MMT Observatory

Smithsonian Institution &
The University of Arizona®

# Quarterly Summary

## January - March 2017

## MMT Observatory Activities

Our Quarterly Summary Reports are organized using the same work breakdown structure (WBS) as used in the annual Program Plan. This WBS includes a major category with several subcategories listed under it. In general, many specific activities might fall a tier or two below that. The WBS will be modified as needed in future reports.

## Administrative

### Program Management

Meetings held this quarter included: one engineering and one telescope operators. Also, two MMT Council meetings were held.

### Staffing

Two Assistant Staff Scientists were added to our staff this quarter: Timothy Pickering started on January 31 and Benjamin Weiner started on February 13.

In January and March, Ken Duffek was involved with the Steward ETS electronics group as a consultant for the assembly of his new TCS (Telescope control system). Part of Ken's transition to the MMTO in September 2016 included an agreement with the Vatican group to finish his design and checkout of the new control system. The system has now been completely checked out and is functional.

During this same time period the TAO (Tokyo Atacama Observatory) group headed up by Tom Connors requested Ken's involvement with the review of their mirror safety design for the 6.5m active primary mirror support electronics. He attended two design review meetings and offered recommendations on risk mitigation.

### Scheduling

### Quarterly Reports

### Strategic Planning

## Reports and Publications

There were 21 publications this quarter. See the listing in Appendix I on p. 23.

### Presentations and Conferences

## Safety

### Training

In cooperation with Steward Observatory Mirror Lab the following new safety videos have been added to the Steward Observatory Safety Training site that is managed by the MMTO:

- An Intergalactic Guide to Using a Defibrillator
- Air Gun Safety
- 30 Years of Mirror Making
- Defensive Driving
- Safety Training Directive
- Winter Driving

Recently, a greater emphasis has been given to the importance and documentation of safety training. Steward Observatory has informed all of their departments that training will be tracked and reflected on individual performance evaluations. Since this notification, C. Knop has had numerous requests from departments within Steward to create new logins for their staff.

As a member of the Steward Observatory safety committee, C. Knop has attended monthly safety meetings chaired by J. Kingsley, Assoc. Dir. of Steward Obs. These meetings are to design policies and ways to promote safety throughout Steward Observatory. This committee is also one of the trend-setters for the University of Arizona, and works closely with the University of Arizona Risk Management.

The following staff members attended ARC Flash training on January 5 at Steward Observatory: C. Knop, B. Comisso, W. Goble, R. Ortiz, M. Alegria, J. Wood, and K. Duffek. The training was conducted by Raines Utility Safety Solutions.

### Safety Inspections

### Procedures and Protocols

### Personal Protective Equipment

### Interlock System

## Primary Mirror

### Coating & Aluminization

### Ventilation and Thermal Systems

### Mirror Support System

As mentioned in the previous quarterly report, a spare cell crate power supply was installed to determine that it was functional. However, it was found to be the cause of voltage monitor (Vmon) errors, and the +15 V supply was found to be drifting by approximately 0.7 volt. An internal Vicor power component was replaced by a new Vicor component, the system was checked, and has since operated with no errors. This spare power supply will be repackaged into new modern packaging with power sense LEDs. The repackaging is ongoing and should be completed in the near future.

While troubleshooting the primary mirror cell crate power supply, a ground loop was discovered. The electronics group felt that this problem could have led to the power supply drift that had been causing our Vmon +15 V errors. Using the previous work that had been done, a plan was formulated to find the root cause of the ground loop issue. With great detective work from all, the problem was found to be actuator 152's load cell cable.

The cable was pinched during actuator 152's installation into the cell, thereby causing the load cell shield to the mirror cell to be shorted. The short was removed and resistance measurements were taken to verify proper isolation.

Re-assembly then proceeded on the sixteen force monitor mux cables and the nine hard point distribution cables to allow for a functional test of the primary mirror support system. The electronics group performed a complete bump test with zero errors reported.

Prior to the removal of the ground loop issue, the primary mirror support system had been, on average, reporting between one to ten random actuators per night either failing or providing warnings on the force read-back during global cell bump tests. These errors have now been reduced to nearly zero per month.

### Hardpoints

### Actuators

## Secondary Mirrors

### f/9

### f/5

### f/15

### Baffling

## Hexapods

### f/5 hexapod

### f/9 and f/15 hexapod

## Optics Support Structure

### Truss

### Secondary Hub

### Spider Arms

### Neutral Members

## Pointing and Tracking

### Azimuth

### Elevation

### Rotator

## Science Instruments

### f/9 Instrumentation

The f/9 instruments were on for 42% of the available nights from January 1 – March 31. Approximately 90% of those nights were scheduled with the Blue Channel Spectrograph, 5% with Red Channel, and 5% with SPOL. 413.6 hours were allocated for f/9 observations. 43% of these hours were lost due to weather. Instrument, facility, and telescope problems account for less than 0.1% of lost time. Blue lost 41% of its time to bad weather, with Red Channel losing 11%, and SPOL losing 100%.

### f/5 Instrumentation

Thirty-two nights were scheduled for f/5 observing this quarter, along with one engineering night. The weather was much worse than average, and 52% of the time was lost to clouds, wind, and very poor seeing. On a dozen nights, weather was sufficiently bad that we did not even open. MMIRS was able to get data on only 3 nights, HectoSpec on 11 nights and HectoChelle on 4 nights. MMTCam took data on 16 nights, and was the exclusive instrument for a couple of nights when a problem developed with the Hecto positioner in early March.

Hecto observed 53 fields on 15 nights before being stopped by a T2 axis following error. There were 186 science exposures taken along with 660 calibrations consisting of bias, flat, comp, sky, and dark images. The 600 line grating was realigned to put light in the expected locations. We started the quarter in poor weather conditions, and one of the grippers reported a failure - possibly related to the cold conditions. 1.75 hours were lost as the issue was examined. It was resolved with added exercise of the axis. The cold temperature policy was revised to reflect the fact that data obtained with seeing larger than 2" is generally not adequate for good science. In marginal conditions, the seeing will be monitored with the Wavefront camera, and configuration of the fibers will happen only if the data is expected to be useful for science. A few nights later the guide cameras were not responding properly to commands. That issue was corrected by restarting servers. It is unclear why the EP box circuitry got “confused” and could not properly control the cameras. Approximately 20 minutes was lost to sorting this issue out.

At the beginning of March we had another, more serious, issue develop with the positioner. The T2 axis reported a following error indicating that the motor was not keeping up with the commanded position. This occurred at the start of the night and we were initially able to recover operation, but the problem recurred a few times over the next hour. We ceased operating the positioner and took observations with MMTCam that night and the next night. The motor amplifier was replaced the next day and more testing was done. Using high resolution data, D. Fabricant and M. Lacasse could see that the T2 axis was moving, but not fast enough to keep up with the commanded position. It is suspected that the nylon drive screw in the actuator was worn out and needed to be replaced. A service mission was required to get the positioner back into operational status. MMTCam took data for a couple of nights and then Blue Channel was mounted.

A couple of new monitoring programs increased the demand this quarter for MMTCam, which took 962 exposures on 32 objects, along with 570 calibration images consisting of darks, flats, and biases. Apparent telescope oscillations were seen on a couple of nights and they are not fully understood.

The WaveFront Sensor system continued to operate well this quarter.

The MMIRS instrument was on the telescope from January 9-17. M. Lacasse was unable to be on the mountain at that time due to a medical issue and, instead, remotely directed the MMT staff on preparing and mounting MMIRS. The staff did an excellent job, and the instrument was ready to take data before sunset.

MMIRS was only able to obtain data on 3 nights this quarter; more than half the run was clouded out. On those nights, MMIRS was able to gather 1203 images and 836 spectra of 25 science objects. It also acquired approximately 3200 calibration/setup exposures consisting of dark, alignment, telluric, comp, and flat images.

The MMIRS observations were run exclusively in queue mode. The nine-night run consisted of 6 programs, 10 individual slit masks, and 75 submitted targets. A mask change was done on January 13 in order to accommodate all of the requested masks. Of the 118.4 hours allocated (106.5 hours observing plus 11.9 hours engineering), 67.5% were lost to weather (71.9 hours) with no hours lost to facility or telescope problems. Despite heavy weather losses, 31 fields were observed.

