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Preparing NIRSpec Observations

NIRSpec Pre-imaging

Using archival HST/ACS/WFC3 and JWST/NIRCam simulated data

Abstract

Most observations with NIRSpec Spectroscopy will require high spatial resolution images of the science field previous to performing the spectroscopy.

This is due to the fact that the standard NIRSpec target acquisition needs to acquire reference stars to deliver a position RMS of less than 20mas. NIRSpec TA uses 8-20 reference stars with accurate astrometry (< 5 mas), calculates pixel centroids of the stars, transforms their pixel coordinate positions to the ideal sky frame and calculates the slew to accurately place the science targets in the MSA shutters.

For some planned observations, very high spatial resolution HST images might be already available, and in other cases NIRCam observations will be performed.

For a planned NIRSpec observation, we describe in detail the proposed method to generate a high resolution image mosaic to plan NIRSpec spectroscopy. We show the results of an example using existing HST/ACS observations. We also describe the proposed procedure using simulated NIRCam images for derivation of source catalogs. Rapid availability of these two NIRCam data products will be crucial for the success of many NIRSpec observations.

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 (3ʹ X 3ʹ) and is highly sensitive over its wavelength 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.

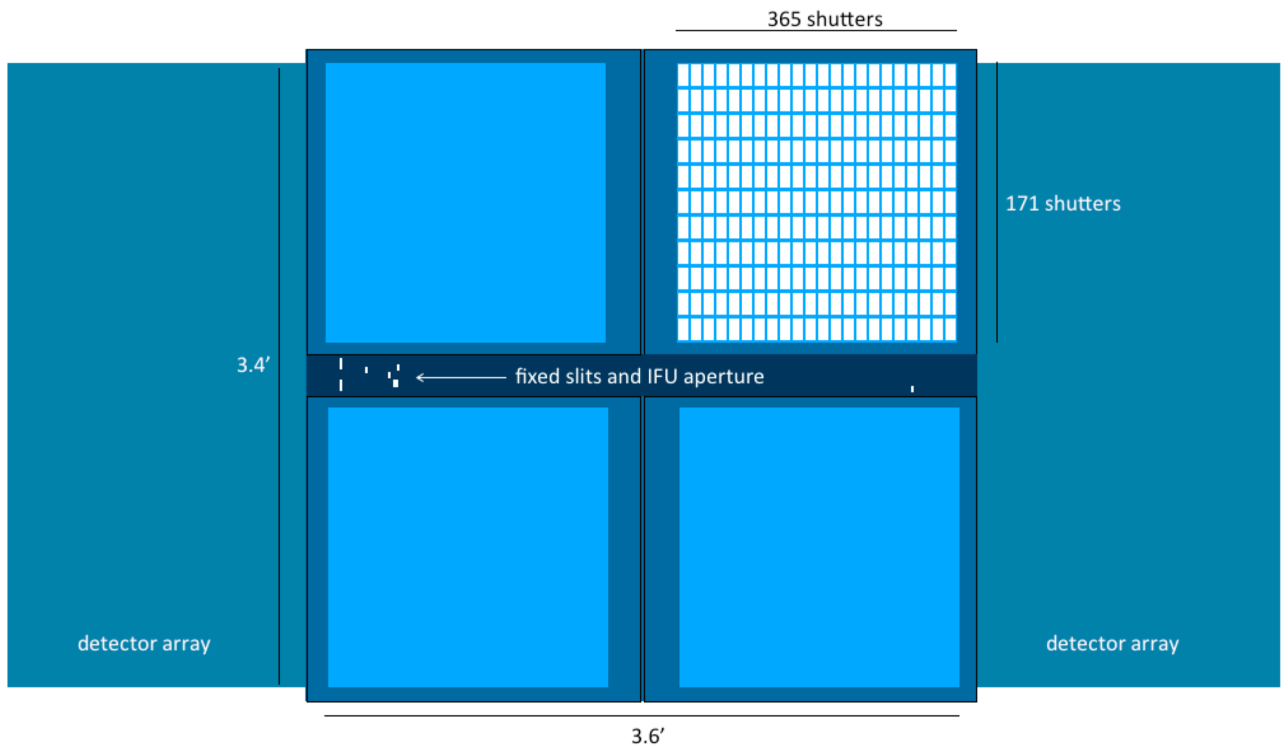

Figure 1: Schematic view of the MSA layout, projected onto the detector plane. Four MSA quadrants are shown.

