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NIRSpec Technical Note
NTN-2013-005 /ESA-JWST-TN-20073

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Date of Issue: 26.11.2014
Revision: 2.0

FPA104 Gain and Readnoise Maps (and Amplifier reference files).

Abstract:

This document describes the format and content of the amplifier reference files used by the STScI ramp-to-slope pipeline and of the gain and readnoise maps for FPA104. The data and algorithm used to create the reference files are also described.

Change Log:

Version	Date	Description of changes
1.0	31.10.2013	Initial version for Build 2 pipeline
2.0	22.11.2014	Updated to reflect changes for build 3 pipeline

1 DELIVERED REFERENCE FILES

Reference Type	**File Name**	**Comment**
Amplifier	nirspec_ampl_nrs1_f_01.00.fits nirspec_ampl_nrs2_f_01.00.fits	Deprecated for Build 3
Gain map	nirspec_gain_nrs1_f_01.01.fits nirspec_gain_nrs2_f_01.01.fits	Update format and header
Read noise map	nirspec_rdns_nrs1_f_01.00.fits nirspec_rdns_nrs2_f_01.00.fits	New for Build 3

2 REFERENCE FILE FORMAT

All reference files are stored in fits format as defined by [1]. The primary data array is always empty and the actual reference data is stored in image or binary table extensions. The primary headers of all reference files contain the necessary keywords defined in [2].

The gain and read noise reference files contain one image extension of type float (BITPIX = -32) that holds the pixel-to-pixel gain map in units of e^-/DN and the CDS noise per pixel respectively. The two maps are 2048x2048 pixels in size, i.e. it is for the full SCA. The gain and CDS noise reference files do not hold any data quality bit maps at the moment.

The amplifier reference files (deprecated for Build 3) contain one binary table extension. This binary table has seven columns containing the designation of the amplifier, the detector area covered by it, the gain, and the read noise, and four rows, one for each amplifier (SCA output). Table 1 below gives an overview of the contents of the binary table.

Table 1 Structure of the amplifier binary table (deprecated for Build 3)

#	Name	Type	Description
1	AMPLIFIER	ASCII	Designation of amplifier (A,B,C, or D)
2	XSTART	Integer	Start column
3	XSTOP	Integer	End column
4	YSTART	Integer	Start row
5	YSTOP	Integer	Stop row
6	GAIN	Float	Gain value in e^-/DN
7	READNOISE	Float	Read noise in e^-/DN

3 DETERMINATION OF THE AVERAGE GAIN

The average conversion gain of the two SCAs was determined with the classical photon transfer curve.

In April 2010 during the characterization of the FPA104 at GSFC/DCL each set of monochromatic flat field exposures acquired for the RQE test was bracketed by a set of three background exposures. These background exposures, each one consisting of a single up-the-ramp integration with five groups of one frame each, provide the dataset needed for creating a photon transfer curve.

Nineteen different sets of three exposures each were acquired during the entire RQE test for a total of 57 background exposures. The operating temperature of the detector was 38.5 K. The full list of the exposures is available in Appendix-1. The mean background value and standard deviation over the full set of background exposures is listed in Table 2 for each output of each SCA. No significant variations of background level were seen in the data acquired over a period of approximately eight hours.

Table 2. Mean background level (e/sec) and standard deviation over the 57 exposures

	SCA 491		SCA 492	
	Mean	Stdev	Mean	Stdev
OUTPUT -1	89.02	0.52	91.29	0.52
OUTPUT -2	86.25	0.49	92.67	0.53
OUTPUT -3	82.08	0.47	91.37	0.52
OUTPUT -4	75.67	0.43	86.76	0.49

All exposures were processed with the raw data pipeline version 0.27 [3] with the IDL script `MS_PT_gain_part1.pro`. Only the following corrections were applied to the data:

- superbias subtraction
- top and bottom reference pixels correction
- linearity correction

For the photon transfer we used the processed data cubes since they provide the different levels of signal needed. The five groups (each group has only one frame), cover signal between 600 and 5000 ADU. We prepared the IDL script `MS_PT_gain_part2.pro` to execute the following steps on each set of exposures:

- the three processed cubes are averaged together frame by frame to create an average signal cube:
- `<signal_cube>=[<frame_1>,<frame_2>,…,<frame_5>]`
- after a 5 sigma rejection clipping the mean value of the signal in each average frame `<frame_j>` is used to build a five-element array `<Signal>`

