Parallel Spaces PhL 11.15.02

People sometimes feel that they are "being watched" in situations where no one could possibly be watching them. In this short essay, we explore how such a thing might be possible.

We refer back to the book *Flatland* (1884) in which Edwin A. Abbott talks about varies lower-dimensional creatures. In one example, as I recall, he imagines a race of people whose bodies are 2-dimensional shapes (perhaps circles, stars, cookie men, squares, etc) and who inhabit the surface say of a sphere. Unlike earthlings who also live on a sphere, these 2D people cannot look "up" or "down" because they simply don't have those dimensions. They could, however, detect that they live on a sphere by the periodicity in travel they would encounter. That is, they go in any direction for a while and find themselves back at the starting point. Admittedly, it is hard to imagine a "real" 2D race because it is so hard to imagine that limited geometry providing enough complexity for things like internal organs, etc. As in an integrated circuit or one-layer printed circuit board, everything would have to be "one layer". Nothing can cross over anything else, and so on. But for our purposes, we regard this example as merely a didactic tool.

Now, imagine that this race of beings exists and lives on its spherical surface, carrying out is normal existence. From their point of view, this surface is a "hypersurface", very hard for them to conceptualize, but easy for us to conceive. Imagine now that a spherical shell is constructed just outside the sphere on which our 2D friends live. On this slightly larger sphere, however, we place what we regard as "normal" 3D creatures. Imagine that the outer sphere is a transparent plastic shell and our 3D folks (the "monitors") live on the outer surface of this shell. We shall ignore issues of gravity and what holds them to the shell. The point is that our 3D friends could wander anywhere on this shell they pleased, and they could look across (down we might say) to the inner shell and observe whatever they liked. No point of the internal shell could be concealed from them! For example, you could imagine a 2-dimensional "room" on the inner shell that is a square perimeter with a little 2D door at one end. A 2D creature might enter this room, shut the door, and then survey in all directions (a 360 degree sweep), and conclude that he could not be observed. But he would be wrong. The 3D creatures could observe him from the outer shell, but he could not observe the them due to his lack of ability to perceive the extra "third dimension".

In our example, we assumed the 2D people lived on a spherical surface, and the "monitors" lived on an adjacent surface. We could just as easily have put our 2D people on a "flat" surface, and put the monitors on another flat surface just slightly separated from the 2D people's surface. The shape of the surface is not the important thing. The idea is that you can make two 2D surfaces that are parallel to each other, regardless of the details of their shape, and these two surfaces exist in 3D space. We refer to these two parallel surfaces as "parallel spaces" in the title of our essay.

In one detail the flat surface would differ from the spherical surface for our 2D friends. On the flat surface, they could come to the "edge" if they went far enough, causing them to wonder what was on the other side of the "edge". This edge would appear to them as an impenetrable wall, so they are in a large "room" in which they are forced to live. The surface does not exist beyond the edge, so they cannot get there. To relieve our 2D friends from having to worry about this, we might just make the flat surface so large, that they can never reach the edge.

Abbott I think made the point that the 3D monitor creatures could, it they wanted, make their presence known to the 2D creatures by causing some object of theirs to intersect the 2D world. For example, suppose the 3D monitors cut a whole in their clear plastic "floor" and lower a bowling ball on a string until that bowling ball intersects the inner surface on which the 2D people live. As the ball is

lowered "through" the inner surface, the 2D people would see a disk appear out of nowhere. That disk would start off as just a point, then get larger until it reached some maximum diameter (the diameter of the bowling ball), then the diameter would decrease to a point again as the bowling ball was lowered completely through the inner surface (we ignore the string). It would be a "miracle" appearance of something out of nowhere. By the way, the 2D people looking at the disk would have to walk around the disk before they could really know it was a disk. When they look at the disk, they just see a line segment, although it might be shaded in their 2D light in such a way that they can guess it is a disk just by looking at it from one point. (Also, they could not distinguish this disk from a hollow circle, unless they drilled a hole through the thing!)

