lines are [S II]. The region shown is 500 pixels on a side.

5.5. IFS Calibration Data and Suggested Integration Times:

Table 5-2: Suggested Integration Times for IFS Calibrations

	Red Grism	Green Grism	Hi-Res
Spectral Trace – Bright Quartz Lamp	7.5s gives 200 counts over background	112s gives 200 count over background	TBD
Wavelength Calibration	Ne 30s gives 2k counts over background: S/N=100 in 150s .	HeNe 150s gives 450 counts over bias for brightest line – S/N=30 in 300s.	TBD

IFS observations will make use of the analog CCD bias and flat field calibrations. Bright Quartz spectral exposures are used to find the spectral traces for each spaxel, and to correct for geometric distortion in the IFS mode. Emission-line lamp spectra are used in the mapping between detector x,y and wavelength for each spaxel. Representative exposure durations are given in table 5-2. Testing in August 2011 demonstrated that the spectral format shifts as the instrument is rotated at Nasmyth focus. We recommend a wavelength calibration if the field of the target will rotate more than 15 degrees in the course of an observation.

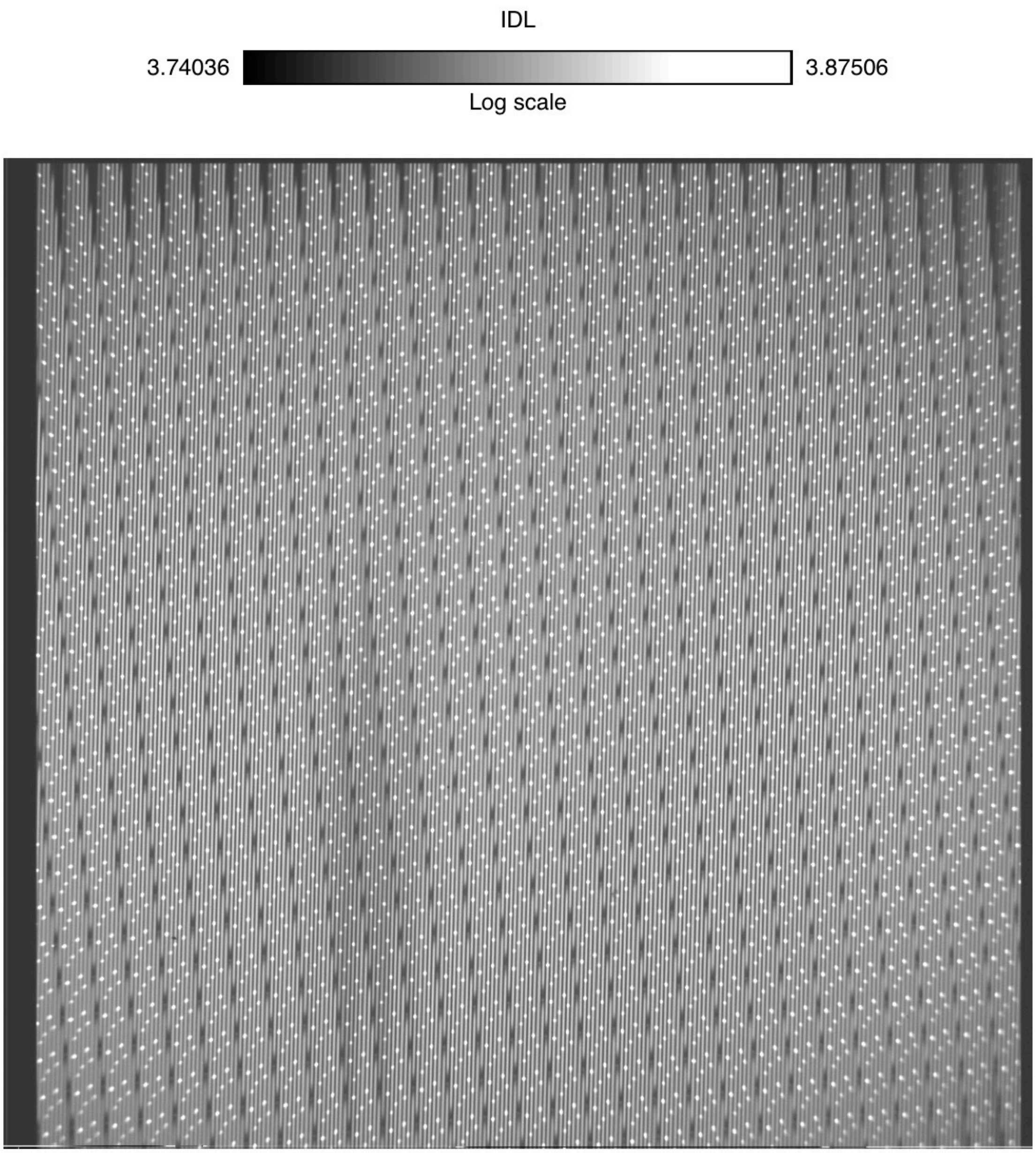


Fig. 5-8: Ne truss lamp + Bright Quartz lamp composite IFS spectral image. Data were taken using the red grism 6622Å blocking filter. Small dark squares are gaps between the spectra associated with each lenslet.

