



# NIRSpec Technical Note

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# NIRSpec reference files and quality flags

## Abstract:

This report provides an overview of the structure and content of the reference files and data quality flags used by the NIRSpec pipeline (version 0.33). A more detailed characterization of the data content of these reference files for each FPA and operational temperature will be provided in a separate document at the completion of the analysis of the data.

## 1 INTRODUCTION

To compute the count rate images from the input exposure raw data and to flag potentially problematic pixels, the pre-processing pipeline uses a set of Reference Files. There are essentially two types of reference files: *data* reference files, encapsulating information used directly by the pipeline to compute the count rate images, and *quality* reference files, or *masks*, capturing information about the quality of a pixel intrinsic response or the quality of the reference data used during a particular processing step, for that pixel. These, mostly binary, quality masks are combined by the pre-processing pipeline into a Data Quality map that provides essential information about the reliability and usability of each pixel count rate value beside that encapsulated in the value formal error. The quality map for each count rate image is stored in the third extension (named DQ) of the pipeline output count rate files. Table 2 in the Appendix lists all the quality flags identified, so far, for the NIRSpec data.

## 2 DESCRIPTION OF REFERENCE FILES

All the Reference Files used by the pre-processing pipeline are (multi-extension) FITS files, stored at the public FTP site: <ftp://ftp.rssd.esa.int/pub/jwstlib/refData/>

The FITS header of each extension in a Reference file provides some basic information about the extension data content and contains the HDU CHECKSUM and DATASUM value to allow the extension and its data content to be uniquely identified<sup>1</sup>. The value of this CHECKSUM for the Reference Files used by the pre-processing pipeline when processing a given exposure is stored by the pipeline in the HISTORY section of the header of the output count rate file.

A summary of the naming convention for the Reference Files, their content and the way they are organized in the directory structure is provided in Table 1, below.

## FILE NAMING CONVENTION FOR REFERENCE FILES

### MAIN PATH:

/Software/JWST\_C/var/

### DIRECTORY STRUCTURE:

'FPA'+3digit FPA ID+'\_T'+4digit Temperature

example: FPA104\_T3850 for FPA 104 at 38.5 K

FPA103\_T4100 for FPA 103 at 41.0 K

### FILENAME STRUCTURE:

4 uppercase letters for content description+"\_" +3 digit for SCA ID+"\_" +3 digits for version+extension

#### LIST OF FILES THAT SHOULD BE PRESENT IN EACH FPAXXX\_TYYYY DIRECTORY:

NAME (example)	Content	Note
BIAS_491_001.fits	Super bias, plus: - Hot pixels mask - Warm pixels mask - Bad reference pixel mask - Bad Bias mask - High total noise pixel mask - Total noise map	Multi-extension file
DEAD_491_001.fits	Map of dead Pixels (shorted pixels)	0=good pixel 1=dead pixel
DRKC_491_001.fits	Dark super cube (for generating dynamic darks)	Multi-extension file – Number of samples used to generate each GROUP also provided in extension NGROUPS
FLAT_491_001.fits	Flat Field, plus: - Unreliable flat pixel mask	Multi-extension file
FFTR_491_001.fits	Coefficients for FFT filtering of reference pixels (prior to subtraction)	
GAIN_491_001.fits	Gain map	

<sup>1</sup> CHECKSUM and DATASUM are not yet present for all Reference Files

IPCC_491_001.fits	Inter Pixel Capacitance Correction	
LINC_491_001.fits	Linearity Correction coefficients map, plus - Unreliable linearity correction mask	Multi-extension file
LOWQ_491_001.fits	Low QE pixels mask	
MASK_491_001.fits	Input mask to the pre-processing pipeline with combined flagging from following masks: DEAD, LOWQ, OPEN, OPAD	See table of Flags
OPEN_491_001.fits	Mask of open pixels	0=good pixel 1=open pixel
OPAD_491_001.fits	Mask of pixels adjacent to open pixels	0=good pixel 1=pixel adjacent to open pixel
RTSP_491_001.fits	Map of pixels with Random Telegraphic Signal	0=good pixel 1=RTS pixel

**Table 1** List of reference files

We describe the content of the Reference Files in more detail in the following sections. Note that all the binary masks are 8-bit images and the convention we use is: 0, for ‘no problem/pixel is OK’ and 1 for ‘problem/bad pixel’.

