

# Hanle Echelle spectrograph

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## Observers guide

### Version History

**05-May-16 - Draft version**

The document aims to provide overview of observing modes, user interfaces and calibrations . Various steps of setting up the instrument for observing are listed. Issues and future plans are discussed

## **Overview**

Hanle echelle spectrograph is a fibre-fed, high resolution ( $R = 30,000$  and  $60,000$ ), spectrograph for the 2m HCT telescope, developed jointly by CI(Callaghan innovation), New Zealand and IIA. The project is funded by Department of Science and Technology (DST), India. For details on HCT please refer <https://www.iiap.res.in/centers/iao> and about the instrument, please refer the instrument manual and the HESP website [www.iiap.res.in/hesp](http://www.iiap.res.in/hesp)

## **HESP Instrument subsystems:**

The instrument has 4 subsystems

1. Cassegrain unit that facilitate the light from the telescope to the spectrograph and the autoguider system. Cass. Unit is attached to one of the side port of the telescope.
2. Spectrograph unit is a optical table mounted spectrograph located at the ground floor of the telescope building. The entire room is thermally controlled to a precision of  $-0.2$ deg.
3. Calibration unit, that has a suit of lamps (ThAr, ThArNe, Halogen) and filters. The lamps feed the calibration fibers that will finally fed the science fiber used to feed the spectrograph slit. The calibration unit is located inside the spectrograph room, in one of instrument control racks.
4. CCD detector system: It is a  $4k \times 4k$  CCD system located inside the spectrograph room

The subsystems are controlled by different control computers

1. Cassegrain control PC - called as CEPC (Cassegrain Embedded PC)
2. Spectrograph and Calibration unit control PC - called as SEPC (Spectrograph Embedded PC)
3. CCD Server & Lakeshore temperature controller - CCD server PC
4. Temperature, pressure and humidity monitoring system

**HESP startup procedure:** ( a detailed startup procedure available in a separate document, normally used by the CREST staff)

- First step is to power ON all the servers (All are switched ON all the time, except the CCD controller that is switched ON by the Hanle Staff)
- All the stages, controllers and lamps need to be powered ON and initialized (Done by the CREST staff)
- CCD system is started (by CREST staff)
- CCD LN2 filling is done (at 10AM and 4PM every day), Once the online timed topup filling mechanism is available, there will be no need for anyone to enter the spectrograph room.
- Daytime calibration exposures taken (by CREST staff)
  - Bias Frames - all readouts, gains, binning?
  - ThAr Frames - low and high resolution
  - Focused and defocused flats - low and high resolution
  - Solar spectra, taken both in low and high-res mode

## **Science observations:**

1. The HCT tertiary mirror rotated to direct the light into the HESP instrument sideport.

2. The image is acquired using the HESP autoguider. The field of view is 100arcsec. The telescope pointing is good most often the target position is within 10arcsec from the center. Telescope is slightly moved to center the star on to one of the pinholes. By default pinhole-1 is used for star, which is decided based on the throughput of the fibers that corresponds to fiber-1 and fiber-2. It is however possible to use pinhole-1 or pinhole-2 for star.
3. Once the target is centered on one of the pinholes, start the HCT autoguider. Currently the HESP autoguider is not used for guiding the telescope. Once the HESP and HCT interface code is tested, HESP autoguider will be used.
4. HESP ADC (atmospheric dispersion corrector) is kept at a nominal position. ADC unit consists of two counter rotating prisms used to correct the atmospheric dispersion, which improves throughput at large elevation and improves guiding. It also reduces systematic in radial velocity at large airmass. Currently, ADC calibration is not completed and will be used in the nominal position, hence observers may avoid low elevation objects.
5. Open observer GUI and choose one of the observing mode

#### HESP observing modes

HESP instrument has dual fibers. Based on the requirement there are four possible observing modes. See the Annexure-1 for a schematic diagram of all the observing modes

