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The Frontiers of Physics, Part I

The Basics

By
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Author's Note: This article was originally published in January, 2000. I thought it was a nice time to look at the state of physics at the end of the 20th century. I manage to do a complete review in only four installments. Warning: things in the mirror of reality appear much less weird than they really are!

Well, we made it through Y2K without a disaster; at least, none that is readily apparent. The clocks are still ticking, the ICBMs are still resting comfortably in their holes, and the banks are still dispensing money from the ATMs. The power is on and the water is running. Just as the world did not end when we went from 3-digit dates to 4-digits (the Y1K problem), we seem to have survived the switchover from 19XX to 20XX. Hallelujah! We won't have to worry about the end of the world for at least another thousand years.

The recent flap over the end of the millennium (which all of us purists know won't end for another 12 months anyway) points out an interesting aspect of human psychology. We small, naked bipeds who lack both fang and claw are nonetheless equipped with a self-centeredness that is breathtaking to behold. As a result, we tend to personalize everything from a stranger's bump in the crowd to physical processes that have been going on a thousand times longer than our puny species has existed. The change from one millennium to another is a good example. The Earth has circled the sun approximately 4.5 billion times now, and there is absolutely no reason to get excited by the fact that our calendars now display a very round number, or that no date in our future lifetimes will ever again be composed of all odd digits.

What we forget in our celebration of "me" is that the whole system is completely arbitrary in the first place. We use a base ten numbering system because of the biological accident that humans come equipped with ten fingers and ten toes. Obviously, before people became good at the abstract thinking required by mathematics, they used their fingers as a de facto calculator, and set up their numbering system accordingly. Our calendar is set to zero arbitrarily (Christ was born in the spring sometime between 4 and 6 BC), and even the time of New Years has changed. Before Pope Gregory redid the calendar, New Years was March 21, a date that actually has some significance in the changing of the seasons. Why January 1, a date in the middle of winter was chosen to change over the calendar, I have no idea.

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In the universal scheme of things, is there any real difference between Year 1999 and Year 2000? Only in our heads. For even though 2000 is the 100th year of the twentieth century and not the 1st year of the twenty-first, it does seem somehow different to be writing those two new digits on checks that were once preprinted with 19__.

So, in the spirit of the "new millennium," I thought we would try something a little ambitious here at Sci Fi – Arizona. In addition to finally getting the new *Astrogator's Handbook, Expanded Edition* online for New Years, it seems the perfect time to review the state of humankind's scientific knowledge. For science is the wellspring from which science fiction flows, and despite the best efforts of those underpaid sages who practice the craft, the science in science fiction is becoming a bit dated. In fact, the science presented in most science fiction stories goes back nearly a century, not good for a group of people who consider themselves on the cutting edge of technological development.

"We're using 100-year-old science?" you exclaim. "How can that be?"

Strange, but true. For nearly its entire history, science fiction has been a vehicle for explaining Einsteinian physics to the general populace. The physics of Einstein were a vast improvement over the classical physics of Newton, but the field is now getting antiquated. The Special Theory of Relativity, for instance, was published in 1905. This is Einstein's principle that nothing can ever exceed the speed of light, and a major headache for anyone attempting to write an interstellar romance. We covered the theory and technology of Special Relativity in *"The Einstein Barrier, Parts I and II"*, but will summarize them again here to make sure everyone is on the same page. Einstein would have been considered a great man had Special Relativity been his only contribution to our fund of knowledge. However, he did not stop there. A few months after publishing Special Relativity, he added a footnote in which he postulated that matter is merely a condensed form of energy, and penned his most famous equation, $E=MC^2$. Then, in 1915, he completely transformed Newton's theory of gravitation, and invalidated tens of thousands of years of conventional wisdom on the subject, when he published his General Theory of Relativity.

Einstein gave science a great deal to think about and science has spent the better part of this century doing just that — thinking about it. Science in the 20th century has largely been devoted to proving Einstein's theories, and having proven them, in expanding on them. Now, at the end of the century, we believe we are on the verge of a major breakthrough in our understanding of the universe.

In Superstring theory and the emerging M-theory, we believe we can see the outlines of what actually makes this old cosmos tick. We do not know why this is so, mind you; only that we have mathematical models of the universe that are seductively elegant in their utility. We don't know *why* they work, only that they seem to.

