ISHELL DESCOPE OPTIONS

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Revision History

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Contents

1 INTRODUCTION

Feedback from the iSHELL PDR panel recommended investigating instrument descope options as a means to remain within budget and schedule. We start by identifying what we consider to be iSHELL's core science objectives and then consider the impact on these of various descope options. Following this discussion we recommend a descoped instrument configuration.

A wholesale redesign of the instrument is not considered since this will lengthen the schedule. The most viable approach is to remove optical modes that are not needed for core science but with the possibility of upgrades at a later date.

2 CORE SCIENCE

The key science cases developed by the iSHELL science team and from which the high level instrument requirements were derived are given in Table 1 together with the required wavelength range of the spectroscopy (implications for immersion grating), filter required for acquisition and guiding (implications for slit viewer), and whether the target is a point source or extended (implications for slit length).

Table 1. Key science cases from iSHELL Science Team

Key Science Case	*Spectroscopy*	*A&G*	*Source size*
Comets	*LM′*	*K* and *L* (daytime)	extended
Atmosphere of Mars	*L*	*K*	extended
Atmospheres of Jupiter and Saturn	*LM′*	*M′* acquisition	extended
Jupiter H_3^+ Juno mission support	*L*	*nbL* acquisition	extended
Atmospheres of hot giant planets	*KL*	*K*	point source
RV searches for young planets	*K*	*K*	point source
Young binaries and PMS calibration	*HK*	*K*	point source
Protostellar envelopes	*M′*	*K*	point source
Protostellar evolution	*LM′*	*K*	point source
Magnetic fields and rotation	*HK*	*K*	point source
Stellar library	*JHKLM′*	*K*	point source

The IRTF's primary science mission is solar system science. Of the original key science cases clearly comets and the atmospheres of Jupiter, Saturn and Mars must be part of iSHELL's core (indispensable) science investigations. These require an immersion grating optimized for use at *LM′* and long slits (at least 15″ and up to 25″ for H_3^+ observations of Jupiter). A descope option is to remove the slit wheel in the slit viewer and used a fixed *K* for acquisition and guiding. However, the planetary science cases require careful positioning of the slit on the plant and therefore need filters in which the features of interest can be identified (e.g. a *nbL* filter for H_3^+ features on Jupiter, and an *M′* for hot spots on Jupiter).

The majority of potential iSHELL users will want spectroscopic capability at *H* and *K* on point sources. This is where CSHELL is currently mostly used and where low background array performance is critical. iSHELL needs to replace this capability. In addition, important protostellar science at *L* and *M′* will be enabled by the high resolving power of iSHELL. Although desirable, there are no strong drivers to include extended objects and *J*-band science in the core (descoped) science.

A further requirement in the original science case was for the slit viewer to function as a science imager in addition to its primary role for acquisition and guiding. The logic being that imaging photometry would enhance the science return for a subset of programs and help the operational efficiency of the telescope by not having to switch in another instrument for ToO programs needing imaging. This requires a full complement of filters in the slit viewer. However, this is not part of iSHELL's core science.

3 DESCOPE OPTIONS

The current optical configuration of iSHELL is given in Tables 2-6. This assumes the use of two silicon immersions grating: one optimized for *LM′* and one optimized for *JHK*. This optimization matches the free spectral range to the width of the H2RG array at about 4.1 μm and 2.5 μm respectively for the most efficient use of the array format. The use of the optimized *JHK* immersion grating also allows the use of relatively long slits (15″) at *JHK.*

The science team encouraged the use of long slits at *JHK* as it was felt that this would enable better sky and bias subtraction by enabling point source nodding along the slit. Long slits were not required for extended objects since all the key *JHK* science was for point sources. However, aside from sparse sky emission lines sky background is below the level of dark current at a resolving power of 70,000. Also, H2RG arrays appear to be bias stable and so darks and biases taken hours earlier can be usefully subtracted from un-nodded raw data frames. Consequently, the use of short slits is a viable descope option. This means that the *LM′* immersion grating can be used at *JHK* where working in the higher orders required means that short slits (5″) must be used (see the optical design documents for a full explanation). As a result the *JHK* immersion grating and the grating selection mechanism can be removed. One disadvantage of this approach is that stray light is not automatically subtracted by nodding along the slit. However, fitting the background along the slit is probably adequate. Also, since the free spectral range at 2.5 μm is no longer matched to the span of the array and the array format is not used as efficiently as possible. However, this is compensated for by being able to fit more orders onto the array because of the shorter slit. This descope does require that the WFE of the *LM′* grating be good enough for it work well at *HK*. This is probably the case. The case for including *J* is not as strong.

The original cross-disperser mechanism had space for 12 gratings. This can be reduced to 8 to accomplish the core science and still allow for changes to accommodate an optimized *JHK* immersion grating should it be installed during an upgrade. An upgrade would allow the use of longer slits or one-shot coverage of the *J*, *H* and *K* bands, compared to the proposed descope in which the *H* and *K* bands are each covered in two observations. Five custom cross-dispersing gratings are required in the original design compared to one in the descoped design. At an estimated cost of $15k per custom grating this is a significant saving. Reducing the number of slots on the cross-disperser mechanism from 12 to 8 allows the wheel to be reduced in size simplifying the design (more space and less mass).

Another significant descope is to reduce the filter complement in the slit viewer filter wheel to just support the core science requirement for acquisition and guiding. Dispensing with this wheel entirely and just using a fixed *K* filter would affect the core science but is still an option. In the proposed approach the slit viewer filter wheel and the order sorter filter wheel can be reduced in size (to 6 or 7 slots) and be made identical.