Principal Investigator (PI) priority ranking was reinstated as a constraint in the queue scheduling software after PIs received instructions on creating priorities. Prompted by the MMT typical weather loss of ~30%, we instructed PIs to split their targets into thirds, with priority 1 targets being the most important and priority 3 being the least important. While PIs continued to use the old target submission tool (MMOST v.1), the "back-end" logistics and bookkeeping were done by D. Porter's new MMTO Scheduler database. This interface helped make gigantic strides in simplifying the reporting, tracking, and planning of MMIRS observations.

The next MMIRS run is in early April, so 12 new masks were ordered in February for the run to ensure on-time delivery. PIs submitted field files by March 21.

Preparations for the arrival of the Binospec instrument and the laser mask cutter continue, though at a slow pace, as issues are discussed and plans revised. The IRF floor is nearly ready for recoating, the electrical outlet and conduit relocation is progressing, a second new crane has been specified, the Common Building basement is being emptied, and the concrete forms and re-bar for the path from the IRF to the external building lift are being worked on.

**f/15 Instrumentation**

The final two adaptive optics runs of the current NGS system were completed in mid- February and mid-March. The February run consisted of eleven nights, including one maintenance and engineering (M&E) night and ten science nights. The March run consisted of six nights including one M&E night and five science nights.

A number of problems occurred during the February run due to the length of the run and the complicated nature of the schedule that required numerous instrument reconfigurations, mainly with the WFS camera. These reconfigurations, along with marginal to poor seeing conditions throughout the run, resulted in numerous issues with the usual suspects: power supply issues, WFS camera, configuration control, and computer and network related issues.

The electronics group supported the February M&E night to assist with any issues that arose. After fixing a problem with the connection of fiber optic cables, they worked on Wavefront synching issues. After trying a different configuration and swapping cards, the problems persisted so the original configuration was put back into use with much better results, and the problem seemed to be resolved.

The second NGS run in March fared much better as the shorter schedule and absence of WFS camera configuration changes meant that once the initial setup was complete, the system could then operate without additional hardware or software changes throughout the run.

After completion of the March run, the NGS system was officially decommissioned, and preparations began to retro-fit both the topbox and adaptive secondary for the "MMT Adaptive optics exoPlanet characterization System" (MAPS) program that began in November of 2016.

By late March, significant work was completed on developing a working simulation for the MAPS voice coil actuators (MVCAS). The simulation is MATLAB/Simulink based and will be very useful for MAPS control system rapid prototyping and development, conducting trade studies for various conceptual designs, gain optimization, and assessing the overall MAPS system performance.

### Instrument Handling

## Topboxes and Wavefront Sensors (WFS)

### WFS Software

Portions of the wavefront software at the MMTO have been in use and largely unchanged for 10-15 years or more. While it has worked well for the most part, it has become difficult to modify and significantly improve due to its lack of a cohesive design. Work has begun on a new, completely refactored wavefront sensor software system built from the ground up using entirely new code. Instead of the original mix of C and TCL, the core of the new system is based entirely on python. This provides the ability to use python's very rich ecosystem of image analysis, visualization, and astronomy-specific tools such as Astropy. It also provides the ability to use the code testing and continuous integration utilities that have also been developed by the Astropy community.

Some key features of the new software include:

- More robust pupil registration and aperture matching. Many of the problems encountered with the current system have a root cause related to errors in determining the pupil center or assigning measured spot positions to the wrong Shack-Hartmann aperture.
- The use of standard ordering for the Zernike polynomial terms. The old software used a custom set of terms with non-standard ordering that made comparison with results from other software, such as Zemax, problematic. The new software also uses recurrence relations to generate the Zernike polynomials and their derivatives, which provides the ability to fit arbitrary numbers of terms.

- Improved analysis of wavefront sensor images via the Astropy-affiliated package, photutils. The two key capabilities that photutils provides are fast, accurate spot finding/centroiding and more sophisticated background modeling/subtraction. The spot finding/centroiding is performed using an updated and complete DAOfind implementation. It is faster and more accurate than the simplified implementation currently in use.

The new software is still being actively developed and validated against existing wavefront sensor data. We hope to deploy it along with the new f/9 wavefront sensor camera during the summer of 2017.

### f/5 WFS

### f/9 Topbox

### Natural Guide Star (NGS) Topbox

Testing on the AO topbox was accomplished in the quest for reduced noise on the CCD camera. The noise level seemed to be lower when the CCD camera pelletier cooler was connected to an isolated power supply. An Acopian DIN rail power supply was installed and tested. Initial results were good, so testing was done on the sky during the next run. Testing on the sky was inconclusive due to other variables.

### Laser Guide Star (LGS) Topbox

## Facilities

### Main Enclosure

The new roof camera / roof shutter heater electronics enclosure was installed on the east roof shutter. Power, 115VAC and 24VAC, were verified to the BAS 20 and the DIN rail mounted power supplies. EMT conduit was run from the enclosure to the east roof shutter, and wiring for the thermal probes was installed. The wiring was connected to the BAS 20. A 4-port POE gigabit network switch was installed to provide POE to the camera as well as any future network devices. The thermal probes for measuring shutter temperature will be installed soon.

In order to monitor the roof heater amperage (current), a BAS 20 controller was installed in the old roof heater shutter box located in the electronic shop loft. AC current transducers, model ACT050-10-S, were installed in the roof heater circuit breaker box in the loft. Transducers were clamped onto each feed line of the seven roof heater circuits (three to the east shutter, three to the west shutter, and the fall-arrest heater circuit). The fall-arrest heater circuit is not connected on the roof at this time. Each transducer was jumpered to the 20A range (scaling 2A/V output 0-10V). The system was tested, and it displayed proper outputs to the BAS-20 controller. Values were verified with a clamp-on ammeter.

In January a data acquisition system consisting of an Arduino micro controller and associated cable interface was installed in the building drive rack electronics. The system was developed to help capture data and to analyze what might be causing building major faults (telescope colliding with the building limit switch).

With the help of the software group, firmware had been written to log event data to the network. Many plots had been generated showing what appeared to be slight and very intermittent motor field voltage sags generating the building major fault. After reviewing the building drive fault board design, it was noted that we could possibly be generating these faults due to noise. A filter was then designed and installed to require the suspected fault condition to exist for a period of 1 sec instead of triggering instantaneously as the original design allowed, and thereby causing a possible false fault condition.

After the filter install, two nights of operation concluded with no major building faults. At this point it looked as though the problem had been resolved until the building drive began exhibiting an oscillation (sashing machine oscillation) on the third night of operation. The electronics group went back to work at the telescope to resolve this issue.

Upon arrival, a new battery of tests had been developed to aid in the further troubleshooting of the building drive issue. Step one was to determine why the building was going into oscillations not revealed in previous observing runs. The electronics group began troubleshooting by commanding telescope slews and visually observing the building to telescope clearance. This test revealed that the telescope was still colliding with the building and that a limit switch designed to disable the building drive was not tripping due to the switches' activator arm being bent. The failure of this switch caused the building to run into the rubber bumper and then recoil off, only to be driven back into the limit by the building drive. Hence, an oscillation began until the telescope operator disabled the building drive.

The building left limit switch was repaired and recalibrated. Several tests were performed manually using the hand crank to assure the limit switch was indeed working properly. This repair solved the oscillation problem.

With the building left limit repaired, the electronics group refocused their efforts on the building collision issue. It was apparent after the addition of the filter board that the problem with building dropouts had been the telescope tripping the building left limit switch all along. The fact that the filter board added a small time delay to the fault chain revealed this to be the case. It became clear that when the telescope activated the limit, drive power was removed (as designed) and the collapsing motor field voltage would rise and set the motor field bits in the Arduino monitor.

So the task at hand was to determine why the telescope continued to hit the left limit. With continued building slews, the group had determined a rotation-dependent fault. Large slews clockwise did not produce a dropout, but large counter-clockwise slews did. So, the electronics group began looking at the LVDT (Linear Variable Differential Transformer) that is used to provide the position feedback of the telescope to the building. In previous trips to the telescope, the electronics group had measured and confirmed that the LVDT was functioning and position data was accurate. Since we had been witnessing a position-dependent problem, the group needed to revisit the telescope.

