JWST/NIRSpec Multi-Object Spectroscopy: Calibration & Data Products

James Muzerolle & the NIRSpec team *(Space Telescope Science Institute)*

Operated for NASA by AURA

(see related posters by Karakla and Gilbert)

Introduction

The Near-Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope (JWST) provides a multi-object spectroscopic capability via the Microshutter Array (MSA). The MSA contains four quadrants each with 365x171 independently operable shutters. An open shutter subtends an area of ~0.2x0.4" on the sky, and the total field of view spans ~3.6' (Fig. 1). NIRSpec contains seven dispersers, including a prism with R~100 and medium-and high-resolution gratings with R~1000/2700, all providing wavelength coverage from 0.7 to 5 μm. The highly configurable nature of the MSA provides considerable flexibility in observational strategies, but at the same time requires considerable complexity on the back-end for data reduction and spectral extraction.

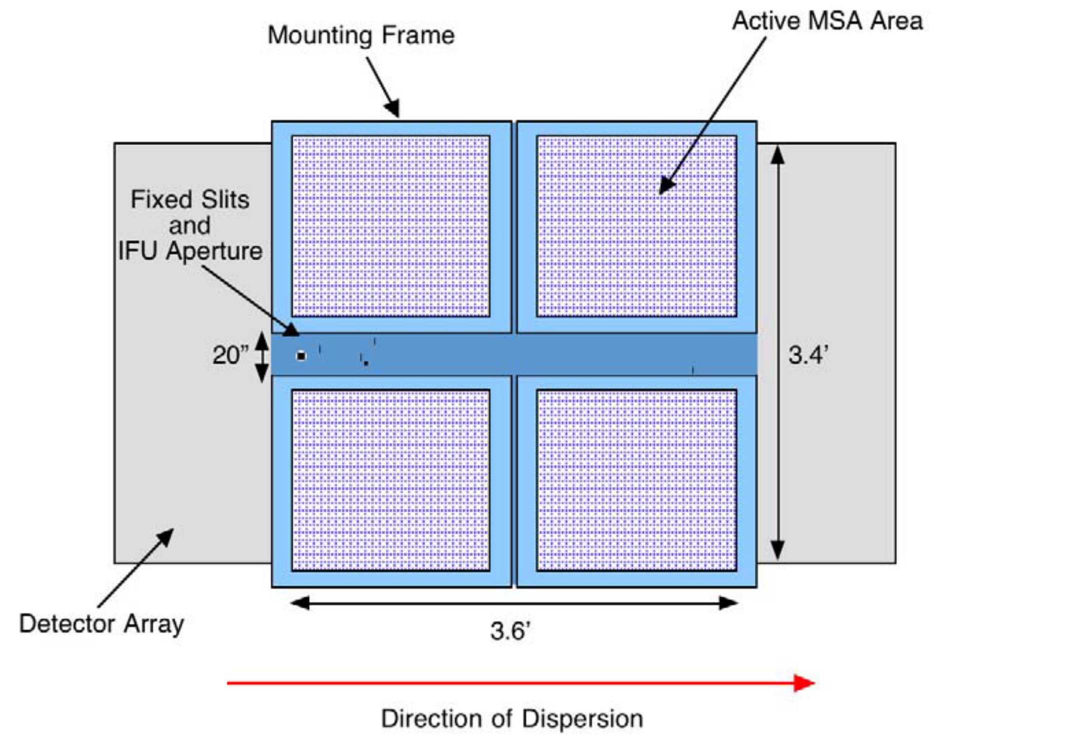

Figure 1. Schematic of MSA superimposed on the detector array FOV.

