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# WAQA QC plots

Guilherme S. Couto[1]

[1]Leibniz-Institut für Astrophysik Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany
e-mail: gcouto@aip.de

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**ABSTRACT**

This document describes the quality control plots performed for the WEAVE-Apertif (WA) survey, a product of the WA Quality Assurance (WAQA) team.

**Key words.**

## 1. Introduction

The plots described in this document have a goal to detail and characterize the data status of WEAVE Large IFU (LIFU) observations related to the WEAVE-Apertif survey. They are a tool to be used to inspect the data quality and help infer if the observed data is good enough to achieve the science goals of the survey. In case of questions or comments, please do not hesitate in contacting me through my email on top of this document. Any type of feedback is very welcome.

For this document, I picked OB 11161 as an example to show what the plots look like (it was observed in low resolution mode). For each OB observed within the WA survey a html file is created containing the plots detailed here. These html pages will become available in the survey website.

A few information on the OB are given on top of the html page. These are: date of observation, the target CNAME, the target IFUNAME, the OB ID, and the LIFU observing mode (either LOWRES or HIGHRES).

## 2. L0 data plots

This section details the L0 data plots. Here we do not refer to proper raw dataset, but the analysis obtained from single files, containing the information of fiber exposition.

I note that plots regarding spectral resolution (sec. 2.2), fiber throughput (sec. 2.3), wavelength calibration (sec. 2.4) and fiber SNR (sec. 2.5) are done only for one exposure for each arm (blue and red, identified on the spectral resolution plot title), while flux calibration plots (sec. 2.6) are performed for all exposures (exposure data file name is in the plot title). The number of flux calibration plots is also an indicative of how many exposures are available for this OB, which should be 3.

Some plots in this section are obtained by measuring the sky lines observed in the fiber spectra, specifically spectral resolution, fiber throughput and wavelength calibration. This means that information is restricted for the blue arm, where only one strong line is measured in low resolution mode. For the high resolution mode no strong line is observed, and thus no data is shown for these plots.

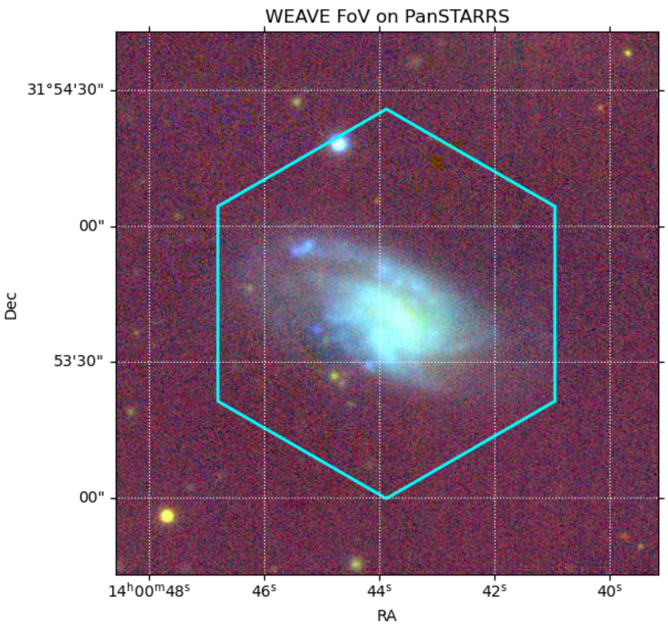


**Fig. 1.** PanSTARRS composite image of the observed target, with WEAVE LIFU FoV imprinted. No fancy plot here (the galaxy looks nice though).

### 2.1. PanSTARRS composite image

Fig. 1 shows a PanSTARRS composite image of the observed target. The coordinates used to do the target query are obtained from the blue arm L1 datacube (CRAVL1 and CRVAL2 of ext=1). The hexagon show an **approximate** WEAVE FoV, as no position angle is assumed (this is usually true for WA).

### 2.2. Spectral resolution plots

For the next few plots, I have used results of measured sky lines. Sky spectra can be obtained by subtracting the ext=1 from the ext=3 in the single files. I then measure the sky line profiles of a

