George and Cynthia Mitchell Spectrograph (GCMS, alias VIRUS-P) User Manual

GCMS is a high-efficiency, low- to moderate-resolution integral field spectrograph with a 1.7 arcmin x 1.7 arcmin field of view. Poisson noise limited, sky subtracted spectra are routinely achieved. The reflective optical coatings set the bandpass of the instrument as 340 - 685 nm, and there are approximately 4.6 pixels per spectral resolution element. The spacing of the fibers on the sky results in a 1/3 fill factor. Therefore, to capture all the flux from a target, the telescope is typically dithered in a 3-position pattern that covers all the flux. The instrument is extremely stable due to the use of invar for thermal stability, and a gimbaled mount for stability against gravitational flexure. The instrument went into service in 2007.

Details on the instrument can be found at
https://mcdonald.utexas.edu/for-researchers/research-facilities/2-7-m-107-harlan-j-smith-telescope/165-researchers/645-virus-p

The instrument paper (that should be referenced in publications) is: Hill, G.J., MacQueen, P.J., Smith, M.P., Tufts, J.R., Roth, M.M., Kelz, A., Adams, J.J., Drory, N., Grupp, F., Barnes, S.I., Blanc, G.A., Murphy, J.D., Altmann, W., Wesley, G.L., Segura, P.R., Good, J.M., Booth, J.A., Bauer, S-M., Popow, E., Goertz, J.A., Edmonston, R.D., & Wilkinson, C.P., 2008, “Design, construction, and performance of VIRUS-P: the prototype of a highly replicated integral field spectrograph for the HET”, Proc. SPIE, 7014, 257.

Table of Contents

1.0 **Startup** (before you start observing)

1.1 Getting the Observing Setup Ready

Login to atlas.as.utexas.edu using the credentials issued to you (if you do not yet have an account, contact mcd-os@utlists.utexas.edu).

You will see a colorful bar across the middle of the screen that contains launchers (icons) for various tasks you will need. At a minimum, you will need the telescope control system (TCS), the night report (NR), DS9, ice-gcms, and GCMS autoguider. Other launchers exist for various cameras, firefox, spreadsheets, terminal windows, etc. Open the various tools mentioned here (**launch DS9 before using ice**).

In ice:

ICE > mytasks
ICE > status

If the CCD is not responding when doing “status”, two things might be happening -

a) the CCD is powered down. If so, power it up by doing

ICE> v2 V2p = 1

and then repeat the above commands.
Note: v2 V2p = 0 powers down the CCD.

or

b) the link fibers to the CCD controller are swapped. This is unlikely as Observing Support will have already run the detector successfully. Contact observing support.

If the pressure is not being reported when doing “status”, the vacuum gauge might be off. Power it on with

ICE> v2 VG=1 (on)
Note: Turn it off with v2 VG=0
Note: The vacuum gauge should be OFF when observing because of it creates stray light that the CCD will detect.

Next you need to check that you can read out frames. First, you should create a folder on one of the data disks for your data. Use the script *tonight* which has a parameter file allowing configuration of its behavior.

ICE> tonight

This will create a folder for tonight’s data on /data1/[user_name] and will change into that directory. Note that the date on this directory is given in UT time not local time. Alternatively, you may manually create a directory on a data disk and call it what you want, and then within ICE change into that directory.

Be sure to do this each night so the data do not go into your home directory (limited room on the disk hosting /home compared with the disk hosting /data1) and they go into different directories by date.

Once you have changed to the data directory for the night, you should test that you can read out a frame.

ICE> test

number of exposures (1) (1): 1

Image type (object|zero|dark|flat|comp|focus|ir} (zero): zero

Choosing "zero" for the image type means you are taking a bias frame. If you get a nice looking frame with mostly a single signal level, you are doing well.

At this point you should start a log sheet (digital or paper) that records things like frame_name, UT, image-type, exposure time, coordinates and anything else you will need for reducing and interpreting the data.

1.2 Setting the Observing Parameters

You need to edit the "observer parameters".

ICE> epar obspars

In this parameter file you should set the name of the observer, the prefix for the frames and the sequence number. If the prefix is GCMS and the sequence number is 1234, then your first frame written to disk will be GCMS1234. The sequence number will increment for each successive frame saved (and will be remembered for another night/run if you do not unlearn obspars).