- Three noise cubes are created by subtracting frame by frame pairs of cubes:
  - `Noise_cube12 = cube_1 - cube_2`
  - `Noise_cube23 = cube_2 - cube_3`

  - `Noise_cube31 = cube_3 - cube_1`
- after a 5 sigma rejection the variance of every noise frame is calculated and the mean variance is created by averaging the three variance estimates from each noise-cube. This step produces a five-element array `<Variance>`
- `<Signal>` and `<Variance>` are used to derive the value of the gain as the inverse of the linear fit to the signal vs variance plot (see Figure 1 for an example of the photon transfer curve derived from a set of three exposures).

The derived gain is biased by the inter-pixel-capacitance (IPC) that introduces noise correlation and therefore decreases the variance and causes to overestimate the gain.

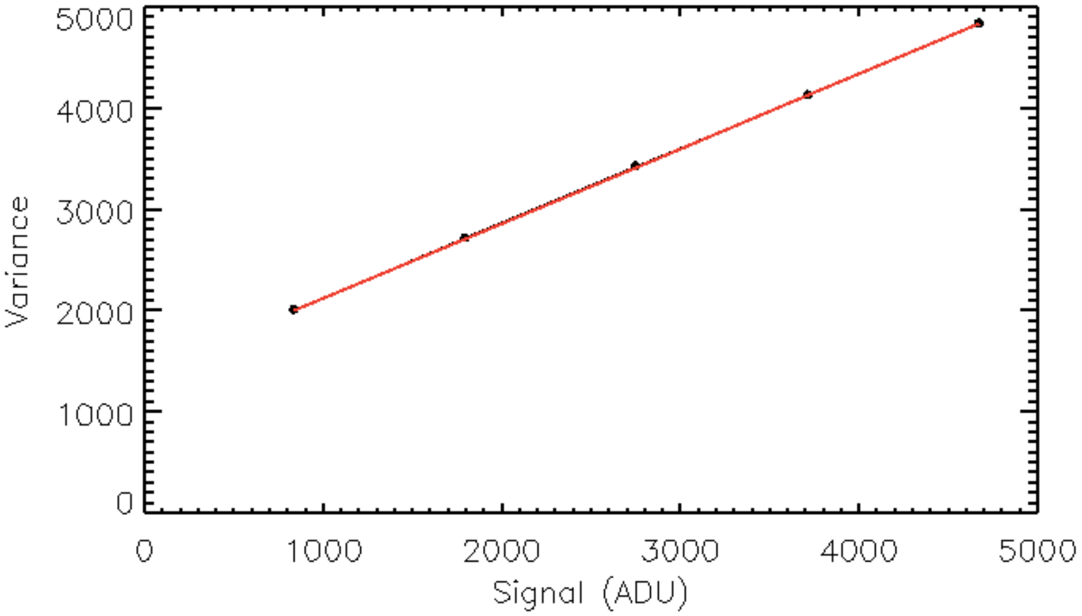

Fig. 1 Example of photon transfer plot used to derive the gain. The inverse of slope of the red linear fit to the average signal/average variance points for the five groups is the conversion gain before the correction for IPC.

The derived gain is then corrected for IPC [`Gain_IPC = Gain/(1+8*α)`] where the two values of α are listed in Table 3.

Table 3 Value of alpha for the IPC correction from [4]

SCA	**α**
491 (SN 055)	0.0103

492 (SN 054)	0.0113

For each set of three exposures a single value of the IPC corrected average gain is determined. Table 4 lists the average gain obtained from the nineteen sets. These values are used to normalize the gain maps described below.

Table 4 Adopted average gain for the two SCA of FPA104

SCA	Gain (e/sec)
491 (SN 055)	1.453 ±0.002
492 (SN 054)	1.339 ±0.002

4 PIXEL-TO-PIXEL GAIN MAPS

Pixel-to-pixels gain maps have been derived from dedicated test data acquired during the FPA104 characterization campaign at GSFC/DCL in 2010. 3549 consecutive exposures of three groups each have been acquired between May 21 and May 24 2010 at GSFC/DCL with jlab81. All exposures were acquired at an operating temperature of 37.0 K and with the DCL black body source. Table 5 lists the basic information for the set of data used.

