KOSMOS guide

Kitt Peak Ohio State Multi-Object Spectrograph

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Version 1.6.1*

Figure 1: Apache Point Observatory. Telescopes from left to right: 2.5 m Sloan Foundation Telescope, 0.5 m ARCSAT, New Mexico State University 1.0 m telescope, Astrophysical Research Consortium Research 3.5 m.

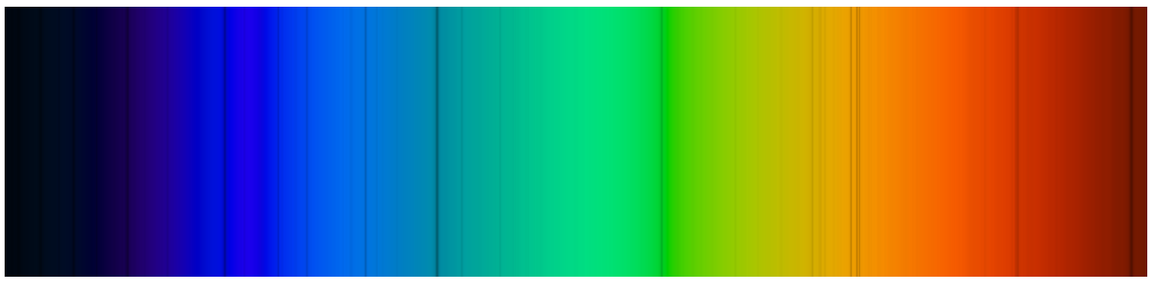

Figure 2: Actual spectrum from KOSMOS spectrograph.

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*Last changed 7 October 2024, see LaTeX document for changelog.

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1 Getting started

Observing can feel overwhelming at times. The purpose of this guide is to be one resource with all the information new observers would need when starting to use KOSMOS.

Here is a list of links that might be helpful while you are observing.

Links and descriptions		
Category	Description	url
Observatory resources	Main page	https://www.apo.nmsu.edu/
	Weather status	https://weather.apo.nmsu.edu/cgi-bin/weather.py
	Hourly forecast	https://weather.apo.nmsu.edu/
	Optical sky camera	https://newapo.apo.nmsu.edu/mainpage/allskycamera/
	Schedule	https://www.apo.nmsu.edu/Planning/obs.calendar/obs.calendar.html
	KOSMOS documentation	https://www.apo.nmsu.edu/arc35m/Instruments/KOSMOS/userguide.html
Observing tools	*Gaia* DR3	https://gea.esac.esa.int/archive/
	Target spreadsheet	https://docs.google.com/spreadsheets/d/1fG5TKoV427jP65BD2EV_8oMTcMJETgFaVmEWJbdMTqQ/edit?gid=867351701#gid=867351701

Table 1: Helpful links

2 Starting TUI

Telescope User Interface (TUI) can be downloaded from the Apache Point Observatory (APO) website[1] and run from your personal computer. KOSMOS is a relatively new addition to APO, so make sure you download the most-recent release of TUI. Running TUI from your own computer will likely necessitate bringing external storage to save the data of the night. A single night can exceed 6 GB! After installation, it should be self explanatory to execute the TUI software.

TUI can also be run from the linux computers on the department cluster. Simply open a terminal window and type "tui &" and press enter.

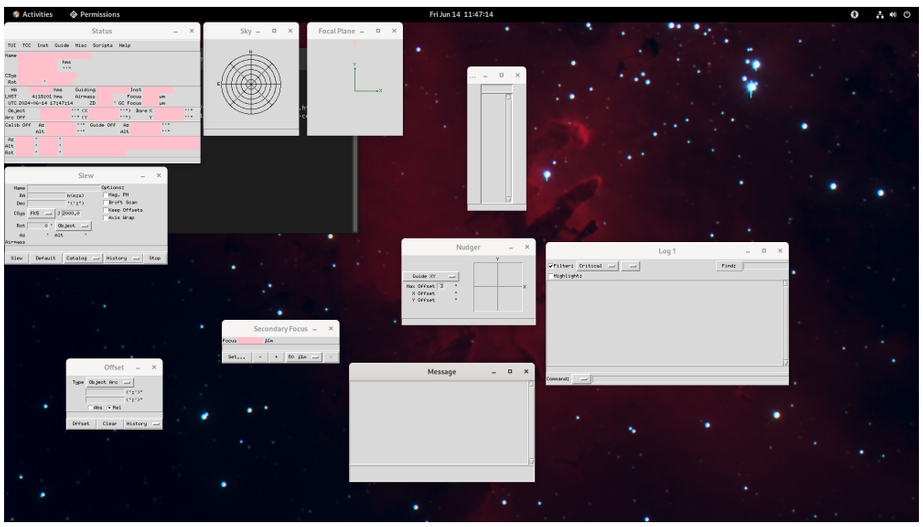

Figure 3: Desktop after launching TUI.

