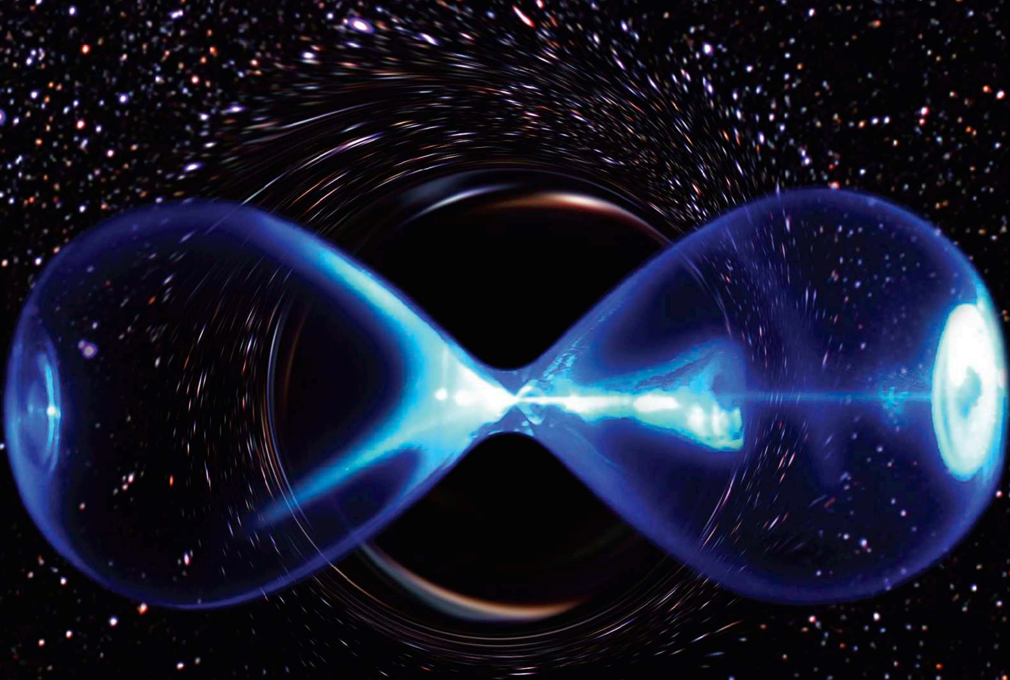
THE SUBSTANCE OF SPACETIME

INFINITY, NOTHINGNESS, AND THE NATURE OF MATTER



ANDREW M. RYAN

Physics/Cosmology $16.99 US

Does Spacetime Exist?

If spacetime does not exist, it certainly does so in a curiously conspicuous way, not at all like other geometric abstractions. Consider this mind-bender: spacetime does not exist at all, but it doesn't exist in the void even more than it doesn't exist in the universe. Is that the description of something that does not exist?

Relativity theory treats spacetime as a mathematical abstraction—a four-dimensional coordinate system analogous to the three dimensions of Cartesian geometry. It does not exist, *per se*. It is not a "thing" in any tangible sense. It merely serves as the background needed to describe the behaviors of the "real" things that exist within it. It is no more than the stage on which the cosmic drama plays out. That's the theory.

What if spacetime exists after all? Are we not obliged to take this stuff seriously and start asking questions? What are its properties? Where did it come from? Is spacetime a simple or a composite thing? Can it be broken into simpler parts? If not, are we compelled to wonder if spacetime is actually the fundamental substance of the universe? And how does this remarkable stuff come together to form the physical world around us?

The Substance of Spacetime sets out to investigate these very mysteries and the results are truly exciting. Treating spacetime, not merely as a coordinate system, but as a real physical substance, opens a window onto reality that would otherwise be impossible to even contemplate.

If spacetime exists, everything changes.

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SUBSTANCE

OF

SPACETIME

Also by Andrew M. Ryan
The Labbitt Halsey Protocol, a novel

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To Jill

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Introduction

What *is*? It is the most basic question of ontology, and has occupied philosophers and scientists ever since man first began plumbing the depths of reality. In its purest form, the question concerns the nature of *sub-stance*—literally, that which is presumed to "stand under" all that exists. This is the stuff that makes something *real*, to which, in some way, an object's properties adhere. It is the existence beneath the thing, the *thing-in-itself*, stripped of its particulars and accidental characteristics.

Through the ages, any number of substances have been proposed. There are mental substances, physical substances, divine substances, mathematical substances, composite substances, and ideal substances, among others. They are frequently described as perfect, atomic, uniform, indivisible, or undifferentiated. Some thinkers have denied the whole notion of substance. We cannot directly experience this hypothetical stuff they argue, but only the superficial properties that objects show to our senses. What then justifies the claim that there is something beneath what we experience?

Though a great deal of effort has been expended on this question, it is far from obvious that we have made any headway whatsoever. Ask a physicist what the fundamental substance is and you will likely get a description of *energy*, either in the guise of multidimensional *strings* or as something that corresponds to the E and the m in $E=mc^2$. But if you press the issue, ask him what this stuff really is, where it came from, or why it behaves as it does, you will discover there is nothing more to the story; it is nothing but a mysterious quantity that makes the equations work. Ask a contemporary philosopher and he will gladly regale you with the history of substance from Heraclitus to Heidegger. But ask him which theory is correct and you will get a blank stare.

As different as the various concepts of substance are, they have one thing in common. They are all utterly impotent. It is impossible to take any particular notion of substance in hand (Leibniz's monads, for example) and apply it to something that exists. One might hope that if a particular substance had anything of value to say about the beings it comprises, we could extrapolate from its characteristics to figure out how objects actually work. Unfortunately, that simply is not the case.

Without exception, concepts of substance are entirely beholden to the workings of the human mind. How we think and perceive and what we believe we know always inform—even determine—our judgments about the nature of reality. Man thinks, "My mind is logical and mathematical, hence reality must be as well." These restrictions on the nature of substance are certainly understandable; if we cannot think, perceive, or know something (if it is neither *empirical* nor *rational*) it cannot be expected to form the basis of a concept. Yet it is not at all axiomatic that reality outside of our own heads is similarly circumscribed by human frailties. Restricting ourselves to substances that can be perceived by the senses or formulated in rational terms simply because those are the skills we have, is reminiscent of the drunk who searches for his car keys under the lamp post because that is where the light is good. With nothing to go by, it is just as likely that the fundamental substance is irrational and imperceptible *and yet exists just the same*.

None of the substances proposed through the ages has ever been successfully applied to reality in order to explain the nature of physical objects. Invariably, the definition of the substance itself is the end of the project. It is as if the philosopher in question believed an intrepid scientist of the future would pick up the ball and run with it, even without an instruction manual or any tangible examples of how to use it. By contrast, the current volume is exactly that *second* book, the instruction manual. Instead of presenting the philosophical thought that got me to this point, I will instead jump ahead and demonstrate how the substance I have uncovered actually works. I decided to do it this way because the world does not need another painstakingly derived but otherwise useless substance. Yes, many fascinating insights were required in order to get here, and I may write about them someday. But a demonstration is always vastly superior to an argument. For the time being, then, this book can be thought of as volume two of a one-part series.

My aim is to explain all that is, the first principle of ontology. But that means I have nothing with which to get started. I cannot very well assume the existence of any substance if it is substance I hope to explain. It appears then that the only way to begin this discussion is to assume *nothing*, and so that is what I will do.

1

Spacetime

The Void

Easily the most perplexing question one can possibly ask is, “Why is there something rather than nothing?” Existence is not an obviously reasonable state of affairs, whereas nothingness does not seem to require any explanation at all. Confronted with an endless void, utterly empty, barren, and cold, one might say, “Well, of course. What did you expect?” But existence, once given any thought at all, quickly becomes an intellectual abomination. It is no wonder that the gods, before they got around to burdening us with all sorts of ethical dicta, first busied themselves with creation. That there are things is more puzzling than any of the things that are.

If the efforts of current cosmologists are any indication, the assumption of nothing is not as easy as it sounds. Typically, it is conceived as a quantum field devoid of matter, but already fortified by the laws, forces, and fields with which physicists are familiar. By contrast, the nothingness I have in mind is what we can call *true nothingness*, an emptiness so complete that it lacks even the structure and energy of a quantum field. To get our bearings, we can think of this brand of nothing as *contentless*, *void*, or *uniformly empty*. These and similar ideas draw attention to the fact that nothingness completely lacks any positive properties. It is defined entirely by absence; it is the opposite of existence. At first glance, this does not bode well for the universe. Without God or something else inexplicable to break the monotony, nothing appears to follow from nothing; *ex nihilo, nihil fit*. This conclusion has certainly been the favorite of philosophers as well as common sense for as far back as one cares to look. It is also the reason modern cosmologists recoil from true nothingness and feel compelled to supplement the void with ready-made quantum fields. But it may be that there is more to the void than meets the eye.

Though it may not yet imply any *thing*, the void does seem to imply infinity and eternity. Placing an edge or boundary somewhere in the void and declaring an end to it involves the imposition of something, and something is more than nothing. Any such boundary violates our assumption as well as raises the question of what lies beyond it. Consequently, assuming nothing implies an infinite expanse of it. Only the *ad hoc* addition of some object—however nebulous or abstract—into the void can prevent it from being infinite. Likewise, there is no temporal beginning or end to the void either. Even if time is defined as nothing more than the passage of events, and there are no events actually occurring, the void *qua* nothingness imposes no restrictions on any hypothetical events that might happen to occur there. For the special case in which there are no events, time can be conceived as simply a *degree of freedom*, much like the three dimensions of space. It makes no difference that there is nothing there, only that, if there were, it would be unrestricted in the temporal dimension just as it is unrestricted in the three spatial dimensions.

It is critical here to note that infinite space and time are not new assumptions but simply an elucidation of the original assumption of nothing. Infinity follows necessarily from nothingness; it is not something that has been added to it. Nothingness *is* four infinite degrees of freedom. It is that which *does not get in the way*. Any object introduced into the void is absolutely unaffected by it. The object is, while the void is not. A philosopher might object here by claiming that I have introduced the notions of *dimension* and *expanse*. Why not assume instead that nothingness is dimensionless? If I were to do that, however, the void would oppose the existence of objects with which we are already familiar, and in that respect, it would not be nothing. Nothingness, after all, is not only or even primarily *way out there*, inaccessible and impossibly distant. Rather, it is all around us, not getting in the way of everything that exists. Only an infinite and eternal four-dimensional expanse—four infinite degrees of freedom—can completely fail to oppose the existence of all that exists. In essence, our familiar four-dimensional world guarantees that nothingness possesses four infinite degrees of freedom.[1]

Infinity

It appears then, that the assumption of nothing implies an infinite, four-dimensional expanse of space and time (not yet *spacetime*, which is significantly different)—still nothing to be sure, but at least a somewhat more interesting version of it. To take another step toward existence we need to examine this curious notion of *infinity* that is inextricably bound to the assumption of nothing.

The first thing to notice is that infinity is an inherently irrational concept. Though we may understand in a strictly formal sense what the word *infinity* means, it is not possible to conjure up an accurate representation of the idea in our minds. The best we can do is acknowledge that however far we go we can always go farther. But man cannot wrap his head around anything truly boundless. Moreover, the machinery of logical and mathematical reasoning also breaks down when applied to infinity. The crux of this breakdown comes from the fact that the *cardinality* (size) of all infinite sets is the same regardless of how those sets are defined. For example, the set of all integers is the same size as the set of all odd numbers even though, intuitively, it seems like

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[1] To be perfectly rigorous here, this claim could be made even less controversial by stating it as a hypothetical, *viz*, that the following theory is [provisionally] based on an infinite, four-dimensional universe. But should it ever be discovered that this assumption is untrue (as it would be if String Theory were proven correct), the theory described in this book would be invalidated. Or, more simply, this theory is true *only* for an infinite four-dimensional universe.

there should be twice as many of the former as the latter. The even numbers are missing from the set of odd numbers but not missing from the set of integers. Therefore, the set of integers must in some sense be the larger of the two even if we concede that both are infinite. But this raises the question of how one infinite set can be any larger than another. They both go on forever.

