

NIRSPEC DRP

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 for assessing the quality of the extracted spectra are also provided.

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 supported but if multiple flat field or dark 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 two header lines. Column names are on the first header line and units, where applicable, are on the second header line. The ‘|’ character is used to delineate columns on the header lines and space characters are used to separate columns on data lines.

2.1.2 Flux Table

Flux tables for evaluating spectra are produced in FITS and ASCII formats for each spectral order. Flux tables in binary FITS format are in `fitstbl/flux/KOAID_NN_flux.tbl` and ASCII-format tables are in `ascii/flux/KOAID_NN_flux.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.
- `synth_sky` – Relative intensity of synthesized sky spectrum.
- `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

Spatial profile tables containing the mean flux profile along the slit are produced for each spectral order. Binary FITS tables profile tables are in `fitstbl/profile/KOAIID_ NN_profile.tbl` and ASCII tables are in `ascii/profile/KOAIID_ NN_profile.txt`.

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

- `row` – Row offset in pixels along the spatial axis relative to the shifted trace fit.
- `prof_flux` – Mean flux of the spatial profile in counts over all columns (wavelengths) of the order.

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 `fits/cal/KOAIID_cal.tbl` and the ASCII table is in `ascii/cal/KOAIID_cal.txt`.

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

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

order	source	col pixels	wave_exp Angstroms	wave_fit Angstroms	res Angstroms	peak counts	disp Angstroms/pixel
38	sky	39.252	1.973492e+04	1.973456e+04	0.356	29	2.894e-01
38	sky	50.471	1.973750e+04	1.973781e+04	0.311	19	2.896e-01
38	sky	168.965	1.977174e+04	1.977226e+04	0.520	21	2.919e-01
38	sky	396.608	1.983964e+04	1.983921e+04	0.432	30	2.963e-01
38	sky	956.912	2.000815e+04	2.000824e+04	0.092	127	3.071e-01
37	sky	290.781	2.033937e+04	2.033911e+04	0.264	60	3.036e-01
37	sky	532.771	2.041306e+04	2.041301e+04	0.045	143	3.072e-01
37	sky	812.992	2.049936e+04	2.049971e+04	0.348	27	3.115e-01
36	sky	164.362	2.086062e+04	2.086023e+04	0.394	14	3.120e-01
36	sky	804.970	2.106269e+04	2.106235e+04	0.339	10	3.190e-01
36	sky	971.878	2.111565e+04	2.111575e+04	0.098	23	3.209e-01
35	sky	338.068	2.150729e+04	2.150776e+04	0.473	115	3.241e-01
35	sky	562.783	2.158050e+04	2.158076e+04	0.258	11	3.255e-01
35	sky	960.713	2.171093e+04	2.171081e+04	0.121	20	3.281e-01
34	sky	88.067	2.205232e+04	2.205216e+04	0.158	14	3.345e-01
34	sky	306.122	2.212488e+04	2.212513e+04	0.258	50	3.348e-01
34	sky	308.831	2.212616e+04	2.212604e+04	0.119	47	3.348e-01
34	sky	862.821	2.231180e+04	2.231179e+04	0.008	19	3.358e-01
34	sky	867.998	2.231365e+04	2.231353e+04	0.121	20	3.358e-01

Figure 1. Sample wavelength calibration table in ASCII format.

2.2 FITS Data Files

Each FITS data file contains a single HDU. The header portion of the HDU (HDU 0) contains keywords from the original science frame plus keywords added by the DRP (see Section 3 – Keywords Added to FITS Files). The data portion of the HDU contains a 1 or 2-dimensional array as described below.

Preview 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/KOAID_NN_order.fits`. A preview is provided as a JPEG image in `previews/order/KOAID_NN_order.jpg`.

