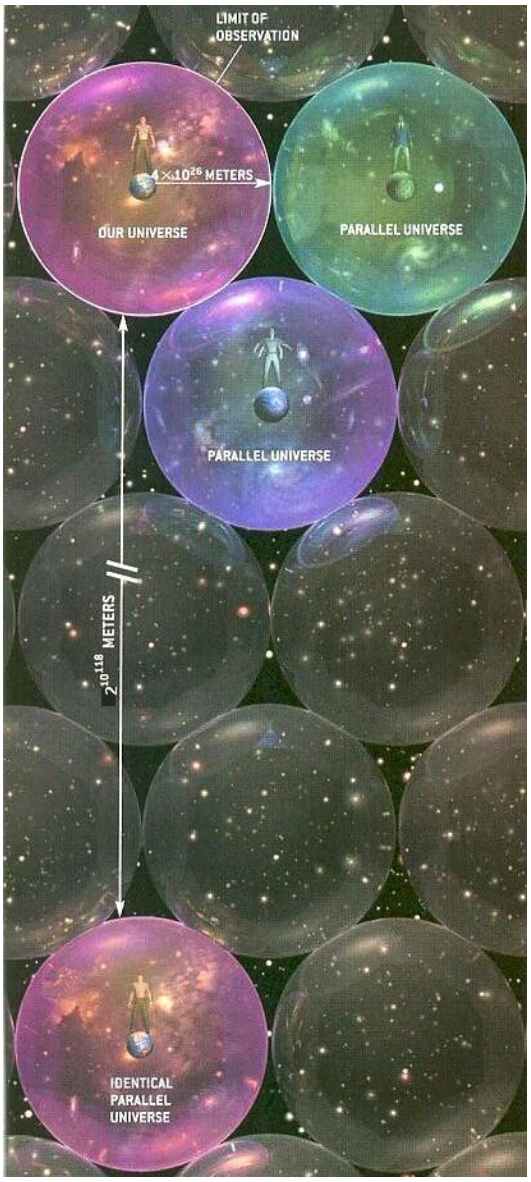
The First Level : Galaxies Far, Far Away

There are four types or "levels" of multiverses, the most basic being a Level 1 Multiverse (ML1). Each individual “universe” in an ML1 is simply a region of space that we can't see, because light from that region hasn’t had time to reach us yet. Our current observational limit is about 42 billion light years, which is the distance light has been able to travel since the Big Bang. The region of space contained within a sphere this big is called a Hubble volume. The entire universe you see when you look up into the night sky is <u>one</u> such Hubble volume.



There have been at least two scientific measurements that indicate space may be infinite, flat, and uniformly filled with matter and energy. If true, this would mean the ML1 we live in is filled with an infinite number of Hubble volumes, each one a “parallel universe”. →
Each would be basically the same as ours except in the way the matter in it is arranged. Consider this : in a truly *infinite* ML1, every event that is even remotely physically possible <u>must</u> occur somewhere. So in some Hubble volume out there, a man named Sherlock Holmes is living every story we have ever read about him, down to the last detail.

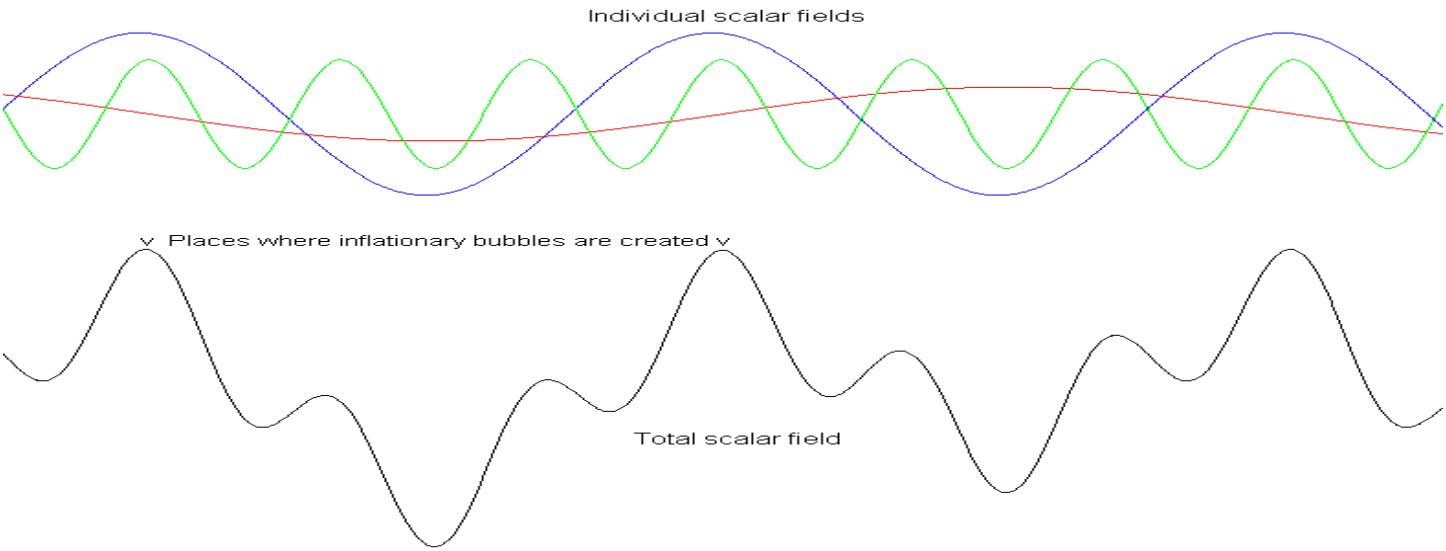
Our Hubble volume is estimated to contain 10^118 particles. That is ten multiplied by itself one hundred and eighteen times, or a 1 with 118 zeros after it. This many particles can form about 2^(10^118) unique parallel universes containing all possible arrangements of particles. However, if there are an infinite number of Hubble volumes, then this extremely large but finite number of possible arrangements of particles <u>must</u> be duplicated many times. Therefore, not only are there Hubble volumes that are completely different from ours, there are also <u>many</u> Hubble volumes that duplicate ours *exactly*, even down to a duplicate of the Earth, with you sitting in the exact same room, reading this exact same essay. And many others that are almost exactly identical – you but with a different job, or a different spouse, or a different car, or one where Elvis is still alive…