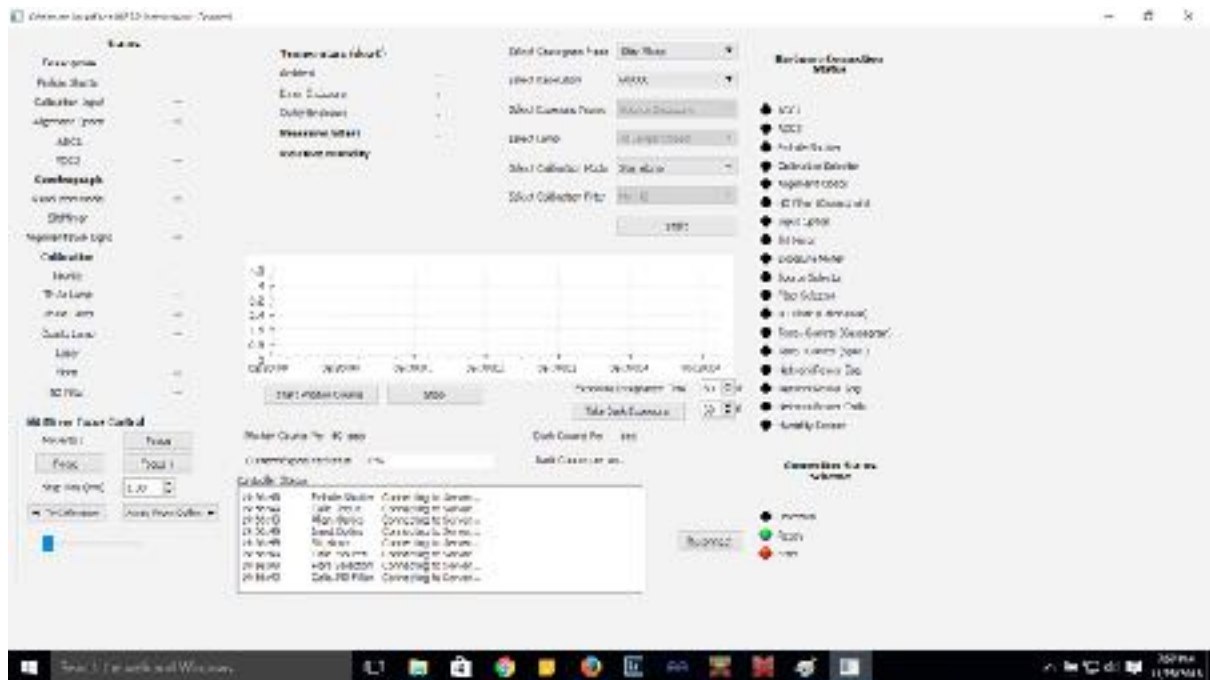
1. Star only mode: One of the pinholes is illuminated by the star light and the other pinhole is closed. This mode can be useful for bright objects that require short exposures. The choice of the pinhole can be decided based on the fiber that has highest throughput.
2. Star-Sky mode: This is primarily used for precise chemical abundance, where sky subtraction is important. One of the pinholes is illuminated by star and the other pinhole is illuminated by the nearby sky
3. Star-Calib mode: This mode is used for precise radial velocities. One of the fiber is illuminated by the star light and the other fiber is illuminated by ThAr wavelength calibration light. Any changes of the spectrograph and the ambient conditions that leads to shift of the wavelength at the detector is tracked by the calibration fiber, that helps in precise velocity determination.
4. Calib-Calib mode: Both the fibers are illuminated with calibration light, either by ThAr lamp (for wavelength calibration) or by halogen-quartz lamp (for flat fielding).

For science observations, in the observer GUI select,

1. Observing mode
2. Resolution
3. Lamp

and click “start button”. This will move the stages to its appropriate positions. Make sure to click “focus” button, sometimes if defocused flats were taken before the science exposure the focus value may not have been changed to default focus.

The figure below shows a screenshot of observer-GUI



### **Calibration exposures:**

Apart from the science exposures, one would need bias, flat, wavelength calibration, order tracing reference, telluric standard, flux and RV standards

**Bias exposures:** It is a good practice to take several bias frames in the beginning and end of the night, though the bias zero level does not change more than 2-5 counts. HESP CCD also as a 50x4056 size prescan region that could be used to estimate any variation in the bias counts level for each science frames.

**Flat exposures:** In case of fiber fed spectrographs, the width of each spectral order is decided by the fiber size, hence the science target and flat exposures will have width. This will make it difficult to accurately flat field correct the edges of the spectral orders. In HESP this is overcome by taking two defocused flats (0.5mm from normal focus, The normal focus is at 15.2mm.) at the either side of focus and a combined image that has a broader order width is used for flat fielding.