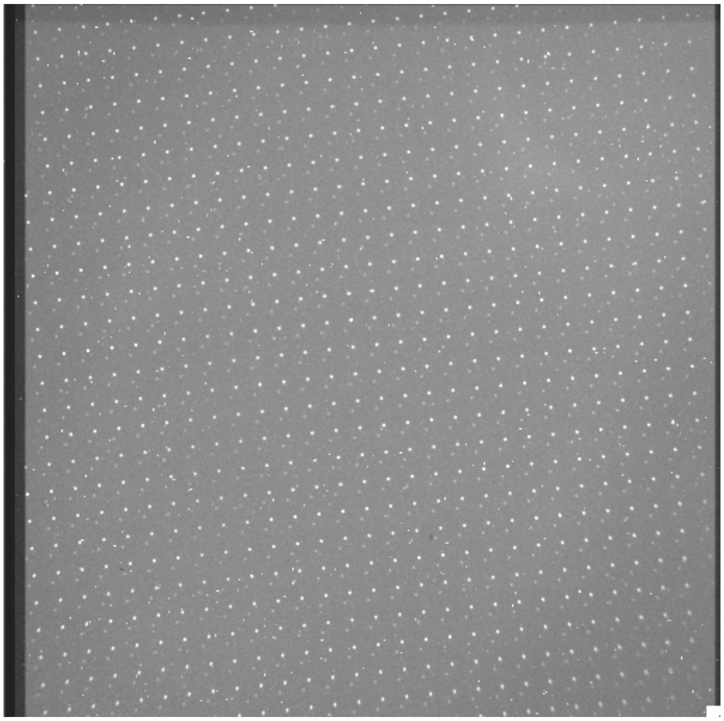


Fig. 5-10: HeNeAr lamp IFS spectral image using the green grism and 4890 Å blocking filter. The emission line spectrum is much fainter and sparser than with the Ne lamp in the red. [replace with better green grism + BrQtz trace data].

5.5.2 IFS Suggested Observing Sequence:

1. IFS spectral image
2. truss lamp wavelength calibration image
3. repeat last 2 steps as needed.

5.5.3 Representative Exposure Times for Astronomical Targets

The lenslet arrays concentrate light into spaxels, which are then dispersed. Under conditions of typical seeing at APO, a point source will have light spread over a number of spaxels. The representative exposure times are for per pixel exposures to obtain S/N=100, not for photometry over an entire point source. Examples are given for a continuum source (BD+28 4211) and a strong emission-line source (DG Tau) observed under photometric conditions. Both sources were sufficiently bright that the pinhole array should have been used, resulting in a need for ~factor of TBD greater integration times.

Table 5-3: Representative IFS Exposure Durations

Source	IFS Acq.	Red grism	Green grism
V=10.5 continuum, Bare 14x14	10s to S/N-100 peak spaxels	~900s to S/N=100 per pixel	~600s to S/N=100 per pixel
V=10.5 continuum Pinhole 14x14	TBD	TBD	TBD
R=11.4 T Tauri star With strong Hα	10-20 for S/N=100 for peak spaxels	Saturate and bleed at Hα in 450s, Continuum near 4500 c/pixel	3000 counts over bias Hβ in 900s in corner of image continuum near 1400 c/pixel [redo]