In this matter, we are in much the same position as the people who first put together the Periodic Table of the Elements. They noted that certain elements appeared to be related (gold, silver and platinum, for instance) and that all known elements could be arranged in a table such that the related elements were put into rational groups. They didn't know why this was so (lacking the atomic theory of matter), but they could see that it was. They could see well enough, in fact, that they knew some of the elements were still missing because there were holes in the table. Knowing this, they went looking for these missing elements and found them.

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The latest developments in physics are as exciting as anything that Einstein ever did. If we thought his insights into the universal speed limit of light speed, variable time, and curved space were at odds with common sense, the universe that is being revealed on the frontiers of modern physics is stranger yet. In fact, the universe that physicists are mapping with their arcane mathematics and insights looks nothing like that with which we are familiar.

The picture of the universe being built up is so bizarre, in fact, that most lay people's brains short out when trying to comprehend these new developments — and that includes the brain of your humble author. So, as a service to the science fiction community and in tribute to the coming of the new millennium (now or in a year), the next few articles in the Art of Science Fiction Series will be devoted to attempting to delve deeply into the modern developments in physics, and to do so in terms that most people can understand.

A warning: These explanations will only be as good as my own imperfect understanding of such matters, so independent study is advised. In these articles, my purpose will be to deliver to you sufficient knowledge that you will be able to perceive the truly revolutionary nature of modern science, and to begin imparting that knowledge to the public through your writing. After all, we science fiction writers have an obligation to continue our function as the human race's Department of Prognostication. And to do that, we must understand what is going on well enough to explain it to others.

So, let us start our exploration into the Frontiers of Physics by establishing a foundation of knowledge from which to launch our future explorations. We will begin by reviewing the historical discoveries that brought us to this point in history, the better to understand the wondrous possibilities that are just now coming into focus. Any discussion of modern science must first look at the work of the two greatest scientific minds to ever live: Sir Isaac Newton and Albert Einstein. Only when you understand Newton and Einstein can you truly understand what is going on in the minds of the theoretical physicists of today.

The Classical Physics of Newton

Newton took the geometry of Euclid and Pythagoras, both of which are good at describing how things "look," and added calculus, which describes how they move. Though Sir Isaac lacked something in the personality department, no one can doubt his intelligence. He invented classical physics by being the first person to codify the laws of motion and came up with a theory of gravity that is still largely used today. Newton's classical physics still dominate the curricula of engineering colleges, where they teach courses with titles like *Statics* and *Dynamics*.

The following is a brief summary of Newton's Laws:

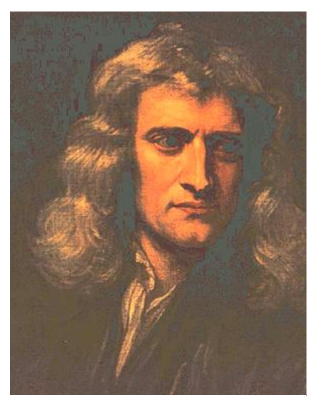

Figure 1: Sir Isaac Newton

Newton's First Law of Motion

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An object remains in a state of rest unless a force causes it to move, and an object continues in motion along a straight line unless a force stops it or causes the object to change direction.

The First Law is also called the Law of Inertia. Inertia is what kills people in car accidents. If unrestrained (i.e., not wearing their seat belts), people in a car crash will fly forward until they hit the windshield or dashboard. And having hit it, they are forcefully brought to a halt by a force that breaks every bone in their body in the process.

Newton's Second Law of Motion

Newton's second law of motion states that the acceleration of an object is directly proportional to the size of the force producing the acceleration and inversely proportional to the mass of the body. This is the familiar formula, F=MA. A trick question you find on final examinations in physics classes asks students to derive the formula. In fact, Newton's Second Law is an observed phenomenon. It cannot be derived. As we shall see later, Einstein's General Theory of Relativity suggests that it would be better to write the formula M=F/A.

Newton's Third Law of Motion

Newton's third law of motion is a very simple one. It states that for every force there is an equal and opposite force. Another way to state Newton's third law is "for every action there is an equal and opposite reaction." This is why billiard balls bounce around the table so enthusiastically. At the start of the game, for instance, the force of the cue ball running into the triangle-shaped "rack" of numbered balls imparts sufficient "reaction force" that the various balls scurry off in all directions.

