MAUVE Quality Control Cookbook

Version	Date	Authors
1.0	12 Jul 2023	Luca Cortese, Barbara Catinella
1.1	02 Oct 2024	Luca Cortese – Added step 4 QC for mosaic flux calibration

Introduction

This document should be used together with the Data Reduction (DR) cookbook to perform some basic data quality checks. Below, “DR step x” refers to the corresponding step in the DR cookbook. As you perform the various data quality checks, please record your findings on the data reduction spreadsheet [at this link](), in the sections provided.

DR step 1

After completion of step1 of the data reduction (basic calibrations), please follow these steps:

- Create a directory “**QC**” inside the folder of the galaxy that you are reducing: e.g.,
    - `cd /cloud/teamdata/mauve/red_test_luca/Data/MAUVE/Muse/NGC4064`
    - `mkdir QC`

- Copy the “`step1_qc.py`” script in the QC directory. You can find all the qc scripts on magpipe under: `/cloud/teamdata/mauve/scripts/qc/`

- From inside the QC folder that you just created:
    - Open python: > `ipython --pylab`
    - Type: `run step1_qc.py`

The script should take a few minutes and you should see the info below gradually appearing.

```
In [3]: run step1_qc.py
Looking for Master Bias Files
Making QC plots for bias ../OB002/Master/Bias/MASTER_BIAS_2023-03-27T10:31:18.fits
Making QC plots for bias ../OB002/Master/Bias/MASTER_BIAS_2023-03-25T09:57:37.fits
Making QC plots for bias ../OB002/Master/Bias/MASTER_BIAS_2023-03-24T10:03:09.fits
Making QC plots for bias ../OB001/Master/Bias/MASTER_BIAS_2023-03-26T10:06:48.fits
Making QC plots for bias ../OB001/Master/Bias/MASTER_BIAS_2023-03-25T09:57:37.fits
Making QC plots for bias ../OB001/Master/Bias/MASTER_BIAS_2023-03-24T10:03:09.fits
Looking for Master Flat Files
Making QC plots for flat ../OB002/Master/Flat/MASTER_FLAT_2023-03-24T11:24:21.fits
Making QC plots for flat ../OB002/Master/Flat/MASTER_FLAT_2023-03-27T11:30:23.fits
Making QC plots for flat ../OB001/Master/Flat/MASTER_FLAT_2023-03-25T16:09:59.fits
Making QC plots for flat ../OB001/Master/Flat/MASTER_FLAT_2023-03-26T13:34:49.fits
Making QC plots for flat ../OB001/Master/Flat/MASTER_FLAT_2023-03-24T11:24:21.fits
Looking for Master Trace Files
Making QC plots for trace tables ../OB002/Master/Trace/TRACE_TABLE_2023-03-27T11:30:23.fits
Making QC plots for trace tables ../OB002/Master/Trace/TRACE_TABLE_2023-03-24T11:24:21.fits
Making QC plots for trace tables ../OB001/Master/Trace/TRACE_TABLE_2023-03-24T11:24:21.fits
Making QC plots for trace tables ../OB001/Master/Trace/TRACE_TABLE_2023-03-25T16:09:59.fits
Making QC plots for trace tables ../OB001/Master/Trace/TRACE_TABLE_2023-03-26T13:34:49.fits
Looking for Master Wavelength Files
Making QC plots for wave cal tables ../OB002/Master/Wave/WAVECAL_TABLE_2023-03-24T11:40:08.fits
Making QC plots for wave cal tables ../OB002/Master/Wave/WAVECAL_TABLE_2023-03-27T11:46:09.fits
Making QC plots for wave cal tables ../OB001/Master/Wave/WAVECAL_TABLE_2023-03-25T16:25:46.fits
Making QC plots for wave cal tables ../OB001/Master/Wave/WAVECAL_TABLE_2023-03-26T13:50:37.fits
Making QC plots for wave cal tables ../OB001/Master/Wave/WAVECAL_TABLE_2023-03-24T11:40:08.fits
Looking for Master Lsf Files
```

Fig. 1: running `step1_qc.py`.

The script will produce several plots in the `QC` directory. Your task is to have a look at each plot and make sure that all is according to specs. We recommend using the browser (i.e., firefox) on magpipe to check the plots as “evince” is not great in dealing with many files at the same time.

BIAS

- Open a terminal and navigate to the `QC` directory, e.g.:
  `cd /cloud/teamdata/mauve/red_test_luca/Data/MAUVE/Muse/NGC4064/QC`
- Type: `firefox *BIAS*.pdf &`

For each master bias, you will see a plot like the one below (Fig. 2).
For each quadrant, you can check the mean, standard deviation and read-out-noise (RON) of the master bias produced during the DR for each of the 24 IFUs.