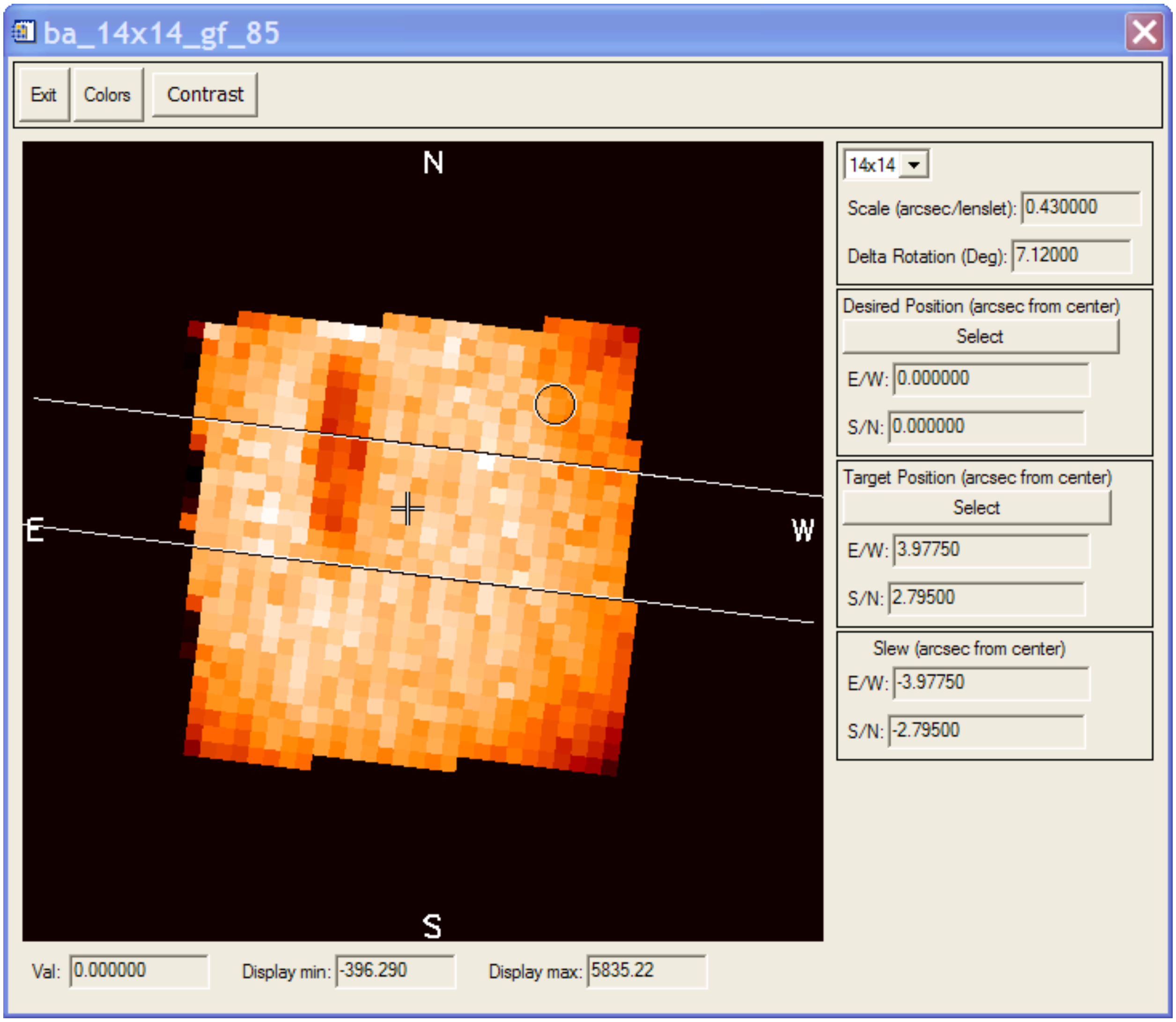
5.6 IDL IFS Reduction Software

As shown in Fig. 5-7 through 5-9, the IFS spectral mode produces a complex, interleaved 2D spectral format, which is hard to interpret from the raw imagery. Similarly IFS acquisition imagery using the lenslet arrays can also be difficult to relate to conventional filter imagery. The IFS data reduction process is described in Carpenter (2011). IDL reduction software is in the IDL file all.sav. Basic steps for processing the target acquisition and spectral data are listed below.

A. Target acquisition using the lenslet array data.

1) Start ifu_slit. (if not already saved, select "File/Parameters" to specify overscan)
2) Read the input image with "File/Read Image"
3) Read appropriate grid file using menu button "File/Read Grid"
From the reference files use *ba_14x14_grid.fits* or *pa_14x14_grid.fits*
4) If the spots are not within the circles, Push the "Shift" button and then drag the grid into position.
5) Push the "Find Centroid" button
6) Push the "Fit All" button
7) Push the Process button.

The following GUI will appear with the integrated flux from each lenslet.



The circle shows the position of the desired target and the + shows the location that you want it.

B. Processing a spectral observation.

1) Read proper spectral trace file with "File/Read Spectral Distortion File"
2) Read proper Grid file with "File/Read Grid"
3) Read wavecal observation with "File/Read Image"
4) If the bright line is not within the circles, use "Shift" to move the grid.
5) Use "Find Max" to center the lines in the circle
6) Push "Fit All"
7) Read the Science target file "File/Read Image"
8) Select the "Spectra" box.
9) Push the "Process" button to extract the spectra

From the IDL command line type:

ifu_final_cube.

- Select the input spectral file you just created.
- Select the proper dispvar file from the reference files.
- Select the wavelength file from the reference files.

The final cube will be written into the file with the input file name followed by _spectra_cube.fits

To run the IDL reduction scripts you also need a set of reference files which are provided with the scripts.

C. Summary of the GSFC IFS reference files.

Reference_files\

- Imaging\
  - ba_14x14_grid.fits
  - pa_14x14_grid.fits
- ba_14x14_gg_gf\
  - dispvar_ba_14x14_gg_gf.fits
  - spectral_grid_ba_14x14_gg_gf.fits
  - trace_ba_14x14_gg.fits
  - wave_ba_14x14_gg_gf.fits
- ba_14x14_gg_slot\
  - dispvar_ba_14x14_gg_slot.fits
  - spectral_grid_ba_14x14_gg_slot.fits
  - trace_ba_14x14_gg.fits
  - wave_ba_14x14_gg_slot.fits
- ba_14x14_rg_rf\
  - dispvar_ba_14x14_rg_rf.fits
  - spectral_grid_ba_14x14_rg_rf.fits
  - trace_ba_14x14_rg.fits
  - wave_ba_14x14_rg_rf.fits
- ba_14x14_rg_slot\
  - dispvar_ba_14x14_rg_slot.fits
  - spectral_grid_ba_14x14_rg_slot.fits
  - race_ba_14x14_rg.fits
  - wave_ba_14x14_rg_slot.fits
- pa_14x14_gg_gf\
  - dispvar_pa_14x14_gg_gf.fits
  - spectral_grid_pa_14x14_gg_gf.fits