After reviewing the building servo board schematic it was decided to remove the LVDT from the system by using the building drive hand paddle. By plugging in the paddle, circuitry on the servo card would switch the LVDT out of the closed loop portion of the card and allow building moves open loop. The day crew installed blocks between the telescope and building so we could push the telescope around using the building drive amplifiers. We chose this process to eliminate any possibility of a drive amp problem. We were able to slew clockwise and counter-clockwise at max slew speeds without any dropouts. The conclusion drawn from this test is that we had a definite LVDT issue.

A review of the LVDT and LVDT mount began after locking out the building drive. The LVDT was disconnected from the telescope and again voltage measurements were taken to confirm proper LVDT voltage range. No anomalies were found; the LVDT was functioning perfectly. The group's attention then turned towards the LVDT mount.

The mount was designed to have two degrees of freedom. After decoupling the LVDT from the telescope it was quite apparent that there was binding in the azimuth section of the LVDT mount. The mount was torn down and cleaned, re-lubricated, and re-assembled. Testing of the assembly by hand showed a large reduction in friction allowing for very smooth azimuth movement.

The day crew removed the blocking form between the telescope and building, and we resumed building slew tests. At a slew rate of 1 deg/s we found that slews in both clockwise and counter-clockwise were now able to be accomplished. The building dropouts were not due to electronic failure, but to the mount itself. The failure of the mount to rotate exerted a side load or bending load on the LVDT plunger causing it to stick. This in turn created the situation where the building could not keep up with the telescope at slew. The telescope then triggered the building left limit and generated the building major fault. To date, since the repair, no errors have been triggered.

**Instrument Repair Facility (IRF)**

**Common Building**

**Bowl Dorm**

**General Infrastructure**

Work began at the summit parking lot in mid-March to create a pathway for easy movement of instruments between the MMT main enclosure and the IRF, where they can be repaired and/or stored. Figure 1 below shows work on the support structures for the pathway before the pouring of concrete. The path will be completed by the end of May.


Figure 1. Support structures being prepared for a concrete pathway to be built between the IRF (shown) and the MMT main enclosure. The pathway will allow instruments to be easily moved between the two buildings.

## Computers and Information Technology

### Software Management

The MMTO has had a Github organization set up for some time. However, it was only configured as a free, basic account so it did not support, for example, private repositories. If we wished to migrate the git repositories currently hosted on our local machines to Github, we would need private repository support. Some of our repositories contain sensitive information that wouldn't necessarily be appropriate to share publicly. Fortunately, Github has a very generous program for providing free services to educational/academic institutions. We applied for this and have now been granted free, unlimited use of all Github capabilities, including an unlimited number of private repositories and unlimited storage/bandwidth for large files via Github Large File Support (LFS). Several projects have since been migrated to Github to take advantage of this, and more will be migrated over time.

### Computers and Storage

### Network

During this quarter, the usual monthly backups and reboots, and the yearly offload of historical data from */mmt* were performed. Fedora machines were upgraded to release 25. Some MMT applications on the *hacksaw* server had not been maintained in a long time and failed under Fedora 25. *Hacksaw* was reverted to Fedora 24 until the overdue maintenance could be performed. The maintenance is now complete, and *hacksaw* will go back to Fedora 25 in early April.

New annunciator checks were implemented for carrier2. Forward and reverse name services were also set up for new AO machines on a new subnet.

**Hardware/Software Interfaces**

The new CCD camera for the f/9 wavefront sensor, a SBIG STT-8300, required a new software interface for network-based camera control and image acquisition. This camera does have its own built-in Ethernet interface. However, it communicates via a proprietary protocol, is prone to lock-up if the protocol is not followed exactly, and limits the camera's readout speed compared to using the USB interface. An alternative solution was pursued based on the INDI (Instrument Neutral Distributed Interface) library: http://indilib.org. INDI provides a well-defined network interface and built-in support for many observatory-related devices, including SBIG cameras/peripherals. This solution consists of two components: a server running on a computer that is attached to the camera via USB, and client software to communicate with the server while abstracting the details of the INDI protocol.

The server portion was solved by using inexpensive ARM-based single-board systems, specifically Raspberry Pi 3s, as the host computers. Since the INDI software is pre-packaged for Debian-based systems, including those running on the ARM architecture, installing it and its dependencies is very straightforward. There is very little configuration required of the server other than specifying the driver(s) to load and the network port to use. Commands to do this are added to the system initialization scripts so that the INDI server is started when the host computer boots up. The systems are run off micro-SD cards. This makes it easy to archive/version system images as well as swap out cards or system boards if they fail.

There is a wide variety of INDI-compatible client software available. However, to more easily integrate INDI with our software we need a client library interface. INDI provides C/C++ libraries plus some shell utilities. The former would require extra effort on our part to integrate with other languages that we use while the latter are limited in what they can do (e.g. they cannot be used to perform CCD exposures). For easier integration with the wavefront sensor software, a pure-python INDI implementation was found and adapted.

This software will also support a new camera system for the mount alignment telescope (MAT): an ST-402 with a B-V-R-clear filter wheel. This ST-402 system was actually procured in 2008 with the intention of installing it on the MAT, but it was decided to use a video-based StellaCam camera instead.

**MMIRS Queue Scheduling Software**

Queue scheduling was done for the January 9-17 MMIRS observing run, making it the fourth time that the queue scheduling software has been used for MMIRS observing. A total of 103 observing blocks were scheduled. This is comparable to the 120 observing blocks scheduled during the 12-day-long December 2016 MMIRS run.

Incremental improvements have been made to the queue scheduling software on each MMIRS run. One improvement for the January run was a consistent approach to a Principal Investigator (PI) priority for each target. Targets were ranked by the PI on a scale of 1 (highest) to 3 (lowest) for each of their targets. These priorities were assigned such that the requested observing time was split evenly between the three priorities for each program. This allows for targets to be scored fairly between the various programs. PIs understand that weather and other circumstances can affect completion of observing blocks, with the highest impact being on priority 3 targets.

Work progressed on modifying both the front-end (i.e., user interface) and back-end (i.e., scheduling) queue software to use Redis (https://redis.io/) for inter-process communication. Commands to begin a dispatcher or scheduler calculation are stored in DISPATCHER.command or SCHEDULER.command Redis parameters. When these Redis parameters are set, separate processes are started to run the desired calculations. The results of a scheduling calculation are stored in separate Redis parameters for the dispatcher (i.e., DISPATCHER.output) and the scheduler (SCHEDULER.output), both in JSON format. These outputs were presented to the queue observers on web pages as seen in Figures 2 and 3. An example of the scheduler output is shown in Figure 2. This output can be used for a variety of observing objectives such as determining: 1) if all targets/observing blocks can be observed during the remainder of the run, 2) when telescope time is over- and/or under-subscribed, and 3) optimal dates for MMIRS mask changes within the run.

**MMT Queue Scheduler**
Updated: 2017-01-17 07:37:42 MST
Constraints: Twilight=Civil(Sun=-6°), MaxAirmass=2.5, MaxElev=88°, MinElev=20°, MaxRot=165°, MinRot=-174°, MoonSep=15°
Dispatcher | Fields/Targets Entries | Mask Schedule | Observed Summary | PI Notes

| Number | Target | Start (MST) | End (MST) | Duration (min) |
|---|---|---|---|---|
| 1 | Unused Time | 2017-01-17 12:00:00 | 2017-01-17 18:15:53 | 375.88 |
| 2 | UAO-S121_udsel61_K-2 | 2017-01-17 18:15:53 | 2017-01-17 19:45:53 | 90 |
| 3 | UAO-S168_SN2016iae_J | 2017-01-17 19:46:31 | 2017-01-17 20:24:31 | 38 |
| 4 | SAO-10_SN2016iae_HK_spec | 2017-01-17 20:24:31 | 2017-01-17 21:14:31 | 50 |
| 5 | UAO-S168_SN2016eso_J_SlitCenter | 2017-01-17 21:14:42 | 2017-01-17 21:56:42 | 42 |
| 6 | UAO-S189_sGRB160408A_Ks | 2017-01-17 21:58:27 | 2017-01-17 22:49:27 | 51 |

Figure 2. Output for the queue scheduler is shown for the first part of the night of January 17. Only the first portion of the schedule for the remainder for the run is shown.