Next set the "detector parameters".

ICE> epar detpars

Set the binning (1x1) and the integrator 2

integrator = 1	not very useful. Relative to integrator 2, has twice the read time for only a 0.1e drop in readout noise (3.6 e)
integrator = 2	The nominal choice for data taking. Is a compromise between readout time (86 sec read binned 1x1) and readout noise (3.7 e)
integrator = 3	highest readout noise (4.2 e), but with half the read time of integrator 2. Useful for speedy setup work, or higher signal targets

Check the read-noise level by typing

ICE> bias

This will take a bias frame, compute and report the readnoise in both electrons and ADU in a set of horizontal sections of the frame. The readnoise should be around 3.7e. If it is much higher than that, contact Observing Support and/or Phillip McQueen.

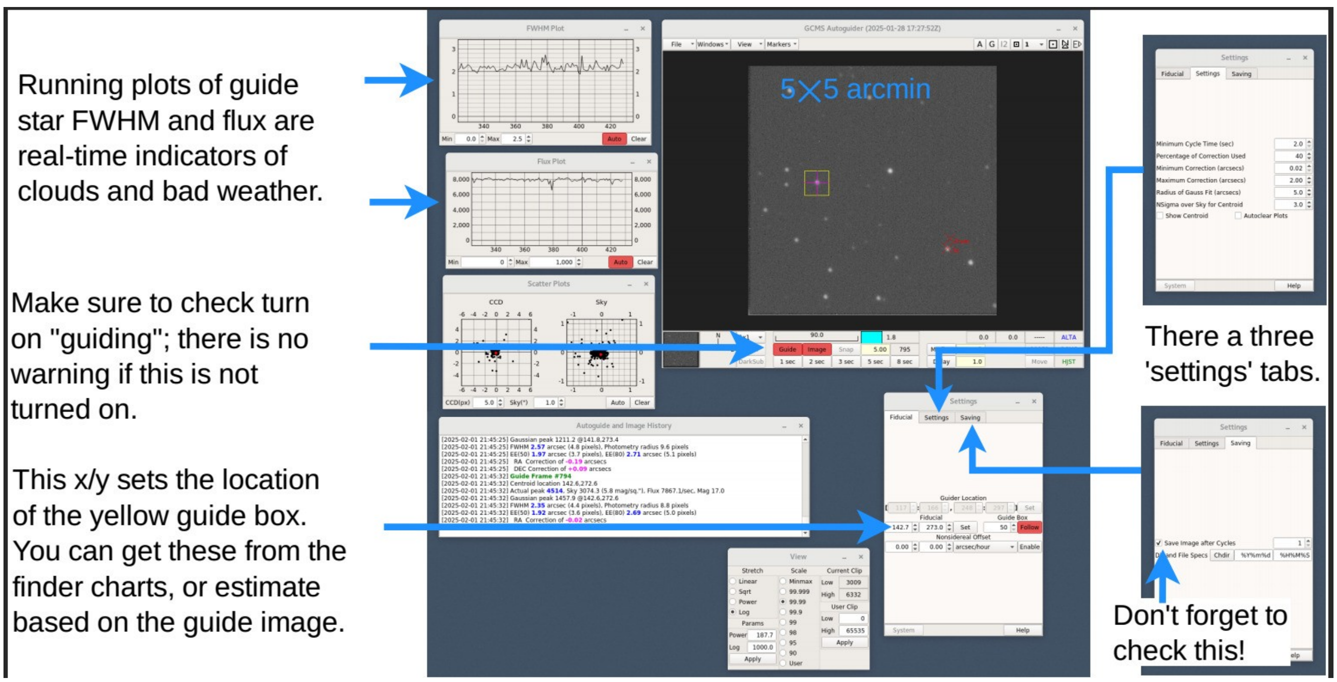
Note that the combination of the detector gain and readnoise means that the detector goes non-linear ~180,000 counts and data above this value will not be accurate. Users are unlikely to hit this count level for the normal (faint) targets. However, be careful of this limit when obtaining calibration data or for you relatively bright standard stars.

1.3 Readying the Telescope and Guider

The TCS Control system GUI on atlas is a duplicate of the console on the dome floor and runs the telescope.