Successfully launching TUI will automatically open several windows. An example desktop after opening TUI is shown in Figure 3. Most of these windows are useful, so keep them

[1]download link: https://www.apo.nmsu.edu/arc35m/TUIdownloads_ARC35m.html

open and arrange your desktop so that everything is visible. We won't need the Secondary Focus, Offset, and Log windows so put them in a corner on top of each other.

With `TUI` open, we are ready to log in. Find the Status window. Navigate the menu bar on the top of the window and click **TUI > Connect**. This will open the "Connect" window prompting you with your log in information. Fill in these prompts. The User Name is simply how your log in will be presented to the observatory technicians. It is helpful to make this your first and last name. The Program ID will always begin with "WY" followed by two numbers. Check the observing schedule for the current quarter if you're unsure which Program we are. The Password is always the same. Ask someone familiar with observing if you are unsure what the password is.

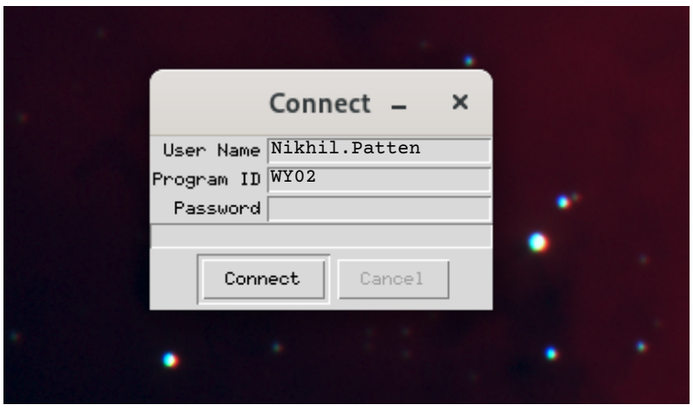

Figure 4: Example log in.

3 Before observing

Before taking data, there are several checks that have to be done. In this section, we'll go over what checks need to be done before observing. To start, go to the Status windows and in the top menu find **Inst>KOSMOS**. This will open the KOSMOS window. Keep this window open the entire night. Be sure to start a log and log every exposure as you go!

3.1 Instrument specifications

In the KOSMOS window from before, check the box that says "Config" and verify that the blue disperser is selected, the 0.83" low slit is active and set the column bin to 2. Finally, save and apply these changes by pressing **Apply** at the bottom. Unsaved changes usually show up in red. Figure 5 shows these changes made before hitting **Apply**.

3.2 Catalog

Upload the catalog of targets. Go to the Slew window (shown in Figure 6) and click on **Catalog>Open...**. This will then open the Catalog File window. Find and open the catalog file. You should notice your targets appear in the Sky window.

3.3 Preferences

One last thing to do before observing is to check some settings regarding exposures. Go to the Status windows and click **TUI>Preferences**. Now in the Preferences window, select **Exposures** in the side menu. Make sure the boxes "Seq By File," "Get Collab," and "View Image" are checked. Set "Get Every" to be 1, so that every image is downloaded. Also, set the save directory you want data to be saved in. An example of what this window should look like after these changes is shown in Figure 7. Hit **Save** and **Apply** before closing the Preferences window.

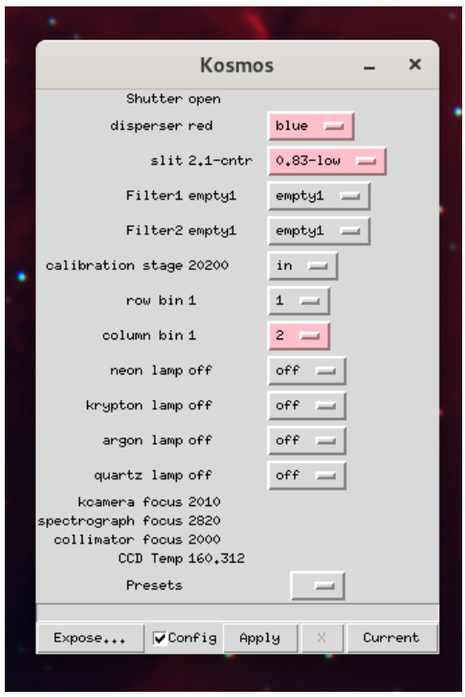

Figure 5: KOSMOS configuration.