Table 5 Basic information of the set of data used to derive the pixel-to-pixel maps

OBS-ID	First NID	Last NID
NRS_A_37_0_p2p_gain	12021	15570
	Starting Date	**Ending Date**
	20100521T213312	20100524T130738

As in the case of the average gain, the gain of each pixel is calculated with the photon transfer test. In this case, the average signal and variance are however calculated for each pixel temporally over many exposures.

Two IDL scripts were prepared to perform the different steps needed to process the raw data and described below:
`MS_p2p_gain_part1.pro` for steps A –C
`MS_p2p_gain_part2.pro` for steps D- E

A. The exposures, each consisting of only three frames, are divided in 34 groups of 100 exposures each

B. For each exposure *j* in a group *k*:

B1- read the raw cube_j and create the two difference frames:

```
D21_j=frame_1_j-frame_0_j
D31_j=frame_2_j-frame_0_j
```

B2- Perform reference pixel correction on `D21_j` and `D31_j` using the IDL routine `msrefsub.pro` with refmode=18[1] and save the reference pixel corrected difference `D21r_j` and `D31r_j` as array `j` of two 3D arrays `C21_k` and `C31_k` (both 2048x2048x100 in size).

C. Once all 100 exposures in a given group have been processed, for each pixel calculate the average signal and variance over the `C21_k` and `C31_k` cubes using the IDL routine `djs_iterstat.pro` with a 4-sigma rejection threshold. Four 2D maps of average signal (`C21_sig_k`, `C31_sig_k`) and variance (`C21_var_k` and `C31_var_k`) are generated in this step.

D. These four 2D maps allow to create for each pixel a `Δ_or each` and a `Δ_Variance_k` and to calculate the gain for the exposures in group k as (Fig 2):

