FY2023
Annual Progress Report

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The National Solar Observatory is operated by the
Association of Universities for Research in Astronomy, Inc. (AURA) under
Cooperative Agreement with the National Science Foundation

MISSION

The mission of the NSO is to advance knowledge of the Sun, both as an astronomical object and as the dominant external influence on Earth, by providing forefront observational opportunities to the research community. The NSO operates the world's most extensive collection of ground-based optical and infrared solar telescopes and auxiliary instrumentation, allowing solar physicists to probe all aspects of the Sun, from the deep solar interior, to the photosphere and chromosphere, to the outer corona and out into the interplanetary medium. These assets also provide data for heliospheric modeling, space weather forecasting, and stellar astrophysics research, putting our Sun in the context of other stars and their environs. NSO accomplishes this mission by:

- providing leadership for the development of new ground-based facilities that support the scientific objectives of the solar and space physics community;
- advancing solar instrumentation in collaboration with university researchers, industry, and other government laboratories;
- providing background synoptic observations that permit solar investigations from the ground and space to be placed in the context of the variable Sun;
- facilitating community understanding of the increasingly complex data produced by NSO's facilities;
- providing research opportunities for undergraduate and graduate students, helping develop classroom activities, working with teachers, mentoring high school students, and recruiting underrepresented groups;
- innovative staff research.

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

- ***Understand the mechanisms generating solar cycles –*** Understand mechanisms driving the surface and interior dynamo and the creation and destruction of magnetic fields on both global and local scales.
- ***Understand the coupling between the interior and surface*** **–** Understand the coupling between surface and interior processes that lead to irradiance variations and the build-up of solar activity.
- ***Understand the coupling of the surface and the envelope: transient events*** – Understand the mechanisms of coronal heating, flares, and coronal mass ejections which lead to effects on space weather and the planet.
- ***Explore the unknown*** – Explore fundamental plasma and magnetic field processes on the Sun in both their astrophysical and laboratory context.

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1 EXECUTIVE SUMMARY

The National Solar Observatory (NSO) is the primary provider of key ground-based solar facilities to the US solar community. NSO makes available to the community a range of assets that allow solar astronomers to probe all aspects of the Sun, from the deep interior to the corona, the interface with the interplanetary medium or Heliosphere. As the Daniel K. Inouye Solar telescope (DKIST) continued its commissioning in FY 2023, NSO provided renewed scientific and instrumentation leadership in high-resolution studies of the solar atmosphere in the visible and infrared, and continued synoptic observations of solar variability, and helioseismology.

Major components of the National Solar Observatory core planning include:

- Operating the National Science Foundation's (NSF) 4-meter DKIST on behalf of, and in collaboration with, the solar and astronomical community.
- Continuing DKIST technical improvements, including site and facility repairs and upgrades.
- Distributing calibrated DKIST data to the community of users.
- Operating the suite of instruments comprising the NSO Integrated Synoptic Program (NISP). This Program includes the Global Oscillation Network Group (GONG) and the Synoptic Optical Long-term Investigation of the Sun (SOLIS).
- Developing partnerships to establish a future network concept (next-generation GONG, ngGONG) that replaces GONG and SOLIS and provides ground-based solar data adapted to the research community's demands and the Space Weather operational stakeholders.

In parallel with these major components, NSO continues to:

- Expand interagency collaborations for NISP following the guidance in the National Space Weather Strategy and Action Plan and the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act[1].
- Finalize the upgrade of the GONG network to adapt it to the Space Weather community's needs, ensuring its competitive continuation in solar Cycle 25.
- Develop Multi-Conjugate Adaptive Optics (MCAO) and other critical instrumental upgrades for the DKIST.
- Continue defining the transition of the Dunn Solar Telescope (DST) operations to a consortium led by New Mexico State University (NMSU).
- Increase diversity of the solar workforce using the REU and Akamai opportunities and others as available.

Some of the programmatic highlights of the NSO Program in FY 2023 included:

- Ending the first Operations Commissioning Phase (OCP1) of the DKIST.
- Starting the execution of experiments derived from observing proposals prioritized by the DKIST Time Allocation Committee (TAC) following the second OCP call (OCP2).
- Commissioning the DKIST Data Center (DC) by receiving, processing, and delivering data obtained during OCP1 and OCP2.
- Planning for restarting operations of the SOLIS suite of instruments at Big Bear Solar Observatory (BBSO).
- Continuing the GONG refurbishment project and testing of the newly acquired cameras.

[1] https://www.congress.gov/bill/116th-congress/senate-bill/881

- Furthering the science case and management aspects of the ngGONG project and submitting a design proposal to the NSF's Mid-scale Research Infrastructure solicitation.
- Testing the Level-2 pipelines with data from OCP as available.
- Advancing the definition of the interfaces between the DKIST Level-1 data and the Level-2 pipelines.

Additional actions to advance solar physics that NSO undertook in FY 2023 include:

- Engaging with the panels of the Decadal Survey for Solar and Space Physics (Heliophysics) 2024-2033 as requested.
- Finalizing and start executing the DKIST Communications Plan to publicize the early science phase of the facility in close coordination with the NSF.
- Strengthening the connections between the in-situ and remote-sensing communities to fully realize the potential of multi-messenger solar and heliospheric physics by coordinated campaigns using Director's Discretionary Time (DDT) and through the activities included in the Windows of the Universe Multi-Messenger Astronomy (WoU-MMA) Supplemental Funding Requests (SFR).

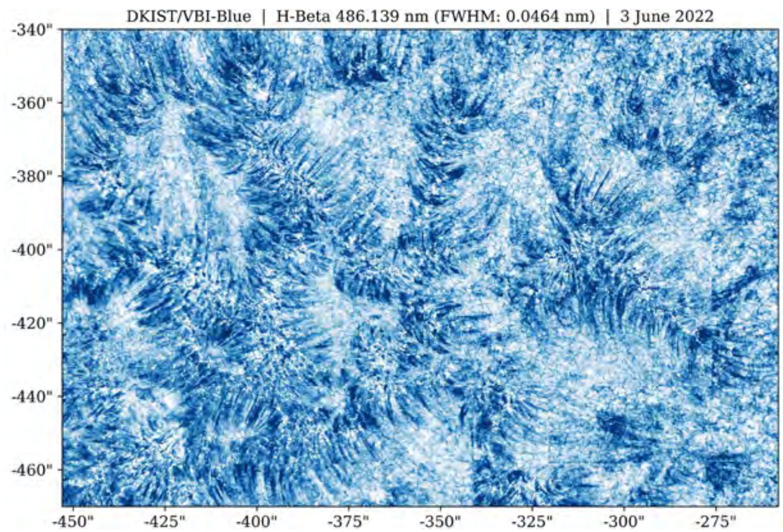

Figure 1.1. *An H-Beta image from Visible Broadband Imager of a plage region near the southeast limb of the sun obtained on June 3, 2022, during a coordinated campaign with Parker Solar Probe. This region was co-observed with the ViSP instrument that obtained photospheric and chromospheric spectropolarimetric data. The data was released on December 12, 2022.*

The NSO budget in FY 2023 remained flat at FY 2022 levels, with expected funding levels for DKIST operations of $19.58M and $5.88M for the rest of the Observatory, i.e., the NSO Director's office, NISP, and NSO Community Science Program (NCSP). NSF obligated for DKIST operations only $4.9M with the expectation that the program will use carry forward funds first and will receive the remaining $14.96M in FY 2024. For the operations of the Sunspot site, NSO received supplemental funding for a total of $1.28M in FY 2023.

The NSO budget was augmented by the corresponding funds from two WoU-MMA supplemental funding actions. The first corresponds to the second year of the FY 2021-awarded WoU-MMA for a total of $660K, with the eclipse's activities as part of the scope. These funds are allocated to NCSP. The second represents the first year of the FY 2022-awarded WoU-MMA SFR $985K managed by NISP. The funding received from NOAA in FY 2023 for GONG operations was of $1.06M and is also governed by NISP.

NSO/AURA held conversations with the NSF about the current Cooperative Agreement (CA) expiration in FY 2024 and the renewal process. To accommodate the new requirement of a DKIST Concept for Operations (ConOps) review, described in the Research Infrastructure Guide (RIG), an extension of the existing CA for at least one, but most likely, two years is necessary. The ConOps review concept appeared as a formal requirement for the Project Execution Plan (PEP) for new facilities in the RIG of 2017. (We note that the DKIST's PEP precedes this date and does not include a ConOps plan as a deliverable.) The conversations with the NSF are still ongoing, but at the time of this writing, NSO is preparing to submit for review a CA extension proposal first and a ConOps plan later. Both submissions require a formal review process with an external committee.

In FY 2023, AURA lifted the COVID-19 emergency telework mandate, and the NSO personnel started working under hybrid and remote working arrangements following revised policies that allow employees to perform their regular job responsibilities at an alternative worksite for a portion of their scheduled workweek. The hybrid/remote agreements are valid for six months, and AURA HR regularly revises them in coordination with supervisors. An updated Coronavirus Exposure Prevention Plan (CEPP) continues to be the AURA-wide reference policy to minimize health risks at the offices and the NSO-operated facilities.

A renewed and expanded NSO Users' Committee (UC) met for the first time on the island of Maui in May 2023. The UC had the opportunity to tour the DKIST and appreciate its complexity. This meeting was the first time the UC included members using data from DKIST. There were in-depth conversations about the current capabilities of the instruments available and the usability of the data. The UC emphasized in their report the necessity for community efforts that provide training on data usage based on the actual performance of the instruments and known challenges. The report also highly values the availability of data obtained using Director's Discretionary Time (DDT) with no proprietary period, immediately available for use by the community after calibration. For NISP, the UC emphasizes prioritizing maintaining the flow of GONG data products, refurbishing the network with the new cameras, and the first light of SOLIS. The UC recommends regular community updates about these efforts. The UC also requests revising the Observatory's website to improve its usability and discoverability.

The NSO's Education and Public Outreach (EPO) team continued to use a multipronged strategy to publicize the scientific and technical achievements obtained by the Observatory in FY 2023. The NSO's Blog (*https://nso.edu/blog/*) is the content pillar for NSO communications in disseminating news, updates, and stories to a diverse audience. Sixteen Blog entries were published in FY 2023 with a subscription service available on the website. The EPO team further distributes the topics that appear in the Blog and NSO's Press Releases on various social media platforms.

Following the highly successful inauguration of the DKIST by the NSF in August 2022, the EPO team collaborated with NSF's outreach team to continue publicizing STEM initiatives that the DKIST project pursued since the start of the construction project and that have contributed to creating a diverse workforce for the facility. The Akamai program was particularly successful over the years and was the basis of a video released by the NSF and the NSO in December of 2022[2]. To continue inspiring the local community in Maui, the EPO team developed the Journey Through the Universe (in collaboration with NOIRLab) on the island of Maui, reaching to 26 classrooms and over 500 students (Figure 1.2). In March of 2023, the EPO team in Maui collaborated on the Solar Fest 2023 at the Haleakalā National Park, organizing science talks from the DKIST science team, and offering solar observations with amateur telescopes to the public.

[2] *https://www.youtube.com/watch?v=mMzEKE443Yw&t=11s*

Figure 1.2. *Participants in the 2023 Journey Through the Universe at a Maui school, including DKIST technical staff and members of the NSO's EPO team.*

A team of four members from the National Solar Observatory traveled in April to the Ningaloo Coast peninsula in Western Australia for the total solar eclipse. This activity is part of the preparatory ones for the 2024 continental US eclipse and was part of the scope of the second WoU-MMA SFR. Coincidentally, this peninsula is also the location of the Learmonth GONG observing station. During totality, NSO live streamed the images from the GONG site taken through an H-alpha filter showing the structures in the solar chromosphere obscured by the moon disc. To measure the temperature of the electrons in the corona during the moment of totality, the team attached a compact spectrograph to the back of an 8-inch diameter telescope (SuperCATE, Figure 1.3). In the days before the eclipse, the crew ran through a series of tests, properly aligning and focusing the image and spectrum on their detectors. The data obtained during totality is being analyzed by a student who participated in the expedition. The same team will prepare similar set-ups for the 2024 total solar eclipse in the continental US and Mexico, where they will benefit from the invaluable experience obtained in Australia.

Figure 1.3. *From left to right, camera with tracker, NSO's CATE2024 setup, and the spectrograph experiment (superCATE) ready for the total solar eclipse on April 20, 2023.*

A new Head of Education and Public Outreach, Dr. Jorge Perez-Gallego, started in June 2023. His main priorities after joining the Observatory have been formulating a unified strategy for the 2024 eclipse activities and continuing the discussion of the Communications Plan for the DKIST program. For the partial and total eclipses in FY 2024, the EPO team will produce a live public broadcast highlighting the science of the NSO with the primary content focused on three scientific observing programs: CATE 2024, SuperCATE, and a 2024's eclipse related DKIST DDT observing proposal. The broadcast ensures reaching a large and diverse audience—including the scientific community, citizen scientists, and the public.

The DKIST Communications Plan targets translating the facility's technical and scientific achievements into broader audiences' terms critical to fully reflecting their relevance. This communication strategy is rooted in generating quality, effective, owned media with essential requirements like access to solar images, scientific results, milestones, and other telescope "happenings" worth communicating. The figure of a communications liaison(s) between the EPO team and the DKIST Program has been identified to facilitate this access. The liaison's main function is to act as the DKIST's primary point of contact by passing information for DKIST-related communication efforts. On-going conversations have identified an Observatory scientist for the role of Scientific Communications Liaison and are expected to identify an Operations Communication Liaison soon.

In FY 2023, DKIST ended the first Operations Commissioning Phase (OCP1) with about 30 observing programs executed. DKIST operations staff also continued the proposal evaluation, experiment generation, and observing process for OCP2. During the execution of the regular on-sun OCP campaigns, operational efficiencies are being gained. However, bad weather during the winter periods affected the first two years of commissioning of the facility with frequent storms and power outages. This weather pattern indicates that winter periods are generally less productive scientifically, therefore DKIST is evaluating an operations model with longer engineering periods during the winter months and increased science observations during periods of optimal weather.

OCP2 received 93 proposals, and the TAC accepted 54 of them. This second commissioning phase started with planning for 109 on-sun days, with the rest of the time dedicated to technical engineering work. The facility will continue coordinating observations with the Parker Solar Probe (PSP) and Solar Orbiter missions using DDT). A total of 13 DDT days were planned at the start of OCP2.

Figure 1.4. *Examples of technical work at the facility. From left to right: enclosure rail work, chiller replacement, and vibrations mitigation.*

The technical time at the facility continues to play an essential role in diagnosing and mitigating issues that appear during regular operations (Figure 1.4). Some of the DKIST systems are already coming of age and need attention. Maintenance of major subsystems like the enclosure azimuthal rails has required considerable technical time. DKIST is tracking and continually improving performance for coronal observing modes through M1 mirror washing and CO_2 snow cleaning. The DKIST team continues to track down vibrations at the Telescope and Coudé levels that limit the performance of some of the instruments, and the team is implementing strategies to identify and attenuate them. For the Visible Spectro-Polarimeter (ViSP), the team repaired a known arm failure and started a camera maintenance program. The technical time also focuses on improving instruments' performance and providing stability for the most demanded observing modes. New additional observing modes that include less-frequently requested spectral lines, are slowly being tested at the facility. A major focus continues to increase the level of automation of systems (e.g. thermal systems), which will enable extending the effective observing time with the available staffing levels. In parallel, the team is working on instrument upgrades and new capabilities such as continued progress of MCAO, the development of new 4kx4k Infrared sensors/cameras, and the second etalon for the Visible Tunable Filter (VTF).

In FY 2023, considerable work was put into improving and finalizing the calibration of the instruments and their pipelines. The Visible Broadband Imager (VBI) data is ingested and distributed by the Data Center. Calibration and speckle reconstruction are currently being performed by members of the science team in Boulder. Calibrated Level-1 ViSP and VBI data were made available to PIs who, in some cases, interacted with the DKIST team, leading to updates of the processing pipelines. Specifically, the ViSP pipeline was subjected to significant improvements by members of the DKIST science team that eliminated known polarization artifacts, resulting in additional distributions of the newly calibrated Level-1 data (Figure 1.5). The Cryogenic Near-Infrared Spectro-Polarimeter (Cryo-NIRSP) off-limb coronal data pipeline is still in development and acceptance by the DKIST Science and Data Center teams. This pipeline is the first created for an infrared instrument performing coronal observations, which brings added complexity. The extreme Signal-to-Noise ratios required for coronal magnetometry result in complex calibration procedures that have to be developed and tested by science team members before the developed prototype code can be implemented at the Data Center. The pipeline leverages the experience gained by the ViSP process.

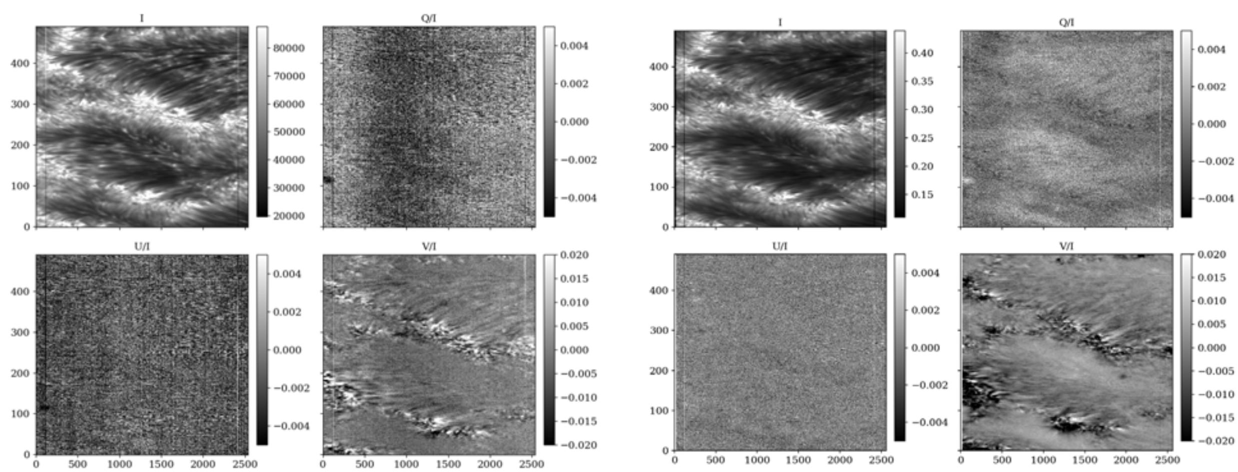

Figure 1.5. *Chromospheric vector magnetograms from ViSP using the Ca II 854nm line before (left) and after (right) the pipeline improvements.*

The Diffraction-Limited Near-Infrared Spectro-Polarimeter (DL-NISRP) pipeline work is progressing slowly, awaiting the IFU upgrade to a reflective image slicer (MISI-36). With this upgrade the DL-NIRSP will gain a factor of three in efficiency. Laboratory acceptance of MISI-36 occurred in July 2023 in preparation for the on-sun science verification phase in the spring of 2024. In parallel, the VTF instrument left Freiburg, Germany in October 2023, following successful laboratory acceptance tests in July. The instrument was disassembled and packaged after addressing the most outstanding issues found in the laboratory. Science verification will also occur during 2024 and is anticipated to be concluded at the end of 2024.

In conjunction with the AGU "DKIST early Science" session in December 2022, the team released the first publicly available data set obtained using DDT time during an on-sun campaign with PSP held in early June 2022. The data sets correspond to the observations from VBI and ViSP of a plage region near the southeast solar limb (see Figure 1.1); the consensus pointing for PSP. Like all DDT datasets, this one had no proprietary period and was extensively downloaded by the community leading to a number of publications. NCSP performed Level-2 inversions on these DDT data sets inverting simultaneously the Fe I 630nm and the Ca II 854nm ViSP channels. Additional DDT observations will become public in the immediate future.

The island of Maui suffered a series of devastating wildfires in early August 2023. One series of wildfires occurred in the upcountry area of Maui near the DKIST Science Support Center (DSSC) and along the road to the summit of Haleakalā. Concurrently, a second series of wildfires occurred on west Maui, obliterating most of the city of Lahaina. The impacts were felt everywhere on the island. NSO personnel and their families were impacted to various degrees, and DKIST operations were suspended for roughly two weeks. The facility itself was without power for several days, and upon the restoration of power, the team returned to performed technical and safety inspections. NSO and AURA requested the use of administrative leave-time for the personnel on the island to allow for coping with the most pressing consequences created by the events. NSF authorized this request on August 10th offering three weeks of administrative leave-time for the personnel on the island. The team was able to regain operational status of the facility and continue scheduled critical work within one week and return to observational readiness within two weeks. These events will have long-term impacts beyond the initial devastation aggravating already existing staffing challenges on the island.

As explained above, FY 2023 was a busy year for the DKIST team. Tremendous progress was achieved despite some typical setbacks encountered during the commissioning of such a complex facility. Throughout FY 2023, the team continued preparing and conducting science observations, fixing bugs, and solving technical problems, maintaining and upgrading the facility, and developing future state-of-the-art capabilities. An inherent goal for the DKIST team, subject to multiple internal discussions, continues to be focused on improving efficiencies, achieving a larger percentage of on-sun science time, and improving data quality. However, achieving this objective has proved challenging as the team in Maui and Boulder is clearly stretched thin. DKIST has strengthened the leadership team with a Deputy Associate Director in FY 2023.

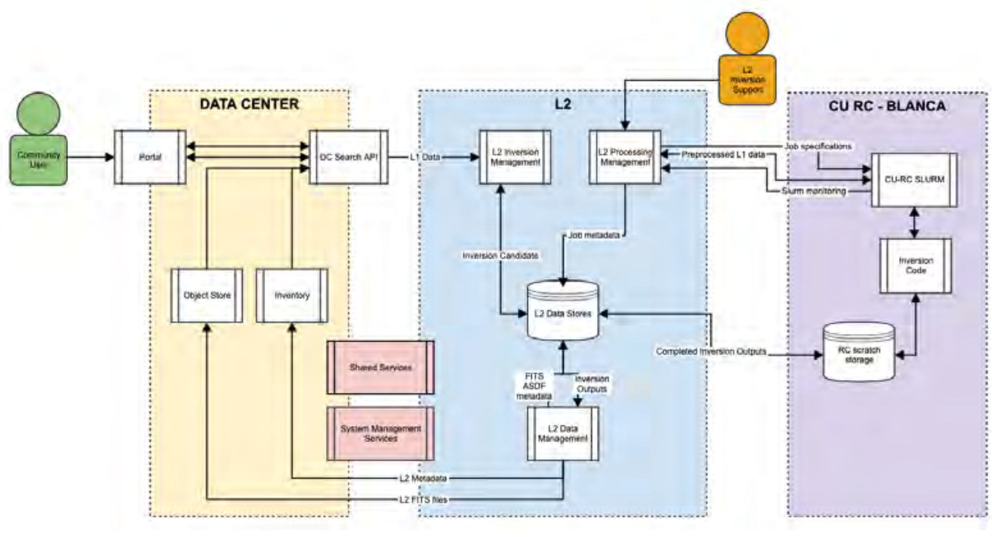

Figure 1.6. *Architecture being implemented at the DKIST DC to transfer Level-1 data to the Level-2 inversion codes and back.*

Using NCSP funds, the DKIST DC hired in FY 2023 a Level-2 engineer to implement the infrastructure that interfaces the Level-1 DC hardware and the Level-2 cluster Blanca (Figure 1.6) used for spectropolarimetric inversions. The DC team is outlining the steps of the process and documenting data dependencies like the metadata required for Level-2 qualification. The requirement is to automate the discovery of the data and the

Level-2 processing inversions, the creation of the metadata for provenance and search, and the retrieval of results and push to the DC. A final step will be determining and implementing changes required in the DC infrastructure and the data portal to accommodate Level-2 data products.

NISP saw an unusual number of stations' downtime due to natural disasters, weather conditions, and technical issues (Figure 1.7). Big Bear Solar Observatory (BBSO) went through one of the strongest snowstorms on record in March 2023. Wildfires in August impacted the station at Teide Observatory, which stopped providing data for a few days. The road closure from the volcano affecting the Mauna Loa (ML) site has prevented the restart of operations there. NOAA expects to reestablish road access in May/June 2024, and we anticipate recovering the ML site before August 2024. A cyber incident at Cerro-Tololo affected data download and prevented all inbound traffic for several weeks. The Learmonth and Udaipur stations required additional preventive maintenance trips, other than the regularly scheduled ones, due to repeated technical problems in both stations. We are clearly seeing an increased rate of failures at different sites due to aging systems like detectors and polarization modulators. Some temporary mitigations have been deployed to the sites, but a more robust medium-term solution requires the deployment of hardware, including new cameras. A new network deployment is the only long-term fix to this issue.

Figure 1.7. *This year, the GONG network sites have been highly impacted by natural disasters. From left to right: snowstorm at BBSO (California), the lava flows at ML (Hawai'i), and the wildfires at Teide Observatory (Canary Islands, Spain).*

The diversity of issues seen in FY 2023 at various GONG locations slowed down other NISP tasks, such as finalizing the camera development or the SOLIS deployment. Three Data Acquisition Systems (DAS) for the new GONG cameras are on hold, awaiting a solution to an image sync issue recently discovered and created by software updates from the vendor. This delay pushes the deployment of the first camera to 2024. SOLIS is also suffering delays due to a combination of vendor responsiveness, limited staffing, and a small team with multiple ongoing projects (GONG operations, GONG refurbishment, and SOLIS relocation). A critical glycol chiller replacement for SOLIS/VSM is waiting for vendor delivery after multiple delays. The glycol chiller unit must be installed before the first light observations, which are now planned for 2024. All other major SOLIS site construction and land mitigation issues have been completed.

New synoptic map development progresses as part of WoU-MMA SFRs. The partner institutions meet regularly at team meetings to report progress. NSO provides new data products for testing to the NASA/GSFC team that uses specific metrics to quantify the improvements in their prediction of in-situ conditions. Incorporating Solar Orbiter Polarimetric and Helioseismic Imager (PHI) observations into GONG synoptic maps continued in FY 2023. The progress has been slow as the data released from the PHI instrument is less than expected, and the PHI team continues reprocessing older data sets. We expect the first combined GONG/PHI synoptic magnetogram will be available in FY 2024. The in-situ predictions of this magnetogram will be compared with those produced routinely using GONG only.

In May 2023, NSO/AURA submitted a design proposal to the NSF's Mid-Scale Research Infrastructure-1 (MSRI-1) Program for replacing the GONG, the Next Generation GONG (ngGONG) network. The proposal covered 2.5 years, reaching Preliminary Design Review. The deliverables of the proposal included the Preliminary Design and specifications of the ngGONG system, a Detailed Construction Schedule and Cost Estimates, Site Characterizations and Selection, the identification of partnerships (construction and operations), a draft construction Project Execution Plan and the related documents; and a high-level concept of operations and associated cost estimate of the network. The current construction cost estimate ($240M) exceeds the MSRI cap; however, considering domestic and international partner contributions, the cost to NSF could fit under the MSRI limit.

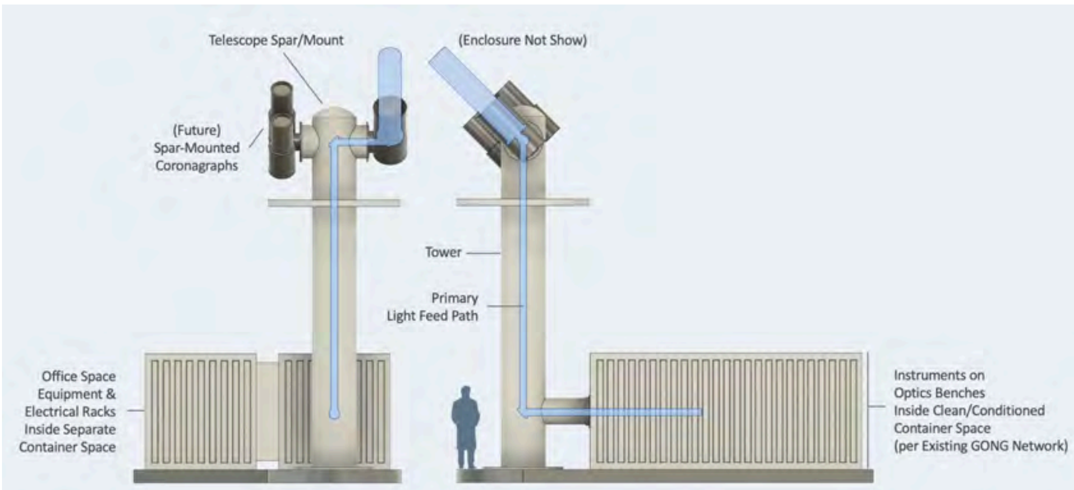

Figure 1.8. *The proposed concept of ngGONG uses a tower for the telescopes to minimize ground layer seeing effects and two shelters, one acting as office space and hosting most of the electronic equipment and another one with a cleaner environment containing the instruments.*

The ngGONG concept (Figure 1.8) builds upon GONG's success using the same sites with known weather and climate patterns, successful "shipping container" design, established site partnerships, and existing infrastructure. The project is estimated to employ about 15-20 FTEs at NSO, with a considerable fraction of them being existing staff. The proposed network can fulfill all the requirements of the research community and the Space Weather operational agencies. Table 1-1 below compares the performance of the proposed ngGONG network with those of the existing GONG.

Table 1.1. *Comparison of ngGONG and GONG High-level Capabilities*

Specification	ngGONG	GONG
Lifetime	30+ years after construction	EOL < 10 years
Duty cycle	>90% (6-site network)	same
Telescope aperture	50 cm (an order of magnitude increase)	2.8 cm
Magnetic field (vector)	photosphere and chromosphere	None
Magnetic field (LOS)	Photosphere (10 minute cadence)	Same
H-alpha	Line core and wings (Doppler velocities)	Line core only
Narrowband imaging	Several bandpasses	None
Cadence (helioseismology)	40-60 seconds	60 sec
Spatial sampling	0.5 arc sec	2.5 arc sec
Coronagraphy	White light and emission line coronagraphs	None
Sun-as-a-star	Disk-resolved and disk-integrated, same spectral lines	None
Future upgrades	Yes (e.g., multi-height helioseismology)	No

In late FY 2023, NSF informed NSO that the ngGONG proposal was not selected for funding in FY 2023 but was not rejected. Depending on the overall funding landscape for the Agency in FY 2024, NSO may receive funding to start design activities of the network.

In FY 2023, NSO and New Mexico State University (NMSU) carried out their responsibilities in Sunspot for scientific operations and site management. The two institutions submit each year an SFR for continued scientific activities at the site and urgent one-time deferred maintenance items categorized by their relevance to site safety and others of interest to NMSU. These SFRs are for one year of continued support to consolidate the ongoing implementation of Alternative 2 from the Final Environmental Impact Study and lays out the foundations for transferring the site's management to NMSU. The main tasks performed by the NSO maintenance team were:

- Main Lab Server Room move to the Dunn Solar Telescope. Final tie-in for new fiber optic cables for internet and telephone systems.
- Final removal of last few relocatable housing units.
- Trenching and replacing of 100 ft. sewer line by unit # 3015.
- Replacement of wastewater lift pumps & discharge line.
- Visitors Center Sewer Lift Station: Replace two lift pumps and replace the discharge line.
- Visitors Center boiler replacement for heating: Research Bid Remove & Install.
- Repaving of Visitor Center Parking lot.
- Road patching for Visitor Center and road by Redwood housing.
- Replacement of two water heaters in housing.
- Caping utility lines in the old relocatable housing area.
- Gathered and shipped out 26,124 pounds of old and obsolete electronics for recycling with certificate of recycling and destruction of all materials.

The above list does not reflect other daily duties as assigned. Examples of these duties are: Water sewer sampling to comply with New Mexico State Environmental Regulations, repairs on old aging equipment, regular minor maintenance calls for the Visitor Center and all housing units, and minor building maintenance.

NSO FY 2023 Program Milestones

- **Daniel K. Inouye Solar Telescope (DKIST)**
  - Continue the execution of experiments from the first OCP call (OCP1).
  - Rank the proposals from the second OCP call (OCP2) via the Time Allocation Committee.
  - Start the execution of proposals from OCP2.
  - Continue the DKIST Data Center implementation plan.
  - Continue developing Multi-Conjugate Adaptive Optics.
  - Continue the DKIST instrumental upgrades.
  - Elaborate the DKIST contribution to the new Cooperative Agreement proposal.
- **NSO Integrated Synoptic Program (NISP)**
  - Operate the GONG network. Continue the network data distribution.
  - Complete the SOLIS site at Big Bear and start operations.
  - Continue refurbishing the GONG network, prioritizing new detectors deployment.
  - Engage stakeholders (NOAA, AF, international partners) in the ngGONG preparatory design phase.
  - Elaborate the NISP contribution to the new Cooperative Agreement proposal.
- **NSO Community Science Program (NCSP)**
  - Execute and test the DKIST Level-2 data products pipelines.
  - Start the implementation of the Level-1/Level-2 hardware interface.
  - Elaborate the NCSP contribution to the new Cooperative Agreement proposal.
- **Sacramento Peak Observatory**
  - Operate the site.
  - Define the transfer of additional operational responsibilities to NMSU.
- **NSO Directorate**
  - Define the requirements and timeline for the NSO Data Center.
  - Lead community-based multi-messenger solar physics opportunities.
  - Lead the NSO proposal for the new Cooperative Agreement.
- **Education and Outreach and Broadening Participation**
  - Disseminate DKIST and Observatory-wide results.
  - Continue local engagement in Boulder and Maui.
  - Train a diverse future generation of solar astronomers.
  - Elaborate the EPO contribution to the new Cooperative Agreement proposal.

2 FY 2023 SCIENTIFIC RESEARCH & DEVELOPMENT HIGHLIGHTS

2.1 The First Infrared Coronal Spectra from DKIST/Cryo-NIRSP: Expanding the Frontier of Quantitative Coronal Spectroscopy and Polarimetry

The Daniel K Inouye Solar Telescope (DKIST) is not only the world's highest resolving solar telescope; it is also the world's largest solar coronagraph, capable of occulting the solar disk so as to measure the million-times fainter off-limb solar corona. As a central part of its science mission, coronagraphy at DKIST seeks to advance routine observations of infrared forbidden emission lines, which provide diagnostic tools for not only the plasma thermodynamic state, but critically, the ill-measured coronal magnetic field. Further in the infrared, the ratio of the magnetic field induced Zeeman line splitting to the thermal line width increases. This fact, plus generally improved scattered light performance, provides the observational advantage necessary to measure the magnetic-field-generated circularly-polarized signal that, while still very weak (on order of 1 to 10 parts per *billion* of the disk intensity), can be resolved using DKIST's large light collecting power.

The first major milestone for DKIST coronal science has been the successful detection and spectroscopic calibration of all four of its principle infrared emission line science targets. The CryoNIRSP team, in a publication lead by NSO's Dr. T. Schad, et al. (ApJ, 943, 59, 2023), reported commissioning observations of the Fe XIII 1074 nm, Fe XIII 1079 nm, Si X 1430 nm, and Si IX 3934 nm lines acquired by CryoNIRSP using a radial oriented slit sampling a coronal streamer. Figure 2.1 displays the fully processed spectral images in each spectral line between 1.06 and 1.52 solar radii, which covers the full range of the accessible DKIST off-limb field-of-view. The published article outlines in detail the processing required to accurately remove the scattered light background, as well as other instrument artifacts, to quantify the line characteristics. These early DKIST observations achieve a dynamic range of 140:1 in the Fe XIII 1079 nm line, comparable to observations acquired during total solar eclipses. Meanwhile, the detections of the Si X 1430 and Si IX 3934 nm are the first coronagraphic spectral observations of these lines in nearly two decades. A few recent observations of these lines have been achieved only during eclipses.

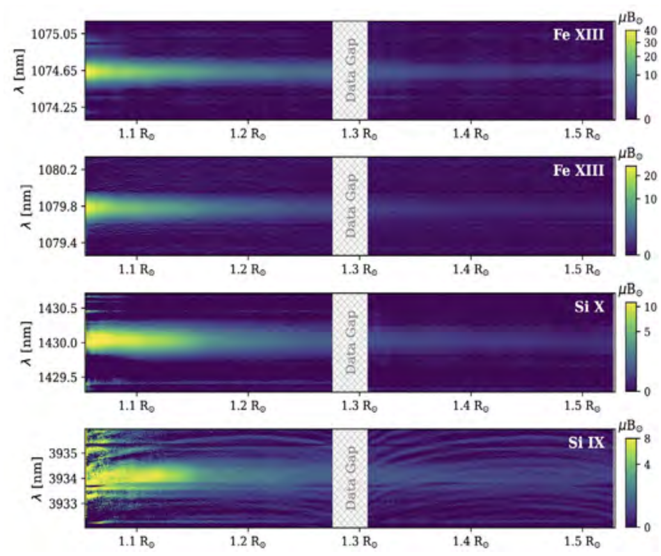

Figure 2.1. *Background corrected slit spectra acquired by the DKIST/CryoNIRSP instrument on 14 February 2022. The spectral radiance of each line is given in parts per million of the solar disk intensities.*

The spectral range of this plot is cropped from the original data. Note the presence of residual interference fringe artifacts in Si IX.

Schad et al. (2023) go on to compare these first DKIST coronal observations with forward calculations of the line radiance emergent from two PSI-MAS global coronal magnetohydrodynamic models that employ unique empirically-defined heating prescriptions. As shown in Figure 2.2**,** the DKIST observations show favorable correspondence with one of these models (#1), importantly, in all four lines simultaneously. This lends credence to the accuracy of the CryoNIRSP photometry in these four widely separated bands, while also demonstrating the potential for these observations as useful constraints on global modeling efforts. In particular, the density and photoexcitation dependence of these forbidden lines has an imprint on the spectral slope of the line radiance decline with elongation, which is unique in comparison to, e.g., EUV coronal lines. The infrared lines can therefore be a valuable supplement for established diagnostic techniques in the EUV, such as DEM and EM Loci analysis. This is in addition to their important polarized diagnostics, which is currently being advanced during DKIST early operations.

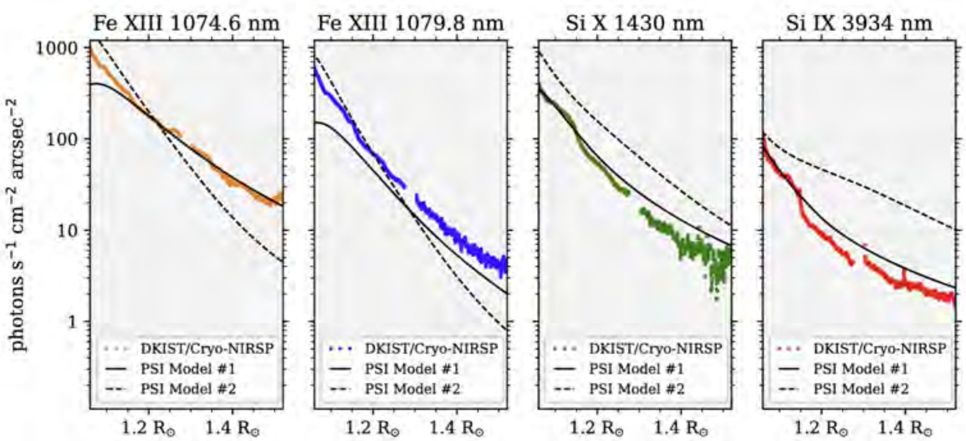

Figure 2.2. *The observed coronal line radiances as a function of elongation between 1.06 and 1.52 solar radii compared to forward synthesized radiances through the two PSI-MAS coronal models.*

2.2 Radial gradient of the solar rotation rate in the near-surface shear layer of the Sun

R. Komm (*FASS, 9, 2022*) studied the radial gradient of the solar rotation rate in the near-surface shear layer (NSSL) from about 0.950 solar radius to the solar surface and its variation during Solar Cycles 23 and 24 with ring-diagram analysis applied to GONG and SDO/HMI Dopplergrams. The NSSL and the tachocline are the two regions of the solar interior with strong radial shear of the rotation rate. Such shear layers may be crucial for the solar dynamo. The average radial gradient is $\partial \log \Omega / \partial \log r = -1.0 \pm 0.1$ at 0.990 solar radius in agreement with previous global helioseismic studies. The average radial gradient is steeper than -1 closer to the surface, while it is increasingly shallower with increasing depth toward 0.950 solar radius. The upper layer of the NSSL with a steep radial gradient might be strongly influenced by supergranulation, since a radial gradient of −2 would be expected assuming angular momentum conservation due to super granules.

The radial gradient of the solar rotation rate varies with the solar cycle. At locations of high magnetic activity, the radial gradient is more negative than average from about 0.970 to 0.990 solar radius, while in quiet regions the radial gradient is less negative than average at these depths (Figure 2.3). Prominent features of the solar-cycle variation of large-scale flows, such as poleward branches or precursor flows, are not obviously present. The variation of the radial gradient thus more likely indicates the presence or absence of magnetic flux above a certain threshold.

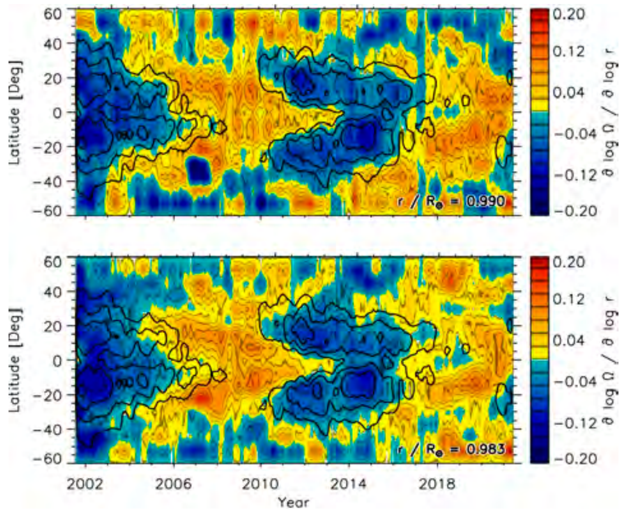

Figure 2.3. *The temporal variation of the residual gradient of the solar rotation rate after subtracting the average offset and the temporal mean at every latitude at two depths (top: 0.990 solar radius, bottom: 0.983 solar radius) derived from GONG data. The values are smoothed over 13 Carrington Rotations (CRs, about one year) to remove remnants of annual systematics. Black contours indicate magnetic activity (5, 10, 20, 40 G) smoothed over five CRs.*

2.3 The Diffraction-Limited Near-Infrared Spectropolarimeter for the Daniel K. Inouye Solar Telescope

To address some of the major questions in solar physics, more detailed knowledge of the Sun's magnetic plasma environment from the photosphere, through the chromosphere and transition region, and into the corona must be derived from observations. New instruments with high spatial resolution, high spectral resolution, high sensitivity, and high cadence are necessary to address long-standing problems and provide a high-quality reference for validating the physics included in modern MHD simulations of the Sun. The Daniel K. Inouye Solar Telescope (DKIST) is the most powerful tool ever built to study the Sun at visible and infrared wavelengths, and it provides a platform for observations of the lower solar atmosphere and corona at unprecedented resolution and sensitivity.

DKIST has a suite of highly capable new instruments, including the Diffraction-Limited Near-Infrared Spectropolarimeter (DL-NIRSP), geared toward characterizing the magnetic plasma throughout the Sun's atmosphere. In a recently published addition to the DKIST collection in the journal *Solar Physics*, S. Jaeggli et al. (*Sol. Phys., 297, 137, 2022*) provide a comprehensive overview of DL-NIRSP. Built by teams at the University of Hawai`i Institute for Astronomy and at the National Solar Observatory, DL-NIRSP is DKIST's first integral field spectropolarimeter, providing detailed spectra of polarized diagnostics targeting multiple heights in the Sun's atmosphere to provide 3-dimensional information about the magnetic field. The integral field units (IFUs) allow DL-NIRSP to record all the spectra from a 2D field of view simultaneously and paired with selectable feed optics and a field-scanning mirror provide great flexibility in spatial sampling (0.03", 0.08", and 0.5") and field coverage (2' x 2'). The spectrograph (shown in Figure 2.4) is an all-reflecting, near-Littrow design, which achieves a resolving power of approximately 125,000. Multiple wavelengths can be observed simultaneously using three spectral arms: one for visible wavelengths (500 – 900 nm) and two for infrared wavelengths (900 – 1350 nm and 1350 – 1800 nm). Each supporting camera sub-system is capable of a 30-Hz frame rate, making it possible to track dynamic phenomena on the Sun.

