12. The Universe
(and everything else)

Draft of 4/20/05

Puzzles:

The Universe is expanding. Into what?

All galaxies are getting further away from our own. Doesn't that mean that we are at the center of the Universe?

The Universe was created about 14 billion years ago. How could we know that? And if it is true, what came before that?

To answer these questions, you first need to know some facts about the "Universe." Many of these were discovered only recently.

By the words "The Universe" we mean everything physical, all the places that we can see, probe, or somehow learn about. It is space, as far as we can see, and everything in it. Cosmology refers to the study of these very large scale things.

The Universe is made of atoms, stars, and bunches of stars known as "galaxies." To understand the answers to the above questions, we begin with understanding the solar system.

The Solar System

By the "solar system" we mean all those objects that are attached to the Sun through gravity. That includes the planets, asteroids, comets, and other things that we haven't discovered yet (such as the hypothetical companion star, dimly lurking at a distance of one light-year).

We believe that the solar system was formed about 4.5 billion years ago from interstellar debris, the ashes of a blown up star. That makes the sun a "secondary" star. The reason that we think it is secondary is that primary stars don't contain heavy elements like lead and uranium, but the Sun does. These heavy elements are created only when stars explode as supernovas.

So here is what we think. 4.5 billion year ago a region of space was filled with the ashes of an exploded star. These ashes started to attract each other through gravity, and they started to form a clump. Apparently the ashes had a little bit of spin to them, because when the material gathered together, it started spinning faster (just as an ice skater does when she pulls in her arms – see Chapter 3). Because the matter was spinning, it splayed itself out into a disk. The big mass at the center became the sun. The smaller masses out in the disk did not fall in, because of their circular motion. They clumped into planets and asteroids.

The sun was so large, that the center became compressed and hot, and that ignited thermonuclear fusion. The planets were too small, so their cores never reached that temperature. But the early planets were molten. They emitted infrared radiation, and eventually a crust formed. Some planets completely solidified. Not the Earth – its core is still molten.

Even though the material of the solar system is mostly hydrogen and helium, those gases were lost from the early Earth because of their high velocity (see Chapter 2). Only hydrogen combined with other elements (to make water, hydrocarbons, etc.) remained.

Light from the Sun takes about 8 minutes to travel the 93 million miles (150 million km) to the Earth. We say that the distance to the Sun is 8 light-minutes. The nearest known start to the Sun is the Alpha Centauri – Proxima Centauri double star system. These stars are about 4.3 light-years away. The light-year is not a unit of time, but of distance. It is the distance that light travels in a year. Stars are, typically, separated by light-years.

Nemesis

Most stars, when they form, form in pairs or triplets, like in the Alpha Centauri-Proxima Centauri system. Most people believe the Sun is an exception, a lone star, with only planets to keep it company.

In 1984, two colleagues (Marc Davis and Piet Hut) and I published a theory that postulates that there is another star orbiting the Sun. We playfully gave it the name Nemesis. Strictly speaking, the Sun and Nemesis are orbiting each other. The reason it hasn't been noticed is that Nemesis is about a light-year away.

The Nemesis theory was devised to account for paleontolgical evidence that great extinctions occurred every 26 million years. The orbit of Nemesis is elliptical, and when it comes close to the Oort comet cloud every 26 million years, it triggers a comet storm. The comet storm brings a few billion comets into the inner solar system. The Earth is small, so the changes that it will be hit by any one comet are one in a billion. But with several billion comets coming in, there are likely to be several hits. For more details, see my Nemesis web page: www.muller.lbl.gov/pages/lbl-nem.htm

Planets around other stars

We once speculated that the solar system is unique, but now we know that most stars have planets orbiting around them. Most of the known extrasolar planets were discovered by Geof Marcy, a Berkeley Professor. His website is www.physics.sfsu.edu/~gmarcy.

These star planets are dim, but we could probably see them in telescopes if they were't so close to bright stars. They were discovered by their effects on the stars they orbit. They make these stars wobble, and we can detect that by observing small changes in the frequencies of their spectral lines as the velocity of the star oscillates. (That's the Doppler shift.)