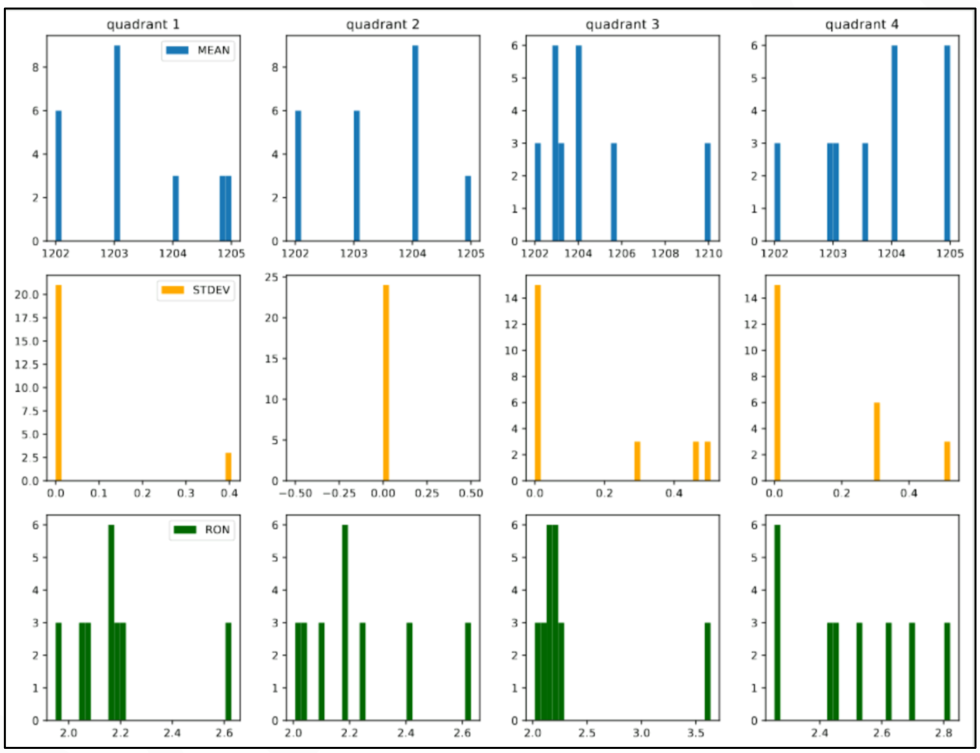

Fig. 2: master bias QC.

Please check that:

- The typical values are:
  - 1200-1210 for the mean
  - <1 for the STD
  - In the 2-4 range for RON
- There is not too much variation between the various master biases.

FLAT

- Type: `firefox *MASTER_FLAT*.pdf`

For each master flat, you can check the distribution of the flat mean (page 1 - Fig. 3) and standard deviation (page 2 – not shown) for each of the 48 slices in the 24 IFU.

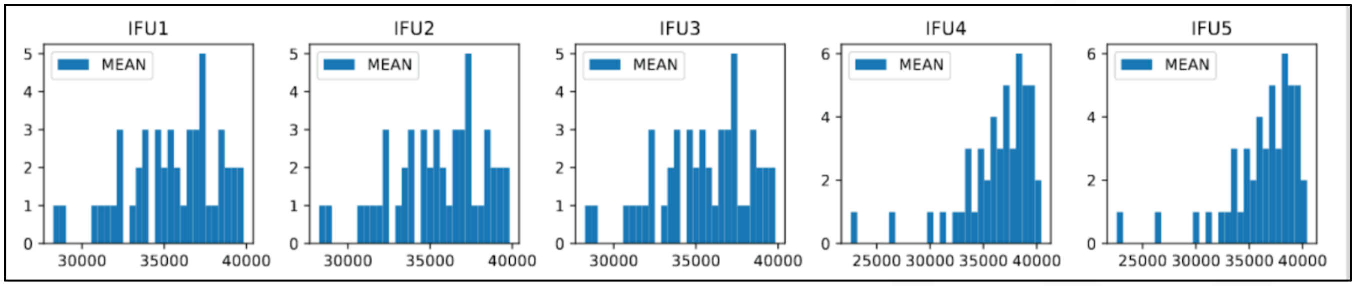

Fig. 3: master flat QC. This figure shows only the first row of the first page.

Please check that:

- Typical values are:
  - ~30,000-44,000 for the mean
  - ~1000-3000 for the standard deviation.
- There is not too much variation between the various master flats.

TRACE

- Type: `firefox *TRACE_TABLE*.pdf`

For each IFU, we plot the distribution of the mean and standard deviations for the trace widths (Fig. 4, top) and the inter-trace gaps (bottom), as well as the correlation between the maximum and minimum gaps and widths (right column). These VERY IMPORTANT plots highlight how well the different IFU have been identified.

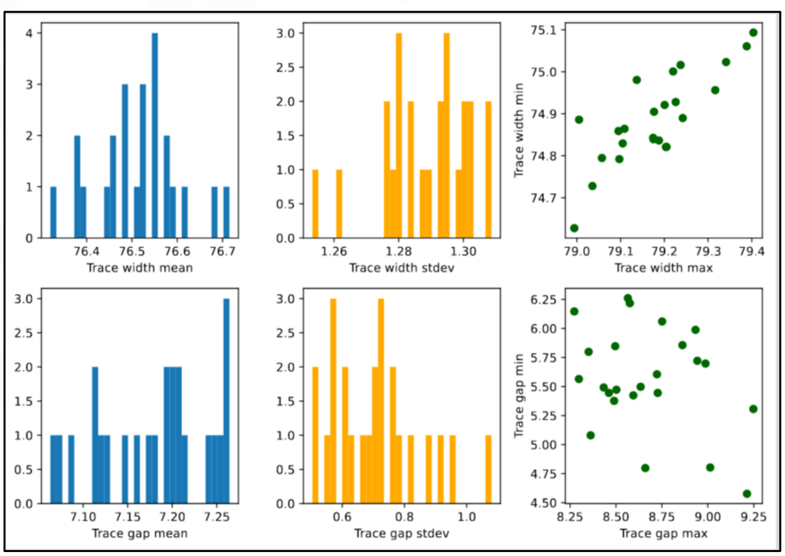

Fig. 4: trace QC.

