12. MaNGA TRM: DAP Data Model

Current Release is: **MPL-9**
DRP Version is: **v2_7_1**
DAP Version is: **2.4.1**

The DAP documentation is being migrated to readthedocs.

See the description of the DAP data model here: https://sdss-mangadap.readthedocs.io/en/latest/datamodel.html . We have somewhat minimized the discussion and appropriately updated the tables for MPL-9 below.

See also the two DAP technical papers:

- Overview: Westfall et al. (2019)
- Emission-line Modeling: Belfiore et al. (2019) .

The DAP data model consists of a number of input files and two main output files, the MAPS and LOGCUBE files, one for each galaxy. The `MAPS` file contains the 2d maps coming out of the DAP, while the `LOGCUBE` file contains the spectral model fits to the data cube.

12.1. Directory Structure

See here.

The SAS root directory for all DAP data products is here: https://data.sdss.org/sas/mangawork/manga/spectro/analysis/

- From this root directory everything is in subdirectories according to [DRP version]/[DAP version]/
- DAP data products for a given MPL are symlinked from the root directory

The current DAP products are available here: https://data.sdss.org/sas/mangawork/manga/spectro/analysis/MPL-9

The top level within a given DAP version contains the following subdirectories:

- `[type]`: User-level directory containing the results from a primary analysis method or "type"
- `log`: Survey-level log files for how the DAP was executed (*this directory can be ignored*)
- `common`: Survey-level directory containing files common to the "type" subdirectories (*this directory can be ignored*)

Most users will only interact with the `[type]` directories. For the current release, these are:

- `SPX-MILESHC-MASTARHC/` - Analysis of each individual spaxel; spaxels must have a valid continuum fit for an emission-line model to be fit
- `VOR10-MILESHC-MASTARHC/` - Analysis of spectra binned to S/N~10 using the Voronoi binning algorithm (Cappellari & Copin 2003)
- `HYB10-MILESHC-MASTARHC/` - Stellar-continuum analysis of spectra binned to S/N~10 for the stellar kinematics (same as VOR10 approach); however, the emission-line measurements are performed on the individual spaxels. See a description of the hybrid binning scheme here.

See the advice for selecting the `[type]` appropriate for your science here.

Within each `[type]` directory, you'll find the following directories:

- `plate`/`ifudesign/`: Subdirectory for each `[plate]-[ifudesign]` combination. DAP maps and logcube output files live here.
  - `qa/`: Contains (limited) PNG plots for quick QA of the output.
  - `ref/`: A reference directory with intermediate files written during processing.

12.2. HDUCLASS

See here.

As with the DRP output data, the DAP output files follow the `HDUCLASS` header group convention; see also ftp://ftp.eso.org/pub/dfs/pipelines/doc/VLT-SPE-ESO-19500-5667_DataFormat.pdf.

All headers specify `HDUCLASS=SDSS`. The `HDUCLASS` header block in, e.g., the `EMLINE_GFLUX` extension in the `MAPS` files looks like this:

```
HDUCLASS= 'SDSS    '            / SDSS format class
HDUCLAS1= 'CUBE    '
HDUCLAS2= 'DATA    '
ERRDATA = 'EMLINE_GFLUX_IVAR'   / Associated inv. variance extension
QUALDATA= 'EMLINE_GFLUX_MASK'   / Associated quality extension
```

The `ERRDATA` and `QUALDATA` keywords provide the names of the extensions with the associated uncertainty and quality flags, respectively, for the data. In the headers of the `EMLINE_GFLUX_IVAR` and `EMLINE_GFLUX_MASK` extensions, the `SCIDATA` keyword provides the extension with the associated science data (`EMLINE_GFLUX)` in this case).

The `QUALDATA` extensions provide bit masks of each property value. **It is important that you use these mask bits when using the data.**

12.3. DAP `MAPS` file

See here.

File template: `type`/`plate`/`ifudesign`/manga-`plate`-`ifudesign`-MAPS-`type`.fits.gz

The `MAPS` files are the primary output file from the DAP and provide 2D "maps" (i.e., images) of DAP measured properties. The shape and WCS of these images identically match that of a single wavelength channel in the corresponding DRP `LOGCUBE` file. Most properties are provided in groups of three fits extensions:

1. `[property]`: the measurement value,
2. `[property]_IVAR`: the measurement uncertainty stored as the inverse variance
3. `[property]_MASK`: a corresponding bit mask for each pixel.

Extensions can either be a single 2D image (`HDUCLAS1= 'IMAGE'`) or they can have a series of images that are organized along the third dimension (`HDUCLAS1= 'CUBE'`). For the latter, each image is said to be in a specific "channel". For example, each Gaussian-fitted emission-line flux is provided in a single channel in the EMLINE_GFLUX extension. The header of extensions with multiple channels provide the names of the quantities in each channel using header keyword `Cn`, where `n` is the 1-indexed number of the channel.

