# Cosmology and the Law of Parsimony

by

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This essay was first completed on Thursday, April 13, 1995 and was most recently revised on Monday, September 26, 2011.

The essay is approximately 6,761 words long.

Other essays in this collection are available on *Pharos*.



*caveat lector*

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## In the Beginning

According to conventional cosmology, the universe began with a bang. The alleged expansion of the universe points back to that supposed explosive beginning, the so-called Big Bang. Entropy, that incurable cosmic disease, portends the hypothetical time when there won't be any more energy gradients by which any thermodynamic process can operate. It follows that all creatures in the universe, at least those that function by transferring energy from one form to another, look forward to the eventual energy death of the universe.

That generally accepted cosmology has a certain anthropomorphic appeal: birth, growth, decline, and death. However, it lacks the elegance of simplicity. A rational consideration of it suggests that it might be flawed.

- The spectrum of light from distant stars has shifted toward lower frequencies. The further away we are from a star, the more pronounced is the observed red shift. We know that there's a red shift because we can observe it. The accepted explanation of the red shift is that it's a Doppler effect. However, there's a better explanation than that.
- A consequence of the Doppler effect explanation of the red shift is the idea that all of the matter in the universe is flying apart, with us at the center, and that the more distant it is from us the faster it's moving away from us. It's an inherently silly notion. After several hundred years of research and study, we've circled right back to where we started. We've progressed from being at the center of a spinning cosmos to being at the center of an expanding universe.
- The idea that everything in the universe is flying apart suggests the Big Bang theory of the origin of the universe. However, calculations of the age of the universe, using data obtained from the Hubble telescope, suggested that the age of the universe is about 8-12 billion years.[1] Sadly for the Big Bang theory, a typical estimate of the age of a star is 15 billion years, which makes many stars appear to be older than the universe. How those stars managed to survive the cataclysmic Big Bang is only one of the problems that arise from the discrepancy. Where they existed before the Big Bang is another such problem. Why they were there at all, before the beginning of the universe, is yet another. You get the idea.
- There's also the problem of the missing mass. That is, 90% of the mass that the theoreticians expected to exist in the universe couldn't be found.[2] I don't know why they expected that particular amount of mass but they previously speculated that it was tied up in the form of dark bodies, dwarf stars, or perhaps dark nebulae, all of which were merely difficult to observe. Research using the Hubble telescope didn't reveal the expected accumulations of such matter.
- Supernovae can radiate, for a few days, with more power than an entire galaxy. I'm not aware of any satisfactory explanation, in the generally accepted cosmology, for such power.
- What keeps all of the matter in the universe from eventually ending up in a black hole?

It seems clear to me that we need a better cosmology.

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1 The calculations were done by Wendy Freedman, of the Carnegie Observatories in Pasadena, California. They were reported by Paul Hoffman, of *Discover Magazine*, on the *MacNeil/Lehrer NewsHour* on Tuesday, April 11, 1995.

2 This was also reported by Paul Hoffman on the same segment of the *MacNeil/Lehrer NewsHour*.

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## All Things Considered

I believe that the conventional cosmology begins from erroneous assumptions.

- There isn't any reason to assume that the red shift is a Doppler effect.
- If the red shift isn't a Doppler effect, then there isn't any reason to assume that the universe is expanding.
- If the universe isn't expanding, then there isn't any reason to assume that it had an explosive beginning. The Big Bang is a silly notion.
- There isn't any reason to assume that the processes that we've observed in the universe are the only processes by which the universe operates. Easily observable processes are more likely to be observed than others....

  Vry's Law
  No observation, however simple, can be made except by those predisposed to make it. —Vry, in *Helliconia Spring* by Brian W. Aldiss

  ... but they're not necessarily more likely to exist than others.

  Gödel's Incompleteness Theorem (a simplified restatement by somebody)[3]
  In any closed mathematical system there are an infinite number of true theorems which, though contained within the original system, cannot be deduced from it. —Kurt Friedrich Gödel (April 28, 1906 - January 14, 1978)
- The generally accepted cosmology relies too heavily for its justification on complex mathematical calculations. Such calculations have been inappropriately elevated to the status of proof. Mathematics doesn't prove anything. It only describes things.[4]
- The generally accepted cosmology is way too complicated.

