

# OSCA Observer's Guide

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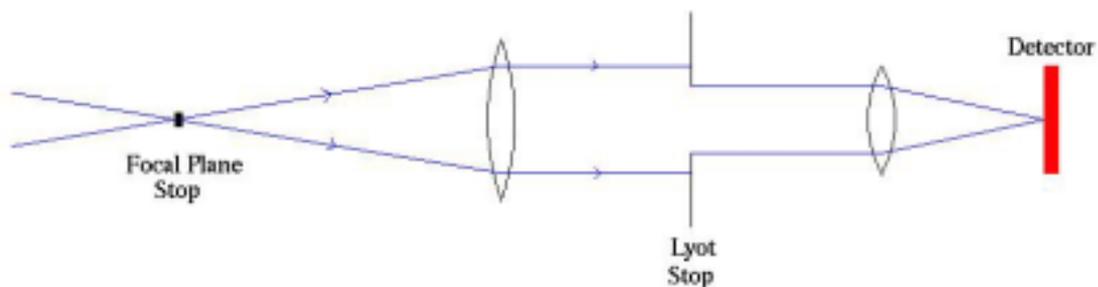
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# 1 The OSCA instrument

## 1.1 Instrument Overview

OSCA (Optimised Stellar Coronagraph for Adaptive Optics) is a stellar coronagraph designed to take advantage of the high resolution performance of the NAOMI adaptive optics system at the William Herschel Telescope.

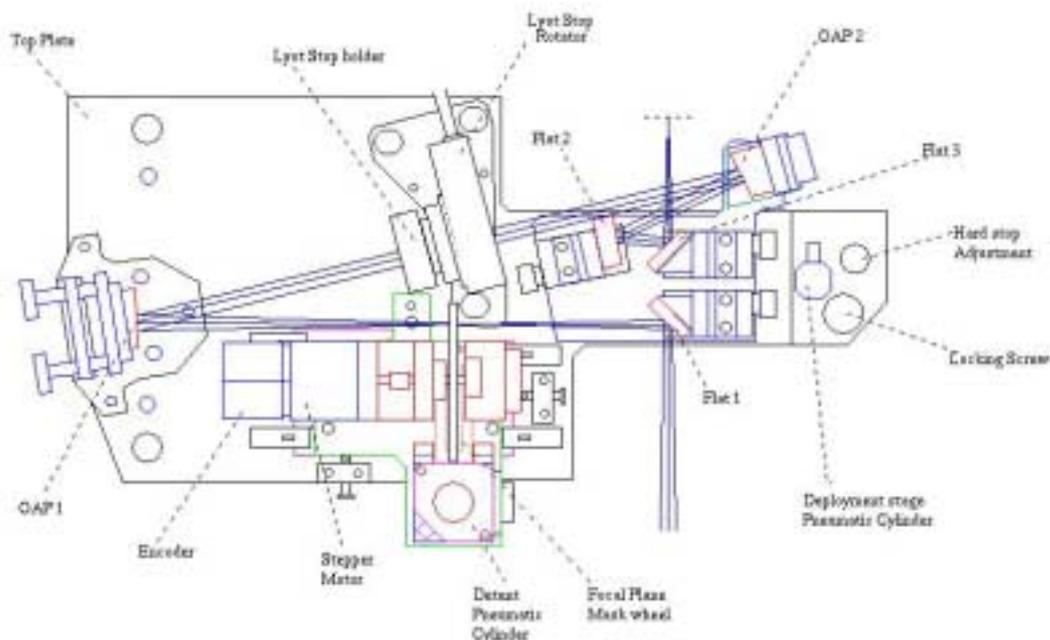
OSCA is a classical Lyot coronagraph consisting of a focal plane stop and an undersized pupil plane stop (Lyot stop)



