A Hubble Law & Large Scale Structure Lab for Astronomy 101 Classes: Background and Summary

The WorldWide Telescope Ambassadors and faculty and staff at Bucknell University have developed a hybrid lab involving both hands-on and virtual activities that focuses on the concepts of the Hubble Law, expansion of the universe, and large scale structure. This lab, designed for non-science undergraduates in an introductory astronomy class, combines investigation with tactile models in a laboratory environment with analysis of real astronomical data, and detailed visualization using virtual environment software. Students are therefore able to both explore the universe on its largest scales and develop physical intuition for its geometry and dynamics.

Why make a lab about the Hubble Law & large scale structure?

The Hubble Law may well be the most important astronomical discovery of the twentieth century on both philosophical and practical grounds. It banished forever the idea of a static, timeless universe, and instead established it as an evolving and changing structure. As a distance measuring tool, the Hubble Law enabled cosmic cartography on the largest scales, allowing us to chart the frothy distribution of galaxies. In the lab environment, students can investigate these concepts with hands-on models and computer visualizations in a guided inquiry process.

Why use WWT?

The WorldWide Telescope (WWT) visualization software is an ideal platform for widely-usable and engaging labs because it is a free resource available to any school or any member of the public, with the potential to reach an ever-broadening and diverse audience, including populations that are traditionally underserved in STEM education. WWT represents real astronomical data in a three-dimensional environment that students can investigate from a variety of physical perspectives. They can virtually "fly through" astronomical structures and thus use the same techniques they use in their local everyday environment to develop an accurate mental model on an astronomical scale.

In this lab, students use WWT data retrieval capability to access real astronomical spectra of galaxies and analyze these data to determine the redshift and distance to each galaxy. Using the pseudo-3D multi-perspective capability of WWT, students compare their results with large galaxy redshift surveys, and examine the distribution of galaxies over 1000 Mpc size scales.

Where does this lab fit into an Astro 101 course?

This lab fits best when classroom discussion turns to the large scale distribution of galaxies in the universe. The analysis of spectra to extract galaxy redshift presumes some basic knowledge of the Doppler Effect, so it would be best if students were exposed to this concept prior to this lab.

What is included in this lab?

This lab begins with an examination of the distance and velocity data Edwin Hubble used to construct his famous law. Students fit a straight line through these data in Excel, and determine a value for the Hubble constant. They then examine a more modern dataset, and consider why and how the measured value of the Hubble constant has changed throughout the twentieth century.

Students then turn to a desktop model for an expanding universe – a large Slinky spring. They mark the positions of galaxies in their one-dimensional universe using paper clips, and then examine how these "galaxies" move relative to one another as their universe expands. They learn that the Hubble Law is a property of the expansion, and use the Hubble constant to determine the age of their Slinky universe.

The next phase of the lab involves a WWT "tour" in which students learn how astronomers have charted the universe using the Hubble Law. They then use WWT to retrieve galaxy spectra from the Sloan Digital Sky Survey (SDSS) for further analysis. They determine the redshift and distance from several galaxy spectra (using an included Microsoft Excel spreadsheet), and compare their dataset with much larger redshift surveys from the professional astronomical community.

The lab closes with a WWT "tour" that details our current knowledge of the distribution of galaxies in the universe, and allows students to explore this environment.

At Bucknell University, where this lab was developed, students complete a pre-lab reading and an online reading quiz before coming to lab, and a post-lab quiz before leaving lab. This lab is structured for a three-hour lab section, but suggestions have been included for modularizing and shortening the activities (see instructor notes).

This distribution contains the following files:

*Hubble Law Lab Background and Summary.pdf (*this document)
Hubble Law Pre-lab reading and quiz.docx (Bucknell version in editable format)
Hubble Lab Writeup for Students.docx (Bucknell version in editable format)

Hubble's Data.xlsx (Microsoft Excel spreadsheet containing galaxy position and velocity data*)*
*GalaxyRedshiftCalculator.xlsx (*Microsoft Excel spreadsheet for calculating redshifts from SDSS galaxy spectra*)*
Hubble Law WWT Tour Part 1.wtt
Hubble Law WWT Tour Part 2.wwt
Hubble Law Post-lab quiz.docx (Bucknell version in editable format)
Hubble Law Lab Instructor Notes.pdf