Table 2. Filters in the slit viewer filter wheel. (ORIGINAL PLAN)

Position #	*Filter*	*Notes*
1	Blank	
2	*Y*	1.00-1.10 μm
3	J_{MK}	1.164-1.326 μm
4	H_{MK}	1.487-1.783 μm
5	K_{MK}	2.027-2.363 μm
6	L'_{MK}	3.424-4.124 μm
7	M'_{MK}	4.564-4.803 μm
8	*J*+*H*	Notch
9	*H*+*K*	Notch
10	Cont *K*	2.26 μm 1.5%
11	Cont *K* + ND 2.0	2.26 μm 1.5%
12	3.454 μm	0.5%
13	3.953 μm	0.5%
14	PV lens + nb*L*	Pupil diameter 325 pixels, spatial resolution 3.6 pixels (33 mm on primary)
15	TBD	

Table 3. Slit wheel

Position #	*Slit width*	*Slit length*	*R*
1	0.375″	25.0″	72,000
2	0.75″	25.0″	39,000
3	1.50″	25.0″	20,000
4	4.00″	25.0″	7,500
5	Blank-off/mirror (darks/slit-less imaging)		

Table 4. Slit dekker wheel

Position #	*Slit length*	*Notes*
1	Blank	For darks
2	5.0″	2.79 mm long
3	10.0″	5.57 mm long
4	15.0″	8.36 mm long
5	25.0″	13.93 mm long

Table 5. Order sorter filter wheel

Position #	*Filter*	*Notes*
1	Blank	
2	1.05-1.45 μm	*J*-band XD
3	1.40-1.90 μm	*H*-band XD
4	1.80-2.60 μm	*K*-band XD
5	2.70-4.20 μm	*L*/*L′*-band XD
6	4.50-5.50 μm	*M*-band XD
7	TBD	
8	TBD	
9	TBD	
10	Open	

Table 6. List of cross dispersers and spectral formats available in iSHELL (ORIGINAL PLAN)

Exp. name (Mode)	*Wavelength coverage (µm)*	*Orders Covered*	*XD (line/mm)*	*Blaze wavel. (µm)*	*Blaze angle (deg.)*	*Order sorter (µm)*	*Slit length (arcsec)*	*XD tilt (degrees)*	*XD size (mm)*	*Custom grating?*
J	1.15-1.35	279-237	800	1.25	29.9	1.05-1.45	5.0	39.4	40x40	Yes
H	1.50-1.80	211-176	530	1.67	25.7	1.40-1.90	5.0	35.2	40x40	Yes
K	1.97-2.52	160-125	290	2.19	18.5	1.80-2.60	5.0	28.0	40x40	Yes
J1	1.15-1.26	280-255	1200	1.2	46.0	1.05-1.45	10.0	56.0	55x40	No
J2	1.25-1.35	255-236	1200	1.2	46.0	1.05-1.45	15.0	61.5	55x40	-
H1	1.50-1.66	211-191	847	1.67	45.0	1.40-1.90	10.0	51.6	50x40	Yes
H2	1.60-1.75	198-181	847	1.67	45.0	1.40-1.90	15.0	55.0	50x40	-
H3	1.68-1.83	188-173	847	1.67	45.0	1.40-1.90	15.0	57.1	50x40	-
K1	1.84-2.03	171-156	720	1.90	43.1	1.80-2.60	15.0	54.1	50x40	No
K2	2.02-2.18	156-144	720	1.90	43.1	1.80-2.60	15.0	58.9	50x40	-
K3	2.12-2.34	148-135	600	2.16	40.4	1.80-2.60	15.0	51.6	50x40	No
K4	2.32-2.52	135-125	600	2.16	40.4	1.80-2.60	15.0	56.4	50x40	-
L1	2.80-3.10	184-167	450	3.14	45.0	2.70-4.20	15.0	51.3	50x40	Yes
L2	3.02-3.30	171-157	450	3.14	45.0	2.70-4.20	15.0	55.0	50x40	-
L3	3.14-3.42	164-151	450	3.14	45.0	2.70-4.20	15.0	57.3	50x40	-
L4	3.28-3.67	157-141	360	3.70	42.0	2.70-4.20	15.0	48.5	50x40	No
L5	3.65-4.01	141-129	360	3.70	42.0	2.70-4.20	15.0	53.5	50x40	-
L6	3.84-4.18	134-124	360	3.70	42.0	2.70-4.20	25.0	56.2	50x40	-
M1	4.55-5.27 s	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No
M2	4.55-5.27 l	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No

By removing filters and gratings as proposed the estimated savings are about $100k. In addition there will savings in effort by removing the *JHK* immersion grating, the grating selection mechanism, and simplifying the OS and SV filter wheels. The only other reasonable descope measure is to replace the SV filter wheel with a fixed *K* filter but at the cost of the core science of iSHELL.

There are no other viable descopes apart from fundamental changes like reducing the resolving power to make the instrument smaller or removing the foreoptics at the cost of performance and operational efficiency (no cold stop or rotator). These would changes would also lengthen the schedule which is not an option.

4 DESCOPED CONFIGURATION

The proposed descoping measures are summarized as follows:

1. Remove *JHK* immersion grating
2. Remove grating selection mechanism
3. Reduce number of grating positions in XD wheel from 12 to 8
4. Reduce number of slots in SV filter wheel from 15 to 7
5. Reduce number of slots in OS filter wheel from 10 to 7
6. Make OS and SV filter wheels identical

Note:
XD = cross disperser
SV = slit viewer
OS = order sorter

Tables 7-11 list the proposed descoped mechanism configurations.