Galaxies

On a clear winter night, look straight up. If you are in a sufficiently dark place you may be able to see a small fuzzy spot, no larger in angular size than the Moon, that looks like a tiny scrap of the Milky Way that was torn off. But it is much further away than the Milky Way. In fact, the nebulous spot is the most distant object that you can see with your unaided eye. A lot more detail can be seen in a long exposure taken with a telescope, such as the one shown below.[1]

[1] from http://antwrp.gsfc.nasa.gov/apod/ap021021.html. Copyright Robert Gendler.

It was Edwin Hubble (after whom the Hubble Space Telescope was named) who discovered that this fuzzy spot actually consists of more than a billion individual stars, forming a flat circular plate, all spiraling around each other in a gravitational whirlpool that we now call a "galaxy." The one above is called the "Andromeda Galaxy."

The Milky Way is also a galaxy. It doesn't look like the picture above only because we are inside it looking out. The milky path could can see across the sky (best seen in summer) is actually the light from millions of stars that you see when you look out towards the edge of the plate. When you look straight up or down, you see out through only a thin layer of stars. But everything you see, every star, is part of the Milky Way – except for that fuzzy patch.

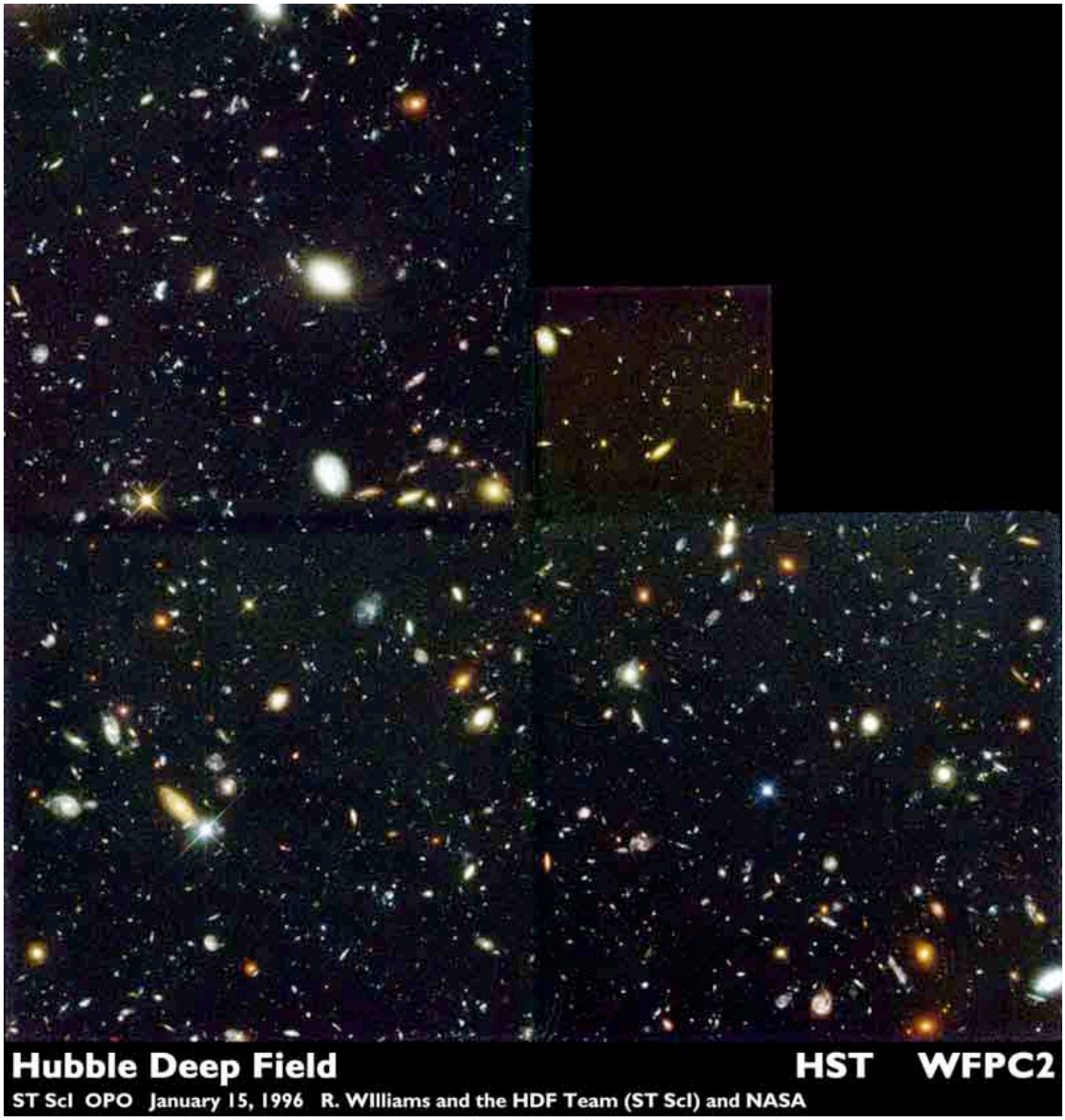
The Andromeda and Milky Way galaxies are like solar systems. They are held together by their own gravity, but they don't collapse because the stars in them are moving in circles. The velocity of the Earth in the Milky Way galaxy is about a million miles per hour. We don't particularly notice, since nearly stars are orbiting our galaxy along with us.

