Information for users of the SOAR Goodman Spectrograph Multi-Object Slit (MOS) mode

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The Goodman Spectrograph has been offered for use in MOS mode starting in the 2014B semester. Following is information that we hope users will find useful in preparing and carrying out their observations.

1) Support Scientists: the main contact is Dr. Sean Points, Goodman HTS Instrument Scientist. He has the primary responsibility of making sure that submitted Goodman MOS masks are cut before observing runs. If Dr. Points is unavailable, questions/inquiries can be directed to Dr. César Briceño, who will then be in charge of overseeing the mask cutting and installation.

2) Field of View for Goodman-HTS MOS masks: ~3 x 5 arcminutes (Figure 1).

3) Slits: Slits should be aligned along the spatial axis. As of this moment, the Goodman Atmospheric Dispersion Corrector (ADC) is not yet commissioned, which is why we recommend users to avoid observations at large airmasses. Objects should not be closer than 5 arcsec in the spatial direction so as to avoid slits overlapping. The system requires 3 alignment stars, which should be bright enough to be readily seen in a short, few seconds alignment exposure (V~< 15), and preferably have similar magnitudes. It is best to avoid very bright stars (V<10), so that scattered light will not be an issue. The MOS Slit Design manual (see below) recommends that the alignment stars form a sort of “L” pattern, avoiding them falling along a straight line.

4) Overheads: Observations during the Science Verification yield overhead times of ~15-20 min per MOS field, measured from the moment the Telescope Operator has the field centered, to the start of the first science integration. This value includes time spent in: initial short exposure field for field acquisition, operating the MOS Alignment module to calculate offsets/rotation and applying these, taking a second image of the mask on the field to verify alignment.

A manual for operating the Goodman HTS in MOS mode, including using the MOS alignment tool, is attached to this document.

5) Slit Design software: the mask design software has been developed at the University of North Carolina at Chapel Hill. It runs on Windows, and we have tested it on both Windows XP and Windows 7 64-bit. Please contact us to obtain the software. Figure 1 shows a sample field with 4 slits and the 3 alignment stars, designed for an angle=0 deg. We include the manual at the end of this document.

6) Submission of MOS masks: masks should be sent at least 1 month in advance of the observations, to the following e-mail address: **goodman_mos@ctio.noao.edu.**

This lead time is needed so that SOAR instrument scientists can verify each mask, send it to the workshop for cutting, and then check the mask before sending it to the telescope to be installed. As usual, the corresponding Instrument Setup form must be filled in and submitted 1 week before the observations are scheduled. We emphasize that **masks not sent by the 1 month deadline, are not guaranteed to be cut and installed in time for the scheduled observations.**

Also, please confirm with us (Sean Points or Cesar Briceño) that your mask files have been received and are in ok for being sent to the cutting machine. Then, you will also need to coordinate with us for checking your masks on the instrument. Once the masks have been cut and sent to the mountain, several days before the start of your run, we expect you to take afternoon lamp flats so you can verify the mask design and orientation, and still have enough time to correct any problems that may arise.

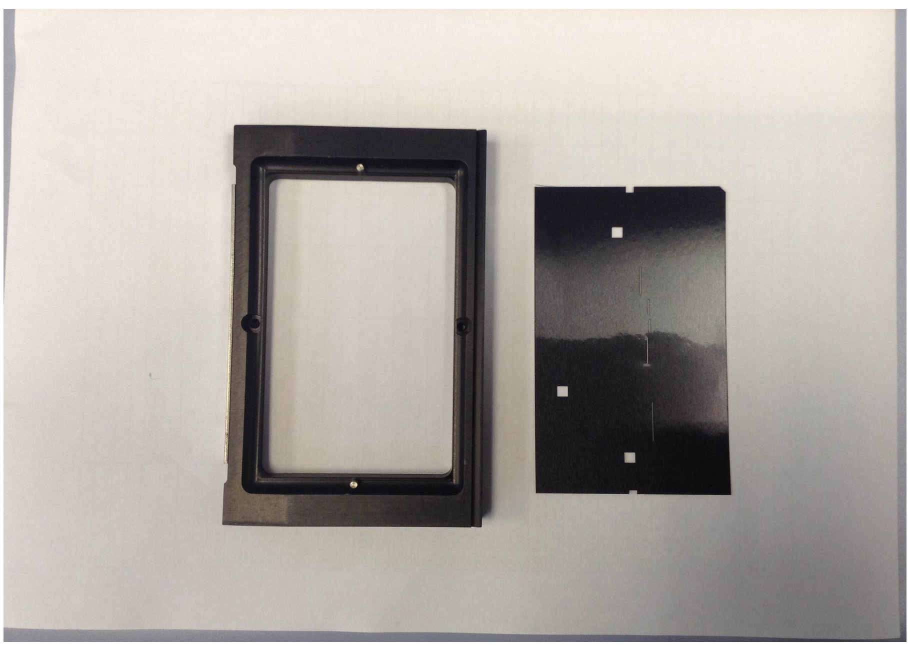


Figure 1: Goodman MOS mask and holder. The three square holes are for the alignment stars. Note that if slits are cut too close to the mask edge they may end up hidden by the holder lip.

7) Wavelength Offsets as a function of slit position in the dispersion direction.

Tests were made using the HgAr comparison lamp with the 400l/mm, 600l/mm, and 930l/mm gratings in all of their preset modes, in order to determine the wavelength shift of spectra for off-axis slits with respect to the nominal central slit position. In the dispersion direction, the Goodman masks are 3 arcmin wide, or 1200 pix. The central slit position is at pixel x=600. Slits to the left of the central slit will see the center wavelength of the spectrum shift toward the blue. Slits to the right of the central position will see the central wavelength shift to the red. If the slits are oriented NS and East is left and West is right, then for slits located 1 arcmin east and west of the central position (1 arcmin = 60 arcsec = 400 pixel at a scale 0.15 arcsec/pixel) spectra are shifted to the blue and to the red by 400 pixels respectively.

The simple formula is:

$\Delta_{pixel} = -1 * 400. * (\Theta_{offset}[arcsec] / 60.)$

where east offsets are positive and west offsets are negative.