Please check that:

- The spread in trace-width-mean, gaps-mean and their standard deviations is less than 1 pixel.
- Trace width max and width mean are correlated.
- There is minimal variation between the various trace solutions.

WAVELENGTH CALIBRATION

- Type: `firefox *WAVECAL*.pdf`

For each lamp, we plot the distributions of the mean FWHM (first page, see Fig. 5), its standard deviation (second page) and resolution (third page) for each of the 48 slices in the 24 IFU obtained by measuring the widths of the lines in the lamp.

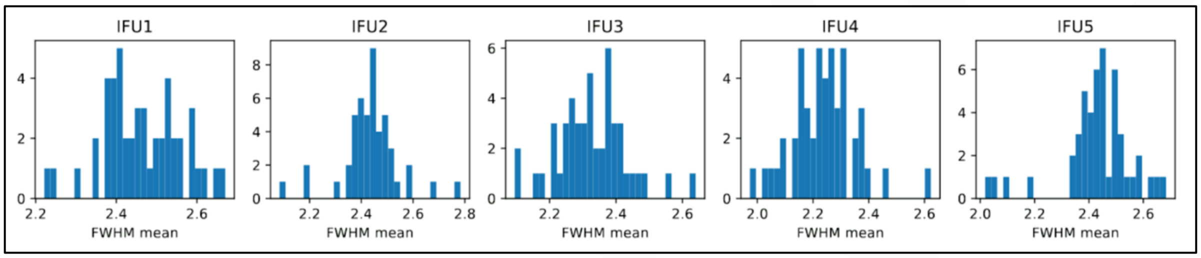

Fig. 5: wavelength calibration QC.

Please check that, for the bulk of the distribution:

- FWHM generally between 2.2 and 2.6
- Standard deviation is generally below 0.5
- Resolution is between 2800 and 3200
- There is little variation between the various lamps.

LSF PROFILE

- Type: `firefox *LSF_PROFILE*.pdf`

We plot the distribution of the mean LSF (first page, see below) and its standard deviation (second page) across the wavelength range for each of the 48 slices in the 24 IFU. The median value of the mean is also printed in each plot of the first page.

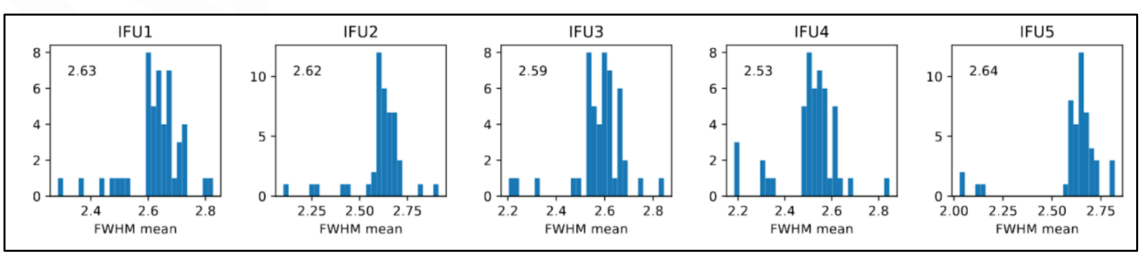

Fig. 5: LSF QC.

Please check that:

- FWHM median of means (the value printed on each subplot) is between 2.5 and 2.65.
- Standard deviations are below ~0.4.
- There is little variation between the various solutions.

TWILIGHT FLAT

- Type: `firefox *SKYFLAT*.pdf`

For each sky flat, you can check the distribution of the mean value of sky flat for each of the 24 IFU and the integrated total flux (in log10 units). OBs done in the same night will have the same sky flat.

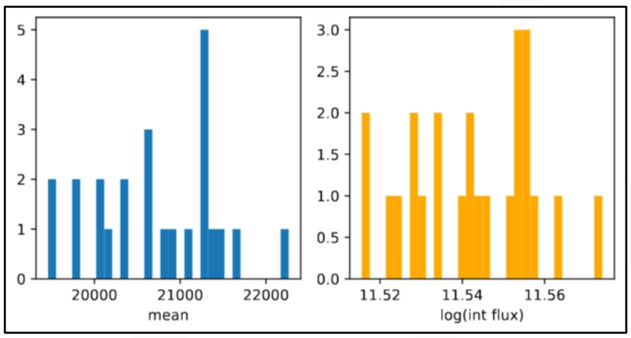

Fig. 6: sky flat QC.

Please check that:

- Means are in the 20,000-23,000 range.
- Integrated fluxes are of the order of 11.5 in log.
- There is little variation between the various flats (if more than one).

STANDARD STAR

Information on the standard star will be printed on screen and saved into a text file (search for `*STD*txt`).

```
NAME    FWHM      FWHM_MAD   THRU5000  THRU7000  THRU8000  THRU9000
LTT3218 0.7297073 0.02575052 0.2476069 0.351536 0.2645803 0.1621126
Extracting info for standard ../OB001/Master/Std/DATACUBE_STD_2023-03-25T23:34:56.fits
Standard Star Calibration values
NAME    FWHM      FWHM_MAD   THRU5000  THRU7000  THRU8000  THRU9000
LTT3218 0.931855 0.02161315 0.2336603 0.334547 0.2525473 0.1565071
```

Fig. 7: standard star QC.