Any number of paradoxes can be formulated by applying the above observation to hypothetical situations. David Hilbert's paradox of the *Infinite Hotel* is one example. In it we are to imagine a hotel with an infinite number of rooms and then wrestle with various notions of vacancy and occupancy. Specifically, would an infinite number of guests result in full occupancy? The answer appears to be no. If a new guest arrives we simply move the guest in room one to room two, the guest in room two to room three, and so on, making room for the new guest. Since there is no end to the number of rooms, even an infinite number of guests cannot fill them all. In this and every other paradox of infinity the problem centers on treating infinity simultaneously as a *number* and as the concept of unboundedness. A number is a discrete, definable entity, while *unboundedness* is exactly the opposite. All numbers are unique, their values rigorously determined, whereas all unboundedness *qua* infinity is the same. But because we can define infinite sets in much the same way that we define particular numbers, it appears as though different infinities are equal and unequal at the same time.

These sorts of paradoxes are interesting but they are only relevant outside of pure mathematics if there are in fact genuine infinities in the physical world. Currently, physicists reject infinities as meaningless and none of the accepted laws of nature require them. On the contrary, an infinite answer to an equation describing a physical phenomenon is regarded as evidence of a mistake. Consider that if there were any infinite physical quantities they would, by definition, take over the entire cosmos. Infinite gravity would pull everything in with an infinite force. An infinite force would generate an infinite quantity of energy.

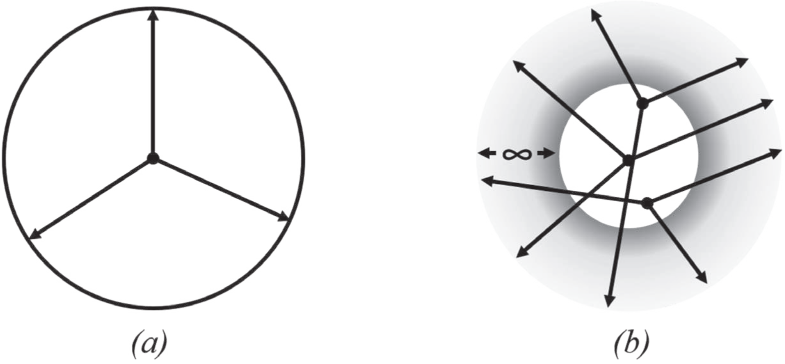

Figure 1.1: Infinite and Euclidean Spheres
While only one point (the center) is equidistant from every point on the surface of a finite, Euclidean sphere (a), every point in the interior of an infinite sphere (b) is equidistant from the surface. Hence, every point in an infinite sphere can be thought of as its center.

Infinite energy in turn would impart an infinite expansive or implosive velocity to everything in the universe. Nothing in our experience justifies these crazy conclusions; hence infinity is never relevant or even possible in the real world.

Yet infinite nothingness appears inescapable. And as with the paradoxes discussed above, it is easy to construct a contradiction between the finite character of any discrete region of the void, and its infinite character taken as a whole. Imagine, for example, an infinite spherical region of the void (**Figure 1.1**); being infinite, the void can contain any number of infinite subregions just as we can define any number of infinite sets using only a subset of the integers (odd numbers, for example). Any discrete point selected anywhere inside of this infinite sphere is by definition an infinite distance from the surface. And because all infinite quantities are equal (equally boundless), every point in the sphere is also an equal distance from the surface. However, the only point in a sphere that is equidistant from every point on the surface is the very center of the sphere. Therefore, the line connecting any point inside the sphere to its surface is a radius of that sphere. That is, every point in the sphere, no matter

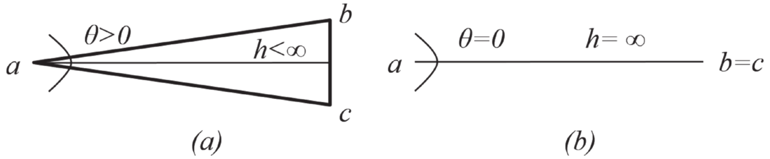

Figure 1.2: Infinite and Euclidean Triangles
As long as the height of the triangle is finite, the angle at *a* is greater than zero and the points *b* and *c* have a positive separation. But when the height becomes infinite, the angle goes to zero and points *b* and *c* become the same point.

where it is, is the same point, namely, the center. The paradox is obvious: every point in an infinite sphere is the center of the sphere, the same point. There is a clear logical contradiction between infinite geometry and Euclidean geometry. Indeed, there is a contradiction between infinity and every variety of math and logic, because every infinity must be treated as both a particular number as well as an equally unbounded quantity. Or again, infinity can be defined in many different (and mutually exclusive) ways, but always ends up equally infinite just the same.

The above paradox is even clearer if we create a simple isosceles triangle (**Figure 1.2**) and vary the height. As the height increases, the angle at *a* decreases, and if the height becomes infinite, the angle becomes zero. However, if this angle becomes zero, points *b* and *c* become the same point. This is true regardless of how far apart in absolute terms *b* and *c* really are. That is, *b* and *c*, from the standpoint of infinity, are the same point even though they are not *really* the same point. Under normal finite conditions, these sorts of paradoxes are no more than interesting intellectual observations having no relationship to reality. But if we are agreed that the void is genuinely and unavoidably infinite, we cannot simply leave this problem unaddressed. The points in an infinite sphere are either all in the center or they are not. Points *b* and *c* either have a particular separation or they do not. The void is either infinite or it is not. In none of these examples can we have it both ways.

From an intuitive perspective, we might try to resolve this matter by pointing out that, with infinite distances at our disposal, it is always possible to "stand back" from an object, however big that object might be, far enough to reduce it to a pin point. Venus, for example, looks to the naked eye like a point, but only because it is so far away. If we launch a space probe to get a closer look, its true size becomes evident. There is no paradox to unravel. But though this might seem to resolve the issue, it ignores the categorical difference between *extremely big* on the one hand and *infinite* on the other. As we increase the height of our triangle, the distance of *a* from *b* and *c* is not merely great enough to make *b* and *c* look the same, it is great enough to render them mathematically as the exact same point. The angle at *a* from an infinite distance is not just very, very small, it is exactly zero. And this is true whether we initially define the base to be an inch or a light year wide. This disparity results in a real, intractable mathematical contradiction. There appears to be a kind of *tension* between the Euclidean and infinite characters of the points *b* and *c*. The question now is, do we treat this tension as entirely theoretical, or is it in some sense real?

Eternity

Whether or not the tension between Euclidean geometry and infinite geometry is real as opposed to entirely conceptual, we can, nonetheless, speculate about what would happen if this tension tried to work itself out. In general, any two discretely defined points within an infinite space *tend* toward the same point. That is, however distant from one another two points are when conceived from a finite perspective, they are the same point when conceived from an infinite perspective. That disparity is the essence of the geometric tension between them. Even so, it seems perfectly obvious that this tension, the tendency of points to merge, is merely a figure of speech. The void after all is absolute nothingness. And in any case, points have no physical extent. They are nothing but mathematical abstractions, *infinitesimals*. It is meaningless to ascribe to them any characteristics whatsoever, particularly anything as definite as a tendency to merge with other points. Or is it?

One outstanding question from cosmology concerns the ultimate fate of our universe. Right now it is expanding and there is some doubt about whether it will continue to do so or will instead reverse course one day and begin contracting. I will address this question in Chapter 4. For now we can treat it as simply a thought experiment. In particular, what will happen if the cosmos goes on expanding *forever*? The void provides an infinite degree of spatiotemporal freedom to anything that exists. If the momentum of expansion exceeds any force of contraction, there will be, literally, *nothing* out there to get in its way. So where does it go?

Mathematically, if we divide any quantity, however large, by infinity we get zero, expressed by the equation,

$$x/\infty = 0.$$

Put simply, if we distribute any finite amount of stuff over an infinite expanse (**Figure 1.3**) it will eventually cease to exist altogether; becoming infinitely diffuse is theoretically equivalent to disappearing. If our cosmos does not reverse course, it has no other choice but to succumb to this strange equation. But because it is expanding at a finite rate, it will require an eternity to undergo this transformation. As I discussed earlier, infinite time (eternity) is, like infinite space, an infinite degree of freedom. Eternity says, “Take all the time you need,” not, “This is never going to end.” This infinite degree of temporal freedom offers no resistance to any process that occurs within it, but it is not something over and above that process. Time does not *flow*; it is not a force that acts on things as if from outside. Physical phenomena tend to evolve in a specific way, from more to less orderly (increasing entropy), but that fact reflects only the phenomena themselves, not the temporal degree of freedom that permits them to occur. If no phenomena are occurring, time,

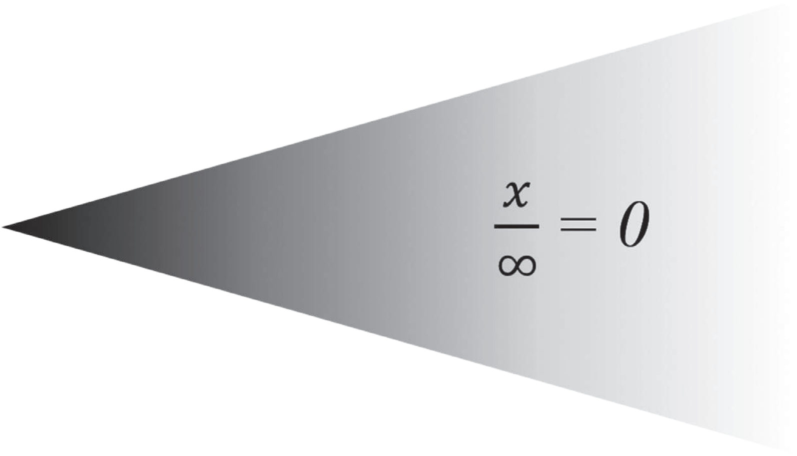

Figure 1.3: Infinity
Any finite quantity ceases to exist when it becomes infinitely diffuse.

like space, appears as nothingness—with no beginning and no end. However, as merely a facet of nothingness, we are under no obligation to explain how it has no beginning. It is not as though time, *qua* nothingness, has always been flowing at some finite rate and could not possibly have gotten here (the present moment) had it not started at some particular time.

Once our cosmos has "taken all the time it needs" in order to blink out of existence according to $x/\infty = 0$, we are confronted with the same sort of paradox, the same sort of tension, between Euclidean and infinite geometry that I introduced above. In particular, it now makes sense to solve the equation for x, suggesting that any infinite expanse of nothingness is equivalent to some specific quantity of something, given by:

$$x = 0 \cdot \infty.$$

That is, if we gather up an infinite quantity of nothing we do not have nothing anymore, but instead we have some particular amount of something. Without question, it is much easier to swallow this idea when we imagine something (e.g., our cosmos) ceasing to exist after eternal expansion than it is when we try to imagine something coming into existence after, presumably, an eternal collapse of nothingness itself. Yet, theoretically, there is no difference. All that distinguishes the two cases is the physical mechanism. We already know our cosmos is expanding, so it requires little to imagine it expanding forever. On the other hand, it borders on the absurd that an infinite expanse of infinitesimal points, nothingness itself, might somehow coalesce into our entire universe.

Ex Nihilo – The Eternal Dialectic

The tension (dialectic) between infinite and Euclidean geometries strikes common sense as nothing more than a conceptual subtlety, an entirely abstract phenomenon or mathematical artifact. Logic dictates that the presence of a paradox is evidence of an error in reasoning. It is most definitely not evidence that reality itself is paradoxical. Yet the void is stubbornly infinite while the four dimensions of space and time are equally stubbornly Euclidean (finite). Therefore, notwithstanding its seemingly abstract nature, in the absence of any compelling reason to doubt it, we must at least consider the possibility that this tension is real, that the infinite-finite dialectic has a physical effect.

