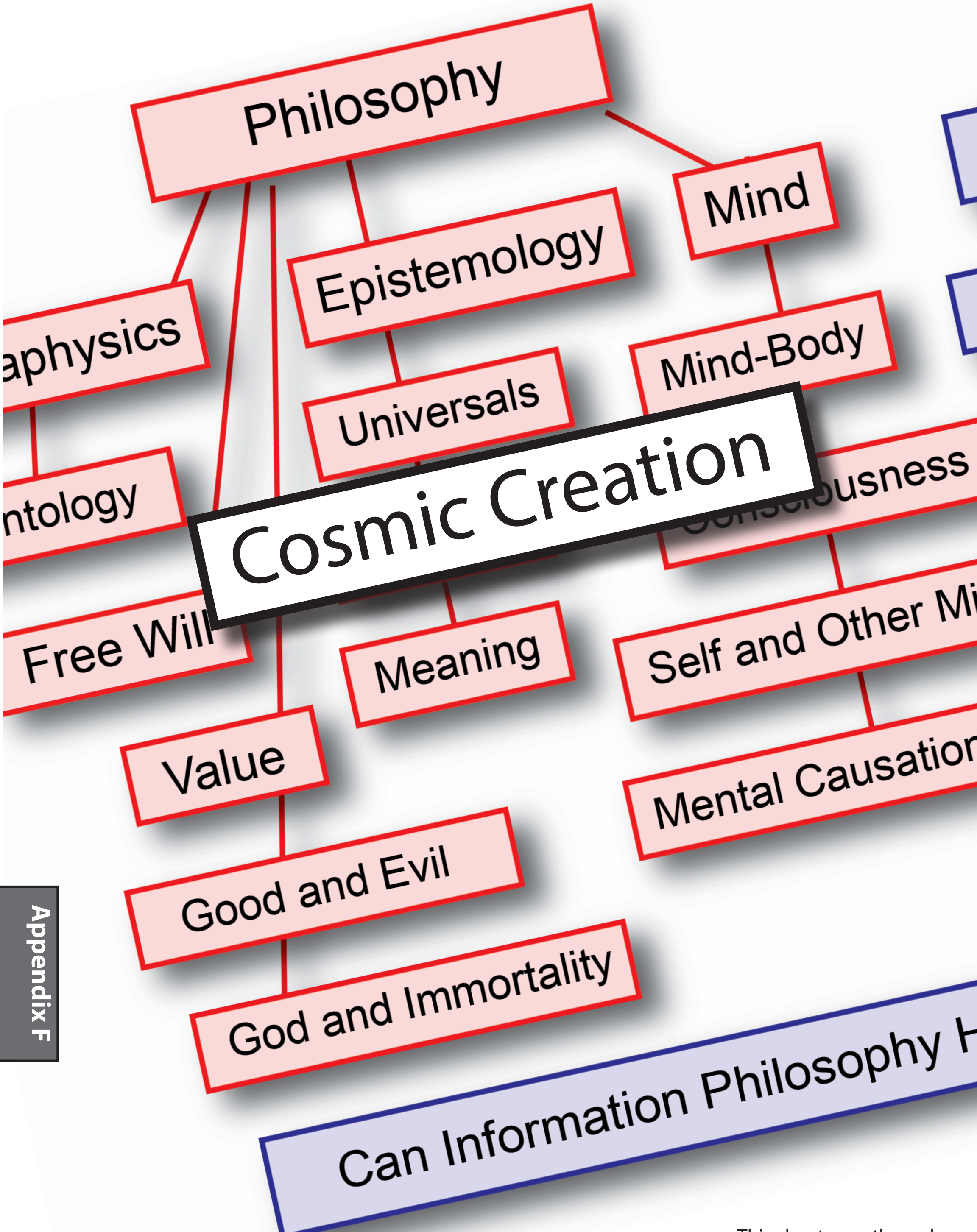


Appendix F

This chapter on the web
informationphilosopher.com/introduction/creation

The Cosmic Creation Process

The Fundamental Question of Information Philosophy

Our fundamental philosophical question is cosmological and ultimately is profoundly metaphysical.

What are the processes that create emergent information structures in the universe?

Given the second law of thermodynamics, which says that any system will over time approach a thermodynamic equilibrium of maximum disorder or entropy, in which all information is lost, and given the best current model for the origin of the universe, which says everything began in a state of thermodynamic equilibrium some 13.75 billion years ago, how can it be that living beings are creating and communicating vast amounts of new information every day?

Why are we not still in that original state of equilibrium?

Broadly speaking, there are only four major phenomena or processes that can reduce the entropy locally, while of course increasing it globally to satisfy the second law of thermodynamics. Three of these do it "blindly," the fourth does it with a built-in "purpose," or telos."