Jaeggli et al. demonstrate the science capability of DL-NIRSP for both disk and coronal observations. Using data taken during the instrument science verification in August 2021, they provide a first look at the spatially reconstructed intensity, Doppler velocity, and circular polarization for photospheric spectral lines from a 30"x30" mosaic of a small pore observed with the three different wavelength channels of DL-NIRSP. An example from this observation is shown in Figure 2.5. Detection of visible and infrared wavelength coronal lines above an active region was also achieved, although the instrument was not yet optimized for this kind of observation.

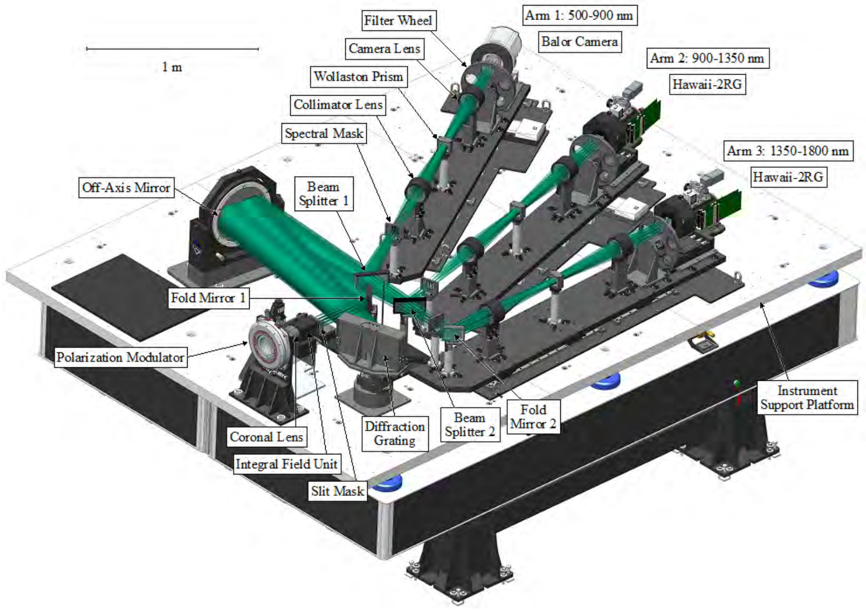

Figure 2.4. *A rendering of the DL-NIRSP spectrograph with the essential optical components labeled. Spectrograph Arms 1, 2, and 3 have similar optical trains; only the components on Arm 1 are labeled for simplicity. The enclosure and covers are not shown; however, the spectrograph optics are fully enclosed on the top and sides to control scattered light.*

Although DL-NIRSP has just been commissioned and made available for Cycle 2 observations, upgrades will soon be carried out to significantly improve the science capability of DL-NIRSP. The original fiber-optic integral field units will be replaced with image slicers based on mirrors which provide improved spatial uniformity and better throughput, which is especially important for coronal observations. The infrared cameras will also be upgraded to provide lower thermal background and improved noise performance. Further publications to advertise these new capabilities can be expected.

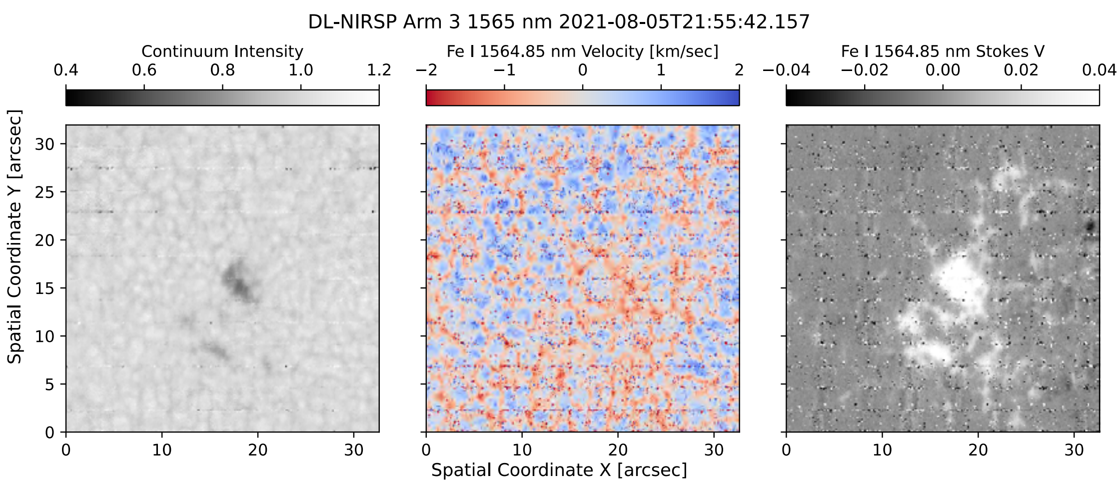

Figure 2.5. *The spatially reconstructed continuum intensity, Doppler velocity, and LOS magnetic field of the leading pore in NOAA 12851 derived from a spectropolarimetric mosaic using the 1565 nm channels of DL-NIRSP.*

2.4 Understanding Sun-as-a-Star Variability of Solar Balmer Lines

Precise, high-cadence, long-term records of stellar spectral variability at different temporal scales lead to better understanding of a wide variety of phenomena including stellar atmospheres and dynamos, convective motions, and rotational periods. S. Criscuoli et al. (*ApJ, 951, 151, 2023*) investigate the variability of solar Balmer lines (Hα, β, γ, δ) observed by space-borne radiometers (OSIRIS, SCIAMACHY, OMI, and GOME-2), combining these precise, long-term observations with high-resolution data from the ground-based NSO/ISS spectrograph. We relate the detected variability to the appearance of magnetic features on the solar disk. We find that on solar-rotational timescales (about 1 month), the Balmer line activity indices (defined as line-core to line-wing ratios) closely follow variations in the total solar irradiance (which is predominantly photospheric), thus frequently (specifically, during passages of sunspot groups) deviating from behavior of activity indices that track chromospheric activity levels. On longer timescales, the correlation with chromospheric indices increases, with periods of low correlation or even anticorrelation found at intermediate timescales. Comparison of these observations with estimates from semiempirical irradiance reconstructions helps quantify the contributions of different magnetic and quiet features.

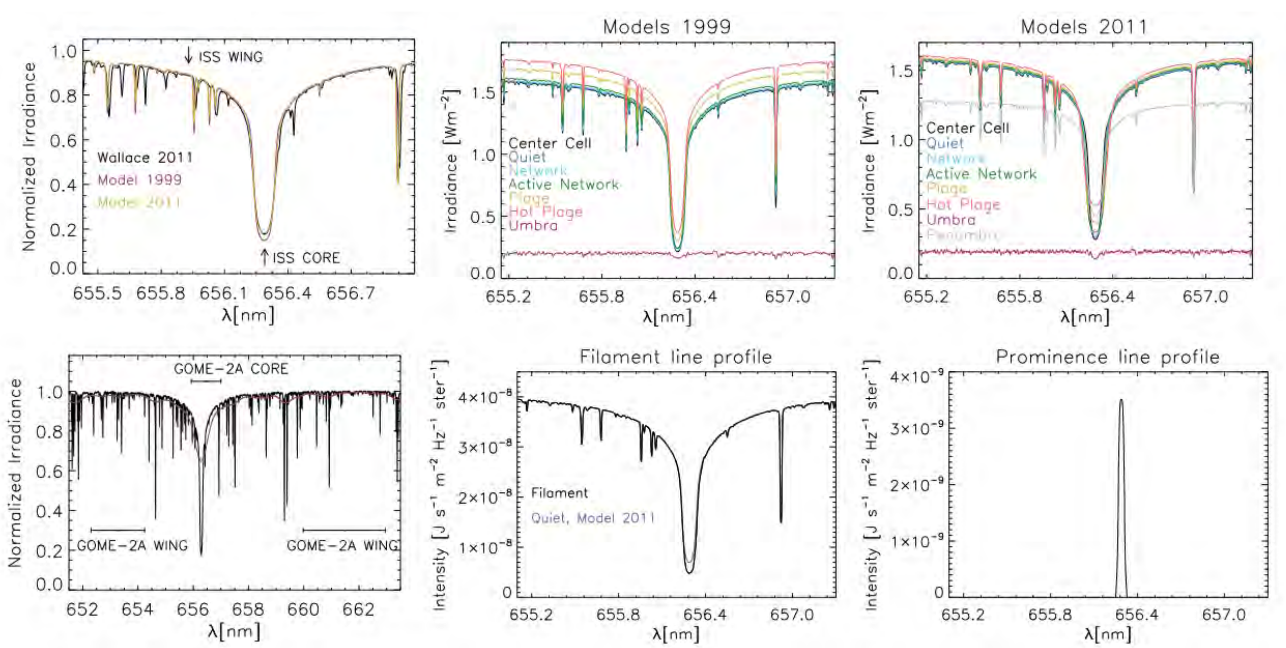

Figure 2.6. Top left: comparison of Ha profiles (normalized to nearby continuum) obtained using the quiet model from the set of FAL1999 and FAL2011 and the observed reference flux (Wallace et al. 2011). Top center and right: Ha irradiance line profiles obtained using the two sets of FAL atmospheric models. Bottom left: Wallace reference spectrum at the original resolution (black) and degraded to the spectral resolution of GOME-2A (red). The spectral ranges used to define the core and wings are also shown. Bottom center and right: filament and prominence line profiles employed in the models. The bottom-center panel also shows for comparison the disk center quiet-Sun profile from Models 2011.

Specifically, we modelled the variability of Balmer lines combining full-disk images daily acquired with the Precision Solar Photometric Telescope, with synthetic spectra obtained from semi-empirical atmosphere models. To this aim, we used and compared reconstructions obtained with two sets of atmosphere models: Fontenla et al. 1999 (Models 1999) and Fontela et al. 2011 (Models 2011). To consider the contribution of filaments in Hα we used the spectrum presented in Kuckein et al. 2016, while the contribution of prominences in Hα was modeled making use of a line profile published in Heinzel et al. 2014. The spectra employed for the models, together with an example of ISS measurements, are shown in Figure 2.6. Models confirm that the variability of Hα on the long temporal scales is positively correlated with the Ca II K index, while the variability of upper Balmer lines may vary in phase or counter phase depending on the spectral resolution of the observations.

We conclude that both the lower sensitivity to network and in part the higher sensitivity to filaments and prominences, may result in complex, time-dependent relationships between Balmer and other chromospheric indices observed for the Sun and solar-like stars (Figure 2.7). The fact that core and wings contribute in a similar manner to the variability, and current knowledge of Balmer-lines formation in stellar atmospheres, supports the notion that Balmer line core-to-wing ratio indices behave more like photospheric rather than chromospheric indices.

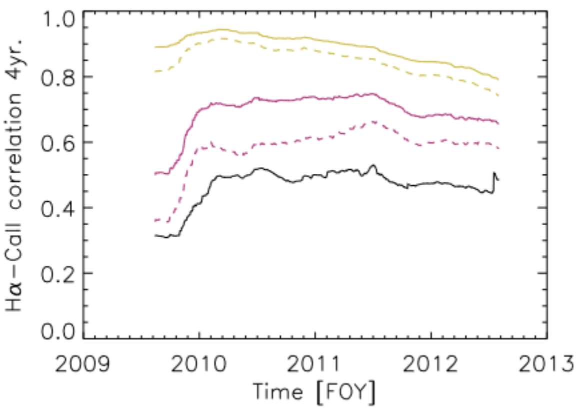

Figure 2.7. *Comparison of temporal variation of the correlation coefficients between the Hα and the Ca II K indices computed over a 4-year temporal window obtained from ISS measurements and models. Dashed lines indicate models taking including filaments contribution. Black: ISS observations. Magenta: Model 1999. Gold: Model 2011. The decrease of correlation between the two indices at periods of minimum activity is reproduces even by models that do not consider filaments contribution, thus suggesting that filaments may play a lesser role in affecting the variability of Hα than previously suggested in the literature for the Sun and solar-like stars.*

2.5 A Statistical Analysis of Magnetic Field Changes in the Photosphere during Solar Flares Using High-cadence Vector Magnetograms and Their Association with Flare Ribbons

A solar flare is caused by magnetic reconnection in the solar atmosphere, leading to the rearrangement of magnetic field lines. Abrupt and permanent changes in photospheric magnetic fields have been observed during solar flares. These changes are believed to be associated with the reconfiguration of magnetic field lines, but their origin remains elusive. In this study, Yadav and Kazachenko (*ApJ, 944, 215, 2023*) conducted a statistical study to investigate the magnetic imprints in the photosphere during 37 solar flares, and their association with the ribbon morphology. For this purpose, we utilized high-cadence (135 sec) vector magnetograms and the UV images (1600 Å) from the Helioseismic Magnetic Imager (HMI) and the Atmospheric Imaging Assembly (AIA) onboard Solar Dynamics Observatory.

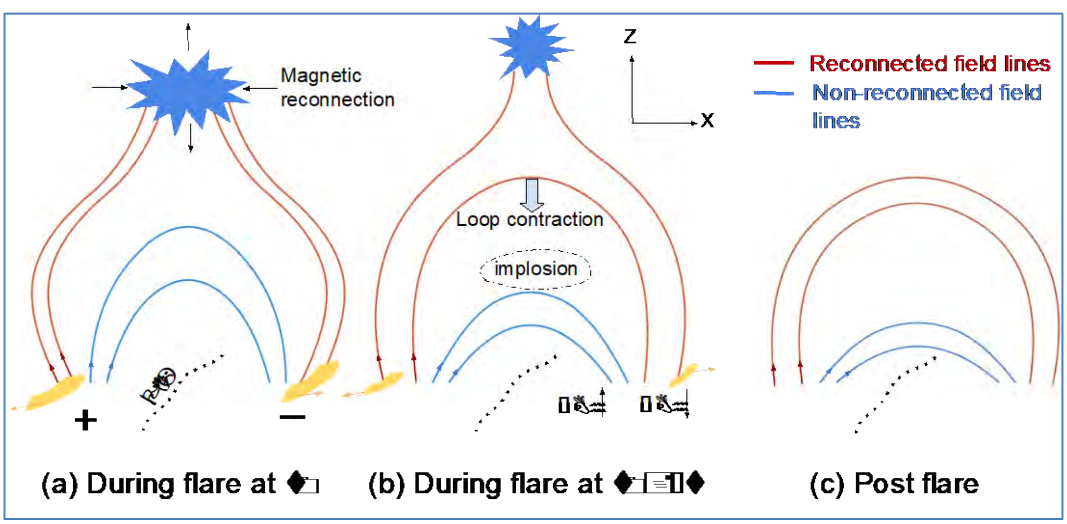

Figure 2.8. *A sketch of the magnetic field configuration during (a, b) and after (c) the time of flaring. Solid lines refer to the field lines connecting opposite polarities, which are indicated by "+" and "−" signs. A dotted line refers to the PIL, whereas the ribbons are shown with a yellow-colored area near the footpoints. Blue field lines contract due to coronal implosion whereas the newly reconnected field lines shown in red shrink after reconnection. Here, the "Z" axis is perpendicular to the solar surface, whereas "X" is along the solar surface.*

The high-cadence vector magnetograms from HMI allowed us to investigate the rapid permanent changes in the field. Our analysis revealed that the largest step-like permanent changes in the horizontal field component lie near the polarity inversion line, whereas changes in the vertical field are less pronounced and are distributed throughout the active region. Moreover, we found that pixels swept up by ribbons do not always exhibit permanent changes in the field. However, when they do, ribbon emission typically occurs several minutes before the start time of field changes. Our observations also showed that the nature of the field changes is not related to the size of active regions but is strongly related to the flare-ribbon properties such as ribbon magnetic flux and ribbon area. For the first time, we discovered that the duration of permanent changes in the field is strongly coupled with the duration of the flare, lasting on average 29% of the duration of the GOES flare.

Our results suggest that changes in photospheric magnetic fields are caused by a combination of two scenarios: contraction of flare loops driven by magnetic reconnection and coronal implosion, which is demonstrated in Figure 2.8. The actual configuration of magnetic field lines during flares may be even more complex. Therefore, to provide a comprehensive understanding of a solar flare, we require multi-height spectropolarimetric observations.

2.6 Magnetic fields in solar plage regions: insights from high-sensitivity spectropolarimetry

J. da Silva Santos et al (*ApJL, 954, L35, 2023*) paper discusses the magnetic and dynamic makeup of solar plages, which are extended magnetized regions on the Sun's atmosphere that emit enhanced radiation from ultraviolet to microwave wavelengths. Plages are often found near sunspots and serve as sources of hot coronal loops. Understanding the magnetic fields in these regions is crucial because they influence dynamics and heating in the chromosphere and corona. While the magnetic fields have been extensively studied deeper in the photosphere, measuring the magnetic fields in the chromosphere has been almost impossible due to the weak polarization signals produced there.

Here, we used data from DKIST to further investigate plages, pushing the detectability limits of the magnetized signals arising from the solar chromosphere. The analysis reveals significant circular polarization signals in both the photosphere and chromosphere (Fig. 2.9d,e). Linear polarization signals differentiate between plage patches and the magnetic canopy and are associated with fibril-like features seen in the intensity images (Fig. 2.9a), substantiating their magnetic origin. Typical chromospheric magnetic field strengths in the studied plages are between approximately 200-300 G (0.02-0.03 T), which is smaller than previously reported values. The magnetic concentrations are spatially associated with regions of enhanced emissions, but that relationship is nonlinear. The spectra taken by the ViSP instrument also revealed complex spectral profiles (Fig. 2.9c) showing supersonic downflows in the chromosphere at the plage periphery (Fig. 2.9b), possibly caused by material draining from fibrils along inclined magnetic fields, heating the chromosphere upon impact.

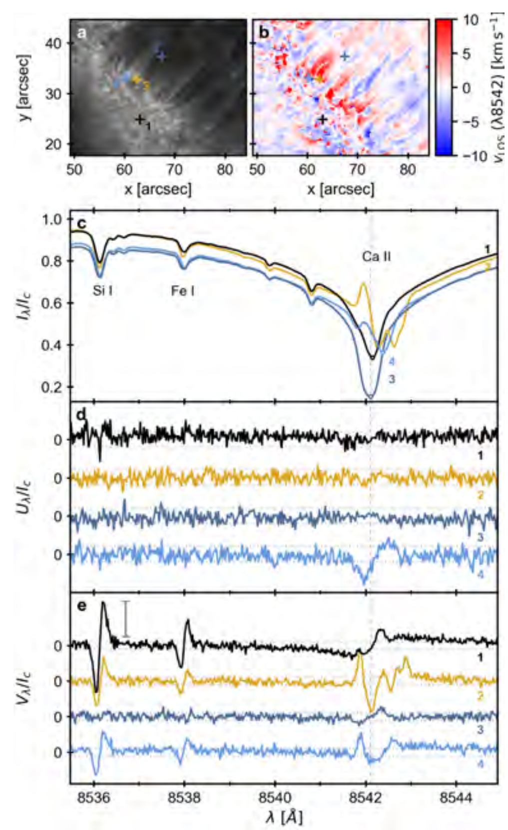

Figure 2.9. *DKIST/ViSP observations of a solar plage region in June 2022. Panel a - intensity in the core of the CaII 8542 line. Panel b - dopplergram in the chromosphere. Panels c/d/e - selected Stokes I/Q/V spectra in and around the plage region as indicated in the upper panels.*

The research highlights the importance of considering magnetic structure and the dynamic environment when studying heating mechanisms within plages. Further research with higher resolution and larger sample size will shed light on the magnetic field expansion with height, the relationship between magnetic fields and heating, and the specific mechanisms driving dynamics and heating in plage regions.

2.7 The Daniel K. Inouye Solar Telescope Cryogenic Near-Infrared Spectropolarimeter

The Cryogenic Near-Infrared Spectropolarimeter (Cryo-NIRSP) instrument paper by A. Fehlmann et al. (*SoPh 298, 5, 2023*) summarizes the science mission, design and fabrication considerations, operating modes, and first science data for this DKIST instrument. Cryo-NIRSP is a combination of slit-based spectrograph and context-imager that is optimized for polarimetric observations of infrared spectral band-passes between 1 and 5 microns. This makes it uniquely suited for polarimetric observations of the solar corona, while also enabling access to other important infrared diagnostics such as the CO fundamental band at 4.6 microns.

The main advantages of infrared observations made available by DKIST are better atmospheric seeing, less atmospheric scattering, less instrumental scattering, less instrumental polarization, and increased Zeeman resolution. However, IR observations beyond about 2 µm must contend with a large environmental thermal background. Figure 2.10 shows how routine mid-IR coronal and high-contrast solar-disk observations require cooling the Cryo-NIRSP optics in front of the cryogenic array detector to overcome this background.

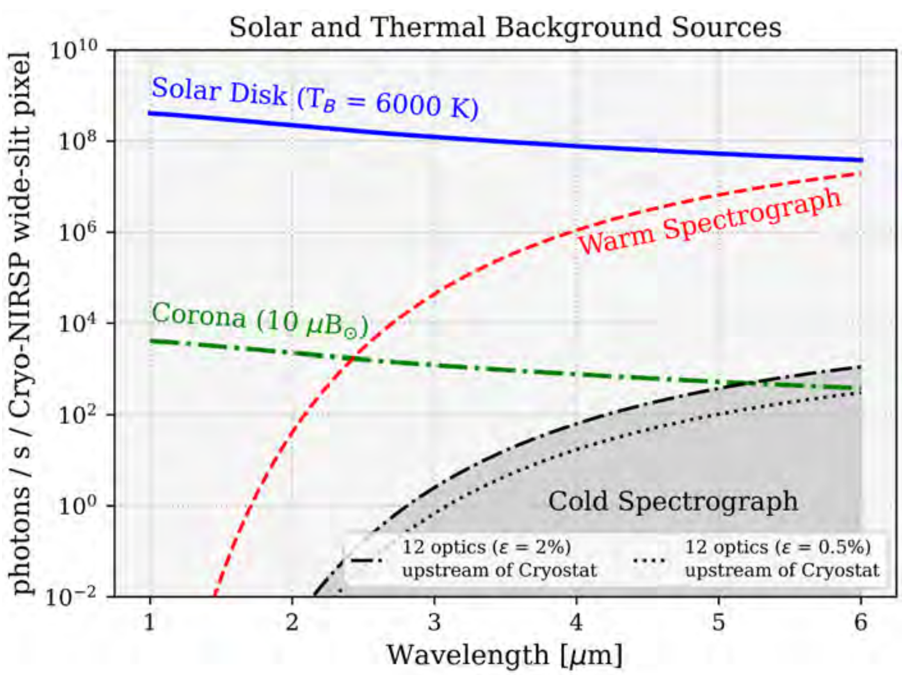

Figure 2.10. *The Cryo-NIRSP instrument is sensitive out to 5 µm because its optics are cooled to below 150 K. The solid blue curve represents the mean photospheric flux, modeled as a blackbody, detected by a single pixel in the Cryo-NIRSP wide-slit configuration, assuming 10% end-to-end throughput. The green dash-dotted line is representative of coronal intensities off-limb. The dashed red line shows the case for a warm room-temperature spectrograph, i.e. with only a cooled detector, assuming a foreground emissivity of 0.5 over a field-of-view set by the detector's numerical aperture. We increase the spectral bandwidth in this case to λ/100 to mimic filtered undispersed thermal background, as compared to the λ/250,000 designed dispersion of the science signal. The two black curves illustrate the case of a cryogenically cooled spectrograph with thermal emission dominated by upstream optics, here modeled using 12 optics with two different emissivity values. Coronal observations above about 2.5 µm are dominated by instrument thermal backgrounds without a cooled spectrograph.*

Early Cryo-NIRSP science verification observations targeted a sunspot in the He I 1083 nm band-pass. This on-disk spectropolarimetric data of strong magnetic fields allows detailed validation of calibrated data products, especially through cross-comparison with other instrumentation. Figure 2.11 shows the Stokes-I Cryo-NIRSP band-pass obtained during this observation along with two example profiles extracted from within the sunspot umbra (orange line) and within the region of solar plage (blue line). The calibrated Si I and He I line Stokes profiles from this observation compared favorably with previous studies and thus verified the Cryo-NIRSP capabilities in this band-pass for on-disk observations.

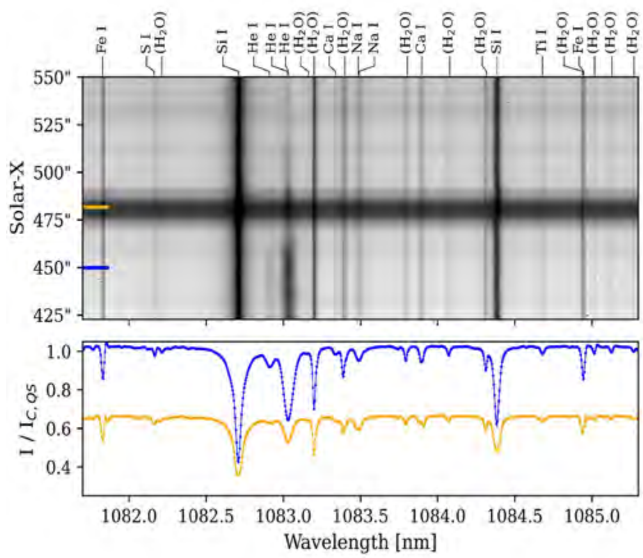

Figure 2.11. *Stokes-I spectrum acquired at one slit position during a sunspot observation with spectral lines identified. Note that parentheses around (H_2O) are used to denote these as telluric absorption lines.*

2.8 Constraining the Systematics of (Acoustic) Wave Heating Estimates in the Solar Chromosphere

The work by M. Molnar et al. (*ApJ, 945, 154, 2023*) focuses on constraining the amount of acoustic wave heating in the solar chromosphere. Acoustic wave heating is one of the candidate mechanisms for transport of the missing energy flux required to maintain the thermodynamic state of the lower solar atmosphere. The main goal of this work is to constrain the systematic differences of acoustic wave heating estimates in the solar chromosphere by combining high resolution solar observations with the different solar modeling approaches used in the previous studies – ranging from 1D semi-empirical models to cutting edge 3D time-dependent radiative magnetohydrodynamic (rMHD) ones. We believe that this will provide a better foundation for concluding if acoustic waves carry (or not) the required energy flux to heat the lower chromosphere. This is the first study to utilize 3D time-dependent rMHD models to infer the acoustic wave flux in the solar atmosphere.

We use a combination of high-resolution observational data from IRIS and the IBIS instrument at the Dunn Solar Telescope (Cavalini et al. 2006) in this study. On the modeling side, we use results from the RADYN and Bifrost codes, as well as semi-empirical FAL models. We created synthetic diagnostics with the RH15D code from these models and degraded them in a similar fashion to the true observations (Figure 2.12). This end-to-end modeling approach provides us with a connection between the plasma parameters in the dynamic simulations of the solar atmosphere and the actual observed properties of the spectral lines.

The main finding of this study is that the highest degree of uncertainty introduced in any modeling approach is the plasma density at the line formation region. This is because the line formation height varies significantly between models. Furthermore, there is a significant variation of the line formation plasma density in different solar features in the same 3D model, which also vary in time. It is a well-known fact that the observed wave amplitude in different regions of the solar atmosphere is attenuated by the time it is detected as Doppler velocity by our telescopes, due to multiple effects (Schmieder and Mein 1980, Molnar et al. 2021). We found that this attenuation effect has a strong dependence on the solar region being modeled in the 3D simulations we studied.

Usually, we expect this attenuation to be described by a coefficient less than one, since our telescopes detect Doppler velocity amplitudes lesser than the true wave amplitudes in the solar atmosphere. However, in the hotter regions of the 3D simulations, we find that the actual vertical velocity fluctuation power is enhanced and not attenuated. The systematic difference from this attenuation phenomenon is that using 1D (semi-empirical) models leads to overestimation of the wave amplitudes and the wave energy fluxes. In conclusion, if we use the most realistic models we have in this study – the 3D rMHD Bifrost models – to compute the acoustic wave energy flux, the result is that acoustic waves are insufficient to maintain the low chromosphere in its thermodynamic state (Molnar et al. 2023), as it is below the required threshold of about 4 kW/m2 (Morosin et al. 2022).

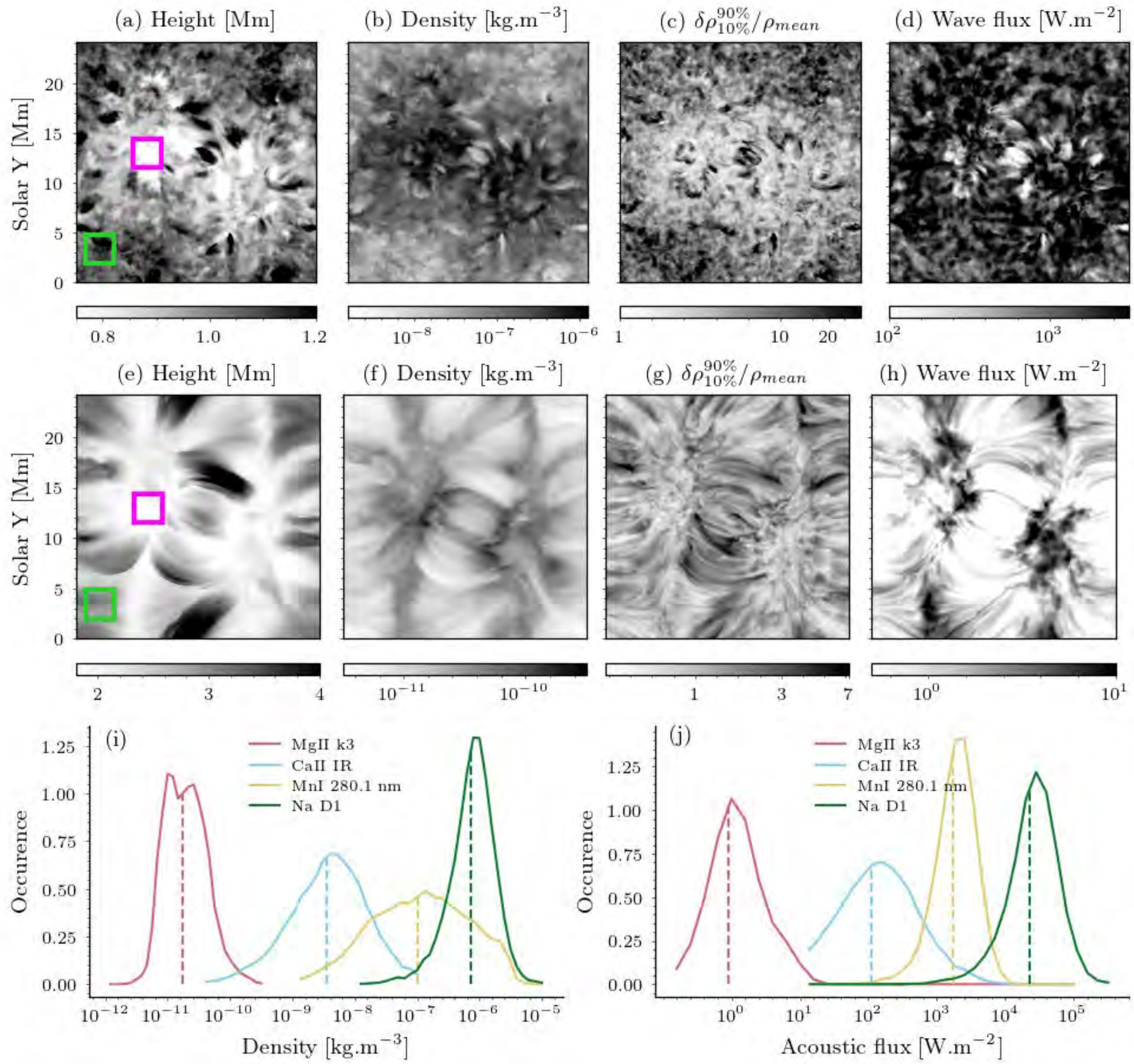

Figure 2.12. Results from the Bifrost spectral synthesis. The top row shows diagnostics derived from the Mn I 280.1 nm line and the middle row shows those for the Mg II k3 feature. Panels (a) and (e) show the time-averaged height of optical depth unity of the line core, panels (b) and (f) the time-averaged density at optical depth unity for the line core; panels (c) and (g) show the ratio of the plasma density change over time to the mean plasma density at the formation height of the spectral lines, and panels (d) and (h) the acoustic flux at the formation height of the spectral line. The green and magenta squares in panels (a) and (e) are the representative regions that we equate to internetwork and plage regions in our observables in the following analysis. The bottom left panel (i) shows the distributions of the density at the height of formation in the simulation for the different diagnostics; the bottom right panel (j) shows the distributions of the acoustic flux at the height of formation of the diagnostics.

2.9 Systems approach to polarization calibration for the Daniel K. Inouye Solar Telescope

The DKIST advances studies of solar magnetism through delivering high-precision and accuracy in polarimetric data at frontier spatial and temporal scales. D. Harrington et al. (SoPh, 298, 10, 2023) developed a system polarization model for the response of each optic as functions of telescope azimuth and altitude to calibrate DKIST instruments across the full wavelength range. This model has been tested with DKIST instruments as well as shown to be consistent over the last few years.

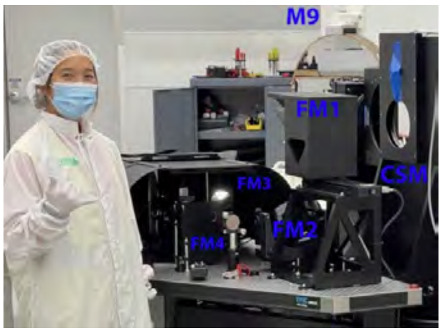

Figure 2.13. *The spectropolarimetric calibration system showing several of the optics along with co-author Sueoka at 1.5m height for scale. The Cryo-NIRSP steering mirror (CSM) is at the far-right. The four NCSP fold mirrors are annotated as FM1, 2, 3, 4. DKIST M9 has a 600mm diameter and is partially seen in the background top right. The NCSP FM3 is at 75 mm diameter and FM4 is at 50 mm diameter for scale.*

The DKIST team has developed several new polarization modeling, and performance-estimation techniques coupled with very thorough metrology on every optic ahead of the DKIST instruments. These efforts ensure that quality polarimetry is delivered to meet stringent accuracy requirements.

A custom spectropolarimetric calibration (Figure 2.13) system was designed, installed, and used to perform end-to-end calibration of the telescope using both the solar beam and the calibration lamp beam within the Cryo-NIRSP instrument.

Extensive optical and polarization characterization efforts allow us to know our optics in detail, and to include the appropriate system variables for the reduction of calibration errors. We calibrate DKIST using a detailed system model that includes elliptical calibration retarder variables, and ellipsometric measurements of every coating on every optic ahead of the instruments (Figure 2.14). Coating witness samples for every relevant optic in the system have been measured in multiple pieces of equipment over time to verify accuracy and stability of our system model.

Aperture-dependent variations in polarizer, retarder, and optic-coating performance have been measured and used to simulate both the polarization dependence on field angle and errors within the optical-system model. Depolarization, dependence on field-of-view, and several calibration errors caused by curved optics, converging beams, coating non-uniformity, retarder non-uniformity, and other things have all been assessed. Multiple observations On-Sun as well as with the DKIST calibration lamp agree well with each other, and with the system metrology model. Upcoming multi-instrument observations are expected to be well calibrated with detailed understanding of major error limitations.

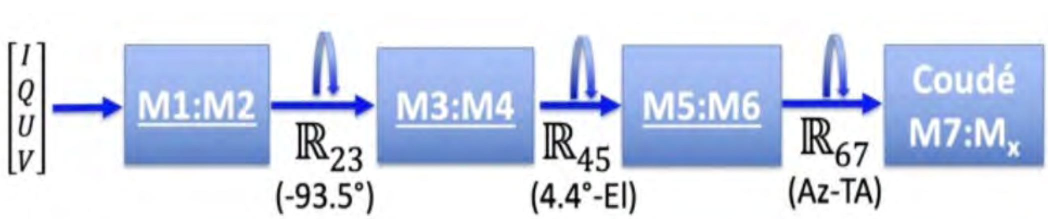

Figure 2.14. *The basic elements of the articulated-system model. The solar incoming Stokes vector is at the far left. The rotation matrices of the articulated optical system are shown with the bold R-elements, including static offset angles from the design. The M1:M2 mirror grouping is encountered first, with a -93.5º rotation to the next mirror grouping M3:M4. The elevation axis along with a 4.4º clocking is included between mirrors 4 and 5. The M5:M6 grouping is ahead of the azimuth axis, which also combines with the Coudé laboratory table angle (TA). All Coudé laboratory mirrors are grouped into the appropriate instrument calibration.*

2.10 First Observation of Chromospheric Waves in a Sunspot by DKIST/ViSP: The Anatomy of an Umbral Flash

The Sun's chromosphere is a relatively thin layer of the Sun, situated above the Sun's surface (the photosphere) and beneath its expansive atmosphere (the corona). Although narrow in size, the chromosphere is a highly dynamic region, hosting a wide range of phenomena over both active and quiet regions of the Sun's surface. One such phenomena is the 'umbral flash' – small-scale periodic brightening found within the center of sunspots. In May 2021, the ViSP instrument on the NSF Inouye Solar Telescope (DKIST) collected its science verification measurements as a part of the instrument commissioning phase. Fortuitously, the instrument observed a small and localized umbral flash within these observations.

Figure 2.15 shows some of the maps created from the observations, mapping the intensity, Doppler velocity, line width and linear polarization (which relates to the orientation of the magnetic field) of the target sunspot region for the Ca II 854.2 nm spectral line. Ca II 854.2 nm originates in the chromosphere, making it a popular spectral line for investigating this layer of the Sun. Clearly visible in the maps are near-horizontal ridges extending over the left side of the field-of-view. Because ViSP observes one row of pixels at a time, there is time delay between each new row in the maps. This means, that unlike regular images, the information in the maps contain information of the plasma property variations in both space and time. The ridges do not truly look this way on the Sun but appear so in the data as ViSP observes row-by-row over a region of the chromosphere that is coherently pulsating up and down during an umbral flash.

By taking a cross-section through the maps above, R. French et al. (*ApJL, 945, 27, 2023*) can plot the time-variation of the plasma properties throughout an umbral flash. These data are shown in the bottom panels of the image and show the highest-signal observations ever captured of the umbral flash phenomena. The measurements paint a picture of plasma rising and periodically falling through the solar atmosphere, through a chain of waves and shocks. For the strongest shocks (seen as sharp spikes in the data), clear magnetic field fluctuations reveal further insights into the behavior of the magnetic field at these shock locations. Magnetic fluctuations in the chromosphere have never before been observed in this manner, made possible by the unprecedented signal-to-noise ratio provided by DKIST.

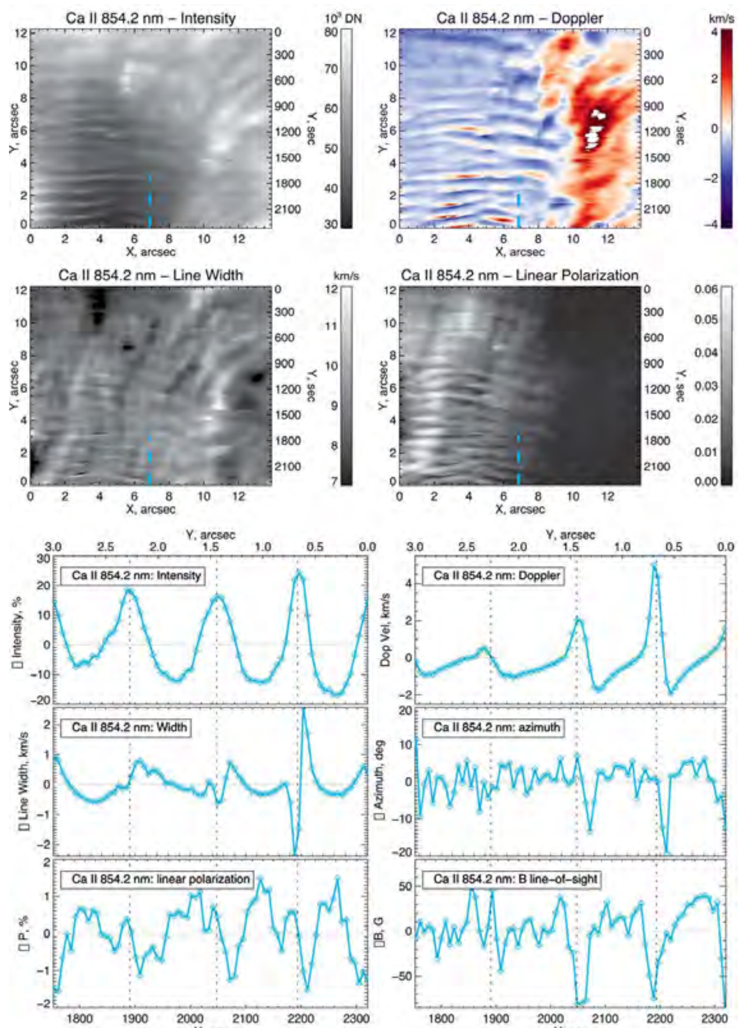

Figure 2.15. *Top: Subset of the maps created by the ViSP Ca II 854.2 nm observations, including intensity, Doppler velocity, line width and linear polarization (which relates to magnetic field orientation). Bottom: Cross-sections of the plasma properties at the location of the cyan dashed lines in the top panels.*

2.11 Solar Polar Magnetic Fields: Comparing Full-disk and High-resolution Spectromagnetograph Data

G. Petrie (*ApJ, 941, 142, 2022*) presented a systematic comparison between photospheric polar magnetic field data from a full-disk synoptic observing program, the NSO's Synoptic Optical Long-term Investigations of the Sun Vector Spectromagnetograph (SOLIS/VSM), and a high-resolution vector spectromagnetograph, the Hinode Solar Optical Telescope Spectropolarimeter (SOT/SP).

Polar synoptic maps for the radial field component were constructed from longitudinal (line-of-sight, LOS) magnetic field data (Stokes I and V measurements) from both telescopes, and also from the SOT/SP full-Stokes inverted vector data distributed by the High-Altitude Observatory. Radial fluxes were derived from LOS data assuming an approximately radial field, whereas the radial fluxes derived from vector data were based on the measured vector magnitude and direction. To build these maps, magnetograms taken over 35-day periods with advantageous rotation axis tilt angle were used, with temporal windows centered at March 6/September 8 for the south/north pole. As the examples in Figure 2.16 demonstrate, all maps show the distinctive super granular concentrations of magnetic flux familiar from quiet-Sun magnetograms for lower latitudes. However, the VSM and SP data are clearly very different from each other: the VSM data are spatially smoother because of lower spatial resolution and seeing, whereas the SP data are magnetically stronger in the strong flux concentrations. The SP vector data show little flux outside these concentrations, unlike the LOS maps, unlike the LOS maps from both telescopes.

