Name _____ Date _____

THE HUBBLE LAW

Galaxy and Spectra Overview

NGC #	Sketch	Type	Description of Spectrum	Keep?
1357		*Spiral*	*Emission spike around 6600 Angstroms; other spikes also*	YES
1832		*Spiral*	*Huge spike at approx 6600 Angs; plus other spikes*	YES
2276				
2775		*Elliptical*	*Strong (deep dips) absorption; no emission really*	NO
2903				
3034				
3147				
3227				
3245				
3310		*Spiral*	*GIGANTIC emission spikes (later eliminated because awful spectrum)*	NO
3368				
3471				
3516				

NGC #	Sketch	Type	Description of Spectrum	Keep?
3623				
3627				
3941		*elliptical*	*Deep absorption lines; no emission at all.*	No
4472				
4631				
4775				
5248				
5548		*Spiral*	*Huge spike around 5100 Angs. and fat one at 6700 Angsj.*	Yes
5866				
6181				
6217		*Spiral*	*Huge spike (emission) around 6600 Angs; small one around 4900 Angs.*	Yes
6643				
6764				
7469		*Spiral*	*Emission spikes at 4900, 5100, and around 6700 Angs.*	Yes

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Data Table

NGC Number	SPECTRAL LINES			Average Redshift	Velocity (km/sec)	Galaxy Size *mrad*	Distance (Mpc)
	Ca K 3933.7	Ca H 3968.5	H-alpha 6562.8				
1357	3962.0	3997.2	6608.6	**0.0071**	**2100**	**0.79**	**28**
	0.0071	0.0072	0.0070				
1832	3960.5	3994.8	6607.0	**0.0066**	**2000**	**0.71**	**31**
	0.0067	0.0066	0.0067				
2276							
2775	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
	xxxxx	xxxxx	xxxxx				
2903							
3034							
3147							
3227							
3245							
3310	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
	xxxxx	xxxxx	xxxxx				
3368							
3471							
3516							

It is still entirely acceptable to eliminate additional galaxies if spectra are “ugly” and lines are hard to identify. Just make sure you have a minimum of 10 galaxies for your graph.

You should not have any negative values for redshifts! If you do, you are measuring the wrong lines.

NGC Number	SPECTRAL LINES			Average Redshift	Velocity (km/sec)	Galaxy Size *mrad*	Distance (Mpc)
	Ca K 3933.7	Ca H 3968.5	H-alpha 6562.8				
3623							
3627							
3941	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
4472							
4631							
4775							
5248							
5548	4002.6	4040.9	6675.7	0.0176	5270	0.33	67
	0.0173	0.0182	0.0172				
5866							
6181							
6217	3950.3	3985.5	6590.7	0.0042	1260	0.45	49
	0.0042	0.0043	0.0042				
6643							
6764							
7469	3990.4	4028.4	6663.2	0.0149	4470	0.34	65
	0.0144	0.0151	0.0153				

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Table of Results

Hubble Constant		km/sec/Mpc
Uncertainty in H_o		km/sec/Mpc
Maximum Age of Universe		**years**
Age with deceleration		**years**
Calculations:		

Step 6: Questions

1. Compare the speed of the galaxy with the highest redshift to the speed of light. Identify that galaxy and state its recessional velocity. What fraction of the speed of light is that galaxy receding from us? Comment on your value—that is, in terrestrial terms, is this speed high? How about celestial terms? (Show all calculations.)

2. Why does the best-fit line to your data need to go through the origin of your graph? Where does the "origin" lie in the Universe?

3. Quantitatively compare your maximum age for the Universe to the age of the Sun (5 billion years), and to the age of the oldest stars in the Milky Way (approx. 15 billion years). Briefly discuss any discrepancies, or comment about your comparisons of these ages.

