A proto-user's manual for OSIS R

J. Bouvier, 26/11/96

1. Introduction

On November 21, Jon Seerveld, Barney Magrath and I performed tests of the new high resolution grisms and new cutoff filters for OSIS R. The new low-resolution H grism (which replaces the previous one whose zero deviation wavelength was in error) was also tested. The tests were done with the instrument on the mezzanine: OSIS R + RedEye Wide. We used an halogen lamp for flat fields and an argon lamp for calibration spectra.

2. Definitions

We use the following acronyms throughout the document
J120: lowres J grism
H100-1: (new) lowres H grism
J360: hires J grism
H316: hires H grism

JH: J+H thermal cutoff filter
C1.6: new <1.6 μm cutoff filter
C1.7: new <1.7 μm cutoff filter

3. HIRES vs LOWRES grisms

Table 1 gives the basic properties of OSIS R grisms.

Table 1: OSIS R grisms

Grism	Dispersion (A/pix)	λ_o (A)	Resolution (FWHM(Argon))	Resolution (2.5 pix)
J120 (1"slit)	13.5 (0.7)	12975 (30)	520	385
J120 (0.5" slit)			865	
J360 (1" slit)	4.5 (0.1)	12050 (10)	1600	1070
J360 (0.5" slit)			2200	
H100-1 (1" slit)	18.5 (0.5)	16550 (50)	551	360
H100-1 (0.5" slit)			1270	
H316 (1" slit)	4.1 (0.1)	16225 (10)	2220	1580
H316 (0.5" slit)			3245	

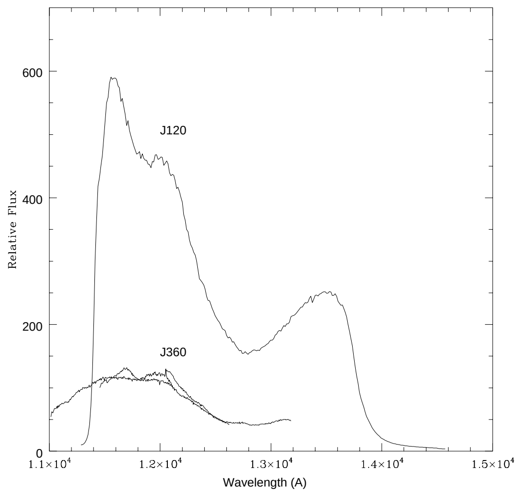

Figure 1: Relative efficiency of the lowres (J120) and hires (J360) J grisms.

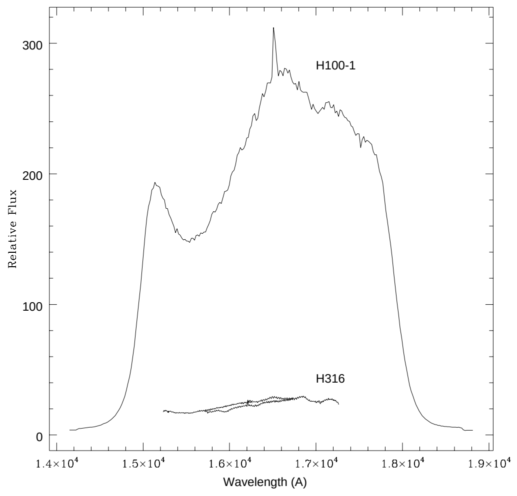

Figure 2: Relative efficiency of the lowres (H100-1) and hires (H316) H grisms.

Table 1:
λ_o: zero-deviation wavelength
Resolution (1): $\lambda/\Delta\lambda$ from FWHM measured on Argon lines
Resolution (2): $\lambda\Delta\lambda$ for 2.5 pixels resolution
Approximate rms uncertainties given in parentheses.

Figures 1 and 2 provide relative efficiency of lowres and hires grisms. These curves were obtained using a white lamp at the entrance of the spectrograph. Therefore, they do NOT show the absolute efficiency of the grisms, not even their spectral response (since we do not know the spectrum of the white lamp and the curves were not corrected for detector response; absolute calibration and spectral response determinations must await observations on the sky). These curves only show the RELATIVE flux per pixel on the detector from lowres and hires grisms (all curves were normalized to the same exposure time). Note that no scaling factor has been applied to correct for the different dispersion of the grisms. The curves therefore show the relative number of photons per pixel obtained on the detector when switching from lowres or hires grisms, not their true relative efficiency (which would require a normalisation of the curves by the respective dispersion of the grism, see Table 1).

