Evidence #1: Scientists expect that the scientific principles we use on and around Earth also work elsewhere in the Universe. Observations of phenomena around the Universe show that this is true.

One example of how scientific principles work everywhere in the Universe is looking at spectra. In a lab, we see that different elements each give off a unique pattern of light, or spectra. These spectra can be used to identify unknown substances. For example, Figure 1 shows the spectra created by helium and neon.

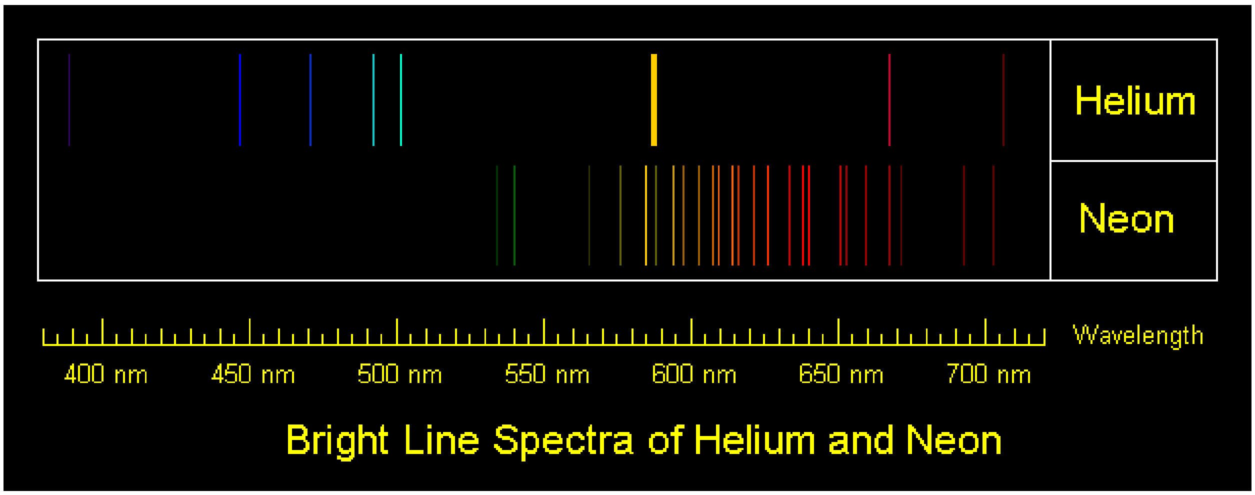


Figure 1. Spectra given off by helium and neon
(http://www.mtholyoke.edu/~mpeterso/classes/phys301/projects/mktrias/spectrum.html)

We can see these same patterns of lines when we look at stars and galaxies. This means that helium and neon are present in those objects as well. Scientists use the spectra of the objects they observe to determine what the objects are made of.

Evidence #2: Stars convert light elements into heavier ones inside their cores. When stars die, the heavier elements are sent outward into space. These elements then become part of new stars and planets. The oldest stars contain mostly lighter elements. Younger stars contain larger amounts of heavier elements.

A star has nuclear fusion at its core. The strong gravitational forces inside the core causes lighter elements to combine to form heavier elements. When stars die, elements are released into space and the elements become part of the next generations of stars. These stars also fuse elements inside their cores. Over several cycles stars make even heavier elements. As part of this process, the oldest stars contain mostly lighter elements. Younger stars contain larger amounts of heavier elements. Because there are more older stars than younger ones, there will be a greater abundance of lighter elements in the Universe compared to heavier elements. Figure 1 shows how much of each type of element is present in the Universe.

