

# NIRSPEC Data Reduction Pipeline

## Data Products Specification

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## 1 Introduction

The NIRSPEC DRP is an automated pipeline for level-1 reduction of NIRSPEC raw data. Data products include flat fielded, sky-subtracted, wavelength calibrated spectra. Data products are also provided for assessing the quality of the extracted spectra.

NIRSPEC DRP data products are intended for quick-look browsing. The pipeline performs best on spectra of point source objects. Stacking of object frames is not performed but if multiple flat field frames are available they are combined.

This document describes the data products generated by the NIRSPEC DRP.

## 2 Data Products

### 2.1 Tables

Flux tables containing calibrated spectral data and profile tables for evaluating flux along the slit are produced for each order of each object frame. A single table of wavelength calibration data is produced for each object frame.

#### 2.1.1 Table Format

Tables are generated in both FITS and ASCII formats.

Each FITS binary table file contains two HDUs (Header Data Units). HDU 0 is type PrimaryHDU. The header portion of HDU 0 contains keywords from the original science frame plus keywords added by the DRP (see section 4 – Keywords Added to FITS Files).

HDU 1 is type BinTableHDU and contains table data. The header portion of HDU 1 contains table column metadata. Metadata used are column name (TTYPE), column format (TFORM) and units (TUNIT). All column values are scalars.

ASCII tables are written as fixed width tables with a single header line containing column names and units where applicable. The ‘|’ character is used to delineate columns and space characters are used for padding.

### 2.1.2 Flux Table

Flux tables for evaluating spectra are produced in FITS and ASCII formats for each spectral order. The binary FITS table is in `fitstbl/flux/KOAID_NN_flux_tbl.fits` and the ASCII table is in `asciitbl/flux/KOAID_NN_flux_tbl.txt` where KOAID is the standard KOA file identifier and NN is order number.

Each flux table row corresponds to a pixel column in the raw image and has the following columns:

- `col` - Column number in the raw image.
- `wave` - Wavelength in Angstroms (vacuum) of this column based on wavelength calibration using OH sky emission lines and/or arc lamps.
- `flux` - Relative flux in counts of extracted spectrum after division by a normalized flat-field image.
- `error` - One-sigma error of the flux in counts.
- `sky` - Background level in counts, scaled to match the total background in the region of object extraction.
- `synth_sky` - Relative intensity of the synthesized sky spectrum used for wavelength calibration.
- `sig_to_noise` - Signal-to-noise ratio, flux divided by error.
- `flat` - Level of the flat field in counts, not normalized. (The normalization scale factor is given by the FLATSCAL header keyword.)

- `trace_upper` – Upper edge of the order in pixels, determined from the flat field.
- `trace_lower` – Lower edge of the order in pixels, determined from the flat field.
- `trace_mean` – The average of the upper and lower trace edges, in pixels.
- `trace_fit` – Average of upper and lower traces smoothed by fitting to a third degree polynomial, in pixels.
- `fit_res` – Difference between `trace_mean` and `trace_fit`, in pixels.

### 2.1.3 Profile Table

Profile tables containing mean flux profile along the slit are produced for each spectral order. The binary FITS table is in `fitstbl/profile/KOAIID_NN_profile_tbl.fits` and the ASCII table is in `asciitbl/profile/KOAIID_NN_profile_tbl.txt`.

Each profile table row represents a row in the spatially rectified spectral order and contains the following columns:

- `row` – Row offset in pixels in the spatial direction relative to the shifted trace fit.
- `prof_flux` – Mean flux of the spatial profile in counts.

### 2.1.4 Wavelength Calibration Identification Tables

A single wavelength calibration identification table is produced for each object frame and lists the sky and/or arc lamp emission lines used for wavelength calibration. The binary FITS table is in `fitstbl/wavecal/KOAID_wavecal_tbl.fits` and the ASCII table is in `tbl/wavecal/KOAID_wavecal_tbl.txt`.

