Mock Spectra Generation - November - 2021

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i) Data is divided into five metallicity bins after obtaining the SFR and the stellar mass (i.e., a first sED fit has been performed to obtain the parameters).

```
metal_1 = data[np.where(metallicities < 0.008)]
metal_2 = data[np.where((metallicities >= 0.008)&(metallicities < 0.009))]
metal_3 = data[np.where((metallicities >= 0.009)&(metallicities < 0.011))]
metal_4 = data[np.where((metallicities >= 0.011)&(metallicities < 0.013))]
metal_5 = data[np.where(metallicities >= 0.013)]
```

They can be divided into redshift bins and then in metallicity bins but it makes the process more complicated and as I am running out of time this is the best compromise to share a first mock catalog. Also because the way to fix logU is not set yet by the MOONS people and the attenuation recipe needs to be changed to CF03 which will make the fit more time-consuming than a simple Calzetti recipe.

ii) The files to be fitted are:

```
Metal_1 = COSMOS_FMOS_MOONS_2021_zCUT_BPT_metal_1.fits
Metal_2 = COSMOS_FMOS_MOONS_2021_zCUT_BPT_metal_2.fits
Metal_3 = COSMOS_FMOS_MOONS_2021_zCUT_BPT_metal_3.fits
Metal_4 = COSMOS_FMOS_MOONS_2021_zCUT_BPT_metal_4.fits
Metal_5 = COSMOS_FMOS_MOONS_2021_zCUT_BPT_metal_5.fits
```

The number of objects per bin 490, 403, 773, 622, and 220. In total 2508 objects + 1 fake object. There is a fake object called -999999 because it is useful to compute the emission lines in the output file given by CIGALE. In the same metallicity bin, there are different redshifts so the SFH must be general.

iii) Following Carton et al., 2017 (*https://arxiv.org/pdf/1703.01090.pdf*) one can obtain the ionization parameter given by

```
logU = -0.8*log10(z/z_sun) - 3.58.
```

There are other relations proposed by Filippo and Fergus that can be explored later.

```
# LogU estimation from literature relations

https://arxiv.org/pdf/2002.05744.pdf (Filippo suggestion)
def logq_mingozzi(EW_Ha):
    return( 0.56*np.log10(EW_Ha) + 6.29 )

https://arxiv.org/pdf/1703.01090.pdf (Emma suggestion)
def logU_carton(z, z_sun):
    return( -0.8*np.log10(z/z_sun) - 3.58 )

def logq_to_logU(logq):
    # U = q/c; q = Q/n; logU = Q/(4*pi*r^2*n*c)
    c = 2.998e10 # cm s^-1
    return( np.log10(10**logq/c) )

# Fergus suggestion
https://arxiv.org/pdf/2008.02282.pdf
https://arxiv.org/pdf/1404.3936.pdf
```

Following the Carton recipe in the five different metallicity bin and assuming that z_sun = 0.0142 we get:

Metal_1 = logU > -3.38
Metal_2 = -3.38 >= logU > -3.42
Metal_3 = -3.42 >= logU > -3.49
Metal_4 = -3.49 >= logU > -3.55
Metal_5 = -3.55 >= logU

As the range only varies over 0.2 dex I decided to do a continuum_lines fit fixing the gas-phase metallicity and leaving logU free (which can be wrong but it's worth having it for comparison) and continuum+lines with two values of logU -3.6 and -3.4 to be in the range computed above.

BEFORE SED FITTING

On VULCAIN there is a copy of the version of CIGALE adapted to the needs of MOONS. The nebular lines are trimmed to have the good ones required for MOONS. The sampling of points to create emission lines is changed from 301 to 21 points. The wavelengths are moved all to vacuum avoiding the problem we discussed with the working groups for the SSPs. In general,

this version should be used to model the mock samples and probably in the future use the version in Gitlab (cigale_bpt).