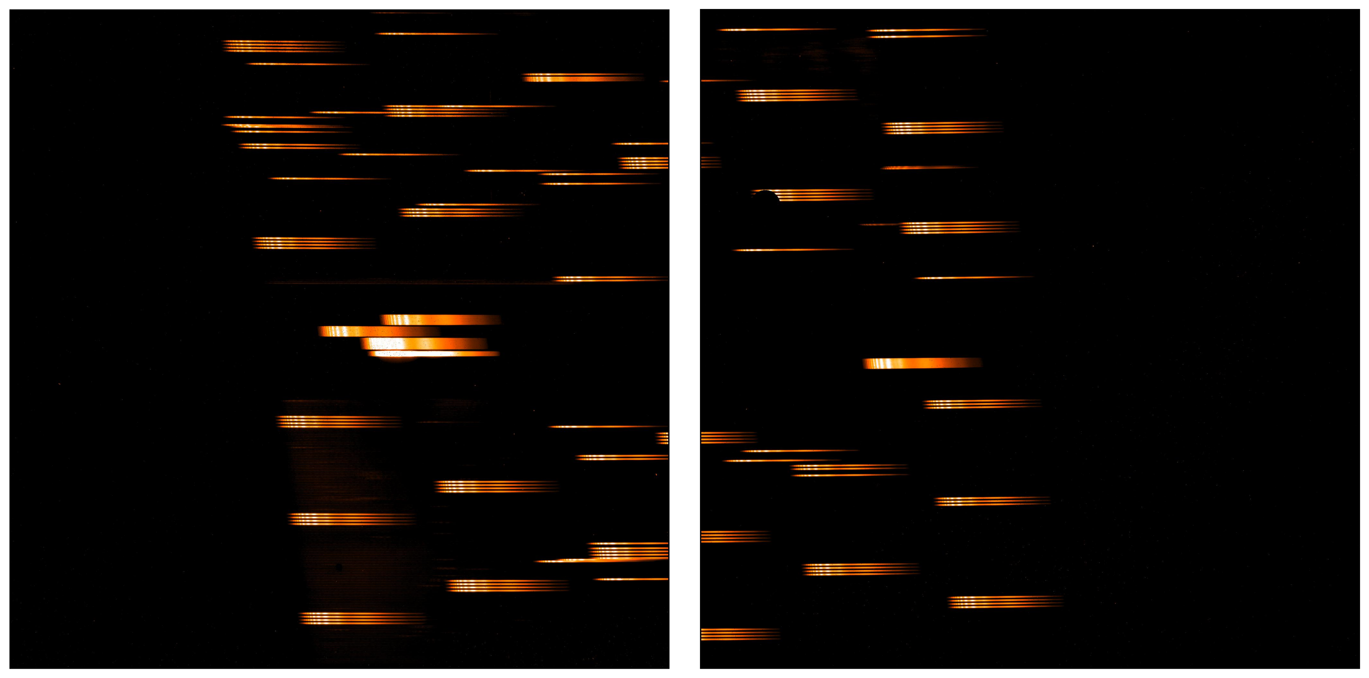

Figure 2. Exposure of an Argon lamp taken with the Prism during ground test. The MSA was configured in "slitlets" with sets of 4 alternating open/closed shutters.

Observing strategies - slitlets

Many different approaches are possible with the MSA. One example is a three-shutter "slitlet" opened for each science source, with the source located in one shutter and the other two used for measuring the local background (Fig. 2). A total of three exposures are taken, with the source moved into each of the three shutters in the slitlet. The observing strategy will inform the pipeline processing, particularly in the case of background subtraction methodology.

