⋒ JWST/NIRSpec

NIRSpec Target Acquisition

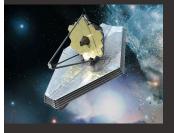
Overview of NIRSpec
Major Functional Elements

NIRSpec Target Acquisition

Target Acquisition Process
Reference Stars

NIRSpec MSA Planning Tool

Preparing NIRSpec Observations NIRSpec Science Operations NIRSpec Engineering Operations





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Preparing NIRSpec Observations

JWST NIRSpec Observations of the Hubble Ultra Deep Field:

An Analysis of Target Acquisition in the "Emptiest" Deep Field

Introduction

NIRSpec is the Near-Infrared Spectrograph for the James Webb Space Telescope. Designed and built by the European Space Agency (ESA), NIRSpec is a multi-object spectrograph that will enable observations of up to 100 astronomical sources simultaneously. It has a large (see Figure 1) field of view (3' X 3') and is highly sensitive over its wevelength range (0.6–5 μm .)

The NIRSpec focal plane assembly contains two closely butted sensor chip arrays (SCA) of 2048 x 2048 pixels. The Micro Shutter Array (MSA) consists of a 2 X 2 mosaic of quadrants. Each quadrant has 365 shutters along the dispersion axis and 171 shutters along the spatial axis.

NIRSpec Target Acquisition

The NIRSpec target acquisition (TA) algorithm uses 8–20 reference stars observed through the MSA to precisely position the science targets within the micro-shutters. The NIRSpec TA process (Figure 1) observes the reference stars through the MSA in one exposure, then offsets the telescope by an average ½ shutter pitch in x and y and takes another exposure to mitigate the effects of the micro-shutter grid. Centroids are calculated on-board the JWST spacecraft for each observed star in both exposures. An algorithm is used to calculate the best slew and orient correction to precisely align the science sources in their planned MSA shutters.

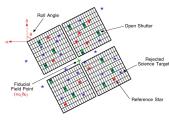


Figure 1: Schematic view of the MSA layout, with target a cquisition reference stars shown in red, and science targets (blue) shown in their open most observed because they lie in the same row as other sources (spectral overlap) or because their thinks of the source shows of the sources of

NIRSpec TA Uncertainties:

This TA procedure imposes strict requirements on the relative astrometry between the reference stars and the science targets. The post-TA uncertainty on science source positioning depends on the input astrometric catalog accuracy $A_{\rm Ast}$ and the number of stars or point-like sources available to use as TA reference, $N_{\rm tars}$. The TA uncertainty is estimated as:

Post TA Uncertainty on science target positions (in milli arcseconds) = $sqrt[(A_{sst}^2+104.0) + (sqrt((647.5+A_{sst}^2))/(sqrt(N_{stars}))^2+62.0)+75.0]$ $A_{Ast} = Catalog \ Astrometric \ Accuracy, \ N_{stars} = \# \ of \ Available \ Reference \ Stars$

5mas catalog accuracy with Nstars > 8 will yield science target placement accuracy of 20 mas ($1/10^{\rm m}$ of a shutter width) or better. Positions with less than Nstars = 3 can not be planned because of poor accuracy (especially on orient correction). These accuracy numbers assume S/N > 20 is reached on reference stars in the TA images. The NiRSpec TA Concept and uncertainties were defined by Peter Jakobsen in 2005.

NIRSpec Estimated TA Exposure Sensitivity

The NIRSpec target acquisition concept requires that reference stars be detected in the set up exposures with a Signal to Noise of 20 or higher. The NIRSpec instrument filter and readout pattern (exposure time) defines the sensitivity in these exposures.

NIRSpec target acquisition exposures are acquired with one of three filters in the instrument: F110W, F140X or the CLEAR filter. The F110W is well matched in central wavelength and throughput profile to the JWST NIRCam instrument's F115W filter. For bright sources, using the NIRSpec filter along with astrometric reference positions derived from NIRCam pre-images will result in optimal TA accuracy. The NIRSpec F140X filter has a broader profile and is useful for fainter objects. The CLEAR filter covers the 1-5µm window and can be used for target acquisition on very faint reference sources. There are presently two* NIRSpec detector readout modes that define exposure time that will be used for target acquisition. NRSRAPID is a short exposure time, ~10.6 seconds, and NRS is four groups of NRSRAPID frames, ~42.4 seconds. In both the NRS and NRSRAPID readouts, three reads are acquired and compared to reject cosmic rays in the TA exposures. Defined in the below table are the TA exposure sensitivities (AB Mag) grouped by Filter and Readout Pattern from the saturation limit to S/N =20.

	F110W	F140X	CLEAR
NRS*	17.7 – 22.0 (ABMag)	18.8 – 23.1	19.6 – 24.0
NRSRAPID	19 2 - 24 1	20 3 = 25 1	21 1 = 25 7

Table 1: Target acquisition reference star sensitivities in AB Magnitudes from the saturation limit to S/N o 20 for each Filter/ Readout Pattern combination. * - A new readout pattern is proposed but not ye implemented that will get near to NRS sensitivity but in shorter exposure overhead time.

