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Status of the Lowell Discovery Telescope (LDT) and assessment of the image quality at the focal plane

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ABSTRACT

The Lowell Discovery Telescope (LDT, formerly known as the DCT) is a 4.3-m telescope designed and constructed for optical and near infrared astronomical observation. We present the evolution over time of LDT's image quality and ways to improve it, upgrades to the instrument suite, and lessons learned from operating during the pandemic.

Keywords: Lowell Discovery Telescope, LDT, Lowell Observatory, Telescope and System Performance, Image Quality, System Status

1. INTRODUCTION

Lowell Observatory's Lowell Discovery Telescope (LDT; formerly named the Lowell Discovery Channel Telescope – DCT) is a 4.3-m telescope designed and constructed for optical and near infrared astronomical observation. The LDT began on-sky commissioning and limited science observing in 2012 and transitioned to full time science operation at the beginning of 2015. The LDT instrument assembly can carry five instruments at the f/6.1 Cassegrain focus of the telescope and is able to switch between the instruments in less than five minutes.

Ref. 1 provides a general overview of the site and facility. Refs. 1–5 chronicle progress at LDT over the years and include discussions of various aspects of the facility and its performance. This contribution extends the longitudinal study of the delivered image quality at the LDT that was first reported in Ref. 3. We also update on the status of the instruments and how the facility fared and what changes we made during the pandemic.

2. DELIVERED IMAGE QUALITY

We are continuing our study of the evolution of and dependence upon environmental factors of the image quality at the LDT. The methodology is to look at the measured image full width at half maximum (FWHM) in science and engineerig data taken with the Large Monolithic Imager (LMI). The reductions follow the steps laid out in Ref. 3, with an added check to remove images taken while tracking at non-sidereal rates (since that leads to streaked stars).

Over the course of the past eight years, there is apparently a degradation in the median FWHM recorded in the imaging data (Fig. 1). The left column of the figure plots the FWHM vs zenith distance and shows something close to the expected degradation with a Kolmogorov type $\cos^{-3/5}(z)$ dependence. There are also clear correlations with both wind velocity and direction. The bulk of the best seeing typically occurs with wind velocity between 2 and 4 m/s, and when the wind is out of the West. Weather patterns coming from the East tend to be associated with storm build up and tend to be more unsettled.

We are actively investigating possible causes for the change in image quality over time. Among those that are actively being investigated are the calibration of the load cells that support the primary mirror (M1) and

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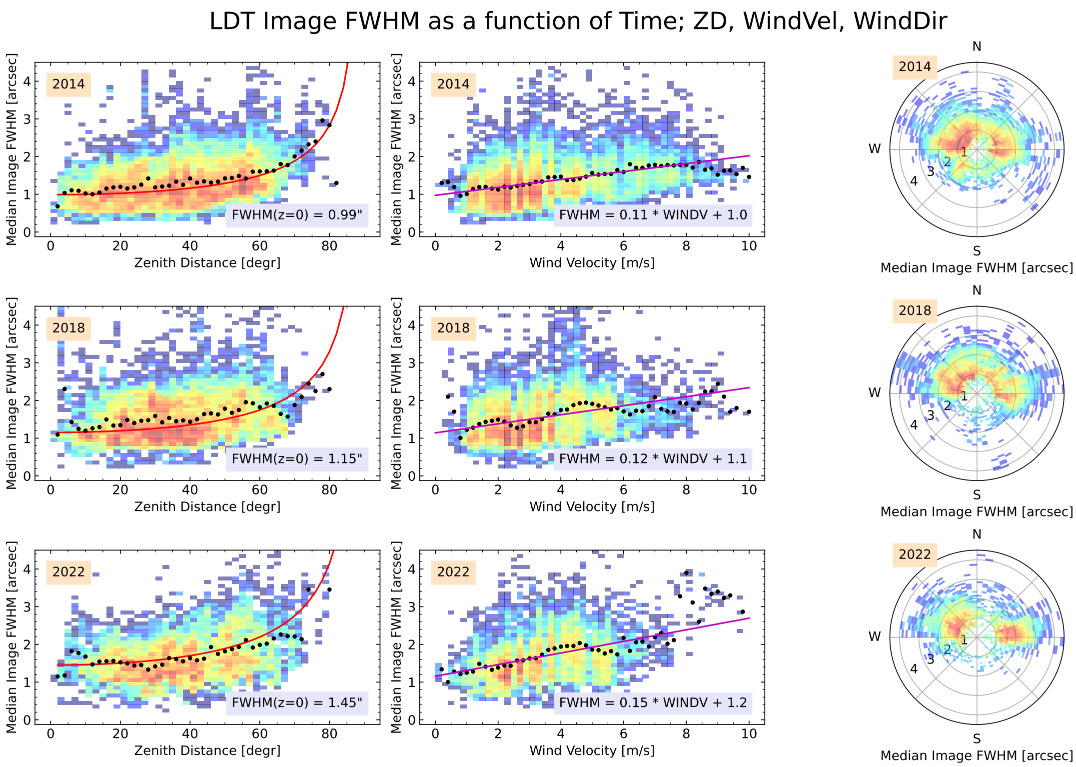