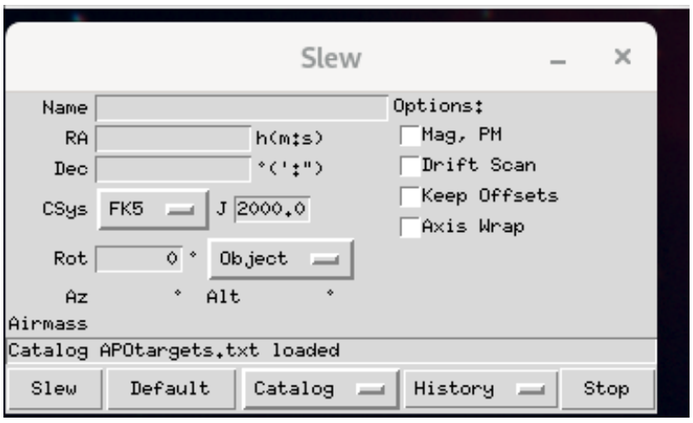

Figure 6: KOSMOS Slew window.

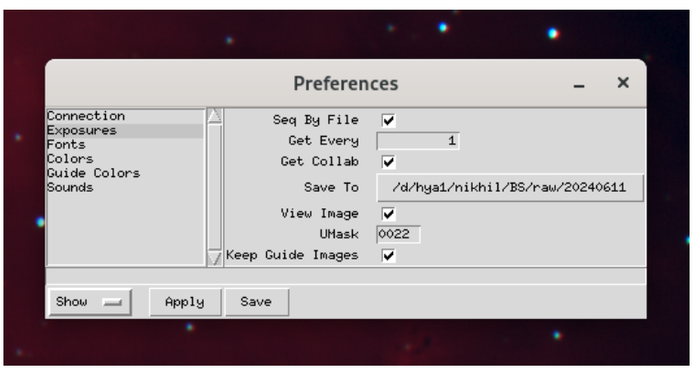

Figure 7: Preferences window with correct settings.

4 Observing

In this section, we'll cover necessary instructions on how to use APO to get a stellar spectrum.

4.1 Picking a target and slewing

Pick a brighter target that is close to meridian to start. You can check the Local Mean Sidereal Time (LMST) in the Status window. In the Slew window, click on **Catalog** and find the target you've chosen. Paste the Right Ascension and Declination coordinates in the Single Search query in the *Gaia* explorer. When ready to, click **Slew** on the bottom of the Slew window. The Status window gives the progress of the slew and an estimated time remaining. Once slewed to the first target, ask the observatory technician if they can measure the seeing and write it down.

4.2 Finding the target

After slewing to a target, we need to verify we've slewed to the correct target. Start by pasting the coordinates of the target into the Single Object search of *Gaia* DR3. A field of stars should appear with cross-hairs on an obvious star.

Now, open the KOSMOS slitviewer in `TUI`. Find the Status windows and click on **Guide>Kosmos Slitviewer**. This should open a new Kosmos Slitviewer window. Make sure the "calibration stage" is set to out and click on **Expose** on the bottom left to view the field. When finished, this should result in a field resembling that shown in Figure 8. Slewing to a target usually places the target slightly above the slit.

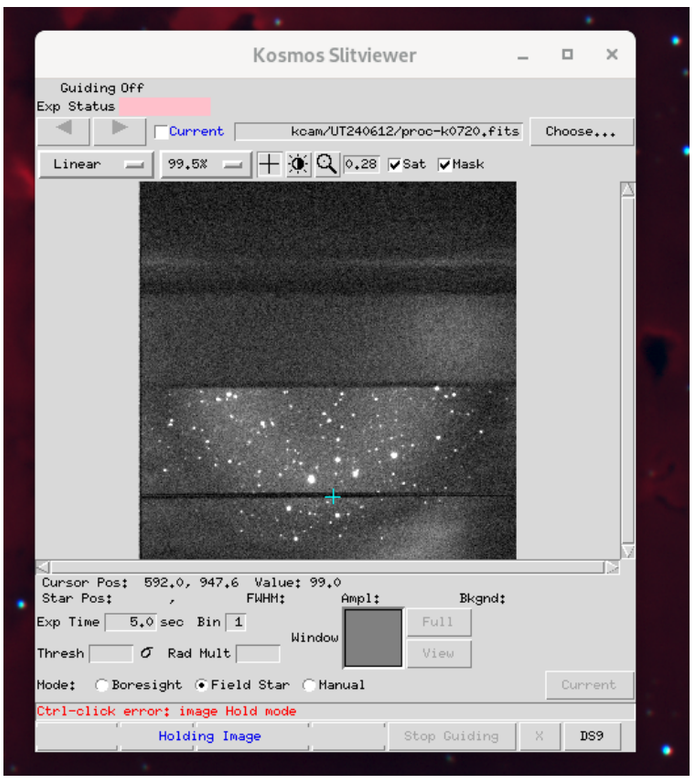

Figure 8: KOSMOS slitviewer after slewing to a target.