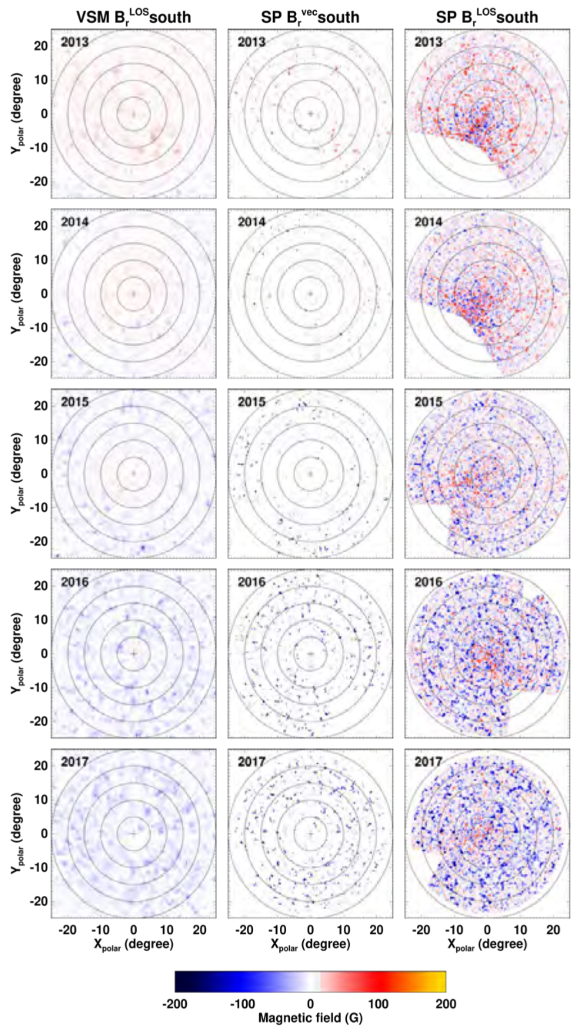

Figure 2.16. *Polar radial flux synoptic maps for the south pole constructed using VSM LOS data (left column), SP vector data (middle column) and SP LOS data (right column), covering 35-day intervals centered on March 6 of each year when the south pole is most visible from (near) Earth. These three sets of maps are plotted using a common color scale for direct comparison, for the years of overlap between the VSM and SP data sets, 2013-2017, which cover the south polar field reversal. The concentric circles are lines of constant latitude in increments of 5° from the pole, which is marked by a plus symbol. Besides the clear differences between the maps discussed in the text, note the super granular organization of the flux into small, strong concentrations and the progress of the polarity reversal from lower to higher latitudes.*

In principle, full-vector data offer more satisfactory polar flux calculation, but these full-vector polar field measurements appear to suffer from a detection problem. Polar fields are observed as mostly transverse from (near) Earth, and Zeeman sensitivity to transverse fields is significantly lower than for LOS fields. Accordingly, the SOT/SP vector-based polar fluxes are lower than the LOS-based fluxes from both telescopes, a result driven by pixels without sufficient Q and U signals for the full-Stokes inversions to derive a reliable solution but with significant Stokes V signal implying presence of field. Moreover, the SOT/SP LOS-based fluxes were significantly higher than their VSM counterparts because of superior seeing-free spatial resolution and longer observation time. The SOT/SP LOS-based polar fluxes appear large enough to be compatible with radial interplanetary field measurements whereas the SOT/SP vector-based and the VSM ones are generally too low.

3 FY 2023 DKIST ACHIEVEMENTS AND MILESTONES

The DKIST Directorate consists of the Associate Director (AD) and the recently added Deputy Associate Director (DAD). The Directorate is responsible for leadership and management of the observatory, specifically its four operational components, namely Science Operations, Instrumentation, Technical Operations and the DKIST Data Center. In addition, the DKIST Associate Director manages the DKIST Science team. The DKIST Directorate interfaces with the NSO Directorate and various support services within NSO, i.e., Administrative Services, Information Technology, Education and Public Outreach, and the Business Office. The Directorate also works with and responds to requests from AURA Corporate and the National Science Foundation as required.

3.1 Directorate Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan laid out the following program goal for the DKIST Directorate.

Program Goal (Dir-1): Elaborate the DKIST contribution to the new Cooperative Agreement proposal.

3.2 Major Directorate Achievements for FY 2023

The DKIST Directorate continued to support day-to-day operations of the facility providing leadership direction and management expertise to the four DKIST operational components. To assist the DKIST AD, NSO/AURA gained approval for and advertised a new DKIST DAD position. The hiring process started in early FY 2023 and continued through July 2023 with the onboarding of the new Deputy. The DKIST DAD will share some of the management responsibilities and administrative burden that previously rested solely on the DKIST AD.

The DKIST AD met with staff from AURA Corporate and NSF-AST on a regular basis to keep each informed of the operational status of the observatory. As part of his leadership responsibilities, the DKIST Associate Director provided briefings regarding the scientific achievements and operational status of DKIST to the following committees/councils:

- NSO Users Committee
- AURA Solar Observatory Council (SOC)
- AURA Board of Directors
- NSF leadership from the Astronomy Division, The Math and Physical Sciences Directorate, the Large Facilities Office, and the Division of Cooperative Support.

In September 2023, the DKIST AD met with NSF, AURA, and NSO management to discuss guidance regarding the renewal of the NSO Cooperative Agreement (program goal Dir-1). The Associate Director provided input on appropriate time constraints and reasonableness of the proposed requirements and schedule. While the guidance is still somewhat in flux, the three entities seem to be converging on a two-year extension (FY 2024 through FY 2025) to the current CA with an external Concept of Operations (ConOps) review during this period providing guidance for NSF for the future CA renewal (FY 2026 through FY 2030). Because of the shift in the schedule and requirements for the renewal of the CA, the DKIST contributions to the CA (program goal Dir-1) have been temporarily put on hold so that the Directorate can prepare the materials required for the FY 2023 Annual Progress Report (this document), the FY 2024 Annual Program Review, the FY 2025-2026 CA extension proposal, and the ConOps review.

A significant unanticipated challenge that the DKIST Directorate and DKIST Operations staff had to deal with in FY 2023 was the wildfires on Maui (Figures 3.1 and 3.2). Due to the impact of these devastating wildfires on the entire Maui community including DKIST staff, all site operations were suspended, and the observatory was closed from August 8-16, 2023. The DKIST AD traveled to Maui to support Maui-based staff in their efforts to recover from the wildfires and get the observatory up and running again. The DKIST AD also worked with AURA and NSF to ensure that administrative leave could be provided, and that staff would continue to be paid during this period of upheaval. Shortly thereafter, DKIST Technical Operations and Safety teams inspected the summit on August 11, 2023. Technical Operations and Instrument Scientists mobilized quickly to restart key systems and resumed chiller installation August 17-18. All systems were re-inspected and started by August 21, and DKIST was back on-sun from August 22, 2023. It is a testament to the dedication of the entire DKIST staff that despite the extreme hardship caused by the wildfires, the observatory was up and running roughly two weeks after the initial shutdown.

Figure 3.1. *Haleakalā as seen from Wailuku, evening of August 8, 2023.*

Figure 3.2. *Fire-damaged fields on the road to DKIST, August 17, 2023.*

3.3 DKIST Science Operations

The DKIST Science Operations (SciOps) team is responsible for the preparation, scheduling, and execution of DKIST science observations. They are the primary interface to the DKIST users as they prepare proposals and plan observations.

3.4 Science Operations Program Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan laid out the following program goals for Science Operations (SciOps).

Program Goal (SciOps-1): Continue the execution of experiments from the first Operations Commissioning Phase (OCP) call (OCP1).

Program Goal (SciOps-2): Rank the proposals from the second OCP call (OCP2) via the Time Allocation Committee.

Program Goal (SciOps-3): Generation of all Cycle 2 experiments.

Program Goal: (SciOps-4): Start the execution of proposals from OCP2.

3.5 Major Science Operations Achievements for FY 2023

The execution of Cycle 1 observations continued into the first quarter of FY 2023 during OCP1.7 and OCP1.8. In addition to the continuation of Cycle 1 proposal observing, observing time was scheduled to perform the first coordination exercises with Solar Orbiter spanning 5 days (October 18 - October 24, 2022, weekend excluded) during OCP1.7. As part of the usual PI notifications regarding the details of an observing window, the Cycle 1 Proposers were informed that the December observing window (OCP1.8) concluded and thus closed Cycle 1 of the OCP.

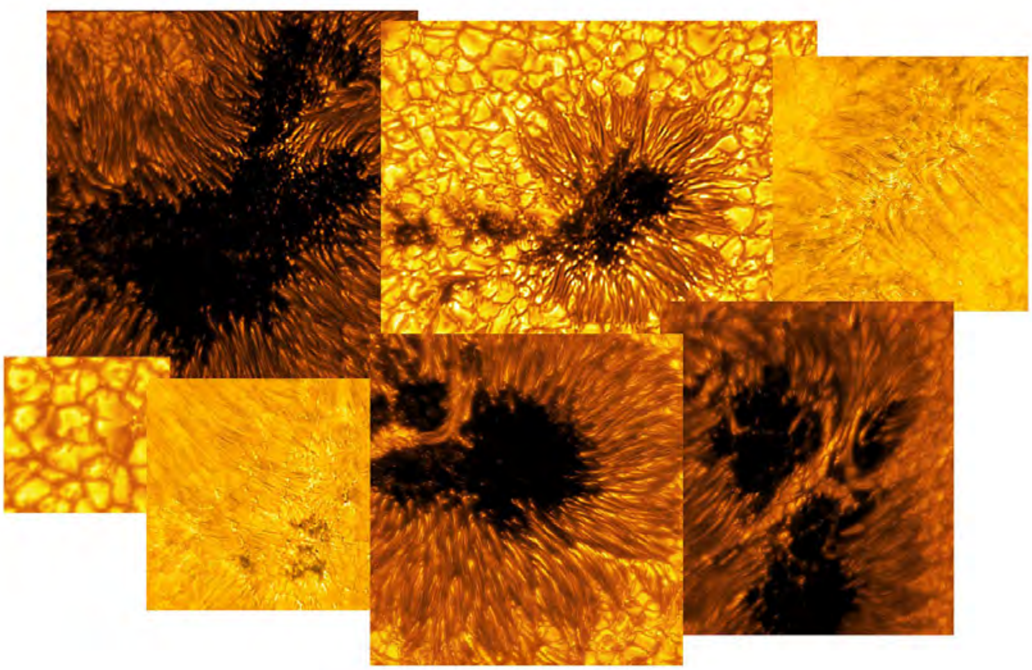

Figure 3.3. *A mosaic of new solar images produced by the Inouye Solar Telescope was released today, previewing solar data taken during the telescope's first year of operations during its commissioning phase. Images include sunspots and quiet-Sun features. Credit: NSF/AURA/NSO.*

Exemplifying some of the finest observations (see Figure 3.3) obtained during Cycle 1, a press release was published on May 19, 2023 (for details see: New Images Released by NSF's Daniel K. Inouye Solar Telescope).

A major achievement in FY 2023 was the completion of the Cycle 2 proposal review process (program goal SciOps-2). Most of the Cycle 2 proposal review (i.e., time allocation) process was achieved in the first quarter of FY 2023, with the exception of the technical review, which had already concluded on September 6, 2022, as part of FY 2022. In total, 93 proposals were submitted to the Cycle 2 Proposal Call, repeating the success of Cycle 1 proposal submissions. The 93 proposals were sent to the Technical Review Committee (TRC) Chair right after the closure of the submission window. The TRC is formed by internal DKIST scientific staff. The anonymous science review by the Science Review Committee (SRC) started in parallel with the technical review and concluded on October 21, 2022. Four remotely convening thematic review panels with six panel members each were formed to distribute the proposal load. After the science review concluded (including the preparation of result reports), the proposals were prioritized by a Time Allocation Committee (TAC) based on science merit, policy guidance and a first and very rough estimation of available observing time based on statistics gathered during Cycle 1. The TAC convened on November 30, 2022, accepted 54 proposals and sent the list to the NSO Director for final approval. All Proposers were notified of the results of the review (including a letter and a document describing the proposal review process) on January 5, 2023, and the accepted Cycle 2 Proposals were published on the NSO webpages (see Cycle 2: Accepted Science Programs). For Cycle 2, time allocation included the official approval of Director's Discretionary Time (DDT) used for high-priority DKIST co-observing efforts during Parker Solar Probes perihelion encounters and Solar Orbiters remote sensing windows in 2022. A total of six days for Parker Solar Probe and a total of eight days for Solar Orbiter were approved for DDT.

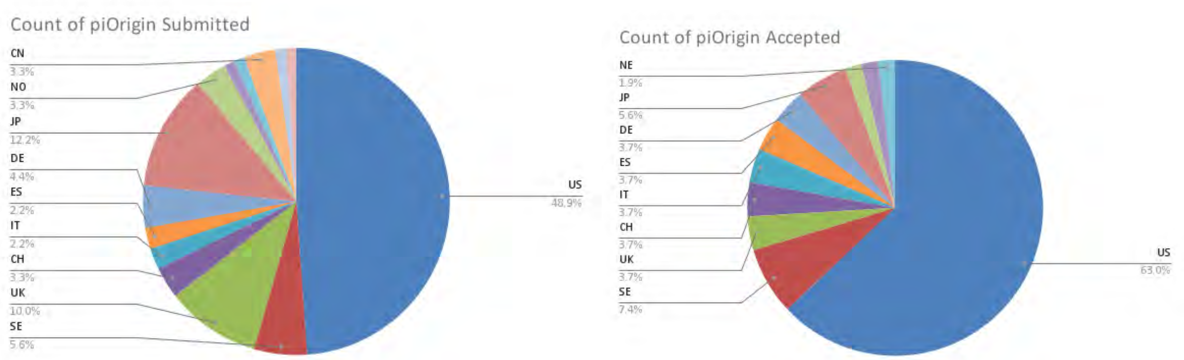

Figure 1.4. *Left: Distribution of US versus Non-US Proposers of submitted Proposals. Right: Distribution of US versus Non-US Proposers of accepted Proposals. Credit: DKIST Science Operations.*

Another major achievement in FY 2023 was the successful execution of the Cycle 2 experiment generation and quality assurance (QA) process (program goal SciOps-3). Cycle 2 experiments differed considerably from Cycle 1 experiments. An additional instrument (DL-NIRSP) had to be folded in, which the experiment generation team had not dealt with in Cycle 1 (except for the DL-NIRSP instrument scientist). The team also dealt with added complexity in the form of additional spectral lines for the ViSP. As a result, additional documentation had to be prepared and more communication had to be managed in order to provide the guidance necessary for the team to be successful.

Cycle 2 Experiments for all 54 accepted proposals were successfully designed and created in communication with the Proposal PI's and validated on the Boulder End-to-End system (Loki). The prioritized Cycle 2 Experiments were then sent to the summit for execution in time over the requested observing window.

For the most part, experiment creation and quality assurance relies on a team of scientists. The Cycle 2 experiment generation team involved 12 DKIST scientists who were each assigned between 1 and 6 experiments depending on skill, experience, workload, and availability in general. The goal was to create as much common knowledge among the scientists as possible, which in the future, will lead to a much more balanced workload. This process will take time especially as instrument and system capabilities continue to change and evolve.

The operations tools that are heavily used during this experiment generation and QA process are the Experiment Architect (EA), the Operations Planning and Monitoring Tool (OPMT) and the End-To-End simulator system (Loki) of the summit Observatory Control System (OCS). The EA was successfully released and had been used in Cycle 1 already, and it continues to evolve driven by new instruments and added functionality, in addition to improvements made to enhance the user experience and overall support. A future goal of the SciOps team is to implement more automation in order to aid specifically the generation of calibration routines to lessen the work involved in the overall process of experiment generation (and some steps have been already taken in that direction). In Cycle 2, for the first time, the validation and QA process also relied on the DKIST science team. That meant that they had to familiarize themselves with the OPMT and use the tool for the first time. Training demonstrations of the tool were performed and high-level documentation providing guidance on the most important interactions with the tool were prepared and made available.

One lesson learned from Cycle 1 was that the Science Operations Specialists (SOSs) that work on the summit heavily benefit from being involved during the validation and QA process during which the generated observing programs are simulated on the end-to-end system. This gives them an opportunity to familiarize themselves with the details of the experiments that they have to later execute at the summit. In this way, additional inconsistencies were discovered by the SOSs that could be corrected beforehand, thus aiding the overall validation and QA process.

In order to manage and monitor the progress made during experiment generation and QA process, science operations implemented a system that connects 1) experiment dedicated Confluence pages to support the design progress and enable team communication, 2) a Jira project for assignment of tasks and progress status tracking and 3) a Help Desk ticketing system to enable SciOps staff to get in contact and communicate with Proposal PI's through Jira service tickets. The progress of the effort can be monitored through a simple dashboard (see Figure 3.5) The Experiment Generation process started on January 17, 2023, and finished on August 31, 2023.

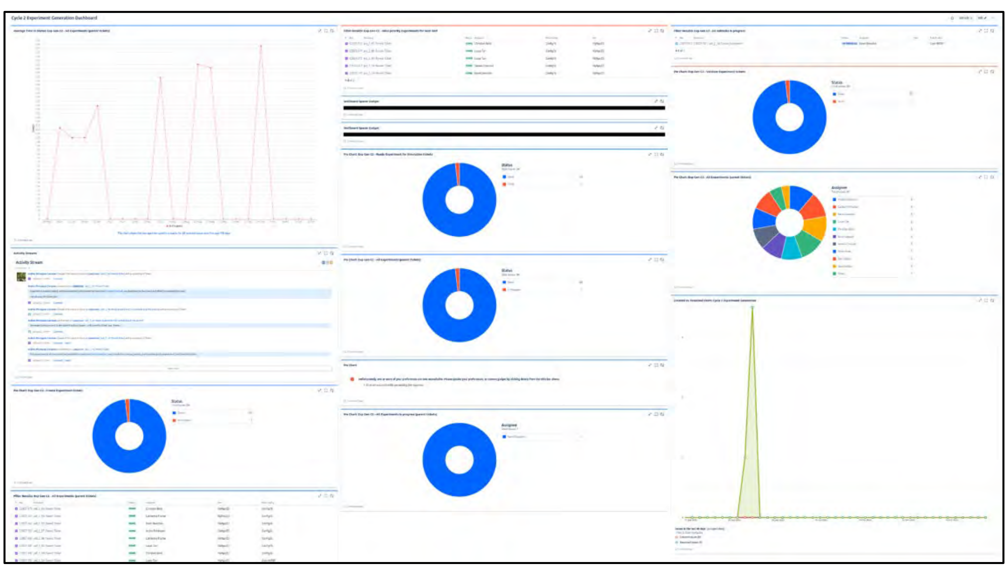

Figure 3.5. *Dashboard view of the Cycle 2 Experiment Generation and Quality Assurance process. Credit: DKIST Science Operations.*

The execution phase for Cycle 2, i.e., the experiment planning, execution, and completion of OCP2.X (program goal SciOps-4) started as planned in February 2023. For Cycle 2, a total of 129 days were planned for science operations (on-sun observing time that is) divided into 5 individual observing windows (OCP2.1 - OCP2.5) interlaced with prioritized technical downtime. Each of these observing windows varied in length, but on average, lasted roughly 26 days per OCP at the summit.

Table 3.1. *Overview of Cycle 2 Observing windows in 2023.*

Observing Window	FIDO	Time Frame	Observing Days planned	Observing Days executed	Experiments PI-led
OCP2.1	1a	02/08/2023 - 03/24/2023	31	2 (scheduled observing, DDT)	0
OCP2.2	1b	04/19/2023 - 05/12/2023	17	4	4
OCP2.3	3a	06/07/2023 - 07/14/2023	26	12 (1 day scheduled observing, DDT)	8
OCP2.4	3c	08/04/2023 - 09/08/2023	25 (Maui wildfire impact)	4	4
OCP2.5	1b	09/26/2023 - 11/03/2023	29	14 (8 days scheduled observing, DDT)	5

Continuing with the approach taken during Cycle 1 (program goal SciOps-1), each of these observing windows was dedicated to one Facility Instrument Distribution Optics (FIDO) configuration, and the pool of proposals/experiments requesting this FIDO configuration. Considering the very short time frame during which the experiments for the first Cycle 2 observing window had to be created, the first observing window (OCP2.1) was dedicated to the least requested FIDO configuration. For a summary of the Cycle 2 observing windows see Table 3.1.

As in Cycle 1, observing during Cycle 2 in FY 2023 continued to include work involved in the planning, preparation for and successful implementation of testing of high-priority coordinated observations during Parker Solar Probe’s perihelion encounters and Solar Orbiter’s remote sensing windows. These coordinated observations were successfully executed first during Parker Solar Probe's 15th perihelion encounter on two consecutive days in the time frame March 16 - March 17, 2023. The second successful testing exercise was successfully executed during Solar Orbiters 11th Remote Sensing Window (RSW11) in the time frame October 11 - October 20, 2023. Specifically for the October exercise, IRIS and Hinode observations are available as well.

3.6 DKIST Data Center

The DKIST Data Center (DC) team is an integral part of DKIST Operations responsible for the ingestion, processing, distribution, and curation of all DKIST data.

3.6.1 Data Center Program Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan laid out the following program goal for the DKIST Data Center.

Program Goal (DC-1): Continue the DKIST Data Center implementation plan.

3.6.2 Major Data Center Achievements for FY 2023

The program goal (DC-1) for the DKIST Data Center in FY 2023 was to continue the implementation of hardware and software solutions as new instruments and capabilities continue to come online. The Data Center consists primarily of two parts, infrastructure (both hardware and software) and instrument calibration pipelines. Below are the FY 2023 accomplishments in these two areas.

3.6.3. Data Center Infrastructure

At the beginning of FY 2023, the Data Center software infrastructure had been completed and ready for the data from the summit to be ingested. The hardware infrastructure was also ready but was augmented (as it will be yearly during the current Cooperative Agreement) with additional servers and storage.
The Data Center portal was completed and went live with the first batch of datasets from the ViSP and VBI instruments. In addition, at approximately the same time, the ancillary sites went live (open to the public) – these included the DC help desk with links to a FAQ, design documentation for both the DC and the available pipelines, as well as pipeline code.

Version 1.0 of User Tools (UTs) was completed as it was awaiting final testing using real data from the VBI and VISP instruments. Testing with real data uncovered a few issues, which were resolved prior to release. Training materials were generated in the use of the UTs, and the DKIST science staff were trained in how to use the UTs as a dry run for training external users at scientific conferences. The dry run with the DKIST science staff uncovered other issues with both the UTs and the training materials, which were both updated as a result.

The DC also performed a security assessment and generated a cyber security risk matrix for DC data assets and developed risk mitigation strategies. The assessment focused on keeping the DC data holdings safe in the event of a ransomware or other attack. Mitigation strategies proceeded from the assumption that an attack would one day occur and would involve locking the data such that it could not be deleted or modified, and/or backing up the data in multiple, geographically separate locations, such that, were an attack on the DC successful, the DC would not lose data and would be able to resume normal operations relatively quickly after the attack vector was investigated and neutralized.

3.6.4 Data Pipelines

The Data Center, with extensive assistance from the DKIST Science team completed and qualified the VBI and ViSP pipelines and began producing data from both these pipelines. After the first datasets from OCP 1.2-1.4 were published, comments generated by the community and DKIST scientists informed an update/upgrade of the ViSP pipeline, which resulted in the reprocessing of all ViSP data.

The DC has also completed the Beta version of the Cryo-NIRSP pipeline, which is now being used to generate L1 data products for internal use during the pipeline acceptance (qualification) phase of pipeline development. The DC and DKIST scientists will iterate over comments and updates to the pipeline until it is found to produce suitable science-ready, Level-1 data, at which point it will be released as Version 1 and used to calibrate the backlog of Cryo-NIRSP data.

The DC has also started working on the DL-NIRSP pipeline with the expectation that it will be completed after the DL-NIRSP instrument is modified on the summit.

As a result of the reprocessing of the ViSP data, the DC led an effort to generate a process by which future pipelines would be updated. This process, which must be used for any software modification that will change the output Level-1 data, includes the generation of Algorithm Change Proposals (ACPs), with a review and approval cycle as prerequisite to pipeline modification.

By the end of FY 2023, the Data Center had published a total of 511 VBI and ViSP datasets for download by PIs and the public. These published datasets constitute 98.3% of the “calibratable” data that the DC has received to date. There are currently 9 ViSP datasets that are awaiting bespoke interventions in order for them to be processed. These will be calibrated once the Manual Processing Worker (MPW) has been completed. The MPW is a suite of software tools that will allow “one off” processing of non-standard data that differ in unique ways from the majority of the standard Level-0 data the DC receives from the telescope.

3.7 DKIST Instrumentation

The DKIST Instrumentation team is a fundamental component to keeping NSO/DKIST at the forefront of scientific discoveries and research in the field of high-resolution solar physics. At its first light, DKIST’s instrumentation suite has already shown its vast potential, and recent discoveries with DKIST data have corroborated this fact. The Instrumentation team, which is distributed between Maui and Boulder, includes staff that are working on Instrumentation Operations and High-Level Software based and Instrumentation Development.

3.7.1 Instrumentation Program Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan laid out the following program goals for Instrumentation.

Program Goal (Inst-1): Continue developing Multi-Conjugate Adaptive Optics.

Program Goal (Inst-2): Continue the DKIST instrumental upgrades.

3.7.2 Major Instrumentation Operations Achievements for FY 2023

DKIST Instrument Operations is responsible for the day-to-day operation, maintenance, upgrades, and enhancements of all summit equipment located in the Coudé and responsible for scientific data collection. Currently this includes the five scientific instruments: Visible Broadband Imager, Visible Spectro-Polarimeter, Diffraction-Limited Near Infrared Spectro-Polarimeter, Cryogenic Near Infrared Spectro-Polarimeter, and the Visible Tunable Filter. It also includes the High Order Adaptive Optics, Low Order Wavefront System, and the Facility Instrument Distribution Optics. Each of these play a very important part in providing quality scientific data to the community.

In addition, Instrument Operations includes the High-Level Software (HLS) group, the team responsible for maintaining HLS systems at the DKIST facility, including the software infrastructure, Observatory Control and Instrument Control Systems and all major telescope control systems (mount, enclosure, M1 & M2 mirrors, facility, calibration hardware, etc.). The HLS team manages all instrument control systems and the data handling system used to collect, store, display, and distribute scientific data to the DKIST Data Center.

3.7.3 Instrumentation Operations

The **Visible Broadband Imager (VBI)** has been one of the principal science instruments used during the Operations Commissioning Phase (OCP). Many enhancements have been made, and are currently underway, to improve the VBI data products. The speckle image reconstruction pipeline has been moved temporarily to Boulder to improve flexibility for application of camera noise reduction algorithms for the final data products. Stray light sources affecting the science data have been eliminated or mitigated. A new H-alpha filter was procured to ensure improved on-band performance. Based on the experience gathered in the OCP phases, the instrumentation team is exploring improved visible light camera systems for low noise scientific data products. With these enhancements, the VBI science data will remain a high-quality instrument for the scientific community in the future.

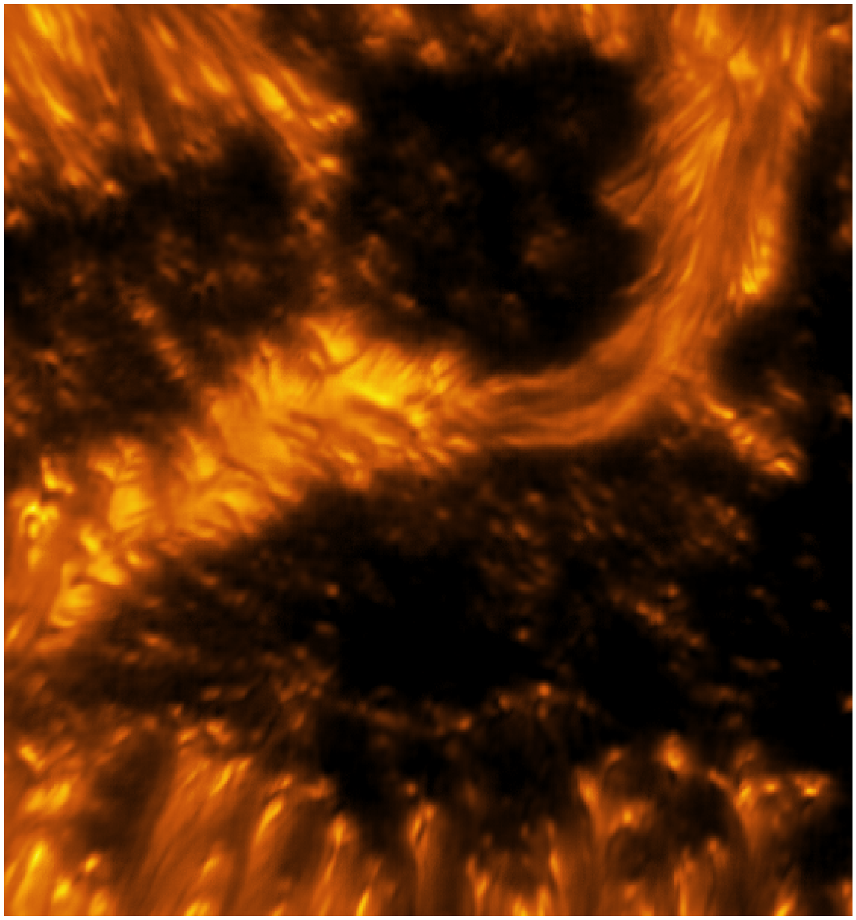

Figure 3.6. *VBI blue channel image of a light bridge inside the umbra of a sunspot (λ=450 nm)*

The **Visible Spectro-Polarimeter (ViSP)**, another key science instrument during the OCP, has been part of the majority of visible light proposals. During OCP 2, ViSP observations have used additional spectral lines, resulting in more hardware and software testing on the instrument. Issues with image quality such as stray light, focus, and mechanism failure were detected, diagnosed, and repaired. Opto-mechanical modifications to simplify the exchange of order sorting and neutral density filters have been implemented to improve operational efficiency. Significant improvements to ViSP's control software and the data calibration pipeline algorithms have resulted in increased efficiency and improved scientific value of the VISP data sets.

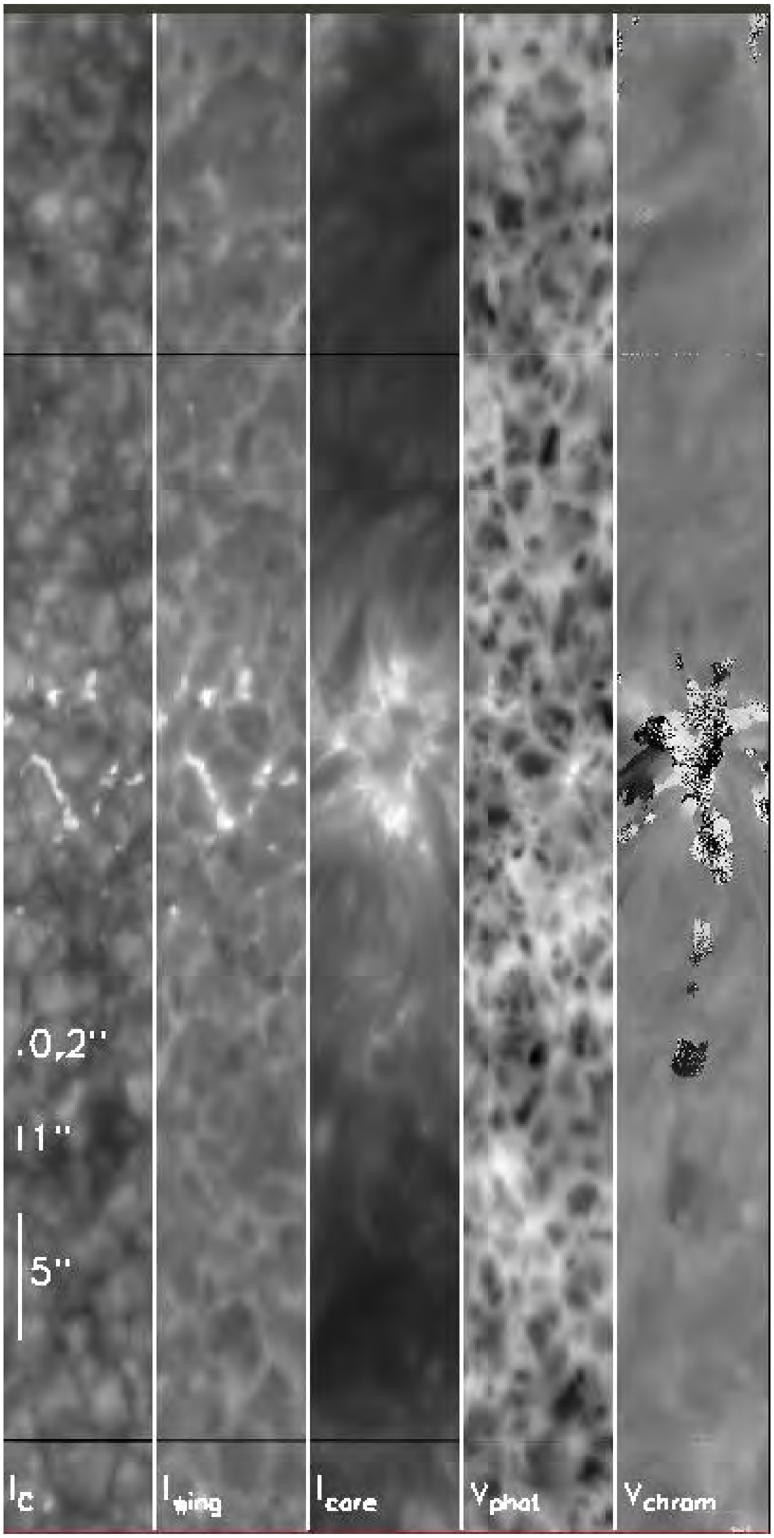

Figure 3.7. *ViSP maps - using data acquired in the Ca II H (λ=396.8 nm) line - of (from left to right): the solar photosphere (I_c), upper photosphere (I_{wing}), chromosphere (I_{core}), photospheric plasma velocities (V_{phot}) and chromospheric plasma velocities (V_{chrom}).*

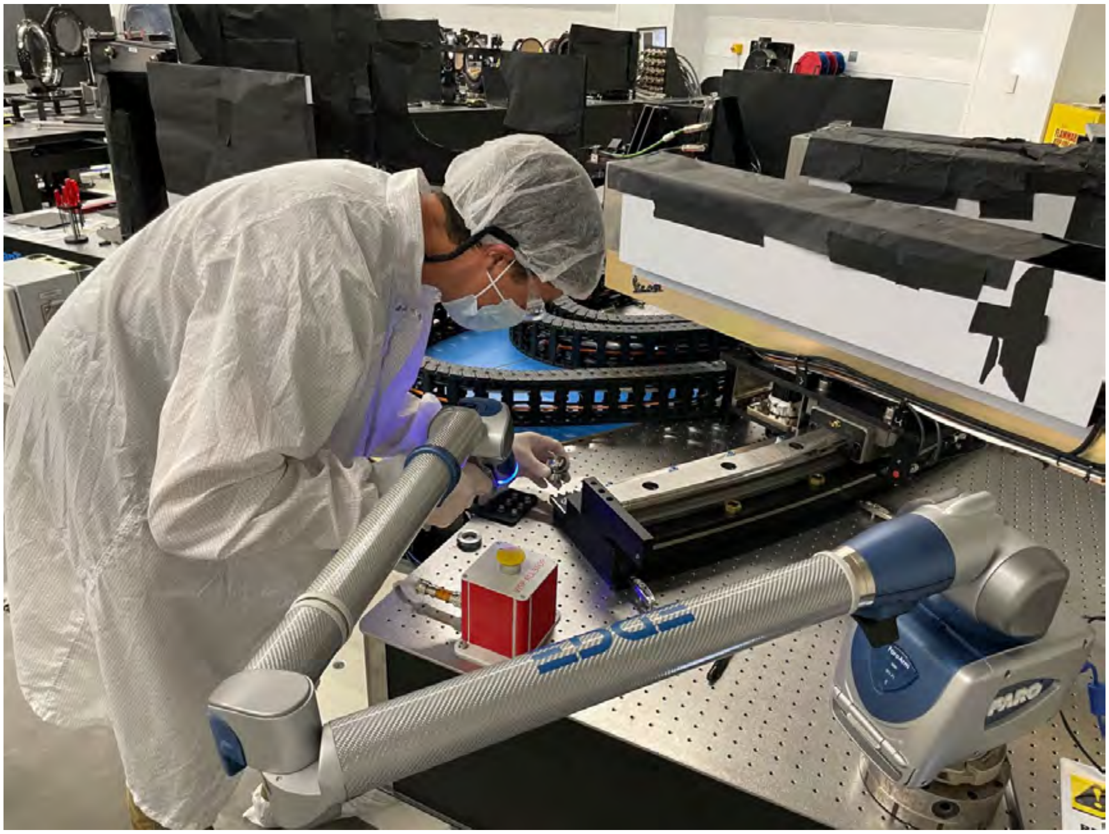

Figure 3.8. *Opto-mechanical measurement of the ViSP arm rail during regular maintenance procedures.*

The **Cryogenic Near-Infrared Spectropolarimeter (Cryo-NIRSP)** is another instrument taking data on a regular basis during the OCP. During 2023, several stray light and ghost image issues within the Cryo-NIRSP were diagnosed and mitigated. Filters with leakage in the mid to far infrared were identified, and replaced. The original modulator was replaced with a new, state-of-the-art optic that uses an unprecedented design; this optic has proven to be superior in performance and reliability to the original modulator. A redesigned and integrated collimator lens mount removed a persistent source of vibration that impacted instrument data. These updates have significantly enhanced the scientific value of the Cryo-NIRSP data.

The Diffraction Limited Near-Infrared Spectropolarimeter (DL-NIRSP) was operated during the OCP to identify multiple issues that arose from instabilities in the fiber-fed Integrated Field Unit (IFU). This led to several data calibration pipeline modifications. A new contract for a machined image slicer, MISI-36, was executed to remove many of the limitations associated with the existing fiber optics. The completed MISI-36 optics assembly has been built and has passed the initial acceptance testing. A second image slicer for improved coronal observations, MISI-116, has been specified and placed under contract for manufacturing. Several stray light issues have been mitigated, including additional instrument baffling and procurement of new cold filters with enhanced out-of-band blocking. New IR sensor control electronics were designed and contracted to reduce IR camera noise. A new modulator was installed to suppress fringes at the DL-NIRSP wavelengths. These updates are in preparation for the upcoming MISI-36 installation and are needed to increase the quality of the science data.

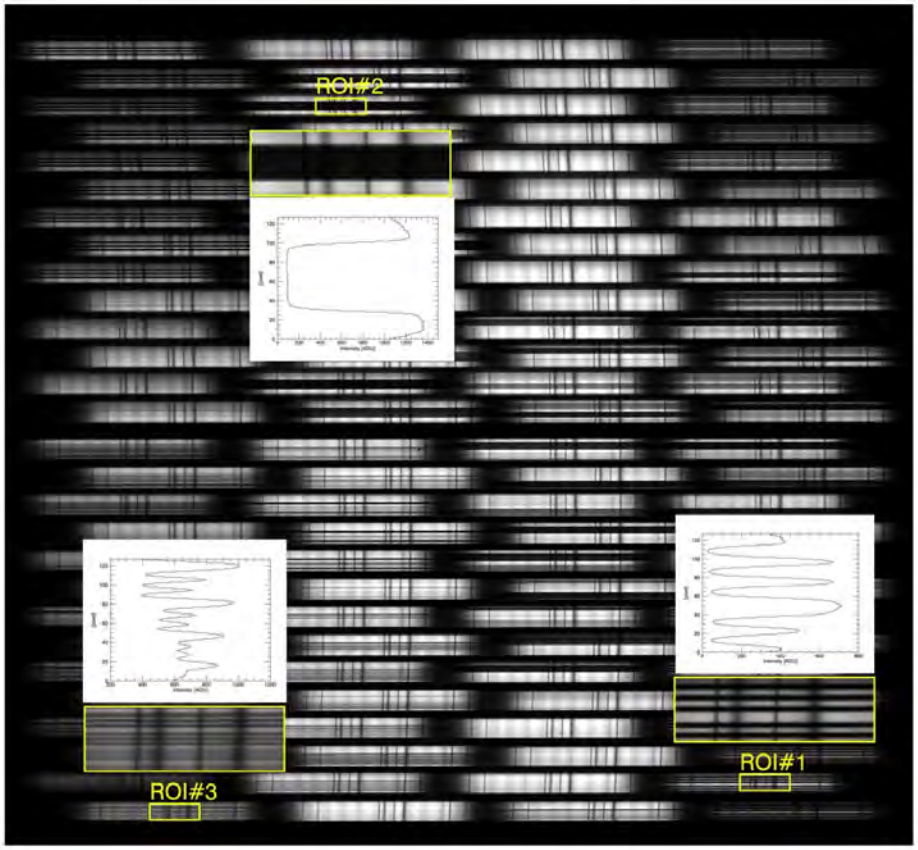

Figure 3.9. *Spatial intensity profiles from 3 regions of interest of an Air Force Target obtained with the DL-NIRSP MISI-36.*

Figure 3.10. *Installation of DL-NIRSP stray light baffles.*

The **Visible Tunable Filter (VTF)** has finished construction and has passed the Laboratory Acceptance Testing phases. The instrument has been disassembled and prepared for shipping to Maui. The second Fabry-Perot Etalon, a vital future enhancement of the VTF instrument, is under development, with the coated etalon plates having been delivered to the Leibniz Institut für Sonnenphysik (KIS) in Freiburg, Germany.

Figure 3.11. *VTF Lab Acceptance Testing and inspection of the VTF mechanical systems prior to disassembly and shipment to Maui.*

The **Wavefront Correction System (WFC)** has been an essential part of observatory operation since the first light of DKIST. The WFC calibration script is under continuous improvement to minimize start-up times at the telescope, leading to increased operational efficiency during the OCP and in the future. Issues related to limb tracking were identified and diagnosed. During the OCP data acquisition periods, a significant amount of jitter in the scientific data was detected originating to a large degree from vibration sources that impact both instruments and the DKIST wavefront correction system (WFC). The instrument team designed and built a flexible, high speed imaging tool that allows the detection, recording and real-time analysis of high frequency vibrations at various locations in the science beam on the code floor. The data provided by this tool, in combination with WFC data, allowed the instrument team to pinpoint various source locations. In collaboration with the technical operations team, the identified sources were identified and mitigated.

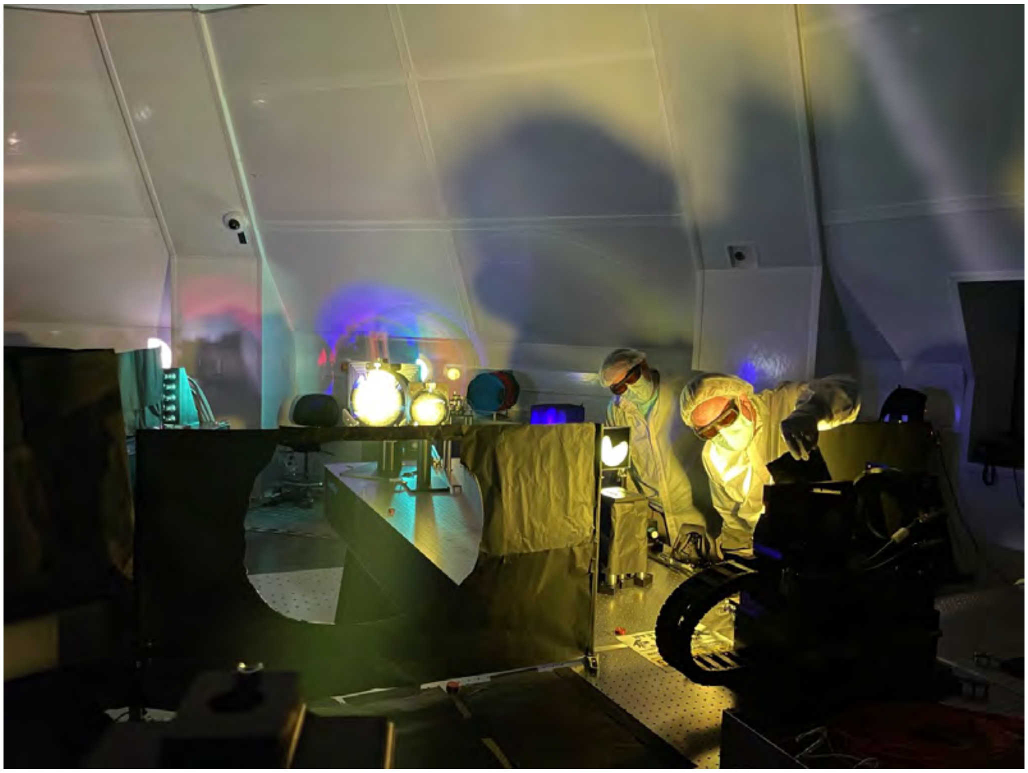

Figure 3.12. *Optical enhancements being applied and verified using sunlight on the Coudé floor.*

The Facility Instrument Distribution Optics (FIDO) were supplemented with an additional beamsplitter, enhancing DKIST's flexibility to combine multiple instruments in a multitude of wavelengths. Contracts for further beam splitter optics have been issued with the goal of addressing as many of the science requests of the solar physics community as feasible. The efficiency of the FIDO optics exchange has been greatly increased with a motion control system that moves optics in the center of the system to an easier to reach location. In addition, the optical specifications for a visible/infrared beam splitter at Cryo-NIRSP pickoff Coudé location (M9B) was finalized, and the long-lead glass substrates were procured, funded through a successful proposal from the NSF Windows on the Universe Multi-Messenger Astrophysics (WoU-MMA) program.

