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Palomar TripleSpec

A USER'S USER GUIDE

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Introduction

The TripleSpec instrument is a simultaneous J,H,K spectrograph mounted at the Cassegrain focus (in the cage) of the Hale 200" (5.1m) telescope at Palomar Observatory in southern California. The goal of this guide is to provide simple instructions for using the (admittedly complicated) GUI to do basic extragalactic observations. If you have experience with NIR spectroscopy in general, you can likely just read Part 1 on TripleSpec's specific GUI.

The layout of this guide is split into several parts. The first part(s) describe each separate functional window (or windows) of the display and what they are used for. Then, I will describe several procedures for getting on sky and conducting observations.

The GUI itself is rather overwhelming at first — with a multitude of windows and buttons and indicators. Once you know how they work, though, it becomes clear that each is used only sparingly, while the vast majority of your efforts are focused on a few buttons and windows. In time, I came to agree that having the other windows and their effects ready to go if needed is a good thing; a seasoned observer could be very efficient using the TripleSpec interface. The drag and drop nudging of boxes and stars can seem odd at first, but at the end of the day it's a fairly intuitive system to sue.

My goal for this guide is to lay out cleanly, but in detail, what each window does, and how that translates into an actual observation session. Having struggled somewhat with the on-site TripleSpec cookbook vis a vis readability, I wanted to write something somewhat more colloquial, and to include some real examples.

This work is the result of my learning the interface during a December 2019 observing run, and that run's bouts of cloudy weather in which I had little to do. I am indebted to the Support Astronomer Kevin Rykoski, who was the first to walk me through the GUI (and extensively so). I've also referred to the cookbook itself at times (particularly in the appendix descriptions).

Part I

The TripleSpec GUI

FACSUM and Weather

Before you can actually start using the instrument, it's good to know what's going on with the telescope oriented windows.

FACSUM Display

The first of these is the `FACSUM` display. This display has a ton of information about what is going on with the telescope at a given moment, and it is useful to have this window visible.

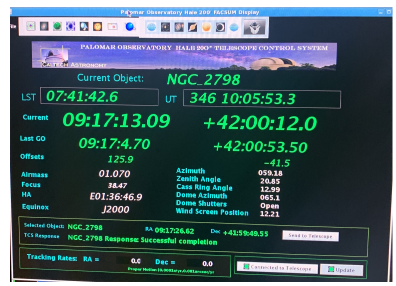

Figure 1: The FACSUM display.

The display contains the name of the current object (as it's listed in the target list; see below), along with

- The LST and UTC times
- The current RA and DEC of the pointing
- The last set of offsets executed[1]
- The Airmass and focus (in mm)
- The *actual* PA of the instrument (you'll see what I mean).

[1] This is useful when executing blind offsets

The Targets Table and Airmass Display

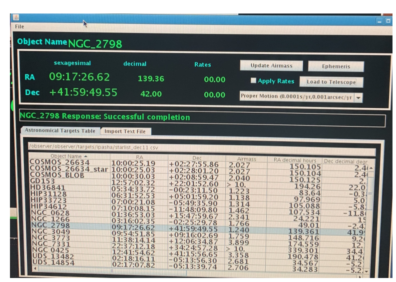

Figure 2: Target list display.

Two other closely linked windows allow you to load your target lists, send objects/coordinates to the telescope, and view their airmass curves at any given time.

The targets window has two tabs, one for imported astronomical targets, and one for importing text files. Before arriving for the day, you should ensure you have a target list in the format of a CSV (easiest) with object name, RA, DEC, Equinox entered, e.g.,

- `NGC_1068,21:10:40.24,30:46:21.245,J2000.00`

You can have comments with extra info at the end of the line using the pound/hashtag symbol. To scp the finished cvs file, use

- `scp targetlist.csv user1@observer1.palomar.caltech.edu:/observer/observer/targets/yourdir/`

(though this address is subject to change). The password can be obtained from your SA. Once you have scp'd your target list, you can open it from within the window under the import text file tab, setting it to csv, comma delimited. Once it's loaded, hit the "parse" button to attempt to parse it. Lines that are read successfully turn blue, issues show up a rust color. Fix any issues and save the file, then parse it again. Once it's all blue, you can click back over to the "Astronomical Targets Table" tab.

ONCE your target list is loaded, you can send new targets to the telescope operator by highlighting them and hitting the "Load to Telescope" button at the top, where you can also see the object name and coordinates listed. The TO can then ask if you're ready to slew to that target, etc. Meanwhile, the loaded list will also show up in the airmass diagram, where you can click to see airmass curves for different (or multiple) objects along with the location of the moon.[2]

[2] If you used, e.g., iObserve to plan your run, you have this information already.

The All Sky Cam

THE FINAL, super critical window on this screen is the *All Sky Cam*, a fisheye lens that takes continuous 1 minute exposures throughout the night. Because the cadence is 1 minute, with very small overheads, this camera allows you to see oncoming clouds, and lets you note and weather conditions of note in your observing log as you go. Helpfully, the locations of your objects are highlighted/indicated on the image. Give or take, for long exposures it is accurate to exactly where your object is, while for short exposures, the current frame probably relates to the last exposure you took. This cam also makes it easy to choose dynamically where to slew next if clouds are covering part of the sky.

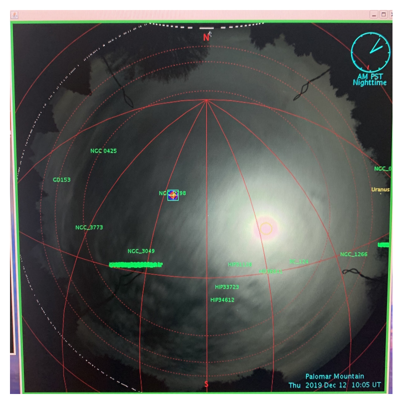

Figure 3: The all sky cam, showing a cloudy night and some targets.

The TSPEC_SPEC Window

The TSPEC_SPEC window is responsible for showing the status of the spectrograph, the progress with the current exposure, the directory where data are being stored, and the current image/frame number being exposed. It is also the place where the user enters information that will be stored in the `HEADER` of the output `FITS` file, including obs. type (object, dark, flat; selected from drop down), object name (entered manually + hit enter), and fowler depths (if fowler read out mode is being used). One can also enter an observer name.

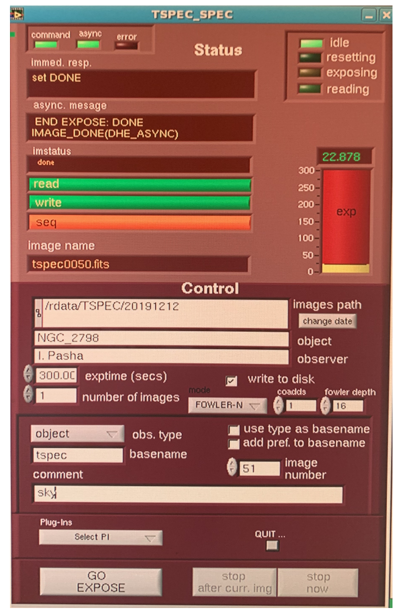

Figure 4: The TSPEC_SPEC window.