The entities to which this tension applies are dimensionless, infinitesimal points—the fundamental elements of any geometry. Being infinitesimal, a point has no mass, no size, no extent of any kind. It is, at least from a Euclidean perspective, nonexistent, a mere abstraction. Therefore, whether or not it makes any sense to say so, it would require no effort to move such an entity. Having no mass, no force is required to push a point around. Or again, having zero mass, a *zero force* would suffice to move a point, particularly if we had an eternity over which to apply such a force. And it is exactly a zero force that we have at our disposal, namely, the theoretical tendency of points to merge in order to reconcile the dialectic between infinite and finite geometries.

The tension between points in the void is a formal abstraction, a zero force. However, given that the entities to which this force applies are also formal abstractions and have zero mass, and that an infinite temporal span is available over which to apply this force, it is not only possible but absolutely certain that points will gradually coalesce. Or again, though this tension is apparently nonexistent (nonphysical), so too are the points to which it applies—they both belong to the same ontological category. In essence, eternity transforms nothing into something just as it turns something into nothing. Infinite time and infinite space come together and give rise to *spacetime*, the fundamental substance of reality.

Collapse

To get a sense of what is going on here, consider the infinite spherical sub-region I mentioned earlier. In that case, the geometric tension manifests itself as a tendency of points to coalesce at the Euclidean center of the sphere. This can be understood as a tendency of points to merge or as a weak (infinitesimal) attraction between nearby points. As the density of spacetime in the central region increases, so too does the force of attraction of that region on the surrounding space. Each point is attempting to merge with all the other points within the infinite sphere. The more spacetime points there are in a region, the more powerfully that region attracts the ambient space in its vicinity. Over time, the rate of convergence increases in proportion to the density of spacetime in the central region.

It is not obvious that it makes any sense to talk about how long this process takes. With no events other than the collapse of space itself, time shows itself for what it really is, merely an infinite degree of freedom. There is *nothing* at this point in the story against which we can judge its rate. The phenomenon of spacetime collapse plays itself out according to its own dynamics. It could just as easily be thought of as mind numbingly slow as incomprehensibly fast. All that changes is the relative rate at which, as the attractive force in the center increases, spacetime accumulates. Eventually, therefore, it stands to reason that the convergence occurs at a virtually (perhaps actually) infinite rate, pulling in space fast enough to transform the nothingness of the void into the somethingness of spacetime.

One critical aspect of this phenomenon is that the tension, the dialectic, between infinite and finite geometries is a genuine *tension*. As such, it pulls in both directions, driven by both paradoxical poles. It is not, as the above discussion might at first suggest, committed to transforming Euclidean geometry entirely into its infinite counterpart. It seeks an *equilibrium state* midway between the two, which is why I have introduced the seemingly incongruous term, *dialectic*, to describe the relationship. As a result, the attractive force of the increasingly dense spacetime at the center of a collapsing region will eventually begin stretching the space way out at the infinitely distant surface of that sphere. Over some indefinite period this stretching will become critical. And after building up for eternity, the tension between the collapsing sphere and the rest of the void will finally *rip* the space connecting them. Space itself tears under the stress.

The *ripping* of space along the surface of an infinite sphere is an inherently incomprehensible concept, depending as it does on the also incomprehensible concept of infinity. In some respect, therefore, it should be treated metaphorically. Referring to Figure 4, we can see that the tension on the surface of an infinite sphere is also infinite, resulting in an infinite implosive velocity of the space at that location. To say that this infinitely imploding surface rips away from the rest of the void is simply to say that this phenomenon, as a whole, extricates itself from the rest of the void so as to become a discrete, bounded cosmic entity. *Rip*, then, is defined as: moving away (imploding) at an infinite rate. It is not necessary (though it is, arguably, permissible) to imagine, at the extremity of the infinite collapsing region, a violent physical separation of two entities that were previously connected.

When this rip occurs, the surface of the sphere snaps down toward the core of its region. The velocity with which any

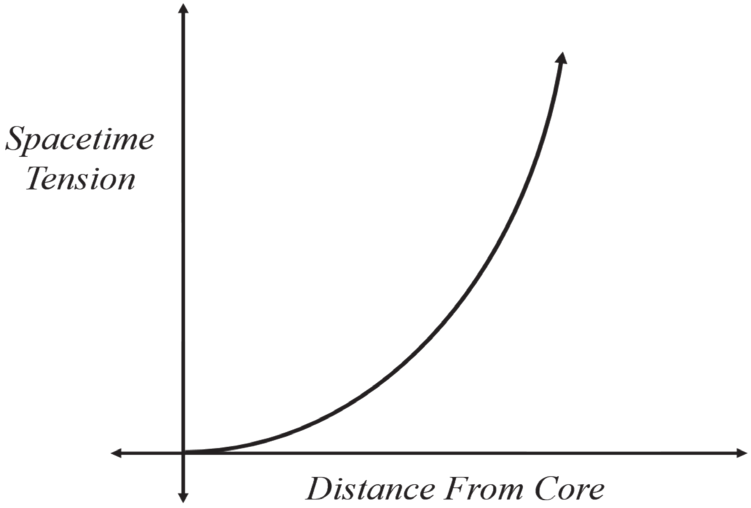

Figure 1.4: Cosmic Snap
The tension between adjacent spacetime points increases in proportion to the square of the distance from the core. That tension, in turn, is responsible for the distribution of velocities when the surface of the infinite region rips free of the rest of the void.

point in space moves toward the core is directly proportionate to the tension (**Figure 1.4**) it possessed when the surface finally snapped. And that means the velocity of each point is proportionate to the square of its distance from the center. The farther a point is from the center the faster it moves toward that center, because that is where the tension was greatest when the surface snapped free. This phenomenon is essential to the subsequent evolution of our cosmos. What we will see in the next chapter is that the Big Bang depended on extremely high but also perfectly uniform pressure. A typical collapsing mass does not reach a uniform pressure. The pressure in a collapsing protostellar cloud of hydrogen, for example, is greatest in the center. Such an uneven distribution of densities would not have created our universe. Only because the surface of the collapsing region of space was held back by its resistance to stretching could it then snap down toward the center with exactly the right distribution of radial velocities to arrive at the core all at the same moment. Moreover,

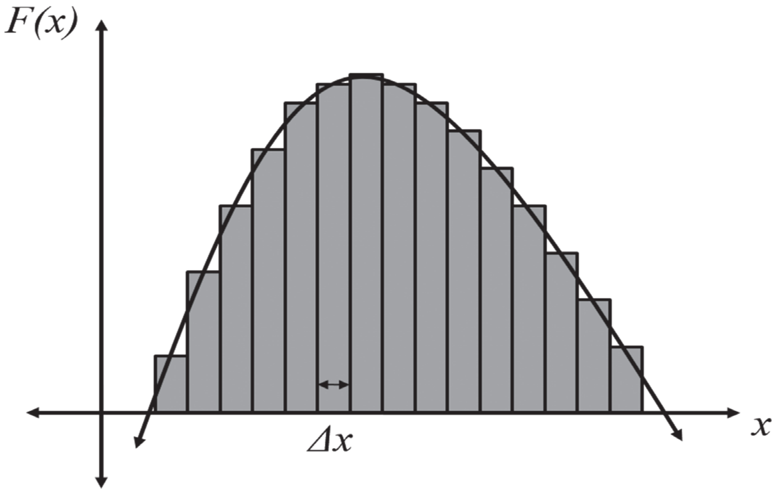

Figure 1.5: Infinitesimals
In integral calculus, the area under a curve is calculated by adding together an infinite number of rectangles. As Δx approaches zero, the rectangles become infinitesimal in size but infinitely numerous. Yet because the region is bounded—by the function and the x-axis—even an infinite number of them results in a finite area.

the extreme high pressure of the Big Bang would also not have been reached had the velocity of the collapsing space not been so dramatically increased by the snapping of the sphere away from the rest of the void. This snap instantly converted an eternity of pent up potential energy into the kinetic energy that ultimately collapsed space into the condensed sphere that exploded into our cosmos.

Something else important occurs when the spherical region tears away from the rest of the void. Our cosmos suddenly becomes a *bounded*, though still infinite, entity. When we calculate the area of a region (**Figure 1.5**) under, for example, a parabola, we use an infinite number of infinitesimal rectangles. But because the region is bounded we get a finite answer. Our universe, therefore, can contain an infinite number of spacetime points and yet still exhibit the finitude associated with a bounded phenomenon. That is how we can end up with a finite quantity of mass and energy in our universe despite the fact that it is composed of an infinite quantity of nothingness. In the equation, $x = 0 \cdot \infty$, the number x is a discrete finite value because the infinity involved is bounded in some way. Presumably, if the entire void collapsed into one location, x would be infinite as well. However, I suspect such a fanciful notion as *entire void* is utterly meaningless, even by comparison to the mind-bending ideas we've been dealing with thus far.

The Cosmological Constant

The region of spacetime that became our cosmos ripped free of the void when the tension between its infinite and Euclidean poles exceeded its maximum threshold at the surface of the sphere. The Euclidean pole pulled out toward the void as the infinite pole pulled in toward the center. As a result, the total quantity of spacetime that constitutes a universe is a *multiversal* constant; all universes have the same mass. Any collapsing region tears away from the void at exactly the same point in its evolution, right as the tension between its infinite and finite poles reaches its maximum threshold.

Furthermore, the tension between the adjacent points in the ensuing universe reflects the total quantity of spacetime in the region at the moment it was separated from the void. As I argued earlier, the force of attraction between adjacent points is a function of their density. This force manifests itself, even to this day, as the *coherence* of spacetime, its inherent resistance to both excessive compression and decompression. The exact value of this coherence is the *cosmological constant* itself, and it underpins every other constant in the universe, from the vacuum pressure to the mass of a neutron. When spacetime is stretched, its infinite pole *pulls* it back toward its equilibrium pressure. If it is compressed, its finite pole *pushes* out against whatever is compressing it. The value of this equilibrium pressure, the cosmological constant, reflects the quantity of spacetime that broke away from the rest of the void. If there were more of it, the equilibrium pressure would be higher, reflecting the greater attractive force exerted by the additional spacetime points. If there were less, it would be lower because the finite pole has no problem with points at greater separations. As we will see, the equilibrium pressure, the coherence, of spacetime dictates the behavior of everything in the universe. It is the fundamental force of nature from which all the others are derived.

Substance (A Brief Overview)

Though its origin may be difficult to comprehend, spacetime itself is remarkably simple stuff. Having collapsed out of the infinite void over eternity, it is nothing but compressed space. It became compressed when the edges of the region from which it collapsed snapped free from the rest of the void, catapulting it toward the center at a velocity proportionate to the square of its distance from the center. The snap transformed eons of built-up potential energy into a phenomenal quantity of kinetic energy that crushed space well past its equilibrium pressure, all the way down into an exceedingly and uniformly dense sphere—a kind of Euclidean minimum. We know an equilibrium pressure exists because the collapse of space from the void depended on the internal attraction of space when it was *below* this pressure, whereas the tremendous force of the Big Bang, as well as the current expansion of the cosmos, depends on the internal repulsion of space when *above* this pressure. Indeed, we will find that the pressure of intergalactic space (~2.7 on the Kelvin scale) is very close to, though slightly higher than, the equilibrium pressure of spacetime.

