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## **JWST Master Class 2019**

### **Moving Target Module**

Space Telescope Science Institute  
San Martin Drive, Baltimore MD 21218

## **Moving Targets Level-2 Session: End-to-End Exercise**

In this exercise, you will plan observations of a solar system minor body (asteroid) that would allow its diameter and albedo to be determined. This can be accomplished by measuring its visual magnitude and thermal emission near the peak emission wavelength. Additional characterization of thermal properties can be obtained by also measuring the thermal emission shortward of the peak – extra credit if you can do that while not requiring additional observing time.

### **A. Moving Target Visibility Tool (MTVT)**

The MTVT calculates the visibility of potential targets (when they are within JWST's field of regard (FOR)). It comes packaged with the General Target Visibility Tool (GTVT) and is run from a *conda* environment that includes the *astroconda* and *astroquery* packages. It queries JPL/Horizons for target ephemerides and determines when the solar elongation angle of the target, as seen from JWST (using a best-guess pre-flight ephemeris), is between 85° and 135°. This tool can be used to determine the visibility of planets, satellites (regular and irregular), minor bodies, comets, and un-bound extra-solar objects (e.g., 'Oumuamua). In addition to information in the Ancillary Tools charts from the Master Class, and slides 7 – 12 in the Moving Targets charts, these links may be helpful:

- **JWST FOR:** <https://jwst-docs.stsci.edu/observatory-hardware/jwst-observatory-coordinate-system-and-field-of-regard>
- **JWST orbit:** <https://jwst-docs.stsci.edu/observatory-hardware/jwst-orbit>

- **GTVT:** <https://jwst-docs.stsci.edu/other-tools/target-visibility-tools/jwst-general-target-visibility-tool-help>
- **MTVT:** <https://jwst-docs.stsci.edu/other-tools/target-visibility-tools/jwst-moving-target-visibility-tool-help>
- **JPL/Horizons:** <https://ssd.jpl.nasa.gov/horizons.cgi>
- **Astroconda:** <https://astroconda.readthedocs.io/en/latest/>
- **Astroquery:** <https://astroquery.readthedocs.io/en/latest/>

***In this exercise, you will use the MTVT to determine the observability of a specific asteroid target.*** You will analyze and become familiar with the terminal and plot outputs of the MTVT. Information determined in this exercise will be used in later exercises with the ETC and APT.

1. Open a terminal and activate *conda*.
2. Run the MTVT for minor body 3041. (Typing `jwst_mvtv -h` will bring up optional arguments and usage information.)
3. Pick a date during Cycle 1 (c. Oct. 1, 2021 – Sept. 30, 2022) from the output in your terminal when the target is in the JWST FOR. Record this date and the start and end date of this observing window.
4. Convert the RA and DEC on that date to hh:mm:ss, dd:mm:ss format for use in the ETC section of this exercise. (Estimating is fine here; just compute hours, minutes for RA, degrees for DEC.)
5. Note the valid V3 Position Angle value for the date you chose above.

## **B. Exposure Time Calculator (ETC)**

After evaluating your target's observability from JWST with the MTVT, the next step is to determine the time required to achieve the desired signal-to-noise ratio (SNR) in the desired observing mode using the JWST ETC. Users can upload their own model spectra of a target, in flux or surface brightness units, but for this exercise we will approximate the spectrum using spectral models that are available within the ETC. In addition to the ETC overview charts from the Master Class, and slides 15 – 18 in the Moving Targets charts, these links may be helpful:

- **JWST ETC web application:** <https://jwst.etc.stsci.edu/>
- **JWST ETC documentation:** <https://jwst-docs.stsci.edu/jwst-exposure-time-calculator-overview>
- **Pandaia engine documentation:** <https://jwst-docs.stsci.edu/jwst-exposure-time-calculator-overview/jwst-etc-pandaia-engine-tutorial>
- **Moving targets in the ETC:** <https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-moving-target-observations/jwst-moving-targets-in-etc>

***In this exercise, you will use the ETC to determine the exposure parameters needed to achieve your desired SNR for a NIRCам and a MIRI observation of the target.*** Specifically, you will set up two sources that model the reflected and thermal components of the asteroid and determine the observation parameters for NIRCам SW Imaging and MIRI Imaging calculations. Information from the MTVT outputs in Section-A will be used.