If possible with your software package of choice, please always select the extension and channel based on its **name**, *not* its extension or channel number. An example of how to do this using python is provided here.

Internally, the DAP performs all spectral fitting on the binned spectra (termed as such even if a bin only contains a single spaxel) *after* they have been corrected for Galactic

NOTE	extinction. Therefore, the output emission-line fluxes have been corrected for Galactic extinction. However, the models and binned spectra in the output `LOGCUBE` file are reverted to their reddened values for direct comparison with the DRP LOGCUBE file.

The `MAPS` files contain the following extensions:

HDU No.	Name	Channels	Units	Description
0	PRIMARY	0		Empty extension with primary header information.
Coordinate and binning extensions				
1	SPX_SKYCOO	2	arcsec	Sky-right offsets -- +x toward +RA and +y toward +DEC -- of each spaxel from the galaxy center
2	SPX_ELLCOO	3	arcsec, unitless, deg	Elliptical polar coordinates of each spaxel from the galaxy center; R, R/R_{eff}, theta. In the limit of tilted thin disk, these are the in-plane disk radius and azimuth; the 2nd channel is the radius normalized by the elliptical Petrosian effective radius from the NSA.
3	SPX_MFLUX	1	$10^{(-17)}$ erg/s/cm^2/angstrom/spaxel	g-band-weighted mean flux, *not* corrected for Galactic extinction or internal attenuation
4	SPX_MFLUX_IVAR	1		Inverse variance of g-band-weighted mean flux
5	SPX_SNR	1		Mean g-band weighted signal-to-noise ratio per pixel
6	BINID	5		Numerical ID for spatial bins for the binned spectra, stellar-continuum results, emission-line moment results, emission-line model results, and spectral-index results; see **below**.
7	BIN_LWSKYCOO	2	arcsec	Light-weighted sky-right offsets -- +x toward +RA and +y toward +DEC -- of each bin from the galaxy center.
				Light-weighted elliptical polar coordinates of

8	BIN_LWELLCOO	3	arcsec,unitless,deg	each bin from the galaxy center. In the limit of tilted thin disk, these are the in-plane disk radius and azimuth; the 2nd channel is the radius normalized by the elliptical Petrosian effective radius from the NSA.
9	BIN_AREA	1	$arcsec^2$	Area of each bin
10	BIN_FAREA	1		Fractional area that the bin covers for the expected bin shape (only relevant for radial binning)
11	BIN_MFLUX	1	$10^{(-17)}$ $erg/s/cm^2/angstrom/spaxel$	g-band-weighted mean flux for the binned spectra, *not* corrected for Galactic extinction or internal attenuation
12	BIN_MFLUX_IVAR	1		Inverse variance of g-band-weighted mean flux for the binned spectra
13	BIN_MFLUX_MASK	1		Bit mask for the g-band-weighted mean flux per bin
14	BIN_SNR	1		Mean g-band-weighted signal-to-noise ratio per pixel in the binned spectra
Stellar absorption line kinematics				
15	STELLAR_VEL	1	km/s	Line-of-sight stellar velocity, relative to the input guess redshift (given as cz in SCINPVEL PRIMARY header keyword and most often identical to the NSA redshift)
16	STELLAR_VEL_IVAR	1		Inverse variance of stellar velocity measurements
17	STELLAR_VEL_MASK	1		Data quality mask for stellar velocity measurements
18	STELLAR_SIGMA	1	km/s	Raw line-of-sight stellar velocity dispersion (**must be corrected** using STELLAR_SIGMACORR to obtain the astrophysical dispersion)
19	STELLAR_SIGMA_IVAR	1		Inverse variance of stellar velocity

				dispersion
20	STELLAR_SIGMA_MASK	1		Data quality mask for stellar velocity dispersion
21	STELLAR_SIGMACORR	1	km/s	Quadrature correction for STELLAR_SIGMA to obtain the astrophysical velocity dispersion.
22	STELLAR_FOM	9		Figures-of-merit for the stellar continuum fit in 9 channels: (1) RMS of residuals (in units of 1E-17 erg/s/cm^2/ang/spaxel), (2) RMS of fractional residuals, (3) reduced chi-square, (4-6) 68th and 99th percentile and maximum value of fractional residuals, and (7-9) 68th and 99th percentile and maximum value of error-normalized residual (chi)
Emission line measurements				
23	EMLINE_SFLUX	35	$10^{(-17)}$ erg/s/cm^2/spaxel	Non-parametric summed flux *after subtracting the stellar-continuum model*. The emission-line fluxes account for Galactic reddening using the E(B-V) value (copied to the DAP primary headers, see EBVGAL) provided by the DRP header and assuming an O'Donnell (1994, ApJ, 422, 158) reddening law; however, no attenuation correction is applied due to dust internal to the galaxy.
24	EMLINE_SFLUX_IVAR	35		Inverse variance for summed flux measurements
25	EMLINE_SFLUX_MASK	35		Data quality mask for summed flux measurements
26	EMLINE_SEW	35	angstrom	Non-parametric equivalent widths measurements (based one EMLINE_SFLUX)
27	EMLINE_SEW_CNT	35	$10^{(-17)}$	**New in MPL-9**: Continuum value used to compute the