Figure 3 shows an example of a dispatcher output. This output shows ranked constraint scores for all remaining observing blocks at a specific time or time slot. It allows the queue observer to use her/his expertise to select which target/observing block to observe next. The dispatcher can be updated after each observation, providing real-time feedback on optimal observing choices. The queue observer uses the dispatcher to make decisions based upon relative constraint scores and changing observing conditions (e.g., pointing downwind, approaching clouds).

**MMT Queue Dispatcher**
Updated: 2017-01-16 10:12:03 MST
Observing Time: 2017-01-16 18:40:00 MST (2017-01-17 01:40:00 UTC)
Constraints: Twilight=Civil(Sun=-6°), MaxAirmass=2.5, MaxElev=88°, MinElev=20°, MaxRot=165°, MinRot=-174°, MoonSep=15°
Scheduler | Fields/Targets Entries | Mask Schedule | Observed Summary | PI Notes

| rank | name | pi_priority | overall_score | ra | dec | duration | alt | az |
|---|---|---|---|---|---|---|---|---|
| 1 | UAO-S121_udsel61_K-2 | 1 | 0.65887473 | 02h17m49s | -05d13m02s | 60 | 52d59m07.5849s | 173d35m08.3799s |
| 2 | UAO-S121_udsel61_K-1 | 1 | 0.57166109 | 02h17m49s | -05d13m02s | 120 | 52d59m07.5849s | 173d35m08.3799s |
| 3 | UAO-S189_sGRB160408A_Ks | 1 | 0.08605658 | 08h10m29.91s | +71d07m42s | 45 | 29d04m27.2195s | 21d45m48.0211s |
| 4 | UAO-S121_udsel51_K | 2 | 0.08228895 | 02h17m17s | -05d14m53s | 60 | 52d58m02.3766s | 173d48m36.1093s |

Figure 3a. Output of the highest scoring observing blocks is shown for the queue dispatcher for the first part of the night of January 16.

| TimeAllocationConstraint | MeridianConstraint | PIPriorityConstraint | AirmassConstraint | AltitudeConstraint |
|---|---|---|---|---|
| [[0.9217916404128191, 0.9217916404128191, 0.9217916404128191]] | [[0.978545608829569, 0.958953260542066, 0.8964499422411124]] | [[1.0, 1.0, 1.0]] | [[ True True True]] | [[ True True True]] |
| [[0.9217916404128191, 0.9217916404128191, 0.9217916404128191]] | [[0.978545608829569, 0.9172877617621863, 0.8131181623593524]] | [[1.0, 1.0, 1.0]] | [[ True True True]] | [[ True True True]] |
| [[0.8435732808256382, 0.8435732808256382, 0.8435732808256382]] | [[0.488748269053521, 0.5241649366473711, 0.559580321814175]] | [[1.0, 1.0, 1.0]] | [[ True True True]] | [[ True True True]] |
| [[0.9217866404128192, 0.9217866404128192, 0.9217866404128192]] | [[0.9792852987459413, 0.9582151231445648, 0.895711290748031]] | [[0.5, 0.5, 0.5]] | [[ True True True]] | [[ True True True]] |

Figure 3b. Details of the constraint scores for the observing blocks listed above. This information is used by the queue observer to select the optimal observing block to be scheduled next.

Figure 4 shows the Queue Admin interface for managing all aspects of the observing queue run. This page shows a summary of each of the programs that have allocated time for the run. Each of the program's catalogs is shown in a second summary table making it easy to see the progress of each of the catalogs. The schedule parameters and mask install/removal schedule is managed in this page, as well as management of the observing block.

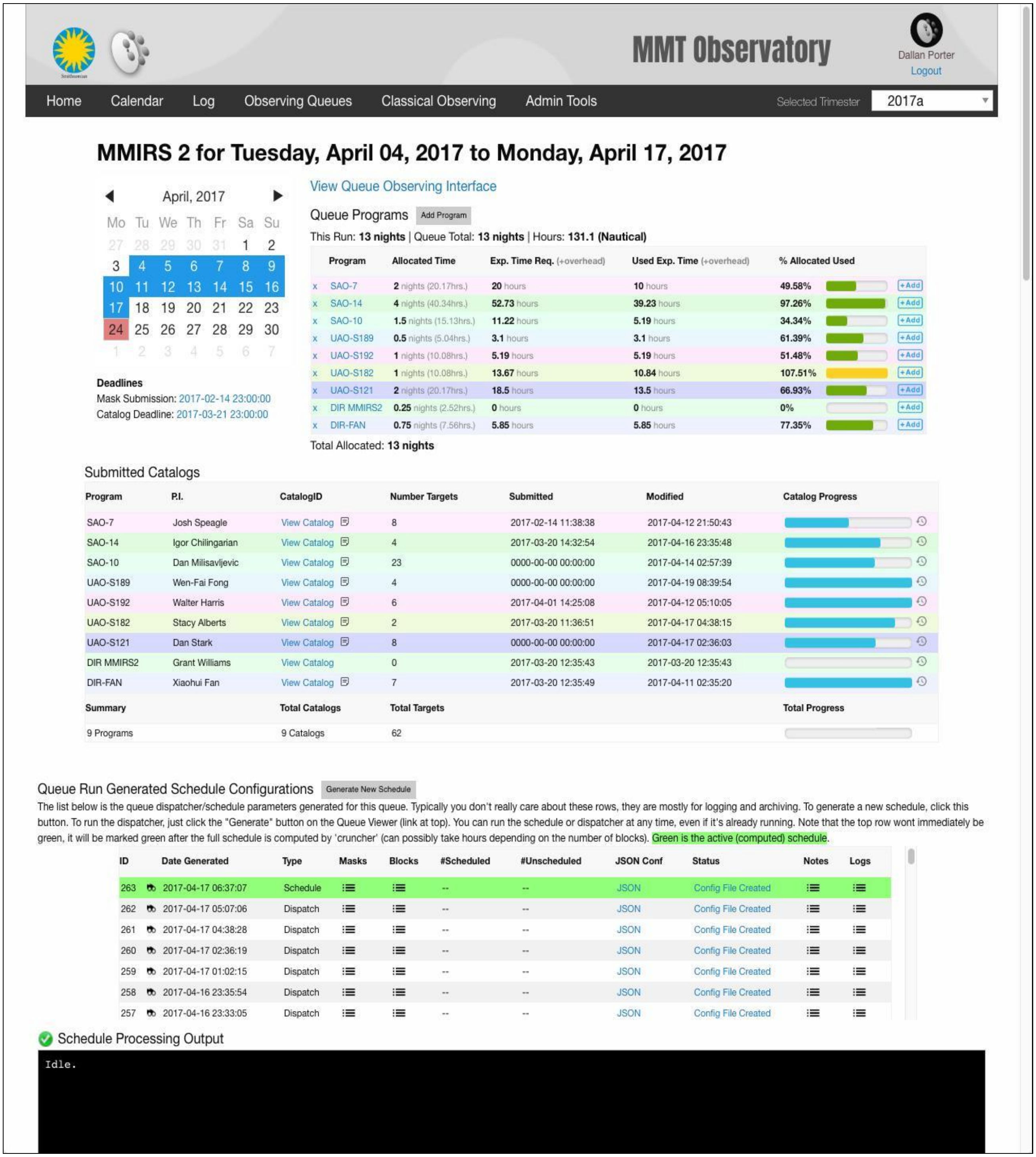


Figure 4. The Queue Admin interface

During nighttime observations, the queue observers have a dedicated interface for accessing and updating the scheduled observing blocks. Figure 5 shows the Queue Observing Interface. The upper section of this new interface shows a sky map with the current tracking target information. An all-sky view is also displayed which allows the all-sky camera image to be overlaid on top. Adding notes and marking observing blocks complete is done using this interface.