The generally accepted cosmology is a good example of the answers only serving to further complicate the questions. Complex and obscure theories such as extra dimensions, curved or warped space, relativistic effects of gravity, and an ever-expanding universe are nothing more than extravagant and unsuccessful attempts to accommodate bad assumptions. The only purposes that they serve are to complicate the technical jargon and to discourage understanding. Of course, that does serve to enhance the job security of the scientists.

3 For any self-consistent recursive axiomatic system powerful enough to describe the arithmetic of the natural numbers (for example Peano arithmetic), there are true propositions about the naturals that cannot be proved from the axioms. —from *Wikipedia*

4 See my essay *There's An Arrow In The Logic -or- Who Says Pie Are Square?*

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## Ockham's Razor

To understand the universe, we ought to start with the universe itself, and not with rigorous mathematical calculations and complex theories. Understanding should proceed from observation, from imagination, and from intuition. It can be formalized theoretically and mathematically afterward, if that's even desirable, by people with the talents and mentality best suited to those jobs.

The first thing that's needed is a different set of assumptions. They must allow simpler explanations. Such assumptions might provide a different view of the universe. Here's such a set of assumptions.

- The red shift is exactly what it appears to be. That is, the light has decreased in frequency as it has traveled. The further it has traveled, the more it has decreased in frequency. Thus, the further away a star is, the more its spectrum has shifted. That's a lot simpler explanation of the red shift than assuming that the stars are all flying away from us.
- The geometry of space is Euclidean. By that, I mean that distances are linear, without warps, curves, discontinuities, or other peculiar phenomena.
- There are processes in the universe whereby the universe will continue to exist forever. The universe didn't have a beginning. It won't have an end. It is eternal.
- The universe doesn't have any physical limits of extent, that is, boundaries of distance. It is infinite in three linear, mutually perpendicular directions.
- Gravity doesn't distort space. It only deflects the direction of travel of matter. If it also deflects the direction of travel of photons, then reconsider your understanding of photons.

These assumptions lead to a much simpler and saner cosmology.

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## Yin and Yang

There are two fundamental, opposite, and parallel processes by which the universe operates and by which it is maintained forever. Those two processes are gravity and entropy.

It's generally believed that entropy is irreversible, inevitable, and that it will eventually cause the universe to coast to a stop. However, gravity prevents that from happening. The way in which gravity does so isn't obvious and, so far as I'm aware, the process hasn't ever been observed. I originally deduced the process, many years before I began writing this essay, as an explanation for the red shift. However, the process also fits neatly into the simple and sane cosmology that I envision.

Here's how gravity reverses the energy degradation that's caused by entropy. As photons travel, they lose energy along the way. A photon cannot lose kinetic energy because it must travel at the speed of light. The only kind of energy that a photon can lose and still remain a photon is the energy that we perceive as its frequency. Such a loss of energy therefore results in a reduction in the frequency of the photon. We see that reduction in frequency as a red shift. The energy loss events are spontaneous, like radioactive decay. They have an extremely low probability of occurrence. However, given a potentially infinite number of objective years of travel time, the energy loss events can and do occur.[5] I don't claim to understand the mechanism. I'm happy to leave that as an exercise for the physicists.[6]

Each such energy loss event results in the transformation of energy into an extremely small particle of matter. Each time that such an event occurs, the energy of the photon is reduced and a particle of matter is deposited in space. Such particles of matter are obviously quite small. Each one corresponds to the lost energy that we perceive as the reduction in frequency of the photon.

As the red shift occurs over vast intergalactic distances, particles of matter are strewn thinly along the photon's path. Gravity is the force that is inherent in the particles. It's the force that brings them together into pebbles, planets, stars, and galaxies. The deposition of those particles by photons and their accumulation by gravity is the process by which the consequences of entropy are reversed, so that the energy death of the universe never occurs.