**Figure 1.1 Schematic of a Lyot coronagraphic system**

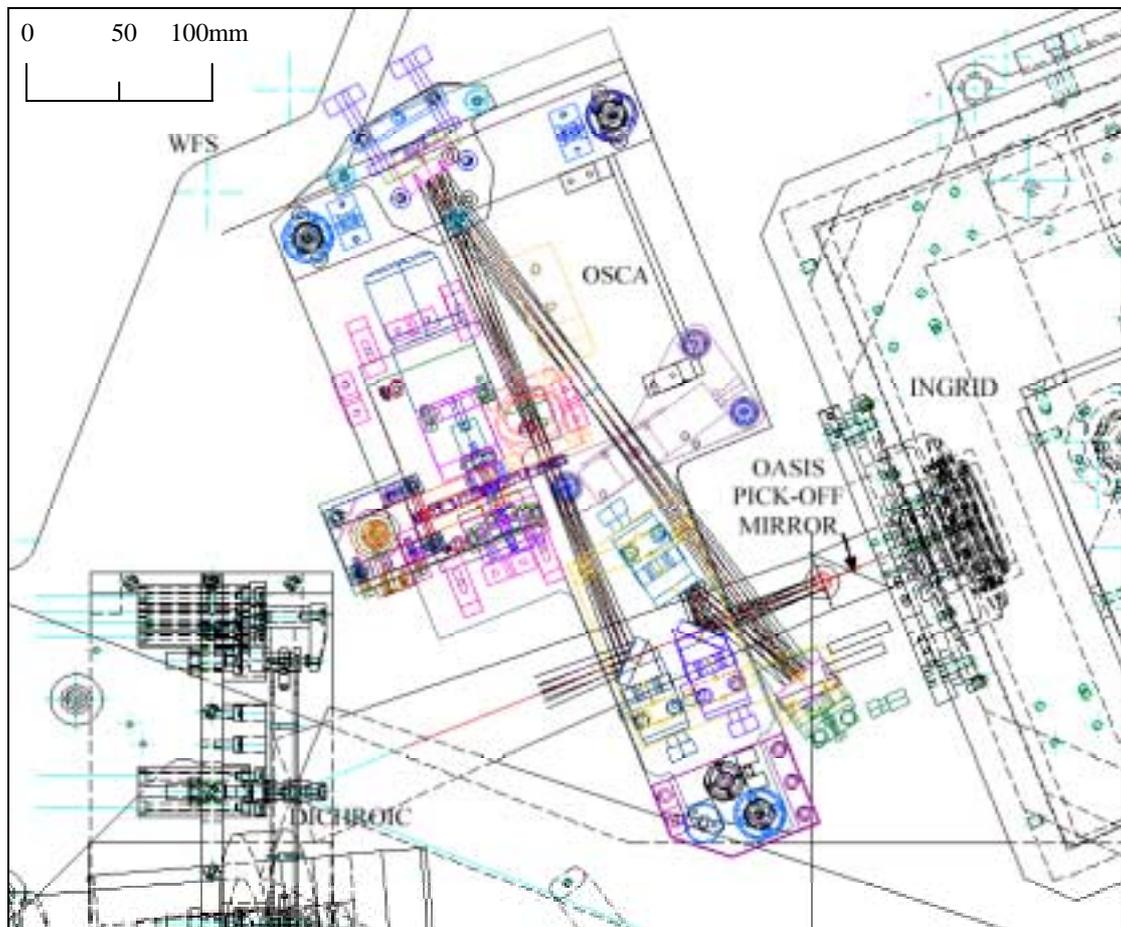
The action of the focal plane stop is to condition the remaining light from the wings of the central object to appear around the edge of the pupil where it can be preferentially removed with an undersized pupil stop.

A schematic of the OSCA instrument is shown below.



**Figure 1.2 Schematic top view of the OSCA unit**

The system is situated on the NAOMI optical bench in the optics room in GHRIL and can be deployed in and out of the corrected beam emerging from the NAOMI system.



