STScI

JWST Science & Operations Centre
3700 San Martin Drive
Baltimore MD 21218
USA
www.esa.int

TECHNICAL NOTE

Dither positions for the NIRSpec fixed slits

Prepared by S. Birkmann, G. Giardino, N. Lützgendorf

Reference ESA-JWST-SCI-NRS-TN-2017-002
Issue/Revision 1.0
Date of Issue March 17, 2017
Status Released

APPROVAL

Title Dither positions for the NIRSpec fixed slits	
Issue Number 1	**Revision Number** 0
Author S. Birkmann, G. Giardino, N. Lützgendorf	**Date** March 17, 2017
Approved by	**Date of Approval**

CHANGE LOG

Reason for change	Issue Nr.	Revision Number	Date

CHANGE RECORD

Issue Number 1	Revision Number 0		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

DISTRIBUTION

Name/Organisational Unit
SCI-ODJ
STScI

Contents

1 INTRODUCTION & SCOPE

The NIRSpec instrument has five fixed slits (FS) available for observations of astronomical sources. These five slits are designated S200A1, S200A2, S200B1, S400A1, and S1600A1 and are cut in the so-called cruciform that is part of the microshutter assembly (MSA). Therefore, the slits are part of the MSA, and a new flight MSA was integrated into NIRSpec between the ISIM CV2 and CV3 test campaigns. The slits in the new MSA exhibit rougher edges than that of the previous unit. As a result, the slit transmission is not fully uniform over the slit length (cross-dispersion direction), but shows peak-to-valley variations of up to $\sim$20 %.

When planning observations with STScI's Astronomer's Proposal Tools (APT), the fixed slits are available in the "NIRSpec Fixed Slit Spectroscopy" template. Apart from the slit/aperture and the subarray, the user can select from a set of "primary dither positions" and a "sub-pixel pattern". The latter supports performing small dithers around each of the primary dither positions. The initial strategy and dither patterns are given in RD1. These were conceived before all features of the flight hardware became known, in particular the significant throughput variations along the cross-dispersion direction. Therefore, new primary dither positions are provided in this note. The secondary or sub-pixel dithers are also briefly discussed and (slightly) new values proposed. It is also noteworthy that, due to the slit profiles, the primary dither positions are different for each aperture, which is a change from the original concept.

All dithers are reported in the ideal coordinate system, i.e. with x being along the dispersion direction and y along the spatial (or cross-dispersion) direction for all slits, in arcseconds relative to the reference position that is defined in the Science Instrument Aperture (SIAF) file that is maintained by STScI. Please see RD2 for more details on the reference positions and how they are derived.

2 DOCUMENT REFERENCE

No	Title	Reference
RD1	NIRSpec Dithering Strategy Part 1: The Fixed Slit Apertures	JWST-STScI-001678, 12 May 2009
RD2	Delivery of coordinates of the SIAF apertures in the V2V3-plane and of reference files for Target Acquisition in the XANYAN-plane	ESA-JWST-SCI-NRS-TN-2017-004, issue 1 rev 0
RD3	NIRSpec Dithers Operations Concept	N/A, draft, 06 Sep 2016

3 CRITERIA FOR DEFINING THE PRIMARY DITHER POSITIONS

The set of new primary dither positions should fulfill the following criteria:

1. No position should be in a low throughput region of the respective slit.
2. For patterns with more than one position, the relative pixel phase (in spatial/cross-dispersion direction) of the positions should provide sub-pixel sampling.
3. The positions should be close to the "optimal" ones in terms of separation.

The meaning of point 3. above is to separate the source well on the detector, so that when exposures taken at different primary dither positions are subtracted from each other the source signal is preserved. Given the relatively short extend of the slits, this is obviously only possible for very compact sources and is complicated by the slit profile (point 1.). Without the impact of the slit profile the ideal positions would yield a separation between adjacent dither positions that is twice the separation towards the slit edge (or where a significant drop

in slit transmission occurs, typically at yslit = $\pm$0.45). These ideal positions would be close, but not identical, to those given in RD1.

The relative pixel phase mentioned in point 2 above is meant to ensure optimal sub-pixel sampling from the primary positions when there is more than one. For a two point dither, the relative pixel phases should be 0 and $\frac{1}{2}$, for a three point dither 0, $\frac{1}{3}$, and $\frac{2}{3}$, and for a five point dither 0, $\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, and $\frac{4}{5}$. In order to accomplish this the relative pixel position (on the detector) was calculated as a function of the relative slit position (in the MSA plane) for each aperture in imaging mode. The change in spatial pixel scale is small between imaging mode and any of the NIRSpec dispersers, so the same primary dither positions can be used for spatial sub-pixel sampling regardless of disperser.

4 SLIT REFERENCE POINTS

The reference points for the fixed slits have been chosen so that they do not fall into a low transmission region of the aperture. Therefore, for all apertures but the S1600A1, the reference point is slightly offset from the center of the slit in cross-dispersion direction. The projected positions of the four slits on the SCA491 side and their reference points in the V2/V3 plane are shown in figure 1 for reference. The reference points for SIAF and their derivation are discussed in RD2.

5 SLIT PROFILES AND PRIMARY DITHER POSITIONS

In this section we present the slit profiles and the proposed primary dither positions for each of the apertures available in the NIRSpec fixed slit spectroscopy template. Each of the slit profiles in figures 2 through 6 shows the normalized throughput for flat field illumination as a function of relative slit position and the corresponding relative spatial pixel position.

Table 1 on page 9 lists the primary dither positions (and reference position) for each of the fixed slits in relative slit coordinates. These are unlikely to change, unless e.g. the slit profiles are determined to be different once in orbit.

