# Imaging Grism Instrument (IGI)

Users Manual, version 4.0
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This constitutes a major rewrite, but does not include polarimetry

## General Overview: Specifications and Capabilities of the Imaging Grism Instrument

The IGI is a high-efficiency, low-resolution grism spectrograph and focal reducer intended primarily for use at the bent Cassegrain f/9 focus of the 107-inch. It can also be used at the 82-inch telescope.

## Basic Design

The IGI is basically a simple 5:1 or 3:1 focal reducer with a grism which can be moved into the collimated beam. It uses commercially-available optics which are coated for wavelengths greater than about 4000A. There are two remotely movable stages one for the grism and one for the slit or a filter. Object acquisition is achieved by moving the slit and grism out of the beam and imaging the approx. 7-arcmin field. There is a fixed mirror offset-guider which uses the PXL or STAR-1 CCD guide cameras. The design is simple, but is intended to be as efficient as possible for setup and observation.

## Specifications

The IGI uses the TK4 CCD only. There is a choice of three Canon camera lenses, 50-mm, 85-mm and 135-mm focal length. The collimator is a 260 mm f.l. doublet and the reduction factors are approx. 5:1, 3:1, and 2:1 respectively. The 85 mm lens is the default choice for normal use, and is normally mounted. Note that the 50 m lens has less vignetting and gives a wider wavelength coverage if you tolerate the 1.0 arcsec/pxl plate scale. I use this lens normally. All numbers such as plate scales given in the following will refer to the 2.7-m.

**Table 1: TK4 pixel scales**

| | Camera Lens | | | |
|---|---|---|---|---|
| | 50-mm | 85-mm | 135-mm | |
| plate scale | 1.0 | 0.62 | 0.41 | "/pxl |
| dispersion | 6.4 | 3.7 | 2.4 | A/pxl |
| camera focus | 0.8 over<br>R.H. f/ll | tbd<br>tbd | tbd<br>tbd | on focus<br>ring |

The usable field of view is set by the filter size rather than the chip. The typical 2x2 inch filters give a 7x7 arcmin. field of view. The dispersion refers to the G6000 grism.

The actual wavelengths covered can be changed by changing the grism or by altering the position of the slit in the dispersion direction, and grism/slit combinations are available to cover the useful wavelength range of 3900A to 9500A. Slits are also available with various widths, and it is a simple matter to exchange slit bolts to change the width or wavelength range during the night. The resolution will vary between about 12A and 20A depending on the slit width which is in turn dictated by the seeing or astronomical considerations. Four grisms are available with undeviated central wavelengths of about 4000, 6000, 8000, and 9000 A. These will be referred to by these wavelengths, as G4000, G6000, G8000, and G9000 respectively. G8000, and G9000 have quite low efficiency as they have large wedge angles and suffer some internal reflection. G600 used to be the best until it was dropped.

**Performance**

The most generally useful grism has its peak efficiency at around 6500A. Below about 4500A the antireflection coatings on the optics cause a serious degradation in efficiency, but the instrument is still useful at 4200A for blue objects, and can work to ~3900A. It is possible to obtain spectra of 20.5 mag objects in a couple of hours under good conditions; fainter if strong emission lines are present. This should be compared with the limit of about 19.5 mag for the LCS in 2 hours integration.

## I. Setting up the Instrument

The tasks prior to the first observation are:

1) install correct optics (generally done by mountain staff)

2) focus camera lens on slit plane (if doing spectroscopy)

3) rotate CCD to align slit with columns

4) focus the telescope

5) focus the guider

### (a) Optics - Mounting and Cleaning

The correct **camera lens** will generally be installed by the mountain staff. It need not be removed unless a change or extensive cleaning is needed. The Canon camera lenses mount on a bayonet mount which locks the iris fully open. To remove the unit as a whole, remove the four thumb screws located at the corners of the mount plate. This is a bit tortuous, but be patient! The camera and collimator lenses can usually be adequately cleaned in place with dust-off. There should not be reason to remove the lenses in normal use. There is a nitrogen gas hookup to the camera lens plate which can be used under extreme humidity conditions if the CCD dewar window is frosting. See David Doss about this if you need to use it.