Table 7. Filters in the slit viewer filter wheel. (DESCOPE PLAN)

Position #	*Filter*	*Notes*
1	Blank	
2	K_{MK}	2.027-2.363 μm (guide)
3	L'_{MK}	3.424-4.124 μm (daytime comet acquisition)
4	M'_{MK}	4.564-4.803 μm (Jupiter acquisition)
5	continuum *K*	2.26 μm 1.5% (guide)
6	3.953 μm	0.5% (H_3^+ acquisition)
7	PV lens + nb*L*	Pupil diameter 325 pixels, spatial resolution 3.6 pixels (33 mm on primary)

Table 8. Slit wheel

Position #	*Slit width*	*Slit length*	*R*
1	0.375″	25.0″	72,000
2	0.75″	25.0″	39,000
3	1.50″	25.0″	20,000
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Table 9. Slit dekker ~~wheel~~

Position #	*Slit length*	*Notes*
1	Blank	For darks
2	5.0″	2.79 mm long
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Table 10. Order sorter filter wheel (DESCOPE PLAN)

Position #	*Filter*	*Notes*
1	Blank	
2	1.05-1.45 μm	*J*-band XD
3	1.40-1.90 μm	*H*-band XD
4	1.80-2.60 μm	*K*-band XD
5	2.70-4.20 μm	*L/L′*-band XD
6	4.50-5.50 μm	*M*-band XD
7	spare	

Table 11. List of cross dispersers and spectral formats available in iSHELL

Exp. name (Mode)	*Wavelength coverage (μm)*	*Orders Covered*	*XD (line/mm)*	*Blaze wavel. (μm)*	*Blaze angle (deg.)*	*Order sorter (μm)*	*Slit length (arcsec)*	*XD tilt (degrees)*	*XD size (mm)*	*Custom grating?*
Spare 1										
Spare 2										
H1	1.50-1.69	350-308	720	1.90	43.1	1.40-1.90	5.0	44.6	50x40	No
H2	1.61-1.82	323-289	720	1.90	43.1	1.40-1.90	5.0	47.6	50x40	-
K1	1.95-2.26	265-229	497	2.25	34.0	1.80-2.60	5.0	41.0	50x40	No
K2	2.24-2.53	231-205	497	2.25	34.0	1.80-2.60	5.0	45.8	50x40	-
L1	2.80-3.10	184-167	450	3.14	45.0	2.70-4.20	15.0	51.3	50x40	Yes
L2	3.02-3.30	171-157	450	3.14	45.0	2.70-4.20	15.0	55.0	50x40	-
L3	3.14-3.42	164-151	450	3.14	45.0	2.70-4.20	15.0	57.3	50x40	-
L4	3.28-3.67	157-141	360	3.70	42.0	2.70-4.20	15.0	48.5	50x40	No
L5	3.65-4.01	141-129	360	3.70	42.0	2.70-4.20	15.0	53.5	50x40	-
L6	3.84-4.18	134-124	360	3.70	42.0	2.70-4.20	25.0	56.2	50x40	-
M1	4.55-5.27 s	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No
M2	4.55-5.27 l	113-98	210	5.0	31.7	4.50-5.50	15.0	40.4	40x40	No

The resulting spectral formats are illustrated in Figures 1-11. (See the OCDD for original spectral formats).