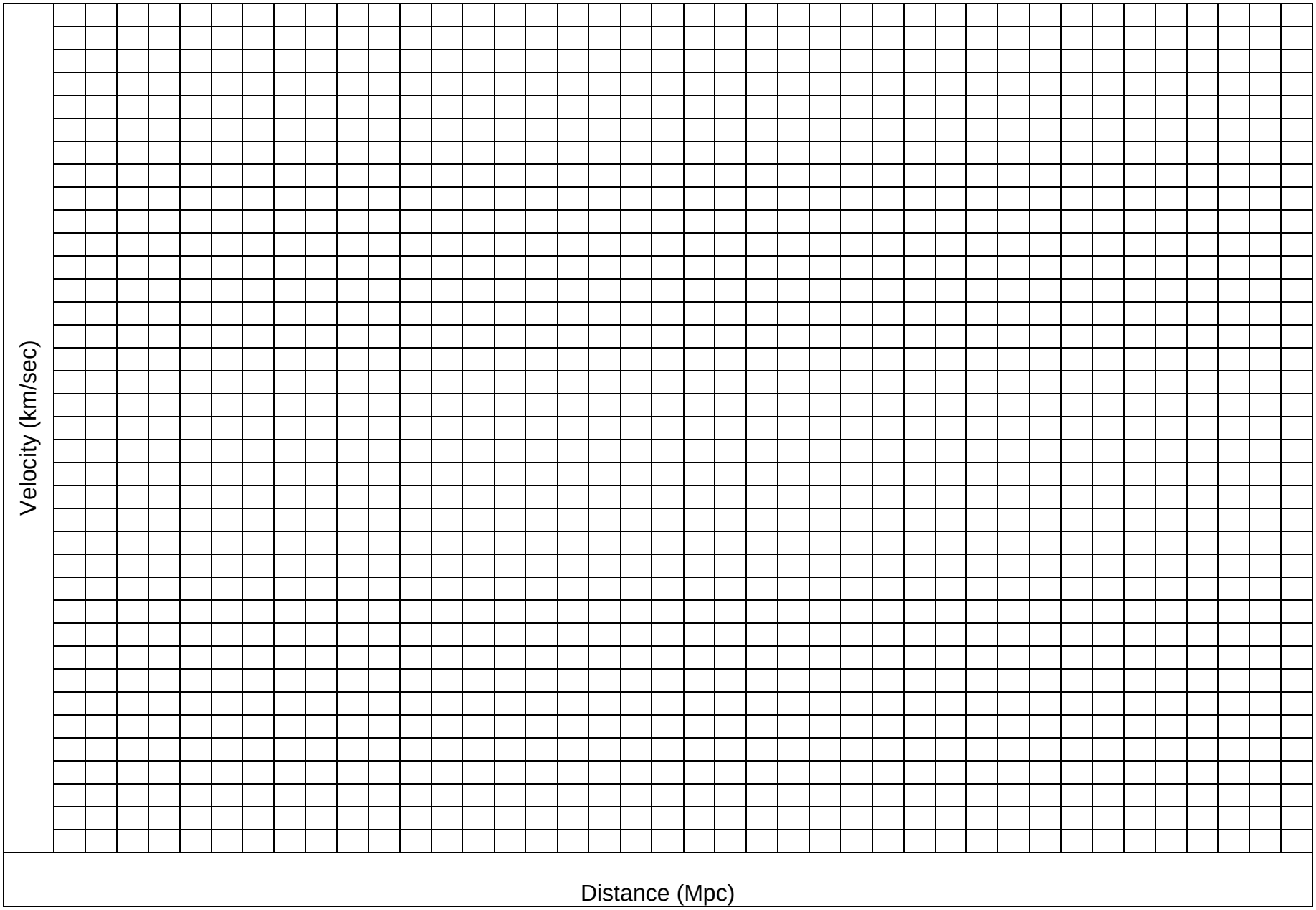
4. Theoretically, your plot should be a straight line, but it probably isn't. Think carefully about the following sources of error and answer the questions.
    a. First, write down the formula you used to determine the distances to these galaxies (the last column of your data table) and explain each term. State whether the distance is **proportional to** or **inversely proportional to each of** the individual terms on the right-hand-side of the equation.

    b. One obvious source of error is the assumption we made that all spiral galaxies have the same **actual** diameter. How would an over-estimate or an under-estimate of the actual diameter (not angular diameter) of a galaxy affect your estimate of the distance to it? Explain. Draw a diagram if you want.

c. You must have noted that for some galaxies you can see at least a vague spiral arm structure, while for others (the more distant?) you could not. What would be the effect on your value for the **Hubble constant** of your consistently **under-measuring** or **over-measuring** the angular diameter of the galaxies? (Hint: look at the distance formula and the Hubble Law formula, or work with your graph—this is a harder question.)

d. A third source of error is in the measurements that you make. Quantitatively (give some numbers) how precise do you believe your measurements to be for the wavelengths? For the angular sizes? Give one example of something that might affect your precision in your measurements.

5. Another consideration is the fact that galaxies are found in groups or clusters. The motion of these galaxies through space as they orbit their common center of mass is called *peculiar motion*. That is, some galaxies will be receding more slowly than others in the cluster while others will be receding more quickly. How does this *peculiar motion* affect your velocity measurements?


Velocity (km/sec)
Distance (Mpc)