Newton's Law of Universal Gravitation

Not content with working out the equations and principles of motion, Newton also turned his thoughts to gravity. The story goes that he began thinking about gravity while seated under an apple tree, after being bonked on the head by an apple. Whether this is true or not, I have no idea. It was his study of gravity that caused Sir Isaac Newton to invent "The Calculus," because he needed to prove that large masses (like the Earth) can be thought of as points of mass acting at the body's center-of-gravity.

Specifically, Newton determined that two objects attract one another with a "gravitational force" that is proportional to the product of their masses and inversely proportional to the square of the distance between their centers-of-gravity. The formula for this is:

$$F = G\frac{M_1 M_2}{r^2}$$

where $\mathbf{M_1}$ and $\mathbf{M_2}$ are the masses of the objects, **r** is the distance between their centers of gravity, **G** is the universal gravitational constant, $6.67 \text{ X } 10^{-11}\ \text{Nm}^2/\text{kg}^2$.

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It should be noted that Newton's equation for the gravitational force is the same form as Coulomb's Law for Electrostatic Forces:

$$F = k\frac{q_1 q_2}{r^2}$$

where $\mathbf{q_1}$ and $\mathbf{q_2}$ are electric charges, **r** is the distance between them, and **k** is the proportionality constant, 8.98×10^9 $Nm^2/coul^2$.

This similarity in the forms of the equations that describe both the gravitational force and the electrostatic force was one of the earliest indications that perhaps the forces of nature are related somehow. However, one aspect of his theory disturbed Newton. For two objects millions of miles apart (such as the Earth and the Sun) to attract one another implies that the masses can exert force instantaneously at a distance. This force-at-a-distance idea was a disturbing one, not only for Sir Isaac Newton, but for the generations of scientists who followed him.

Yet, despite his misgivings about how the gravitational force is transmitted, Newton's theory of gravitation proved highly utilitarian. It ruled the roost in physics for the next 250 years, until a bored Swiss patent clerk to turn his own mighty intellect to the problem.

The Relativistic Physics of Einstein

The accepted model of light in the 19th century was that it is an "electromagnetic wave", meaning that it consisted of oscillating electric fields and magnetic fields. Electric fields are caused by electric charges. Magnetic fields are caused by electric currents. Magnetic fields put a force on moving charges, but not on stationary charges.

As a wave, light displays the phenomenon of interference — constructive and destructive. When two light beams of the same wavelength meet and are in phase with one another, they will interfere constructively and the light will be brighter. If they are precisely out of phase with one another, they cancel completely. This phenomenon of interference is a very important property of waves, and it was this property that allowed Michelson and Morley to use an instrument called an interferometer to first measure the speed of light. Later, the two scientists decided to use their instrument to measure the speed of the Earth with respect to the firmament. They planned to do this by measuring the speed of light as it entered their interferometer from various directions. From Newtonian physics, it was assumed that sometimes the speed of the Earth would be added to the speed of light, and other times it would be subtracted. By subtracting the smallest light-speed reading from the largest and then dividing by two, they would then be able to measure how fast the Earth was moving with respect to surrounding space.

Figure 2: Albert Einstein

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They ran into a problem with their measurement, however, when the speed of light turned out to be the same in all directions. No matter which direction they pointed their interferometer, light always traveled at 300,000 kps (186,000 mps). This result was very counter-intuitive and perplexing. Where light was concerned, it seemed, the classical physics of Newton did not seem to work.

Although Einstein claims to have been unaware of the work of Michelson and Morley at the time he postulated his Special Theory of Relativity, what he actually did (aware or not) was solve the puzzle of why the speed of light always seemed to be constant.

The Special Theory of Relativity

Einstein began thinking about his theory with two postulates, and then went on to reinvent everything else. His postulates were:

- **The Relativity Principle: The laws of physics have the same form in all inertial reference frames.** (An inertial reference frame is one in which the reference frame is not accelerating.)