The primary dither positions in ideal coordinates (in arcseconds with respect to the aperture reference point) are shown in figures 7 through 11 and in table 2 on page 12. These are subject to change during commissioning, once the combined transforms of OTE and NIRSpec FORE optics have been determined/refined.

From the plots and tables it is obvious that for some slits dither patterns with many (e.g. five) positions have less than ideal separation between positions due to the slit profiles. The profile of the S1600A1 aperture is basically flat and we can adopt the ideal spacing, but due to the small extent of the aperture in cross-dispersion direction (less than half of the other slits), the separation on the detector is still very limited.

5.1 Sub-Pixel Dither Patterns

In addition to the four available primary dither patterns, the NIRSpec Dither Ops Concept (RD3) calls for four sub-pixel dither patterns (NONE, SPECTRAL, SPATIAL, and BOTH) to provide the option of small dithers around the primary dither positions. This should allow the observer to improve the spatial and spectral sampling of the NIRSpec PSF even when using only a small number of primary positions.

The proposed sub-pixel dithers are listed in table 3 on page 12. They are the same for all apertures. Sub-pixel dither amplitudes have been designed to yield $\pm\frac{1}{4}$ (or $\frac{1}{2}$) pixel offsets in spatial direction using the plate scale of approximately 105.4 mas/pix. It must also be noted that the proposed sub-pixel dithers for the SPECTRAL pattern are different than those in RD3, which calls for roughly $\sim \pm\frac{1}{3}$ (plus the central position) offsets in

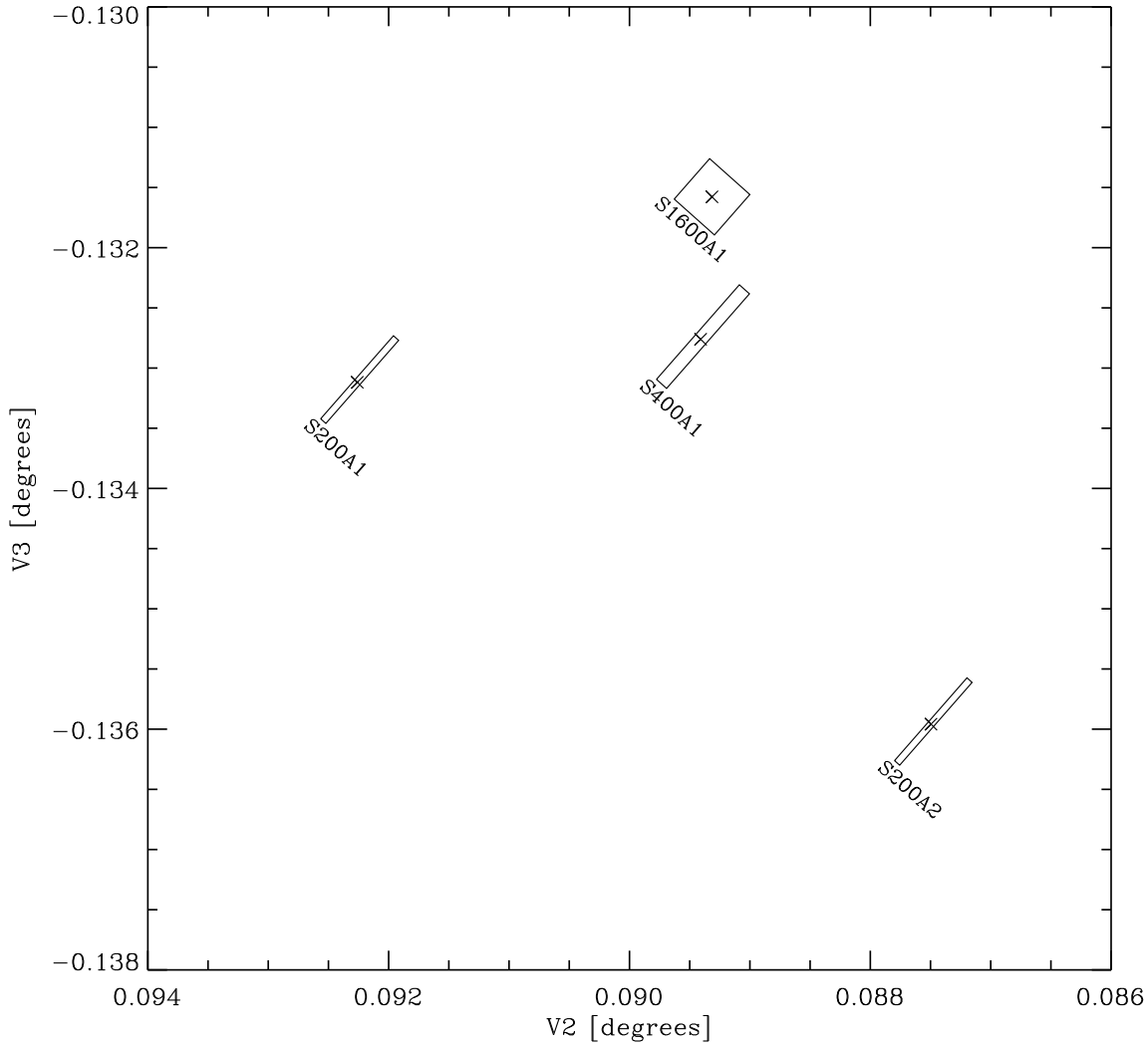

Figure 1: Aperture position of the SXXXAX slits in V2/V3 coordinates. The reference points are denoted by crosses.

spectral directions, while the BOTH sub-pixel dither has $\sim \pm\frac{1}{4}$ in spectral direction. The newly proposed sub-dithers have the advantage that they result in less slit loss (variation) and also simplify the slit loss calibration, because now the two sub-pixel dither patterns NONE and BOTH will cover all possible secondary positions.

