The JWST NIRSpec Calibration Pipeline

Abstract

The James Webb Space Telescope will launch in 2018 with the Near Infrared Spectrograph on board. NIRSpec will be capable of observing the sky at 0.6 - 5.0 microns in three modes: fixed slits, the integral field unit and the micro-shutter array. The Space Telescope Science Institute (STScI) is currently building a data reduction pipeline that will provide not only basic calibrated data but also higher level science products. The pipeline is divided into three main levels. Level one will produce calibrated slope data for individual integrations (ramps). Level two will create the calibrated spectra for an integration and level three will combine data from multiple integrations. Details of the NIRSpec pipeline steps will be presented and demonstrations will be available.

Ramps-to-Slopes Pipeline
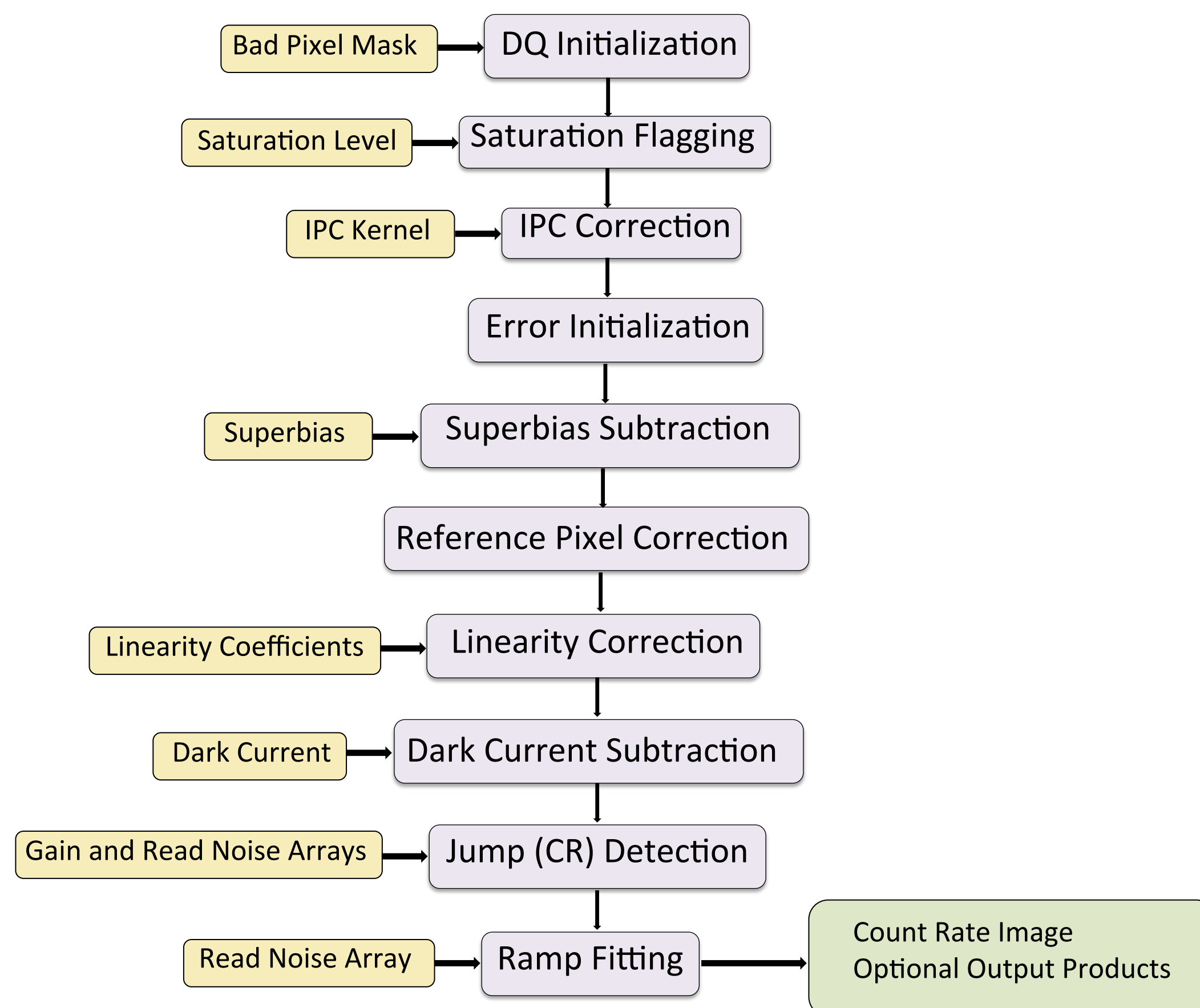
The pipeline flows presented here are in the default order of the step tasks written by the Science Software Branch at STScI. The JWST ramps to slopes pipeline is common to all NIR instruments. Raw data from the telescope is input and is first initialized with science, error and data quality (and populated with flags from the reference file) extensions. Next the science array is checked against the saturation array and flagged appropriately. Because the ramps to slopes pipeline is common to all NIR instruments there is an IPC correction module, for NIRSpec the current default is for this to be turned off. After error initialization, a superbias is subtracted For NIRSpec there are 2 methods of reference pixel correction, a standard boxcar method of the vertical and horizontal reference pixels or the IRS[2] method described further at the right. Next, using the coefficients in the reference file each pixel is corrected for non-linearity, followed by subtracting the dark current. The last two steps are to identify jumps in the ramp data using the technique described to the right and then fitting a ramp to the pixel to produce the slope image that will be used as input to the spectroscopic pipeline. Additionally, the user can choose to produce an optional output product containing the slopes, uncertainties in the slopes, y-intercept, uncertainty in the y-intercept, and fitting weights for each ramp interval of each pixel, to further explore the details of the jump detection and ramp fitting.

