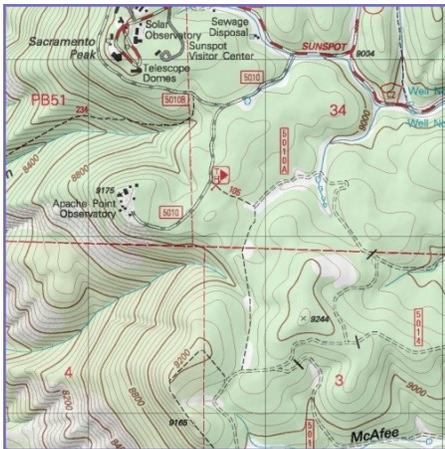


# SDSS Mapping the Universe in Three Dimensions - Your Piece of the Sloan Digital Sky

The Sloan Digital Sky Survey is now entering its 4<sup>th</sup> generation of mapping the night sky in three dimensions. Why do scientists care so much about mapping the universe? How DO you map objects in space, and what does this aluminum plate with all the holes in it have to do with it? With your own piece of the SDSS survey in your possession, keep reading and exploring to discover what modern astrophysics and engineering are doing to uncover the secrets of the universe from here on Earth.

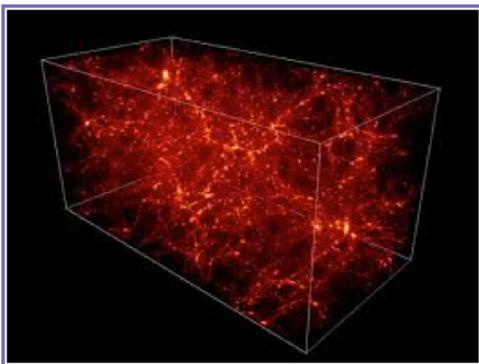
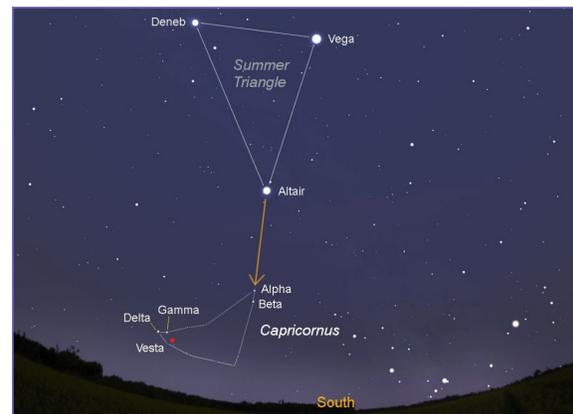
## A Different Kind of Map

Our familiar understanding of a map, whether we use a phone, GPS unit, or a large paper version that is impossible to fold into its original compact form, is as a tool for getting from point A to point B. It tells us what lies in between points A and B and sometimes describes the terrain, but if we want to get a sense of the land elevations and geographic features, we need more information. This information is found on a topographic map.



In order to describe the additional dimension of elevation on a two-dimensional surface, we need elevation information at many points. Points of equal elevation are connected to one another; these connections create contour lines that reveal information from which geologists can see the geography of an area and infer its geologic history.

The same types of maps exist in astronomy. If you want to know where in the sky to point a telescope, a two-dimensional view is all you need. If, however, you want to know where objects are actually placed in three-dimensional space, you need to collect distance information, and then you need to devise a way to display that information.



## Making a Three-Dimensional Map of Space

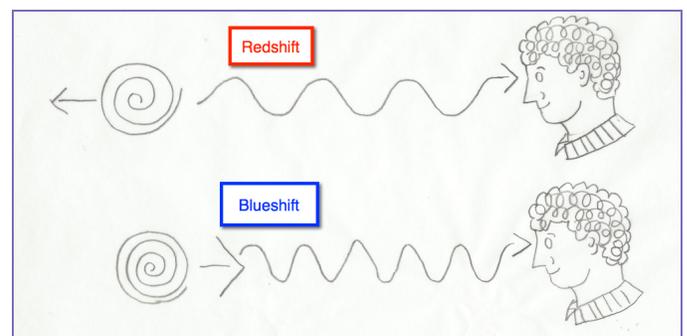
In the same way that cartographers measure elevation information to create a topographic map on Earth, astronomers need distance information to stars and galaxies to make three-dimensional maps of space. The Sloan Digital Sky Survey (SDSS) is concerned with a specific kind of map, one that reaches out beyond our Milky Way to the large-scale structure of the universe itself. For this we need a long distance measuring tool called **redshift**.