			erg/s/cm^2/angstrom/spaxel	emission-line equivalent width
28	EMLINE_SEW_IVAR	35		Inverse variance for non-parametric equivalent width measurements
29	EMLINE_SEW_MASK	35		Data quality mask for non-parametric equivalent width measurements
30	EMLINE_GFLUX	35	$10^{(-17)}$ erg/s/cm^2/spaxel	Gaussian profile integrated flux *from a combined continuum+emission-line fit*. **The flux ratio of the [NeIII], [OIII], [OI], [NII], and [SIII] lines are fixed and cannot be treated as independent measurements**. The emission-line fluxes account for Galactic reddening using the E(B-V) (copied to the DAP primary headers, see EBVGAL) value provided by the DRP header and assuming an O'Donnell (1994, ApJ, 422, 158) reddening law; however, no attenuation correction is applied due to dust internal to the galaxy.
31	EMLINE_GFLUX_IVAR	35		Inverse variance for Gaussian flux measurements
32	EMLINE_GFLUX_MASK	35		Data quality mask for Gaussian flux measurements
33	EMLINE_GEW	35	angstrom	Gaussian-fitted equivalent widths measurements (based on EMLINE_GFLUX)
34	EMLINE_GEW_CNT	35	$10^{(-17)}$ erg/s/cm^2/angstrom/spaxel	**New in MPL-9**: Continuum value used to compute the emission-line equivalent width
35	EMLINE_GEW_IVAR	35		Inverse variance of the above
36	EMLINE_GEW_MASK	35		Data quality mask of the above
				Line-of-sight emission-

37	EMLINE_GVEL	35	km/s	line velocity, relative to the input guess redshift (given as cz in SCINPVEL PRIMARY header keyword and most often identical to the NSA redshift). A velocity is provided for each line, **but the velocities are identical for all lines** because the parameters are tied during the fitting process.
38	EMLINE_GVEL_IVAR	35		Inverse variance for Gaussian-fitted velocity measurements, which are **the same for all lines and should not be combined as if independent measurements**
39	EMLINE_GVEL_MASK	35		Data quality mask for Gaussian-fitted velocity measurements
40	EMLINE_GSIGMA	35	km/s	Gaussian profile velocity dispersion as would be measured from a direct Gaussian fit (**must be corrected** using EMLINE_INSTSIGMA to obtain the astrophysical dispersion). **The velocity dispersions of the [OII], [NeIII], [OIII], [OI], [NII], [NI], [SIII], and (H-zeta + HeI 3889) lines are tied and cannot be treated as independent measurements**.
41	EMLINE_GSIGMA_IVAR	35		Inverse variance for Gaussian profile velocity dispersion
42	EMLINE_GSIGMA_MASK	35		Data quality mask for Gaussian profile velocity dispersion
43	EMLINE_INSTSIGMA	35	km/s	The instrumental dispersion at the fitted center of each emission line
44	EMLINE_TPLSIGMA	35	km/s	The dispersion of each emission line used in the template spectra; see below
			$10^{(-17)}$	The amplitude of the

45	EMLINE_GA	35	erg/s/cm^2/angstrom/spaxel	model Gaussian fit to each emission line
46	EMLINE_GANR	35		The amplitude of the model Gaussian fit relative to the median noise in two sidebands near the line; the sidebands are identical to those used in the equivalent width measurement
47	EMLINE_FOM	9		Figures-of-merit for the continuum+emission-line model fit in 9 channels: (1) RMS of residuals (in units of 1E-17 erg/s/cm^2/ang/spaxel), (2) RMS of fractional residuals, (3) reduced chi-square, (4-6) 68th and 99th percentile and maximum value of fractional residuals, and (7-9) 68th and 99th percentile and maximum value of error-normalized residual (chi)
48	EMLINE_LFOM	35		The reduced chi-square of the fit to each line calculated in 15-pixel windows centered on each line.
Spectral index measurements				
49	SPECINDEX	46	ang or mag	Spectral-index measurements
50	SPECINDEX_IVAR	46		Inverse variance for spectral index maps
51	SPECINDEX_MASK	46		Data quality mask for spectral index maps
52	SPECINDEX_CORR	46	unitless or mag	Corrections to apply to account for the velocity dispersion and effectively determine the index without Doppler broadening; see below.
53	SPECINDEX_BCEN	46	angstrom	**New in MPL-9**: Luminosity-weighted center of the blue sideband used during the absorption-line index measurment.
54	SPECINDEX_BCNT	46	$10^{(-17)}$	**New in MPL-9**: Continuum in the blue sideband used to compute linear

			erg/s/cm^2/angstrom/spaxel	continuum in the absorption-line index measurment.
55	SPECINDEX_RCEN	46	angstrom	**New in MPL-9**: Luminosity-weighted center of the red sideband used during the absorption-line index measurment.
56	SPECINDEX_RCNT	46	$10^{(-17)}$ erg/s/cm^2/angstrom/spaxel	**New in MPL-9**: Continuum in the red sideband used to compute linear continuum in the absorption-line index measurment.
57	SPECINDEX_MODEL	46	ang,mag	**New in MPL-9**: Spectral-index measurements for the best-fitting model spectrum.