race_pa_14x14_gg.fits
wave_pa_14x14_gg_gf.fits

pa_14x14_gg_slot\
dispvar_pa_14x14_gg_slot.fits
spectral_grid_pa_14x14_gg_slot.fits
trace_pa_14x14_gg.fits
wave_pa_14x14_gg_slot.fits

pa_14x14_rg_rf\
dispvar_pa_14x14_rg_rf.fits
spectral_grid_pa_14x14_rg_rf.fits
trace_pa_14x14_rg.fits
wave_pa_14x14_rg_rf.fits

pa_14x14_rg_slot\
dispvar_pa_14x14_rg_slot.fits
spectral_grid_pa_14x14_rg_slot.fits
trace_pa_14x14_rg.fits
wave_pa_14x14_rg_slot.fits

7. Pre-Observation Planning

7.1 Direct imaging

Observers can select 6 filters from among the suite of filters in Tables 3-1, 3-2, and 3-3. Filters will be mounted in holders prior to the start of the observing time. We suggest mounting the filters in order of increasing wavelength. APO will specify the lead time for filter selection and the policy on middle of the observing time filter changes. Since changing filters requires 20-30 minutes to reinitialize the instrument, we suggest loading all filters to be used in a half night prior to the start of the half night.

7.2 IFS observations

IFS observations require blocking filters for each grism to be used, limiting the number of other filters which can be mounted for direct imaging.

Appendix A: Sample FITS Header as of 12/08/23

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 1072 / length of data axis 1
NAXIS2  =                 1032 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
BZERO   =                32768 / offset data range to that of unsigned short
BSCALE  =                    1 / default scaling factor
SECTION1= '//////////////// GFP/IFS Astrometry information/////////////'
FIMPIX  = '0.165 arcsec/pix'   / Filter imaging pixel scale
IFS14SS = '0.0139 arcsec/pix'  / IFS 14x14 spaxel scale
IFS7SS  = '0.00688 arcsec/pix' / IFS 7x7 spaxel scale
IFS14LS = '0.43 arcsec/lenslet' / IFS 14x14 lenslet scale
IFS7LS  = '0.215 arcsec/lenslet' / IFS 7x7 lenslet scale
FIMSSX1 = '570     '           / Filter_imaging_sweet_spot X1
FIMSSY2 = '480     '           / Filter imaging sweet spot Y1
IFSDR   = '172.87 or 187.12 degrees' / IFS_Delta_Rotation
SECTION2= '///////////////Science Instrument Configuration//////////// '
INST    = 'gfp-ifs '           / Goddard Fabry-Perot and Integral Field Spectrog
OBS_MODE= 'IMAGING '           / Observation Mode - IFS, Fabry-Perot or Imaging
D_POS   =               264968 / Numerical position of disperser
D_TYPE  = 'CLEAR   '           / Disperser element type setting
L_POS   =               456938 / Numerical position of lenslet
L_TYPE  = 'CLEAR   '           / Lenslet element type setting
C_POS   =               119970 / Numerical position of Collimator lens
C_TYPE  = 'IMAGING_RED'        / Collimator lens type setting
M_POS   =               349956 / Numerical position of magnifier lens
M_TYPE  = 'CLEAR   '           / Magnifier lens type setting
F_POS   =                    4 / Position of filter on wheel
FILTER  = 'V       '           / Filter element type
FWAVE   = '5500    '           / Filter center wavelength
F_FWHM  = '900     '           / Filter full-width at half max
CALMIRR = 'OUT     '           / Setting of calibration mirror
SECTION3= '/////////////Fabry-Perot Paramters///////////////'
ETALON  = '        '           / Fabry-Perot etalon
ETALPOS = '        '           / Etalon position
FPX     = '        '           / Fabry-Perot X setting
FPY     = '        '           / Fabry-Perot Y setting
FPZ     = '        '           / Fabry-Perot Z setting
FPTEMP  = '        '           / Fabry-Perot etalon temperature
AIRTEMP = '        '           / Fabry-Perot air temperature
FPCALZER= '        '           / Fabry-Perot calib zero point offset
```