Once the Δ_{pixel} is calculated, one can find the Δ_{lambda} by multiplying by the dispersion for the grating in use. For the various gratings a slit located 1 arcmin from the central position will produce wavelength shifts of:

400l/mm: ± 400A
600l/mm: ± 260A
930l/mm: ± 170A
1200l/mm: ± 125A
2100l/mm: ± 75A

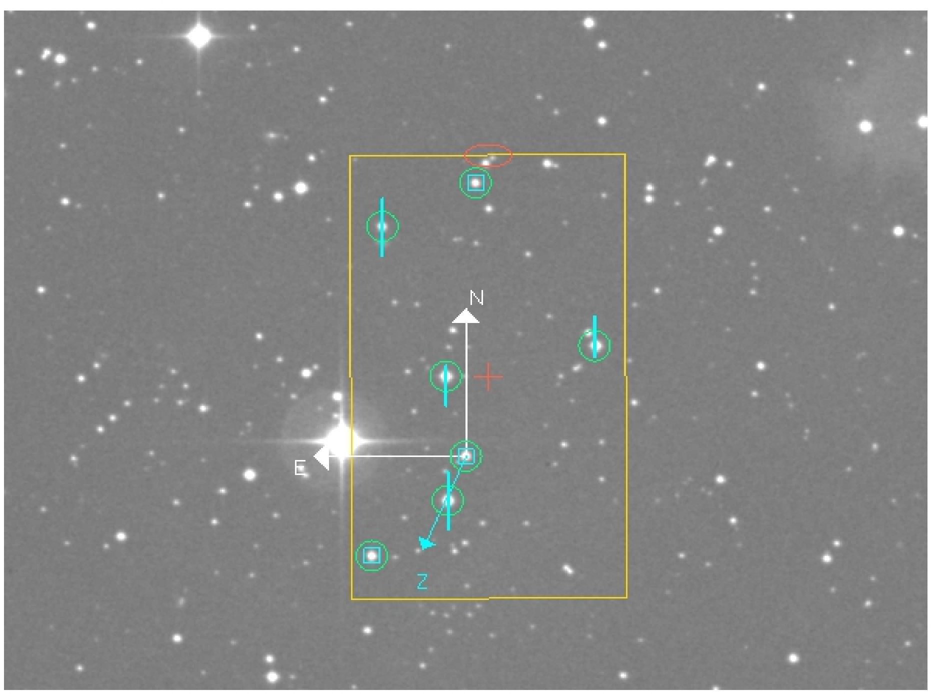


Figure 2: Screenshot of a mask designed with the SlitDesigner software. The yellow box is ~3' x 5'. The 3 alignment stars are indicated with the small boxes (5” x 5”). The slits (0.7” x 10”) are shown projected on the target stars.

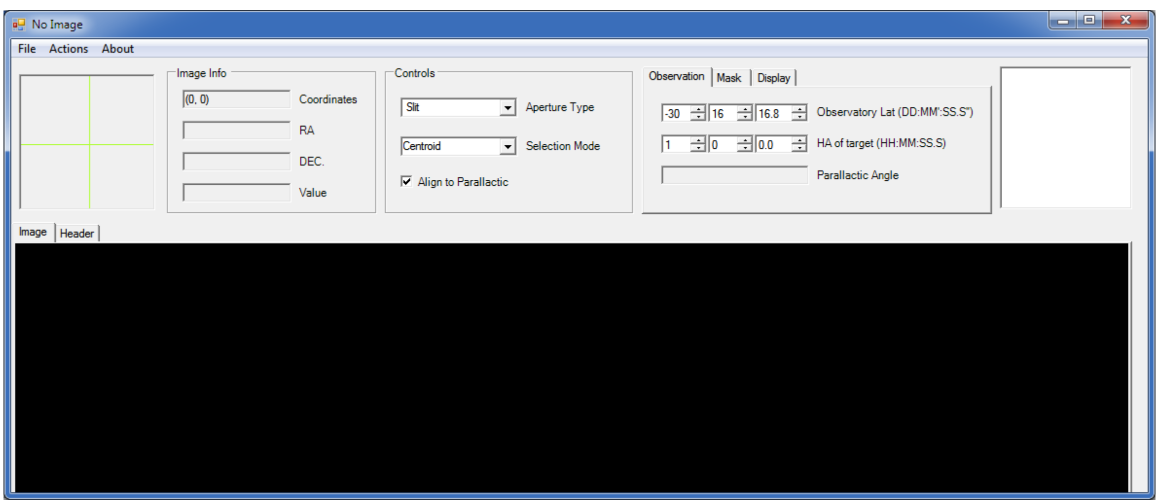
Goodman Slitmask Design Software

Summary:

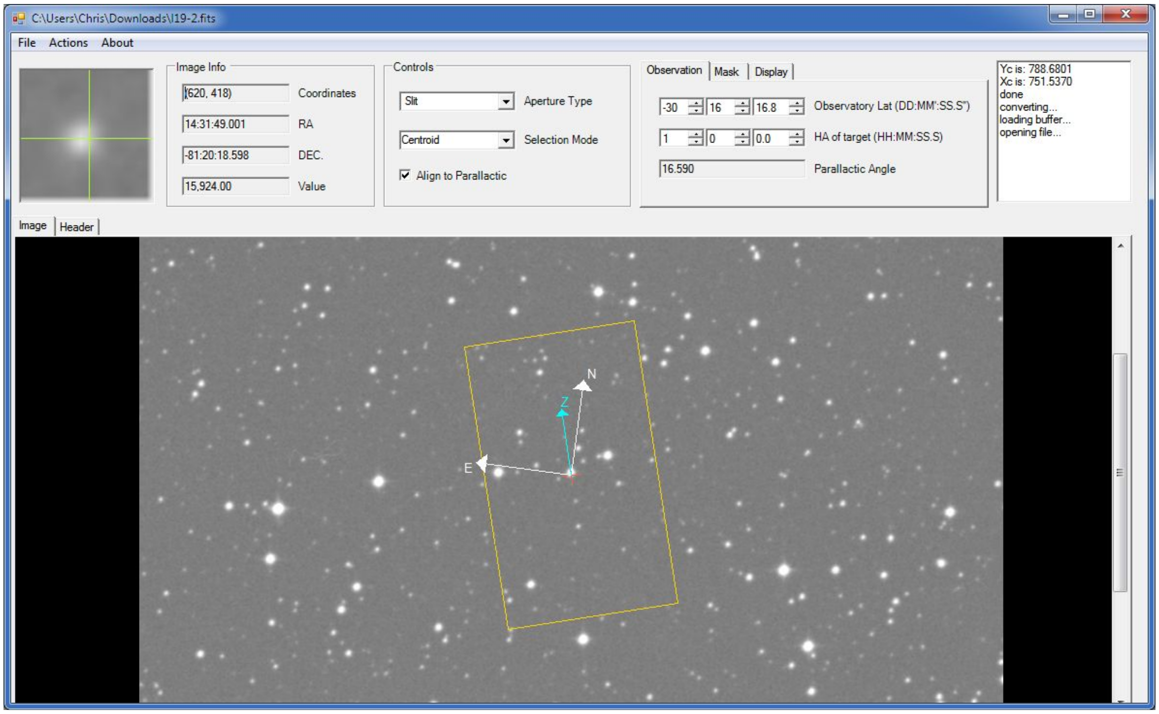
The slitmask designer software for the Goodman Spectrograph is meant to be intuitive to use and this manual will test that notion by summarizing only the bare basic procedure for using it. To start, you need an image with WCS information in the header. This image may be one taken by the Goodman Spectrograph in imaging mode, or one extracted from the digitized sky survey. If the former, you will have to add astrometric information by uploading it to astrometry.net, but first load it into the slit designer software which will prepare it for astrometry.net by changing some non-standard header characters. Once you load an image with WCS information in into the designer, you will follow the instructions in this manual to choose your targets, and set the mask position and alignment. Finally, you will generate g-code files that can be sent to SOAR for cutting the masks.

Using the Program:

The beta release version of the software comes as a zipped directory. Unzip it and run the file SlitDesigner.exe from within the directory. The program should look like the screen below:



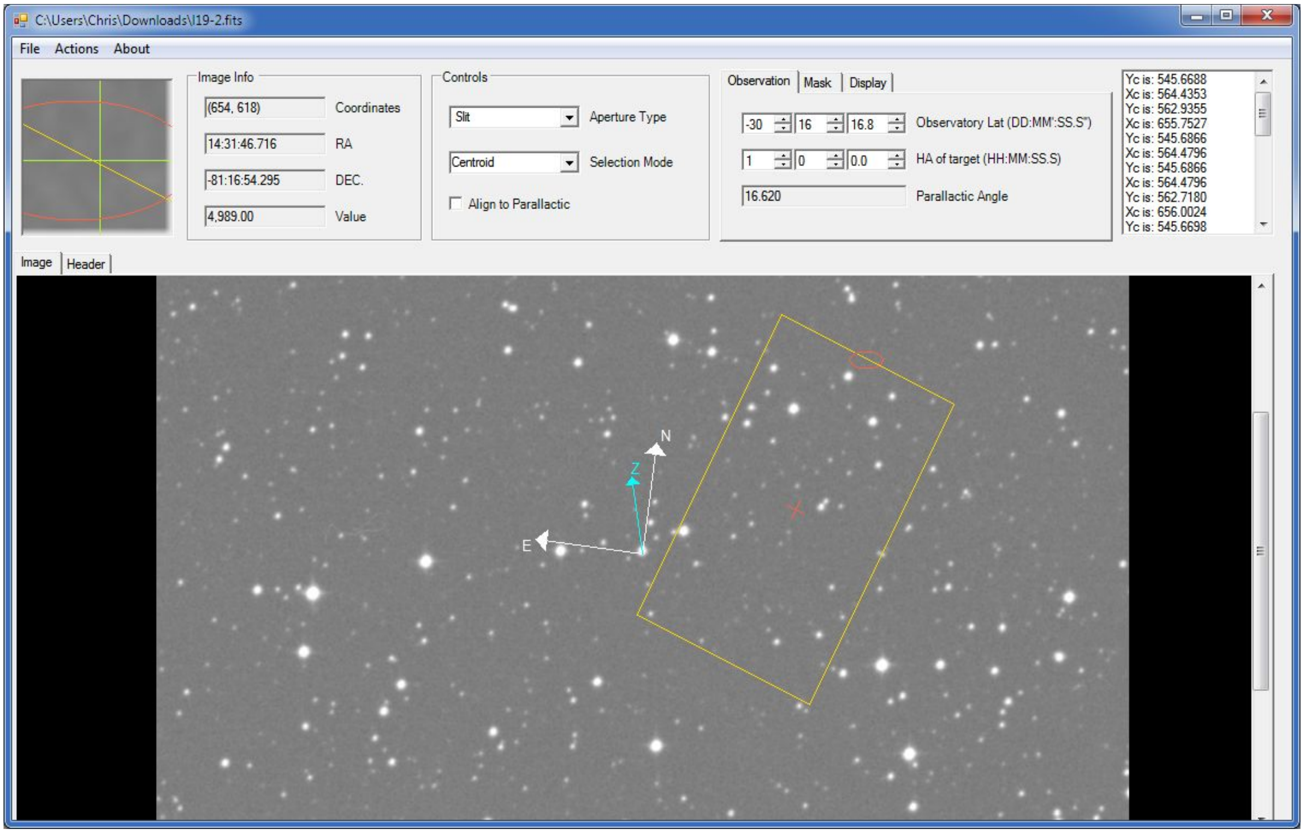
Go to the file menu and choose "Open Image", and you will be allowed to choose the fits image file you want to use to build your slitmask. If the file is a raw image from the Goodman Spectrograph, the program will ask if you want to prepare it to be sent to astrometry.net. You should do this, submit the file to astrometry.net, and then open the image file returned. The program will now see WCS information and allow you to design a mask.