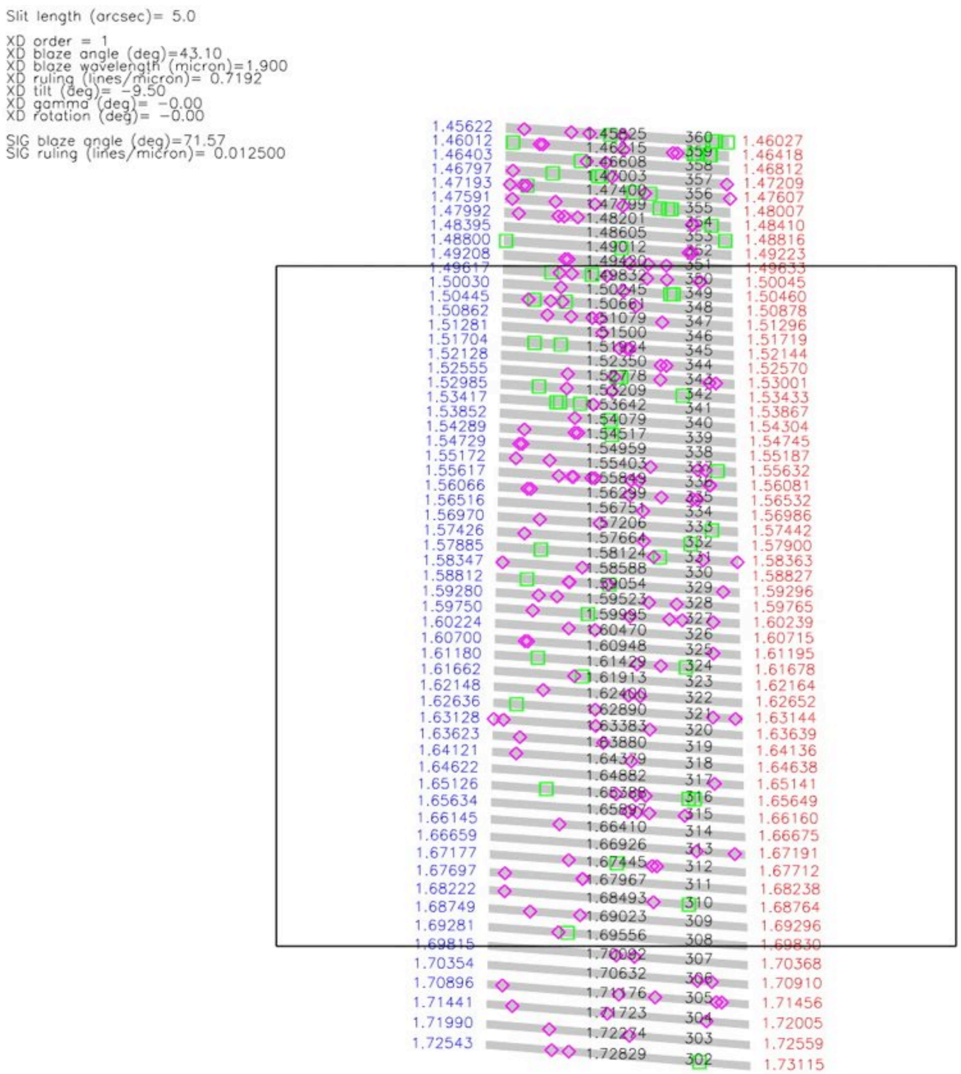

Figure 1. Exposure H1 (see Table 5), slit length 5″, 720 line per mm grating. The box indicates the H2RG array.

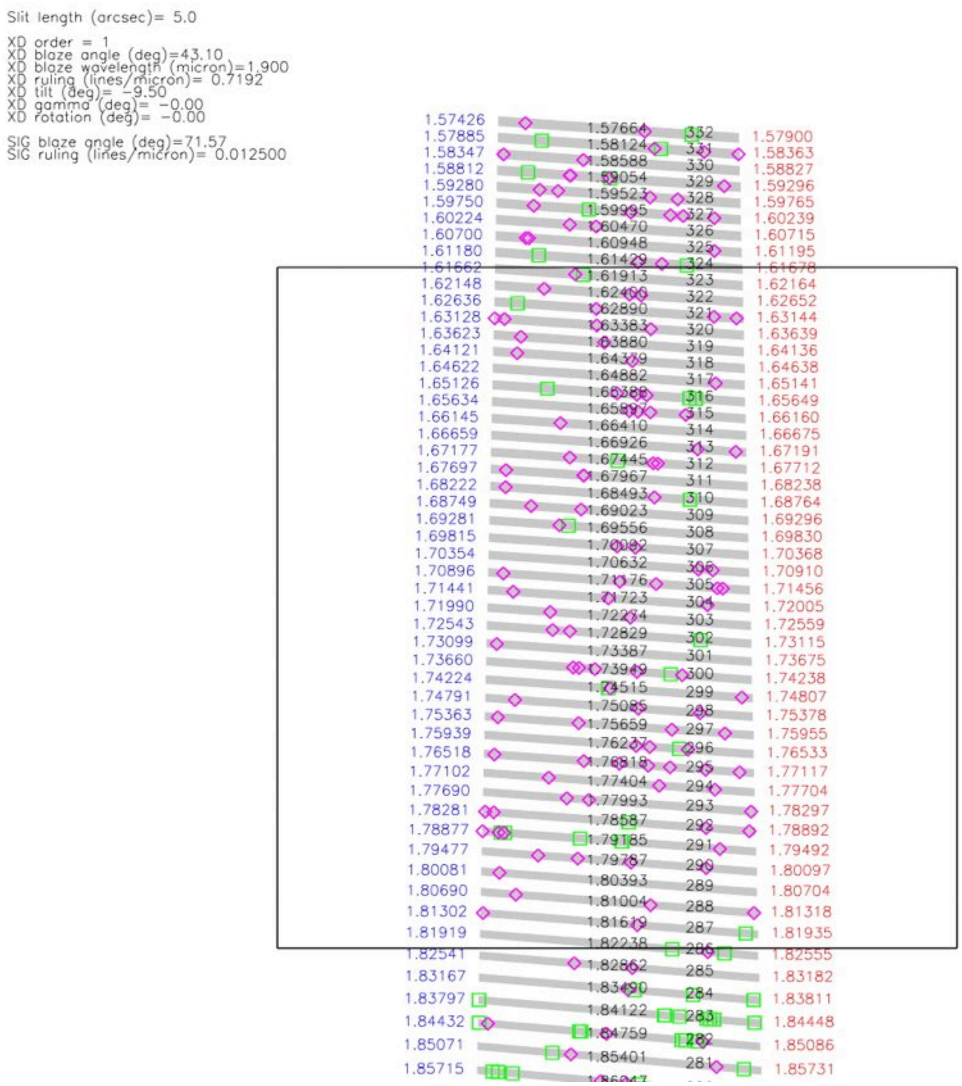

Figure 2. Exposure H2 (see Table 5), slit length 5″, 720 line per mm grating. The box indicates the H2RG array.