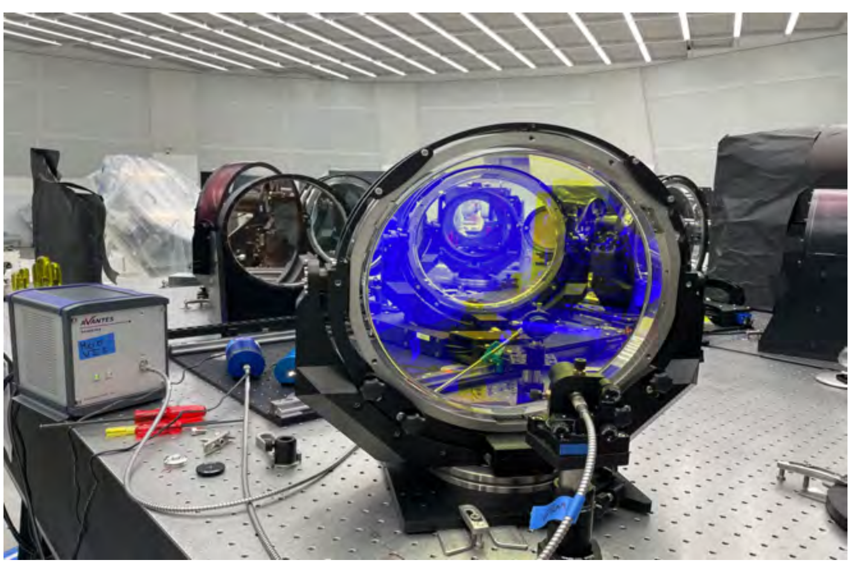

Figure 3.13. *Final optical alignment checks for FIDO reconfiguration for OCP 2.5.*

The Instrument Operations team archived a number of milestones in FY 2023 relevant to program goal Inst-2, which included:

- Maintaining DKIST instrumentation to ensure science operations during the OCP.
- Identifying areas for performance improvements in the individual science instruments, and integrated relevant enhancements to provide highest possible quality in science data.
- Detecting, identifying, and mitigating - in collaboration with the technical operations team - facility wide vibration sources.
- Enhancing DKIST capabilities for flexible science beam distribution to instrumentation.
- Improving operational efficiency in instrumentation and wavefront correction.
- Completing VTF Laboratory Acceptance Test phases.

3.8. High Level Software

The DKIST High Level Software (HLS) team entered full operations mode on the summit, with the start of regular and routine software maintenance and performance upgrades. The HLS team has transitioned from the "Alakai" first OCP Operational software release, to the new "Pono" release, focusing on continuing operational support. This transition emphasizes that the 2023 software releases show an emphasis on a maintenance and performance upgrade model, having successfully transitioned from a construction to operations model the prior year. Examples of this transition include server upgrades, development of testing simulators, and implementation of an 'agile' software development model.

The HLS team achieved a number of milestones in FY 2023 relevant to program goal Inst-2, which included:

- Upgrading the summit high-speed real-time data network (InfiniBand) from 56 gbps to 100 gbps to support future instrument data rates.
- Building an end-to-end simulator (Loki) in Boulder that performs Science Operations pre-tests for all experiments executed on the telescope.
- Building a motion control test bench at the DSSC in Maui so that motion tests and debugging can be done off-summit.
- Transitioning to a modern, continuous integration testing system, Bitbucket Pipelines, to facilitate testing more code more often.
- Upgrading all 23 summit instrument servers to modern hardware.
- Purchasing and installing an upgraded Data Storage System to allow more scientific data storage and simultaneous read/process/write capability.
- Creating an on-summit local storage cluster for engineering data.
- With increased stability of all the telescope subsystems, the HLS team has transitioned from 100% on-site support to 50% on-site and 50% remote support during observing.

3.8.1 Major Instrumentation Development Achievements for FY 2023

As part of the DKIST instrumentation mission, development programs are delivering new systems and upgrading existing instrumentation capabilities. Among these new systems are advanced adaptive optics systems and new infrared sensors. In addition, there are several instrumentation upgrades either in progress or in the planning stages. These include upgrades for visible cameras, new optical components for modulators and filters, improved software for automation and efficiency, and advanced data storage and processing capabilities.

Multi-Conjugate Adaptive Optics (MCAO)

The DKIST project intends to be at the forefront of scientific discoveries for the duration of its lifetime using state-of-the-art technology. An important requirement for meeting this goal is the continuous facilitation of data acquisition with the highest possible image quality given prevailing atmospheric conditions.

The initial High-Order Adaptive Optics (HOAO) system of DKIST is a classical adaptive optics system and is based upon well-established techniques and scaled-up technologies, such as the first and pioneering high-order system in solar adaptive optics developed at the Dunn Solar Telescope. Since it is a single conjugate or classical system, the DKIST HOAO deploys one deformable mirror conjugate to the telescope aperture to correct the light path, and one unidirectional wavefront sensor to measure the adjustments needed. In such a system, the corrected field of view is typically limited to a patch on the order of 10 arcseconds in diameter around the viewing direction of the wavefront sensor. However, scientifically interesting regions can span dozens of arcseconds. Deployment of multiple deformable mirrors that are conjugate to different atmospheric altitudes in which strong turbulence occurs—the concept of a Multi-Conjugate Adaptive Optics (MCAO) system—can widen the corrected field by several factors, providing a data set that is scientifically more useful.

For over a decade, NSO has been collaborating with the Leibniz-Institute for Solar Physics (KIS, previously the Kiepenheuer-Institute for Solar Physics) and the New Jersey Institute of Technology (NJIT) in the development of MCAO. Under the leadership of NSO and funded by NSF grants, the experimental solar MCAO pathfinder, called "Clear," was developed for NJIT's 1.6-meter Goode Solar Telescope (GST) located at the Big Bear Solar Observatory in Southern California.

Given the excellent progress made with Clear, DKIST has been pursuing the design and development of a much larger MCAO system for DKIST, with plans to correct atmospheric turbulence in three different layers (ground layer, four and eleven kilometers above the telescope).

The design and development of the MCAO system has significantly progressed in several areas, in particular executing contracts for the two long-lead, complex deformable mirrors, and engineering of the wavefront sensor, including its custom cameras and low-level, real-time software.

The Instrumentation team achieved several milestones in FY 2023 relevant to MCAO development (program goal Inst-1), which included:

- The specifications of the MCAO system were defined and put under signature.
- The 4km deformable mirror (DM) underwent a design review and is being manufactured.
- The 11km DM is under design in collaboration with the contractor.
- The custom high-speed cameras have passed a design review and are under construction.
- The optical design for the MCAO Wavefront Sensor has been finalized and is in preparation for a review.
- Preliminary designs for the opto-mechanical system that allows an interchange between DKIST M9 and the 4km DM have been reviewed, and a solution has been selected for implementation.
- The real-time control system continues to make significant progress and is ahead of schedule.

Infrared Cameras

The infrared detector technology used for the DL-NIRSP and Cryo-NIRSP instruments continues to be an operational concern for the observatory. These infrared camera systems use an older generation analog detector and custom-built electronics and control systems for which there are currently no available spare devices or electronics. To meet requirements for solar observations, the detectors are controlled in non-standard ways (*e.g.,* at fast frame or even sub-frame rates). Many problems with the analog technology used to control these devices have been revealed during science verification and the OCP phase. These problems, such as bias flicker, frame synchronization, and pedestal subtraction, can be greatly reduced or eliminated completely with the new digital technology.

In 2022, DKIST issued a Request for Proposal for the development of new digital IR sensors that meet more advanced requirements. The project selected a vendor for the fabrication of two short-wave IR (SWIR) and two mid-wave IR (MWIR) sensors. Using newly available infrared detector technology these new sensors will be able to meet DKIST's challenging requirements and provide additional capability and robustness. Specifications for the sensors include features such as digital focal planes, 4K by 4K pixels, 60 frames per second with low read noise, high quantum efficiency, non-destructive readout capability, and reliable timing and triggering functionality.

During FY 2023, the IR camera program has advanced on several levels. The contractor has delivered a readout integrated circuit prototype sensor (ROIC) to the DKIST project. The silicon for the SWIR and MWIR sensors has been fabricated and down-selection is underway for selection of the best grade sensors.

To operate these new sensors, DKIST has begun implementing an IR Camera program to integrate these sensors into IR cameras for replacement in the Cryo-NIRSP and DL-NIRSP instruments. This effort will standardize the differing electronics in each instrument easing maintenance and will significantly upgrade their scientific capabilities. The IR camera program has begun the development of a lab system in Boulder, and a prototype controller hardware system has been procured that will help define the specifications for the final IR camera. Initial mechanical, electrical, and optical work on the integration process for each instrument has also begun.

The Instrumentation team achieved several milestones in FY 2023 relevant to the infrared camera development (program goal Inst-2), which included:

- A Return on Invested Capital (ROIC) sensor has been delivered to DKIST for testing and verification.
- Vendor site testing of initial sensors has occurred using DKIST controller equipment.
- Prototype controller hardware has been procured and delivered.
- An Operations Concept Definition document for the IR Camera development has been written and is under review.
- Mechanical and electrical investigations into changes required by the existing instruments have started. Draft preliminary designs for these changes are under review.
- A draft Specification for an infrared camera controller is under review.

3.9 DKIST Technical Operations

The DKIST Technical Operations (TechOps) team comprises Maui-based management, engineers, and technicians. In essence, TechOps performs three main functions:

1) Support of On-Sun observing and proactively minimizing the loss of Science Operations time. Activities under this function are categorized as ***Availability***.
2) The second is maintenance, which can be subdivided into planned (preventive) and unplanned (repair) maintenance, with further division of planned maintenance into activities that may be conducted concurrently with observing and activities incompatible with observing. These activities are categorized as ***Reliability***.
3) The third category is upgrades to the facility and equipment. These upgrades are categorized under ***Capability Now*** for activities that are being implemented in the current period and ***Capability Future*** for activities that are in the design and planning stage in the current period.

3.9.1 Technical Operations Program Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan did not specifically lay out program goals for Technical Operations (TechOps), however the TechOps achievements for FY 2023 are consistent with the following three program goals.

Program Goal (TechOps-1): Provide technical support during Science Operations by maximizing staff efficiency and increasing automation to minimize downtime due to planned and unplanned technical outages (*Availability*).

Program Goal (TechOps-2): Continue a program of preventive maintenance to reduce technical downtime for the DKIST facility (*Reliability*).

Program Goal (TechOps-3): Continue to upgrade the facility to keep it on the leading edge of science (*Capability Now* and *Capability Future*).

3.9.2 Major Technical Operations Achievements for FY 2023

Availability

At the start of this period, TechOps was supporting science observing and on-sun testing with a rotating team of 5 personnel: Duty Engineer, Programmable Logic Controller (PLC) Engineer, Thermal Systems Engineer, Electrical Technician, and Mechanical Technician.

To increase availability (program goal TechOps-1) The TechOps team prioritized reducing the number of roles required for observing support. Doing so would allow for the cross-training of personnel who could then become available to fulfill the remaining observing support roles, i.e., a larger pool with sufficient personnel to support additional On-Sun support.

The initial changes in TechOps observing support roles in FY 2023 occurred with the modification of the Mechanical Technician support position (May 2023) and the PLC engineer (September 2023) from both being present during observing to being on-call during core On-Sun hours. This was made possible through increased system reliability as well as training of WFC SOS to assist the on-duty Electrical Technician during the walkaround, opening sequence, and mirror cover removal. During the summer period, the Electrical Technician was trained in the use of the engineering Human Machine Interface (HMI) designated IGNITION such that they could take over the PLC Engineer role in front-line troubleshooting during the September period. By the end of FY 2023 TechOps had achieved its goal of reducing the number of personnel required for observing from 5 to 3.

Hand in hand with the cross-training of staff were increases in automation with respect to start-up / shut down and fault handling procedures. TechOps worked with Inst-HLS and SciOps during this period to specify a number of standard routines that had previously been manually implemented. Examples of these scripts are, Thermal End Users Startup and Shutdown, Enclosure Parking at the end of observing, Mount Observing Ready Parking, Mount Wet Weather parking, and Enclosure Shutter Dump used for removing residual water from the shutters prior to observing start. Each script had to be specified/defined/coded/tested and then deployed to the summit system. In addition, scripts were implemented in the Facility Thermal System control for starting and shutting down secondary facility thermal loops and the active ventilation system

Further development of the IGNITION interface for use by the TechOps personnel in observing support continued throughout FY 2023 focusing on fault handling, identification, prioritization, and ease of user access. IGNITION was also interfaced with the Mount and Coudé Motion Controllers to allow troubleshooting through the same engineering interface as is used for the Enclosure and the Facility Thermal System.

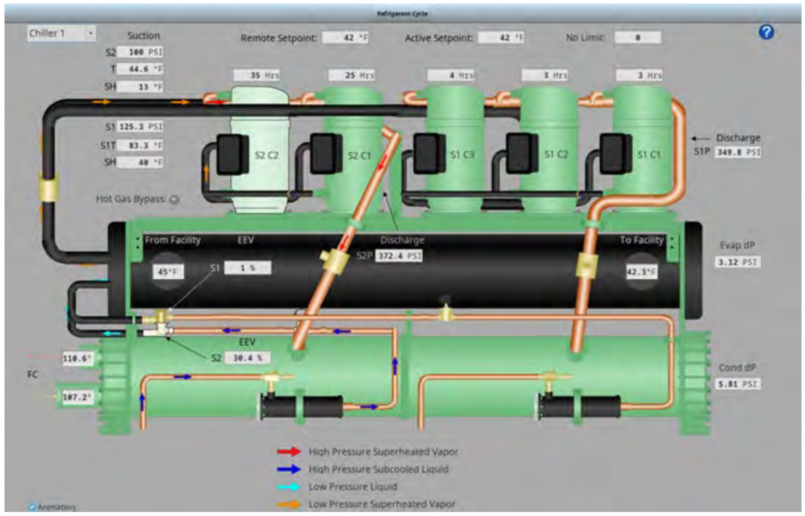

Figure 3.14. *Human Machine Interface IGNITION display for Chiller 1.*

Reliability

Maintenance Management - During FY 2023, in line with program goal TechOps-2 there was a major push to incorporate more of the DKIST systems into the observatory's Computerized Maintenance Management System (CMMS) - HIPPO. This involved a significant amount of effort from the engineering staff covering all the disciplines and involving systems as widespread as regular overhead crane inspections to cleaning optical elements with CO_2 or N_2. This also involved developing/documenting the maintenance processes and routines from manuals, industry standards, etc.

An important part of the maintenance process is ensuring that it can be, and is, conducted safely and efficiently. Therefore, during FY 2023, there was a review of lock-out tag-out (LOTO) capability and processes for thermal equipment. This was to ensure that appropriate and documented procedures for LOTO processes could be made available to improve work efficiency, e.g., Mechanical Technicians can do their own LOTO on systems requiring regular maintenance. Implementation of the findings of this review will continue in FY 2024.

The bulk of regular and recurring Planned Maintenance (PM) is mechanical and so by releasing the Mechanical Technicians from observing support duty, TechOps was able to make significant progress on the backlog of preventative maintenance from construction and stay current with recurring maintenance. The MTech team still has two vacant Mechanical Technician and one vacant Maintenance Technician positions. Recruitment continued throughout FY 2023 with limited success. Recruiting and retaining skilled staff in Maui as a remote and extremely expensive job market continues to be one of the most significant challenges for TechOps.

The TechOps team achieved several Electrical Maintenance milestones in FY 2023 relevant to system reliability (program goal TechOps-2), which included:

- Site-wide full power shutdown in Jan 2023 for the first annual Panel maintenance.
- System Drive rack maintenance process was documented, PM procedures incorporated into HIPPO, and inspections started in FY 2023 (and will continue into FY 2024).
- In conjunction with Mechanical Technicians inspection and maintenance was carried out for all the thermal system fans and pump motors.

- The Utility level Intermediate Distribution Frame (IDF) cabinet was rebuilt for improved reliability (workmanship) and ability to troubleshoot. This is a central hub on the control and safety system network.

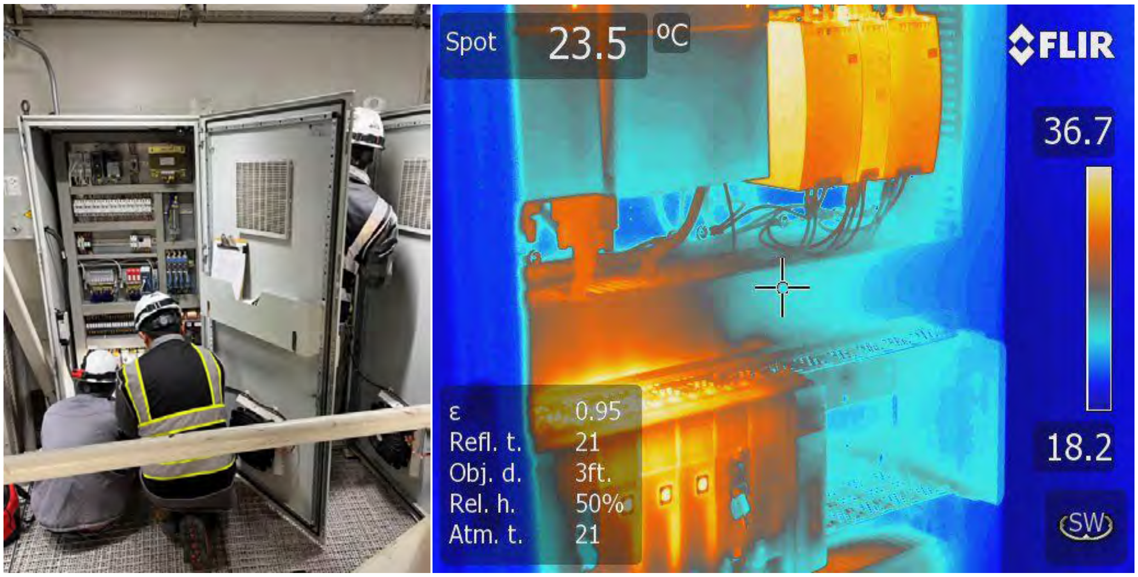

Figure 3.15. *Utility Level IDF before (left) and after (right) the rebuild for reliability.*

The TechOps team achieved several Optical Maintenance milestones in FY 2023 relevant to system reliability (program goal TechOps-2), which included:

- M1 in-situ wash process, multiple tests on optical samples to determine the optimum process and method followed by perform full contact in-situ wash in Jan 2023.
- M3 spare procurement completion and delivery for coating.
- Non-contact and Contact Cleaning methods/processes were tested for various small and large optics.
- The Heat Stop was replaced and an investigation into improved coatings for the replacement spare was undertaken.

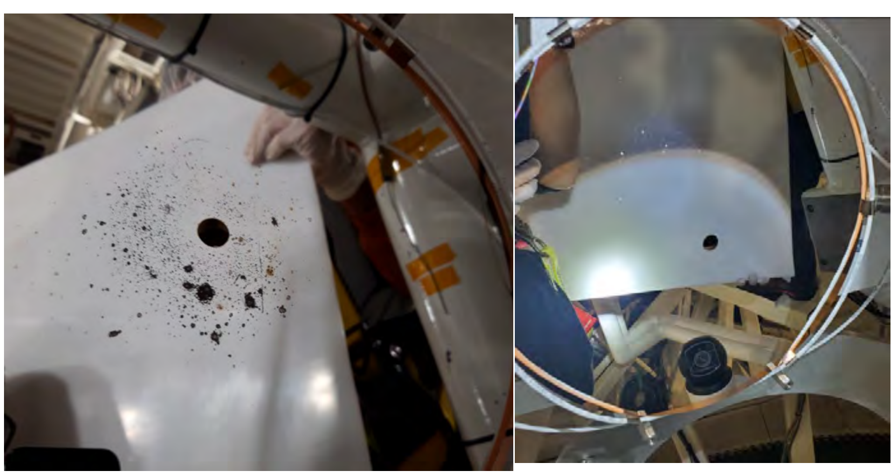

Figure 3.16. *Heat Stop with surface damage prior to replacement and undamaged spare after installation.*

The TechOps team achieved several Thermal / Mechanical Maintenance milestones in FY 2023 relevant to system reliability (program goal TechOps-2), which included:

- Normalizing routine maintenance on various mechanical systems such as pumps, air handlers, fan coils, and heat exchangers.
- Initiation of Spring and Fall maintenance periods where lubrication of the main axes of the Telescope Mount, the Coudé platform and the Enclosure mechanisms was undertaken.
- Took ownership and led inspections on the major motion assemblies for the Telescope Mount, Coudé platform, and Enclosure.
- Began and continued to manage inventory, including parts, spares, equipment, and components.
- Continued personal and professional development. Including becoming I, II, and universal EPA608 certified

Figure 3.17. *Mechanical Technician in Main Enclosure Arch Girder lubricating a shutter mechanism.*

The major push during FY 2023 for the TechOps group was the stabilization of the **facility thermal system** through the replacement of two of the three primary chillers that had developed unrecoverable faults. The first chiller to be ordered was #3 which was primarily used for ice-making with the secondary duty of supporting the facility in the event of chillers #1 and #2 being unavailable. Chiller #3 was installed in June – July 2022, but had a number of issues that required further investigation by both DKIST thermal team and the contractor. These issues relating to ice-making were resolved in May 2023 during a troubleshooting trip. Chiller #1 was installed during July – August 2023 and commissioned in September 2023. Chiller #1 has worked without issue since. This allowed for the replacement of chiller #2, which is now underway. Chiller #2 is being swapped to match the other two new units so that there is commonality among all three allowing for more straightforward control and fault handling for the purposes of automation.

Figure 3.18. *Replacement Chiller #1 ready for commissioning.*

The DKIST **Individual Wastewater System (IWS)**, which was installed during the construction project, had a number of issues relating to the obsolescence of equipment as well as problems with the pipe gradients such that it was not possible to fully commission the DKIST bathrooms. The portable toilets that were used in construction have continued to be used in Operations. The first part of the repair process in FY 2023 was to employ an engineering firm to review and propose a replacement set of tanks. The employed engineering firm submitted on behalf of DKIST the permit application to Hawai'i Department of Health. Approval of the permit was received in April 2023. In the months following, quotes for the repair work were solicited from companies on Maui that specialize in septic systems as well as had experience working in the unique and challenging environment that is Haleakalā Summit. In parallel discussions with Hawai'i Department of Land and Natural Resources (DLNR) were initiated through the University of Hawai'i Institute for Astronomy (UH IFA) Director’s office regarding permitting. In conjunction with UH IFA a Site Approval Plan was developed and submitted to DLNR for review. DLNR responded in Sep 2023 with an analysis concluding that the repair work did not require a permit from the department or board. AURA procurement is currently in the process of placing the contract for the repair.

The **Enclosure azimuth rail** was showing signs of premature wear in the latter stages of DKIST construction, and a dedicated project was set up to study the wear and identify the cause with proposed solutions. Through this project, a level of misalignment was identified that explained the wear as well as control issues with wheel slippage. The proposed solution was to carry out a series of targeted re-alignments of specific rail sections. The first of these alignments happened in November 2022, with subsequent sections carried out in May 2023. The last section alignment is planned for December 2023. The changes in wheel loading/slippage are shown in Figure 3.19 below.

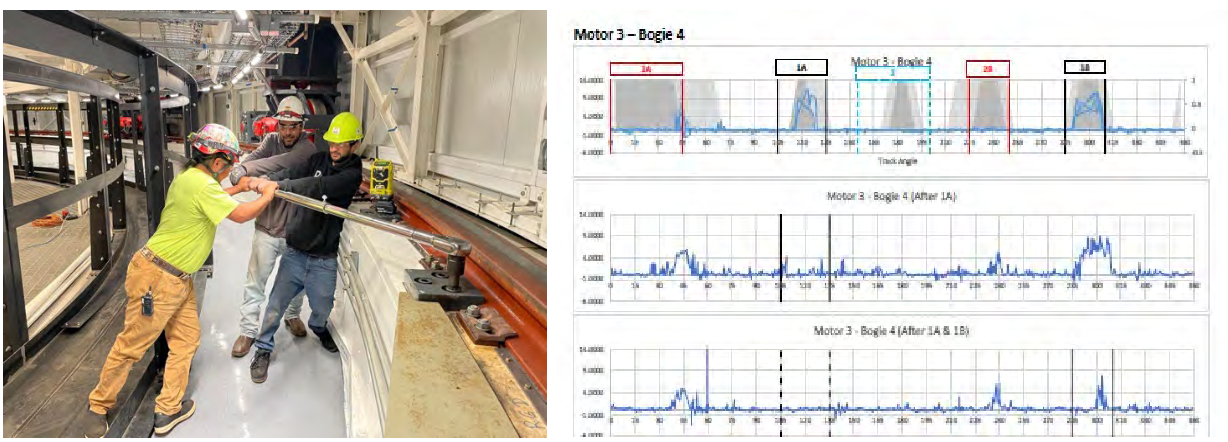

Figure 3.19. *Rail section re-alignment and the measured wheel slip before and after adjustment.*

A number of dropouts during Enclosure tracking had occurred in FY 2022, and a subsequent investigation determined the cause to be the **Enclosure azimuth encoding system**. From this determination, a project was initiated to specify and plan the replacement of the encoding system. Within the operations paradigm, it was decided to fully install the new system in parallel with the existing system so that any issues in commissioning would not reduce the availability of the system. During FY 2023, the new encoding system was installed, tested in parallel, and then after a suitable proving period was switched over such that the new 4-head system was the primary system.

As the operations commissioning phase continued, vibration effects on DKIST VBI image quality were an ongoing investigation as system noise levels reduced. The TechOps team was involved in the detection of vibration through the use of a Telescope Mount and Coudé accelerometer network that was completed in FY 2023 in conjunction with data provided by the Wave Front Correction group. In addition, a number of sources were identified, and corrective action plans were put in place. The most significant of these in FY 2023 was the standard Rittal rack cooler fans that were mounted on all the Telescope Mount and Coudé drive racks. A custom **vibration isolation system** was designed and tested before being deployed on all the Mount racks, effectively reducing the vibration signature of these systems to an acceptable level. The Coudé drive racks will be retrofitted during FY 2024.

Figure 3.20. *Enclosure azimuth with new barcode encoder and read head.*

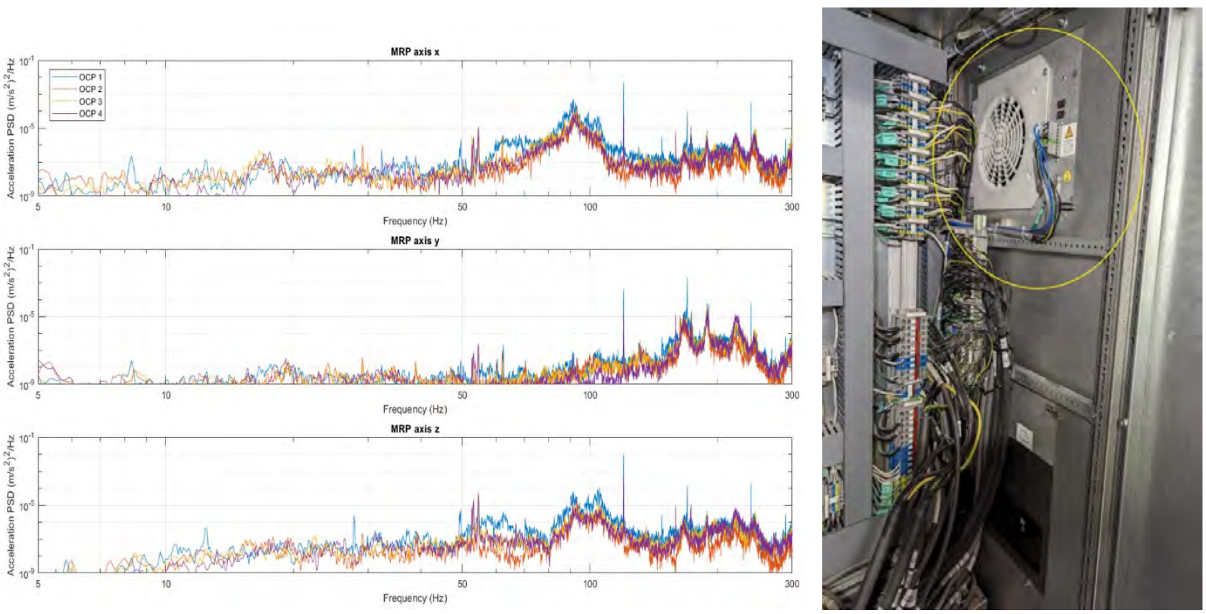

Figure 3.21. *Mount rack fans and vibration signature before and after the redesign.*

DKIST **light-path safety** has been an ongoing issue during observing, especially with regards to finding a technology that can be used to safely and independently constrain the telescope pointing to the limits of the heat stop (approximately 1.5 solar radii from sun center). The previous sun sensor was problematic due to false positives relating to clouds vs. movement on sun and was, therefore, never fully implemented. After review, it was decided to pursue an independent ephemeris model running in the safety system using independent safety encoders on the telescope's main axes. The hardware changes for the addition of the new safety encoders and initial code deployment were implemented in FY 2023 with full implementation in the Global Interlock System (GIS) software in September 2023.

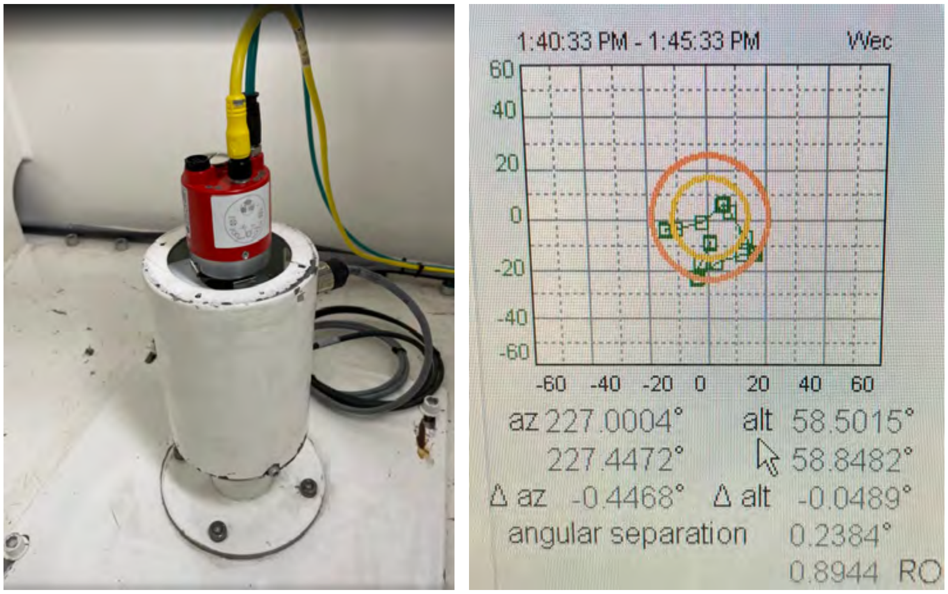

Figure 3.22. *Telescope Mount azimuth safety encoder and GIS ephemeris model readout during limb finding.*

Capability Future

In FY 2023, the TechOps team continued the process of planning for future upgrades to the facility to keep it on the leading edge of science (program goal TechOps-3). In pursuit of this goal, the team began planning for several future upgrades including:

- the Visible Tunable Filter (VTF) arrival and installation,
- the cleaning and coating of the primary (M1) mirror,
- the upgrading of the Telescope Maount and Coudé control system,
- updates to multiple facility cooling loops, and
- training and retention of future TechOps staff.

Preparation for TechOps support of the **integration and commissioning of VTF** picked up speed with TechOps representatives accompanying Instrumentation group staff to the Lab Acceptance Tests at KIS in Freiburg, Germany in July 2023. Serious discussions were held with the VTF team on integration practicalities and expected challenges during the process. Upon return, TechOps staff began preparing to route various services (i.e., electrical, network, and thermal) to the VTF instrument on the Coudé floor and for on-site storage of equipment during the integration process.

While there is currently no planned date for the next M1 coating, the TechOps team concentrated on getting the **M1 in-situ cleaning** maintenance set up and running. In addition, TechOps began cross training more staff for the cleaning processes to improve availability.

The obsolescence of the **Telescope Mount and Coudé control system** is an upcoming known issue that will involve the porting of the control system from Twincat version 2 to version 3. In long-range preparation for this TechOps organized an on-island training course for the PLC engineers during FY 2023. This training enabled initial discussions on hardware changes required as well as potential supplier support in the porting process.

A study was undertaken on the **Aperture Plate cooling loop** for the feasibility of switching from Dynalene to a water + biocide/corrosion inhibitor. This was due to continued issues with the Aperture Plate pump seizing due to the negative interaction between pump materials the Dynalene. The conclusion of the study was that

Dynalene was not required for the thermal operating conditions of this loop. The decision was therefore made to switch to a water + biocide/corrosion inhibitor system. The inhibitors were specified and the required material including a replacement twin pump system was ordered with the intent to install during FY 2024 in the January - February 2024 timeframe.

Initial planning for the extension of the **TAC cooling loop to the Coudé Instrument** rack was started. This will enable improved cooling of instruments and Wavefront Correction (WFC) electronics along with better control of vagrant thermals in the lower Coudé area.

Another issue that has become more obvious in operations has been dew point control in **coolant loops supplying different end-user systems**. In the secondary loops, dew point control was introduced via the thermal control system in FY 2023. However, there are a number of primary systems where this was not possible. The main system that was experiencing condensation issues was the server room door heat exchangers, which were supplied directly from the Chilled Water (CHW) primary loop that is not dew point controlled. The CHW could not have dew point control as it was also the supply for a number of secondary loops, and as such, has to operate below dew point. In order to stop condensation in the server room a feasibility study was conducted on a separate heat exchanger/controller specifically for the server room. This study was concluded in FY 2023 with a unit specified and ordered. Installation started in FY 2023 and will continue into FY 2024.

Figure 3.23. *Server Room Chiller installation.*

A major challenge to the future capability of TechOps is the recruitment and retention of a pool of available and able technical staff to support the observatory in the coming years. To plan for and mitigate **future staffing challenges**, the TechOps Manager and TechOps E-Tech Supervisor began working with the University of Hawai'i, Maui College (UHMC) to set up DKIST's first Electrical Technician Summer Intern position during FY 2023. Feedback from UHMC and the selected intern on completion of their placement was extremely positive and the intent is to continue this in FY 2024 and beyond. Similarly, TechOps hosted three AKAMAI interns during FY 2023 summer months working on such projects as completing a trade study on computer maintenance management systems, investigating the standardization of vibration procedures, and designing encoder-based position & velocity feedback system concepts for the DKIST aperture cover system.

3.10 DKIST Science

The DKIST Science team consists of a group of dedicated DKIST science staff who serve in a variety of roles from supporting instruments (instrument scientists) to supporting observations (resident scientists) to scrutinizing data products developing and improving calibration pipelines (data/calibration scientists), development of new instrument capabilities, supporting the community, EPO and DEI efforts. The Science team is also tasked with publishing DKIST science results, promoting DKIST science at meetings and conferences, and training new DKIST users. Individual scientists often perform multiple of the support functions listed above.

3.10.1 Science Program Milestones/Goals for FY 2023

The FY 2023 Annual Program Plan did not specifically lay out program goals for the Science team, however the Science achievements for FY 2023 are consistent with the following program goals.

Program Goal (Science-1): Provide scientific support during the planning, execution, calibration, and analysis of DKIST science observations.

Program Goal (Science-2): Promote DKIST science through the dissemination of DKIST results and the training of current and future DKIST users.

3.10.2 Major Science Achievements for FY 2023

The accomplishments of the DKIST Science team with regards to science support (program goal Science-1) were vital to the overall success of the facility in FY 2023. In the area of Instrumentation, DKIST instrument scientists supported operations by assisting the Instrumentation Operations group in keeping the instruments running at an optimal state and introducing new modes of operation. The instrument scientists also helped debug hardware and software problems and provided fixes to improve data quality. Some of the issues that DKIST scientists helped to debug and solve in FY 2023 include:

- Mitigation of stray-light and ghost images within the ViSP and VBI instruments,
- Re-work of the VISP calibration pipeline to mitigate polarization calibration artifacts,
- Multiple iterations of the VBI speckle reconstruction code,
- Design, development, and implementation of improved polarization calibration optics, and
- Design and implementation of a high-speed imaging system to diagnose image jitter and help identify sources of vibration.

DKIST scientists also provided input to the Instrumentation Development group on potential new capabilities like the development of the MCAO system and the IR Cameras.

The DKIST Science team supported the SciOps team in the planning, evaluation, scheduling, and execution of the Cycle 2 programs in FY 2023 (program goal Science-1). DKIST scientists play an integral role in the proposal evaluation process by providing the technical review of DKIST proposals through the Technical Review Committee (TRC). The TRC is formed by DKIST Science team staff. In FY 2023, the TRC evaluated 93 Cycle-2 proposals. In addition to providing technical expertise, some DKIST scientists participate in the scientific review of DKIST proposals through the Scientific Review Committee (SRC). DKIST scientists also assisted PIs and SciOps staff in the experiment generation process for the 54 accepted Cycle-2 proposals using the Experiment Architect. They also participated in the QA process using the End-to-End Simulator to test experiment execution procedures. DKIST Science team members also participated in the actual execution of the Cycle-2 experiments by serving as Resident Scientists on a rotating basis. In the current operations model, a DKIST Resident Scientist is present for every observation that is taken on the summit.

The DKIST Science team also supported the post-observation efforts of the DKIST Data Center and DKIST Data Scientist with regards to calibration and analysis of the data (program goal Science-1). DKIST scientists worked with the Data Center to improve calibration pipelines, especially for the ViSP and Cryo-NIRSP instruments, through an iterative process of analyzing calibrated data, developing calibration algorithms/code, working with the DC to implement production code, and scrutinizing reprocessed data. Many of the instrumentation issues described above were solved through this iterative process. For the VBI instrument, this process currently goes one step further, with DKIST scientists manually performing the calibration and speckle reconstruction of the imaging data then returning it to the DC for distribution. DKIST scientists regularly responded to Help Desk tickets generated by users regarding DKIST data and worked to find solutions and resolve issues. Approximately 50 Help Desk tickets were submitted and resolved in FY 2023.

In addition to their scientific support duties, the DKIST Science team are also tasked with the generation and dissemination of DKIST science results (program goal Science-2). DKIST scientists are active researchers that apply for DKIST time as PIs or co-PIs, design observations, analyze data, and publish DKIST results. They attend meetings and conferences presenting their results to the rest of the solar physics community. In December 2022, a “DKIST early Science” session was held at the American Geophysical Union (AGU) meeting where the DKIST Science team presented exciting DKIST early results. The team also announced the release of the first publicly available data set obtained using Director’s Discretionary Time (DDT). These data were recorded during an on-sun campaign in coordination with a PSP encounter in June 2022. The data sets correspond to the observations from VBI and ViSP on a plage region near the southeast solar limb; the consensus pointing for PSP. DKIST scientists worked intensely to prepare this early DDT data for community. Like all DDT datasets, this one had no proprietary period and was extensively downloaded by the community leading to a number of publications. Level-2 inversions were also performed on these DDT data sets inverting simultaneously the Fe I 630nm and the Ca II 854nm ViSP channels. Additional DDT observations will become public in the immediate future with the help of the DKIST Science team. More recently, DKIST scientists attended Boulder Solar Day, September 29 at the High-Altitude Observatory in Boulder. Several scientists presented their recent results from DKIST.

As part of their duties, DKIST scientists work to train the current and future generation of DKIST users through community workshops and mentorship programs (program goal Science-2). The DKIST scientists led by the DKIST Data Scientist held the following community workshops/training presentations in FY 2023:

- ***DKIST User Tools Training Workshop***; 24-26 May 2023; NSO, Boulder, CO;
- ***Calibrating DKIST Data*;** AGU Fall 2022; 12-16 December 2022; Chicago, IL;
- ***The DKIST Data Center Portal and Tools for Working with DKIST Level 1 Data***; AAS SPD annual meeting 2023; 13-18 August 2023; Minneapolis, MN;
- ***Challenges in the Data, Analysis and Software in the Heliophysics Environment, which talked in detail about how we meet those challenges with DKIST***; Data, Analysis, and Software in Heliophysics (DASH) annual meeting: 9-11 October 2023; JHU/APL, Laurel, MD***;***
- ***The Daniel K. Inouye Solar Telescope (DKIST): All things Metadata + Other Bits***; International Heliophysics Data Environment Alliance (IHDEA) annual meeting; 12-13 October 2023; JHU/APL, Laurel, MD.

In addition to these in-person trainings, DKIST scientists have generated several video tutorials providing information on topics ranging from creating a Globus account for data downloading, to searching and filtering the DKIST archive, to downloading and reducing DKIST data.

DKIST scientists also participated in training through mentorship programs like the Boulder Solar Alliance's Research Experiences for Undergraduates (REU) program, the DKIST Ambassador program and the Hale Fellowship program shared between NSO and the University of Colorado, Boulder (CU). NSO is one of six institutions that participate in the Boulder Solar Alliance REU program, which is led by CU's Laboratory for Atmospheric and Space Physics. In FY 2023, 18 undergraduate students from across the country participated in the 10-week REU program, of which, 3 worked with DKIST scientists. The DKIST Ambassador program provides financial support for graduate students and/or postdoctoral researchers at U.S. universities for up to two years. Ambassadors work with advisors at their home institutions and DKIST scientists on DKIST-related solar research. In FY 2023, there were 12 DKIST Ambassadors from universities spread across the U.S. working with DKIST scientists. Finally, NSO shares the Hale Fellowship program with CU. The program supports faculty, postdocs, and graduate students that work jointly with NSO and CU scientists. In FY 2023, there were 2 post-doctoral and 7 graduate student Hale fellows working on research topics relevant to DKIST

4 FY 2023 NISP ACHIEVEMENTS AND MILESTONES

Providing background synoptic observations that permit solar investigations from the ground and space to be placed in the context of the variable Sun is one of the key aspects of NSO's mission, which are entrusted to the NSO Integrated Synoptic Program (NISP). Figure 4.1. shows organizational structure of NISP with corresponding funding sources to support Program activities.

NSO Integrated Synoptic Program (NISP)

FACILITIES

- GONG[a,b]
- SOLIS[a]

DATA CENTER

- Data reduction[a,b]
- Data dissemination[a]
- Data curation[a] (historical data)[c]

R & D

- Science support[a,c]
- New instrument, data products[a,c]
- ngGONG[a,c]
- WoU (2 year)

Figure 4.1. *NISP organizational structure with funding sources as the following: (a) NSF-base (ops, refurbishment, R&D); (b) NOAA funding (GONG operations. Current NSF-NOAA IAA was signed in CY2021; FY 2022-2026.); (c) External grants funding.*

The overarching Program goals are: (a) to provide the background synoptic observations to characterize the variable solar activity, (b) to operate/develop ground-based facilities to enable long-term observations, and (c) to conduct innovative staff research. To meeting the Program goals, in FY 2023 NISP organized its activities around the following objectives: (1) to operate the GONG network and continue the network data distribution, (2) to complete the SOLIS site at Big Bear and start operations, (3) to continue refurbishing the GONG network, prioritizing new detectors deployment, (4) to engage stakeholders (NOAA, AF, international partners) in the ngGONG preparatory design phase, and (5) to elaborate the NISP contribution to the new Cooperative Agreement proposal. Objectives 1, 3, and 4 were met. While some progress was made on Objectives 2 and 3, these objectives were not fully met in FY 2023.

Table 4.1. GONG Refurbishment and SOLIS Restart Milestones

Project	Sub-project	Major Milestone	Milestone Date	Critical Element
GONG Refurbishment	Camera Deployment	First camera deployment	(Early) CY2023	Camera software development, personnel shortage
	HVAC	Install air-to-air exchanger at ML	Summer 2024	ML restart
	Workstations upgrade	Will be completed during camera deployments		
SOLIS Restart	VSM observations	First light with VSM	Spring 2024	Glycol chiller; Personnel shortage
	FDP observations	First light with FDP	Sprint/Summer 2024	VSM readiness
	ISS observations	First light with ISS	Summer 2024	VSM ops

Objective 1: to operate the GONG network and continue the network data distribution.

