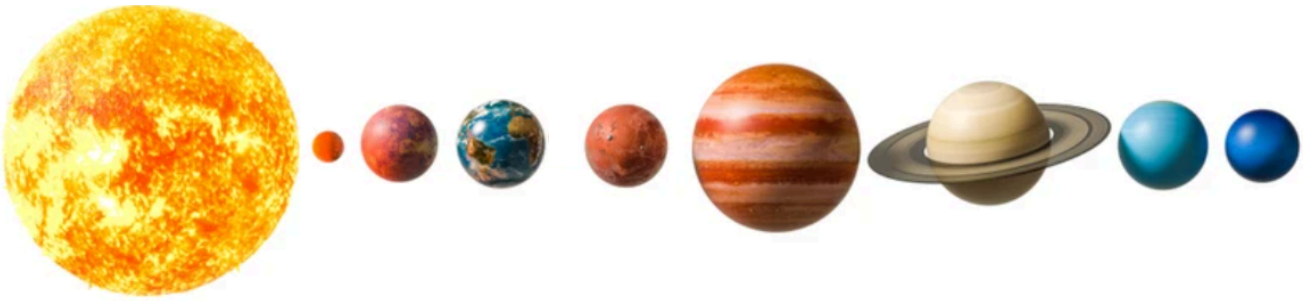
The Masses of Spinning Galaxies

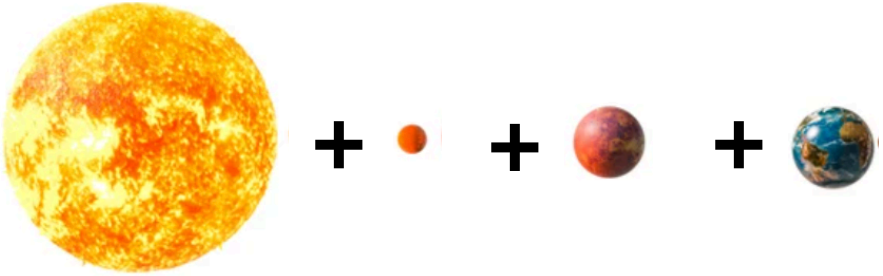
Most things in the universe rotate: the earth spins around its axis, the planets orbit around the sun, and the sun moves around the center of the Galaxy. We also know from **Kepler** and **Newton** that how fast objects orbit is related to the **gravity** that they feel, which comes from the **enclosed mass** of the object(s) they are orbiting.

Let's start by looking at our solar system.

	Mass in suns	Orbital Speed
Sun	1 sun	
Mercury	0.00000016 suns	50 km/s
Venus	0.0000025 suns	35 km/s
Earth	0.000003 suns	30 km/s
Mars	0.0000003 suns	25 km/s
Jupiter	0.001 suns	15 km/s
Saturn	0.0003 suns	10 km/s
Uranus	0.00004 suns	7 km/s
Neptune	0.00005 suns	5 km/s



To get the mass inside of a planets orbit (**the enclosed mass**) add up the masses of all of the objects closer to the center than it is, including the sun! So, the enclosed mass at the distance of Mars would be:

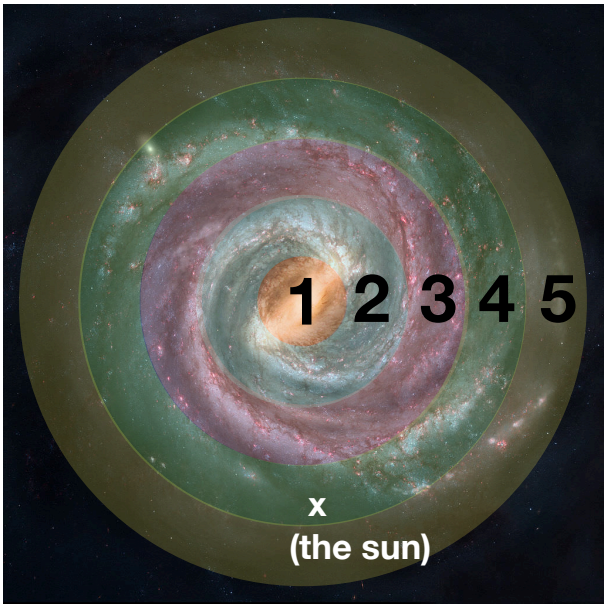
Enclosed Mass = 

How much does the enclosed mass of the solar system increase as the distance from the sun increases?