## 2.1 BIAS File (BIAS\_491/2\_XXX.fits)

As shown in Fig. 1, the BIAS reference file consists of one primary array and six extensions. The primary array of this file contains the super-bias or master bias. This is in fact the first-group image of the super-dark cube (see DARK file below for an explanation of how the super-dark cube is obtained). Note that to improve the statistic significance of this Bias image, the list of dark exposures used to produce the super-dark cube includes also a 100-integrations (of 1 group each) dark exposure especially acquired during the Performance and Calibration tests. The header provides the file name of all the exposures that were used by the ‘*imcombine*’ program to generate the super-dark cube and, hence, the super-bias. The total number of exposures used is also given in the header (Keyword IMCMB\_NO). Note that, by default, the pre-processing pipeline subtracts the bias image from the first group of the integration-ramp of the exposure.

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BIAS_491_004.fits has 6 extensions
Primary header: 396 records
Image -- Real*4 array ( 2048 2048 )
Extension 1 -- HOT
      Header : 13 records
      IMAGE ( 2048 2048 )
Extension 2 -- WARM
      Header : 13 records
      IMAGE ( 2048 2048 )
Extension 3 -- BREF
      Header : 12 records
      IMAGE ( 2048 2048 )
Extension 4 -- BBIAS
      Header : 12 records
      IMAGE ( 2048 2048 )
Extension 5 -- HINDOISE
      Header : 13 records
      IMAGE ( 2048 2048 )
Extension 6 -- TOTNOISE
      Header : 12 records
      IMAGE ( 2048 2048 )

```

**Fig. 1** FITS File structure for the BIAS reference file

The first extension of this file (named HOT) contains the **Hot Pixels mask**. Hot pixels are defined as pixels with dark current greater than 0.1 e-/s. The mask is derived from the super-dark cube count rate image computed from the super-dark cube by the pre-processing pipeline. Note that in this case, during processing, Inter-Pixel Capacitance (IPC) correction is applied to the each group in the integration ramp; this is done to prevent that normal pixels adjacent to Hot pixels are classified as ‘Hot’ because, due to IPC, a fraction of signal from the Hot pixel effectively spills over to the adjacent pixels.

The second extension of this file (WARM) contains the **Warm Pixels mask**. Warm pixels are defined as having dark currents within the range 0.01–0.1 e-/s and are derived in the same way as the Hot pixels from the super-dark count rate image.

The third extension (BREF) contains the **Bad Reference Pixels mask**. The Reference Pixels are located in the 4 rows and columns at the detector edges. They are insensitive to light and are used by the pre-processing pipeline to correct each group in the integration ramp for bias drifts. Also in this case the count rate image derived from the super-dark cube is used to identify the Bad Reference Pixels. We flag a reference pixel as bad if its

value in the super-dark image is greater than the reference pixels average<sup>2</sup> plus 3.5 times their standard deviation (STD).

The fourth extension (BBIAS) contains the Bad Bias Pixels mask. Pixels are defined as having an unreliable bias, if their standard deviation is more than five times the average (clipped) standard deviation of all pixels.

The fifth extension of the BIAS file, named HINOISE, contains the **High Noise Pixels mask**. High Noise Pixels are defined to be pixels with total noise value greater than 12 e- in the **Total Noise Map** which is stored in the sixth (and last) extension of this file (named TOTNOISE). This map is created from the count rate images of all the dark used to build the super-dark cube (using only the 88-groups exposures), generated on the fly while building the super-dark cube. For each pixel, the percentile clipped STD<sup>3</sup> over all the dark images in electron rates is computed, and then this STD map is multiplied by the integration time of an 88-group exposure. The Total Noise map itself is not used by the pipeline but it is saved within the BIAS file as reference for the High Noise Pixels mask.

## 2.2 DEAD mask (DEAD\_491/2\_xxx.fits)

This file provides the mask of dead or shorted pixels, i.e. pixels that do not respond to light. Dead or shorted pixels are identified as those with response less than 0.05 times the local Quantum Efficiency (QE) calculated over a 15x15-pixel box. This reference mask is not used directly by the pre-processing pipeline, but it is used as an input to the program that builds the pipeline input MASK reference file (see 2.10).

## 2.3 DARK Cube file (DRKC\_491/2\_xxx.fits)

This reference file is used by the pipeline to, optionally, subtract the dark current signal from the count rate images of illuminated exposures. However, rather than using a single dark count rate image, for each detector, for every (illuminated) exposure, the pre-processing pipeline uses the dark cube to dynamically generate a dark count rate image using the same number of groups as the illuminated count rate image. This is because, during the analysis of the detector test data, it was found that the accuracy of the dark subtraction is improved by using dark images obtained from up-the-ramp integrations with the same number of groups as used to generate the illuminated count rate image itself. Thus, to be able to produce dark rate-images with the appropriate number of groups for any given exposures, the pipeline uses the reference super-dark cube to generate, on the

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<sup>2</sup> 3sigma-clipped average and STD is used.

<sup>3</sup> By percentile-clipped average and STD we mean average and STD computed after discarding from the data-set the lowest and highest 5%

fly, the appropriate dark rate-image. Note that the number of groups actually used by the pipeline to compute the count rate image may vary from pixel to pixel due to saturation; in computing the dark rate image, the pipeline uses the same number of groups used to generate the illuminated count rate image, for each individual pixel; this number is stored in the extension SAMP (number 4) of the pipeline output count rate FITS files (see description of count-rate file format in NTN-2011-004). The knowledge of the number of groups used in computing the count rate signal for each individual pixel can also be used, subsequently, to re-create the dark image which was actually subtracted from the count rate image of a given exposure, starting from the reference super-dark cube<sup>4</sup>.

The reason why we refer to this file as the ‘super’-dark cube is that the cube is generated by combining many dark exposures, group-by-group. Each group of the super-cube integration ramp is the percentile clipped average over the same group in many dark exposures. The super-dark cube is stored in the primary data array of the DRKC file. The header lists the total number and file name of all dark exposures that were used to generate the super-cube. Because the number of samples that are used to build the groups of the super-cube may differ (for example there are many more samples going into computing the average for the first group of the super-dark cube – which is in fact the super-bias – than there are for the subsequent groups), the number of samples actually used to compute each group image of the super cube is recorded in a binary table stored in the first extension of the DRKC file. This extension is named NGROUPS.

