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 unique patterns 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.

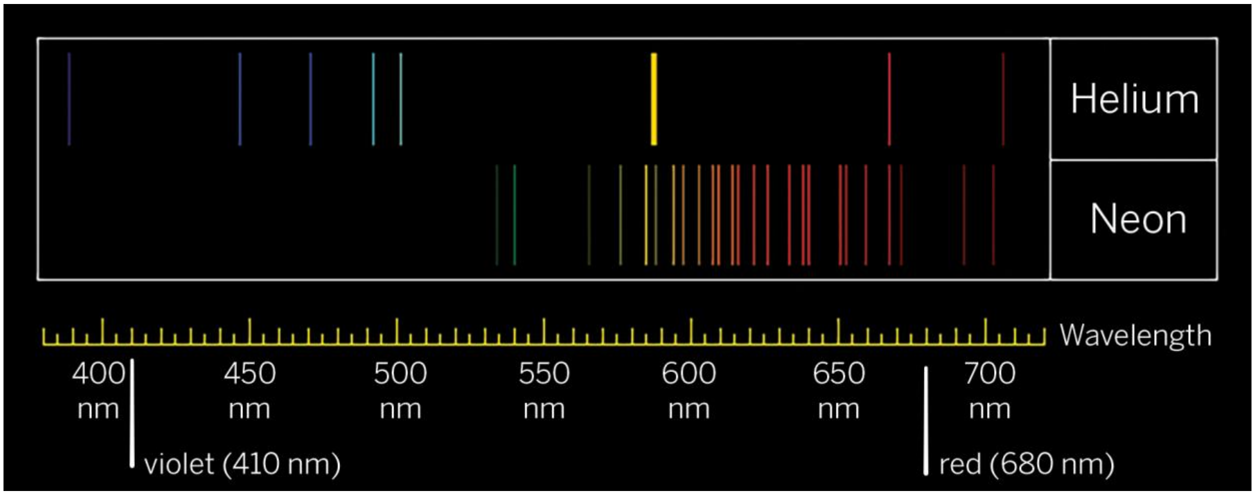

Figure 1. Spectra given off by helium and neon. Credit: Wright Seneres

Scientists use the spectra of the objects they observe to determine what the objects are made of. If we see the same pattern as helium when we look at an object in space, we would know that the object contains helium. This is because the scientific principles about how spectra are created work everywhere in the Universe.

Evidence #2: Models of the Universe predict how much we should see of the lightest elements. Our observations of hydrogen, helium, and other light elements match these predictions.

Early in the Universe, elements formed as atoms collided in nuclear fusion reactions. This created the lightest elements, mostly hydrogen and helium. A few other elements were created as well. Figure 1 shows how much of each type of element is present in the Universe.

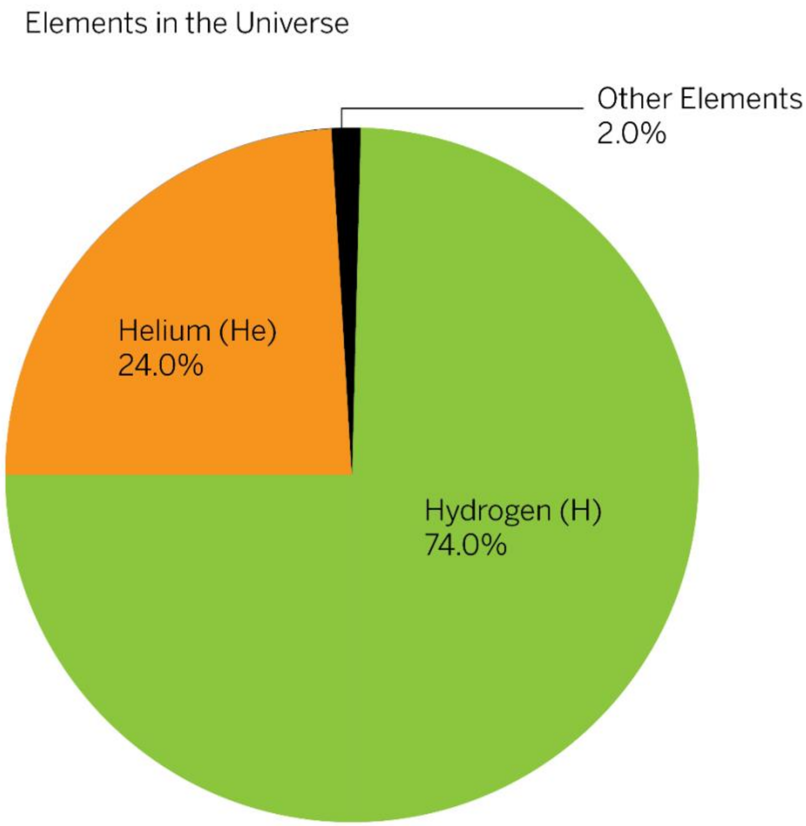

Figure 1. The percentages of elements in the Universe today. Credit: Wright Seneres

The amount of each element shown in Figure 1 matches predictions made by scientists who make models of the early Universe and how it changed over time.