other galaxies

Look at the photo of the Andromeda Galaxy again. There is a small fuzzy patch just below and to the right of the center; that is another, but smaller, companion galaxy. You can also see a lot of bright points – those are stars. But those stars are not part of the Andromeda galaxy. Stars in Andromeda are too far away to be seen in this image. The

stars that you see are nearby, in our own Milky Way. Although they look like background stars, that's an optical illusion based on your experience that stars are always in the background. They are really in the foreground.

There are many more galaxies then Andromeda, its companion, and the Milky Way. Examine the following photograph, made of a combination of images taken by the Hubble Space Telescope. It looks like it is full of stars, and in some sense it is. But most of the bright spots that you see are not individual stars. They are galaxies, spinning clumps of a billion stars each. The Hubble team has counted over 1500 galaxies in this image. Some of them are four billion times dimmer than can be seen with the unaided human eye.



This image was taken by the Hubble space telescope. The composite image took 10-days expose. The picture was taken in the direction of the Big Dipper. That region was chosen since there were not very many foreground stars to obscure the distant galaxies.

The image covers only a tiny part of the sky, about as much as would be covered by a dime that is 75 feet away. Although it is a small part of the sky, we believe that it is typical. Based on this image, we can estimate[2] that the total number of such galaxies that are visible to such an instrument is about 40 billion. That means that there are more galaxies in the Universe than there are stars within our own Milky Way. These galaxies fill up the observable Universe, although there is a lot of empty space in between.

Dark Matter

Our star is moving around the Milky Way galaxy, held in by the gravitational attraction of the other stars. But here is a serious problem: if we estimate the number of stars, and the mass of each one, and add them all together, there is NOT enough mass to hold the sun. Yet we can determine that we are in a circular orbit. What is holding us in?

The guess is that there is some kind of object that has all that mass, but doesn't glow like stars, and so we don't see it. The material is called "dark matter." Look up this term on the web, and you'll find a million hits.

Moreover, if we look at clusters of galaxies, those that are swirling around each other, we find again that there is not enough mass unless we postulate a huge amount of dark matter – more than exists in all the stars of the galaxy.

Think about that for a moment. The startling conclusion is that most of the mass of the Unvierse is in Dark Matter. And we don't know what dark matter is. Put even more dramatically, we have not figured out what the Universe is made out of!

There are two serious candidates for dark matter. These are:

WIMPs

WIMPs stands for weakling-interacting massive particles. These are ghost-like particles like neutrinos that pass through the Earth and stars without hitting anything. The reason is that they have no electric and no nuclear "charge", and they feel only the weak interaction (that's where the W comes from) and gravity. They are "massive" (not zero rest mass) so that their gravitational pull can be important. If WIMPs exist, they are everywhere, and sensitive detectors to find them are being built at laboratories around the

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[2] A dime has an area of about 2.6 square centimeters. At a distance of 75 feet = 23 meters, a sphere would have a surface area of 65 million square centimeters, so it would take about 25 million dimes to obscure our view. If each had 1500 galaxies covered by each dime, the total number would be $25 \times 10^6 \times 1500 = 38 \times 10^9 \approx 40 \times 10^9$.

world. Physics Professor Bernard Sadoulet of Berkeley is one of the world leaders in this search. WIMPs could exist, but maybe they don't.