So, quite obviously, we can try to extend this didactic idea up one level, where it might be more "practical". Now imagine that those being observed are 3D creatures living in their 3D world. But suppose this world is really constrained to a surface of some shape (flat, spherical, whatever) in 4D space. The 3D people are just as unaware of the "fourth spatial dimension" as the 2D people were unaware of the "third spatial dimension". How you block someone's view of the next dimension, if it "exists", is unclear, but we just imagine that to be the case.

So our 3D guinea pigs are living in their 3D world of galaxies and stars and planets and continents and oceans. But all these objects, such as planet Earth, are stuck on a 4D surface, just the way you might stick a round patch onto a normal 2D surface. We then place on a parallel surface some 4D "monitor" creatures who can look across from their surface to the 3D people's surface and observe whatever they like. Again, a 3D person could lock himself in a room and close the door, but all points in the room would be trivially observable by the monitors who are just casually looking across from their parallel surface, which might only be 3 feet away. They could read the words you write on a piece of paper, no problem.

There are various enhancements we could add to our little theory. Perhaps the 4D monitors don't want the 3D guinea pigs to know they are being observed, for whatever reason. In that case, they make sure they don't "drop anything" onto the 3D surface when people are around. In analogy with the bowling ball example, as I think Abbott points out, the 4D people could lower a 4D bowling ball (we would call this a hypersphere) through the 3D surface. The 3D people nearby would see a sphere appear out of nowhere. It would start off as a point, increase in diameter to some maximum diameter, then recede back to a point. All the while, this miracle sphere would be centered at a fixed spot in 3D space, and appear to be floating in air. (The 3D people would have to drill a hole in this sphere in order to know whether it was a solid sphere, or a hollow spherical shell.)

Notice that there would be no reason for the 4D monitors to "enter" the 3D world, because they can see everything just fine from where they are. They could, from time to time, elect to perhaps "do something" to the 3D world in an undetectable fashion. They could take a nail on a stick and momentarily poke it into the 3D world and give a car a flat tire. Who in the 3D world would ever know?

Another variation of the idea might be that 3D people who "die" are merely moved to the 4D monitor surface, where they live a more exciting life and who can look across, at their convenience, at all their old friends still slugging along in their 3D world.

Another enhancement to our theory would be that there might be a hierarchy of "monitors" and "guinea pigs". In our example above, we had the 4D monitors observing the 3D guinea pig citizens of what we think of as our "normal" world. There could be 5D monitors watching the 4D monitors, without their knowledge, and so on up the line to some higher level, perhaps without limit.

Is there any support for this idea? There might be no direct "3D" scientific support possible as long as the 4D monitors merely observe the 3D world and make no interventions. Perhaps some 3D genius could develop a 4D "viewer" that allows observation of the monitors in the 4D world.

Conventional physics "as we know it" supports 3 space and 1 time dimension. Sometimes this is called a 4D space, but of course that is not what we have in mind with the examples above. In the second case above, we have in mind monitors whose world has 4 spatial dimensions and 1 time dimension that we don't think much about.

In the last 80 years or so, physics has been quite successful in explaining the behavior of small objects using quantum mechanics, and explaining the behavior of large objects using general relativity, a partial theory of gravity. But there are a loose screws and missing bolts in both these theories. Physicists have always wanted one "grand unified theory" (GUT) to explain both large and small objects at the same time, and are constantly thwarted in this effort. The most popular area of research on this topic nowadays is called "string theory". This theory does unify many things, but has some notable drawbacks that relate to our little essay here. The drawbacks are that the string theory only "works" if the number of spacetime dimensions is something other that what we are capable of perceiving. The two numbers that always come out at 10 and 26 dimensions, corresponding to 9 and 25 spatial dimensions. Let's just leave it at that, and you can read the following well-written review article on string theory which I stole from this website: http://www.astronomy.pomona.edu/Projects/moderncosmo/John's%20string%20theory.html

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STRING THEORY: A Super Unified Theory, by John Urgo

The power of string theory lies in the potential it has to unify two fields of physics that have been at odds for several decades--quantum mechanics and general relativity. As a result, string theory has been hailed by some as a “theory of everything,” an ultimate unifier that will be the one grand theory that explains how every bit of matter and every pulse of energy in the universe came into being and why each has the properties it has. This new, as yet unproven theory, quite understandably has many skeptics and it remains to be seen if it will live up to its potential as the "super unified theory."

