NIRCam Time-Series Imaging Target Acquisition

JWST NIRCam Target Acquisition (TA) positions the source with sub-pixel accuracy on a specific part of the detector. A TA is required for all NIRCam Time-Series observations.

Introduction

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Observations in NIRCam's time-series imaging mode require a target acquisition (TA) to precisely place the target at specific pixels. Precise positioning is required in order to achieve the highest possible calibration stability and enable enhanced flat field determination.

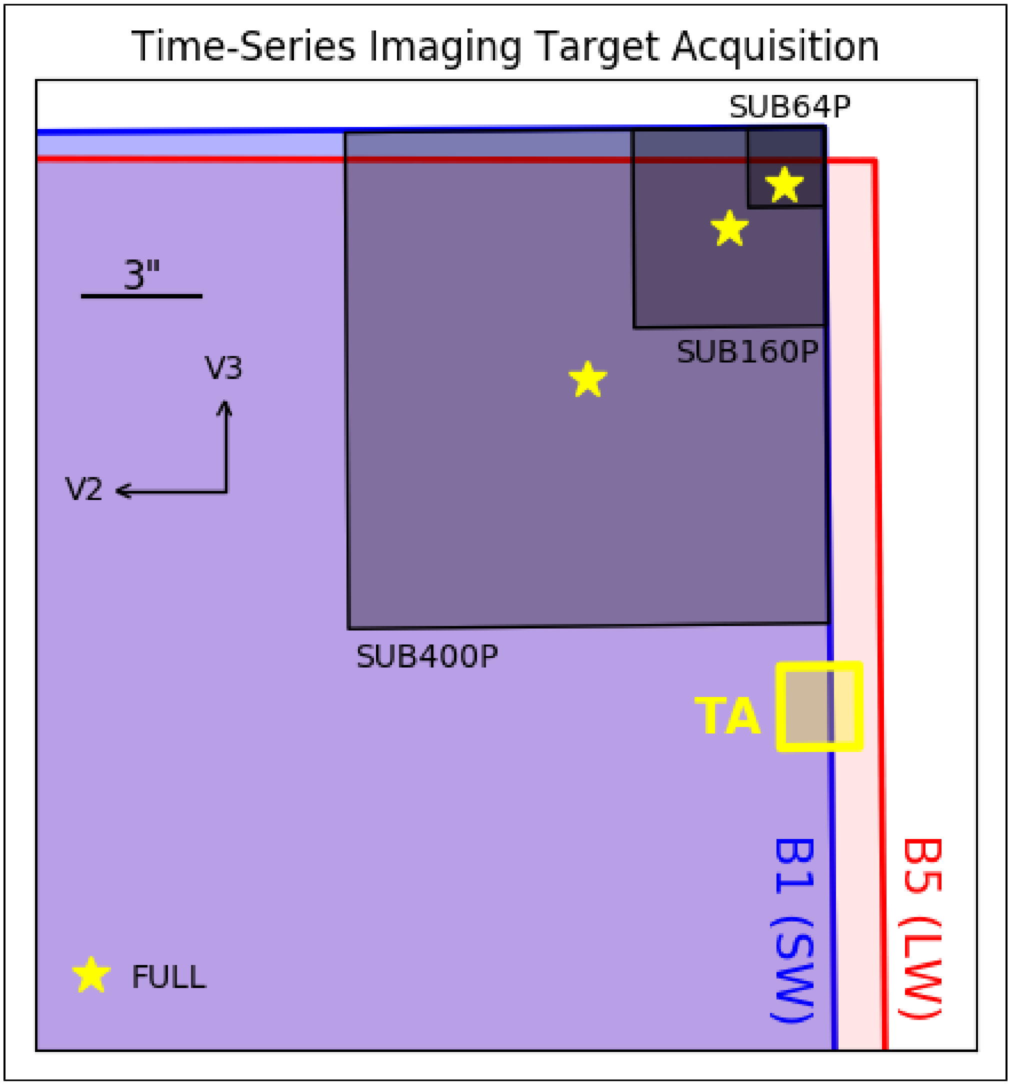
This is particularly critical for the data from the long wavelength (LW) channel, because the in-focus images there will be concentrated on just a few pixels. Time-series observations will often use the WLP8 weak lens element in the short wavelength (SW) channel to defocus the light of a bright source, improving the saturation limit and photometric precision. TA precisely positions the target so that most/all of the defocused light is on the detector and/or within a selected subarray. The diameter of the defocused SW image for WLP8 is approximately 132 pixels.

