size) to observe with the AO system. With the new differential-tracking capability for the LGS-AO system, observations of even greater clarity will be possible whenever Mars is close enough to a star which can be used for tip/tilt reference.

As an example of the spatial resolution achievable on the Martian surface with Keck AO, [Fig. 8](#) shows NIRC2 data collected during June 2009. At this time, Mars subtended 4.7 arcsec and could thus be observed directly with AO in NGS mode. Note that features as small as Schiaparelli crater are easily resolved in these images, making these the highest-resolution ground-based images of Mars ever acquired.

This new capability for NIRSPA0 could prove useful for other programs; for example, NIRSPA0 may now be capable of resolving emission from CO, or volatiles such as ammonia and methane, within circumstellar disks well enough to determine their location within the disk. However, observers considering such applications should be aware that the background flux in NIRSPA0 mode is almost five times higher than for NIRSPEC without AO due to the additional “warm” surfaces in the optical path. Please refer to the [NIRSPEC web pages](#) for further information. «

Operations Notebook

Robert Goodrich, Observing Support Manager, WMKO

The WMKO operations team continues to make behind-the-scenes changes to promote efficiency at the observatory. In some cases, these changes should lead to subtle improvements in the observing experience. For example, the Instrument Preventative and Predictive Maintenance (IPM) team has reported finding nearly fifty incipient problems as they perform new PM tasks on various instruments. Presumably, some of these problems would have led to failures on sky and subsequent loss of observing time had the team not found and fixed them. Other changes, such as reducing our Night Attendant (NA) hours, can make troubleshooting a subset of night-time problems less efficient. Determining whether the likelihood of such problems outweighs the cost of the corresponding preventive measures is our continuing challenge.

The NAs have also taken on the important task of watching for aircraft during LGS-AO operations to prevent our laser from inadvertently illuminating a plane. This task involves spending long hours outside in the cold, continuously scanning the sky, and we salute our hardworking NA crew — Scotty Paiva, Sniffen Joseph, Nick Jordan, and Douglas Macilroy — for performing this job. Several members of our operations staff, including Steve Shimko, Dennis Callan, Jamie Higginson, and Kirk Tateishi, are working with the NAs to make this task more comfortable by designing wind breaks and procuring appropriate cold weather gear.

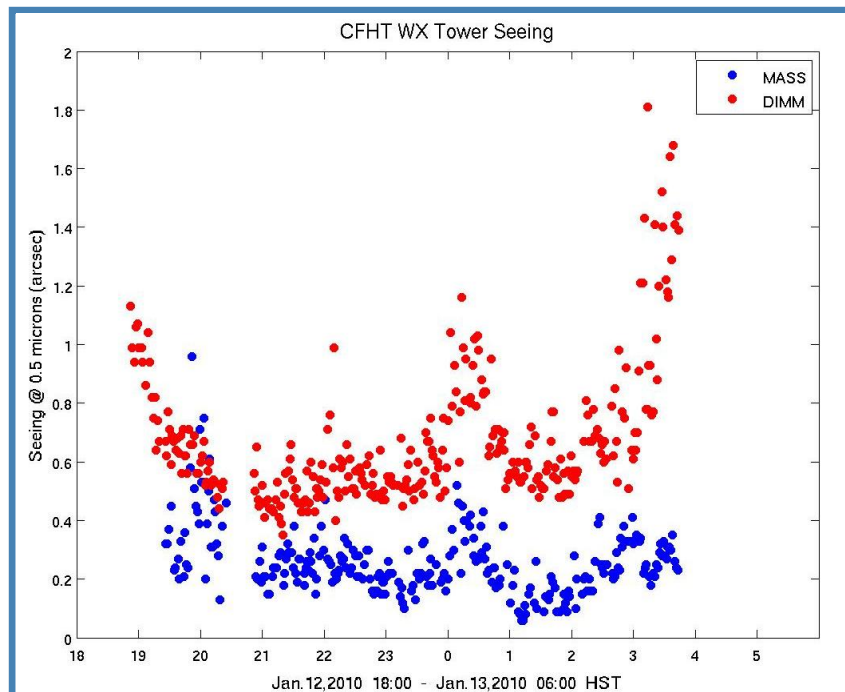


Figure 9. Estimated V-band seeing vs. time as measured by the new MASS/DIMM unit installed on Mauna Kea. The DIMM values (red dots) are the better predictor of telescope seeing since they reflect ground-level conditions.

In a welcome development, real-time data on Mauna Kea weather and seeing conditions are now available on the [Mauna Kea Weather Center \(MKWC\) website](#) thanks to a MASS/DIMM instrument loaned by the TMT project. The equipment consists of a Multi-Aperture Scintillation Sensor (MASS), sensitive to atmospheric turbulence above 500 m, and a Differential Image Motion Monitor (DIMM), measuring the ground layer below 500 m. CFHT houses the instruments on its summit weather tower, maintains the instrumentation, and provides a low-level interface, while MKWC provides the high-level interface. An example of the MKWC graphic from January 12–13, 2010 is shown in [Fig. 9](#). Note that the DIMM data are more relevant to telescope seeing. Raw data can be

downloaded using the links in the section labeled “Last Seeing Data” on the [MKWC website](#). «

UCO/Lick Seeks Input on Next-Generation Slitmask Tools

Steve Allen, Programmer/Analyst, UCO/Lick

The software which Keck observers currently use to design and submit LRIS and DEIMOS slitmasks is based on technologies over a decade old. The Scientific Programming Group at UCO/Lick is starting to plan how observers will create and submit slitmask designs for use with the next generation of slitmask-enabled instruments and solicits advice from the WMKO observer community to assist in the design process. If you would like to offer your input, please take a few minutes to complete our online slitmask survey at <http://spg.ucolick.org/cgi-bin/Masks/slitmasksurvey.cgi>. Many thanks in advance for your suggestions and comments. «

Espresso Returns to Keck

Jim Lyke, Support Astronomer, WMKO



After a long hiatus, observers may once again treat themselves to a great cup of coffee while observing! We have purchased a small espresso machine and installed it in the kitchen/lounge in the wing adjacent to the remote observing rooms. The *Espressione Café Retro* is easy to use and produces a great cup of coffee. Instructions are provided on the machine; coffee, milk, and barista not included. «

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