Entropy is the other of the two fundamental, opposite, and parallel processes by which the universe operates and by which it is maintained forever. Within stars, matter that was accumulated there by gravity is converted back into energy and dispersed throughout the universe, where photon decay can convert it back into matter again. The cycle endlessly replenishes the eternal universe.

5 It's interesting to note that, according to the theory of time dilation, the amount of subjective time experienced by a traveling observer is reduced as compared to objective time, as the traveling observer approaches the speed of light. An observer travelling at near the speed of light might experience a few weeks of time while the outside universe might experience thousands of years of time. At the speed of light, subjective time becomes zero as compared to objective time. Thus, the subjective time of a photon traveling at the speed of light is exactly zero from the time of its origin until the time of its destruction. From the point of view of the photon, it never existed.

6 In that regard, I recommend *The Hubble Red Shift by Photon Decay: A sensible explanation*, by Michael Lewis.

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## The Black Sky At Night

I've asserted that the universe is three dimensional, linear, infinite, and eternal. Given such a simple universe, the night sky ought to be white, not black. Here's the reason. If photons don't decay then, given my assertions, photons have to travel until something gets in their way. In that case, regardless of which direction you look, you're looking in the direction of a star, however distant it might be. You ought to be able to see the light from that star. Thus, the entire sky, whichever direction you look, ought to be entirely blanketed by a background of stars. The night sky ought to be white.

There are at least two things that can explain the black sky that we observe at night. Both of those things are a consequence of my understanding of the red shift. First, there might be material in space, between you and any star toward which you're looking. The further away the star is, the more of that material there might be between you and it. If the star is far enough away then there might be so much of the material between you and it that the material completely blocks your view of the star. What's in the way is the tiny particles of matter that were deposited by decaying photons. That also explains the missing mass that the scientists couldn't find, way back at footnote 2 on page 1.

The second reason that the night sky is black instead of white is that the further a photon travels, the more particles of matter it deposits. The more particles it deposits, the further its frequency is reduced. Eventually, its frequency is reduced to the point where the next particle of matter that it deposits reduces its frequency to zero, and it ceases to exist. The night sky is black because there's a limit to how far photons can travel.

Those two phenomena define the visual horizon of the universe, which we perceive as a black background. We cannot see beyond that visual horizon. Within it, we can see the bodies and the materials that reside within the universe. Beyond it, the universe continues without end but we cannot see it. However far our descendants might travel, they will never approach the visual horizon. It will move as they move, remaining always at the same distance from them. It is eternally unattainable. Thus, any observer will always be at the exact center of the observable universe.

There's another fascinating consequence of my cosmology. Given infinity in a Euclidean universe (see page 5), each and every point in the entire universe, without exception, is at the exact center of the universe. Think about it. No matter which direction you point, there's exactly as much of the universe in that direction as there is in any other direction. So, you're at the very center of the universe. It gets even better. The exact same thing is true for anybody, anywhere in the entire universe. No matter which direction he points, there's exactly as much of the universe in that direction as there is in every other direction. So every creature, anywhere in the universe, is at the exact center of the universe. An infinite Euclidean universe consists entirely of nothing but central points. The ancient practitioners of the geocentric cosmology were closer to the truth than they ever imagined, but in a way that they could never have imagined.

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## Black Holes

What keeps all of the matter in the universe from eventually falling into a black hole? After all, the inability of energy to escape from a black hole prevents the dispersal of energy. Thus, by the mechanism of black holes, gravity traps matter and energy. That prevents entropy from functioning. It appears to interrupt the eternal processes of the universe. There must be some way for energy to get back out of a black hole or, given the fact that the universe has been here forever, all of the matter and energy in the universe would by now be in a black hole. It's obvious that we need to consider black holes.

What would the universe look like to a black hole? By considering gravity, I can answer that question intuitively. Gravity is a conservative force. By that, I mean that energy is conserved in a gravitational process. Something thrown up comes back down to the same elevation with the same kinetic energy with which it was thrown, discounting of course losses due to friction, collisions with other objects, and so forth. However, kinetic energy lost to other objects or substances will be acquired by those objects or substances. That energy will appear as kinetic energy when those objects or substances fall. So, on the average, energy isn't lost when something is thrown up and then falls back down again. Therefore, the material that erupts from the "surface" of the body within a black hole will fall back to that surface, on the average, with exactly the same amount of energy that it had when it erupted. Thus, looking up, a black hole would "see" the universe as a perfect reflector. This leads to an interesting intuitive model of a black hole.