Time-series imaging uses one SW detector and the LW detector in module B. In addition to the ***FULL*** [1] array, users can select the point source subarrays located at the upper right of the module: ***SUB64P***, ***SUB160P***, or ***SUB400P*** (Figure 1). These subarray locations were selected to minimize the number of bad pixels on the detectors and to include reference pixels along two edges of the subarrays. The TA subarray is a 32 × 32 pixel subarray on the LW detector, located near the point source subarrays. The center of the TA subarray is offset from the other subarrays to avoid saturating the pixels used for science observations. All TAs are performed using the F335M filter for operational simplicity, and because it offers a good combination of sensitivity and saturation limits (see below). The TA procedure is as follows:

- The telescope slews to place the target in the TA subarray.
- One TA exposure is taken with the F335M filter.
- The on-board TA software processes the image as needed (to realign the image, flag bad pixels, remove cosmic rays, and subtract the background level), and applies a centroiding algorithm to determine the target coordinates.
- A small slew then moves the target to the nominal center of the TA subarray.
- A larger slew is then executed to precisely position the target at the science position on the detector.

Data from the TA exposure will be delivered to observers along with that from subsequent science exposures.

Figure 1. Target acquisition for time-series imaging



Target acquisition is performed with a 32 × 32 pixel subarray (yellow square) on the long wavelength detector B5, near the point source subarrays. The target acquisition pointing is centered on the TA subarray, followed by a telescope slew to one of the yellow stars at the center of the SW subarray for the science exposures. For simplicity, only the SW subarrays are shown here. For information on the location of the LW subarrays, see the NIRCam Detector Subarrays article.

[1] ***Bold italics*** font style is used to indicate parameters, parameter values, and/or special requirements that are set in the APT GUI.

Target acquisition saturation and sensitivity limits

See also: NIRCam Bright Source Limits

The TA subarray frame time is 0.015 s. It is recommended that users choose a TA exposure time that achieves a total integrated signal-to-noise ratio (SNR) of >30, which enables a centroid accuracy of <0.15 pixel. Any readout pattern is available for TA, with N_{groups} = 3, 5, 9, 17, 33, or 65. The saturation and sensitivity limits for the TA subarray are summarized in Table 1. Sensitivity assumes SNR ~ 30 with N_{groups} = 65. Saturation limits are derived for N_{groups} = 3. All calculations use the F335M filter. Users should use the Exposure Time Calculator (ETC) to estimate saturation and sensitivity for their targets.

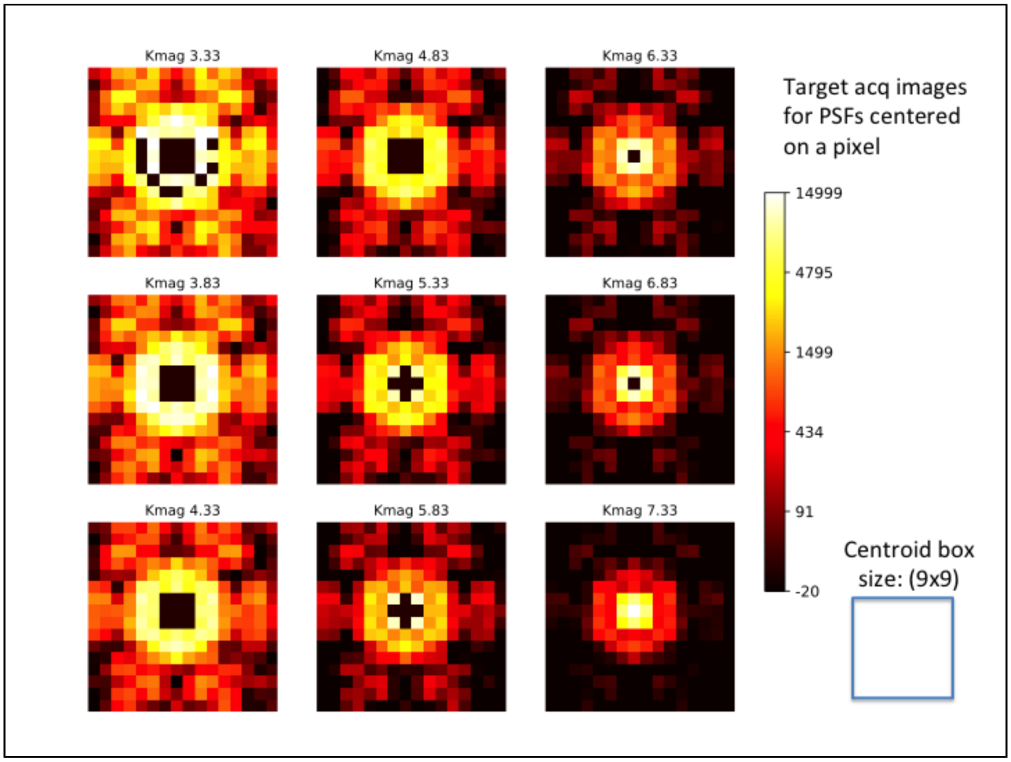
Table 1. Bright source saturation limits and sensitivity for the TSO target acquisition sub-array (*SUB32*)

Readout Pattern	Saturation (Vega Mags) K_{sat} (G2V)	Sensitivity (Vega Mags) K_{sat} (G2V)
RAPID [1]	7.20	14.57
BRIGHT1	7.75	15.32
BRIGHT2	7.95	15.65
SHALLOW2	8.70	15.64
SHALLOW4	8.87	16.95
MEDIUM2	9.36	17.39
MEDIUM8	9.62	17.98
DEEP2	10.06	18.14
DEEP8	10.21	18.71

[1] ***Bold italics*** font style is used to indicate parameters, parameter values, and/or special requirements that are set in the APT GUI.

