SIERRA COLLEGE OBSERVATIONAL ASTRONOMY LABORATORY EXERCISE		
NUMBER V.Aa.	**TITLE: HUBBLE'S LAW (part I)**	
DATE- **DAY-** **LOCATION**	**PRINT NAME/S AND INITIAL BELOW:**	**GROUP** ☐

OBJECTIVE:

Be able to:

Graph data, visually fit the data with a line, graphically evaluate errors.
Determine the dispersion of spectroscopic data.
Determine redshifts; infer cosmic distances using Hubble's law.

DESCRIPTON:

Because of the Big Bang, spacetime is expanding. As a result, distant galaxies are receding from us. They are not truly moving away from us—it is space itself which expands between the galaxies. This is the origin of Hubble's Law:

$$v = H\,r \qquad \textbf{Equation 1}$$

Where: v is the recessional velocity (in km/s),
H = Hubble's constant (in km/s per Mpc),
r = distance to the galaxy (in Megaparsecs).

Graphing the recessional velocities of galaxies, as a function of distance, allows us to observe this linear relationship, and to determine the value of Hubble's constant.

Once Hubble's constant is determined, it can be used to determine the distances to other galaxies, after their recessional velocities are measured. These velocities are determined by measuring their redshifts (i.e., shifts in wavelength) and converting them via the Doppler equation:

$$v = c\,(\Delta\lambda/\lambda_o) \qquad \textbf{Equation 2}$$

Where: v is the recessional velocity (in km/s),
c = the speed of light (3×10^5 km/s),
$\Delta\lambda$ = the change in wavelength (the redshift)
λ_o = the wavelength of light being studied, when not redshifted.

PART I

Construct a plot of galaxies, graphing distance versus recessional velocity. From this, Hubble's constant will be determined.

PROCEDURE:

1. Table IA lists distance estimates to a variety of galaxies, their recessional velocities, and the methods the distance estimates were obtained[1]. These galaxies were studied by astronomers engaged in a number of separate research programs, and so many have strange-sounding catalog names. Plot these data on the graph supplied. Use the scale of 2500 km/s for each major vertical tick and 50 Mpc for each major horizontal tick. Make sure each scale starts at 0.
2. Using a ruler, estimate a best fit with a straight line.
3. Draw two more lines to estimate an upper and lower boundary for data, as demonstrated in class.
4. Read a value of **v** and **r** from each of your three lines, to calculate three estimates for Hubble's constant—a best fit value, an upper value, and a lower value. Record your results in Table IB.
5. Using the discrepancy formula, calculate uncertainties in your estimate for Hubble's constant. Record your results in Table IB.

