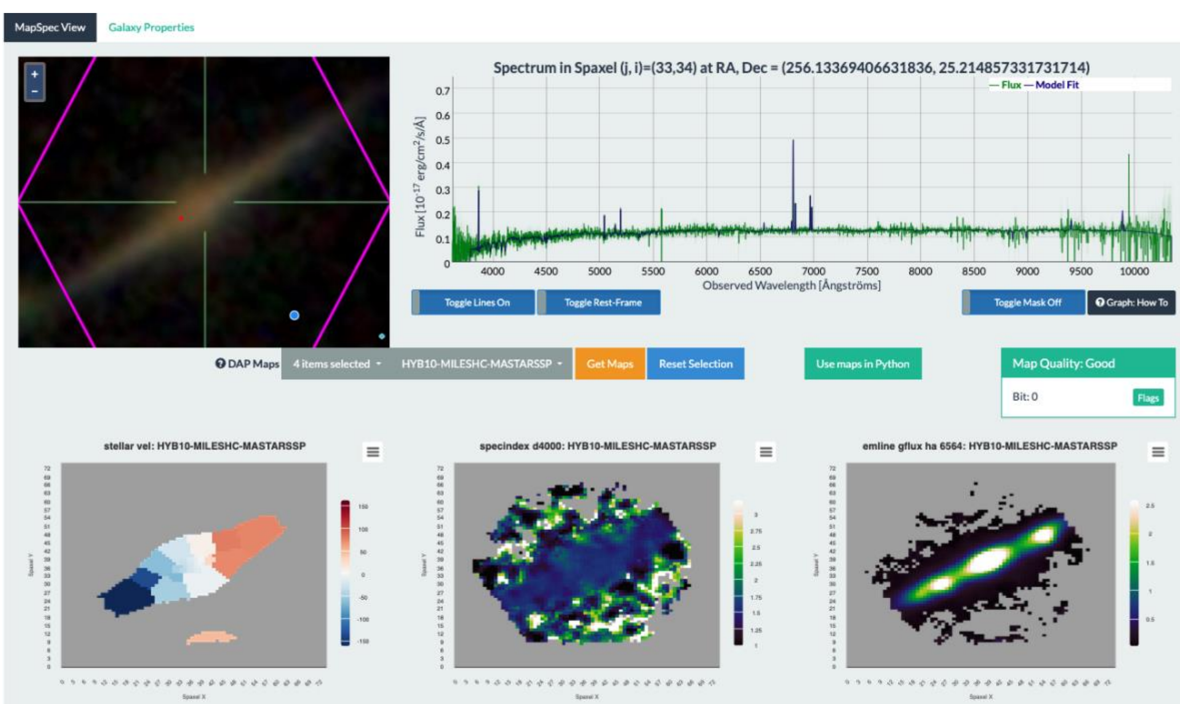
ASTRO 330: Galaxies
Class 7 Exercise: Feb. 12
Dynamical Masses of MaNGA Galaxies
Due Feb. 20 as Class 07 Activity

*Follow the instructions below. Where a response, explanation, or calculation is asked for in **boldface**, add that to the submission template at the bottom of the document.*

1. Go to **https://dr15.sdss.org/marvin/.** Try clicking “Image Roulette” until you find an edge-on spiral galaxy. (I got an error message on my first attempt and was successful when I tried clicking again). Check that at least 3/4’s of the galaxy fits within the IFU footprint (purple hexagon), as we want to be sure we reach out to the “flat” part of the rotation curve. Click on the large image of the galaxy to open its page.

2. After you’ve selected your galaxy **(make note of its Manga-ID)**, make sure you see the green button “Map/SpecView On” (if it’s red, click on it and it will become green). The maps show quantities measured from the galaxy spectra. Three maps are shown by default:

    i. stellar vel: this map shows the velocity of the stars in km/s. This is the classic “spider diagram”.
    ii. emline gflux ha 6564: this map shows the galaxy’s Hα emission line flux. Hα is a good tracer of star formation.
    iii. specindex d4000: this is a measure of the strength of the “4000 Å break”. Galaxies with old stellar populations have a strong 4000 Å break.



3. Let's add one more map. Click on the grey button under the image of the galaxy that says "3 items selected". In the long list that comes up, click on "emline_gvel: ha 6564" — this is the measured doppler velocity of the Hα emission line (with the redshift of the galaxy subtracted off). Then click "get maps."

4. Compare the stellar velocity and the Hα gas velocity**. Which map looks smoother? Why do you think that is?**

    i. *Hint:* In the large image of the galaxy, click on any part of the galaxy disk inside the hexagon, and the 1D plot will display the spectrum taken by the individual fiber covering that part of the galaxy. Click on the dark grey "Graph: How To" button to see how to zoom in and out on the spectrum.