- Universal Gravitation
- Quantum Cooperative Phenomena (e.g., crystallization, the formation of atoms and molecules)
- "Dissipative" Chaos (Non-linear Thermodynamics)
- Life

None of these processes can work unless they have a way to get rid of the positive entropy (disorder) and leave behind a pocket of negative entropy (order or information). The positive entropy is either conducted, convected, or radiated away as waste matter and energy, as heat, or as pure radiation. At the quantum level, it is always the result of interactions between matter and radiation (photons). Whenever photons interact with material particles, the outcomes are inherently unpredictable. As Albert Einstein discovered ten years before the founding of quantum mechanics, these interactions involve irreducible ontological chance.

Information philosophy (actually information physics) has now identified the exact steps needed to create any new information structures in the universe. This includes the first matter - elementary particles like quarks, gluons, photons, and electrons. It also includes the first atoms and molecules (which did not appear until at least 380,000 years after the origin of the universe).

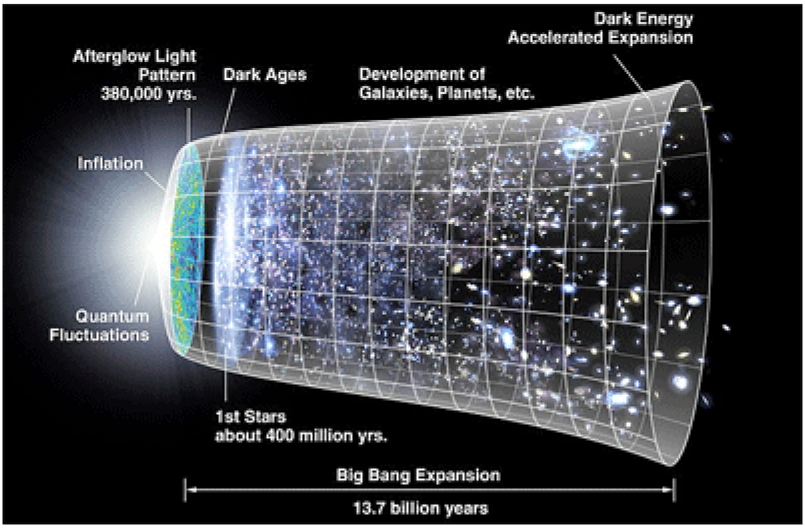


Figure 34-1. An artist's rendering of the cosmic expansion.

The very same steps are needed to form the galaxies, stars, and planets, which were starting to form about 400 million years after the origin. All these cosmic information structures are informationally passive. Their interactions follow the relatively simple laws of physics and chemistry. They do not process or communicate information.

Although we call it cosmic creation, the very same steps create all life on Earth. But biological structures are far from informationally passive. They have the extraordinary active and emergent capability of replicating, communicating, and processing information. They are cognitively aware of their environment. They exhibit purposeful, *teleonomic* behavior.

Finally, those same two steps are involved in our minds when we create a new idea! Information philosophy tells a story of cosmic and biological evolution that is one creation process all the way from the original cosmic *material* to the *immaterial* minds that have now explained the creation process itself!

Sadly, cosmic creation is horrendously wasteful. In the existential balance between the forces of destruction and the forces of construction, there is no contest. The dark side is overwhelming. By quantitative physical measures of matter and energy content, there is far more chaos than cosmos in our universe. But it is the cosmos that we prize.

Information philosophy focuses on the qualitatively valuable information structures in the universe. The destructive forces are entropic, they increase the entropy and disorder. The constructive forces are anti-entropic. We call them ergodic. They increase the order and information.

By information we mean a quantity that can be understood mathematically and physically. It corresponds to the common-sense meaning of information, in the sense of communicating or informing. It also corresponds to the information stored in books and computers. But it also measures the information in any physical object, like a stone or a snowflake, in a production process like a recipe or formula, and the information in biological systems, including cell and organ structures and the genetic code.

The Two Steps in Cosmic Creation

For some years, we have argued that the creation of any new information structure requires two fundamental steps. The first involves quantum mechanics, the second thermodynamics. But the thermodynamics is not the usual entropy-producing kind. It must produce negative entropy, the "order out of chaos" that is new information. We call such a process *ergodic* and find that it works differently in the material, biological, and mental domains

Furthermore, the quantum mechanics of information creation raises metaphysical questions that suggest further analysis might be helpful. So we may have to break down each of these steps as needed for the best explanation.

The *first step* in the creation of new information needs the metaphysical existence of multiple future possibilities as a precondition. In a deterministic universe such possibilities do not exist. There is but one possible future. We thus need an ontological commitment to the existence of multiple possibilities, which like any "ideas" have questionable existential status.