Figure 1. Dependence of the measured FWHM as a function of (left) zenith distance, (middle) wind velocity and (right) wind direction for the years 2014, 2018 and 2022. In the left column, we have fit a $\cos^{-3/5}(z)$ model to the median data. For the dependence of FWHM vs wind speed, a linear model provided an adequate approximation, though there is some sub-structure visible. The data for 2022 cover the first half of the year.

some apparent vibration feed through at 60 and 120Hz. It is also possible that there has been a change in the site seeing.

In 2015, we took some image data at roughly 300Hz to assess the stellar jitter as part of the input to the specification of the EXPRES front end module tip tilt system. The stellar centroid jitter power spectra from April 2015 are shown in the left panel of Fig. 2. We repeated the exercise in late 2021 and early 2022. Power spectra from Feb. 2022 are shown in the right panel of Fig 2. The most prominent changes are in the power visible at 120 and at 60Hz in the later power spectra. The coolers for several of the LDT instruments are known to operate at frequencies that are multiples of 60Hz and the current thought is that the power seen at 60 and 120Hz is likely feed through from these instrument coolers.

3. INSTRUMENT UPDATE

The DeVeny Optical Spectrograph[4] (see the left panel of Fig. 3) slit viewing assembly is in the process of being upgraded. This includes the addition of a filter wheel and replacement of the current camera with one with better sensitivity. The hardware for the upgrade is in place, and the software work has been mostly completed. Data from the DeVeny spectrograph are now reduceable using the PypeIt[6] pipeline.

Operation of the Quad-camera Wavefront-sensing Six-channel Speckle Interferometer (QWSSI)[7] (right panel of Fig. 3) has been refined and QWSSI is now in routine use at the LDT (see for example Ref. 8). Typically it is scheduled for two or three runs per semester.

The Extreme Precision Spectrograph (EXPRES),[9] built to search for low mass planets around low mass stars, is in routine operation. It is reaching its design goals.[10] An important part of the credit for that is due

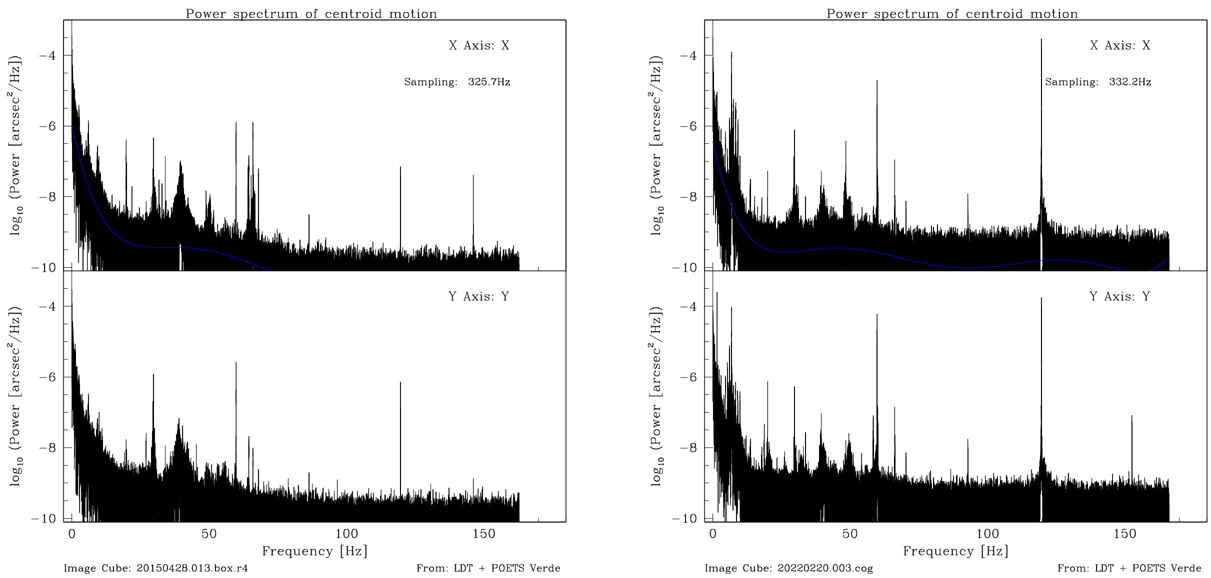

Figure 2. Power spectra of the jitter of stellar centroids taken in 2015 (left) and 2022 (right). The most prominent increase is in the power at 120Hz.