```
DRKC_492_002.fits has 1 extensions
Primary header: 397 records
Image -- Real*4 array ( 2048 2048 88 )
Extension 1 -- NGROUPS
                Header : 14 records
                Binary Table ( 2 88 )
```

**Fig. 2** – FITS file structure for the DRKC reference file.

## **2.4 FOURIER COEFFICIENTS for Reference Pixel subtraction (FFTR\_491/2\_XXX.fits)**

This file provides the weighting coefficients to be applied to the Fourier transform of the reference pixel signal. To suppress part of the  $1/f$  noise affecting the detector electronics,

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<sup>4</sup> A specific program to recreate the dark image used by the pipeline starting from the Reference super-dark cube and using the SAMP extension in the count rate file will be provided (not available yet)

the signal of the reference pixels is filtered in Fourier domain using the weighting coefficients provided in this reference file, before subtracting it from each group image (see detail in the Pre-processing Pipeline documentation).

## 2.5 FLAT FIELD file (FLAT\_491/2\_xxx.fits)<sup>5</sup>

The primary extension of this file provides the count rate images of the detector response under flat illumination at 20 different wavelengths.

The second extension (named BFLAT) provides a mask of pixel with **Unreliable Flat Field** value.

## 2.6 GAIN file (GAIN\_491/2\_xxx.fits)

This file provides the detector gain map, i.e. the coefficient used by the pre-processing pipeline to convert the derived count rate, for each pixel, from counts/s to e-/s. Note that the map is normalised to 1 and the Gain scale factor is stored in keyword GAIN\_EDN of the file header.

## 2.7 INTER-PIXEL CAPACITANCE correction kernel (IPCC\_491/2\_xxx.fits)

This file provides the 3x3-kernel for the Inter-Pixel Capacitance correction that can be, optionally, executed by the pre-processing pipeline during the computation of the count rate images. For each detector there are 4 different kernels (organized as cube in the reference file), one for each detector output.

## 2.8 LINEARITY correction coefficients (LINC\_491/2\_xxx.fits)

The primary data array of this file provides, for each pixel, the saturation threshold and the four coefficients used by the pre-processing pipeline to correct the detector non-linear response. The first extension of the file (named BLIN) provides a mask of pixels with **Bad Linearity Correction**: pixels for which the linearity correction is unreliable.

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<sup>5</sup> At the time of writing this document the Flat Field correction is not applied as part of the pipeline steps.

## **2.9 LOW QE (LOWQ\_491/2\_XXX.fits)**

This file provides a mask of pixels with low Quantum Efficiency. A pixel is flagged as having low QE if it is not an open pixel (see 2.11) and its QE falls between 0.05 and 0.5 times the local median QE. This reference mask is not used directly by the pre-processing pipeline, but it is used to generate the pipeline-input MASK reference file (see 2.10)

## **2.10 MASK file (MASK\_491/2\_XXX.fits)**

This mask file is the only non-binary mask of the reference set, i.e. the only mask containing integer values other than zeros and ones. It is a 16-bits map obtained by computing the flag value for each pixel according to its value in the binary masks of Dead, Low QE, Open, and Adjacent-to-Open pixels (see Table 1). This file therefore does not contain any extra-information beside that already available in the corresponding binary-masks. It is generated only for convenience: to provide the pipeline with a single input file, rather than four. Note that all these four input binary masks are expected to evolve slowly during the detector lifetime, so that new version of these and of the MASK file will be relatively infrequent, compared to e.g. new versions of Hot and Warm Pixels masks, which have to be re-created each time a new super-dark is generated.