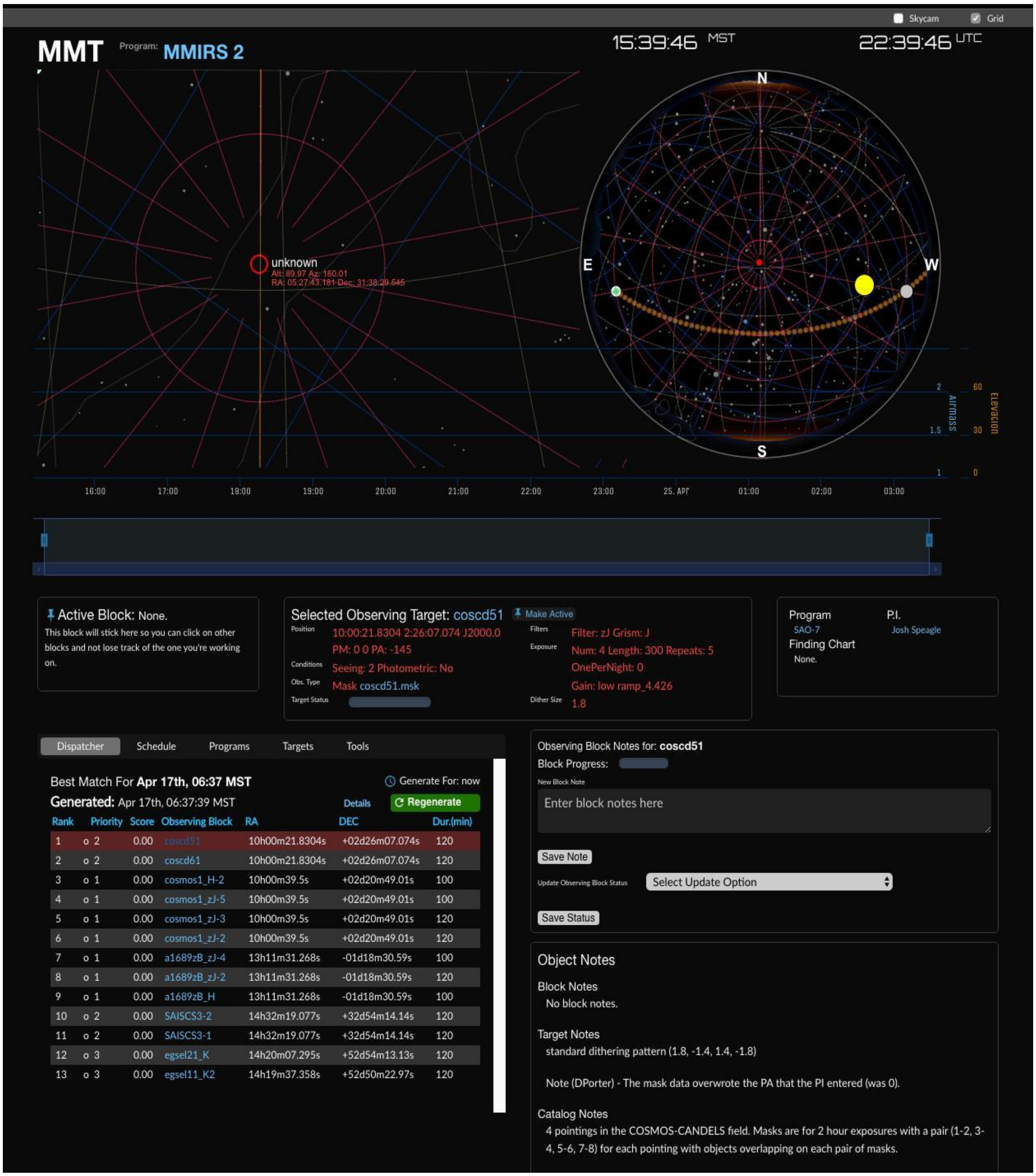


Figure 5. The Queue Observing Interface

### Telemetry, Logging, and Database Management

### Annunciator

## Weather and Environmental Monitoring

### Weather Stations

Summit weather was extremely rough on the weather stations this quarter. A severe snow storm with heavy ice buildup wreaked havoc on the units.

RM Young 1 wiring was pulled out of the terminal block inside the junction box during the storm. Excessive ice formed on the cable, weighing it down. The wiring was inspected, strain relieved, and reinstalled into the junction box. The bird was realigned and tested. All values were nominal.

RM Young 2 lost its tail section during the same storm. A new tail section was ordered, received, and installed. The unit alignment was checked. All values were nominal.

Vaisala 3 wind sensor section failed during the storm. Inspection identified the problem as a broken ultrasonic sensor probe. The entire WXT-520 was replaced with the repaired unit from Vaisala 4. The system was aligned and readings were nominal.

Vaisala 4 stopped displaying wind data during the storm. It was replaced with the spare unit. The defective unit was removed, inspected, and found to have water in it. The unit was dried, inspected, and resealed. It was reinstalled as Vaisala 3.

### All Sky Camera and Web Cameras

The new roof camera / roof heater electronics enclosure was installed and power was verified to the BAS 20 and the DIN rail mounted power supplies. The roof webcam was replaced with a new POE webcam, and heater wiring was run to the camera enclosure front window. The camera is fully operational, and the enclosure window heater appeared to work during a snow storm.

### Seeing

As discussed in previous Quarterly reports, the MMT and Magellan Infrared Spectrograph (MMIRS), a wide-field near-IR imager and multi-object spectrograph, generates WFS-related seeing values much more quickly than other f/5 or f/9 instruments. This instrument was on the telescope January 9-17, 2017. 1941 of the 4926 total WFS data samples for the period of January 1, 2017 to April 1, 2017 are from MMIRS. There are 917 f/5 seeing values that are not from MMIRS (e.g., Hecto), and 2068 seeing measurements that are from f/9 instruments.

Figures 6 and 7 present apparent seeing values, corrected to zenith, during this reporting period. These values are derived from measurements made by the f/5 (MMIRS and non-MMIRS) and f/9

WFSs. Figure 6 presents the seeing values as a histogram with 0.1 arcsec bins while Figure 7 presents the same data as a time-series chart. f/5 WFS values are divided into MMIRS and non-MMIRS categories. In Figure 6, f/5 (MMIRS) seeing data are shown in blue, f/5 (non-MMIRS) data are in green, f/9 data are in red, and the combination of all three WFS values is in cyan. In Figure 7, seeing measurements for the f/5 are similarly shown as blue (MMIRS) and green (non-MMIRS) diamonds while f/9 WFS seeing measurements are represented by red squares.

The median f/5 seeing value for MMIRS data is 1.26 arcsec. This is higher than the 1.05 arcsec value in the October-December 2016 quarter. The median non-MMIRS f/5 seeing is 0.94 arcsec while the median f/9 seeing value is 0.64 arcsec. This latter seeing quality is better than the 0.78 arcsec value of the October-December 2016 quarter. The combined median seeing for all data WFS systems is 0.95 arcsec. As previously stated, the combined data set is biased towards nights of MMIRS observing.