### Redshift

If you have ever stood by the side of the road as a car passed by, you have an idea of what redshift is. As the car moves toward you, its engine sounds higher-pitched than the engine of a stationary car. As the car moves away from you, its engine sounds lower-pitched than the engine of a stationary car. The reason for this change is the Doppler effect, named for its discoverer, Austrian physicist Christian Doppler. As the car moves toward you, the sound waves that carry the sound of its engine are pushed together. As the car moves away from you, these sound waves are stretched out.



The same effect happens with light waves. If an object moves toward us, the light waves it gives off appear shorter, so the light will become bluer. If an object moves away from us, the light waves appear stretched out, becoming redder. The degree of "redshift" or "blueshift" is directly related to the object's speed in the direction we are looking.



### From Redshift to Distance



Milton Humason

Almost one hundred years ago, astronomers Edwin Hubble and Milton Humason gathered the observational data they needed to establish the relationship between distance and redshift.

Their work revealed that the further away a galaxy, the greater its observed redshift. Once we were able to describe this relationship using mathematics, astronomers could calculate the distance to any object with a known redshift. Now, with

our new distance-estimating tool in hand, we now consider how galaxies are distributed in space.



Edwin Hubble (second from left, center) with the

## Measuring Redshift on a Massive Scale

The first step in building these 3D maps of the cosmos was to take detailed color images of about 1/4 of the night sky, as visible from the Earth. The first generation of the SDSS (SDSS-I) achieved this between 2000-2005, using one of the largest and most powerful digital cameras at the time, which was designed and built exclusively for the survey. This camera is now located in the Smithsonian Air & Space museum.

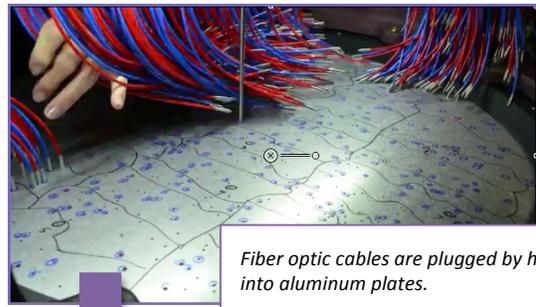
As a result of the SDSS-I's imaging, we now have a composite color image of the sky that contains about 200 million galaxies. Targets for the spectroscopic study are chosen from these images.

Astronomers and engineers took advantage of this extremely accurate sky map when they designed a spectroscope that allowed them to capture light from not one but one thousand stars and galaxies at a time. The aluminum plate you've received has 1000 holes, each drilled to match the position of a star or galaxy in the 2D image. When the plate is installed on the back end of the telescope, an individual fiber optic cable attaches to each of these holes and guides the light from individual objects to the spectrograph. In this way the SDSS-III can obtain spectra for 1000 objects in only 45 minutes! Multiple plates can be used each night. This makes for a busy crew of people plugging fibers into holes!

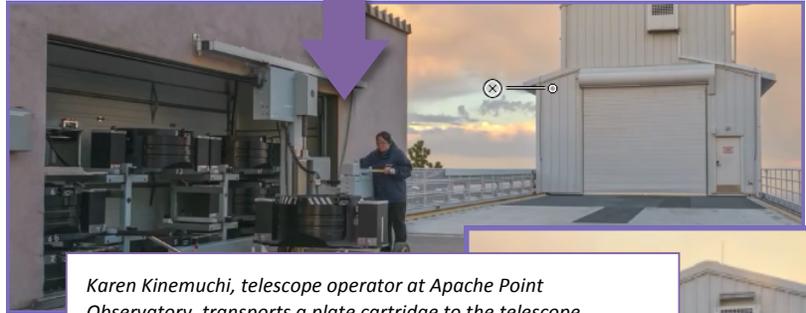
The primary aim of the SDSS-III BOSS survey is to map the locations of distant galaxies, so about 90% of the fibers are placed on objects that look like distant galaxies in the imaging. The remaining holes are drilled to match the positions of ordinary stars and blank parts of the sky. Measurements from these positions are used make adjustments to the system to ensure accuracy when less well-understood targets are chosen.

With redshift information calculated for each spectroscopic target, astronomers are now able to place objects in three dimensions and look for patterns in the distribution of galaxies, galaxy clusters, and mysterious objects called quasars. To learn more about quasars and the data astronomers recorded about your piece of the SDSS sky, go to the Voyages website at

[voyages.sdss.org](http://voyages.sdss.org).



Fiber optic cables are plugged by hand into aluminum plates.



Karen Kinemuchi, telescope operator at Apache Point Observatory, transports a plate cartridge to the telescope.



Karen Kinemuchi loads the cartridge containing the aluminum plate and fiber optic cables into the spectrograph that is attached to the back end of the