```
FPCALN  = '        '           / Fabry-Perot Y setting
FPW     = '        '           / Fabry-Perot Z setting
GFPX0   =                  0.0 / X Optical Center
GFPY0   =                315.0 / Y Optical Center
GFPF    = '        '           / Gradient
LAMP    = '        '           / Calibration lamp
XCOARSE = '        '           / CS-100 X course
XFINE   = '        '           / CS-100 X fine
XRBAL   = '        '           / CS-100 X R-Balance
XGAIN   = '        '           / CS-100 X gain
XTIME   = '        '           / CS-100 X Time constant
YCOARSE = '        '           / CS-100 Y course
YFINE   = '        '           / CS-100 Y fine
YRBAL   = '        '           / CS-100 Y R-Balance
YGAIN   = '        '           / CS-100 Y gain
YTIME   = '        '           / CS-100 Y time constant
ZCOARSE = '        '           / CS-100 Z coarse
ZFINE   = '        '           / CS-100 Z fine
ZRBAL   = '        '           / CS-100 Z R-Balance
ZGAIN   = '        '           / CS-100 Z gain
ZTIME   = '        '           / CS-100 Z time constant
SECTION4= '//////////////////CCD information//////////////'
DETECTOR= '        '           / E2V CCD 201-BI
CTRLTYPE= 'Leach   '           / CCD controller type
CCD_MODE= 'Analog  '           / Analog or photon counting
CCD_PARA= 'CCD parameters for analog mode'
PIX_SIZE= '13.3 x 13.3 microns' / Pixel Size
GAIN    = '2.3 e-/ADU'         / CCD readout gain
R_NOISE = '2.88 e- rms'        / CCD readout noise
FWELL   = '80 Ke-  '           / Full Well
FWELLADU= '34.7826086957 Ke-/gain' / Full Well (ADU)
BIAS    =                 3000 / Bias read noise
DCURRENT= '1e-/pix/hour'       / static dark current of detector (at 170K)
TGT_TEMP=                160.0 / Target CCD temperature (K)
CCD_TEMP=                160.0 / Current CCD temperature (K)
HTR_POWR=                 53.0 / Current CCD heater power (% of max)
SRO_RATE=                100.0 / Serial Readout Rate (kHz)
CLK_MODE= '        '           / Either IMO or NIMO (currently IMO)
EMCCD   = 'Photon Counting Mode Parameters'
HVCLK   = '        '           / High Voltage Clock (Volts)
EMGAIN  = '        '           / electron multipying gain parameter
F_RATE  = '        '           / CCD Frame Rate (frames per second)
ETH     = '        '           / Event Threshold (e-)
CIC     = '        '           / Clock induced charge (e-/pix/frame)
SECTION5= '/////////////////Exposure information////////////////'
EXP_TIME=                  1.5 / Exposure time in seconds
```

