Star Formation Rate data from SDSS Marvin

Jacob Yuzovitskiy

November 2023

1 Introduction

Here, I outline a method to pull star formation data for arbitrary galaxies in the Mapping Nearby Galaxies at Apache Point (MaNGA) galaxy survey. I also discuss intended future uses for this strategy in E+A+ galaxy analysis.

2 Methods

Pulling the data we need from Marvin is simple thanks to built in commands which generate appropriate BPT diagrams and maps of star forming space pixels. Initially, we define some

```
rand = marvin.tools.Maps('xxxx-xxxxx'),
```

storing an arbitrary MaNGA galaxy code in a python variable. Then, we use

```
snrdict = {}
masks, fig, axes = rand.get_bpt(snr_min=snrdict)
```

to pull a BPT diagram for our MaNGA galaxy. We use these diagrams to diagnose a galaxy as star forming, checking that we've chosen an appropriate sample. See the random one I selected for this test, below.

After getting our BPTs, we plot a map of $H\alpha$, masking out all non-star forming pixels. The result is a large NumPy array with all missing values masked out.

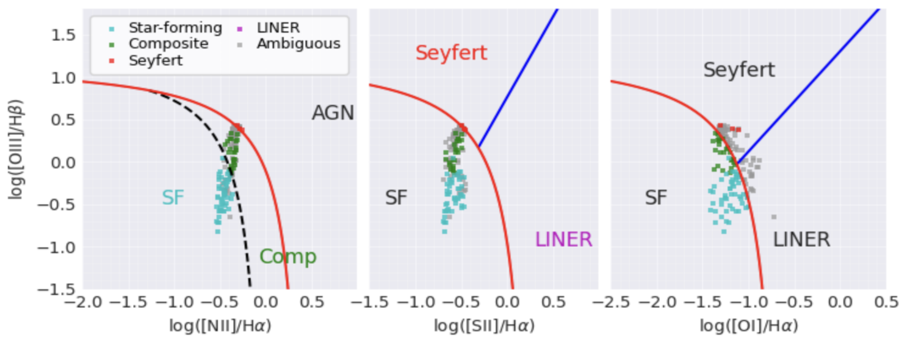

Figure 1: BPT diagrams for 7961-12704.

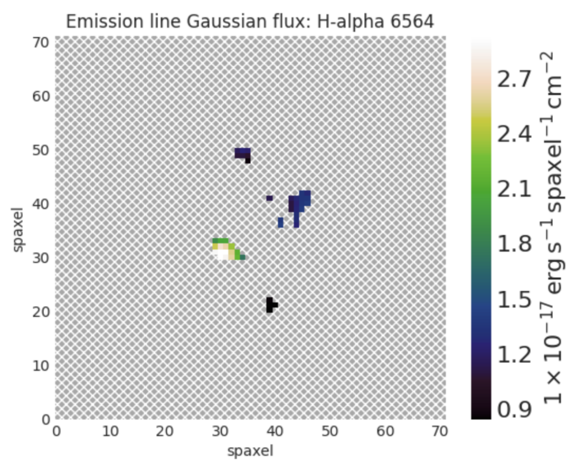

Figure 2: Hα diagram for 7961-12704.

After pulling Hα and masking out non star-forming spaxels, we do the same for Hβ, and then take the ratio of the two quantities. So far, we have an array of values for Hα, Hβ, and Hα / Hβ. Before continuing, we should calculate the dust attenuation-corrected Hα flux. This is done with a formula applied to our array of values, which looks like

$$F_{H\alpha,0} = F_{H\alpha} * 10^{2.468*0.934*ln(\frac{F_{H\alpha}}{F_{H\beta}2.86})}.$$

This comes from the more general formula

$$F_{H\alpha,0} = F_{H\alpha} 10^{k(H\alpha)E(B-V)}.$$

Regrettably, I have not found a source for this yet beyond the SDSS Marvin Science Exercise I pulled the formula from. I am not quite sure how the extinction fits in, or where $k = 2.468$ comes from, but I assume a gap in general knowledge is responsible.

Next, we use our masked arrays to calculate a dust-corrected luminosity for Hα. We do this using

$$L_{H\alpha} = F_{H\alpha} 4\pi D_L^2,$$

where $F_{H\alpha}$ represents the dust corrected flux, and D_L represents the luminosity distance calculated using the redshift of the galaxy.

We finally find star formation rate of our sample galaxy using

$$SFR = 5.5 * 10^{-42} L_{H\alpha}.$$

The equation comes from a 2009 paper analyzing nearby galaxies, linked below. These are, presumably, the most up-to-date numbers for this relationship, although I read back to work as far as 1994 to find older "calibrations." This manipulation yields a python array of SFR data in each spaxel, which can be further worked or turned into a graph using Matplotlib.

3 Discussion and Next Steps

The SFR data has multiple applications. Most immediately, with some more calculations, we can use these values to find star formation rate density (SFRD) values for our chosen galaxy. These will also be in the form of a NumPy array, which we can turn into a graph using Matplotlib. A reasonable exercise would be to plot SFRD against the radius of a sample galaxy, yielding a visual representation of star formation.

This code is also a quick way to find SFR data of "E+A+" galaxies. These galaxies, with spectra similar to that of E+A galaxies, present with $H\alpha$ emission lines which suggest star formation. Using this code, we can quickly "locate" the remaining star formation in these galaxies, which will hopefully reveal some trend or novelty about SFR in these "almost post-starburst" samples.

These computations are (probably) mathematically imperfect, but the structure of the code allows us to easily tweak the math without significant rewrites. With some computation, we will have a more accurate codebase with which to perform analysis. Below, I've included some preliminary per-spaxel SFR results for a sample galaxy. The numbers may be imperfect, but the method will likely stay the same.

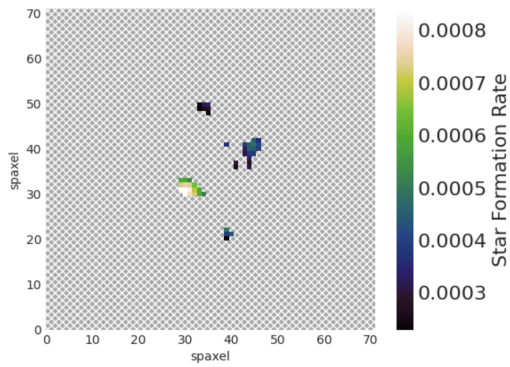

Figure 3: SFR diagram for 7961-12704 in solar masses/yr.

3.1 References

Here, a quick list of articles and websites referenced to write the code for this project, and a brief description of the use case

- SDSS Marvin Science Exercises. These had a tutorial on how to do a lot of what I needed, and solutions for different problems that I could compare my code to. Unfortunately missing a lot of sources and full of broken links, but incredibly useful regardless.
- Converting Luminosity to Star Formation Rate. A more in-depth presentation of some information that was already in the Marvin science exercises. The units are documented better here, which made it easier to do some dimensional analysis.
- SDSS Marvin Plotting Tutorial. A great help for basic plotting of "enhanced maps," which contain the SFR data. Originally, I turned my final data into a python n-dim array to plot with Matplotlib, but this made it easier to get a better format.
- UCLA Cosmology Calculator. Initially, I needed this online calculator to find luminosity distance, but after I wrote that calculation into the code, this site served as a helpful reference for units and calculations.
- Kennicutt 2009. The referenced 2009 paper above, from which I took the final SFR equation.
- Kennicutt 1997 Contains one of the earlier Kennicutt models for SFR.

This is (of course) not an exhaustive list of all the sources referenced to write this code, just the ones that were most notable to me looking back.