It is important to note that while there are also options to set the exposure time (`exptime`) and number of images, this should *only be done when taking calibrations.* That is, any science exposure times, sequencing, coadds, etc., will be handled from elsewhere in the GUI setup. During calibrations *only*, one will

- Set the obs type to `dark` or `flat`[3]
- Set the exp time (usually 30s)
- Set the number of images (usually 10)
- Change the fowler depths to 1 (because exptime is short)
- Hit `GO EXPOSE` to execute the sequence.

[3] When you are ready for cals, confirm the dome is dark with the Telescope Operator (TO) and then, after taking darks, ask them to turn the high lamps on for flats.

Once calibrations are complete, you will no longer be updating exposure settings in this window. At this time, it would be wise to change the fowler depth[4] to the number you are using for your observations (typically 10-20) by entering the number and hitting <enter>.[5] Also, reset the "number of images" to 1. The Slow Guider (below) will handle the number of images in your sequences (or single).

[4] Fowler depths refer to a method of non-destructively reading the NIR detector while exposing to achieve better noise properties.

[5] This is the preferred method of changing settings, as sometimes the buttons for changing values are glitchy.

After this point, you will primarily use this window to

- Change the object name that will be written to the fits header
- watch the exp bar to see the progress of exposures.

The TSPEC;cl + DS9 Windows

In the same instrument VNC as the TSPEC_SPEC window is a terminal that is running a "wirc" terminal. You will also see two DS9 windows open. The SA will typically set this up before you arrive. One of the terminals (usually set to red hues) is a live updating DS9 window that shows incoming frames — but it is usually glitchy in what it shows, and not very useful for extragalactic astronomers because we cannot learn much from a single exposure.

The second DS9 window is one that can be used normally (file–> open) to look at your exposures. It can also be used for quick analysis. The simplest and most useful analysis you can perform is a simple A-B subtraction between your two most recent frames (whether they be part of a dither or a source-sky pair).

To view a subtracted image, you mouse over the terminal window and type "**snap**", which will load the subtraction into DS9 for you to observe.[6] You can now interact with the image normally in DS9 (adjust scaling, etc). When you are done, or want to snap the next two images, mouse back over the terminal and hit <enter>, then when the `iraf` imexamine circle appears, mouse over the ds9 image and hit <q> to return the terminal to normal. Then you can run snap again.

[6] You can see which two frames were subtracted in the terminal after running the command.

The Slow Guider Display

The Slow Guider Display is, despite its name, actually the central control station for the TripleSpec instrument, and it (plus its sub windows) is where you will be performing most of your observing setup and execution.

The Display itself is split into various sub-parts. It will be useful to name these conveniently for reference. I will call these:

- Panel A: The top horizontal panel, containing a zoomed image of the slit with dither positions marked, as well as the guiding options and exposure settings and buttons.
- Panel B: The view of the guider itself, along with the brightness/contrast bars below it.[7]
- Panel C: The side panel on the right hand side, containing the paddles for nodding the telescope, and below it, the zoom box that shows what is inside the `guide star box` (a yellow box in Panel B). It has its own contrast bars.

[7] The other standalone windows in this screen can be launched from dropdowns at the bottom of Panel B, in case you close them by accident.

Detailed Panel Descriptions

Here we discuss each panel within the main window of the *Slow Guider Display*; this is where most of the action happens.

PANEL A

Panel A has several purposes and, despite being extremely small in the overall UI, the right hand corner of Panel A is actually where all science exposures are set up and executed. The largest part of Panel A is taken up by the zoomed in image of the slit.[8] This is used to visualize the location of several plus symbols, which represent locations on the slit used when dithering.[9]

[8] This image is laggy, and thus should not be used to examine if objects are aligned on the slit. Use a zoom box centered on the slit instead.

[9] You can also use a dither pattern if you're not dithering; in particular, a pattern where the '1' plus is placed somewhere on the slit will allow you to quickly bring any colored box in the guider image to that location.

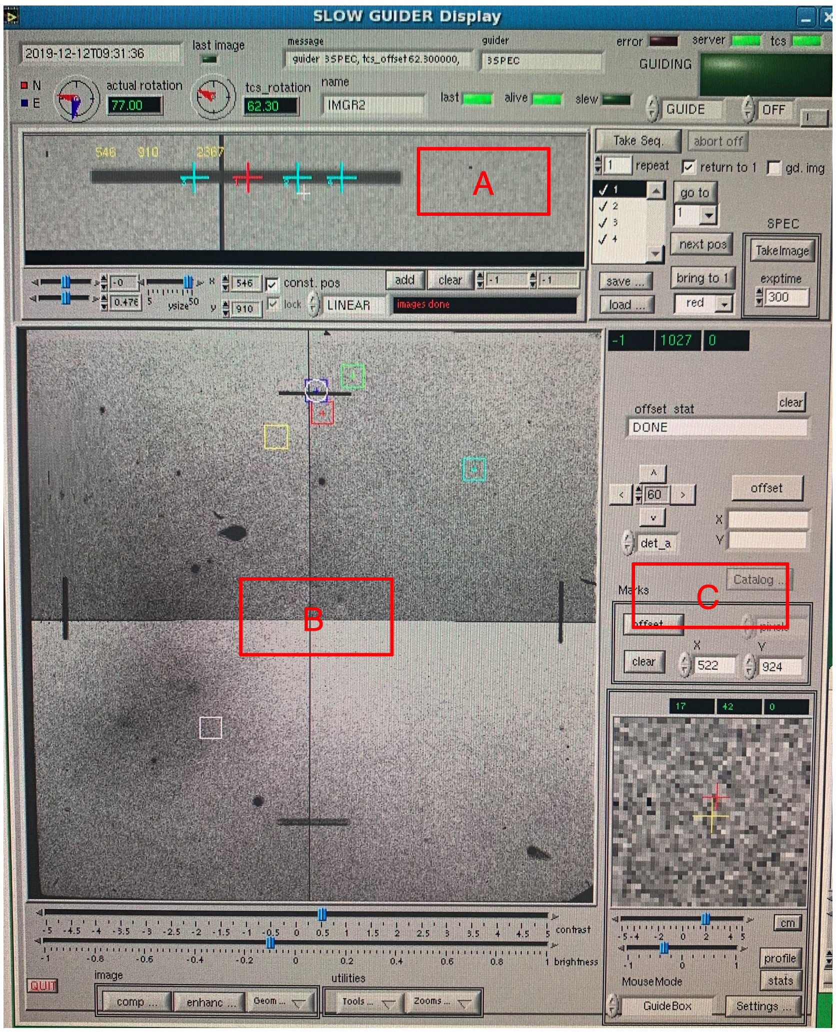

Figure 5: The Slow Guider Display Window, with panel designations marked.