FY 2023 was a difficult year for the aging GONG network. At the end of November 2022, Mauna Loa volcanic eruption shut down the Mauna Loa Observatory. On evening of 22 November 2022, just before the lava flows cut off the access road and downed the power lines, NISP engineering team (S. Bounds, D. Branston, S. Nguyen, T. Purdy) shutdown the instrument remotely. Since then, the GONG/ML instrument was inoperable. Current estimates from NOAA/Mauna Loa Observatory are that the access road would be completed in May-June 2024. The power to the site would be restored within one month after the access road is completed (about July 2024). We anticipate that it would take another month for NISP engineering crew to restart GONG/ML after that (tentatively, August-September 2024).

In March 2023, the Big Bear site in California experienced a record snowfall with snowdrift almost reaching the top of GONG shelter there. Fortunately, the BBSO/NJIT local support crew made a major effort to enable access to the GONG shelter and thus, the impact on operations was minimal.

In August 2023, a wildfire at Tenerife led to a personnel evacuation and temporary observatory closure. GONG/TD was preventively shut down, and due to its robotic operations, it was able to restart even prior to the observatory re-opening. In the aftermath of the fire, large quantities of ash were present in the air including some very dramatic dust (ash) devils. A potential negative impact of (abrasive) ash on optical surfaces were considered, but due to extremely low network duty cycle, the decision was made to re-start the observations.

At the end of August 2023, the GONG at Cerro Tololo Inter-American Observatory lost communications due to a cybersecurity incident which affected CTIO operations. Due to robotic operations of GONG, the observations continued, but the data were stored on site and not transmitted to NISP data center in Boulder, Colorado. Eventually, outbound access to GONG/CT was granted due to its critical importance for operations space weather forecasting, and all past observations were transmitted to NISP DC. As of October 2024, GONG/CT is still operating in outbound connection mode only.

During FY 2023, two preventive maintenance (PM) trips were conducted: 13-24 March, Udaipur, India and 31 July – 17 August, Learmonth, Australia.

To ensure continuation of GONG operations until its estimated end-of-life, the project has identified a list of (electronics) parts needed for the next 10 years, based on the prior rate of failure. The parts in this list were acquired (either via eBay or the original manufacturers). Several new issues were also identified: LCVR failure, and replacement of failing H-alpha filters. To mitigate the first issue, 5 new LCVRs were acquired. The acceptance tests, however, fail all new LCVRs due to a manufacturing defect, which has been since remedied by the vendor. Another new issue is the replacement of failing H-alpha filters. The filters were sent for evaluation to the vendor but are not timely repaired. The Program continues working with the vendor in trying to find a solution to the current stalemate.

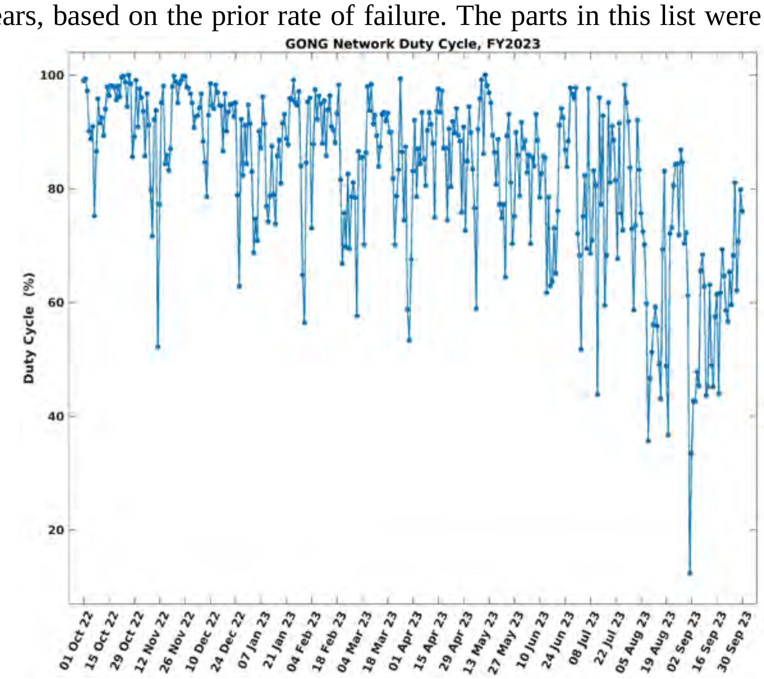

Figure 2.2. *GONG merged network Duty Cycle for fiscal year 2023.*

Figure 4.2 shows the duty cycle of GONG network during FY 2023. The effect of some natural and manmade disasters described earlier can be traced in the duty cycle. Until July 2023, the duty cycle remained at an acceptable level, but in early September it dropped to about 10%. At the end of FY 2023, several GONG stations (BB, UD, and LE) began exhibiting an increased number of restarts. This development may be a further indication of the aging of some electronic equipment**.**

At the same time, NISP Data Center (J. Britanik, O. Burtseva, M. Creelman, B. Harker, A. Hughes, N. Oien, K. Shuman, T. Wentzel) saw a significant increase in volume of data downloaded by the international research community.

In FY 2023, total FITS data volume doubled. Tar/Zip data downloads went up by a factor of 6, likely due to the added H-alpha movie download capability.

Total FITS Data Download Volume: FY 2023 – 45956 GB

Tar/Zip data download volume from GONG Data Archive Tool and Movie downloads: FY 2023 – 4446 GB

The top 10 IPs (by FITS data volume) for FY 2023 are shown in Table 4.2.

Table 4.2. *Top 10 IPs for GONG Data Volume in FY 2023*

IP	GB	Institution - products
14.139.159.162	8624	Indian Institute of Astrophysics
130.206.30.200	6445	Universidad De Las Islas Baleares, Spain
114.247.188.23	5187	Beijing China
169.154.198.73	3083	NASA Goddard
106.120.73.130	2564	Beijing, China
171.64.103.156	1717	Stanford
171.64.103.183	1333	Stanford
130.206.76.8	999	Universidad De Las Islas Baleares, Spain
118.46.88.231	899	South Korea
35.46.124.39	758	Western Michigan University

In FY 2023, NISP Data Center upgraded four 1U servers, which replaced four pipelines as production servers in the new container environment.

This objective is fully met.

Objective 2: to complete the SOLIS site at Big Bear and start operations.

In preparation for SOLIS instruments installation, during FY 2023, the team made two trips to California. The mitigation of soil erosion resulting from heavy rains in August 2022 was completed in November 2022. In February 2023, insulation work in the utility shed was completed, and in April 2023, a split-unit HVAC system was installed. Unfortunately, the original estimate of heath load/removal was incorrect (the heat removed from SOLIS/VSM was not considered). This required adding HVAC units, which effectively tripled the total HVAC costs from the original estimate. The Glycol chiller unit required for cooling the VSM focal plane has been ordered in Spring 2023 with a targeted ship date of 8/11/23. Unfortunately, the vendor defaulted on the delivery date. A new delivery date is now stated as 15 December 2023. This is a major setback to SOLIS relocation, which pushes the first light observations to Spring 2024.

This objective is only partially met, see Table 4.1 above.

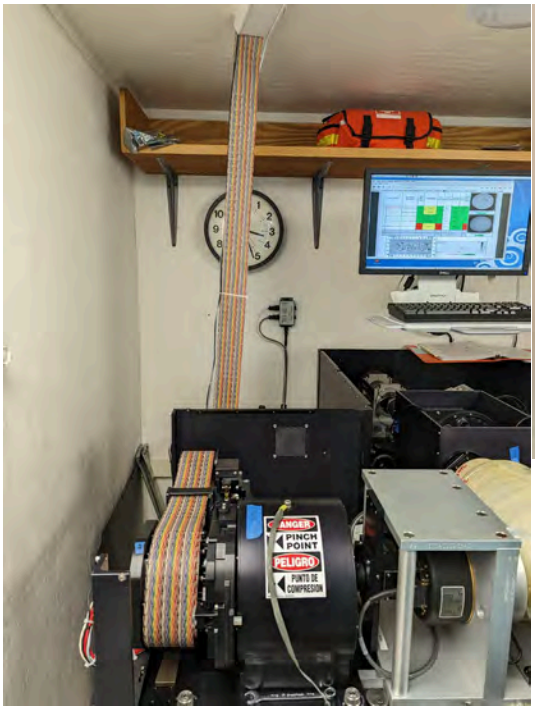

Figure 4.3. *Comparison of old (left) and new (right) wiring for GONG cameras.*

Objective 3: to continue refurbishing the GONG network, prioritizing new detectors deployment.

In FY 2023, the design of the new Data Acquisition System (DAS-4G) was finalized and tested. Three DAS-4G chassis were assembled. One Camera-DAS pair went through the observational test at the engineering site in Boulder, CO. During testing of the second DAS-Camera pair, an artifact in images was discovered. The origin of artifact was traced to the camera reading (manufacturer) software, which was not fully comparable with old computer OS used by GONG. The OS was successfully upgraded (which required additional modification to GONG software), and the work is underway to verify that this resolves the artefact. To objectively identify the artefact Objective 3: to continue refurbishing the GONG network, prioritizing new detectors deployment.

In FY 2023, the design of the new Data Acquisition System (DAS-4G) was finalized and tested. Three DAS-4G chassis were assembled. One Camera-DAS pair went through the observational test at the engineering site in Boulder, CO. During testing of the second DAS-Camera pair, an artifact in images was discovered. The origin of artifact was traced to the camera reading (manufacturer) software, which was not fully comparable with old computer OS used by GONG. The OS was successfully upgraded (which required additional modification to GONG software), and the work is underway to verify that this resolves the artefact. To objectively identify the artefact in GONG images, NISP Data Center developed the code based on a machine learning approach. Once the artefact is fully mitigated, the camera-DAS testing will resume, with a plan of start deployment of new cameras to GONG sites after the third Camera-DAS pair went to a testing. Figure 4.3 shows comparison between old and new cameras and their outside cabling.

As part of the GONG refurbishment, HVAC system was upgraded to split unit at GONG CTIO site. Due to inaccessibility of GONG Mauna Loa site, the HVAC upgrade there was put on hold. Meanwhile, the window type air conditioning unit at GONG/BBSO has failed and it was replaced by a similar type. Given the lifetime of these units, their cost as compared with the cost of converting GONG/BBSO to a split-unit HVAC, it was decided to continue with the window-type air conditioning units at that GONG location.

The work was also continued GONG magnetic zero-point improvements. As part of observational tests, S. Gosain demonstrated that zero point can be improved significantly by optimizing the LCVR voltages. A simple attachment was designed by G. Card, 3D printed by A. Pevtsov and deployed to all GONG sites. The voltage tuning was done on selected GONG sites, and will become a part of routine operations.

In early FY 2023, it was determined that GPS cards on all GONG sites need to be replaced due to GPS week number rollover. The GPS week number rollover is a phenomenon that happens every 1,024 weeks, which is about 19.6 years. The Global Positioning System (GPS) broadcasts a date, including a week number counter that is stored in only ten binary digits, whose range is therefore 0–1,023. After 1,023, an integer overflow causes the internal value to roll over, changing to zero again. The GPS cards were acquired in early CY2023 and shipped to all sites. The installation of the new GPS cards will be completed in FY 2024 due to GONG/ML site being inaccessible.

This objective is only partially met, see Table 4.1.

Objective 4: to engage stakeholders (NOAA, AF, international partners) in the ngGONG preparatory design phase.

In FY 2023, the program-initiated communications about ngGONG with NOAA, DoD, and NSF on different levels (from NOAA office of observations visit to the Space Weather enterprise forum on Capitol Hill. ngGONG presentations were made at the research conferences (e.g., American Meteorological Society), and several white papers were submitted to the Heliophysics Decadal Survey. The team was invited to present ngGONG to the Heliophysics Decadal Survey committee. The team has regular meetings with the European partners to coordinate the activities funded under the SOLARNET/SPRING EU funded project. As part of the ngGONG proposal review, the team was invited to discussions as part of NSF's reverse site visits.

This objective is fully met.

Objective 5: to elaborate the NISP contribution to the new Cooperative Agreement proposal.

NISP is contributing to the development of a new Cooperative Agreement with respect to continuation of GONG and SOLIS operations and developing ngGONG as GONG replacement. As a new program element, the Program will argue for expanding its role with respect to preservation and curation of historical data for ground based solar astronomy in US.

This objective is fully met.

NISP is an essential provider of solar data needed to predict space weather events, particularly to the Space Weather Prediction Center (SWPC) in Boulder. Funded by NOAA, SWPC uses GONG data as input to drive a predictive model of terrestrial geomagnetic storms. SWPC, recognizing the value of the data and the need for its availability, declared GONG data essential for national security during the 2013 and the 2019 Government shutdown episodes. A support agreement between NOAA and the NSF has been renewed for FY 2022-FY 2026, with NOAA providing SWPC for GONG operations about $1M annually. As of April 2021, the near-real-time GONG space weather data products (including synoptic maps) are being produced within SWPC's operational environment. NISP Data Center personnel continue assisting SWPC with occasional issues related to GONG data. NISP data are also used to drive models hosted by NASA's Community Coordinated Modeling Center (CCMC), and all NASA solar space missions use NISP data for context and supporting observations. Extending beyond space weather forecasting examples, the open software repository available in GitHub that predicts the magnetic connectivity with the Sun of the Parker Solar Probe (PSP) mission also has GONG as provider of the necessary boundary data. NISP personnel actively participates in the Committee on Space Research (COSPAR)-led International Space Weather Action Teams (ISWAT) initiative.

During FY 2023, the Parker Solar Probe, launched by NASA on August 12, 2018, completed four closest approaches to the Sun: December 11, 2022 – Perihelion #14, March 17, 2023 – Perihelion #15, June 22, 2023 – Perihelion #16, and September 27, 2022 – Perihelion #17. The PSP perihelion passages were supported by the coordinated observations organized in the framework of the Whole Heliosphere and Planetary Interactions (WHPI) initiative. GONG instruments provide regular observations of the photospheric magnetic fields, which were extensively used for modeling magnetic connectivity between the solar surface to the PSP location in the heliosphere between Sun and Earth. GONG magnetograms are also used for comparison with observations of magnetic fields from Solar Orbiter (e.g., comparison of SO/PHI observations and GONG far-side imaging, Kiran Jain, and creation of a merged GONG-Solar Orbiter synoptic maps Luca Bertello and Alexander Pevtsov to provide a better representation to the evolution of magnetic fields used for modeling of solar corona and solar wind).

NISP scientists use insights from their own research to monitor and improve the quality of the data and to suggest and develop new data products. Examples of such interplay include the GONG refurbishment, GONG magnetic zero-point improvements, photospheric and chromospheric full-disk vector field observations and synoptic maps, H-alpha limb maps, mean polar field time series, helioseismic measurements of subsurface vorticity as a forecast of flare activity, and detection of active regions from far-side imaging. In 2022-2023, the NISP scientific staff continued to work on several research projects, including (only NSO authors are listed):

- improving the understanding of subsurface structure and dynamics of solar active regions using multi-height helioseismology (Tripathy, S., Jain, K., Kholikov, S. Pevtsov, A.A.);
- helioseismic investigations of the quasi-biennial oscillation (Jain, K., Tripathy, S.C.);
- the timing and properties of helioseismic minima between cycles 24 and 25 as an indication of the existence of a relic magnetic field in the Sun’s core (Tripathy, S.C., Jain, K.);
- sub-surface plasma flows and the flare productivity of solar active regions (Jain, K., Komm, R.);
- a compact full-disk solar magnetograph based on miniaturization of GONG instrument (Gosain, S., Harvey, J., Hill, F.);
- the IAU-women in astronomy working group and inclusivity (Leibacher, J.);
- the European Solar Telescope and fundamental science questions it would address (Hill, F.);
- the compact Doppler magnetograph (CDM) for solar polar missions and space weather research (Gosain, S., Harvey, J.);
- magnetograph saturation and the open flux problem (Harvey, J.);
- subsurface horizontal flows during solar Cycles 24 and 25 with large-tile ring-diagram analysis (Komm, R.);
- the properties of subsurface non-zero meridional flow at solar equator (Komm, R.);
- a detailed analysis of the duty cycle using GONG observations spanning over 18 years (Jain, K., Tripathy, S.C., Hill, F., Pevtsov, A.A.);
- studies of solar chromospheric activity using historical data from the Kodaikanal and Mount Wilson Observatories (Bertello, L, Pevtsov, A.A.);
- reconstruction of the photospheric magnetic field from 1915 to 1985 (Bertello, L, Pevtsov, A.A.);
- reconstructing the Total Solar Irradiance (TSI) during the last five centuries (Bertello L., Criscuoli, S.);
- the exoplanetary magnetosphere extension in Sun-like stars based on the solar wind - solar UV relation (Bertello, L.);
- magnetohydrodynamic simulation of a solar active region with realistic spectral synthesis using AWSoM model (Pevtsov, A.A., Bertello, L.);
- constraining global coronal models with multiple independent observables (Petrie, G.);
- searching for a solar source of magnetic-field switchbacks in Parker Solar Probe's first Encounter (Petrie, G.);
- using AIA 1600 Å contrast as a proxy of solar magnetic fields (Pevtsov, A.);
- application of the Faraday rotation to probing the properties of solar wind (Pevtsov, A.)

5 FY 2023 SPENDING REPORT

The NSO CSA AST-1400450 spending plan was based on receiving in FY 2023 $25.46M for NSO as described in the President's Budget Request (PBR) (see Table 5.1). The FY 2023 PBR included $19.58M for DKIST operations and $5.88M for other NSO infrastructure operations and maintenance. The NSO's Program allocations followed the guidelines in Table 10.4-2 of the Cooperative Agreement proposal submitted by AURA in October 2013 but include the reprofile of the carryforward funds in the DKIST Operations Program discussed in Section 10 of the FY 2020 – FY 2024 Long Range Plan (LRP) and updated in the FY 2021 – FY 2022 APRPP. This reprofile is based on updated estimates of the costs of operating the facility obtained during the early operations phase.

Table 5.1. FY 2023 President's Budget Request

Total Obligations for NSO
(Dollars in Millions)

	FY 2021	FY 2022	FY 2023	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
NSO	$4.65	-	$7.06	$6.24	$6.24	$6.24	$6.24	$6.24
Operations and Maintenance	*4.65*	-	*5.88*	*6.24*	*6.24*	*6.24*	*6.24*	*6.24*
Special Projects[2]	-	-	*1.18*	-	-	-	-	-
DKIST Operations[3]	$19.54	-	$20.68	21.30	21.30	21.30	21.30	21.30
Operations and Maintenance	*19.54*	-	*19.58*	*21.30*	*21.30*	*21.30*	*21.30*	*21.30*
Special Projects[4]	-	-	*1.10*	-	-	-	-	-
Total	**$24.19**	**-**	**$27.74**	**$27.54**	**$27.54**	**$27.54**	**$27.54**	**$27.54**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends September 2024.

[2] Includes research infrastructure funding for transition activities at Sacramento Peak Observatory.

[3] FY 2021 Actual includes $2.0 million to another awardee for cultural mitigation activities as agreed to during the compliance

[4] Reflects additional funding for research infrastructure to optimize community access.

Table 5.2 summarizes the funding obligated to the NSO by the NSF in FY 2023 (including Supplemental Funding Requests) and the non-NSF (NOAA) support for GONG operations in FY 2023. The NSO Spending Plan in FY 2023 was developed based on receiving $25.46M of NSF funding for the regular base operations, with $19.58M dedicated to DKIST. However, for the DKIST Program NSF only obligated $4.9M in FY 2023 in anticipation of reducing the Program's carryforward. The remaining unobligated funds for DKIST Operations are $14.69M that will be received in FY 2024.

Table 5.2. Obligated NSO FY 2023 Funding
(Dollars in Thousands)

DKIST Operations	$4,900
DKIST Operations Unobligated	($14,690)
NSO	$5,880
SFR WoU-MMA NCSP (Year 2)	$660
SFR WoU-MMA NISP (Year 1)	$985
Transision activities Sunspot	$1,180
FY 2023 NOAA Support	$1,060
Total NSO Funding	**$14,665**

Table 5.3 shows the six subdivisions and the corresponding FY 2023 NSF new funds allocations for NSO Headquarters (NSO HQ or Director's Office); DKIST Operations; NISP; Sunspot Operations (NSO SP), NCSP; and the NSO Fee (NSO-F). The funds include base funding and SFRs when applicable.

Table 5.3. NSO Allocations of NSF Funds

Fiscal Year: 2023
Funding Source: New Funds

Project ID	Project Name	FTEs	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
CS006.1	NSO Directors Office	8.50	1,455,750	1,008,783	2,464,533	0	2,464,533
CS006.2	NSO NISP	15.82	2,404,269	1,516,095	3,920,364	0	3,920,364
CS006.3	NSO Sunspot	3.61	374,037	974,012	1,348,049	0	1,348,049
CS006.4	NSO NCSP	6.45	765,368	359,904	1,125,272	0	1,125,272
CS006.5	NSO DKIST Ops	66.26	10,310,484	9,216,442	19,526,926	0	19,526,926
CS006.9	NSO AURA Fee	0.00	0	69,012	69,012	0	69,012
Overall - Total		**100.64**	**15,309,908**	**13,144,248**	**28,454,156**	**0**	**28,454,156**

Table 5.4 provides the distribution of carryforward funds for each program. For additional details on the allocation of funds within the NSO subprogram, see the FY 2022 – FY 2023 APRPP[3] Section 8.

Table 5.4. NSO Carryforward

Fiscal Year: 2023
Funding Source: Carryforward

Project ID	Project Name	FTEs	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
CS006.1	NSO Directors Office	1.08	251,712	564,600	816,312	0	816,312
CS006.2	NSO NISP	0.00	0	746,190	746,190	0	746,190
CS006.4	NSO NCSP	6.45	744,479	1,332,408	2,076,887	0	2,076,887
CS006.5	NSO DKIST Ops	35.42	5,916,958	22,247,684	28,164,642	0	28,164,642
CS006.9	NSO AURA Fee	0.00	0	103,542	103,542	0	103,542
Overall - Total		**42.96**	**6,913,149**	**24,994,424**	**31,907,573**	**0**	**31,907,573**

[3] *https://nso1.b-cdn.net/wp-content/uploads/2023/03/NSO-2022_23_Final.pdf*

5.1 Subdivisions Breakout

This section presents an overview of the FY 2023 expenditures at the WBS level for each subdivision (or Program). A brief narrative is provided for all budget items above $200K. All tables are constructed from reports run on the Deltek platform.

5.1.1 Director's Office (NSO HQ)

The FY 2023 Director's Office achievements, goals, and milestones are provided in section 1. In this subsection, we provide corresponding budgetary expenditure information.

Funding Operation	Project ID Level	Project ID Name	YTD Expenditures
NSO Directors Office	CS006.1.P1.OM.01.FC 30	Arizona Base Cost - Total	14,900
	CS006.1.P1.OM.01.16	NSO Director Search - Total	31,750
	CS006.1.P1.OM.01.02	NSO-DO AURA Committees - Total	82,580
	CS006.1.P1.OM.01.09	NSO-DO AURA Corp Direct - Total	0
	CS006.1.P1.OM.03.01	NSO-DO Boulder HQ - Total	323,089
	CS006.1.P1.OM.01.03	NSO-DO Business/Admin- Total	356,437
	CS006.1.P1.OM.04.03	NSO-DO CMAG - Total	857
	CS006.1.P1.OM.01.13	NSO-DO COVID-19 Safety - Total	0
	CS006.1.P1.OM.01.11	NSO-DO CU Recharge Fees - Total	607
	CS006.1.P1.OM.03.03	NSO-DO Computing - IT	229,966
	CS006.1.P1.OM.03.05	NSO-DO Cybersecurity -Total	6,535
	CS006.1.P1.OM.02.06	NSO-DO DKIST Ops Service - Total	0
	CS006.1.P1.OM.01.01	NSO-DO Directorate - Total	660,383
	CS006.1.P1.OM.05.02	NSO-DO EPO Exhibits - Total	16,922
	CS006.1.P1.OM.02.13	NSO-DO Faculty Appointmnt - Total	0
	CS006.1.P1.OM.04.01	NSO-DO HQ Dev & Relocate - Total	1,953
	CS006.1.P1.OM.02.12	NSO-DO Hale Post Doc - Total	32,733
	CS006.1.P1.OM.01.10	NSO-DO Indirect Cost Cred- Total	(77,217)
	CS006.1.P1.OM.04.02	NSO-DO Instrument Dev - Total	3,387
	CS006.1.P1.OM.01.08	NSO-DO Insurance - Total	7,825
	CS006.1.P1.OM.02.09	NSO-DO Joint CU/NSO - Total	0
	CS006.1.P1.OM.03.02	NSO-DO Library - Total	1,964
	CS006.1.P1.OM.05.01	NSO-DO NSO EPO - Total	436,977
	CS006.1.P1.OM.01.14	NSO-DO PostRetire Benefit - Total	47,844
	CS006.1.P1.OM.01.12	NSO-DO RateReconciliation	(669,974)
	CS006.1.P1.OM.01.04	NSO-DO Recruit/Relo New - Total	10,134
	CS006.1.P1.OM.02.01	NSO-DO Research	97,453
	CS006.1.P1.OM.02.02	NSO-DO Research Assistant	(231)
	CS006.1.P1.OM.01.06	NSO-DO Safety - Total	34
	CS006.1.P1.OM.01.15	NSO-DO Unfunded Liability - Total	5,675
	CS006.1.P1.OM.03.04	NSO-DO Vehicles - Total	4,494
	CS006.1.P1.OM.06.01	ngGONG MREFC-Labor - Total	242,748
	CS006.1.P1.OM.06.02	ngGONG MREFC-NonLabor - Total	19,306
NSO Directors Office - Total			1,889,132
Overall - Total			1,889,132

Table 5.5. Director's Office (NSO HQ) WBS Description for YTD Expenditures >$200k

CS006.1.P1.OM.03.01: NSO-DO Boulder HQ	**$323,089**
Cost of the Director's Office share of the Boulder Lease of office, cubicle, and common spaces.	
CS006.1.P1.OM.01.03: NSO-DO Business/Admin	**$356,531**
Labor associated with administrative services provided to the Director's Office ($292K including fringe) and non-payroll expenses for travel ($20K) and supplies ($5K).	
CS006.1.P1.OM.03.03: NSO-DO Computing – IT	**$229,966**
Labor associated with support to the Director's Office ($160K including fringe) by the IT team, including the Head of IT.	
CS006.1.P1.OM.01.01: NSO-DO Directorate	**$660,383**
Labor associated with the management of the NSO ($509K including fringe), including the Director, Head of Administration, and non-payroll-expenses for travel ($15K) and software licenses ($4K).	
CS006.1.P1.OM.05.01: NSO-DO EPO	**$436,977**
Labor associated with NSO EPO support in Boulder and Maui ($359K including fringe), including the Head of EPO. Travel to and from Maui ($25K).	
CS006.1.P1.OM.01.12: NSO-DO Rate Reconciliation	**($669,974)**
Credit from the FY 2020 and FY 2021 AURA final rate reconciliation.	
CS006.1.P1.OM.06.01: ngGONG MREFC-Labor	**$242,748**
Labor associated with the ngGONG Project Manager ($222K).	

5.1.2 DKIST Operations Program

The FY 2023 DKIST Program achievements, goals, and milestones are provided in sections 1 and 3. In this subsection, we provide the Program's budgetary expenditure information.

Funding Operation	Project ID Level	Project ID Name	YTD Expenditures
NSO DKIST Ops	CS006.5.P1.OM.04.05	Camera Development - Total	294,312
	CS006.5.P1.OM.09.01	Community Support - Total	0
	CS006.5.P1.OM.01.02	DKIST Administration - Total	490,586
	CS006.5.P1.OM.08.02	DKIST Boulder HQ - Total	501,974
	CS006.5.P1.OM.01.08	DKIST COVID-19 Safety - Total	1,248
	CS006.5.P1.OM.05.02	DKIST Computing-Nonlabor - Total	447,987
	CS006.5.P1.OM.02.03	DKIST DKIST EPO - Total	86,996
	CS006.5.P1.OM.07.01	DKIST DKIST Science Ops - Total	241,363
	CS006.5.P1.OM.08.01	DKIST DSSC - Total	279,064
	CS006.5.P1.OM.06.01	DKIST Data Center OPS - Total	4,183,981
	CS006.5.P1.OM.04.01	DKIST Dev-Engineer Staff - Total	2,516,760
	CS006.5.P1.OM.01.01	DKIST Directorate - Total	827,552
	CS006.5.P1.OM.05.01	DKIST IT Support-Labor - Total	664,127
	CS006.5.P1.OM.01.11	DKIST Inauguration - Total	26,150
	CS006.5.P1.OM.02.04	DKIST Joint CU/NSO - Total	0
	CS006.5.P1.OM.04.02	DKIST MCAO Development - Total	1,196,951
	CS006.5.P1.OM.04.04	DKIST Machine Shop - Total	218,782
	CS006.5.P1.OM.03.01	DKIST Maui Tech& Fac Mgmt - Total	953,613
	CS006.5.P1.OM.01.07	DKIST NSO Insurance-AURA - Total	31,019
	CS006.5.P1.OM.02.05	DKIST New Development - Total	389,338
	CS006.5.P1.OM.04.03	DKIST Next Gen Instr Dev - Total	5,212,480
	CS006.5.P1.OM.02.02	DKIST Operations Support - Total	1,756,389
	CS006.5.P1.OM.07.03	DKIST Operations Tools - Total	439,233
	CS006.5.P1.OM.01.09	DKIST Post Retire Benefit - Total	0
	CS006.5.P1.OM.01.04	DKIST Quality Control - Total	50,011
	CS006.5.P1.OM.08.03	DKIST Rental House - Total	186,235
	CS006.5.P1.OM.02.01	DKIST Research - Total	1,555,554
	CS006.5.P1.OM.01.03	DKIST Safety Programs - Total	272,181
	CS006.5.P1.OM.07.02	DKIST Sci Ops Specialists - Total	697,381
	CS006.5.P1.OM.03.03	DKIST Summit Engineer NL - Total	493,380
	CS006.5.P1.OM.03.02	DKIST Tech Support Fac - Total	1,980,339
	CS006.5.P1.OM.01.06	DKIST UltiPro - Total	30,649
	CS006.5.P1.OM.01.05	DKIST Unfunded Liability - Total	38,640
	CS006.5.P1.OM.04.06	Instrument Upgrades - Total	1,010,953
	CS006.5.P1.OM.10.01	Maui DKIST Rental Houses - Total	0
	CS006.5.P1.OM.03.05	Observing Support - Total	823,616
	CS006.5.P1.OM.03.06	Preventative Maintenance - Total	563,400
	CS006.5.P1.OM.01.10	Professional Development - Total	98,938
	CS006.5.P1.OM.03.09	TechOps EPO - Total	24,837
	CS006.5.P1.OM.03.08	Training & Professional D - Total	251,488
	CS006.5.P1.OM.03.07	Unplanned Repairs - Total	106,488
	CS006.5.P1.OM.03.04	Upgrades - Total	2,197,211
NSO DKIST Ops - Total			31,141,208
Overall - Total			31,141,208

Table 5.6. *DKIST Operations WBS Description for YTD Expenditures >$200k*

CS006.5.P1.OM.04.05: Camera Development	**$294,312**
Labor associated with the development of the new infrared detectors for DL-NIRSP and CRYO-NIRSP ($103K including fringe) and non-payroll expenses, including a prototype controller ($159K).	
CS006.5.P1.OM.01.02: DKIST Administration	**$490,586**
Labor associated with administrative services provide to DKIST operations ($347K including fringe) and non-payroll expenses ($36K), including contracted services and supplies.	
CS006.5.P1.OM.08.02: DKIST Boulder HQ	**$501,974**
Cost of the DKIST share of the Boulder Lease of office and laboratory space.	
CS006.5.P1.OM.05.02: DKIST Computing-Nonlabor	**$447,987**
Non-labor equipment costs associated with DKIST IT supplies for Boulder and Maui.	
CS006.5.P1.OM.07.01: DKIST Science Ops	**$241,363**
Labor associated with the management of the Science Operations WBS element.	
CS006.5.P1.OM.08.01: DKIST DSSC	**$279,064**
Labor associated with managing the operations of the DSSC ($42K including fringe) and non-payroll operating expenses ($214K), including, utilities, contracted services such as cleaning services, property management, landscaping, communications, equipment lease, supplies and travel.	
CS006.5.P1.OM.06.01: DKIST Data Center Ops	**$4,183,981**
Labor associated with the operations of the DKIST data center ($1.782M) and non-payroll expenses ($2.06M), including storage and processing hardware, software contracts and travel.	
CS006.5.P1.OM.04.01: DKIST Dev-Engineer Staff (Instrument Ops)	**$2,516,760**
Labor associated with the operations and maintenance of first-light DKIST instruments ($1.937M) and non-payroll expenses ($373k), including computers, support contracts, optics, motors, software licenses, supplies and travel.	
CS006.5.P1.OM.01.01: DKIST Directorate	**$827,552**
Labor associated with the management of the DKIST Program ($684K including fringe), including DKIST Associate Director, Deputy Associate Director, and fractions of Program Scientists, and non-payroll-expenses ($74K), including professional development and travel.	
CS006.5.P1.OM.05.01: DKIST IT Support (Labor)	**$664,127**
Labor associated for DKIST IT support for Boulder and Maui.	
CS006.5.P1.OM.04.02: DKIST MCAO Development	**$1,196,951**
Engineering labor associated with the development of the MCAO system ($617K including fringe) and non-labor expenses ($494K), including contract milestone payments for a deformable mirror, computers, electronics and mechanical parts, supplies and travel.	
CS006.5.P1.OM.04.04: DKIST Machine Shop	**$218,782**
Machinist Labor ($133K plus fringe) for Boulder Machine shop and non-payroll expenses ($71K), including the Machine shop building lease, supplies and materials.	
CS006.5.P1.OM.03.01: DKIST Maui Tech&Facilities Management	**$953,613**
Labor associated with management of the DKIST summit operations, including engineering managers and systems engineering ($831K including fringe), non-payroll expenses ($43K) including supplies and travel.	
CS006.5.P1.OM.02.05: DKIST New Development (Science)	**$389,338**
Science support labor associated with the development of new instrumentation, such as MCAO, IR detectors, polarimetry systems and the development of the data center.	
CS006.5.P1.OM.04.03: DKIST Next Gen Instrument Dev	**$5,212,480**
Non-labor expenses associated with the development of new instrumentation, including Raytheon IR detector contract milestone payments ($3.35M), UH MISI36 image slicer contract milestone payments ($953K), instrument and software support contracts, supplies and materials, optics and electronics parts, travel and non-labor indirects ($340K).	
CS006.5.P1.OM.02.02: DKIST Operations Support (Science)	**$1,756,389**
Labor cost associated with Science Support functions for DKIST Operations ($1.49M) and non-payroll expenses ($75K), including specialized computer hardware and software. Travel ($45K).	

CS006.5.P1.OM.07.03: DKIST Operations Tools	**$439,233**
Labor associated with the development of software tools in support of DKIST operations ($361K) and non-payroll expenses ($41K), including computer hardware and software.	
CS006.5.P1.OM.02.01: DKIST Research (Science)	**$1,555,554**
Labor associated with the scientific research performed by the DKIST Science staff ($997K) and non-payroll expenses ($367K), including the cost of the two joint CU/NSO faculty members, community support provided by a CU staff scientist (Rast), optics components, publishing costs, and travel ($70K).	
CS006.5.P1.OM.01.03: DKIST Safety Programs	**$272,181**
Labor cost for two safety personnel ($214K) and nonpayroll expenses for safety gear and training.	
CS006.5.P1.OM.07.02: DKIST Sci Ops Specialists	**$697,381**
Labor cost for the Science Operations Specialist staff.	
CS006.5.P1.OM.03.03: DKIST Summit Engineer (Nonlabor)	**$493,380**
(Non-capital) equipment, materials and supplies and contracts in support of telescope operations.	
CS006.5.P1.OM.03.02: DKIST Technical Support Facilities	**$1,980,339**
Labor associated with upkeep of summit facilities ($87K) and non-payroll expenses ($1.7M), including electricity ($724K), utilities, vehicles, support contracts (e.g. thermal control installation and optimization), elevator servicing, lease payments for storage and baseyard.	
CS006.5.P1.OM.04.06: Instrument Upgrades	**$1,010,953**
Non-payroll expenses associated with upgrades to the DKIST instrumentation including additional storage capacity for the summit Data Handling System ($492K), optics components such as modulators and polarimetry calibration optics, computer replacements, electronics parts, supplies and materials.	
CS006.5.P1.OM.03.05: Observing Support	**$823,616**
Payroll cost for Engineering staff in support of observing campaigns ($730K) and travel ($25K).	
CS006.5.P1.OM.03.06: Preventive Maintenance Work Orders	**$563,400**
Payroll cost for Engineering staff in support of preventive maintenance of summit systems.	
CS006.5.P1.OM.03.08: Training & Professional Development	**$251,488**
Labor cost associated with staff training and professional development.	
CS006.5.P1.OM.03.04: Upgrades & Demand Work Orders	**$2,197,211**
Payroll cost associated with upgrades and on-demand work orders for summit systems, including the main telescope systems and some instrumentation support.	

5.1.3. NSO Integrated Synoptic Program (NISP)

The FY 2023 NISP achievements, goals, and milestones are provided in section 1 and 4. In this subsection, we provide the Program's budgetary expenditure information.

Funding Operation	Project ID Level	Project ID Name	YTD Expenditures
NSO NISP	CS006.2.P1.OM.01.02	NISP Administration - Total	67,612
	CS006.2.P1.OM.03.15	NISP Boulder HQ - Total	170,374
	CS006.2.P1.OM.01.06	NISP COVID-19 Safety - Total	2,919
	CS006.2.P1.OM.01.03	NISP CU IT Connectiv fee - Total	1,462
	CS006.2.P1.OM.04.10	NISP Camera Upgrade - Total	32,343
	CS006.2.P1.OM.03.16	NISP Computing - IT - Total	121,267
	CS006.2.P1.OM.03.18	NISP Data Center - Total	861,492
	CS006.2.P1.OM.03.22	NISP Data Processing - Total	0
	CS006.2.P1.OM.03.23	NISP Data Provision - Total	0
	CS006.2.P1.OM.03.21	NISP Data Storage - Total	33,677
	CS006.2.P1.OM.01.01	NISP Directorate - Total	284,918
	CS006.2.P1.OM.03.06	NISP Engineer Ops SOLIS - Total	92,336
	CS006.2.P1.OM.04.03	NISP Engineering - Total	17
	CS006.2.P1.OM.03.01	NISP Engineering Ops GONG - Total	259,082
	CS006.2.P1.OM.04.16	NISP GONG - Total	0
	CS006.2.P1.OM.03.02	NISP GONG Network - Total	0
	CS006.2.P1.OM.04.01	NISP GONG Refurbishment - Total	4,286
	CS006.2.P1.OM.04.11	NISP H-Alpha - Total	0
	CS006.2.P1.OM.04.08	NISP HVAC Upgrades - Total	14,404
	CS006.2.P1.OM.04.09	NISP LT Upgrade & Support - Total	720
	CS006.2.P1.OM.04.14	NISP Management - Total	14,664
	CS006.2.P1.OM.04.12	NISP Optical Upgrade - Total	0
	CS006.2.P1.OM.01.05	NISP Post Retire Benefits - Total	0
	CS006.2.P1.OM.03.07	NISP SOLIS - Total	12,463
	CS006.2.P1.OM.03.09	NISP SOLIS Relocation - Total	713
	CS006.2.P1.OM.02.01	NISP Science Research - Total	126,149
	CS006.2.P1.OM.02.02	NISP Science Service - Total	303,729
	CS006.2.P1.OM.01.04	NISP Ultipro - Total	4,767
	CS006.2.P1.OM.04.06	NISP Workstation Upgrade - Total	0
	CS006.2.P1.OM.04.17	SOLIS Construction - Total	133,297
	CS006.2.P1.OM.04.25	SWPC Big Bear (BB) - Total	0
	CS006.2.P1.OM.04.27	SWPC Boulder - Total	0
	CS006.2.P1.OM.04.21	SWPC Learmonth (LE) - Total	32,733
	CS006.2.P1.OM.04.26	SWPC Mauna Loa - Total	0
	CS006.2.P1.OM.04.20	SWPC Spt of GONG - Total	0
	CS006.2.P1.OM.04.23	SWPC Tenerife (TD) - Total	51
	CS006.2.P1.OM.04.22	SWPC Udaipur (UD) - Total	0
	CS006.2.S1.OM.06.01	WoU-MMA NISP - Total	481,410
	CS006.2.P1.OM.05.01	ngGONG Proposal Prep - Total	250
NSO NISP - Total			3,057,135
Overall - Total			3,057,135

Table 5.7. NISP WBS Description for YTD Expenditures >$200k

CS006.2.P1.OM.03.18: NISP Data Center	**$861,492**
Two major contributors for this project are the Labor ($789K including fringe). Together, these two items correspond to about 92% of the total. Labor is to support the work of NISP Programmers staff working on NISP base-funded projects.	
CS006.2.P1.OM.01.01: NISP Directorate	**$284,701**
The individual items included in the total for this project are less than $200K. The largest contributors are Labor ($233K including fringe), which is 82% of total. Labor is for the NISP Program Director work.	
CS006.2.P1.OM.03.01: NISP Engineering Ops GONG	**$259,082**
The individual items included in the total for this project are less than $200K. The largest contributors are Labor ($237K including fringe), which is 91% of total. Labor is to support the work of NISP Engineering personnel for NSF-funded GONG operations.	
CS006.2.P1.OM.02.02: NISP Science Service	**$303,729**
The individual items included in the total for this project are less than $200K. The largest contributors are Labor ($278K including fringe), which is 92% of total. Labor is to support service and research components of NISP Scientific staff working on NISP base-funded projects.	
CS006.2.S1.OM.06.01: WoU-MMA NISP	**$481,410**
All individual items that are included in the total for this project are less than $200K. The two largest contributors are Subawards ($188K) and Labor ($255K including fringe). Together, these correspond to about 92% of the total. The subawards are issued to Catholic University of America (CUA) and George Mason University (GMU). Labor is to support the work of NISP Scientific and programmer staff working on this project.	

5.1.4 NSO Community Science Program (NCSP)

The FY 2023 NCSP achievements, goals, and milestones are provided in section 1. In this subsection, we provide the Program's budgetary expenditure information.

Funding Operation	Project ID Level	Project ID Name	YTD Expenditures
NSO NCSP	CS006.4.P1.OM.06.03	2024 Total Solar Eclipse - Total	111,780
	CS006.4.P1.OM.06.01	DKIST Coronal Synoptic Pr - Total	1,275
	CS006.4.P1.OM.06.02	MvM GONG-Solar Orbiter/PH - Total	82,890
	CS006.4.P1.OM.01.02	NCSP Administration - Total	10,075
	CS006.4.P1.OM.03.01	NCSP Boulder HQ - Total	41,420
	CS006.4.P1.OM.01.03	NCSP COVID-19 Safety - Total	0
	CS006.4.P1.OM.05.01	NCSP Curriculum Prep - Total	1,966
	CS006.4.P1.OM.02.06	NCSP Data Center Support - Total	71,700
	CS006.4.P1.OM.04.01	NCSP Data Training Wrkshp - Total	733
	CS006.4.P1.OM.01.01	NCSP Directorate - Total	4,063
	CS006.4.P1.OM.02.02	NCSP Grad Student Support - Total	137,764
	CS006.4.P1.OM.02.01	NCSP Research - Total	362,081
	CS006.4.P1.OM.02.05	NCSP Service - Total	143,114
	CS006.4.P1.OM.01.05	NCSP Unfunded Liabilities - Total	5,014
	CS006.4.P1.OM.02.03	NCSP Visitors Program-ST - Total	7,278
NSO NCSP - Total			981,153
Overall - Total			981,153

Table 5.8. NCSP WBS Description for YTD Expenditures >$200k

CS006.4.P1.OM.02.05: NCSP Research	**$362,081**
Support of CU DKIST Ambassador Andrei Afanasev and Ambassador Yingjie Zhu at the University of Michigan. Although the Ambassador program was funded by a supplemental funding request in FY 2018 and FY 2019, the various Ambassadors that were appointed had widely different starting times, dependent on the stages of their appointments with their home university.	