3 curves describe the response curve of the high-resolution grisms. This is because the detector is too small to accomodate the whole spectral range of these grisms with only one slit. Therefore, 3 spectra were taken with each hires grism through 3 slits located at the bottom (Y=5), middle (Y=129), and top (Y=240) of the 256×256 detector, respectively. This provides a *lower limit* to the accessible wavelength domain with these grisms (the slit may lie outside of the detector, thus slightly extending the spectral range shown in the figures).

4. Cutoff filters: response curve

Figures 3 and 4 show the effect of the cutoff filters on the spectral response. The 3 cutoff filters (JH, C1.6, C1.7) have the same transmission in the J-band. They of course have quite different transmission in the H-band, with a sharp cutoff at 1.6 μm for C1.6, and at 1.7 μm for C1.7.

5. Cutoff filters: thermal background

Table 2 provides thermal background measurements with different combinations of grisms and cutoff filters. All measurements were done with a LAMA mask in the way. The 2 new cutoff filters are very efficient in reducing the thermal flux arising from beyond their respective cutoff limits and should be preferred to the JH thermal cutoff filter for J-band observations and for H-band observations below the cutoff limit.

On average, the thermal flux in the H-band is 4.2 ADU/s with the JH cutoff filter and is down to 1.1 ADU/s with the C1.7 cutoff filter, and further reduced to 0.55 ADU/s with the C1.6 cutoff filter. In the J-band, the thermal flux amounts to 0.23 ADU/s on average, whichever cutoff filter is used.

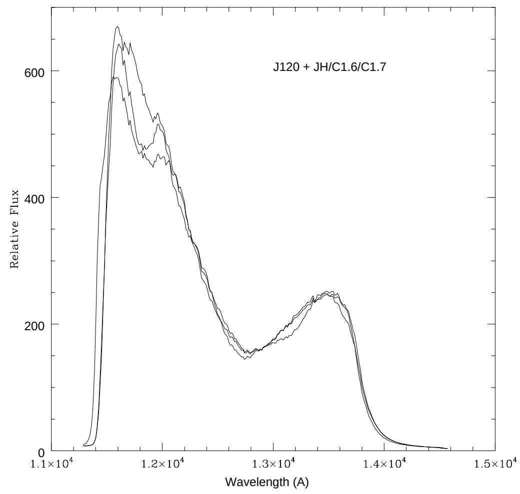

Figure 3: Relative efficiency of the lowres J grism (J120) used in combination with the JH, C1.6 and C1.7 cutoff filters.

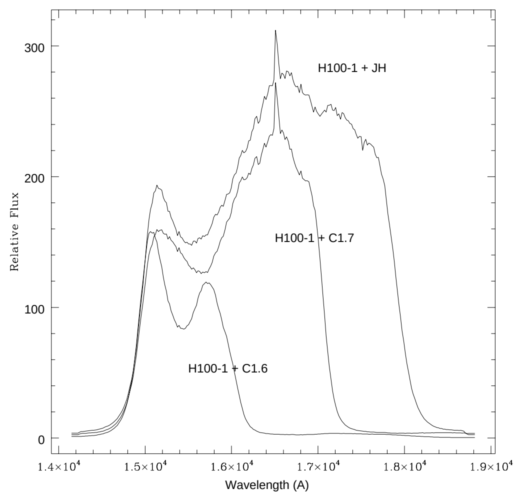

Figure 4: Relative efficiency of the lowres H grism (H100-1) used in combination with the JH, C1.6 and C1.7 cutoff filters.

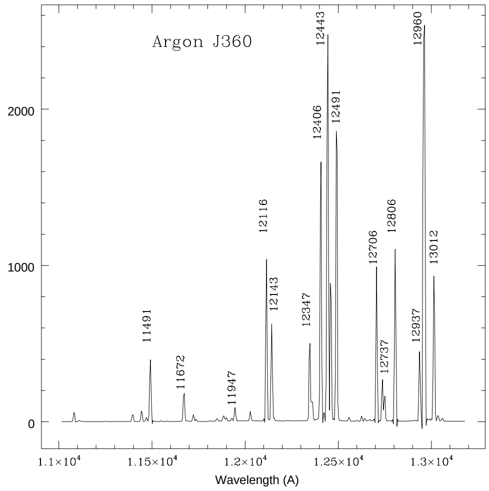

Figure 5: J360 Argon spectrum.