You can move the "+" symbols on the slit to new locations, add new ones (via the add button), or clear them. You can also save your patterns to a config file that can be loaded later via the "save..." button located under the sequence settings just to the right of the zoomed slit image (you can also load patterns from the button below it).[10]

[10] There is theoretically no limit to how many positions one can have in a dither pattern, but I wouldn't use more than 4 or 5 for a 30″ slit.

The most important part of Panel A is the right hand block to the right of the zoomed slit image. Inside it are a few key controls. To the very far right, you'll see the word "SPEC" on top of a tiny box with a "TakeImage" button and below it an exposure time entry. **Believe it or not, any time you are taking a non-sequential (i.e., single) spectrum exposure, you'll set the exposure time and start it from right here**.

To the left of the exposure time entry is a useful little button: "bring to 1", which allows you to bring one of the colored boxes (select from the drop-down below the button) to the position of the first PLUS in a given sequence. For example, if you are using an ABA'B' dither sequence, you can use the Blue box to center it on your object somewhere in the guider, and then hit "bring to 1" to offset it precisely to the "A" position of your dither.

To the left of *that* is the save and load buttons described before, and directly above them is a display showing the number of locations in the current sequence (equal to the number of plusses).[11] Above that list is a repeat option for repeating the sequence.[12] To the right of that is a check box for returning to 1. **Always check this**. You want the telescope to return to position 1 of the pattern after the last exposure. Above that is the "Take Seq." button. This is the button one presses once the right sequence pattern is loaded, the object is aligned with position 1, and you are ready to expose.

[11] When you're actively taking a sequence, completed positions will have a checkmark by them, and current ones will have a small window shaped icon.

[12] I would recommend against using this. Especially in the NIR, it is valuable to be assessing sequences one-by-one, realigning on your object, etc.

PANEL B

Panel B is the most straightforward; it simply shows the continuous reads of the guider imager. What you're looking at is a camera that is pointed at the *outside* of the metal sheet with the slit in it, which is reflective. You can see the slits as dark lines, and the field the telescope is pointed at is reflected into the camera. Thus, you can move the telescope until an object in the field is on top of the slit (and thus, its light is entering the spectrograph).

Below the image is the standard brightness/contrast sliders, which you can toy with to try to see things better, as well as the drop-down menus that launch all the pop out windows discussed before.

Panel C

Panel C is the side panel on the right, aligned with Panel B. This panel holds two disparate UI elements: The offset paddles, and the zoom box for the guide star box.

The Offset Paddles

The offset paddles are one of the most useful elements of the UI. They allow you to nod the direction of the telescope in small amounts, with different options. These options are

- pixels: Move the telescope such that objects in the image move X pixels in the direction of the arrow pressed.
- arcsec: Move the telescope such that objects in the image move X arcsec in the *cardinal direction* implied by the arrow (N, S, E, W; with East to the left and North up).
- det arcsec: Move the telescope such that objects move X arcseconds in the directions of the detector (i.e., L/R is along the slit, and up/down is perpendicular to the slit)[13]. This accounts for the position angle for the instrument.

[13] This is the most useful

We already mentioned the paddles in the context of grabbing new sky background reference images. These can also be used to fine-align objects in the slit, e.g., after moving a box to position 1, if it's poking out the top or bottom of the slit asymmetrically, you can nudge it up or down by 1-2 pixels to line it up. It can also be used to execute small offsets.[14]

[14] For example, to create a 'long slit' by taking spectra at nods in the slit direction.

WHEN YOU ENTER a value in the center of the paddles and hit enter, and confirm the units you want to move in from the drop-down below, you can hit the appropriate paddle. You'll see the message box above flash red as it executes the offset, and then it should say DONE. You should see the change in your next guider exposure. You can also enter numbers into the X and Y boxes and hit offset, but I haven't used this and can't speak to its efficacy.

SKIPPING OVER THE MARKS section[15] we come to the final part of Panel C, the zoom box for the guide star box. It's unclear to me why this is here and not a separate zoom box, but functionally it operates exactly the same. The only difference is this zoom box is the only one that affects the guiding, and what appears in the radial profile and stats windows. Hence, hitting the CM button here might actually change your seeing/stats as it recalculates.

[15] Because I don't know what it does... likely something the TO handles.

Pop Out Windows

The other small windows on this screen (with the exception of TSPEC_IMGR) are all pop-out windows from the *Slow Guider Display*. They are as follows:

Image Enhancement

Normally located below the *Slow Guider Display*, this panel is usually not used during observations. It's main use is being able to change the display settings in the guider image displayed in Panel B from "linear" to "3-sigma;" however, usually messing with the brightness and contrast bars in Panel B is sufficient.

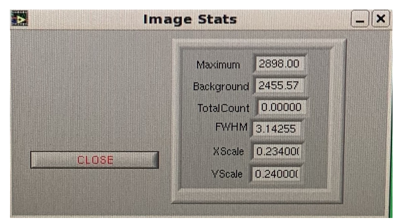

Figure 6: Image Stats Screen.

Image Stats

The image stats panel shows some summary statistics about the pixels *inside the yellow guider box* of Panel B. The most useful of these is the FWHM entry, which gives you an idea of the seeing in the K-band so long as the guide-star box has been moved to a star.[16] The FWHM entry is also what is used, in concert with the `Radial Display` window (below) to focus the telescope at the start (or partway through) the night.

[16] I'll cover this later, but the guide star box is moved by double clicking a location in the guider image. The other boxes are moved via clicking and dragging.

Radial Profile

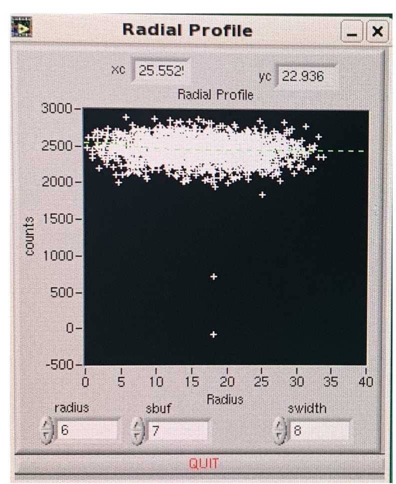

Figure 7: Radial Profile Window.

Like the `Image Stats` box, the Radial Profile panel is showing you details of what is going on inside the guide star box. It shows a radial profile that is somewhat self-explanatory. The FWHM of the curve shown in this plot is what appear in the `Image Stats` FWHM entry.