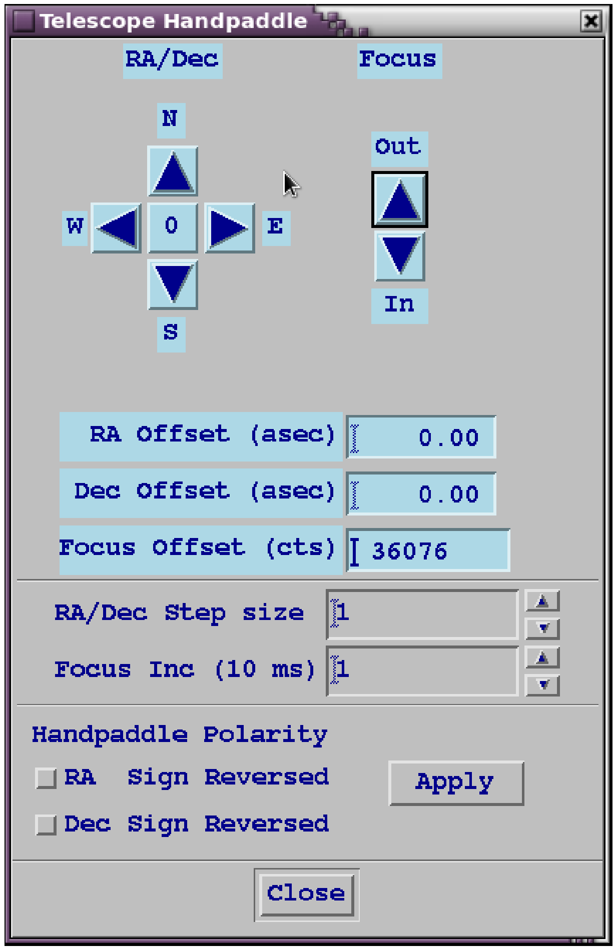
Click the button near upper left to make the telescope control system *Active*.
Under the “Tools” menu, click on “handpaddle”
Under “view” click on “sky plot”

Use the GCMS autoguider window(s) to set up the guider. The program remembers which windows were open along with their on-screen locations when you last ran the guider. At a minimum, you will want the expose, view, history, display charts and fiducial windows in use. The figure shows a representative setup for users.



Note that the guide camera views a piece of sky 540 arcsec away from the part of the sky that the IFU is imaging. Thus, when you point to the coordinates, you will not see the field of your target. Instead, you will be viewing a region 540 arcsec **North** of your object. To center your object on the IFU, move the telescope 540 arcsec south using the TCS digital handpaddle and check the field. Once you identify your target, place it on the IFU marker (see below) and move the telescope 540 arcsec north and choose a star to guide on. Alternatively, you can position the telescope for your target by using the finders generated for this instrument (see below).

To make it easier to move back and forth, set the step size for Dec on the digital handpaddle (opened on the TCS gui under the “offset” button on the left hand side of the gui) to 540 arcsec. Then, you will only need a single step to move between IFU and guide field. However, as the system might lose steps over such a large distance, change the handpaddle reference position rate (menu “Tools”, item “Handpaddle rates” in TCS) from the default 600 arcsec/sec to 120. It would be a courtesy to following observers if you set the step size back to ~1 arcsec and the speed to 600.



Under the expose menu, set the exposure time for the guider images or use the buttons under the guider image to pick an exposure time. During acquisition, a short integration time of 1 or 2 seconds allows faster work. During guiding, 5 seconds is recommended to prevent the guider chasing image motion out of phase with the motion. You can set up the system to autosave guider frames. It can save every image or every nth image, depending on the parameters picked. The default is to place those images in the directory from which you started the autoguider and to save every image. You can change both those options. It might be useful to check this box when you start up just to confirm what directory they are being saved to. Then when you have the desired location and cadence you can turn saving off again if you do not need it.

Under the view option, you can adjust the scaling. “zscale” often works but sometimes changing the scaling parameters makes it easier to see some objects.

Under the marker menu, you may create or delete markers of various sorts. One marker that is helpful is to put a marker such as “Target 1” in the place on the offset position image that corresponds to where you need to put your target so that it is on the detector when you move back the 540 arcsecs offset position.