All of the energy in the cosmos is contained in the pressure and velocity of spacetime. In the current epoch, because it is marked by the ongoing decompression of the Big Bang, positive pressure dominates. Though, as I have just shown, negative pressure dominates the long spans of time during which spacetime coalesces out of the void. Still, because negative pressure plays a critical role even in our epoch, we must define *energy* as the *absolute value* of the pressure of spacetime[2]. As a result, negative spacetime pressure (in the form of implosive force) yields positive energy. From this we can conclude, based on $E=mc^2$, that mass is also defined by the pressure of spacetime. Mass composed of positive pressure spacetime is *matter*; mass composed of negative pressure spacetime is *antimatter*. The quantity of matter greatly exceeds the quantity of antimatter because our current epoch is dominated by positive pressure spacetime; its finite, Euclidean pole is actively striving to restore equilibrium. One could argue that the interminable span during which spacetime collapses out of the void is characterized by a preponderance of antimatter. However, as I will show, there are no naturally occurring particles of antimatter. Spacetime itself is neither matter nor energy, but is the fundamental substance on which they both depend. What we normally think of as *solid matter* is composed of spacetime that still possesses the enormous compression value associated with the Big Bang. In the following chapter I will explain how this phenomenon is possible.

Traditionally, a gravitational field is represented as spacetime *curvature* on a two-dimensional surface. Clearly this is meant as an analogy. Curvature in three dimensions is geometrically meaningless. But it is generally left to the imagination to decide what the genuine, three-dimensional equivalent might be. Transforming this analogy into a meaningful reality (**Figure 1.6**), we get, not spacetime curvature, but a spacetime *pressure gradient*. The depth of a two-dimensional spacetime curve is analogous to the intensity of its pressure in a real three-dimensional universe. In every case in which curvature seemed to make sense, pressure gradients make far more sense. And in every other case, including within the atomic nucleus, curvature only obscures the truth, while pressure gradients make it perfectly clear.

In summary, every phenomenon in the universe can

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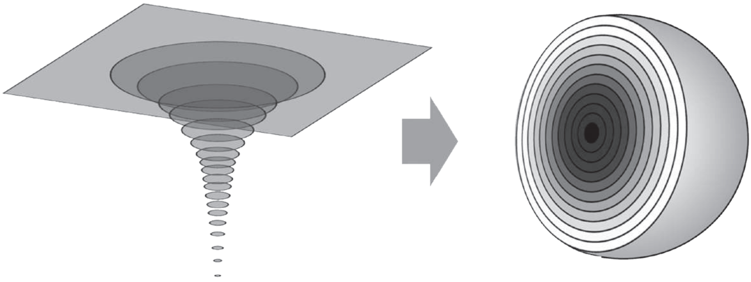
[2] The relationship between pressure and energy is not linear, but hyperbolic, related to the Lorentz Factor. As spacetime approaches extreme pressures (related to either high velocities or strong gravitational fields) the corresponding energy increases without bound.



Two Dimensional Spacetime Curve

Three Dimensional Spacetime Pressure Gradient

Figure 1.6: Spacetime Curvature
A three-dimensional curve is meaningless, whereas anything but a three-dimensional pressure gradient is meaningless. The traditional analogy of spacetime curvature, therefore, translates into a pressure gradient in a real three-dimensional universe.

be understood as the interactions between regions of different spacetime pressure. Spacetime strives to reach its equilibrium state. In our epoch, that means most phenomena will be dominated by high pressure, expansive or explosive events. Differences in pressure manifest themselves within spacetime gradients, not curves. A three-dimensional curve is meaningless, whereas anything but a three-dimensional pressure gradient is meaningless. This brief overview is enough to get us started and these concepts will become clearer as they are applied to actual phenomena. We now know enough to see how matter arises from compressed spacetime. But first there is one final order of business before we move on.

I started this book by asking the most basic question of ontology. What *is*? We now know enough to give a provisional answer.

Reality is the evolution of the eternal dialectic of infinity and finitude. The tension between these two paradoxical poles of Nothingness manifests itself in Being as the coherence of space and time—the equilibrium pressure of spacetime.

As promised, the fundamental substance of the universe is both irrational and imperceptible and yet exists just the same. The rest of this book is devoted to proving beyond any reasonable doubt that the above statement is the *Law of Physics*—the ontological principle underlying all that *is*.

2

Protons

The Big Bang

When the resistance of spacetime to additional compression finally overcomes the tremendous kinetic energy of its collapse, it is left as a hyper-compressed sphere of perfectly uniform density. This uniformity is critical and is the result of the snap, the tearing of space, along the surface of an infinite bounded region. Every point in space is accelerated toward the center at a rate proportionate to its tension when the sphere snapped free of the void. That tension is equal to the square of the distance of a point from the core. Hence, the entire mass arrives at the core simultaneously, resulting in a sphere of uniform pressure and density. There is no need to assume this sphere is a *singularity*. In fact, a singularity would imply infinite potential energy, and while the Big Bang was certainly impressive, there is no evidence it was infinite. The instant it comes to a halt it immediately begins decompressing at a rate proportionate to the Lorentz Factor associated with its internal pressure.

As cosmologists have already suggested (though for different reasons) the first fraction of a second saw the nascent cosmos expand to many times its initial volume and at many times the speed of light. The first question we might ask is why the universe at its maximum compression does not simply collapse into a singularity under its own gravitational pull as predicted by Relativity Theory. The answer is that spacetime is always repulsive at pressures above its equilibrium value—when its finite pole dominates its infinite pole. There are no exceptions.

Gravity is not simply a measure of the total mass of an object. To form a gravitational field there must be a spacetime pressure gradient. In its initial condition, there is no spacetime field, only the void, surrounding the cosmos. And within the sphere of spacetime itself the pressure is equal everywhere; no gradient means no gravity. In general, spacetime, when above its equilibrium pressure and not organized into complex matter (atoms), is not attracted but repelled by gravitational fields. The Big Bang is explosive, pure and simple. There is no paradox.

In the tiny fraction of a second after the Big Bang, the universe expands at a preposterously high, inflationary velocity, far above the speed of light, proportionate (according to the Lorentz Factor) only to its internal pressure. This is so because the void surrounding the expanding sphere offers no resistance to its expansion. This dramatic increase in volume is accompanied by a correspondingly precipitous drop in pressure but not, as we might expect, uniformly everywhere at the same rate.

The initial velocity of the inflationary expansion is proportionate to the initial pressure. This velocity cannot be slowed because there is no compressed spacetime ("normal space") occupying the void into which the universe is expanding.[1] The void as always does not get in the way. As a result, except for the first instant, the actual expansion rate of the universe exceeds the preferred expansion rate and by an ever increasing amount. The internal pressure of the expanding sphere drops precipitously as the volume increases, but the velocity continues to increase. The velocity increases (the universe accelerates) because of the diminishing but still positive force applied by the decompressing spacetime, and because there is nothing (the void) to slow it down.[2] Had the sphere begun its expansion at a lower pressure,

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[1] The speed of light in a vacuum, *c*, is its speed through spacetime at its equilibrium pressure. There is no analogous speed limit for objects traveling through the void. Interestingly, Newtonian physics applies precisely, at all velocities, in the void.

[2] To eliminate any ambiguity here, the *force* in question is the finite pole of the eternal dialectic between infinity and finitude. As described in Chapter 1, the infinite pole of absolute nothingness tends to pull space together, while the finite pole tends to push it apart. The force of expansion provided by the finite pole is

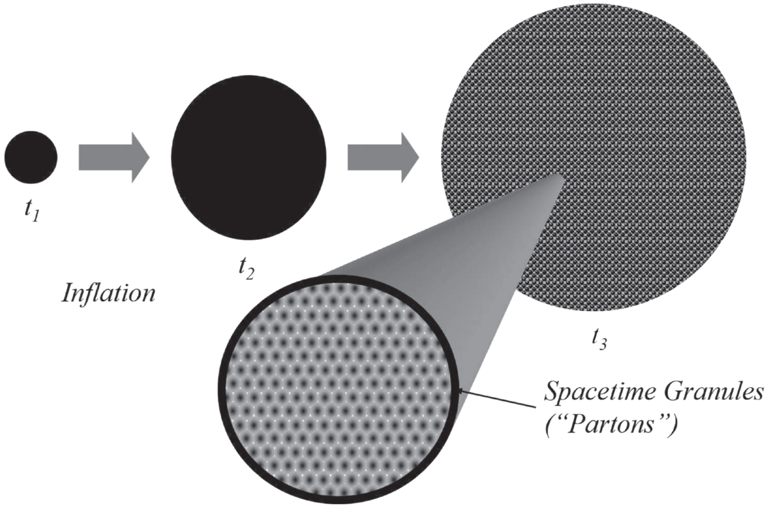

Figure 2.1: Spacetime Granule Formation
During the inflationary period, the pressure drops while the expansive velocity continues to increase. The disparity between the accelerating expansion of the whole cosmos and the slowing expansion of individual points results in the formation of spacetime granules.

the expansion rate would have been lower by a proportionate amount. Therefore, the early expansion of the universe results in an ever increasing disparity between the actual expansion rate and its preferred or necessary (as dictated by the finite pole) expansion rate. That disparity leads to the formation of *spacetime granules* (**Figure 2.1**).

Unlike a standard explosion, the Big Bang is not composed of a large quantity of inert matter being propelled away from a center of detonation. Every single point in the expanding sphere contributes equally to the expansion and propels itself away from neighboring points with equal intensity.[3] At the very first moment, the repulsion of those spacetime points manifests

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currently referred to as *Dark Energy*, and it performs the same function today that it did during the Big Bang. The infinite pole, then, could be referred to as negative dark energy.

[3] In this context, the word *point* does not refer, as in Chapter 1, to an infinitesimal spacetime point but rather to a very small (sub-nucleonic) discrete region. Though it is small, it is composed of an infinite number of spacetime points, just like everything else that exists.

itself in the expansion of the entire cosmos. As the pressure drops, the intensity of repulsion (the acceleration) drops proportionately though the overall velocity continues to increase. That means the expansion of each granule within the sphere is exceeded by the expansion of the universe as a whole. Something has to give. Very soon after the bang, the individual granules within the sphere have plenty of room to expand at a rate proportionate to their decreased pressures. If we look closely at one of these granules, we see that its own internal pressure demands a rate of expansion considerably lower than that of the whole sphere, and indeed it is now expanding at exactly that lower rate. Each one of these granules constitutes a local expansion that is slowing in proportion to its decreasing pressure, even as the whole cosmos is accelerating geometrically. Each granule of spacetime is a pressure gradient, denser in the center and progressively less dense as it approaches the limits of the adjacent granules. At the surfaces of these gradients the spacetime rapidly approaches its equilibrium value because the volume it is expected to fill vastly exceeds the lower rate at which it is now expanding.

Very quickly, the pressure at the surfaces of these granules drops all the way to the spacetime equilibrium pressure (SEP). To reiterate, the cosmological constant is the pressure of spacetime at which its infinite and finite poles are perfectly balanced. When this happens, the granules begin to exert an increasingly powerful resistance to any further expansion; the infinite pole begins to exert itself. However, the momentum of the entire cosmos greatly exceeds this resistance and it keeps right on expanding at the same breakneck pace. This moment, when the increasing volume of the cosmos outstrips the ability of the expanding granules to fill it *without their surfaces falling below the equilibrium pressure of spacetime*, marks a major event in the evolution of the universe.

So long as the granules are pushing out against the expanding cosmos, everything proceeds apace without any significant changes. After all, the goal of spacetime is to reach its equilibrium pressure. But as soon as the geometrically expanding volume of the cosmic sphere reaches the point at which the surfaces of the granules are no longer pushing but are instead being pulled, spacetime quickly changes course. The resistance of spacetime to stretching is analogous to the surface tension of water, except that it increases in intensity with increased stretching. If we imagine the whole universe at this moment, we see a huge expanse of granules with their surfaces under increasing stress from the expanding sphere. Given the dynamics of a spherical expansion, the rate at which any two granules are moving apart is proportionate to the distance between them. Granules on opposite sides of the sphere are moving apart much faster than two adjacent granules. Also, the strength of the attraction along the surfaces of any two granules is related to the intrinsic resistance of spacetime to further stretching—to the force exerted by the infinite pole. Essentially, we have a tug of war between the expanding sphere and the attractive granules. Very quickly, this unstable state of affairs must be resolved.