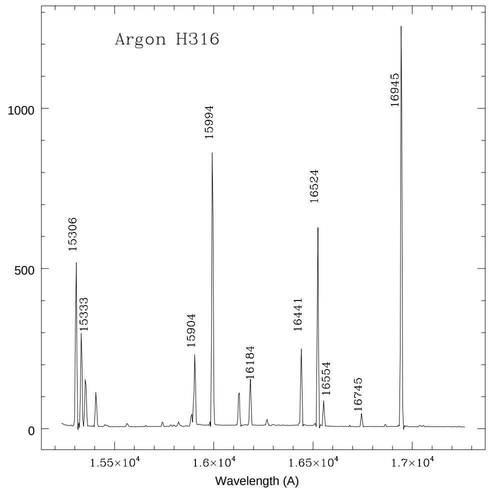

Figure 6: H316 Argon spectrum.

6. Argon spectra

FIgures 5 and 6 provides line identification for calibration Argon spectra in the J and H band for the hires grisms (1" slit).

Table 2: Thermal background (ADU's)

Grism+filters	10s	30s	60s	120s
H316+H+JH	55	125	227	423
H136+H+C1.7	14	32	57	106
H136+H+C1.6	8	18	28	40
H100-1+H+JH			200	
H100-1+H+C1.7			56	
H100-1+H+C1.6			19	
J360+J+JH			15	
J360+J+C1.7			13	
J360+J+C1.6			13	

7. Tips for obtaining high-quality near-IR spectra (from Meyer's thesis 1996)

A. Determination of and correction for telluric absorption.

Telluric absorption features and their variation with airmass can be estimated by observing the same A0-type star (A0 stars contain the fewer number of metallic lines in the H band) at different airmasses. Assuming that the opacity of telluric absorption is directly proportional to airmass, and that extinction did not vary during the night, the ratio of two A0 spectra obtained at extreme airmasses (e.g. X1=1.0 and X2=2.5) will provide an opacity map

$$\tau(\lambda, X = 1.0) = \frac{1}{(X2 - X1)} \times \ln \frac{I(\lambda, X1)}{I(\lambda, X2)}$$

The opacity map can then be scaled to any airmass X to provide the location and strength of telluric absorption features in the target's spectrum:

$$\tau(\lambda, X) = X \times \tau(\lambda, X = 1.0)$$

The target's spectrum corrected for telluric absorption is then obtained from:

$$I(\lambda, X = 0) = I(\lambda, X) \times \exp^{\tau(\lambda, X)}$$

.

Another way to proceed is to observe an A0 star at the same airmass than the target and use a theoretical A0 spectrum to estimate the location and strength of the telluric absortion features.

B. Flats, darks and bias

Here is *one possible way* to deal with flats, bias and darks. You may have a better one.

a. Get several (>7) flat-field frames on the dome both with lights ON and with lights OFF with the same exposure time. The lights-off frames provide background measurements including dark, bias, and the thermal emission from the telescope. This is to be done for all different grisms/filter/mask combinations you plan to use on the targets.

b. Median filter lights-off dome frames and subtract the median from lights-on frames.

c. Median filter the resulting lights-on frame and use that as a flat-field.

C. Get the spectra

The following considerations (again, without any guaranty this is the best way to proceed) complement but do NOT replace the procedure outlined by J.-G. Cuby for getting high-quality near-IR spectra of very faint objects (attached below). It also applies to bright objects as long as they are not too extended.

Take several (n) spectra of the target at different and non-overlapping locations along the slit. Median filter the n spectral frame to obtain a background frame containing both thermal background as well as molecular sky-line emission from OH and O_2. Subtract this background frame from each spectral frame. You are now ready to flat-field (divide) the background-corrected spectral frames by the flat-field of 7.B.c.

D. Near-IR sectrophotometric standards.

There are no such things as near-IR spectrophotometric standards yet. If you wish to correct the continuum slope of your spectrum from the spectral response of the instrument (grism+detector), you may want to get a spectrum of a hot star whose spectral energy distribution in the near-IR is well-approximated by a black-body curve.

8. Data reduction within IRAF

Although you probably have your own preferred data reduction package, there are dedicated packages for long-slit and multi-slit data reduction in NOAO/IRAF. Documentation is to be found on-line within IRAF in the packages TWODSPEC.longslit and TWODSPEC.apextract.

9. A few references

Here is a non-exhaustive list of references of atlases of near-IR stellar spectra (luminosity class I to V, spectral type O to M):

Meyer M.R. (1996) Ph.D. Thesis, Univ. Massachussetts (Sp. O-M, Lum. I-V)
Dallier R., Boisson C., Joly M. (1996) A&AS 116, 239 (O-M, I-V)
Lançon A., Rocca-Volmerange B (1992) A&AS 96, 593 (O-M, I-V)
Walborn N.R., Bohlin R.C. (1996) PASP 108, 477(O-B supergiants)

Jones H.R.A. et al. (1996) MNRAS 280, 77 (M dwarfs)
Legget S.K. et al. (1996) ApJS 104, 117 (M dwarfs)

10. OSIS R and OSIS V

Most of the capabilities of OSIS infrared (OSIS R) are a near-IR extension of those of OSIS visible (OSIS V). You therefore have to read the detailed and updated OSIS V manual available on CFHT's Home Page as a first step towards the use of OSIS R.

