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1.0 PURPOSE

This document describes the key operational modes for the RSS-NIR system.

2.0 SCOPE

This document described the operational modes that are to be designed into the RSS-NIR to meet the needs of the scientific community.

3.0 ACRONYMS AND DEFINITIONS

3.1 **AGN –** active galactic nuclei

3.2 **CCD –** charge-couple device

3.3 **FOV –** field of view

3.4 **NIR –** Near InfraRed

3.5 **RSS –** Robert Stobie Spectrograph

3.6 **SALT –** Southern African Large Telescope

3.7 **VPHG –** volume phase holographic grating

4.0 RESPONSIBILITIES

4.1 **Principal Investigator** is responsible for ensuring the project is adequately defined and the design meets the scientific goals of the project.

4.2 **SSEC QA** is responsible for ensuring that appropriate procedures for document creation, review, approval, change and maintenance are followed.

4.3 **Project Scientist** is responsible for creating/updating this document, and ensuring the information herein is current, complete and correct.

5.0 RECORDS

This document serves as the record of this activity.

6.0 OPERATIONAL CONCEPTS DEFINITION

For consistency with the original draft of this document, the Operational Concepts portion of this document will restart with section 1.0.

1.0 Overview of RSS-NIR Operation

RSS-NIR is a near-infrared imaging spectrograph, which duplicates the versatility in operational modes of RSS, including Fabry-Perot imaging and spectropolarimetry. The major differences in the two instruments arise because of the differences in detectors. The HgCdTe IR detector does not have charge shuffling capabilities like CCDs, which was the basis for all the high time resolution modes of RSS that shuffled charge quickly on the CCD and read it out later. This document introduces the major operational modes and associated concepts of RSS-NIR.

The operational modes are grouped into 5 major categories: 1) Imaging, 2) Longslit spectroscopy, 3) Multi-object spectroscopy, 4) Fabry-Perot Imaging, and 5) Polarimetry. Each of these modes uses a variety of the 4 types of mechanisms in the instrument: 1) the focal plane slits and masks; 2) the dispersive elements, consisting of either gratings or the Fabry-Perot etalon; 3) the polarizing optics, two waveplates and a polarizing beamsplitter, and 4) broadband and narrowband filters in the pre-dewar, and long wavelength cutoff filters in the cryogenic dewar. Permutations of these mechanisms combine to give RSS-NIR the versatility to address a broad range of astrophysical research programs.

1.1 Focal Plane Mechanism

O – Open (implies direct acquisition and peak-up)
S – Slit (reflective longslit plate; implies visual acquisition and peak-up)
M – Multi-slit mask (non-reflective carbon fiber; implies blind peak-up)

O – Direct imaging is likely to be the only mode where there is no element in the focal plane. By implication, the camera is unarticulated. Acquisition and peak-up operations are performed by direct imaging or by the guide probes.

S – Many spectroscopic modes will use the single longslit in the focal plane. The longslits are made of a reflective material and tilted at an angle of 12 degrees to allow a slit-viewing device (SALTICAM) to image the focal plane. The reflective area of the slit is approximately 2’ in the dispersion direction by the length of the slit in the cross-dispersion direction. Eight standard longslit plates that are always available in the focal plane magazine. Slits 1-6 are 7.5’ in length and span a range of widths to accommodate the full range of expected seeing. These will be used for standard longslit grating spectroscopy. Slit plate #7 covers the central 4’ of the focal plane and is used for spectropolarimetry. It should be constructed with shims to allow a variety of slit widths. Slit #8 is used for high-speed spectroscopy and spectropolarimetry modes of RSS and will not be used by RSS-NIR.

Table 1. Complement of Standard Reflective Focal Plane Plates for RSS.

Reflective Slit Plate #	Length	Width
1	7.5’	0.45”
2	7.5’	0.6”
3	7.5’	0.9”
4	7.5’	1.1”

5	7.5’	1.3”
6	7.5’	3.0”
7	Central 4’	1.1” adjustable for spectral polarimetry
8 (used for RSS-VIS only)	12” above charge transfer boundary	1.1” adjustable for high speed spectroscopy
9	4”	1.1” w/coronographic center

M – Multi-object spectroscopy, multi-object spectropolarimetry, and Fabry-Perot polarimetery require the use of a carbon fiber mask in the focal plane. The masks are milled with a laser cutter and placed in a slitmask magazine designed to hold 20-30 masks. Several standard masks will be available, including one which masks the upper and lower quarters of the field of view for imaging polarimetry, and one which masks the lower half of the CCD for high time resolution work with the RSS visible arm CCD. User-designed slitmasks are cut and stored on-site. Each mask and its frame are labeled with a barcode for identification.