The Slitmask Area Controls:

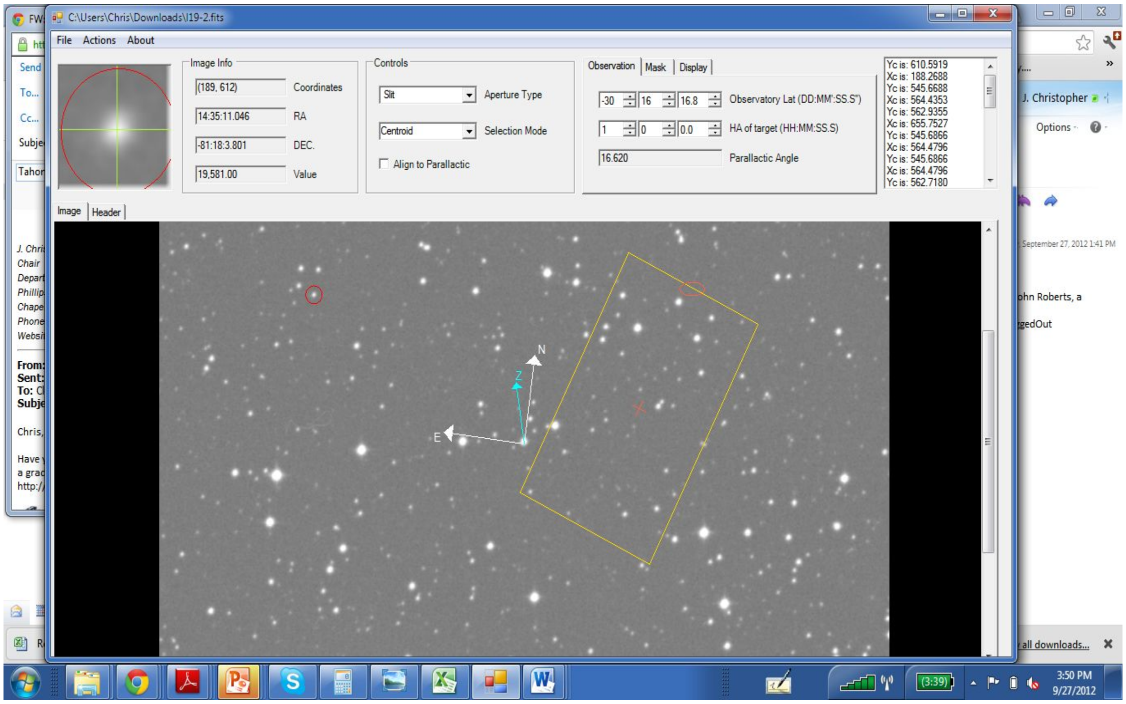
The yellow frame in the main program window represents the useable area of the slitmask, with the spatial dimension of the spectrograph aligned to the long side of the rectangle. If you cannot see it, be sure you have not clicked the "header" tab at the top of the image window. The frame can be moved around in the field by right clicking and dragging the red + in its center. It can also be rotated, but the program defaults to the assumption that you want the rotation of the mask to align the slitlets to the parallactic angle. This is a good idea, especially until the atmospheric dispersion compensator (ADC) for SOAR is finished. Correct alignment requires that you enter the latitude of the observatory (SOAR is there by default) and the hour angle at which you want to observe the target. These are available on the "Observation" tab of the rightmost box on the menu bar. If you are unsure when you will reach a target field during the night, you can make several versions of the mask at different choices and pick the appropriate one when observing.
Right now the useable area in the program overlaps with the mask holders. This will be corrected in the future. For now, do not place slits or boxes near the edges of the useable field.

If you want to rotate the box freely, as might be the case if you are trying to separate objects so their spectra don't overlap, uncheck the "align to parallactic" box in the controls section of the menu bar. Now an ellipse appears at the top of the rectangle (see image below) and you can rotate by right clicking and dragging it around



Identifying your targets:

To identify your targets, set the Aperture Type to “Slit”, put the mouse on each target, and right click. A red circle will appear. If the “Selection Mode” in the controls box is set to “Centroid” the program will automatically try to center the circle on the object (see below). For manual placement, select “Manual” instead of “Centroid”, the zoom window in the upper left helps identify the right pixel for centering. The targets need not be inside the slitmask frame, but if they are they will be auto-assigned slitlets. Moving the frame over selected stars changes the red circles into slitlets for any objects whose spectra will not overlap on the camera. To remove targets, right click on the center of the circle. Choosing “Box’ for the aperture type before selecting targets will also identify the objects with a red circle, but these will be assigned boxes when they lie within the slitmask frame. Bozes are useful for assigning alignment stars that will assist in aligning the slitmask to the sky.



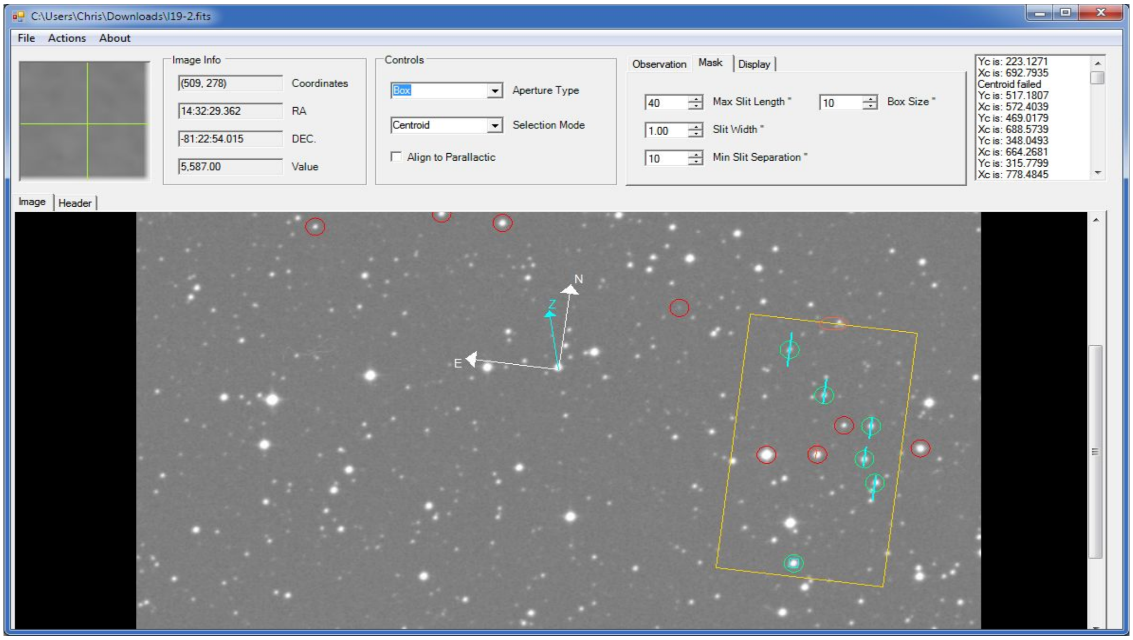
It is possible to save targets (and the mask design) to a mask file (.msk). From the File menu choose "Save Mask". Choose "Load Mask" to reload the targets from the file. This feature also offers a way to load multiple targets from a list. The .msk file is in a text format, so putting targets lists into the format used by the .msk files will allow them to be read.