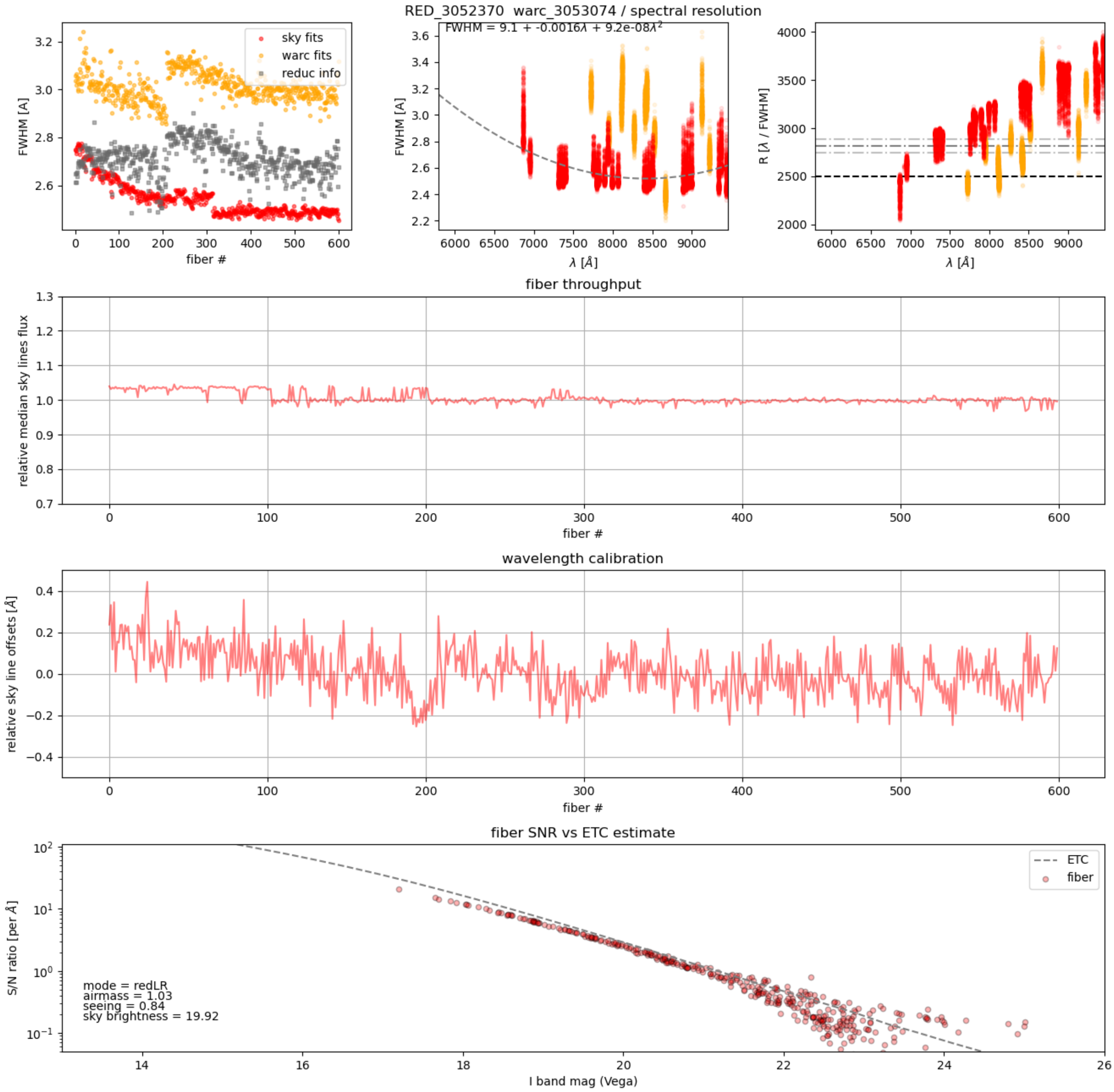


**Fig. 2.** Spectral resolution, fiber throughput, wavelength calibration and fiber SNR plots. These are explained in the text, between sec. 2.2 and 2.5.

list of strong lines by fitting a Gaussian function. These fittings then provide integrated line fluxes, central wavelength and line width (full width at half maximum, FWHM). For spectral resolution plots I perform the same measurements in the ARC lamp spectra.

The top row of Fig. 2 shows three plots related to spectral resolution of these observations. Red or blue points (depending on the spectral arm being measured) are related to sky line measured FWHM, orange points are related to the measured ARC lamp lines FWHM, and gray points are the output from the data reduction pipeline, and can be found in the table on ext=6 of the single files (FIBTABLE, under 'Resol' column). These last values should have been measured using ARC lines.

The left plot shows how line FWHM changes with fiber number. The sky points represent the median sky line FWHM within each fiber number. The warc points represent the same for ARC lamp lines, while the gray points are just the values given by the pipeline.

The middle plot shows now the variation of line FWHM with wavelength. This time no median is shown, but each point represent a sky (or ARC lamp) line measurement. Several point are located at the same wavelength because these are measurements of the same line along all different fibers. For the red arm a 2-order polinomial fit is provided.

The right plot shows the change of resolving power R with wavelength. The black dashed line shows the expected resolution from the instrument specifications, while the gray dot dashed

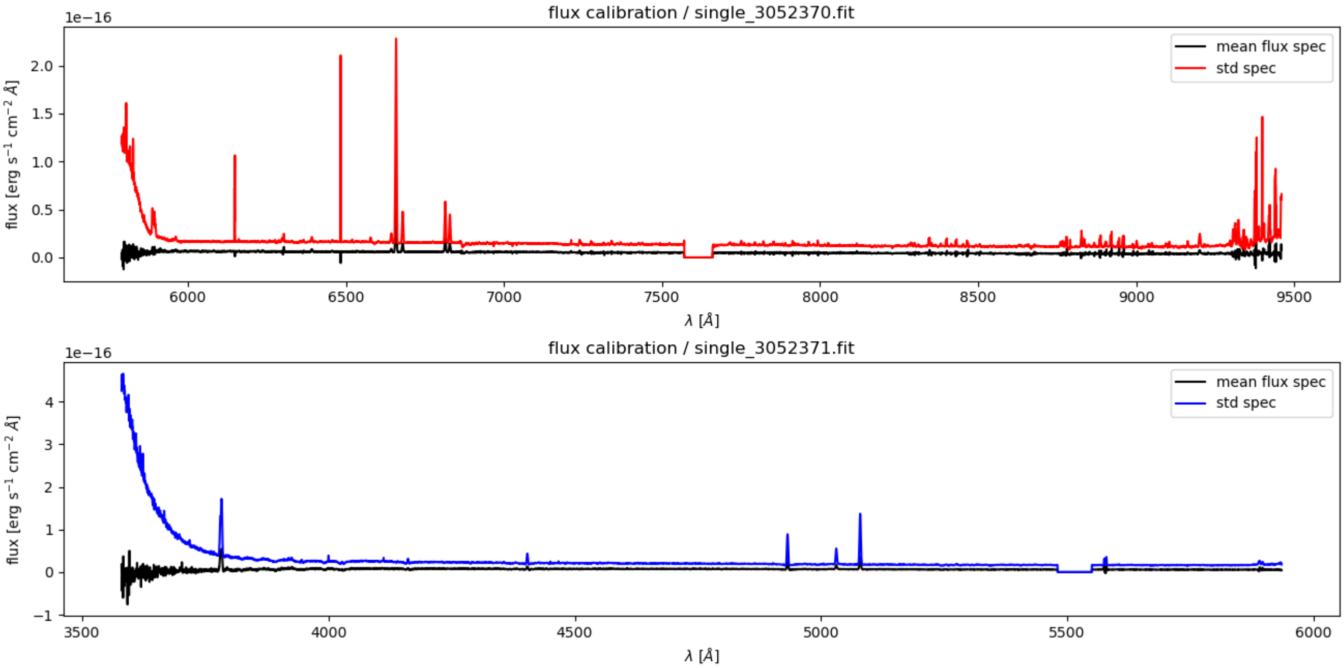


**Fig. 3.** Flux calibration plots at fiber level. These are explained in the text, in sec. 2.6

lines represent the median value (strong line) from the pipeline (gray points in the left plot), summed and subtracted by 1 sigma (weak lines). These last values, the gray lines, are calculated using the mean wavelength of the spectral coverage.

### 2.3. Fiber throughput

The fiber throughput plot is obtained following the measurements of the sky lines, as explained in sec. 2.2, and is shown in the second row in Fig. 2. With the sky lines integrated fluxes, a median of all measured line fluxes within one fiber spectrum is estimated (sky_flux_med). The plot is then this value divide by the median value over all fibers (median(sky_flux_med), used for normalization purpose). This plot thus show the general trend of sky flux change between fibers, in relative numbers.

### 2.4. Wavelength calibration

The wavelength calibration plot is also done using the sky line measurements, as described in sec. 2.2, and is shown in the third row in Fig. 2. This plot makes use of the measured line profile spectral center. I estimate the difference between each line center (within a given fiber) to the median center value of the respective line along all fibers. Given this difference, for each sky line, within a given fiber, I estimate the median of all sky lines within this fiber. This is what the y-axis represent in this plot, as a variation of fiber number, in Å unit.