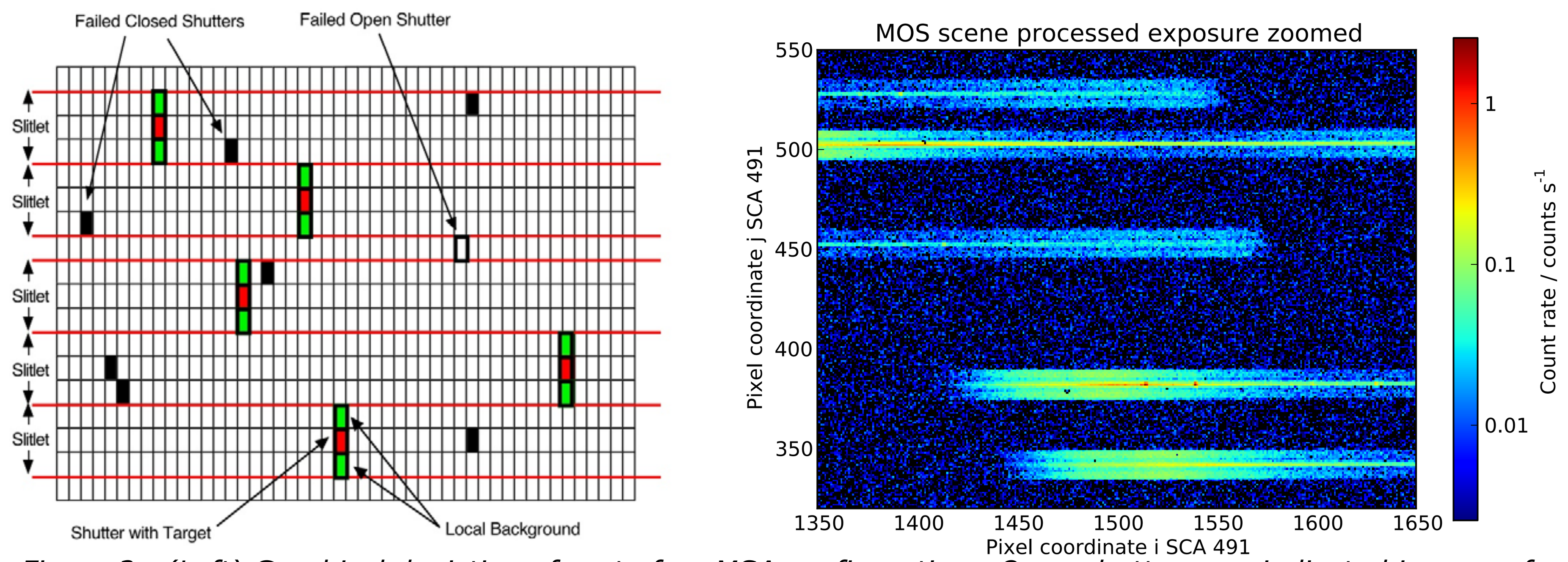

Figure 2. (Left) Graphical depiction of part of an MSA configuration. Open shutters are indicated in green for background and red for a science source. (Right) Portion of simulated exposure of spectra of high-z galaxies using 3-shutter slitlets (courtesy Ferruit/ESA).

Calibration pipeline

The automated processing pipeline will extract both 1D and 2D spectra from MSA observations (Fig 4). The process is complicated by the fact that spectra from different shutters are imaged in different locations on the detector arrays (Fig. 2). Moreover, the positioning of the spectra in the dispersion direction is not strictly repeatable in between moves of the Grating Wheel Assembly (GWA), with shifts of several pixels possible. The shift is correctable to <1/10 pix using telemetry from the GWA position sensors (Fig. 5). The pipeline must take this into account in order to derive an accurate wavelength solution.

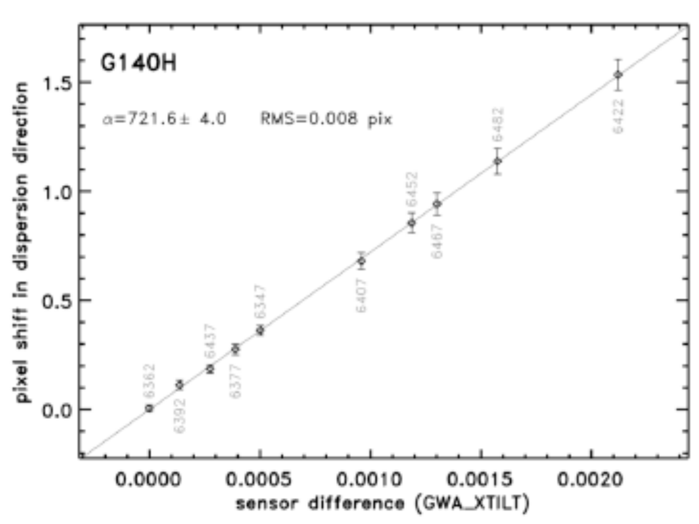

Figure 5. GWA position sensor voltage vs. spectral shift. Courtesy DeMarchi/ESA.