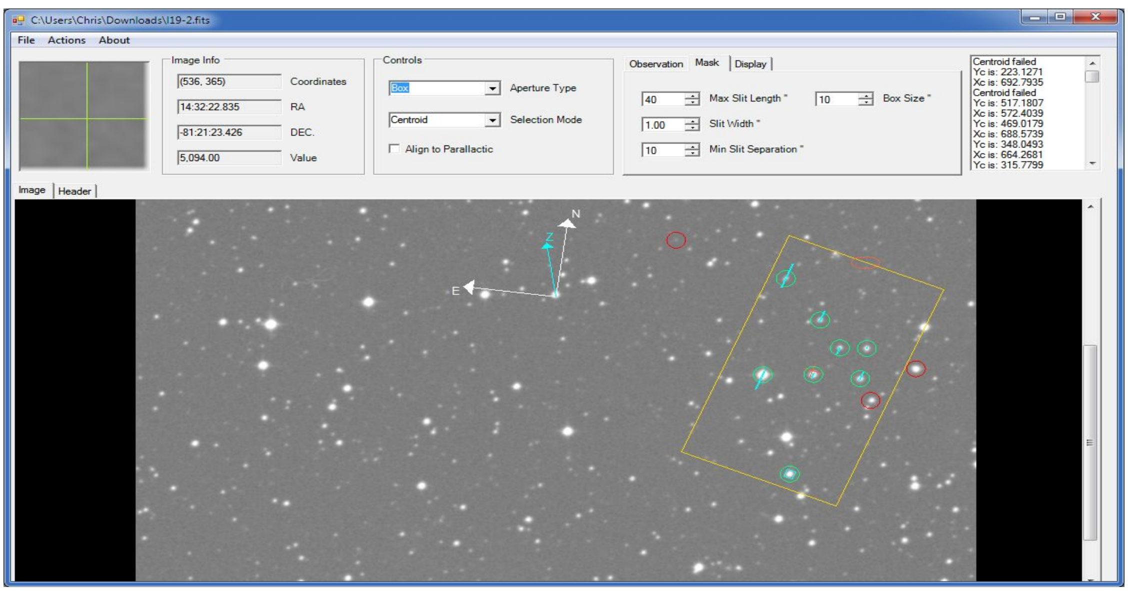
**If you load a saved mask after loading a previous saved mask the Hour Angle does not update to the Hour Angle stored in the loaded mask.

Assigning slitlets to targets:

Slitlets are automatically assigned to targets that fall within the mask frame according to rules that are set on the 'Mask" tab on the menu bar. The maximum slit length will be used unless it runs into the slit for another object. The minimum separation between slits can be adjusted to make sure all slits have adequate sky background included and do not cut off light from the star. On this tab it is possible to set the slit width, and the size of any objects that were selected with the Box aperture type.

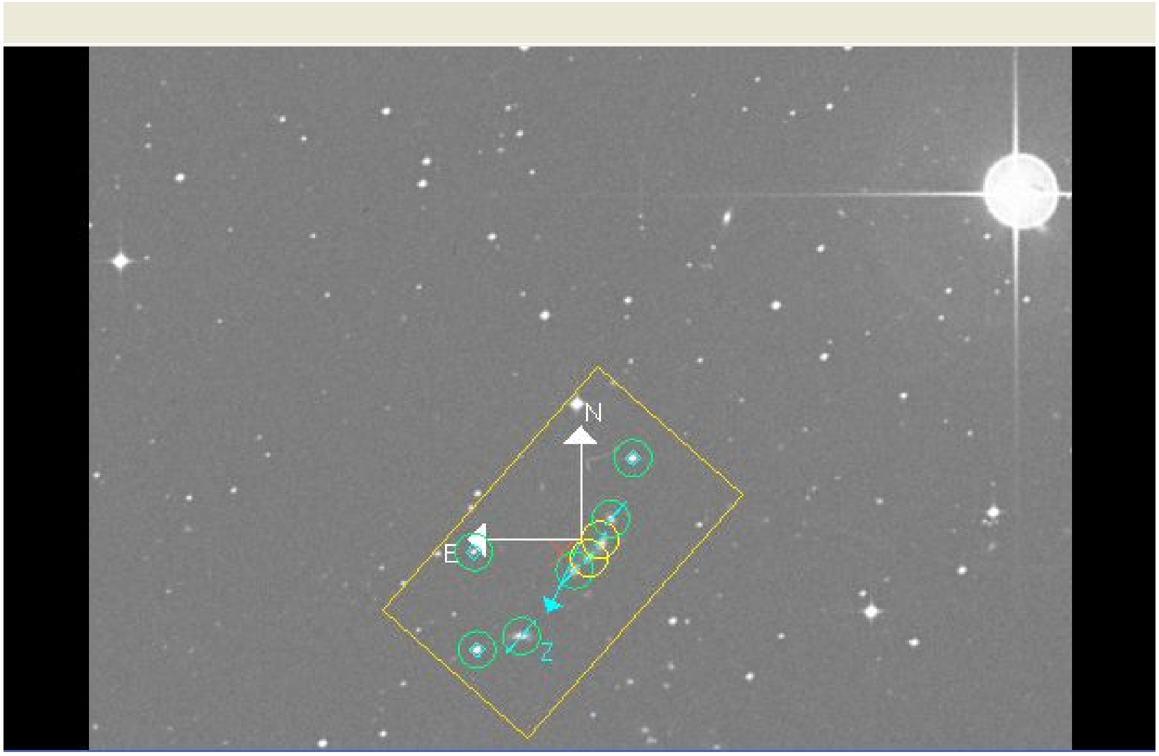
Stars that are in conflict for spectral rows on the CCD will not be assigned slits. Sometimes it is possible to get more stars assigned by slightly rotating the frame (see below). Remember that this requires unchecking the "Align to Parallactic" box.