```
TIM_FILE= 'fw5_0.lod'          / timing-load file for CCD exposure
DATE-OBS= '2012-08-21T15:45:46.926978' / TAI time at start of exposure
MJD-OBS =    2456161.156388889 / Mean Julian Date of exposure
STARTCLR= '2012-08-21T15:45:12.926978' / UTC time at start of exposure
ENDRD   = '2012-08-21T15:45:12.926988' / UTC time at end of reading final frame
TIME2CLR=                 0.01 / Estimated time (sec) to clear the chip
TIME2RD =                 18.0 / Estimated time (sec) to read the chip
EXP_TYPE= 'FLAT    '           / Type of image taken
CNPIX1  =                 35.5 / Lower Left X pixel pos of image (overscan)
CNPIX2  =                  3.5 / Lower Left Y pixel pos of image (overscan)
END
```

Appendix B: Trouble-shooting GIII

B.1 Detector Heating

The CCD temperature and Lakeshore heater current are recorded in the fits header for each observation, under keywords CCD_TEMP and HTR_PWR. The preferred CCD temperature is listed in TGT_TEMP. At the current temperature of 160K, HTR_PWR should be 53%. CCD temperatures above this value should be brought to the attention of the observing specialists. The CCD temperature will rise if LN2 fills have not been done sufficiently slowly to fill the CCD.

B.2 Stray-light in Birger Shutter/Canon Camera Lens

The Birger shutter assembly and Canon camera lens are equipped with IR LEDs which produce a straylight signal when plugged in. When unplugged, dark exposures are indistinguishable from bias frames except for the higher incidence of cosmic ray events. As of 2012 January 10, the assembly is unplugged.

B.3 Balancing the Filter Wheel

When fewer than 6 filters are to be loaded into the filter wheel, care must be taken to ensure that either empty filter holders are loaded into the blank slots or that filters are mounted on opposite sides of the wheel, to ensure that the wheel is balanced for normal rotation. For example, if only 2 filters are to be loaded they need to be in slots 1 and 4, or 2 and 5, or 3 and 6.

B.4 Rotational Displacement of GIII on Nasmyth.

GIII has some flexure which changes as the instrument rotates at the Nasmyth port. This can result in significant displacement of sources at the detector for either long integrations or in spectral mode. At this time we recommend interleaving IFS spectral observations with wavelength calibration data every ~30 minutes.

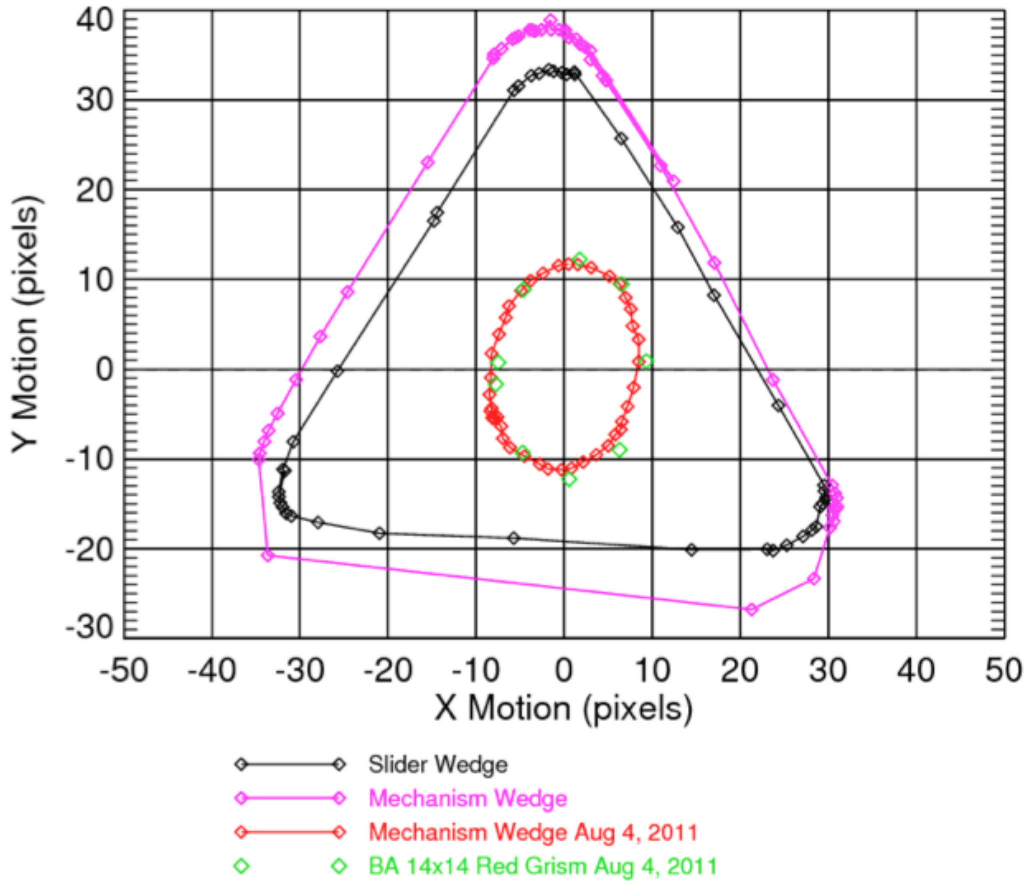


Figure B-1: Image displacement of a point source at the GIII detector over the course of 360° instrument rotation. [check for update?]

C. Readying GIII for Observing

C.1 Lead Time and Time Requirements

Readying the GFP for observing is a bit more involved than the typical facility instrument at APO, and requires both some hardware installation and calibration effort before the instrument is ready to go on the telescope.

Table C-1: Time requirements for Installation

Activity	Lead Time	Time Requirement
Dewar hold time		16 hours
Cooling CCD from ambient to 160K	2-3 hours?	
Filter Mounting in Holders		30 min-1 hour
Filter loading and software updates including reinitialization of Newmark drive		30 min
Instrument Take-down		15 min to 2 hours
Etalon and Filter Equilibration	24 hours ahead of need, bring to dome	
FP etalon installation		30 min
FP coarse parallelization		30 min
FP Fine Parallelization		1-2 hours

C.2 **Storage Locations for GFP Equipment:**

1. Filters, Etalons, and related materials: Between observing runs, the GFP filters, and related materials need to be stored under controlled humidity and dust conditions. At APO, they are stored in a variety of shipping containers on top of cabinets lining the back wall of the computer room. Note: if you are under 5'8" you will need to get assistance in lifting the containers down.

2. Other materials: Other tools, etc. that are specific to the GFP are stored in the 3rd shelf from the top of the tall, tan storage cabinet nearest the stairs on the observing level.

