

Guide to the Imaging Observation with MOIRCS

For the Upgraded MOIRCS (since 2016)

2016-07-27

Introduction

This document describes how to prepare an OPE file for Imaging Observation by MOIRCS. *Please first read through the MOIRCS website below.*

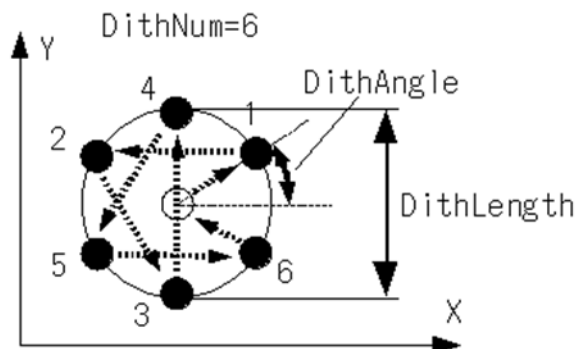
<http://www.naoj.org/Observing/Instruments/MOIRCS/index.html>

There you will find the general information about the specification of the instrument. The basic characteristics of the detectors, the FOV, sensitivity, overhead, the guide for exposure time are summarized in the website, and not given here. You will also find a template OPE file with typical sequences for deep imaging and standard star observations from the *information* page for imaging mode.

Questions regarding MOIRCS should be directed to Ichi Tanaka (ichi_AT_naoj.org: _AT_ → @).

Imaging Observation Guidelines

- (1) In near-infrared observation, accurate sky sampling is the key for the success of the observation. If target is enough small compared to the detector array field of view, we move telescope with a pre-defined pattern, and exposures are taken at each point in the pattern. This “dithering” method is the efficient method to achieve good sky sampling for each objet data. For MOIRCS, the dither pattern available is the N-point circular dither, plus the center (see figure below). Typical N is 9 or less ($N \leq 10$). The diameter of dither circle should be larger than the biggest size of the objects in your FOV. The default is 20”.



- (2) The typical unit exposure for faint objects would be 150-360 s for Y, 45-90 s for J, 10-30 s for H, 20-50 sec for Ks, respectively¹. It is recommended to keep the maximum pixel count of your target below 25000 ADU per readout in order to keep the data within 3 % non-linearity level².
- (3) In order to reduce the overhead by the dither, we usually take more than 1 frame at a dither position (NEXPOSURE option)³. Please keep the staying time at a dither position less than 3 minutes for open-tracking case. Staying at a position too long might result in a poor sky subtraction, which makes the data reduction more complex.
- (4) In default, we don't use the AutoGuider (AG) for broadband imaging. For the NB119 Narrowband Imaging (and Spectroscopic) observation, we recommend to use the AG. Note that the use of the AG will increase the overhead for dither significantly (>30sec/dither for typical case: it will be more for faint AG star).
- (5) We will take the standard stars with slightly defocused (for bright star case). We recommend to avoid too bright stars (>11 mag in K).
- (6) We usually start the observation from focusing. At the evening, we do the two-kind of focusing. One is the FOCUSAG, which is the Autoguider focusing for telescope (in r-band). This is the observatory request. After this, we do the MOIRCS focus. For this, we will go to a crowded star field where >50 stars are distributed over the entire FOV of MOIRCS. We use the fwhm distribution with the detector x coordinate. We define on-focus position when the x-fwhm distribution is flat.
- (7) We recommend taking the "dome flats" data for imaging observation, especially for Ks-band. However, the "sky flats" will also work with reasonable accuracy. However, the dome flats are essential for the NB filter data, because the sky is not "flat" due to the dependence of the filter transmission curve with the angle of incidence to the filter. Strong sky gradient is often observed if the strong OH night emission line is at the edge of the filter transmission curve.
- (8) Dark frames are usually only required for the dome-flat data (except filters in K-window). We subtract the combined dark frame taken with the same exposure

¹ The minimum exposure time has become fairly short by the detector upgrade. Note that the old NDUMMYREAD option and the partial read option have been eliminated for new detector.