Consider a black hole to consist of a spherical reflector facing inward with a "kernel" at its exact center. As an idealization, regard the kernel as having a diameter in the conventional sense and the reflector as having an effective radius at some distance above the center of the kernel. Of course, the kernel might not have a definite surface and the reflector is only a convenient way of thinking about the effect of the gravity field around the black hole but just bear with me.

Assume, for the sake of simplicity, that we can consider the material in the black hole, whether it's matter or energy, to be just material. That material can then occupy one of two regions. It can exist within the kernel or it can exist above the kernel, in the region between the reflector and the surface of the kernel.

In fact, material will be continually erupting from the surface of the kernel. That's true because the kernel will be hot. Whether or not there's any nuclear process at work is irrelevant. No energy can escape from the black hole. Therefore, the black hole will contain all of the energy that it had when it became a black hole plus all of the energy that it accumulated from the captured debris that fell into it after it became a black hole. Some of that debris might be stars or possibly even entire galaxies.[7] The thing will be hot.

7 Incidentally, that addition of material from outside of the reflector means that the reflector will not, after all, appear to the kernel as only a perfect reflector. It will appear, instead, as a perfect reflector and as a source. That's true because it will radiate back at the kernel all of the material that erupts from the kernel and also appear to be the source of the material that falls into the black hole.

Material that erupts from the surface of the kernel will exist for a time in the region between the kernel and the reflector. It will go up, reflect from the reflector (that is, reach the top of its trajectory and start to fall back toward the surface), and then return to the kernel. The process will be dynamic, with material constantly traveling up and down. It will be turbulent, with material in a constant process of collision.

Density in the kernel will be high. Density near the reflector will be low, relatively speaking. There will be a density gradient between the two extremes. The average density of the entire black hole will depend on the total mass of the black hole as compared to the effective volume of the black hole, out to the reflector. The total mass will be nearly constant but will increase with time as debris falls past the reflector from the outside. The effective volume will vary according to the effective diameter of the reflector, as determined by the interaction between the kernel and the reflector.

Given sufficient time, and the black hole has infinite time at its disposal, a random fluctuation might result in more material going up than down at some instant. If more material than usual erupted from the surface, a slight and temporary reduction in the size of the kernel would result. The total mass of the black hole would be temporarily distributed over a larger than normal volume, resulting in a slight reduction of the average density of the black hole. That would reduce the steepness of the gravitational gradient and allow material to rise higher before it fell back to the kernel. In terms of my simple model, it would increase in the effective radius of the reflector. It's reasonable to speculate that such a little surplus of material going up might be followed by a surplus of material going down. In that case, a greater than normal amount of material would impact the surface of the kernel shortly afterward. The effect would be to increase the average density of the kernel. That would increase the steepness of the gravitational gradient and pull the reflector in by a small amount, increasing the average density of the black hole.

Given enough time, the pulses might not completely taper off to the normal random condition. Instead, they might establish a permanent oscillation. Here's why. Each time that there's a larger than average amount of material moving out, the reflector will retreat from the kernel. That will make it easier for material to move out, away from the kernel. That results in more material than normal falling back toward the kernel, some time later. Each time that there's a larger than average amount of material moving toward the kernel, the reflector will collapse toward the kernel. That will increase the impact of material hitting the surface of the kernel, compressing the kernel. That will result in more material being thrown upward, a short time later. A permanent oscillation might be established in which the average density of the black hole would oscillate drastically between two extremes. The effective diameter of the reflector would also oscillate. Such an oscillation might be stable. It might continue for eons and be completely invisible from outside of the black hole.

One possible consequence of such an oscillation is that, eventually, the reflector might fall so close to the surface of the kernel that it would momentarily attempt to dive below the surface. Since it's a perfect reflector, nothing can get past it. Therefore, it couldn't dive below the surface. Instead, it would tend to compress the kernel.