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

Images have been taken of many areas of the night sky. We see galaxies and empty spaces in all of these. Computer models made by scientists show the same kinds of patterns. This is true whether the models are made from Earth's perspective or imagining we were someplace else in the Universe. When comparing the models and observations, the number and pattern of galaxies in each image is about the same (Figure 1). This average distribution of matter would not occur if there is a central point to the Universe, like you would see in an explosion.

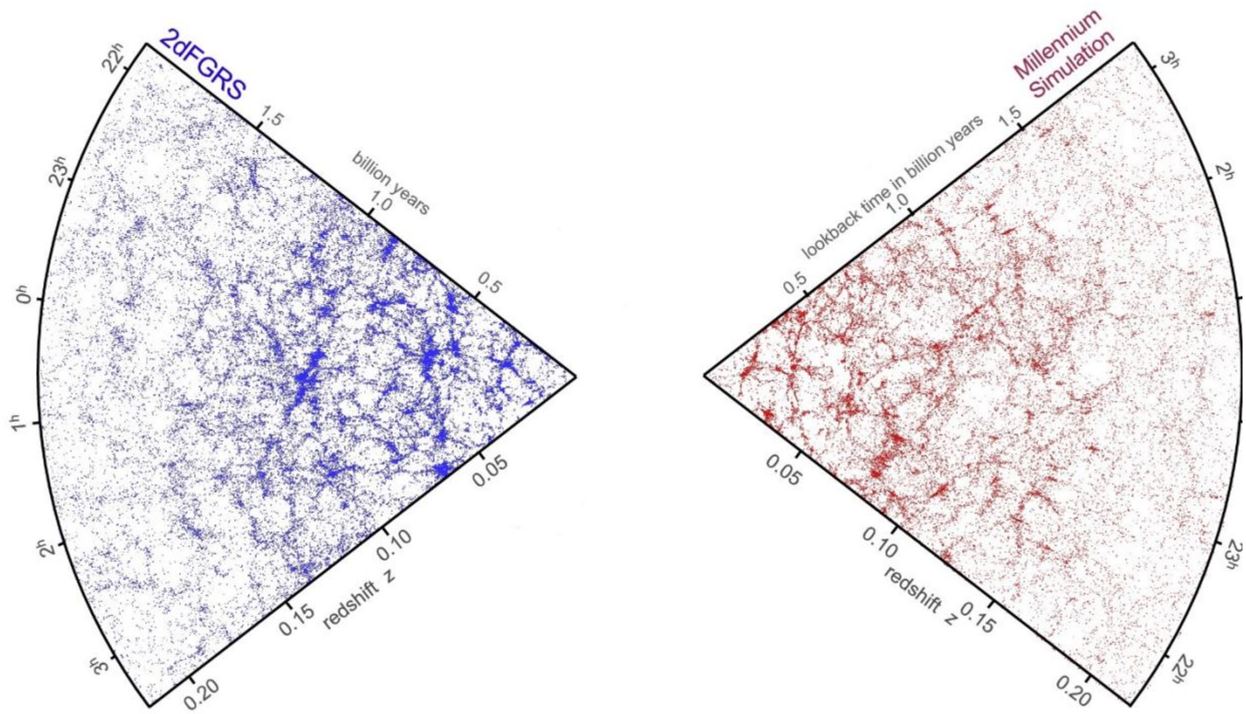

Figure 1. A comparison of observed data (left) and a simulation (right) of a slice of the night sky. Each dot represents a galaxy. Although the panels are not identical, they show the same type of patterns. Credit: Volker Springel, Max-Planck-Institute for Astrophysics; used with permission.

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

Astronomers have observed a background 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 is a 360-degree view of the sky—in other words, it covers all areas of the sky. The left panel of Figure 1 shows that the background is essentially the same no matter where in the sky you look. The color differences in the right panel are due to very small variations in temperature (less than 0.0001 K).