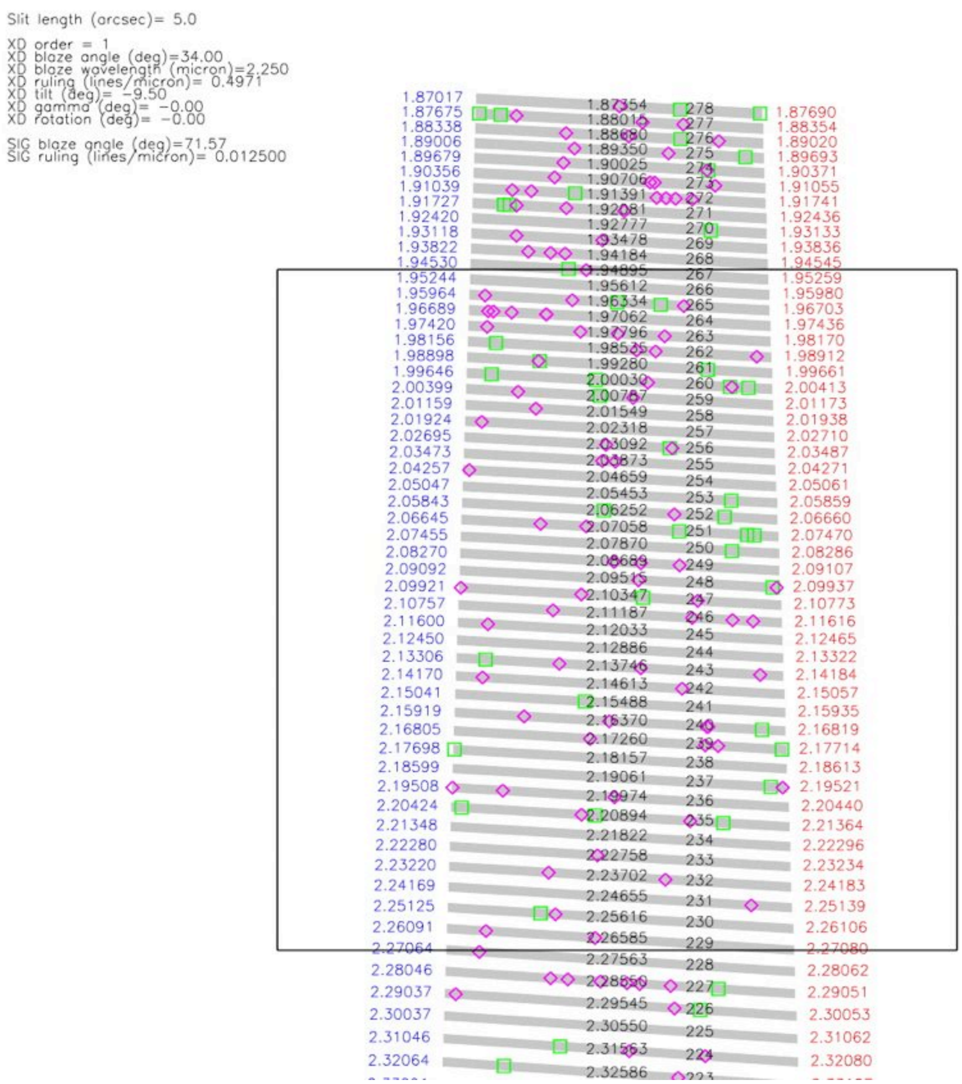

Figure 3. Exposure K1 (see Table 5), slit length 5″, 497 line per mm grating. The box indicates the H2RG array.

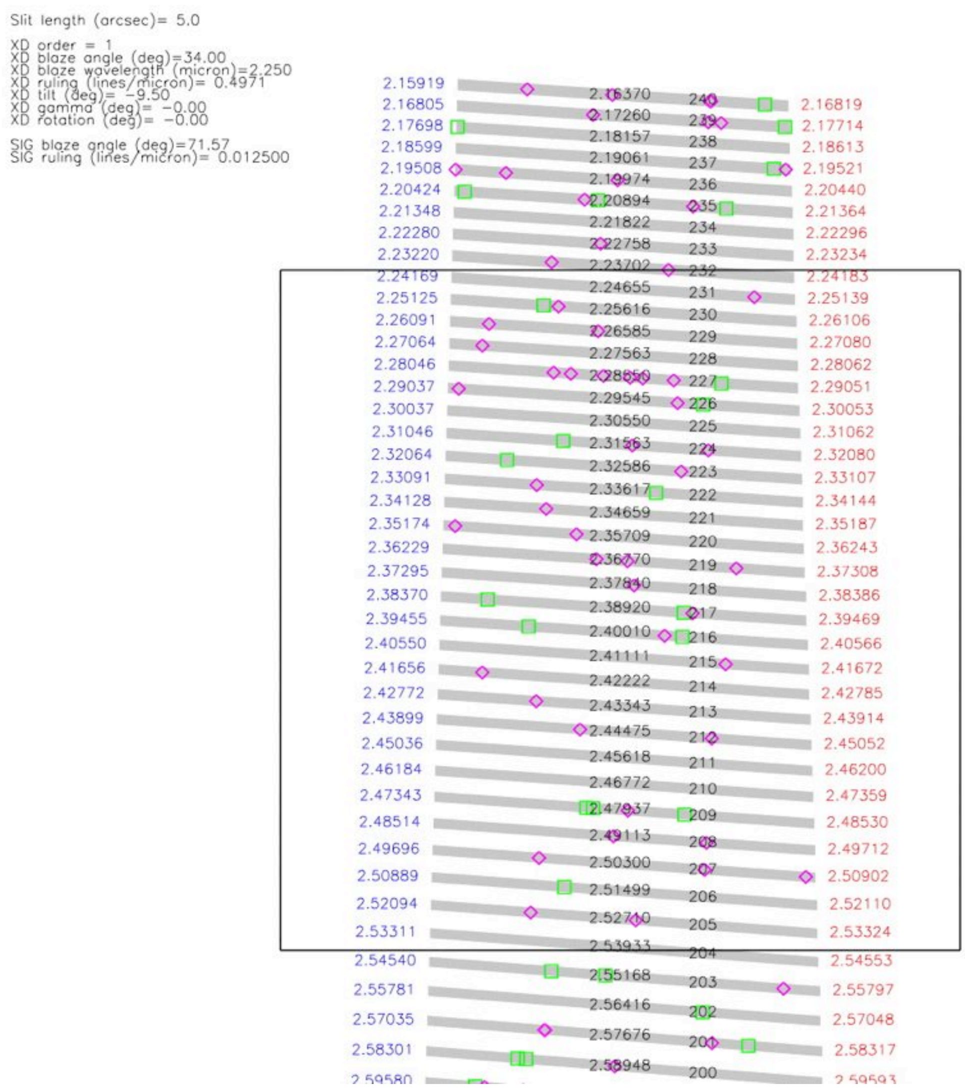

Figure 4. Exposure K2 (see Table 5), slit length 5″, 497 line per mm grating. The box indicates the H2RG array.