MACHOs

MACHOs are MAssive Compact Halo Objects. These may be large planets, black holes, or other massive but compact objects. The H is in there because these objects must fill up the galactic "halo", a region that extends above and below the galactic disk. Some experiments have detected MACHOs by looking at their effects in blocking star light. But so far nobody has found enough of them to account for the dark matter.

MACHOs and WIMPs form the cutest acronym pair in all of physics.

Extraterrestrial Life and Drake's Equation

In 1971, Frank Drake tried to estimate the number of planets in our galaxy that would have intelligent life trying to communicate with us. To do this, he wrote down an equation that has subsequently become famous, and is now called "Drake's Equation." Look it up on the web. The equation is:

$$N = N^* f_p n_e f_l f_i f_c f_L$$

N* is the number of stars in the galaxy, probably about 10^{10}. $f_p \approx 0.5$ is the fraction that have planets. You'll see that it won't matter that we don't know this number very well, ne is the fraction of the planets that can sustain life; f_l is the fraction of these in which life evolves, f_i is the fraction of these in which intelligent life evolves, fc is fraction that choose to communicate, and f_L is the fraction that survive to the right time to be communicating to us right now.

Put it all together, and N will be the number of civilizations in planets around other stars whose signals we should be able to pick up.

Put in some reasonable numbers, and do the calculation yourself. On one web page they suggest the values $n_e = 1$, $f_l = 0.5$, $f_i = 0.2$, and $f_L = 10^{-6}$. That gives N = 1000. So we expect 1000 stars out there to have planets sending us signals!

Belief in the Drake equation has been the inspiration for SETI, the "Search for Extra-Terrestrial Intelligence". Look up SETI on the web. You'll learn that you can participate, by doing some analysis on your home computer through the SETI at Home program. (Their website is http://setiathome.ssl.berkeley.edu/.)

I remain skeptical of the use of the Drake Equation. Suppose fl = 10^{-9}, instead of 0.5. Then there would be no extraterrestrial signals. Some SETI advocates argue that fl, the probability of life evolving on a suitable planet, must be very high, since it happened so

quickly here on Earth. But that is a weak argument for this important number. After all, if life hadn't developed quickly on Earth, we wouldn't be here thinking about such problems.

We really don't understand how life began on Earth. Simple organic molecules such as amino acids (the building blocks of proteins) can form accidentally, or be catalyzed by lightning strikes. But we have no idea how complex molecules such as RNA and DNA formed. It is conceivable that the probability of them forming is 10^{-15}. If that's the case, then we would be the only intelligent life in the entire Universe.

A fascinating book skeptical of extraterrestrial intelligence is "Rare Earth" by Peter Ward and Don Brownlee, both of whom are famous and highly esteemed scientists. If you find this subject interesting, you would enjoy that book.

I can't say there isn't intelligent life out there. I just don't believe that the Drake Equation demonstrates that it is probable

Looking back in time

The galaxies in the "Deep Space" photo are so far away, that they light we are observing was emitted about 13 billion years ago. That means that we are not seeing the galaxies the way they are now, but the way they were back then. In fact, careful measurements show that the galaxies are somewhat different from ours, and this can be attributed to the fact that we are seeing them when they were young. They contain fewer of the heavy elements (such as iron) that take time for stars to manufacture. We believe that the galaxies, by now, should have generated enough of these elements, that by now they are similar to the Milky Way and to Andromeda. We think the image shows galaxies the way they used to be, soon after they were created.

This sounds exotic, but you look back in time every time you see the Sun. It took the light about 8 minutes to reach you. You see the Sun the way it looked 8 minutes ago, not the way it looks now. We often measure distances in terms of light travel time, as in the following table. Note that the unit "light-year" measures distance.

Object	**distance**
Moon	1.3 light-seconds
Sun	8 light-minutes
Sirius	8.6 light-years
Andromeda Galaxy	2 million light-years
Hubble "Deep Space" galaxies	13 billion light-years

Expansion of the Universe

There is another difference seen in the image. The galaxies back 13 billion years ago are closer to each other, on average, than they are now. The space between galaxies has been

increasing. This fact is called "the expansion of the Universe" and was discovered by Hubble.