The compressive effect of the reflector attempting to fall below the surface would only serve to increase the strength of the next oscillation. The reflector would be forcefully sent back up. It might be blown further away from the kernel on each oscillation.

Eventually, the reflector might be blown so far above the surface of the kernel, and allow so much of the material in the black hole to momentarily disperse into such a large volume, that the average density of the black hole would become significantly reduced. The gravitational gradient might be so slight that it would be unable to contain some or all of the rising material. That's the same thing as saying that the reflector would become less than perfect, allowing at least some of the material to escape from the black hole. If enough material escaped, if the black hole lost sufficient mass, then the black hole wouldn't have sufficient mass to maintain its reflector. If that happened, then the reflector would be destroyed. All material that was moving upward at greater than escape velocity would escape. All that would remain of the black hole would be the quantity of material that lacked sufficient energy to achieve escape velocity.

This is all entirely intuitive. I'm happy to leave the rigorous development of the scientific explanations to the scientists. However, even in its intuitive version, it's as good an explanation of a supernova as any that I've heard. It explains how a supernova can outshine an entire galaxy. It also provides an explanation of how all of the material of the universe doesn't eventually end up trapped in a black hole.

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## Keep it Simple

The cosmology that I envision is, of course, entirely intuitive. I don't regard that as a deficiency. I don't see any reason to assume that understanding must be based on complex theories, devious assumptions, or excruciating mathematical acrobatics. That approach results more in egotism and job security for cliquish specialists than it does in understanding. I believe instead that the universe is fundamentally understandable and entirely accessible to all of us. Any theory too complex for ordinary people to understand is a flawed theory. Simplicity in science, as in other things, is a great virtue.

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## Afterword

Here's another possible explanation of the universe as we see it. Maybe we're inside of an oscillating black hole. If we're in the expansion part of the oscillation, then that would explain our perception that the universe is expanding. It would be because the black hole, of which we're a part, is expanding. If the reflector is moving outward at the speed of light, or nearly so, then that might explain the black sky that we see at night. It would also provide an argument in favor of the universe, that is, our situation inside of the black hole, having a beginning and an end. Those would be the beginning and the end of this current oscillation. Just a thought.

Here's a variation on the thought. Maybe the reflector of our black hole disintegrated fairly recently, as such things go. Maybe everything that we see in the universe is the expanding debris that has recently escaped from our erstwhile black hole.

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## Glossary

**anthropomorphism** ... *n.* Attribution of human motivation, characteristics, or behavior to inanimate objects, animals, or natural phenomena. **—anthropomorphic** *adj.* —**anthropomorphically** *adv.*

—*The American Heritage Dictionary of the English Language*, 1992

**assumption** ... *n.* **1.** The act of taking to or upon oneself: *assumption of an obligation*. **2.** The act of taking over: *assumption of command*. **3.** The act of taking for granted: *assumption of a false theory*. **4.** Something taken for granted or accepted as true without proof; a supposition: *a valid assumption*. **5.** Presumption; arrogance. **6.** *Logic*. A minor premise. **7. Assumption. a.** *Theology*. The bodily taking up of the Virgin Mary into heaven after her death. **b.** A Christian feast celebrating this event. **c.** August 15, the day on which this feast is observed....

—*The American Heritage Dictionary of the English Language*, 1992

**big bang** *n.* The cosmic explosion that marked the origin of the universe according to the big bang theory.

—*The American Heritage Dictionary of the English Language*, 1992

**big bang theory** *n.* A cosmological theory holding that the universe originated approximately 20 billion years ago from the violent explosion of a very small agglomeration of matter of extremely high density and temperature.

—*The American Heritage Dictionary of the English Language*, 1992

**black hole** *n.* **1.** An extremely small region of space-time with a gravitational field so intense that nothing can escape, not even light. **2.** A great void; an abyss: *The government created a bureaucratic black hole that swallows up individual initiative*.