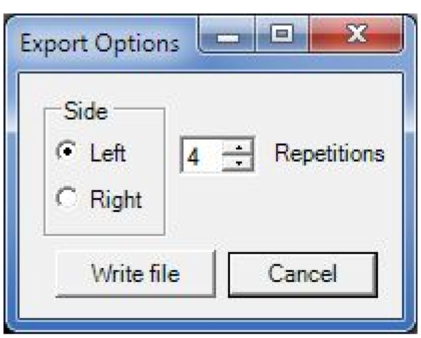
Alignment Boxes:

In the Controls section of the Designer, you can change the Aperture Type to Box. This allows you to choose three relatively bright stars to use for aligning the mask on the objects. The boxes should be not be arranged in a line. An 'L' shape is ideal (see below).



Generating the cutting file:

To generate the file for the laser cutter, choose “Export G-Code” from the File menu. A requester like the one below will pop up. The Goodman Spectrograph uses the mask cutting frame for the Gemini instrument FLAMINGOS, which can accommodate two Goodman masks. Choosing left or right side will determine on which side the mask will be cut. It is most efficient of material to make half of your masks left and half of them right. The number of laser repetitions should not be changed from 4 unless SOAR personnel have told you to do so. Clicking ‘Write File” will write the file out as a text g-code (gerber format) file compatible with the Gemini laser cutter. The filename convention is that the last 5 characters before the extension are the design position angle of the mask in 1/10 degrees and an L or an R for left or right. Please do not change these characters as assigned by the program. The L/R is needed for the machine operator to cut efficiently, and you will want the position angle when it is time to set up at the telescope.



Other Features:

For very crowded fields, the first mask made will not have slitlets for all the objects. To speed up the making of subsequent masks, selecting “Remove Slits” from the Actions menu will unmark all of the objects with valid slits, allowing additional objects to be assigned slitlets. (try this feature and it wll be clear why it is useful). Be careful not to save the mask file after this step, or the removed objects will be lost (I think).

If the “Show Labels” box on the Display tab is unchecked, the compass rose that also shows parallactic angle will disappear. If the .msk file has object names, they will show up next to each object. To put object names in the .msk file, add the field:

NAME = G29-38

to the record for the object, and the label “G29-38” will appear next to the object whenever “Show Labels” is checked on the Display tab.

The image info box shows the pixel coordinates of the cursor, and the RA and DEC of the cursor calculated from the WCS header information. The bottom box shows the pixel flux value in ADU. Clicking the Header tab will switch the main window view to the FITS header.

Finally, the text screen on the right hand end of the menu bar shows the pixel values of centroids and may display centroid errors if the algorithm fails (e.g. on an extended or binary object).

Missing features:

We want to be able to write a gerber file to engrave the mask identifier on the mask itself, to avoid confusion at the telescope. We are awaiting more information to implement.

Manual for Goodman Spectrograph Multi-Object Spectroscopy

0) Pre-Observing Planning

Before observing with Goodman MOS, please see the Mask Design Manual for instructions on making masks for Goodman. It is helpful to have the mask design software accessible as a reference for alignment as you proceed below.

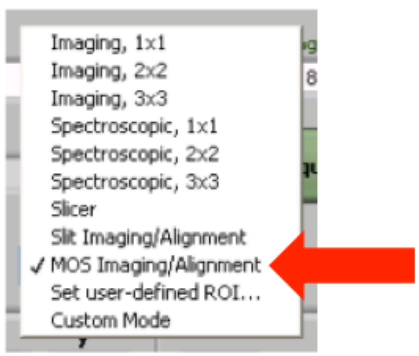
1) Setting up the Instrument

Before setting up on the field, you should give the operator the coordinates of the mask you made. You also need to tell the operator the Position Angle at which you made the mask. In the Mask Drop-Down Menu, the name of the MOS mask should include the Position Angle. You will most likely need to adjust the Position Angle. Thus, it is quickest if you tell the operator to not find a guide star before you have the correct Position Angle. Once you have adjusted the Position Angle, ask the operator to find a guide star.

Select the mask that you want to use from the Mask drop down menu.

2) Image the field

Withdraw the mask. Under the CCD ROI Mode, choose MOS Imaging/Alignment. This will only readout the mask area:



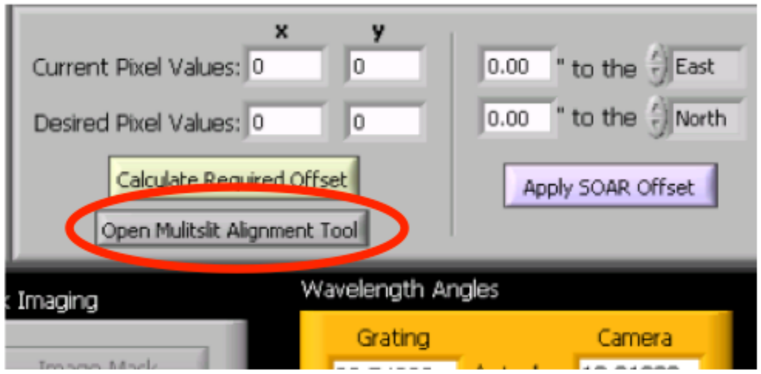
It is suggested that you use “400 kHz, ATTN 0” for the CCD Readout Speed, as this will help things go a bit faster. Take an image of the field. Check this image to make sure you can see the stars you will align to. If you cannot, you should adjust the field until you can.

3) Image the Mask

Replace the MOS mask. Take another image once the mask is replaced.