**Figure 1.3 Schematic showing the placement of OSCA relative to other instruments on the NAOMI optical table.**

The system has a 1:1 magnification so leaving the NAOMI field scale unchanged.

At present the only science instrument available is the INGRID infra-red camera, but the system is also designed to feed the OASIS spectrograph when it is commissioned at the WHT.

## 1.2 Focal Plane Masks

The system has a wheel containing a number of focal plane stops of various sizes that can be remotely selected. The sizes of focal plane stop that the wheel contains are shown in table 1.1.

Stop Number	Stop Size (arcsec)	Stop Edge Type
1	0.26	Hard
2	Target	Target
3	0.4	Hard
4	0.65	Hard
5	0.8	Hard
6	1.6	Hard
7	2.0	Hard
8	-	-
9	-	-
10	-	-

**Table 1.1 Focal Plane Stop Sizes**

### 1.3 Lyot Mask

Mounted on the rotation stage is the Lyot mask. This is an etched aperture mask that is situated at the conjugate pupil position. The Lyot stop rotates so as to keep alignment between the secondary and tertiary mirror struts and the masking vanes in the Lyot stop, in order to eliminate the central star light that arises along these strut edges in the pupil plane.

The Lyot stop size is not remotely changeable but two different size stops are available that can be interchanged manually. The two sizes are:-

**Lyot mask (80,20)** which has an outer radius that is 80% of the pupil and an inner obscuration which is 20% over sized. The throughput of the mask compared to the unobstructed throughput is 53%

**Lyot mask (90,10)** which has an outer radius that is 90% of the pupil and an inner obscuration which is 10% over sized. . The throughput of the mask compared to the unobstructed throughput is 72%

### 1.4 Instrument throughput

Measured throughputs are:-

**J      90%**  
**H      90%**  
**Ks     TBD**

### 1.5 Field of View

The field of view of the system is 27 arcseconds

## 2 Graphical User interface

The OSCA control panel can be used by the observer to control the various mechanisms associated with OSCA. The control page can be selected by the user by clicking on the tab labelled OSCA Control at the top of the window. The OSCA control panel looks as follows;

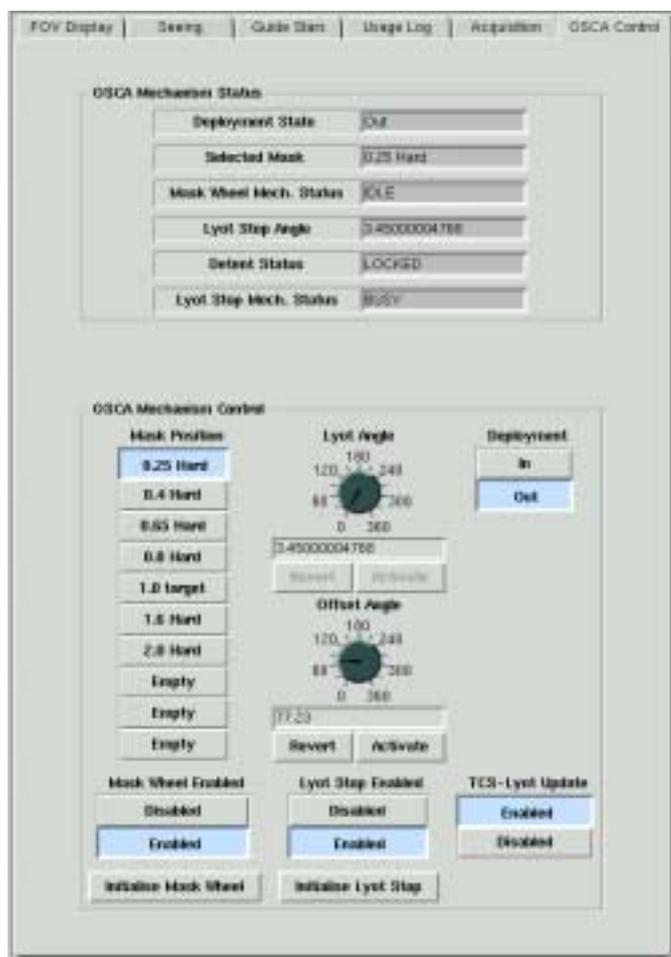


Figure 2.1 OSCA Control Panel

### The OSCA Status Panel

The OSCA status panel displays various status information relating to the OSCA EPICS VME system. This information is updated in real-time as status parameters change within the EPICS system.

