The Big Bang

We tend to envision space as emptiness, as the void between objects. We tend to think of time as the empty moments between events, moving slowly but certainly in one direction for all of us, as the future becomes the present becomes the past. We tend to think of matter as the physical stuff of the universe, and energy is what makes that stuff move. All of these beliefs are in some respect inaccurate.

Matter and energy seem to be two ways of looking at the same thing. Einstein’s famous equation of E=MC2 is essentially a mathematical statement that provides the conversion formula from energy to mass and back. Energy is the ability to use work to move masses, but masses are also sources of energy. By converting energy into masses, the universe has built every element from hydrogen to ununoctium. By converting mass into energy, mankind has found an energy source that can power a city, or obliterate it.

Space and time, similarly, seem to be the obverse sides of a single coin. The two properties of the universe that seem the most unchangeable from our Earthly perspective are in fact quite variable. As matter moves through space, events for that matter occur less frequently when compared to the rest of the universe. Essentially, as matter moves faster, time slows for it.

But the problem here is that if time and space change based on the movement of matter, which depends on energy, then in a very real sense time and space and matter and energy are all really just the same thing. Which is really weird, because based on our modern lives, they all seem very separate. But the science that led to the modern engineering feats such as cellphones and the internet are based on an understanding that they are not truly different. Our perceptions evolved in a world and on a level where we can reasonably treat time and space as fixed, unchanging quantities, where matter and energy are separate things. But even on our scale of existence, there is good evidence that the universe was not always this way.

Our universe began not with a whimper, but with a bang. A little less than 14 BYA, all the matter, and space, and time, and energy was all found in a single point. From what we can tell, all space was compressed to a single point, sometimes called a singularity. Since space was a single point, all energy and matter were also compressed into that single point, and since time depends on energy and space, to talk about time also becomes meaningless. Based on the same scientific understanding that lets your cellphone work, we cannot really even talk about what that singularity was like. Words like heat and light and mass and distance and time all become meaningless. We can only talk about what came after the moment of the Big Bang.

At the moment of the Big Bang, space occurred, and rapidly began expanding. This effect is known as inflation. As the distance between things increased, the ability to move between those points became important, and the general heat of the universe converted in many cases to form matter. In a sense, as matter started changing positions, time began to exist in a real way. Also, since matter could change position, it became possible to discuss energy in the way we are used to. There are many ideas of how or why this happened, but since we know that time doesn’t mean anything at the time, we can only talk about the aftermath.

Once time started to happen, and space also, the universe began expanding. As this happened, energy got converted into matter: primarily the basic parts of the universe. Of these, the first bits of modern matter to cohere were protons and electrons. The expansion accelerated, and then slowed, until things had cooled off enough that the attraction between the positively charged protons and negatively charged electrons was sufficient to bring them together: the first hydrogen atoms had been born. The early universe was mostly made up of this simple element, with about 24.9 % made of helium, and a tiny fraction of matter made up of lithium.

These early atoms then were drawn together into large clouds of gas: these were the first nebula. These nebula then collapsed further to form the earliest stars. Many of those early stars were huge, resulting from accumulations of unimaginably large amounts of hydrogen gas. Unlike our star, these massive conglomerations of primordial matter used up their fuel within millions of years rather than billions, only to collapse and erupt into supernova. As this occurred, heavier elements like carbon, oxygen and iron were blasted out to form new, heavier nebula, made not only of gases, but now of dust: tiny lumps of congealed matter, almost like an early version of powdery sand.

By now, gravity had been doing its work even over vast distances. Stars continued to form as the new dusty nebulae were drawn together by gravity, but also now clusters of stars began to accumulate into larger groups: these were the first galaxies. Unlike later galaxies, these earliest assemblies of hundreds upon thousands of stars were simple clouds, almost irregular globs of stars pulled into irregular spheres by the shared gravitational force.

As millions of years became billions, many of these galaxies were then drawn together by gravity, spinning around their shared center of gravity in order to merge together. As they spun, like a pirouetting ice skater, they flattened into disc galaxies, and some flung their arms out to form spiral galaxies.

As the cycle of stellar birth, growth and death continued, the early matter of the universe was used to generate a new class of heavier elements that would go on to form something near and dear to our hearts: solar systems.

Before we conclude, though, there is an important question to resolve: how on Earth do we know all this? Well, the usual answer is that it is complicated, and for many elements of the story of the Universe’s birth, it is genuinely too complicated to explain right now. There is, however, one element that is relatively easy to explain: we know a lot about what the early universe looked like, because we can see it. We know for a fact that light takes time to travel. It may travel very fast, but it must still move from point a to point b. What this means is, when we see something, we are looking at the past.

In our everyday life, this doesn’t matter, because we are seeing something basically at the same time it happens. In astronomy, though, the distance involved is so substantial that the difference in time also becomes substantial. With our best telescopes, we can gather and focus light that is from so far ago that it is also from billions of years ago. To look into deep space is to look into old space…and old space is filled with massive stars and globular galaxies. To look at nearby space is to see more recently evolved structures…spiral galaxies like the Milky Way, and smaller stars with more complex and rocky solar systems, like our own. Speaking of which, we need to discuss how stars live and die before we can move on to our own home system…

Use this text to create definitions for the following terms.

1. Big Bang
2. Inflation
3. Nebula

Write a response to the following questions that will be graded by CARs rubric.

1. Explain how it is possible to know what the early universe was like.