        Click on the blue "Toggle Rest-Frame" button to remove the galaxy's overall redshift, and then zoom in to the range ~4500-7000 Å. The green line is the data, with a light green band indicating the likely range of error. The blue line is the best model fit. Zoom in again to ~5800-6800 Å. Is it easier to fit the gas (emission lines) or the the starlight (absorption lines)? When MaNGA spectra have insufficient signal-to-noise (S/N) to get a good fit, adjacent spectra are binned together. That can make some of the maps look more blocky.

5. Chose whichever velocity map (stellar or Hα) looks better to you (it will depend on your galaxy.) Look along the major axis of the galaxy (long axis) and try to estimate v_{flat}, the velocity on the flat part of the rotation curve. There might be some local variations so don't just pick the max velocity — look for the average velocity in the outer part of the disk. **Report the value you find.**

    i. Doing this by eye in 2D sufficient for the purpose of this assignment. If you want a more precise estimate and you're fluent in Python you can download the map (see the "Use maps in Python" button) and plot the rotation curve by taking a slice along the major axis.

    ii. The first galaxy I found had a different absolute value on opposite sides of its rotation curve (+88 km/s vs. -120 km/s, approximately). If you find something like that, use the average value ignoring the signs (104 km/s in my case).

6. Now you're ready to work out your galaxy's dynamical mass. In general we know that $v_{rot} = \left(\frac{GM(r)}{r}\right)^{1/2}$, so measuring v_{rot} at a particular radius will yield the mass enclosed within that radius. But what radius do we use to calculate the total mass? A frequent convention is to use the radius where the density of the dark matter halo is 200 times the average density of the Universe. Assuming a Navarro-Frenk-White dark matter halo, there's a well-defined relation between M_{200} and R_{200} that we can use. Skipping some intermediate steps, we get the following relation for halos at z~0:

$$M_{200} = \left(\frac{v_{flat}}{129\ km/s}\right)^3 10^{12} M_{\odot}$$

Even if you had a perfect measurement of v_{flat} , this equation only approximates the dynamical mass, since it assumes the total mass in the galaxy follows the Navarro-Frenk-White density profile. **Report your value of M_{200}.**

7. Now that you've computed the dynamical mass for your galaxy, see how it compares to the stellar mass. Just above the galaxy image in Marvin click on "Galaxy Properties" and record the value of "elpetro_logmass". The is the log (base 10) of the galaxy's stellar mass assuming h=1 (H_0 = 100 km/s/Mpc). To correct back to H_0 = 70 km/s/Mpc multiply the stellar mass in linear units by $(h=0.7)^2$, since the computed mass depends on distance^2 and hence $H_0{}^2$.

8. **Report your corrected value of stellar mass, and the ratio of stellar to dynamical mass for your galaxy.**

- **i.** For context, the Milky Way has $M_* \sim 5 \times 10^{10}\ M_{\odot}$ and $M_{dyn} \sim 1 \times 10^{12}\ M_{\odot}$.
- **ii.** If you are finding $M_* \approx M_{dyn}$ or even $M_* > M_{dyn}$, what might have gone wrong? Was your galaxy completely edge on? If not, that would lower the velocity you measure. Were you tracing far enough out in the disk to reach V_{flat}?

Submission Template

Submit this page as Class 07 Activity. Your responses will be graded holistically according to the in-class activity rubric. Item #s match steps in the instructions above.

2. Write your galaxy's Manga-ID

Manga-ID: 1-214319

4. Does the stellar velocity or gas velocity map look smoother? Why do you think that is?

The gas velocity map looks smoother than the stellar velocity map because bright emission lines often have higher signal-to-noise, requiring less binning. By contrast, the stellar velocity map relies on weaker absorption features, so more binning is needed to achieve a reliable fit, making it appear blockier. Basically, it all comes down to differences in data quality and how each type of signal is measured. Gas velocities can be resolved on finer scales, while stellar velocities must be averaged over larger regions.

5. Report your value of v_{flat}

The value of my v_flat is 88 km/s

6. Report your value of M_{200}.

M_200 = 3.17451 x 10^11 M_sun

8. Report your corrected value of stellar mass, and the ratio of stellar to dynamical mass for your galaxy.

elpetro_logmass = 9.4403

corrected value of stellar mass = 1350504638 = 1.3505 x 10^9 M_sun

ratio of stellar to dynamical mass for the galaxy = 4.26 x 10^-3