Now we have to match up the field in the KOSMOS slitviewer to the finder image from *Gaia*. This can be challenging, especially for dim targets and crowded fields. Keep in mind the KOSMOS field is rotated with North usually orientated to the right and East vertically up. You can see the orientation of the field in the Focal Plane window. An example guide image and finder image are shown in Figure 9 below. Look for patterns and shapes of bright stars in the field to help identify where your target is in the Slitviewer window.

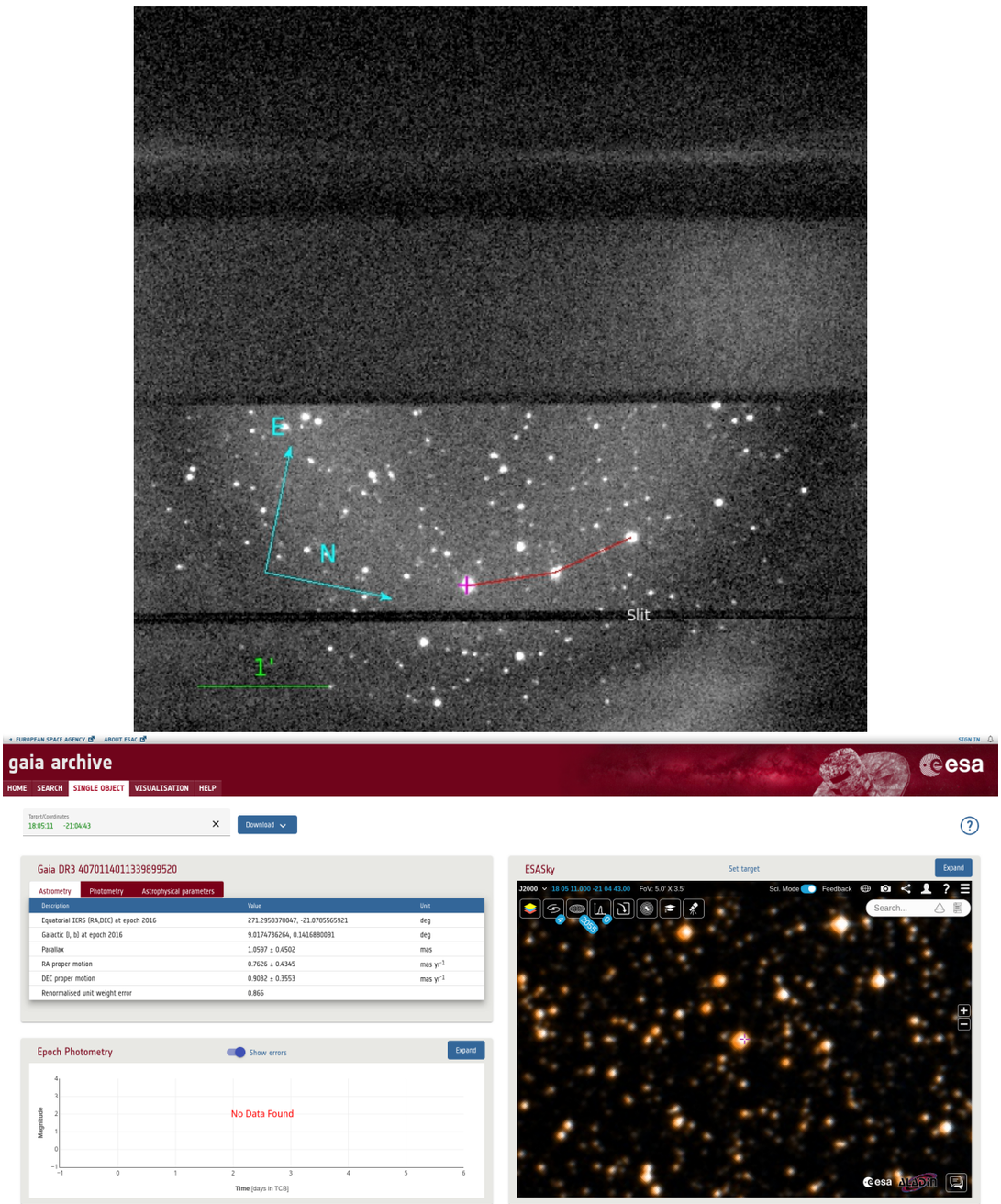

Figure 9: Top: KOSMOS slitviewer field with North and East indicated by the cyan arrows. A magenta cross is overlayed on top of the target star and a red line illustrates the line of bright stars going north east of the target. Bottom: *Gaia* finder image.

4.3 Moving the target into the slit

Bearing in mind that the slew target is intentionally placed just above the slit, it's now time to move it into the slit. In the Kosmos Slitviewer window, select the cross at the top menu. Hold down left control on the keyboard and left click on your target. Then, at the bottom menu, click **Center Select**. This will move the star into the slit and automatically re-expose the Slitviewer field. If you want to reset, click again on **Slew** in the Slew window and this should place the target where it originally was before adjustments.