Please check that:

- FWHM is reasonable (between 0.6” and 1.4”). If only one star is measured, FWHM_MAD=NaN
- Throughputs are in line with what expected (see example above)

- Type: `firefox *Std*.pdf`

For each standard star, you will have a plot like the one shown below (Fig. 8) showcasing the response function of the standard star: unsmoothed (black) and smoothed (red).

Please check that the smoothed version does not show any strong discontinuities.

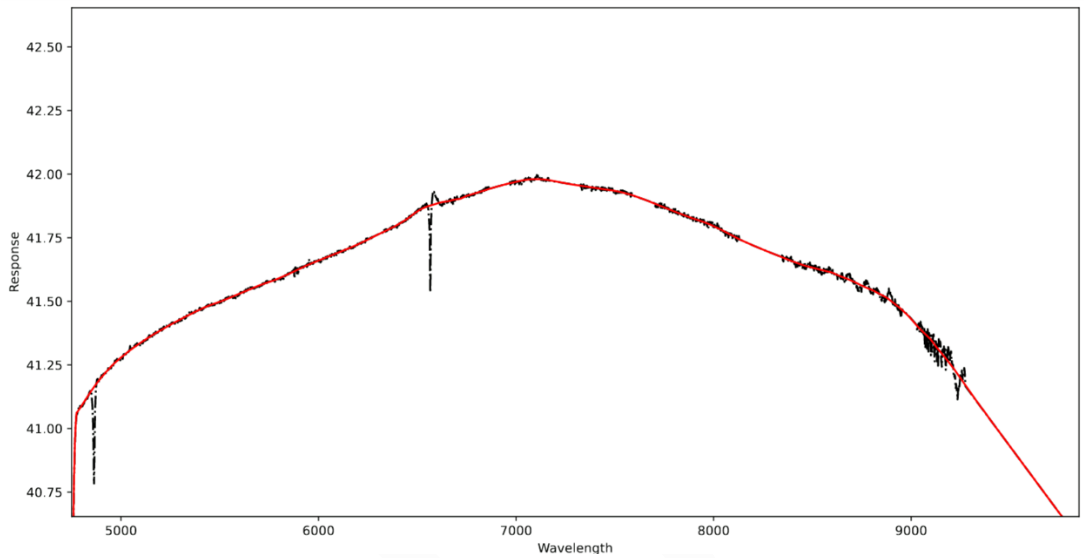

Fig. 8: Response function for the standard. Unsmoothed and smoothed in black and red, respectively.

SKY CONTINUUM

Basic info on sky continuum is printed on screen and saved into a text file (look for `*SKY_CONT*txt`).

```
Looking for Sky continuum files
Extracting info for sky continuum ../OB002/Sky/SKY_CONTINUUM_2023-03-27T03:22:49_0001.fits
Sky continuum values
CONTINUUM  MAX DERIVATIVE
400456.558406258 1930.06240391135
Extracting info for sky continuum ../OB001/Sky/SKY_CONTINUUM_2023-03-26T02:52:02_0001.fits
Sky continuum values
CONTINUUM  MAX DERIVATIVE
454281.712934491 2433.02073873281

In [4]: ls *STD*txt
```

Fig. 9: sky continuum QC.

Please check that:

- Continuum value is around 300,000-500,000.
- Derivative is no more than a few %: e.g., less than 3000-5000.

ERROR LOG

Look for error log under each OB directory:
e.g., from the QC directory type: > `ls ../OB*/Log/*err*`
If a log is found, look at what happened, and mark it in the data reduction spreadsheet.

Well done! You have reached the end of the QC for step 1. Before moving to step 2, please remember to mark all your findings in the data reduction spreadsheet for the galaxy you are reducing!

DR step 2

After the entire alignment procedure (including flux rescaling) has been completed and you are happy with the results, please navigate to the `QC` folder:

- Make sure that you have the `step2_qc.py` file in the QC folder. You can find it under `/cloud/teamdata/mauve/scripts/qc`
- Check that the `alignment_dir` and `alignment_file` names are correct (see below).

```
from astropy.io import fits
import numpy as np
import matplotlib.pyplot as plt
plt.rcParams['figure.figsize'] = [12, 12]
from matplotlib.backends.backend_pdf import PdfPages
import os


######
###### Update alignment dir folder
alignment_dir='/cloud/teamdata/mauve/red_test_luca/Data/MAUVE/Alignment_tables/'
######
###### Update offset table folder
alignment_file='NGC4064_offset_table_red_test_luca.fits'
#######

#########################################################
#### DO NOT CHANGE THE CODE BELOW UNLESS YOU KNOW WHAT YOU ARE DOING
############################################################
```

Fig. 10: `step2_qc.py` script.

- Start python: > `ipython`
- Type `run step2_qc.py`

You will see the values of the alignment shown on screen as shown in Fig. 11. Please note that there is a cos(declination) difference in the RA_OFFSET table.

```
In [28]: run step2_qc.py
DATASET_OBS - RA_OFFSET - DEC_OFFSET -ROTANGLE
[[ 1.          -1.38719613  0.18539623  0.04115407]
 [ 1.          -1.19916529  0.32630503 -0.03329094]
 [ 1.          -0.99223263  0.2313331  -0.04481634]
 [ 1.          -0.97327192  0.12734088 -0.08051885]
 [ 2.          -0.96344335  0.3259709  -0.5805006 ]
 [ 2.          -0.8394811   0.42561239 -0.46865905]
 [ 2.          -0.60091441  0.51513948 -0.95336892]
 [ 2.          -0.65738383  0.29729636 -0.72740141]]
```

Fig. 11: alignment QC.