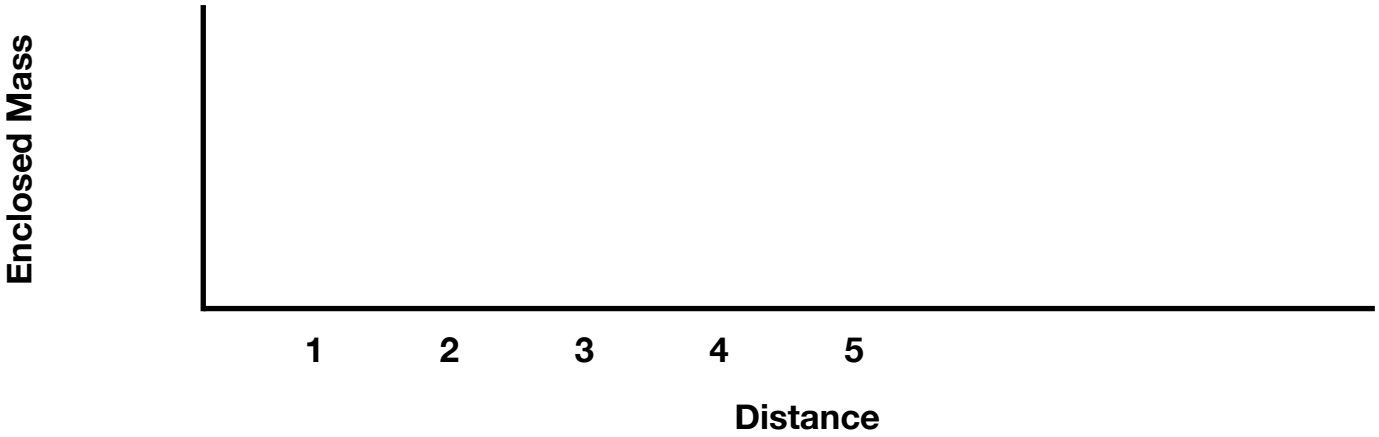
Compare this to what we call a **'Keplerian'** rotation curve, or how fast the planets move as a function of their distance from the sun (recall: this comes from Kepler's third law).

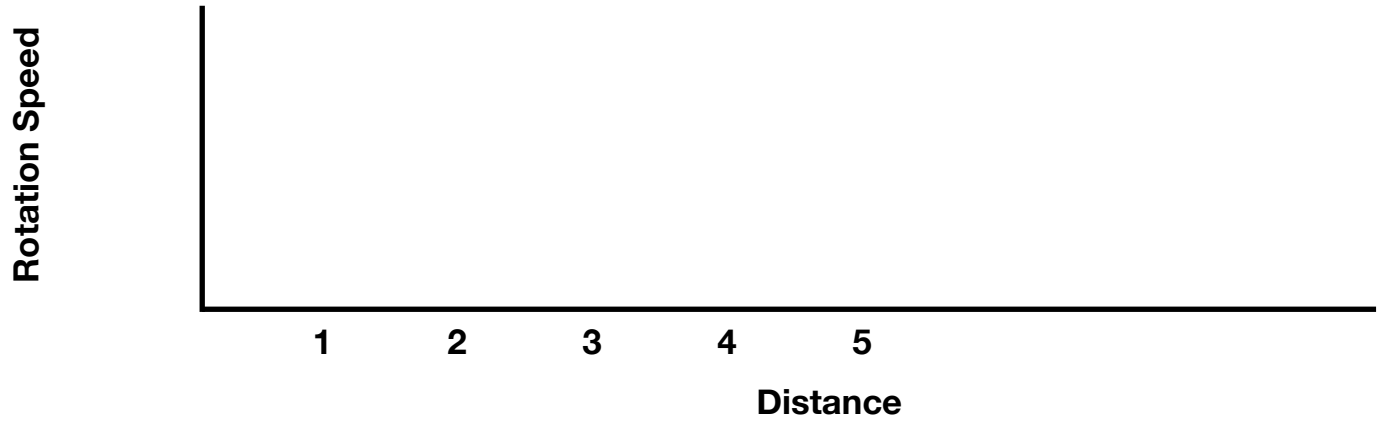
How does the orbital speed change compared to the enclosed mass?