Guiding Settings

The *Guiding Settings* window is responsible for tweaking how the guider actually uses the star in the guide star box to guide. I've never personally touched any of the settings, and would ask the SA if guiding is messing up enough that you think these need to be changed. The one setting on this panel that *does* matter is the `Xsize` option on the far right of the window. This sets the size of the yellow guide star box. Sometimes, for a weak guide star, this box needs to be made smaller (roughly 30-50) to facilitate guiding, as larger boxes introduce too much noise.

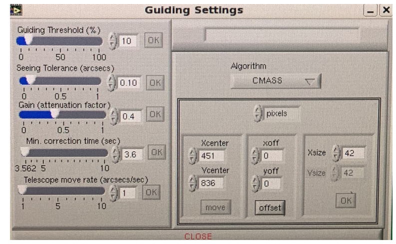

Figure 8: Guiding Settings.

It is valuable to take a step back at this moment and note that we have just discussed three windows that are linked to the guide-star box. The total number of places is actually five:

1. The zoom box inside panel C which shows the interior of the guide star box
2. The guiding toggle/display at the top right of Panel A
3. The Radial Profile window
4. The Guiding Settings window
5. The Image Stats window

That seems, to me, somewhat clunky on the UI side. But it is what it is. The important thing is you know that all of these are giving you complementary information on the same box in the guider image.

The Zoom Windows

There are four zoom windows which appear next to the *Slow Guider Display*. Each one is tagged with a color (bottom right corner, selectable via drop-down). Those colors correspond to the four colored boxes superimposed on the guider display image.[17]

[17] There *is* an option to make one of these boxes yellow... but don't do that.

These zoom boxes are just there to help you facilitate alignments of targets, either on the slit or simply in frame. A typical use of one of these boxes would be

- Clicking + dragging one of the colored boxes to a star or target
- Mousing over to the zoom box for the color of the box you dragged, and clicking the "cm" button on the right edge of the window (just below the zoom image) to center on the center of mass.
- (*optional*) if this is insufficient, using the arrow keys to align the cross on the object
- Then, doing something else, such as moving the center of the box to the slit, or to the location of another box.[18]

[18] I'll cover this more in the procedural section.

Each Zoom Box also has its own (small) contrast and brightness sliders below the image to help improve your ability to see your target, as well as the option to change from linear to 3-sigma scaling.

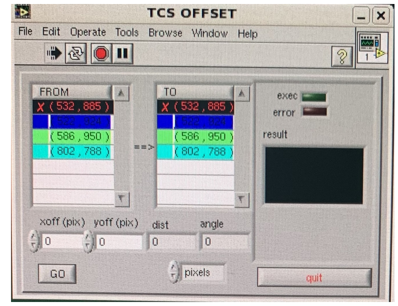

Figure 9: TCS offset Window.

TCS OFFSET

The TCS OFFSET window allows you to offset the telescope from the position of one colored box to the position of another colored box. For example, if you used the procedure above to align the Blue zoom box on a star, and you had the Red zoom box aligned with the center of the slit, you could then go to the TCS OFFSET window and check the box you want to move from the left hand list, the box you want to move it to from the right hand list, and then hit GO.[19] Personally, I almost never use this window — if I'm moving an object to the slit, I have dither positions loaded on the slit to use, and if I'm just nodding the telescope, I can use the offset paddles to execute those offsets.

[19] When you select a box on either side, the box (somewhat annoyingly) turns black, meaning it is hard to see which you are on. The text is the right color (though hard to see), but the easiest thing is just knowing by elimination which of the four boxes is selected.

Image Settings

The Image Settings window is where you set reference images to be used for live background subtraction in the guider image, which allows for objects and stars to stand out more easily. This is accomplished through a somewhat arcane procedure.

1. First, one slews to their desired target (be it an object, offset star, blank patch of sky, whatever).

2. Then, with the guider taking continuous images, click the `Clean Ref. Image(s)` switch in the Image Settings window. This clears any previous images stored for subtraction. You should see the indicator at the top of the window (the circle by the text "Ref. images stored") be not lit up at this point.[20]

3. Next, you'll use the offset paddles in Panel C to nod the telescope some small-ish amount (I usually do 30 det arcsec or whatever was last entered if it was reasonable).

4. Once a full image has been taken and shown from the new position (depends on exp time), click the button to "Store last image as Ref." in the Image Settings window.

5. Once you've clicked it, wait one more exposure for good measure. You should see the image change in quality, to a noise map that looks consistent with 0, and no stars/objects.

6. Finally, undo the nod you did by offsetting the telescope with the opposite paddle (and the same amount). After 1-2 exposures

[20] The image will also turn crappy (because it's not performing any sky subtraction).

you should then see the sky-subtracted guider image, which has stars/sources more easily identified.[21]

[21] You can continue with the same reference sky until (1) you change guider exposure time (2) you notice the sky has changed enough (or you're pointed in a different part of the sky) such that it warrants taking a new one.

AND THAT'S IT! Or rather, that is a breakdown of all the pop-out windows from the *Slow Guider Display*. There is one more important window on this screen, however.

TSPEC_IMGR

This window is responsible for setting up the exposures that appear in Panel B of the *Slow Guider Display*. The only things you need to deal with in this window is to check the `cont_read` box, and set the exposure time. Then hit GO EXPOSE.

If you need to change exposure times on the guider during the night, first hit the "stop after curr. img" box. After finishing the next exposure and reading it out, you can then enter a new exp time and hit <enter>. Then hit GO EXPOSE again to resume taking images.[22]

[22] Remember that if you do this, you'll want to acquire a new sky reference image via the procedure above.

Ancillary Notes and Best Practices with the GUI

WITH THE MAIN body of the GUI covered, I'll take a moment to mention a few quirks of the system and best practices to avoid them.

FIRST, you'll notice that in the top left corner of Panel A, there are rotations shown — both an actual rotation and tcs rotation. **Ignore these**. For arcane reasons dating back to how 0 degrees was defined by the instrument manufacturers at Cornell, neither of these numbers corresponds to the position angle of the slit on sky. It's also something you don't enter yourself (you tell the telescope operator), so you should be able to trust you're at the right PA.[23]

[23] If you're on site, there's a small space-age Panasonic screen which shows the actual PA. It's also there (correct) on the FACSUM.

SECOND, there are many locations on the GUI where a value can be entered in, or buttons can be pressed to change values . I recommend typing the numbers in and hitting <enter> (and sometimes <enter> plus OK), as this seems to be less laggy and prone to error. **However**, a weird quirk of the system is that for most of the number entry fields, simply clicking into the field advances or reduces the value by 1. No idea why, but be careful when clicking in to highlight and change values that afterwards it has been done correctly.

THOUGH WE haven't covered the procedure for taking exposures yet, it's worth noting that for *many* near-IR instruments, the process of aborting an exposure can be somewhat harrowing, and often lead to system hangs/crashes which must be rebooted. Generally, it is safe to use a “stop after current image" button to attempt to stop exposures. Stopping mid-frame is more dangerous. If absolutely needed though, you’ll have to try hitting the abort button on the TSPEC_SPEC window. You may need to try more than once. All this is to say, double checking all settings before exposing is never a bad practice.