Emission-line measurements : For the Gaussian-fitted measurements of the emission lines, the channels in each extension are:

```
C01     = 'OII-3727'          / Data in channel 1
C02     = 'OII-3729'          / Data in channel 2
C03     = 'H12-3751'          / Data in channel 3
C04     = 'H11-3771'          / Data in channel 4
C05     = 'Hthe-3798'         / Data in channel 5
C06     = 'Heta-3836'         / Data in channel 6
C07     = 'NeIII-3869'        / Data in channel 7
C08     = 'HeI-3889'          / Data in channel 8
C09     = 'Hzet-3890'         / Data in channel 9
C10     = 'NeIII-3968'        / Data in channel 10
C11     = 'Heps-3971'         / Data in channel 11
C12     = 'Hdel-4102'         / Data in channel 12
C13     = 'Hgam-4341'         / Data in channel 13
C14     = 'HeII-4687'         / Data in channel 14
C15     = 'Hb-4862 '          / Data in channel 15
C16     = 'OIII-4960'         / Data in channel 16
C17     = 'OIII-5008'         / Data in channel 17
C18     = 'NI-5199 '          / Data in channel 18
C19     = 'NI-5201 '          / Data in channel 19
C20     = 'HeI-5877'          / Data in channel 20
C21     = 'OI-6302 '          / Data in channel 21
C22     = 'OI-6365 '          / Data in channel 22
C23     = 'NII-6549'          / Data in channel 23
C24     = 'Ha-6564 '          / Data in channel 24
C25     = 'NII-6585'          / Data in channel 25
C26     = 'SII-6718'          / Data in channel 26
C27     = 'SII-6732'          / Data in channel 27
C28     = 'HeI-7067'          / Data in channel 28
C29     = 'ArIII-7137'        / Data in channel 29
C30     = 'ArIII-7753'        / Data in channel 30
C31     = 'Peta-9017'         / Data in channel 31
C32     = 'SIII-9071'         / Data in channel 32
C33     = 'Pzet-9231'         / Data in channel 33
C34     = 'SIII-9533'         / Data in channel 34
C35     = 'Peps-9548'         / Data in channel 35
```

Notes:

- **The order of the emission-line channels has changed since MPL-8!**
- For the emission-line moments:
  - Channels 2 ('OII-3729'), 8 ('HeI-3889'), 10 ('NeIII-3968'), and 19 ('NI-5201') are empty because the line falls in the passband of another line: 'OII-3729' in 'OIId-3728', 'HeI-3889' in 'Hzet-3890', 'NeIII-3968' in 'Heps-3971', and 'NI-5201' in 'NI-5199'. To compare these fluxes with the Gaussian-fitted values, you should sum the Gaussian-fitted fluxes first.
  - OIId is contaminated by H14 and H13
  - Hzet is contaminated by HeI
  - Heps is contaminated by NeIII
  - Red sideband of Hbeta is contaminated by HeI
  - Unknown line at 4990 and may contaminate red sideband of OIII 4960 and the blue sideband of OIII 5008
  - OIII 5008 contaminated by HeI 5017