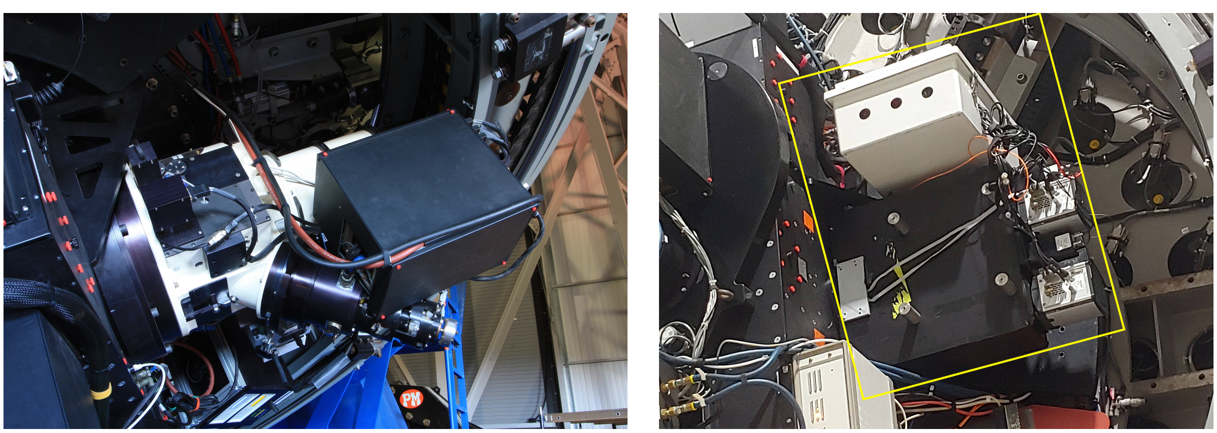

Figure 3. *Left*: The DeVeny optical spectrograph. *Right*: QWSSI outlined in yellow (image courtesy G. van Belle). Both are shown mounted on the LDT instrument cube.

to the performance of the Laser Frequency Comb used for spectral calibration.[11] Temporal programs like this are well served by the scheduling flexibility of the LDT. In the 2022A semester, the primary RV program had 93 individual observing slots over the course of 181 nights (see below in §4 for more discussion of scheduling).

The Lowell Observatory Solar Telescope (LOST)[12] (see the left panel of Fig. 4) was designed specifically to make use of EXPRES during the daytime. This setup is design to study intrinsic stellar variability using the Sun. LOST provides high resolution spectral data at high cadence, using the same instrumental setup that is used to study sun-like stars.

As part of a design study for an external project, we looked into the possibility of adding an additional small port to the existing Cassegrain focus instrument assembly. From this came the preliminary design for what we are calling a Sidewinder port (see the right panel of Fig. 4). This would allow us to mount an additional small instrument below one of the large instruments. For example, the POETS occultation camera could make good use of such a port, giving us six instruments and avoid the current instrument swaps that we do several times per semester between POETS and QWSSI.