It is noteworthy that the fine steering mirror is capable to offset 60 mas without the need for changing the attitude of the spacecraft, and all proposed sub-pixel dithers have a small enough extend for this.

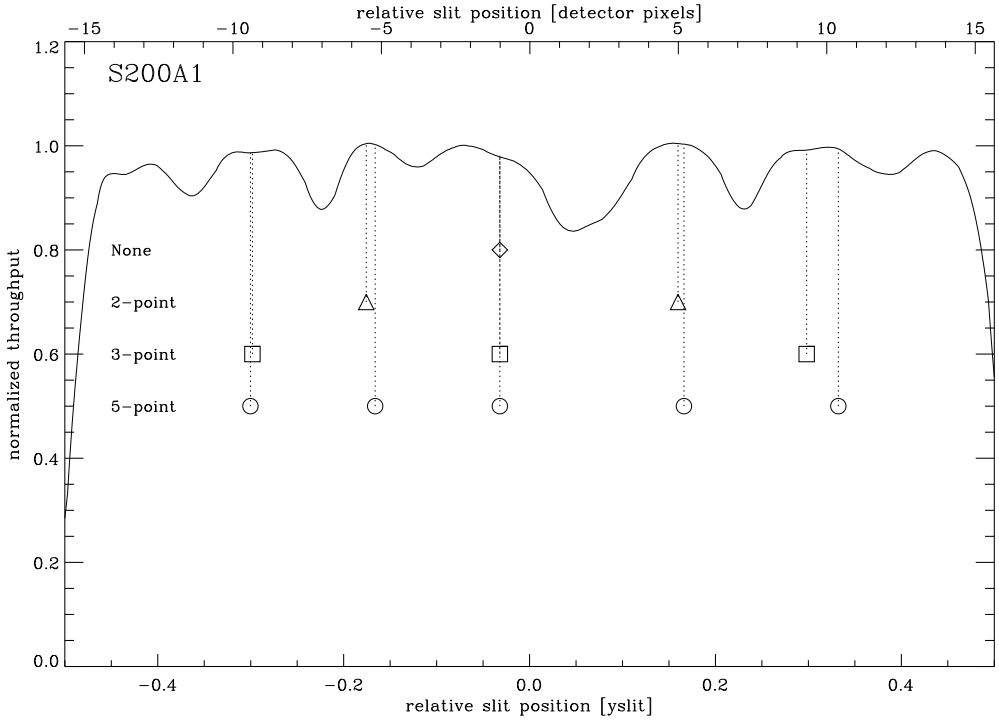

Figure 2: Slit throughput profile and proposed primary dither positions for aperture S200A1.

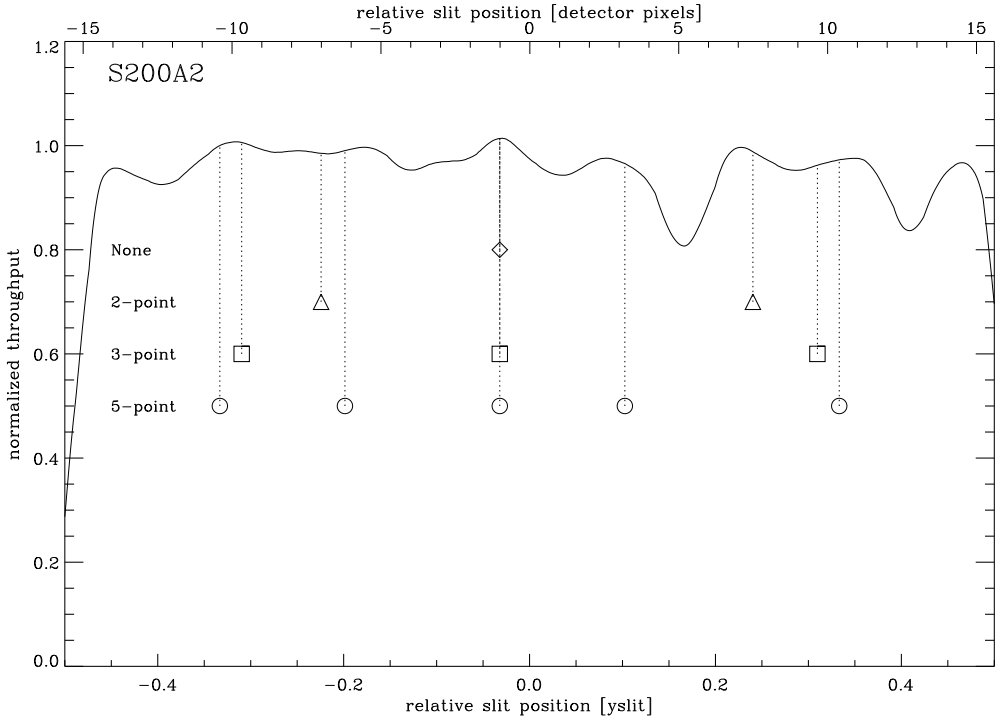

Figure 3: Slit throughput profile and proposed primary dither positions for aperture S200A2.