—*The American Heritage Dictionary of the English Language*, 1992

**contradistinguish**... *tr.v.* **-guished. -guishing, -guishes.** To distinguish by contrasting qualities.

—*The American Heritage Dictionary of the English Language*, 1992

**cosmic** ... also **cosmical** ... *adj.* **1.** Of or relating to the universe, especially as distinct from Earth. **2.** Infinitely or inconceivably extended; vast: *"a coming together of heads of government to take up the cosmic business of nations"* (Meg Greenfield) ....

—*The American Heritage Dictionary of the English Language*, 1992

**cosmology** ... *n., pl.* **-gies. 1.** The study of the physical universe considered as a totality of phenomena in time and space. **2.a.** The astrophysical study of the history, structure, and constituent dynamics of the universe. **b.** A specific theory or model of this structure and these dynamics....

—*The American Heritage Dictionary of the English Language*, 1992

**Doppler effect** *n. Physics*. An apparent change in the frequency of waves, as of sound or light, occurring when the source and the observer are in motion relative to each other, with the frequency increasing when the source and observer approach each other and decreasing when they move apart. [After Christian Johann DOPPLER.] —*The American Heritage Dictionary of the English Language*, 1992

**egocentric** ... *adj*. **1.** Holding the view that the ego is the center, object, and norm of all experience. **2.a.** Confined in attitude or interest to one's own needs or affairs. **b.** Caring only about oneself; selfish. **3.** *Philosophy*. **a.** Viewed or perceived from one's own mind as a center. **b.** Taking one's own self as the starting point in a philosophical system....

—*The American Heritage Dictionary of the English Language*, 1992

**elegance** ... *n*. **1.a.** Refinement, grace, and beauty in movement, appearance, or manners. **b.** Tasteful opulence in form, decoration, or presentation. **2.a.** Restraint and grace of style. **b.** Scientific exactness and precision. **3.** Something elegant.

***SYNONYMS:*** *elegance, grace, polish, urbanity*. The central meaning shared by these nouns is "refined and tasteful beauty of manner, form, or style": *a woman of unstudied elegance; walks with unconscious grace; comported herself with dignity and polish; tact and urbanity, the marks of a true diplomat.*

***ANTONYM:*** *inelegance*.

—*The American Heritage Dictionary of the English Language*, 1992

**energy** ... *n*., *pl*. **-gies. 1.** The capacity for work or vigorous activity; vigor; power. See Synonyms at **strength. 2.a.** Exertion or vigor or power: *a project requiring a great deal of time and energy*. **b.** Vitality and intensity of expression: *a speech delivered with energy and emotion*. **3.a.** Usable heat or power: *Each year Americans consume a high percentage of the world's energy*. **b.** A source of usable power, such as petroleum or coal. **4.** *Physics*. The capacity of a physical system to do work. —*attributive*. Often used to modify another noun: *energy conservation; energy efficiency; an energy czar*....

—*The American Heritage Dictionary of the English Language*, 1992

**entropy** ... *n*. *pl*. **-pies**. **1.** Symbol **S** For a closed thermodynamic system, a quantitative measure of the amount of thermal energy not available to do work. **2.** A measure of the disorder or randomness in a closed system. **3.** A measure of the loss of information in a transmitted message. **4.** A hypothetical tendency for all matter and energy in the universe to evolve toward a state of inert uniformity. **5.** Inevitable and steady deterioration of a system or society....

—*The American Heritage Dictionary of the English Language*, 1992

**fundamental** *adj*. **1.a.** Of or relating to the foundation or base; elementary: *the fundamental laws of the universe*. **b.** Forming or serving as an essential component of a system or structure; central: *an example that was fundamental to the argument*. **c.** Of great significance or entailing major change: *a book that underwent fundamental revision*. **2.** *Physics*. **a.** of or relating to the component of lowest frequency of a periodic wave or quantity. **b.** Of or relating to the lowest possible frequency of a vibrating element or system. **3.** *Music*. Having the root in the bass: *a fundamental chord*. **—fundamental** *n*. **1.** Something that is an essential or necessary part of a system or object. **2.** *Physics*. The lowest frequency of a periodically varying quantity or of a vibrating system. **—fundamentally** *adv*.