For example, where do such possibilities go when one of them is actualized? When one "becomes" and now has "being," are the others destroyed? Have they become "nothingness," as existentialists claimed?

In a *deterministic* universe no new information is ever created. Information is a conserved quantity, like matter and energy, say many mathematical physicists and theologically minded philosophers, who think constant information fits well their idea of an omniscient god, for whom there is "nothing new under the sun."

Quantum physics provides us with a model for the first step. A quantum system has possible states. The wave function provides calculable probabilities for each state. And the wave function may "collapse," instantaneously and randomly, into one actual state if and when there is an interaction with another system. Some interactions may project the system into a different linear combination (a "superposition") of possible states, but we shall ignore that here.

Because the "collapse" is genuinely random, quantum physics is the origin of *ontological chance* in the universe, as first discovered by Albert Einstein, many years before the "founders" of quantum mechanics and the "uncertainty principle."[1]

The inventor of the mathematical theory of the communication of information, Claude Shannon, explained how there would be no communication of new information without the existence of possible alternative messages.

A *deterministic* universe is one in which all messages from the past contain only the fixed totality of information in the past, nothing is ever "new." So the indeterminism of quantum mechanics opens possible futures and gives us humans the chance to be creative authors of our lives.

1 See Appendix D.

So why do we need a *second step* in the creation of information? The short answer is *irreversibility*.[2]

A quantum event may be reversible. It may not leave a permanent record in the universe.[3] Until it does, we have nothing new. For the many scientists and philosophers of science who deny the collapse of the quantum-mechanical wave function, the universe is left forever in a superposition of states. Nothing ever "happens." Claims of decoherence theorists that explain the *appearance* of something happening are *incoherent*.[4]

Making a quantum event irreversible is the job for thermodynamics in our second step. But thermodynamics is a two-edged sword. Every thermodynamic process is *irreversible*. Thermodynamicists invent hypothetical reversible processes to calculate the efficiency of engines, but in practice, as Ludwig Boltzmann showed, there is always an increase in the entropy. So irreversibility alone cannot help us with the creation of information, which we identify with local *reductions* in the entropy. The creation of information requires the creation of local *negative* entropy, in the form of an information structure.

There are just a few natural processes that can create information structures. One is gravitation, which can attract matter from random distributions of dust and gas into structures with spherical or circular symmetry like planets, stars, and galaxies. Another is crystallization, when a snowflake with elaborate hexagonal symmetry forms from amorphous water vapor. But the most important ergodic processes are life and mind.

In order to satisfy the second law of thermodynamics, which demands that the overall entropy of the universe must increase, these anti-entropic or *ergodic* processes must transfer an amount of positive entropy (we can call Boltzmann entropy) away from the new information structure with local negative entropy (that we can also call Shannon entropy).[5]

2 See chapter 25.
3 See appendix C for a reversible quantum experiment.
4 See chapter 21.
5 See Appendix B for entropy and the second law.

Shannon's information is mathematically the negative of the Boltzmann formula for entropy. For Shannon it was the logarithm of the number of messages, weighted by their probabilities. For Boltzmann it was the logarithm of the number of possible distributions of gas particles in phase space.[6]

Should we consider the transfer away of positive entropy only a part of the second step? The means by which the transfer occurs is somewhat different in material, biological, and mental information processes.[7]

The Flatness Problem in Cosmology

The universe is very likely flat because it was created flat. A flat universe starts with minimal information, which is fine since our cosmic creation process can create all the information that we have today. Leibniz' question, "Why is there something rather than nothing?" might be "the universe is made out of something and the opposite of that something."

When I was a first-year graduate student in astrophysics at Harvard University in 1958, I encountered two problems that have remained with me all these years. One was the fundamental problem of information philosophy - *"What creates the information structures in the universe?"* The other was the flat universe.

At that time, the universe was thought to be positively curved. Edwin Hubble's red shifts of distant galaxies showed that they did not have enough kinetic energy to overcome the gravitational potential energy. Textbooks likened the universe to the surface of an expanding balloon decorated with galaxies moving away from one another.

That balloon popped for me when Walter Baade came to Harvard to describe his work at Mount Wilson. Baade took many images with long exposures of nearby galaxies and discovered there are two distinct populations of stars. And in each population there was a different kind of Cepheid variable star. The period of the

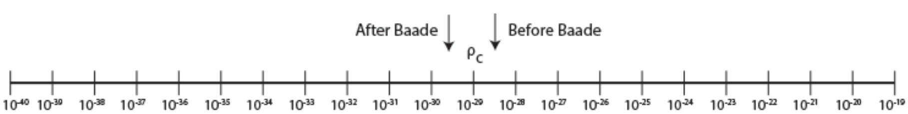
6 See appendix A for the mathematics.
7 See chapter 28.