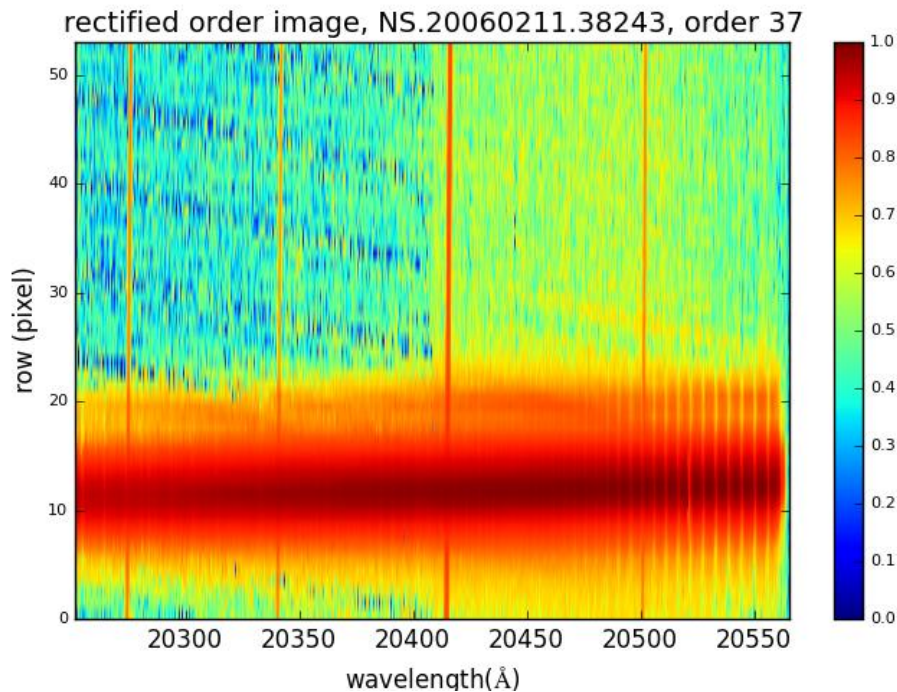


Figure 2 - Example of rectified order 2-D image preview.

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`.

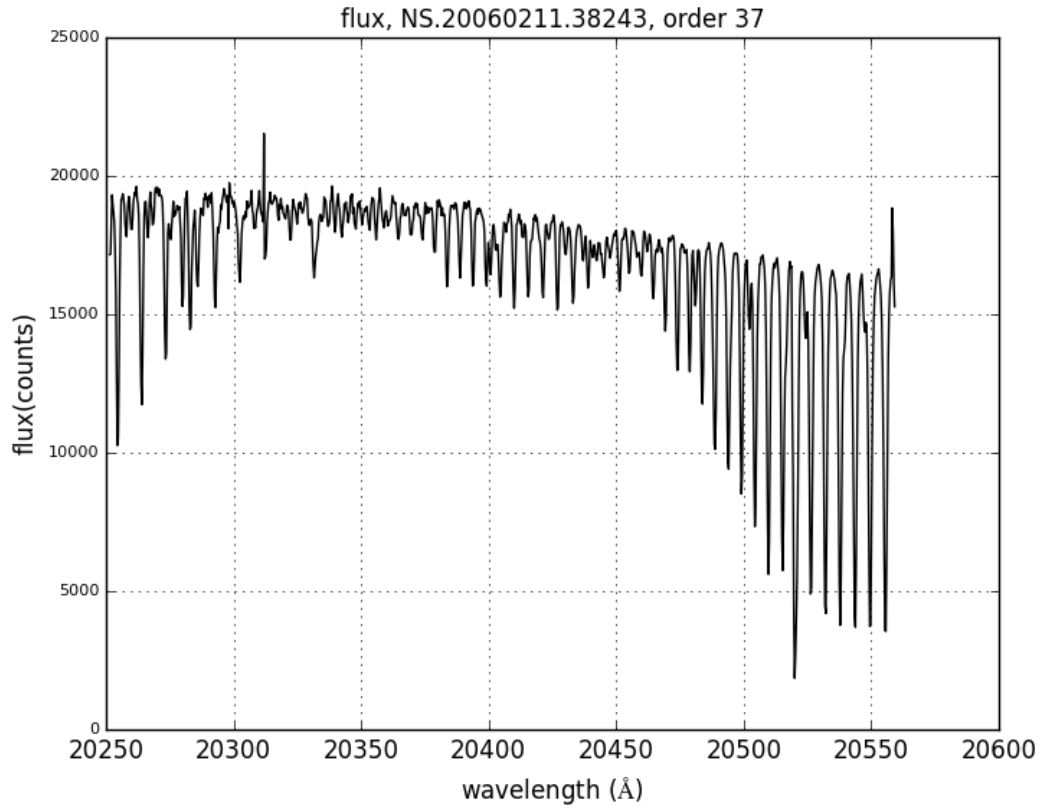


Figure 3 – Example of flux preview plot.