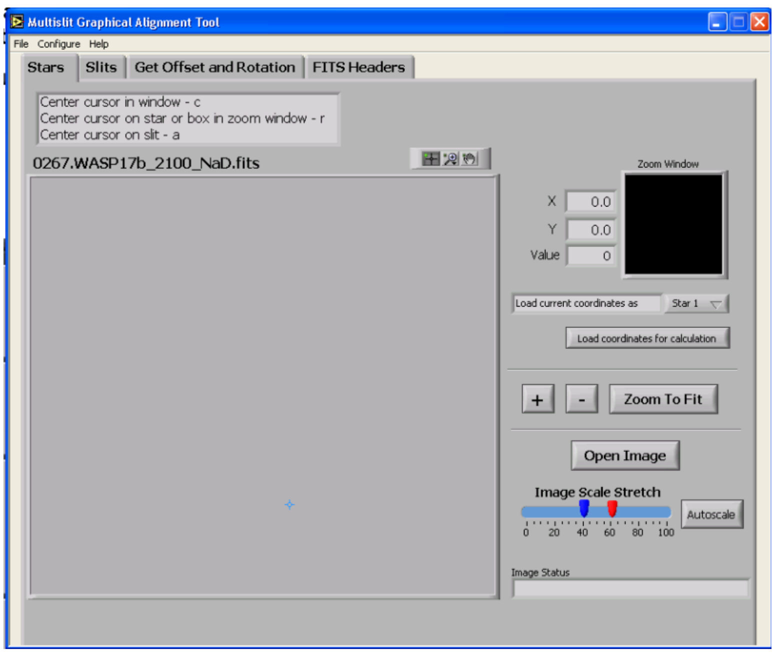
4) Open the Multislit Alignment Tool

Once you have both these images you are ready to run the Multislit Alignment Tool. Click “Open Multislit Alignment Tool”:



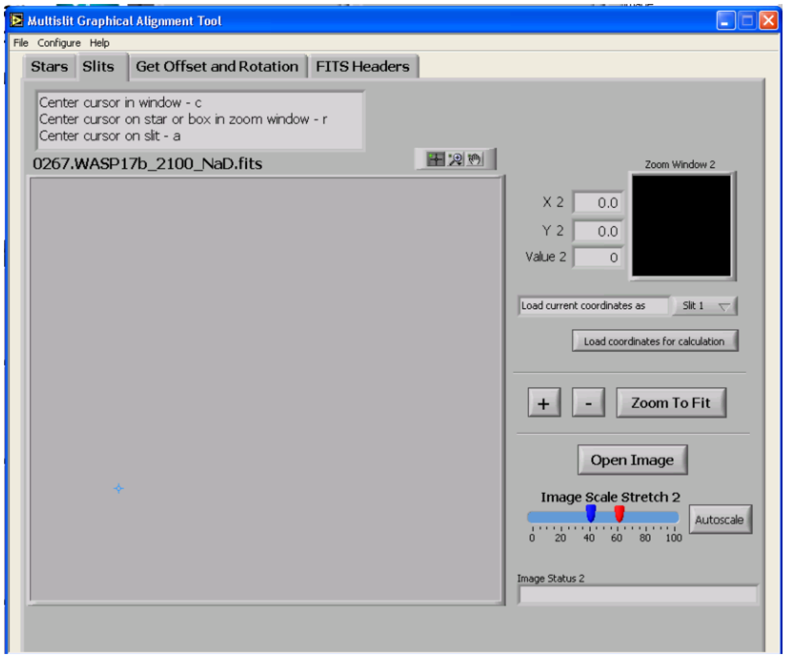
5) Open the Image of the Field

You should be in the “Stars” tab of the MOS Alignment Tool, shown below. Click the “Open Image” button. The images you just took should be in the current directory. Open the image of the field you just took. Once the image loads, it might appear off-centered, but this will be corrected momentarily.



6) Open the Image of the Slit Mask

Once you have the image of the field open, switch the tab at the top to “Slits,” shown below.



Now, use the "Open Image" button to open the image of the MOS mask. Again, the image is located in the current directory. Click "Zoom to Fit" and "Autoscale" after you open the image. If the scaling is not useful, you can use the red and blue sliders to adjust the scaling of the images.

7) Find the Coordinates of your alignment stars

Go back to the "Stars" tab. Click "Zoom to Fit" and "Autoscale." If the scaling is not useful, you can use the red and blue sliders to adjust the scaling of the images.

Find the first alignment star (one of the stars in the boxes). For this part it is helpful to have open the mask design software showing the mask you created. The stars you align to must be the same as the stars you placed in the boxes when you made the mask. Mouse over the star and it should appear on the zoomed in view in the upper right. The following keys allow you to quickly centroid on the star:

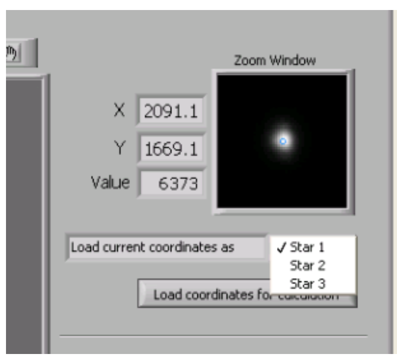
Center Cursor in Zoom Window	c
Center Cursor on Star or Box in Zoom Window	r
Center Cursor on Slit	a
Move Cursor Left	j
Move Cursor Down	k
Move Cursor Right	l
Move Cursor Up	i

At the top right of the image field lie the above three tools:

Left	Select
Middle	Zoom – A variety of zoom options will first be presented
Right	Pan

These options can be useful if you need to zoom into various parts of the image. You must use the "Select" tool to get the coordinates of the stars and slits as described below.

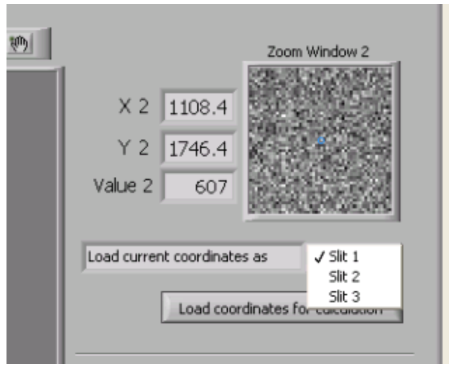
Most of the time, r is sufficient to centroid on the star. Make sure the "Star 1" option is selected below, then click "Load Coordinates for Calculation." After you load the coordinates, use the drop down menu to switch from Star 1 to Star 2.