What happens is that the universe fractures into an inconceivably complex network (**Figure 2.2**) of interlaced *filaments*, the scale of which corresponds to the distance at which the attraction between the granules is just barely exceeded by the pull of the expanding sphere. For the sake of simplicity, I will assume that a typical filament ranges anywhere from a few centimeters or so in diameter to no more than a few kilometers. The ideas to follow are not dependent on the exact dimensions, just so long as they are much larger than the granules and much smaller than stars—roughly halfway between the extremes of magnitude that characterize the cosmos. Because the fracture of the cosmic sphere is perfectly symmetrical, the exact geometry of the filaments is invariably chaotic, balanced on a knife-edge between the competing forces. What this means is that neither the momentum of cosmic expansion nor the surface tension of adjacent granules dominates the phenomenon. And when com-

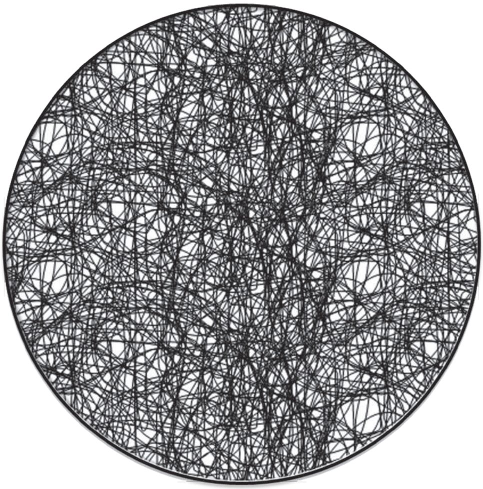

Figure 2.2: Partonic Filaments

A view of the cosmos at the end of the inflationary period. Because this shape is a fractal, this view could be 100 kilometers or 100 million light years across. The large-scale isotropy and small-scale anisotropy of the universe is a consequence of this fracturing process. A computer simulation will no doubt reveal that the actual shape is far more complex than the one pictured here. But it will, like this one, be a highly compressed analog of the observed filamentous architecture of the cosmos.

peting forces are balanced so precisely, the resulting geometry naturally reflects this balance at every location and at every scale—a shape referred to as a *fractal*.

Deceleration

Before we continue our investigation into the formation of protons, we must take note of another consequence of the critical moment following the inflationary period. As mentioned, the rapidly expanding sphere of the cosmos was in a tug of war with the intrinsic attraction, the surface tension, of the granules. That war resolved itself in the formation of filaments of granules. But in so doing the cosmos was dramatically decelerated as it was forced to break the bonds between the granules along the surfaces of all of those filaments. This is important because at its highest rate of expansion, the cosmos would have been flung to the far reaches of the void in very short order had something not arrested its motion. The collective inhibitory effect of pulling apart the granules—borrowing the terminology of particle physics, I will refer to these granules as *partons* from now on—along the surfaces of the filaments slowed the cosmic expansion rate to a more familiar value.

Looking more closely at these filaments, we can see that the total surface area of the cosmos—the total surface area of all the filaments taken together—is proportionate to the force that was needed to separate them. The finer the structure of the network (the smaller they are), the greater the total surface area. That surface area in turn is proportionate to the surface tension that held those partons together. And each parton was bonded to adjacent partons with an equal force. The amount of force required to separate the filaments, therefore, is proportionate to the number of partons actually separated, and that is proportionate to the total surface area of the entire network taken as a whole. Consequently, the amount of momentum sapped from the rapidly expanding cosmos can be precisely calibrated. If the filaments were large (low total surface area, implying fewer broken partonic bonds) the cosmos would have lost relatively little momentum while separating them. Correlatively, if the filaments were small (high total surface area, implying more broken partonic bonds) the cosmos would have been slowed much more. So the question now is: How much was the universe slowed? The answer is subtle but very important.

Scientists are understandably made queasy by phenomena that could have evolved differently but seem to be very precisely calibrated to give us the cosmos as we actually find it. The exact value of the cosmological constant (equilibrium pressure of spacetime), the size of a proton, the extreme weakness of gravity compared to the other forces, etc., seem unreasonably perfect for life as we know it. Such unlikely coincidences are more like winning the lottery than discovering a physical law, and often prompt uncomfortable applications of the anthropic principle. When we find an event such as the deceleration of the initial inflation of the Big Bang that could have happened along a continuum of values, we need to offer a reason that it turned out the way it did that does not involve dumb luck. We need to explain why the cosmos, expanding at perhaps millions of times the speed of light, was slowed to a dead stop all at once even though it could have been slowed far less, allowing it to continue expanding off into the void and leaving matter too thinly distributed to create any complex and interesting configurations. Thankfully, in this case there is a good explanation.

When the cosmos fractures into filaments, there are two important considerations: the momentum of the cosmos as a whole and the attraction or surface tension binding adjacent partons to one another. Once the pressure along the surfaces of the partons has dropped below the equilibrium value of spacetime, each one exerts an equal—and increasing—attraction on adjacent partons. Across the entire cosmos, the total attractive force contained in these interpartonic bonds exceeds the total momentum of the expanding universe. That may sound like a bold claim, but it follows from an extrapolation of the behavior of any two adjacent partons. Regardless of how rapidly the universe expands, its speed is driven by the expansive ambitions of the individual partons, and no two adjacent partons repel one another with more force than the breaking point of spacetime itself. Indeed, any two adjacent partons are nearly stationary with respect to one another and are highly attractive at their surfaces. Spacetime attempts to reach its equilibrium pressure by expanding, but that expansion is checked by its equally strong resistance to stretching below its equilibrium pressure. It does not behave like compressed gas being released into space. Its resistance to expansion below its equilibrium pressure holds it together no matter how high its initial pressure or how rapid its initial expansion. Therefore, no two adjacent partons taken in isolation from the whole can repel one another with enough force, regardless of their initial pressures, to break the bond on their surfaces. That means that, collectively, the force of attraction between all the partons exceeds the momentum of the universe.

Though the *total* attractive force is greater than the *total* momentum, that is only because the *collective* effect of the interpartonic bonds is so great. Individually, partons are very tiny and their bonds are—at least by comparison with total cosmic momentum—very weak. What we need to do is look at the conditions just before the universe fractures. At that moment the total momentum of the cosmos is devoted to stretching the interpartonic bonds. If that momentum exceeded the total bond strength (which we have seen that it does not) then the cosmos would break apart in such a way that much momentum would remain and the filaments would continue expanding away from each other at great speeds, possibly becoming too distant from one another to form the universe as we know it. But because the collective bond strength exceeds this momentum, we have an equilibrium condition. And wherever an equilibrium condition exists, the resolution must conform to that equilibrium.

At the moment the cosmos fractures, the interpartonic bonds are stretched near their breaking point. But because their total strength exceeds cosmic momentum, only a specific fraction of them must break in order to restore equilibrium. As we have seen, the total surface area of the resulting network of filaments is proportionate to the force required to create it, and that force is exactly equal to the momentum of the cosmos when the fracture occurs. The number of interpartonic bonds that break will be the absolute minimum necessary to counterbalance the momentum. Or, looking at it from the opposite perspective, the momentum of the universe, because it is less than the total interpartonic force, breaks exactly the number of bonds that correspond with its total energy. Either way we look at it, the momentum of the cosmos is completely sapped when it fractures the partons into filaments, and the size of those filaments is directly related to the momentum so sapped. In brief, the universe comes to a dead stop. The inflationary expansion is over.

It may be difficult to imagine, but we are still within the first few moments[4] after the Big Bang. The partons of which our network of filaments is composed are nothing but unstable spacetime gradients—minuscule bits of Big Bang. Left to themselves they would decay in far less than the blink of an eye. Yet when we consider these events at extremely small time increments, we can resolve the amazing structure that develops. Now we need to look more closely at one of these filaments.

Protogenesis

When the surface tension holding the cosmos together fractures, creating the filaments of partons, those partons recoil at their surfaces back toward the equilibrium pressure of spacetime. I point this out only because it implies that there is no longer any rapid expansion going on within the filaments, just as there is no longer any rapid expansion generally. The filaments are separated from one another and their behavior is determined only by their own internal properties, which are determined entirely by the partons of which they are composed.

Partons are highly unstable, each one a moment of expansion, a spacetime pressure gradient that wants nothing more than to explode outward until it reaches its equilibrium pressure. That being the case, whatever happens next must happen very rapidly in order to preserve the structure implied by these ephemeral entities. If we look closely at the filaments, what we find is a very important asymmetry. Now that the filaments are separated, drifting alone in the void, the partons near the surface are less constrained than the ones in the interior. In other words, the outer partons can expand more freely than the inner partons. It might seem that the filaments would simply evaporate, starting from the surface and moving toward the center. But that is not what happens. Bear in mind, the surfaces of the partons

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[4] Current theory has provided very precise predictions for the duration of this brief inflationary period. Clearly, those predictions will not apply to this new theory, though it is still quite likely that the inflationary period was very brief.

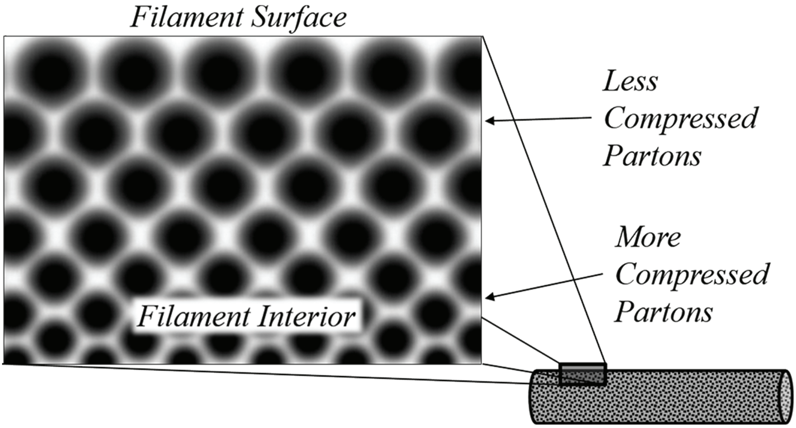

Figure 2.3: Filament Surface
The partons on the surface of the filaments are less constrained and decompress more freely than the partons in the interior.

are mutually attractive so long as they are at or below their equilibrium pressures. Though the partons do expand somewhat, they do not drift apart, and this is where the asymmetry in pressure (between the surface and interior of the filaments) becomes critical. It is also important to note that because the partons are moving through the void (at least near the surfaces of the filaments), their rectilinear velocities can greatly exceed their expansive velocities; they can move around a great deal before they decay. Movement through the void can be superluminal (essentially infinite), whereas the expansion of the partons is proportionate only to their internal pressures.

As the outer partons expand, their pressures drop. As their pressures drop, adjacent partons, those closer to the center, move into the slightly more decompressed partons (**Figure 2.3)**. Every parton attempts to expand into whatever surrounding region offers the least resistance, and that means partons closer to the center (more compressed) rush into the relatively low pressure regions occupied by partons closer to the surface (less compressed). This movement of the more compressed partons into the less compressed ones tends to recompress those

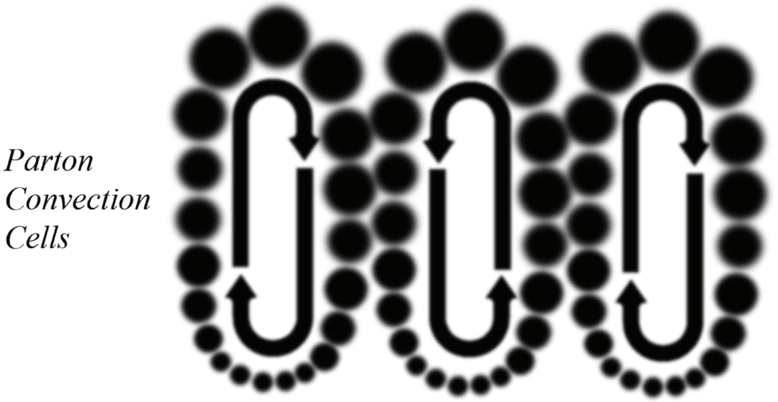

Figure 2.4: Parton Convection Cells
Because the partons are mutually attractive at their surfaces, instead of flying apart they exhibit convection currents. The filaments boil.

that were attempting to decompress, pushing them back into the filament away from the surface. Overall, this motion results in a vast number of localized convection currents, partons alternately decompressing and recompressing as they migrate into one another on the basis of relative pressure differences (**Figure 2.4**). In a sense, the filaments begin boiling, and it is here that something truly amazing happens.