Each row of the table represents one emission line used in the calibration and contains the following columns:

- o `order` – The Echelle order number in which this line appears.
- o `source` – sky for OH emission lines, arc lamp for lamp lines.
- o `col` – Measured column of the line in pixels.
- o `wave_exp` – Expected wavelength of the line in Angstroms.
- o `wave_fit` – Wavelength in Angstroms of the measured column from the wavelength fit.
- o `peak` – Peak intensity of this line in counts.
- o `disp` – Dispersion of the fit at this wavelength in Angstroms/pixel.

order	source	col (pix)	wave_exp (A)	wave_fit (A)	peak (cnts)	disp (A/pix)
50	sky	972	1.539526e+04	1.539486e+04	197	2.235e-01
49	sky	33	1.550057e+04	1.550061e+04	48	2.106e-01
49	sky	75	1.550956e+04	1.550947e+04	122	2.114e-01
49	sky	113	1.551771e+04	1.551751e+04	30	2.121e-01
49	sky	216	1.553971e+04	1.553946e+04	141	2.140e-01
49	sky	222	1.554094e+04	1.554074e+04	124	2.141e-01
49	sky	246	1.554589e+04	1.554589e+04	138	2.146e-01
49	sky	357	1.557007e+04	1.556982e+04	81	2.167e-01

Figure 1- First few rows of a wavelength calibration table in ASCII format.

## 2.2 FITS Data Files

Each FITS data file contains a single HDUs. The header portion of the HDU (HDU 0) contains keywords from the original science frame plus keywords added by the DRP (see section 4 – Keywords Added to FITS Files). The data portion of the HDU contains a 1 or 2-dimensional array as described below.

Previews images are generated for each of the FITS files.

### 2.2.1 Rectified Order 2-D Image

This file contains the rectified 2-dimensional image of the order. There is one file per order in `fits/order/KOAIID_NN_order.fits`. A preview of this data is provided as a JPG image in `previews/order/KOAIID_NN_order.jpg`.

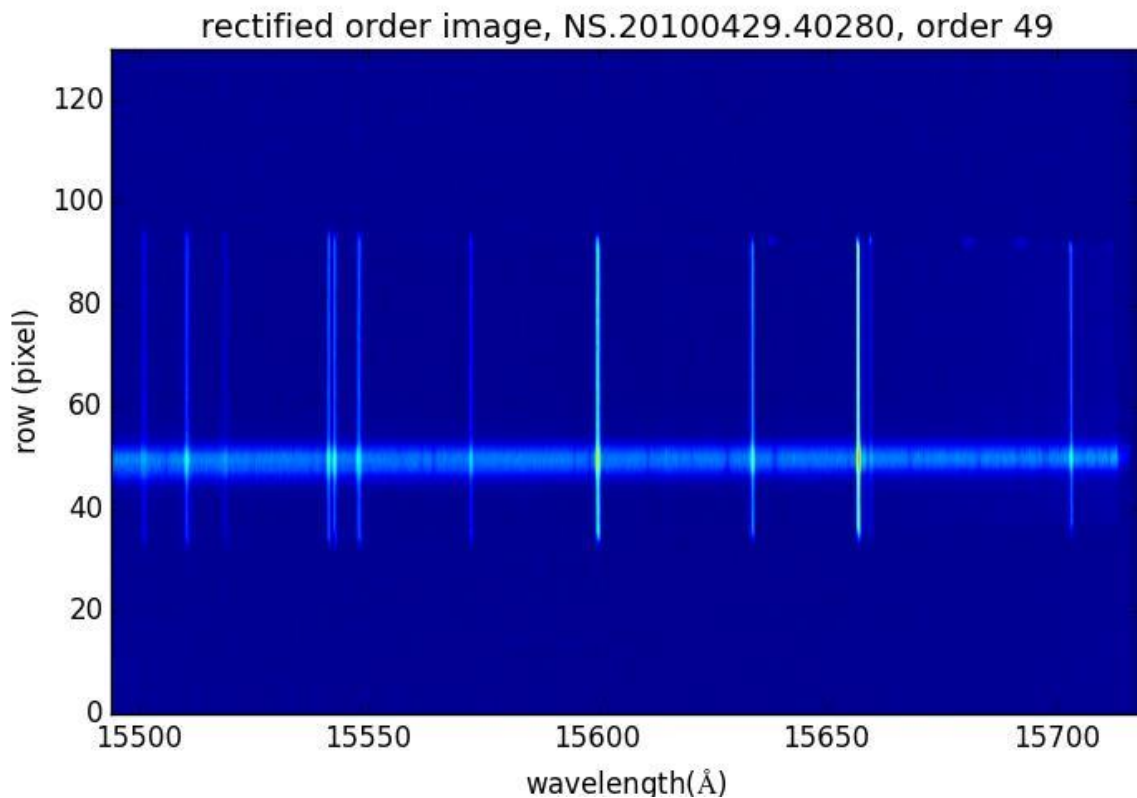


Figure 2 - Example of rectified order 2-D image preview.