Though referred to as parallel universes, Hubble volumes are all part of the same space-time. So it *might* be possible to visit them, if we could figure out how to cross the enormous distances involved. But if the universe is expanding at an accelerating rate as recent observations indicate, they will remain forever out of sight and out of reach.

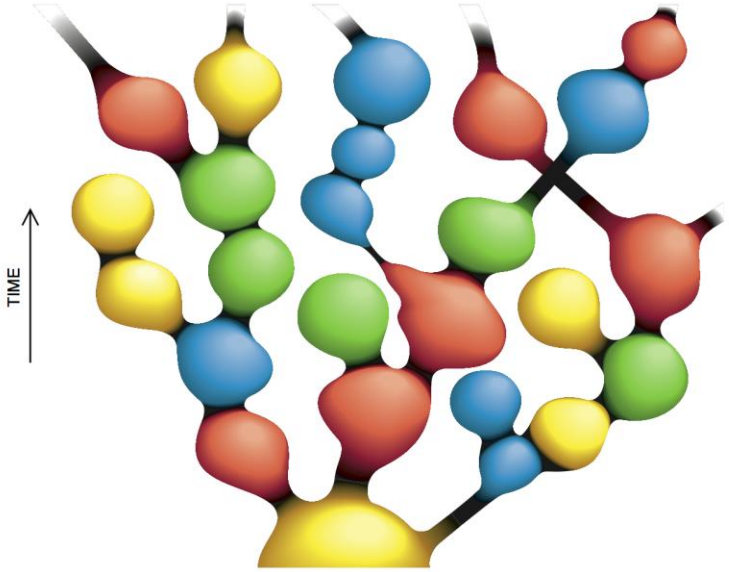
The Second Level : Eternally Self-Replicating Bubbles of Space-Time

A Level 2 Multiverse (ML2) consists of an infinite number of ML1s, each containing an infinite number of Hubble volumes. But in each one of these ML1s, physics works differently.

A little background : a “scalar field” has a single directionless value at every point in space, like temperature. Realistic models of the particles and forces that populate our universe require several kinds of scalar fields, which fill the universe and affect the various properties of elementary particles. You can visualize quantum fluctuations of the scalar fields as waves : they first move in all possible directions and then freeze on top of one another. Each frozen wave slightly increases the total scalar field in some parts of the universe and decreases it in others (see diagram below).



Those places in the universe where these newly frozen waves increase the total scalar field high enough begin expanding with exponentially ever-increasing speed. The higher the scalar field, the faster this newly-inflating bubble expands. While rare, in an infinite universe there will still be an infinite number of places where the scalar field is high enough to create these bubbles. From this it follows that if the universe contains at least one inflationary domain of a sufficiently large size, it begins unceasingly producing new inflationary domains. In essence, one inflationary universe sprouts other inflationary bubbles, which in turn produce other inflationary bubbles. The bubbles where inflation has ended are the ML1s of our ML2 multiverse. Each bubble is infinite in size, and there are infinitely many bubbles since the chain reaction never ends. This means there is also no "beginning" of time : there is, was and always will be an infinite number of inflating bubbles and post-inflationary regions like the one we inhabit. This process, called "eternal inflation", produces a fractal-like pattern of ML1 universes, like branches sprouting off of branches sprouting off of branches on a tree. →