Figure 5. Exposure L1 (see Table 5), slit length 15″, 450 line per mm grating. The short wavelength limit (about 2.80 μm) is set by the need to keep orders separated by at least 10 pixels. The box indicates the H2RG array.

Figure 6. Exposure L2 (see Table 5), slit length 15″, 450 line per mm grating. The box indicates the H2RG array.

Figure 7. Exposure L3 (see Table 5), slit length 15″, 450 line per mm grating. The box indicates the H2RG array.

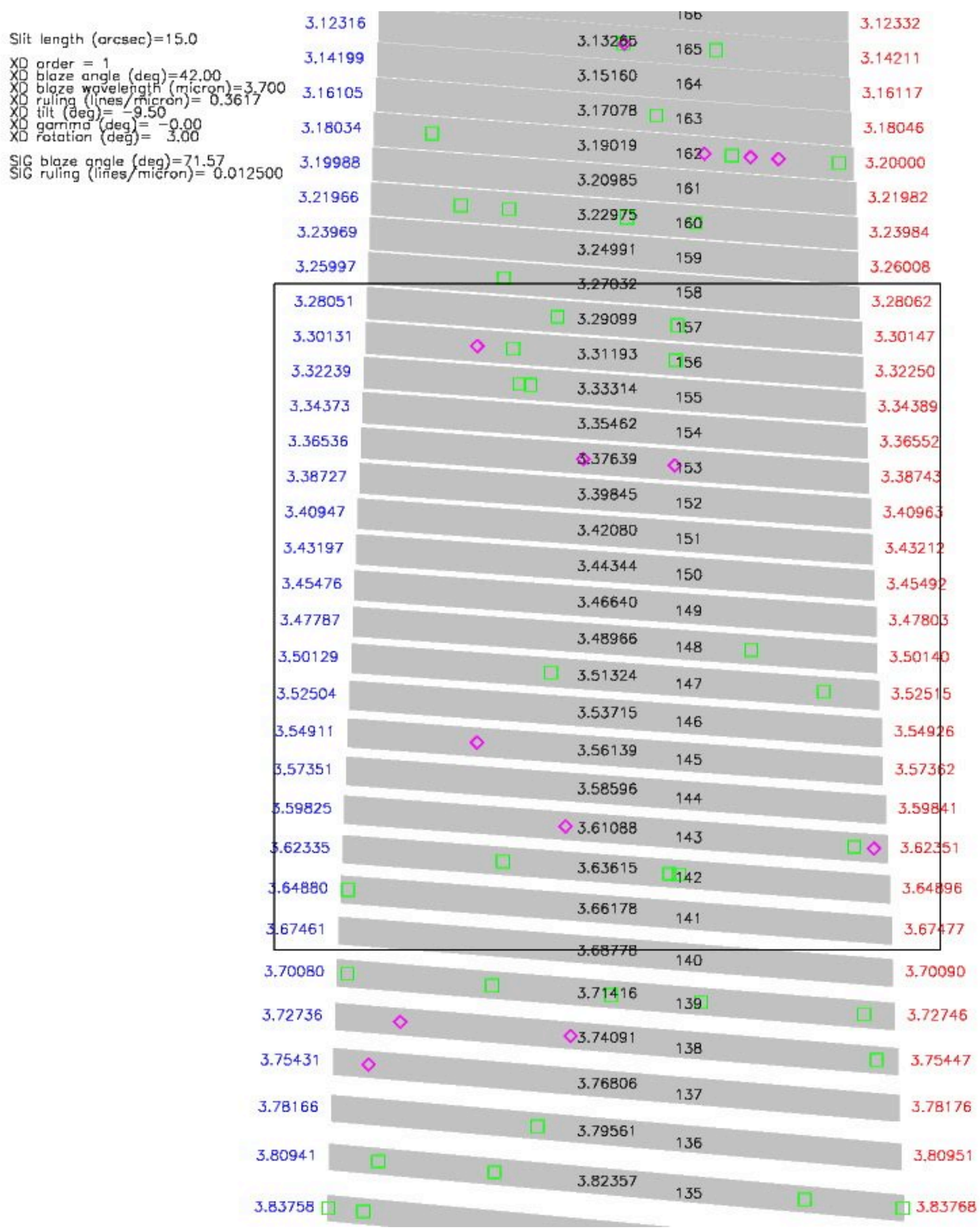

Figure 8. Exposure L4 (see Table 5), slit length 15″, 360 line per mm grating. The short wavelength limit (about 3.28 μm) is set by the need to keep orders separated by at least 10 pixels. The box indicates the H2RG array.