Cepheid's curve of light variation indicated its absolute brightness, so they could be used as "standard candles" to find the distances to star clusters in the Milky Way.

Baade then realized that the Cepheids being used to calculate the distance to Andromeda were 1.6 magnitudes brighter than the ones used in our galaxy. Baade said Andromeda must be twice as far away as Hubble had thought.

As I listened to Baade, for me the universe went from being positively curved to negatively curved. It jumped right over the flat universe! I was struck that we seemed to be within observational error of being flat. Some day a physicist will find the reason for perfect flatness, I thought.

I used to draw a line with tick marks for powers of ten in density around the critical density ρ_c to show how close we are. Given so many orders of magnitude of possible densities, it seemed improbable that we were just close by accident. We could increase the density of the universe by thirty powers of ten before it would have the same density as the earth (way too dense!). But on the lighter side, there are an infinite number of powers of ten. We can't exclude a universe with average density zero, which still allows us to exist, but little else in the distance.



In the long run we are approaching a universe with average density zero. Some say all the non-gravitationally bound systems will slip over our light horizon as the expansion takes more and more of them faster than the velocity of light. At this time, galaxies with a redshift greater than z = 1.8 are already over our light horizon. We can never exchange signals with them.

But note that we may always be able to see back to the cosmic microwave background, all the same contents of the universe that we see today will always be visible, just extremely red-shifted!

What evidence could there be for a perfectly flat universe?

First, there is the problem of the "missing mass" needed to slow down the cosmic expansion so that it will never stop, except at an infinite time, when there will be no kinetic enrgy left over

Second, there is evidence for acceleration of the cosmic expansion. It depends on observations of a single kind of "standard candle," the type 1a supernovae.

It is essential that some other visible bodies at extreme redshifts can be used to show acceleration. The type 1a supernovae that exploded at the earliest times might have some systematic difference from those that exploded later.

Beyond any obdervations, there is pure theory. When Alan Guth presented his inflation thesis at Harvard in the 1980's, I asked him why not assume the universe has always been exactly flat. He replied, "That's too easy." The great cosmologist Steven Weinberg agrees that it is easy. He wrote

> "The simplest solution to the flatness problem is just that we are in a spatially flat universe, in which K = 0 and ρ is always precisely equal to ρ_{crit}." [8]

The Problem of Missing Mass

Given our assumption that the universe is exactly flat, the missing mass problem is that there is not enough observable material so that in Newtonian cosmology the gravitational binding energy can exactly balance the kinetic energy. The visible (luminous mass) accounts for only about 4-5 percent of the needed mass. Studying the rotation curves of galaxies and galaxy clusters reveals an invisible mass (called dark matter) contained inside the galaxies and clusters that amounts to perhaps 6 times the visible matter, which accounts for about 30 percent of the critical mass density needed to make the universe exactly flat. Current theory accounts for the balance by "dark energy," an interpretation of the cosmological constant Einstein considered adding to his equations as a pressure to keep it from collapsing (known as "vacuum energy"). But the miss-

8 *Cosmology*, p.39

ing mass could just be more dark matter between the galaxies and clusters. About three times their dark matter would do.

This much material can close the universe and explain its flatness. But it would not explain the apparent expansion acceleration seen in Type 1a supernovae. This might be an artifact of the assumption they are perfect "standard candles." Recent evidence suggests that distant Type 1a supernovae are in a different population than those nearby, something like Baade's two populations.

It seems a bit extravagant to assume the need for an exotic form of vacuum energy on the basis of observations that could have unknown but significant sources of error. And I am delighted that observations are within a factor of three of the critical density ρ_c.

When Baade showed the universe was open in the 1950's, we needed thirty times more matter for a flat universe. Now we need only three times more. More than ever, we are obviously flat!

The Horizon Problem

The horizon problem arises from the perfect synchronization of all the parts of our visible universe, when there may never have been a time in the early universe that they were close enough together to send synchronization signals.

We propose a solution to the horizon problem based on Einstein's insight that in the wave-function collapse of entangled particles, something is "traveling" faster than the speed of light. That something is *information about possibilities*. When the universal wave function Ψ collapsed at $t = 0$, parts of the universe that are outside our current light horizon may have been "informed" that it was time to start, no matter the physical distance.

This radical idea is consistent with Richard Feynman's path integral (or "sum-over-histories") formulation of quantum mechanics. In calculating the probability of a quantum event, the path integral is computed over all the possible paths of virtual photons, many travelling faster than the speed of light.