Where is the needed space coming from? There are two possibilities. The first is that the Universe is like a rising (expanding) loaf of raisin bread. As the bread bakes, the whole thing grows, and all the raisins (galaxies) get further apart from each other.

Note that if you are sitting on any raisin, all the other raisins will be getting further away from you. It doesn't matter which raisin you are on.

Hubble's Law

The first indication that the Universe was expanding came when Hubble measured the velocity of galaxies. He found that all distant galaxies were moving away from us, and the further away they were, the faster they receded. His result is now summarized by a formula known as Hubble's Law:

$$v = H\,R$$

If we measure the velocity v in km/sec, and the distance to the galaxy r in kilometers, then Hubble's constant H is approximately 2.3 x10^{-18}. This number is so small only because the Universe is so large. But it has a surprise meaning, as we'll see in the next section.

The beginning

In the past, galaxies were closer together. How close? Hubble's Law tells us that the distance grows with time. Was there a time when the distance was zero? According to Hubble's Law, the answer is yes. A galaxy at distance R moving at velocity v moving away from us, must have been here in the past. To get the time, divide the distance by the velocity:

$$T = \frac{R}{v}$$

Now substitute v from Hubble's Law to get

$$T = \frac{R}{v} = \frac{R}{HR} = \frac{1}{H} = \frac{1}{2.3x10^{-18}}$$
$$= 4.4x10^{17}\,\text{sec}$$
$$= 14x10^{9}\,years$$

This says that 14 billion years ago the distance between all galaxies was zero. Could that be true? We think the answer is *yes*.

Dark Energy

In the Hubble expansion, galaxies are flying apart from each other. No force is needed for this; they are just sailing from their initial velocity. (I haven't told you where this initial velocity came from. Some people attribute it to a quantum fluctuation, but I find that explanation implausible. My answer is simpler: I don't know.

But as they fly apart, they do experience a force of mutual gravitational attraction, and that should slow them down. The dark matter will contribute too.

I started a project at Berkeley to measure this slow down; it was eventually taken over by my former student Saul Perlmutter. The idea was to make a very careful measurement of galaxies at different distances, and look for a change in the Hubble Law as galaxies are decelelerated. We measured distances to galaxies by looking at the brightness of exploding stars (supernovas) in those galaxies, and we measured their velocities by the Doppler shift of their spectral lines.

Under the direction of Perlmutter, the project finally succeeded; it was also successfully done at about the same time by another international group including Alex Fileppenko of the UC Berkeley Astronomy Department. The results were completely shocking. The expansion of the Universe was not slowing down. It was speeding up!

Why is the universe expansion accelerating? Nobody knows, so they did what people do when they don't understand something – they gave it a name, "dark energy." The word energy sounds plausible, because the galaxies are picking up kinetic energy. But it was unexpected.

Some physicists think the effect might be due to quantum mechanics effects. But when they do the calculation, they get an answer that is wrong by a factor of 10^120. This disagreement is thought to be the biggest ever in the history of science.

It is also possible that the dark energy is something simpler, such as the self-repulsion of the vacuum. This is not now part of quantum mechanics (which purports to describe the vacuum) but that may be because measurements of the properties of the vacuum over distances as large as billions of light years never previously existed.

The Big Bang

What was the Universe like 14 billion years ago? It didn't consist of galaxies right on top of each other, because we don't think that galaxies (or even stars) had yet formed. But the mass (hydrogen and helium gases) would have all been right on top of itself, at extremely high density.

This idea sounds ridiculous. The first person who took it seriously was George Gamow (who had been the first person to understand alpha-particle emission in radioactivity). He eventually joined with Alpher and Hermann to analyze what would have happened – if the compressed early Universe really happened.

You can image what it would be like by running the Hubble expansion backwards. Stop the expansion, and let the galaxies all fall into each other. As they fall, they will collide, and their kinetic energy will turn into heat. So the early Universe must have been very hot. And dense.

Gamov realized that these were the conditions that could induce nuclear fusion. And that might answer a mystery: why do most stars consist of 90% hydrogen, 10% helium? (Other elements, such as carbon and oxygen, are much less than 1%).

Gamov's answer: the very early universe consisted of nothing other than protons, electrons, neutrons, and a few other elementary particles. But the conditions were so hot and so dense, that the hydrogen underwent fusion, and created helium. Modern calculations show that this would have happened in the first four minutes of the explosion.

