Notes

Marco Codato

April 19, 2022

1 Introduction

Moved to the GitHub repository `codatomrc/tesi`.

2 Background spectrum extraction

2.1 Automatic detection

- Explore the working directory to find all the raw files automatically.
- Integrate over all the wavelenghts by summing the data in the dispersion direction. In this way a can synthetically see the flux along the spatial direction, regardless the source (i.e. continuum or line).
- Detect the peaks the integrated flux using the function `scipy.signal.find_peaks`. This function finds the local maxima of an 1D signal.

  On the current data it was convenient to filter the detected peak to have a prominence (in this case $\sim$ height from the background) higher than 0.5% the highest peak on the signal. This helped to neglect local maxima due to spatial noise fluctuations.
- Measure the width of each peak with `scipy.signal.peak_widths`. This function is designed to work with noisy signal and several maxima and minima, instead of just some maxima above a flat background. I set the option `rel_height=0.5` to measure the FWHM of each peack instead of the width at the base, which turned to be not very solid for the data we had.
- Mask the regions around the peaks. After some testing, the best strated (with the data available) is to remove a region of width $5\times$ FWHM around each peak.

  Note if peak profile fits a gaussian appriximation (i.e. sharp peaks and/or high SNR and/ord profile intrisically gaussian) then 5 FWHM correspond span to 5.89σ from the maximum, when the flux is dimmed by a factor 10^{-8}.

  Such an high span is required as many sources have not gaussian profiles and in particular might present bright wings wrt the gaussian prediction (e.g. galaxies have a bright nearly gaussian core plus faint but extended spiral arms).
- Extract the data of the background as those outside the region of the peaks. These are the areas that will be used for the analysis.

Note that due to the variety of luminosity profiles of astronomical sources it is not very efficient to develope a qualitative approach to compute the best width. This empirical treatment is good enough (if it will prove to be solid with more data though).

A quantitative approach. I tried to sketch a qualitative model where I assumed gaussian profiles of the sources. The source ended when its flux was comparable to the amplitude of the bkg noise. The final distance Δ from the center of the source was

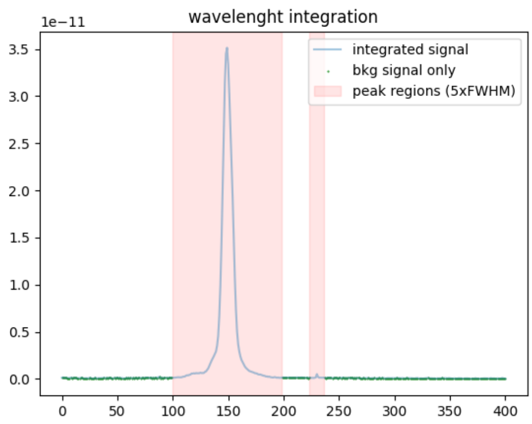
$$\Delta = \frac{1}{2\sqrt{2\ln 2}}\mathrm{FWHM}\sqrt{\ln(S_{\max}^2/B)}$$

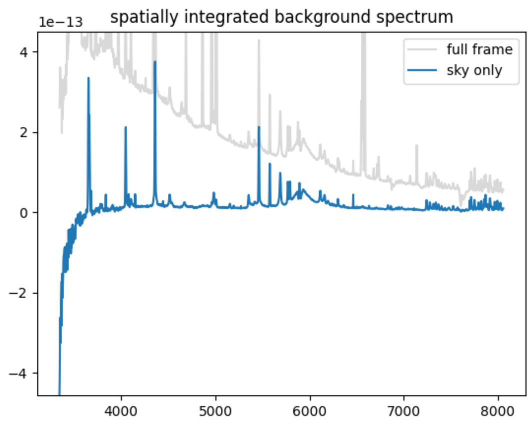
where $S_{\max}$ was the maximum counts of the source, while B the average level of bkg around the object. Since many extended objects cannot be reproduced by gaussian profiles this estimation may be misleading in many cases. Since the empirical procedure discussed above seems quite solid with current data, implementing a rigorous analytical approach that accounts for different luminosity profiles of the sources, is definitively unecessary.

