JWST Master Class 2020

Slit Spectroscopy hands-on

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Infrared spectroscopy of Y dwarfs

1. Introduction

The goal is to obtain spectroscopic observations of a Y dwarf across the entire JWST NIRSpec and MIRI LRS wavelength ranges to understand whether these atmospheres are shaped by chemical disequilibrium driven by vertical transport or the formation of water clouds, and constrain the object's gravity, hence mass.

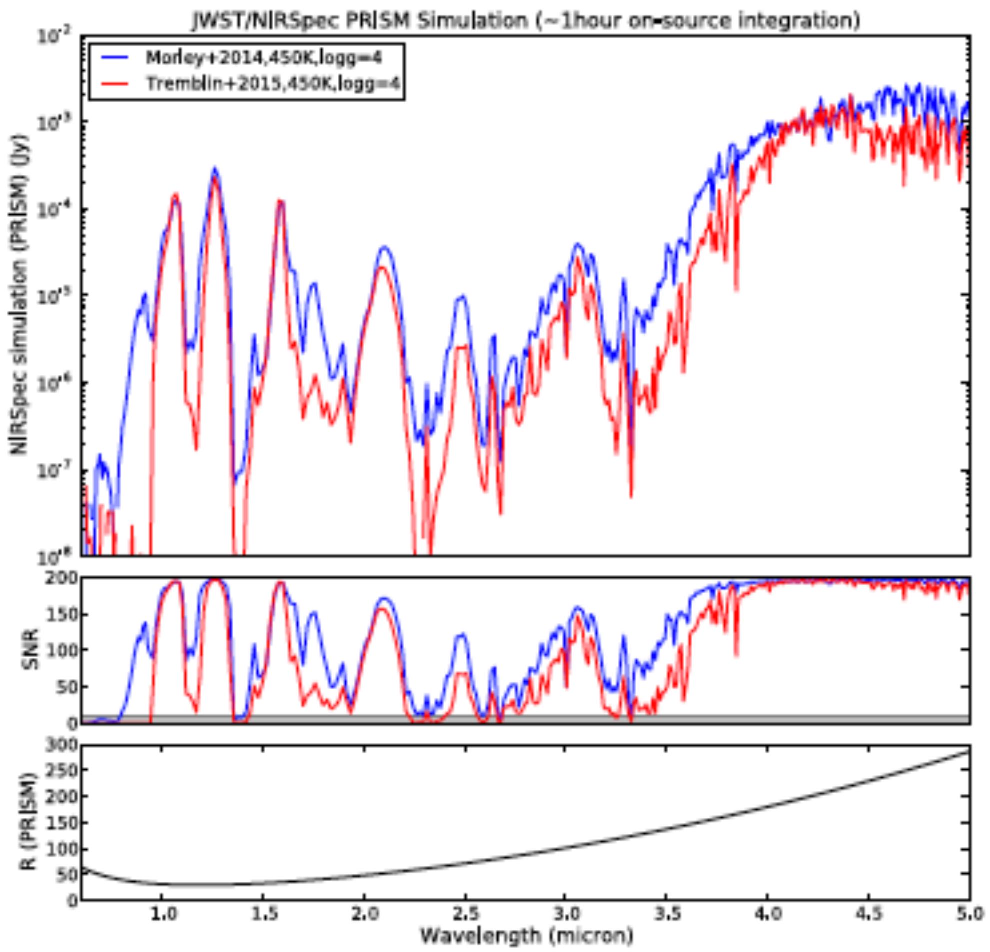

Figure 1 PRISM simulations of Y dwarf. Kirkpatrick et al. 2012 (discovery), Leggett et al. 2015, Leggett et al. 2017, Morley et al 2014 (model).

2. Methodology

We will design slit spectroscopy observations to compare high-quality NIRSpec spectra in low (from 0.6 to 5.3 μm) and medium (from 2.87 to 5.27 μm) resolution, to models of cool atmospheres at different temperatures, gravity, degrees of turbulence, chemical equilibrium or disequilibrium driven by vertical transport, and clouds (see Figure 1).
We will extend the study to MIRI LRS (5.0 to 12 μm) at low resolution.
Object type: Point-like source
Spectral configuration:

- NIRSpec/PRISM (0.6 to 5.3μm) and MIRI LRS (5.0 to 12 μm) data gives access to several diagnostics that can constrain models probing different:
    - temperatures
    - gravity
    - degrees of turbulence
    - in chemical equilibrium or with disequilibrium driven by vertical transport
    - water clouds coverage
- NIRSpec/G395M (2.87 to 5.27μm) data provides additional information in a region of the spectrum where the effect of water clouds is very pronounced and which contains the ammonia feature at 4.2 μm which is sensitive to temperature.