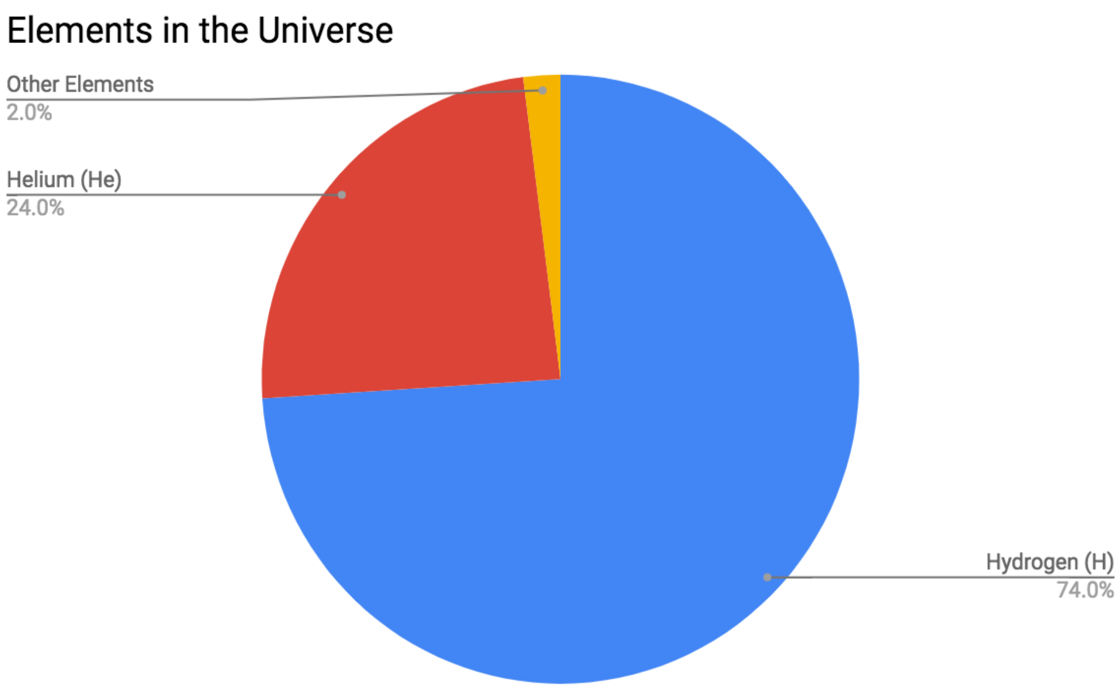


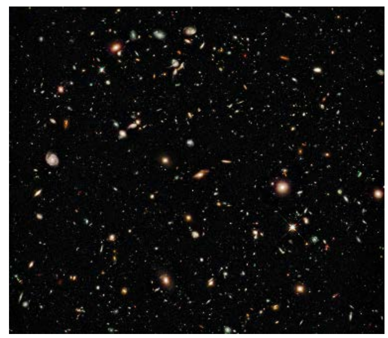
Figure 1. The composition of the Universe by element. (Figure by Scott; data from http://periodictable.com/Properties/A/UniverseAbundance.html)

Evidence #3: On average we observe about the same distribution of galaxies in any area of space. We would also make this observation from different galaxies elsewhere in space.

Images have been taken of random areas of the night sky past the stars. The figures below were taken by the Hubble Space Telescope. We can see galaxies in these pictures. When comparing the images, the number of galaxies in each image is about the same. This means that no matter which direction outward from our own galaxy you look, the Universe contains an evenly distributed number of galaxies.

Hubble Deep Field South in infrared

Hubble Ultra Deep Field in infrared (2004)



Hubble Ultra Deep Field in infrared (2009)

Figure 1. Three deep field images taken at different times and at different areas of the sky. The objects in the photographs are galaxies. (http://www.spacetelescope.org/science/deep_fields/)

Evidence #4: Astronomers observe a uniform glow in the background of the sky no matter where we look.

Astronomers have observed a background noise, or glow, everywhere in the sky. It does not appear to come from a single source like a star or a galaxy. The glow is strongest in the microwave region of the electromagnetic spectrum. Microwaves are a form of invisible light. Figure 1 shows measurements of this background, indicated by red crosses.