In order to establish a local equilibrium, all we need is for a precise number of partons to begin circulating together. That number is just however many partons are required in order to create—while in convective circulation—a total average pressure that is equal to the internal pressure of each of the participating partons. It might seem unlikely that the exact number of partons would happen to assemble themselves in just the right way to create a stable circulation, but the contrary is true. They have no choice but to assemble themselves that way. As partons circulate within the filaments, stable configurations will spontaneously dissociate themselves from the rest as soon as they come together because, as a stable particle, they no longer require the overall circulation in order to maintain their own local equilibria. As a result, stable convective parton circulations (I will refer

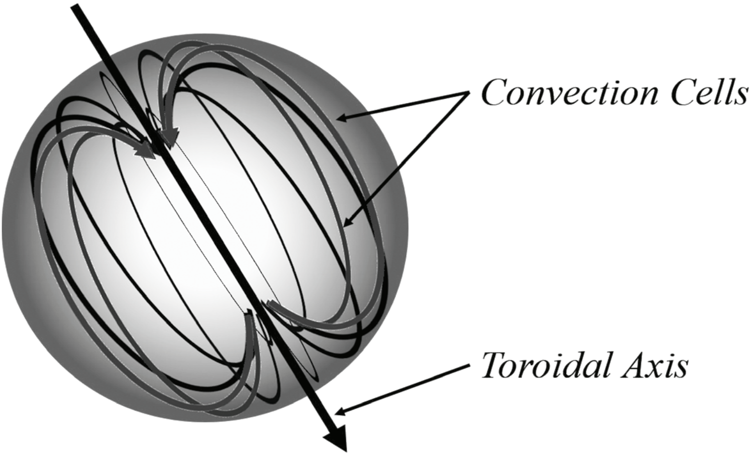

Figure 2.5: Parton Convection within a Proton
Partons circulate through the proton's major axis, around the surface, and back through the core. By way of this convective motion they are compressed in the interior and allowed to decompress on the surface. The constant disparity in pressure drives the proton's circulation. Note: though only the surface and major axis are shown here, this particle is solid and partons circulate, in direct contact with one another, throughout the entire volume of the proton.

to them as *protons* from now on) at the surfaces of the boiling filaments break free of the circulating mass and drift away into the void (**Figure 2.5**). Very rapidly, the entire cosmic network disintegrates into protons in this way. Each proton is exactly the same size because only a very specific number of partons can maintain but not exceed an average pressure that exactly balances the internal pressure of all of its constituent partons.

This phenomenon does not rely on a lucky coincidence of partons magically coming together in the right numbers. Rather, within the roiling mass of partons, virtual protons are implied by any association that is, by virtue of its own internal characteristics, stable. To use an analogy, consider the manner in which raindrops form in a cloud. Small droplets of water vapor coalesce on dust or pollen particles and gradually increase in mass. These protodrops, in turn, collide and combine. At some point, gravity exceeds their buoyancy and they fall. It is not a coincidence that the same amount of water comes together in each drop. The quantity of water that constitutes a drop is implied by the entire system. When a drop forms, it falls, but not before. Likewise, a proton forms whenever the local circulation of partons happens to form one. Yet, the conditions are such that the necessary number of partons will easily come together over and over.

Nevertheless, it is reasonable to assume that many, perhaps most, of the partons do not find their way into protons. If several protons form in a region, only a very specific number of partons can be used. Any leftover partons would not be able to move to other regions fast enough to become part of a proton before decompressing to the point at which they are no longer suitable for convective circulation. Moreover, unstable associations—those with too few or too many partons—will rapidly decay.[5] This has several important consequences. As these leftover partons decompress and unstable associations decay, the void is very rapidly filled with spacetime at its equilibrium pressure, setting the stage for "normal physics." It also means that our newly minted protons are blasted away from their places of origin by the leftover decompressing partons. Finally, it means the cosmos enters another period of rapid expansion (though far slower than the Big Bang), as these decaying partons expand to their equilibrium pressure. This expansion is governed by the equation, $E=mc^2$, in which c^2 is the factor by which a parton expands in order to reach its equilibrium pressure (the cosmological constant). Viewed from a cosmic perspective, we now have protons being propelled in all different directions and mixed together in all different concentrations. Such asymmetric distribution is critical for the subsequent evolution of galaxies and stars.

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[5] For reasons that will be explained in later chapters, neither neutrons nor other intrinsically unstable particles persist at this point in cosmic evolution. If a neutron did form, it would not be able to capture a proton in order to sustain itself because there is, as yet, no "normal space" surrounding these phenomena to facilitate the formation of atoms.

Proton Spin

A proton is a nearly spherical convective circulation of partons. As the partons are circulated through the major axis of the proton, they are compressed. They are then allowed to decompress as they circulate through the particle and around its surface. It is the constant disparity between the pressure on the surface and the pressure in the core that drives the circulation and maintains the proton's equilibrium. Each parton is a pressure gradient that observes the inverse square law—very dense in the center and progressively less dense near its surface. At their surfaces, the partons are in direct physical contact; there are no forces-at-a-distance and no particles (i.e., gluons) are exchanged between them. Their relative motions are determined exclusively by their mutual reactions to their differing pressures and to their momenta.

To understand the angular momentum characteristics of the proton, we need to examine any one of an infinite number of possible sets of radially symmetrical cross sections (**Figure 2.6a**). Each cross section intersects two opposing convective cells. We can draw in the angular momentum vectors for each cell (**Figure 2.6b**), and then use simple vector addition to calculate the net value for the entire object. Incredibly, no matter what set of cross sections we select, the net angular momentum for the proton as a whole always has a value of exactly zero (**Figure 2.6c**).

This zero angular momentum value is fascinating because it means the whole object does not, like a gyroscope, resist any effort to push it out of a particular orientation. No matter how vigorous the convection, any applied force will cause the object to move or rotate just as if it were a solid, stationary ball. It also means that a tremendous amount of energy (kinetic) can be stored inside the proton without it having the slightest effect on anything outside of the particle. Correlatively, no matter how energetic the proton is internally, even the slightest exter-

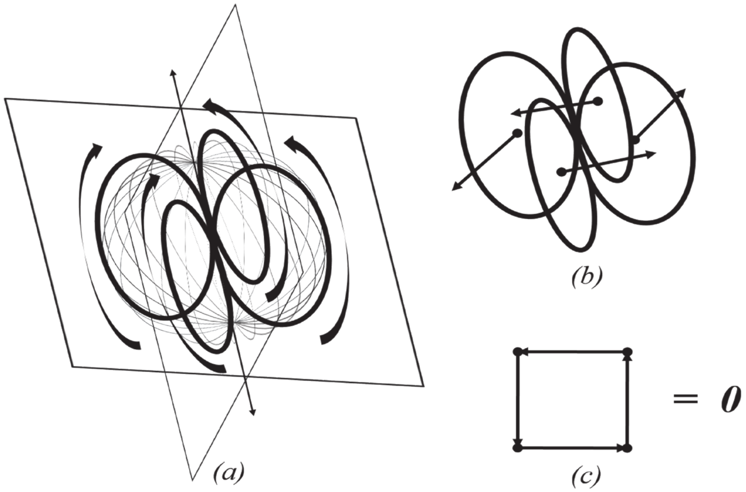

Figure 2.6: Proton - No Angular Momentum
Various radial cross sections (*a*) of a proton reveal angular circulations (*b*) that might seem to contribute to the proton's spin. However, when we add the angular momentum vectors of all possible circulations (*c*) they sum to zero. Hence, protons have no intrinsic spin.

nal force can have an effect on it. In fact, the proton, because it possesses no net angular momentum, will only move in response to externally applied forces.

During their formation, protons represented an equilibrium condition that exactly balanced the internal pressure of each parton against the average pressure of the entire particle. The proton, by turning itself inside out, concentrates the explosive force of the partons into its core rather than out beyond its surface. One very interesting aspect of this equilibrium is that it was achieved in the void, not in normal space (space infused with spacetime just above its equilibrium pressure). That means the proton is the only configuration of matter that is stable—though just barely—in the void. In normal space, the proton is what we might call *superstable*. By modulating its rate of convection, a proton can very precisely regulate its internal pressure. It does this by drawing spacetime in through its northern pole and expelling it from its southern pole (**Figure 2.7**).

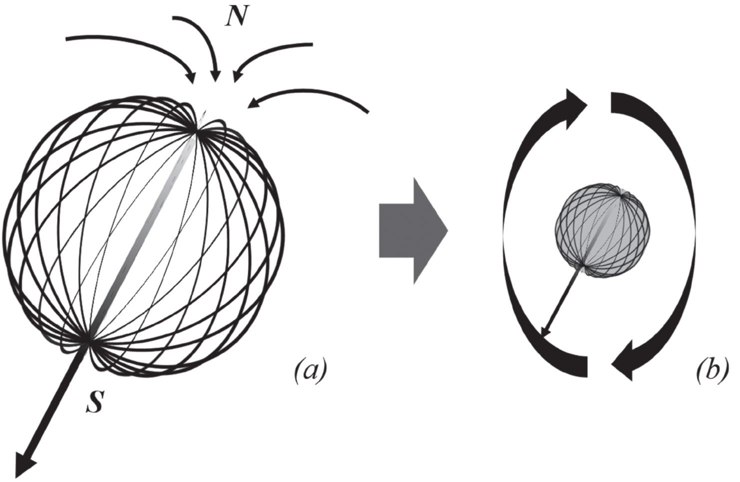

Figure 2.7: Proton Rotation
Spacetime is drawn in through the north pole and expelled from the south pole (a), resulting in a disequilibrium state—high pressure around the south pole and low pressure around the north pole. As the poles push and pull on the ambient spacetime, the proton rotates (b) in order to put the north pole into a region of higher pressure and the south pole into a region of lower pressure.

If we look closely at the north pole of a proton, we find partons being rapidly pulled down into the proton's interior. Any ambient spacetime that is in contact with the surfaces of these partons will resist decompression below its equilibrium pressure, thereby being pulled down into the interior along with the partons with which it is in contact. Once inside the proton, the ambient spacetime is dramatically compressed, contributing to the pressure of the entire particle in direct proportion to the proton's rate of convection.[6] The faster the proton circulates, the more spacetime is drawn in and the higher the internal pressure becomes. This relationship enables the proton to precisely regulate its pressure by modulating its convection. That is the reason protons are so amazingly stable in normal space.

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[6] In fact, the pressure in a proton's core is proportionate to the Lorentz Factor associated with the proton's convective velocity. Linear increases in convective velocity, as the ambient spacetime approaches c, result in geometric increases in core pressure.

When the spacetime that is drawn into the proton is expelled from the south pole, it is emitted as an extremely focused and intense beam or jet of compressed spacetime. This jet in turn compresses the ambient spacetime around the south pole well above its equilibrium value. At the same time, the spacetime around the north pole is being dramatically decompressed as it is pulled in. Since spacetime resists both decompression below and compression above its equilibrium value, the proton must rotate in such a way that the north pole is moved into a region of higher pressure while the south pole is moved to a region of lower pressure. In essence, the jet of spacetime coming from the south pole pushes against the ambient spacetime, which in turn pushes back against the proton, causing it to spin. Since the proton has no net angular momentum of its own, it does not resist this spinning at all. Proton spin comes entirely from the pushing and pulling of the ambient spacetime in response to the proton's convective circulation.