Table 2. Standard Slitmasks.

#	Configuration	Use
1	Masks lower 4’ x 8’	High time resolution imaging
2	Masks upper and lower 2’ x 8’	Imaging and Fabry-Perot polarimetry

1.2 Dispersive Elements

I – Imaging (none). Implies no camera articulation.
F – Fabry-Perot etalon. Implies no camera articulation.
G – Grating. Articulated camera.

I – Imaging mode, no dispersive element is in the beam. This implies that the camera is in the unarticulated position.

F – Fabry-Perot etalon is in the beam. Fabry-Perot imaging and polarimetry are modes that use this configuration.

G – The majority of spectroscopic modes employ one of 5 gratings as the dispersive element. Both longslit and multi-object spectroscopy and spectral polarimetry are performed with this configuration.

1.3 Polarization Elements

U – Unpolarized measurement (quartz compensator in place of waveplates)
L – Linear polarization measurement (1/2-waveplate operational; implies max 4'x8'spatial field)
C – Circular polarization measurement (1/2-waveplate and ¼-waveplate operational; max 3' diameter spatial field)
A – All stokes mode (both waveplates operational in sync; implies max 3' diameter spatial field)
* All polarimetric modes require use of a focal plane mask or longslit plate to block the upper and lower quarters of the field of view.

U – All modes where polarimetric data are not required employ a block of fused silica in place of the waveplates to preserve the focus of the collimator.

L – Imaging and spectral polarimetry where linear polarization data is desired require that the ¼ and ½ waveplates are inserted in place of the block of fused silica. The ¼-waveplate is not in operation, but is required to preserve overall focal length of the collimator. The ½-waveplate steps through 8 position angles separated by 22.5 degrees in order to perform a complete linear polarization measurement.

C – In circular polarimetry mode the ¼-waveplate is in operation with the ½-waveplate. Two positions of the ¼-waveplate, in conjunction with 8 positions of the ½-waveplate are required to complete a measurement of the circular polarization. Imaging, Fabry-Perot, and single object spectropolarimetric measurements are envisioned.

A – All stokes mode involves simultaneous stepping of both waveplates in order to measure circular and linear polarizations.

2.0 Description of Major RSS-NIR Operational Modes

The main operational modes of RSS-NIR are 1) Imaging, 2) Long slit spectroscopy, 3) Multi-object spectroscopy (MOS), 4) Fabry-Perot imaging, and 5) Spectropolarimetry, which can be added to any of the previous 4 modes. These duplicate the modes of the visible arm of RSS, except for the ones requiring special detector modes of operation. The HgCdTe detector used in RSS-NIR does not have charge shuffling capabilities like a CCD, so all modes utilizing those capabilities are not possible with RSS-NIR. Figure 1 summarizes the operational modes available for RSS-NIR and also indicates the RSS-VIS modes that will not be available: the high-speed, shuffle, and drift scan detector configurations.

Optics configuration			Detector Configuration			
Config	Pol	Slit	Normal	Hi Spd	Shuffle	Drift
Imaging	No	No	X	x		x
	L,C,S	No	x			
		Multislit	X		x	
VPH Spectro-scopy	No	No	x			x
		Longslit	X	X	x	
		Multislit	X		X	
	L,C,S	Longslit	X		x	
		Multislit	X			
Fabry-Perot	No	No	X		x	
	L,C,S	No	x			

Figure 1. Summary of the modes of operation for RSS-NIR, with an indication of RSS-VIS modes that are not available with the NIR detector.

2.1 Imaging

The imaging mode of RSS-NIR is performed with the camera in the non-articulated position. Standard z', Y, J, and H broadband filters are provided inside the pre-dewar, though H will be H-short due to our detector cutoff at 1.7 microns. Narrowband filters for use with the Fabry-Perot mode reside in the cooled pre-dewar enclosure. The cryogenic dewar contains 3 long wavelength blocking filters, primarily for use in spectroscopy mode, but available for imaging as well.

Science uses:

Broadband imaging in z', Y, J, and H-short bands over the entire 8 arcmin FOV
Narrowband imaging using Fabry-Perot filters over the entire 8 arcmin FOV
Imaging for MOS setups

Involved mechanisms:

Pre-dewar filter inserter
Cryogenic dewar filter wheel (if blocking filter required)

Target acquisition: Target acquisition is performed using RSS-NIR itself or SALTICAM.

