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The Near-Infrared High Throughput Spectrograph

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Abstract

NIHTS is a low resolution near-infrared spectrograph on the Discovery Channel Telescope in Happy Jack, AZ, USA. NIHTS has been fully operational since March of 2018. The instrument will enable many science use cases, including investigations into water-ice in Kuiper Belt Objects and comets, and classification of Near-Earth asteroids and ultracool brown dwarfs.

1. Introduction

The Near-Infrared High Throughput Spectrograph (NIHTS) is a low resolution (R$\sim$200) spectrograph on the Lowell Observatory 4.3-m Discovery Channel Telescope (DCT) in Happy Jack, AZ, USA [8]. NIHTS completed its preliminary commissioning phase at the end of February, 2018. The instrument achieves wavelength coverage 0.86–2.4 μm in a single order. NIHTS contains no moving parts and employs a single slit mask with 7 slit widths, each $12''$ in length.

An instrument schematic is shown in Figure 1 where the following steps of the lightpath are labeled: light enters from the telescope on the lower right (1), is redirected twice off of an Offner relay (2), passes through the slit mask (3), out to a large fold mirror (4) and a ZnSe prism (5), and then back through the fold mirror to be imaged onto a HAWAII-1 array (6). The entire assembly is chilled with two Sunpower closed-cycle Stirling cryocoolers shown on the top right and top left in the diagram.

NIHTS is fed by a dichroic at the center of the DCT instrument cube which enables simultaneous visible imaging with the Large Monolithic Imager (LMI), an independent visible wavelength (0.4–0.7 microns) CCD. In combination with the premier non-sidereal tracking capabilities of the DCT, NIHTS is an extremely efficient instrument and is expected to make significant contributions to several fields in astronomy.

I will present an overview of the primary science use cases for NIHTS that will be pursued by Lowell Observatory and DCT partners.

2. Science Implications

NIHTS will enable novel studies of a number of astrophysical and planetary objects including Kuiper Belt Objects (KBOs), Comets, Near-Earth Asteroids (NEAs), and cold low mass stars.

2.1 Kuiper Belt Objects

Large KBOs show spectroscopic evidence of water-ice on their surface, whereas small KBOs do not [1, 2]. There is visible evidence of this transition in objects between absolute magnitudes of $\sim$3–5 in the 2 micron water absorption feature [1, 2]. Currently, this transition between water-rich and water-poor surfaces is not clearly understood. These objects are distant and very faint ($V \geq 20$), and therefore not easily detected in the near-infrared. However, the LMI, NIHTS, and DCT tracking combination will make this feasible. As a result, NIHTS will allow for the study of objects near the transition size to be analyzed for their water-ice abundance.

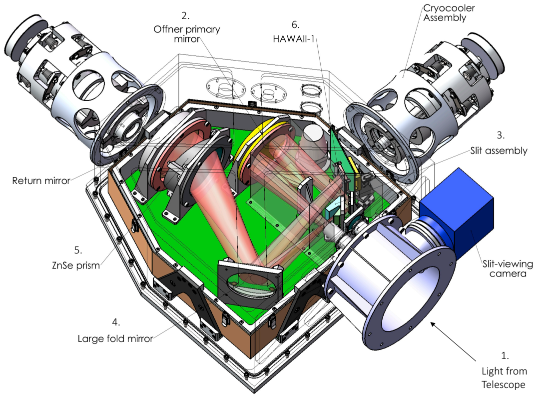

Figure 1: NIHTS Layout

2.2 Comets

The primary component of cometary nuclei is water-ice, yet it is difficult to make direct observations of cometary nuclei. When a comet makes a close passage to the Sun, volatiles are outgassed and water-ice grains can be detected in the coma [5, 9, 13, 12, 11]. High spatial resolution observations, like that from spacecraft, allow for direct observations of water-ice grains are required to validate, disprove, or improve various comet formation models [10]. However, high spatial resolution from close approaching comets can also allow for investigation into formation models. The unique abilities of the DCT to acquire simultaneous spatial context from visible imaging with near-infrared spectral data make NIHTS and the DCT suitable for this investigation.

2.3 Near-Earth Asteroids

Key physical properties of an asteroid (e.g., grain size, mineralogy, albedo, extent of space weathering) can be inferred through photometry and spectroscopy. One can categorize the physical composition of targets via the Bus-DeMeo spectral taxonomic system [6]. This classification scheme identifies common broad absorption features at visible to near-infrared wavelengths. [7] show spectroscopic differences between the small NEAs and meteorites based on data at visible wavelengths. It remains unclear to what extent this difference is due to: observational bias, size dependent differences in physical properties, and atmospheric bias towards selection of meteorite types. NIHTS will provide new data at near-infrared wavelengths and thus allow for the classification of small NEAs to better define any compositional differences between NEAs and meteorites.

2.4 Low Mass Stars

There is a gap in the current knowledge between the coolest stars (brown dwarfs) $T_{\text{eff}} \sim 500$ K and gas giant planets like Jupiter $T_{\text{eff}} \sim 124$ K. The study of these ultracool brown dwarfs will provide important insights into both ultracool atmospheric physics and the low-mass end of the stellar mass function. Seven such objects were discovered by Cushing et al. [3]. These are the coldest spectroscopically confirmed brown dwarfs at temperatures in the range of 300 K–500 K [3]. NIHTS has already demonstrated its ability to classify brown dwarfs [4], and we will explore its capability to capture spectra of the coldest faint brown dwarfs.

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