—*The American Heritage Dictionary of the English Language*, 1992

**galaxy** ... *n.*, *pl.* **-ies. 1.a.** Any of numerous large-scale aggregates of stars, gas, and dust that constitute the universe, containing an average of 100 billion ($10^{11}$) solar masses and ranging in diameter from 1,500 to 300,000 light-years. Also called *nebula*. **b.** Often **Galaxy.** The Milky Way. **2.** An assembly of brilliant, glamorous, or distinguished persons or things: *a galaxy of theatrical performers*....

—*The American Heritage Dictionary of the English Language*, 1992

**gradient** ... *n.* *Abbr.* **grad. 1.** A rate of inclination; a slope. **2.** An ascending or descending part; an incline. **3.** *Physics*. The rate at which a physical quantity, such as temperature or pressure, changes relative to change in a given variable, especially distance. **4.** *Mathematics*. A vector having coordinate components that are the partial derivatives of a function with respect to its variables. **5.** *Biology*. A series of progressively increasing or decreasing differences in the growth rate, metabolism, or physiological activity of a cell, an organ, or an organism....

—*The American Heritage Dictionary of the English Language*, 1992

**gravity** ... *n.* **1.** *Abbr.* **gr.** *Physics*. **a.** The natural force of attraction exerted by a celestial body, such as Earth, upon objects at or near its surface, tending to draw them toward the center of the body. **b.** The natural force of attraction between any two massive bodies, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. **c.** Gravitation. **2.** Grave consequence; seriousness or importance: *They are still quite unaware of the gravity of their problems*. **3.** Solemnity or dignity of manner....

—*The American Heritage Dictionary of the English Language*, 1992

**intuition** ... *n.* **1.a.** The act or faculty of knowing or sensing without the use of rational processes; immediate cognition. See Synonyms at **Reason. b.** Knowledge gained by the use of this faculty; a perceptive insight. **2.** A sense of something not evident or deducible; an impression....

—*The American Heritage Dictionary of the English Language*, 1992

**intuitionism** ... *n.* *Philosophy*. **1.** The theory that truth or certain truths are known by intuition rather than reason. **2.** The theory that external objects of perception are immediately known to be real by intuition. **3.** The theory that ethical principles are known to be valid and universal through intuition....

—*The American Heritage Dictionary of the English Language*, 1992

**intuitive** ... *adj.* **1.** Of, relating to, or arising from intuition. **2.** Known or perceived through intuition. See Synonyms at **instinctive. 3.** Possessing or demonstrating intuition.... —*The American Heritage Dictionary of the English Language*, 1992

[Note: I've included here, for the record, the three definitions just above. However, they don't convey exactly the meaning that I intend when I use, in this essay, the word *intuitive* as, for example, in the phrase "*By considering gravity, I can answer that question intuitively*." As used in such statements, I intend the word to describe an explanation that is easy to understand and that appears to adequately explain some phenomenon, as contradistinguished from an explanation that is technically rigorous.

—author]

**kinetic energy** *n.* The energy possessed by a body because of its motion, equal to one half of the mass of the body times the square of its speed.

—*The American Heritage Dictionary of the English Language*, 1992

**law of parsimony** *n.* See **Ockham's razor.**

—*The American Heritage Dictionary of the English Language*, 1992

**linear** ... *adj.* *Abbr.* **lin. 1.** Of, relating to, or resembling a line; straight. **2.a.** In, of, describing, described by, or related to a straight line. **b.** Having only one dimension. **3.** Characterized by, composed of, or emphasizing drawn lines rather than painterly effects. **4.** *Botany.* Narrow and elongated with nearly parallel margins: *a linear leaf*.... **—linearly** *adv.*

—*The American Heritage Dictionary of the English Language*, 1992

**nebula** ... *n.*, *pl.* **-lae** ... or **-las**. **1.** *Astronomy.* **a.** A diffuse mass of interstellar dust or gas or both, visible as luminous patches or areas of darkness depending on the way the mass absorbs or reflects incident radiation. **b.** See **galaxy** (sense 1a). **2.** *Pathology.* **a.** A cloudy spot on the cornea. **b.** Cloudiness in the urine. **3.** A liquid medication applied by spraying....