Once things are set up, you can click “snap” in the guider box to get a single image or “Image” to get continuous readouts. In order to autoguide, you must tell the program what to lock onto. You do this by creating a guide box, either by drawing the box around the appropriate place with the mouse or choosing the “specify fiducial” item in the guider window. The latter will create a box of 50 pixels with a cross hair centered at the given coordinates. Specifying the coordinates for the fiducial will only work if the star is in the 50 pixel box.

On nights with poor seeing, you might want to change the “radius of gauss fit” from 5 to 10 arcsec.

1.4 Filling the Dewar

The dewar must be filled with liquid nitrogen once a day. It is best to fill it within 30 hours of the last fill. This will be done by the Observing Support team. They will note when it was filled in the night report. Users should *always* check the night report to see if it has been done.

1.5 Calibrations

The calibrations that are needed for this instrument include bias frames, arcs for wavelength determination, and twilight flats. Typically, you should obtain 11 bias, 11 arc, and 11 twilight flats (though more are also acceptable). The CCD has essentially no dark signal in 30 minute observations, so taking and applying dark frames will simply increase the noise without any positive benefit.

For biases, use the “zero” command:

```
ICE> zero
    number of frames = 11
    frame title = bias
```

For dispersion curve (wavelength) determination, arc lamps are observed through the telescope with the telescope pointed towards the curtain at the side of the dome.

- Point the telescope to AZ=180, ALT=20
- Enable telescope automation (so the dome slit follows the telescope)
- Raise the lower windscreen high enough to completely cover the telescope aperture
- Open the mirror cover (hold button on console until the light turns on)
- Turn on lamps by turning on power sources and wait about 2 minutes for warm up
  - Use Ne + Cd for the red low-resolution VP1 setup (4500-6800A)
  - Use Hg + Ar for the blue high-resolution VP setup (3600-4400A)
- The bulbs are irreplaceable and must be treated with the greatest care. Observing Support will normally do the bulb changes. If you need to change bulbs, do NOT touch the bulb bare handed – use gloves that are provided

Observe the lamps with the “comp” command”

[This section needs updating with new stuff]

ICE> comp

11 frames

20 seconds each for red low-resolution

300 seconds each for blue high-resolution

Over typical bandpasses there are both strong and weak features. One approach often used is to obtain both long exposure times to bring out the weaker features plus short exposure times to not saturate the stronger features.

To build a flat field for GCMS, observations of the twilight sky are obtained. These may be obtained at either dusk or dawn (or both for highest accuracy!). Observations should be made with no telescope tracking.

Open the telescope if it is not open.

If it is dawn, stop tracking.

Move the upper and lower windscreens so they are not in the way.

Point the telescope to: AZ = 90, ALT=80 (dusk, east)
AZ = 270, ALT=80 (dawn, west)

Run a test exposure of 0.5s (dusk) or 60s (dawn)

ICE> test

0.5 (60) second

image type = flat

If you see ~10,000 counts in the peak of the fibers, then it is dark enough (bright enough) to start taking flats. Use the autotwi command. At dusk, you can start shortly after sunset as the autotwi script will fail with “exposure too short” if it is still too bright.

ICE> epar autotwi

set integration to your best guess (based on test above) to get ~25000 counts

set sense =0, dusk or beginning of night
=1, dawn or end of night

also set

month = decimal of current month (e.g. 1.5 for Jan 15, 9.3 for Sept. 10)

target = number of desired counts (25,000 is recommended)

max_t = 300s (autotwi will stop when next integration is longer than this)

min_t = 0.1s (autotwil will stop when next integration is shorter than this)

tot_num = 11 (number of frames to attempt)

save the parameters and run

ICE> autotwi

If it is dusk, start the telescope tracking.

If it is dawn, close the telescope and stow. (see section 3.0)

Note: When using autotwi in the evening, you will sometimes try to obtain data through the time when the sky becomes too dark. You may then receive the following error message:

ERROR: log of a negative or zero argument

"tc1*log(a_val)/s_val)/log(a_val))-(t_i+real_rt)"

line 103: scripts$autotwi.cl
called as: `autotwi (mode=h)

This is normal behavior as it is getting dark. You should NOT get such an error message in the morning twilight.