Tracking during exposure: Uses guide probes.

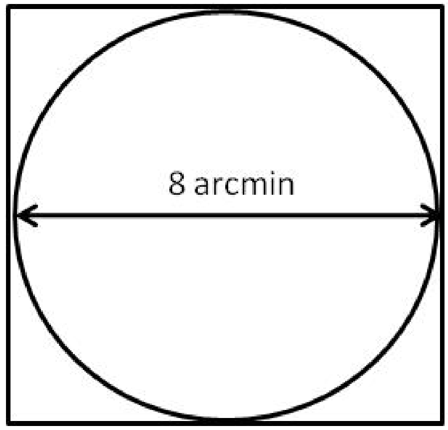

Figure 2. The imaging field of view is an 8 arcmin diameter circle inscribed on the 2048 x 2048 x 18 micron pixel detector.

2.2 Long slit spectroscopy

Single slit spectroscopy is offered with the same suite of slits as the visible arm, 7 long slits available at the focal plane slit mask magazine. The only difference is that the back sides will be gold coated to lower the thermal emissivity for the NIR arm. Slits vary from 0.45” to 3.0” in width and are 7.5’ long. A complement of 4 VPH gratings cover the operational wavelength range from 0.9 to 1.7 microns at resolutions of R ~ 2000 – 7000. An additional low resolution grating with R ~ 800 will allow coverage of the entire spectral range in one observation. This option will be useful for time variability studies of non sky-limited bright objects where simultaneous wide spectral coverage is important. This low resolution grating will not be a VPHG because of their poor performance in this regime.

Science Uses:

Conventional long slit spectroscopy over 7.5’ fields at arbitrary position angles.

Involved Mechanisms:

Slit magazine
Grating inserter
Grating rotation
Camera articulation
Cryogenic filter wheel for long wavelength blocking

Typical sequence of operation:

Select grating and slit to be used; insert elements
Rotate grating and camera to required positions
Rotate the field rotator to desired position angle
Image field with slit viewing camera (SALTICAM)
Locate desired object and move tracker to place object in slit
Begin tracking/guiding using either guide probes or slit viewer
Begin exposure

Target acquisition: By guide probe, and using visual peak-up with SALTICAM as slit viewing camera.

Tracking during exposures: By guide probe, or by reflected light from slit viewed by SALTICAM.

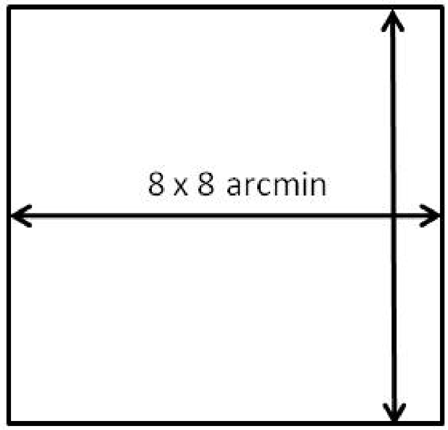

Figure 3. The spectroscopic field fills the detector plane resulting in an 8' x 8' square field of view for the dispersed spectra.

2.3 Multi-Object Spectroscopy

Science Uses:

Multi-object spectroscopy in fields up to 8' diameter. Redshift surveys. Spectral surveys of stars and galaxies.

Involved Mechanisms:

Grating inserter
Grating rotator
Slitmask magazine for custom multi-slit masks
Camera articulation
Cryogenic filter wheel for long wavelength blocking

Target acquisition: Multi-stage process, similar to that at other multi-object spectrographs.

Afternoon flats to locate positions of slitmask guide star boxes on detector
Image of science field with RSS-NIR (or SALTICAM)
Movement of tracker to align science field with anticipated mask position
Insertion of slitmask
Image field with RSS-NIR to fine-tune pointing
Final tweak of tracker position to center objects in slits
Insert and rotate grating
Articulate camera
Begin guiding using guide probes
Start science exposures

Anticipated acquisition time required: 15 minutes (this is increased from the 5 minutes stated in the PFIS documentation, based on experience at the HET)

Tracking during exposure: By guide probe

Limitations: No slit viewing system is available

2.4 Fabry-Perot Imaging

Science Uses:

High resolution imaging spectroscopy of multiple or extended objects. Dynamical studies of H II regions, star clusters, galaxy clusters.