Spectral-index measurements : Because the spectral index measurements can be either angstroms, magnitudes, or unitless, the header of the spectral-index extensions also include the units using header keywords `Un`. The index and unit in each channel is:

```
C01     = 'CN1     '           / Data in channel 1
U01     = 'mag     '           / Units of data in channel 1
C02     = 'CN2     '           / Data in channel 2
U02     = 'mag     '           / Units of data in channel 2
C03     = 'Ca4227  '           / Data in channel 3
U03     = 'ang     '           / Units of data in channel 3
C04     = 'G4300   '           / Data in channel 4
U04     = 'ang     '           / Units of data in channel 4
C05     = 'Fe4383  '           / Data in channel 5
U05     = 'ang     '           / Units of data in channel 5
C06     = 'Ca4455  '           / Data in channel 6
U06     = 'ang     '           / Units of data in channel 6
C07     = 'Fe4531  '           / Data in channel 7
U07     = 'ang     '           / Units of data in channel 7
C08     = 'C24668  '           / Data in channel 8
U08     = 'ang     '           / Units of data in channel 8
C09     = 'Hb      '           / Data in channel 9
U09     = 'ang     '           / Units of data in channel 9
C10     = 'Fe5015  '           / Data in channel 10
U10     = 'ang     '           / Units of data in channel 10
C11     = 'Mg1     '           / Data in channel 11
U11     = 'mag     '           / Units of data in channel 11
C12     = 'Mg2     '           / Data in channel 12
U12     = 'mag     '           / Units of data in channel 12
C13     = 'Mgb     '           / Data in channel 13
U13     = 'ang     '           / Units of data in channel 13
C14     = 'Fe5270  '           / Data in channel 14
U14     = 'ang     '           / Units of data in channel 14
C15     = 'Fe5335  '           / Data in channel 15
U15     = 'ang     '           / Units of data in channel 15
C16     = 'Fe5406  '           / Data in channel 16
U16     = 'ang     '           / Units of data in channel 16
C17     = 'Fe5709  '           / Data in channel 17
U17     = 'ang     '           / Units of data in channel 17
C18     = 'Fe5782  '           / Data in channel 18
U18     = 'ang     '           / Units of data in channel 18
C19     = 'NaD     '           / Data in channel 19
U19     = 'ang     '           / Units of data in channel 19
C20     = 'TiO1    '           / Data in channel 20
U20     = 'mag     '           / Units of data in channel 20
C21     = 'TiO2    '           / Data in channel 21
U21     = 'mag     '           / Units of data in channel 21
C22     = 'HDeltaA '           / Data in channel 22
```

```
U22     = 'ang     '            / Units of data in channel 22
C23     = 'HGammaA '            / Data in channel 23
U23     = 'ang     '            / Units of data in channel 23
C24     = 'HDeltaF '            / Data in channel 24
U24     = 'ang     '            / Units of data in channel 24
C25     = 'HGammaF '            / Data in channel 25
U25     = 'ang     '            / Units of data in channel 25
C26     = 'CaHK    '            / Data in channel 26
U26     = 'ang     '            / Units of data in channel 26
C27     = 'CaII1   '            / Data in channel 27
U27     = 'ang     '            / Units of data in channel 27
C28     = 'CaII2   '            / Data in channel 28
U28     = 'ang     '            / Units of data in channel 28
C29     = 'CaII3   '            / Data in channel 29
U29     = 'ang     '            / Units of data in channel 29
C30     = 'Pa17    '            / Data in channel 30
U30     = 'ang     '            / Units of data in channel 30
C31     = 'Pa14    '            / Data in channel 31
U31     = 'ang     '            / Units of data in channel 31
C32     = 'Pa12    '            / Data in channel 32
U32     = 'ang     '            / Units of data in channel 32
C33     = 'MgICvD  '            / Data in channel 33
U33     = 'ang     '            / Units of data in channel 33
C34     = 'NaICvD  '            / Data in channel 34
U34     = 'ang     '            / Units of data in channel 34
C35     = 'MgIIR   '            / Data in channel 35
U35     = 'ang     '            / Units of data in channel 35
C36     = 'FeHCvD  '            / Data in channel 36
U36     = 'ang     '            / Units of data in channel 36
C37     = 'NaI     '            / Data in channel 37
U37     = 'ang     '            / Units of data in channel 37
C38     = 'bTiO    '            / Data in channel 38
U38     = 'mag     '            / Units of data in channel 38
C39     = 'aTiO    '            / Data in channel 39
U39     = 'mag     '            / Units of data in channel 39
C40     = 'CaH1    '            / Data in channel 40
U40     = 'mag     '            / Units of data in channel 40
C41     = 'CaH2    '            / Data in channel 41
U41     = 'mag     '            / Units of data in channel 41
C42     = 'NaISDSS '            / Data in channel 42
U42     = 'ang     '            / Units of data in channel 42
C43     = 'TiO2SDSS'            / Data in channel 43
U43     = 'mag     '            / Units of data in channel 43
C44     = 'D4000   '            / Data in channel 44
U44     = '' / Units of data in channel 44
C45     = 'Dn4000  '            / Data in channel 45
U45     = '' / Units of data in channel 45
C46     = 'TiOCvD  '            / Data in channel 46
U46     = '' / Units of data in channel 46
```

12.3.1. MAP corrections

See here.

Note that the stellar and gas velocity dispersions **must be corrected for instrumental resolution effects** to obtain the astrophysical Doppler broadening.