String theory is so exciting to physicists because it is a very promising solution to a puzzle that has been plaguing them for the last eighty years. If the puzzle can be solved, physicists say they will have achieved a virtually complete understanding of the nature of existence.

The puzzle is that the two greatest theories of modern physics-general relativity and quantum mechanics-give what seem to be conflicting explanations of gravity. These theories are well established in the scientific world, causing their irreconcilable differences to be even more plaguing. Albert Einstein’s general theory of relativity and quantum mechanical theory, which began with Einstein and was developed further by many others through the 1920s, have both been verified in countless experiments. Both are embodied by mathematical formulas that can be used to predict natural phenomena. “In fact,” says Jim Gates, “every experiment ever done to test relativity has given positive results. The theory correctly predicts what happens in the real world. And the same is true of quantum theory. They’re both firmly established. They work, and there’s no way to escape that fact.” General relativity and quantum mechanics are the finest achievements of human understanding of the fundamental

nature of matter and energy. Their seemingly contradictory statements about gravity, however, show that something is lacking in our understanding of one of the most basic and observable forces of our everyday lives.

Quantum theory is a very successful framework for describing three of the four fundamental forces in the standard model . Quantum theory portrays forces as fields transmitted by particles called quanta. The strong force holds the atomic nucleus together. Carried out by gluons, the strong force binds protons in the nucleus and is the source of the sun's energy and thermonuclear explosions. The weak force governs radioactive processes within the nucleus of the atom and is carried by W-bosons. The two forces that we are able to perceive in the everyday world are gravity and electromagnetism. Electromagnetism, carried by photons moving through space, binds electrons to atomic nuclei and thus is responsible for all chemical reactions. Electromagnetism also makes electrons jump from atom to atom in a wire, producing electricity. In recent decades, physicists have unified electromagnetism and the weak force into one electroweak theory, describing a process in the early universe through which one force could have broken down to yield these two forces. Physicists believe that all four forces are present day remnants of one original force that existed at the time of the Big Bang. As the universe expanded and cooled, this one force eventually changed into the other four forms that we recognize today.

Physicists have been less successful using quantum theory to describe the force of gravity. According to quantum theory, gravity must be like the other forces in that it must be carried by special force carrying particles, called gravitons, which move back and forth between particles of matter. The problem is that no one has ever found a graviton. However, based on the strength of the mathematical equations that predict them, scientists have faith that they exist.

The conflict is that general relativity also describes gravity, not as a force mitigated by sub-atomic particles, but as kind of an illusion created by the curvature of space. The basic idea is that mass curves space in an infinite number of directions, which causes the force of gravity. This phenomena reaches in all directions from anything that has mass and causes things with less mass to be attracted to things of greater mass, as if they were rolling across rubber sheets curved by the more massive objects. Though this theory is hard to visualize, the mathematics of relativity theory passes every test in the real world that says that this must be what gravity is.

Thus, the two sets of mathematical equations describing gravity in both quantum theory and relativity theory are diametrically opposed. Physicists see this as a problem because they have learned to have faith in mathematics. They have discovered that the universe is unfailingly mathematical. The only way to reconcile the two theories, physicists say, is to find some overarching theory such that both relativity's gravity and quantum theory's gravity can be derived from it. This is where string theory comes in.

Since its quiet beginnings in the 1960s, string theory has flared and faded through a first "superstring revolution" in the mid-1980s to a second revolution a decade later. In recent months, a new wave of discoveries and enthusiasm has begun what many have hailed as the third revolution that may lead toward the day when all the laws of creation will be explained on the same terms.