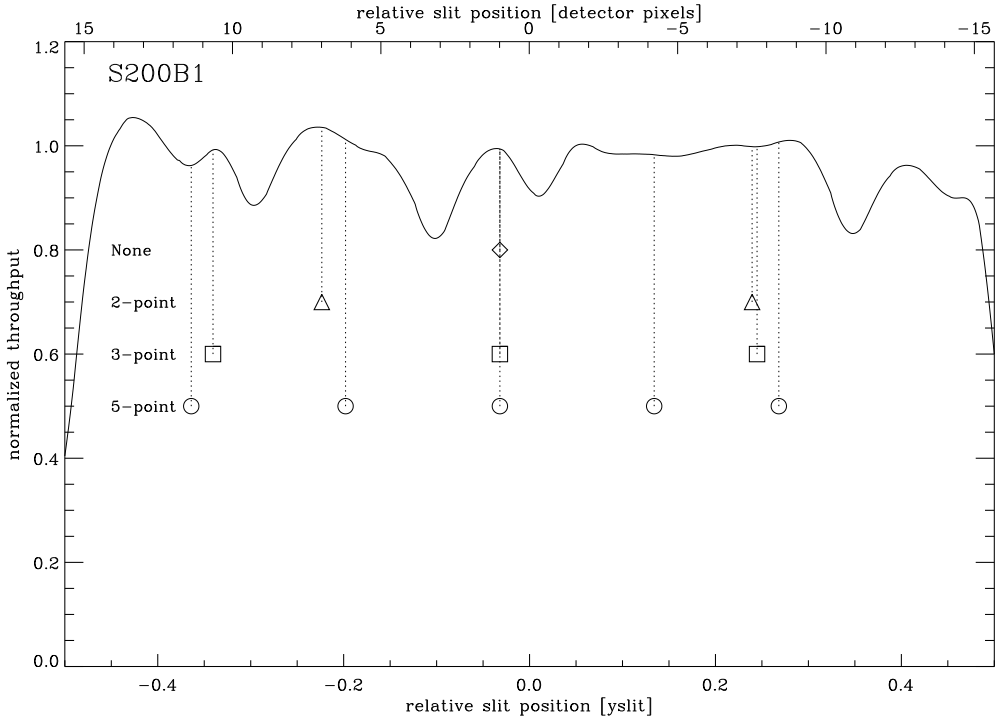

Figure 4: Slit throughput profile and proposed primary dither positions for aperture S200B1.

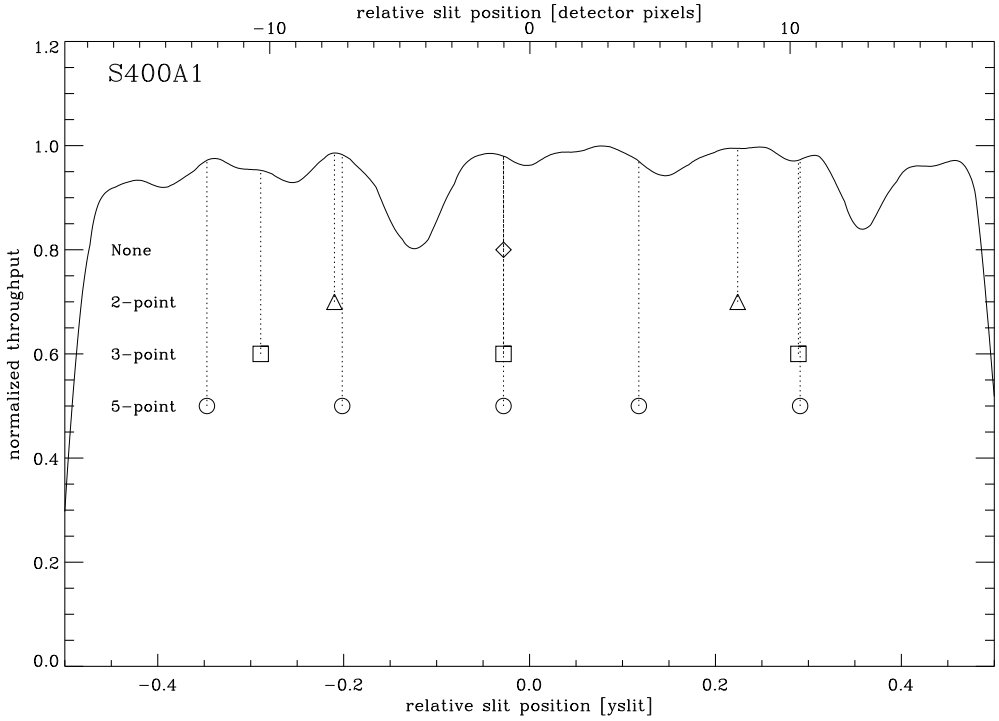

Figure 5: Slit throughput profile and proposed primary dither positions for aperture S400A1.