Generalized Least Squares Ramp Fitting

The generalized least squares (GLS) fitting technique in the ramp fitting step offers a quick and accurate method of detecting cosmic rays, noise spikes and negative jumps in a ramp. To do this it employs a covariance matrix to derive the slope and variance in the slope directly. It is optimal for the read noise dominated regime, therefore the 2 point difference method will be used as a first pass and GLS ramp fitting only as a second pass.

IRS[2]

NIRSpec has the most stringent total noise requirement (6 e- rms) of all the JWST instruments. In order to meet this requirement a new reference pixel sampling method was developed that interleaves the reading of reference pixels within the readout of the science section of the detector. IRS2 allows for background measurements to be taken farther away from the target, possibly allowing for more MOS shutters to be used for targets. IRS2 is only for full frame mode.

Demos

Demonstrations of the NIRSpec fixed slit pipeline (ramps to slopes and spectroscopic levels) are available at anytime during the meeting. Development of the pipeline is ongoing and any feedback you have is welcome and appreciated. Please find Cheryl Pavlovsky to set up a time.

What's Next?

Build 5 – Delivery Fall 2015
Includes algorithms for the FS pipeline, implementation of generalized least squares fitting for ramp fitting.

Build 6 – Delivery May 2016
Will include the infrastructure for level 3 (combination of exposures) processing for all NIRSpec modes and the implementation of the spectroscopic level processing algorithms for the IFU and MOS modes

Build 7 – Delivery January 2017
Will include the implementation of the level 3 processing algorithms for all 3 NIRSpec modes: fixed slits, IFU and MOS