Involved Mechanisms:

Pre-dewar filter inserter
Cryogenic filter wheel (if long wavelength blocking is required)
Etalon inserter

Mode of operation:

Acquire field using RSS-NIR (or SALTICAM)
Begin tracking using guide probe
Select and insert appropriate blocking filter
Insert and tune etalon
For each wavelength desired
- Set etalon
- Wavelength zero point calibration
- Expose and readout detector
- Obtain transmission measurement from guide system

Target acquisition: By guide probe, and using visual peak-up with SALTICAM

Tracking during exposures: By guide probe

2.5 Polarimetry

Polarimetry can be added to any of the main instrument modes of operation. A standard slitmask is inserted into the focal plane to block the upper and lower quarters of the field of view. This is required to limit the size of the input image because the polarizing beamsplitter later in the optical path shears the two orthogonal polarizations in the science field onto the upper and lower halves of the detector for recording.

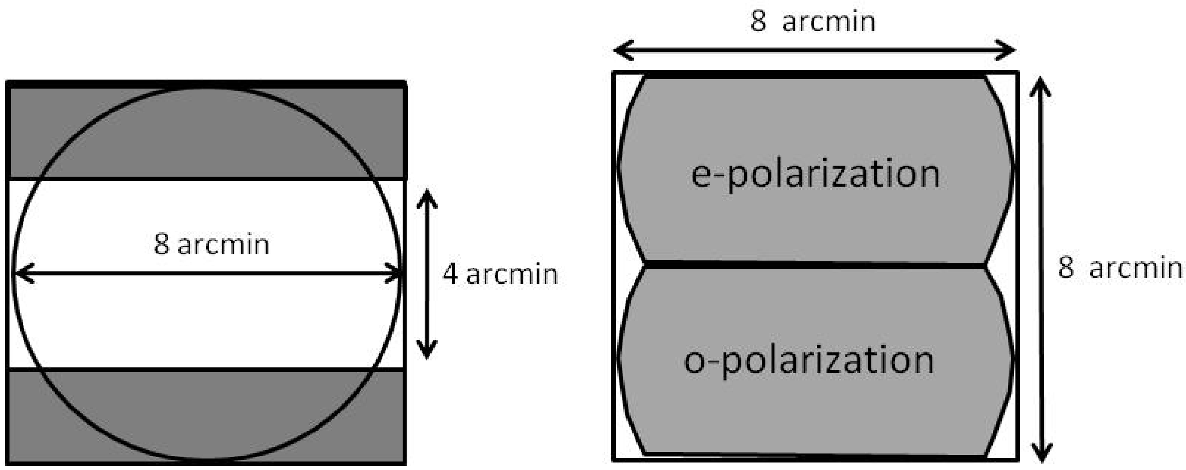

Figure 4. The upper and lower 2’ x 8’ portions are masked off during polarimetric observations, leaving the central ~4’ x 8’ as the available science field of view. Left: image focal plane. Right: detector plane.

2.5.1 Imaging Linear Polarimetry

Sciences Uses:

Broadband or narrowband polarimetric surveys of interstellar polarization; intrinsic stellar polarization

Involved Mechanisms:

Pre-dewar filter inserter (if required)
Cryogenic dewar filter wheel (if required)
½-wavelplate
Polarizing beam splitter
Slitmask mechanism (standard slitmask #2)

Target acquisition: By guide probe and direct imaging with RSS-NIR or SALTICAM

Mode of operation:

Point to field using guide probes or imaging on RSS-NIR or SALTICAM to acquire
Begin guiding using guide probes
For each of 8 1/2-waveplate positions
- Rotate waveplate to desired angle
- Expose
- Readout

Limitations: Spatial field of view is limited to 4’ x 8’

2.5.2 Imaging Circular Polarimetry

Science Uses:

Broadband or narrowband circular polarimetric surveys of interstellar polarization; intrinsic stellar polarization; low-resolution spectral polarimetry

Involved Mechanisms:

Pre-dewar filter inserter (if required)
Cryogenic dewar filter wheel (if required)
½-waveplate
¼-waveplate
Polarizing beamsplitter
Slitmask magazine (standard slitmask #2)

Target acquisition: By guide probe and direct imaging with RSS-NIR or SALTICAM

Mode of operation:

Point to field using guide probes or direct imaging on RSS-NIR or SALTICAM to acquire
Begin guiding using guide probes
For each of 8 ½-waveplate positions
- Rotate waveplate to desired angle
- For each of 2 ¼-waveplate positions
  - Expose
  - Readout orthogonal polarizations (in separate locations on detector) in one image

Limitations: Spatial field of view is limited to the central 3’ diameter, due to the smaller size of the ¼-wave plate.