## **2.11 OPEN Pixels mask (OPEN\_491/2\_XXX.fits)**

This mask file flags the position of the “Open pixels” (Simms et al. 2007). Some pixels are considered “open” in the sense that the signal generated within this pixel is not correctly collected by the detector electronics but leaks into neighbouring pixels, altering their values. Open pixels do not record any useful signal and cannot be used for science. A pixel is masked as open if the pixel’s QE falls between 0.05 and 0.5 times the local median QE and the median of the four-neighbour pixels is greater than 1.05 the local median QE. This reference mask is not used directly by the pre-processing pipeline, but it is used to generate the pipeline-input MASK file (see 2.10)

### **2.11.1 ADJACENT TO OPEN Pixels mask (OPAD\_491/2\_XXX.fits)**

Pixels Adjacent to Open Pixels are the eight neighbours of an open pixels. When the detector is illuminated, these pixels do not provide any useful reading because their signal is contaminated by the signal “leaking” out the central open pixel. They can be used to collect Dark Current statistics (because in this case there is no signal incident on the central pixel).



## **2.12 TELEGRAPHIC Pixels mask (RTSP\_491/2\_xxx.fits)**

The signal reading for these pixels is compromised by Telegraphic Random Noise injected by the detector electronics and the pixels cannot be used.

## **3 REFERENCES**

L. M. Simms, Donald F. Figer, Brandon J. Hanold, Daniel J. Kerr, D. Kirk Gilmore, Steven M. Kahn and J. Anthony Tyson, "First use of a HyViSI H4RG for astronomical observations", Proc. SPIE 6690, 66900H (2007); doi:10.1117/12.740088

NTN-2011-004, Description of the NIRSpec pre-processing pipeline, S. Birkmann

## 4 APPENDIX

Flag value	Bit setting	Data quality	Comment	Processing stage
0	0000 0000 0000 0000	OK		Input
1	0000 0000 0000 0001	Open pixel	Unusable	Input
2	0000 0000 0000 0010	Adjacent Open pixel	Unusable for science (OK for darks)	Input
4	0000 0000 0000 0100	Hot pixel (#)	Unusable	Input
8	0000 0000 0000 1000	Warm pixel (#)	Higher error in science data	Input
16	0000 0000 0001 0000	Shorted pixel	Unusable	Input
32	0000 0000 0010 0000	Telegraph pixel	Unusable - values fluctuates randomly	Input
64	0000 0000 0100 0000	Low QE pixel	Probably unusable for science	Input
128	0000 0000 1000 0000	Bad Reference pixel (#)	Unusable	Input
256	0000 0001 0000 0000	Unreliable Linearity correction	Probably unusable for science	Linearity correction
512	0000 0010 0000 0000	Unreliable Flat Field correction(*)	Probably unusable for science	Flat-field correction
1024	0000 0100 0000 0000	High Total Noise (#)	Probably unusable for science	Input
2048	0000 1000 0000 0000	Unreliable Bias correction(*#)	Probably Unusable for science	Bias correction

4096	0001 0000 0000 0000	Pixel affected by ghost/crosstalk	Unusable for science	Output
8192	0010 0000 0000 0000	Cosmic ray	Higher error in science data	Output
16384	0100 0000 0000 0000	Saturated pixel(+)	Probably Unusable for science	Output
32768	1000 0000 0000 0000	No Linearity correction and saturation check applied	Probably Unusable for science	Output

(#) Derived from Super-Dark-cube

(\*) Pixel will not be corrected

(+) Saturation occurred before second group

**Table 2** List of quality flags for NIRSpec data