# ASTR 257 Project 5:
# Preparing an Observation with the *James Webb Space Telescope*

## Overview

The *James Webb Space Telescope* (JWST) will be humanity's premier space telescope during your years in graduate school, and I hope many of you will have the chance to use it. Cycle 2 and 3 programs are ongoing and Cycle 4 proposals will be due in October.

A telescope like JWST is designed to be used by all astronomers, even theorists. The Space Telescope Science Institute (STScI), which operates JWST, provides much more documentation, pre-processed data, and user support than exists for any other telescope so that the best scientific ideas are minimally limited by the technical challenges of planning observations and reducing data.

In this project, we will use STScI's Exposure Time Calculator (ETC) to plan a JWST observation of a cold brown dwarf. ETC simulations are a required step for preparing a JWST proposal. Your goal will be to design a maximally efficient observation that achieves a signal-to-noise of 70 per pixel at 4.55 μm in JWST's high-resolution spectroscopy mode. If this sounds strangely specific, this was what Andy's team simulated for a (rejected) Cycle 1 proposal to detect deuterium on a brown dwarf. See former UCSC grad student Caroline Morley's paper (https://arxiv.org/pdf/1810.04241.pdf) for a description of the science case.

## Learning Objectives:

- Students will learn to plan observations for space telescopes.
- Students will learn to present their observation plans in a standard written format that is appropriate for telescope proposals.

## Planning Your Observations

### *How Bright is My Object?*

The first step in simulating an observation is to develop a reasonable guess for the object's brightness. In this case, we'll use a theoretical model to simulate an observation of one of my favorite brown dwarfs, WISE 1541. Here is a grid of brown dwarf models:

https://zenodo.org/record/1309035#.XUBxnpNKiL8

Let's use the file sp_t350g100nc_m0.0, which is a brown dwarf with a temperature of 350 K (WISE 1541's temperature), a surface gravity of 100 m/s^2, no clouds and Solar metallicity. The file contains columns with wavelength and flux. Note that the website says the fluxes are "the emergent flux from the top of the atmosphere." To turn this into fluxes observed by JWST, you will need to multiply these spectra by $R^2/D^2$, where R is the radius of the brown dwarf (Jupiter's radius is a good guess) and D is the distance to the brown dwarf (5.7 pc for WISE 1541). After

you've done that calculation, you will need to save your result in a format that can be uploaded to the *JWST* ETC:

https://jwst-docs.stsci.edu/jwst-exposure-time-calculator-overview/jwst-etc-scenes-and-sources-page-overview/jwst-etc-user-supplied-spectra

### *What Instrument / Modes Should I Use?*

We would like a spectrum of WISE 1541 that covers 4.55 μm with as high of a spectral resolution as possible. What instrument should we use? What disperser should we use? What slit/aperture should we use?

A good place to start is the *JWST* pocket guide:

http://www.stsci.edu/files/live/sites/www/files/home/jwst/instrumentation/_documents/jwst-pocket-guide.pdf

You should be able to determine which instrument and which disperser to use from this. Determining the slit/aperture might take a little bit more digging. A more complete set of documentation is available here:

https://jwst-docs.stsci.edu/

I acknowledge that skimming through all of this material and getting up to speed on the jargon is taxing, but once you know your way around these tools and websites, it will be easy to plan JWST observations.

### *Using the JWST Exposure Time Calculator*

The JWST ETC is an online tool:

https://jwst.etc.stsci.edu/

I recommend using the QuickStart at first, which will guide you through designing your first observation. Eventually, it may be convenient to sign up for an account so that you can save and share your work.

You will upload your model spectrum to create a "Scene", choose the instrument properties in "Instrument Setup" and set integration times in "Detector Setup". You can ignore "Backgrounds" and "Strategy" for this assignment. "Backgrounds" only matters for longer wavelengths and "Strategy" is mostly useful if you're planning lots of observations. At any point while you're working on this, you can press "Calculate" and it will make a S/N plot at the bottom of the page.

Start by getting your spectrum uploaded and your instrument configuration(s) correct. The detector setup is a bit trickier. You want to increase your integration time until you get S/N=70 at 4.55 μm, but there are multiple ways of doing this and it's important to achieve your goal with as little telescope time as possible. The JDox website has a recommended strategies page:

https://jwst-docs.stsci.edu/jwst-recommended-observing-strategies

Follow the links and you will find flowcharts and other advice for an optimal detector setup. I'm not giving you the direct link because I want you to look around for a bit, but if you're stuck, just ask me.

## Writeup (To Be Completed After the Field Trip)

Every observing proposal (ground and space) has a science justification and a technical description. In the science justification, you would argue why you need to achieve a S/N=70 at 4.55 μm. In the technical description, you would describe how your observations will meet that goal.

Please write a short technical section describing and justifying your instrument setup and integration times. Reviewers will want to see that your proposed observations meet your science goals, and that they use the minimum amount of telescope time to do so.

Ordinarily, the conclusion of your technical section would say how many hours of telescope time you need to complete your program. For JWST, there's an additional tool called the Astronomer's Proposal Tool (APT) that converts your scripted observational plans into the number of hours your program needs:

http://www.stsci.edu/scientific-community/software/astronomers-proposal-tool-apt

We're going to skip the APT step for this project, since it's a lot of work and not particularly instructive. This means you'll leave out what I would ordinarily consider to be a mandatory sentence in your technical description, "We input these observations into the APT and calculate that the program will take ?? hours."