`Gain_k =Δ_ain_k =p Δ_ain_k =p k`

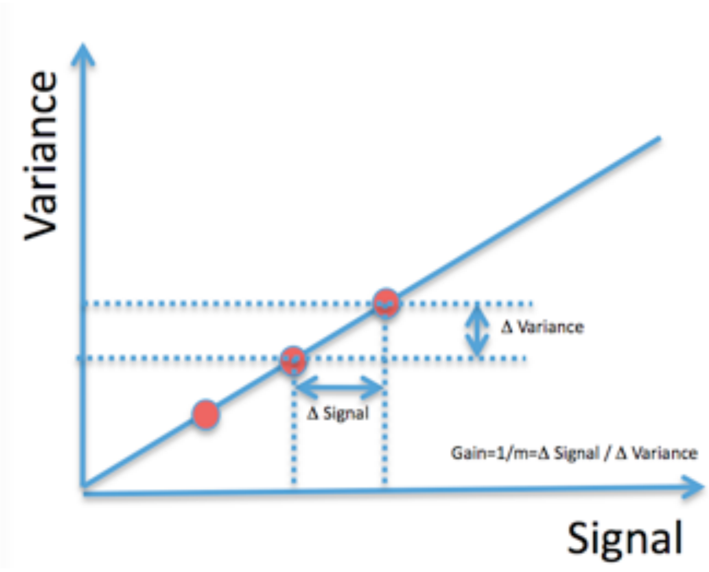

Fig. 2 Gain estimate for each pixel in a 100 exposure group

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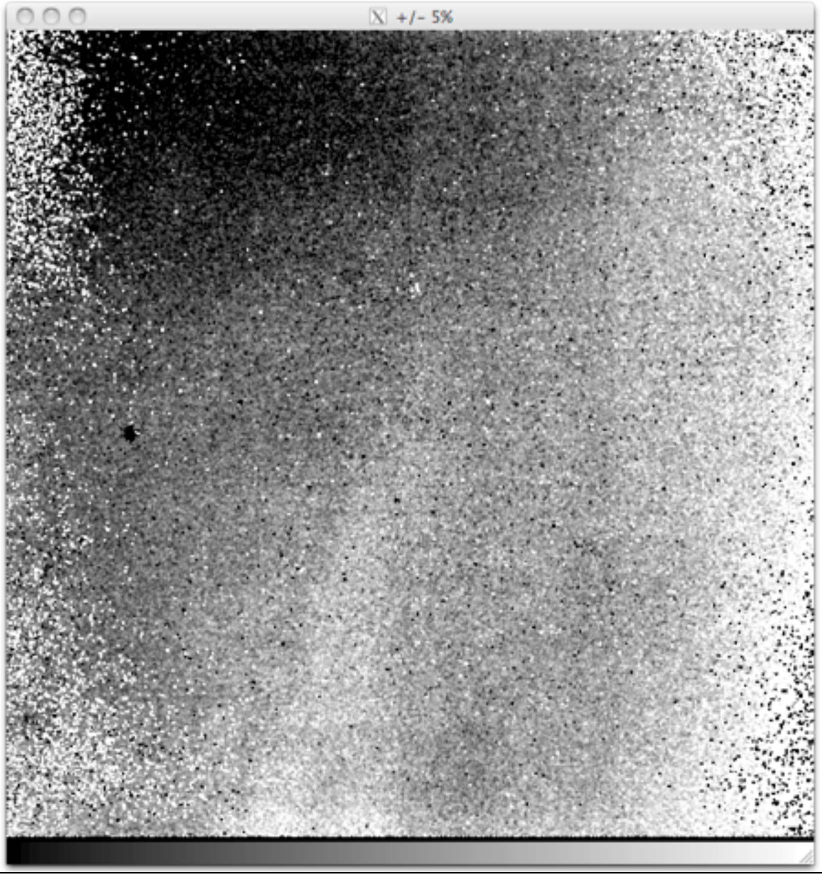
[1] Refmode=18 in n[illegible] each output the median value (after sigma clipping rejection with djs_iterstat.pro) of the top and bottom reference pixels separately for even and odd columns and by subtracting the results from each even/odd column.

However in order to improve the statistics, we create for each pixel an average `<Δ_Signal>` and average `<Δ_and aver>` using all the groups and calculate the conversion gain of each pixel as: `Gain=<Δ_ain=< allΔ_ain=< all`

E. The derived Gain in e-/DN is finally corrected with the values in Table 3

As in the case of the average gain, the gain of each pixel is calculated with the photon transfer test. In this case, the average signal and variance are however calculated for each pixel temporally over many exposures. Figures 3 and 4 display the pixel-2-pixel gain map for SCA491 and SCA492 respectively and their distributions. There is a significant variation in gain across the array for both SCAs that warrants the use of pixel maps rather than an average value for the entire array or for each amplifier. The distribution of gain value in each output are depicted in figure 5.

	SCA 491

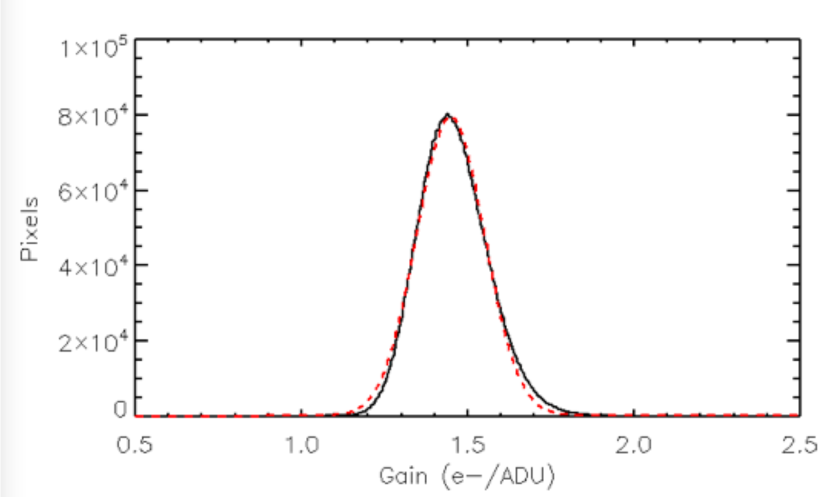
	Gaussian Fit Peak: 1.447 Sigma:0.102

Fig. 3 Pixel-to-pixel gain map for SCA 491 (top) and distribution with Gaussian fit (bottom)