2.0 Observing

It is assumed that the observer has been trained how to run the telescope, including how to start and stop tracking, how to turn on the automation so the dome follows the telescope, etc. Running the telescope is documented at TCS Manual. If the telescope dome is not open at this point, check the weather and open the dome. As part of opening the mirror cover, extend the light shield/baffle from the console. This blocks off-axis sky from reaching the detector. Be sure to turn on tracking (it will automatically get turned on when you point to an object). Be sure to note the time you opened in the night report. Add information on weather, seeing and time lost on the night report throughout the night.

Creating finder charts and other useful procedures are in section 4.0.

2.1 Check Pointing, Update Zero Points

In order to check the pointing of the telescope, choose a bright star near the zenith (on the TCS under the next menu click “Bright Stars Near Zenith”). A list and a sky plot will open. Choose a star from either the list or plot. It should load the coordinates into the next object on the TCS gui. Choose “Go Next” and go out to the telescope and hold down the deadman switch until the TCS says “on target”.

Back in the control room and using the digital handpaddle, click “South” 1 step to move the telescope 540 arcsec south (this assumes you set up the digital handpaddle as in section 1.3). Start the guider integrating. You should see the bright star on the guider window. Center the star on the marker that you loaded in section 1.3.

Now you want to put the star back into the IFU field. Click “North” 1 step on the digital handpaddle so that the telescope moves 540 arcsec north, centering the star on the IFU. On the TCS, zero the telescope coordinates. Note that you should probably check that the mount model is 2.7m Cass prior to changing the zeroes, especially on the first night.

If you want, you can take a science (or test object) frame to see that the central fibers in the IFU show the star. This is not necessary since this procedure works, but it can give peace of mind.

2.2 Focus the Telescope

Focusing the telescope with GCMS is very hard and requires patience. However, focusing is actually not that critical since the fibers are 4.3 arcsec in diameter.

In the guiding field (the one 540 arcsec from the IFU field), find a bright star and draw a box around the star. Start the guider exposing with an exposure time of 3s. Now look at the FWHM on the strip chart. Average the FWHM for 5 – 10 readouts. Write down (or otherwise remember) the focus value from the TCS gui and the average FWHM. With the handpaddle, change the focus one way or the other by about 100 counts. Again, derive the average FWHM of 5-10 frames. Keep changing the focus until you reach a minimum FWHM. Be sure to check in both directions. It is good practice, when setting to the final value, that you approach the desired value from below to reduce the hysteresis.

2.3 Observing Targets

The 1/3 fill factor of the focal plane means that an observation at a single position on the sky will have gaps between observed sky and sky that is not observed. Hence, it is common to dither the telescope in order to observe all the flux from a target. Scripts within ice exist for just this purpose.

To observe a target, the telescope must first be pointed at it and the object centered.
Enter the coordinates in the TCS gui and hit "Go Next". Hold down the deadman switch on the dome floor until the console shows you are "on target". However, recall that the field seen in the guider is 540 arcsec north of where the IFU is viewing and where your target presumably is.

To verify the pointing and center your target on the IFU, you may take one of two approaches. The first approach is to use the digital handpaddle and move the telescope 540 arcsec south and expose with the guider. Identify your target (by eye or with a finder chart) and place it on the mark you made in Section 1.3. Be sure to match the orientation of the guider field with that of any finder chart you use (the guider window shows a compass rose for orientation and the orientation of the guider window may be flipped with one of the buttons in the upper right). Now move the telescope 540 arcsec north to place the target on the IFU, set up a guide star and start your observation. [Needs updating – will this still work?]

Alternatively, there is a program to create finder charts that show not only the field of the target but also the field that is seen in the guider when the target is on the IFU. This program is described in section 4.XXX. The finder chart image for the guiding field shows that field with some stars marked with coordinates within the guide field for you to place the guide star to align your target on the IFU.

Once you have the guider set up, you can start observing. There are 4 different scripts that can be used to obtain data. Two of these will dither the telescope (move between positions) to three different positions to cover the fill factor. The other two scripts will also include sub-dither positions to ensure all light is captured and takes observations over 6 different positions. The dither routines are set up to get to each position and wait a short time for the telescope to "settle" prior to starting the observation. The settle time can be adjusted in the scripts. Probably a settle time of at least 2X the guider camera exposure time is a safe value. However, for very long exposure on very faint targets, a shorter wait can be used.