Repeat the same procedure for Star 2. Then send the coordinates to the calculator. Again, use the drop down menu to switch from Star 2 to Star 3, then find and load the coordinates for the third star and send then to the calculator.

8) Find the Coordinates of the alignment boxes

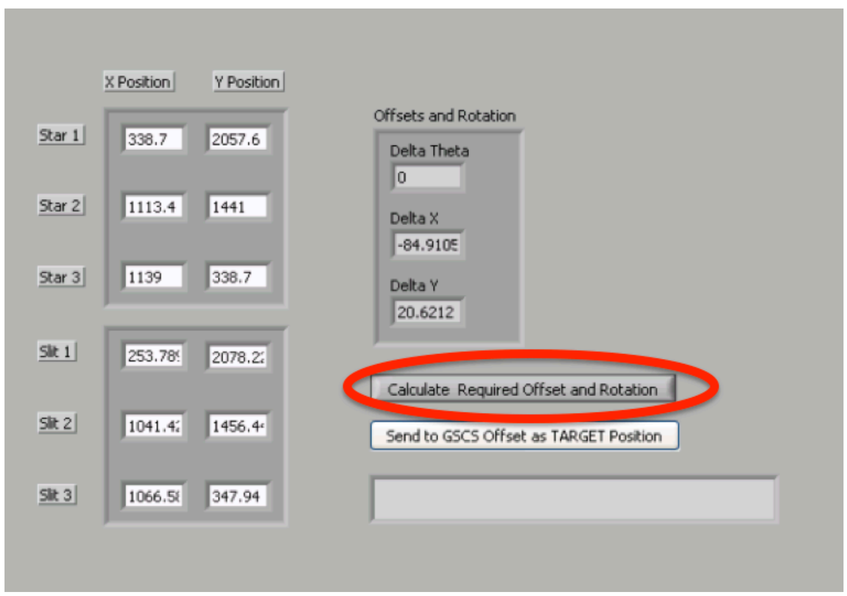
Go to the "Slits" tab. Report the above procedure to get the coordinates of each alignment box. Make sure you use the same numbering you used for the stars.



Do not forget to switch the number of the slit before you load the coordinates for calculation. Often times, for the alignment boxes, it is easier to find the centroid by eye instead of using the centroiding algorithm.

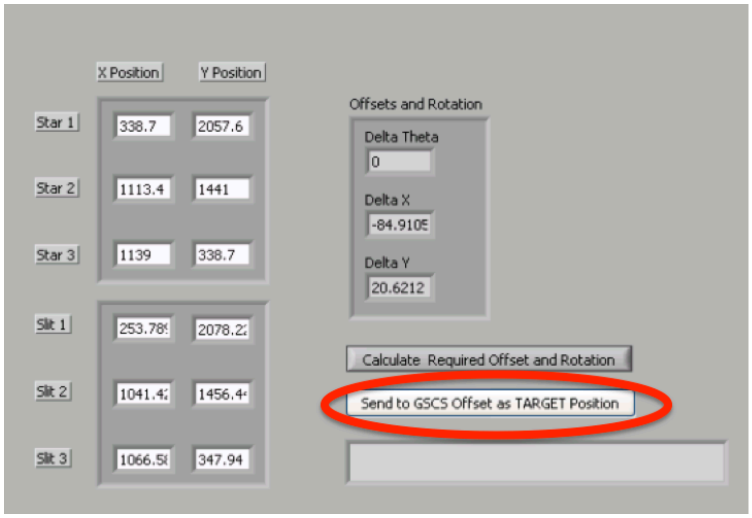
9) Determine the Offset and Rotation

After you have captured the coordinates of all three alignment stars and boxes, go to the "Get Offset and Rotation" tab. You should see the coordinates in the boxes for the stars and alignment boxes. Click "Calculate Required Offset and Rotation." Your rotation and translation offset will be computed and displayed.

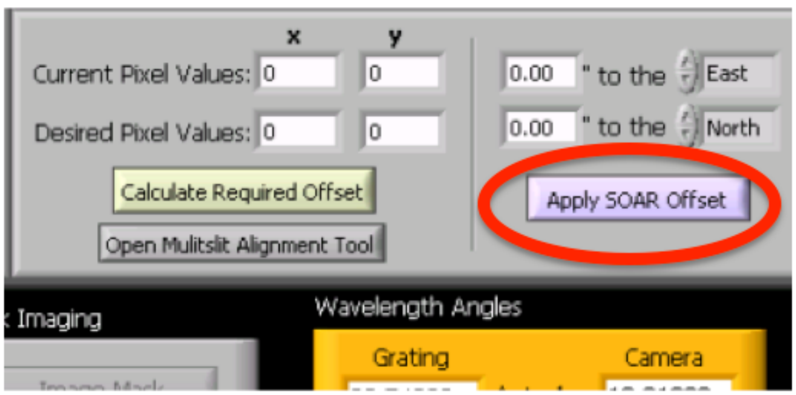


10) Adjust the Position Angle and apply the offset

You must first adjust the Position Angle of the telescope before making the translation offset. Add or subtract the given delta theta from the current Position Angle and tell the Telescope Operator the new Position Angle. After the rotation is applied, click "Send Offset Coordinates to GSCS."



This sends the offset coordinates to the main GUI panel. On the main GSCS Panel, click "Apply SOAR Offset."



11) Check Alignment
Now, take an image of the slit mask and see if you are lined up. If you are not, repeat the above procedure.

Once you are aligned, ask the operator to mark the current position as the one to come back to. This will make it possible to return to alignment if anything happens with the telescope. You should also ask them to find a guide star and begin guiding once you will no longer be making rotations or offsets.

12) Take Spectra
Once you are aligned, you are ready to take spectra. Do not withdraw the mask again. Put in the grating and move to the correct grating and camera angles. If you need more information, please reference the "Taking a Spectrum" Manual.

Notes and Tips

- **If you prefer to not use the MOS Alignment GUI to find the coordinates for the alignment stars and alignment boxes, you can enter coordinates directly into the “Get Offset and Rotation” Tab.**
- **Use the standard spectroscopic ROI modes.**