Detector configuration:

- NIRSpec: subarray, traditional readout mode
- MIRI LRS: FULL

Target acquisition:

- NIRSpec: Wide Aperture (WATA) with science object
- MIRI LRS: TA with science object

3. ETC

Goal

Hands-on creation of the ETC workbook for science and target acquisition for NIRSpec (MIRI LRS was demonstrated as part of the ETC hands-on).

Scenes and Sources

- Define a source using as target WISE J035000.32-565830.2
    - Name: WISE J035000.32-565830.2
    - Coordinates: RA=03:50:00.328 Dec=-56:58:30.23
    - Magnitudes (e.g.):
        - F140W= 22.30±0.20 mag (HST/WFC3)
        - W2=14.75±0.04 mag (WISE)
        - W3=12.33±0.28 mag (WISE)
    - Spectral type: Y1
    - Example model spectrum: morley_spec_ETC_noscale.txt, renormalized to the above measured F140W magnitude.
    - Shape: Point source
- Set up scene with the above defined point source

Calculations

1. NIRSpec Fixed-slit:

- Setup a representative background by using the target's coordinates and an example date for the observations derived using the target visibility tool to fall in the Cycle 1 window (2021-09-30 - 2022-09-30).
- Required SNR for science:
    - Extracted spectrum S/N>25 at ~1 μm using PRISM
    - Extracted spectrum S/N>100 at ~4.7 μm using G395M
- Derive N_{groups}, N_{ints} and N_{exp} necessary to achieve the above S/N. Choose an adequate detector readout pattern. Consider which nodding/dither pattern to use.

Hints:

- The N_{exp} defined in the ETC can be translated later as Number of dithers/exposures to be implemented in APT. The SNR given by the ETC assumes full redundancy in the exposures per pixel.
- For NIRSpec in general do not use integrations longer than ~3000 seconds, to avoid cosmic ray issues.
- Note that when setting up the detector with subarrays, the only readout patterns available are NRS and NRSRAPID (only traditional mode).

2. NIRSpec Target Acquisition:

- Set up ***WATA*** calculations in the instrument setup area
- Required SNR for Target acquisition:
    - Extracted spectrum SNR> 20 at the central wavelength of the selected filter.

Hints:

- NIRSpec TA Filters: F110W/F140X/CLEAR from narrower to wider bandpass.
- Use same readout pattern as science, not to be charged extra time

4. Aladin

- Use Aladin (or ESA Sky) to find the source of interest, and superimpose the JWST instrument footprints.
- Identify the science apertures (NIRSpec slit S200A1).

5. APT

Generate a JWST proposal using APT including NIRSpec and MIRI LRS observations using the ETC exposure times of the two NIRSpec and MIRI LRS workbooks, and the correspondent considered dither patterns.

- Target definition using the Fixed target resolver by position (SIMBAD):
    - Target name: WISE J035000.32-565830.2
    - Target coordinates: RA=03 50 00.328 Dec=-56 58 30.23
- Target category: Star
- Target description: Y dwarfs
- Target extended: NO

- APT Templates: NIRSpec fixed slit spectroscopy and MIRI low resolution spectroscopy
- Complete Target Acquisition pane using science object for both instruments

Hints:
In order to have both PRISM and G395M done in the same observation (only one target acquisition needed) the dither pattern in APT needs to be the same for PRISM and G395M.

Data Volume Considerations: Are the individual visits running into data volume issues? If so, what are the possible solutions?
Special Requirements: Do you need to impose some (scientifically justified) time constraint? For this case, we don't require PA constraints.
Aladdin Visualization: Use Aladdin to visualize instrument footprints/coverage/dithers. You can also play with the orientation.
Visit planner: Highlight the Observation folders and run the Visit Planner. Verify the schedulability of the program. Go to the visit planner menu and run smart accounting to remove potential unnecessary overheads.
Review the program: Do you have errors or warnings? If yes, are they expected? Can they be "fixed"?