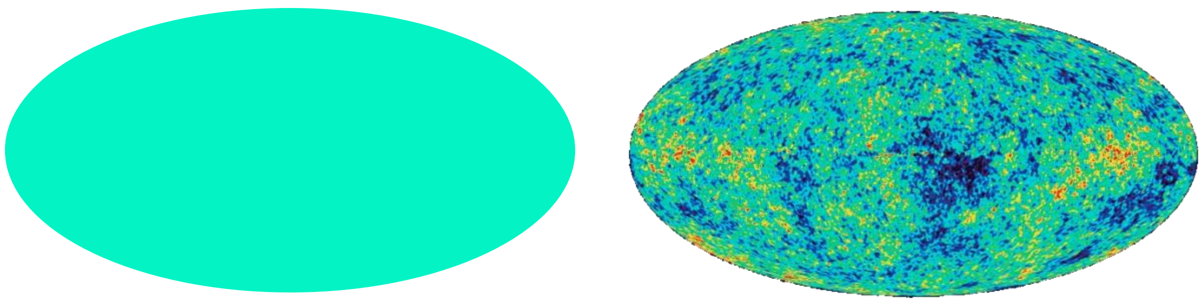

Figure 1. On the left is the background glow of the sky. The uniform color is because the temperature is about the same everywhere. On the right, the same view of the sky shows very small temperature variations by exaggerating the colors. Here, blue spots are about 0.0001 K cooler than the red spots. Credit: NASA/Goddard/WMAP Science Team

Evidence #5: Observations of the sky's background glow match predictions from models very well. This data tells us that the temperature of the Universe is about 2.7 K.

The uniform glow visible everywhere in the Universe is called the cosmic microwave background radiation (CMB). Figure 1 shows the spectrum of the CMB. It shows intensity versus frequency of light. The shape of the spectral curve (the green line) is called a blackbody. It is a model of what astronomers predicted if the Universe were hotter and denser than it is today. The red crosses are data from a satellite instrument called COBE. The data and model match extremely well. Scientists, using the data and model, calculate that the average temperature of the Universe is 2.725 Kelvin. The model comes from the earliest time period in the Universe. The model also tells us that the temperature of this blackbody would be higher in more recent times. An explosion of matter would not match the blackbody model.

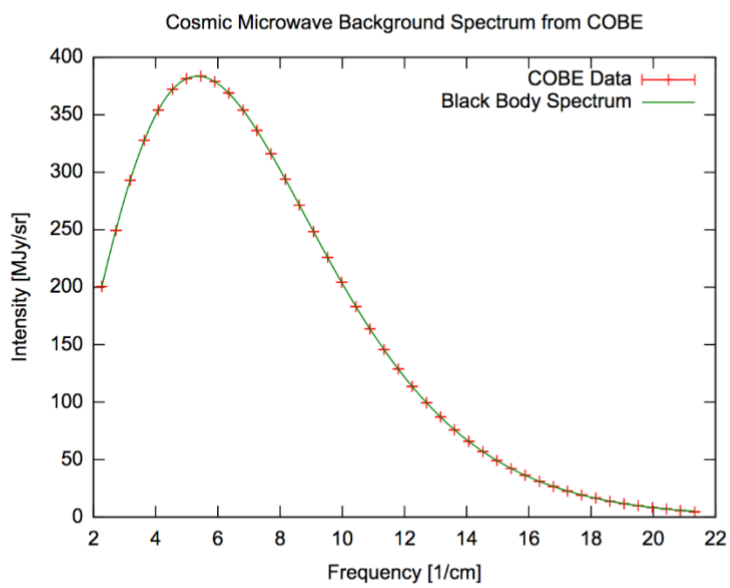

Figure 1. A graph of the intensity of the cosmic microwave background versus frequency. Credit: Wright Seneres

Evidence #6: All galaxies are moving with space. Galaxies that are farther from Earth are moving faster than galaxies closer to Earth. Most galaxies are moving away from each other.

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. The top picture in Figure 1 shows the visible light spectrum given off by iron.

