The JWST Exposure Time Calculator Assignment

This Master Class homework package is intended to help you become familiar with the JWST Exposure Time Calculator (ETC) and its basic functions. The exercise consists of step-by-step instructions, which will familiarize you with the ETC, followed by questions, which will test your understanding.

1. Before we start

The ETC user has to get familiar with three concepts: sources, scenes and calculations. We will go into more details later in the assignment, but here are some short definitions:

- The JWST ETC uses one or several **sources** to be included in the astronomical scene for the ETC calculation. The sources are described by parameters that characterize their brightness, spectral properties, and shape.
- **Scenes** are used for calculations. A scene may contain one or multiple sources; it is an idealized representation of the spatial distribution of a target and nearby sources with defined intrinsic spectral properties.
- In the JWST ETC a new **calculation** can be initiated by choosing an instrument, mode and detector configuration. The calculation requires an existing scenes and sources.

2. Getting Started

YouTube ETC Home Overview

1. Point your favourite browser to jwst.etc.stsci.edu.
2. If you have never used the ETC before, click on the green "Quick Start" button and follow the on-screen directions for a brief tutorial on basic functionality.

3. Click on the "Exposure Time Calculator" label in the top left to get back to the beginning. You can always use this label to return to the ETC landing page.
4. If you do not already have a MyST account, click on the "Create User" button, click "OK" in the dialog box that pops up, click on "New User or Guest User," and follow the instructions to create an account. You will need a MyST account to log in to the ETC and save workbooks.
5. Click on the blue "Login" button to enter the ETC. Click "Proceed" on the next screen.
6. You are now on the "Available Workbooks" page where you can view your full list of workbooks.
7. Click on the "Sample Workbooks" and "Example Science Program Workbooks" dropdowns to familiarize yourself with the options for pre-made workbooks. Select an item from either dropdown to add a copy of that workbook to your list. Click the "Load" button to open the workbook in a new tab in your browser and examine its contents. Note: This will open a new browser tab.
8. Return to the Available Workbooks browser tab and click the "Create New Workbook" button. This will add an empty workbook to your list. Click on the load button to open this workbook.

   Exploratory Work:
   - What do you think the "out-of-date" field in the workbook list means?
   - Try to find out how you can share a workbook with a collaborator. Experiment with read and write permissions.

3. Create and Explore an ETC Workbook

Visit the ETC General Overview You Tube Video

1. Workbooks open in the "Calculations" tab. You will see three other tabs are also available: "Scenes and Sources," "Upload Spectra," and "Caveats and Limitations."
2. A workbook always includes three boxes at the top of the page.
   a. One contains a unique workbook ID, which cannot be edited.
   b. The second is a box for the title of the workbook. Name your workbook.
   c. The third is a box for you to provide additional information on what is contained in the workbook. Add a description.
3. Move to the "Available Workbooks" browser tab. You will see that the title and description have automatically updated for this workbook.
4. Now, return to the workbook. Take note of the "Help" dropdown menu at the top right. Click on each of the options in the dropdown to see what they link to.
5. Scroll to the bottom of the page and view the "Notes" section. Typing in this section will automatically save notes you leave for yourself or your collaborators. Type something in the Notes.

Exploratory work:
- Find the known issues under the help menu. Which one, if any, do you think could most affect your favourite science case?

4. Using the Calculations Tab

1. In the Create a NIRCam SW Imaging calculation. Remember the first step in the "Quick Start" walkthrough.
2. Highlight the calculation by clicking on it. This populates the "Calculation Editor" pane in the top right with additional options for customizing the calculation.
3. A new calculation always begins with the "Instrument Setup" tab selected. For NIRCam SW Imaging, you will see a dropdown providing a list of all available short-wavelength filters. Change the filter.
4. Now move to the "Detector Setup" tab. Change the "Readout pattern" from DEEP2 to RAPID. Click calculate. Note: The ability to change other parameters is not available while the calculation is running.
5. Locate the "Expand" dropdown menu in the top bar. This dropdown lets you easily copy calculations with one parameter altered. Select the "Expand Groups" option.
6. In the dialog box, fill in 11 for the "Start Value," 1 for the "Step Size," and 10 for the "Iterations." Click "Submit" to create 10 new NIRCam SW Imaging calculations covering the range from 11 to 20 groups. Observe that the exposure time increases with the number of groups.
7. Highlight the original calculation and repeat the process for the "Expand Integrations" option (Start Value=2, Step Size=1, Iterations=10).
8. You can view the results of all the calculations at once in the "Plots" pane by clicking on the checkmark icon above the rows of calculations and selecting "All." Then scroll down to view the "Plots" pane.
9. Since all of these calculations were made using the same filter, the default "SNR" tab is not particularly illuminating. Switch to the "SNR (time)" tab.

Exploratory work:
- Note the two different slopes in the signal-to-noise ratio (SNR) for increasing the number of groups and increasing the number of integrations. What do you think causes this behavior?
- Experiment with the readout patterns (under the Detector Setup tab) to find the highest SNR for a total exposure time of about 1000 seconds. What is it?

