

Target Acquisition for Time-Series Observations

Target acquisition (TA) for JWST time-series observations may be necessary for observations taken at different epochs that require repeated target placement at sub-pixel accuracy.

Introduction

Target Acquisition (TA) may be important for TSOs if multiple observations taken at different epochs are to be combined to increase signal to noise. When studying exoplanet atmospheres, faint signals may be detected by combining observations of multiple transits. In these cases, the ability to place the target at the exact same location with sub-pixel accuracy may help with subsequent calibration and analysis of the data.

Astronomers Proposal Tool

Main article: [APT Target Acquisition](#)

See also: [JWST Astronomers Proposal Tool Overview](#)

The [Astronomers Proposal Tool](#), is a GUI-based software package proposers use to write, validate, and submit proposals for the James Webb Space Telescope. It allows users to both enter information necessary for their proposal, including target acquisition, and gather information about the absolute time usage and data volume usage. APT also includes many useful features for planning observations and placing the FOV on the sky. It is required to submit your proposals through the canonical proposal system. Moreover, full observational constraints (what HST refers to as `Phase 2`) are required for JWST submissions. Use of the ETC (Pandeia) or PandExo (Pandeia for Exoplanets) is strongly recommended to develop JWST proposals.

Exposure Time Calculator

Main article: [JWST ETC Target Acquisition](#)

See also: [JWST Exposure Time Calculator Overview](#)

The [Exposure Time Calculator Old](#) is a pixel-based ETC paired with a modern graphical user interface. It supports all JWST observing modes: imaging, spectroscopy (slitted, slitless, and IFU), coronagraphy, aperture masking interferometry, and target acquisition calculations for all relevant instrument modes. For time series observations of transiting exoplanets, the PandExo simulation tool provides dedicated ETC functionality built on top of the Pandeia ETC engine. It takes stellar and planetary modeled spectra as input, and produces the optimal groups and integration settings for the required mode and SNR (as well as a range of predicted model outputs). For calculations of the science exposures, we therefore recommend the use of PandExo. See also the [Preparing Time-Series Observations with JWST](#) article.

Many TSOs will however require target acquisition to place the target in a particular aperture with sub-pixel accuracy. TA exposure parameters must also be specified by the user in the APT template. The ETC provides dedicated calculation options for TA with settings consistent with the APT templates and instrument requirements. Failed target acquisition can result in aborted observations or a wrong pointing location. We strongly recommend that TA exposures are calculated using this functionality in the ETC.

We refer to dedicated documentation pages on [JWST ETC Target Acquisition](#), [JWST ETC NIRCам Target Acquisition](#), [JWST ETC NIRISS Target Acquisition](#), [JWST ETC NIRSpec Target Acquisition](#) and [JWST ETC MIRI Target Acquisition](#) for instructions on these calculations.

Several Use Cases have been written to show how to use APT, ETC, and PandExo. They give precise examples, with values, to teach users how to develop the exposure settings for a given Time-Series Observation (TSO) proposal. All of the Step-by-Step guides for ETC (Pandeia) include examples for how to estimate the Target Acquisition saturation limits and sensitivity limits. The ETC Step-by-Step pages include the necessary information to compute the SNR (and saturation limits) for target acquisition with each instrument.

- [NIRISS SOSS Time-Series Observations of HAT-P-1](#)
 - [Step-by-step APT NIRISS SOSS Use Case](#)
 - [Step-by-Step ETC Guide for NIRISS SOSS Time-Series Observations of HAT-P-1](#)
 - [Step-by-Step PandExo Guide for NIRISS SOSS Time-Series Observations of HAT-P-1](#)
- [NIRCам Grism Time-Series Observations of GJ 436b](#)
 - [Step-by-Step APT Guide for NIRCам Grism Time-Series Science Use Case](#)
 - [Step-by-Step ETC Guide for NIRCам Grism Time Series Science Use Case](#)
 - [Step-by-Step PandExo Guide for NIRCам Grism Time Series Science Use Case](#)
- [NIRCам Time-Series Imaging of HAT-P-18 b](#)
 - [Step-by-Step APT Guide for NIRCам Time Series Imaging Science Use Case](#)
 - [Step-by-Step ETC Guide for NIRCам Time Series Imaging Science Use Case](#)
- [NIRSpec BOTS Observations of GJ 1214b](#)
 - [APT Step-by-Step Instructions for Gliese 1214b](#)
 - [ETC Step-by-Step Instructions for Gliese 1214b](#)

