Activity Worksheet

In this 2-hour Level 2 TSO project, you will work on a proposal to observe transit(s) of the habitable-zone exoplanet K2-18 b with JWST. The objective of the proposal is to confirm the water signature in its atmosphere that was observed by the Hubble Space Telescope (HST; Benneke et al., 2019, arXiv:1909.04642; Tsiaras et al., 2019, Nature Astronomy, Adv. Acc. Pub.) using data from 8 transits of this exoplanet.

1. *Target & Transit Observability*

   a) Your first task will be to know when the transits actually happen during JWST Cycle 1 (September 2021 to September 2022). Use Astroplan (https://astroplan.readthedocs.io/en/latest/tutorials/periodic.html) to figure out what transits happen during Cycle 1. The period of this exoplanet is P = 32.940038 days, the transit duration is t_{dur} = 0.14 days and the time-of-transit center is t_0 = 2457527.91121.

   b) From the homework solutions, you are most likely aware that JWST must remain shielded from the sun, which imposes observability constraints on the portions of the sky it can observe during the year (https://jwst-docs.stsci.edu/observatory-hardware/jwst-target-viewing-constraints). Using the JWST General Target visibility tool, find out when K2-18 is observable during Cycle 1 and cross-match those observability windows with the transits you found on part a). Are all transits observable? If not, which ones are?

   c) One important consideration to observe transiting exoplanets with slitless modes is that nearby stars can contaminate your spectra. Use the ExoCTK Contamination Calculator tool (https://exoctk.stsci.edu/contam_visibility --- note the tool only supports NIRISS SOSS in the meantime) to check what Position Angles (PA) are optimal to observe the target. Cross match this with what you found on b) to find out the best dates to observe the transits of K2-18 b. (Make note of the PA constraints --- you might need them for your APT proposal!)

2. *Simulating Transiting Exoplanet Observations*

   a) Use PandExo (https://exoctk.stsci.edu/pandexo/) and a model of K2-18 b's transmission spectrum that you can find in the activity package attached to this activity sheet (k218_model.txt) to simulate JWST transit observations for this exoplanet; let PandExo optimize the groups and integrations of the observations. Try the most promising JWST instrument modes shown in the webpage for the detection of any of the water features predicted for this exoplanet: I) what is the best instrument to use for this objective?, II) what is the exposure time of the integrations? Consider the recommendation that saturation happens

at 70% of the full well capacity for MIRI and 80% for NIRCam, NIRISS and NIRSpec (note: *this recommendation might change in the near future!*).

b) Using JWST's Exposure Time Calculator (ETC), model a frame using the setups recommended by PandExo for any of the modes you tried in a). Do the numbers reported by the tool (e.g., maximum electron count, exposure times, etc.) match the ones given by the JWST ETC tool? What happens if you use one or several fewer groups than the one recommended by it? What if you use one or more groups? Use the ETC to generate (and optimize) a Target Acquisition exposure.

c) So far we have focused on *spectroscopic* time-series observations of K2-18 b. However, MIRI and NIRCam offer time-series *imaging* (or combination of imaging + spectroscopic) modes that could be useful for our scientific case as well. I) Based on their wavelength ranges, which would be the best instrument to target the water features predicted by the HST observations? II) Using your response in I) and guided by the JWST Documentation, propose an observational idea to target any of the said water features with the selected instrument.

d) Check if your idea in d) is feasible using the JWST ETC. For this, model a frame using the instrument and mode(s) you selected as the best for the science case at hand, and calculate the approximate photometric precision per minute you would achieve with that mode. For this, write down the extracted flux F in electrons per second reported by the ETC and the standard deviation S reported in the same units by it: obtain the ratio S/F and multiply it by a million. This will give you the approximate photometric precision (in parts-per-million, ppm) *per second*. As a rule-of-thumb for giant exoplanets like K2-18 b orbiting main sequence stars such as K2-18, the transit depth error given a precision *per minute* is 1/10 this precision (e.g., if the precision per minute you calculated is 300 ppm, then the transit depth error will be approximately 300/10 = 30 ppm).

3. *The APT Challenge*

   In parts 1) and 2) you have managed to get all the information necessary to write a full TSO proposal for JWST, at least in terms of the instrumental setup and observability constraints.

   For this last activity, imagine the following situation: the deadline for JWST proposals is tomorrow, and a colleague of yours, knowing you attended the Master Class, sends you the APT file to perform observations of K2-18 b that you can find in the attached material (TSO_level2_MC19.aptx). Using the JWST Documentation's "Step-by-Step APT Guide for NIRISS SOSS Time-Series Observations of HAT-P-1", spot and correct **5 errors your colleague made in the APT file**. Consider only errors made in the "Observations" form and ***not*** on the "Proposal Information" form. Use the space below to write down what the errors were, why they are important and how did you fix them:

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