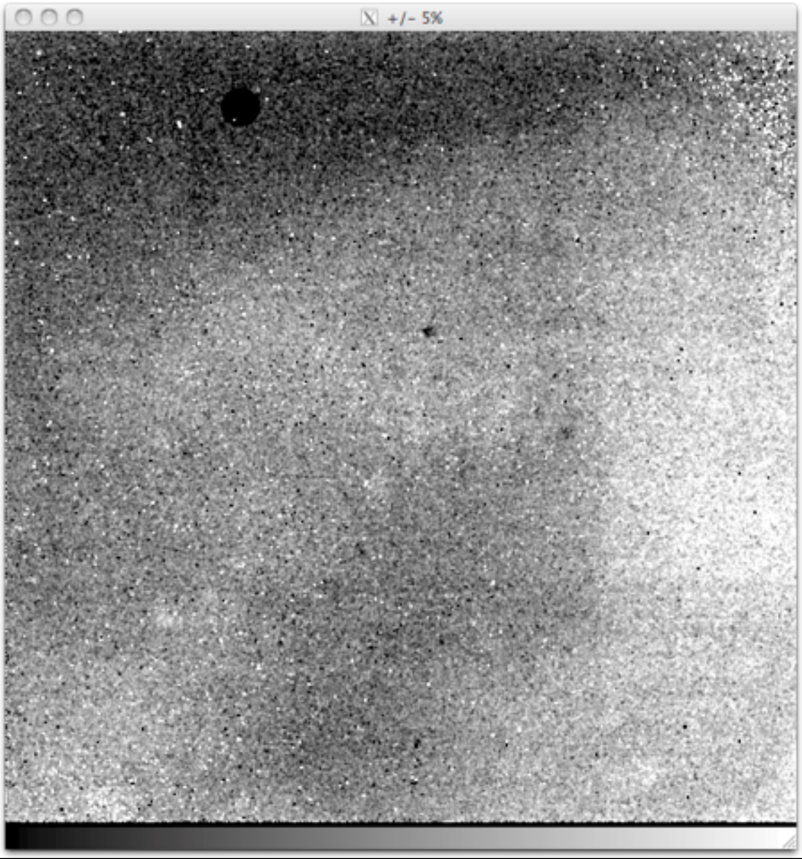
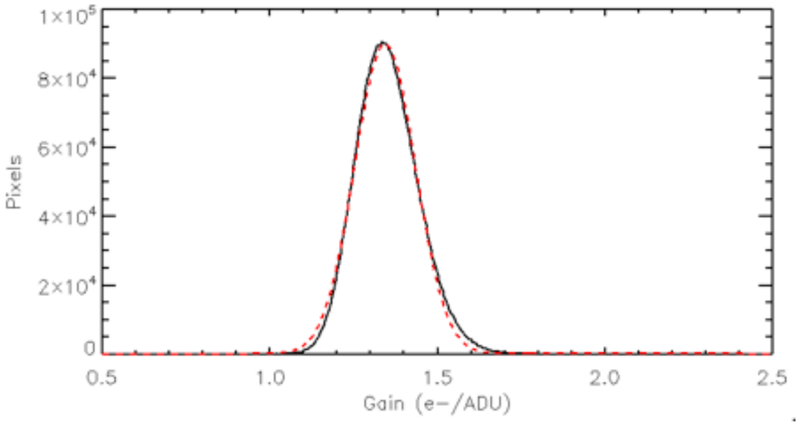
	SCA 492
	Gaussian Fit Peak: 1.348 Sigma:0.098

Fig. 4 Pixel-to-pixel gain map for SCA 492 (top) and distribution with Gaussian fit (bottom)