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Appendix: J.-G. Cuby's important recommendations

The pixel size is 0.5" with the current OSIS / Redeye wide configuration. Therefore, you will have difficulties if you are interested in fine spatial resolution. In consequence, it is not really necessary to resort to the SIS guide probe + active mirror (as explained in the OSIS V manual). Moreover, the combination of the small field of view and of the high skies in the IR make that you will have little chance to find an object of suitable brightness in your field, unless you observe in regions crowded with bright objects. Therefore, I would suggest that you do not waste your time trying to use the active mirror, unless you really want to get the best possible images.

HERE IS THE MOST IMPORTANT THING:

It is extremely important to take at least 5 biases after almost each exposure, and even more after bright exposures (flats, calibration stars, etc.), to reduce residual images due to redeye (*update: this may change soon as CFHT is implementing an automatic and transparent procedure to reset the detector between each exposure. Inquire.*). This biases have no interest in themselves, apart reducing the level of persistence which is the most problematic thing of redeye. This is not an extremely swift operation to take 5 to 10 biases, therefore you have to take the reflex, after each image, to immediately take these biases. If this really becomes a reflex, then, you will not really waste time while you are looking at your image, or discussing with the TO to change your field,etc. Also, to save a bit of time, you'd better combine (by clicking on the relevant button in the 'expose' window) these biases: this is faster, and you will not get hundreds of bias images which are useless, just a few tens...

DEEP IMAGING: acquiring the field

To identify your objects and cut the masks, you clearly need deep images of you field(s). It is stongly recommended to acquire these deep images with

a shift and add technique. For that, you send offsets with the 'offset' button on the Pegasus session. There, you can type offsets in X and Y, in number of pixels.
E.g., in the 'offset' window, you type:
CURRENT POSITION NEW POSITION (approx. terminology)
X = 0 Y = 0 X = 0 Y = 1

if you want to move your object one pixel vertically. You can use fractional pixels, though this is not recommended because you will need to recombine your image afterwards, therefore you want to deal with integer offsets. **DON'T FORGET TO CAREFULLY NOTE YOUR OFFSETS**, most preferably with respect to the first image. Also, because that will help you when you will re-acquire your field for spectroscopy, carefully note the telescope / guiding probe of the telescope. The TO will do that for you if you ask him with a smile. In J, you can use integration times of 3', less in H (1', to be confirmed). The total integration time is of course at your convenience, at least 15' if you have really faint objects. The offsets to give between individual images are also at your convenience. You can try a Swiss-cross-like pattern with offsets of 2 to 5", or probably better use a random pattern.

You create a flat field by a simple summation of all the images you got, without any offsets. If you have bright objects in your field, you probably want to reject them before generating this super flat, otherwise you will get poor results. You can also try using flats taken on the dome, at twilight, or with the calibration unit.

Then, process the individual - flat fielded- images with IRAF (imcombine for combining the images), note that you have to enter the offsets in a list with the opposite offsets that you have given, still wrt the first image in the list. You should now see your objects. Don't expect to see much before having reached this point, unless you have moderately bright objects in your field.

From this combined image, you will cut the mask. Be aware that your combined image has now a new format (no more 256 x 256), because of the offsets you gave. Therefore, to recover the original format, with the same centering as e.g. the first image, you have to do a bit of arithmetic, not necessarily trivial at the altitude of CFHT, and extract the correct 256 x 256 image you want. This is not a big issue if don't deal with this point, the only consequence is that you will have an offset between your mask and your field when re-acquiring it. You will have offsets anyway, but say larger than what you would normally expect. The larger the offsets you gave, the larger the output combined image, and the larget the offset between your mask and your re-acquired field.

IMPORTANT NOTE ABOUT BONNETTE ROTATION (see also SIS manual).

If you are not happy with the orientation of your field, because you cannot assign slits to your objects in a convenient way, you may want to rotate the bonnette and re-acquire (this is mandatory) your field at the changed orientation. Here you run a risk: the bonnette control is not sufficiently precise, and you will never re-position yourself at another bonnette rotation position. For example, you have two fields, of which you want to do MOS, but not with the same bonnette orientation. You will therefore design your masks according to the images you got in the two different orientations. And when going from one field/mask to the other, you will have to rotate the bonnette, and will not come exactly at the same position you had when you took the image. Then, your field is slightly mis-aligned wrt the mask. However, given the rather limited field of view of OSIS for the time being, this is unlikely to significantly affect your data, therefore all this paragraph you could have skipped, and you can do all the offsets you want. But don't forget when changing the masks to change the bonnette rotation accordingly.