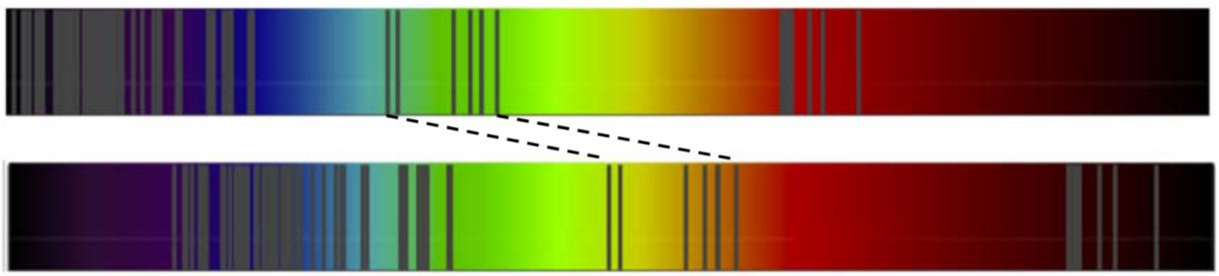

Figure 1. Iron gives off this spectrum when it is at rest (top) and moving away from us (bottom). The dashed lines connect the same line in each spectrum. Credit: Wright Seneres

As a galaxy moves with 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. This happens because space is stretching over time, carrying the galaxies with it.

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

Scientists model the expansion of the Universe over time. If we run the model backwards (similar to watching a movie in reverse), there was a time when everything was closer together. We call this time the age of the Universe. Table 1 shows how the age of the Universe compares to the age of some objects and events within it.

Table 1. Ages of objects and events in the Universe.

Object	**Age**
Universe	13.8 billion years
Oldest galaxy: GN-z11	13.4 billion years
Milky Way Galaxy	About 13 billion years
Oldest globular star clusters	12-13 billion years
Sun	4.6 billion years
Earth	4.54 billion years
Single-celled life appeared	About 3.5 billion years
Jurassic Period started	201 million years
Jurassic Period ended	145 million years
Homo sapiens appeared	300,000 years

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.

The early Universe was extremely hot and dense. In these conditions, matter (like protons) and energy (like photons) can change back and forth very easily. Over time, the conditions changed enough that this couldn't happen anymore. 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 of the graph.

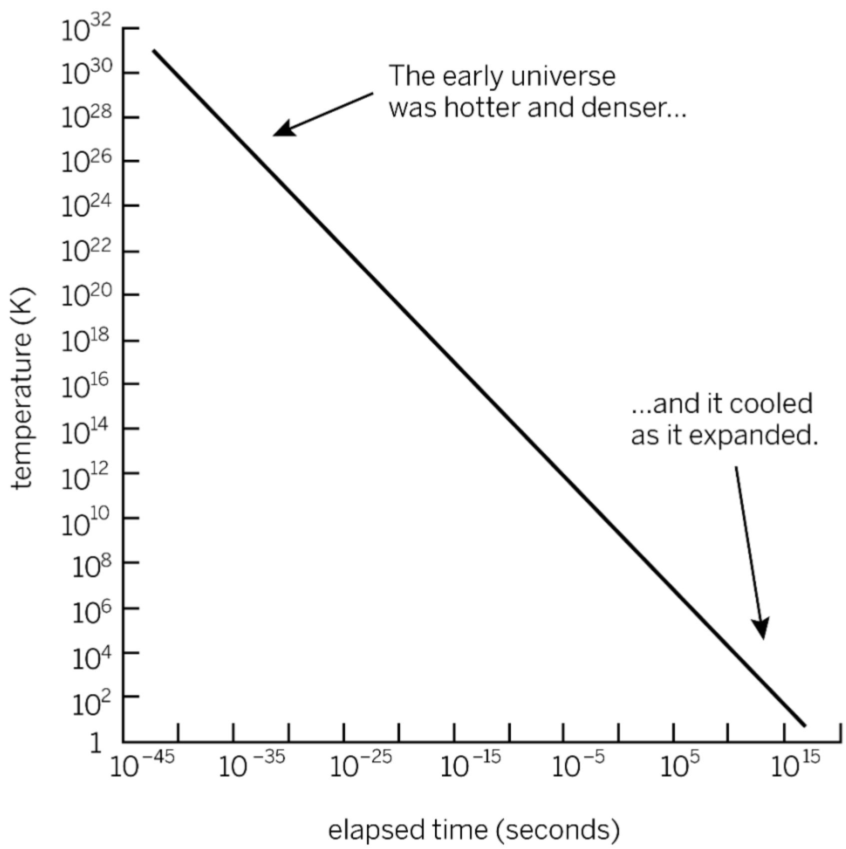

Figure 1. Graph showing temperature (in Kelvin) of the Universe vs. the time elapsed (in seconds) after the origin of the Universe. Credit: Wright Seneres