

## Lab 13. CLEA Hubble Redshift

### Equipment

- Computer; CLEA Software

### Mini Lecture prior to Lab & General Procedure

- Put Hubble's discovery into the historical perspective – the existence of galaxies outside our own had just been discovered a couple of years ago.
- If students did not do the pre-lab, please make them do it before they start with the main lab. The need to know about Doppler Shifts & Redshift.
- Remind the students about stellar spectra, particularly of late-type stars. Most normal galaxies (excluding starburst galaxies and active galaxies) will therefore show the H and K Lines.
- Maybe go over how difficult it is to measure distances in Astronomy

### Procedure and Lab Setup

- Part I is very easy and should take no longer than 10 minutes. The purpose of is to put this exercise into context, and to let the students know a little more about clusters of galaxies and the various assumptions and problems in this area of research. Although the redshifts can be measured relatively accurately, the problem lies in the distance determination (and local motions and...)
- By now the students should have a good idea of how to use the CLEA programs and they should be able to collect the data relatively quickly.
- There are some challenges in Part III since the students have to calculate redshifts, distances, and the Hubble constant. It is all explained step by step, but the students will need to read the (dreaded) instructions... The algebra is pretty easy, but arithmetic slips tend to be rather common.

### Notes & Suggestions

- It is absolutely fascinating to have the students discover the expansion of the universe in a 100 level lab, and the students get only marginally excited if this is (specifically!) pointed out to them.
- This exercise can be shortened by having the students only observe ONE galaxy per field (i.e., determine  $H_0$  from 5 data points), however they often end up collecting data of 5 galaxies in one field – and that results in rather strange values of  $H_0$ .

### General Concepts & What students might get out of this Lab

- That it is relatively straightforward to discover the expansion of the universe and the origin of the Big Bang Theory in a two-hour student laboratory.
- A sense of how Hubble himself may have discovered the expansion of the universe
- Some feeling of the uncertainties that go into determining  $H_0$ .

### Scientific Methodologies

- Using Graphs to present data in Tables
- Thinking about the meaning of certain arithmetic operations – in this case understanding the real meaning of  $H_0$ , which was determined by dividing two quantities (i.e., velocity by distance), and finding that this is a constant number.
- Determining some type of subjective estimate of an error by “looking” at a graph and calculating the worst possible slopes that still fit the data