—*The American Heritage Dictionary of the English Language*, 1992

**Ockham's razor** also **Occam's razor** ... *n.* A rule in science and philosophy stating that entities should not be multiplied needlessly. This rule is interpreted to mean that the simplest of two or more competing theories is preferable and that an explanation for unknown phenomena should first be attempted in terms of what is already known. Also called *law of parsimony*. [After William of OCKHAM.]

—*The American Heritage Dictionary of the English Language*, 1992

**parsimony** ... *n.* **1.** Unusual or excessive frugality; extreme economy or stinginess. **2.** Adoption of the simplest assumption in the formulation of a theory or in the interpretation of data, especially in accordance with the rule of Ockham's razor....

—*The American Heritage Dictionary of the English Language*, 1992

**photon** ... *n.* **1.** The quantum of electromagnetic energy, generally regarded as a discrete particle having zero mass, no electric charge, and an indefinitely long lifetime. See table at **subatomic particle. 2.** A unit of retinal illumination, equal to the amount of light that reaches the retina through 1 square millimeter of pupil area from a surface having a brightness of 1 candela per square meter....

—*The American Heritage Dictionary of the English Language*, 1992

**red shift** *n.* An increase in the wavelength of radiation emitted by a celestial body as a consequence of the Doppler effect. [From the fact that the longer wavelengths of light are at the red end of the visible spectrum.]

—*The American Heritage Dictionary of the English Language*, 1992

**rigorous** ... *adj.* **1.** Characterized by or acting with rigor: *a rigorous program to restore physical fitness*. **2.** Full rigors; harsh: *a rigorous climate*. **3.** Rigidly accurate; precise. See Synonyms at **burdensome. —rigorously** *adv.* **—rigorousness** *n.*

—*The American Heritage Dictionary of the English Language*, 1992

**spectrum** ... *n.*, *pl.* **-tra** ... or **-trums. 1.** *Physics.* The distribution of a characteristic of a physical system or phenomenon, especially: **a.** The distribution of energy emit-

ted by a radiant source, as by an incandescent body, arranged in order of wavelengths. **b.** The distribution of atomic or subatomic particles in a system, as in a magnetically resolved molecular beam, arranged in order of masses. **2.** A graphic or photographic representation of such a distribution. **3.a.** A range of values of a quantity or set of related quantities. **b.** A broad sequence or range of related qualities, ideas, or activities: *the whole spectrum of 20th-century thought*....

—*The American Heritage Dictionary of the English Language*, 1992

**spontaneous** ... *adj.* **1.** Happening or arising without apparent external cause; self-generated. **2.** Arising from a natural inclination or impulse and not from external incitement or constraint. **3.** Unconstrained and unstudied in manner or behavior. **4.** Growing without cultivation or human labor; indigenous.....

—*The American Heritage Dictionary of the English Language*, 1992

**supernova** ... *n.*, *pl.* **-vae** ... or **-vas**. A rare celestial phenomenon involving the explosion of most of the material in a star, resulting in an extremely bright, short-lived object that emits vast amounts of energy.

—*The American Heritage Dictionary of the English Language*, 1992

**thermodynamics** ... *n.* **1.** *(used with a sing. verb).* Physics that deals with the relationships between heat and other forms of energy. **2.** *(used with a pl. verb).* Thermodynamic phenomena and processes.

—*The American Heritage Dictionary of the English Language*, 1992

**time dilatation** *n.* The relativistic slowing of a clock that moves with respect to a stationary observer. Also called *time dilation*.

—*The American Heritage Dictionary of the English Language*, 1992

**universe** ... *n.* **1.** All matter and energy, including Earth, the galaxies and all therein, and the contents of intergalactic space, regarded as a whole. **2.a.** The earth together with all its inhabitants and created things. **b.** The human race. **3.** The sphere or realm in which something exists or takes place. **4.** *Logic*. See **universe of discourse. 5.** *Statistics*. See **population** (sense 5)....

—*The American Heritage Dictionary of the English Language*, 1992

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