In order to perform a NIRSpec observation it is important to generate a finder image with correct relative astrometry. The NIRSpec target acquisition algorithm uses 8–20 reference stars observed through the MSA to precisely position the science targets within the micro–shutters. This procedure imposes strict requirements on the relative astrometry between these reference stars and the science targets.

Imaging data from Hubble Space Telescope's cameras have sufficient astrometric accuracy, and NIRCam should also satisfy these requirements. For this reason, NIRSpec MOS users will likely have to provide either verified astrometry from HST images or to obtain NIRCam pre-imaging of their target fields as part of their program. With this in mind we developed a procedure to generate both a finder image and a precise catalogue of astronomical sources.

Procedure

At STScI we developed a procedure that will allows us to deliver to the observer a finder image with verified astrometry, and a catalogue of the astronomical sources in the field of view.

As an example of the procedure, we create the deliverables for the Science Operations Design Reference Mission (SODRM) program entitled NIRSPec Dense Field Spectroscopy of Omega Centauri proposed by J. Tumlinson.

Observation description

This program uses several MSA configurations to observe thousands of stars in the centre of the Omega Centauri globular cluster. The goal of the program is to measure radial velocities and determine chemical abundances of the sources. The requirement is to observe the sources to obtain R=2700 NIRSpec spectra in all available high resolution gratings: G140H, G235H, and G395H.

Creating the finder image

We selected images of Omega Centauri that were obtained under program 13066 (PI: Linda Smith). These are ACS images in filter F435W and 339 sec exposure time each. The first step in the procedure consists of the image registration. This step is crucial since it determines the accuracy of the final product. The requirement is that sources used for the alignment of individual images should be precise in a 5mas scale. We used one arbitrary images as reference and aligned the other eight using the task tweakreg within the DrizzlePac software package. Details of the images and the alignment precision are listed in Table 1.

Filename	Instrument	Filter	Date	Exposure Time (sec)	RMS (mas)
jc3c02abq	ACS/WFC	F435W	18 AUG 2012	339.0	0.00
jc3c02afq	ACS/WFC	F435W	18 AUG 2012	339.0	3.50
jc3c02ajq	ACS/WFC	F435W	18 AUG 2012	339.0	3.25
jc3c02anq	ACS/WFC	F435W	18 AUG 2012	339.0	3.75
jc3c02arq	ACS/WFC	F435W	18 AUG 2012	339.0	3.50
jc3c02avq	ACS/WFC	F435W	18 AUG 2012	339.0	3.75
jc3c02b1q	ACS/WFC	F435W	18 AUG 2012	339.0	4.25
jc3c02b5q	ACS/WFC	F435W	18 AUG 2012	339.0	3.75
jc3c02b9q	ACS/WFC	F435W	18 AUG 2012	339.0	3.75

Table 1: List of properties of ACS/WFC images used for this study. The reference image is the one on top. Note that the alignment RMS (given in milli-arc-seconds) is lower than 5 mas.

Figure 2 shows the ACS/WFC footprints plotted on a Digitized Sky Survey mosaic of Omega Centauri. Once the images are perfectly aligned, we used the image combination software astrodrizzle to co-add the images into a final finder image.

Creating a source catalogue

The source catalogues follow immediately from the finder image. Source identification algorithms like DAOFIND within IRAF or SExtractor can be used to create a reliable list of objects. This catalogue should then be cleared from spurious detections and customized to the specific science goal of the observer.

Cuts can be performed in terms of magnitude range, colour range, source position within the field of view, etc.

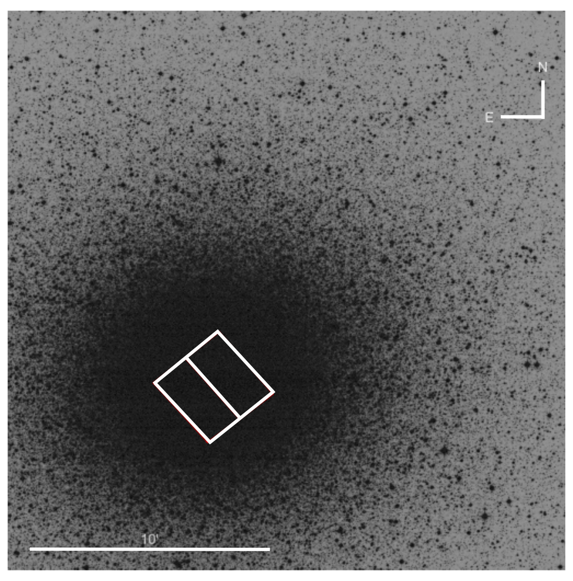

Figure 2: DSS image of globular cluster Omega Centauri where we have marked the ACS/WFC image footprints used for this study.