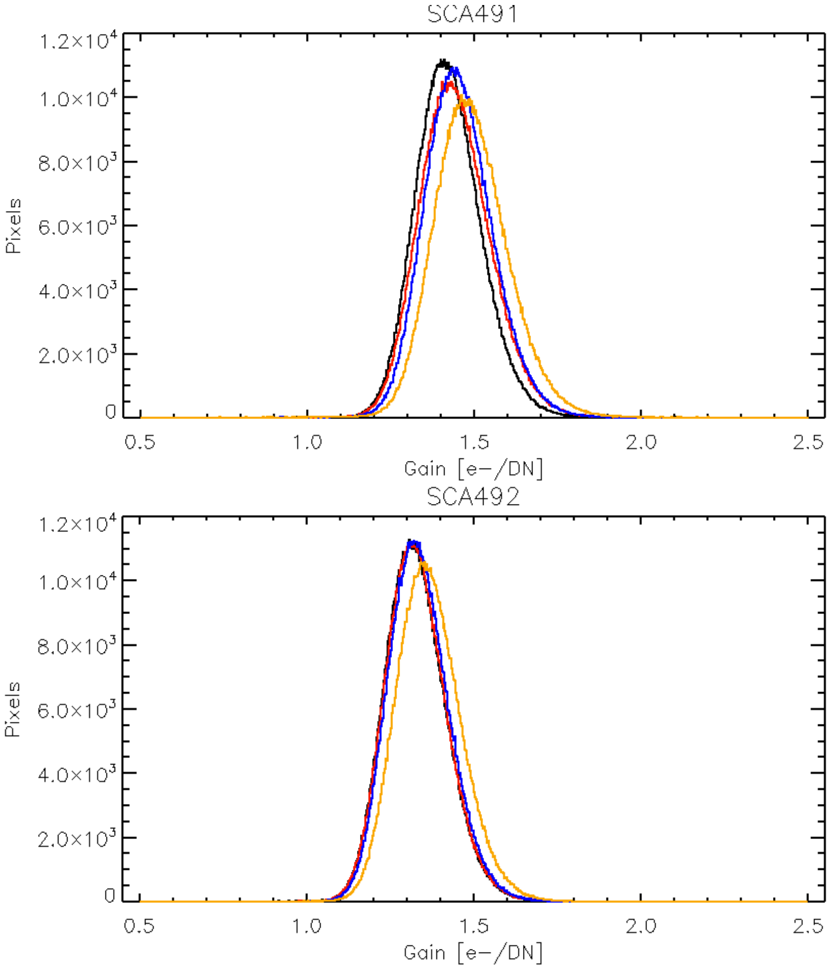


Fig. 5. Distribution of the gain in each output (1-Black, 2- Red, 3-Blue, 4-Orange) in SCA491 (top) and SCA492 (bottom).

The final gain maps have been renormalized to the average gain listed in table 4. While new gain maps cannot be obtained anymore once the focal plane is installed in NIRSpec, the global gain cans still be measured at instrument level. Small variation of the tuning can produce variations in the global gain. If necessary the global gain can be adjusted and the gain maps can be re-normalized. For pixels with zero or negative gain, the average gain obtained in paragraph 3 and listed in Table 4 is used.

5 READNOISE MAPS

New for Build 3. The read noise reference files contain the average correlated double sampling (CDS) noise calculated from the difference of the first two consecutive frames in dark exposures. Although CDS noise varies from pixel to pixel for FPA104 we deliver maps where the pixel CDS noise is the average CDS noise in a given output. FPA104 is rapidly degrading and shows an increasing number of hot pixels. For those pixels the CDS noise measurement is contaminated by the possson noise of the charge generated in a frame time. An accurate determination of the CDS noise per pixel does requires many exposures, many dark than those available from ISIM CV2 testing. Due to the limited data available we calculated a spatial average CDS noise for each output.

For each output the average CDS noise in regular and reference pixels has been converted in units of electrons by multiplying the calculated CDS noise with the conversion gain factor listed in table 6.

6 AMPLIFIER TABLES

Deprecated for BUILD 3 . The amplifier tables have been created using the matching pixel-to-pixel gain maps. For each SCA output, the gain values have been averaged using the IDL meanclip.pro procedure considering only positive gain values greater than zero. The read noise values were not calculated and are set to a value of 14 e- in all cases. Table 6 lists the contents of the two delivered reference files. The x/y start/stop values are in the Python slicing convention, i.e. start/stop values of 0/512 correspond to 1/512 in the fits I/O indexing convention.

Table 6: The contents of the two delivered amplifier reference files. The values in the GAIN column are in e^-/DN, the ones in the READNOISE column in e^-.

Filename	AMPLIFIER	XSTART	XSTOP	YSTART	YSTOP	GAIN	READNOISE
nirspec_ampl_nrs1_f_01.00.fits	A	0	512	0	2048	1.459	14.0
	B	512	1024	0	2048	1.444	14.0
	C	1024	1536	0	2048	1.454	14.0
	D	1536	2048	0	2048	1.537	14.0
nirspec_ampl_nrs2_f_01.00.fits	A	0	512	0	2048	1.327	14.0
	B	512	1024	0	2048	1.328	14.0
	C	1024	1536	0	2048	1.336	14.0
	D	1536	2048	0	2048	1.366	14.0

7 REFERENCES

[1]. Hanisch et al. 2001, Astronomy & Astrophysics, 376, 359

[2]. NTN-2013-007, NIRSpec reference data product specification, G. Giardino 2013

[3]. NTN-2011-005 Description of the NIRSpec pre-processing pipeline, S. Birkmann 2011