2.5.3 Fabry-Perot Imaging Linear Spectral-Polarimetry

Science uses:

R=2500 imaging spectropolarimetic studies of extended objects such as H II regions, reflection nebulae, star cluster, young stellar associations, nuclei of galaxies

Involved Mechanisms:

Narrowband filter inserter
Etalon slide
½-waveplate
Polarizing beam splitter
Slitmask magazine (standard slitmask #2)

Target acquisition: By guide probe and direct imaging with RSS-NIR or SALTICAM

Tracking during exposures: By guide probe

Mode of operation:

- Point to field using guide probes or direct imaging on RSS-NIR or SALTICAM to acquire
- Begin guiding using guide probes
- For each wavelength desired
  - Select and insert order blocking filter
  - Set etalon
  - Wavelength zero point calibration
  - For each of 8 ½-waveplate positions
    - Rotate waveplate to desired angle
    - Expose
    - Readout orthogonal polarizations (in separate locations on detector) in one image
  - Wavelength zero point calibration

Limitations: Field of view limited to central 4’ x 8’

2.5.4 Fabry-Perot Imaging Circular Spectral-Polarimetry

Science Uses:

R=2500 imaging circular spectropolarimetric studies of extended objects such as HII regions, reflection nebulae, star clusters, young stellar associations, nuclei of galaxies

Involved Mechanisms:

Narrowband filter inserter
Etalon slide
½-waveplate
¼-waveplate
Polarizing beam splitter
Slitmask magazine (standard slitmask #2)

Target acquisition: By guide probe and direct imaging with RSS-NIR or SALTICAM

Tracking during exposures: By guide probe

Mode of operation:

- Point to field using guide probes or direct imaging on RSS-NIR or SALTICAM to acquire
- Begin guiding using guide probes

For each wavelength desired
- Select and insert order blocking filter
- Set etalon
- Wavelength zero point calibration
- For each of 8 ½-waveplate positions
  - Rotate waveplate to desired angle
  - For each of 2 ¼-waveplate positions
    - Expose
    - Readout orthogonal polarizations (in separate locations on detector) in one image
- Wavelength zero point calibration

Limitations: Field of view limited to central 3’ diameter.

2.5.5 Longslit Linear Spectral-Polarimetry

Science Uses:

R = 800, R=2000 - 7000 slit spectral polarimetric studies of cataclysmic variables, young stellar objects, stars with disks, AGN, interstellar absorption features

Involved Mechanisms:
- Cryogenic filter wheel for long wavelength blocking filter
- Grating inserter and rotator
- Camera articulation
- ½-waveplate
- Polarizing beamsplitter
- Slitmask mechanism (long slit plate #7)

Target acquisition: By slit viewing on SALTICAM

Tracking during exposures: Guide probe or reflected light from slit viewed by SALTICAM

Mode of operation:
- Point to field using guide probes or slit-viewing on SALTICAM to acquire
- Place object on slit
- Begin guiding using guide probes or slit-viewing camera
- Insert and rotate grating
- Articulate camera
- For each of 8 1/2-waveplate positions
  - Rotate waveplate to desired angle
  - Expose
  - Readout orthogonal polarizations (in separate locations on detector) in one image

Limitations: Only central 4’ x 8’ of longslit spatial field is available. Slit plate #7 is designed for use as the main spectropolarimetric longslit.

2.5.6 Longslit Circular Spectral-Polarimetry

Science Uses:

R=800, R=2000 - 7000 slit spectral polarimetric studies of cataclysmic variables, young stellar objects, stars with disks, AGN, interstellar absorption features

Involved Mechanisms:

Cryogenic filter wheel for long wavelength blocking filter
Grating inserter and rotator
Camera articulation
½-waveplate
¼-waveplate
Polarizing beamsplitter
Slitmask mechanism (long slit plate #7)

Target acquisition: By slit viewing on SALTICAM

Tracking during exposures: Guide probe or reflected light from slit viewed by SALTICAM

Mode of operation:

- Point to field using guide probes or slit-viewing SALTICAM to acquire
- Place object on slit
- Begin guiding using guide probes or slit-viewing camera
- Insert and rotate grating
- Articulate camera
- For each of 8 1/2-waveplate positions
  - Rotate waveplate to desired angle
  - For each of 2 ¼-waveplate positions
    - Expose
    - Readout orthogonal polarizations (in separate locations on detector) in one image

Limitations: Only the central 3' diameter spatial field is available. Slit plate #7 is designed for use as the main spectropolarimetric longslit.