5.1.5 Sacramento Peak (Sunspot)

The FY 2023 Sacramento Peak (Sunspot) Program achievements, goals, and milestones are provided in section 1. In this subsection, we provide the Program budgetary expenditure information.

Funding Operation	Project ID Level	Project ID Name	YTD Expenditures
NSO Sunspot	CS006.3.P1.OM.03.11	NMSU Sci Ops - Total	75,183
	CS006.3.P1.OM.01.02	Sunspot Administration - Total	223,028
	CS006.3.P1.OM.01.03	Sunspot COVID-19 Safety - Total	0
	CS006.3.P1.OM.03.02	Sunspot DST Observ Support - Total	71,629
	CS006.3.P1.OM.01.01	Sunspot Directorate - Total	0
	CS006.3.P1.OM.03.06	Sunspot Electr Syst Maint - Total	80,297
	CS006.3.P1.OM.03.08	Sunspot Housing - Total	(159,912)
	CS006.3.P1.OM.03.05	Sunspot Propane Syst Maint - Total	24,570
	CS006.3.P1.OM.03.09	Sunspot Relocatables - Total	64,920
	CS006.3.P1.OM.03.10	Sunspot Safety - Total	0
	CS006.3.P1.OM.03.04	Sunspot Sewer Syst Maint - Total	42,379
	CS006.3.P1.OM.03.01	Sunspot Support Non-DST - Total	332,765
	CS006.3.P1.OM.03.07	Sunspot Vehicle Maint - Total	6,583
	CS006.3.P1.OM.03.03	Sunspot Water Syst Maint - Total	28,283
NSO Sunspot - Total			789,724
Overall - Total			789,724

Table 5.9. *Sunspot WBS Description for YTD Expenditures >$200k*

CS006.3.P1.OM.01.02: Sunspot Administration	**$223,028**
Labor associated with the operations of the site by the Sunspot's site manager ($186K including fringe).	
CS006.3.P1.OM.03.01: Sunspot Support Non-DST	**$332,765**
Labor associated with the operations of the site including the maintenance staff ($137K) and non-payroll expenses ($75K) for moving fiber communication lines and monthly services with Tularosa Communications, ($28K) for the Visitors Center boiler replacement, and ($37K) for contracted services.	

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APPENDICES

APPENDIX A. SCIENTIFIC AND KEY MANAGEMENT STAFF

The NSO staff provide support to users including observational support, developing and supporting state-of-the-art instrumentation to ensure that users obtain the best data, and maintaining data archives and the means to accessing the data. Members of the scientific staff are defining how DKIST will be operated and how NSO will handle the data. In addition, both scientific and engineering staff serve as mentors for undergraduate and graduate students and postdoctoral fellows. They also organize community workshops on critical areas of solar research and planning. Staff science and instrument development allow NSO to stay at the forefront of solar physics and play a crucial role in fulfilling user support.

The current NSO scientific and management staff, as well as affiliated scientific staff, are listed below with their primary areas of expertise and key observatory responsibilities.

Scientific Staff

Tetsu Anan	Assistant Scientist: Solar electric fields; magnetic reconnections; solar chromospheric heating; high-energy non-thermal particles; integral-field-unit spectropolarimetry including instruments, data reduction, and data analysis.
Christian Beck	DKIST Resident Scientist. Post-focus instrumentation; data reduction pipelines; high-resolution spectroscopy and spectro-polarimetry of the photosphere and chromosphere; development of inversion tools for chromospheric spectral lines; DKIST instrumentation and data calibration approaches.
Luca Bertello	NISP Solar Atmosphere Program Scientist and SOLIS Data Scientist; solar variability at different temporal, spectral, and spatial scales; calibration of solar magnetic field data; solar-stellar research; space weather.
David A. Boboltz	NSO Deputy Associate Director for DKIST; Radio astronomy; Very Long Baseline Interferometry (VLBI); stellar evolution; late-type stars; circumstellar atmospheres; astrophysical masers; radio stars, e.g., RS CVn and Algol binaries; high-resolution imaging; spectro-polarimetry; instrumentation.
Gianna Cauzzi	High resolution imaging and spectroscopy of the lower solar atmosphere; chromospheric structure and dynamics, including wave dynamics and heating. Flare physics and lower atmospheric signatures. Chair of the Science Review Committee for the DKIST OCP. Head of the DKIST Ambassador Program. Member of the Panel on Sun and Heliosphere for the NAS Decadal Survey 2024-2033.
Serena Criscuoli	High-spatial resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; radiative transfer; solar and stellar spectral variability; DKIST Resident Astronomer.
Alisdair Davey	CMEs and associated phenomena; acceleration and heliospheric propagation of SEPs during solar flares and CMEs; use of computer vision/AI in identifying solar features and events; development of the VSO and the heliospheric data environment, including integration of data and modeling efforts.
Andre Fehlmann	DKIST infrared instrumentation specialist; IR instrumentation; precision spectro-polarimetry; coronal magnetic fields; student engagement and community outreach.

Catherine Fischer	Data reduction pipelines, high-resolution imaging, spectroscopy, and spectropolarimetry, solar small-scale magnetic field evolution.
Sanjay Gosain	Observatory Scientist, NISP Instrument scientist; optical design and calibration of the instruments for polarimetry and spectroscopy, instrument modeling; study of solar flares, eruptive phenomena; chromospheric magnetism; magnetic helicity, Public outreach: Training Citizen Scientists for Experiments during Eclipse, Diversity Advocate (Boulder).
David Harrington	DKIST polarimetry scientist; instrumentation; spectropolarimetry, adaptive optics, novel optical systems, detector systems, applied research, community workforce development.
Sarah A. Jaeggli	3D structure of sunspot magnetic fields; atomic and molecular physics of the photosphere and chromosphere; radiative transfer modeling and spectral synthesis; instrumentation for spectroscopy and spectropolarimetry, including DKIST facility instrument development; engaging the community to perform multi-facility observations.
Kiran Jain	Scientist; Farside Project Lead Scientist; Helioseismology – global and local; farside acoustic imaging of the Sun; multi-wavelength helioseismology; acoustic oscillation mode characteristics; time-series analysis; solar variability; solar interior structure and dynamics; subsurface flows; active regions and solar magnetism; space weather; Sun-Earth connection.
Maria Kazachenko	Inversion techniques to derive the electric fields and Poynting fluxes on the surface of the Sun using magnetic field measurements; data-driven simulations of the solar coronal magnetic fields; statistical properties of solar flares.
Rudolf W. Komm	Helioseismology; dynamics of the solar convection zone; solar activity and variability.
Adam Kowalski	Flare observations and radiative-hydrodynamic modeling; white-light flare radiation and continuum properties; connection between magnetic activity and flares on the Sun and younger M dwarf stars; teaching physics of stellar atmosphere modeling and observational astronomy and spectroscopic analysis; student mentor.
Maxim Kramar	Physics of the solar corona. Particularly, developing techniques for the inferring coronal plasma properties such as density, temperature, and magnetic field and its application to study various coronal phenomena such as Coronal Mass Ejections (CME), solar wind, space weather.
David Kuridze	Plasma diagnostics in the solar atmosphere; high-resolution spectroscopy and spectropolarimetry; Chromospheric and coronal magnetic field measurements; chromospheric fine-structures and flares.
Gordon J. D. Petrie	NISP; solar magnetism; GONG magnetogram zero-point analysis; the Sun's polar magnetic fields and their responses to activity cycles, comparing high-resolution and full-disk magnetogram data; coronal magnetometry in support of heliospheric modeling for solar encounter missions and other applications; end-to-end calibrations of magnetogram observations.
Alexei A. Pevtsov	NSO Associate Director for NISP; solar magnetic fields; corona; sunspots; chromosphere; solar-stellar research; space weather and space climate.
Valentín M. Pillet	NSO Director; solar activity; Sun-heliosphere connectivity; magnetic field measurements; spectroscopy; polarimetry; astronomical instrumentation with an emphasis on spectropolarimetry.
Kevin P. Reardon	Dynamics and structure of the solar photosphere, chromosphere, and corona; implementation of modern techniques for data archiving, processing, and discovery; application of imaging spectroscopy techniques; post-focus

	instrumentation development; spectropolarimetry of the solar atmosphere; transit studies of inner planets; history of solar astronomy.
Thomas R. Rimmele	NSO Associate Director for DKIST; DKIST Construction Project Director; sunspots; small-scale magnetic surface fields; active region dynamics; flares; acoustics waves; weak fields; adaptive optics; multi-conjugate adaptive optics; instrumentation.
Thomas Schad	Chromospheric and coronal magnetic field diagnostics; precision spectro-polarimetry; DKIST Operations, DKIST Instrumentation; DKIST Technical TAC chair; student engagement and community outreach
Dirk Schmidt	DKIST adaptive optics, high spatio-temporal resolution observation techniques; development of adaptive optics systems, in particular multi-conjugate adaptive optics systems.
Lucas A. Tarr	Observational, theoretical, and numerical investigations of the low solar atmosphere; active region evolution; development of 3D MHD data driven simulations; MHD wave propagation; DKIST operations; student mentorship; public outreach.
Sushanta Tripathy	NISP Interior Program Lead Scientist; magnetoseismology of active regions; global and local helioseismology; solar activity cycle; ring-diagram analysis, sub-surface flows, cross-spectral analysis of oscillation time series.
Alexandra Tritschler	Senior Scientist; DKIST Operations Scientist; DKIST operations development; DKIST Observatory Control System Scientist; DKIST Target Acquisition System Scientist; DKIST Visible Broadband Imager; solar fine structure; magnetism; Stokes polarimetry.
Han Uitenbroek	Associate Director for NSO Community Science Program; atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere; Development of the DeSIRe inversion code; Development of the Level 2 pipelines for spectropolarimetric data from DKIST.
Friedrich Wöger	Senior Scientist; DKIST Instruments Project Scientist. Image reconstruction techniques; adaptive optics; two-dimensional spec-troscopy, and spectro-polarimetry; DKIST instrumentation, in particular the visible broadband imager; DKIST wavefront correction system; DKIST data handling system.

Grant-Supported Scientific Staff

Shukirjon S. Kholikov	Helioseismology; data analysis techniques; time-distance methods.

Postdoctoral Fellows

Andrei Afanasev**	Data-driven MHD modeling of solar active regions.
Joao da Silva Santos	Solar magnetism and atmospheric heating.
Ryan French	Coronal and chromospheric observations of solar flares.
Amr Hamada	Machine Learning application on GONG dataset and solar flare forecasting.
Alin R. Paraschiv	Inversion problems, data calibrations, and data interpretation of the Solar Corona.
Yuta Notsu	Stellar magnetic activity and flares.

**DKIST Ambassador

Key Management Staff

David Boboltz	DKIST Deputy Associate Director.
Gregory Card	NISP Engineering & Technical Manager.
Eric Cross	Head of Information Technology.
Jennifer Ditsler	Head of Administration & Support Facilities.
Bret Goodrich	DKIST Instrumentation Manager.
Heather Marshall	DKIST Technical Operations Manager.
Jorge Perez Gallego	Head of Education & Public Outreach
Robert E. Tawa	DKIST Data Center Project Manager.
Mark Warner	DKIST Program Manager.
Carolyn Watkins	NSO Business Operations Manager.

Graduate Students

Abdhullah Alshaffi	University of Colorado	MHD simulations of eruptive events on the Sun.
Sarah Bruce	University of Colorado	Solar eclipse research.
Marcel Corchado-Albelo**	University of Colorado	Flare current sheet properties.
James Crowley	University of Colorado	Spectral inversions and photospheric structure.
Caroline Evans	University of Colorado	Solar surface magnetism.
Ryan Hofmann	University of Colorado	Solar chromospheric thermodynamics with ALMA.
John Stauffer**	University of Colorado	Molecular and millimeter temperature diagnostics.
Cole Tamburri**	University of Colorado	Chromospheric flare dynamics.
Dennis Tilipman	University of Colorado	Energy transfer in the quiet Sun.
Isaiah Tristan	University of Colorado	Stellar flares.
Ayla Weitz	University of Colorado	Chromospheric and coronal connections.
Amanda White	University of Colorado	Optical element polarization characterization.
Leah Zuckerman	University of Colorado	Machine learning applications in solar physics.

**DKIST Ambassador

DKIST Ambassadors

Shah Bahauddin	University of Colorado	Magneto-convection; acoustic source.
Melissa Bierschenk	George Mason University	Magnetic activity; solar eruptions.
Yingjie Zhu	University of Michigan	CME diagnostics in the inner corona.

APPENDIX B. SCIENTIFIC STAFF RESEARCH AND SERVICE

(*GRANT SUPPORTED STAFF)

Tetsu Anan, Assistant Scientist

Areas of Interest

Solar chromospheric heating; integral-field-unit spectropolarimetry; electric field diagnosis.

Recent Research Results

T. Anan is developing an integral-field-unit spectropolarimetry Diffraction-Limited Near-Infrared Spectropolarimeter (DL-NIRSP) as a DKIST facility instrument (Jaeggli et al. Solar Physics 297, 137). He published a paper presenting measurements of shock heating energy in a sunspot umbra using an integral-field-unit spectrograph of the Dunn Solar Telescope (Anan et al. 2019, ApJ, 882, 161). Another paper was published in the Astrophysical Journal, revealing magnetic field structures in the photosphere and the chromosphere associated with strong chromospheric heating over a plage region using another integral-field-unit spectropolarimeter of the GREGOR telescope (Anan et al. 2021, ApJ, 921, 39). He contributed to interpretations of HeI1083 nm Stokes profiles of a strong shock resulting from a coronal downflow within a sunspot umbra (Schad, Dima, and Anan, 2021, ApJ, 916, 5).

Future Research Plans

Dr. Anan will continue to develop the DL-NIRSP. He is writing a manuscript presenting a new electric field diagnosis using DKIST data.

Service

Dr. Anan is a member of Technical Review Committee for DKIST proposals for the Operations Commissioning Phase (OCP) and Resident Scientist for the OCP.

Christian Beck, Associate Scientist

Areas of Interest

Post-focus instrumentation; data reduction pipelines; high-resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; development of inversion tools for chromospheric spectral lines; polarimetric calibration techniques.

Recent Research Results

In continuation of collaborations with D. P. Choudhary (California State University Northridge, CSUN), R. Louis (Udaipur Solar Observatory), and the solar physics group at the University of Alabama in Huntsville (UAH), Dr. Beck has published papers a filament eruption (Wang et al., *ApJ*, **926**, 2022), the magnetic topology of the inverse Evershed effect (Prasad et al., *A&A*, **662**, 2022), and a heating event of unknown origin above a sunspot light bridge (Louis et al., *ApJ*, **942**, 2023).

Future Research Plans

With his full-time commitment to the Daniel K. Inouye Solar Telescope (DKIST) project, Dr. Beck's main focus is on the successful execution of the DKIST observation cycles and technical improvements of the Visible Spectro-Polarimeter at the telescope. In collaboration with CSUN and current or former members of the solar physics group of UAH, the primary research focus is on the development of analysis tools for chromospheric spectral lines, especially Hydrogen α (NSF Grant "*Multi-wavelength Spectroscopic and Spectropolarimetric Diagnostics of the Solar Atmosphere*", PI D. P. Choudhary/CSUN). The collaboration with UAH will concentrate on establishing the relevance of heating in the upper solar atmosphere by Cowling resistivity and current dissipation.

Service

C. Beck is a member of the DKIST Operations team and the Technical Review Committee, acts as DKIST Help Desk agent, and is a Resident Scientist on Maui for the execution of observing proposals for DKIST

Operations. C. Beck is the DKIST point of contact for the Visible Spectro-Polarimeter (ViSP). During the past year, Beck has reviewed publications for The Astrophysical Journal and Astronomy & Astrophysics.

Luca Bertello, Scientist

Areas of Interest

Solar variability at different temporal, spectral, and spatial scales; calibration of solar magnetic field data; solar-stellar research; space weather.

Recent Research Results

Over the course of 2023, in collaboration with different national and international research groups, I have been involved in several distinct projects. Some of these projects are briefly described here. A major task I have undertaken with my colleagues at NSO is the testing and validation of new GONG cameras. The new cameras will replace the old cameras at each of the six GONG sites, with the major goal of improving the quality of current GONG data. In addition, I am the PI for the NASA-funded simplest magnetograph project. This project explores a novel instrument concept based on measuring a broad-band polarization which could be done without moving elements and complicated optical schemes. This concept will lead to the creation of an extremely simple and compact magnetograph suitable for space missions. A pair of successful observational campaigns have been conducted showing the potential performance of this instrument. Another ongoing collaboration is with the Solar Orbiter PHI team. Solar Orbiter is an international cooperative mission between ESA (the European Space Agency) and NASA that addresses a central question of heliophysics: How does the Sun create and control the constantly changing space environment throughout the solar system? Its payload includes 10 different instruments, including the Polarimetric and Helioseismic Imager (PHI) instrument. My major responsibility in this project is the intercalibration of GONG and PHI magnetograms for the purpose of creating almost synchronic synoptic charts of the solar magnetic field.

Other ongoing projects include collaborations on a variety of programs with colleagues at the University of Michigan, University of Graz (Austria), Georgia State University, Stanford University, University of Alabama in Huntsville, and the University of Tor Vergata (Rome, Italy). These collaborations comprise studies of multi centuries long solar irradiance reconstruction, the operational use of GONG H-alpha images using machine learning for solar flare predictions, and the improvement of synoptic magnetic charts to be used for driving numerical coronal and heliospheric models in space weather applications and operations.

Future Research Plans

One of my main future research plans is to better understand the nature of the solar dynamo, and the role played by the magnetic field in affecting the topology of the outer layers of the solar atmosphere and heliosphere. Another area of interest in future research activity is the investigation of observational data on global properties of the Sun to better characterize the physical processes that should be incorporated in the next generation of solar (stellar) models. A significant portion of my future efforts will also be dedicated to the analysis of historical solar data, with particular emphasis on magnetic and Ca II K observations. I maintain strong collaborations with several national and international institutes. This synergy has grown consistently over the years and has opened several new research channels.

Service

As the Data Scientist for SOLIS, my major responsibility is to provide the solar and helio-physics community with high-quality and reliable NISP data. During 2023 I have peer-reviewed publications for several different journals and provided technical/scientific support for outside data users.

David A. Boboltz, Senior Scientist

Areas of Interest

Radio astronomy; Very Long Baseline Interferometry (VLBI); stellar evolution; late-type stars; circumstellar atmospheres; astrophysical masers; radio stars, e.g., RS CVn and Algol binaries; high-resolution imaging; spectro-polarimetry; instrumentation.

Recent Research Results

Dr. Boboltz recently joined the NSO as DKIST Deputy Associate Director. Prior to that, he served for more than 10 years as the NSF Program Director for both the NSO and the $362M DKIST construction project. Dr. Boboltz's time is fully committed to assisting the DKIST Associate Director with the extensive management, organizational, and service tasks required for operations of the facility.

Future Research Plans

Dr. Boboltz's future research plans will primarily focus on enabling colleagues within NSO and the wider solar physics community to accomplish their research goals with DKIST. He hopes to continue to keep DKIST on the cutting edge of solar physics by improving operational efficiencies and enabling the development of new capabilities such as multi-conjugate adaptive optics and new instrumentation like the Visible Tunable Filter (VTF).

Service

Dr. Boboltz serves as the NSO Deputy Associate Director for the DKIST. He supervises key NSO staff members and works closely with the DKIST Associate Director regarding the operations of the facility. He currently oversees the DKIST Data Center. He provides insight and advice to the DKIST Associate Director and NSO Director regarding interactions with NSF. He also continues to maintain a connection with the radio astronomy community serving on advisory panels for the Square Kilometer Array (SKA).

Gianna Cauzzi, Associate Scientist

Areas of Interest

High resolution imaging and spectroscopy of the lower solar atmosphere; chromospheric structure and dynamics, including wave dynamics and heating. Flare physics and lower atmospheric signatures. Imaging instrumentation based on Fabry-Perot interferometers. Outreach and education of the broader research community.

Current and Future Research Plans

Dr. Cauzzi is working on the thermal and magnetic structure of the chromosphere, using a variety of complementary facilities and diagnostics, including first VBI and ViSP data with DKIST. Future research will deal with quiet Sun magnetism and flare energy deposition characteristics.

Service

Dr. Cauzzi is the Head of the DKIST Ambassador Program, which currently supports 10 graduate students and 2 postdoctoral fellows at multiple US universities. The program aims at developing a cohort of young US scientists well versed in the science of DKIST. Workshops are being developed to introduce and train this cohort in the use of DKIST data.

Dr. Cauzzi is currently a member of the Panel on the Physics of the Sun and Heliosphere for the National Academy of Sciences Decadal Survey for Solar and Space Physics. The Panel is tasked to provide an overview of the current state of research on the physics of the Sun and the heliosphere, and identify the highest priority science goals for 2024-2033.

Dr. Cauzzi routinely helps with student projects and serves on various committees for CU graduate students associated with NSO. She routinely serves as reviewer for multiple astrophysical journals (ApJ, A&A, Solar Physics), and international research agencies.

Finally, Dr. Cauzzi is the Chair of the Science Review Committee for the DKIST OCP (Operation Commissioning Phase). After the experience of the first two Calls for Proposals for the DKIST OCP, work is underway on revising and adapting the procedures guiding the overall review process.

Serena Criscuoli, Associate Astronomer

Areas of Interest

High-spatial resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; radiative transfer; numerical simulations; solar irradiance variations.

Recent Research Results

Dr. Criscuoli recently worked on topics in the framework of the Areas of Interests mentioned above. She continued investigating the puzzling variability of solar Balmer lines and other chromospheric lines, at different temporal scales in order to improve our understanding of both solar and stellar chromospheric variability. She continued working on the development of new models to estimate solar irradiance in the past and make predictions for future solar cycles. She is also working on using DKIST observations to validate state-of-the-art numerical simulations.

Service

Dr. Criscuoli actively contributed to several aspects of the execution of the second DKIST Call for Proposals (member of the scientific review panel, development and validation of DKIST Experiments, Resident Astronomer). She was a referee for scientific journals, member of NASA review panels and supervised undergraduate students.

Alisdair Davey, Associate Scientist

Areas of Interest

CMEs and associated phenomena such as EUV waves and Dimming Regions. The acceleration and Heliospheric propagation of SEPs during solar flares and CMEs. The use of computer vision/AI in identifying solar features and events. Development of the Virtual Solar Observatory (VSO), and the Heliospheric data environment, including integration of data and modeling efforts and meta-data standardization efforts.

Recent Research Results

Dr. Davey and colleagues continued development on a framework for the coronal analysis of shocks and waves (CASHeW). The framework combines analysis of NASA Heliophysics System Observatory data products and relevant data-driven models, into an automated system for the characterization of off-limb coronal waves and shocks and the evaluation of their capability to accelerate solar energetic particles (SEPs). With this framework, Davey and colleagues hope to contribute to the overall understanding of coronal shock waves, their importance for energetic particle acceleration, as well as to the better ability to forecast SEP events fluxes.

Service

Dr. Davey worked on a number of topics for the VSO including bringing new data sets online for the solar physics community. He also maintains the Solar Physics E-print Archive and is the web master for the AAS Solar Physics Division. Dr Davey is a member of the EarthCube sponsored working group “Uniform Semantics and Syntax of Solar Observations and Events” and part of a NASA sponsored working group looking at capabilities that enable open science across NASA’s scientific disciplines. In 2020-2021, he was a referee for a number of scientific journals.

Andre Fehlmann, Associate Scientist

Areas of Interest

Infrared instrumentation; precision spectropolarimetry; coronal magnetic fields; infrared camera systems; student engagement and community outreach.

Recent Research Results

A. Fehlmann performed final alignment and installation of the Cryogenic Near-Infrared Spectropolarimeter (CryoNIRSP), a DKIST first-generation facility instrument, at the summit of Haleakala. He performed the site acceptance tests and science verification for the instrument.

Future Research Plans

Dr. Fehlmann will help refining and implementing the DKIST calibration plan and integrate and commission the facility instruments on the telescope. He is working on the next generation of infrared camera systems for the facility and upgrades to the CryoNIRSP instrument. As a member of several teams, he will be involved in analyzing data from the initial DKIST observations.

Service

Fehlmann is a member of the DKIST science team and infrared instrumentation specialist for DKIST facility instruments. He was working on setting up a data reduction pipeline for CryoNIRSP. In preparation of the first observation phase he was involved in preparing experiments that can be executed at the telescope. In the Summer months Fehlmann helped co-mentor two AKAMAI students during their internship at DKIST.

Catherine Fischer, Assistant Scientist

Areas of Interest

Data reduction pipelines, high-resolution imaging, spectroscopy, and spectropolarimetry, solar small-scale magnetic field evolution.

Recent Research Results

Dr. Catherine Fischer's research primarily focuses on the dynamic evolution of small-scale magnetic elements. Her work has delved into topics such as the interaction of magnetic fields with horizontal vortex tubes (published in Fischer et al. ApJ Letters 2020) and the emergence of small-scale magnetic flux (as documented in Fischer et al. A&A Letters 2019).

More recently, she has extended her investigations by analyzing data from the DKIST, revealing discoveries like small-scale chromospheric shocks triggered by magnetic vortices (Fischer et al., in preparation). This study contributes to our understanding of small-scale magnetic fields with regard to solar atmospheric heating.

Additionally, she has been involved in exploring the application of Machine Learning techniques for solar structure classification (Díaz Castillo et al., Frontiers Astron. Space Sci. 2022), being part of the DKIST Critical Science Plan (Rast et al., SoPh 2021), and participating in the NASA SAG 21 study analysis (report reproduced in Rackham et al., RAS Techniques and Instruments, 2023).

Future Research Plans

As a Principal Investigator (PI) and Co-PI for DKIST experiments, Dr. Catherine Fischer intends to maintain her involvement in the scientific analysis of DKIST data.

Her current interest research are centered around processes like magnetic field intensification, magnetic vorticity, and magnetic flux emergence and cancellation to study the temporal development of quiet sun small-scale magnetic fields.

As part of the international WALSA (Waves in the Solar Lower Atmosphere) team, she is also interested in studying wave phenomena and their imprint in the solar atmosphere.

She also collaborates on several ongoing projects, studying, for example, fibrils and acoustic wave generation. One of her recent projects involves the analysis of solar data from two different satellites delivering a comprehensive data set for a stereoscopic study of photospheric horizontal supersonic flows.

Service

Dr. Catherine Fischer has been contributing to the data calibration pipeline work for the VBI/DKIST. As part of the DKIST Operations team she has been supporting telescope observing runs in the role of Resident Scientist and contributing to the creation and testing of DKIST science experiments.

Furthermore, she has served as a member of the Scientific Organizing Committee (SOC) in international meetings and has been a member of the Technical Review team for DKIST experiment proposals.

Sanjay Gosain, Observatory Scientist

Areas of Interest

Astronomical instrumentation: Optical design of instruments for imaging spectropolarimetry, Instrument Modeling. Solar Physics Research: Study of key physical parameters and their evolution in relation to flares, eruptive filaments and coronal mass ejections; Three-dimensional magnetic and thermal field properties of active regions via photospheric and chromospheric spectropolarimetry.

Recent Research Results

Dr. Gosain summarized the compact GONG instrument concept in an article (Gosain et al 2023, PASP vol. 135, 045001). The details of the instrument design, model simulations and proof-of-concept observations taken at GONG Boulder site were described. This novel conceptual design was made available to the heliophysics community for building deep space missions where a compact GONG-like instrument can be accommodated inside a 10U to 12U format cubesats. He also led the development of a semi-automatic calibration procedure for remote LCVR calibrations at GONG sites. This calibration was needed to mitigate the effects of magnetic field bias in the magnetograms. This calibration system proved crucial in identifying the failing LCVRs at the GONG TD and LE sites. Dr. Gosain strongly recommended routine LCVR calibrations and adding a UV protective glass window for the long-term stability of the GONG magnetic field measurements. Dr. Gosain led citizen science experiment CATE-2023, where measurements were made during the Total Solar Eclipse (TSE) event at Exmouth, Australia and he helped train volunteers and high school teachers. He also helped write camera image acquisition software for Super-CATE experiment, a separate NSO setup for the spectroscopy of the corona. Dr. Gosain led a broad search of vendors with strict specifications to replace the failed entrance window filters of GONG. After several iterations a vendor was selected, he is now developing laboratory tests for verification of performance of the windows. He has recently verified a set of five new LCVRs for GONG. He also participated in the preparation of “Next generation GONG” or ngGONG proposal submitted to NSF to design a future generation network to replace GONG and SOLIS.

Future Research Plans

Dr. Gosain plans to build a prototype for GONG H-alpha tunable Doppler imaging system for GONG to study the eruptive filaments. He also plans to provide support for: (i) the re-commissioning of SOLIS/VSM, FDP and ISS instruments at Big Bear, (ii) testing and deployment of the new GONG cameras, (iii) LCVR calibration, (iv) entrance window characterization. He has used DKIST VISP observations to derive chromospheric temperature stratifications in a plage and fibril region and plans to carry out more detailed study.

Service

Dr Gosain served as a reviewer for several international journals. He serves as a diversity advocate for NSO Boulder site and regularly participates in the EIC council meetings, makes SOC DEI presentations, and leads NSO diversity working group discussions. He regularly participates in NISP meetings for addressing concerns in instrumentation, data reduction and analysis and calibration issues. He participated in the ngGONG proposal development efforts. He has developed software programs for detecting solar features such as filaments, prominences in GONG H-alpha images using machine learning algorithms. He has also worked on the development of programs to improve H-alpha image quality by using the concept of lucky-imaging. He has also improved algorithms for fast grid search based NLTE inversions by utilizing GPU parallelization.

David M. Harrington, Scientist

Areas of Interest

Instrumentation; spectropolarimetry, adaptive optics, novel optical systems, detector systems, applied research, community workforce development.

Recent Research Results

Dr. Harrington has been developing polarization system performance models, optical system models and calibration algorithms for large telescopes. He has also been working on the design and fabrication of a high precision lab spectropolarimeter for full Mueller matrix characterization of optics in the visible and near-IR. Other activities include: daytime sky polarization calibration technique development for large telescopes (AEOS, Keck, Dunn Solar Telescope); and data reduction and analysis pipelines for polarimetric instrumentation (HiVIS & InnoPOL on AEOS, LRISp on Keck, curvature adaptive optics and EMCCD imaging polarimeters).

Future Research Plans

Dr. Harrington is actively developing new techniques to calibrate, model and improve the polarimetric performance of astronomical telescopes and instruments. New lab equipment and methods are in development for characterizing and modeling large polarimetric optics. Software modeling improvements and new mathematical techniques will advance the state-of-the-art for calibration precision and accuracy. Applying new interdisciplinary techniques both from theory and components will keep DKIST on the cutting edge of technology. With DKIST first-light instruments and novel data sets, a wide range of science cases for a diverse community will be impacted by system improvements.

Service

Harrington is an active member of the DKIST Science Group and is the DKIST polarimetry scientist working with the instrument partner teams and Polarimetry Analysis & Calibration team to integrate and calibrate the first-light instrument suite. The DKIST user community is being engaged and educated in anticipation of the new DKIST polarimetric capabilities. Harrington is an active participant in the Akamai Workforce Initiative, which involves working with industry and academic partners, mentoring Hawaiʻi-connected local interns for summer and year-long projects and facilitating connections between industry and various STEM-focused educational programs.

Sarah A. Jaeggli, Associate Astronomer

Areas of Interest

The 3-dimensional structure of sunspot magnetic fields; atomic and molecular physics of the photosphere and chromosphere; radiative transfer modeling and spectral synthesis; instrumentation for spectroscopy and spectropolarimetry, including DKIST facility instrument development; engaging the community to perform multi-facility observations.

Recent Research Results

With the completion of the DL-NIRSP instrument in 2021, Dr. Jaeggli published the instrument paper in 2022 (Jaeggli et al 2022 *Sol. Phys.*), with instrument P.I. Dr. Haosheng Lin, instrument support scientist Dr. Tetsu Anan, and the DL-NIRSP team. Dr. Jaeggli is leading preparations for the installation and alignment of an upgraded integral field unit for DL-NIRSP. This IFU is based on mirrors, rather than fiber optics, and it will significantly improve the instrument sensitivity. During the course of DL-NIRSP data preparation, Dr. Jaeggli identified an improved method for residual polarization crosstalk characterization and correction using sunspot photospheric observations, resulting in a publication of the method (Jaeggli, Schad, Tarr, & Harrington 2022 *ApJ*). Dr. Schad quickly realized this method could also be applied to coronal observations and published a second paper with this technique (Schad, Jaeggli, & Dima 2022 *ApJ*). Dr. Jaeggli is continuing to apply this method to Cycle 1 and 2 ViSP observations in order to confirm correct polarization calibration of DKIST data.

Future Research Plans

Dr. Jaeggli is also working with Dr. Graham Kerr and Dr. Adrian Daw on continued work to understand the fluorescence spectrum of molecular hydrogen seen in spectra from the Interface Region Imaging Spectrograph (IRIS) satellite. Molecular hydrogen is primarily bright during flares, when the plasma radiation environment can be complex, so Dr. Jaeggli is working to synthesize the flare radiation based on radiation-hydrodynamic flare models using both optically thin and optically thick radiative transfer to determine realistic excitation of the H_2 electronic transitions. Dr. Jaeggli continues to serve as an unfunded collaborator on the machine-learning for spectropolarimetric inversions project (SPIN4D) with collaborators at the University of Hawaii Institute for Astronomy. This project recently obtained its first DKIST dataset during Cycle 2 observations and she is supporting analysis of this data. Dr. Jaeggli is a co-I for a new EUV satellite-based spectrograph called the Multi-Slit Solar Explorer (MUSE), P.I. Dr. Bart de Pontieu, to support collaborative science between MUSE and DKIST. In 2021, this project was selected for implementation by NASA on a delayed schedule, and is currently gearing up for the start of Phase C in 2024 in expectation of a launch date in 2027. During DKIST Cycle 2, Dr. Jaeggli's experiment on delta-sunspots was executed and the ViSP data is now available for further analysis.

Service

Dr. Jaeggli is supporting the DKIST project, acting as instrument scientist on the DL-NIRSP team, and as a member of the polarization calibration team. As a DKIST scientist, she participated in the technical review, preparation, and execution of the experiments during DKIST proposal cycle 2. Dr. Jaeggli also served as a member of the AURA Diversity and Inclusion Council as the Astronomer representative through 2023. Dr. Jaeggli is an avid participant in public outreach and joined the NSO EPO team in activities during Haleakala Solar Week 2023 and for the MEDB Excite Camp.

Kiran Jain, Scientist

Areas of Interest

Helioseismology – global and local; farside acoustic imaging of the Sun; multi-wavelength helioseismology; acoustic oscillation mode characteristics; time-series analysis; solar variability; solar interior structure and dynamics; subsurface flows; active regions and solar magnetism; space weather; Sun-Earth connection.

Recent Research Results

Global Oscillation Network Group (GONG) has been routinely producing seismic maps of the Sun's far hemisphere for about two decades which are sometimes affected by high noise. Dr. Jain investigated the origin of noise in these maps and developed methods for its reduction. The new calibration procedures have significantly reduced the noise in seismic maps and improved the signal especially when the farside active region approaches the limb.

Dr. Jain carried out a detailed analysis of the evolution of flows in these "rogue" active regions, e.g., anti-Joy and anti-Hale active regions, and compared their flow characteristics with "normal" active regions as they pass through the disk. Our study provides a better understanding of the sub-surface flow patterns near active regions and their connection with surface flux transport.

Dr. Jain also investigated the relationship between the subsurface plasma flows associated with flaring active regions and their surface magnetic flux and current helicity. The near-surface horizontal flows were used to compute the fluid dynamics descriptors like vertical divergence, vorticity and kinetic helicity used in this work. The flaring active regions were observed to have large values of vertical vorticity and kinetic helicity. We observe that the integrated values of the flow and magnetic parameters observed one day prior to the flare are significantly correlated with the integrated flare intensity of the active region.

Using solar oscillation frequencies from GONG, Michelson Doppler Imager, and Helioseismic and Magnetic Imager, Dr. Jain and collaborators investigated the solar cycle dependence on the presence and periodicity of the Quasi-Biennial Oscillation (QBO). The analyses were performed using Empirical Mode Decomposition Fast Fourier Transform and the Morlet wavelet analysis. We find that the presence of the QBO was not sensitive to the depth to which the p-mode travelled, nor the average frequency of the p-mode. The analysis further suggested that the magnetic field responsible for producing the QBO in frequency shifts of p-modes is anchored above approximately 0.95 $R_\odot$.

Future Research Plans

Dr. Jain will continue to work on improving the quality of farside seismic maps and their prediction capabilities. She will supervise a postdoc and a data center scientific programmer in the development of artificial intelligence/machine learning tools for enhancing the signal-to-noise ratio in these maps. She will also develop automated methods for checking the quality of Dopplergrams and other observables which are crucial inputs for NISP/GONG scientific data products.

With the availability of helioseismic observations for more than two solar cycles, Dr. Jain will continue to study the long-term trends in acoustic modes. She will investigate the variability of solar oscillation parameters with the changing level of magnetic activity to improve the understanding of their complex relationship.

Dr. Jain will continue to work on the International Solar Rotation Project for studying the systematics in helioseismic observations, and for computing a unique internal rotation profile.

Dr. Jain is partially supported by the various NASA-funded projects where major topics being addressed are; sub-photospheric flows in active regions and their influence in solar eruptions, long-term variations in sub-surface flows and their depth dependence. She will use observations from both ground-based and space-borne instruments.

Service

Dr. Jain continues to serve as a member of the NSO Scientific Personnel Committee (SPC) and NSO Diversity and Inclusion (D&I) working group, and the lead scientist of NSO/NISP Farside Project. In addition, she manages the regular monthly meetings of the International Solar Rotation Project.

She works extensively on improving the farside seismic mapping of the Sun by developing new tools/procedures for GONG observations. She regularly monitors and validates the quality GONG helioseismology data products and provides inputs to the data center team. In particular, she has been a scientist support for the GONG position-angle determination pipeline and renders expertise whenever needed. She contributes to the testing of new GONG cameras for helioseismic studies.

She was the principal author on a White paper emphasizing the importance of farside seismic mapping in space weather forecasting and participated in writing several other White Papers submitted to the National Academies. She also co-mentored REU students.

She edited a topical issue of Frontiers of Astronomy and Space Sciences – Stellar and Solar Physics entitled “Connecting Solar Flows and Fields to Understand Solar Magnetism” and serves as a Review Editor for the same journal.

Maria Kazachenko, Assistant Astronomer

Areas of Interest

Inversion techniques to derive the electric fields and Poynting fluxes on the surface of the Sun using magnetic field measurements; data-driven simulations of the solar coronal magnetic fields; statistical properties of solar flares.

Recent Research Results

In 2020, Dr. Kazachenko continued working on the “Areas-of-Interest” topics as detailed below. Dr. Kazachenko has been collaborating with Dr. George Fisher and the members of the Coronal Global Evolutionary Model (CGEM) on the details of the electric-field inversions on the staggered grid; the results of this work have been published in Hoeksema et al. 2020 and Fisher et al. 2020. Together with her student Dennis Tilipman and Dr. Valentin Martinez-Pillet, Dr. Kazachenko has been working on developing tools to analyze the quiet-Sun magnetic field properties using high temporal and spatial resolution IMaX observations. Together with the Hale postdoctoral fellow, Benoit Tremblay, Maria has been working on Inferring Depth-dependent Plasma Motions from Surface Observations using Deep Learning DeepVel — the results of this work have been presented at the AGU meeting in CA and published in the Space Reviews. Together with a DKIST ambassador Andrei Afanasev, Dr. Kazachenko has tested PDFI electric field inversion software using Yuhong’s Fan flux emergence simulations – the results of this work have been presented at the AGU and will be submitted to the Astrophysical Journal early next year. Together with Dr. Benjamin Lynch, Dr. Kazachenko has worked on analyzing the properties of the filament eruption using observations and the MHD simulations – the results of this study will be submitted to the Astrophysical Journal early next year. Together with Hugh Hudson, Dr. Kazachenko has published a first-author paper on using EVE/SDO observation to derive properties of active-region irradiance; the results of this work have been featured on the AAS Nova website. Together with an undergraduate student, Vincent Ledvina, Maria has studied analysis of the small-scale flux emergence and cancellation using SST observations – the results of this work have been presented at the AAS meeting and will be submitted to the Astrophysical Journal. Together with Dr. Criscouli and Dr. Rempel, Dr. Kazachenko has written two white papers on modeling the solar magnetic fields in solar corona. In 2020 Dr. Kazachenko submitted 5 proposals: one to Packard Fellowship as a PI, one to a Ford Fellowship (as a Co-I), one to NASA (as a Co-I, step 1) and two proposal to an ISSI workshop (as a Co-I): two ISSI proposals have been selected, we are still waiting to hear the other results. Together with her postdocs and students, Dr. Kazachenko submitted 6 observational proposals to DKIST as a Co-I: we are still waiting to hear the results.

Service

In 2020, Dr. Kazachenko continued to serve as a member of the Solar Physics Division Committee and a Chair of the Metcalf Travel Award Committee. As a result of the fundraising campaign, Dr. Kazachenko together with Prof. Richard Canfield, raised 100K from the SPD and the Metcalf family to establish the Metcalf travel award fund in perpetuity. Maria also continued to serve as a member the Daniel K. Inouye Solar Telescope (DKIST) Science Working group; Rast et al. 2020 paper has been submitted to the Solar Physics as a result of this work. Together with Dr. Georgios Chintzoglou, Dr. Kazachenko has written a proposal to organize an international Data-driving session at the next COSPAR meeting in Athens, Greece. In 2020 Maria mentored three graduate students (Marcel Corchado, Dennis Tilipman, Cole Tamburri) and two postdoctoral fellows (Benoit Tremblay and Andrei Afanasev). She also continued to serve as a referee for scientific journals (Astrophysical Journal, Nature Communications) and NASA and NSF funding proposals

*Shukirjon S. Kholikov, Scientist

Areas of Interest
Helioseismology; data analysis techniques; time-distance methods.

Recent Research Results
Shukur Kholikov works primarily on time-distance applications using GONG++ data. He has developed a time-distance pipeline, which provides travel-time maps of daily GONG-network data and produces reconstructed images with specified filters. At present, the pipeline has been tested to produce several types of specific travel-time measurements to probe the deep layers of the Sun.

The main focus of the pipeline is deep meridional flow measurements. Meridional flow measurements were obtained by using GONG/MDI/HMI spherical harmonic (SH) time series for using travel-time differences from velocity images reconstructed from SH coefficients after applying phase-velocity and low-L-filters. This particular approach is the key tool for extending the local time distance applications to the deep convection zone diagnostic analysis. The depth profile of meridional flow obtained using the above described pipeline shows a distinct and significant change in the nature of the time differences at the bottom of the convection zone. Travel-time measurements are affected by center-to-limb (CTL) variations across the solar disk. Corrections of this artifact on meridional flow measurements revealed an evidence of return flow at ~60 Mm depth of the solar interior. Using several years of GONG data, detailed meridional flow profiles of both poleward and equatorward components were obtained. Initial inversions of measured meridional travel-time differences showed single-cell structure of the meridional flow in both depth and latitude. Recently, new inversions based on spherical Born kernels including lower thresholds for singular value decomposition were applied to the same dataset. In this case, refined results exhibit a multi-cell structure in depth. It should be noted that the magnitude of the meridional flow, circulation profile and its topology strongly depend on CTL—in particular, return component of flow is not possible to measure without an understanding of CTL origin and removing this artifact from measured time differences. Kholikov is working on new ways of obtaining and removing CTL systematics and explaining its nature.

At present, Dr. Kholikov is working on comparative analysis of the deep meridional flow between HMI, MDI and GONG projects. Preliminary results from these measurements show a new detail of depth latitude profile of the meridional flow.

Another important research focus of Kholikov's is a new estimation of solar-core rotation. Based on multi-skip time-distance approach, acoustic time shifts due to internal solar rotation can be measured up to R=0.05, while rotation profile from global helioseismic inversions provide acceptable results only up to R=0.3. This project requires involving low-degree acoustic modes into multi-skip time-distance and using as many portions as possible of the solar disk from all available observations (GONG, MDI, HMI).