² Saturation is ~50k ADU, which slightly depends on the input flux level (smaller for stronger input).

³ This is the same purpose as the old COADD option. Typical time for a dither step is 10-15 sec for the open tracking small dither case.

as the lamp-on dome flats. For filters in K-window, we take the lamp-off dome flat data just after taking the lamp-on dome flats.

(9) On average, about 100-200 GB of data is generated each night.

Table 1: Examples of overheads for imaging mode (9+1-point dither)

$$[\text{Overhead}] = [\text{Typical exposure time}] * [\text{nexposure}] / [\text{Overhead Time}]$$

Exposure & NEXPOSURE are set to keep the staying time at a dither <3 min.

Filter	Overhead	Exposure time per readout [s]	NEXPOSURE	Total exposure time per dither [s]
<i>Y</i>	16%	165	1	165
<i>J</i>	27%	75	2	150
	23 %	120	1	120
<i>H</i>	56 %	30	4	120
	105 %	15	6	90
<i>Ks</i>	34 %	60	2	120
	40 %	45	3	135

(Note) The Overhead Calculations Spreadsheet (Microsoft Excel format: last update 2016-01-27) for the upgraded MOIRCS is available below.

http://www.naoj.org/Observing/Instruments/MOIRCS/nuMOIRCS_efficiency.xlsx

MOIRCS Abstract Commands

OPE file

As of 2016, most observations are executed using the “Observation Procedure Execution file (OPE file)” in Subaru Telescope. The main part of the OPE file is written in the instrument-dependent local commands called the “Abstract Commands”. The OPE file also includes the object definition and the instrument configuration parameter definition. In the appendix you can find the example of the imaging OPE file.

The OPE file consists of the three main parts, namely the Header part, the PARAMETER_LIST part, and the Command part.

```

<Header>
.... (proposal id, observation date etc)
</HEADER>
<PARAMETER_LIST>
.... (target definition, instrument setup definition etc.)

```

```

</PARAMETER_LIST>>
<COMMAND>
... (abstract commands for series of observation sequence)
</COMMAND>

```

In the following subsection we describe the format of target definition, parameter definition, and each Abstract Commands.

Object definition

Please define the object name parameters for your targets in the PARAMETER_LIST part. The target coordinate specifies the center of the MOIRCS FOV (the star mark in Figure 1) and the position angle is given counterclockwise as shown in Figure 1. For the object name alias, please use Capital, numbers (0~9), as well as underscore “_”. Do not use dash (“-”).

Note that the format of RA and DEC is hhmmss.sss and +/-ddmmss.ss, respectively.

Example:

```

FS31=OBJECT="FS31 Standard" RA=231221.600 DEC=+104704.10 EQUI
NOX=2000.0 PA=0.0

```

First “FS31”
is the alias for
texts after “=”

(The words after “OBJECT=” will be the OBJECT keyword value in the FITS header. If you bind up the words by “ ”, you can use any letters or marks, including space or dash.)

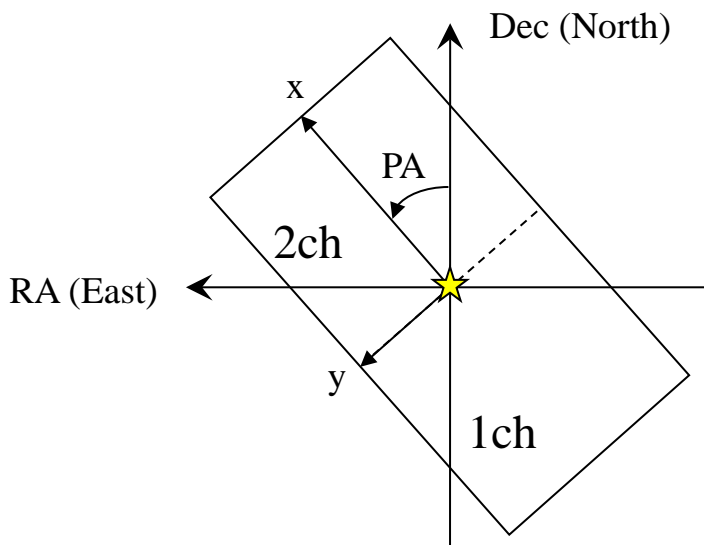


Figure 1. Definition of the position angle (PA) used in OPE file: PA =0 when Channel 2 x-axis is to the North.