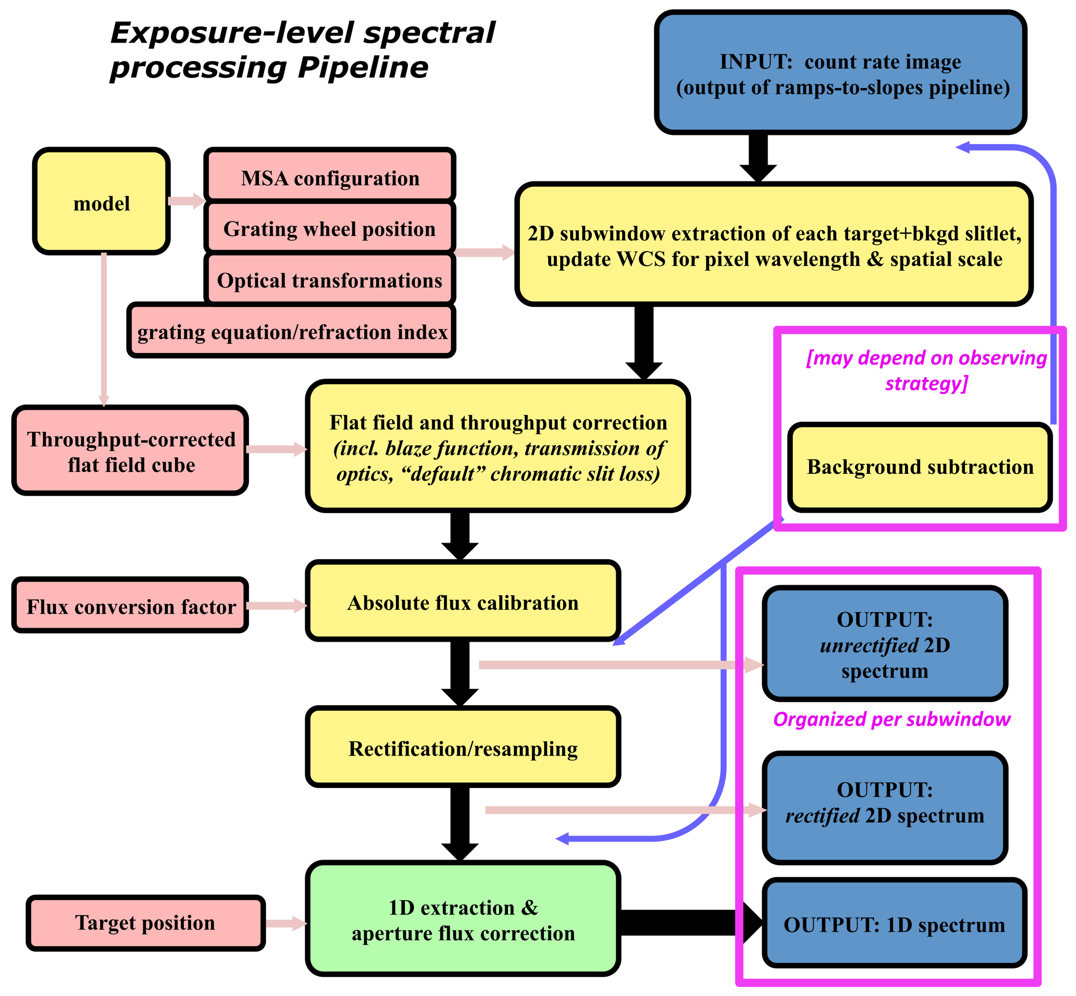

Figure 4. Flow of the spectral extraction pipeline.

To deal with these effects, we are implementing an extraction algorithm based on a parametric model of the instrument. Developed by the ESA Science Operations Team, the model calculates coordinate transforms between each of the principal optical planes in the instrument (Fig. 6), including parametric descriptions of each component (MSA apertures, GWA, detectors, etc.) that are tuned using test data taken during ground testing of the instrument. The pipeline will use the model to determine the location of a 2D "subwindow" around each spectrum, extract them, and at the same time calculate the wavelength of each pixel in the subwindow.

Further processing occurs on each 2D extracted spectrum. The method of background subtraction will depend on observing strategy. In the case of the 3-shutter slitlet, separate exposures will be subtracted before the 2D extraction step. To minimize resampling errors, spectral rectification will be done only once when multiple exposures are combined.

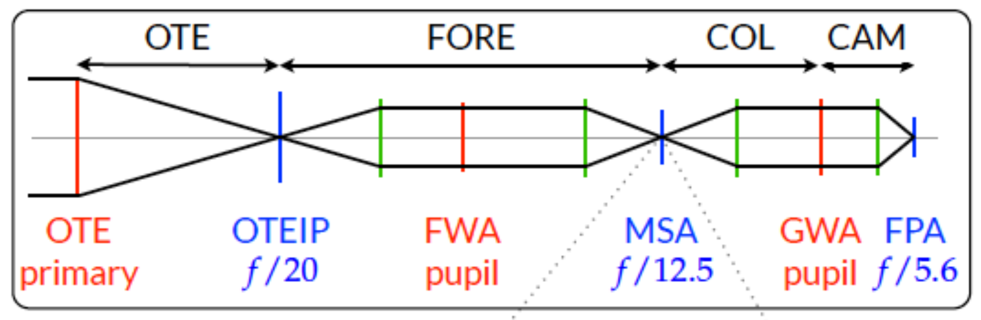

Figure 6. Principal optical planes treated by the instrument model. Courtesy Giardino/ESA.