IT’S BEEN MENTIONED elsewhere but it’s good to remember that often (especially for bright stars or very faint stars), the “cm" button will not do a good job finding the center of mass of the star. If the goal is just to align on the slit, you can hover over the zoom window to activate it and simply tap the arrow keys until they are over the center of the star. Then run your command.[24]

[24] Note: this does **not** work in the zoom box for the guide star box. So you do not want to choose guide stars too bright/faint such that the software itself can’t accurately track the centroid of the star.

FINALLY, there is quite a lot that the TO handles at Palomar, including position angles and offsets (if you’re using a blind offset from a star). The TO will also handle non-sidereal tracking rates if you have them, and can take you to pointing calibration stars on the fly. It’s good to have all that information for each target consolidated in one place before observing so that you can be as efficient as possible.

Part II

Observing with TripleSpec

Run Preparation

In this short section, I'll try to lay out a few of the things you should keep in mind if you are preparing for a TripleSpec observing run and haven't observed with it before. Some of the advice will also be more general run preparation, which if you are old-hat at, you can skip straight over to get into the nuts and bolts of this specific instrument.

An observing run is a lot like building a bridge.[25] Often, it starts with an observing proposal, which sketches out broadly the science goals it will attempt to answer, and some fore-thought into the observing strategy and feasibility of those observations.[26] Some proposals are very specific about having a few key targets, others are broader, encompassing a sample that will become better defined in the lead-up to the run (or at the telescope). But, like building a bridge, the two additional things that need to occur to make the enterprise a success are

[25] Or house, or whatever. The metaphor doesn't care.

[26] E.g., is the source flux detectable in the amount of time you have, at the wavelengths you're observing? Or, is the grating/resolution of the instrument high enough to measure the line-widths you're after?

- Actual, detailed plans need to be drawn up (don't want your bridge to meet halfway in the middle but half a meter off).
- The plan needs to be executed well (at the telescope, for example, with sufficient flexibility to account for issues).

I am going to assume if you're reading this that you are past the early stages, and more focused on.

Finder Charts and Target Lists

At the telescope, everything is hectic and time is of the essence. Ideally, all information you need about a certain target should be instantly available to you. Having a card with a finder chart (around 4x4 arcmin is good for TripleSpec, plus a larger one for reference) along with the RA, DEC, PA[27], etc., of that target is very useful. Simultaneously, having a compact sheet with *all* your targets and that

[27] Some observatories can handle negative PA values, but Palomar prefers PA's to be given in the positive direction.

info (condensed) is also valuable. You'll call on both at different moments.

HAVING A CODE which can generate target lists in the format of the given observatory on the fly from various inputs and cuts is extremely valuable. At Palomar, it is easy to `scp` a new target list and parse it during the night, or from night to night, so you can add and remove targets as necessary. The all sky cam really helpfully overplots your targets onto the sky so you can get a sense for when they are rising/setting, and at what airmass. As a reminder, the targetlist format at Palomar is

- `target_name,RA,DEC,Equinox`
- `NGC_1052,10:54:23.53,12:48:21.542,J2000.00`

with any comments coming after.[28] For objects with more complicated information, having searchable files is great, e.g.,

---

Target Name: NGC 3031
Coordinates: `12:41:56.52 +02:14:56.6`
Offset star: `12:41:25.52 +02:13:12.3`
Offsets: `-25.65” E, 37.21” N`
PA: `15 degrees`
Exposure Time: `300 s`
Tracking rates:
RA: `-1342.35 arcsec / hour`
DEC: `1295.25 arcsec / hour`

---

[28] P.A. is a great thing to put in.

Calibrations

Let us now see how all the panels discussed earlier are used when you actually get on-sky with TripleSpec.

At ∼3:30 PM, the visitor viewing area of the Hale telescope closes and the TO will bring the dome to dark. At this point, once you've confirmed with them everything is set up, and the SA has loaded up the TripleSpec instrument panels, you're ready to take calibrations.

Calibrations are dead easy with TripleSpec, and taken from the tspec_spec window. Starting with darks, you can set the object type from the drop down, set the exposure time to 30s and number of images to 10. You then set the Fowler depth to 1 (exposure is short). Then hit GO EXPOSE. Once those are done, you'll hear the beep from the instrument (or see it has read out the last frame).

You can now ask the telescope operator to turn on the high lamps for flats. Once they're on, change the object type to flat, and go expose for 10 more images.[29] Then you're done. Go eat some dinner.

[29] Depending on your mode of observing, you may not need the darks (if they are included in your subtraction imaging). The flats are always useful.

Calibrations is also a good time to scp your target list over, if you haven't already.

Opening On Sky + Focusing

The telescope is generally parked at zenith when the TO opens the dome and gets everything going. Before you begin observing, the telescope must be focused. If you are on-site, you will do this yourself with a physical hand-paddle[30], while if you're observing remotely, the TO will come over and attempt to focus the telescope on a decently bright star somewhere near zenith. Insofar as actually focusing, it's a matter of nudging the focus in and out until the star minimizes its FWHM (pick a non-saturated bright star to put in the guide star box by double clicking + cm).

[30] Yup, there's a dinky hand-paddle with in and out buttons like for your backyard telescope, except it's controlling a 5.1 meter mirror.

ADDITIONALLY, if you have a dither pattern you'll be using, load it up now (or before) from the load menu in Panel A of the *Slow Guider Display.*

Pointing Calibration

Both at the beginning of the night, and whenever you change PA, it's good to pointing calibrate the telescope. This process basically amounts to entering some precise coordinates of a known star and letting the telescope go there. Upon arrival, the star will not be exactly centered on the slit (though it will be within a few arcseconds, generally). You then move the star to the slit and the T.O. will save that offset into the system for the night's pointing. Generally this is followed up by jumping to a second pointing calibration star, which (if the first one went well) should actually fall basically onto the slit.

I HAVE RUN INTO situations where we arrive at a target field and I don't seem my object or offset star. At this point, you would ask for a pointing star. If something has happened to the model, you might discover that even the pointing star does not appear in the field of view. This has a (somewhat time consuming) fix, but is relatively straightforward. The T.O. will slew to an unmistakably bright SAO star. If it is not in the field of view, they will initiate what is called a "spiral search," where they will tile increasing annuli around that start point in chunks of the 4x4 arcmin guider view until you see the tell tale streak of a giant bright star going by. You then call out, they back up to the last tile where you find the star, and you bring it to the slit.[31] This usually fixes things such that upon going to a second point star, it's somewhere decently close to the slit in the FOV.

[31] But only for a split second if possible!