Future Research Plans
Dr. Kholikov will continue to improve the time-distance pipeline and provide the scientific community with specific GONG/HMI data for local helioseismology analysis. The main focus will be the deep equatorward return-flow measurements and its temporal variations involving GONG, MDI and HMI data series. He will incorporate HMI time series with extended solar disk usage to produce a new set of measurements of solar-core rotation.

Service
Dr. Kholikov will monitor the quality of available local helioseismic data products provided by NISP. He also provides time-distance measurements and high-degree SH time series of GONG data upon request.

Rudolf W. Komm, Scientist

Areas of Interest
Helioseismology; dynamics of the solar convection zone; solar activity and variability.

Recent Research Results

Dr. Komm continues to perform research in helioseismology. He is deriving solar sub-surface fluid dynamics descriptors from GONG data analyzed with a ring-diagram. Using these descriptors, he was able to derive, for example, the divergence and vorticity of solar sub-surface flows and study their relationship with magnetic activity. Komm is exploring the relationship between the twist of subsurface flows and the flare production of active regions and, in collaboration with S. Gosain, he started exploring the relationship between flare-activity, helicity, and lifetime of long-lived activity complexes. Komm is studying the solar-cycle variation of the zonal and the meridional flow in the near-surface layers of the solar convection zone, in collaboration with F. Hill, and R. Howe. He has focused on the variation of the flows during solar Cycles 23 and 244.

Future Research Plans

Dr. Komm will continue to explore the dynamics of near-surface layers and the interaction between magnetic flux and flows derived from ring-diagram data, and will focus on the relationship between subsurface flow characteristics and flare activity in active regions and long-lived activity complexes. He will continue to explore the long-term variation of subsurface flows, focusing on the differences between regions of high and low magnetic activity and, in collaboration with M. Dikpati (HAO). explore the influence of the meridional flow on dynamo models.

Service

R. Komm has improved a correction for systematic effects present in subsurface flow data and is working on turning the corrected subsurface flows into a data product. He also works on creating a data product from the measured helicity of the corrected subsurface flows. He works on creating daily and synoptic maps of these corrected fluid-dynamics descriptors.

Adam Kowalski, Assistant Astronomer

Areas of Interest

Flare observations and radiative-hydrodynamic modeling; white-light flare radiation and continuum properties; connection between magnetic activity and flares on the Sun and younger M dwarf stars; models of broadening in hydrogen emission lines that will be observed by the DKIST during flares; teaching the physics of stellar atmosphere modeling and observational astronomy and spectroscopic analysis; multi-wavelength observations of solar and M dwarf flares. Dr. Kowalski is also a recipient of the 2022 American Astronomical Society/Solar Physics Division Karen Harvey Prize.

Future Research Plans

Dr. Kowalski lead an article accepted for publication in ApJ (The Atmospheric Response to High Nonthermal Electron Beam Fluxes in Solar Flares. II. Hydrogen Broadening Predictions for Solar Flare Observations with the Daniel K. Inouye Solar Telescope; https://arxiv.org/abs/2201.13349) reporting on the updated hydrogen broadening in RADYN, in preparation for DKIST/ViSP observations of solar flares. He is also leading a paper that presents on unprecedented broadband colors in the largest flare observed in the AU Mic flare campaign. He is finishing a review article on “Stellar Flares” to be published in the “Living Reviews in Solar Physics” in the first half of 2022. Other projects that are nearly finished are on the following topics: a large grid of radiative hydrodynamic flare atmospheres for the interpretation of M dwarf optical observations, a study of the high-cadence ROSA/DST data of a C9.7 solar flare, and a study of the effects of stellar flare neutrons on exoplanet habitability.

Service

Dr. Kowalski’s service to the National Solar Observatory consists of frequently interacting with and mentoring undergraduate students, graduate students, and postdocs. He is a member of the DKIST experiment generation team. He is PI of a grade-A DKIST proposal, which is being turned into a PhD thesis for a student. He hosts workshops and seminars on solar physics topics, he works on advancing the science capabilities of the Dunn Solar Telescope, and he enhances synergies and collaborative efforts between NSO and the APS department at CU.

Maxim Kramar, Associate Scientist

Areas of Interest

Dr. Kramar's primary research interest is the physics of the solar corona. Particularly, developing techniques for the inferring coronal plasma properties such as density, temperature, and magnetic field and its application to study various coronal phenomena such as Coronal Mass Ejections (CME), solar wind, space weather.

Recent Research Results

Dr. Kramar developed the tomographic inversion tool for the DKIST/CryoNIRSP, DKIST/DLNIRSP, mxCSM, and UCoMP data for the 3D reconstruction of the coronal magnetic field. He conducted an error analysis assessment of the developed inversion tool using the Predictive Science (PSI) coronal magnetohydrodynamical model (MHD) as a Ground Truth (GT) model. It is concluded that the combined use of the linear polarization (LP) data from mxCSM or UCoMP and circular polarization (CP) data from DKIST/CryoNIRSP will allow us to calculate the 3D coronal vector magnetic field with better accuracy than the potential field model.

Future Research Plans

Process the obtained during Cycle-2 DKIST/CryoNIRSP data suitable for the inversion. Then, apply the vector tomographic inversion to this data in order to obtain 3D coronal vector magnetic field.

Service

Dr. Kramar also works as a Resident Scientist during the DKIST observations and prepare experiments for observations.

David Kuridze, Assistant Astronomer

Areas of Interest

Plasma diagnostics in the solar atmosphere; high-resolution spectroscopy and spectropolarimetry; chromospheric and coronal magnetic field measurements; chromospheric fine-structures and flares.

Recent Research Results

Author of 38 refereed papers, 51 NASA/ADS entries, 886 citations, H-index 16.

Before joining NSO as an **Assistant Astronomer in 2023**, Dr. David Kuridze was "F-CHROMA Flare Chromospheres: Observations, Models and Archives" (project funded by the European Commission under Framework 7) Post-doctoral Fellow at Queens University Belfast (UK).

In 2017, he joined Aberystwyth University (UK) as a Ser Cymru (ERDF; European Regional Development Fund) research fellow and lecturer.

He has extensive experience with the planning and analysis of ground-based spectropolarimetric observations and the plasma diagnostics in the solar atmosphere.

Future Research Plans

His future focus is to perform international-quality research by analyzing the data from the DKIST and participate in the DKIST science operations.

Service

Dr. David Kuridze is an assistant astronomer of the National Solar Observatory. He is a resident observer of DKIST and participating in DKIST science operations. In 2018, he became a member of proposal review panel for NASA's Heliophysics Supporting Research solicitation program. He is a member of science review committee of DKIST proposals. Dr. David Kuridze has been the PhD supervisor of two postdoctoral scientists in Aberystwyth University.

He is an external examiner for the PhD defense in 2023, University of Glasgow, UK.

Gordon J. D. Petrie, Scientist

Areas of Interest

Solar magnetic fields.

Recent Research Results

Petrie continued developing the SOPHISM magnetograph instrument simulator for application to the Solar Dynamics Observatory's Helioseismic and Magnetic Imager (SDO/HMI), mainly with Valentin Martinez Pillet and Han Uitenbroek (NSO) and members of the HMI team including Phil Scherrer (Stanford U). This simulator is fed with synthesized spectra for the Stokes parameters I and V, which are calculated from an MHD simulation using Han Uitenbroek's RH radiative transfer code. Comparisons between SOPHISM-simulated and real HMI spectra, and between RH-simulated and FTS spectra were successful. A crucial step was refining the derivation and application of contribution functions, which can be derived by RH as a byproduct of the radiative transfer calculation, telling us line formation heights, enabling a meaningful comparison between the instrument simulator results and ground-truth information from the MHD data cube. An error in the calculation for the ray path length was corrected, which improved the results, and gave better correlation between ground-truth and modeled magnetograms especially for large viewing angles, and more regular calibration curves.

Petrie published two peer-reviewed articles, 'Solar Polar Magnetic Fields: Comparing Full-disk and High-resolution Spectromagnetograph Data', 2022, ApJ, 941, 142, and 'Polar Photospheric Magnetic Field Evolution and Global Flux Transport', 2023, SoPh, 298, 43. The former presented synoptic maps of the north and south polar fields assembled from full-disk line-of-sight SOLIS/VSM images and full-vector polar magnetograms from Hinode/SOT/SP, covering 35-day windows centered around the optimal observing data from our Earthward direction each year (March 6 for the south, September 8 for the north). Petrie also derived line-of-sight magnetograms from SP circular polarization data and repeated the calculation for a more direct comparison. The SP vector data recorded less magnetic flux than the VSM line-of-sight data with radial field assumption applied, and these line-of-sight SP data recorded most polar flux of the three sets, apparently more consistent with in situ interplanetary field measurements. These results point to a problem in detecting transverse fields with the SP instrument or with the Stokes inversion codes used. Further work on this problem with full-vector magnetograms from the much larger DKIST telescope and its more sensitive instruments is essential. The second analyzed time-latitude 'butterfly' flux patterns using an application of Stokes theorem to the magnetic flux data, enabling the latitudinal flux transport rate to be estimated at all times and latitudes and, together with the supergranular diffusion rate, giving a description of latitudinal flux transport contributions based directly on observational data, over 40 years of KPVT and SOLIS line-of-sight magnetograms (1974-2017), with particular attention to the polar magnetic flux changes and their responses to activity. These calculations associated the largest polar magnetic flux changes to the maximum activity phases, which occur relatively early during the solar cycle and relatively distant from the equator. Major active regions emerging near the equator often feature prominently in flux-transport models' polar field changes, but cycle maxima were found here to have much greater effect on the polar fields.

To meet the above urgent need for DKIST polar data and to prepare for a possible DKIST polar synoptic program, Petrie submitted an observing proposal for the DKIST 2nd commissioning phase proposal call: 'High-Resolution Observations of the Sun's Polar Fields'. Observations were performed recently, and Petrie has been preparing by experimenting with the SIR Stokes inversion code on Hinode SP Stokes data cubes.

Petrie has been preparing for a DKIST coronal magnetometry synoptic program by submitting an observing proposal 'Coronal Magnetic Field Observations in Support of PSP and Solar Orbiter', for which Cryo-NIRSP observations were recently performed. In preparation, Petrie has been studying the pyCELP coronal Stokes synthesis code of Tom Schad (NSO), which models Stokes profiles using MHD data cubes for direct comparison with Cryo-NIRSP full-Stokes polarization data.

Service

Petrie has participated in regular meetings with NISP colleagues on the status of the GONG zero-point correction pipeline as it faces the cycle 25 activity maximum and the approaching polar reversal. Petrie presents regular status updates to the GONG zero-point group based on a selection of data products, and he suggests and helps to develop improvements to the pipeline. These GONG magnetograms are heavily used by space weather scientists at NASA, NOAA, AFRL and elsewhere. Besides regularly testing the zero-point correction, Petrie developed and applied polar field correction methods for different types of synoptic magnetogram produced by NSO. Petrie also supplied ideas and a time-latitude 'butterfly' plot for the recent blog by Alexei Pevtsov on this impending cycle 25 polar reversal that we are observing with GONG.

Petrie submitted two white papers for the Decadal Survey for Solar and Space Physics (Heliophysics) 2024-2033: 'Improving Solar Polar Field Observations from the Ground', emphasizing the need for a large telescope to detect weak polar field contributions, and 'Improving Global Solar Magnetic Field Maps: Why Multiple Low- and High-latitude Vantage Points are Necessary', quantifying the game-changing benefits of assembling full-surface synoptic maps with observational coverage from polar vantage points and/or full coverage from the ecliptic plane.

Petrie has provided NSO data user support on accessing and applying NSO magnetograms for various users including AFRL, NASA/CCMC, NOAA/SWPC, Predictive Science, U. Michigan, as well as users outside the US. Petrie refereed manuscripts for journals including the ApJ and SoPh.

Alexei A. Pevtsov, Astronomer

Areas of Interest

Solar magnetic fields, corona, sunspots, chromosphere, solar-stellar research, space weather and space climate.

Recent Research Results

A. Pevtsov worked on several projects aimed at (1) representing the solar activity using historical and modern data, and (2) new initiatives in synoptic long-term observations for space weather. He and his colleagues used the observations of Doppler velocities to study early filament rise in association with coronal mass ejections (CMEs). It has been demonstrated that the observations can be used to detect precursors of filament eruptions with an advance of several hours and to estimate the initial acceleration of CMEs. Our limited case study also suggests that while detecting an early filament rise may serve as an indicator of a possible eruption, the filament ascent alone is not a definite sign of a CME. In a separate study A. Pevtsov and his colleagues successfully reconstructed the photospheric magnetic field from 1915 to 1985. The number and total magnetic flux of the reconstructed active regions shows a realistic cyclic behavior that mostly follows the evolution of the sunspot number, even on relatively short timescales. The polar field strengths of cycles 19 and 20 do not reflect the evolution of the sunspot number very accurately, which may be related to problems related to the calcium data during cycle 19 and the long data gap during cycle 20. The polarity of polar fields and the amount of open field both at high and low latitudes all demonstrate the expected cyclic behavior. Reconstructed magnetograms were used to model magnetic fields in the corona for solar eclipses in 1922 and 1923. The agreement of the modeled coronal structure with eclipse drawings in 1922 and 1923 is found to be fair.

The performance of the Alfvén Wave Solar atmosphere Model was investigated with near-real-time (NRT) synoptic maps of the photospheric vector magnetic field. These maps, produced by assimilating data from the Helioseismic Magnetic Imager (HMI) on board the Solar Dynamics Observatory, use a different method developed at the National Solar Observatory (NSO) to provide a near contemporaneous source of data to drive numerical models. We apply these NSO-HMI-NRT maps to simulate three full Carrington rotations: 2107.69 (centered on the 2011 March 7 20:12 CME event), 2123.5 (centered on 2012 May 11), and 2219.12 (centered on the 2019 July 2 solar eclipse), which together cover various activity levels for solar cycle 24. We show the simulation results, which reproduce both extreme ultraviolet emission from the low corona while simultaneously matching in situ observations at 1 au as well as quantify the total unsigned open magnetic flux from these maps.

Future Research Plans

Dr. Pevtsov will continue his research on evolution of magnetic fields on the Sun, studies aimed at better characterization of benefits of an instrument at Lagrange L_5 and L_4 points for space weather forecasting, and the solar-stellar research. He will continue promoting development of next generation ground-based networks for solar research and operational space weather.

Service

Dr. Pevtsov is an NSO Associate Director and the Director of NSO Integrated Synoptic Program (NISP). In FY2023, he served on the Executive Committee of NASA's Living with a Star Program Analysis Group (LPAG). He reviewed research proposals for NASA and articles for several professional publications. A. Pevtsov continued serving on the Users' Committee for HAO's Mauna Loa Solar Observatory and the Advisory Board for the Historical Archive of Sunspot Observations (HASO) at the University of Extremadura (Spain).

He is a co-chair for the International Astronomical Union (IAU) Inter-Division B-E Working Group on Coordination of Synoptic Observations of the Sun. He is a member of the Editorial Advisory Board for the *Open Astronomy* journal and the Editorial Board for the *Bulletin of Crimean Astrophysical Observatory*. Dr. Pevtsov also leads the ISSI International Team on Reconstructing Solar and Heliospheric Magnetic Field Evolution over the Past Century and the working group on Promoting international collaboration in multi-vantage observations of the Sun, with a special focus on unique scientific advantages of L_4+L_5 combined observations under auspices of the International Living with a Star Program. He is a co-moderator for S1 cluster and the lead for one action team for COSPAR ISWAT - International Space Weather Action Teams initiative.

Valentín Martínez Pillet, NSO Director

Areas of Interest

Solar activity; Sun-heliosphere connectivity; magnetic field measurements; spectroscopy; polarimetry; astronomical instrumentation.

Recent Research Results

Author of 135 refereed papers, 283 NASA/ADS entries, 6458 citations, H-index 46.

Before joining NSO as Director, Dr. Martínez Pillet was leading the Imaging Magnetograph eXperiment (IMaX) for the balloon borne SUNRISE solar telescope (a Germany, Spain and USA collaboration). IMaX/SUNRISE has flown twice from the Arctic circle within the Long-Duration Balloon program of NASA (June 2009 and June 2013). The data obtained during the first flight has produced the most accurate description of the quiet Sun magnetic fields, reaching unprecedented resolution of 100 km at the solar surface and a sensitivity of a few Gauss. These data have produced well over 80 papers in the last few years, describing a large variety of processes including the discovery of small-scale supersonic magnetized flows. These jets have been recently identified in the *Hinode* satellite data that provide full Stokes spectral profiles and allow for a detailed study of the atmospheric context in which they are generated.

Dr. Martinez Pillet was also leading (as co-Principal Investigator) the design and construction of the Polarimetric and Helioseismic Imager for the Solar Orbiter mission (a Germany, Spain and France collaboration).

Future Research Plans

As Director, Dr. Martinez Pillet has overall responsibility for the operation of NSO, to maintain and rejuvenate the NSO synoptic program, and prepare for observatory operations at the new NSO directorate site in Boulder, Colorado. Dr. Martinez Pillet plans to be involved in the analysis of the data from the Sunspot/DST taken as part of the synoptic filament observations program led by NMSU.

Service

Dr. Martinez Pillet is Director of the National Solar Observatory. In the past, he has provided services for a variety of international institutions, including: member of the High Altitude Observatory Science Advisory Board; member of the DKIST Science Working Group; member of the European Space Agency Solar System Working Group; former President of the International Astronomical Union Commission 12 on Solar Radiation and Structure; former President of the International Astronomical Union Division II The Sun and the Heliosphere; and member of the Editorial Board of the journal *Solar Physics*. In 2014, Dr. Martinez Pillet became a member of the Kiepenheuer Institut für Sonnenphysik (Freiburg, Germany) scientific advisory committee. KIS is a partner on DKIST contributing with a first-light instrument.

Dr. Martinez Pillet has been the PhD advisor of three students at the IAC (Tenerife) and supervisor of three postdoctoral scientists from various international institutions.

Kevin Reardon, Scientist

Areas of Interest

Dynamics and structure of the solar photosphere, chromosphere, and corona; implementation of modern techniques for data calibration, analysis, and discovery; application of imaging spectroscopy techniques; post-focus instrumentation development; spectropolarimetry of the solar atmosphere; transit studies of inner planets; public outreach and student training; history of solar astronomy.

Recent Research Results

K. Reardon has continued studies of the small-scale dynamics of the solar atmosphere, as well as exploring new approaches and tools for analyzing ground-based solar data. He has provided scientific input on to the DKIST Data Center and the NSO Community Science Program.

Reardon is collaborating with several graduate students at CU and beyond to perform research on a variety of topics. He is working with Johnathan Stauffer on observations of the carbon monoxide lines obtained with the CYRA instrument at Big Bear Solar Observatory and interferometric imaging of the millimeter continuum with ALMA, with the goal of understanding the intermittent appearance of cool plasma in the upper photosphere. He continues to work with Ryan Hofmann on understanding the local heating produced by the passage of acoustic waves in the chromosphere by comparing time series of brightness temperatures in the millimeter with velocities derived from the Ca II 8542 Å spectral line obtained with IBIS. He published a paper with Oana Vesa from New Mexico State University (NMSU) about the detailed phase and power of oscillations, in particular gravity waves, in the solar photosphere and chromosphere. He began working with Leah Zuckerman (CU) and Benoit Tremblay (HAO) on applying machine learning techniques to the classification of granulation and other structures in images of the quiet-Sun photosphere obtained with DKIST. He also collaborated with another CU student, James Crowley, as well as Ivan Milic (KIS) and Gianna Cauzzi (NSO) on a synoptic study of the temperature gradient in the solar photosphere based on Hinode spacecraft measurements.

He also collaborated with João da Silva Santos (NSO) to process and analyze some of the first publicly released DKIST data from the ViSP and VBI instruments. After they developed techniques to accurately coalign and calibrate the data, they were able to gain new insights from the direct measurements of the magnetic fields in the solar chromosphere. He performed additional studies employing comparisons between ALMA and IBIS data with Momchil Molnar (HAO), Lucas Tarr (NSO), and others.

As part of a multi-messenger science grant from the NSF, Reardon also designed, prepared, and carried out an experiment to measure the temperature of the electron corona at the total solar eclipse on 20 April, 2023. He led an expedition to Exmouth, Australia, together with CU graduate student Sarah Bruce and NSO scientists Sanjay Gosain and John Williams. They successfully observed the 52 seconds of totality and are currently analyzing the data that were obtained.

Future Research Plans

Reardon will continue to work with graduate students, Ryan Hofmann (CU), Johnathan Stauffer (CU), Sarah Bruce (CU), Leah Zuckerman (CU), James Crowley (CU), and Oana Vesa (NMSU), as well as João da Silva Santos, Mark Rast, Lucas Tarr, Lucia Kleint, and others to analyze the rich data sets from DKIST, ALMA, IBIS, CYRA, and other instruments in order to better understand the heating and dynamics of the solar chromosphere on the smallest scales.

He is part of an HSO Connect project led by Haimin Wang (NJIT), and a member of the Parker Solar Probe (PSP) Science Team, through which he will coordinate community science goals for DKIST observations related to multi-messenger investigations of the connections between the solar atmosphere and the solar wind. He will further develop the eclipse experiments to be carried out at the total solar eclipse of 08 April, 2024, with observations planned to be carried out from Mazatlàn, Mexico. He will also collaborate with the Continental-America Telescopic Eclipse (CATE) team in planning and analyzing polarization-sensitive observations from multiple sites during that same eclipse.

Service

Reardon continues to support the DKIST team during the operations commissioning phase (OCP), including the generation of observational experiment definitions for execution at the telescope and serving as a Resident Scientist. He worked with members of the solar community to encourage and contribute to numerous observing proposals for DKIST. Using some of the early observations from DKIST, he began testing techniques for destretching, atmospheric dispersion correction, image quality metrics, and data mosaicking, which are valuable for the scientific usage of the data. These methods are being developed into a toolkit, which solar scientists can use to make the DKIST data better amenable to scientific analysis of the calibrated DKIST data.

Reardon will continue working on the application of new methods for processing the challenging volumes of data to be obtained with the DKIST. This includes techniques for calibrating, compressing, and classifying the contents of those data. He will help develop standardized methods to process and calibrate the Level 1 data to make them suitable for spectral inversion as part of the NCSP program. He will help define data formats for sharing and delivering these Level-2 data products.

He will contribute to educating and engaging the community through DKIST and NCSP Data Training workshops (and other community interaction opportunities), helping potential DKIST users understand how to employ the facility capabilities in service of their science goals.

Reardon will continue to mentor students and engage them in the field of solar physics, while promoting a welcoming environment for all that promotes diversity and equity. He serves as a liaison with the APS department to support recruitment and retention of new students engaged in solar science.

Reardon will continue to serve as a member of the SunPy board, supporting the development of SunPy and other open source software packages needed by the solar community. Reardon also served on several community eclipse committees and on NASA's Study Analysis Group on exoplanet detection using transmission spectroscopy.

Reardon continues to provide content to and to participate in NSO's public outreach efforts, especially as related to eclipses.

Thomas R. Rimmele, Astronomer

Areas of Interest

Sunspots; small-scale magnetic surface fields; active region dynamics; flares; acoustics waves; weak fields; adaptive optics; multi-conjugate adaptive optics; instrumentation.

Recent Research Results

As DKIST Associate Director with responsibility for the construction of the $344M DKIST as well as the ramp up to full operations of DKIST in 2019, Dr. Rimmele's time is fully committed to the extensive management, organizational and service tasks. Rimmele, however, maintains a strong interest in the development of AO technology.

Future Research Plans

T. Rimmele hopes to continue his efforts to perform observations at the highest spatial resolution in order to study the properties and the dynamics of small-scale magnetic elements. He will continue to develop multi-conjugate adaptive optics for implementation at DKIST. He plans to participate in the DKIST first-light observations with the primary objective of verifying the DKIST facility and instrumentation for science use on behalf of the community. He plans to actively engage in the execution of a number of Critical Science Plan experiments during early operations of DKIST. He will continue to improve the understanding of structure and dynamics of sunspots and test existing MHD models.

Service

Rimmele is NSO Associate Director for the DKIST. He mentors students and postdocs, supervises key NSO staff members and works closely with the DKIST Science Working Group and its chair. He guides the NSO multi-conjugate adaptive optics development effort. He continues to serve as referee of a number of papers submitted to astrophysical and technical journals.

Thomas A. Schad, Associate Astronomer with Tenure

Areas of Interest

Spectropolarimetry diagnostics of magnetic fields and their relation to the chromospheric and coronal heating problem; infrared instrumentation, including DKIST facility instrument development and operations; student engagement and community outreach.

Recent Research Results

Dr. Schad's recent work in FY 2023 has focused on early science with DKIST. He contributed as a co-author to a number of published papers, including DKIST instrument overview papers for Cryo-NIRSP (Fehlmann et al., 2023, Solar Physics, 298 5), DL-NIRSP (Jaeggli et al. 2022, Solar Physics, V297, 137), and Polarization Systems (Harrington et al., 2023, Solar Physics, 298, 10). The first scientific publication using DKIST/Cryo-NIRSP data was published by Dr. Schad entitled "First Infrared Coronal Spectra from DKIST/Cryo-NIRSP: Comparisons with Global MHD Models" (Schad et al. ApJ, 943, 59S). This work reported new measurements of all key coronal emission lines targeted by Cryo-NIRSP from 1 to 4 microns, and further compared them photometrically to global MHD models to develop these diagnostics as constraining tools for modeling efforts. Dr. Schad further published results with a group of Northumbria University scientists quantifying coronal rain production over solar active regions (Sahin et al., 2023, ApJ, 950, 171). Dr. Schad also contributed to an article discussing coronal diagnostics in the context of the Decadal Survey for Solar and Space Physics (Heliophysics) 2024-2033, as published in Landi et al., 2022, Frontiers in Astronomy and Space Sciences, 9, 355. Dr. Schad's work extended to efforts to improve the data calibration approaches for the ViSP instrument, through which he became involved in a number of science efforts. He is a co-author on the first DKIST science articles by da Silva Santos et al. (2023, ApJ, 954L, 35), Campbell et al. (ApJL, in press), and Judge et al. (under review).

Future Research Plans

As DKIST early science operations continue, Dr. Schad is involved in a large number of proposing collaborations aimed at novel chromospheric and coronal observations using DKIST. He was involved in 12 proposed programs during DKIST Cycle 1, and an additional 9 proposed programs in Cycle 2. These efforts include deep investigations of near-limb spicule magnetic fields and their connectivity to the mass and energy flow of the corona, the formation of carbon monoxide in the lower chromosphere and its role in chromospheric dynamics, as was as cool and hot coronal polarimetry; however, each study is in different phases of maturity and execution. Dr. Schad's near-future plans focus on coronal magnetic field studies using the Cryo-NIRSP instrument.

Service

Schad is an active member of the DKIST Science Group, supports the facility instrument operation and calibration efforts, and provides support to the polarimetric calibration and analysis team. He was appointed the chair of the Technical Review Committee in 2020 in advance of the DKIST Cycle 1 proposal call and also served as TRC chair for Cycle 2. Schad also participates in outreach to the local and national community, *e.g.*, by acting as a judge in the Maui County science fairs, giving outreach talks to students on the Nepris website, and participating in the NOIRLab’s Gemini’s Journey Through the Universe.

Dirk Schmidt, Associate Scientist

Areas of Interest

Adaptive optics, high spatio-temporal resolution observation techniques; development of adaptive optics systems, in particular multi-conjugate adaptive optics systems.

Recent Research Results, Future Research Plans & Service

Schmidt leads the multi-conjugate adaptive optics upgrade for DKIST.
Schmidt collaborates with the New Jersey Institute of Technology Big Bear Solar Observatory and leads the development of the Goode Solar Telescope multi-conjugate adaptive optics system ”Clear″, which is the experimental pathfinder for the DKIST system, as well as the development of adaptive optics for use with solar prominences.

Lucas Tarr, Assistant Astronomer

Areas of Interest

Observational, theoretical, and numerical investigations of the low solar atmosphere, with a focus on active region evolution. Primary focus is now on the development of 3D MHD data driven simulations; student and postdoc mentorship, and community outreach.

Recent Research Results

Dr. Tarr has continued his work in several disparate aspects of solar physics. His major recent accomplishment is the analytic development, numerical implementation, and initial validation of a novel method for data driven boundary conditions for 3D magnetohydrodynamic simulations. The method guarantees that a driven simulation's boundary evolution is strictly consistent with the MHD equations and maximally consistent with observational data. The method directly handles the noise, bias, and missing data that occur in any observational data set. A paper describing the method (Tarr et al 2023) was recently submitted to the Astrophysical Journal and is currently under review. An immediate follow-up paper (Kee et al 2023), which applies the same methodology to the problem of arbitrary open boundary conditions, will be submitted in the near future. Both papers include NSO postdoc N. Dylan Kee and Tarr's collaborators at NRL (Mark Linton) and NASA-Goddard (Pete Schuck, James Leake) as coauthors. Dr Tarr is working with colleagues at Newcastle, Australia (David. Pontin, Abbas Raboonik) to extend the same methodology to analyze the propagation and interaction of MHD wave modes in 3D simulations. Meanwhile, analysis of an extensive and heterogeneous set of coordinated observations between multiple ground and space-based observatories (ALMA, DST, Hinode, IRIS, and SDO) has led to two papers (Kobelski et al 2022 ApJS 261, Tarr et al 2023 FrASS 9) that trace energetic events throughout the solar atmosphere and characterize chromospheric oscillations. The project combines imaging, slit spectra, spectropolarimetric, and interferometric observations. The fully calibrated and co-aligned data was made publicly available and the whole project serves as a prototype for dealing with the heterogeneous data sets forthcoming from DKIST. This work involves colleagues at NSO (Sarah Jaeggli, Gianna Cauzzi, Kevin Reardon), NASA (Adam Kobelski, Sabrina Savage), and HAO (Momchil Molnar). Dr Tarr collaborated with NSO colleagues Sarah Jaeggli, David Harrington, and Tom Schad to develop a new ad hoc polarization calibration method (Jaeggli et al 2022 ApJ 930) which has since been applied to some of the first published research using DKIST data (da Silva Santos et al ApJ 2023 954).

Future Research Plans

Dr. Tarr is involved in several DKIST Cycle2 observing proposals aimed at exploring the magnetic field in the atmosphere above active regions, the details of delta-type sunspots, interchange reconnection and electric current systems near the solar surface, and advancing coronal magnetometry. Comparing the observations with the newly developed data driven simulations is his primary focus on the computational side (with significant overlap with the collaboration networks for the DKIST observations). This includes applying data driven simulations to study flux rope formation, stability, and eruptions in active regions, and using radiative MHD simulations and machine learning techniques to perform fast, spatially coupled inversions of spectropolarimetric data.

Service

Dr Tarr serves on the DKIST Operations Team and is involved in Technical Review, Scientific Review, Experiment Generation, and execution of experiments at the observatory as a Resident Scientist, and provides support for coordinated observations with, e.g., Parker Solar Probe and Solar Orbiter. He is engaged in community and student outreach, this year participating in Solar Fest in partnership with Haleakala National Park and the Excite Camp/STEMworks project for middle school women on Maui. He is a member of the Metcalf Travel Committee of AAS/SPD. He was the primary author on one paper for the Heliophysics Decadal Review and an active co-author on several others. He continues to review papers and proposals and serve on the organizing committees for meetings as necessary.

Sushanta C. Tripathy, Scientist

Areas of Interest

Global and local helioseismology; solar activity cycle; ring-diagram analysis, sub-surface zonal and meridional flows, Magneto-seismology of active regions; cross-spectral analysis of time series.

Recent Research Results

Helioseismic studies have illustrated that the most significant changes with the solar cycle occur in the near-surface shear layer (NSSL). Dr. Tripathy and collaborators have used a non-traditional approach to reconstruct Dopplergrams using spherical harmonic coefficients and process them through the technique of ring-diagram to measure the subsurface flows up to a depth of 30 Mm. Preliminary results computed from six years of HMI observations indicate that the subsurface flows are generally consistent with those measured from standard

HMI and Global Oscillation Network Group (GONG) ring-diagram pipelines. This work is funded by a NASA grant.

Dr. Tripathy and collaborators have derived subsurface flows from the GONG, Michelson Doppler Imager (MDI) and HMI observations covering the period of May – July 2010 to investigate how the sub-surface flows agree between different instruments. After correcting for the systematic errors and removing the offset values between the three measurements, they find that the large-scale flows are consistent with each other. This work is partially funded by NASA grants.

Recently, cross-equatorial flow has become a major research topic since in surface-flux transport models, these flows enhance the resulting polar fields. If the average magnetic activity is stronger in one hemisphere than in the other, the average cross-equatorial flow would be non-zero and will be in the direction of the hemisphere with excess flux. Dr. Tripathy and collaborators measured the cross-equatorial flow using HMI data and found that the magnitude of the flow is about 1-2 m/s just below the surface but increases with depth. Dr. Tripathy is planning to extend the measurement to a depth of about 30 Mm.

Dr. Tripathy and collaborators estimated subsurface flows in the upper 1-2 Mm using the fundamental mode since these are believed to provide better estimates of the flow near the surface. These flows were compared with those derived from the entire mode sets. The flows between the two measurements were found to be consistent just below the surface but the error estimates using only the fundamental modes were found to be slightly higher in comparison to the error estimates when all modes were used.

Dr. Tripathy and collaborators investigated the spatio-temporal evolution of high-degree acoustic mode frequencies of the Sun and surface magnetic activity over the course of multiple solar cycles, to improve our understanding of the connection between the solar interior and atmosphere. This was carried out by analyzing high-degree acoustic modes from the Global Oscillation Network Group (GONG) over a period of 22 years. Dr. Tripathy and collaborators report strong correlations between the mode frequencies and various activity indices. Dr. Tripathy and collaborators further investigated the hemispheric asymmetry associated with oscillation frequencies and magnetic activity proxies and find that both were dominant in the southern hemisphere during the descending phase of cycle 23, while in cycle 24 these quantities fluctuated between northern and southern hemispheres. This work was carried out as part of the REU project under Boulder Solar Alliance in 2022.

Dr. Tripathy and collaborators using local helioseismic technique of ring diagrams have investigated the power, energy and damping rates of local high degree solar acoustic modes covering the period 2001-2022. Using data from GONG, Dr. Tripathy and collaborators examined the variations in mode amplitude and line width with solar activity as well as the differences and similarities between different cycles since each solar cycle behaves differently. Dr. Tripathy and collaborators report a strong positive correlation between magnetic flux and mode width which is proportional to the damping rate. They also found that the mode amplitude is in anti-phase with magnetic flux, where amplitude values are found to be decreasing during periods of high magnetic flux. The study also reported a few anomalous periods of time where the amplitude values appear to be in phase with magnetic flux. Dr. Tripathy and collaborators are investigating the exact cause for this anomaly including a plausible instrumental origin. This work was carried out as part of the REU project under Boulder Solar Alliance in 2023.

Future Research Plans

Dr. Tripathy will further continue his work on subsurface flow measurements covering more than two solar cycles and investigate their variations using data from GONG, MDI, and HMI. Dr. Tripathy will also identify the flow parameters that best predict the solar cycle 25. Dr. Tripathy will continue his participation in the international collaborative project to derive a better solar rotation profile using the longest and best possible splitting coefficients and inversion technique. Dr. Tripathy and collaborators have initiated a project to study the flow signature of the emerging active regions using HMI data. Dr. Tripathy will work on various NASA funded proposals where he serves as a PI and Co-I. Dr. Tripathy will continue to provide support to the data center personnel as required.

Service

S. Tripathy serves as the science lead for the interior group and is responsible for organizing the weekly NISP interior science meeting and monthly NISP science meetings. One of the major tasks of Dr. Tripathy has been to validate and apprise the output from various data reduction pipelines, for example image quality and time series pipelines. He also continues to provide support to the data analysis team and answers queries from external users. Dr. Tripathy actively participated in the new GONG camera selection procedure by validating the observations and providing other required scientific support. Dr. Tripathy participated in writing several white papers which were submitted to Helio2024. As part of public outreach and training future scientists, Dr. Tripathy guided REU students during the summer of 2022 and 2023.

Alexandra Tritschler, Senior Scientist

Areas of Interest

Operations of large astronomical facilities; operations tools used by users and operators of such facilities; high-resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere of active regions; solar magnetic fields; fine-structure of sunspots; numerical simulations of magneto-convection in (and around) sunspots and using those as input for spectral synthesis; post-focus instrumentation.

Current and Future Research Plans

Dr. Tritschler's main interests will continue to be focused on the operations of astronomical facilities and the high-resolution aspects of the photospheric and the chromospheric atmospheric layers of solar active regions. She will continue to develop the operational modes and tools for DKIST Science Operations. As time permits, she will further use ground-based high-resolution spectroscopic and spectropolarimetric observations to determine the properties of photospheric and chromospheric layers of active regions and to infer their three-dimensional dynamic and magnetic structure and to compare those results to forward modeling.

Service

Tritschler is the DKIST's Program Scientist for Operations and as such guides the development of DKIST Science Operations. She is responsible for the planning of the DKIST Operations Commissioning Phase and the development and specification of all operations tools to be used to efficiently operate the DKIST. Tritschler has been developing the training plan for future DKIST observers in close collaboration with the Chief Science Operations Specialist and the Science Operations Manager, preparing them for the DKIST Operations Commissioning Phase. She has been mentoring numerous summer REU and SRA students over the years. Tritschler has served and continues to serve on NSO and DKIST hiring committees, and has been a reviewer of publications for *ApJL*, *ApJ*, *A&A*, *SoPh, and AN.*

Han Uitenbroek, Astronomer

Areas of Interest

Radiative transfer modeling and structure and dynamics of the solar atmosphere; modeling and measurement of polarized light; spectropolarimetric inversions under Non-LTE conditions.

Recent Research Results

Han Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code RH, as well as helping to create the Non-LTE inversion code DeSIRe. The RH code has been made available to the community from the start and is widely used by the solar community and, in some cases, even outside that(https://github.com/han-uitenbroek). It has been incorporated as the forward engine in two recently developed Non-LTE spectropolarimetric inversion codes: STiC (de la Cruz Rodriguez et al. 2019, A&A 623, A74) and the new inversion code DeSIRe, combining RH with the well-established LTE inversion code SIR of Ruiz Cobo (Ruiz Cobo et al.,2022A&A...660A..37R). RH is also extensively used as Non-LTE spectral line modeling code for RADYN simulations.

Dr. Uitenbroek has contributed to several papers investigating the diagnostic capabilities of spectropolarimetric observations and spectropolarimetric inversions, including in da Silva Santos et al, (2023ApJ...954L..35D), Grant et al (2022ApJ...938..143G), and Hoffman et al (2022ApJ...933..244H). He is involved in several ongoing efforts of analyzing and inverting new DKIST observations.

Future Research Plans

Development and maintenance of the RH code will continue. Concentration will be on the new inversion code DeSIRe.

Service

Dr. Uitenbroek is the Associate Director for the NSO Community Science Program (NCSP). He leads the effort of DKIST Level-2 definition and implementation of standard inversions, helps guide the organization of DKIST Data Training workshops, and teaches lectures in these workshops. Han chairs the NSO Scientific Personnel Committee.

Friedrich Wöger, Senior Scientist

Areas of Interest

Image reconstruction techniques; adaptive optics; two-dimensional spectroscopy and spectropolarimetry; DKIST instrument systems, in particular the visible broadband imager (VBI); DKIST wavefront correction system (WFC); DKIST data handling system (DHS).

Recent Research Results

F. Wöger studies image processing techniques related to enhancing the resolution by reducing the impact of atmospheric turbulence (e.g. image reconstruction using triple correlation), photometric calibration of images using models for atmospheric transfer functions, and denoising of images impacted by noise sources ranging from characteristic detector artifacts to photon noise. This work provides the foundation for the characterization of the photometric precision in images generated by DKIST's imaging instrumentation such as VBI and visible tunable filter (VTF).

Wöger oversees, guides and aids in the definition, construction, integration and testing of all DKIST instrumentation subsystem components.

Future Research Plans

Dr. Wöger began work on improved methods for image reconstruction for data acquired with 2D spectroscopic and spectropolarimetric instruments, such as DKIST VTF data. These algorithms will be based on speckle interferometry and allow the post-processing of data to achieve diffraction-limited spatial resolution. He is researching denoising techniques using neural networks. He continues to work on developing accurate models for atmospheric transfer functions and is interested in investigating expanding current models for use with multi-conjugate adaptive optics systems.

Service

Wöger is the DKIST instrument systems scientist, and as such, is the scientific interface between the DKIST project and the partner institutes that build instruments for DKIST. He has been involved in the DKIST VBI instrument effort as its principal investigator, overseeing its construction at NSO Boulder, and its integration and verification at the DKIST site on Maui. As the DKIST Data Handling Scientist, he has been supervising the DKIST data handling system development, ensuring the integration and verification of the system on Maui. Furthermore, Wöger has created and is responsible for the data model for DKIST that is a vital interface for the DKIST Data Center in Boulder. As the DKIST Wavefront Correction Scientist, Wöger has guided the DKIST WFC team towards successful site acceptance of the WFC subsystem at DKIST.

Wöger is supervising a calibration pipeline engineer who implements the prototype data calibration pipelines for the majority of DKIST's first light instrumentation. These pipelines are provided to the DKIST Data Center for integration into its automated system.

Wöger will guide and support the efforts for new instrumentation for DKIST; he is involved in the multi-conjugate adaptive optics program, the procurement of new optics for the facility instrument distribution optics, the upgrade with new infrared sensors and other instrumentation efforts.

Wöger is part of the Technical Review Committee for DKIST proposals and is participating in the technical feasibility review of proposals for DKIST observing time, and is involved in generating Experiments for the DKIST Observatory Control System that are executable at the DKIST site.