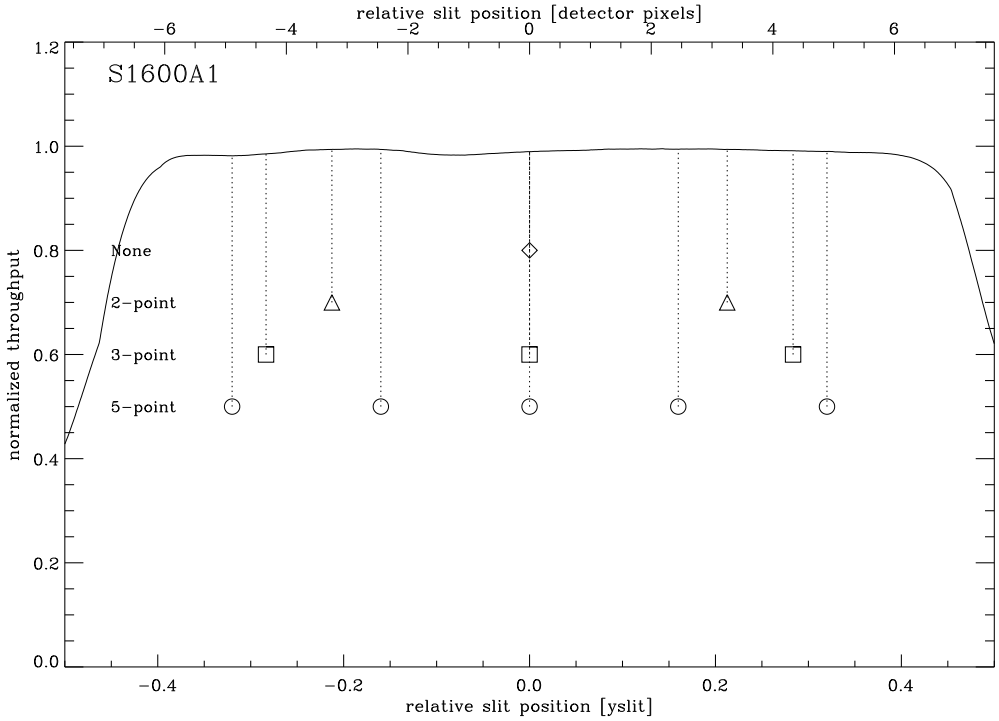

Figure 6: Slit throughput profile and proposed primary dither positions for aperture S1600A1.

Aperture	Dither pattern	Primary dither positions [yslit]
S200A1	None	-0.0319457
	2-point	-0.175703, 0.159722
	3-point	-0.298164, -0.0319457, 0.298142
	5-point	-0.300294, -0.166118, -0.0319457, 0.166112, 0.332214
S200A2	None	-0.0320383
	2-point	-0.224272, 0.240279
	3-point	-0.309711, -0.0320383, 0.309691
	5-point	-0.333208, -0.198641, -0.0320383, 0.102522, 0.333183
S200B1	None	-0.0319265
	2-point	-0.223490, 0.239441
	3-point	-0.340561, -0.0319265, 0.244760
	5-point	-0.363978, -0.197949, -0.0319265, 0.134089, 0.268173
S400A1	None	-0.0279916
	2-point	-0.209941, 0.223927
	3-point	-0.289256, -0.0279916, 0.289236
	5-point	-0.347112, -0.201543, -0.0279916, 0.117563, 0.291101
S1600A1	None	0.00000
	2-point	-0.212641, 0.212641
	3-point	-0.283525, 0.00000, 0.283518
	5-point	-0.320000, -0.160000, 0.00000, 0.160000, 0.320000

Table 1: Primary dither positions in relative (spatial) slit coordinates for the five apertures. The relative slit position in dispersion direction (xslit) is 0 in all cases. The position for the "None" Dither pattern is equal to the reference pointing for that aperture.

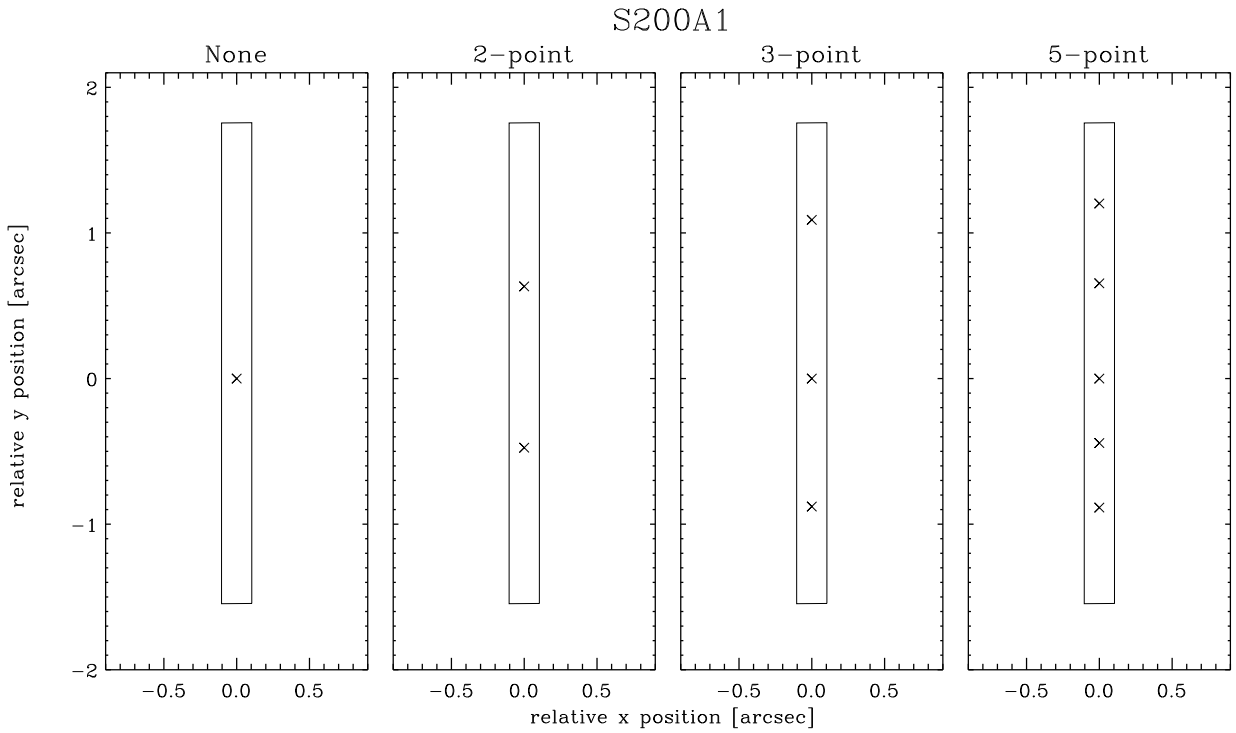

Figure 7: Primary dither positions for the S200A1 aperture in NIRSpec ideal coordinates for the four available dither patterns.