SETUPFIELD: Target Acquisition Command

Target acquisition command is “SETUPFIELD”. This will move telescope to the target position and set the MOIRCS PA appropriately.

Example:

```
SETUPFIELD $DEF_IMG $FS31 AUTOGUIDE=NO
```

- If you need the AutoGuider (AG) for long exposure, change as AUTOGUIDE=YES. You will be asked to select the appropriate AG star. For the AG star selection region information, see the MOIRCS Spectroscopy Information website below.

http://subarutelescope.org/Observing/Instruments/MOIRCS/spec_information.html#autoguider

- For the non-sidereal tracking (NST) target, you can prepare the non-sidereal tracking file (e.g. Pluto.DAT) and submit to the SA. For the target acquisition, you can add “COORD=FILE TARGET="08 Pluto.DAT" to the SETUPFIELD command. Currently only open-tracking observation is available for the NST mode.
- You can also add the Filter name alias here (see below).
- As is seen in Figure 1, the pointing position is at the center of the mosaic boundary between channels. As there is a slight gap (a few arcseconds) along the mosaic boundary, you can move the target to the center of the ch1/2 by the TEOFFSET command if the target is a single object, such as a standard star.

SETUPOBE: Filter setup commands:

Filter change command is “SETUPOBE”. See the examples below.

(1) Setup for dark frames

```
SETUPOBE $DEF_IMG $DEF_DARK
```

(2) Setup for a J-band imaging observation

```
SETUPOBE $DEF_IMG $DEF_IMJ
```

The aliases for the filter turret settings are now listed in the system file “moircs_mec2016.prm”, and is automatically loaded to your OPE file. So you don’t have to care about them. Listed below are some examples of the alias definition for filters. MOIRCS has 3 filter turrets for each channel. Filter1

current is for imaging filters. Filter2 is for Cold Stop and some NB/order-sorting filters. Filter3 is for Grisms, BP, etc.

DEF_DARK=FILTER3=BP

DEF_IMJ=FILTER1=J FILTER2=CSL FILTER3=HOLE

DEF_IMH= FILTER1=H FILTER2=CSL FILTER3=HOLE

DEF_IMKS= FILTER1=KS FILTER2=CSL FILTER3=HOLE

If you specify the alias (\$DEF_J etc) for filter setting, each filter turrets are set to the defined positions. If not specified (such as the example for DEF_DARK), each turret receives “NOP”, namely “no change”.

For the list of the alias name you will use, ask the SA during the preparation of the OPE file. Or, you can refer the following website for the complete list of the alias name for filters turret configuration.

http://subarutelescope.org/Observing/Instruments/MOIRCS/FilterSetting_all.htm

CHECKFIELD: Field-of-view check commands:

You can use the command “CHECKFIELD” for the quick check of your field.

Example:

```
CHECKFIELD $DEF=IMG EXPTIME=30 SKYSUB=NO
```

- After the exposure, the image (of channel-2: default) will appear the QDAS fitsviewer window. You can control which channel to be shown by adding QDAS_FRAME parameter (e.g., QDAS_FRAME =1). The default is “QDAS_FRAME =2”.
- If SKYSUB parameter is set to YES, an image on target position and subsequently a “sky” image (which is offseted by +20” in raw X coordinates) are acquired. If you want more offset, you can specify the offset value (in arcsec) by e.g., “ DITHLENGTH=60” to the command. By subtracting the second image from the first image you can see faint objects. This is automatically done by QDAS display (QDAS_FRAME controls which channel to be processed and displayed), or you can do this by “cf recent” command on summit terminal manually (both channel are processed).
- If you are using the AutoGuider, you should add AUTOGUIDE=YES.