The script will also create plots summarising the results of the offset (in arcsec) and flux rescaling.

Type `firefox *offset*pdf &`

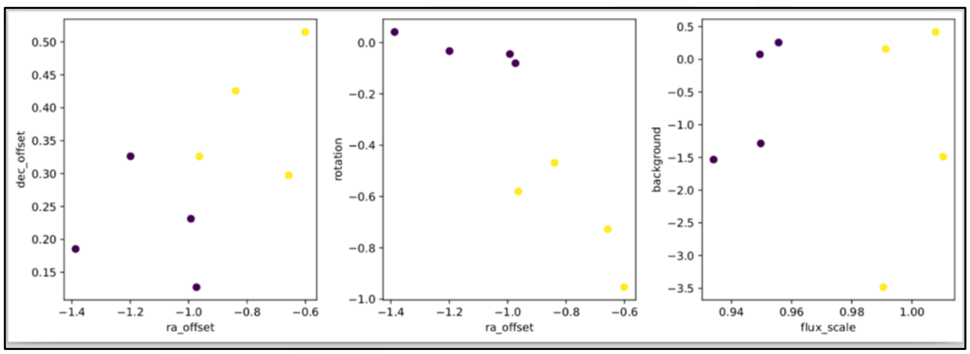

Fig. 12: Offsets (in arcsec) and flux rescaling QC. Different colors are different OBs

Please check that:

- Offset values are the same as those you just put in the spreadsheet. If not, you did not save your alignment results! Go back to step 2 of the DR.
- Offsets and rotations are not massive (no more than a few arcsec and 1 deg, respectively).
- There is some consistency among different exposures in the same OB.
- Flux scale is within 0.9 and 1.1 (i.e., within 10% expected range of our calibration).
- Background is around “0”. Generally, between +5 and -5 (but to check with time).

Well done! You have reached the end of the QC for step 2. Before moving to step 3, please remember to mark all your findings in the data reduction spreadsheet for the galaxy you are reducing!

DR step 3

No QC plots are produced for this step, but you need to make sure that the alignment has worked.

To do so, the best way is to load the individual data cubes produced for each pointing.
You will find them in the "`Combined/Cubes`" folder in the data reduction output.

You want to focus on the collapsed r-band images.
These will have the "`IMAGE_FOV_P00N_-filter-.fits`" extension.

The best way to do so is to use CARTA (until I have time to write a script). This is currently installed in Luca's directory.

Just type in a terminal > `/data/home/lcortese/soft/carta-3.0-x86-64.AppImage`

The current advice is to load 2 OBs at a time.
Do "`File Open`" for the first and "`File Append`" for the second.

Create the contours on both (using the same limits) and overlay them as in the image below showing a case of bad alignment and a case of decent alignment.

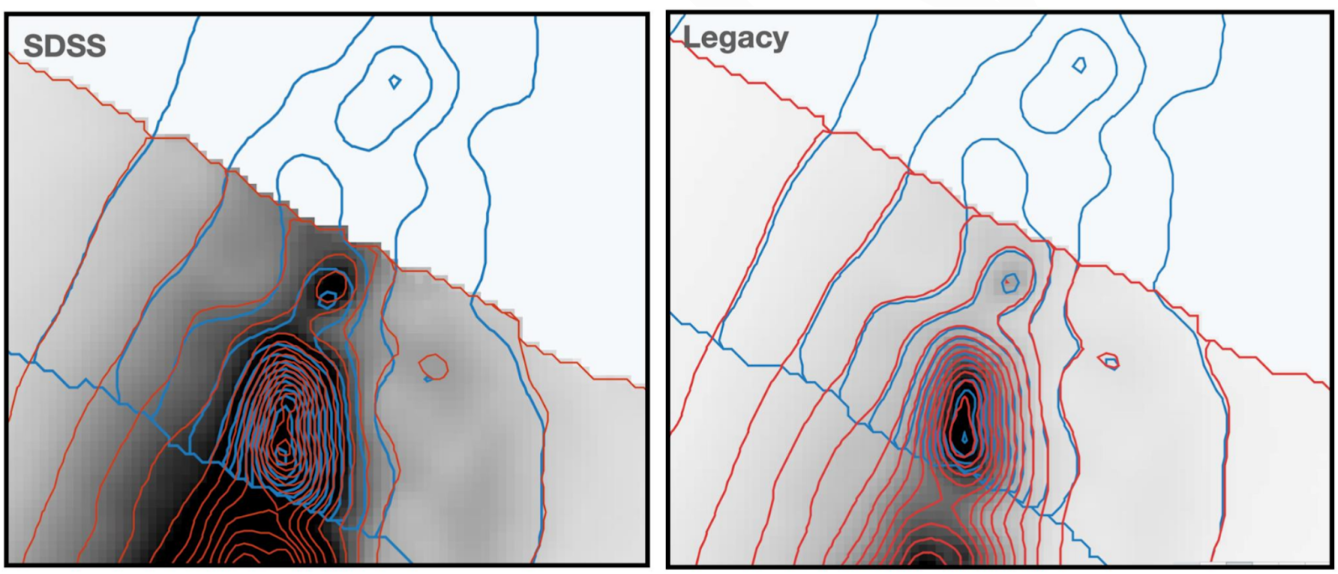

Fig. 13: examples of bad (left) and good (right) alignment.

If you can, save some screenshots for future reference.