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`.

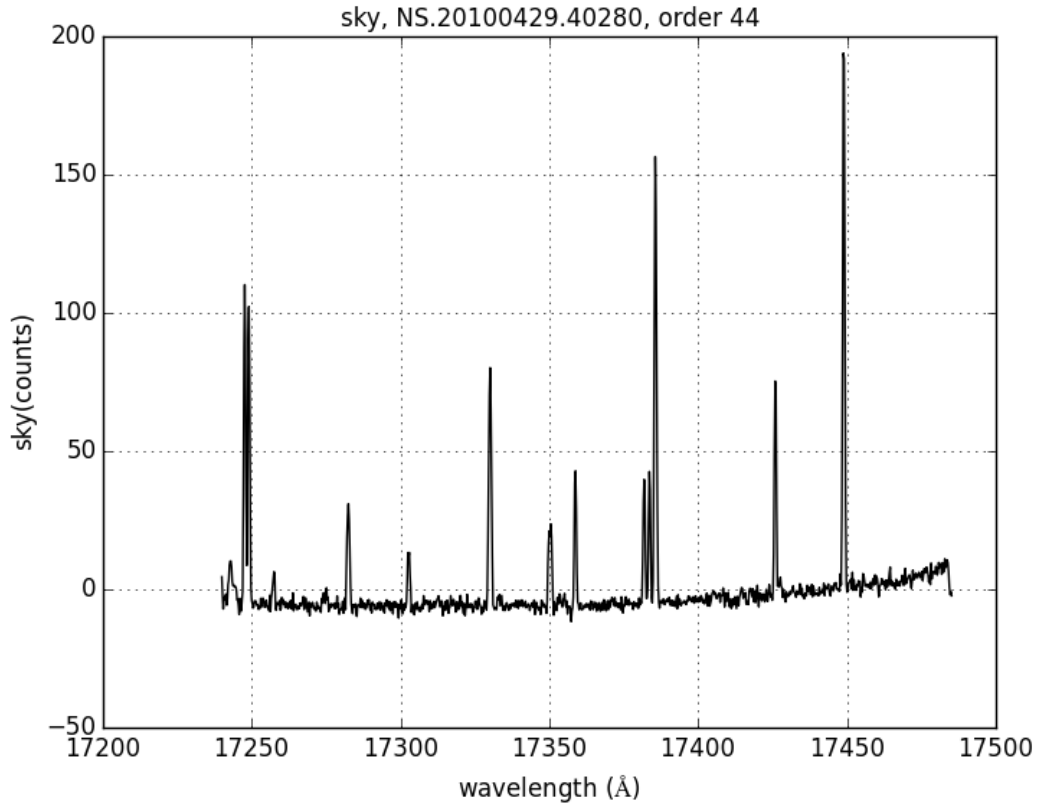


Figure 4 – Example of sky spectrum preview plot.

2.2.4 SNR

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 SNR column of the flux table. There is one file per order in `fits/snr/KOAID_NN_snr.fits`. Signal-to-noise ratio is plotted against wavelength and provided as a preview image in `previews/snr/KOAID_NN_snr.jpg`.

2.2.5 Trace

This file contains average of the upper and lower traces 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/KOAID_NN_trace.fits`. A plot of trace row vs. column is provided as a preview image in `previews/trace/KOAID_NN_trace.jpg`.