- If you are doing the non-sidereal tracking, just add NST=YES. However, you have to start the SETUPFIELD command with the NST mode.

TELOFFSET & PAOFFSET : Telescope offset & rotation commands:

You may want to change the layout of the FOV then use the command “TELOFFSET”.

Example:

- (1) To move *the position of targets* by dx=10 (arcsec) and dy=20 (arcsec).

TELOFFSET \$DEF_TOOL DX=10.0 DY=20.0 AUTOGUIDE=NO

(See Figure 2)

- (2) To change position angle by 10 (degree).

PAOFFSET \$DEF_TOOL DPA=10.0 AUTOGUIDE=NO

(See Figure 3)

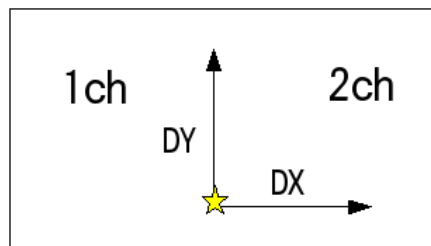


Figure 2. Direction of DX and DY of TELOFFSET in a FITS image

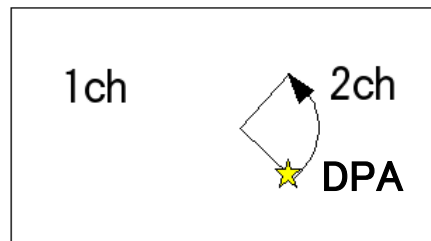


Figure 3. Direction of DPA of PAOFFSET in a FITS image

- During the AG guiding (AUTOGUIDE=YES), you can do a very accurate telescope offset by adding “PROBESYNC=NO”. This offset is done by changing the guiding reference position on the AG calculation window. Use the option only for small offset value (<5”). This is often used for the Spectroscopy mode during the target acquisition on the slit. Note that under “PROBESYNC=YES”, the AG probe physically moves while the guide reference position does not change. The accuracy is less good.

GETOBJECT: Data acquisition command:

The science exposure is done using the command “GETOBJECT”. The command has a number of control parameters as described in Table 2. It is the observer’s responsibility to choose a suitable value for each parameter.

GETOBJECT \$DEF_IMG EXPTIME=50.0 NEXPOSURE=3 DITHNUM=9
 DITHCENTER=YES DITHLENGTH=20.0 DITHANGLE=0 AUTOGUIDE=NO

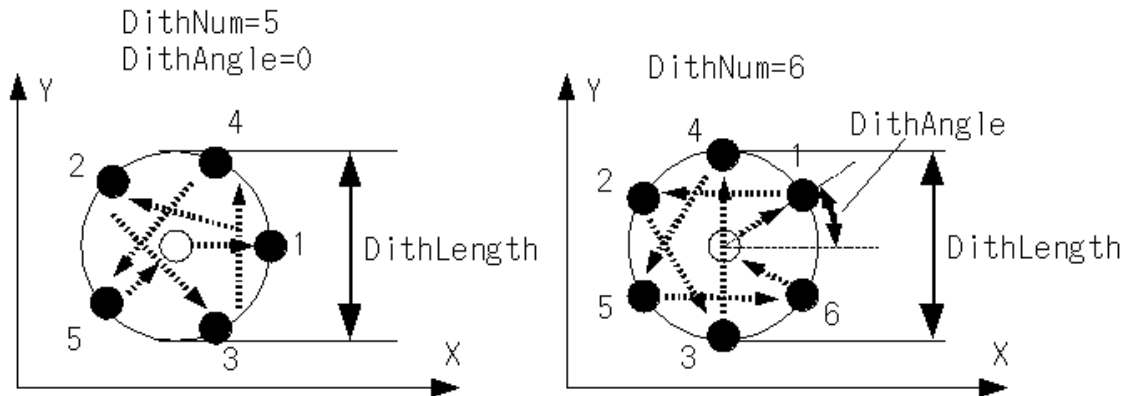


Figure 4. Dither pattern of GETOBJECT: If you assign DITHCENTER=YES, the image at the center position is taken first and a total of (DITHNUM+1) images are taken for each dither pattern.