The corrected gas velocity dispersion is:

sigma_gas_corr = sqrt(`EMLINE_GSIGMA`^{2} - `EMLINE_INSTSIGMA`^{2})

The corrected stellar velocity dispersion is:

sigma_star_corr = sqrt(`STELLAR_SIGMA`^{2} - `STELLAR_SIGMACORR`^{2})

In both cases, beware of imaginary numbers. That is, when the correction is larger than the provided value, the above equations result in taking the sqrt of a negative number. Stellar velocity dispersions are provided for two approaches to the calculation: A nominal correction is calculated using the quadrature difference between the instrumental dispersion of the template and galaxy spectra over the fitted wavelenghth range. This is the correction provided in MPL-5, MPL-7/DR15. **Please consult the DAP Overview paper.** In MPL-9, we also provide a correction based on a fit of the optimal template with and without the resolution matched to the MaNGA data. **For now, use the correction in the first channel of the `STELLAR_SIGMACORR` until the data in the second channel can be vetted.**

Also, velocity-dispersion corrections are provided for the spectral indices, and **these corrections must be applied by the user.** Note that this is different to the approach taken by the Firefly VAC. To apply the corrections, you have to know the unit of each index. For angstrom units:

specindex_ang_corr = `SPECINDEX` * `SPECINDEX_CORR`

and for magnitude units:

specindex_mag_corr = `SPECINDEX` + `SPECINDEX_CORR`

An example of how to apply the corrections to both velocity dispersion measurements and the spectral indices is provided here.

12.4. DAP `LOGCUBE` file

See here.

File template: `type`/`plate`/`ifudesign`/manga-`plate`-`ifudesign`-LOGCUBE-`type`.fits.gz

The `LOGCUBE` files provide the binned spectra and the best-fitting model spectrum for each spectrum that was successfully fit. These files are useful for detailed assessments of the model parameters because they allow you to return to the spectra and compare the model against the data. As described by the DAP Overview paper, the DAP fits the spectra in two stages, one to get the stellar kinematics and the second to determine the emission-line properties. The emission-line module (used for all binning schemes) fits both the stellar continuum and the emission lines at the same time, where the stellar kinematics are fixed by the first fit. The stellar-continuum models from the first fit are provided in the `STELLAR` extension; to get the stellar continuum determined during the emission-line modeling, you calculate:

stellar_continuum (from emission-line modeling module) = `MODEL` - `EMLINE`

WARNING	In the HYB binning case, the binned spectra provided in the `LOGCUBE` files are from the Voronoi binning step; however, the emission-line models are fit to the *individual spaxels*. See discussion of special considerations for the HYB binning case below.

An example of how to plot the model cube data using python is provided here, which also demonstrates how to effectively use the provided masks.

NOTE	Internally, the DAP performs all spectral fitting on the binned spectra (termed as such even if a bin only contains a single spaxel) *after* they have been corrected for Galactic extinction. Therefore, the output emission-line fluxes have been corrected for Galactic extinction. However, the models and binned spectra in the output `LOGCUBE` file are reverted to their reddened values for direct comparison with the DRP LOGCUBE file.

The `LOGCUBE` files contain the following extensions:

HDU	Name	Units	Description

No.			
0	PRIMARY		Empty extension with primary header information.
1	FLUX	10^{-17} erg/s/cm^2/angstrom/spaxel	Flux of the *binned* spectra
2	IVAR		Inverse variance in the binned spectra
3	MASK		Bitmask for the binned spectra. Note that this mask only applies to the binned spectra.
4	WAVE	angstrom	Vacuum-wavelength vector
5	REDCORR		Reddening correction applied during the fitting procedures; `dereddened_flux = FLUX * REDCORR`
6	MODEL	10^{-17} erg/s/cm^2/angstrom/spaxel	The best-fitting model spectra (sum of the fitted continuum and emission-line models)
7	MODEL_MASK		The mask from the combined continuum+emission-line model fit
8	EMLINE	10^{-17} erg/s/cm^2/angstrom/spaxel	The model spectrum with *only* the emission lines
9	STELLAR	10^{-17} erg/s/cm^2/angstrom/spaxel	The best-fitting model spectra fit from the stellar-continuum-only fit (used to model the stellar kinematics)
10	STELLAR_MASK		The mask for the best-fitting model spectra fit from the stellar-continuum-only fit (used to model the stellar kinematics)
11	BINID		Numerical ID for spatial bins in 5 channels: (1) binned spectra, (2) stellar-continuum results, (3) empty, (4) emission-line model results, and (5) empty; i.e., channels 1, 2, and 4 are the same as the BINID extension in the `MAPS` files and channels 3 and 5 are empty.

The shape and WCS of all the datacubes identically match that of the corresponding DRP `LOGCUBE` file.

12.5. Special considerations

Please consult the DAP Overview and Emission-line Modeling papers for usage guidelines and limitations of the data.

See here also.

12.5.1. DAP BINIDs and usage

See here.

It's important to understand that, for all but the SPX binning type, not all of the data in the `MAPS` and `LOGCUBE` files are independent. Putting aside the issue of covariance, we *repeat* measurements for a given binned spectrum in all the spaxels associated with that bin for consistency between the DAP and DRP data formats. Therefore, if you are, e.g., fitting a model the the `MAPS` data or calculating azimuthal averages, you should pull out the binned quantities that *are* unique before proceeding. **In addition to any associated MASK values**, you should use the BINID extension (and, indeed, its main purpose is) to extract the unique (but still correlated) data to use in such an analysis.