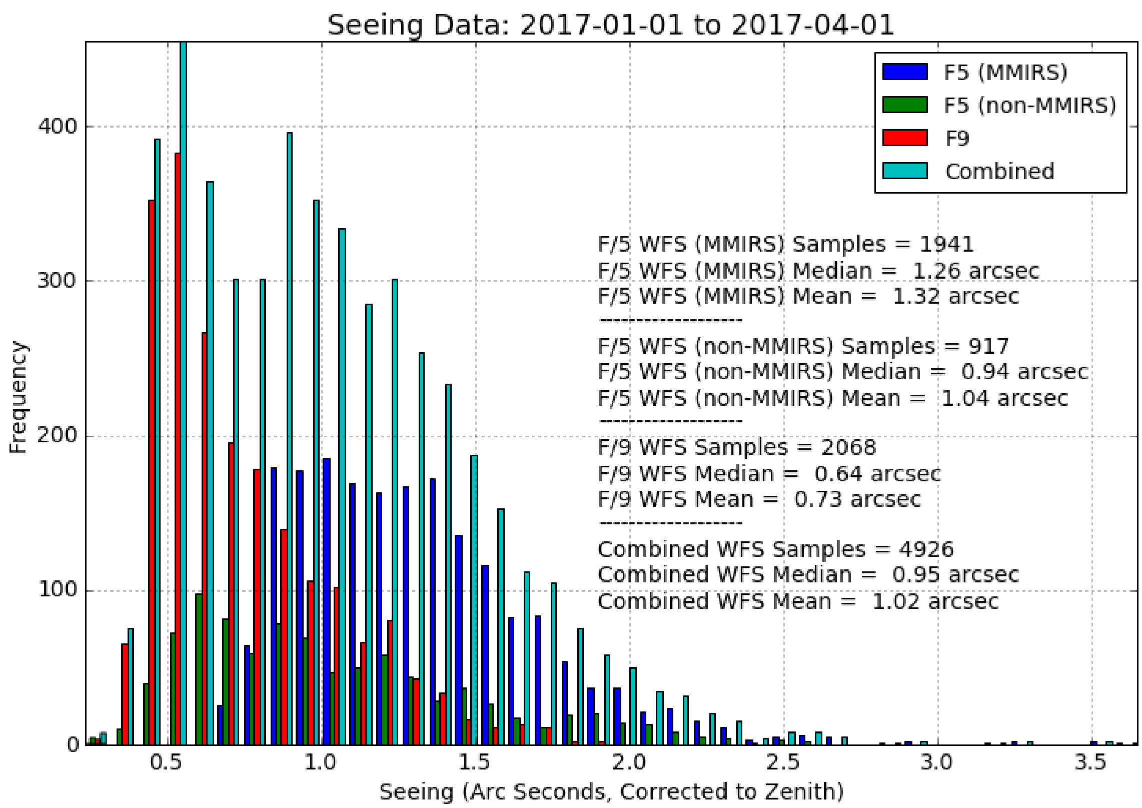


Figure 6. Histogram (with 0.1 arcsec bins) of derived seeing values for the f/5 (MMIRS and non-MMIRS) and f/9 WFSs from January through March 2017. Seeing values are corrected to zenith. The median f/5 MMIRS seeing is 1.26 arcsec, and f/5 non-MMIRS seeing is 0.94 arcsec, while the median f/9 seeing is 0.64 arcsec. A combined median seeing value of 0.95 arcsec is found for the total 4926 WFS measurements made during this period.

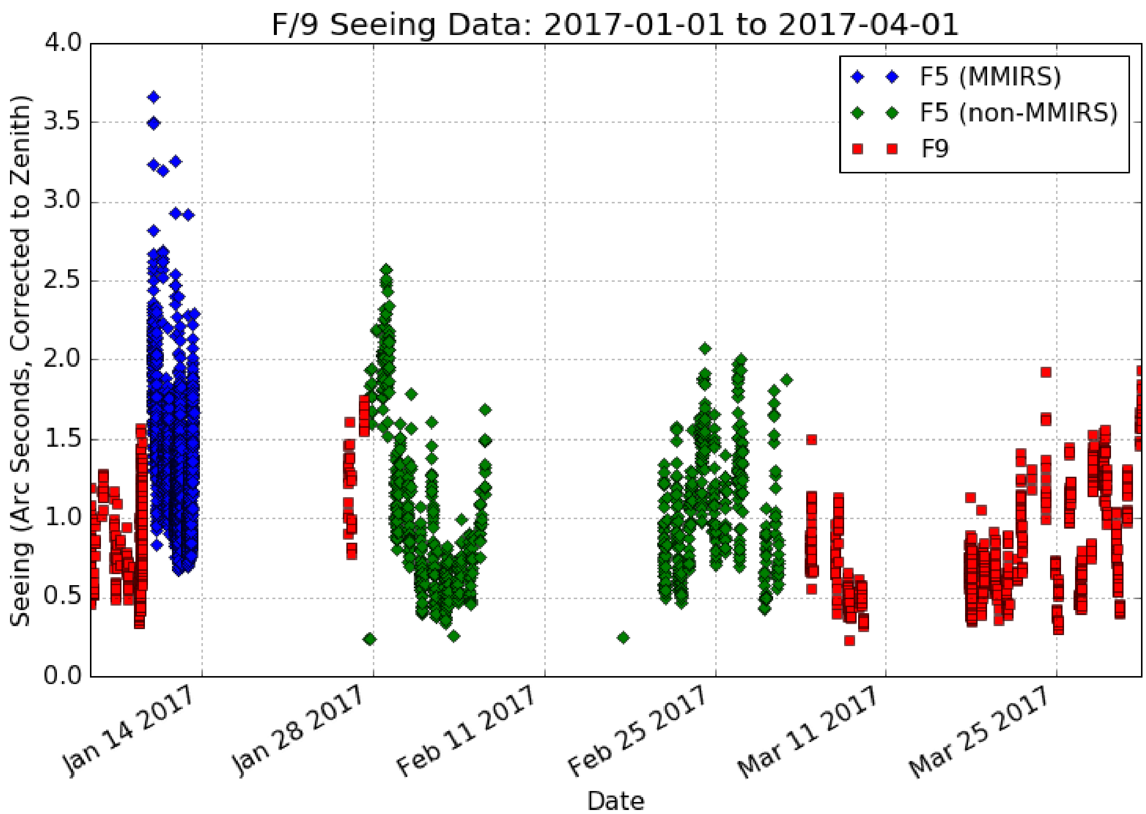


Figure 7. Derived seeing for the f/5 (MMIRS and non-MMIRS) and f/9 WFS's from January through March 2017. Seeing values are corrected to zenith. f/5 seeing values are shown in blue (MMIRS) and green (non-MMIRS) while f/9 values are in red. Data from MMIRS are typically sampled more frequently than for other instruments.

## User Support

### Web Pages

B. Weiner began collecting material for an updated web page for Binospec, in anticipation of user needs for information for proposals in future semesters.

### Remote Observing

The MMTO supported 21 nights of remote observing this quarter. Eleven nights were for UA observers, with 10 nights for CfA observers.

### Data Quality Assessment

### Data Archive

### Reduction Procedures

B. Weiner is assisting Hectospec users who are having problems with Hectospec data reduction, and has prepared a web page listing common problems and solutions.

## Documentation

### Document Database

### Procedures

## Public Relations and Outreach

### Visitors and Tours

1/11/17 and 1/16/17 – Candidates for the Public Affairs Specialist for FLWO toured the facilities and were interviewed. J. Hinz and P. Fortin hosted these tours.

2/11/17 – Active Galactic Videos, a UA undergraduate student group, interviewed and filmed G. Williams at the MMTO. Under the guidance of Dr. C. Impey, the group has filmed various observatories and telescopes in southern Arizona. The final MMT video is posted on YouTube at: https://www.youtube.com/watch?v=rKfHWmWCyVE

3/4/17 – D. McCarthy led a tour of the MMT and FLWO facilities for prospective astronomy graduate students for Steward Observatory. D. McCarthy is also the chair of the MMT Council.

3/30/17 - Members of the Benson City Council and Planning and Zoning Committee toured the FLWO and MMTO, with J. Hinz, A. Terry, and E. Falco in attendance.

### Public Presentations

G. Williams gave a talk on "The 3D Nature of Supernovae: Are Exploding Stars Round?" at an *Astronomy on Tap* evening on January 25.

J. Hinz hosted the 47th annual Smithsonian Lecture Series on Astronomy held at the Green Valley Recreation Center West. Five lectures featured astronomers from The University of Arizona, Arizona State University, and FLWO.

The MMTO once again hosted a booth at the 2017 Tucson Festival of Books in the Science City area on March 11 and 12. The virtual reality tour of the observatory created by D. Porter again proved to be popular with visitors!

G. Williams gave a presentation on March 1 to the FLWO tour guides and volunteers as a refresher course before tours re-started on March 13.

G. Williams gave a presentation at the "Night Under the Stars" held at the Historic Hacienda de la Canoa on March 31.

**MMTO in the Media**

**Site Protection**

G. Williams and J. Hinz continue to attend monthly meetings of the Arizona Astronomy Consortium (AzAC), formerly named APSS. The newly designed website for this organization is at http://azastronomy.org.

J. Hinz continued to serve on the Benson Outdoor Lighting Code Committee, which met January 19 and February 9. A draft of the new outdoor lighting code was passed to the Benson Planning and Zoning Committee for review and will be subject to public hearings in the near future.