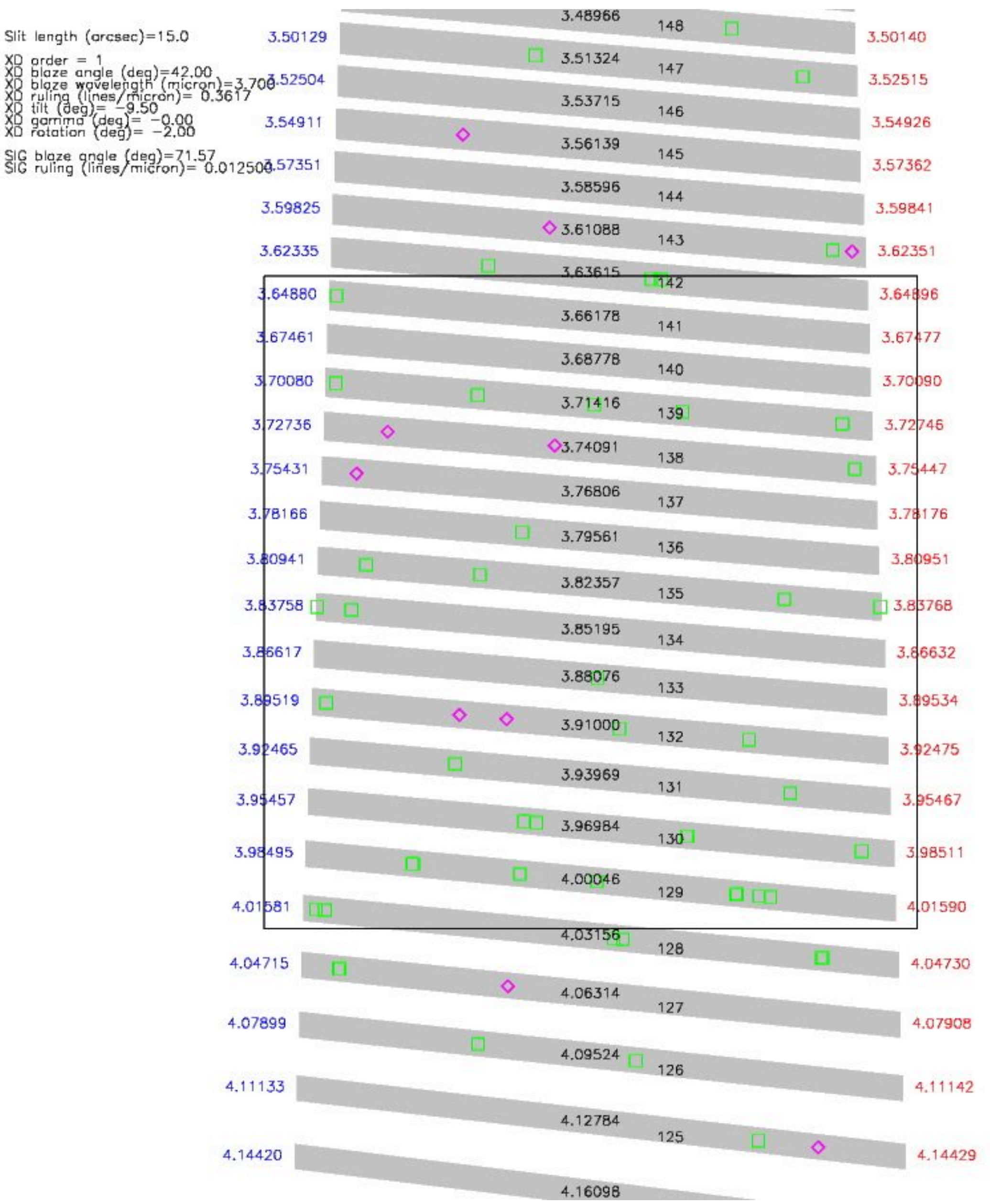

Figure 9. Exposure L5 (see Table 5), slit length 15″, 360 line per mm grating. The box indicates the H2RG array.