Fig. C.3 Back View of GIII mounted on the telescope. The gold circle is the GIII dewar. The silver rectangle to the left of it is the Leach controller. The disperser drive is the large, black rectangle.

Fig. C.4 GIII components on the Mezzanine Level, with the Lakeshore heater controller sitting on top of the Newmark drive controllers.

Fig. C5 Detail of Newmark controllers. Power switches are to the left, with green power indicator lights. Various drive components controlled by each Newmark are indicated to the right. The filter wheel controller is at the bottom of the stack.

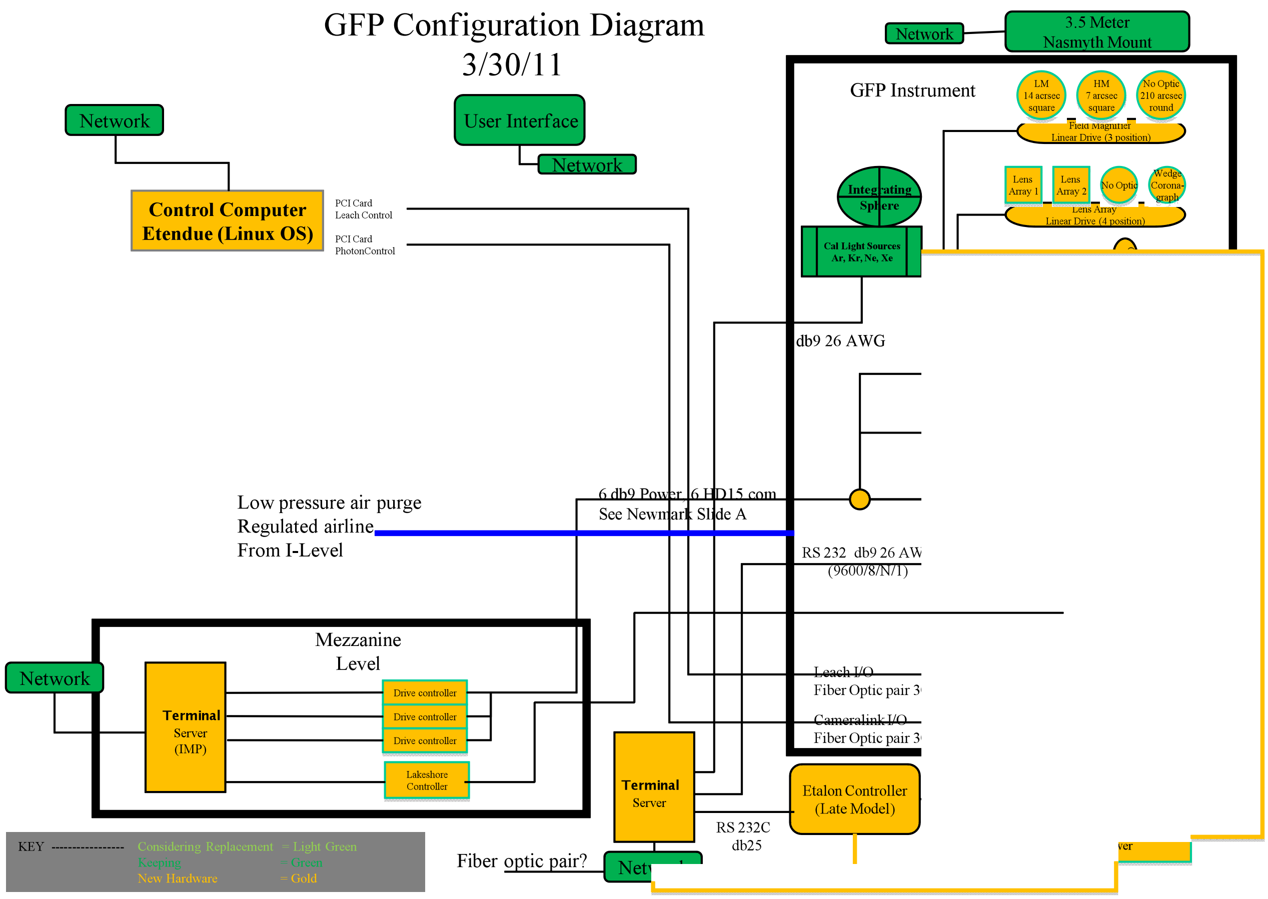


Fig. C-6: GFP Configuration Diagram (see TBD).

C. 3 Filter Installation

The observer should specify which filters are to be used during the observing run, and the preferred order that they should be mounted in the filter wheel. We suggest that the default order be by increasing wavelength. Make a table listing the filters in the correct order. The table will be needed both to ensure correct placement in the wheel, and to update the instrument configuration files.

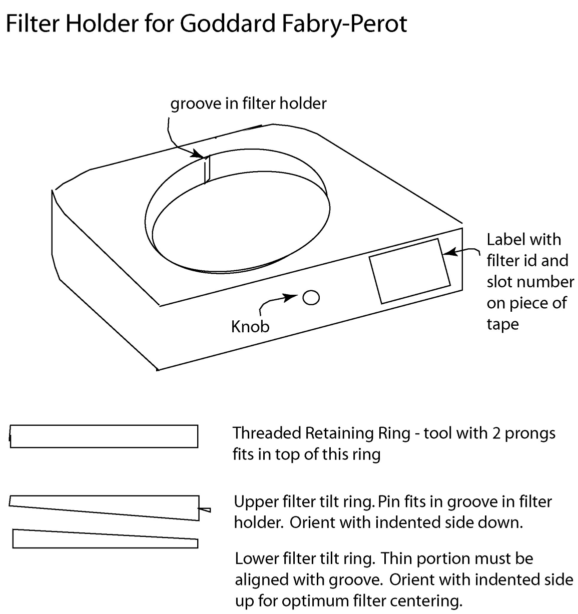


Fig. C.7 : GFP Filter holder parts

- filters are listed in section 3 of the manual.

- filters are stored in large black boxes labeled filters. The boxes are stored on top of the shelves on the back side wall of the computer room. They are generally ordered by wavelength, but may be stored in boxes provided by the manufacturer within the larger black boxes.

- The filters mount in housings with knobs in such a way that the filter is tilted to avoid ghost images in GFP data. The filters mount in the housings in the following order :
  - bottom spacer which has a small tilt
  - have the thinnest part with groove aligned with groove in Al filter holder.
  - place filter in carefully (use lens paper over hand to cushion drop of filter into holder. Orient the filter so that the lettering on the side of the frame will be right side up as you mount the filter in the holder. This will put the reflective side of the filter facing down.
  - place other spacer with pin in the groove.
  - screw in the outer ring using the 2-prong tool (stored in TBD box).
  - Rotate the mounted filter so that the knob is up and the installation side faces you. Make a label for the holder on a piece of cloth or masking tape with central wavelength and bandwidth. Stick this to the top of the holder, so that it is right side up as you look down on the holder. Filter Installation: Filters can be installed in the wheel either manually with the stepper motor power off, or with power under computer control (best with laptop brought to the dome level).
  -
    - Turn off the third Newmark drive from the top of the stack (see fig. C-5.)

- Unscrew large screws to filter access panel, which will hinge open
- With the motor off, you can easily manually turn the wheel.
- When changing or installing filters, load the filters on opposite sides of the wheel (e.g. 1 and 4) sequentially to maintain balance in the wheel. This step is especially important for lighter filters such as B,V,R, I. Place filters in the slot number specified by the observer with the tape patch identifying the filter on the right side of the knob as you face the telescope.
- Verify that the correct filter is in the slot as requested by the observer.
- Button up the filter access.
- Turn on the Newmark drive. You will need to reinitialize this drive.
- Place filters which have been changed out into the plastic transport box. If these will be used later in the run, leave in dome near the etalon storage box. Otherwise, bring the filters to the large storage boxes for dismounting and returning to their storage boxes.

o Update the filter configuration file filters.cfg

Contents of filters.cfg which is a text (ASCII) file which can be edited using the editor of your preference. Filters are identified by mnemonic, central wavelength and FWHM.