The **collimator** is located behind the large non-hinged hatch. The collimator is mounted in a simple focusing collar and the lens-mounting barrel should not be removed from the locking-collar. If the unit needs removing, it should be taken out as a unit by removing the mount bolts but *not* the locking bolt. Th epolarimeter mode has a separate collimator marked 'IGP'.

The **field lens** will require more careful cleaning as it is close to the focal plane. Its unit is secured by three captured thumb screws and is accessed through the same hatch as the collimator. It is helpful to also remove the small non-hinged hatch below the slit access door. When removing the large field lens, be careful not to get finger prints on it! The lens has a Magnesium Fluoride coating and can be cleaned with lens tissue and your breath or spectroscopic-grade alcohol if there are finger prints. Usually a dust-off is all that is necessary, I do not recommend the canned dusting gas as the propellant sometimes escapes onto the optic. If you use this, start the flow before introducing the optic, and move the optic rather than the can. During the day a slit unit or filter can be left in the beam to keep dust off the field lens.

The **grisms** are rather vulnerable pieces of optics, as evidenced by the damage to G6000, and should be kept in their holders when not in the instrument. The grism mounts in the grism translation unit accessed through the lower hinged door: the unit should be in the 'in' position to mount the grism. Remove the camera lens cap before installing the grism to give extra clearance (it is tight). The grism should slide easily into the unit glass-face first. It should be obvious but make sure you know what you're doing before undertaking this maneuver. The grisms cannot be cleaned or repaired, so if you scratch one or put a finger print on it, you pay for it (~$2500)! The grism should be left in the unit unless you need to change to another grism. There is a slight danger of the grism slipping in certain orientations so it should be secured to the stage with the small clip on the RH side of the stage.

The **slits** and **filters** mount in the upper slit-translation unit above the field lens. There are a number of available slits (see below), and it is a simple matter to change them or insert a filter during the night. The slits consist of razor blades attached to machined blocks (don't get blood on the optics!), and mount **razor-blade side down** (towards the CCD). The fit is tight, and you may require a pair of long-nosed pliers (from the users tool box on the first floor) to remove the units, though they are easy to push in to the unit. The handles make removal easy enough, and can be changed from one side of the slit to the other to change the wavelength range on those slits which are offset from the center of the unit (see table 2).

The filter holders take 2x2-inch filters, which give a 7x7 arcmin. fov. L-clamps hold the filters in the units. If you have an interference filter be careful about the clamps. It is advisable to use a bit of filter paper as a buffer between the filter and clamp. The holders are put into the stage with the clamps facing down (towards the CCD: it should be obvious). There are also several **double-filter holders** which allow the slit/filter translation stage to switch between two filters remotely (e.g. for line and continuum imaging, or B and R).

### (b) Mounting the CCD

This will be done by the day crew but it is helpful to know how it is done. The CCD mount incorporates a simple rotation unit allowing the CCD to be aligned with the slits. The normal orientation of the CCD gold LN2 dewar is vertical with the fill-neck pointing towards the top of the telescope. This prevents LN2 spillage during the night. The orientation puts the dispersion direction along the rows of TK4, and aligns the slit E-W. With ICE on the ximtool or ds9 image displays, the orientation is N left and E up. You can use the display flip buttons to bet the standard orientation.

To mount the CCD, place the lock ring over the CCD, lip face away from the dewar, and then attach the mount plate with its lip in the same direction. This whole unit then mounts on the spectrograph with four bolts which tighten the lock ring down on the mount plate. This procedure requires two people, and is easier with three: be careful to insure that the lip on the mount plate engages in the circular recess in the back plate of the spectrograph and that things are flush. The slit can be aligned with the rows of the CCD in an interactive manner with one person on the platform and one coaxing ICE. Fine adjustment is possible by slightly releasing the lock bolts. When happy lock them hard to avoid slipping. For this process, have a slit in the beam and the grism out of the beam. Note that the mountain crew usually manages to get a very good rotation by eye, but it is worth checking.

The normal orientation of the slit is E-W, with the south-port rotation encoder set at 063.0. Unfortunately, this zero point appears to change occasionally, so if this is important, you should verify the orientation with a star trail. The position angle can be changed by rotating the port, and the formula is encoder # = 153.0 - PA (measured N thru' E).