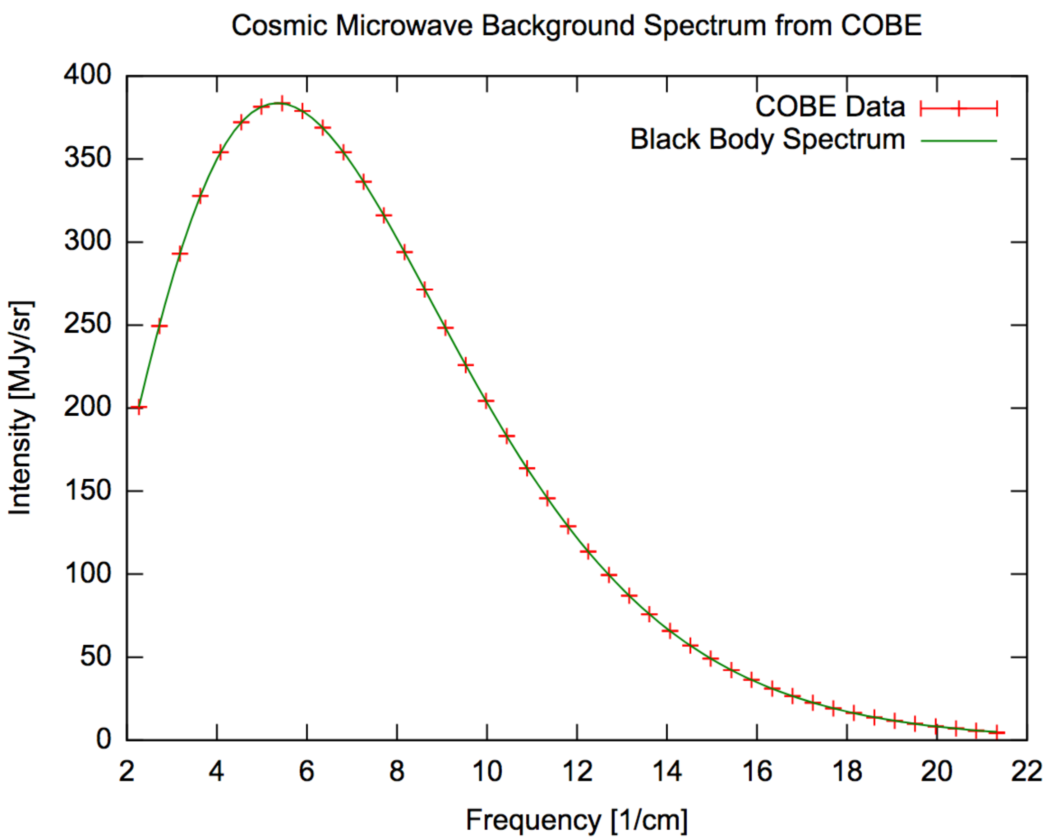


Figure 1. A graph of the intensity of the cosmic microwave background versus frequency. (Credit: Quantum Doughnut / Wikimedia Commons)

The green line in the figure is a model of what astronomers predicted if the Universe were hotter, denser, and smaller than it is today. Scientists, using the data and model, calculate that the average temperature of the Universe is about 2.7 Kelvin.

Evidence #5: All galaxies are moving through space. Galaxies that are farther from Earth are moving faster than galaxies closer to Earth. Most galaxies are moving away from each other.

Astronomers have measured the movement of galaxies by looking at their spectra. Most of them appear to move away from Earth. Only a handful of very close galaxies appear to be moving toward Earth. Edwin Hubble first noticed that there is a relationship between how far away a galaxy is and how fast it is moving. Figure 1 shows this relationship, now called Hubble's Law.

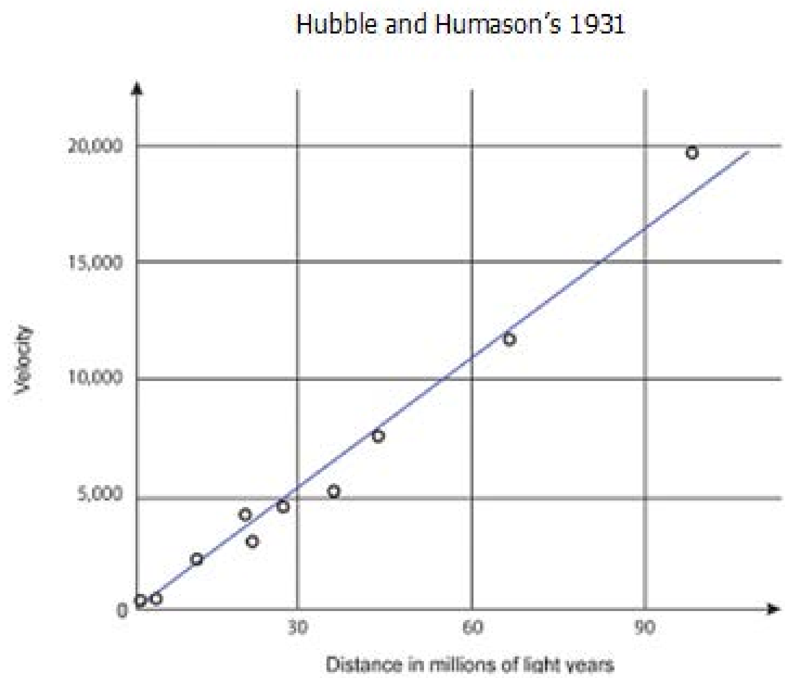


Figure 1. Circles in the figure represent galaxies, with their distance plotted on the x-axis and their velocity on the y-axis. (Figure from *The Big Ideas in Cosmology* based on original data by Hubble and Humason)

Evidence #6: The light of most galaxies appears more red than it really is. This means most galaxies are moving away from Earth.

All galaxies give off light, which can be analyzed by looking at spectra. Spectra are created when you take light and break it up into its component parts. Different chemicals give off distinct spectra--each one is unique, much like a person's fingerprints. The top picture in Figure 1 shows the visible light spectrum for iron.

Figure 1. Iron gives off this spectrum when it is at rest (top) and moving away from us (bottom). (Figure from *The Big Ideas in Cosmology*)

As a galaxy moves through space, the light in the spectrum is shifted to appear more blue or more red. Figure 1 (bottom) shows iron's spectrum redshifted. The black lines, caused by the absorption of light, are now farther into the red portion of the spectrum than they were. This is the same idea as how sound seems to shift in pitch as a source (such as a train or a car honking its horn) passes by you. For light, blueshifts occur if the galaxy is moving toward Earth, while redshifts occur if the galaxy is moving away from Earth. The greater the shift of the lines, the faster the galaxy is moving.