### 2.5. Fiber SN ratio

The last row in Fig. 2 shows the signal-to-noise ratio (y-axis) variation with an optical broadband magnitude (V band for blue arm, I for red low resolution arm and R for red high resolution arm). Each point represents a fiber. Optical band are obtained by integrating fiber spectra flux within Johnson filter sensitivity curves. SNR are obtained within specific spectral windows: between 5000Å and 6000Å for blue low resolution, 8000Å and 9000Å for red low resolution, 5000Å and 6000Å for blue high resolution and 6550Å and 7550Å for red high resolution.

Along with the observed SNR points from fiber spectra, a dashed line shows the expected SNR considering the WEAVE LIFU ETC, developed by Scott Trager, and available at the WEAVE Confluence pages [1]. The parameters used for estimating the SNR are showed on the plot bottom left corner, and are obtained in the single file header. The goal of this plot is to compare the observed SNR to the estimated using the ETC, and check if the observed SNR is compliant to the science objective.

### 2.6. Flux calibration

Flux calibration is a tricky thing to properly analyze. Fig. 3 shows the plots performed at fiber level. Here I display two plots, one for a red arm and another for a blue arm exposure. At the html pages plots are provided for all exposures available in the given OB, which should be 3 for each arm. This also indicates cases where less exposures were taken, damaging the final data quality of the OB products. In these plots, black lines show the mean flux spectra along all fibers, with blue or red (depending on the single file arm exposure) lines showing the standard deviation. The goal of these plots are to see any dramatic non-physical flux changes along wavelength regions from fiber to fiber.

## 3. L1 data plots

This section details the L1 data plots, which entails plots related to the blue and red arms datacubes. The text in the top of this section displays the CASUVERS keyword, which is the data reduction version used to produce the data analyzed.

[1] WEAVE ETC . An interactive version is available here.

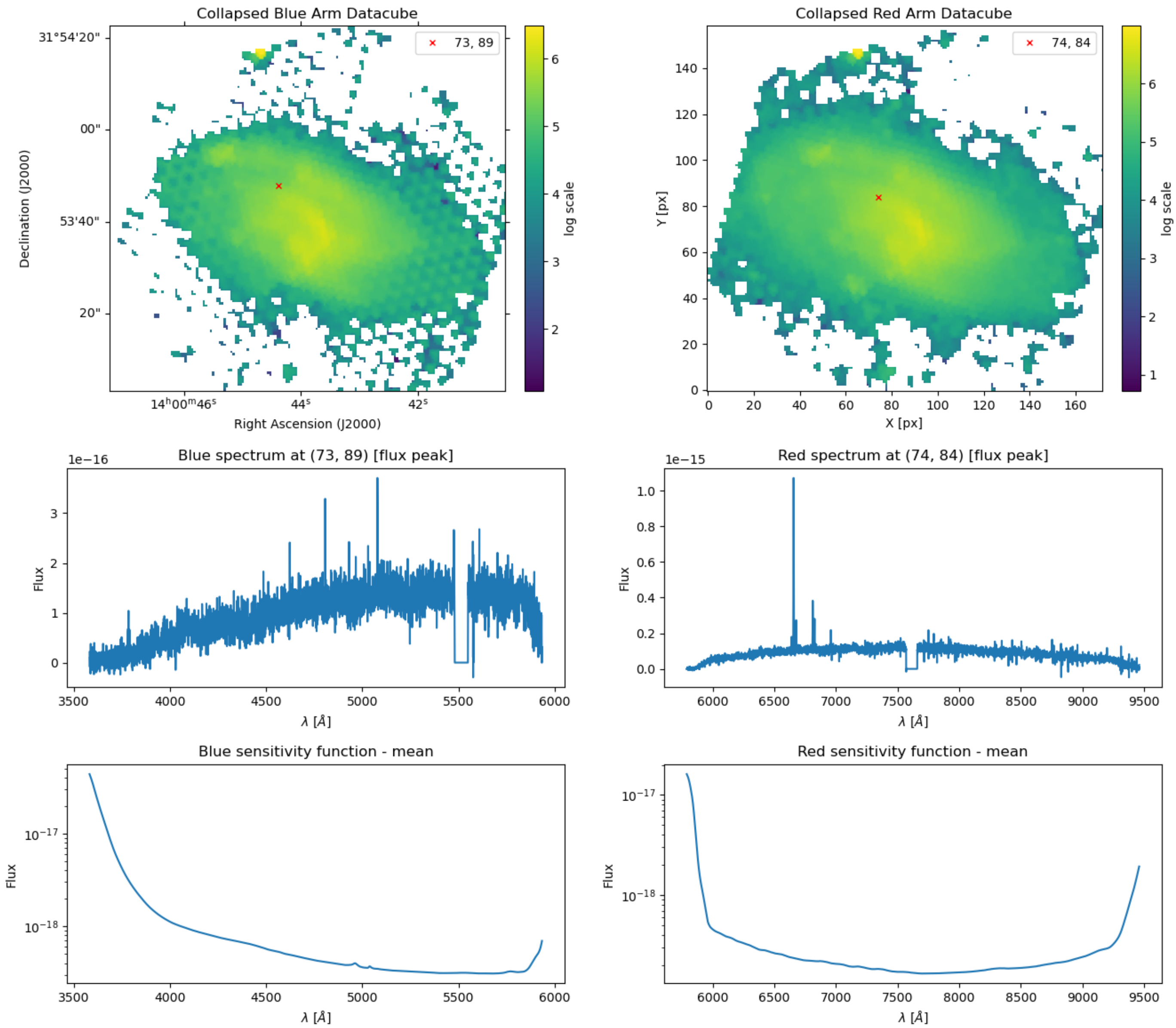


**Fig. 4.** Collapse arm datacubes (top panels), flux peak spectra (middle panels) and sensitivity functions (bottom panels) for blue (left panels) and red (right panels) arms. These are explained in the text, in sec. 3.1.

### *3.1. Collapsed cube, flux peak spectra and sensitivity function*

Fig. 4 shows three plots for the blue (left panels) and red (right panels) arm datacubes. On the top row, a map of the collapsed datacube flux map is shown. The map shows a simple summation of the entire datacube, given in counts log scale, along wavelength direction. A flux peak spaxel is shown as a red cross. This is not measured from the nominal peak flux, but from a flux distribution fit which tries to avoid field stars by sigma clipping the flux profile. This procedure is not always successful, as it is shown in the case of Fig. 4, especially for cases where field stars are close the the datacube border.

The second row in Fig. 4 shows the spectrum observed in the “flux peak” spaxel selected above. These are not in counts now, but in the given flux unit, as they were multiplied by the sensitivity function.

The third row shows the mean sensitivity function of the datacube. The change of the function is (currently) negligible through the datacube spaxels, and should be pretty much the same in all regions[2].