This extension has one channel for each of the 5 main processing steps: binning, stellar-continuum and -kinematics fitting, emission-line moment measurements, emission-line Gaussian modeling, and spectral indices. Keep in mind the following:

- *BINID == -1 means that the spaxel was not included in the analysis.* For example, BINID values of -1 in the first BINID channel means that either the spaxel had insufficiently good/unmasked pixels or too low S/N to be included in the binning procedure. Any spaxel with BINID = -1 should also be masked as DONOTUSE in the respective property map.
- *A BINID may be >-1 in one channel and = -1 in a different channel.* For example, a spaxel in the binning BINID map may be >-1 but be -1 in the stellar-continuum BINID. This likely means that the spaxels were successfully binned, but the bin had S/N < 1 meaning it was not analyzed by the stellar-continuum fitting module.
- *For MPL-9, the only difference in BINIDs is the -1 vs. non-negative distinction described in the last point,* **except for the HYB binning scheme**. For the HYB binning case, the emission-line moments, emission-line modeling, and spectral-index measurements are done on a spaxel-by-spaxel basis, meaning that the BINIDs are redetermined and is just a running number (not, e.g., ordered by S/N) for the spaxels that were analyzed.

Example python code that extracts both the unique and unmasked data from a `MAPS` file to produce the g-band and H-alpha surface brightness profiles is provided here.

12.5.2. HYB binning scheme

See here.

In all cases except the HYB binning approach, each analysis module only works with the "binned" spectra after the binning is performed. (I've put "binned" in quotes here because all spectra are treated the same after the binning step, even if the "bin" only includes a single spaxel.) In the HYB case, the emission-line modeling is done by first fitting the continuum+emission-line data simultaneously, distributing those results as a starting point for fitting the (spatially) closest spaxels, and then redoing the simultaneous fit for each spaxel. By fitting the data as a hybrid between the VOR10 and SPX binning schemes, there are a few things to keep in mind:

- Because the stellar kinematics are held fixed to the binned results during the spaxel-by-spaxel continuum+emission-line fit, there will be (hopefully subtle) covariance issues between spaxels associated with a single bin, beyond what one would expect from the datacube construction alone.
- The binned spectra provided in the HYB `LOGCUBE` files are from the Voronoi binning step; however, the emission-line models are fit to the *individual spaxels*. When using the `LOGCUBE` files for this binning scheme:
  - The stellar-continuum fits (in the `STELLAR` extension) should be compared to the Voronoi binned spectra in the file, but
  - the best-fitting model spectra (stellar continuum + gas emission) in the `MODEL` extension should be compared to the individual spectra from the *DRP* LOGCUBE file!
- Because the emission-line modeling is done on the individual spaxels, the emission-line moments are recalculated after the emission-line modeling to ensure the stellar continuum used for both the Gaussian model and the moment is identical. In the HYB case, this means the emission-line moments are also provided for the individual spaxels. It also means that the spectral indices are measured on the individual spaxels because the emission-line model is first subtracted from the data before the index measurements.

12.5.3. Usage Guidlines

12.5.3.1. Stellar velocity dispersions

See here.

12.5.4. Emission-line template resolution

See here.

12.6. DAP global header data

See here

The first extension of each of the main DAP output files (the `MAPS` and `LOGCUBE`) is empty apart from the header data. The header data is an exact copy of the primary header for the DRP manga-PLATE-IFUDESIGN-LOGCUBE.fits.gz file except that the **BSCALE**, **BZERO**, and **BUNIT** keywords are removed and the **AUTHOR** and **MASKNAME** keywords are changed.

The following keywords are also added, any keyword enclose in () are only written under certain conditions:

Keyword	Description
VERSPY	Python version
VERSNP	Numpy version
VERSSCI	Scipy version
VERSAST	Astropy version
VERSPYDL	pydl version
VERSDAP	MaNGA DAP version
DAPTYPE	The [type] identifier for the DAP analysis (e.g. `HYB10-MILESHC-MILESHC`)
DAPFRMT	The format of this output file, either `MAPS` or `LOGCUBE`
RDXQAKEY	Configuration keyword for the method used to assess the reduced data
ECOOPA	Position angle used for the semi-major axis polar coordinate calculations
ECOOELL	Ellipticity (1-b/a) used for the semi-major axis polar coordinate calculations
BBWAVE	Wavelength of the `LOGCUBE` channel used for calculating the covariance used in the per spaxel S/N calculation
BBINDX	Index of the channel
REFF	Effective radius
BINKEY	Configuration keyword for the spatial binning method
BINMINSN	Minimum S/N of spectrum to include in the binning
FSPCOV	Minimum allowed fraction of good pixels across the full spectral range
NBINS	Number of unique spatial bins
(**EMPTYBIN**)	List of empty bins, if any exist
BINTYPE	Spatial binning method
(**BINCX**)	If radial binning, on-sky X center for all bins
(**BINCY**)	If radial binning, on-sky Y center for all bins
(**BINPA**)	If radial binning, position angle used for all bins
(**BINELL**)	If radial binning, ellipticity (1-b/a) used for all bins
(**BINSCL**)	If radial binning, the radius has been scaled by this value (arcsec)
(**BINRAD**)	If radial binning, provides the start, end, and number of radial bins
(**BINLGR**)	If radial binning, the geometric step used to set the radial bins
(**BINSNR**)	If Voronoi binning, the target S/N for each bin
(**BINCOV**)	If Voronoi binning, the method used to incorporate covariance into the S/N calculation
(**NCALIB**)	If Voronoi binning and using a calibration of the noise vector that incorporates covariance, the noise calibration coefficient
(**STCKOP**)	If binning spectra, the operation used for stacking spectra
(**STCKVREG**)	If binning spectra, a boolean flag that the spectra were shifted in velocity before stacked
(**STCKCRMD**)	If binning spectra, the approach used to account for covariance in the resulting inverse variance of the binned spectrum
(**STCKCRPR**)	If binning spectra, the method-specific parameters used to incorporate covariance in the stacking procedure

(**STCKRES**)	Stacking operation performs a stack of the individual spaxel resolution vectors (DISP) as opposed to the single median vector (SPECRES)
(**STCKPRE**)	Stacking operation uses the pre-pixelized spectral resolution instead of the post-pixelized version
GEXTLAW	Galactic extinction law used to deredden the data
RVGAL	Ratio of total to selective extinction, R(V)
VSTEP	Velocity step per spectral channel
SCKEY	Configuration keyword for the method used to model the stellar-continuum
SCMINSN	Minimum S/N of spectrum to include in stellar-continuum fits
SCINPVEL	Initial guess stellar velocity
SCINPSIG	Initial guess stellar velocity dispersion
NSCMOD	Number of unique stellar-continuum models
(**EMPTYSC**)	List of bins without a stellar-continuum model, if any exist
SCTYPE	Type of spectral fitting method used for the stellar-continuum fits
SCMETH	Algorithm used for the stellar-continuum fits
PPXFTPLK	Configuration keyword for the template library key used with pPXF
PPXFBIAS	pPXF bias value
PPXFMOM	Number of fitted LOSVD moments in pPXF
PPXFAO	Order of additive polynomial in pPXF
PPXFMO	Order of multiplicative polynomial in pPXF
PPXFRBOX	Size of the boxcar filter used during rejection iterations
ELMKEY	Configuration keyword that defines the emission-line moment measurement method
ELMMINSN	Minimum S/N of spectrum to include in emission-line moment measurements
ARTDB	Artifact database keyword
MOMDB	Emission-line moments database keyword
ELFKEY	Configuration keyword that defines the emission-line modeling method
ELFMINSN	Minimum S/N of spectrum to include in emission-line modeling
EMLDB	Emission-line database keyword
NELMOD	Number of unique emission-line models
ELTYPE	Type of spectral fitting method used for the emission-line fits
ELMETH	Algorithm used for the emission-line modeling
SIKEY	Configuration keyword that defines the spectral-index measurement method
SIMINSN	Minimum S/N of spectrum to include in spectral-index measurements
SIFWHM	FWHM of index system resolution (ang) to which the galaxy spectra were matched
ABSDB	Absorption-line index database keyword
BHDDB	Bandhead-index database keyword
SICORR	Flag that indices have been corrected for velocity dispersion
SNRGMED	Median g-band signal-to-noise of spaxels within 1-1.5 Re
SNRGRING	Total g-band signal-to-noise of a binned spectrum using spaxels within 1-1.5 Re bin
SNRRMED	Median r-band signal-to-noise of spaxels within 1-1.5 Re
SNRRRING	Total r-band signal-to-noise of a binned spectrum using spaxels within 1-1.5 Re bin
SNRIMED	Median i-band signal-to-noise of spaxels within 1-1.5 Re
SNRIRING	Total i-band signal-to-noise of a binned spectrum using spaxels within 1-1.5 Re bin
SNRZMED	Median z-band signal-to-noise of spaxels within 1-1.5 Re

SNRZRING	Total z-band signal-to-noise of a binned spectrum using spaxels within 1-1.5 Re bin
DAPQUAL	DAP quality mask bit

The headers of the data extensions are more minimal. They include:

- the WCS information,
- the HDUCLASS keyword block,
- the channel description for the MAPS files,
- the units for any single image or datacube extensions (**BUNIT**), and
- the **DATASUM** and **CHECKSUM** values.

Last modified on 11/27/19 10:42:02