Table 2: Parameters of GETOBJECT for imaging mode

Parameter	Default value	Description
EXPTIME	0	Exposure time per readout [s]
AUTOGUIDE	NO	Use of the auto guider (YES or NO)?
DITHNUM	0	Number of points of a dither pattern [0-10]
DITHLENGTH	20.0	Diameter of a dither circle [arcsec]. See Fig 4.
DITHANGLE	0	Position angle for a first dither position in degrees. See Fig. 4.
DITHCENTER	NO	Take an image at the center of a dither pattern in a dither sequence (YES or NO)? See Fig.4.
DATYPE	OBJECT	Data type. (OBJECT / TEST / STANDARD_STAR)
NEXPOSURE	1	Number of images taken at each dither position
NDR	1	Number of Multisampling during readout

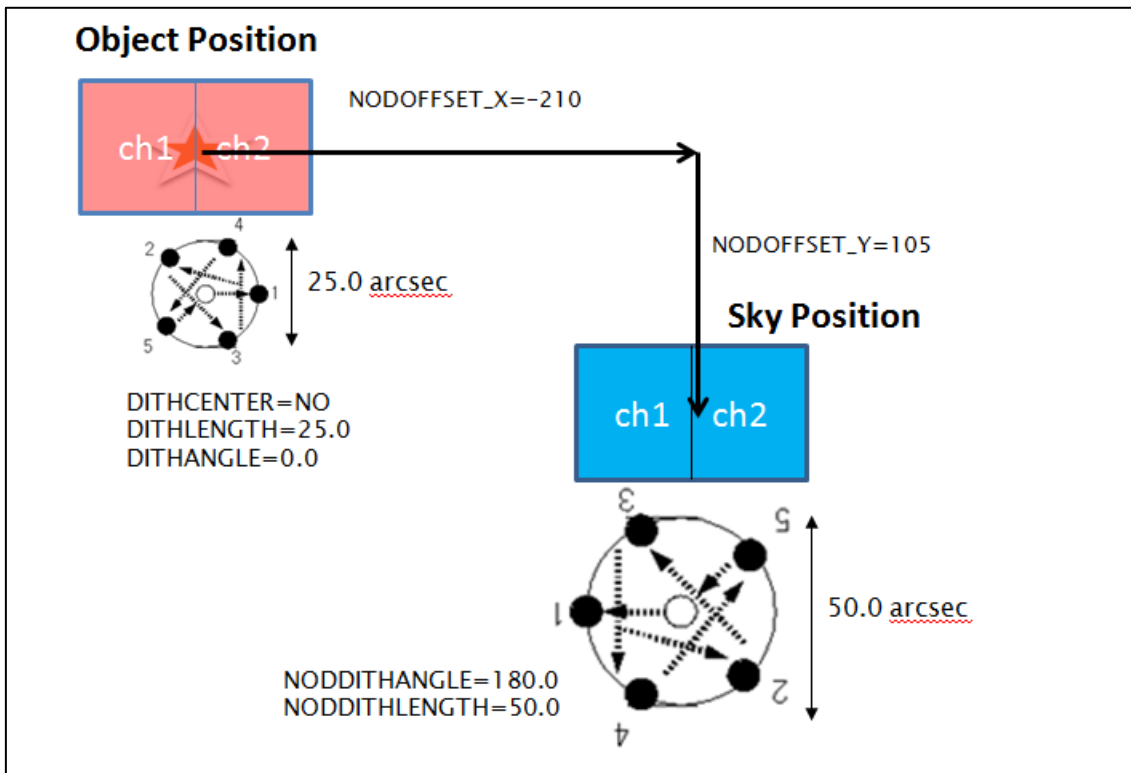
- (1) When you do the big dither with AUTOGUIDE=YES, make sure that (a) the AG star is always available within the AG-usable region during the dither and (b) the AG probe does not vignette the field of view. See MOIRCS website for the AG selection (in [Information](#) page).
- (2) If you want to repeat the GETOBJECT command more than once, set the different DITHANGLE (e.g. +15) for second one. Changing the center position is not effective for avoiding the potential effect of the latent (or the footprint) of the dither pattern.
- (3) Using the NDR parameter (multisampling) can effectively reduce the readnoise, thus is effective for some NB or Y-band imaging. Please refer the MOIRCS website for more detail.
- (4) The COADDS, NDUMYREAD, and PRD_SIZE parameters for old moircs are eliminated by the detector upgrade since 2016.