### *3.2. Median and mean maps*

Fig. 5 shows four maps for the blue and red datacubes (left and right, respectively). The top row shows the median flux maps, the second row shows the median sky flux maps (obtained by subtracting the sky subtracted datacube from the datacube without sky subtraction), while the bottom two rows show the same but for mean values. These are all in counts log scale. Nothing too fancy, but still data.

[2] this refers to the actual output of the L1 pipeline, and it is probably **not** physically true, as the sensitivity seems to vary quite a lot between fibers.

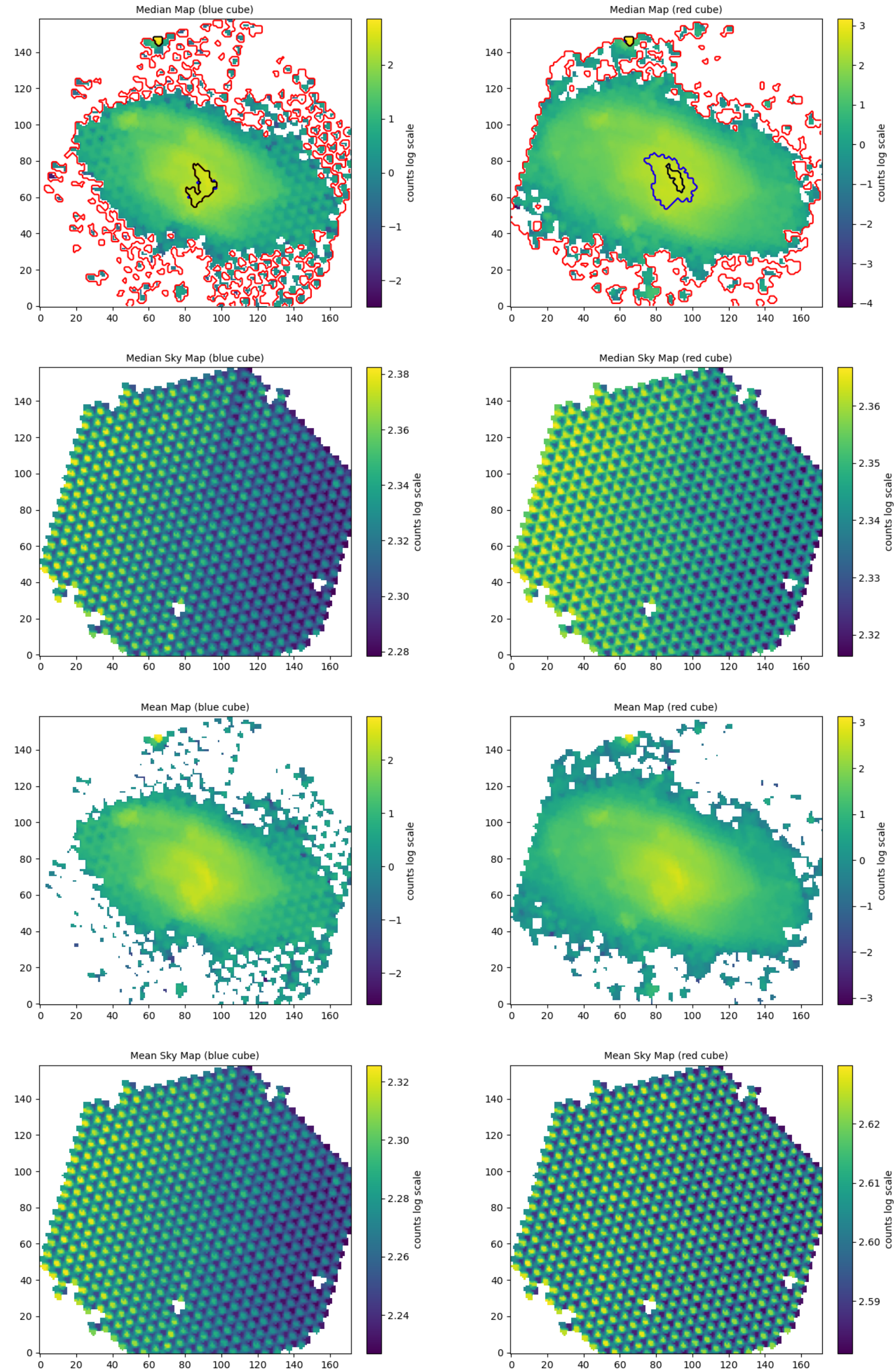


**Fig. 5.** Median flux maps (top panels), median sky flux maps (second row panels), mean flux maps (third row panels) and mean sky flux maps (bottom panels) for blue and red arms (left and right panels). These plots are explained in more detail in the text, in sec. 3.2.

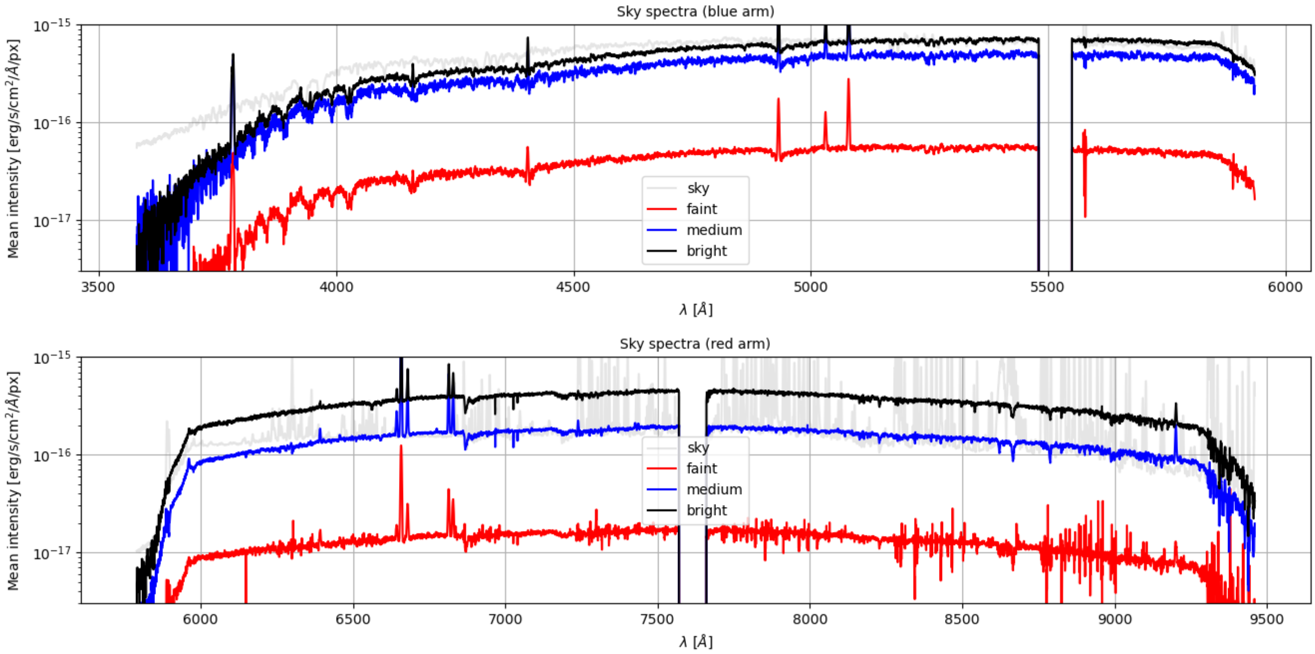


**Fig. 6.** Sky and brightness levels spectra for the blue (top panel) and red (bottom panel) arms. These plots are explained in more detail in the text, in sec. 3.3.