NIRSpec 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 main purpose of the APT is to provide an accurate and visually accessible projection of the MSA shutter grid onto a given scene of the sky. The APT is able to display an image of the region which must be corrected for all distortion effects. The APT overlays the boundaries of the active area of the MSA as well as that of individual shutters.

After the ingestion of the source catalogue into APT, it is possible to create an observing plan using the APT planner. For this study we selected a simple configuration with one shutter slitlet and a combination of three gratings for maximum resolution spectroscopy: G140H, G235H, and G395H. This process generates 58 MSA configurations for the selected input source catalogue.

As part of the APT, each exposure produces a visual distribution of the observed sources with respect to the MSA quadrants. Figure 3 shows in green the primary sources. Figure 4 shows a detail area of the region marked with a red rectangle. This close-up view shows that most of the shutters (light gray) are closed, some others (dark gray) are failed closed, there is one example (red) of a stuck open shutter. The yellow slitlets represent the open shutters for this exposure. The green dots in those slitlets are sources that can be observed in this exposure.

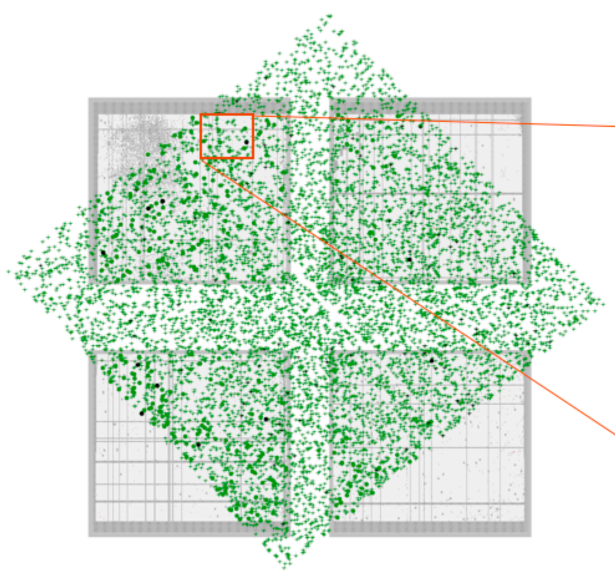

Figure 3: Distribution of catalogue sources with respect to the MSA quadrants. Micro shutters are difficult to see. A detailed view of a small are marked in red is shown in Figure 4.

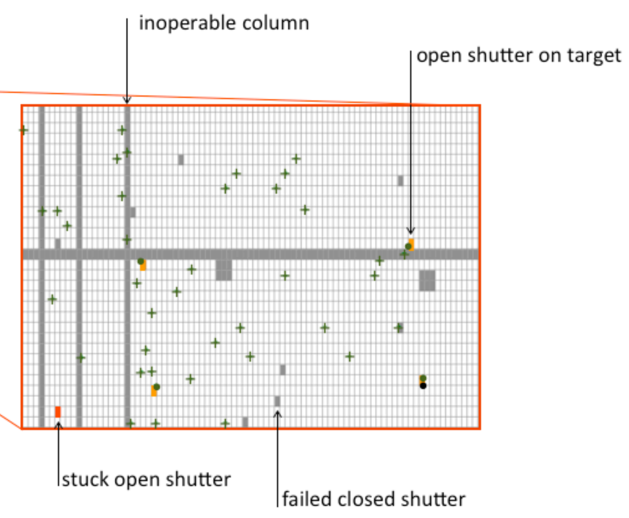

Figure 4: Close-up view of a small area in the upper left MSA quadrant. Labels explain the meaning of the colored shutters.

Current and future work

When Hubble Space Telescope imaging is not available, the observer will have to design Near-Infrared Camera (NIRCam) observations of the desired field before the proposed NIRSpec MSA observation. In order to prepare for this type of observations we are using the public JWST imaging simulation tool. This software allows us to simulate several astronomical scenes (stellar populations, galactic clusters, etc) and generate exposures in a variety of dither patterns.

We are investigating the possibility of using distortion-corrected HST images as input to replicate the same field of view as seen with a JWST/NIRCam PSF.

We are also testing several registering algorithms (tweakreg, SCAMP) in order to fulfill the desired 5mas alignment precision, as well as co-adding routines (Montage, astrodrizzle, SWarp) that would produce the required finder image.

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