GETOBJECT with SKYNOD Option

For observation of very large targets, it is effective to acquire the data of the adjacent blank region (“sky region”) as well as main target for better sky subtraction (nodding observation). Below is the example of GETOBJECT for nodding observation (SKYNOD=YES).

```
GETOBJECT          $DEF_IMG  EXPTIME=45.0  NEXPOSURE=3
DITHNUM=5  DITHCENTER=NO  DITHLENGTH=25.0  DITHANGLE=0.0
AUTOGUIDE=NO          SKYNOD=YES          NODOFFSET_X=-210
NODOFFSET_Y=105.0  NODDITHANGLE=180.0  NODDITHLENGTH=50.0
```

Here the position of the “sky region” is specified by NODOFFSET_X and NODOFFSET_Y. The coordinate system is the Image: i.e. the raw detector coordinates (x-y). Note that the move is for object, not telescope. Make sure that the NODDITHANGLE is largely different from DITHANGLE (e.g. by 180 degree). You can use the same size for NODDITHLENGTH as DITHLENGTH. Please set DITHCENTER=NO for SKYNOD observation.



A caution is that the SKYNOD observation will introduce significant overhead due to large telescope move.

FOCUSTELESCOPE : Telescope focusing command:

(Note: Usually operator or SA will execute it. Please ask it as necessary.)

```
FOCUSTELESCOPE $DEF_TOOL EXPTIME=13.0 NSTEP=9 Z=0.1250
DELTAZ=0.025 FOCUS_MODE=FITSVIEW
```

Description: This command changes a position of the secondary mirror and acquires an image at each focus position. The Z value specified in the FOCUSTELESCOPE command is the central Z value for the focus test. The step size of the focus test is given with DELTAZ (mm). This command provides a set of NSTEP images whose focus positions are defined with the values of Z and DELTAZ.

The automatic seeing-measurement program runs on each image, and then calculates the best Z value by the parabola fit for each data points. The result will appear on the “Ginga” fitsviewer display by the option "FOCUS_MODE=FITSVIEW"⁴.

⁴ The old graphical display on sumda PC is also available by setting FOCUSMODE=ANA.

Find the Z value on which the X vs FWHM distribution displayed shows the flattest -- at that Z-value the stellar fwhm should show smallest value. If not, take flatter x-fwhm distribution rather than the size (as it could be variable).

Usually Z value is set as the best FOCUSAGSEQUENCE value + 0.17 (this value is for the “instrument-delta-z”, the Z-value offset between MOIRCS and the AG).

The focus value will shift significantly ($dz=0.1-0.2$) for the first 2-5 hrs in evening by the significant temperature change (and by the poor correction by telescope) after sunset.