Acquiring Targets

Once the telescope is focused and pointing calibrated, you'll send the first target to the TO by highlighting it in the `Astronomical Targets Table` and clicking the "Load to Telescope" button.[32] If your object has a specific position angle,[33] now is also the time to inform the TO and give them that information, as they can start the rotation as the telescope slews to the target.

[32] If you haven't yet, import your text file and parse it so it appears in the target table. Your SA can help with this.

[33] which it probably should...

Once the telescope is at the location of your object or offset object, it is time to check the pointing.[34] Ask the telescope operator to move to a nearby SAO star, preferably a faintish one (>~10-11 mag). You will definitely see that star pop up on the guider, and it should be somewhere pretty near the slit already.[35]

[34] It is good practice to check the pointing anytime you change PA more than a few degrees, or when you move to a very different part of the sky.

[35] Palomar has famously good pointing.

Use one of the zoom boxes to center on the star — if it's too bright to use "cm", just use the arrow keys while moused over the zoom box to find the center. Then, either use the "bring to 1" button if you have a dither position 1 at the desired location on the slit, or use a second box centered on the slit and the tcs offset window to bring the star to the slit.

Inform the Telescope operator that you're aligned and they can 'TX' (mark the base, essentially). Then have them move back to your object coordinates. **Note: If it's going to take a minute to start moving, as soon as they've marked base use the paddle to get the star off the slit. Bright stars can leave behind persistence on the detector.**[36]

[36] See the section on persistence below.

Back at your target, your pointing should now be relatively well aligned for the new PA and position. If you can actually see your object in the right position on the slit, great! Otherwise, move it onto the slit as described above.

Once you are on target, look around and see if there are any suitable guide stars on the guider image (anything decently bright and well defined as a star). Double click to move the guide star box there, center it (that window only allows clicking cm), an then turn on guiding from the toggle at the very top right part of Panel A.[37]

You can then double check all your settings, adjust the object name over in the TSPEC_SPEC window, and then hit the

- `Take Seq` button if you have a dither pattern loaded.
- `TakeImage` button if you're taking a single spectrum.

[37] Palomar, as mentioned, has pretty good tracking. If you can't find a guide star, the telescope should be fine for ∼5 minutes on its own.

A Note on Blind Offsets

A problem known to many a near-IR extragalactic astronomer is our sources are too faint to show up on even a 20 or 30 second guider image. We thus have to trust what are called "blind offsets" to line up on our targets.

IF THIS is your observing mode, the target you send the T.O. from the target list is actually the coordinates of your offset star.[38] You should be able to see the star near the slit once the T.O. moves there. Nudge it into the right spot on the slit, and let the T.O. know they can zero the offset (mark base).

[38] Typically you want to find the brightest offset star you can within ∼50″ separation for your source (and only that large at Palomar).

WITH THAT DONE, you will tell the T.O. the offsets to your object. These are given in arcseconds East, followed by arcseconds North, so having a comment in your target list like

- `# offsets:  21.532" E, -43.164" N`[39]

[39] By this convention, East and North are positive, and West and South are negative east and negative north.

can be handy for your reference. The T.O. will then execute the offset. Perform the same guide star procedure as above.

THEN, crossing your fingers and praying to the observational gods, will hit the `Take Seq.` button to begin your sequence.

Scanning the Slit

A FUN, semi-unique observing mode is one in which you manually drag the slit across a large source (almost always a galaxy) at a particular tracking rate that is non-sidereal, in order to build up a luminosity-weighted integrated spectrum. It can be tricky to wrap your head around, but the execution in TripleSpec is pretty straightforward.

FIRST, you'll have to calculate for a given scan dimension (usually slit length x galaxy length, or similar) and exposure time, the *tracking* *rates* in RA and DEC that will cover your desired aperture in the right amount of time.[40] The Palomar system expects these in units of arcseconds per hour, so you might, for e.g., exposure times of 5 minutes and aperture lenghts of ∼100s of arcseconds, end up with rates in the thousands.[41]

[40] These calculations are left as an exercise to the reader.

[41] The sign convention is again E/N positive, so positive motion in RA and DEC corresponds to a negative RA rate and a positive DEC rate, etc.

Downloading Your Data

To get your data from the Palomar servers to your own system, you can use the `rsync` command.[42] Again, you'll need a password from your SA, at which point you should be able to run the command between the folder the data is stored on (example below but subject to change) to your own computer (I default to the current directory I run from):

```
rsync user1@observer1.palomar.caltech.edu:/remote/instrument5
  /TSPEC/<date>/*.fits .
```

which should pull the latest un-synced files down to your laptop for quick reduction.[43]

[42] This is a nifty file transfer protocol which syncs between the two folders, so that it doesn't re-transfer frames you already downloaded. It even has a flag to avoid the file being currently written!

[43] On that note, I highly recommend having some type of quick-reduction software on hand at the telescope, which really helps you see what you're getting and make informed observing decisions.

Persistence

PERSISTENCE is the phenomenon by which "phantom light" from previous sources remains visible on the detector (and in your data). It is a problem that is particularly bad in the near infrared, because of a quirk of NIR detectors: They don't have a shutter. That is, whatever light is passing through the slit is *always* hitting the detector. An *exposure* is simply the period of time you choose to read out those counts. Bright objects (i.e., stars), should *never* be left on the slit for long periods of time[44], because while the detector is supposed to "clean" the counts when starting a new exposure, the saturated pixels from the star can take a long time[45] to fade out.

[44] Like, more than a few seconds.

[45] Sometimes several exposures.

THERE ARE A FEW STEPS you can take to minimize the effects of persistence on your data.

- First, avoid bright pointing stars. I would say ask for at maximum an 11$^{\text{th}}$ magnitude pointing star – anything in the 8-10 range can cause strong persistence.
- If you do need to use a bright star for something, like focusing, do so off the slit. Additionally, make the guider integration time as short as possible (enter 1 second to access min exposure time), so that you can be updated quickly.
- If you are going to put a bright star on the slit in order to TX, coordinate with the T.O. to have you execute the move, see in the next exposure that it's on the slit, and immediately TX and move to a different pointing. You may still get some persistence, but it won't be as bad. Remember, every second spent on the slit, whether you are exposing or not, is putting that starlight on the detector.
- Finally, a critical step is to line up the star at a location on the slit you **will not** be using in your science images. For example, if you have an ABBA or ABA′B′ dither pattern, then you can place the

star at the center of the slit, which will not coincide with any of those pointings (this is a downside of using ABC dithers).

- If you *do* need the full slit to be usable, then after calibrating the pointing using the star, offset to a blank patch of sky near your target and take multiple "dump frames" to help work out the persistence, and watch the trace of the star fade in each until you are satisfied it is gone. Then return to your object.