### 2.2.2 Flux

This file contains the extracted spectrum in counts as a 1-dimensional array indexed by order column pixel number and is equivalent to the flux column of the flux table. There is one file per order in `fits/flux/KOAID_NN_flux.fits`. Flux is plotted against wavelength and is provided as a preview image in `previews/flux/KOAID_NN_flux.jpg`.

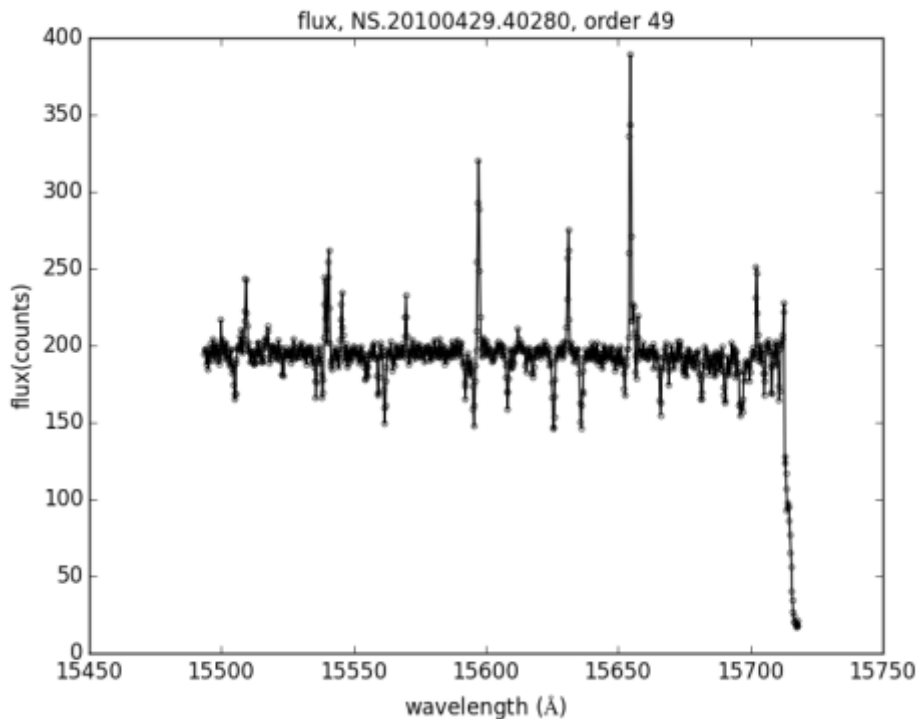


Figure 3 - Sample flux preview plot.

### 2.2.3 Sky

This file contains the background level spectrum in counts as a 1-dimensional array indexed by order column pixel number and is equivalent to the sky column of the flux table. There is one file per order in `fits/sky/KOAID_NN_sky.fits`. Sky background level is plotted against wavelength and provided as a preview image in `previews/sky/KOAID_NN_sky.jpg`.