For most targets, you will want to use the 3 position dither. The scripts for these observations are vp2_dither.cl and vp2_dither2.cl. The first will point to each of three positions, taking spectra at each, starting with position 1.

ICE> epar vp2_dither

fill in parameters:

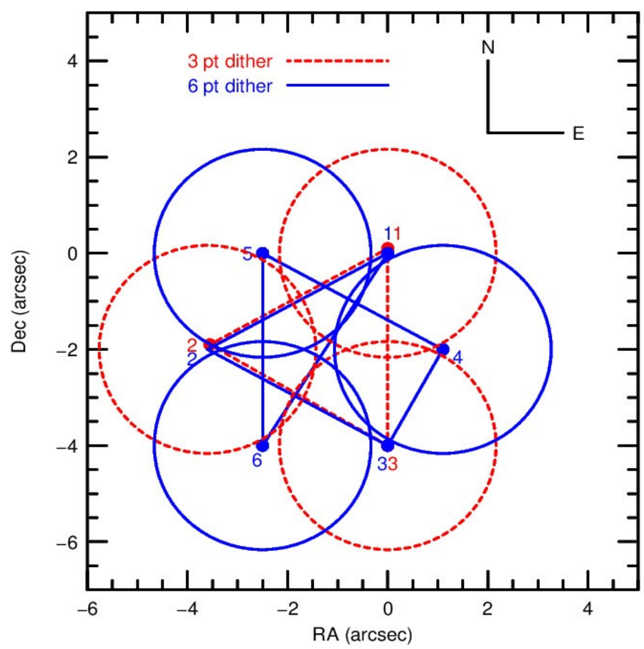
- object title
- exposure time for each position
- number of exposures at each position
- number of times to cycle through all 3 positions
- do you want to return to position 1 at the end

The second version allows the user to start from any dither position

ICE> epar vp2_dither2

fill in the same parameters and add firstpos, which of the three positions to start at

The other two scripts are vp2_subdither.cl and vp2_subdither2.cl. These differ from the first two by the use of 6 different positions for the dither pattern. All 6 positions cover approximately the same region of the sky as the 3 position dither. This is illustrated in the figure. The first 3 positions of the 6pt dither are the same as for the 3 point dither with 3 more points added to cover all of the sky.



In general, this 6 position pattern is used for standard stars, where it is critical that *all* the light from the star be collected. For other targets, the 3 position dither is probably sufficient. The 6 dither pattern takes two times as long to collect the data on a target but the signal/noise does not increase as square root of 2 because some pixels are seeing no light on each frame.

While any of these scripts are running, you can always abort (A), pause (P) or readout (R) frames in ice. The script will smoothly continue with the next frames. You might find this useful if you want to skip a frame for instance. If you want to stop the whole script while it is running, you can type ctrl+C but **ONLY WHILE THE TELESCOPE IS DITHERING**. You must abort the frame and let the telescope start moving before you hit ctrl+C. If you hit ctrl+C while exposing or reading out, BAD THINGS MIGHT HAPPEN. To fix this, you might need to log out of ICE and restart it.

3.0 End of Night Procedures

At the end of the night, there are various procedures that should be done.

Stop the guider camera.

If doing end of the night (dawn) twilight flats, see section 1.5 on calibrations. Be sure to set the sense = 1 and point to the west (away from where the Sun rises).

After the twilight flats are done, or if you are not doing twilight flats, close the dome and mirror cover and lower the upper windscreen to cover the telescope.

Move the telescope to the stow position and park the dome

Close the doors and louvers.

Hit the E-stop button when completely stowed and dome has stopped.

Turn the passage lights on low as a courtesy to someone entering the dome floor.

If you have not yet done so, fill in the night report on atlas and exit (upper right corner).

Log off atlas so that others may use it during the day. If you must leave something running on it, leave a note giving approximately when you will be finished and others can log you out.

4.0 Other Helpful Procedures

Other things we might want to include

- finding charts
- emergency procedures
- remote observing
- transferring data
- Troubleshooting – including if there are pointing issues.
- Picking wavelength region and setting up – note in night report