- **Light propagates through empty space with a definite speed, *c*, which is independent of the speed of the source or observer.**

While the first postulate seems intuitively obvious (the laws of physics are the same in a speeding plane as they are on the ground), the second is not. The assumption of the Michelson-Morley experiment was that velocities add. Such an idea is intuitive, as a simple example will show. Assume that you are an observer at Point A, moving at 0.999 c toward Point B, where someone has a very strong flashlight. Assume also that Points A and B are one light-year apart. If Observer A heads for Point B at the precise moment that Flashlight B is turned on, then the observer and the light beam should reach each other in six months, and the speed of light should appear to Observer A as 1.999 c (the speed of light plus his own velocity). We are all familiar with this idea from our experiences on the highway. Two cars that undergo a head-on collision while each is doing 60 mph actually experience an effective 120-mph collision.

The only problem with this reasoning is that it does not work with light. Even though Observer A is moving at 0.999 *c*, when he measures the speed of the light from Flashlight B, it is traveling at 1 *c*. Since velocity is a measure of the distance traveled in a particular amount of time (V=D/T), for the velocity of light to be invariable, that means that either the distance or the time (or both) has to change as a function of velocity to make the equation come out correct.

According to Einstein, as one goes faster and faster, approaching the speed of light, time actually slows down. At 0.999 *c*, it slows down a lot! This causes Observer A to believe the light is traveling at 1.0 *c* rather than the 1.999 *c* that one would expect. The formula for the time dilation effect is:

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$$T = \frac{T_0}{\sqrt{1 - \frac{u^2}{c^2}}}$$

where $\boldsymbol{T}$ is the time experienced by an observer traveling at velocity $\boldsymbol{u}$ compared to the time measured by an observer at rest $\boldsymbol{T_0}$, and $\boldsymbol{c}$ is the speed of light.

As can be seen from the time dilation equation, as $\boldsymbol{u}$ approaches $\boldsymbol{c}$, $\boldsymbol{T}$ approaches infinity. In other words, time comes to a screeching halt as you reach the speed of light, which is why it is impossible to reach that speed. All one can do is approach it closer and closer, never quite getting there. Mass obeys a similar relationship, causing mass to go to infinity when velocity equals $\boldsymbol{c}$, and since there is insufficient energy in the universe to accelerate an infinite mass even a little faster, that is another aspect of Einstein's Universal Speed Limit. Perhaps an easier way to look at the question is to ask what happens to the time dilation equation when velocity $\boldsymbol{u}$ exceeds the speed of light, $\boldsymbol{c}$. The answer, of course is that $\boldsymbol{T}$ would then become imaginary and all of our elegant mathematics would explode on us.

No matter how we look at Einstein's Special Theory of Relativity, we must conclude that travel beyond the speed of light is physically impossible, at least at our current understanding of how the universe works. Luckily for us science fiction people, our current level of understanding is far from the final word on the subject. Modern science gives us hope that we may yet crack this particular barrier to getting out among the stars.

The Equivalence of Mass and Energy

Once Einstein had his Special Theory of Relativity, it was a fairly simple matter to conclude that mass and energy are two forms of the same thing. If this, too, seems counter-intuitive, consider that we have lived in fear of this principle for most of our lives. Not only is mass-energy equivalence the source of the sun's power, it is also the reason why nuclear weapons explode.

The mass-energy equivalence equation is the most famous in history. The equation is:

$$E = MC^2$$

where $\boldsymbol{E}$ is the energy equivalent of mass, $\boldsymbol{M}$, and $\boldsymbol{c}$ is the speed of light.

Since $\boldsymbol{c}$ is such a large number, which we then square, the formula demonstrates that matter is a very dense form of energy. As an example of just how dense a form of energy, consider that the atom bomb that exploded at Hiroshima converted approximately 1 gram (1/30 of an ounce) of mass into energy.

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The General Theory of Relativity

Einstein left scientists with more than enough to think about with his Theory of Special Relativity. He did not stop there, however. For one thing, his theory screwed up Newton's Law of Universal Gravitation.

Astronomers had used Newton's formulation of gravity for a couple of hundred years before Einstein and they found it more than adequate for their needs. The whole universe appeared to obey Newton's Law of Gravitation as precisely as the astronomers could measure things. In fact, the universe still does.

However, Einstein's Theory brought the force-at-a-distance problem into sharp focus. Einstein had just proved that nothing can exceed the speed of light, not even "gravitational force." If limited to the speed of light, then the gravitational attraction of the sun has not had time to travel more than one-third of the distance across the universe. That is because the sun is 4.5 billion years old and the universe has been around for 15 billion years. Yet, when we look at the universe as a whole, it appears that every atom in it is pulling on every other atom in accordance with Newton's Law of Universal Gravitation.