2.5.7 Multi-slit Linear Spectral-Polarimetry

Science Uses:

Multi-object linear spectropolarimetry in fields up to 4' x 8'. Polarimetric surveys.

Involved Mechanisms:

- Cryogenic filter wheel for long wavelength blocking filter
- Grating inserter and rotator
- Camera articulation
- ½-waveplate
- Polarizing beamsplitter
- Slitmask mechanism

Target acquisition: Multi-stage process, similar to that in use at other multi-object spectrographs

Mode of operation:

- Afternoon flat fields to locate positions of slitmask guide star boxes in detector
- Image of science field with SALTICAM (or direct image with RSS-NIR)
- Movement of tracker to align science field with anticipated mask position
- Insert slitmask
- Image of field to fine-tune pointing
- Final tweak of tracker position to center objects in slits
- Insert and rotate grating
- Begin guiding using guide probes
- Articulate camera
- For each of 8 1/2-waveplate positions

Rotate waveplate to desired angle
Expose
Readout orthogonal polarizations (in separate locations on detector) in one image

Tracking during exposures: By guide probe

Limitations: Field of view limited to 4' x 8'. No slit-viewing system is available

2.5.8 Multi-slit Circular Spectral-Polarimetry

Science Uses:
Multi-object circular spectropolarimetry in fields up to 3' diameter. Polarimetric surveys.

Involved Mechanisms:
Cryogenic filter wheel for long wavelength blocking filter
Grating inserter and rotator
Camera articulation
½-waveplate
¼-waveplate
Polarizing beamsplitter
Slitmask mechanism

Target acquisition: Multi-stage process, similar to that in use at other multi-object spectrographs

Mode of operation:
Afternoon flat fields to locate positions of slitmask guide star boxes in detector
Image of science field with SALTICAM (or direct image with RSS-NIR)
Movement of tracker to align science field with anticipated mask position
Insert slitmask
Image of field to fine-tune pointing
Final tweak of tracker position to center objects in slits
Insert and rotate grating
Begin guiding using guide probes
Articulate camera
For each of 8 1/2-waveplate positions
Rotate waveplate to desired angle
For each of 2 ¼-waveplate positions
Expose
Readout orthogonal polarizations (in separate locations on detector) in one image

Tracking during exposures: By guide probe

Limitations: Field of view limited to the central 3' diameter. No slit-viewing system is available

2.5.9 Simultaneous Visible / NIR Operation

Simultaneous operation of both the visible and NIR instruments has been envisioned from the beginning. After configuration and verification of the placement of common components that affect both spectrographs, such as the slitmasks and waveplates, further operation and data acquisition of each spectrograph will be set up as two separate threads to run each individually, but simultaneously. This will avoid the situation of either arm waiting on the other during the data acquisition phase.

One complication for simultaneous visible and NIR observations is the different observing style required in the near infrared. Because the night sky is so bright and variable in this part of the spectrum, observations are normally limited to relatively short exposures and the telescope is nodded to slightly different locations on the sky for each exposure. In the case of spectroscopy, this would mean nodding the science target along the slit, if its subtended angle on the sky is small. This technique improves the quality of the resulting sky subtraction in the presence of a highly variable background, while allowing each exposure to still contain the science target. In the case of spectroscopy on extended objects that fill the slit, nods would be off to sky areas away from the science target.

In imaging mode on an 11-m telescope, exposure times in most cases should be short enough that sky variations will not be an issue. If, however, long exposures are desired, multiple visible and NIR images can be collected simultaneously, nodding the telescope on the sky between exposures. Then the visible images can be sky-subtracted and co-added in the same way as the NIR images.

Simultaneous visible and NIR observations will also occur in the case of spectroscopy on faint sky-limited objects for which very long total exposure time and broad spectral coverage is required. Multiplexing with both spectrographs at once will significantly decrease the total required observing time, even if simultaneity of the obtained spectra may not be a specific requirement of the science program. For cases where exposure times of individual frames on the NIR side need to be shorter than on the visible side and the objects subtend small angles on the sky, we have the capability to nod along the slit by 10’s of arcsec using the NIR fold mirror.

For extended objects that fill the slit, nodding off the field by many arcminutes will have to be achieved using the telescope. In this case exposure times may have to be selected as a compromise between sky variations on the NIR side and read noise limits on the visible side.