TA centroid accuracy is a function of the source brightness as well as the location of the source within a pixel. Pixels that saturate prior to the second group of the three that are used to create the target location algorithm input image will appear with little or no signal, as seen in Figure 2. This will negatively impact the centroiding results of the algorithm.

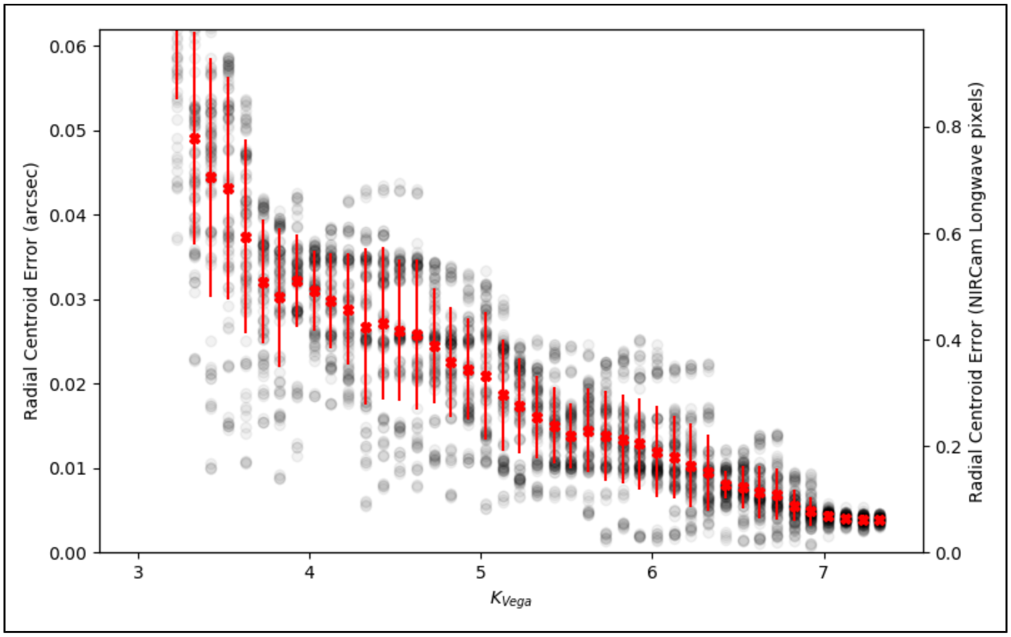
Figure 2. TA images



These TA images were produced from sources with K band magnitudes of 3.33 to 7.33. Pixels that saturate prior to or during the second group used to create the TA image will contain no signal (modulo noise) and appear dark in the images. In this case, no more signal can accumulate between the second and third groups, leading to a group 3 and group 2 difference close to zero. This value then propagates into the final TA image. The blue box to the lower right shows the 9 × 9 pixel box used in the centroid calculations.

Figure 3 shows the centroiding accuracy of the target location algorithm versus the K band Vega Magnitude of a G2V source. These calculations were performed using a dataset of simulated point sources located within a grid of subpixel locations and with several Poisson noise realizations at each location. The gray points show the accuracy of the calculated centroid compared for all observations. The red points and error bars show the mean accuracy and standard deviation at each magnitude.