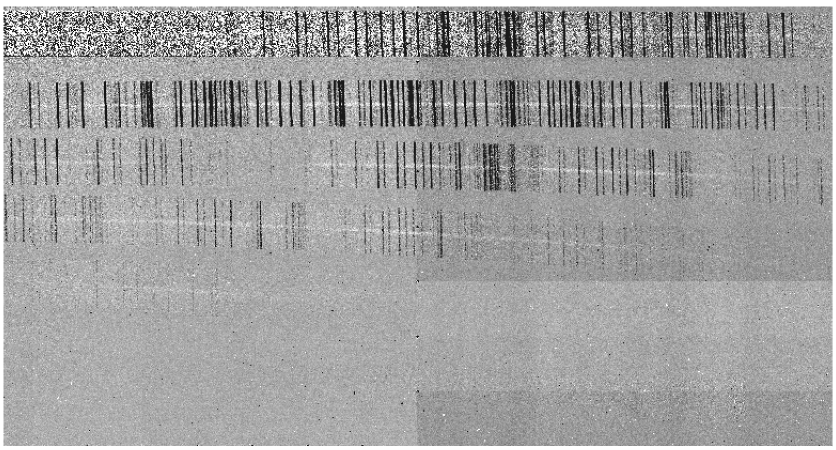

Figure 10: Example of persistence in a sky subtracted science frame. The central trace is *not* the object; it is the residual light from a pointing star used during calibrations that was never technically exposed on.

A Sample Observation: Dithering on an Object

Here I'll describe the actual procedure for observing something like a faint, distant galaxy using TripleSpec. This will be specific to my experience but should be generalizable to your observing needs. The observing procedure is as follows:

1. Select the new target's offset star from the target list and send it over to the T.O. Also tell them the PA you want for the slit so they can rotate while slewing.

2. When arrived, if the PA is more than ∼few degrees from previous, ask to move to a nearby pointing star. T.O. will find one, and it will appear in frame near the slit.

3. Center the pointing star in the slit and inform the T.O., who'll "TX" at that position. They then move back to your offset star.

4. Carefully move the offset star[46] to position 1 on the slit, using the "bring to 1" button and then nudge it to be centered on the slit using the paddles in "pixel" mode.[47]

5. Tell the T.O. the blind offset distances you measured from somewhere[48], which they will then execute. You're now (hopefully) at your target, with your object lined up with dither position one on the slit.[49]

6. Confirm the metadata for your object is good in the TSPEC_SPEC window, and that exposure time and Fowler depths are set correctly. Maybe check the all cam for incoming weather.

7. Confirm the proper dither sequence is loaded (are the positions of the pluses on the slit (and their order) what you want?)

8. Hit `Take Seq` to begin the exposure.[50] Sit back and relax.

9. (*optional*) After 2 frames, use "snap" in the iraf window to see a difference image and look for a trace (spectrum) in your data.

[46] We often have quite faint offset stars, you may need to bump up integration times on the guider.

[47] I usually do 1 or 2 pixel nods

[48] in arcsec E, arcsec N

[49] If your object is bright enough, simply go there from the pointing star and line it up.

[50] If you are not dithering, but taking a spectrum at one spot on the slit, hit `TakeImage` instead.

Troubleshooting

This will be by far the least useful section since I have so little experience with the instrument. But I'll add to it as I run into more things.

"Snap" isn't working in the terminal

If the snap command isn't working, it's likely because it needs to be restarted. To do so, close the analysis SAOImage DS9 window, and the TSPEC;cl terminal. Then double click the TSPEC IRAF icon on the desktop. Two terminals will appear; minimize the one that isn't the iraf terminal (i.e., not ecl>) and then in the iraf terminal, type ">wirc", then cd into the current night's data directory, then type ">!ds9 &" to open a new synced up ds9 window. Now you should be able to snap again.

There are no guide stars in the field of view

Ouch, that's rough. There are a few things you can do here.

- Bump up the exposure time on the guider to something like 12-15 seconds, and make sure you have an accurate reference image (nod, set ref, nod back). See if anything pops in.[51]
- If that doesn't work, see if there's another position angle for your target that is workable.[52] It's especially likely that, because the slit is near the edge of the guider imager and the point of rotation is just under the slit, that swinging into a new PA will bring some stars into frame.
- If all else fails, you can expose without guiding — Palomar's tracking is accurate on its own on at least ~minute timescales, so while you'd increase your read noise, you could lower your exposure times to around that amount, and then check against a pointing or offset star between each sequence.

[51] Even if it's faint, TripleSpec can use it to update it's positions every once and a while.

[52] The obvious first try is 180° rotated, as it is effectively the same.

Part III

Reducing TripleSpec Data

Setting up for Success

Okay, this part is somewhat of a misnomer — I'm not going to attempt to write out a guide for constructing an entire pipeline for reducing near-IR data.[53] What I'm focusing on in this section is instead what you can do *at the telescope* to make your life easier later on when you *are* trying to reduce your hard-won data.

[53] Mostly because it's a pain. I sure would've liked one.

Tip No. 1: Take Your Skies FAST

Whether you are taking blank, offset sky exposures or dithering, it's critical to make sure sky exposures are as close to your science exposures as possible. The near-IR sky changes really fast, and the strong OH lines vary on timescales that prohibit their subtraction if any significant time has passed. This is more for when you are in charge of your own skies (i.e., a dither sequence isn't doing it for you). But remember, you also don't want to go so short that you're read noise dominated rather than sky noise dominated.[54]

[54] For TripleSpec/NIRES we find this to be $\sim$5 min, which is a tough lower limit. MOSFIRE, for example, is sky-limited in $\sim$2 minutes.

Tip No. 2: Write down your dither positions

The dither positions you make and save to (or load from) a config file have values associated with them that you can read off when you look at Panel A of the *Slow Guider Display*. **Write those numbers down**. You have no way to access them once you're gone.

Tip No. 3: Keep a detailed log

This one is obvious, but for Palomar, where the weather is highly variable, it's especially important to note the weather + quality of different exposures. It also helps, if you do any manual nodding / offsetting, to write down what they were for later reconstruction.

Some Thoughts on Standard Stars

The main task when reducing these type of data is actually just the spectral calibration: Accounting for both the instrumental response function as well as for those pesky OH / telluric lines in the atmosphere. Conventional wisdom claims you need a standard star for every target in your sample, at the airmass your object will be when it's observed, and at the same declination.

These are somewhat stringent requirements, both on time as well as on location (the best stars for this are featureless O-stars that are rarer than, e.g., A0V stars which are commonly used but require fitting and removal of broad hydrogen features. If your spectrum is super bright (high S/N), you can actually fit the molecular absorption in your template directly using high resolution templates (see, e.g., van Dokkum et al. 2012). An additional, hybrid approach, is to take spectra of O-stars at a span of airmasses on the night of observation (all in one go) which span the airmasses of your targets; then fit the template to the O-star that best matches the airmass of your target and produces the minimal residuals when subtracted from your spectrophotometric standard star and your objects. This method, of course, works best when you're less interested in the full, accurate spectral shape and more on, e.g., individual emission lines that are generally well separated from the absorption features.

