# *Application:*   The Size of the Observable Universe

In 1929, the astronomer Edwin Hubble announced an important discovery. He had observed that all stars, galaxies, nebulae visible from Earth were receding, that is, they were moving away from the Earth. He also noticed that those objects that were the farthest away were moving the most rapidly. Most importantly, he saw that the speed of the object was related to its distance from the Earth by a simple relation,

$$v = kd$$

(v for velocity, d for distance, and k, a constant). What was the explanation? Is the Earth the center of the universe? Why is everything is moving away from *us*?

The simplest explanation (and the scientists look, usually, for the simplest explanation) is that the universe is expanding. Imagine a balloon being inflated. In your imagination, draw some ×'s on the balloon.
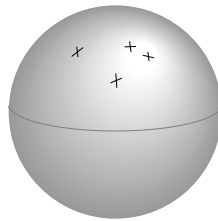
Then as the balloon grows, the distance between any pair of ×'s increases.
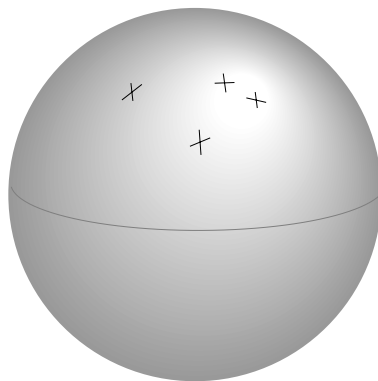
In other words, in an expanding universe, all distances are increasing. Not only that, they're increasing proportionally. The rate of recession is proportional to the distance.

We can write Hubble's formula as a differential equation:

$$d' = kd.$$

The constant k is usually written H_0 now, in honor of Hubble, and the value of H_0 is an important astronomical number.

$$d' = H_0 d.$$

Laboratory: The Size of the Observable Universe

We ask you to estimate the size of the observable universe. All you need are the following facts:

1. Objects d megaparsecs from the Earth are moving away from the Earth at a speed of $d' = H_0 d$ kilometers per second.

2. Objects that are moving away from us at faster than the speed of light are not observable.

Express your answer in terms of H_0, the Hubble constant, and c, the speed of light.

For your interest: Hubble's constant is somewhere between 50 and 100 kilometers per second per megaparsec; a megaparsec is approximately 3.26 million lightyears; a lightyear is the distance travelled by light in a year; and the speed of light is approximately 300 thousand kilometers per second.