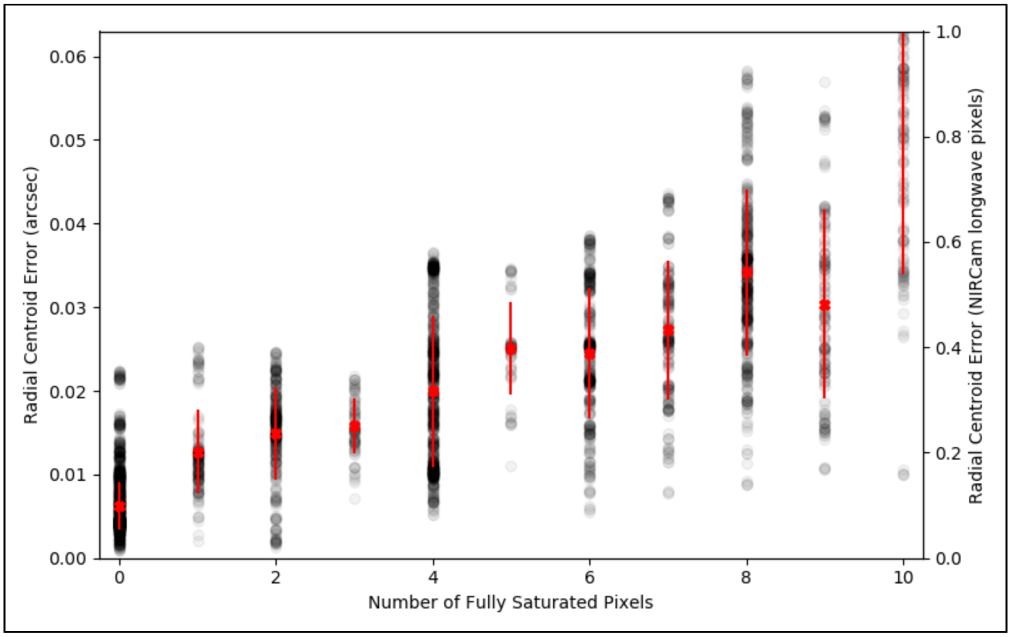
Figure 3. Centroiding error versus source brightness



Accuracy of the target location algorithm results for NIRCam time-series and grism time-series observations versus the K band Vega magnitude of a G2V source. The accuracy is calculated for a grid of subpixel locations and Poisson noise realizations. Individual results are shown as gray points. Red points and error bars show the mean and standard deviation over all pixel phases and noise realizations at each magnitude.

Figure 4 shows the centroiding accuracy versus the number of fully saturated pixels in the scene. These are pixels that are saturated in all three of the groups used to create the TA image. The ETC also uses this definition when reporting the number of pixels that have reached "full saturation".

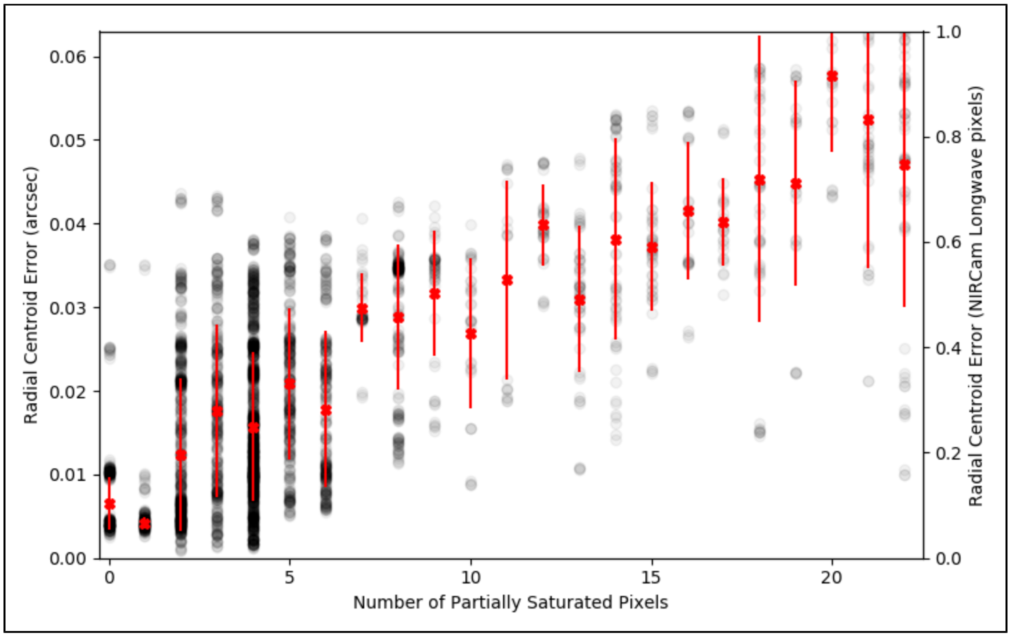
Figure 4. Centroiding error versus the number of fully saturated pixels.



The number of pixels on the X axis is equivalent to the number of fully saturated pixels reported by the ETC. The red x's and error bars show the mean and standard deviation of the centroiding error.

Figure 5 shows the centroiding accuracy plotted against the number of pixels that saturate in groups 2 or 3 of the 3 groups used to produce the TA image. This is equivalent to the number of "partially saturated" pixels reported by the ETC.

Figure 5. Centroiding error versus the number of partially saturated pixels.



The number of pixels on the X axis is equivalent to the number of partially saturated pixels reported by the ETC. The red x's and error bars show the mean and standard deviation of the centroiding error. Note that fully saturated pixels begin to occur at limits described on the ETC NIRCam Target Acquisition article.