NIRSpec •

The Near-Infrared Spectrograph (NIRSpec) aboard the James Webb Space Telescope (JWST) will excel at deep spectroscopic observations of the faintest objects in the universe. The multi-object mode using the Micro-shutter Arrays (MSAs) increases multiplexing to acquire up to hundreds of simultaneous spectra of high redshift galaxies. The Hubble Space Telescope's Ultra-Deep Field (HST UDF) provides a foundation for analyzing and simulating deep observation cases with the NIRSpec MSAs. The target acquisition method for NIRSpec MSA observations uses sets of reference stars to align the MSA shutters with exquisite accuracy on faint galaxies. However, the HST UDF field was selected because it has a dearth of available bright stars that would be optimal for field acquisition. This poster presents application of the MSA target

Analyzing the Hubble UDF for TA Sources

NIRSpec.

NIRSpec Target Acquisition is optimally designed to work on stars. In the Hubble Ultra-Deep Field, stars are sparse. Figure 2 shows an analysis of the number of available stars vs. magnitude bins within the UDF catalog. Bright (AB mag <24) sources with stellarity profiles of 0.9 or greater are very rare. Expanding TA source criteria to 0.7 Stellarity does not gain many potential reference objects. In total, there are only ~20 sources with Stellarity > 0.7 and AB mag brighter than 25!

acquisition method to the emptiest deep field and some strategies that can be adopted to accurately acquire the ultra-deep spectroscopy with

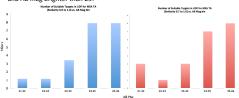


Figure 2: Histogram plots of the number of available reference stars in 1 magnitude bins from AB Mag = 21 – 22 to AB mag = 25 – 26. There are only three stars in the catalog with AB mag < 20.0. The left plot presents stars / compact objects (stellarity > 0.9) and the right plot shows sources with Schlading of the Characteristic Stars of the Stars of the

Tests on the UDF using the MSA planning tool

The Astronomer's Proposal Tool (APT) is the primary software tool used by general observers to select astronomical objects of interest for a given exposure. The MSA Planning Tool (MPT) is a NIRSpec component within APT that is used to plan NIRSpec MSA mode science. The MPT can display an image of the MSAS with shutter state information and potential targets over-plotted. The NIRSpec MSA quadrants have many failed closed shutters, and our studies have shown that planning target acquisition reference stars away from failed closed shutters is very important.

Figures 3 and 4 present some test cases of multiple pointings found using the MSA Planning Tool with target acquisition reference catalogs as input. In this case, the plans were made to specifically place as many of the TA reference objects into the MSA quadrants as possible. The candidate reference objects are relatively well distributed throughout spatial area covered by the UDF catalogs.

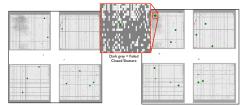


Figure 3: Two MSA pointings on the Hubble UDF Field with potential reference stars shown as green circles. In the Left case, the Stellarity O9 criteria was used for sources brighter than 25° A8 magnitude. To the right, the same analysis is done at a different pointing and with stellarity > 0.7. At most, 5-8 Reference stars are found within the magnitude bins described in Table 1. The zoomed view to the upper right for Pointing 2 shows a candidate reference star that must be rejected because of a high probability of centroiding problems caused by failed closed shutters.

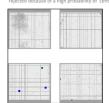


Figure 4: This figure shows a pointing on the outskirts of the UDF catalog field that has only three potential reference stars within the one of the MSA quadrant regions. Of these three stars, at most two are available in the magnitude sensitivity bins shown in Table 1. This possible pointing within a UDF observing plan where NIRSpec standard Target acquisition might not be successful. Expanding the Stellarity criteria to more restended sources might make TA possible, but here extended sources might make TA possible, but here scheded sources. Acquiring a deep NIRCam imaget accuracy in the final placement of science sources. Acquiring a deep NIRCam image to protect the control of the science sources. Acquiring a deep NIRCam image potential TA reference objects in the outer pointings.

NIRSpec TA in the UDF

We carried out an analysis of the availability of NIRSpec reference objects for Target Acquisition in Hubble Ultra Deep Field, which is notably "empty" of stars. Our key findings were:

- → Many pointings in the central region of the Hubble Ultra Deep Field can find suitable reference objects (to ABMag~25) for Target Acquisition.
- → Only a few candidate TA reference objects are gained by relaxing catalog Stellarity criteria. But every added source should improve TA results.
- → The number of reference stars at a given pointing is typically on the order of 5-8. Uncertainty on placement of science sources should be in the 20-25mas range (or better) if catalog astrometric accuracy is 5mas.
- → Pointing positions on the outskirts of the Hubble UDF have few TA reference objects. Expanding the available catalogs or relaxing Stellarity criteria to very extended objects might be necessary to execute quality target acquisition.