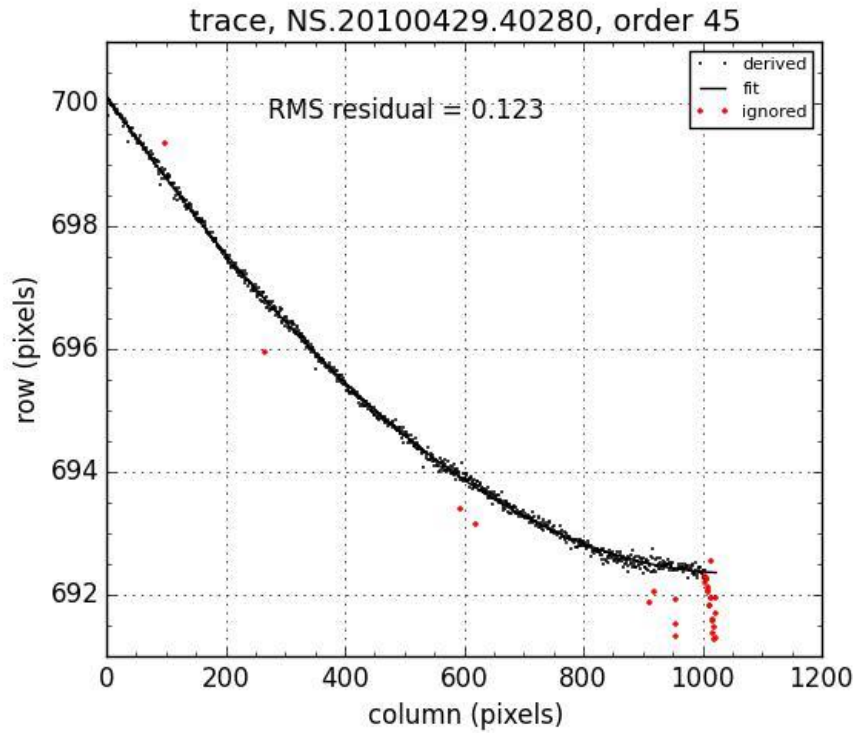


Figure 5 - Example of order trace_mean preview plot.

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`.

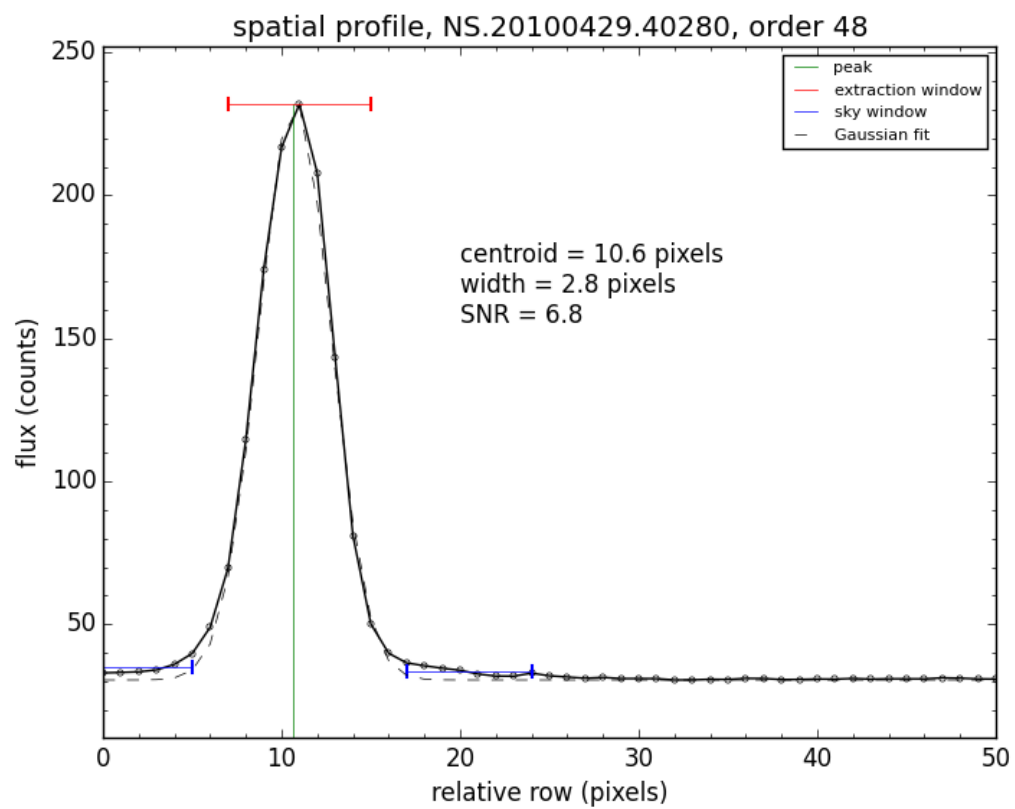


Figure 6 - Example of spatial profile preview plot.