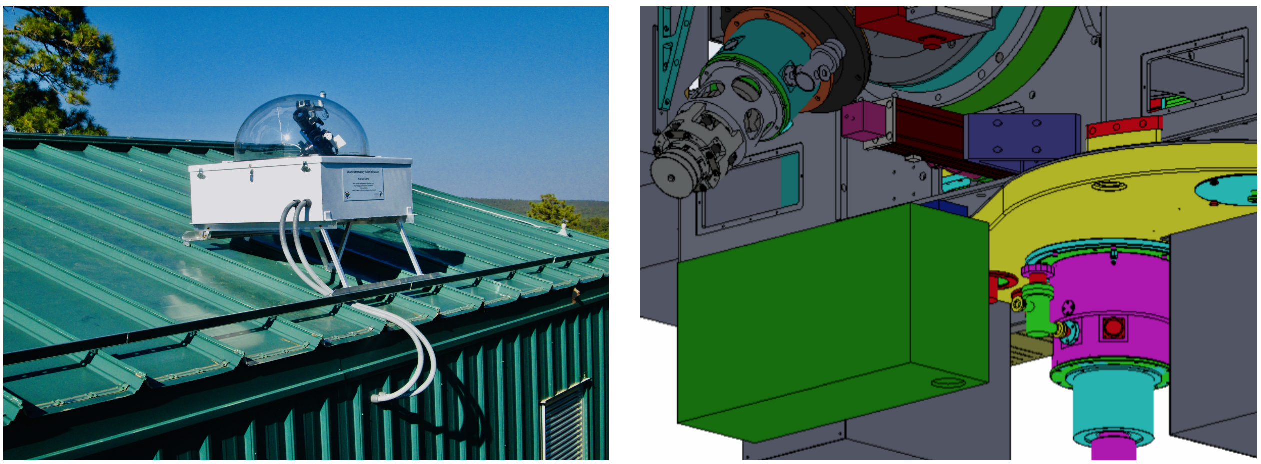

Figure 4. *Left*: LOST on the roof of the LDT auxiliary building (image courtesy J. Llama). The 70-mm aquisition scope can be seen inside the weatherproof dome. *Right*: Schematic design for the small Sidewinder add-on instrument port. The pick-off assembly sits along the bottom face of the instrument cube (just above the yellowish filter wheel case) and can divert the telescope beam below the RC corrector into an instrument in the green box to the lower left.

4. PANDEMIC AND OPERATIONS

As with many large telescopes, LDT wa forced to suspend operations in March, 2020 due to the onset of the pandemic. The facility was fully closed for roughly six weeks. At that point, we shifted to supporting only remote observing and were able to re-start operations four nights per week. In late June, LDT operations changed to full-time remote observing, and the telescope has been in full operations ever since. As of late 2021, we re-opened to on-site observers, though most observers continue to observe remotely. In total, LDT lost 54 nights of science time to pandemic related closures. Several items were critical to successful operations during these stressful times, and allowing LDT to return to operations as quickly as it did; most of these items are also generally useful for efficient operations under normal circumstances.

1. LDT remote observing tools were already in place, and our user base was familiar with them. The tools are all industry standard access applications: VPN for network access, VNC to access the instrument control computers and Zoom or Skype to coordinate with the telescope operator.
2. The LDT instrument cube carries five instruments, which significantly reduces the need for daytime instrument changes, and also expands the options available to an observer at night. Over the course of a typical semester, we may only need to change instruments 6 or 8 times.

3. We significantly expanded the set of tools for remote monitoring of instrument and site status.
4. Because LDT is the only facility at its site, we have always operated with a requirement that at least two people be on-site. Since observers were not able to come, we added night time safety staff, and implemented policies to ensure healthy staff separation during worst of the pandemic.
5. The LDT is classically scheduled. We have reduced the scheduling block size to 1/4 night (from 1/2). We also support pre-approved Target of Opportunity programs, which are permitted to interrupt any non-time critical observations and can be between 1/2 and 2 hours in length. Multiple short time slots have been very popular with programs that need high cadence (e.g. extreme precision RV exoplanet observations, transient object follow-up), and when coupled with remote observing are very efficient for the observers.

5. CURRENT AND FUTURE WORK

During July and early August this summer, we are removing and re-aluminizing the LDT primary mirror. While the mirror is out of its cell, largely motivated by open questions about the image quality, we will take the opportunity to check and re-calibrate the load cell sensors on all 120 actuators that support and shape the mirror. The team has designed and built a bench top jig to do the test and calibration. All of this will be documented in a future contribution. We are also planning to upgrade the vibration dampers on the instrument coolers. Additionally, we are actively working to design a permanent DIMM installation for the site and have been collecting data with a temporary DIMM setup for comparison with the original site testing data.[13]

ACKNOWLEDGMENTS

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These results made use of Lowell Observatory's Lowell Discovery Telescope (LDT). Lowell is a private, non-profit institution dedicated to astrophysical research and public appreciation of astronomy and operates the LDT in partnership with Boston University, the University of Maryland, the University of Toledo, Northern Arizona University and Yale University.

The LDT is sited on land in the Coconino National Forest of the US Forest Service, and we are delighted to acknowledge their willingness to work with us.

Lowell Observatory sits at the base of mountains sacred to tribes throughout the region. We honor their past, present, and future generations, who have lived here for millennia and will forever call this place home.

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