Termination Shock

With no angular momentum, the proton's rotation is governed almost entirely by the action of the south polar jet—the north pole contributing a small but perhaps important component as well. The jet, in turn, is governed by the proton's convective velocity. If, then, we examine the system after one full rotation, we will find, surrounding the proton, a very dense ring of spacetime at a distance that marks the termination shock of the jet.

Termination shock occurs, in general, when the forced or fast flow of a substance succumbs to the steady or slow flow of that same substance. The most celebrated example of this phenomenon is the termination shock of the solar wind, way out at the inner edge of the solar system. In fact, due to sudden and pronounced changes in the prevalence of cosmic radiation at its current location, it is believed that the Voyager I spacecraft has recently passed through the termination shock. A far less gran-

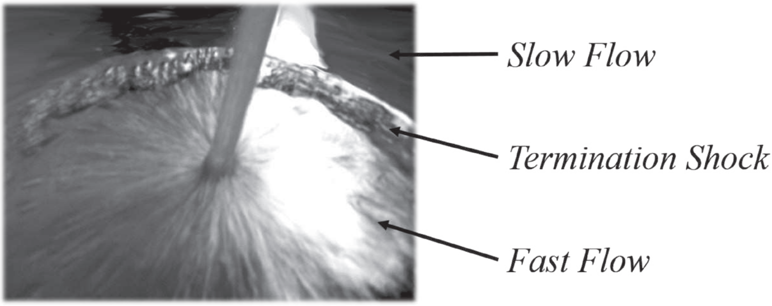

Figure 2.8: Termination Shock
The phenomenon of termination shock prevents a substance from dissipating smoothly all the way out from a high-pressure point of origin. Instead, it stops abruptly at a specific distance from its source.

diose but still instructive example of termination shock can be created in a kitchen sink (**Figure 2.8**).

Termination shock is interesting for many reasons, not least of which is its applicability to the solar wind, but my focus for now is on nothing more than the simple fact that it exists at all. What it means for the proton is that the energetic south polar jet, at a well-defined distance from the particle, will suddenly succumb to the ambient spacetime, driving up the pressure at that radius. The spacetime pressure does not dissipate gradually, either smoothly or turbulently, off into the distance with no specific stopping point.

Derivative Axes

The simplest possibility is that the proton spins in a circle, but it is obvious that such a pattern would merely clear a two-dimensional disk around the particle and lead to a significant disequilibrium between the spacetime in that disk and the spacetime in the surrounding areas (**Figure 2.9a**). Another possibility is that the proton spins such that the simple disk just mentioned itself spins around what we might call a *derivative axis*, thereby sending both the north and south poles of the proton through every point in a spherical volume around the particle. That is certainly an improvement, but even this motion sends the

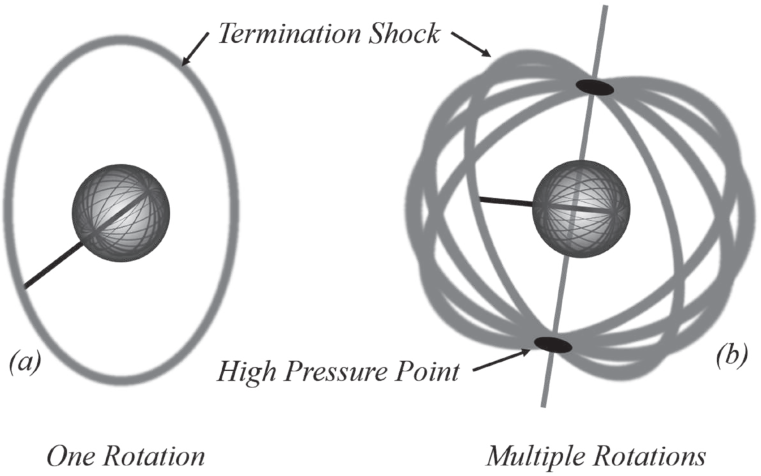

Figure 2.9: Multiple Rotations
After one rotation (*a*), the south polar jet clears a two-dimensional disk, while the termination shock creates a high pressure ring around the proton. After multiple rotations (*b*), the proton rotates on a derivative axis in order to minimize the pressure through which its jet passes, but the jet has no alternative but to pass through the poles of the first derivative axis with each rotation, resulting in two high pressure points.

poles through some points more than others. In particular, the proton's north and south poles—its major axis—pass through the poles of the first derivative axis on every primary rotation but only pass through any given point on the equator once per total derivative cycle. To remedy this, we must introduce a second derivative axis.

This next axis is derived from the first derivative axis by drawing a line through the two points through which the major axis passes most frequently (**Figure 2.9b**). With the second derivative axis, we are definitely getting closer to an equilibrium condition. However, even this axis sends the major axis through certain points more than others. And because the proton has exactly zero angular momentum of its own, there is nothing else acting on it except for the pressure exerted by the spacetime in its immediate environment. Consequently, if the pressure in the spherical volume of space around the proton can be made even

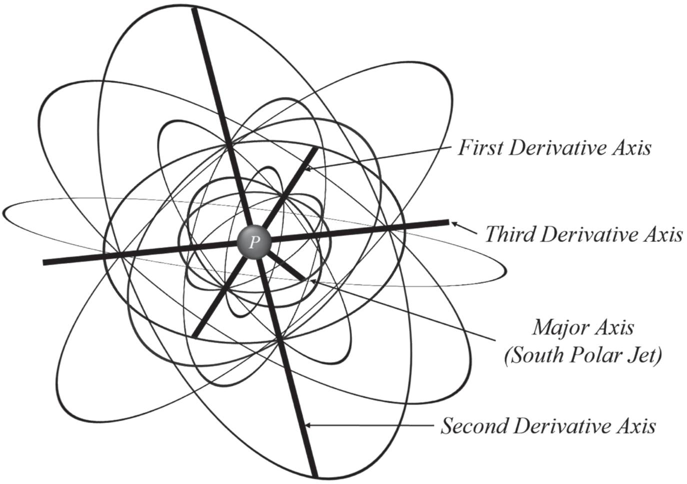

Figure 2.10: Derivative Axes

Each derivative axis sends the south polar jet through its poles more frequently than its equator. Hence the poles of each derivative axis must, like the major axis, rotate such as to reduce the pressure variations. In this diagram, the axes are shown with different radii for clarity. In a real atom, they are all the same size.

more uniform, however nit-picky this might appear, the proton must rotate in such a way to make it so, giving rise to the third derivative axis.

The third derivative axis is derived just like the second one, by drawing a line through the poles of the one preceding it. And the fourth, fifth, sixth, and n^{th} derivative axes (**Figure 2.10**) are the same, each one responsible for fine-tuning the equilibrium pressure of the spherical volume immediately surrounding the proton. If we look at the proton up close, what we see is simply the major axis (the south polar jet) moving through an incredibly complex pattern that seems to magically avoid passing through any particular point more than any other. Nevertheless, despite this complexity and apparent randomness, there remains an echo of all of those derivative axes that gave rise to its ultimate motion. To see this, we must have a closer look at the nature of these axes.

The first thing to notice is that each axis spins somewhat more slowly than the one from which it is derived. This is so because the pattern that makes any n^{th} derivative axis necessary only emerges after the *n-1* axis has rotated long enough to begin creating a disequilibrium in the ambient spacetime. Therefore, the major axis spins the fastest, the first derivative axis somewhat slower than but nearly as fast as the major one, the second derivative axis more slowly than the first and the n^{th} slower than the *n-1*. Moreover, the *difference* in rotational velocity between any two successive axes increases as *n* increases, because the total number of rotations implied by any particular axis increases exponentially as a function of *n*.

The next important aspect to notice is that each successive axis is responsible for maintaining a smaller fraction of the total equilibrium than its predecessor. The greatest disequilibrium is created when the highly compressed spacetime is first emitted from the proton's south pole; the simple circular motion of the major axis contributes more, simply by moving any direction at all, than any of the derivative axes. Similarly, the first derivative axis is responsible for mitigating the effects of the major axis' simple circular motion. By the time we get all the way to the n^{th} derivative axis, we are dealing with only the smallest fraction of the disequilibrium. Nevertheless, a somewhat counterintuitive fact emerges from these considerations. The purpose of all of these various interdependent rotations is to alter the path of the major axis in such a way that it passes through every point in the sphere with equal frequency. As a result, the motion of the major axis is defined by the path of the n^{th} derivative axis, while the path of the first derivative axis is defined by the path of the *n-1* axis, the path of the second derivative axis by the path of the *n-2* axis, etcetera. Hence, the intensity of any axis is inversely proportional to the fraction of the equilibrium for which it is responsible.

Let us look at this relationship in a slightly different way. According to our discussion, the major axis moves in a simple circle. The first derivative axis in turn rotates the circle of the

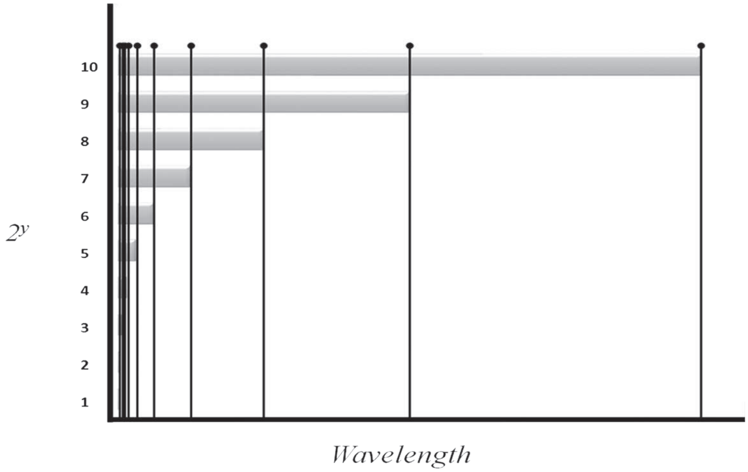

Figure 2.11: Emission Spectrum
The exponential relationship between the derivative axes results in a distribution of wavelengths that closely mirrors any one of the observed electromagnetic spectral series of hydrogen.

major axis. The second derivative axis rotates the poles of the first derivative axis. Finally, the n^{th} axis rotates the poles of the *n-1* axis. This progression of axes is as much an explanatory tool as a description of reality. In fact, the major axis never actually spins in a simple circle. The complex pattern implied by all *n* axes defines the path of the major axis right from the start. The dynamics of the derivative axes do not imply that any particular axis ever existed independent of the rest. Rather, this model of proton spin is designed to rigorously explain the path of the major axis itself. Which is not to imply that these derivative axes do not really exist. Indeed, if we graph (**Figures 2.11 and 2.12**) the various axes and their intensities, we get a very interesting picture. You may recognize it as any one of several series of lines from hydrogen's electromagnetic emission spectrum.

As mentioned, there is an exponential relationship between the axes. If, for the sake of simplicity, we assume that each axis must rotate only twice in order to generate the next one, then the first derivative axis implies two rotations of the proton, the second derivative axis implies 2 x 2 or 4 rotations, the third,

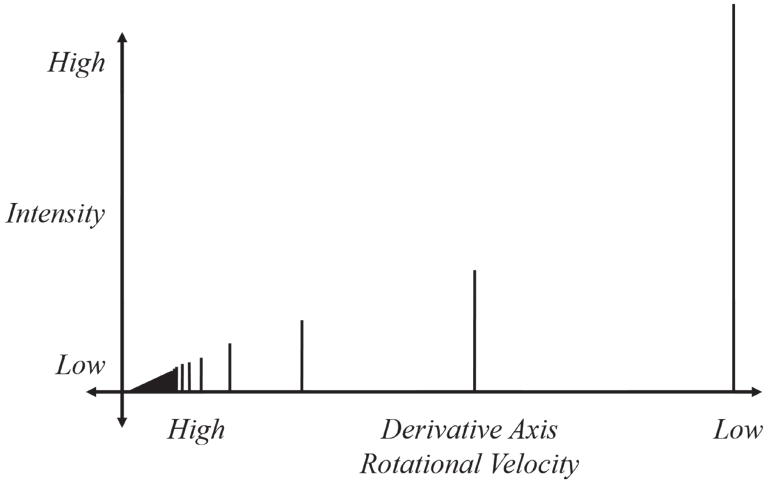

Figure 2.12: Rotational Axes Graph - Intensity vs Velocity
The intensity of any axis is inversely proportionate to the fraction of the disequilibrium for which it is responsible. Combined with the exponential relationship depicted in Figure 2.11, these dynamics give us not only the wavelengths but also the relative intensities of the lines in hydrogen's electromagnetic emission spectrum.

