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

PART II

Distant galaxies exhibit cosmological redshifts. Figure IIA shows Hale Observatory photographs of cluster galaxies in five different constellations. The five galaxies were selected because they are believed to be the same physical size (about 100,000 LY across).

Each photograph is accompanied by the galaxy's spectrum. Above and below each spectrum are reference lines produced by helium. The wavelengths of the brighter lines are labeled a—g, and are identified in Table IIA. The two calcium absorption lines visible in each spectrum are at the unshifted wavelengths 393.4 nm and 397.9 nm.

TABLE IIA: REFERENCE SPECTRA

a = 388.9 nm b = 396.5 nm c = 402.6 nm	d = 447.2 nm e = 471.3 nm f = 501.6 nm

PROCEDURE:

1. Select two widely separated reference lines (such as "a" and "f") from Table IIA, and calculate the difference between them. Measure the distance between these two wavelengths on any of the five spectra in Figure IIA. Enter this information in Table IIB.

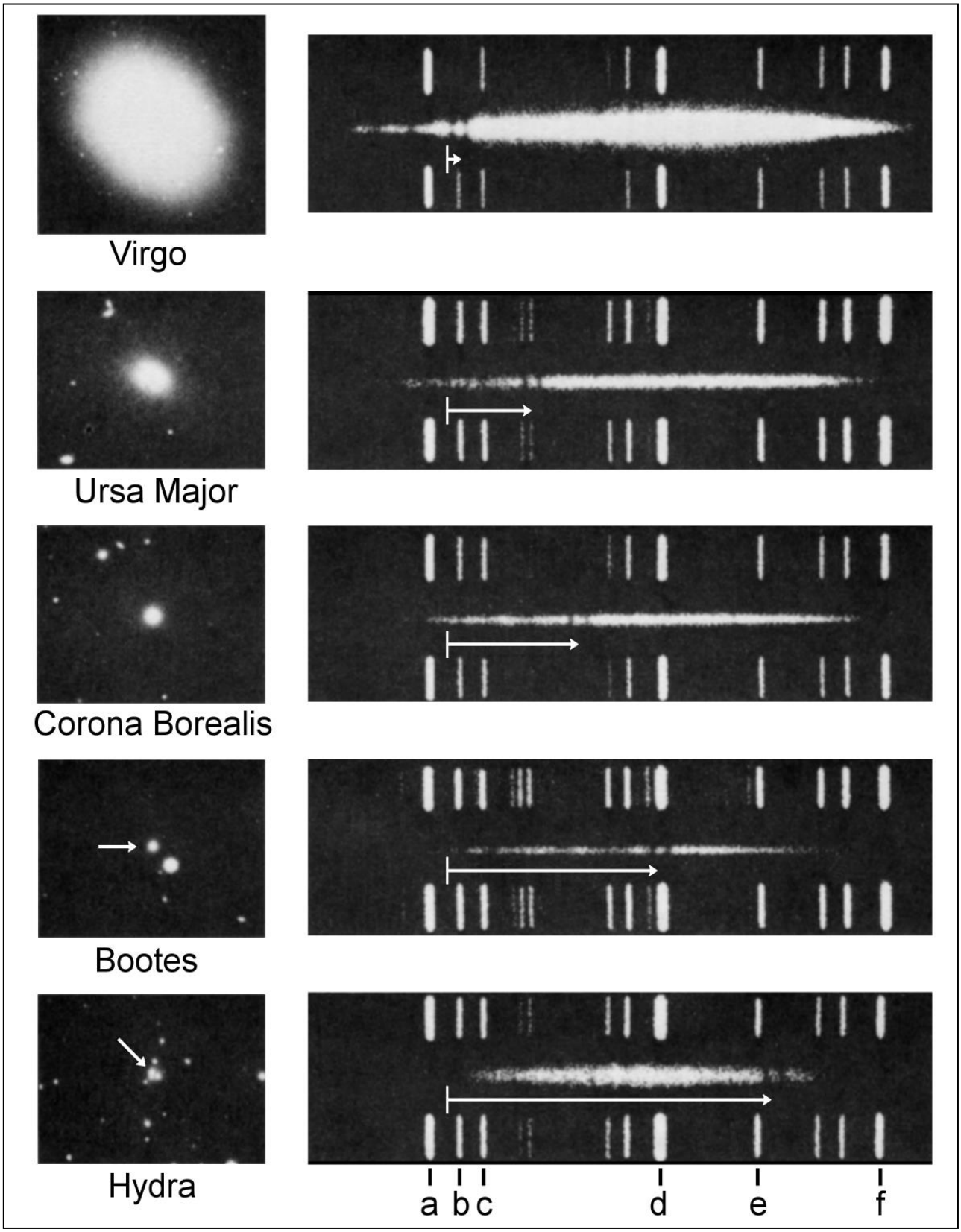
2. From the reference data, determine the spectral image scale (aka "dispersion") for the five spectra, and enter this in Table IIB.

TABLE IIB: DETERMINING SPECTRAL IMAGE SCALE

λ_1 (nm)	λ_2 (nm)	$\lambda_2 - \lambda_1$ (nm)	Image distance (mm)	Dispersion (nm/mm)

3. Measure the length of the horizontal arrow in each spectrum in Figure IIA. This is the spectral shift for the average of the two calcium spectral lines. Record the data in Table IIC.

FIGURE IIA: GALACTIC REDSHIFTS



4. Use the spectral dispersion to convert the spectral shift to actual wavelength changes; record the data in Table IIC.

5. Using Equation 2 (from the first page of Part I), convert the wavelength shifts into recessional velocities for Table IIC, then use your best fit value of Hubble's Constant (Table IB) to estimate the distance to each galaxy.

TABLE IIC: CALCULATING GALACTIC REDSHIFTS AND DISTANCES

λ_o = average of the two calcium lines = _____				
Galaxy	**Shift (mm)**	**$\Delta\lambda$ (nm)**	**v (km/s)**	**r (Mpc)**
Virgo				
Ursa Major				
Corona Borealis				
Boötes				
Hydra				

QUESTIONS

1. 1 Gyr (gigayear) = 3.15×10^{16} seconds, and 1 Mpc = 3.086×10^{19} km. Using these factors, calculate the age of the Universe as given by 1/H. Make sure your answer is in Gyr.

2. The galaxies in Figure IIA are all believed to be the same size, and their photographs are all printed at the same image scale. Inspect the photographs—is there anything about them that supports or contradicts your distance estimates?

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