### (c) PXL and STAR-1 Guiders

The guiders mount on a translation stage in the guider box, and will generally be installed by the day crew. In order to provide a better plate scale, a simple focal reducer consisting of a 50mm camera lens and an achromat is used. The camera lens should be focused at infinity.

To install, first remove the back plate of the guider box. The two captured thumb bolts are unscrewed, while also turning the translation thumb-screw anti-clockwise. In this way the back plate can be unscrewed from the rest of the unit. The translation plate can be withdrawn and the guide camera mounted to it. There is a separate plate to which the camera mounts, and this then attaches to the translation plate. The unit then slides back into the guider box. If things are too tight, loosen the bolts holding the lock bar (on the left of the unit as you look at it) a little. Once the guider is installed re-tighten a couple of these bolts until movement is possible but a little stiff. To re-install the back-plate, screw the translation thread into the translation plate, and screw in the thumb screws.

Once the focus has been adjusted on a star, the guider can be locked in place by tightening the four T-head bolts on top of the guider box, to prevent shifts in its position (David Doss can show where these are if it is not obvious). To be absolutely sure, the bolts on the lock bar can be tightened fully from the underside, with a T-bar allen wrench from the LCS. This is a rather laborious exercise, but needs doing only once per run. There is now a scale pasted inside the box with a nominal position marked for PXL.

**(d) Control Box**

There is no computer interface for IGI. Instead, the silver remote control box is located in the control room and is cabled via the patch panel on the south side of the platform. It should be set up by the mountain staff. Use the 6-1 six-pin military connector in the patch panel to run the cable from the instrument. The other end of the cable attaches to the large 8-pin connector on the instrument. In the control room the patch comes out on the back side of the rack containing the TVmonitor and TC switch panel: the second rack from the right looking from behind. It is labeled ’107" Cass 6-1’ and is located on the right side of the unit at the bottom (hard to find!). Attach the 6-pin plug on the short control box cable to this and the other end to the back of the control box. Find a power outlet in the same general vicinity for the control box and verify that it has power (smoothly turn on the circuit breaker on the back and the red neon indicator should light). There is also a power indicator light on the front of the unit. You now have control!!

Check the operation of the remote translation stages for the slit and grism. The slit is now run by a pneumatic cylinder and the LEDs on the control unit indicate the position. The grism is run by a servo motor, which can be tested by changing the position of the switch and looking for current on the ammeter. The stage should draw current while it is moving and then the current will drop to zero when the movement is complete. The translation takes ~10 seconds. Both stages can be moved at the same time.

Note that the grism stage has a disable switch. For historical reasons it used to be possible to hit the long f.l. camera lenses with the grism so it needed to be disabled. It is still possible to hit, but these modes aren’t used any more. If the grism stage doesn’t work, check that the switch is in the UP position.

**(e) Periferal equipment.**

(i) **Calibration lamps:** There is no internal calibration source for the IGI, and it is necessary to use external emission tube sources which are best set up on the roof of the control room near the crane if the IGI is mounted on the South port. These lamps have a power supply and are controlled simply by plugging the supply into a mains outlet. They take a few minutes to reach maximum brilliance. Be careful changing the lamps when they are hot! Do not handle them with bare ahnds in any case as grease shortens their lives. Use a tissue or pair of gloves. At the 82" be careful to set up the lamp and power supply far enough away from the pulpits and dome rotation hardware to avoid collisions!. The lamps should be requested in your rfs. Of the available lamps, the Neon, the Argon, the Mercury, and the Cadmium are the most useful. The Neon has good lines for use in the red, and argon has faint blue lines which can be detected in a long exposure (try 500s in a dark dome). Cd and Hg have strong well-spaced lines that are excellent for IGI. A third or fifth order polynomial provides a good fit to the dispersion relation. BE VERY CAREFUL WITH THE NEON LAMP AS IT IS NO LONGER POSSIBLE TO BUY A REPLACEMENT!!

(ii) A **flat field lamp** mounted on the back-side of the secondary is very useful for spectroscopic flats, but will be too bright for broad-band imaging (use the incandescent passage lights in that case). This should be requested in your rfs. It is controlled with one of the buttons on the "garage door opener" remote control.

## II. Testing, Focusing and Calibrations

A quick test that everything is functioning would involve turning on the control box in the control room and verifying that the translation stages work. Check that the guider reads out, that the telescope focus works, and that TK4 reads out in ICE.