Target Acquisition Algorithm

1. The observatory will slew to place the target acquisition source onto target acquisition position, located within a relevant "region of interest" (ROI) on the detector.
2. One to Three exposures – with one integration per exposure -- of the sky are taken. The instrument team decided how many exposures; this option is not available to the user.
 - a. If more than one exposure is taken, then the individual images are offset from one another using small integer pixel offsets in both X and Y to allow for removal of bad pixels via dithering.
3. The on-board TA software processes the images as needed (to realign the images, flag bad pixels, remove cosmic rays, and subtract the background level), and applies a centroiding algorithm to determine the target coordinates.
 - a. To locate the target, the on-board software first passes a square *checkbox* of pixels (the size of which was set by the instrument teams) over the TA image and determines the intensity contained within the checkbox at each pixel in the ROI.
 - b. The software then selects the checkbox with the maximum intensity and estimates the flux-weighted centroid of the brightest object in the frame, using a pixel window (the size of which was set by the instrument teams) centered on that checkbox.
 - i. If there is a brighter object in the target acquisition ROI, the algorithm with center on the brighter object.
 - c. This is discussed in more detail in the Target Acquisition links above
4. The spacecraft is then moved to place the target at the nominal center of the TA subarray being used, which is listed in on-board tables.
5. Some instruments (i.e. NIRISS, MIRI slitless LRS) have chosen to re-image the acquisition target with a single (undithered) exposure. This is a so-called "TA verification" exposure.
 - a. If a "TA verification exposure" was taken, then this exposure will be available to the user upon downloading the full observational data set.

Instrument-specific information

Each JWST Instrument Operations Team has chosen parameters for target acquisition that work best for their instrument. In particular, each instrument has its own brightness limits, sensitivities, region of interest on the detector, and other parameters for target acquisition. These parameters can be found on the instrument-specific target acquisition pages:

- [NIRISS Target Acquisition](#)
- [NIRCam Grism Time-Series Target Acquisition](#)
- [NIRCam Time-Series Imaging Target Acquisition](#)
- [NIRSpec Wide Aperture Target Acquisition](#)
- [MIRI LRS Slitless Target Acquisition](#)

Here is limited summary table for important information. See Instrument-specific links above for full information:

Instrument	Filter + Pupil	Brightness Limit	Region of Interest	Comments
NIRISS	F480M + Clear	K = 8.1 (Vega) (SOSSFAINT)	4".18 × 4".18 (64×64 pix)	Acquiring a target on saturated pixels has been tested
	F480M + NRAM	K = 3 (Vega) (SOSSBRIGHT)	4".18 × 4".18 (64×64 pix)	Uses Non-redundant aperture mask to acquire on bright targets (SOSS-BRIGHT)
NIRCam	F335M	K = 7.2 (Vega)	2".09 × 2".09 (32×32 pix)	Acquiring a target on saturated pixels has been tested
NIRSpec	F170LP	J = 10.2 (Vega)	1".60 × 1".60 (16×16 pix)	Acquiring a target on saturated pixels has been tested
MIRI	F560W	K = 7.5 (Vega) (120 mJy @ 5.6 μm)	7".04 × 7".04 (64×64 pix)	Limits computed for NGROUPs=3 with G2V template
	F1000W	K = 5.6 (Vega) (225 mJy @ 10 μm)	7".04 × 7".04 (64×64 pix)	Limits computed for NGROUPs=3 with G2V template
	F1500W	K = 3.9 (Vega) (510 mJy @ 15 μm)	7".04 × 7".04 (64×64 pix)	Limits computed for NGROUPs=3 with G2V template
	FND (a neutral density filter)	K ~ 0.0 (Vega) (~40 Jy @ 10 μm)	7".04 × 7".04 (64×64 pix)	Limits computed for NGROUPs=3 with G2V template

Offset target acquisition

In the event that the science target saturates the target acquisition subarray, here are two options for acquiring on a saturated target:

1. NIRISS, NIRCam, and NIRSpec have tested the viability of acquiring a target on a saturated target. Although results vary, it is expected that JWST will be able to acquire a target (radial centroid error < 0.1 pixels) with up to 4 saturated pixels. Note that a radial centroid error < 0.15 pixels is the engineering requirement. NIRCam has shown that it is possible to acquire a target with 8 saturated pixels to a radial centroid error < 1.0 pixels.

- a. MIRI is able to use a neutral density filter for target acquisition, and is thus expected to acquire almost any target (including Vega) without saturating.
 - b. NIRISS TA saturates at lower magnitude (brighter objects) than NIRISS-SOSS, because NIRISS TA can use the NRAM to reduce flux.
2. JWST can acquire a target on a nearby, fainter source and slew between the offset source and the science source. The radial centroid error for acquisition on the offset source will be <0.15 pixels (engineering requirement); but the uncertainty in the relative positions of the offset and science targets could also be >0.1 pixels. Resulting pointing uncertainty could then be greater than 0.1 pixels total. It is expected that a suitable (known and moderately bright) offset target within 20 arcsecs would result in a pointing uncertainty of <0.1 pixels. Outside of 30", the pointing increases significantly

It is highly recommended that the proposer read the target acquisition pages, and follow the guidelines in the APT template pages, for the instruments that are relevant to the proposal.

References

[Batalha, N. E. et al., 2017](#)

PandExo: A Community Tool for Transiting Exoplanet Science with JWST & HST