The version is in my home directory and it's called "cigale_bpt_moons". It is installed on VULCAIN in the pyenv "cigale_bpt". This version is already installed using the HR BC03 models. If it needs to be reinstalled just use "python setup.py build --bc03res=hr" and then "python setup.py develop". Run:

```
pyenv activate cigale_bpt
export OMP_NUM_THREADS=1
```

The "pcigale.ini" files are inside each metallicity bin folder.

iv) First, the continuum is fitted. Then, continuum+lines either leaving logU free and fixing it to a -3.6 to -3.4 range. The three results are stored on VULCAIN on three different folders at "/mnt/pdg-space/jvilla/Feb_2021_MOONS_BPT/metal_bins/metal_bins_nov_2021" (continuum, continuum_lines_logU_free, continuum_lines_logU_fixed). I only ran this time for the chabrier IMF because before I was also distributing Salpeter. I think people can just convert their parameters if needed.

For the future steps when I'm gone!

In Particular, for MOONS these files need to be reprocessed, interpolated, and saved in a 1D-format useful for the ETC. I left instructions on the other PDF file. There is a notebook already prepared to do this. Maybe this time that I changed the line points from 301 to 21 the interpolation will go faster and the 1D-spectra files won't be too heavy as the last time.

This can be adapted for PFS taking into account their requirements although I guess the resolution of the emission lines needs to change to be compatible with the PFS requirements. So running again CIGALE and fitting again the SEDs will be useful.

Note: If one wants to enlarge the sample of Laigle, the notebook "File_to_CIGALE-format.ipynb" has all the instructions to follow the process of correcting the photometry, replacing data inside each band if the filter falls inside the Balmer break at a given redshift, and splitting the samples in redshift bins. There are also some functions that can be used to check after the first fits the SFR and stellar mass to compute the gas-phase metallicity and then to create the final files with fake emission line values to be fitted with fixed values of gas-phase metallicity and ionization parameter.

Note: I did some runs which are stored in the folders /mnt/pdg_space/jvilla/Feb_2021_MOONS_BPT_redshift_bins where the metallicity bins fitted can be found for continuum and continuum+lines although I think I used LR models. Also in /mnt/pdg_space/jvilla/Feb_2021_MOONS_BPT/metal_bins. I do not recommend using these ones as I did not leave any instructions while creating these files. This is why I re-ran the fits with the instructions above so the results can be trusted. This was from February 2021.

I started this process ....

COSMOS2015 catalog is put into shape in different files (Check the COSMOS2015_File_to_CIGALE-format.ipynb notebook). The most general file is '/Users/lam/Desktop/MOONS/MOONS_2021/Laigle_all/COSMOS_Laigle_MOONS_2021.fits ' which contains all the photometry and COSMOS2015 data but already in a good shape to be saved or cut as one pleases to later be analysed with CIGALE.

I cut in redshift because I only want positive values in phot_z and I create a catalog in which I only put the information I want for the fit, so the bands cover from GALEX NUV to IRAC4.

These files contain fake emission lines with -9999.99 values which are used to model the lines with CIGALE if the nebular module is included but they won't be taken into account if only photometry is added. There is a fake galaxy in the last row to allow the computation with non-zero values for the lines. Everything is in the folder 'files_lines'.

The next step is to divide the sample in the redshift bin. The files are in the 'FILES_redshift_bins' folder and additionally they are copied to the individual redshift folder with the corresponding name. This is to facilitate the next step which is splitting each redshift bin in metallicity bins after the first analysis.

In the notebook I leave the tool to carry out the task. I will only try to analyse the redshift bin 1.5-2.0 if it doesn't take too much time as there are 74054
Objects. The continuum needs to be fitted, then metallicity and logU derived, and splitted into metal bin to be refitted again with the nebular module.

Procedure:

Compare the SFR and Mstar derived with the COSMOS2015 values
Check the SEDs in the diagram at each wavelength
Check metallicity distribution and logU distribution

Create the new sample divided in metal bins

The results will be stores at

"/mnt/pdg-space/jvilla/Feb_2021_MOONS_BPT/metal_bins/metal_bins_COSMOS2015_nov_2021" in each folder (continuum, continuum_lines_logU_fixed) containing the metallicity bins for the nebular case continuum_lines_logU_fixed.