This theory was wild, and other astronomers mocked it. In particular, the famous British astronomer Fred Hoyle (who made some wonderful discoveries himself about how stars worked) called Gamov's theory "The Big Bang". The name stuck.

The 3 K cosmic microwave radiation

Gamov also realized that such a hot early Universe would have emitted visible light. Even after a half million years, the entire Universe would be at the temperature of the Sun (6000 K) and full of matter radiating intensely bright light. When the Universe cooled, electrons and protons would form neutral hydrogen atoms, and the Universe would suddenly become transparent. (Except for a few stars and planets, but they don't fill up much of the sky.)

Radiation emitted from a region 15 billion light years away would just be reaching us now. Because the matter that emitted it was moving away from us at very high speed, it would have its frequency shifted. (That's the Doppler shift again.) The effect would be so large that the light, in our frame of reference would be microwave radiation. So Gamov and collaborators predicted that the Universe would be full of microwave radiation.

That radiation was finally discovered by Penzias and Wilson in 1965. They found the radiation coming from all directions in space, just as the Big Bang Theory predicted. It had a "black body" spectrum corresponding to a temperature of 3 K, again, just as the theory predicted. They were give a Nobel Prize for their discovery. (Gamov had died.)

Starting with this discovery, people took the Big Bang theory seriously. Now we calculate what happened in the first three microseconds of the Big Bang. We postulate that in the very early Universe, even protons didn't exist, only a quark-gluon plasma. Of course, we have no idea if these calculations are true or not, except for the success of the Big Bang theory.

Gravity and Relativity

Einstein's theory of gravity is often called General Relativity. There are several parts of this theory that I would like you to learn:

TWIN AGES. According to relativity theory, the twin at the top of the mountain will be older than the twin at the bottom. If the difference in altitude is h, and the gravitational constant is g = 9.8 (in our standard meters & seconds units), then:

$$A_h = A_0(1 + gh/c^2)$$

Where A_h is the age at height h, and A_0 is the age at height zero. ****
This equation is only approximate. The more exact equation is that the relative age at any distance R from the center of a planet or moon of mass M is given by

$$A_R = A\ G\ M/R$$

where G is the gravitational constant (= 6.7 x10^-8) and A is the age if the object were far from the mass (i.e. at infinity).

Another consquence of relativity theory is that matter is not attracted to an object because it has mass, but because it has energy. Since most of the energy of most objects is due to their mass, the two are almost the same, unless objects are traveling near the velocity c.

Black holes occur when the gravity of a star is so strong, that enormous energy must be used to throw the object off it. But when you give it that much energy, that increases the gravitational attraction, so the energy is not enough. If the object is a black hole, then you can never win: more energy always increase the attraction so much that the object will not leave.

We could turn the sun into a black hole if we squeezed all of its mass into a sphere with radius 3 km (about the size of Berkeley). Such squeezing does take place in a supernova explosion, and we think that the celestial x-ray emitter called "Cygnus X-1" is such a black hole. X-rays are emitted by particles falling into the black hole.

We could turn the earth into a black hole if we squeezed all of its mass into a sphere with radius 1 cm.

We also believe that the center of the Milky Way galaxy contains a black hole, as well as the center of many other galaxies. This is a relatively recent discovery, and we do not yet know how they were formed.

Finite Universe?

In the Theory of Relativity, space is "flexible" in the sense that the distance between two objects depends on the frame of reference. In the General Theory of Relativity, gravity is included by allowing for accelerated reference frames. This winds up making space even more variable.

The most fascinating part of General Relativity is the possibility of curved space. In this section, I am not going to try to explain what this means, but I'll give some examples.

Suppose there were no dark energy, and the mass density of the Universe was fairly high – high enough so that the expansion of the Universe would eventually stop, and turn around, and ultimately result in a big crunch. In that case, the equations of General Relativity predict that the Universe would be finite. It would be finite in the same way that the surface of the Earth is finite. Now here is the amazing analogy: the geometry of the Universe, under those circumstances, would be identical to the geometry of the surface of a four-dimensional sphere. (The surface of that sphere is the three-dimensional space that we are accustomed to.)