4.4 Adjusting the slit

With the target roughly in the center of the slit, it might be beneficial to make finer adjustments before taking an exposure. Getting a target in the center of the slit will ensure that you are collecting as much light as possible in the spectrograph. First click on the magnifying glass in the top of the Slitviewer window and draw a box on the field around your target. Double clicking the magnifying glass will reset the zoom.

Go to the Status window and click **TCC>Nudger**. This should open a new Nudger window. Click on the box that says **Guide XY** and change it to **Object Arc XY** instead. This makes it so up in the Nudger window is the same direction in the Slitviewer window. Clicking in the XY plane will move the slit in the corresponding direction. The important thing to note is that the Nudger moves the slit and **NOT** the field. So for example, if you want to move the target down in the Slitviewer, you would need to move the slit up! Be sure to re-expose the slitviewer by clicking **Expose** after each adjustment.

The example field shown in Figure 8 is shown in Figure 10 with the target placed correctly in the slit. Strive to have the target overflowing equally above and below the slit if the target is bigger than the slit width.

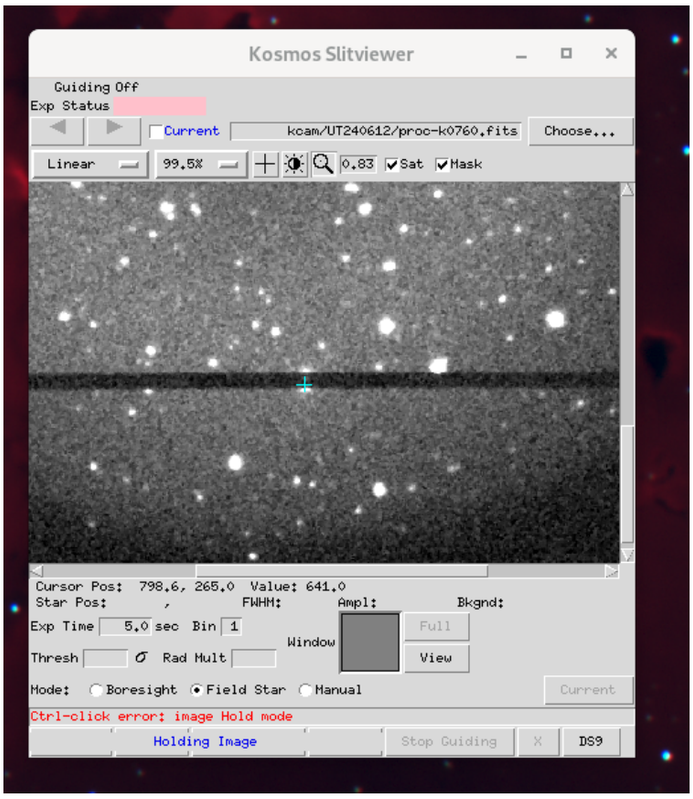

Figure 10: KOSMOS slitviewer after centering target and adjusting.

4.5 Guiding

Now that the target is squarely in the slit, we want to keep it that way! Click on the cross in the top of the KOSMOS Slitviewer window. While holding down left control, left click on a bright star outside of the slit. With the cyan cross over this bright field star, click **Guide** on the bottom of the Slitviewer window. This will automatically keep this field star in the same position, ensuring our target remains in the slit throughout the exposure.

4.6 Exposing

Now it's time to expose on our target. In the Kosmos window we opened in Section 3, click on **Expose...** in the bottom left. This should open a new windows titled Kosmos Expose. Be sure to select a Type of Object and write "**BS/k**" in the File Name space. This will save exposures in a sub directory BS with incrementing file names k.####.fits. Put the desired exposure time in seconds in the Time box, specify the number of exposures in the **# Exp** box, and click **Start**. Update your log as you go!

4.6.1 Suggested exposure times

The time you expose for will depend on the magnitude of the target (duh). But also, the required exposure time will also vary based on seeing conditions and sky brightness. The catalog I send will have Gaia G magnitudes commented under each target. However, a lot of my targets lie in the Galactic plane and some targets are behind a lot of dust and exhibit significant reddening. Gaia G magnitudes therefore are not the best indicators of brightness but rather Gaia BP is a more-accurate indication. Find the BP magnitude in the *Gaia* DR3 explorer and click on the **Photometry** button. Use this magnitude as an indicator for exposure times. Here's a table of magnitudes and *suggested* exposure times.