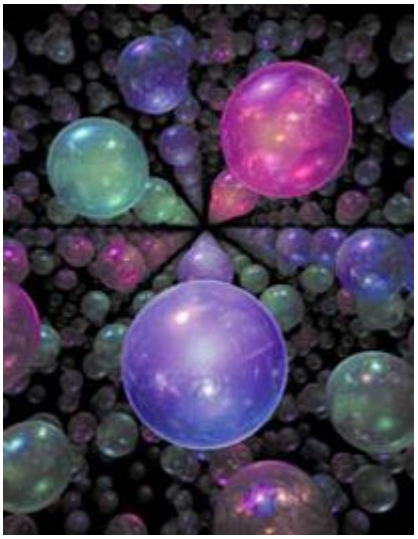
However, because the quantum fluctuations in the scalar fields differ at the instant each bubble started inflating, each ML1 can have radically different physical constants (such as the strengths of the four fundamental forces), different types of particles, and even different numbers of observable space and time dimensions (compared to our 3 space and 1 time). The result is that there are many ML1s where stable stars cannot form, or complex molecules cannot exist, or all atoms break down over time, or certain elements cannot exist. This infinite variety of ML1s explains something that has bothered physicists for a long time : the fact that if any one of two dozen or so constants that describe our universe were just *slightly* different, life as we know it could not exist (the "fine-tuning problem"). But with an infinity of ML1s being created, many of them will have the proper combination of constants to support life, so our universe becomes nothing "special".

These other ML1 domains are <u>more</u> than infinitely far away from us (and each other) in the sense that you could never get from one to the other even if you traveled at the speed of light forever. The reason is that the space *between* the ML1s is still undergoing inflation, which keeps stretching it out and creating more volume faster than you can travel through it. And even if we could reach another ML1, how could we survive in a place where physics works differently, and the atoms or molecules of our bodies might break down or fly apart?

It is important to note that the fundamental laws and equations of physics are the same in all ML1s of our ML2 universe, it is just the constants used in those equations that differ between them. Even if some of the effective equations differ between ML1s – for instance, moving from a three-dimensional space to a four-dimensional space changes the gravitational force equation from an inverse square law to an inverse cube law – the basic concept (inverse power law) is still the same. In ML4 (below), the fundamental laws themselves change.

The Third Level : Infinite Quantum Possibilities

The next step is the Level 3 Multiverse (ML3). ML3 is based on the idea that, according to quantum mechanics, every event has a number of possible outcomes, each described by a probability. These outcomes are known as quantum states. Each state has its own parallel universe, so that there is one parallel universe for every possible way the universe could be, depending on which quantum state occurs ("many worlds"). Another way to put it is that for any outcome that has a non-zero probability, there must be at least one parallel universe in which that outcome happens. This includes choices made by intelligent creatures, as well as random physical events.



Unlike Hubble volumes and ML1s, the parallel universes of an ML3 are not separated by great distances, they are instead separated within an abstract realm called Hilbert space that permits all possible quantum states to exist.→ Each universe is real, but each one exists in different dimensions of this Hilbert space. These parallel universes are like different pages in a book, existing independently and simultaneously, but there is no way to even think about traveling between them.

The principle of ergodicity says that all the possible universes in ML3 are no different than those in an infinite number of Hubble volumes in an ML1. The arrangement of matter into all possible combinations, along with the fact that these combinations will be duplicated endlessly, means that all the possible quantum states in ML3 will exist in some ML1 somewhere, but separated by distance rather than by quantum abstractness. Ergodicity also says that all possible parallel universes that can exist in an ML3 can also exist in an ML2, with all its ML1s. Thus, oddly enough, ML3 does not add any new "kinds" of universes to the mix.

The Fourth Level : And Now for Some Completely Different Physics

A Level 4 Multiverse (ML4) contains an infinite number of ML2s, each of which differs in its physical laws (represented by the particular equations used to describe how the universe works). As with the previous levels, where every possible arrangement of matter is represented by at least one Hubble volume, and every possible set of cosmological properties (physical constants, numbers of space and time dimensions, etc.) is represented by at least one ML1, here every possible combination of all possible physical laws is represented by at least one ML2.

The existence of ML4 also answers another question that has bothered physicists for a long time : even if we find equations that describe our universe perfectly, then why these particular equations and not others? The answer is that the other equations describe other ML2s! Our universe has these particular equations just because with an infinite number of combinations of laws to choose from, this particular combination must exist, and at least one of the ML1 universes that these particular laws can create is able to support observers like us.

http://space.mit.edu/home/tegmark/multiverse.pdf - describes all 4 levels; 18 pages, moderately technical
http://www.stanford.edu/%7Ealinde/1032226.pdf - describes level 2 in detail; 8 pages, less technical

Portions of this document were copied from http://www.medbherenn.com/parallel-universes.html without permission.