A summary of the displayed status values follows;

1) The **Deployment Status** of the instrument reports whether or not OSCA is deployed into the light path. The status should report either *In* to signify that OSCA is in the light path and *Out* to signify that OSCA is not in the light path.

2) The **Selected Mask** indicates the currently selected mask which is being reported by the EPICS system.

3) The **Mask Wheel Mech. Status** indicates what the activity status of the mask wheel mechanism is. This can be one of *Busy*, *Disabled*, *Init*, *Undefined* or *Idle*.

4) The **Lyot Stop Angle** indicates the current rotation angle in degrees of the lyot stop mechanism as reported by the EPICS system.

5) The **Detent Status** indicates the current position of the mask wheel detent pin and be either *Undefined*, *Locked* or *Unlocked*.

6) The **Lyot Stop Mech. Status** indicates the current movement status of the lyot stop mechanism and can be one of the following values; *Busy*, *Disabled*, *Init*, *Undefined* or *Idle*.

## The OSCA Mechanism Control Panel

The OSCA mechanism control panel is located at the foot of the OSCA control page and can be used by the user to control the mask wheel deployment and Lyot stop mechanisms. The controls on the panels are described in the following sections.

It should be noted that whilst any of the mechanisms are moving, controls on the display which are specific to that mechanism will remain disabled to user control.

### 1) *The Mask Position Control*

The control consists of 10 buttons stacked vertically labelled with each of the masks which can be found in the positions on the mask wheel.

The user can request a mask position by simply clicking on the corresponding mask button. Should the mechanism be in an error state, disabled or moving, this control will be disabled.

### 2) *The Mask Wheel Enabled Control*

The low level EPICS system allows two states for the mask wheel mechanism, enabled and disabled. When the mechanism is in the disabled state, the OSCA EPICS system will forbid any requests for movement of the mechanism. The user can toggle the system between the two modes by clicking on the **enabled** or **disabled** buttons. It should be noted that when the OSCA low level EPICS system is requested to enable the mechanism, it performs an initialisation of the mechanism which takes a short amount of time to perform.

### 3) *The Initialise Mask Wheel Control*

The button labelled **Initialise Mask Wheel** can be used to initialise the mask wheel mechanism. This action will take a short period of time to perform and the application will request user confirmation prior to performing the action.

### 4) *The Lyot Angle Dial Control*

The lyot angle dial control can be used to manually set the angle of the Lyot stop mechanism. In order to specify the value, the user can either turn the dial

until the desired angle is reached or edit the value in the entry field located directly below the dial. Anytime the value displayed differs from the value of the actual mechanism, the text in the entry field will be shown in red.

By clicking on the button labelled **Activate**, the OSCA EPICS system will be requested to move the mechanism during which time the control will be disabled. Once the mechanism has reached its demand position, the control will become enabled once again.

It should be noted that whilst the mechanism is disabled, in an error state or moving, the control dial will remain disabled.

The button labelled **revert** can be used to instruct the dial to re-read the current value of the Lyot angle. This is useful after the user has modified the value in the control but decides to abandon his change request.

While the Lyot Stop Rotation Angle Update daemon is running, the user will find that this mechanism is updated every couple of seconds and therefore in order to disable this, he should refer to the section on enabling and disabling the rotation angle update.