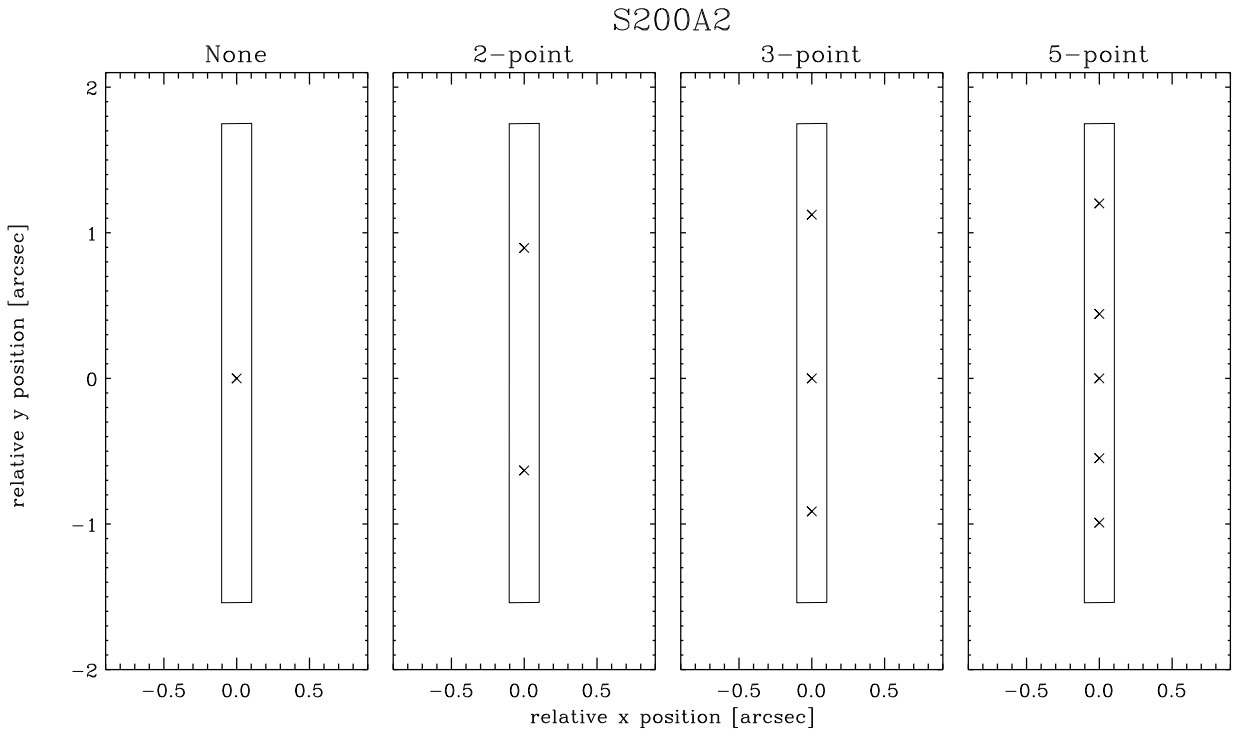

Figure 8: Primary dither positions for the S200A2 aperture in NIRSpec ideal coordinates for the four available dither patterns.

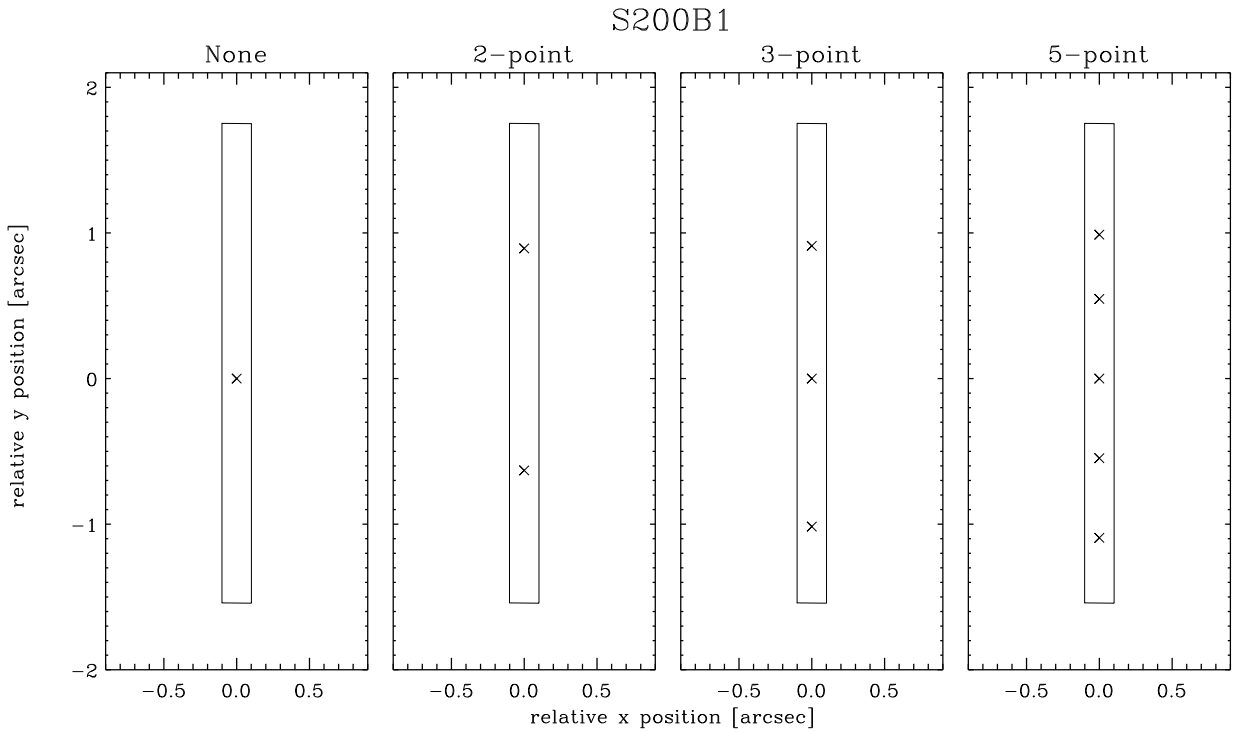

Figure 9: Primary dither positions for the S200B1 aperture in NIRSpec ideal coordinates for the four available dither patterns.