Now, let's do the same thing for our galaxy. We divide it into 5 different rings.
Plot the **enclosed mass** from stars and the **rotation speed** as a function of distance.



Ring	Stellar Mass	Rotation speed
1	5 billion suns	260 km/s
2	20 billion suns	210 km/s
3	15 billion suns	240 km/s
4	10 billion suns	220 km/s
5	1 billion suns	240 km/s

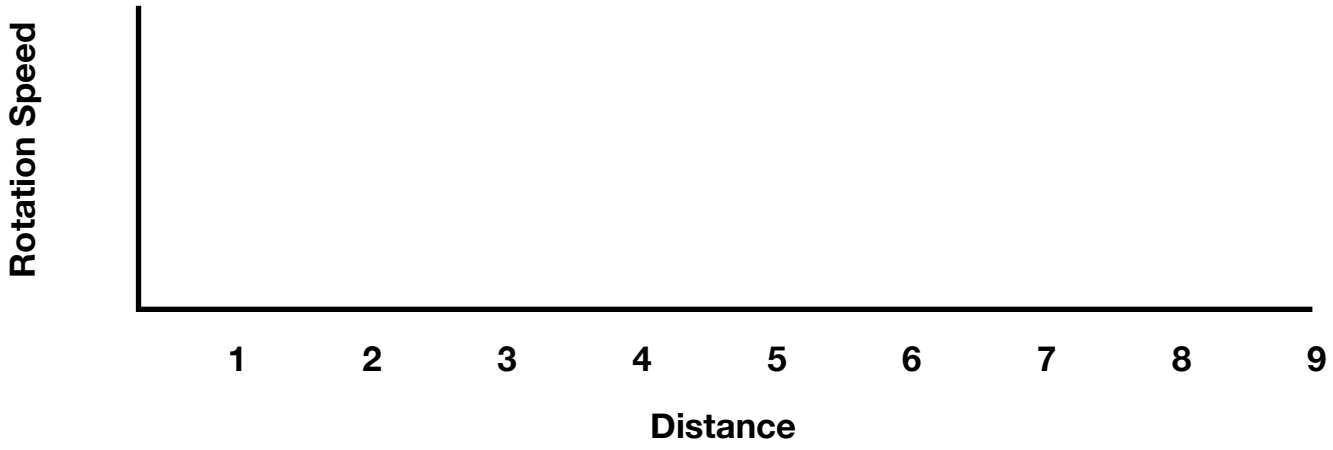




Assume there are no stars beyond Ring 5. **Draw your prediction** for what the rotation speed of the galaxy would look like beyond this point, based on what we see in our solar system

Now compare this to what we actually see at larger distances, based on the motions of clouds of diffuse hydrogen gas surrounding the galaxy (which have a negligible mass)

Ring	Stellar Mass	Rotation speed
6	0 suns	270 km/s
7	0 suns	280 km/s
8	0 suns	290 km/s
9	0 suns	300 km/s



What does this say about how the total enclosed mass at these distances?
How can we explain this?