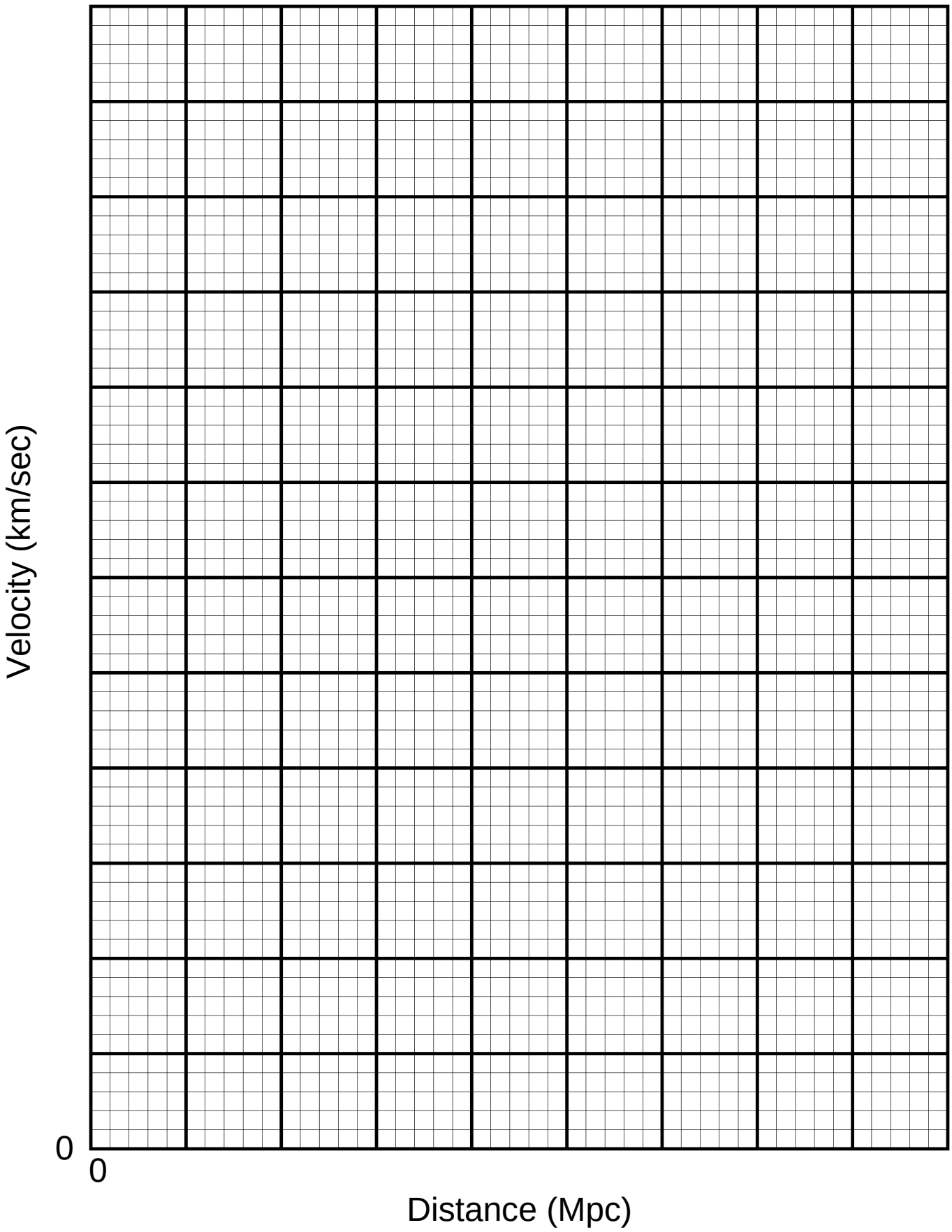
TABLE IA: GALAXY DISTANCES AND VELOCITIES

Galaxy name/catalog listing	r (Mpc)	v (km/s)	Method
1) NGC 0048	61	1972	Sosies (Milky Way look-alikes)
2) IC 1601	120	3642	Sosies (Milky Way look-alikes)
3) UGC 00646	80	5474	SNIa
4) UGC 03576	108	5994	SNIa
5) MH92d 074119.0-622406	165	10377	SNIa
6) P96 J003618.17+112334.7	142	10719	SNIa
7) MH92b 100643-2624.0	182	12977	SNIa
8) LSBG F119-024	237	12998	SNIa
9) UGC 05691	275	15968	SNIa
10) 2dFGRS S839Z607	271	17665	SNIa
11) MH93a 103235.1-341103	262	19760	SNIa
12) MH93a 103235.1-341103	342	19760	SNIa
13) MH93a 100125-3513.1	217	20310	SNIa
14) MH92n 033422.3-183104	340	22670	SNIa
15) MH93 014355.4-562057	387	25108	SNIa

TABLE IB: CALCULATING HUBBLE'S CONSTANT

Estimate	v (km/s)	r (Mpc)	H (km/s per Mpc)	Uncertainty (% difference from "best fit value")
Low value				
Best fit value				
High value				

[1] Data from NASA/IPAC catalog, http://nedwww.ipac.caltech.edu/level5/NED1D/


Velocity (km/sec)
0
0
Distance (Mpc)

QUESTIONS

1. A research program is studying an object called “EXO 0706.1+5913”, with v = 35150 km/s. What do you calculate for the distance for this object, using your best fit value of Hubble’s constant?

2. The research program, using a new method to determine the distance to EXO 0706.1+5913, concludes the distance is 531 Mpc. Assuming your value is correct, does this new method seem to provide accurate results? (Use the discrepancy formula to determine how far off the team’s distance is from your value.)

3. The distances to the first two galaxies in your list were determined using a method called “sosies.” Draw a new Hubble line on your graph, but in drawing this new line, fit only those two galaxies. What is the value of Hubble's constant that you would calculate using this method?

4. Suppose a research team using the sosies method was studying EXO 0706.1+5913. What would they calculate the distance to this galaxy to be? Is this in agreement with your method from question 1? (Use the discrepancy formula to determine how far off the sosies team's distance is from your value.)