The focusing and rotation are best done by two people. Focusing of the spectrograph should be done in the afternoon before the first night's observing. One way to focus is to use the 'focus slit' which is the unanodized aluminum bolt. You can do it in imaging mode or with a grism depending on your preference: there is not a huge difference. I usually focus against the passage lights in imaging mode, and then check the spectrum. If doing it in spectral mode, the bright mercury lines in the fluorescent dome lights are suitable for obtaining the first-order focus, while the external calibration lamps (such as Neon or Cd) should be used for the fine adjustment. Integration times around 10 sec are adequate for the Ne or Cd lamps and 1 sec for the fluorescents. The instrument is focused by adjusting the focus of the Canon camera lens. Note that only very small adjustments from the nominal positions given in table 1 will be necessary. Table 1 gives the position as read from the focus ring in term sof a particular distance inscription being over a particular f-ratio number (either left or right). It should be obvious when you look at it. The unanodized focusing slit tapers and will allow a focus <2 pxl to be achieved. Note that it is not aligned correctly with the other slits, though.

The simple optics in IGI do have some abberations, so that lines at the ends of the spectrum have slightly asymmetric wings. Note that there is some barrel distortion in the spectra, but this is at a low level, and can be easily removed from the spectra in software if there are comparison lamp observations over the whole wavelength range. Generally though, for small objects this need not be done. If you are concerned about a true 2-dimensional reduction, a bright star should be observed at several points along the slit in addition to the comparison spectra. This will give the routines in IRAF sufficient information. We will supply a mask of pinholes for this calibration in the future.

## III. Observing

### (a) Slits and Filters.

There is quite a large selection of slits available, and it is a relatively simple matter to fabricate slit inserts for specific needs such as multi-slit spectroscopy. The present slits are summarized in table 2. The wavelength range can be adjusted to some extent by changing the position of the slit and hence the angle of incidence onto the grism.

**Table 2**
Available Slits and Wavelength Ranges
(Blue Grism, TK4, but not updated)

| Slit | Width arcsec | blue range | red range | resolution A | Comment |
|---|---|---|---|---|---|
| 1 | 2.0 | 4720 - 7920 | --- | 12 | |
| 2 | 2.0 | 4300 - 7500 | 5150 - 8350 | 12 | |
| 3 | 2.0 | 4140 - 7340 | 5330 - 8530 | 12 | |
| 4 | 2.0 | 3870*- 7070 | 5600 - 8800 | 12 | |
| 5 | 2.5 | 4720 - 7920 | --- | 16 | |
| 6 | 2.5 | 4300 - 7500 | 5150 - 8350 | 16 | |
| 7 | 2.5 | 4140 - 7340 | 5330 - 8530 | 16 | |
| 8 | 2.5 | 3870*- 7070 | 5600 - 8800 | 16 | |
| 9 | 3.25 & 5.8 | 4720 - 7920 | --- | 20 | 2 slits on insert |
| 10 | 2 & 10 | 4300 - 7500 | 5150 - 8350 | 12 | 2 slits on insert |
| 11 | 2 & 10 | 4140 - 7340 | 5330 - 8530 | 12 | 2 slits on insert |
| 12 | 2 & 10 | 3870 - 7070 | 5600 - 8800 | 12 | 2 slits on insert |
| 13 | 1.0 | 4320 - 7520 | --- | 6 | Focusing slit |

*There is little throughput below 4000A

Note: The wavelength ranges refer to the G6000 grism with TK4 as the detector and the 50 mm camera lens. Add ~2050A to these numbers for the G8000 grism wavelength ranges.

The blue range is achieved by having the slit on the right of the optical axis and the red range by having it on the left. It is pointless using the blue side for most of the slits though as there is little throughput below 4000 A. Change the side of the slit handle to change between. Vignetting reduces efficiency about 15% as the slit is moved off axis.