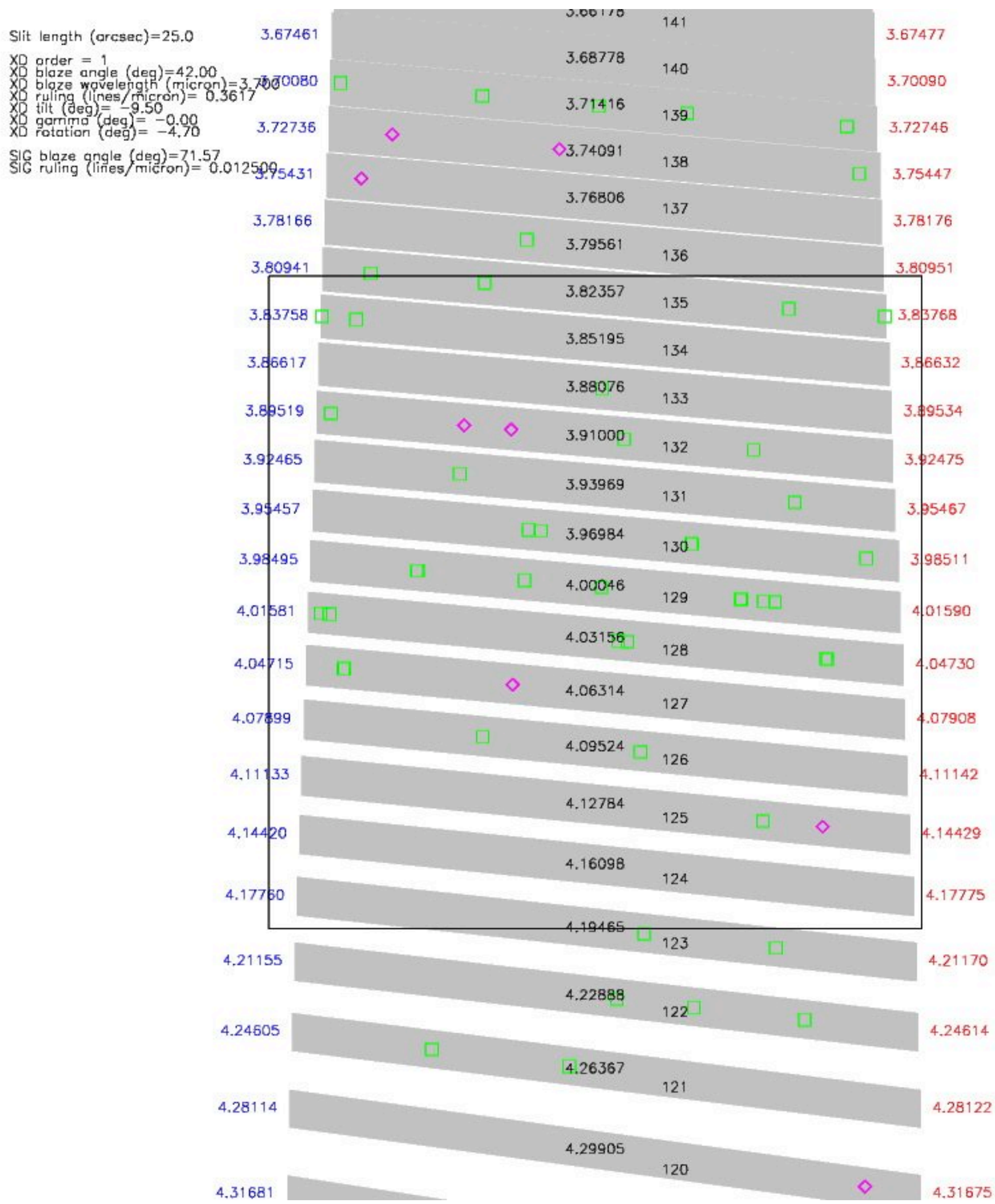

Figure 10. Exposure L6 (see Table 5), slit length 25″, 360 line per mm grating. The short wavelength limit (about 3.81 μm) is set by the need to keep orders separated by at least 10 pixels. The box indicates the H2RG array.

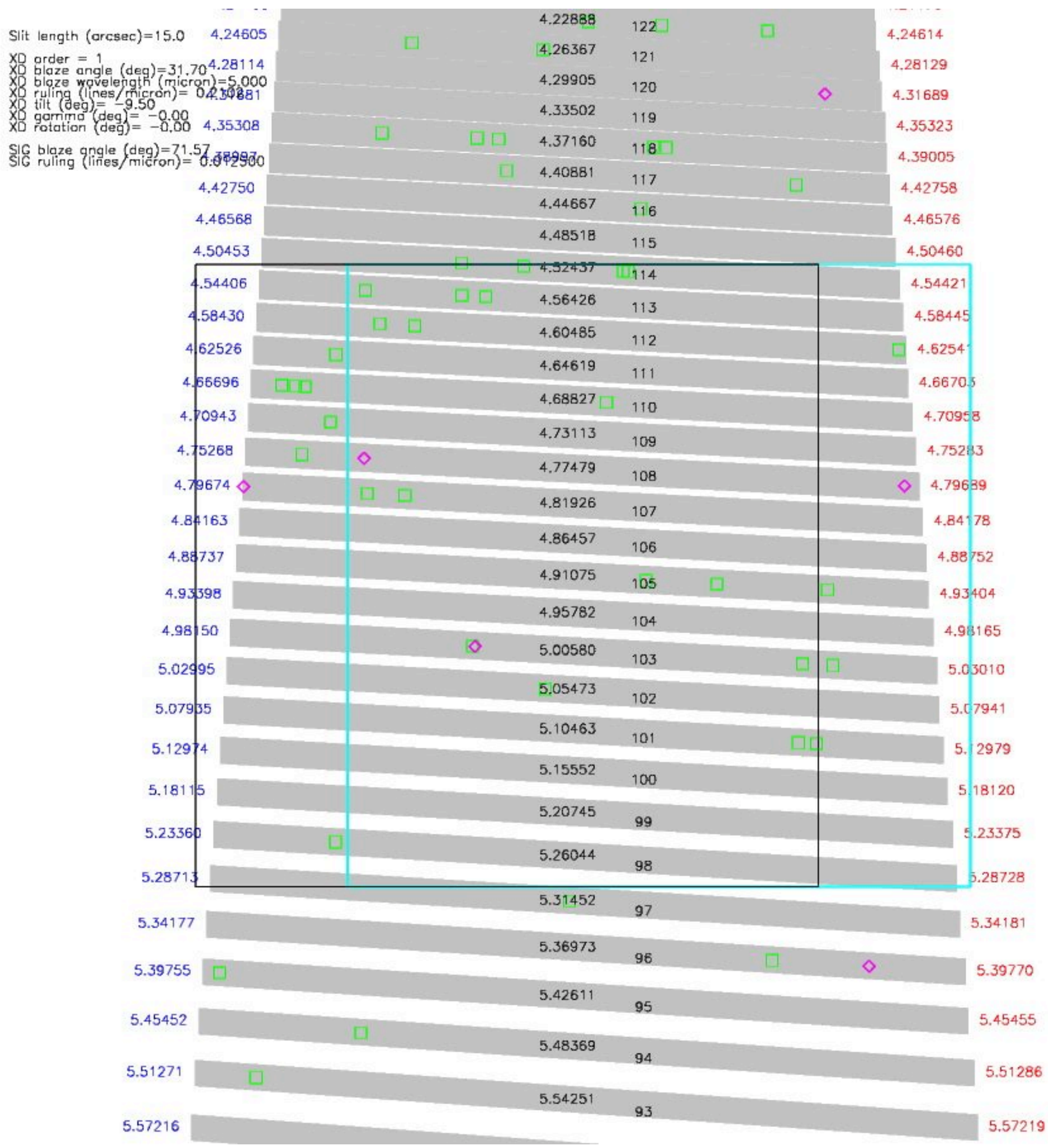

Figure 11. Exposures M1 (black box) and M2 (blue box) (see Table 5), slit length 15″, 210 line per mm grating. The short wavelength limit (about 4.55 µm) is set by the need to keep orders separated by at least 10 pixels. The boxes indicates the

H2RG array. To cover the full FSR two exposures are required with two different XD gratings (same grating in different slots but with different tilts in the dispersion direction).