```
# GFP/IFS filter element config file##
# Use lowercase letters for names of filter elements#
[Filter_Elements]
clear: 1
green: 2
red: 3
blue: 4
h_alpha: 5
s_ii: 6

[Filter_Centers]
clear: NA
green: 4891
red: 6622
blue: 4700
h_alpha: 6565
s_ii: 6750

[Filter_Widths]
clear: NA
green: 314
red: 419
blue: 135
h_alpha: 120
```

s_ii: 200

D.4 GIII Startup Procedure

A. In the dome - Detector/Dewar (EMCCD)
   1. Make sure the CCD201 Dewar two cables are connected to the LEACH electronics box, the lakeshore cable is connected, and the fiber optic pair are connected to the control computer IMP. If they are not connected use safe ESD protocols to connect them.
   2. Check the CCD201 temperature and last fill time. Refill dewar if needed, slowly (!).
   3. Turn on main power located on main power box:
      On Grey Aluminum (~12" x 18" x 10") power supply box where power cord connects to box is a small on/off switch. Simply flip this switch to the on position.

B. Location – 3.5M Mezzanine level CIII Main Instrument Rack:
   4. Turn on all three Newmark Controllers Located in Rack (fig. C-5 and below)

   The power switch is on the front of each controller. Flip each switch for the three controllers to the on position.

5. Start up / turn on the control computer IMP:
   Press the power button on the front of the chassis.

E. GFP/IFS Emergency Shut Down Procedure

Location - 3.5M Dome GFP/IFS Main Instrument:
Detector/Dewar (EMCCD)

1. Turn off main power located on main power box:

   On Grey Aluminum (~12" x 18" x 10") power supply box where power cord connects to box is a small on/off switch. Simply flip this switch to the off position.
   "Please elaborate Tim"

Location – 3.5M Mezzanine level GFP/IFS Main Instrument Rack:

2. Turn off all three Newmark Controllers Located in Rack:

   The power switch is on the front of each controller. Flip each switch for the three controllers to the off position.
3. [UPDATE – GEORGE-JAMES-JON] Shut down the control computer IMP in the computer room.

Log in as 'apoadmin' and issue the command 'sudo shutdown -h now'. If immediate shutdown is necessary, it is OK to hold down the power button on the front of the chassis.

F. Python Commanding via TUI.

See TBD.

G. REFERENCE MATERIALS in folder GIII_Materials

- GFP Configuration Diagram New 7.ppt (George Hilton, 2012)
- IFU_Slit_instructions2.docx (Lindler, D. 2011)
- IFU_Slit_walkthrough.dox (Carpenter, B. 2011)
- IFS_reduction_using_current_reference_files.docx
- all.sav (IDL save file containing compiled code for IFS data reduction)
-