<u>If the alignment is not good, you will need to go back to step 2 of the DR.</u>

Well done! You have reached the end of the QC for step 3. Before moving to step 4, please remember to mark all your findings in the data reduction spreadsheet for the galaxy you are reducing!

DR step 4

This step creates the cubes (e.g., `NGC4064_DATACUBE_FINAL_WCSPall_mad.fits`).

Please open the cube and check that there are no major issues: e.g., overlapping regions seem fine and spectra do not show unusual features.

If all is good, then the last thing left to do is to check the flux calibration against SDSS fiber spectra, if available.

- Make sure the SDSS spectra for your target are on magpipe: the standard directory at the moment is `/cloud/teamdata/mauve/data/sdss_spectra`
- If not, please make sure to get the DR16 spectra.[1]
- Copy the `qc_flux_sdss.py` script on your QC folder.

```
################################################################################################
### DO NOT MODIFY THE CODE ABOVE UNLESS YOU ARE SURE WHAT YOU ARE DOING
##############################################################################################
############################################################################################

##### Make sure path to folder including sdss fiber spectra is up-to-date. Technically this should n
path_sdss='/cloud/teamdata/mauve/data/sdss_spectra/'

##### Update path to the cube you want to check. This should be in the "Combined" folder for the gal
path_cube='../Combined/Cubes/'

###### Un-comment relevant file list or, if not already in the list, add info for your galaxy.
###### If the SDSS spectrum is of a star, please check any proper motion.

#### NGC 4064
sdss=['NGC4064_1_spec-2608-54474-0048.fits','NGC4064_2_spec-2595-54207-0442.fits']
pmra=[+0.0001112,0.]
pmdec=[-0.0001112,0.]

##IC3392
#sdss=['IC3392_spec-1768-53442-0235.fits']
#pmra=[0.]
#pmdec=[0.]


### Update cube file name
cube='NGC4064_DATACUBE_FINAL_WCS_Pall_mad.fits'
```

Fig. 14: `qc_flux_sdss.py` *script.*

- Go to the bottom of the file and (see figure):
  - Make sure the path to SDSS spectra is correct (`path_sdss`)
  - Update the path to the cube you want to check (`path_cube`)

---

[1] https://dr16.sdss.org/optical/spectrum/search. The easiest way is probably to go through the legacy website: https://www.legacysurvey.org/viewer "Jump" to the galaxy you are interested (bottom left field); activate from the top left, "Spectroscopy" and then "SDSS Spectra (DR16)", and then click on the the relevant target. This will take you to the SDSS page where to download the spectrum. Make sure you name it by keeping the original name and adding at the start the name of the galaxy it belongs to.

- If already there, uncomment the `sdss,pmra,pmdec` variables relative to your galaxy
- If not there, create `sdss,pmra,pmdec` variables. Proper motion should be 0 unless you are dealing with a star.
- Update the `cube` variable to the name of the cube that you want to check.

Now, from within a python session in the QC folder, type

- `run qc_flux_sdss.py`

This will create a plot showing the ratio between the MUSE and SDSS spectra like the one below:

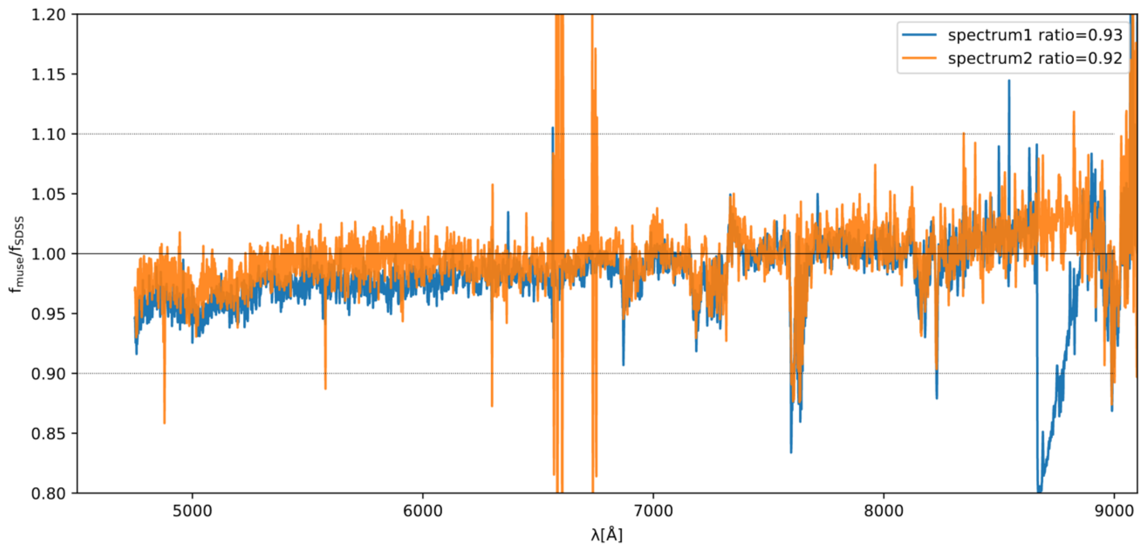

Fig. 15: flux QC.

Please note that the spectra have been rescaled to the same flux scale. The scale factor is in the label.

Please check that:

- The ratio value in the label is between 0.9 and 1.1.
- The ratio across wavelength stays within the dotted lines, indicating the 10% margin.

If the cube you have reduced is a mosaic, there is a very last step of the QC to check that the flux calibration in the overlapping regions of a mosaic does not show major difference. This procedure is relatively simple, but requires a bit of "human intervention".