[4]. JWST-RPT-016094 NIRSpec DS Focal Plane Assembly S/N 104 Characterization Report, GSFC 2010

8 APPENDIX -1

List of background exposures used for the classical photon transfer method:

NRS_A_38_5_QE_BG_600nm_01_1_6617_JW1_jlab81_20100402T114504_20100402T114625
NRS_A_38_5_QE_BG_600nm_01_2_6618_JW1_jlab81_20100402T114634_20100402T114751
NRS_A_38_5_QE_BG_600nm_01_3_6619_JW1_jlab81_20100402T114759_20100402T114915
NRS_A_38_5_QE_BG_600_02_1_6620_JW1_jlab81_20100402T115402_20100402T115521
NRS_A_38_5_QE_BG_600_02_2_6621_JW1_jlab81_20100402T115530_20100402T115647
NRS_A_38_5_QE_BG_600_02_3_6622_JW1_jlab81_20100402T115655_20100402T115813
NRS_A_38_5_QE_BG_600_03_1_6626_JW1_jlab81_20100402T121100_20100402T121221
NRS_A_38_5_QE_BG_600_03_2_6627_JW1_jlab81_20100402T121229_20100402T121345
NRS_A_38_5_QE_BG_600_03_3_6628_JW1_jlab81_20100402T121354_20100402T121511
NRS_A_38_5_QE_BG_700_01_1_6629_JW1_jlab81_20100402T122546_20100402T122707
NRS_A_38_5_QE_BG_700_01_2_6630_JW1_jlab81_20100402T122716_20100402T122833
NRS_A_38_5_QE_BG_700_01_3_6631_JW1_jlab81_20100402T122842_20100402T122959
NRS_A_38_5_QE_BG_800_01_1_6635_JW1_jlab81_20100402T124808_20100402T124927
NRS_A_38_5_QE_BG_800_01_2_6636_JW1_jlab81_20100402T124936_20100402T125053
NRS_A_38_5_QE_BG_800_01_3_6637_JW1_jlab81_20100402T125103_20100402T125219
NRS_A_38_5_QE_BG_800_02_1_6641_JW1_jlab81_20100402T133320_20100402T133441
NRS_A_38_5_QE_BG_800_02_2_6642_JW1_jlab81_20100402T133449_20100402T133607
NRS_A_38_5_QE_BG_800_02_3_6643_JW1_jlab81_20100402T133616_20100402T133733
NRS_A_38_5_QE_BG_900_01_1_6647_JW1_jlab81_20100402T140719_20100402T140839
NRS_A_38_5_QE_BG_900_01_2_6648_JW1_jlab81_20100402T140848_20100402T141005
NRS_A_38_5_QE_BG_900_01_3_6649_JW1_jlab81_20100402T141014_20100402T141131
NRS_A_38_5_QE_BG_1000_01_1_6653_JW1_jlab81_20100402T142826_20100402T142947
NRS_A_38_5_QE_BG_1000_01_2_6654_JW1_jlab81_20100402T142955_20100402T143114
NRS_A_38_5_QE_BG_1000_01_3_6655_JW1_jlab81_20100402T143121_20100402T143239
NRS_A_38_5_QE_BG_1200_01_1_6659_JW1_jlab81_20100402T145247_20100402T145409
NRS_A_38_5_QE_BG_1200_01_2_6660_JW1_jlab81_20100402T145418_20100402T145535
NRS_A_38_5_QE_BG_1200_01_3_6661_JW1_jlab81_20100402T145544_20100402T145659
NRS_A_38_5_QE_BG_1400_01_1_6665_JW1_jlab81_20100402T151218_20100402T151337
NRS_A_38_5_QE_BG_1400_01_2_6666_JW1_jlab81_20100402T151346_20100402T151503
NRS_A_38_5_QE_BG_1400_01_3_6667_JW1_jlab81_20100402T151512_20100402T151629
NRS_A_38_5_QE_BG_1600_01_1_6671_JW1_jlab81_20100402T153256_20100402T153415
NRS_A_38_5_QE_BG_1600_01_2_6672_JW1_jlab81_20100402T153424_20100402T153541
NRS_A_38_5_QE_BG_1600_01_3_6673_JW1_jlab81_20100402T153552_20100402T153707
NRS_A_38_5_QE_BG_1800_01_1_6677_JW1_jlab81_20100402T154954_20100402T155113
NRS_A_38_5_QE_BG_1800_01_2_6678_JW1_jlab81_20100402T155122_20100402T155239
NRS_A_38_5_QE_BG_1800_01_3_6679_JW1_jlab81_20100402T155248_20100402T155405
NRS_A_38_5_QE_BG_2000_01_1_6683_JW1_jlab81_20100402T161258_20100402T161417
NRS_A_38_5_QE_BG_2000_01_2_6684_JW1_jlab81_20100402T161426_20100402T161543
NRS_A_38_5_QE_BG_2000_01_3_6685_JW1_jlab81_20100402T161554_20100402T161709
NRS_A_38_5_QE_BG_2300_01_1_6689_JW1_jlab81_20100402T163129_20100402T163243
NRS_A_38_5_QE_BG_2300_01_2_6690_JW1_jlab81_20100402T163251_20100402T163410
NRS_A_38_5_QE_BG_2300_01_3_6691_JW1_jlab81_20100402T163417_20100402T163535
NRS_A_38_5_QE_BG_2600_01_1_6695_JW1_jlab81_20100402T164952_20100402T165113
NRS_A_38_5_QE_BG_2600_01_2_6696_JW1_jlab81_20100402T165121_20100402T165239
NRS_A_38_5_QE_BG_2600_01_3_6697_JW1_jlab81_20100402T165248_20100402T165405