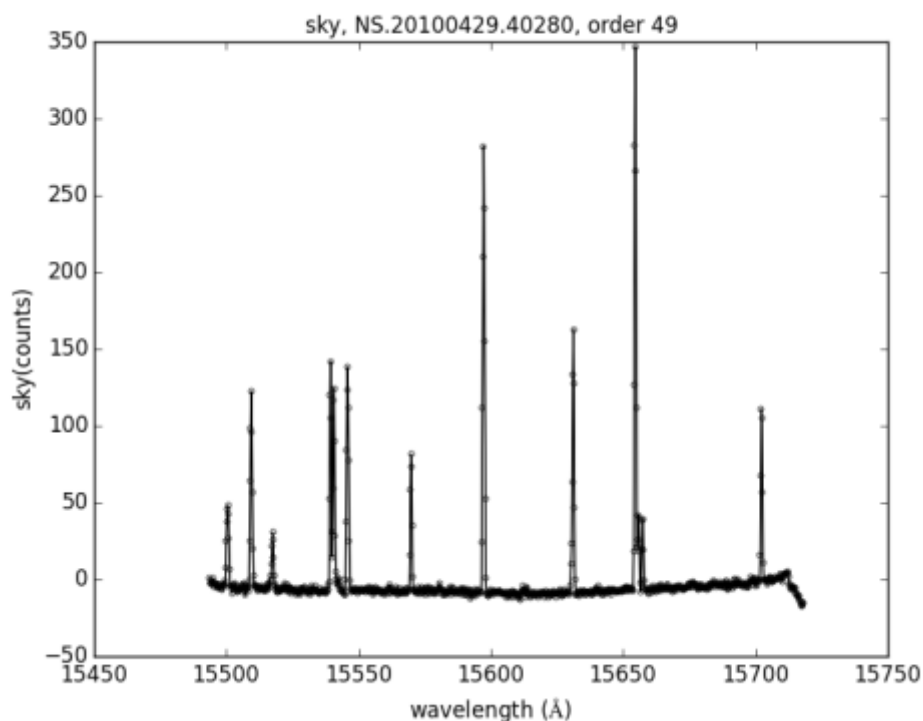


Figure 4 – Example of sky spectrum preview.

#### 2.2.4 Singal-to-Noise

This file contains the signal-to-noise ratio spectrum as a 1-dimensional array indexed by order column pixel number and is equivalent to the flux column of the flux table. There is one file per order in `fits/snr/KO Aid_NN_snr.fits`. Signal-to-noise ratio is plotted against wavelength and provided as a preview image in `previews/snr/KO Aid_NN_snr.jpg`.

#### 2.2.5 Trace

This file contains the trace of the order along the spectral dimension as a 1-dimensional array indexed by order column pixel number and is equivalent to the `trace_mean` column of the flux table. There is one file per order in `fits/trace/KO Aid_NN_trace.fits`. A plot of trace row vs. column is provided as a preview image in `previews/trace/KO Aid_NN_trace.jpg`.