The black, red and blue contours on the top panels display three brightness regimes: bright, medium and faint, respectively. Bright regions contains spaxels with mean fluxes (calculated along the wavelength axis, as shown in the maps in the third row) above the sky mean fluxes (as shown in the maps in the fourth row). The medium brightness regions have mean fluxes smaller than the sky mean fluxes, but their median values (as in the top maps) are higher than the sky median values (as in the second row maps). The faint regions are selected as having a median flux values smaller than sky median values, but still having a mean value above 0. These regions are used to plot integrated spectra on the next section.

### 3.3. Sky and brightness levels spectra

Fig. 6 shows two plots with set of spectra, for the blue (top panel) and red (bottom panel) arms. The strong spectra represent the bright (black line), medium (blue line) and faint (red line) regions average spectra, extracted as described in Sec. 3.2. The faint gray line shows the average sky spectrum. This plot aims to illustrate the sky level in comparison to the brightness level of the galaxy spectra, as well as the spectral regions mostly affected by sky emission.

### 3.4. SNR plots

Fig. 7 shows continuum SN ratio related plots for the L1 data, with left and right panels corresponding for the blue and red arms, respectively. The top panels show a SNR map estimated within a wavelength range, mentioned in the x-axis labels of the middle panels plots, which changes with the galaxy redshift. The central wavelength is mentioned in the top panel titles. As displayed in the labels, contours of SNR=5 and 30 are shown (if available). The middle panels show the SNR values dependency on the median flux within the measured wavelength range, with each point representing a spaxel. Ideally this plot should show a smooth increase typical of a root-main square function. However, the different observing conditions in the different exposure pointings may lead to a significant spread in the distribution, as well as bright field stars. Finally, the bottom panels display a spaxel histogram within the different SNR values measured. An integrated spectra is shown in the subplot, with the chosen wavelength range delimited by vertical dashed lines.

### 3.5. Flux calibration maps

Fig. 8 shows two columns of five maps, with blue and red arms being represented in the left and right columns, respectively. Each of the five maps shows the mean flux minus the flux standard deviation, in absolute values, for a given wavelength range. The wavelength range is given in the map title. Together the five maps cover the entire wavelength range of each arm.

The mean and the standard deviation are estimated along the wavelength dimension. The goal of these maps is to trace sudden changes of flux in specific wavelength regions and spatial regions, which would result in increase in the standard deviation in relation to other galaxies regions. A median value throughout the map is shown by the dashed contours. One also need to consider that regions with a peak of emission lines also result in a higher values in these maps, as can be seen in map number 2 of the red arm, in Fig. 8. HII regions can be observed due to the emission of H$\alpha$ and [NII] lines.

### 3.6. Voronoi binning and flux peak variation

Fig. 9 shows plots related to the Voronoi binning and the variation of the flux peak. Again, the plots are done for the blue and red arms, in the left and right panels, respectively. The top panels show the Voronoi binning maps with target SNR as pointed in the title. Only spaxels with SNR > 1 are considered for binning. Currently the Voronoi binning do not take into consideration the covariance correction that should be applied when binning spax-

