**Create a Universe![[1]](#footnote-1)**

That galaxies appear to be moving away from us at faster and faster speeds the further out we look is a sign that our universe is expanding. It's not that there was some explosion in space that sent galaxies flying away from us; instead, space itself is expanding, carrying all galaxies away from one another. Observesr in any galaxy would see every other galaxy rushing away from them; it's not that we are at the center of the expansion (and in fact, there is no center of the expansion).

If we measure the expansion rate of the Universe, we can explore the past and future. If we "run the clock backwards" space gets smaller and smaller until you have gone back so far in time that space occupies an infinitesimally small point -- this is the time of the Big Bang, the beginning of the universe. When did this happen? If we knew the expansion history of the Universe, we could solve for the universe's age.

Three factors control the expansion of the Universe:

* the current expansion rate, known as the Hubble Constant, H0
* the amount of mass in the universe, measured by a parameter called OmegaM (M for mass)
* the acceleration factor of the universe, measured by OmegaL (L for lambda)

If we can determine these three parameters, we can solve for the age of the Universe, as well as determine its ultimate outcome. Will it expand forever? Will it ultimately recollapse?

The Hubble Constant H0, relates the distance of galaxies (d) to their apparent speed of recession (v).

v=H0 x d

Current measurements of the Hubble Constant suggest that the expansion rate of space is about 67.8 km s-1 Mpc-1.

The gravitational mass of the Universe is the next important factor. Mass alters the expansion of the Universe through its gravitational effect on space. If there is enough mass in the Universe, gravity can slow down or even halt the expansion, and perhaps cause the Universe to recollapse on itself. We define a "critical density" -- the density of mass which is just sufficient to halt the expansion. We then define the mass density of the universe by a term called OmegaM, which is the density of the universe divided by the critical density:

OmegaM = density/densityCritical

Most current theoretical models of the universe predict that the universe should have Omega = 1. If OmegaM = 1, the Universe has just enough mass to halt the expansion. If OmegaM < 1, the Universe has insufficient mass and would keep expanding. If OmegaM > 1, the Universe has more mass and will actually recollapse on itself.

A basic constraint on all cosmological models is that the Universe should not be younger than the objects in the universe. For example, in our galaxy we estimate that the globular clusters have an age of 13 billion years (Gyr). This means that a cosmology which gives a universe age of 9 Gyr won't work. We can reject some cosmology models based on this simple observation.

Observations of Type Ia supernovae in distant galaxies indicate the Universe is not only expanding, but that its expansion is accelerating with time, as if the Universe is dominated by “anti-gravity.”

Since the Universe is accelerating, the expansion history and future evolution will be different. For example, an OmegaM > 1 universe can keep expanding forever, if the acceleration can overcome the gravitational collapse. An accelerating universe also implies an older universe, since it was expanding more slowly in the past.

The acceleration factor is termed OmegaL (L for “lambda”) and is defined in such a way that it can be compared to the density parameter OmegaM.

So given our three parameters, H0, OmegaM, and OmegaL, we can solve for the expansion age and future fate of the universe. If we know these three cosmological parameters, we can determine the age of the universe at any given redshift we observe. Or, since we also can calculate the current age of the universe, we can solve for the "lookback time" -- ie how far back in time we are looking.

Using the browser, load the “Cosmo Applet” at <http://burro.cwru.edu/JavaLab/>. We will investigate several possible models of the universe.

* **Case 1**: This universe contains an amount of mass just equal to the critical density, and is not accelerating. Start by entering the three parameters Ho=68, OmegaM=1, OmegaL=0 as “Case 1,” select “plot age” with the pull-down menu, and click trace to plot the age of the Universe as a function of redshift.

*What does this model predict the current age of the Universe to be; ie, how old is this universe at a redshift z=0?*

* **Case 2**: This universe contains too little mass, but is also not expanding. Current estimates of OmegaM suggest that the mass density of the Universe is only 31% of the critical density (OmegaM = 0.31). Enter a Hubble constant to Ho=67.8, with OmegaM=0.3, and OmegaL still equal to 00 as Case 1.

*What does this model give for the age of the Universe?*

*Why does the age of the Universe change when the amount of mass is reduced to only 31% of the critical density?*

* **Case 3**: Now add some acceleration to the universe! How much acceleration is needed to get a universe of the right age? With H0=67.8 and OmegaM=0.3, adjust the value of OmegaL to obtain a model that matches the observed age of the Universe, 13.8 Gyr.

*What value of OmegaL is needed for Case 3 to reach an age of 13.9 billion years?*

*From the plot of the size of the Universe, what is the future fate of the Universe in Case 3?*

* **Case 4**: Explore different values of H0, OmegaM, and OmegaL. Can you devise a universe model that will recollapse at an age of 20 Gyr? What are the values of these three parameters in this case?

H0 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

OmegaM = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

OmegaL -

1. Adapted from a lab by Chris Mihos. [↑](#footnote-ref-1)