**Wavelength calibration:** Thorium Argon and Thorium Argon-Neon lamps are available for wavelength calibration. There are extensive accurate compilation of ThAr lamps are available by HARPS, hence ThAr lamps would be useful for precise RV observations. ThArNe lamp is similar to that is used at ESO-VLT-UVES spectrograph. ThAr lamp calibration exposure in high and low resolution modes are taken normally at the beginning and the end of the night, this should suffice most science program. Extensive tests on repeatability of various instrument testing is not available yet, hence observations that require precise velocities are requested to take a calib-calib exposure before the start of the target observation.

### **Additional calibrations:**

### **Order tracing reference:**

Solar spectra, that is taken in the daytime through both pinholes can be used for tracing the orders, instead of flats (until the color filters are available). However the observer wants to use a bright star, then the object need to be observed through both the pinholes, to be able to trace the orders for calib-calib mode. The high-resolution and low resolution slits slightly shifted, hence separate reference image is needed to trace two of the resolution modes, if the science exposures are done in both resolutions.

#### Telluric Standard

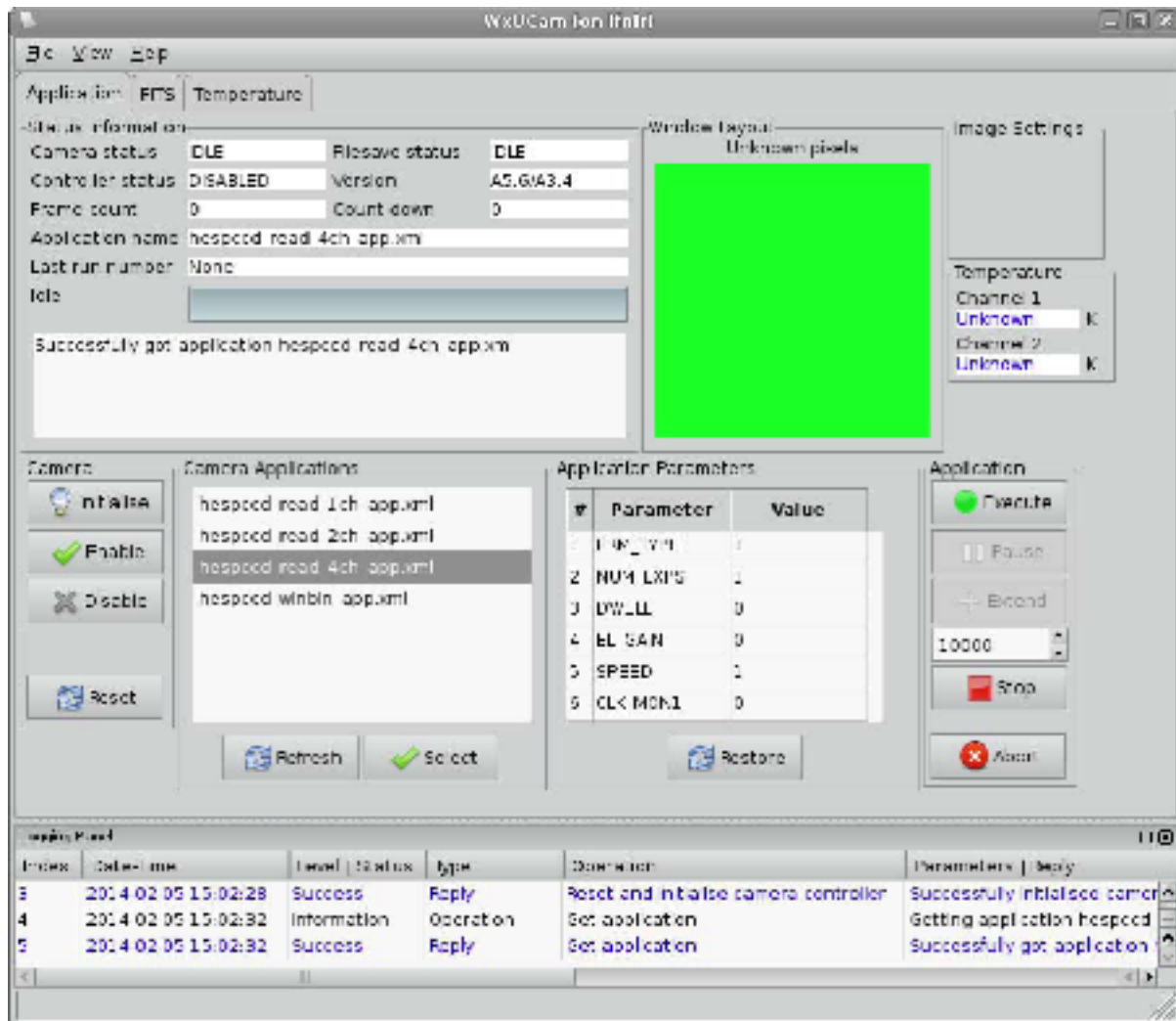
A bright fast rotating B-type main-sequence star is recommended for telluric line removal. Since the spectrograph is housed inside a thermal chamber that is controlled at  $\pm 0.2\text{C}$ , the spectrograph expected to be stable and reference spectra from the previous observations can be used for tracing.