#### 5) *The Lyot Offset Angle*

The Lyot offset angle dial control can be used by the user to manually set the Lyot stop offset angle which is used in the calculation which sets the angle of the Lyot stop mechanism when the position of the derotator angle on the telescope changes. This angle should only be changed by trained staff and performed after engineering work on OSCA when the position of the instrument has been changed. The angle is permanently stored in the WHT ICS database and is thus preserved across restarts of the system. Valid values for this angle are in the range 0 to 360 degrees expressed as a real number.

The angle can be modified by the user by either turning the dial until the desired angle is reached or editing the value in the entry field located directly below the dial. Anytime the value displayed differs from the value of the actual mechanism the text in the entry field will be shown in red.

By pressing the button labelled **Activate**, the Lyot Stop Update Daemon will be informed of the new value and subsequent automatic calculations of the Lyot stop rotation angle will be calculated based on the new offset value.

#### 6) *The Lyot Stop Enabled Control*

The low level EPICS system allows two states for the Lyot stop mechanism, enabled and disabled. When the mechanism is in the disabled state, the OSCA EPICS system will forbid any requests for movement of the mechanism. The user can toggle the system between the two modes by clicking on the **enabled** or **disabled** buttons. It should be noted that when the OSCA low level EPICS system is requested to enable the mechanism, it performs an initialisation of the mechanism that can take about 6 minutes to perform.

### 7) *The Initialise Lyot Stop Control*

The button labelled **Initialise Lyot Stop** can be used to initialise the Lyot stop mechanism. It should be noted that this action can take almost 6 minutes to perform and cannot be interrupted once started.

### 8) *The OSCA Deployment Control*

The OSCA deployment control can be used to deploy OSCA into the light path. The user can deploy OSCA by pressing the button labelled **In** and remove OSCA from the light path by pressing the button labelled **Out**.

### 9) *The TCS-Lyot Update Control*

This control reflects the current status of the Lyot Stop Update daemon and whether or not it is automatically updating the position of the rotation angle when the derotator angle on the telescope changes. This can be either **enabled** or **disabled** by pressing the corresponding button.

## 3 Observing procedure

### 3.1 Focal plane stop size selection

Choice of the size of the focal plane mask is strongly dependent on both the science requirements and the seeing conditions. Smaller focal plane stops allow structure closer to the central star to be observed but produce a smaller differential suppression of the central star wings.

Without OSCA take some star images and calculate the FWHM, to get an estimate of the corrected seeing. It is best to pick occulting mask sizes of a similar or larger size than this to get the best suppression. If the structure to be observed is  $> 1.5$  arcsec away from central object pick the 2 arcsec mask (diameter) as this gives the best suppression.

### 3.2 Lyot stop size selection

Choice of the Lyot stop is also dependent on the science observation. The small Lyot stop (80,20) will provide a greater relative suppression of the central star but with a lower overall throughput. It is recommended that for most observations the (80,20) stop is used.

The Lyot stops are changed over manually (by observatory staff).

### **3.3 Calibration star**

Clearer images of the underlying structure around a bright central object can be obtained by post exposure subtraction of a point source (calibration star) imaged under near identical conditions.

Images of the reference star should be taken along with the science object and for best results the reference star should be of similar brightness and colour and within a few degrees of the science object, preferably with no companion stars.

### **3.4 Using OSCA with INGRID**

Currently NAOMI only has one science instrument, the INGRID infra-red camera. INGRID has several special internal cold stops for use with OSCA. These stops are OSCA\_CLEAR and OSCA\_OBS. OSCA\_CLEAR is an under sized circular stop 80% of the full pupil. OSCA\_OBS is a under sized stop with an over sized central obscuration, the being undersized by 80% compared to the full aperture and the central obscuration being oversized by 20%