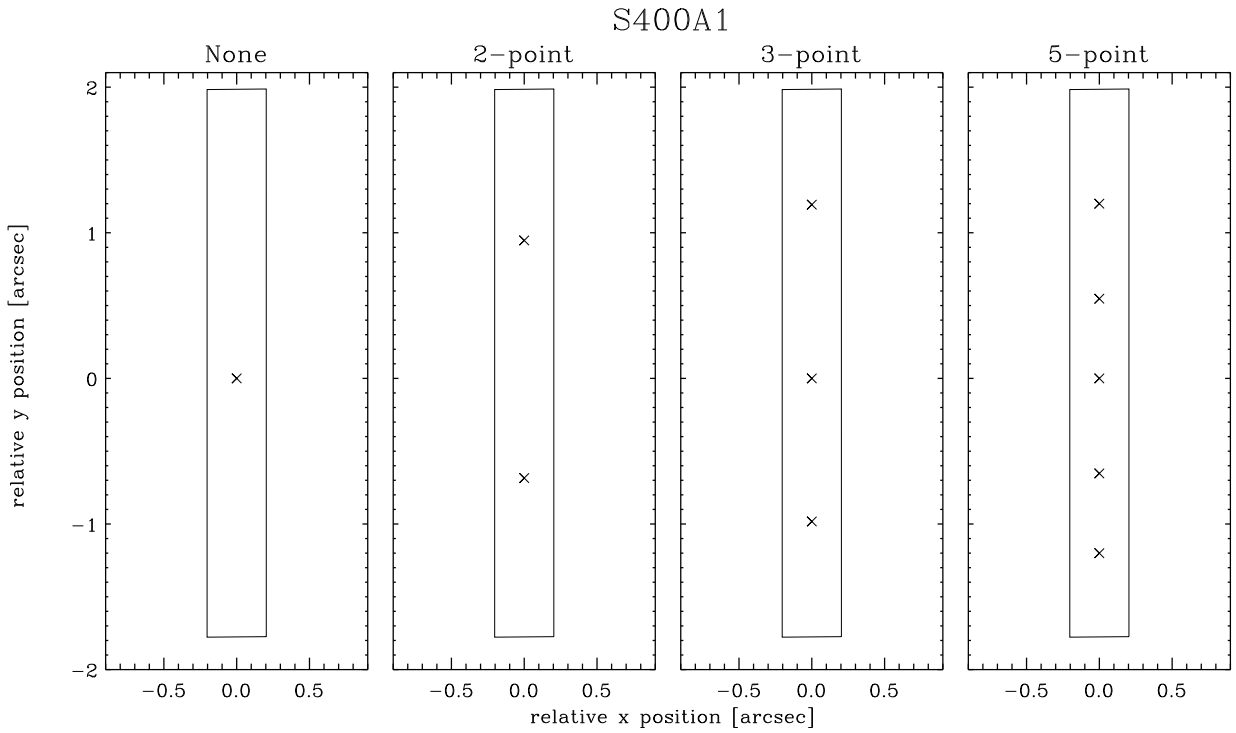

Figure 10: Primary dither positions for the S400A1 aperture in NIRSpec ideal coordinates for the four available dither patterns.

Aperture	Primary y position [arcsec]			
	None	2-point	3-point	5-point
S200A1	+0.0000	+0.6328 -0.4747	+1.0898 +0.0000 -0.8790	+1.2023 +0.6539 +0.0000 -0.4430 -0.8860
S200A2	+0.0000	+0.8958 -0.6324	+1.1241 +0.0000 -0.9136	+1.2013 +0.4426 +0.0000 -0.5481 -0.9908
S200B1	+0.0000	+0.8936 -0.6310	+0.9111 +0.0000 -1.0165	+0.9882 +0.5467 +0.0000 -0.5468 -1.0937
S400A1	+0.0000	+0.9474 -0.6844	+1.1930 +0.0000 -0.9827	+1.2000 +0.5474 +0.0000 -0.6528 -1.2004
S1600A1	+0.0000	+0.3419 -0.3419	+0.4558 +0.0000 -0.4558	+0.5145 +0.2573 +0.0000 -0.2572 -0.5145

Table 2: Primary dither positions for the five apertures in the ideal coordinate frame in cross dispersion (y) direction in arcseconds. The x position (dispersion direction) is zero arcsec in all cases. All dither positions are relative to the reference point for that aperture.

Sub-pixel dither postions in NIRSpec ideal coordinates [arcsec]							
NONE		SPECTRAL		SPATIAL		BOTH	
x	y	x	y	x	y	x	y
0.000	0.0000	-0.0264 0.0000 +0.0264	0.0000 0.0000 0.0000	0.0000 0.0000	+0.0264 -0.0264	-0.0264 0.0000 +0.0264 0.0000	0.0000 +0.0264 0.0000 -0.0264

Table 3: The relative offset (with respect to the primary dither positions) of the available sub-dither patterns in NIRSpec ideal coordinates in arcseconds.