FITS Images

The detailed information on the fits image after the detector upgrade in late 2015 can be found at the MOIRCS website below.

http://www.naoj.org/Observing/Instruments/MOIRCS/inst_detector.html


```

SETUPOBE          $DEF_IMG $DEF_DARK

#####
### DARK #####
#####
#>>> To Users: Dark is usually not necessary for imaging obs.
#>>   However you can take some darks to take bad pixel data
#>>   for Dome Flats (especially NB imaging and spec dome and
#>>   Arc-Lamp data).

SETUPOBE          $DEF_IMG $DEF_DARK

GETOBJECT         $DEF_IMG OBJECT=DARK EXPTIME=6 NEXPOSURE=6 DATTYPE=DARK

GETOBJECT         $DEF_IMG OBJECT=DARK EXPTIME=15 NDR=5 NEXPOSURE=10 DATTYPE=DARK
#####
### IMAGING DOME FLATS  ##
#####
#<<< Lamp Setting -- use 600W>>>
# Counts should be around 15k-20k ADU.
# Y 18V 5sec
# J 16V 5sec
# H 10V 8sec
# Ks 16V 3sec
# NBs TBD

# CLOSE CELLCOVER BEFORE TURN THE LAMP ON
CELLCOVER $DEF_TOOL POSITION=CLOSE

# FILTER CHANGE
SETUPOBE          $DEF_IMG $DEF_IMY
SETUPOBE          $DEF_IMG $DEF_IMJ
SETUPOBE          $DEF_IMG $DEF_IMH
SETUPOBE          $DEF_IMG $DEF_IMKS

# OPEN CELLCOVER AFTER ADJUSTING THE LAMP
CELLCOVER $DEF_TOOL POSITION=OPEN

# COUNTCHECK
CHECKFIELD        $DEF_IMG EXPTIME=5

# EXPOSURE
GETOBJECT         $DEF_IMG OBJECT=DOMEON EXPTIME=5.0 NEXPOSURE=7 DATTYPE=DOMEFLAT

# !!! FOR K-band Imaging: TAKE LAMP-OFF DOME DATA !!!
GETOBJECT         $DEF_IMG OBJECT=DOMEOFF EXPTIME=5.0 NEXPOSURE=7 DATTYPE=DOMEFLAT

# !!! FOR OTHER FILTERS: TAKE DARK DATA TO SUBTRACT !!!
SETUPOBE          $DEF_IMG $DEF_DARK
GETOBJECT         $DEF_IMG OBJECT=DARK EXPTIME=5.0 NEXPOSURE=6 DATTYPE=DARK

#####
##### OBSERVATION PART #####
#####

#####
### FOCUSING #####
#####
SETUPFIELD        $DEF_IMG $M3