There is no separate filter holder in IGI, so using blocking filters is difficult. If you need to use a blocking filter for wavelengths redwards of ~7800A, these should be requested and mounted above the slit unit. The way to do this is to remove the guider box access hatch with the slit/filter translation unit *in* the beam, and place a 2" square blocking filter on top of the slit unit: it will rest in the recess there (this obvious when looking at it, though difficult to explain. At present there is no permanent arrangement, so hold the filter in place with tape. The telescope focus will be changed by the extra path length through the glass so if you’re going to use a blocking filter, focus the telescope with it in place (i.e. focus a star through the slit: this is a little time-consuming, but once done once, the differential focus shift introduced by the filter can be noted and then applied ’blind’). We will probably create a filter holder for large blockers above the slit. See Gary Hill about this.

2" and 2.5" filters for imaging can be mounted in the filter holders using the L-shaped lock brackets. The brackets should again go down (towards the CCD) when the unit is mounted in the slit translation unit. Note that 2.5 inch filters will give a larger fov, but with worse vignetting and image quality. We do not have 2.5 inch filters at present.

**(b) The First Night**

Once the instrument is focused the next steps require a star. Acquire a bright star and zero the pointing (use a 0.1 second exposure as the system is very fast). You may need to roughly focus on this star if the telescope is way out of focus. The nominal telescope focus is 37800. Then move the bright star to the offset guide field about 10 arcminutes West. At this point there should be stars in the spectrograph's field of view (imaging mode) to focus the instrument with. Use imexamine in IRAF to check the profile.

Once in focus, equip your assistant with the intercom on the phone, and send him/her out to the platform to focus the guider. Rotate the thumb screw at the back of the guider box until the star is in focus. If the thumb-screw will not turn easily, loosen the clamping bolts a little to prevent the thread stripping. The minimum is quite broad. Once happy it is important to clamp the guider to prevent it shifting during the night (it can jump a few arcseconds if not clamped). First tighten the four T-head bolts on top of the guider box. Then if you want to be completely sure, tighten the lock-bolts inside the guider box.

Now observe!

**(c) Setting up on an Object**

The CCD is used for object acquisition. Move the grism and slit OUT of the beam, having first noted the pixel position of the center of the slit, take a short integration and identify the object. Acquire a guide star. The object can then be moved onto the slit position and the slit and grism then moved back into the beam for the observation.

**(d) Guiding**

Since the offset guide mirror is fixed, guide star acquisition is simply a matter of exposing the guide camera and choosing a star to guide on. Typically there will be at least one star visible in the field (~2x1 arcmin. with STAR-1 and 4x4 arcmin. with PXL), without the need for long integration times. The offset field is displaced by a significant amount (about 10 arcmin West) from the optical axis.

**(e) Software**

The optimum setup for IGI at the 107" is to use ICEX on oberon for data acquisition, the PXL guider run from mimas in a window on oberon, and the TCS in another window. There are three monitors, and we like to set up with the guider on the left, the science data in the middle and the TCS on the right. The following command sequences will assume this setup.

**A. Guider**

For both Guiders: run the guider on mimas. open a window on oberon, log into mimas, be careful how you set up so as to avoid encription which really slows things down.

oberon> xhost + mimas
mimas> setenv DISPLAY oberon:0.0

**PXL:**

mimas> ˜pso/pgdr-3.31 &
set **instrument to igi**

**Expose.single** will take a frame. You can set the readout region with the left mouse button and then

the centroid box within that region also with the left mouse button. The delete key removes them sequentially.
**Expose.guider** brings up the guider control where autoguide can be turned on/off and the readout sequence can be started/stopped.

**STAR-1:**

STAR-1 is used with the Coude frame grabber which is harder to set up.

mimas> ˜pso/fgdr-3.25 & (frame grabber)
**Instrument** CS1 Slit Rotator
**Instrument.modify** position angle offset = -65, Arcsec/pxl = 0.40, Flip both axes
**Expose.guider** set minimum correction to 0.25 arcsec
**Expose.setup** set integration (frames) = 30 x integration time (it is a 30 frame per second grabber). After a star-1 scan has completed, hit start in the **Expose.guider** window.

Set star-1 going. Use integration of about 3 sec (don't go less than 1 sec). Set ROI 0 (middle mouse button stops ROI but you have to keep hitting it)

**B. TCS**

Open a window on right monitor of oberon
oberon> tcsgui &

Use 2.7m Cass f/9 model. I recommend that you load your coordinates into a worklist as there are nice features that plot the objects and you won't have to type coordinates. **File.open worklist** to load the list, and **Next.Work Lists** to select coordinates from the list. Once an object is selected with **Apply**, use **Go Next** to send the telescope. Hold down the deadman switch on the dome floor to slew the telescope.