APPENDIX C. LIST OF DKIST ACCEPTED SCIENCE PROGRAMS

Proposal ID	Title	PI and co-PIs	PI Country
3	On the Physics of Prominence Cavities	Benjamin Boe Shadia Habbal (US), Bryan Yamashiro (US)	US
6	Helium in the off-limb corona	Vincenzo Andretta Giulio Del Zanna (UK)	IT
8	Unraveling the Interplay of Alfven Waves, Density Fluctuations, and Turbulence in the Quiet Solar Corona	Michael Hahn Daniel Savin (US), Mahboubeh Asgari-Targhi (US), Stefan Hofmeister (DE), Alexandros Koukras (BE), Xiangrong Fu (US), Aneta Wisniewska (DE)	US
9	Poynting Flux and Velocity Inversions in the Photosphere and Chromosphere of the Quiet Sun	Dennis Tilipman Benoit Tremblay (US), Maria Kazachenko (US), Ivan Milic (US), Valentín Martínez Pillet (US)	US
10	Mapping the magnetic field of small-scale structures in sunspots penumbrae	Sara Esteban Pozuelo Luis Bellot Rubio (ES), Andres Asensio Ramos (ES), Azaymi Siu (ES)	ES
11	The Origin of Extreme Broadening of the Hydrogen Emission Lines in Solar Flares.	Cole Tamburri Adam Kowalski (US), Gianna Cauzzi (US), Maria Kazachenko (US), Yuta Notsu (US), Isaiah Tristan (US), Alexandra Tritschler (US)	US
12	Probing Flare Reconnection Dynamics from High-Cadence Ribbon Observations	Ryan French Maria Kazachenko (US), Rahul Yadav (US), Marcel Corchado-Albelo (US)	US
13	Contribution to Solar Brightness of small-size magnetic elements	Serena Criscuoli Martin Snow (US), Mark Rast (US), Matthias Rempel (US), Courtney Peck (US), Alexandra Tritschler (US), Viacheslav Sadykov (US), Irina Kitiashvili (US)	US

Proposal ID	Title	PI and co-PIs	PI Country
14	Multi-height magnetic observations of a solar active region	Andrei Afanasev Maria Kazachenko (US), Rahul Yadav (US), Dennis Tilipman (US), Yuhong Fan (US), Lucas Tarr (US), Mark Linton (US), Nathaniel Dylan Kee (US)	US
16	Inferring vector magnetic fields at the base of the heliosphere using spectropolarimetric and alfvenic wave propagation techniques	Alin Paraschiv Momchil Molnarat (US), Daniela Lacatus (US)	US
17	Heating and jets in plage atmosphere	Reizaburou -Kitai Tetsu Anan (US), Kevin Reardon (US)	JP
18	Evolution of magnetic fields in flares	Lucia Kleint Jaime de la Cruz Rodriguez (SE), Xudong Sun (US), Gianna Cauzzi (US), Graham Kerr (US), Kevin Reardon (US), Matthias Rempel (US)	CH
19	Unraveling the magnetic landscape of solar coronal loops with DKIST	Lakshmi Pradeep Chitta	DE
21	The Observation and Simulation of the Magnetic Field and Plasma Properties in the Off-limb Active Region	Yingjie Zhu Enrico Landi (US), Judit Szente (US)	US
22	Thermodynamic and magnetic properties of solar filaments	Carlos José Christoph Kuckein (ES), Flavio Calvo (SE)	SE
23	Investigating the degree of magnetic field alignment of chromospheric fibrils	Thomas Schad Tetsu Anan (US), Karin Muglach (US), Jaime de la Cruz Rodriguez (SE), Andres Asensio Ramos (ES), Xudong Sun (US), María Jesús Martínez González (ES)	US
24	Unraveling plasmoid-mediated vs turbulent-induced magnetic reconnection	Carlos José Luc Rouppe van der Voort (NO), Jaime de la Cruz Rodriguez (SE), Viggo Hansteen (US)	SE

Proposal ID	Title	PI and co-PIs	PI Country
26	Strategic Advancement of DKIST Coronal Magnetometry through Data-Model Comparisons and Tomography	Thomas Schad Andre Fehlmann (US), Jeffrey Kuhn (US), Lucas Tarr (US), Gabriel Dima (US), Maxim Kramar (US), Haosheng Lin (US)	US
27	Probing Fine-Scale Magnetic and Electric Current Systems in the Low Solar Atmosphere	Xudong Sun Thomas Schad (US), Lucas Tarr (US), Sarah Jaeggli (US), Matthias Rempel (US), Jiayi Liu (US), Kai Yang (US), Peter Sadowski (US)	US
28	Zooming in on the Magnetic Fields in the Solar Polar Region	Xudong Sun Ivan Milic (US), Sarah Jaeggli (US), Bryan Yamashiro (US), Milan Gosic (US), Rebecca Centeno (US), Shah Mohammad Bahauddin (US)	US
29	Study of a Delta-Sunspot Polarity Inversion Line from the Deep Photosphere to the Upper Chromosphere	Sarah Jaeggli Xudong Sun (US), Jiayi Liu (US), Lucas Tarr (US)	US
31	Generation of small-scale turbulence and interaction with magnetic fields in the solar photosphere	Ryohtaroh Ishikawa Alfred de Wijn (US), Marc De Rosa (US), Mark Rast (US), Carlos Quintero (ES), Tino L. Riethmueller (DE), Yukio Katsukawa (JP)	JP
34	Constraining chromosphere heating of plage with DKIST observations	Jaime de la Cruz Rodriguez Jorrit Leenaarts (SE), Adur Pastor Yabarat (SE), Sanja Danilovic (SE), Rebecca Centeno (US), Matthias Rempel (US)	SE
36	Chromospheric heating through ubiquitous small-scale magnetic reconnection in the quiet-Sun	Jaime de la Cruz Rodriguez Jorrit Leenaarts (SE), Adur Pastor Yabar (SE), Sanja Danilovic (SE), Rebecca Centeno (US), Matthias Rempel (US)	SE

Proposal ID	Title	PI and co-PIs	PI Country
38	DKIST Coronal Cavity Study	Sarah Gibson Jie Zhang (US), Suman Dhakal (US), Yuhong Fan (US), Roberto Casini (US), Urszula Bąk-Stęślicka (PL), Mari Paz Miralles (US), Susanna Parenti (FR), Nour E. Raouafi (US)	US
45	Fine-scale Dynamics of Sunspot Umbrae: The Relationship Between Small-Scale Umbral Brightenings, Short Dynamic Fibrils, and Umbral Flashes	Chris Nelson Mihalis Mathioudakis (UK), Vasco M. J. Henriques (NO), Luc Rouppe van der Voort (NO), Sanjiv Tiwari (US)	NE
51	Small-Scale Chromospheric Dynamics in Quiet Sun Areas and at Boundaries of Coronal Holes	Vasyl Yurchyshyn Jeong woo Lee (US), Wenda Cao (US), Eun-Kyung Lim (KR), Nour E. Raouafi (US), Xu Yang (US), Haimin Wang (US)	US
52	Origin and role of Moving Magnetic Features in the evolution of sunspots	Francesca Zuccarello Sanjiv Tiwari (US), Hanna Strecker (ES), Serena Criscuoli (US)	IT
57	Resolving the convective collapse with DKIST	Catherine Fischer Oskar Steiner (DE), Karin Muglach (US), Luis Bellot Rubio (ES), Saida Milena Diaz Castillo (DE), Elena Khomenko (ES), Anjali John (DE), Alexandra Tritschler (US), Friedrich Wöger (US)	US
58	Understanding small-scale flaring dynamics with Cryo-NIRSP Linear Polarization	Ryan French Maria Kazachenko (US), Marcel Corchado-Albelo (US), Joel Dahlin (US)	US
59	Spectropolarimetric diagnostics of off-limb spicules from inversions of the Ca II 8542 Å line	David Kuridze Kevin Reardon (US), Rebecca Centeno (US), Ramon Oliver (ES), Gianna Cauzzi (US), Matheus Kriginsky (ES), Hector Socas-Navarro (ES)	UK

Proposal ID	Title	PI and co-PIs	PI Country
62	Revealing the picture of coronal Alfvénic waves: exploring a new frequency regime with Cryo-NIRSP	Richard Morton Hui Tian (CN), Zihao Yang (CN), Rahul Sharma (UK), Yajie Chen (CN), Steven Tomczyk (US)	UK
63	Magnetic Structure and Motions of Prominences	Shuo Wang Thomas Schad (US), Ivan Milic (US), Valentín Martínez Pillet (US), Qiang Hu (US), R. T. James McAteer (US)	US
64	Flare Signatures in the Photosphere and the Chromosphere	Rahul Yadav Maria Kazachenko (US), Gianna Cauzzi (US), Ryan French (US), Marcel Corchado-Albelo (US)	US
66	Probing the Photospheric Conditions for Spectral Line Scattering in Sr 4607	Ivan Milic Kevin Reardon (US), Rebecca Centeno (US), Ryan Hofmann (US), Franziska Zeuner (CH), Gianna Cauzzi (US)	US
67	Unveiling the Origin of Umbral Fine-Structure	Vasco M. J. Henriques Chris Nelson (NL), Sanjiv Tiwari (US), Luc Rouppe van der Voort (NO), Mihalis Mathioudakis (UK)	NO
68	Measuring Strong Coronal Magnetic Fields	Stephen White Valentín Martínez Pillet (US), Gianna Cauzzi (US), Bin Chen (US), Dale Gary (US), Timothy Bastian (US), Kevin Reardon (US)	US
69	Mini-filaments at a low-latitude coronal hole boundary	Jeongwoo Lee Hameedullah Farooki (US), Haimin Wang (US), Shuo Wang (US), Kevin Reardon (US)	US
70	Spatio-temporally resolved linear scattering polarization in the Sr I line at 4607 A: a window to the small-scale photospheric magnetism	Franziska Zeuner Roberto Casini (US)	CH

Proposal ID	Title	PI and co-PIs	PI Country
71	Observing coronal Alfvén-like waves with Cryo-NIRSP	Momchil Molnar Alin Paraschiv (US), Steven Cranmer (US), Kevin Reardon (US), Chris Gilly (US)	US
73	Coronal Magnetic Field Observations in Support of PSP and Solar Orbiter	Gordon Petrie Valentín Martínez Pillet (US), Kevin Reardon (US), Pete Riley (US), Maxim Kramar (US)	US
75	Penumbral superstrong magnetic fields	Sebastian Castellanos Duran Andreas Korpi-Lagg (DE), Alex Feller (DE), Sami Solanki (DE), Lakshmi Pradeep Chittaat (DE), Smitha Narayanamurthy (DE)	DE
76	High-Resolution Observations of the Sun's Polar Fields	Gordon Petrie Valentín Martínez Pillet (US), Alexandra Tritschler (US), Serena Criscuoli (US), Sanjay Gosain (US), Xudong Sun (US)	US
78	Towards an understanding of sources of heating in plage regions	João M. da Silva Santos Juan Martínez-Sykora (US), Bart De Pontieu (US), Thomas Schad (US), Alexander Pietrow (DE), Momchil Molnar (US)	US
80	Connection of magnetic bright points to the plasma supply in filaments	Andrea Diercke Christoph Kuckein (ES), Sergio Javier Gonzalez Manrique (ES), Catherine Fischer (US), Alexandra Tritschler (US)	US
81	Investigating Interchange Reconnection as the Origin of Switchbacks	Nathaniel Dylan Kee Valentín Martínez Pillet (US), Lucas Tarr (US), Sarah Jaeggli (US), Stuart Bale (US)	US
83	Latitudinal Variation of Faint HeI 1083 nm Coronal Emission	Gabriel Dima Andre Fehlmann (US), Jeffrey Kuhn (US), Thomas Schad (US), Isabelle Scholl (US), Ian Cunnyngham (US)	US

Proposal ID	Title	PI and co-PIs	PI Country
84	Exploring the propagation and dissipation of high-frequency waves throughout the lower solar atmosphere	Momchil Molnar Kevin Reardon (US), Steven Cranmer (US), Ivan Milic (US)	US
85	Unresolved flux removal process at magnetic flux cancellation sites: manifestation of magnetoconvective evolution	Masahito Kubo Serena Criscuoli (US), Marc De Rosa (US), Shin Toriumi (JP), Yukio Katsukawa (JP), Joten Okamoto (JP)	JP
86	New and multi-scale measurements of photospheric flows as drivers of coronal energy flux	Sam Van Kooten Steven Cranmer (US), Brian Welsch (US), Kevin Reardon (US), Johnathan Stauffer (US), James Klimchuk (US), Gianna Cauzzi (US)	US
87	The propagation and dissipation characteristics of slow magneto-acoustic waves in a sunspot umbra	Krishna Prasad Sayamanthula	BE
92	Properties of internetwork magnetic fields at 10^-4 sensitivity	Luis Bellot Rubio David Orozco (ES), Roberto Casini (US), Thomas Schad (US), Haosheng Lin (US), Azaymi Siu (ES), Valentín Martínez Pillet (US), Karin Muglach (US)	ES
94	Acoustic sources and Local Wavefield	Shah Mohammad Bahauddin Mark Rast (US), Ivan Milic (US)	US
95	Height dependence of the photospheric magnetic field as inferred from inversions	Ryan Hofmann Kevin Reardon (US)	US

APPENDIX D. NSO FY 2023 STAFFING SUMMARY

(In Full-Time Equivalents)

Table D.1. NSO FY 2023 Staffing Summary

	Director's Office			NCSP	NSO	DKIST				NISP		TOTAL
	Tucson	*Boulder*	*Maui*	*Boulder*	*Sunspot*	*Tucson*	*Sunspot*	*Maui*	*Boulder*	*Tucson*	*Boulder*	
Scientists	-	1.00	-	1.00	-	-	-	8.00	13.00	0.05	6.45	29.50
Engineering/Science Support Staff	1.00	1.00	-	-	-	-	-	31.00	26.00	3.00	7.00	69.00
Administrative Staff	-	5.00	2.00	-	1.50	-	-	4.00	1.00	-	1.00	14.50
Technical Staff	-	-	-	-	1.00	-	-	11.00	1.00	-	3.00	16.00
Maintenance & Service Staff	-	-	-	-	1.00	-	-	1.00	-	-	-	2.00
												0.00
Total Base Program	1.00	7.00	2.00	1.00	3.50	-	-	55.00	41.00	3.05	17.45	***131.00***
Other NSF Projects (AO, FTS/CHEM)	-	1.00	-	-	-	-	-	-	-	-	-	1.00
Graduate Students	-	-	-	-	-	-	-	-	-	-	-	0.00
NASA Supported Science Staff	-	-	-	-	-	-	-	-	-	0.95	0.55	1.50
NASA Support Engineering Staff	-	-	-	-	-	-	-	-	-	-	1.00	1.00
NASA Supported Technical Staff	-	-	-	-	-	-	-	-	-	-	-	0.00
Emeritus Science Staff	3.00	1.00	-	-	3.00	-	-	-	-	-	-	7.00
Visiting Scientists	-	-	-	-	-	-	-	-	-	-	-	0.00
Total Other Support	3.00	2.00	-	-	3.00	-	-	-	-	0.95	1.55	***10.50***
Total Working at NSO	4.00	9.00	2.00	1.00	6.50	-	-	55.00	41.00	4.00	19.00	**141.50**
Scientists	-	-	-	-	-	-	-	-	-	-	-	0.00
Engineering/Science Support Staff	-	-	-	-	-	-	-	-	1.00	-	-	1.00
Administrative Staff	-	-	-	-	-	-	-	-	-	-	-	0.00
Technical Staff	-	-	-	-	-	-	-	4.00	-	-	-	4.00
Maintenance & Service Staff	-	-	-	-	-	-	-	-	-	-	-	0.00
Total Open Positions	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***4.00***	***1.00***	***0.00***	***0.00***	***5.00***
Total NSO FTEs	**4.00**	**9.00**	**2.00**	**1.00**	**6.50**	**0.00**	**0.00**	**59.00**	**42.00**	**4.00**	**19.00**	**146.50**

Table D.2. NSO Scientific & Key Management Staff Estimated Percent FTE by Activity (FY 2023)					
Name	**Admin/Mgt[1]**	**Research[2]**	**Service[3]**	**Project Support[4]**	**TOTAL**
Anan, T.		26.0	74.0		100.0
Beck, C.		26.0	74.0		100.0
**Bertello, L.		62.0	4.0	34.0	100.0
Card, G.	7.0			93.0	100.0
Cauzzi, G.		27.0	73.0		100.0
Criscuoli, S.		49.5	49.5		100.0
Davey, A.		32.0		68.0	100.0
Ditsler, J.	100.0				100.0
Fehlmann, A.		2.0		98.0	100.0
Fischer, C.		46.0	54.0		100.0
Goodrich, B.	100.0				100.0
**Gosain, S.		20.0	80.0		100.0
Harrington, D.		22.0	22.0	56.0	100.0
Jaeggli, S.		41.0	59.0		100.0
**Jain, K.		58.0	20.0	22.0	100.0
[a]Kazachenko, M.		50.0			50.0
**Kholikov, S.S.		60.0	40.0		100.0
**Komm, R.W.		96.0	4.0		100.0
[a]Kowalski, A.		50.0			50.0
Kramar, M.		34.0	16.0	50.0	100.0
Kuridze, D.		83.0		17.0	100.0
Marshall, H.				100.0	100.0
Martinez Pillet, V.	100.0				100.0
**Petrie, G.J.D.		71.0	9.0	20.0	100.0
Reardon, K.P.		31.0	48.0	21.0	100.0
Rimmele, T.R.	100.0				100.0
Schad, T.A.		50.0	50.0		100.0
Schmidt, D.		3.0		97.0	100.0
Tarr, L.		60.0		40.0	100.0
Tawa, R.E.				100.0	100.0
**Tripathy, S.C.		76.0		24.0	100.0
Tritschler, A.	2.0	1.0	1.0	96.0	100.0
Uitenbroek, H.		39.0	46.0	14.0	100.0
Warner, M.	100.0				100.0
Watkins, C.	100.0				100.0
Woeger, F.	35.0	1.0		64.0	100.0

[1]Administrative and/or Management Tasks
[2]Research, including participation in scientific conferences
[3]Includes Educational and Public Outreach (EPO), Internal & External Committees, NCSP activities
[4]Includes Project Science Ops, Technical Ops

*Fully grant supported
**Partially grant supported
[a]NSO-CU Boulder shared tenure-track faculty

APPENDIX E. ACRONYM GLOSSARY

A&E	Architecture and Engineering
AAAC	Astronomy and Astrophysics Advisory Committee (NSF)
AAG	Astronomy and Astrophysics Research Grants (NSF)
AAS	American Astronomical Society
ACE	Advanced Composition Explorer (NASA)
ACP	Algorithm Change Proposal
ADAPT	Air Force Data Assimilative Photospheric flux Transport
AD	Associate Director (NSO)
AF	Air Force (US)
AFRL	Air Force Research Laboratory
AFWA	Air Force Weather Agency
AGS	Atmospheric and Geospace Sciences Division (NSF)
AGU	American Geophysical Union
AIA	Atmospheric Imaging Assembly (SDO)
aka	Also Known As
ALMA	Atacama Large Millimeter Array
AMO	Access-Mode Observing (DKIST)
AMOS	Advanced Maui Optical and Space Surveillance Technologies (MEDB)
aO	Active Optics
AO	Adaptive Optics
AOX	Adaptive Optics Associates – Xinetics Inc.
APRPP	Annual Progress Report and Program Plan (NSF)
APL/JHU	Applied Physics Laboratory, Johns Hopkins University
APS	Astronomy and Planetary Science (University of Colorado, Boulder Department)
AR	Active Region
ARRA	American Recovery and Reinvestment Act
ASP	Advanced Stokes Polarimeter
APDA	Astronomical Photographic Data Archives (PARI)
ATI	Advanced Technology Instrumentation (NSF)
ATM	Atmospheric Sciences (Division of NSF)
ATRC	Advanced Technology Research Center (University of Hawai‘i)
ATST	Advanced Technology Solar Telescope (NSO)
AU	Astronomical Unit
AURA	Association of Universities for Research in Astronomy, Inc.
AWI	Akamai Workforce Initiative (Hawai‘i)
AWS	Amazon Web Services
BE2E	Boulder End-to-End (DKIST)
BiFOIS	Birefringent Fiber-Optic Image Slicer
BLNR	Board of Land and Natural Resources (State of Hawai‘i)
BB	Big Bear (GONG site)
BBSO	Big Bear Solar Observatory (California)
BOE	Basis of Estimate
BO/ITL	Biological Opinion/Incidental Take License (U.S. Fish & Wildlife Service)
BSA	Boulder Solar Alliance
CA	Cooperative Agreement
CAS	Central Administrative Services (AURA)
CATE	Citizen Continental America Telescopic Eclipse (NSO Project)
CAM	Cost Account Manager (DKIST)

CCD	Charge Coupled Device
CCMC	Community Coordinated Modeling Center
CDAW	Coordinated Data Analysis Workshop
CDM	Compact Doppler Magnetograph (SWRI)
CDN	Content Delivery Network (NSO EPO)
CDO	Chief Diversity Officer (AURA)
CD-ROM	Compact Disk – Read Only Memory
CDR	Critical Design Review
CDUP	Conservation District User Permit
CEPP	Coronavirus Exposure Prevention Plan (AURA)
CES	Coudé Environmental System
CfA	Center for Astrophysics (Harvard Smithsonian)
CfAO	Center for Adaptive Optics (University of California, Santa Cruz)
CGEM	Coronal Global Evolutionary Model
CGEP	Collaborative Graduate Education Program (University of Colorado, Boulder)
CHU	Critical Hardware Upgrade
CHW	Chilled Water primary coolant loop (DKIST)
CISM	Center for Integrated Space Weather Modeling
CJS	Commerce, Justice, Science (Subcommittee, US House Appropriations Committee)
CLEA	Contemporary Laboratory Exercises in Astronomy
CMAG	Compact Magnetograph (NISP)
CMEs	Coronal Mass Ejections
CMMS	Computerized Maintenance Management System
CNC	Computer Numerical Controlled
CNSF	Coalition for National Science Funding
CoDR	Conceptual Design Review
COLLAGE	COLLAborative Graduate Education (University of Colorado, Boulder)
ConOps	Concept for Operations (DKIST)
COS	College of Optical Sciences (University of Arizona)
CoRoT	COnvection ROtation and planetary Transits (French Space Agency CNES)
CoSEC	Collaborative Sun-Earth Connection
COSI	Code for Solar Irradiance
COSPAR	Committee on Space Research
COTS	Commercial Off-the-Shelf
CPR	Cost Performance Report (DKIST)
CR	Carrington Rotation
CRIM	Coudé Rotator Mechanical Interface
Cryo-NIRSP	Cryogenic Near-Infrared Spectropolarimeter (DKIST)
CS	Center Services (NSO)
CSA	Cooperative Support Agreement
CSAP	Center Services Action Plan (NSO)
CSF	Common Services Framework
CSIC	Consejo Superior de Investigaciones Cientificas (Spain)
CSM	Cryo-NIRSP Steering Mirror
CSP	Critical Science Plan
CSS	Camera Software
CSSS	Current Sheet Source Surface
CT	Cerro Tololo (GONG site)
CTL	Center-to-Limb
CU Boulder	University of Colorado, Boulder
CYRA	Cryogenic Infrared Spectrograph (NJIT, Big Bear Solar Observatory)

DA	Diversity Advocate
DAD	Deputy Associate Director
DAG	Directed Acyclic Graphs
DAS	Data Acquisition System
DB-P	Dual-beam Polarizer (McMath-Pierce Telescope)
DC	Data Center (DKIST)
DD	Diverse Discussions (NSO)
DDT	Director's Discretionary Time
D&D	Design & Development
DASL	Data and Activities for Solar Learning
DC	Data Center
DCAP	Data Center Action Plan (NSO)
DE&I	Diversity, Equity, and Inclusion
DE&I-WG	Diversity, Equity, and Inclusion Working Group (NSO)
DEIS	Draft Environmental Impact Statement
DEM	Differential Emission Measure
DHS	Data Handling System
DIL	"Day in the Life" (DKIST)
DKIST	Daniel K. Inouye Solar Telescope (formerly ATST)
DL-NIRSP	Diffraction-Limited Near-Infrared Spectropolarimeter (DKIST)
DLNR	Department of Land and Natural Resources (State of Hawai'i)
DLSP	Diffraction-Limited Spectropolarimeter
DLT	Digital Linear Tape
DM	Deformable Mirror
DMAC	Data Management and Analysis Center (GONG)
DoD	Department of Defense
DOE	Department of Energy
DRD	Design Requirements Document
DRMS	Decision, Risk and Management Sciences (NSF)
DSF	Disappearing Solar Filament
DSPAC	DKIST Science Policy Advisory Committee
DSSC	DKIST Science Support Center (Maui, Hawai'i)
DST	Dunn Solar Telescope
DWDM	Dense Wavelength Division and Multiplexing
EA	Environmental Assessment
EA	Experiment Architect
EAST	European Association for Solar Telescopes
EF	Evershed Flow
EGSO	European Grid of Solar Observations
EGU	European Geosciences Union
EIC	Equity and Inclusion Council (AURA)
EIS	Extreme-ultraviolet Imaging Spectrometer (*Hinode*, NASA)
EIS	Environmental Impact Statement
EIT	Extreme ultraviolet Imaging Telescope (SOHO)
EMR	Experience Modifier Rate (OSHA)
EPA	Environmental Protection Agency
EPD	Energetic Particle Detector
EPO	Education and Public Outreach (NSO)
ESA	European Space Agency
ESF	Evans Solar Facility
ESO	European Southern Observatory

EST	European Solar Telescope
EU	European Union
EUI	Extreme Ultraviolet Imager (Solar Orbiter)
EUV	Extreme Ultraviolet
EVMS	Earned Value Management System (DKIST)
FAA	Federal Aviation Administration
FAT	Factory Acceptance Test
FCR	Final Construction Review
FDP	Full-Disk Patrol (SOLIS)
FDR	Final Design Review
FEIS	Final Environmental Impact Statement
FIDO	Facility Instrument Distribution Optics (DKIST)
FIP	First Ionization Potential
FIRS	Facility Infrared Spectropolarimeter
FMS	Flexible Manufacturing System
FLC	Ferroelectric Liquid Crystal
FLI	First Light Initiative
FOCS	Feed Optics Control Software
FOV	Field of View
FPGA	Field Programmable Gate Array
FSR	Free Spectral Range
FTE	Flux Tube Expansion
FTEs	Full Time Equivalents
FTS	Facility Thermal Systems (DKIST)
FTS	Fourier Transform Spectrometer (McMP)
FY	Fiscal Year
GAM	Gravity Assist Maneuvers
GB	Giga Bytes
GBPs	G-band Bright Points
GBSON	Ground-Based Solar Observing Network
GEH	George Ellery Hale (University of Colorado, Boulder)
GIS	Global Interlock System
GISS	Global Interlock System Software
GNAT	Global Network of Astronomical Telescopes, Inc. (Tucson, Arizona)
GOES	Geostationary Operational Environmental Satellites (NASA and NOAA)
GOME-2	Global Ozone Monitoring Experiment–2
GONG	Global Oscillation Network Group
GOS	Gregorian Optical System (DKIST)
GPS	Global Positioning System
GRIS	GREGOR Infrared Spectrograph (GREGOR Telescope)
GSFC	Goddard Space Flight Center (NASA)
GST	Goode Solar Telescope (Big Bear Solar Observatory, California)
GUI	Graphical User Interface
HAO	High Altitude Observatory
HASO	Historical Archive of Sunspot Observations
HAZEL	HAnle and ZEeman Light
HCP	Habitat Conservation Plan (Hawaiʻi State Division of Forestry & Wildlife)
HCS	Heliospheric Current Sheet
HIDEE	Heliophysics Infrastructure and Data Environment Enhancements (NASA)
HIPPO	CMMS Software (DKIST)
HIS	Heavy Ion Sensor

HLS	High-Level Software
HMI	Helioseismic and Magnetic Imager
HNP	Haleakalā National Park (Hawai‘i)
HO	Haleakalā Observatory (Hawai‘i)
HOAO	High-Order Adaptive Optics
HPCF	High Performance Computing Facility (University of Colorado, Boulder)
HQ	Headquarters
HR	Human Resources
HSG	Horizontal Spectrograph
HST	Hubble Space Telescope
HXR	Hard X-Ray
IAA	Instituto de Astrofísica de Andalucía (Spain)
IAA	Interagency Agreement (US Government)
IAC	Instituto de Astrofísica de Canarias (Spain)
IAU	International Astronomical Union
IBIS	Interferometric BIdimensional Spectrometer (Arcetri Observatory)
ICD	Interface Control Document
ICM	Inversion by Central Moments
ICME	Interplanetary Coronal Mass Ejections
ICS	Instrument Control System
IDF	Intermediate Distribution Frame
IDL	Interactive Data Language
IEF	Inverse Evershed Flow
IfA	Institute for Astronomy (University of Hawai‘i)
IFU	Integrated Field Unit (McMath-Pierce Solar Telescope Facility)
IGNITION	Human-Machine Interface (DKIST)
IHY	International Heliophysical Year
IMAP	Interstellar Mapping and Acceleration Probe (NASA)
IMaX	Imaging Magnetograph eXperiment (SUNRISE)
IMF	Interplanetary Mean Field
INAF	Istituto Nazionale di Astrofisica (National Institute for Astrophysics, Italy)
IPC	Integration Progression Criteria (DKIST)
IPS	Integrated Project Schedule (DKIST)
IR	Infrared
IRES	International Research Experience for Students (NSF)
IRIS	Interface Region Imaging Spectrograph
IRIS SMEX	Interface Region Imaging Spectrograph Small Explorer Mission (NASA)
ISEE	Institute for Scientist and Engineer Educators (UCSC)
ISIS	Integrated Science Investigation of the Sun (Parker Solar Probe)
ISOON	Improved Solar Observing Optical Network
ISP	Integrated Synoptic Program (NSO)
ISRD	Instrument Science Requirement Document
ISS	Integrated Sunlight Spectrometer (SOLIS)
ISWAT	International Space Weather Action Teams (COSPAR)
IT	Information Technology
ITAR	International Traffic in Arms Regulations
ITF	Infrared Tunable Filter
ITAR	International Traffic in Arms Regulations
IT&C	Integration, Testing, & Commissioning
IWS	Individual Wastewater System (DKIST)
JCI	Johnson Controls

JPL	Jet Propulsion Laboratory (NASA)
JSOC	Joint Science Operations Center (SDO)
JTTS	Journey to the Sun (NSO Teacher Workshop and Telescope Program)
KAOS	Kiepenheuer Adaptive Optics System
KCE	KC Environmental (Maui, Hawai‘i)
KIS	Kiepenheuer Institute for Solar Physics (Freiburg, Germany)
KPI	Key Performance Indicators (DKIST)
KPNO	Kitt Peak National Observatory
KPVC	Kitt Peak Visitor Center
KPVT	Kitt Peak Vacuum Telescope
KS	Kamehameha Schools (Maui, Hawai‘i)
KTH	KTH Royal Institute of Technology, Stockholm, Sweden
LAPLACE	Life and PLAnets Center (University of Arizona)
LASCO	Large Angle and Spectrometric Coronagraph (NASA/ESA SOHO)
LASP	Laboratory for Atmospheric and Space Physics (University of Colorado, Boulder)
LAT	Lab Acceptance Test
LCROSS	Lunar CRater Observation and Sensing Satellite
LCVR	Liquid-Crystal Variable Retarder
LE	Learmonth (GONG site) VIC, Australia
LESIA	Laboratoire d'études patiales et d'instrumentation en astrophysique (Paris Observatory)
LFM	Large Facilities Manual (NSF)
LIC	Local Interlock Controller
LMSAL	Lockheed Martin Solar and Astrophysics Laboratory
LoHCo	Local Helioseismolgy Comparison Group
Loki	End to End Simulator System (NSO)
LOS	Line Of Sight
LOTO	Lock-out Tag-out
LRP	Long-Range Plan
LTE	Local Thermodynamic Equilibrium
LWS	Living With a Star
M1CA	Primary Mirror Cell Assembly (DKIST)
MAG	Magnetometer
MagEX	Magnetic Explorer (LASP CU-Boulder Mission)
MBP	Magnetic Bright Point
McMP	McMath-Pierce
MCAO	Multi-Conjugate Adaptive Optics
MCC	Maui Community College (Hawai‘i)
MDI	Michelson Doppler Imager (SOHO)
ME	Milne-Eddington
MEDB	Maui Economic Development Board
METIS	Coronagraph (onboard Solar Orbiter)
MF	Management Fee
MHD	Magnetohydrodynamic
MKAOC	Mauna Kea Astronomy Outreach Committee (Hawai‘i)
MKIR	Mauna Kea Infrared
ML	Mauna Loa (GONG site) (Hawai‘i)
MOU	Memorandum of Understanding
MLSO	Mauna Loa Solar Observatory (HAO) (Hawai‘i)
MOI	Memorandum of Intent
MPI	Message Passing Interface
MPR	Midterm Progress Review

MPW	Manual Processing Worker
MR	Management Reserve
MREFC	Major Research Equipment Facilities Construction (NSF)
MRI	Major Research Instrumentation (NSF)
MSAC	Math and Science Advisory Council (State of New Mexico)
MSFC	Marshall Space Flight Center (NASA)
MSIP	Mid-Scale Instrumentation Program (NSF)
MSRI-1	Mid-Scale Research Infrastructure-1 (NSF)
MWIR	Mid-Wave Infrared
MWO	Mt. Wilson Observatory (California)
NAC	NSO Array Camera
NAI	NASA Astrobiology Institute
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NCAR	National Center for Atmospheric Research
NCOA	National Center for Optical-Infrared Astronomy
NPR	National Public Radio
NPS	National Park Service
NCSP	NSO Community Science Program
NCSP	NSO Coudé Spectro-Polarimeter (DKIST)
NDSC	Network for the Detection of Stratospheric Change
ngGONG	Next Generation Global Oscillation Network Group
NHPA	National Historic Preservation Act
NHWG	Native Hawaiian Working Group
NIR	Near Infrared
NISP	NSO Integrated Synoptic Program
NJIT	New Jersey Institute of Technology
NLFFF	Non-Linear Force-Free Field
NLTE	Non-Local Thermodynamic Equilibrium
NMDOT	New Mexico Department of Transportation
NMSU	New Mexico State University
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NOIRLab	National Optical-Infrared Astronomy Research Laboratory
NPDES	National Pollutant Discharge Elimination System (EPA/HI Dept of Health)
NPFC	Non-Potential Field Calculation
NPR	National Public Radio
NPS	National Park Service
NRAO	National Radio Astronomy Observatory
NRC	National Research Council
NREL	National Renewable Energy Laboratory
NSBP	National Society of Black Physicists
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSHP	National Society of Hispanic Physicsts
NSO	National Solar Observatory
NSOC	NMSU Sunspot Observatory Committee
NSO/SP	National Solar Observatory Sacramento Peak (New Mexico)
NSO/T	National Solar Observatory Tucson (Arizona)

NSSL	Near-Surface Shear Layer
NST	New Solar Telescope (NJIT Big Bear Solar Observatory)
NSTC	National Science Technology Council
NTT	New Technology Telescope (ESO)
NWNH	New World New Horizons (Astro2010: Astronomy & Astrophysics Decadal Survey)
NWRA/CoRA	NorthWest Research Associates/Colorado Research Associates
O&M	Operations and Maintenance
OCD	Operational Concepts Definition (DKIST)
OCC	Operations Commissioning Call (DKIST)
OCM	Operations Commissioning Module
OCP	Operations Commissioning Phase (DKIST)
OCP1	Phase 1 - Operations Commissioning Phase (DKIST)
OCP1	Phase 2 - Operations Commissioning Phase (DKIST)
OCS	Observatory Control System (DKIST)
OEO	Office of Education and Outreach (NSO)
OFCM	Office of the Federal Coordinator for Meteorology
OLPA	Office of Legislative & Public Affairs (NSF)
OMI	Ozone Monitoring Instrument
OMB	Office of Management and Budget
OP	Observing Program
OPMT	Operations Planning & Monitoring Tool
OSHA	Occupational Safety and Health Administration
OSIRIS	Observing System Including PolaRisation in the Solar Infrared Spectrum
O-SPAN	Optical Solar Patrol Network (formerly ISOON)
OSTP	Office of Science and Technology Policy (US Office of the President)
PA	Programmatic Agreement (State Historic Preservation Office/Federal Historic Preservation Office)
PA	Proposal Architect
PAARE	Partnerships in Astronomy & Astrophysics Research & Education (NSF)
PA&C	Polarization Analysis & Calibration
PAEO	Public Affairs and Educational Outreach (NOAO)
PB	Peta Bytes
PBR	President’s Budget Request
PARI	Pisgah Astronomical Research Institute
PCA	Principal Component Analysis
PDR	Preliminary Design Review
PEP	Project Execution Plan
PFSS	Potential Field Source Surface
PhET	Physics Education Technology (University of Colorado, Boulder)
PHI	Polarimetric and Helioseismic Imager (Solar Orbiter)
PI	Principal Investigator
PLA	Project Labor Agreements
PLC	Programmable Logic Controller
PM	Project (or Program) Manager (NSO)
PM	Preventive Maintenance
PM	Planned Maintenance
PMCS	Project Management Control System
PRC	Portfolio Review Committee (NSF)
PRD	Partial Frequency Redistribution
PRI	Public Radio International
ProMag	PROminence Magnetometer (HAO)

PROSWIFT	Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (US Senate Act S881)
PSP	Parker Solar Probe
PSPT	Precision Solar Photometric Telescope
QA/QC	Quality Assurance/Quality Control
QAS	Quality Assurance System
QBP	Quasi-Biennial Periodicity
QL	Quick-Look
QSA	Quasi-Static Alignment
QU	Queen's University (Belfast, Ireland, UK)
QWIP	Quantum Well Infrared Photodetector
RA	Resident Astronomer
RASL	Research in Active Solar Longitudes
RDSA	Reference Design Studies and Analyses
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFP	Request for Proposal
RHESSI	Reuven *Ramaty High Energy Solar Spectroscopic Imager* (NASA)
RIG	Research Infrastructure Guide
RISE/PSPT	Radiative Inputs from Sun to Earth/Precision Solar Photometric Telescope
rMHD	Radioactive Magnetohydrodynamic
RMS	Root-Mean-Square
ROB	Remote Office Building
ROD	Record of Decision
ROI	Region of Interest
ROIC	Return on Investment Capital
ROSA	Rapid Oscillations in the Solar Atmosphere
RPW	Radio and Plasma Wave
RTC	Real-Time Control (DKIST)
SACNAS	Society for the Advancement of Chicanos and Native Americans in Science
SAMNet	Solar Activity Monitor Network
SAN	Storage Area Network
SASSA	Spatially Averaged Signed Shear Angle
SAT	Sight Acceptance Testing
SCB	Sequential Chromospheric Brightening
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SciOps	Science Operations (DKIST)
SCM	Small Complete Mission (NASA)
SCOPE	Southwest Consortium of Observatories for Public Education
SDO	Solar Dynamics Observatory (NASA)
SDR	Solar Differential Rotation
SED	Stellar Energy Distribution
SSERVI	Solar System Exploration Research Virtual Institute (NASA)
SFC	Space Flight Center (NASA)
SFR	Supplemental Funding Request
SFT	Surface Flux Transport
SH	Spherical Harmonic
SI	Strategic Initiative
SIM	System Integration Module (DKIST)
SM	Service Manager (NSO Data Center)
SMEX	Small Explorer (IRIS)

SMO	Service-Mode Observing (DKIST)
SNA	Surface Normal Actuator
SNR	Signal-to-Noise Ratio
S&O	Support and Operations (DKIST)
SOA	Service Oriented Architecture
SOC	Solar Observatory Council (AURA)
SOHO	Solar and Heliospheric Observatory
SOI	Solar Oscillations Investigations (SOHO)
SOLARC	Scatter-free Observatory for Limb Active Regions and Coronae (Univ of Hawai‘i)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SONG	Stellar Oscillation Network Group
SOP	Science Operations
SORCE	Solar Radiation and Climate Experiment
SOS	Science Operations Specialist (DKIST)
SOT	Solar Optical Telescope
SOT/SP	Solar Optical Telescope Spectro-Polarimeter (*Hinode*, NASA)
SOW	Statement of Work
SPA	Surface Parallel Actuator
SPC	Scientific Personnel Committee (NSO)
SPD	Solar Physics Division (AAS)
SPEs	Solar Proton Events
SPICE	Spectral Imager of the Coronal Environment (Solar Orbiter)
SPIES	SpectroPolarimetric Imager for the Energetic Sun (Dunn Solar Telescope)
SPINOR	Spectro-Polarimeter for Infrared and Optical Regions
SPRING	Solar Physics Research Integrated Network Group (European Union)
SPSC	Space Science Center (University of Colorado, Boulder)
SRA	Summer Research Assistant
SRC	Science Review Committee
SRD	Science Requirements Document
SREC	Southern Rockies Education Centers
SSA SWE	Space Situational Awareness – Space Weather Segment (European Space Agency)
SSEB	Source Selection Evaluation Board (Federal Government)
SSL	Space Sciences Laboratory (University of California, Berkeley)
SSOC	Sunspot Solar Observatory Consortium
SSP	Source Selection Plan (DKIST)
SST	Swedish Solar Telescope
SSWG	Site Survey Working Group (DKIST)
STARA	Sunspot Tracking and Recognition Algorithm
STEAM	Science, Technology, Education, Arts, and Mathematics
STEM	Science, Technology, Engineering and Mathematics
STEP	Summer Teacher Enrichment Program
STEREO	Solar TErrestrial RElations Observatory (NASA Mission)
STIC	Stockholm *Inversion* Code
STS	Science for a Technological Society (2013 Solar and Space Science Decadal Survey)
SUC	Science Use Case
SUCR	Summit Control Room (DKIST)
SUMI	Solar Ultraviolet Magnetograph Investigation (NASA, MSFC)
SUP	Special Use Permit
SuperCATE	Spectrograph experiment (NSO)
SV	Science Verification
SVP	Science Verification Phase

SW	Solar Wind
SWA	Solar Wind Analyzer
SWEAP	Solar Wind Electrons Alphas and Protons (Parker Solar Probe)
SWG	Science Working Group (DKIST)
SWIR	Short-wave Infrared
SWMF	Space Weather Modeling Framework
SWORM	Space Weather Operations, Research and Mitigation (NTSC)
SWPC	Space Weather Prediction Center (NOAA)
SwRI	Southwest Research Institute
SWx-*TREC*	*Space Weather* Technology, Research and Education Center (University of Colorado, Boulder)
SXR	Soft X-Ray
TAC	Telescope Time Allocation Committee
TB	Tera Bytes
TBD	To Be Determined
TCS	Telescope Control System
TD	El Teide (GONG site) (Canary Islands, Spain)
TechOps	Technical Operations (DKIST)
TED	Technology, Entertainment, Design (YouTube)
TEOA	Top End Optical Assembly (DKIST)
TI	Tenant Improvement
TMA	Telescope Mount Assembly
ToO	Target of Opportunity
TOP	Technical Operations
TPC	Total Project Cost
TRC	Technical Review Committee
TRACE	Transition Region and Coronal Explorer
TRC	Technical Review Committee
UA	University of Arizona
UC	User’s Committee (NSO)
UD	Udaipur (GONG site) (Rajasthan, India)
UH	University of Hawai‘i
UBF	Universal Birefringent Filter
UCSC	University of California, Santa Cruz
UK	United Kingdom
UPS	Uninterruptible Power Supply
UROP	Undergraduate Research Opportunities Program
USAF	United States Air Force
USF&WS	US Fish and Wildlife Service
USNO	United States Naval Observatory
UT	User’s Tool
UV	UltraViolet
UVCS	UltraViolet Coronagraph Spectrometer (SOHO)
VBI	Visible-light Broadband Imager (DKIST)
VCCS	Virtual Camera Control System (Dunn Solar Telescope)
VFD	Variable Frequency Drive
VFISV	Very Fast Inversion of the Stokes Vector (Inversion Code, HMI)
ViSP	Visible Spectropolarimeter (DKIST)
VLA	Very Large Array
VSM	Vector SpectroMagnetograph (SOLIS)
VSO	Virtual Solar Observatory

VTF	Visible Tunable Filter (DKIST)
VTT	Vacuum Tower Telescope (Tenerife, Spain)
WBS	Work Breakdown Structure
WCCS	Wavefront Correction Control System
WDC	Workforce and Diversity Committee (AURA)
WFC	Wavefront Correction (DKIST)
WFS	Wavefront Sensor (DKIST)
WHI	Whole Heliospheric Interval
WHPI	Whole Heliosphere and Planetary Interactions
WISPR	Wide-Field Imager (Parker Solar Probe)
WIT	Women In Technology (MEDB)
WoU-MMA	Windows on the Universe Multi-Messenger Astrophysics (NSF Program)
WOW	World of Work (Patsy T. Mink Summit, Hawai‘i)
WSA	Wang-Sheeley-Arge (Solar Wind Model)
WSDL	Web Service Description Language
WSHFH	White Sands Habitat for Humanity
WWW	World Wide Web

APPENDIX F. PUBLICATIONS

(OCTOBER 2022 THROUGH SEPTEMBER 2023)

Author—NSO Staff	**Author**—REU
Author—Grad Student	**Author**—Undergrad

The following is a list of known refereed papers, conference proceedings and non-refereed papers published during FY 2023 by NSO staff, as well as summer and academic-year graduate and undergraduate students. Papers resulting from the use of NSO facilities are also listed.

Refereed Publications

1. Nagovitsyn, Y., **Pevtsov, A.**, & Osipova, A. (2023), Two Populations of Sunspot Groups and Their Meridional Motions, SoPh, 298, 108.
2. Penza, V., **Bertello, L.**, Cantoresi, M., **Criscuoli, S.**, & Berrilli, F. (2023), Prediction of solar cycle 25: applications and comparison, Rendiconti Lincei. Scienze Fisiche e Naturali, 34, 663.
3. Liu, J., Sun, X., Schuck, P. W., **Jaeggli, S.** A., Welsch, B. T., & Noda, C. Q. (2023), Large Photospheric Doppler Shift in Solar Active Region 12673. I. Field-aligned Flows, ApJ, 955, 40.
4. **Bahauddin, S. M.**, & Rast, M. P. (2023), Identifying Acoustic Wave Sources on the Sun. II. Improved Filter Techniques for Source Wavefield Seismology, ApJ, 955, 31.
5. **da Silva Santos, J. M.**, **Reardon, K.**, **Cauzzi, G.**, Schad, T., **Martínez Pillet, V.**, **Tritschler, A.**, **Wöger, F.**, ***Hofmann, R.***, ***Stauffer, J.***, & **Uitenbroek, H.** (2023), Magnetic Fields in Solar Plage Regions: Insights from High-sensitivity Spectropolarimetry, ApJl, 954, L35.
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