# Appendix I - Publications

**MMT Related Scientific Publications**
*(An online publication list can be found in the MMTO ADS library at http://www.mmto.org/node/244)*

17-01 Core-collapse Supernova Progenitor Constraints Using the Spatial Distributions of Massive Stars in Local Galaxies
T. Kangas, L. Portinari, S. Mattila, et al.
*A&A*, **597**, 92

17-02 Chromospheric and Coronal Activity in the 500 Myr old Open Cluster M37: Evidence for Coronal Stripping?
A. Núñez, M.A. Agüeros, K.R. Covey, et al.
*ApJ*, **834**, 176

17-03 Mapping the Polarization of the Radio-Loud Lyα Nebula B3 J2330+3927
C. You, A. Zabludoff, P. Smith, et al.
*ApJ*, **834**, 182

17-04 Multi-epoch Spectropolarimetry of SN 2011fe
P.A. Milne, G. Grant Williams, A. Porter, et al.
*ApJ*, **835**, 100

17-05 An Ultraviolet Excess in the Superluminous Supernova Gaia16apd Reveals a Powerful Central Engine
M. Nicholl, E. Berger, R. Margutti, et al.
*ApJ Lett*, **835**, 8

17-06 Infrared Polarimetry of Mrk 231: Scattering of Hot Dust Grains in the Central Core
E. Lopez-Rodriguez, C. Packham, T.J. Jones, et al.
*MNRAS*, **464**, 1762

17-07 Ejection of the Massive Hydrogen-rich Envelope Timed with the Collapse of the Stripped SN 2014C
R. Margutti, A. Kamble, D. Milisavljevic, et al.
*ApJ*, **835**, 140

17-08 On the Dearth of Ultra-faint Extremely Metal-poor Galaxies
J. Sánchez Almeida, M.E. Filho, C. Dalla Vecchia, et al.
*ApJ*, **835**, 159

17-09 To the Edge of M87 and Beyond: Spectroscopy of Intracluster Globular Clusters and Ultracompact Dwarfs in the Virgo Cluster
Y. Ko, H.S. Hwang, J.G. Lee, et al.
*ApJ*, **835**, 212

17-10 Luminous and Variable Stars in M31 and M33. IV. Luminous Blue Variables, Candidate LBVs, B{e} Supergiants, and the Warm Hypergiants: How to Tell Them Apart
R.M. Humphreys, M.S. Gordon, J.C. Martin, et al.
*ApJ*, **836**, 64

17-11 The Dependence of Cluster Galaxy Properties on the Central Entropy of their Host Cluster
J.-W. Kim, J. Ko, H.S. Hwant, et al.
*ApJ*, **836**, 105

17-12 A Multi-epoch Kinematic Study of the Remote Dwarf Spheroidal Galaxy Leo II
M.E. Spencer, M. Mateo, M.G. Walker, et al.
*ApJ*, **836**, 202

17-13 A Survey of the Local Group of Galaxies for Symbiotic Binary Stars – I. First Detection of Symbiotic Stars in M33
J. Mikolajewska, M.M. Shara, N. Caldwell, et al.
*MNRAS*, **465**, 1699

17-14 The SLUGGS Survey: A Catalog of Over 4000 Globular Cluster Radial Velocities in 27 Nearby Early-type Galaxies
D.A. Forbes, A. Alabi, J.P. Brodie, et al.
*AJ*, **153**, 114

17-15 A Ringed Dwarf LINER 1 Galaxy Hosting an Intermediate-mass Black Hole with Large-scale Rotation-like Hα Emission
W.-J. Liu, L. Qian, X.-B. Dong, et al.
*ApJ*, **837**, 109

17-16 The X-Ray and Mid-infrared Luminosities in Luminous Type 1 Quasars
C.-T. J. Chen, R.C. Hickox, A.D. Goulding, et al.
*ApJ*, **837**, 145

17-17 The Diversity of Diffuse Lyα Nebulae Around Star-forming Galaxies at High Redshift
R. Xue, K.-S. Lee, A. Dey, et al.
*ApJ*, **837**, 172

17-18 The Metallicity Distribution and Hot Jupiter Rate of the Kepler Field: Hectochelle High-resolution Spectroscopy for 776 Kepler Target Stars
X. Guo, J.A. Johnson, A.W. Mann, et al.
*ApJ*, **838**, 25

17-19 Blue Diffuse Dwarf Galaxies: A Clearer Picture
B.L. James, S.E. Koposov, D.P. Stark, et al.
*MNRAS*, **465**, 3977

17-20 Dust Masses for SN 1980K, SN1993J and Cassiopeia A from Red-Blue Emission Line Asymmetries
A. Bevan, M.J. Barlow, and D. Milisavljevic
*MNRAS*, **465**, 4044

17-21 Separating Galaxies from the Cluster Dark Matter Halo in Abell 611
A. Monna, S. Seitz, M.J. Geller, et al.
*MNRAS*, **465**, 4589

**MMT Technical Memoranda / Reports**

None

**Non-MMT Related Staff Publications**

Updated 34-Band Photometry for the SINGS/KINGFISH Samples of Nearby Galaxies
Dale, D. A., et al. (J. Hinz)
*ApJ*, **837**, 90

## Appendix II - Service Request (SR) and Response Summary: January - March, 2017

The MMT Service Request (SR) system is an online tool to track ongoing issues that arise primarily during telescope operations, although the system can be used throughout the day and night by the entire staff. Once an SR has been created, staff members create responses to address and eventually close the SR. These SRs and associated responses are logged into a relational database for later reference.

Figure 8 presents the distribution of SR responses by priority during the period of January through March 2017. As seen in the figure, the highest percentage (38%) of responses have "Important" priority, followed by 33% as "Information Only" priority. There were 21% for both the "Near Critical" and 8% for the "Critical" priority. There were no "Low" priority responses.

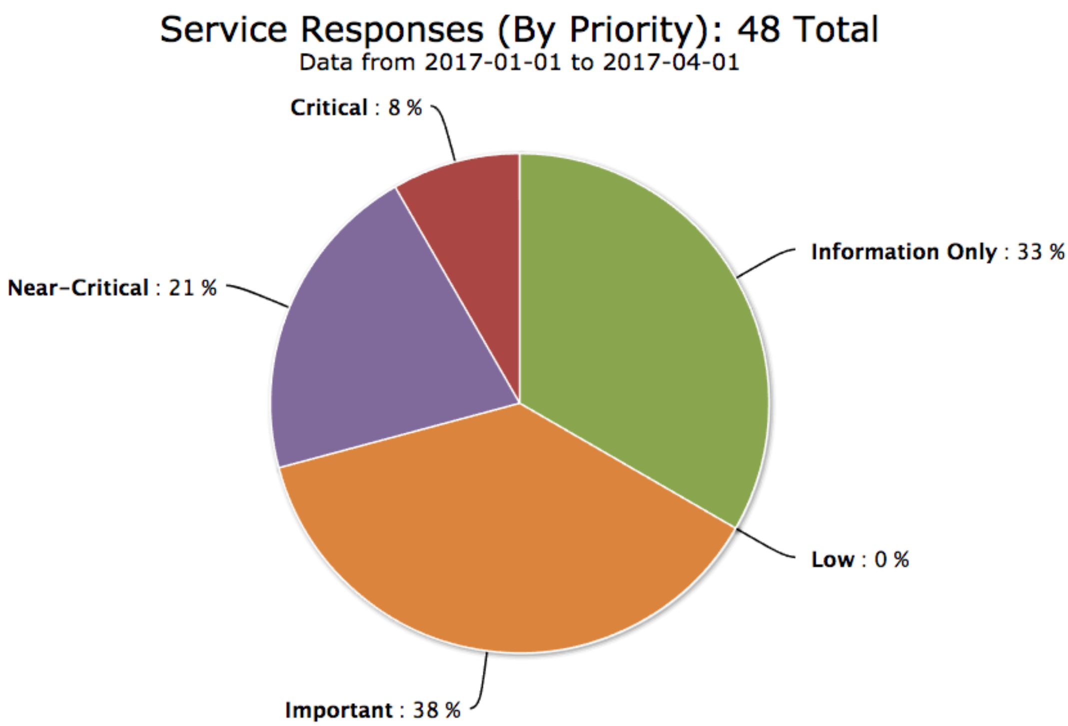


Figure 8. Service Request (SR) responses by priority during January through March 2017. 38% of the SRs were "Important" while 33% were "Information Only" priority. 21% of the SRs were "Near Critical" while only 8% were "Critical" priority. There were no "Low" priority SRs.

"Critical" SRs address issues that are preventing telescope operation, while "Near-Critical" SRs relate to concerns that pose an imminent threat to continued telescope operation. There was a total of 48 SRs during this three-month period, down from 54 SRs during the previous three-month reporting period.