Gaia magnitudes and suggested exposure times	
BP (mag)	**Exposure time**
5	5 s
7.5	60 s
10	600 s
12.5	900 s
15	2×1800 s

Table 2: Suggested exposure times

4.7 Examining spectra

After obtaining a stellar spectrum, you can get a rough assessment of the spectrum's signal-to-noise ratio. Start by examining the image in ds9. Convert to a log scale and adjust the scaling until the stellar spectrum becomes visible. If you can clearly distinguish the stellar spectrum throughout the entire dispersion direction, then that's a good indicator that the spectrum is good! If the stellar spectrum fades as you move up the image and is no longer visible at the top, then either expose again for longer, or ditch this star! Use your judgement. Figure 11 shows examples of useful and unhelpful stellar spectra straight from the telescope.

5 Calibrations

The purpose of this section is to give an overview of the types of calibration frames needed and how to obtain each calibration.

5.1 Arc lamps

Take a comparison lamp exposure after exposing on a target but before slewing on to the next one. Only one comparison lamp spectrum is needed at each position. To take an arc spectrum, click **Stop guiding** on the KOSMOS slitviewer windows and set the calibration stage inwards by clicking on the menu next to calibration stage on the Kosmos window. Next, turn on the krypton and argon lamps. When each of these changes are made, click **Apply** and wait for the changes to set. Then, in the Expose window, change the type to Flat and set the Time to 45 seconds. Figure 12 shows an example arc spectrum in the left side of the panel. When you are done, set the calibration stage to **out** if you want to use the telescope agian, and turn off the arc lamps.

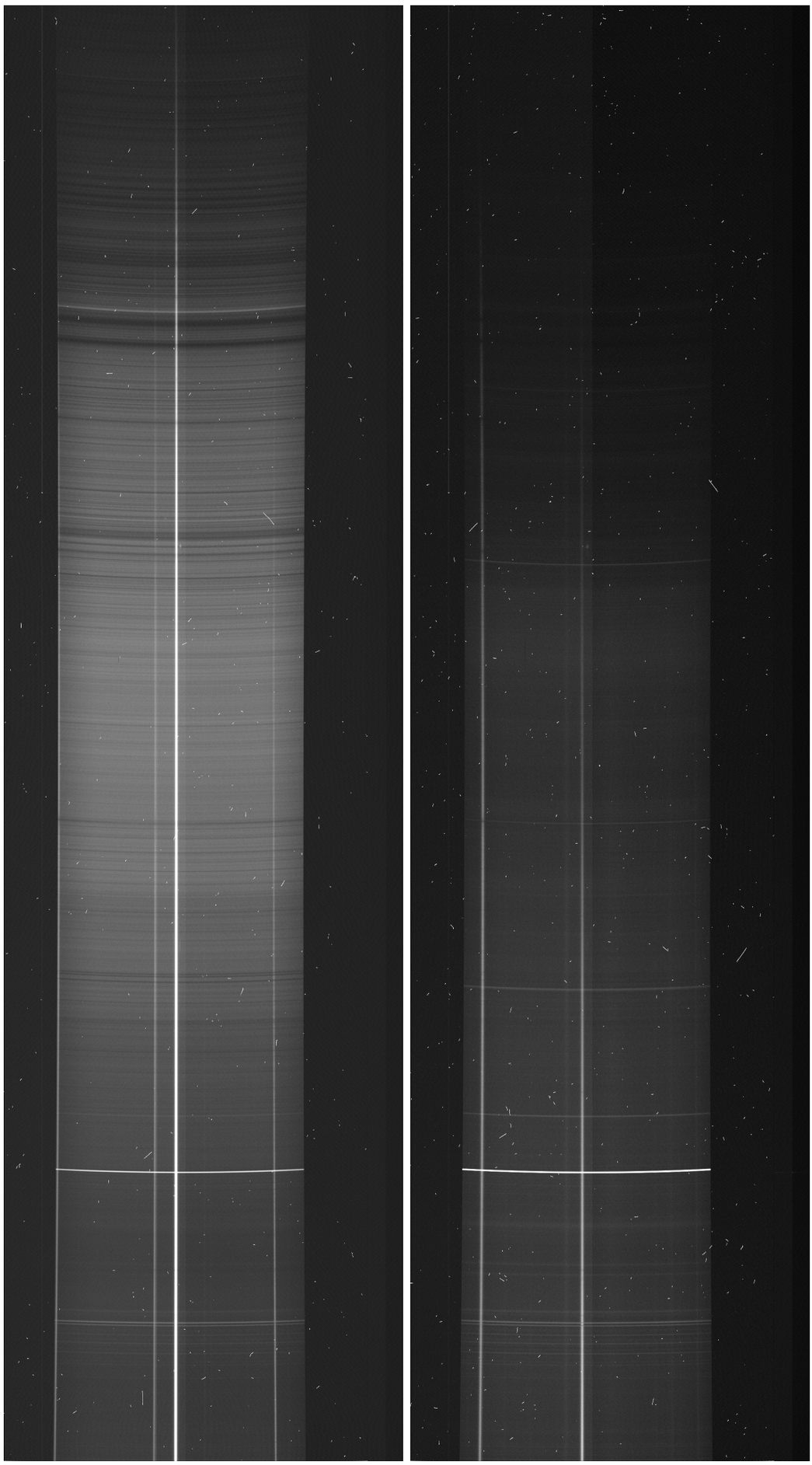

Figure 11: Good and bad stellar spectra. Left: An ideal stellar spectrum. Notice how even at the blue end (top), the stellar spectum is still detectable above the background. Right: A subpar spectrum. The main difference being how the spectrum significantly fades at the top of the image and is no longer visible.