Part IV

Appendix, Glossary, and Index

Appendix

Here I include for reference various raw information about the instrument and detector. Most of this is directly from the cookbook/binder onsite:

The Spectrograph

- Slit: 1″ x 30 ″
- Wavelength Coverage: 1.0 -2.4 μm in 4 spectral orders
- R: 2500-2700
- Sampling: 2.7 pixels / resolution element
- Min integration: 4 seconds
- Gain: ∼3.8 e^-/DN
- Saturation: 28000 DN
- Data sampling: CDS, Fowler, UDR[55]
- Read noise: 10 e^- (CDS), 8 e^- (8 Fowler samples), 3.5 e^- (16 Fowler samples)
- Dark current: ∼0.085 e^-/s
- Detector size: 1024 x 2048

[55] I've never used nor seen people use anything other than Fowler sampling at Palomar.

The Guider/Imager

- Imaging: K band
- Field of View: 4′ x 4′[56]
- Minimum integration: 1.8s (if you type something less it will default to this).

[56] It's useful to have, in addition to your normal finding charts, charts with this FOV to match what you see on the guider. Keep in mind, the slit is near the top of the frame, not at the center.

It's important to note that the guider imager (and images), though they can be saved to disk and retrieved later), are not of science grade, and the imager chip(s) have many messed up pixels, blemishes, etc. So one can use those images (if you save them) for reference, but should not use them for science.

Instrument Startup [usually not necessary]

Here I provide for completeness a step by step guide to opening up the instruments and setting them up. Generally *you do not need to do this*, as it is the S.A's responsibility to have the instrument set up and ready for observing by the time you arrive / log in to take calibrations. These setup instructions are as they were in Dec of 2019 and are subject to change.

VNC into the Instrument Computers

To VNC into the instrument computers, from the Desktop click the `Instrument 4` and `Instrument 5` icons, and enter the password.[57] Drag the VNC's to the appropriate screens.

[57] I'm sure this changes frequently enough it's not worth including here.

Launch GUIs

Launch the main TSPEC_SPEC window in Instrument 5 using the desktop icon for it. You should see a green startup window which indicates it is running the startup scripts, then the GUI window should appear.

Open an iraf session and DS9 windows:

1. Click TSPEC IRAF desktop button. Minimize empty terminal.
2. Type `wirc` into the `ecl>` prompt.
3. CD into the current day directory (e.g., 20191216).
4. Type `!ds9 &` in the `wirc>` prompt to launch DS9 in a subroutine.

Also open the live-view DS9 window by double clicking the "`DS9 real time TSPEC_SPEC`" button.[58]

[58] This live view renders weird and I almost never look at it — I leave it tucked behind the other DS9 window.

I will trust that the camera is working. If the camera head electronics need to be restarted, the SA should do this. You will know if that's needed if you take a short test exposure and it looks wrecked.

OVER ON INSTRUMENT 4, we now need to setup the Guider windows. Start by clicking the "`TSPEC_IMGR`" icon on the desktop. You'll see a similar startup green window as before. The *Slow Guider Display* is the first to appear, along with the actual `TSPEC_IMGR` window. We now need to open all the pop out windows.

1. Click the `comp` button at the bottom of Panel B in the *Slow Guider Display* to open the Image Settings window.
2. Click the `enhanc` button to open the Image Enhancement window.
3. Click the `Zooms` pulldown four times clicking on each zoom name to open all 4. Drag them into the desired configuration.[59]
4. Over under the zoom box for the guide star in Panel C of the *Slow Guider Display*, click the `profile` and `stats` buttons to open the Radial Profile and Image Stats windows.
5. Click the `Settings...` button in the lower right corner of the guider zoom box area in Panel C to open the Guiding Settings window.
6. Open the TCS OFFSET window by licking the `ofsett...` button inside the **Marks** box in Panel C (just above the guide star zoom box).

[59] Zoom 2 tends to open in a weird spot, the others form most of the square.

WITHIN the **TSPEC_IMGR** window, set the image number to 1, uncheck the write to disk option, and check the cont read option. Then hit **Go Expose** to take a test image, and adjust the contrast slider for both the guide box and primary image to fix the weird rainbow of colors.

Final Adjustments

IN THE *Slow Guider Display*, in the top right of Panel A, check the "return to 1" box.[60]

[60] This ensures that at the end of a dither sequence the telescope nods back to the start position.

CLICK THE **boxmap** button in the Image Enhancement window[61] to bring up a white box to the main image which will autoscale each incoming exposure.

[61] It looks like an indicator light not a button — bottom left corner of the window.

FINALLY, change the size of the guide star box (the yellow one) down by going over to the Guiding Settings window, and on the far right changing `Xsize` to 40 or 50, hitting <enter> and then clicking OK.

Glossary of Terms

Blind Offset: When observing faint sources that can't be seen in a reasonable exposure time of the guider, the pointing of the telescope is first calibrated, then coordinates for a bright, point like object (usually a star) which are close to the target object[62] are used to align the slit. Then, carefully measured offsets between the star/point and the target object[63] are applied "blindly" and the exposure sequence is conducted.

[62] Depends on the telescope and its precision, but usually <50″

[63] Usually measured from much deeper data.

Dither Sequence: In spectroscopy, the practice of taking spectra at multiple positions along a slit, which is accomplished by nodding the telescope ∼few arcseconds in the slit direction between exposures.[64] Because this routine is so common, most telescopes have scripts which can execute dither patterns automatically — common examples include ABBA, ABC, and ABA′B′.[65]

[64] Doing this facilitates both sky subtraction, noise-reducing image combinations, and the correction for bad pixels in the detector.

[65] There is interesting statistics behind which dither sequences maximize the signal-to-noise you can obtain from the same total exposure time, which I encourage you to look into.

Guide Star: A star selected in the field of view of the guider/imager which software can continuously (and accurately) measure the location of.[66] This allows it to make minor adjustments to the pointing / tracking to keep objects in the field/frame nearly perfectly in place.[67]

[66] Usually a centroid.

[67] This is especially important when placing very small objects on slits.

Position Angle (PA): In spectroscopy, some measure of the angle of the slit (and thus, usually, the detector and instrument) with respect to the sky. Usually measured counterclockwise from North (that is, in sky-coordinates, from north to east) in degrees. One usually gives the PA to the telescope operator who rotates some element of the instrument to achieve this angle on sky.

S.A. (Support Astronomer): The individual responsible for setting up the instrument at the beginning of the night, and for generally being knowledgeable about the instrument's operation and capabilities. Can usually answer questions about using the instrument as well as troubleshoot issues that arise.

T.O. (Telescope Operator): The individual responsible for the telescope on the night of your observations. This person decides when it is safe to open, opens the dome, and moves the telescope between targets.

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