HomeworkI-galaxyimage

July 27, 2022

Due on Friday July, 30th, by 5pm.

Please read the assignment *carefully* and submit a `jupyter` notebook that responds to all steps of the Coding Assignment outlined below. Include all the code you write as "Code" cells and any written responses as "Markdown/Raw NBConvert" cells.

In your notebook, please indicate clearly at the start of a block of code which part of the assignment it is in

Be sure to use comments throughout your code to explain how it works, variables, etc. You don't need to include full docstrings for any functions you write, but it *is* good practice! (1 pt)

1 Background: Analyzing Astronomical Images as 2D Arrays

In this assignment you will load three images from the Sloan Digital Sky Survey (SDSS). These images cover the same area of the sky and represent the flux the SDSS camera detected through three seperate filters. The large galaxy in each image is NGC 450. Each pixel in each image represents a measurement of the flux at that tiny patch of the sky. In this assignment, you will analyze a galaxy in the u, g, and r filters. These correspond to wavelengths of roughly 360 nm, 470 nm, and 620 nm, respectively. Non-astronomers might call these filters near-ultraviolet, blue, and orange.

2 Coding Assignment: Describe a Galaxy in an Image

This homework requires the `astropy` package (which we will use in more detail later). If you used anaconda to install Python, it should be already installed on your computer. If you have trouble with `astropy`, please contact me ASAP!

1. (1 pt) The images are located on `scorpius` at `/home/hama2717/astr2600/shared/sdss_images.fits` and on `Canvas`. Load the data from the FITS file into three 2D `numpy` arrays (named `u`, `g`, and `r`), using the following commands:

```
# JupyterHub
# set the directory where the file(s) are located
directory = '/home/hama2717/astr2600/shared'

# Anaconda
```

```
# Set directory to the directory where you stored the file(s)
# (Be sure to use \\ for directories if on Windows.)
# or leave blank if it is in the same directory as this homework
directory = ''

from astropy.io import fits
with fits.open(directory + "sdss_images.fits") as f:
       u = f[1].data
       g = f[2].data
       r = f[3].data
```

2. (3 pts) For each of the three images, print the following information:

- its *shape*
- its *min*imum and *max*imum flux value
- its *mean* and *median* flux value
- the *st*andard *d*eviation of its flux values
- the 1^{st} and 99.9^{th} *percentile* of the flux values in each image

3. (5 pts) Display the three separate images with `imshow`, plotting image row on the y-axis and image column on the x-axis. Within `imshow`, you will need to set the `vmin=` and `vmax=` keyword arguments to exclude some very bright pixels from setting the limits of the colormap. Use `np.percentile` to dynamically set the lower and upper limits to the 1^{st} and 99.9^{th} percentile values, respectively. The image should show multiple stars and at least one galaxy.

4. (2 pts) Once you locate the largest galaxy visually, make these plots again but "zoom in" on the galaxy by adjusting the x and y limits of the image so you can see it in more detail.

5. (8 pts total) What is the diameter, d, of this galaxy in pc? The distance D to this galaxy is known to be 21 Megaparsecs (Mpc) or 2.1×10^7pc. Recall that 1pc $\approx 3.1 \times 10^{16}$m. Each pixel of the SDSS camera represents a tiny angle of 0.396 arcseconds on the sky. The apparent angle a galaxy subtends on the sky θ is given by:

$$\tan\theta = d/D$$

in which $\tan\theta$ is closely approximated by:

$$\tan\theta \approx \theta \text{ (in radians)}$$

for the very small angles we're talking about here. You must do this *computationally* to receive full credit, including finding a way to *quantitatively* (using Python) define and measure the apparent size of the galaxy in the image. There are many reasonable different choices you could make about how to do this; describe any assumptions and choices you make. *One hint: Spiral galaxies are typically circular in shape. Any apparent ellipticity is likely due to a projection effect of seeing the galaxy tilted in the plane of the sky. Measure across the largest diameter of the galaxy (including the spiral arms). You are allowed to define where this "largest diameter" is by eye but must use python to create the criteria for measurement and make the measurement itself.* Plot a slice of your galaxy across a single row or column to visually justify your choice.

- **5a.** (3 pts) Pseudo-code is a great way to start thinking about a problem before diving in to the coding itself. Before writing your code for the above question, write pseudo-code in a Markdown/RawNBConvert cell for how you plan to accomplish the task. Your pseudo-code does not need to identify exactly which code/functions you might use, but should be a general outline of what your code will do. In particular, you should describe how you plan to measure the diameter. Your pseudo-code should be no less than 5 steps but probably not more than 15.

- **5b.** (5 pts) Write the code itself. Include your pseudo-code bits from above as comments in your actual code to identify where you mapped pseudo-code to code.

6. (3 pts) Let's determine which part of the galaxy is the bluest. Reddest? Use the `u` and `g` band images to compute a color index:

$$\text{color index} = 2.5 \log_{10} \left(\frac{g}{u} \right) \tag{1}$$

This should be an image (2D array), with a color index defined for every pixel. Display that color-index image with `imshow` and a non-gray colormap of your choice. Display a colorbar. You might want to use limits close to `vmin=0` and `vmax=0.4`.

7. (2 pts) Smaller astronomical color indices, as defined above, correspond to bluer colors. Given that blue (hot) stars live a very short time, their presence indicates relatively recent star formation. Is there likely to have been recent star formation in the nucleus of this galaxy? What about in the spiral arms? Using your results for Q6, explain your reasoning.

3 Turn in your Assignment

Your final version of your assignment should run from top to bottom without errors. (You should comment out or delete code bits that were just used for testing purposes.) To create a clean version, rerun your notebook using "Kernel|Restart & Run All." Be sure to save this final version (with output). To submit, click "File|Download As >|HTML (html)" inside jupyter notebook to convert your notebook into an HTML web page file. It should have a name like `homework#_{identikey}.html` (where # is the appropriate letter for this week's homework). Please upload this HTML file as your homework submission on Canvas.