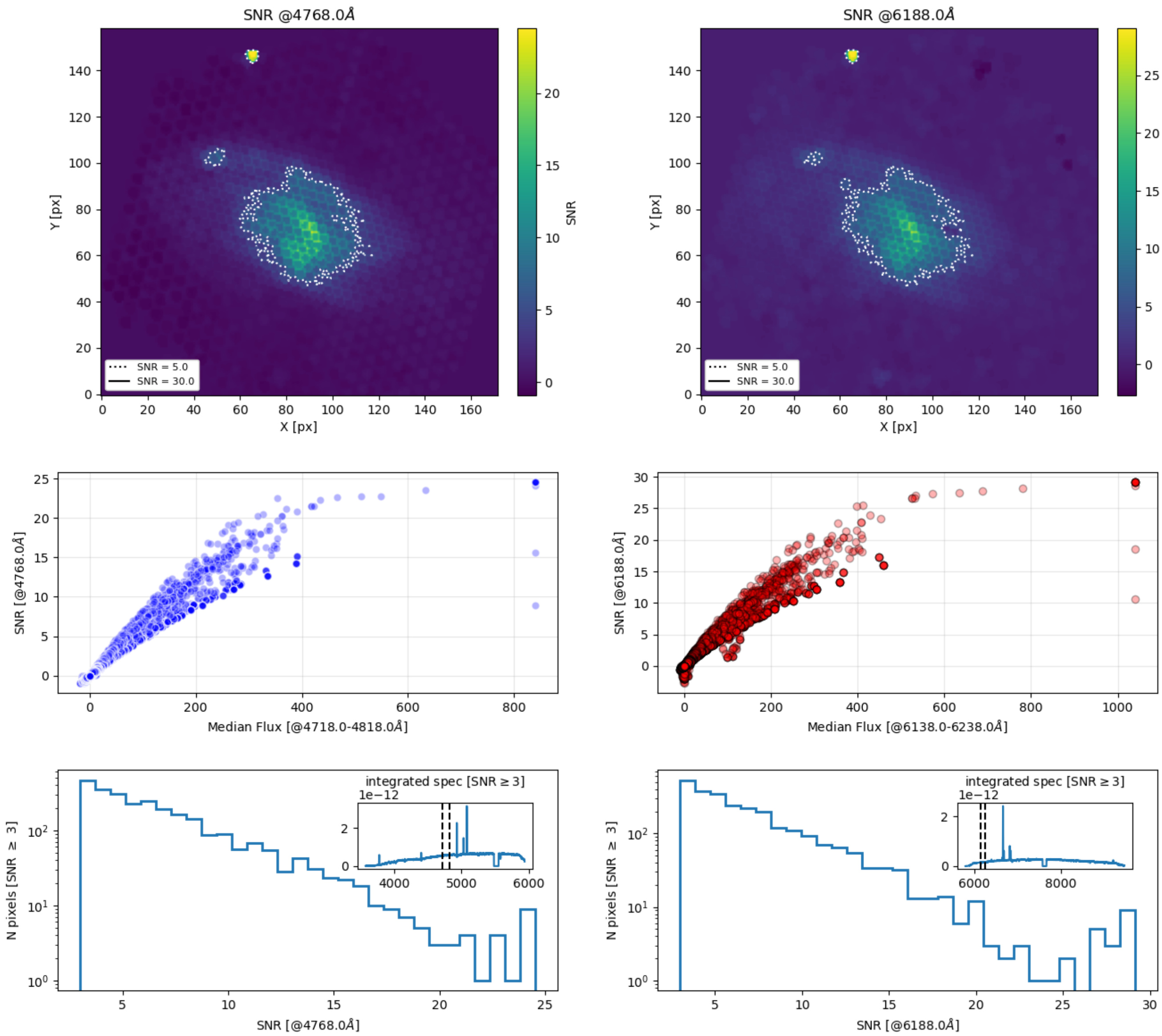


**Fig. 7.** SN ratio plots estimated with the L1 data, with left and right panels representing the blue and red arms, respectively. The top panels show SNR maps, the middle panels show the SNR distribution along different flux values and the bottom panels display a SNR histogram for the datacubes. These plots are explained in more detail in the text, in sec. 3.4.

els. This is because Vorbin has not behaved well with it, and sometimes crash when the correction is applied. Hopefully this correction will be applied in the future. The middle plots show the SNR of the original spaxels as black points, and the SNR of the Voronoi regions as red points, with blue crosses representing spaxels where no binning was needed.

The bottom plots show the variation of the flux peak. These plots are done after a brightness profile fit is performed in the datacube. Before the fit is done, a sigma clipping is applied to remove field stars, which is not always successful. The brightness profile is fitted and flux peak coordinates are estimated. This is done for maps extracted in bins of 20 spectral pixels, and then a mean value is estimated along the entire data cube. These values are shown in the plot legend. The blue and red points in the plot show how much these values vary (for x and y, respectively) along the wavelength coverage, in comparison to the mean. The goal of this plot is detect a possible atmospheric refraction effect. In practice this plot is very sensitive to SNR, and seems to only really work for bright early-type galaxies without field stars.

## 4. L2 data plots

This section details the L2 data plots, which entails plots related to the APS (Advanced Processing System) pipeline products. In resume, this pipeline merges the blue and the red arms spectra, and performs stellar continuum and emission line spectral fitting. The text in the top of this section displays the APSVERS keyword, which is the APS version used to produce the data analyzed.

### 4.1. Similar plots to L1 analysis

Fig. 10 shows several plots already performed for L1 data and explained in detail in Sec. 3. The top panels show the collapsed APS datacube, as well as the spectrum at the detected peak flux