5. Working with Scenes and Sources
Watch this YouTube Video guide.

1. Now, move to the "Scenes and Sources" tab. A default scene and a source already exist and were used for your previous calculations. Note: the default scene can be edited, but not deleted.
2. Clicking on the scene in the "Select a Scene" pane highlights the scene in yellow. Any sources in the highlighted scene will show up in green in the "Select a Source" pane.
3. Click on the source. This changes the highlight for both the scene and source to a striped green and yellow pattern. The striped pattern marks the "active" source for which you can edit the parameters in the "Source Editor" pane.
4. Familiarize yourself with the various options for customizing a source by clicking on the blue question mark icon in the Source Editor pane.
5. Now, click the "New" button in the "Select a Scene" pane and in the "Select a Source" pane. Highlight the new scene and new source by clicking on each. Click the "Add Source" button in the "Select a Scene" pane to add the new source to the new scene.
6. Move to the ID tab in the Source Editor and name your new source and scene.
7. On the "Continuum" tab, select the "Phoenix Stellar Models" option from the dropdown that currently reads "Flat Continuum." Then select a stellar type from the dropdown below "Phoenix Stellar Models".
8. Click on the "Renorm" tab. Explore the many renormalization options. Ultimately, renormalize the target to 0.01 mJy at 1.3 microns. Click Save.

Exploratory Work
- A scene can contain multiple sources. Using the "Offset" parameter in the scene, determine the minimum unblended separation of a binary star for your chosen NIRCam imaging filter.

6. Target Acquisition
Read the content of the JDox Target Acquisition Page.

1. Now move back to the Calculations tab.
2. Create a NIRISS Target Acquisition calculation.
3. Click on the "Scene" tab. In the "Scene for Calculation" dropdown (left side), select your new scene and verify that your new source is shown in the "Sources in that Scene" dropdown. Note: that the remainder of this tab is identical to the Source Editor in the Scenes and Sources tab. Source properties can be changed in either location.
4. For target acquisition (TA) calculations, the Instrument Setup tab will provide options for which instrument mode you would like to use TA for. Choose one of the two NIRISS options.
5. Note the limited options on the Detector Setup tab by clicking on all the dropdowns. Most TA calculations have a limited number of options.
6. Note that NIRISS TA calculations with SNRs below 30 will present a warning, indicated by the orange exclamation point at the end of that calculation's row. You

can view the warning in the "Reports" pane by clicking the "Warnings" tab, which is written in red text. Note: MIRI and NIRSpec require a SNR of at least 20 for TA; NIRCam also requires a SNR of 30.

Exploratory Work.
- What is the faintest point source that will yield a "SOSS or AMI faint" target acquisition without a warning for NIRISS?

7. Uploading Spectra
Visit this JDox page.

1. Click on the "Upload Spectra" tab.
2. Click on the blue question mark icon to view the JDox page on the process of uploading spectra. Familiarize yourself with the proper format for spectra that can be uploaded to the ETC.
3. Now, return to the ETC and click on the "Choose File" button. Select the file provided with this homework. This file contains a model of the reflected and thermal components of Pluto's spectrum between 0.5 and 30 microns (without absorption features).
4. Click the "Upload" button. The ETC will present a dialog box asking you to confirm the units in the file. Note: when using a simple ASCII-format file, the ETC assumes that the input spectrum is formatted with columns in units of microns and mJy. Be careful when uploading your own spectra! When using a FITS table, you can specify the units in the file.
5. The file now shows up in the list with the name, minimum wavelength, and maximum wavelength. Note: Once a spectrum is uploaded, it cannot be removed. Additionally, you cannot download a spectrum from the ETC. Any uploaded spectra in a workbook you share with a collaborator will be available to that collaborator.
6. Create a new scene and a new source.
7. In the Source Editor, on the "Continuum" tab, you will see an option for "Uploaded File" under the "Spectral Energy Distribution" heading. Click this radio button and select "Pluto.txt" from the dropdown menu.
8. Move to the "Renorm" tab, scroll to the bottom, and select the "Do not renormalize" option. In many cases, an uploaded spectrum will already be properly normalized (in units of mJy)! Note: You can of course still renormalize an uploaded spectrum if you like.
9. Pluto is not quite a point source, so move to the "Shape" tab and select the "Extended" option.
10. Select the "Flat" "Flux distribution" from the dropdown menu and choose semi-major and semi-minor axes of 0.1" each. Leave the "Normalization choice" on "Integrated Flux."
11. In the "Select a Scene" pane, click the star next to the Pluto scene. This adds a purple star next to this scene and marks it as the new default scene. Note: This will

be the default scene when creating calculations. You can check this by clicking on the "Scene ★" tab in the Calculation Editor pane and looking at current selections in the "Scene for Calculation" and "Sources in that Scene" dropdowns.

Exploratory Work

- What if you knew that the surface brightness of Pluto at 3micron is 1000MJy/sr. How would you renormalize the spectrum to this value?

8. NIRSpec IFU, optimization and downloads

1. Create a NIRSpec IFU calculation. Look at the "Images" pane. Note the positive and negative source PSFs by hovering over the "2D SNR" image.
2. Select any "Grating/Filter Pair" on the Instrument Setup tab.
3. Move to the "Strategy" tab and change the strategy in the dropdown from "IFU Nod In Scene" to "IFU Nod Off Scene." Click Calculate.
4. After the calculation completes, examine the 2D SNR image again. Why might the "IFU Nod Off Scene" strategy be a better option for an extended source?
5. Now, optimize the calculation so that you obtain the highest SNR possible without saturating any pixels.
6. After optimization, move to the "Reports" pane and select the "Downloads" tab. Click on the tar file to download it. These data products can be used for offline analysis.
7. Explore the different products in the "cube" and "image" directories using ds9, or your favorite fits viewer. You can also explore the input.json file using a text editor. It contains the calculation input and gives an alternative way of recording or sharing calculations

Exploratory Work

- How can the "Groups Before Saturation" image help you quickly determine the optimal number of groups?
- How much exposure time is needed to observe Pluto with the NIRSpec IFU in high resolution at 2.7-5.2 micron with a minimum SNR of 20?

9. Sharing the Workbook
Watch this video tutorial to learn how to share a workbook with collaborators.