That means, that an object moving in a straight line would eventually come back to the same point, just as an object moving on the surface of the Earth would eventually return, after going all the way around the Earth. The Universe curves around, but only in the hidden fourth dimension that we don't see or experience. (If there are four spatial dimensions, then time will be considered the fifth, rather than the fourth dimension.)

This is what we mean when we say that the Universe is finite, but has no boundaries. If you traveled enough, you could visit everywhere. There would be no new places to go. The Universe would be finite. You could even write down the number of cubic meters in the Universe.

Why don't I tell you how many cubic meters? The reason is that the recent evidence shows that the Universe is not finite, but appears to be infinite. The General Theory of Relativity, when you include the dark energy, says that the current Universe goes on forever.

That doesn't mean that the Universe really is infinite, since the General Theory of Relativity may not be valid for really large distances. So maybe some day we'll conclude that the Universe is finite. But, for now, it is infinite.

Here's a philosophical question. Some people are bothered by the thought that the Universe is infinite. Some are bothered by the possibility that it may be finite. Clearly, no matter what the Universe turns out to be, it will bother people.

Before the Big Bang

Many people wonder, what caused the Big Bang? What came before it? Here is a view of the Big Bang that is not shared by all physicists, but is held by many.

The Big Bang, in this view, was not an explosion of matter within space, but it was an explosion of space itself. In the Big Bang, space was created. The galaxies are not really moving; they are staying stationary, but the space between them continues to expand.

Remember, another name for "space" is "the vacuum". An ancient name for it is "the aether." Space is not made of particles; rather, particles are waves in the medium of space. Don't worry if this makes no sense to you. This is the last chapter, and this kind of knowledge is hardly needed by presidents.

In Relativity Theory, space and time are often treated as different dimensions in the "space time continuum." So, if space was created in the Big Bang, maybe time was created too. If so, then the question of "what happened before the Big Bang" makes no sense, because time did not exist. It's like asking, what is shorter than a line of zero length? What happens when molecules go below absolute zero, i.e. what happens when they move slower than no movement at all? These questions cannot be answered because they make no sense. If time didn't exist, then there would be no time before the Big Bang.

If that is true, then we may never be able to answer the question of what caused the Big Bang. The answer may lie outside of our sense of reality.

Theory of Everything

In the newspapers you will sometimes read that somebody has devised a new "theory of everything." There are popular books with the title "The theory of everything." It is worth knowing what physicists mean when they use this term.

First, you should know that physicists once thought that they already had a theory of everything. In the late 1800s, physicists believed that everything could be explained by two fundamental sets of laws: the laws of mechanics, and those of electromagnetism. Mechanics told you how objects behaved when they bounced into each other. The theory of gases had recently been explained by the postulate that gases were just large numbers of molecules bouncing into each other. Although direct evidence for atoms was missing, the "kinetic theory of gases" seemed to account for all behavior. Add to this the theory of electromagnetism: charged particles (such as the electron) have a "field" that surrounds them, and this field affects other particles. The field can even be shaken off if the particle is accelerated, and this gives rise to electromagnetic waves -- which includes both radio waves and light.

It was believed that this was a complete theory. It gave rise to a strong atheistic movement. People said that if you knew the position and velocity of every particle in the universe, these laws would predict exactly where those particles would be in the future. Life and free will was an illusion. We were really just complicated machines.

That version of the theory of everything disturbed a lot of people, but it seemed undeniable. There were a few problems, but these seemed minor. There appeared to be no completely compelling evidence for the existence of atoms. That changed in 1905, when Einstein showed that Brownian motion, the apparently random motion of small particles suspended in water, was actually due to the bombardment of individual atoms hitting the sides of the particle randomly. That convinced most skeptics that atoms really existed. The other problem (and many people at the time didn't realize how serious it was) was a difficulty in explaining the glow of objects that were heated to high temperature. The theory seemed to predict that such objects would emit an infinite amount of radiation, and that was impossible. The surface of objects would cool off with infinite speed, no matter how hot they were.

[There will be a section here – not yet written -- about quantum mechanics, and how it made us lose hope that could predict everything in the future. Present attempts at theories are trying to include a quantum theory of gravity. Superstring theory does this, but we don't know if that theory is correct or not.]