Obviously, something was wrong.

Much of Einstein's work involved asking questions so simple that they would not occur to ordinary mortals, and then answering them with courage. To consider the problem of the instantaneous nature of gravitational force, he considered the difference between gravitational force and the force one feels when accelerating, such as in a car that is speeding up to merge with traffic on the freeway. He concluded that there was no difference between the force on feels due to gravity and the force caused by acceleration. If locked in a windowless room, he said, it is impossible to determine whether you are in an accelerating spaceship or sitting on the surface of a planet. In other words, anything that happens in an accelerating frame of reference will also happen under the influence of gravity.

This idea seems childishly simple until one follows through the implications. Take, for example, a laser beam being shot horizontally across the cabin of an accelerating spaceship. For the sake of our example, we will assume that the speed of light is very slow, say about 5 mph. It isn't, of course, but slowing light down will aid in the explanation of Einstein's insight. The conclusions do not change so long as light has a finite speed.

A spaceman enters the darkened room and turns on his laser. The slow photons move horizontally away from the laser. However, as they move horizontally in a "straight line" in space, the floor of the cabin accelerates toward them. The result is that to an observer aboard the spaceship, the beam seems to follow a curving downward path until it hits the floor. This is essentially the same path you see when you spray water from a garden hose (the path curves because of the acceleration of gravity).

Einstein reasoned that if light follows a curved path in an accelerating frame of reference, and if there was no difference between acceleration and gravity, then light will also follow a curved path in a gravitational field. The idea is deceptively simple until one thinks about it for a moment. After a few seconds of cogitation, one suddenly realizes that if gravity is a force, and light has no mass, and gravity bends light; then we have just violated Newton's Second Law of Motion, **F=ma**. That is because a particle traveling in

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a curved line is undergoing acceleration (remember that Newton's First Law that states that an object in motion will tend to travel in a straight line unless acted on by an external force). Yet, if **m=0**, how can a force produce any acceleration?

In other words, if photons lack mass (which we believe they do), then no amount of force can cause them to undergo any acceleration and light should travel in a straight line regardless of gravity.

It was Einstein's thesis that gravity bends light that brought him to the attention of the public. That is because in November 1919, there was an eclipse of the sun and astronomers noted that some of the stars near the sun's disk appeared to be out of their normal positions. They weren't of course, they just looked that way. The reason was that the light from the star was bent slightly by gravity as it passed near the sun. This bending of the light beam caused the star to appear to have moved to those observers watching on Earth.

The results of this simple experiment were profound as Newton's elegant, centuries-old model of how the universe works came crashing down around the physicists' ears.

Gravity, it turns out, is not a force!

The Birth of the Curved Space-Time Continuum

"Huh?" you ask. "What do you mean that gravity is not a force?"

Just that. The problem of force-acting-instantaneously-at-a-distance is solved. Since there is no force, it has no requirement to act instantaneously. Which, of course, begs the question. For, if gravity is not a force, what the hell is it?

Gravity, it turns out, is a "curvature of the space-time continuum," and to understand that statement is to open up vistas of understanding never before dreamed by mortal man.

The light bends, Einstein concluded, because the universe, which consists of four dimensions (length, breadth, width, and time) are curved in some other (fifth) dimension. Exactly how this fifth dimension works was not clear at the time, but the fact that the geometry of the universe is curved gives rise to that which we perceive as the "force of gravity." If this seems confusing, join the club. Still, it is important for science fiction writers and readers to understand because it bears so directly on our chosen field of endeavor.

Einstein's great insight in his General Theory of Relativity is that space is curved by the presence of mass-energy, which causes all matter and light to move along curved lines, which result in acceleration, which in turn is perceived by the human senses as a force. The planets then are not held in place around the sun by the pull of gravity, but rather, orbit along particular lines of curvature caused by the presence of the sun's mass and energy. When you step out of a tenth floor window, you do not accelerate toward the ground because a force is pulling you down. You do so because when you are not being held up by anything, you have a natural tendency to slide down the walls of the Earth's gravity well from your current position of curvature to one of greater curvature.