Spectroscopic Pipeline for Fixed Slits
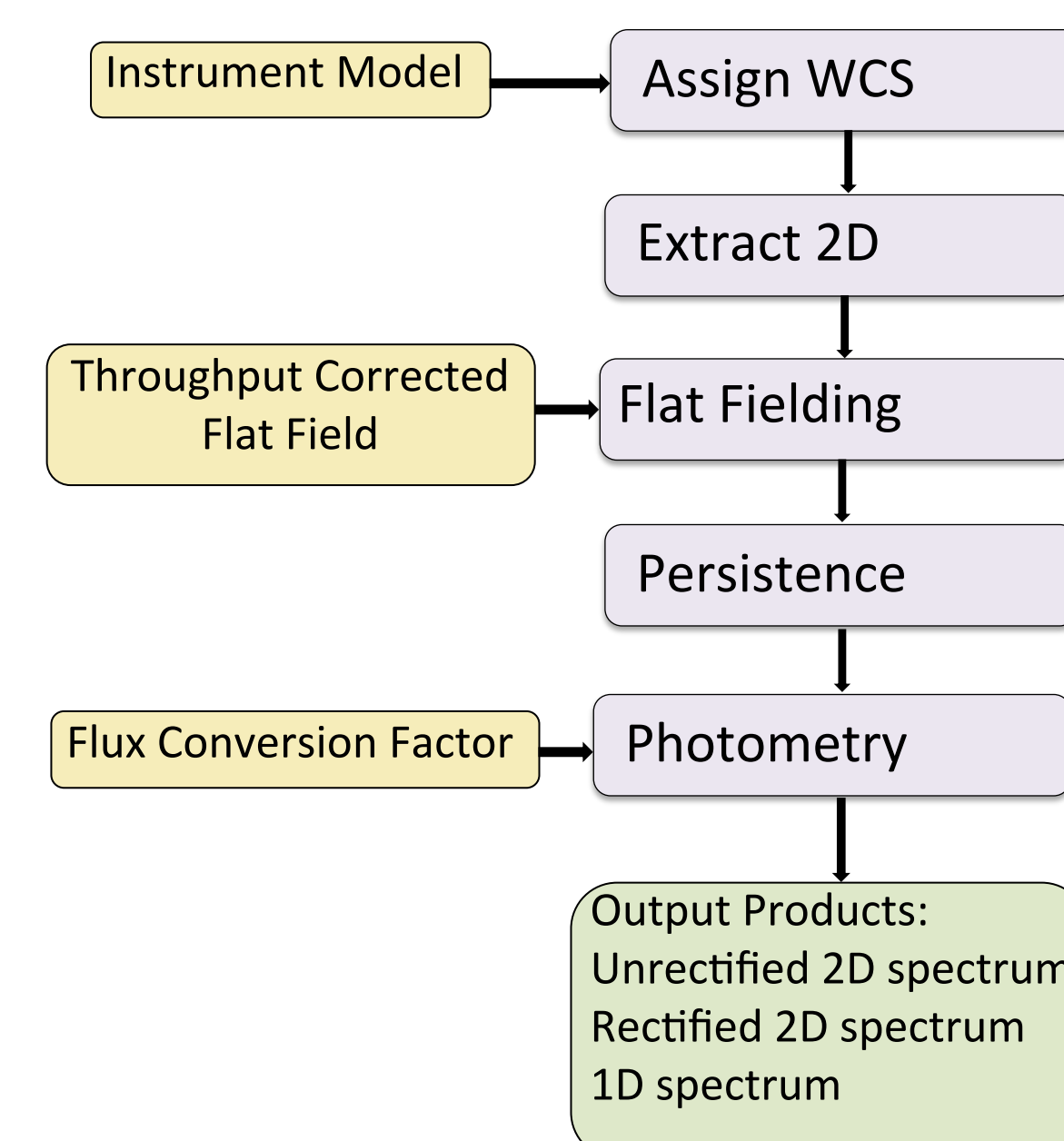
At the spectroscopic level the JWST pipeline diverges for the different NIR instruments and the modes within the instruments. Presented here is the current flow of the spectroscopic fixed slit pipeline. One option for fixed slits is to dither within the slit to obtain a measure of the background. When the user selects this option, their nodded data will be subtracted from each other to obtain the inverse before the assign WCS step. The pipeline will also automatically create the necessary association table.

The assign WCS task then uses the instrument model to adjust for the MSA configuration, grating wheel position, and optical transformations before each slit is extracted and placed in its own extension of a single file. To do the flat field correction, corresponding data from the reference file is extracted before applying to the individual science extensions. Afterward, a correction for persistence will be done before the flux calibration is done in the photometry step. The photometry step will either attach a keyword value corresponding to the relative response curve or attach a flux calibration curve as an extension.

There will be 3 standard output products from the spectroscopic pipelines, an unrectified 2D spectrum for input into the level 3 pipeline, and a rectified 2D spectrum and 1D spectrum for quicklook products for the user.

NIRSpec Level 3 Pipelines

The main tasks of the level 3 pipeline for all 3 instrument modes is to rectify and combine the spectra for individual targets. For data that has not been nodded the level 3 pipeline will also perform background subtraction.

There is an ongoing effort to supply users with higher level data products from the pipeline such as mosaicked images for IFU data and target catalogs of MOS data. In addition, a working group at STScI is also developing data analysis tools for further inspection of pipeline processed data. Please see the posters by Muzerolle and Kassin for further information.

Previous Builds

Build 1 was delivered in 2012 and included infrastructure for the ramps to slopes pipeline common for all the instruments on JWST.

Build 2 was delivered in Fall 2013 and included the processing algorithms for the ramps to slopes pipeline and the infrastructure for the NIRSpec Fixed Slit (FS) Spectroscopic pipeline.

Build 3 was delivered in Fall 2014 included updates to the ramps to slopes pipeline, and infrastructure for the FS, IFU and MOS spectroscopic pipelines.

Build 4 was delivered in April 2015 and included the coronagraphic pipelines on the other JWST instruments.

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