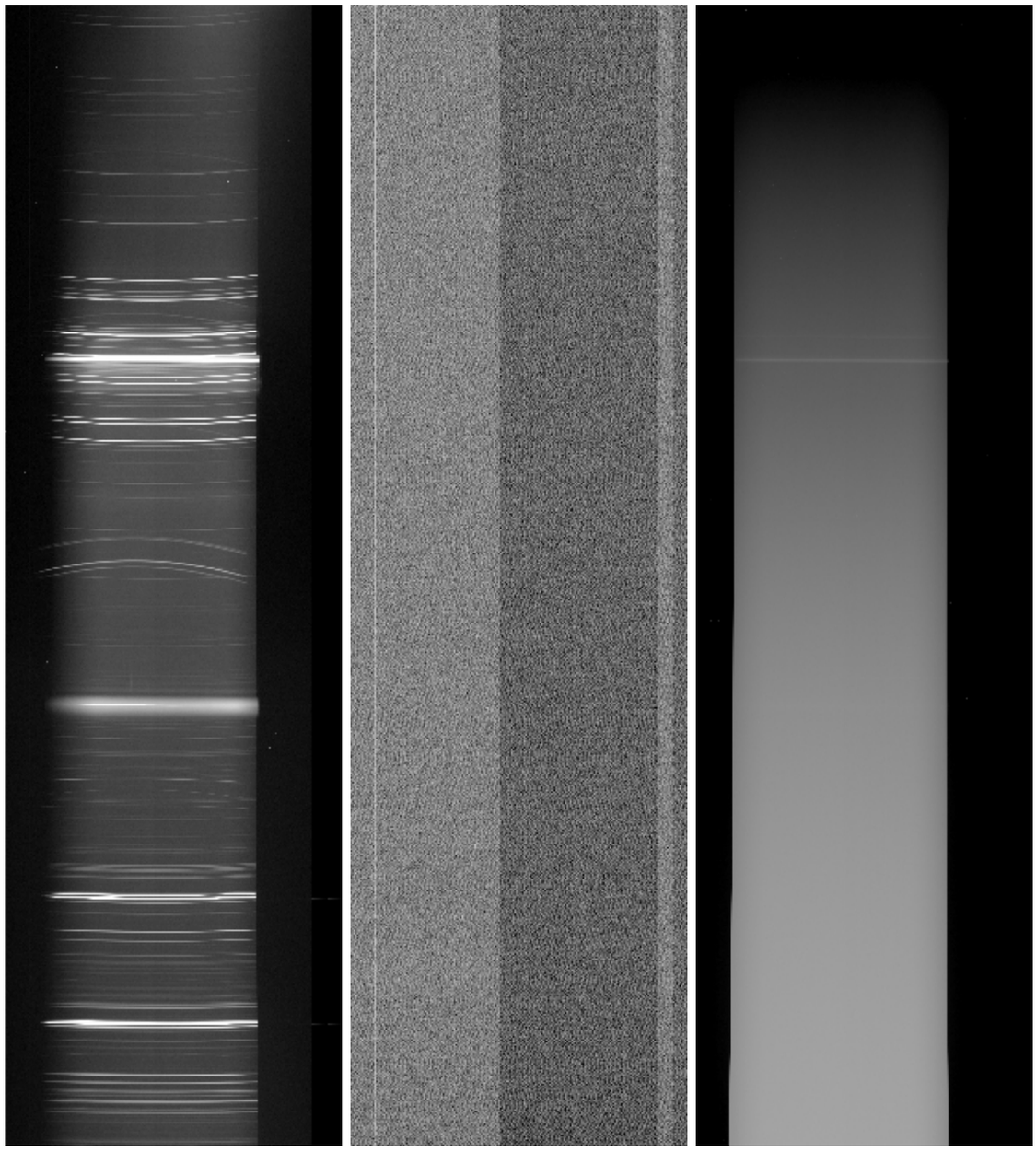

Figure 12: Calibration frames. Left: A comparison lamp spectrum. Middle: A bias frame. Right: A quartz spectrum.

5.2 Bias

To take a bias image, first change the image Type to Bias. This should automatically grey-out the Time box. Change the number of exposure to the desired amount (10 should be good) and expose. Figure 12 shows an example Bias image in the middle of the panel.