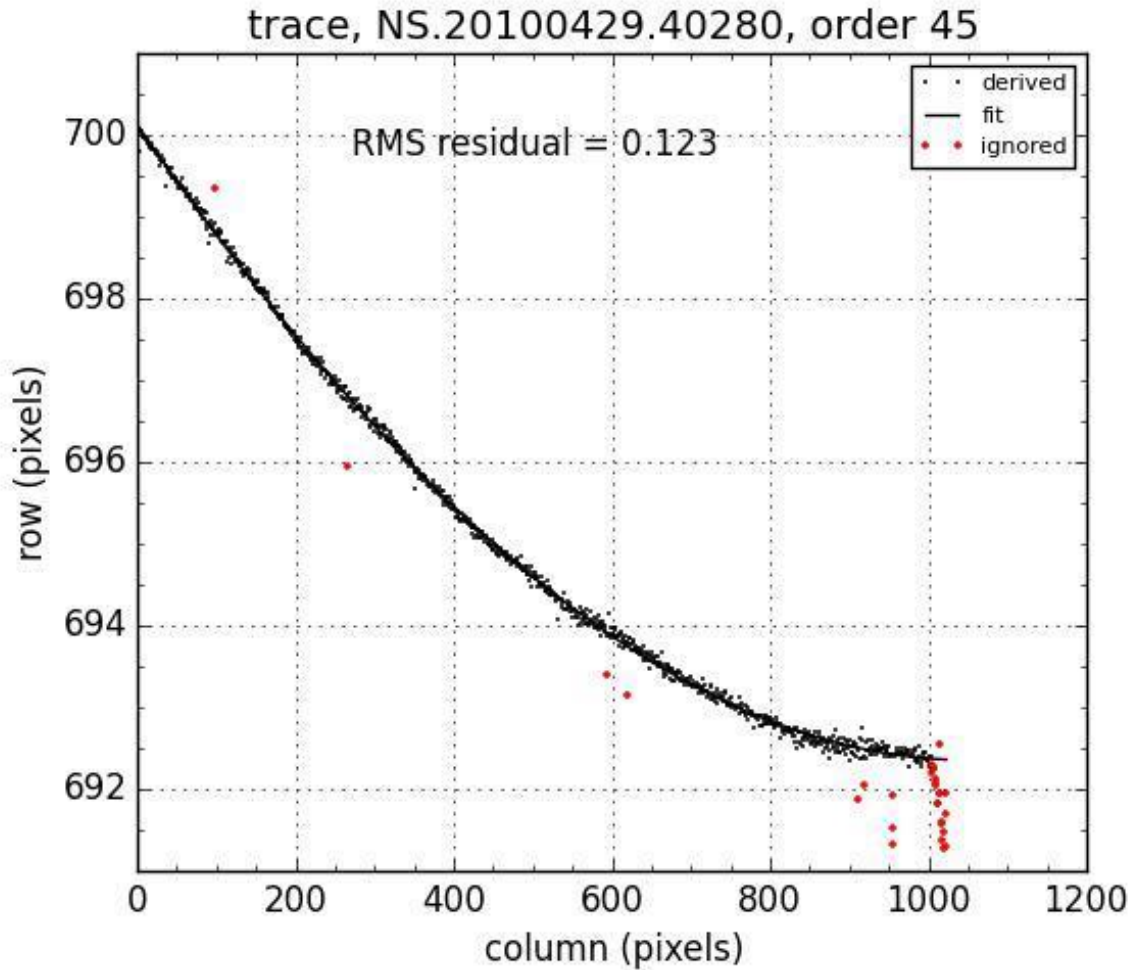


Figure 5 - Example of order trace plot preview.

### 2.2.6 Profile

This file contains the mean flux profile along the slit as a 1-dimensional array indexed by relative order row pixel number and is equivalent to the flux column of the profile table. There is one file per object frame in `fits/profile/KOAID_NN_profile.fits`. A plot of the profile is provided as a preview image in `previews/profile/KOAID_NN_profile.jpg`.