First copy the relevant script in your QC folder

- `cp /cloud/teamdata/mauve/script/qc/step4_fluxmos_example.py`
- Rename the script: e.g., `mv step4_qc_example.py step4_fluxmos_NGC4064.py`
- Open the file, it should look like Fig. 15

```
##############################################################
#### SETUP - NO NEED TO CHANGE
import sys
sys.path.insert(len(sys.path), '/cloud/teamdata/mauve/scripts/qc/')
import qc_flux_mosaic as qm
##############################################################


####### path to the folder containing the final cubes to compare
path='/cloud/teamdata/mauve/red_v2/Data/MAUVE/Muse/NGC4064/Combined/Cubes/'

####### name of the final mosaic
mosaic='NGC4501_DATACUBE_FINAL_WCS_Pall_mad.fits'

##### pointings to compare
pointings=['NGC4064_DATACUBE_FINAL_P001.fits','NGC4064_DATACUBE_FINAL_P002.fits']

##### add [x1,y1,x2,y2]
qm.mkplot(path,mosaic,pointings,150,409,405,263)
```

Fig. 16: Script to check flux on overlaps of mosaic.

- Update the `path` variable with the folder where the final cubes of your data reduction are stored.
- Update the `mosaic` variable with the fits file containing the final mosaic.
- Update the `pointings` variable with the fits files of the two individual pointings you want to compare

The last thing you need to do is to identify the region of overlap between the two pointings. To do so, open the final mosaic in CARTA, ds9 or you favourite visualisation software

- `/data/home/lcortese/soft/carta-v4.1.0-x86_64.AppImage`

- Open the 'STAT' extension of the cube, there it will be easier to identify the overlapping regions.

- Identify the two extremes of the overlapping region you want to compare. Generally, try to avoid the edges (I generally draw a line as shown in Fig. 16). Mark the coordinates (in pixels!) of the two extremes (x1,x2,y1,y2) and update them in the `qm.mkplot` call of the script.

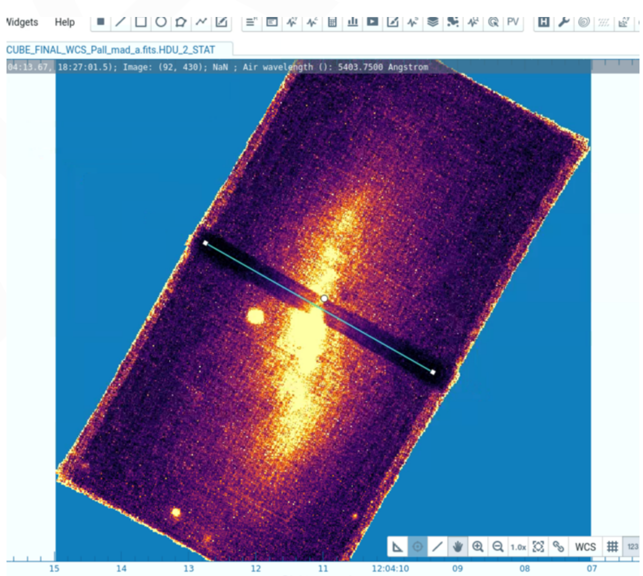

Fig. 17: Example on how to select the pixel coordinates of the overlapping regions for flux comparison.

- If you have more than two pointings in the mosaic, add a new `pointings` variable definition and re-call `qm.mkplot` updating the x1,x2,y1,y2 coordinates. You can do this as many times as you want, just make sure to re-define every time the `pointings` variable and find the new coordinates (in pixels) of the overlapping regions.

- Once all is done, within python, type: `run -i step4_fluxmos_NGC4064.py`

Depending on the size of the mosaic, the script may take between a few, and a few tens of minutes to run. What it will do is extract 10 spectra using 1” radius apertures equally spaced in between the two extremes you provided, and compare them. The main outputs are a .pdf and .fits files: e.g., `NGC4064_fluxck_0001_002.fits` and `NGC4064_fluxck_0001_002.pdf`

The .fits is a multi-dimensional fits table storing the extracted spectra, so they are available for future plots, analysis. Most of the times, for QC, you can “ignore” them and focus on the pdf. It should look like the plot in Fig 17.