### **3.5 Taking an image with OSCA and INGRID**

Since the brightness can vary so much across the small OSCA fov then it is highly recommended to take sky images between your object observation. Otherwise it is difficult to obtain a good estimate of the sky background level for subtraction purposes in the reduction. Object is acquired by steering the telescope until it can be seen within the NAOMI fov. When roughly centred on the fov the telescope is switched to tracking mode. NAOMI then uses its steering mirror to position the star as accurately as possible to the centre of the OSCA occulting mask. OSCA masks have a small throughput so the object should be faintly seen behind the mask and so can be centred accurately. For some faint objects though this might not be visible. Observe object in given filter, take a sky exposure away from object, observe a nearby calibration star and take a sky again. System parameters should not be changed during this sequence. Remember in K band the sky background can be very variable over time, so ensure to take sky images often during observing object. The use of a coronagraph and adaptive optics can leave residual artefacts in an image which can sometimes look like real objects. To confirm any observations you make it is important you rotate the fov (change derotator angle) and repeat the above process. Objects of interest may also have been caught in the bright diffraction spikes from NAOMI and so rotation the field will move any objects here into a high contrast area. A rotation of 60 degrees is suggested and if time permits a third set of observations with the field rotated again at 60 degrees. Unless different structure is expected at other wavebands, to save time this rotation procedure can just be performed in one waveband.

At the end of the night darks must be taken for every exposure time you used for bias subtraction (the dark current is not linear with time and cannot be deduced otherwise). Flat fields need to be taken for every combination of INGRID and OSCA filter. If you had OSCA out of the beam for comparison images don't forget to take flat fields without OSCA too!

Outlined below is an observing procedure to be used for taking OSCA observations.

1. Select INGRID filter and cold stop using INGRID GUI
2. Select the OSCA control panel in the NAOMI GUI.
3. Select the OSCA deployment in button.
4. Focal plane mask sizes can be selected by clicking on the appropriate mask button.
5. Move the telescope until images of the guide star to be used are seen on the NAOMI wavefront sensor.
6. Close loop on NAOMI and move guide star position to centre of focal plane mask using the NAOMI guide probe offsets.
7. Take exposure of object.
8. Open loop on NAOMI and move telescope off object to clear patch of sky.
9. Take a sky exposure.
10. Move telescope to calibration star and switch on NAOMI (without any change of settings or movement of pick-off position).
11. Take exposure of calibration star.
12. Open loop on NAOMI and move telescope off calibration star to clear patch of sky.
13. Take sky exposure.
14. Open loop on NAOMI and move telescope back to object.
15. Rotate field of view by 60 degrees.
16. Close loop on NAOMI and recenter object on mask, if necessary, using pick-off.
17. Repeat procedures 6-12.

## 4 Data Reduction

INGRID data files contain a pre and post image, so firstly this must be reduced down to a (post-pre) image. This can be done in the 'ingrid\_q1' package downloadable from the INGRID webpages. If you reduce your dark frames first in this manner you can

subtract the dark images at the same time as performing the (post-pre) reduction (using command *framediff*). Average the object images (sorting by type etc) and subtract the corresponding sky images (compensated for any difference in exposure time). Divide by normalised flat fields. The image can be viewed now, however further suppression (by subtraction of the wings of remaining PSF) and removal of other image defects (diffraction spikes, ghosting etc) can be obtained by subtracting the calibration star image.

View the object frame and corresponding calibration star in a suitable display package. Run *imexam* and use *l*, *v*, *r* etc to obtain a cross section through the images and measure the pixel counts in the wings outside the occulting mask. Multiply or divide the calibration star image by a suitable factor to match the count level in the wings of both images. Try a straight subtraction of (object frame - calibration frame) and view the results. If the stars were both centred well on the mask and the counts matched then a good subtraction image should result. If the stars were not well centred and the wings are over bright on one side, try subtracting the calibration star image with an offset to try and match the centres of the underlying stars.

All that remains is to mask out those parts of the image outside the OSCA field of view, any remaining diffraction spikes and the central mask to further enhance contrast and tidy up the final image.