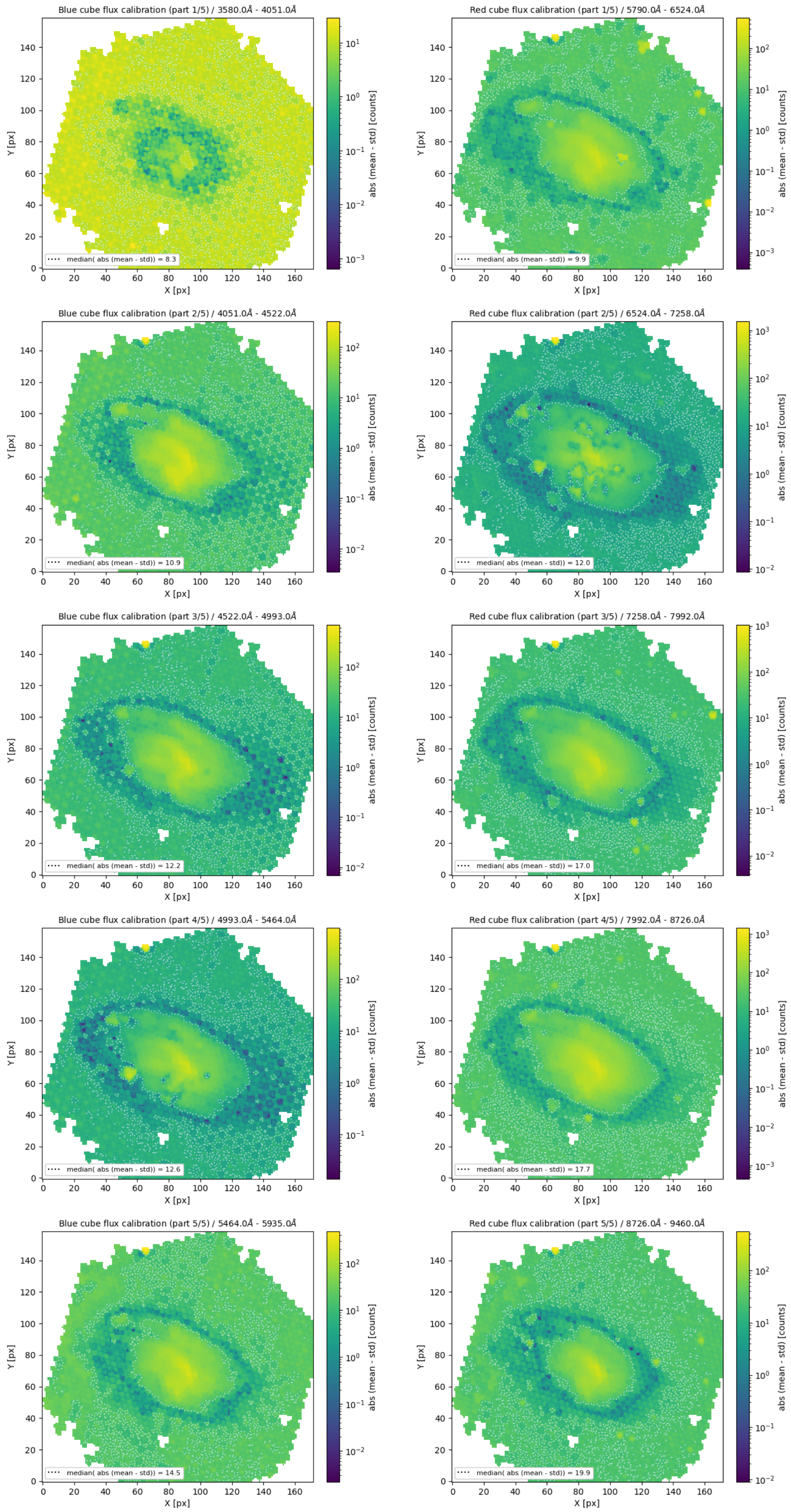


**Fig. 8.** Flux calibration maps. These plots are explained in more detail in the text, in sec. 3.5.

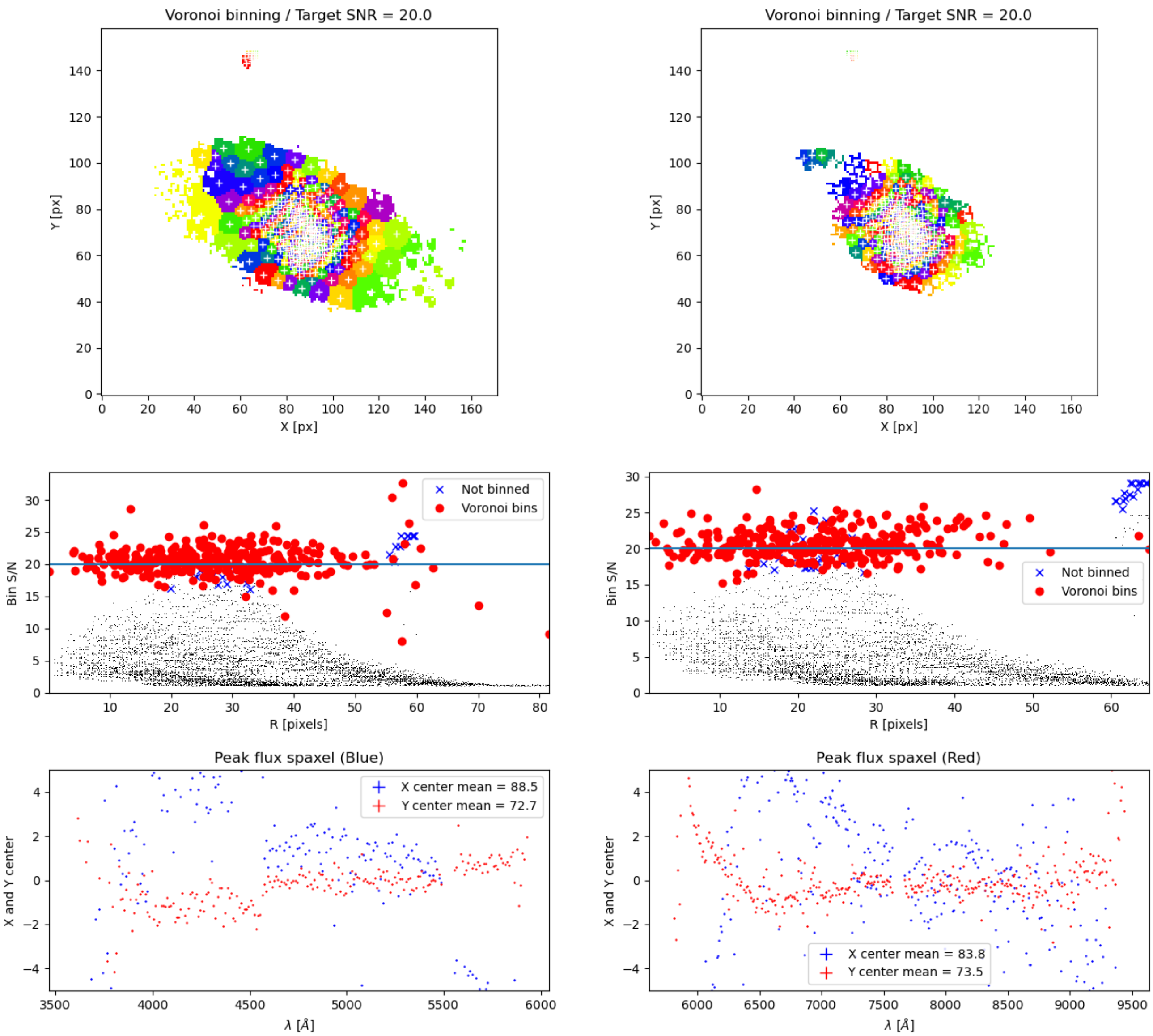


**Fig. 9.** Voronoi binning region maps (top panels), SNR due to Voronoi binning (middle panels) and peak flux variation (bottom panels) for blue and red arms (left and right panels). These plots are explained in more detail in the text, in sec. 3.6.

spaxel. These plots are performed in the samy way as detailed in Sec. 3.1. The second row shows SNR maps and histograms, as explained in Sec. 3.4 for L1 data. Voronoi binning map and resulting SNR plots are show in the third row, and are detailed in Sec. 3.6. Finally, in the bottom panel is displayed the flux peak variation with wavelength, as detailed as well in Sec. 3.6.

### 4.2. Stellar and emission line maps

The last plots shown are the maps displayed in Fig. 11. These are maps obtained from the APS stellar continuum and emission-line fitting, after applying the Voronoi binning. I note that the Voronoi binning displayed in Fig. 11 is performed by APS, and is not the same as the one shown in Fig. 10, where another binning is performed independently. The stellar velocity and velocity dispersion maps are displayed in the top panels, while the flux, velocity and velocity dispersion maps for the H$\alpha$ and [OIII] emission lines are displayed in the middle and bottom panels, respectively.