If we do have such a theory (and some people think that super string theories will eventually qualify) then it will be called the "theory of everything." But -- it is quite different from the original theory of everything. This theory makes no pretense of being able to predict the future perfectly, provided we had perfect knowledge of the present. That's because it is a "quantum" theory, so it only predicts probabilities. And it cannot predict things very far into the future because the probabilities compound and grow. The quantum theory of everything still will not be able to predict when any radioactive atom will explode. An atom of potassium-40, the theory says, will probably explode sometime in the next billion years. Beyond that, it cannot say. If the decay of that atom was used to trigger a nuclear explosion, then the theory of everything would only be able to say that such an explosion would occur sometimes in the next billion years. By its very probabilistic formulation, the theory of everything can do no more.

Unlike the original 1880s version, the new theory of everything is not in contradiction with the idea of free will.

Summary

I summarize this chapter in verse.

The Creation

a scientist's myth

At first there is nothing
no earth, no sun
no space, no time
nothing

Time begins
and the vacuum explodes, erupts
from nothing, filled with fire
everywhere
furiously hot and bright

Fast as light, space grows,
and the firestorm grows
weaker. Crystals appear
droplets
of the very first matter. Strange matter
fragile bits
a billionth of the universe
overwhelmed in turbulence
of no importance
they seem
as they wait
for the violence to subside

The universe cools and the crystals shatter
and shatter again,
and again and again
until they can shatter no more. Fragments
electrons, gluons, quarks,
grasp at each other, but are burned back apart
by the blue-white heat, still far too hot
for atoms to endure

Space grows, and the fire diminishes
to white to red to infrared
to darkness.
A million year holocaust has passed.
Particles huddle in the cold and bind themselves
into atoms -- hydrogen, helium, simple atoms
from which all else is made.

Drawn by gravity, the atoms gather
and divide
and form clouds of all sizes
stars and galaxies
of stars, clusters of galaxies. In the voids
there is empty space
for the first time.

In a small star cloud, a clump of cool matter
compresses and heats
and ignites
and once again there is light.

Deep within a star, nuclei
are fuel and food, burning and cooking
for billions of years, fusing
to carbon and oxygen and iron, matter of life
and intelligence, born slowly, buried
trapped
deep within a star

Burned and burdened, a giant star's heart
collapses. Convulses. A flash. In seconds
energy from gravity, thrown out
overheats, explodes, ejects
the shell of the star. Supernova! Growing brighter
than a thousand stars. Still brighter, brighter
than a million stars, a billion stars, brighter
than a galaxy of stars. Cinders of carbon, oxygen, iron
expelled into space
escape
free! They cool and harden
to dust, the ashes of a star
the substance of life

In Milky Way galaxy at the edge of Virgo Cluster
(named five billion years later, for a mother),
the dust divides and gathers and begins to form
a new star. Nearby a smudge of dust begins to form
a planet. The young sun
compresses, and heats
and ignites
and warms the infant earth

by Richard A. Muller

Do future presidents need to know cosmology? For your amusement, here is a quote from A Study in Scarlet, a novel about Sherlock Holmes by Arthur Conan Doyle.

Watson says:
My surprise reached a climax, however, when I found incidentally that he was ignorant of the Copernican Theory and of the composition of the Solar System. That any civilized human being in this nineteenth century should not be aware that the earth travelled round the sun appeared to me to be such an extraordinary fact that I could hardly realize it.

> "You appear to be astonished," he said, smiling at my expression of surprise. "Now that I do know it I shall do my best to forget it."
>
> "To forget it!"
>
> "You see," he explained, "I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. A fool takes in all the lumber of every sort that he comes across, so that the knowledge which might be useful to him gets crowded out, or at best is jumbled up with a lot of other things, so that he has a difficulty in laying his hands upon it. Now the skillful workman is very careful indeed as to what he takes into his brain-attic. He will have nothing but the tools which may help him in doing his work, but of these he has a large assortment, and all in the most perfect order. It is a mistake to think that that little room has elastic walls and can distend to any extent. Depend upon it there comes a time when for every addition of knowledge you forget something that you knew before. It is of the highest importance, therefore, not to have useless facts elbowing out the useful ones."
>
> "But the Solar System!" I protested.
>
> "What the deuce is it to me?" he interrupted impatiently: "you say that we go round the sun. If we went round the moon it would not make a pennyworth of difference to me or to my work."