```

```
SETUPOBE      $DEF_IMG $DEF_IMBRG
CHECKFIELD    $DEF_IMG EXPTIME=5

FOCUSTELESCOPE $DEF_TOOL  EXPTIME=10.0  NSTEP=7  Z=0.175  DELTAZ=0.025
FOCUS_MODE=FITSVIEW
```

```
#####
### IMAGING OBSERVATION #####
#####
```

```
# POINTING TO TARGET
SETUPFIELD    $DEF_IMG $ARP220F1 AUTOGUIDE=NO
SETUPOBE      $DEF_IMG $DEF_IMJ
# FIELD & SKY COUNT CHECK
CHECKFIELD    $DEF_IMG EXPTIME=10 SKYSUB=YES QDAS_FRAME=1
# IF NECESSARY...
TELOFFSET     $DEF_TOOL DX=0.0 DY=0.0 AUTOGUIDE=NO
```

```
### J deep
# Exposure
GETOBJECT     $DEF_IMG EXPTIME=60.0 NEXPOSURE=2 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=10.0 AUTOGUIDE=NO
GETOBJECT     $DEF_IMG EXPTIME=60.0 NEXPOSURE=2 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=-10.0 AUTOGUIDE=NO
GETOBJECT     $DEF_IMG EXPTIME=60.0 NEXPOSURE=2 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=0.0 AUTOGUIDE=NO
```

```
### Y deep
SETUPOBE      $DEF_IMG $DEF_IMY
# SKY COUNT CHECK
CHECKFIELD    $DEF_IMG EXPTIME=5 SKYSUB=NO QDAS_FRAME=1
# Exposure
GETOBJECT     $DEF_IMG EXPTIME=150.0 NDR=3 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=10.0 AUTOGUIDE=NO
GETOBJECT     $DEF_IMG EXPTIME=150.0 NDR=3 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=-10.0 AUTOGUIDE=NO
```

```
### Ks deep
SETUPOBE      $DEF_IMG $DEF_IMKS
# SKY COUNT CHECK
CHECKFIELD    $DEF_IMG EXPTIME=5 SKYSUB=NO QDAS_FRAME=1
# Exposure
GETOBJECT     $DEF_IMG EXPTIME=45.0 NEXPOSURE=3 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=25.0 AUTOGUIDE=NO
GETOBJECT     $DEF_IMG EXPTIME=45.0 NEXPOSURE=3 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=5.0 AUTOGUIDE=NO
```

```
### NB deep
SETUPOBE      $DEF_IMG $DEF_IMBRG
# SKY COUNT CHECK
CHECKFIELD    $DEF_IMG EXPTIME=5 SKYSUB=NO QDAS_FRAME=1
# Exposure
GETOBJECT     $DEF_IMG EXPTIME=150.0 NDR=5 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=25.0 AUTOGUIDE=NO
GETOBJECT     $DEF_IMG EXPTIME=150.0 NDR=5 DITHNUM=9 DITHCENTER=YES DITHLENGTH=20.0
DITHANGLE=5.0 AUTOGUIDE=NO
```

```
# SKYNOD SAMPLE
GETOBJECT          $DEF_IMG EXPTIME=180.0 DITHNUM=9 DITHCENTER=NO DITHLENGTH=20.0
DITHANGLE=10.0    SKYNOD=YES  NODOFFSET_X=600   NODOFFSET_Y=900   NODDITHANGLE=180
NODDITHLENGTH=50.0 AUTOGUIDE=YES
```

```
### IMAGING STANDARD STAR ACQUISITION #####
SETUPFIELD        $DEF_IMG $FS151
```

```
## FILTERS
SETUPOBE          $DEF_IMG $DEF_IMH
SETUPOBE          $DEF_IMG $DEF_IMJ
SETUPOBE          $DEF_IMG $DEF_IMY
```

```
## OFFSET
# Note that you will have to move the standard star to the center of each channel.
```

```
#
# POINTING POSITION -> CHIP-2 CENTER
TELOFFSET        $DEF_TOOL DX=107.5 DY=0 AUTOGUIDE=NO
# POINTING POSITION -> CHIP-1 CENTER
TELOFFSET        $DEF_TOOL DX=-107.5 DY=0 AUTOGUIDE=NO
# CHIP-1 TO CHIP-2
TELOFFSET        $DEF_TOOL DX=215 DY=0 AUTOGUIDE=NO
# CHIP-2 TO CHIP-1
TELOFFSET        $DEF_TOOL DX=-215 DY=-0 AUTOGUIDE=NO
```

```
# FOR FURTHER CORRECTION
TELOFFSET        $DEF_TOOL DX=0.0 DY=0.0 AUTOGUIDE=NO
```

```
## CHECK SATURATION -- PEAK SHOULD BE < 25000 (RAW) ON CH2.
### for nuMOIRCS: ##
# Saturation --- should start at 55000 to 60000 ADU.
# 4-5% non-linearity would occur around 30000ADU.
# high accuracy photometry would do at around 5000-20000ADU.
# Sky background noise limited obs require 500 to 1000 ADU sky level (CDS)
```

```
CHECKFIELD       $DEF_IMG EXPTIME=3.0
```

```
## DATA ACQUISITION wide dither x3+1
GETOBJECT          $DEF_IMG EXPTIME=5 DITHNUM=3 DITHCENTER=YES DITHLENGTH=30.0
DITHANGLE=15 DATYPE=STANDARD_STAR
```

```
</COMMAND>
```