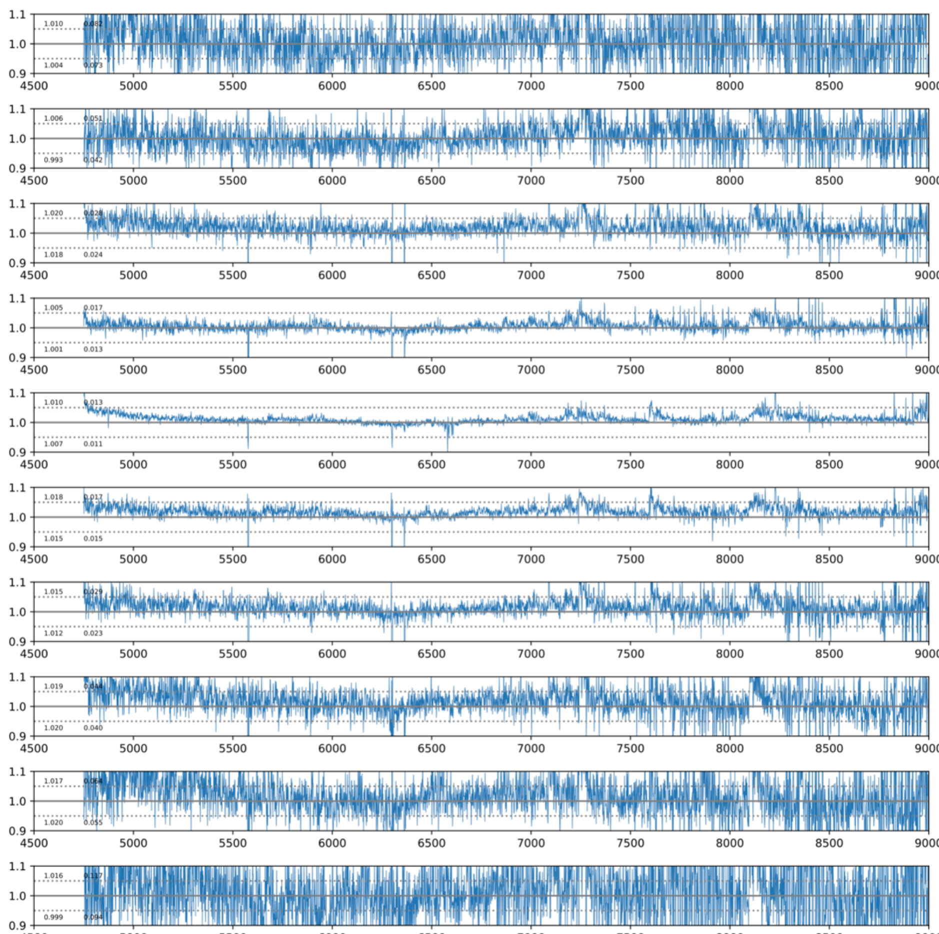

Fig. 18: Example of output of step4_fluxmos script.

Each panel shows the ratio of spectra extracted from the same WCS region in the two independent pointings. The solid grey horizontal line shows a ratio of 1, with the dotted lines show +/- 5%. The numbers in the top and bottom left corners show the median and 30%-70% interquartile ranges for the ratio spectrum across the entire wavelength range (top) and up to 7000 Angstrom (bottom). If all is good, median values should be within a a few % close to one and ratio spectra should be roughly flat.

Lastly, if this is a re-reduction of a cube already reduced, it is good to carry out a quick comparison. To do so, there is an easy script.

```
cp /cloud/teamdata/mauve/scripts/qc/dr_compare.py
```

You should update lines 20,21 (see Fig. 19) with the new and old versions of the cube. You may also want to modify the axis lbel of the plots if the version of PMP does change.

```
11
12  from astropy.io import fits
13  import numpy as np
14  from matplotlib import pyplot as plt
15
16
17  #### compare white images
18
19
20  new1=fits.open('/cloud/teamdata/mauve/red_v3/Data/MAUVE/Muse/IC3392/Combined/Cubes/IC3392_IMAGE_FOV_white_WCS_Pall_mad.fits')
21  old1=fits.open('/cloud/teamdata/mauve/red_v2/Data/MAUVE/Muse/IC3392/Combined/Cubes/IC3392_IMAGE_FOV_white_WCS_Pall_mad.fits')
22
```

Fig. 19: Extract of dr_compare.py script.

Then

```
run -i dr_compare.py
```

The script will create a pdf file called `compare_new_vs_old.pdf` showing the ratio between the white (left) and r-band (right) images extracted from the two cubes. An example is provided in Fig. 20. Here, it is important to check that the differences are not too crazy.

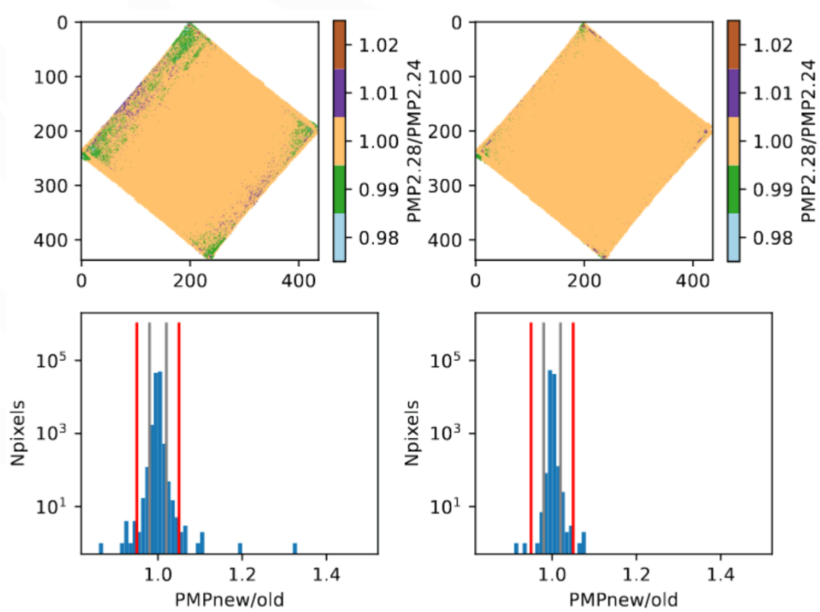

Fig. 20: Ratio between two versions of the cube reduced with two versions of PMP.

Well done! You have reached the end of the QC for step 4… and the very end of the whole MAUVE data reduction process!

Before moving on, please remember to mark all your findings in the data reduction spreadsheet for the galaxy you are reducing!

Now the cubes are ready for science and for being passed to the value-added products team. Thank you very much for your time and efforts with the MAUVE Data Reduction!