Evidence #7: The Universe has a predictable age based on its rate of expansion. Nothing in the Universe is older than that age.

Astronomers have observed that almost all galaxies are moving away from each other. This means there is no central point of space special to the Universe and that the Universe is expanding. Figure 1 shows how astronomers have modeled the expansion of Universe over time. These models suggest that the he early Universe was much smaller and hotter than it is now. In the future, these models suggest it will be larger and cooler.

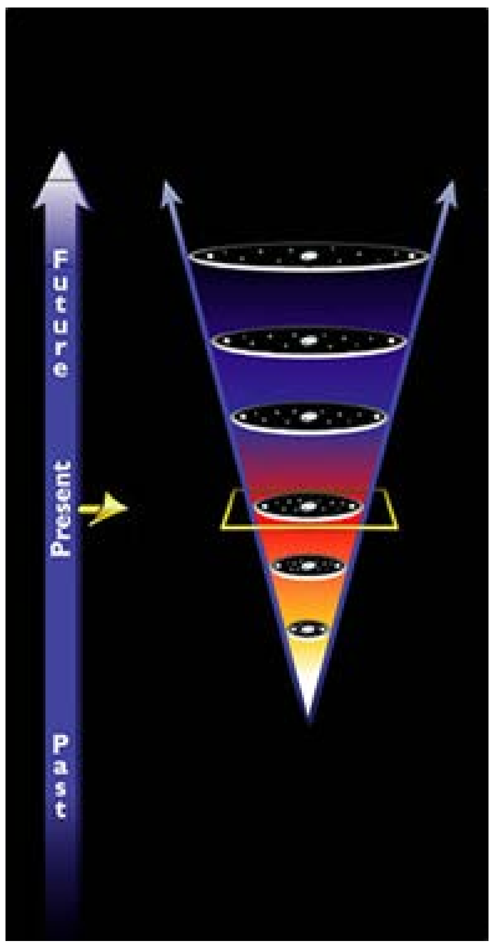


Figure 1. The Universe at different times in the past and the future (adapted from *The Cosmic Perspective*)

Evidence #8: The Universe was once extremely hot and allowed for matter and energy to spontaneously convert back and forth into each other. Today, the Universe is far cooler than it once was.

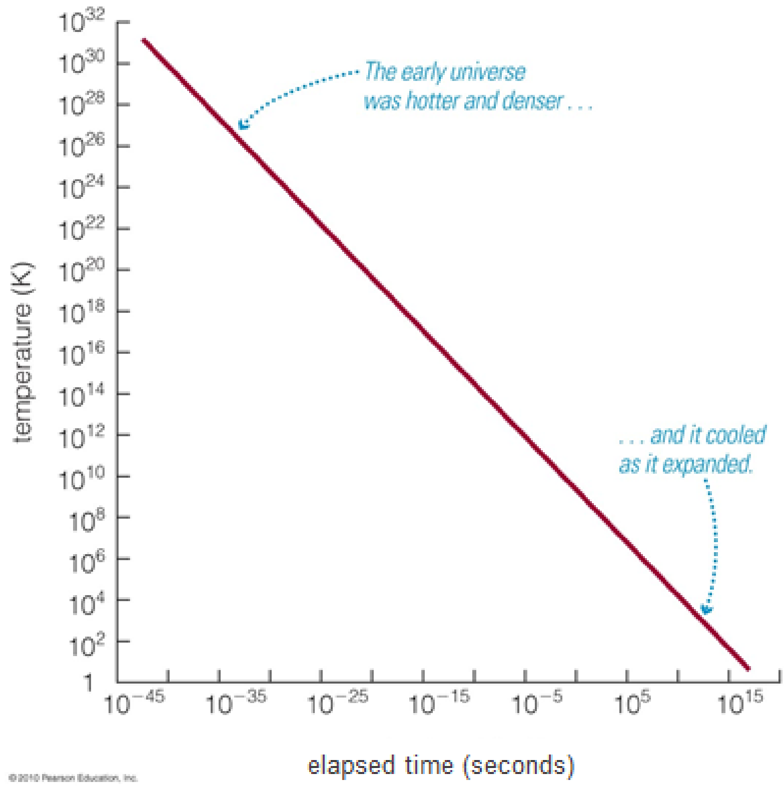


Figure 1. Graph showing temperature (in Kelvin) of the Universe vs. the time elapsed (in seconds) after the origin of the Universe. (Source: http://linus.highpoint.edu/~mdewitt/phy1050/images/week8/temperature-history-of-universe.jpg)

When high densities of matter or energy are exposed to extremely high temperatures, they can convert between one another. These conditions existed during the beginning of the Universe. Not long after, the conditions changed. The Universe expanded and cooled and became less dense as well. Figure 1 shows the temperature of the Universe over time, with the present at the far right.