**C. ICE and data acquisition**

This is not an ICE tutorial, but the specific IGI/TK4 related stuff is here. IGI is not controlled from ICE, so be careful not to start a 60 min spectral exposure without the slit or grism! The instrument status is not reported in the header except for the rotator angle of the waveleplate in polarimetry.

**detpars** We recommend using integrator 2 of the CCD controller, which is a good compromise between speed and read noise (3.33 electrons). If you have very low signal observations and need the lowest possible noise, use integrator 1. 18 bit operation makes proper use of the large dynamic range of the detector (full well 150K electrons or 228K ADU at 0.657 electrons/ADU).

From Phillip MacQueen's TK4 controller upgrade memo:

```
 - There are three readout speeds, corresponding to the three different
   integrators in the signal processor:
     int=1:  25 kpixel/s readout rate,
             45 s full frame 1x1 coaddition readout time,
             2.7 electron readout noise for 18-bit data
     int=2:  50 kpixel/s readout rate,
             23 s full frame 1x1 coaddition readout time,
             3.3 electron readout noise for 18-bit data
     int=3:  100 kpixel/s readout rate,
             12 s full frame 1x1 coaddition readout time,
             4.6 electron readout noise for 18-bit data
 - The readout noise is not a function of serial coaddition
 - The full well has increased to 150,000 electrons, which corresponds to
   full scale of the data range.
```

```
ic> lpar detpa
     (firstcol = 1)              First column of data (device coordinates)
      (lastcol = 1024)            Last column of data (device coordinates)
     (firstrow = 300)             First row of data (device coordinates)
      (lastrow = 750)             Last row of data (device coordinates)
       (colbin = "1")             Column binning factor (1,2,3,4,8)
       (rowbin = 1)               Row binning factor (1,2,...,8)
    (amplifier = "3")             Detector amplifier(s) to use
         (gain = 1)               Detector gain setting (1=1x,2=2x)
   (integrator = 2)               Detector integrator (1=slow 2=medium 3=fast)
       (detpix  =  "l")             Data  type  of  detector  pix  (u=16-bit  l=18-bit)  (iflushperiod  =  100)
Period between flushes when idle (-1 to 15000 s
    (dumpdrain = no)               Use the dump drain for flushing if CCD has one
      (srdrain = no)              Use serial register as a drain during flushing
     (preflush = yes)             Flush the CCD before all integration types
      (detname = "TK4")             Detector name
       (detcap = "runlib$detcap") Detector capabilities file
      (detinfo = "")              Optional image header info about detector
        (angle = 0)               Detector angle from nominal
      (nframes = "")               IR Detector sum/average nframes
        (debug = no)               Debug the detector interface
       (bypass = no)               Place the detector interface into bypass mode
```

**instrpars**, the only entries are:

```
    (instrname = "igi-50")        Instrument name
     (instrcap = "runlib$instrcap") Instrument capabilities file
        (debug = no)               Debug the instrument interface
       (bypass = no)               Place the instrument interface into bypass mode
```

The IRAF script **offset.cl** in /home/oberon/hill/ICE/scripts allows quite accurate offsets of the telescope. Its parameters for the 50 mm camera lens are:

```
ic> lpar offset
     (platesca = 1.03)             Plate scale (arcsec/pixel)
     (centroid = no)               Use imexamine to centroid
        (slitx = 489.2)           slit X coordinate
        (slity = 200.)            slit Y coordinate
         (flip = yes)             Flip RA direction
      (sendtcs = yes)              Send offset to TCS
      (bigmove = yes)               Allow moves over 120 arcseconds
```

Set the center of the slit (slitx,slity). Start the script and then center accurately on the object, and press q. The telescope will offset and the guider will move the guidebox in sympathy so long as it remains within the readout region. You typically need 2-3 moves to get the object on the slit, but it can be done in less than 5 minutes, with high accuracy.

## III. Who to call...

IGI is a very reliable instrument due to its simplicity. However, things can go wrong, and if you have identified a problem which is specifically due to an IGI malfunction, it is best to talk to David Doss. If he cannot solve it, call Gary Hill.