2 x 2 x 2 or 8, etc., which generates a graph like Figure 2.11 over the first ten derivative axes. Since this is an entirely notional model, figures 2.11 and 2.12 do not exactly replicate any of the series of lines in hydrogen's EM spectrum. However, this is very obviously the type of phenomenon that could generate them.

Energy States

The lines in Figure 2.12 are not meant to represent any particular series. At this point in the discussion, it could be the *Lyman, Balmer, Paschen*, or any of the other series (**Figure 2.13**). They all operate according to the same principle, though each of them represents a distinct energy state of the atom. The first thing to note is that, contrary to the current quantum model, an energy state is defined by an *entire series*, not by only one of its spectral lines. Every hydrogen atom emits the entire series all at once. Atoms do not fluctuate between the various lines within a series. When an atom changes energy states, it immediately be-

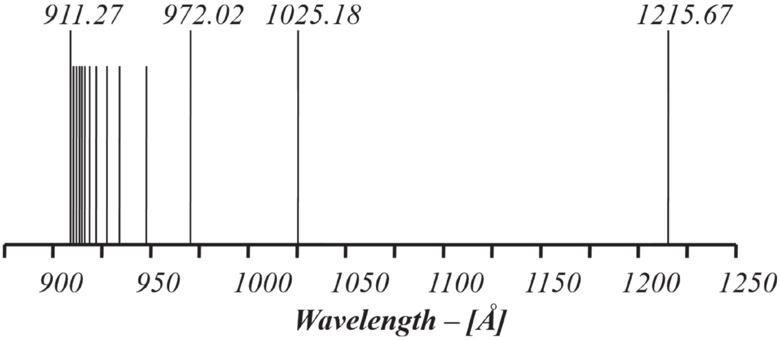

Figure 2.13: The Lyman Series
The 911.27 line—often referred to as the limit—corresponds to the actual rotational velocity of the proton itself. The other lines represent the rotations of various derivative axes. And the 1215.67 line is the last—n^{th}—derivative axis.

gins emitting all the lines within a different series. Correlatively, no single atom ever emits lines from two different series at the same time.

The purpose of an energy state is to maintain a uniform pressure in the immediate vicinity of the proton. That means the convective velocity of the proton must evacuate spacetime from that region at the same rate that it is reabsorbed. It might appear that this equilibrium could be accomplished by simply varying the convection rate of the proton in exact proportion to the ambient spacetime pressure. That is, as the ambient pressure (temperature) gradually rises or falls, the convection rate slows or increases at the same continuous rate. However, the relationships between all the derivative axes that characterize a convective pattern—an energy state—are related only to the geometric demands of those axes, which are indifferent to the smooth continuous pressure changes around the atom. Most importantly, only certain series of axes are able to evacuate spacetime at the same rate that it is absorbed. As a result, the proton must jump between discrete energy states rather than slowing or accelerating continuously in direct response to the ambient pressure. If we were to speed up a proton only slightly, placing in between two accepted energy states, spacetime would either be evacuated faster than it is absorbed, or vice versa, resulting in a disequilibrium condition. The proton cannot maintain a constant convective velocity unless the pressure of the spacetime in its immediate vicinity is also constant. This idea is far from intuitive and merits some further explanation.

As mentioned, a single energy state of hydrogen is defined by an entire series of derivative axes. The fact that hydrogen only exhibits one well-defined set of such series (e.g., the Lyman, Balmer, and Paschen series) means that for some reason nature excludes any, seemingly plausible, intermediate wavelengths. Why should that be? In other words, why should the hydrogen atom not be allowed to spin at whatever velocity best reflects the ambient pressure at every moment? Why instead should it be required to jump back and forth between a limited set of energy states, none of which is perfectly suited to the local conditions? The answer is literally *complex* (see Chapter 9 for more detail), and would be difficult to glean from even a perfectly clear computer simulation because the rigid relationships between the derivative axes within a series cannot be visualized in any straightforward way. Nevertheless, these relationships exist and are decisive.

If we assume, as above, that each axis must complete two, and only two, rotations to give rise to the next axis, then it follows that each axis (from the major axis all the way to the n^{th} axis) is capable of evacuating neither more nor less than a well-defined fraction of the spacetime in the proton's vicinity. Alternatively, the major axis would be capable of evacuating twice as much spacetime (by itself) if it could complete four rotations instead of two before creating the next axis. The same variations and restrictions apply to all of the derivative axes as well; each one is capable of evacuating no more or less spacetime than is associated with its particular intensity over the course of exactly two rotations. Put as simply as possible, this means that each of the axes in a series restricts and is restricted by all of the others. If the major axis were to speed up only slightly, perhaps in response to a minor change in the ambient spacetime pressure, all of the other axes would also speed up, but (and this is the critical point) in an exponential, non-linear, and ultimately unpredictable way. Such a state (in between two of nature's approved energy states) would not be able to maintain the delicate equilibrium between the ambient spacetime pressure and the rate at which spacetime is evacuated from the atom. Each energy state, therefore, corresponds to a unique internal constant pressure between the proton and its electronic shell, a concept to which we will now turn.

The Electronic Shell

Looking at the entire phenomenon of a hydrogen atom (**Figure 2.14**), we have a proton nucleus pulling spacetime in through its northern pole and expelling it from its southern pole. Its rotational pattern exhibits the complex geometry of one entire series of derivative axes. Because the proton evacuates a spherical region of space in its immediate vicinity, we can conclude that the spacetime pressure between the nucleus and the electronic shell, with the exception of the south polar jet, is lower than the pressure of the ambient spacetime just outside of the atom. The electronic shell in turn is the spherical surface at which the polar jet's outward pressure is balanced by the inward pressure of the ambient spacetime in the atom's vicinity. To visualize this, imagine the proton gathering up the spacetime within the atom, concentrating it into its south polar jet, and then firing it at the electronic shell. The rate at which any series of derivative axes evacuates the atom and concentrates the associated spacetime into a jet determines the pressure inside the electronic shell. If the proton rotates very rapidly, the internal pressure drops. When the proton slows down, the internal pressure rises.

From these considerations, it is clear that an *electron* is not an independent particle of matter, but is rather the *bump*

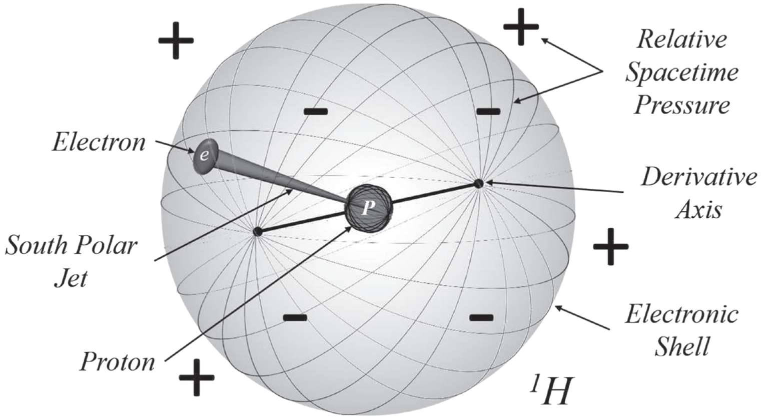

Figure 2.14: Hydrogen
The hydrogen atom has a primary electron at the end of the south polar jet, which tracks the course of the n^{th} derivative axis. The poles of every other derivative axis can be thought of as derivative electrons (only two shown here). The pressure inside the electronic shell is negative relative to the ambient spacetime. And the electronic shell is the termination shock radius at which the atom achieves cosmological equilibrium.

on the electronic shell at which the proton's south polar jet is balanced by the ambient spacetime—a phenomenon captured by the principle of *termination shock*. This is the reason protons and electrons have an "equal but opposite charge"; they are both part of the same phenomenon. Atomic electrons would not exist without the protons that generate them. Still, if we treat an electron as a discrete particle, we can see that it is a point of high pressure that corresponds to and balances the low pressure inside the atom. The faster the proton spins, the lower the internal pressure and the more intense the electron becomes. This explains the perhaps counterintuitive fact that EM waves from cold hydrogen atoms (atoms in low energy states) are shorter and more intense than waves from atoms in high energy states. At low temperatures, atoms must rotate more rapidly in order for their internal pressures to remain proportionate to the low ambient pressure.

We can refer to the electronic shell as an atom's *cosmological equilibrium*, a concept that dominates everything in the universe from atoms to stars. In general, this equilibrium state reflects the competing requirements that spacetime decompress from the highly compressed condition left over from the Big Bang, while not recompressing the ambient spacetime that has already decompressed and which now constitutes the vacuum pressure of the cosmos. Notice that the electronic shell of an atom would not exist were it not for the ambient spacetime, near its equilibrium pressure, pushing back against the proton's polar jet (creating its termination shock). Nor would the polar jet exist. The electron is nothing more than the point at which these two—polar jet and cosmos—collide.

By way of foreshadowing, *free electrons* and *beta particles* are similar to atomic electrons though obviously they are not generated in the same way. Any positive pressure shock wave (longitudinal wave) propagating through spacetime is phenomenologically similar to the positive pressure point on an atom's electronic shell. In later chapters, we will examine several of the myriad ways in which such longitudinal waves are generated.

Intrinsic and Extrinsic Mass

In the previous chapter, I mentioned briefly that spacetime is not itself either energy or matter but is rather the substrate upon which the latter depend for their existence. *Matter* and *energy* refer to the intensity of spacetime pressure. And because spacetime has an equilibrium pressure, it has the *capacity to do work* (possesses energy) at both positive and negative pressures. At negative pressures, spacetime *pulls* (driven by its infinite pole), while at positive pressures, it *pushes* (driven by its finite pole). Hence, negative pressure gives rise to positive energy and positive mass, and that means energy must be defined as the *absolute value* of spacetime pressure.

We have just seen that the pressure inside the electronic shell of a hydrogen atom is lower than the surrounding space.

We know this because the proton evacuates spacetime from that region, lowering its pressure relative to the local region. If the pressure of that surrounding space is very close to the equilibrium pressure of spacetime, lowering the pressure even further can yield a negative value. Since negative pressure results in positive energy and mass, the mass of an atom is at least partly determined by its rotational velocity or energy state, leading to a very complex situation.

Obviously, the overwhelming majority of a hydrogen atom's mass comes from its extremely high-pressure proton nucleus. This mass would remain even if the particle were returned to the void, effectively ending any discussion of polar jets and electronic shells. Therefore, we can refer to the proton itself (the partons) as the *intrinsic mass* of the hydrogen atom. If this mass were to change, the nucleus would no longer be a proton but something else entirely. On the other hand, the rotational velocity of the proton can and does change rather dramatically in response to external conditions. That rotational velocity determines the intensity of the pressure within the atom and therefore the fraction of the atom's mass that is associated with the energy generated by that pressure. We can refer to this phenomenon as *extrinsic mass* since it fluctuates according to the behavior of the proton, but would disappear completely if the proton were returned to the void.

For the time being, it is enough to file away this distinction between intrinsic and extrinsic mass in the back of your mind. The process of weighing a particle and disentangling these two different contributions to its mass will have to wait. Ultimately, this concept will be instrumental in explaining atomic binding energies, as well as the curious behavior of neutrons. But before we can examine it any further, we must first gain a better understanding of gravity and neutrons. To understand those we must have a look at somewhat larger phenomena—stars.