NRS_A_38_5_QE_BG_2900_01_1_6701_JW1_jlab81_20100402T170758_20100402T170919
NRS_A_38_5_QE_BG_2900_01_2_6702_JW1_jlab81_20100402T170928_20100402T171045
NRS_A_38_5_QE_BG_2900_01_3_6703_JW1_jlab81_20100402T171054_20100402T171212
NRS_A_38_5_QE_BG_3200_01_1_6707_JW1_jlab81_20100402T172459_20100402T172621
NRS_A_38_5_QE_BG_3200_01_2_6708_JW1_jlab81_20100402T172630_20100402T172747
NRS_A_38_5_QE_BG_3200_01_3_6709_JW1_jlab81_20100402T172756_20100402T172913
NRS_A_38_5_QE_BG_3500_01_1_6713_JW1_jlab81_20100402T174134_20100402T174255
NRS_A_38_5_QE_BG_3500_01_2_6714_JW1_jlab81_20100402T174304_20100402T174421
NRS_A_38_5_QE_BG_3500_01_3_6715_JW1_jlab81_20100402T174430_20100402T174546
NRS_A_38_5_QE_BG_3800_01_1_6719_JW1_jlab81_20100402T180012_20100402T180133
NRS_A_38_5_QE_BG_3800_01_2_6720_JW1_jlab81_20100402T180142_20100402T180257
NRS_A_38_5_QE_BG_3800_01_3_6721_JW1_jlab81_20100402T180306_20100402T180423
NRS_A_38_5_QE_BG_4100_01_1_6725_JW1_jlab81_20100402T181724_20100402T181845
NRS_A_38_5_QE_BG_4100_01_2_6726_JW1_jlab81_20100402T181854_20100402T182009
NRS_A_38_5_QE_BG_4100_01_3_6727_JW1_jlab81_20100402T182018_20100402T182135
NRS_A_38_5_QE_BG_4400_01_1_6731_JW1_jlab81_20100402T184137_20100402T184251
NRS_A_38_5_QE_BG_4400_01_2_6732_JW1_jlab81_20100402T184300_20100402T184418
NRS_A_38_5_QE_BG_4400_01_3_6733_JW1_jlab81_20100402T184428_20100402T184544
NRS_A_38_5_QE_BG_4700_01_1_6737_JW1_jlab81_20100402T190038_20100402T190157
NRS_A_38_5_QE_BG_4700_01_2_6738_JW1_jlab81_20100402T190206_20100402T190323
NRS_A_38_5_QE_BG_4700_01_3_6739_JW1_jlab81_20100402T190332_20100402T190449
NRS_A_38_5_QE_BG_5000_01_1_6743_JW1_jlab81_20100402T192417_20100402T192537
NRS_A_38_5_QE_BG_5000_01_2_6744_JW1_jlab81_20100402T192545_20100402T192703
NRS_A_38_5_QE_BG_5000_01_3_6745_JW1_jlab81_20100402T192712_20100402T192829