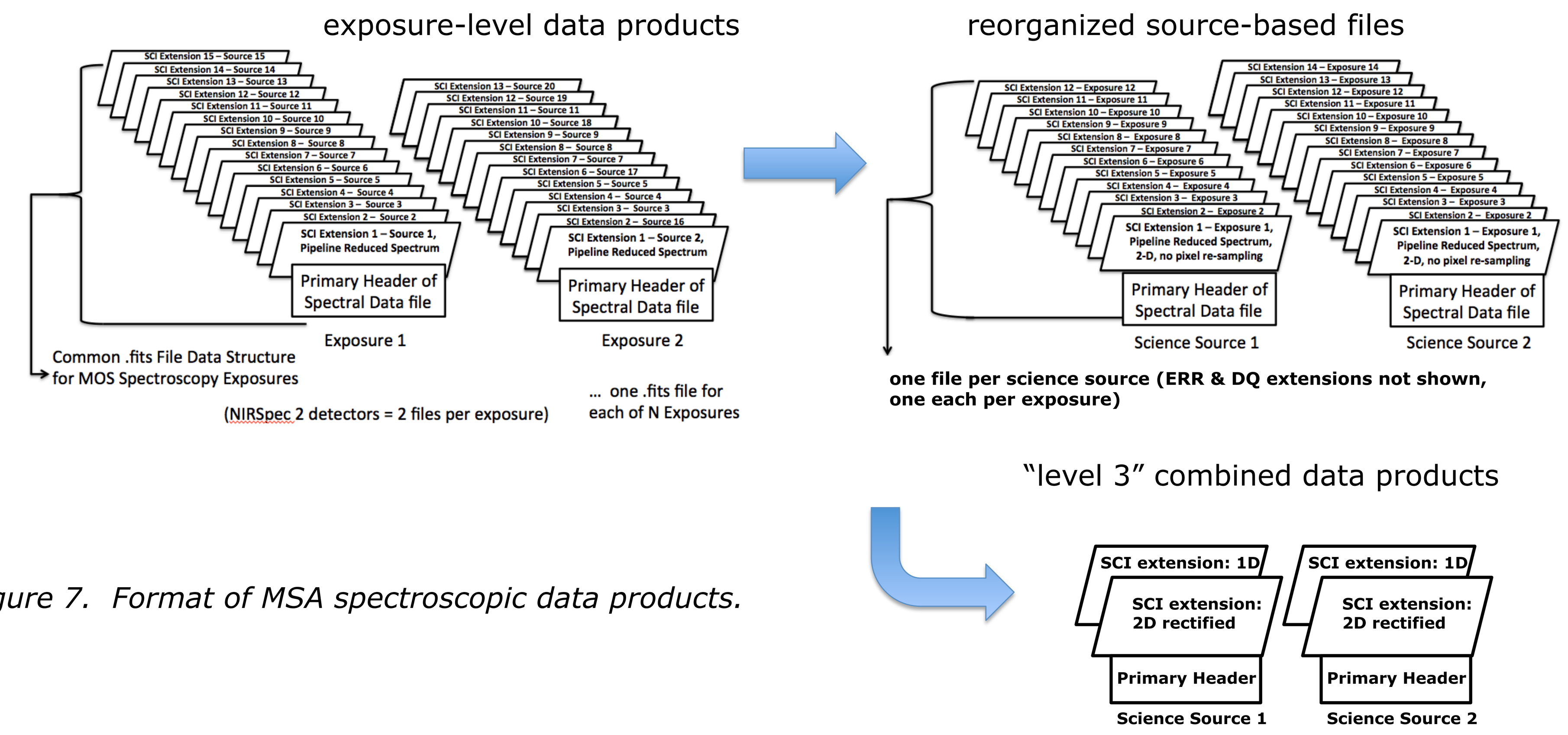

Figure 7. Format of MSA spectroscopic data products.

Data products, format, & analysis tools

Exposure-level data products will be packaged as a single fits file per configuration, with extensions containing each 2D source spectrum (Fig. 7). Before multi-exposure combination, the data will be reformatted to a source-based structure. The final combined products will include one file per source per grating, and will be organized in directories corresponding to the input source catalogs used in the MSA Planning Tool. We have just begun to scope out functionality of analysis tools that will allow interactive visualization of the spectra and related data such as NIRCam pre-imaging mosaics, and carry out various analysis tasks such as spectral line measurements, redshift determinations, template fitting, etc.

We welcome your input at this early stage!