## References

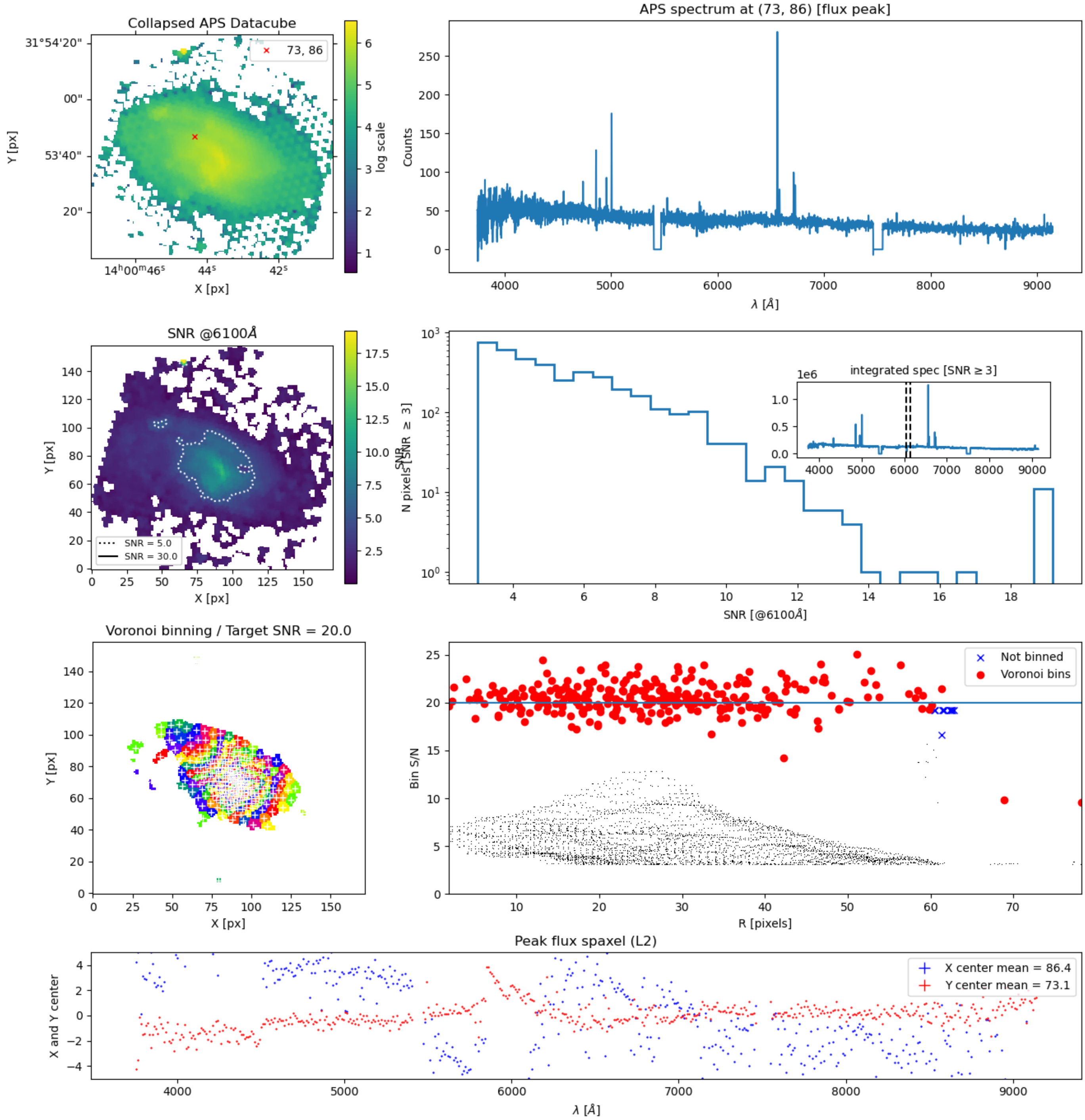


**Fig. 10.** Plots related to APS L2 spectra: collapsed image and flux peak spectrum (top panels), SNR map and histogram (second row panels), Voronoi binning regions map and SNR values (third row panels) and flux peak variation (bottom panel). These plots are explained in more detail in the text, in sec. 4.1.

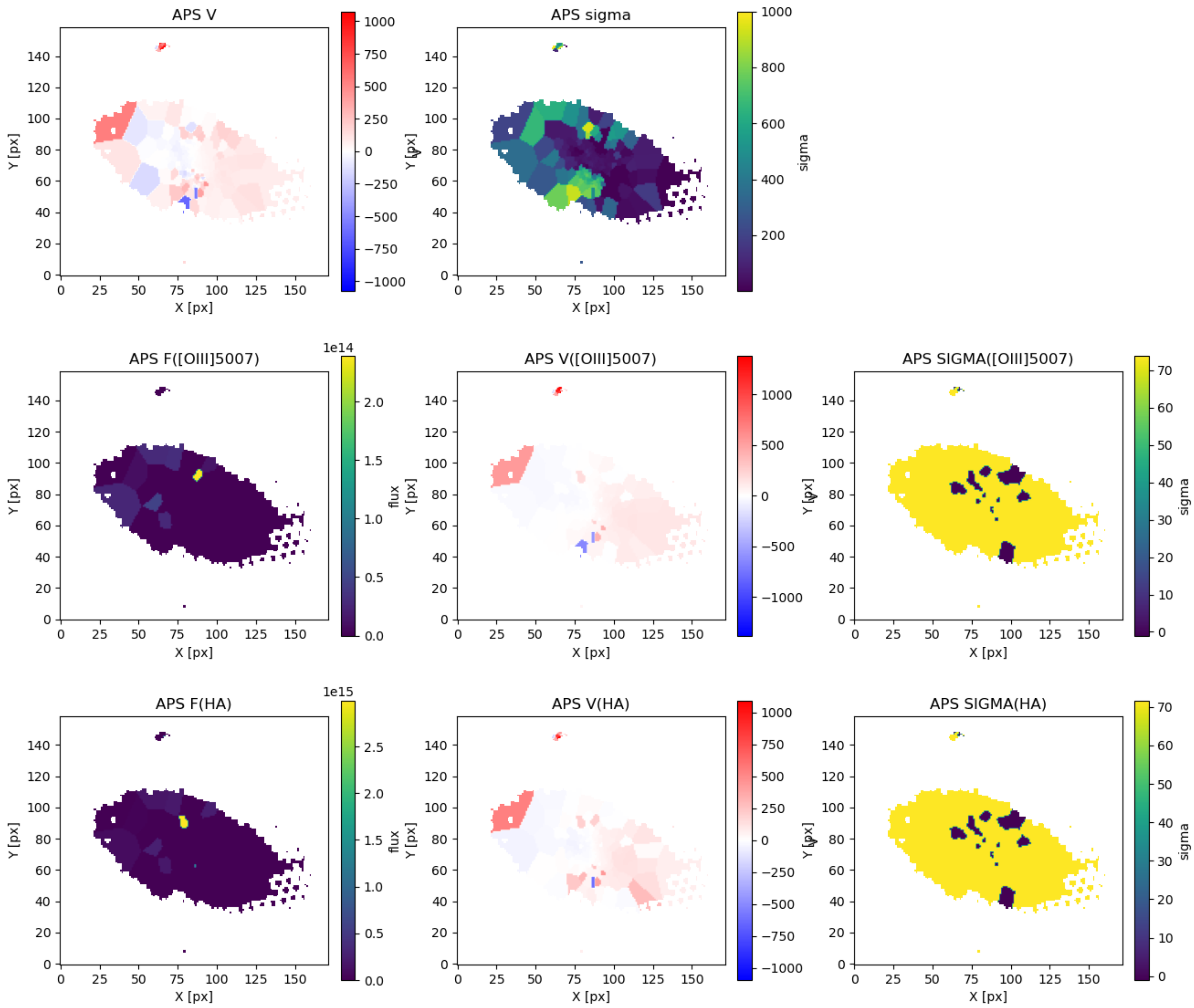


**Fig. 11.** Stellar continuum maps (top panels) and H$\alpha$ and [OIII] emission line maps (middle and bottom panels) obtained from APS L2 data products. These plots are explained in more detail in the text, in sec. 4.2.