Image re-acquisition before spectroscopy

Later in the night, or the day after, you start being serious: spectroscopy. You have properly installed your masks in the holder, and you have to re-acquire your field. Because it is most likely faint without bright objects in it, this is not that easy. You may have to integrate for some time (a few minutes), and go to the data reduction workstation to process your image (flat fielding at least, be extremely cautious if you use offsets for shift and add at this stage, you can make BIG errors), to re-identify your brightest object(s). Because you have assigned a slit or a hole to this 'bright' object (don't hesitate to use 3" diameter), you will be able to offset the telescope to the mask position. For that, AFTER you re-acquired your field, you position the mask, without the grism for the time being. You take a short exposure (a few seconds), and you get an image of the mask (the sky through the slits). You measure the position of the hole (or slit) assigned to your 'bright' object, and you just send the offset to the telescope.

If the measured position of your 'bright' object was X 123 Y 99 and if the measured position of the hole this object shall be in is X 110 Y 105, then you have to type:

CURRENT POSITION NEW POSITION (approx. terminology)
X = 123 Y = 99 X = 110 Y = 105

FILTERS

I recommend to always use the J or H filter on wheel A, plus the cutoff J+H on the other wheel, at least on faint objects (*update: see new cutoff filters now available above*). This allows to reduce the thermal background in both bands, since there is some 'red leak' in the wings of both J and H filters in the K band which give extra background. The penalty is 10 transmission, but you still gain in S/N on faint objects.

CALIBRATIONS

+ Ar. A few second integrations, more in H than in J. These exposures are not vital since OH imprints a good wavelength reference spectrum on the sky exposures. Always helpful anyway.

+ flat fields: there is a pb with the gumball machine (the calibration unit): absorption due to the Fresnel lenses, mostly important in H. Prefer dome flats whenever possible. Note: with the gumball machine, use the halogen image lamps even in spectroscopy (with the low resolution grisms), the spectral ones are too bright.

+ darks. A difficult piece of work. Take several darks for each exposure time used during the observations. i.e. for each exp. time used on calibration exposures, sky exposures etc. I prefer to take several darks of the sky exposure times along the night, since the dark background (which is a complex mixture of detector dark current and thermal background) may vary significantly during a night. It is common to see darks with highly variable count levels. Hence, it is preferable to have many of them for building some kind of reliable super-dark that you can use at the end. Note however that darks are not a priori necessary if resorting to nodding along the slit, because you then reduce the data subtracting pairs of exposures. Still useful anyway, to further subtract residuals. Anyway, take darks with the same filters you used during the observations, and with the same exposure times, at least at beginning and end of night. I would recommend at least one during the night.

+ Standard stars: photometric standards can be found in the redeye manual. For telluric absorption correction, the best is to use hot stars, O, B, eventually A if O or B stars are difficult to find. These stars have essentially no absorption lines in the near IR, hydrogen lines becoming apparent in A stars. Surprinsingly, there are no spectroscopic standards as in the visible. To correct for instrumental response, then the stars used for telluric absorption may be used, as their spectral type is better known than for the photometric stars.

SKY EXPOSURES

In J, you can integrate up to 20' in spectroscopy, less in H. The best compromise has to be found on the sky. On the one hand, you don't want to saturate the array on the bright sky lines, on the other hand you want to get enough signal in the very few clear windows between the sky lines to 'see' your objects and trace them for data reduction. A further trick is sky variability with time, which if you use nodding along the slit may become a problem when you subtract pairs of exposures. Here we are: until the reverse is demonstrated, I still think that the best procedure for observing is to resort to telescope nodding along the slit(s). This requires that you have sufficiently long slits, for nodding by at least 5" between pairs. A further refinement is to shift and add. Schematically:

——————————————————-

A1 A2 A3 B1 B2 B3

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with typically a few arcsec between A and B, and a few tenths of arcsec between Xi and Xi+1. Sequences of exposures are: A1 B1 A2 B2 A3 B3 or A1 B1 B1 A1 A2 B2 B2 A2 A3 B3.. Then, you can reduce the data subtracting pairs of exposures A1 - B1, A2 - B2 etc. This way, you subtract automatically the sky + dark backgrounds. What you can get is sky line residuals if sky varied between pairs of exposures. These residuals can then in principle be removed by simple interpolation across the slit.