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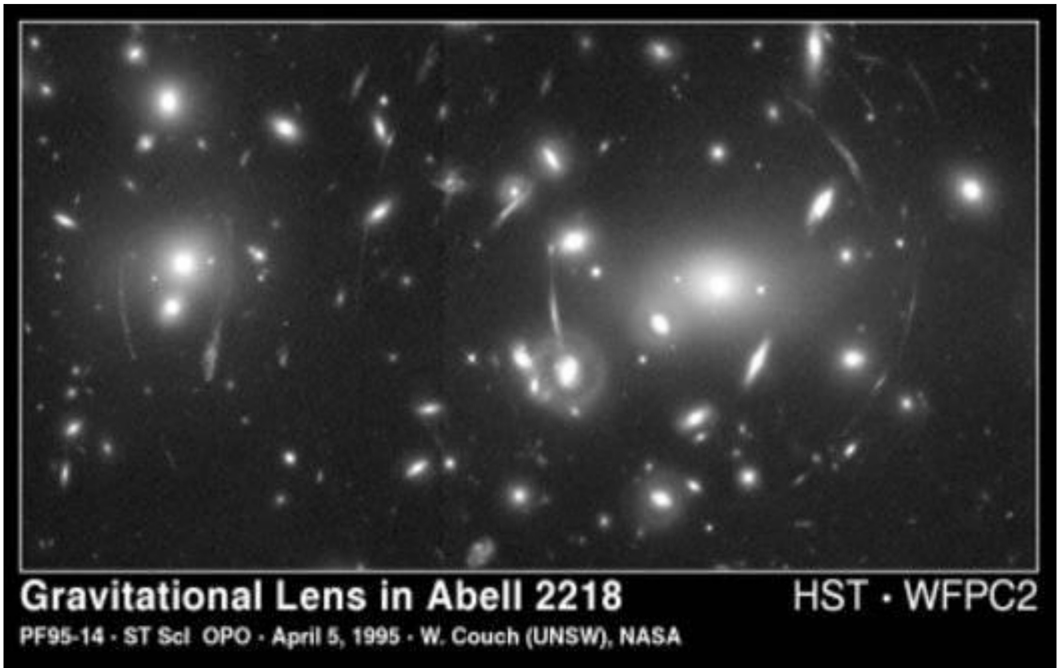

Figure 3: Gravity Lens Demonstrating Einstein's Point That Gravity Bends Light

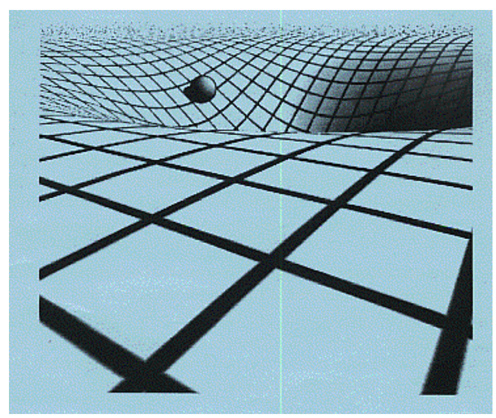

Figure 4: Diagram of Curved Space

The Implications of General Relativity

This new theory of gravity brings with it some truly frightening questions. For instance, if space-time is curved locally by the presence of matter or energy (which are, remember, the same thing), then it is reasonable to ask *curved into what*? Wasn't it enough of a shock to discover that time is a dimension just like height, width, and breadth, and that time and space can both be distorted by velocity? That is basically what is happening as you approach the speed of light. Time is being rotated into space and space is being rotated into time. It is the degree of this rotation that drives the time dilation and space dilation equations.

Having four dimensions is bad enough, but for those four dimensions to be "curved," there must be at least one more dimension for them to be "curved" into. "And why stop at five?" you ask. "Why not six, seven, eight, nine, ten, or eleven?" Funny you should mention that. Recently, we have begun to think that we have discovered the basic equation governing the operation of the universe. We don't know *why* it is the basic equation, mind you; or what it really represents, but it is mathematically elegant and is able to account for just about everything we know about the universe.

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The problem is that, to be internally consistent, this equation requires a universe of 10 dimensions — possibly 11. If we live in a universe of 10 dimensions, it is natural to inquire into why we are only aware of four. Where can the other six dimensions be? Understanding the answer to that question will take us very far in the direction of figuring out whether Einstein was right when he said that it is impossible to travel faster than light. Indeed, understanding the true nature of the universe will tell us whether it is possible to travel back in time to shoot our own grandfathers.