RV standards: To understand the long term stability of the instrument, a set of RV standard stars are observed regularly (e.g. Tau Ceti, more stars will be added to the list to cover a larger sky over the year). The stars will be selected from the [CORALIE/ELODIE list of Radial-Velocity Standards](#) (for details see [Udry et al. 1999](#))

#### **Starting science observing:**

Use the CCD control interface to initiate the science exposures. Currently, the instrument setup, telescope position and details of the science targets are entered manually into image headers.

The figure below shows the CCD controller GUI. The quick start up procedure and CCD reference manual and test results are available as separate documents and observers may refer to that for more details.



HESP CCD detector:

HESP has E2V CCD231-84 4kx4k 15micron square pixel CCD. In addition to the 4kx4k active pixels, it has 50 prescan elements, these rows help to track changes to bias counts. HESP CCD is AR coated with a custom graded coating following the echelle format to improve the efficiency and also helps reduce the fringing in the red.

HESP detector settings:

HESP CCD has four output amplifiers and 7-different readout modes. It has two speeds and two gain settings.

Electronic gain setting	Output E		Output F		Output G		Output H	
	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)
1	1.23	3.85	1.24	3.67	1.25	4.00	1.22	3.82
0	2.56	4.42	2.56	4.18	2.60	4.38	2.54	4.20

Table 1: Gain and read noise figures for all readout combinations in speed-1

Electronic gain setting	Output E		Output F		Output G		Output H	
	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)	System gain (e/ADU)	Readout noise (e rms)
1	1.26	3.67	1.33	3.50	1.33	3.50	1.30	3.45
0	2.88	4.50	2.93	4.42	2.96	4.12	2.88	4.00

Table 2: Gain and read noise figures for all readout combinations in speed-0

**The optimal settings are speed -1 single readout with output amplifier-H (number-3 in the CCD user interface-GUI)**

The reason to choose output amplifier -3 is avoid strong ThAr lines to spoil the rest of the frame.

During the science exposures the exposure meter of the spectrograph will starts photon counting. The exposure meter has a large fresnel lens that collects light that is reflected off the cross-disperser prism and photomultiplier tube. Currently the PMT data is stored as a separate file, in the future it will be stored as a fits extension to the echelle spectra.

The CCD controller has options to modify the exposure time while the exposure is still going ON, one can increase, stop and pause the exposures.

**Issues that needs to be fixed:**

Electrical grounding issues - During CCD frame readout if the telescope dome happen to rotate, then there is an electrical interference that gives streaks in the science frame for the those rows when the dome moved. This could be due to grounding of the spectrograph room not isolated well from the dome. The appearance of streaks can be stopped if the dome track is switched OFF while readout (this takes about 50sec).

Fluctuation of ThAr lamp line intensity:

Weak lines in the ThAr spectra appears and disappears in a sequence of continuous exposures. This is due to fluctuation of the input voltage to the lamp power supply. Due to this there may be difficulty in identifying lines and systematic errors in RV.

Flat fielding:

The quartz halogen lamp that is used currently does not emit enough flux in the blue to be useful for flat fielding in the blue. We are in the process of procuring color balancing filters that is expected to give reasonably flat spectra.

ThAr line saturation:

ThAr spectra has very many strong lines beyond 700nm. Since HESP covers wavelength between 350-1000nm in one instrument setup, it is difficult to get enough signal in the faint bluer lines without saturating the strong emission lines in the red wavelengths (beyond 700nm)

ADC calibration: Due to ADC not available, there could be reduced throughput if observed at low elevation angles. Due difference in the blue and red centroids there is a systematic error in the RV derived from blue and red wavelengths.



# Observing Modes