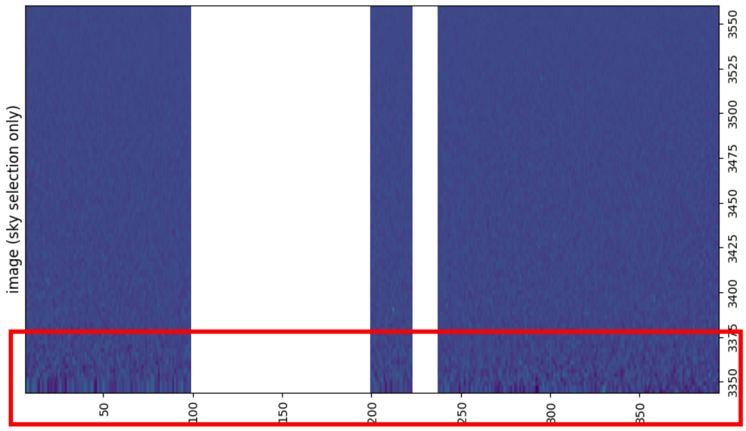
2.2 Preliminary results

Here the results with the two frames available.

NGC2392 (2006/ima_010). The Eskimo Nebula. There is a sharp peak with strong wings. Probably another very faint source is present in the field. The script does recognize both the signals and removes them.







We integrate over all the position along the slit where we no astronomical sources/signals are present. Then we plot it against the wavelenght to obtain the spectrum of the background (atmospheric emission + light pollution).

In the removal they comes out negative fluxes in the bluer hand of the spectrum. We realize that the wavelenght range in this frame begins at $\sim 3344\,\text{Å}$ which considerable as UV radiation. It is not so surprising to find inaccurate results at those extreme wavelenghts.

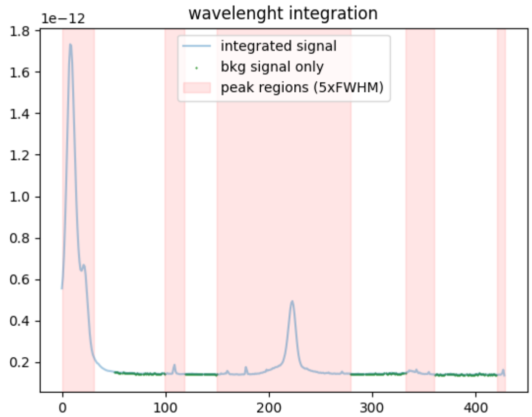
Ark564 (2006/ima_015). In this case the sources along the slit seems to be several but the script seems to be able to manage all of them. In this case the spectrum of the background do not seem to present any issue.

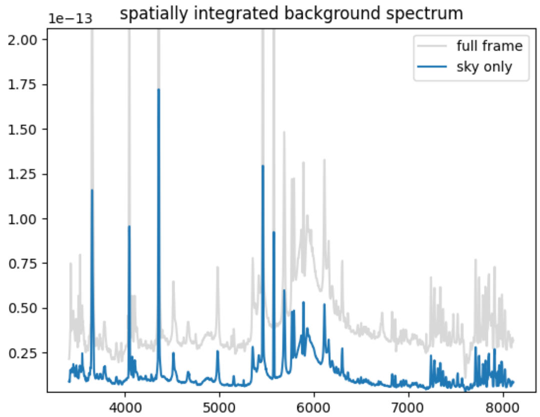
2.3 Comments on the first results

Wavelenght limitations. It would be convenient to set a wavelenght treshold for the analized data. Wavelenghts outside the spectrograph+telescope working range may led to biased measurements.

Frame limitations(?) I wonder wether the whole CCD area is suitable for collecting data or it would be better/necessary to neglect some specific regions, both in the spatial and dispersion directions.

What about the lines “CCDSEC” and “BIASSEC” in the header of the frames?