5.3 Quartz images

Ask the telescope operator if you can take truss exposures and wait for permission. Once they give you the go-ahead, navigate to the Status window and click **Misc>Truss Lamps**. Then, in this new window, check "Br. Quartz" to turn the quartz lamp on. Note that you will not need to confirm this setting and the quartz lamp will turn on immediately after checking the box. Then, in the Expose window, change the Type to Flat and Time to 400 seconds. Change the number of exposure to 4-5, and begin the exposure. An example quartz image is shown below in Figure 12 on the right side of the panel. Note that the counts at the bottom of the image should be around 100,000 and around a few thousand at the top. Be sure to turn off the quartz lamps when you are done.

6 End of the night

At the end of the night, be sure all lamps are turned off. Then, in the Status windows click **TUI>Disconnect** followed by **TUI>Quit**.

7 Accessing Data

APO is a state-of-the-art observatory and it is very easy to access data. There two methods for accessing data from the observatory which are outlined below.

7.1 Saving data the night of

The simplest way to access data is to save your data as you observe. Simply set the save directory at the beginning of the night. Open the Preferences windows as described in Section 3.3 and choose set the "**Save To**" path to the desired directory.

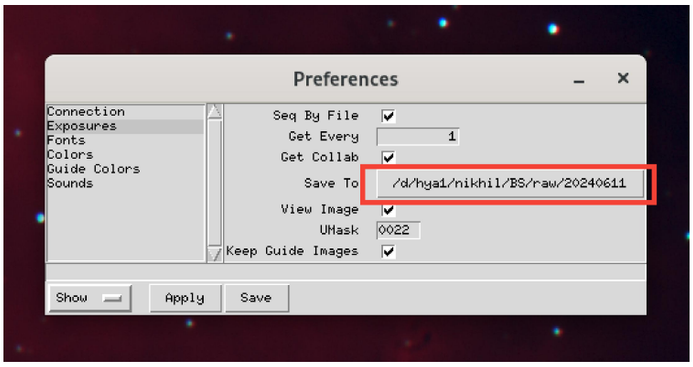

Figure 13: Preferences windows with **Save To** option highlighted.

7.2 APO servers

Data can also be accessed remotely. APO keeps data for all programs for up to a year[2]. This method is a little more complicated than saving as you go. You will need the quarterly password for your program. If you are unsure what it is, ask someone familiar with observing and they will help you get it.

Open up a terminal windows and type

scp (-r) uwyobserver@arc-gatewateway.apo.nmsu.edu:/export/images/Q#WY##/UTYYMMDD .

[2]According to their documentation.

Replace the number signs in "**Q#WY##**" with the current quarter and program number and "**UTYYMMDD**" with the year, month, and date, respectively of the night you wish to download data. The "**-r**" is optional and only needed if you are downloading sub-directories. See this page[3] for more details. For example, if you wanted to copy data from 8 July 2024 (remember, this is the UT date, **NOT** the local date you observed) for program **WY01** to the current directory, the command to obtain these data would look like:

scp -r uwyobserver@arc-gateway.apo.nmsu.edu:/export/images/Q3WY01/UW240708/ . .

Alternatively, you can navigate the data directory on APO servers by using the **ssh** command. This may be beneficial if you are unsure the exact date you are trying to obtain. In a terminal window, type the following command,

ssh arc-gateway.apo.nmsu.edu -l uwyobserver .

This should prompt you to enter a password. This is the quarterly password for our program. Again, ask someone familiar with observing if you are unsure what this is. 3.5 m data should then be located in directory **/export/images/**. **cd** into this directory and you are free to access data from all programs!

[3] https://www.apo.nmsu.edu/arc35m/Data_ARC35m.html

8 FAQ

- **When do I log in to `TUI`?**

  Log in about 1 hour before the scheduled start time. This gives you plenty of time to prepare for observing!

- **When do I take calibrations?**

  For A-half, take calibrations before the sun sets. For B-half, take them after sunrise. Biases and Quartz images usually take 45 minutes.

- **How often do I take comparison lamp exposures?**

  Take a 45 second Krypton and Argon exposure at each position after exposing on a star. Take one comparison lamp spectrum at each slew position i.e., only one arc lamp per target regardless of how many spectra of one target you choose to take.

- **How many target spectra do I take?**

  Up to you! I usually stick to one spectrum, but if you notice there aren't that many counts in the blue end then take another. Use your judgement!

- **What do I name my files?**

  For consistency, I'd prefer if you put "BS/k" for the file name.

- **How many biases do I take?**

  Take 10 bias images.

- **How many quartz images do I take?**

  Take five quartz images.

Have fun! It is a privilege to work with such a high-end observatory, so enjoy it! Be sure to take lots of pictures at APO :)