2.3 Summary of Data Products

Filename	File Type	Subdirectory	Freq.	Description
KOAID_NN_flux.tbl	FITS table	fitstbl/flux	per order	Flux table
KOAID_NN_flux.txt	ASCII table	ascii/flux	per order	Flux table
KOAID_NN_profile.tbl	FITS table	fitstbl/profile	per order	Profile table
KOAID_NN_profile.txt	ASCII table	ascii/profile	per order	Profile table
KOAID_cal.tbl	FITS table	fitstbl/cal	per object	Wavelength calibration
KOAID_cal.txt	ASCII table	ascii/cal	per object	Wavelength calibration
KOAID_NN_order.fits	FITS 2D	fits/order	per order	Rectified order image
KOAID_NN_order.jpg	JPEG	previews/order	per order	Rectified order image
KOAID_NN_flux.fits	FITS 1D	fits/flux	per order	Flux spectrum
KOAID_NN_flux.jpg	JPEG	previews/flux	per order	Flux spectrum plot
KOAID_NN_sky.fits	FITS 1D	fits/sky	per order	Sky spectrum
KOAID_NN_sky.jpg	JPEG	previews/sky	per order	Sky spectrum plot
KOAID_NN_snr.fits	FITS 1D	fits/snr	per order	Signal/noise spectrum
KOAID_NN_snr.jpg	JPEG	previews/snr	per order	SNR spectrum plot
KOAID_NN_trace.fits	FITS 1D	fits/trace	per order	Order trace
KOAID_NN_trace.jpg	JPEG	previews/trace	per order	Order trace plot
KOAID_NN_profile.fits	FITS 1D	fits/profile	per order	Spatial profile
KOAID_NN_profile.jpg	JPEG	previews/profile	per order	Spatial profile plot
log.txt	ASCII	logs	per night	Night summary log
KOAID_log.txt	ASCII	logs	per object	Object summary log

3 FITS Keywords Added to Generated FITS Files

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

- WFITRMS – RMS of wavelength fit residual.
- WFIT1..6 – Wavelength fit coefficients.
- DARK – KOAID of dark frame used, if any. If multiple darks were used then the KOAID of one of them is given.
- FLAT – KOAID of flat frame used, if any. If multiple flats were used then the KOAID of one of them is given.
- FLATSCAL – Flat field normalization scale factor.
- ECHLORD – Echelle order number (where appropriate).
- OBJEXTRW – Width of object extraction window in pixels.
- SKYEXTRW – Width of background extraction windows in pixels.
- SKYDIST – Separation between object and background extraction windows in pixels.
- PROFPEAK – Fractional row number of spatial profile peak.
- ORDERSNR – Signal-to-noise ratio for order (where appropriate).

4 Log Files

4.1 Per-Night Logs

Contains summary information about data reduction for entire night.

4.2 Per-Object Frame Logs

Contains information about reduction of individual object frame.

5 Directory Structure

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

Directory	Contains
<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/cal</code>	Wavelength calibration tables as binary FITS tables.
<code>ascii/flux</code>	Flux tables as formatted ASCII tables.
<code>ascii/profile</code>	Profile tables as formatted ASCII tables.
<code>ascii/cal</code>	Wavelength calibration tables as formatted ASCII tables.
<code>previews/order</code>	Rectified orders as JPEG images.
<code>previews/flux</code>	Flux vs. wavelength preview plots as JPEG images.
<code>previews/sky</code>	Sky background vs. wavelength preview plots as JPEG images.
<code>previews/snr</code>	Signal-to-noise ratio vs. wavelength preview plots as JPEG images.
<code>previews/trace</code>	Trace preview plots as JPEG images.
<code>previews/profile</code>	Profile preview plots as JPEG images.
<code>logs</code>	Log files.

6 Revision History

Revision	Date	Who	Section	Changes
1	2015-02-10	R. Goodrich	All	Draft
2	2015-04-25	R. Cohen	All	Second draft
3	2015-05-06	R. Cohen	All	Changes based on feedback from Hien
5	2015-12-15	R. Cohen	All	Miscellaneous updates and corrections.