However, the article has been a bit dense this month, and we all need to give our brains a rest. Having laid this foundation, we will explore the Frontiers of Physics in future articles, working our way up to Superstring and M-Theory, stopping briefly at the standard model of bosons and leptons, quarks and supersymmetry, along the way.

If anything you have read in this article seems unbelievable, be assured that we have been discussing conventional physics up to this point. Be forewarned, however. From this point on, it gets weird!

Stay tuned for the Frontiers of Physics, Part II. If you think you are confused now, just wait. The universe is a much stranger place than anyone has heretofore imagined. To quote the late, great Al Jolson: "You ain't seen nothin' yet!"

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The End

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3. Antares Dawn - US$6.00

When the super giant star Antares exploded in 2512, the human colony on Alta found their pathway to the stars gone, isolating them from the rest of human space for more than a century. Then one day, a powerful warship materialized in the system without warning. Alarmed by the sudden appearance of such a behemoth, the commanders of the Altan Space Navy dispatched one of their most powerful ships to investigate. What ASNS Discovery finds when they finally catch the intruder is a battered hulk manned by a dead crew.

That is disturbing news for the Altans. For the dead battleship could easily have defeated the whole of the Altan navy. If it could find Alta, then so could whomever it was that beat it. Something must be done…

4. Antares Passage - US$7.50

After more than a century of isolation, the paths between stars are again open and the people of Alta in contact with their sister colony on Sandar. The opening of the foldlines has not been the unmixed blessing the Altans had supposed, however.

For the reestablishment of interstellar travel has brought with it news of the Ryall, an alien race whose goal is the extermination of humanity. If they are to avoid defeat at the hands of the aliens, Alta must seek out the military might of Earth. However, to reach Earth requires them to dive into the heart of a supernova.

5. Antares Victory – First Time in Print – US$7.50

After a century of warfare, humanity finally discovered the Achilles heel of the Ryall, their xenophobic reptilian foe. Spica – Alpha Virginis – is the key star system in enemy space. It is the hub through which all Ryall starships must pass, and if humanity can only capture and hold it, they will strangle the Ryall war machine and end their threat to humankind forever.

It all seemed so simple in the computer simulations: Advance by stealth, attack without warning, strike swiftly with overwhelming power. Unfortunately, conquering the Ryall proves the easy part. With the key to victory in hand, Richard and Bethany Drake discover that they must also conquer human nature if they are to bring down the alien foe …

6. Thunderstrike! - US$7.50

The new comet found near Jupiter was an incredible treasure trove of water ice and rock. Immediately, the water-starved Luna Republic and the Sierra Corporation, a leader in asteroid mining, were squabbling over rights to the new resource. However, all thoughts of profit and fame were abandoned when a scientific expedition discovered that the comet's trajectory placed it on a collision course with Earth!

As scientists struggled to find a way to alter the comet's course, world leaders tried desperately to restrain mass panic, and two lovers quarreled over the direction the comet was to take, all Earth waited to see if humanity had any future at all…

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7. The Clouds of Saturn - US$7.50

When the sun flared out of control and boiled Earth's oceans, humanity took refuge in a place that few would have predicted. In the greatest migration in history, the entire human race took up residence among the towering clouds and deep clear-air canyons of Saturn's upper atmosphere. Having survived the traitor star, they returned to the all-too-human tradition of internecine strife. The new city-states of Saturn began to resemble those of ancient Greece, with one group of cities taking on the role of militaristic Sparta...

8. The Sails of Tau Ceti – US$7.50

Starhopper was humanity's first interstellar probe. It was designed to search for intelligent life beyond the solar system. Before it could be launched, however, intelligent life found Earth. The discovery of an alien light sail inbound at the edge of the solar system generated considerable excitement in scientific circles. With the interstellar probe nearing completion, it gave scientists the opportunity to launch an expedition to meet the aliens while they were still in space. The second surprise came when *Starhopper's* crew boarded the alien craft. They found beings that, despite their alien physiques, were surprisingly compatible with humans. That two species so similar could have evolved a mere twelve light years from one another seemed too coincidental to be true.