Figure 9 presents the same 48 SR responses grouped by category. These categories are further divided into subcategories for more detailed tracking of issues. The majority of the responses from January through March are related to the "Software" category with 16 responses. Nine responses were made under the "Cell" category while seven responses were within the "Telescope" category. Responses also occurred in the "Building," "Computers/Network," "Pit," and "Weather Systems" categories.

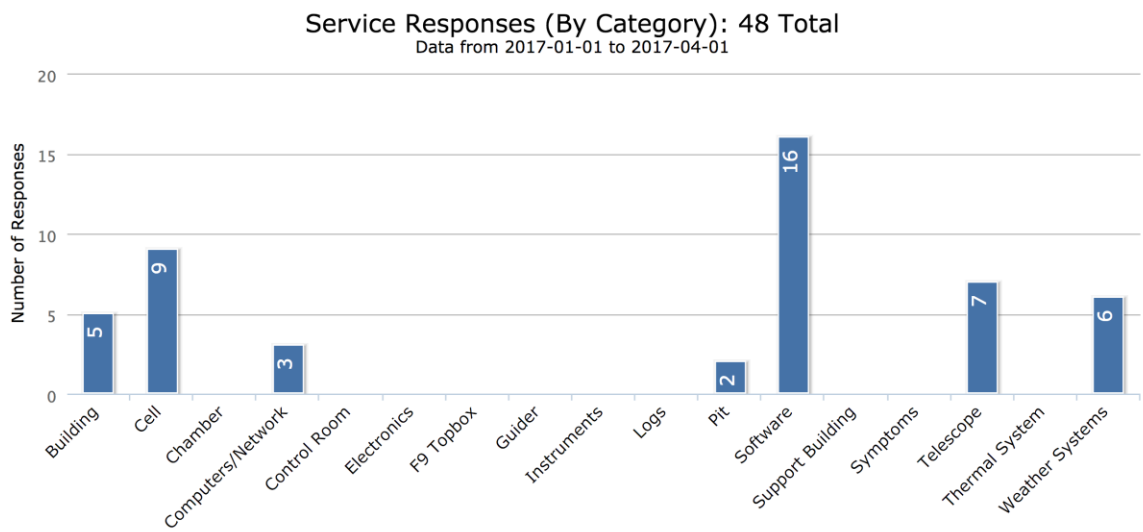


Figure 9. Service Request responses by category during January through March 2016. The majority of responses were within the "Software," "Cell," and "Telescope" categories.

## Appendix III - Observing Statistics

The MMTO maintains a database containing relevant information pertaining to the operation of the telescope, facility instruments, and the weather. Details are given in the June 1985 monthly summary. The data attached to the back of this report are taken from that database.

# Use of MMT Scientific Observing Time

## January 2017

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 15.00 | 177.10 | 116.30 | 0.00 | 0.00 | 0.00 | 0.00 | 116.30 |
| PI Instr | 14.00 | 164.10 | 105.40 | 1.75 | 0.00 | 0.00 | 0.00 | 107.15 |
| Engr | 2.00 | 23.80 | 8.50 | 0.00 | 0.00 | 0.00 | 0.00 | 8.50 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **31.00** | **365.00** | **230.20** | **1.75** | **0.00** | **0.00** | **0.00** | **231.95** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 93.5 |
| Percentage of time scheduled for engineering | 6.5 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 63.1 |
| Percentage of time lost to instrument | 0.5 |
| Percentage of time lost to telescope | 0.0 |
| Percentage of time lost to general facility | 0.0 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 63.5 |

* Breakdown of hours lost to instrument
1.75 H'chelle fiber positioner gripper claw malfunction

## February 2017

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PI Instr | 27.00 | 300.90 | 146.23 | 1.08 | 8.50 | 0.25 | 0.00 | 156.06 |
| Engr | 1.00 | 11.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **28.00** | **312.20** | **146.23** | **1.08** | **8.50** | **0.25** | **0.00** | **156.06** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 96.4 |
| Percentage of time scheduled for engineering | 3.6 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 46.8 |
| Percentage of time lost to instrument | 0.3 |
| Percentage of time lost to telescope | 2.7 |
| Percentage of time lost to general facility | 0.1 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 50.0 |

* Breakdown of hours lost to instrument
0.33 Hecto guider camera gain issue
0.50 Aries imager side crashed
0.25 Hecto robot hung up

** Breakdown of hours lost to telescope
4.00 AO-M2 power supply
0.50 Topbox power issues
1.00 AO camera issues
2.50 DM/BCU com. issues due to Microgate switch moved
0.50 Oscillation

*** Breakdown of hours lost to facility
0.25 Water spilled on Observer keyboard (it was replaced)

## Year to Date February 2017

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | Lost to Instrument | Lost to Telescope | Lost to Gen'l Facility | Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 15.00 | 177.10 | 116.30 | 0.00 | 0.00 | 0.00 | 0.00 | 116.30 |
| PI Instr | 41.00 | 465.00 | 251.63 | 2.83 | 8.50 | 0.25 | 0.00 | 263.21 |
| Engr | 3.00 | 35.10 | 8.50 | 0.00 | 0.00 | 0.00 | 0.00 | 8.50 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **59.00** | **677.20** | **376.43** | **2.83** | **8.50** | **0.25** | **0.00** | **388.01** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 94.8 |
| Percentage of time scheduled for engineering | 5.2 |
| Percentage of time scheduled for sec/instr change | 0.0 |
| Percentage of time lost to weather | 55.6 |
| Percentage of time lost to instrument | 0.4 |
| Percentage of time lost to telescope | 1.3 |
| Percentage of time lost to general facility | 0.0 |
| Percentage of time lost to environment (non-weather) | 0.0 |
| Percentage of time lost | 57.3 |

**March 2017**

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | *Lost to Instrument | **Lost to Telescope | ***Lost to Gen'l Facility | ****Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 19.00 | 193.30 | 47.59 | 0.00 | 0.25 | 0.25 | 0.00 | 48.09 |
| PI Instr | 8.00 | 83.90 | 23.20 | 1.00 | 2.00 | 0.00 | 0.00 | 26.20 |
| Engr | 4.00 | 41.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **31.00** | **318.50** | **70.79** | **1.00** | **2.25** | **0.25** | **0.00** | **74.29** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 87.0 |
| Percentage of time scheduled for engineering | 13.0 |
| Percentage of time scheduled for secondary change | 0.0 |
| Percentage of time lost to weather | 22.2 |
| Percentage of time lost to instrument | 0.3 |
| Percentage of time lost to telescope | 0.7 |
| Percentage of time lost to general facility | 0.1 |
| Percentage of time lost to environment | 0.0 |
| Percentage of time lost | 23.3 |

* Breakdown of hours lost to instrument

1.00 Hecto robots sequence-following failure

** Breakdown of hours lost to telescope

0.25 WFS problems

2.00 Trouble shooting telescope oscillation

*** Breakdown of hours lost to facility

0.25 Az drive problems

**Year to Date March 2017**

| Instrument | Nights Scheduled | Hours Scheduled | Lost to Weather | Lost to Instrument | Lost to Telescope | Lost to Gen'l Facility | Lost to Environment | Total Lost |
|---|---|---|---|---|---|---|---|---|
| MMT SG | 34.00 | 370.40 | 163.89 | 0.00 | 0.25 | 0.25 | 0.00 | 164.39 |
| PI Instr | 49.00 | 548.90 | 274.83 | 3.83 | 10.50 | 0.25 | 0.00 | 289.41 |
| Engr | 7.00 | 76.40 | 8.50 | 0.00 | 0.00 | 0.00 | 0.00 | 8.50 |
| Sec Change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **90.00** | **995.70** | **447.22** | **3.83** | **10.75** | **0.50** | **0.00** | **462.30** |

Time Summary

| | |
|---|---|
| Percentage of time scheduled for observing | 92.3 |
| Percentage of time scheduled for engineering | 7.7 |
| Percentage of time scheduled for secondary change | 0.0 |
| Percentage of time lost to weather | 44.9 |
| Percentage of time lost to instrument | 0.4 |
| Percentage of time lost to telescope | 1.1 |
| Percentage of time lost to general facility | 0.1 |
| Percentage of time lost to environment | 0.0 |
| Percentage of time lost | 46.4 |