1. Create and load a new JWST ETC workbook for this session.
2. Model the minor body with one point-source representing the reflected component and one point-source representing the thermal component. (Should the two point sources be offset from one another?) Assume the target has a Johnson V magnitude of 16.5 and a surface temperature of 200 K, normalized to 1 mJy at 10  $\mu\text{m}$ . Keep in mind that the reflected component is ultimately from the Sun, which is a G2V star.
3. Determine the approximate peak wavelength for the thermal component.
4. Create a NIRCам SW Imaging calculation to measure the reflected component near V-band, and a MIRI Imaging calculation to measure the thermal emission near its peak.
5. On the Backgrounds tab populate the fields based on the MTVT results.
6. Adjust the parameters (subarray, readout pattern, number of groups) on the Detector Setup tab for both calculations for 1 integration and 1 exposure, to achieve the longest integration possible while avoiding saturation and providing the largest FOV possible. (Remember the “Groups Before

Saturation” plot and the “Maximum Number of Groups Before Saturation” quantity in the Report.)

### **C. Astronomer’s Proposal Tool (APT)**

Now that you have determined your observation parameters for the target for both NIRCcam SW Imaging and MIRI imaging, you will have to transfer those values into an APT file. The APT includes “templates” for every instrument mode available for science and uses the same instrument and exposure parameters (filter, grating, subarray, readout pattern, groups, integrations, exposures, etc.) as in the ETC. However, some features, such as dithers and special requirements, are not available in the ETC. In addition to the APT overview charts from the Master Class plenary session, and slides 20 – 50 in the Moving Targets charts, these links may be helpful:

- **Moving targets in APT:** <https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-moving-target-observations/jwst-moving-targets-in-apt>
- **APT Solar System Target Windows:** <https://jwst-docs.stsci.edu/jppom/special-requirements/solar-system-special-requirements>
- **Visualizing Moving Target Observations:** <https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-moving-target-observations/jwst-moving-targets-in-apt/tutorial-on-visualizing-dither-of-a-solar-system-observation-in-apt>
- **APT Special Requirements:** <https://jwst-docs.stsci.edu/jwst-astronomers-proposal-tool-overview/apt-workflow-articles/apt-special-requirements>
- **ETC to APT interface:** <https://jwst-docs.stsci.edu/jwst-etc-to-apt-interface-support-information>
- **APT Visit Planner:** <https://jwst-docs.stsci.edu/jwst-astronomers-proposal-tool-overview/apt-workflow-articles/apt-visit-planner>
- **General APT documentation:** <https://jwst-docs.stsci.edu/jwst-astronomers-proposal-tool-overview>

***In this exercise, you will create a target specification for the asteroid in APT and design observations of it in the NIRCam and MIRI Imaging templates.***

Specification of moving targets in the APT is different from specification of fixed targets and there are some additional features that will be explored. You will then create NIRCam SW Imaging and MIRI Imaging observations of the asteroid using the relevant parameters from your ETC results in Section-B, specify Solar System Target Windows, and use the Visit Planner in APT to evaluate schedulability. Finally, you will implement constraints to allow subtraction of background sources in your observations (i.e. moving follow-on strategy).

1. Open APT and create a new JWST proposal.
2. Move to the Targets folder and create a new solar system target. Fill in the fields for minor body 3041.
3. Now create NIRCam and MIRI observations corresponding to the ETC calculations above.
4. For both observations, require that the target is less than 2.2 au from JWST.
5. Run the Visit Planner for both observations, including setting the Processing Date Range to focus on the Cycle-1 epoch.
6. Examine the Visit Planner results. Would you say these observations are overly constrained? Relax or remove the Distance constraint on the observations and run the visit planner again.

***Advanced Topics: Moving Follow-on & Visualization***

1. Duplicate the NIRCam observation you already created and remove the Distance constraint (if you haven't already). Using the results from the `jwst_mvt` run in step A.2, estimate the apparent rate of motion (arcsec/sec) of the target at the beginning and the end of your preferred observing window. Using the slower of those two rates, add a solar system target "New Angular Rate Observing Window" and a "Timing" → "After Observation Link" such that the target will move at least 2 arcseconds but no more than 10 arcseconds between the 2 observations.
2. Create a new fixed target for the open cluster M35, select it as the target for your NIRCam observation, and view it in Aladin. Add a "Position Angle" →

“PA Range” special requirement to constrain the V3 position angle to be the range indicated in your MTVT results. Note how the Aladin display changes. In Aladin, change the Frame for the display to “Ecliptic” and overplot the coordinate grid. Make sure that the subarray and the dither pattern you have selected don’t put the target into a gap between the SW detectors. If that happens, adjust the observation such that the target is on one SW detector for all dither positions.