One human being soon discovered that coincidence had nothing to do with it...

9. Gibraltar Earth – First Time in Print — $7.50

It is the 24th Century and humanity is just gaining a toehold out among the stars. Stellar Survey Starship *Magellan* is exploring the New Eden system when they encounter two alien spacecraft. When the encounter is over, the score is one human scout ship and one alien aggressor destroyed. In exploring the wreck of the second alien ship, spacers discover a survivor with a fantastic story.

The alien comes from a million-star Galactic Empire ruled over by a mysterious race known as the Broa. These overlords are the masters of this region of the galaxy and they allow no competitors. This news presents Earth's rulers with a problem. As yet, the Broa are ignorant of humanity's existence. Does the human race retreat to its one small world, quaking in fear that the Broa will eventually discover Earth? Or do they take a more aggressive approach?

Whatever they do, they must do it quickly! Time is running out for the human race…

10. Gibraltar Sun – First Time in Print — $7.50

The expedition to the Crab Nebula has returned to Earth and the news is not good. Out among the stars, a million systems have fallen under Broan domination, the fate awaiting Earth should the Broa ever learn of its existence. The problem would seem to allow but three responses: submit meekly to slavery, fight and risk extermination, or hide and pray the Broa remain ignorant of humankind for at least a few more generations. Are the hairless apes of Sol III finally faced with a problem for which there is no acceptable solution?

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While politicians argue, Mark Rykand and Lisa Arden risk everything to spy on the all-powerful enemy that is beginning to wonder at the appearance of mysterious bipeds in their midst…

11. Gibraltar Stars – First Time in Print — US$7.50

The great debate is over. The human race has rejected the idea of pulling back from the stars and hiding on Earth in the hope the Broa will overlook us for a few more generations. Instead, the World Parliament, by a vote of 60-40, has decided to throw the dice and go for a win. Parliament Hall resounds with brave words as members declare victory inevitable.

With the balance of forces a million to one against *Homo sapiens Terra*, those who must turn patriotic speeches into hard-won reality have their work cut out for them. They must expand humanity's foothold in Broan space while contending with a supply line that is 7000 light-years long.

If the sheer magnitude of the task isn't enough, Mark and Lisa Rykand discover they are in a race against two very different antagonists. The Broa are beginning to wonder at the strange two-legged interlopers in their domain; while back on Earth, those who lost the great debate are eager to try again.

Whoever wins the race will determine the future of the human species… or, indeed, whether it has one.

12. Gridlock and Other Stories - US$6.00

Where would you visit if you invented a time machine, but could not steer it? What if you went out for a six-pack of beer and never came back? If you think nuclear power is dangerous, you should try black holes as an energy source — or even scarier, solar energy! Visit the many worlds of Michael McCollum. I guarantee that you will be surprised!

Non-Fiction Books

13. The Art of Writing, Volume I - US$10.00

Have you missed any of the articles in the Art of Writing Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 72,000 words. Now you can learn about character, conflict, plot, pacing, dialogue, and the business of writing, all in one document.

14. The Art of Writing, Volume II - US$10.00

This collection covers the Art of Writing articles published during 1998. The book is 62,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

15. The Art of Science Fiction, Volume I - US$10.00

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Have you missed any of the articles in the Art of Science Fiction Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 70,000 words. Learn about science fiction techniques and technologies, including starships, time machines, and rocket propulsion. Tour the Solar System and learn astronomy from the science fiction writer's viewpoint. We don't care where the stars appear in the terrestrial sky. We want to know their true positions in space. If you are planning to write an interstellar romance, brushing up on your astronomy may be just what you need.

16. The Art of Science Fiction, Volume II - US$10.00

This collection covers the *Art of Science Fiction* articles published during 1998. The book is 67,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

17. The Astrogator's Handbook – Expanded Edition and Deluxe Editions

The Astrogator's Handbook has been very popular on Sci Fi – Arizona. The handbook has star maps that show science fiction writers where the stars are located in space rather than where they are located in Earth's sky. Because of the popularity, we are expanding the handbook to show nine times as much space and more than ten times as many stars. The expanded handbook includes the positions of 3500 stars as viewed from Polaris on 63 maps. This handbook is a useful resource for every science fiction writer and will appeal to anyone with an interest in astronomy.

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