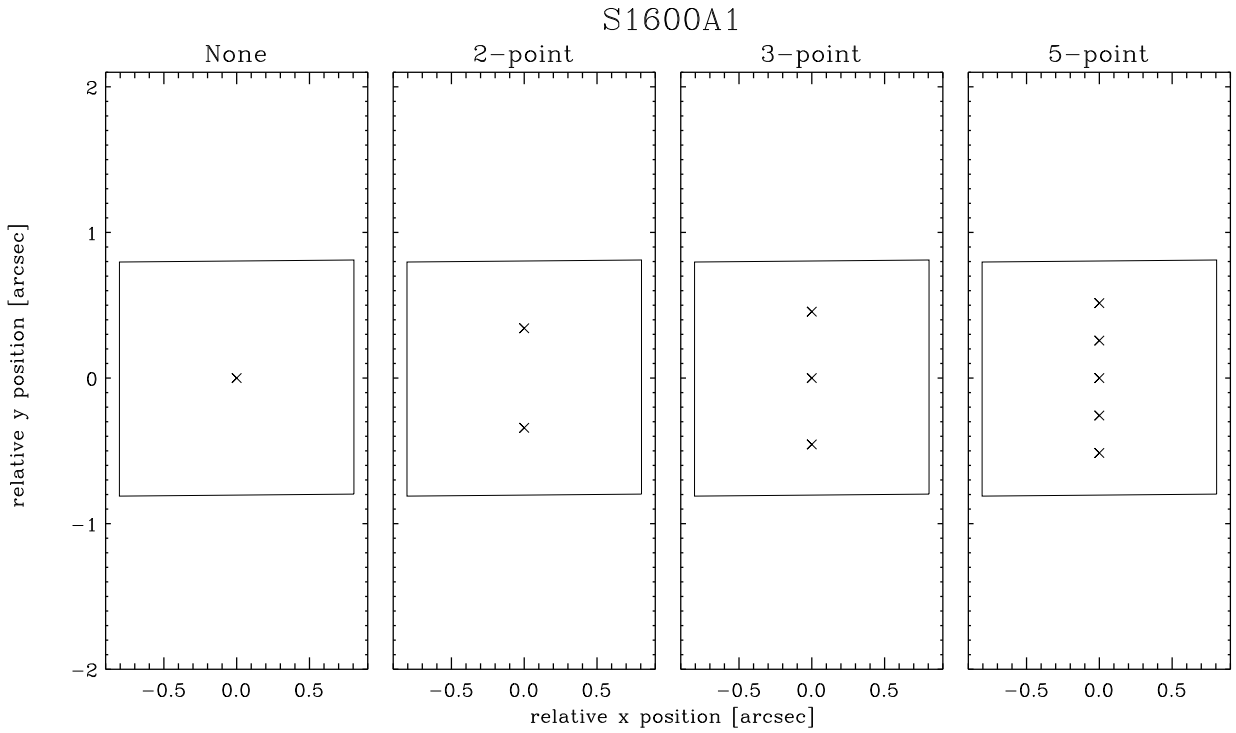

Figure 11: Primary dither positions for the S1600A1 aperture in NIRSpec ideal coordinates for the four available dither patterns.

6 FIXED SLIT DITHER REFERENCE FILES

6.1 Reference File Format

The fixed slit dither reference files are plain ASCII text files. According to Gary Curtis (personnel communication, email on 10 Feb 2017) the dither files should be named `<Instrument><Mode>Dithers.txt`, with the instrument being `NIRSpec` and the mode `FS` for the NIRSpec fixed slit dithers. Because each aperture will now have its own primary dither positions, we opted to also include the aperture name to the file name, and the file name becomes `<Instrument><Mode><Aperture>Dither.txt`.

Each file can hold several dither specifications conforming to the following format:

```
<Dither Name>
1 <x offset> <y offset>
2 <x offset> <y offset>

<Dither Name>
1 <x offset> <y offset>
2 <x offset> <y offset>
...
n <x offset> <y offset>
```

where the x and y offset are the dither positions in NIRSpec ideal coordinate system with respect to the aperture reference point in acrseconds and the first column gives the dither number. The `<Dither Name>` gives the name of this dither pattern, and we chose to compose it from the primary and sub-pixel dither names in APT 25.0.3,

e.g. /verb+NONE NONE+ or 3 SPECTRAL. There are four primary and four sub-pixel dither patterns to chose and combine, therefore there are 16 dither specifications per aperture in total.

In order to record when the reference file was created we add a few comments to the first two lines of the text files. An example for the S200A1 aperture is given below:

```
# NIRSpec fixed slit dither specification for S200A1 aperture
# Created on YYYY-MM-DD:hh:mm:ss
# Author: fixed_slit_dithers.pro - version 0.1 2017-03-16
# Reference: ESA-JWST-SCI-NRS-TN-2017-002, issue 1 rev 0
```

6.2 Delivered Files

There is one dither positions reference file per slit/aperture and therefore five reference files in total. The names of the delivered reference files are:

```
NIRSpecFSS200A1Dithers.txt
NIRSpecFSS200A2Dithers.txt
NIRSpecFSS200B1Dithers.txt
NIRSpecFSS400A1Dithers.txt
NIRSpecFSS1600A1Dithers.txt
```

7 FUTURE UPDATES TO THE DITHER POSITIONS AND REFERENCE FILES

It is expected that the dither positions will be updated during in-orbit commissioning once the plate scale of NIRSpec has been measured. This is necessary, because dithers are specified in arcseconds and it is important to keep 1) the positions in the MSA plane (slit throughput profiles) and 2) the relative pixel phase.