3 Appendix: Python source code

The code I am using.

```
import numpy as np
import matplotlib.pyplot as plt
from astropy.io import fits
import astropy.coordinates as coord
from astropy import units as u
from scipy.signal import find_peaks, peak_widths
from datetime import datetime
import glob

######################

#browse all the *.fc.fits files in a directory and its subdirectories
main_path = '.'
file_ls = glob.glob(main_path+'/**/*.fc.fits', recursive= True)

######################
######################

#process all the files found
for file in file_ls:

    #open a FITS file
    hdul = fits.open(file)
    hdr = hdul[0].header

    #extract wavelenght information from the header
    LAMBDA0 = hdr['CRVAL1']
    DELTA = hdr['CDELT1']
    NAXIS1 = hdr['NAXIS1']
    LAMBDA = np.arange(LAMBDA0, LAMBDA0+NAXIS1*DELTA, DELTA)
    NAXIS2 = hdr['NAXIS2']

######################
    #integrate along the wavelenghts (dispersion direction)
    integr = 0
    for i in range(2047):
        integr = integr + hdul[0].data[:,i]

    #find peaks and measure their widths
    peaks,properties = find_peaks(integr, prominence=max(integr)/200.)
    peak_FWHM = peak_widths(integr, peaks, rel_height=0.5)[0]

    #set left and right boundaries of the source region along the slit
    width_mult = 5
    left_width = peaks-peak_FWHM*width_mult
    right_width = peaks+peak_FWHM*width_mult

######################
    #remove overlapping ranges

    #compress left and right boundaries into a single array
    widths = np.array([left_width.T, right_width.T]).T
```

```python
    widths = np.reshape(widths, 2*len(left_width))

    #find and mark overlaps
    for i in range(len(widths)-1):
        if widths[i] > widths[i+1]:
            widths[i] = np.nan
            widths[i+1] = np.nan
    #shrink the array to unmasked values
    widths=widths[~np.isnan(widths)]

    #reshape the array into the original two
    left_width, right_width = np.reshape(widths, (int(len(widths)/2),2)).T

    #remove values beyond the CCD size limits
    if left_width[0] < 0:
        left_width[0] = 0
    if right_width[-1] > NAXIS2:
        right_width[-1] = NAXIS2

######################
    #mask the source/background regions
    sign_sel = np.zeros(np.shape(integr), dtype=bool)
    for i in range(len(integr)):
        for peak,width in zip(peaks,peak_FWHM):
            if abs(i-peak) < width*width_mult:
                sign_sel[i] = True
    bkg_sel = ~sign_sel

    #plot the integrated flux, show source and bkg regions
    if 1 == False:
        plt.title('wavelenght integration')
        plt.plot(integr, alpha=0.4) #integrated flux
        plt.scatter(np.arange(len(integr))[bkg_sel],
                    integr[bkg_sel],
                    s=0.2, c='green') #select bkg

        for i in range(len(left_width)): #show all the source regions
            plt.axvspan(left_width[i],
                        right_width[i],
                        alpha=0.1, color='red')

        plt.legend(['integrated signal','bkg signal only', f'peak regions ({width_mult}xFWHM)'
            ↪ ])
        plt.show()

######################
    #integrated spectrum (along the slit)
    spectrum = hdul[0].data #original data
    total = np.sum(spectrum, axis = 0) #integration along the slit
    sky = np.sum(spectrum[bkg_sel,:], axis = 0) #integration of bkg rows only

    #plot the spatially integrated spectrum of the bkg
    if 1 == False:
        plt.title('spatially integrated background spectrum')
        plt.plot(LAMBDA, total, label='full frame', color='gray', alpha=0.3)
        plt.plot(LAMBDA, sky, label='sky only')
        plt.ylim(min(sky),1.2*max(sky))
        plt.legend()
        plt.show()

######################
    #extract only the bkg rows

    ma_spectrum = spectrum #set masked data
    for i,row in enumerate(bkg_sel):
        #cancel data from the source rows
        if row == 0:
            ma_spectrum[i,:] = np.nan

    #plot as image the bkr rows only
    if 1 == False:
        plt.title('image (sky selection only)')
        plt.imshow(ma_spectrum, extent = [LAMBDA[0], LAMBDA[-1], NAXIS2, 0])
        plt.show()

######################
```

```
#save masked data in a new FITS file
if 1 == False:
    now = datetime.now()
    now_str = now.strftime("%Y-%m-%d %H:%M:%S")

    hdr.set('BKGEXTR', now_str, 'Time of bkg extraction')
    new_hdu = fits.PrimaryHDU(ma_spectrum)
    new_hdul = fits.HDUList([new_hdu])
    new_hdul[0].header = hdr

    file_new = file[:-5]+'.bkg.fits'
    new_hdul.writeto(file_new, overwrite=True)
    print(file_new,' saved')
```