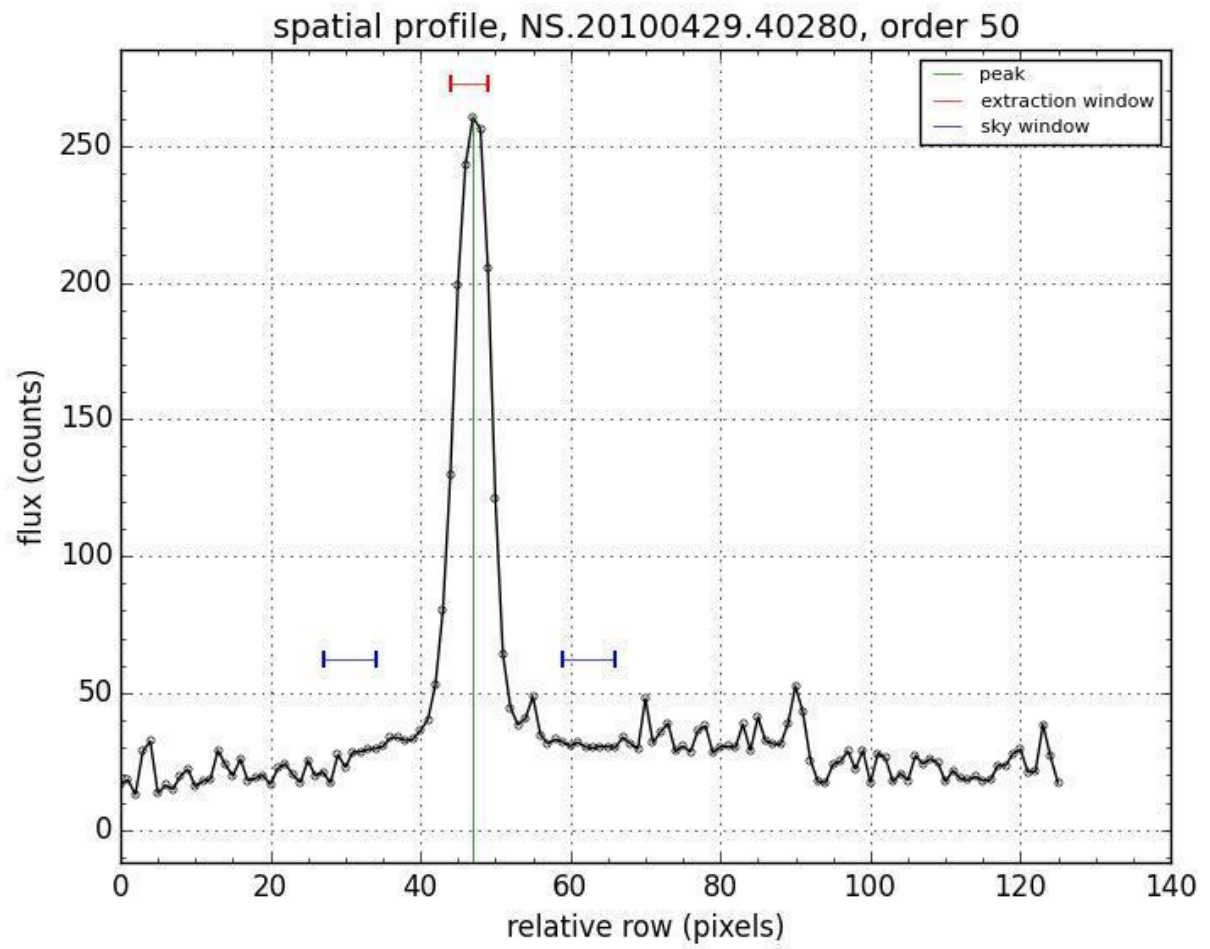


Figure 6 - Example of spatial profile preview.

### 3 FITS Keywords Added to Generated FITS File

Keywords from the original object frame are included in the derived FITS data and table files, plus the following keywords are added:

FLATSCAL – flat field normalization scale factor.

DARK – KOA image ID of dark frame used, if any.

FLAT1..FLAT10 – KOA image ID of flat field frames used.

WFIT1..6 – Polynomial fit coefficients determined for wavelength calibration equation.

WFITRMS – RMS of wavelength fit residual.

ECHL\_ORD – Echelle order number (where appropriate).

OBJEXTRW – Width of object extraction window in pixels.

SKYDIST – Distance between the object and sky window

SKYEXTRW – Width of sky extraction window in pixels.

NSDRPVER – Version number of NSDRP.

## 4 Log Files

### 4.1 Per-Night Logs

Contains summary information about reduction of data from entire night. Details TBD.

### 4.2 Per-Object Frame Logs

Contains information about reduction of individual object frame. Details TBD.

## 5 Directory Structure

The root of the directory structure is passed to the DRP as a command. Subordinate to the root directory are the following subdirectories.

<code>fits/order</code>	Two-dimensional rectified order as FITS images.
<code>fits/flux</code>	Object spectrum 1-D FITS files.
<code>fits/sky</code>	Sky spectrum 1-D FITS files.
<code>fits/snr</code>	Signal-to-noise ratio spectrum 1-D FITS files.
<code>fits/trace</code>	Order trace 1-D FITS files.
<code>fits/profile</code>	Mean flux along slit 1-D FITS files.
<code>fitstbl/flux</code>	Flux tables as binary FITS tables.
<code>fitstbl/profile</code>	Profile tables as binary FITS tables.
<code>fitstbl/wavecal</code>	Wavelength calibration tables as binary FITS tables.
<code>asciitbl/flux</code>	Flux tables as formatted ASCII tables.
<code>asciitbl/profile</code>	Profile tables a formatted ASCII tables.

asciitbl/wavecal	Wavelength calibration tables as formatted ASCII tables.
previews/order	Rectified orders as JPG images.
previews/flux	Flux vs. wavelength preview plots as JPG images.
previews/sky	Sky background vs. wavelength preview plots as JPG images.
previews/snr	Signal-to-noise ratio vs. wavelength preview plots as JPG images.
previews/trace	Trace preview plots as JPG images.
previews/profile	Profile preview plots as JPG images.
logs	Log files.