String theory first arose in the late 1960s as an ill-fated attempt to understand the strong force. Some physicists took this failure as a sign that quantum field theory ought to be scrapped and replaced with a whole new vision. What emerged was the possibility that particles were really different notes produced

by vibrating strings. This is the major deviation that string theory has from the ways physicists used to think. Until now, physicists have treated everything as a point particle, an infinitesimal, dimensionless dot. One big problem in dealing with the infinitesimally small particles of quantum theory is that they cause mathematical absurdities to pop up in the equations. String theory, by contrast, says the smallest particles are not dimensionless points but one-dimensional strings. They are on the scale of 10^-33 centimeters long and to our instruments look like points. An attractive feature of string theory is that if sizeless particles are replaced by little strings, the infinities go away.

Physicists say these short strings vibrate at different frequencies, much like a guitar string, producing various tones. The differing vibrations of these sub-atomic strings show up in scientific instruments as protons, neutrons, photons, and other fundamental particles. For example, a proton can be thought of as three vibrating strings, one for each quark. The different combinations of the vibrations of the strings produce the different properties of the proton, such as charge, mass, and spin. Furthermore, if you give each string a characteristic way to vibrate and calculate the properties of those vibrations with the same formulas developed for describing the vibrations of strings in musical instruments, string theory will give you good mathematical descriptions of all known fundamental particles of matter and energy. Even better, string theory effectively includes gravitons as one of the fundamental particles. Researches studying string theory have found a particle similar to the graviton, arising from the vibrations of the strings. The famous mathematical inconsistency that for decades made it impossible to incorporate quantum gravity with the other fundamental forces of the standard model is absent in string theory. It is almost as if gravity needs strings in order to exist.

Strings can be open or closed, sweeping out a worldsheet through space-time. A closed string has periodic boundary conditions while an open string has an endpoint free to move about. Strings interact by splitting and joining. The vibrational modes of strings can be characterized by various quantum numbers, such as mass, spin, etc. This means that each mode carries a set of quantum numbers that correspond to a distinct type of particle, as described above. Thus, all fundamental particles can be described by one object, a string.

The **hardest pill to swallow** concerning string theory is that it makes mathematical sense only if the universe has 26 dimensions. When an early version of string theory emerged in the 1970s, it was realized that one could only believe the equations if the strings were vibrating in a space of 26 dimensions. This is 22 more than the four space-time dimensions that we are in contact with in our everyday existence. Mathematically, it is trivial to add dimensions, but it is only plausible to claim 26 dimensions if it is asserted that 22 of them are hidden from our perception. This is where the idea of compactification plays a major role.

Compactification means the “curling up” of extra dimensions of the strings to a very small size. To curl up two dimensions, for example, take a doughnut and begin squeezing it down to a circular wire with an unobservably small cross section. Then squeeze the wire loop down to a point. The wire thus appears one-dimensional and the point appears to have zero dimensions.

In 1984, four Princeton University physicists found a way to make string theory work in a 10-dimensional world, having compactified the other 16 dimensions, curling them up so that they no longer played a role in the everyday world. Later, it was discovered that of all the possible ways to compactify a string into 10-dimensions, only five were mathematically sturdy. Physicists continued to toil with

compactification until in the mid 1990s they realized that the five ways to hide the extra dimensions were closely related. The five 10-dimensional string theories were found to be just different views of a single underlying 11-dimensional theory, called **M theory**. All of the five theories could be connected by "dualities," mathematical relationships describing the same physics.

As the varying string theories began to funnel into one, physicists realized that their equations spoke of a world made not just from strings but also from membranous things called p-branes, with the p standing for the number of dimensions. Especially important to M theory is a special type called a D-brane. In 1995, Dr. Joseph Polchinsky of the University of Santa Barbara showed that D-branes, which come in as many as nine dimensions, described surfaces on which strings can end. D-branes are now seen as entities at least as fundamental as strings and they may even be the fundamental objects from which strings and everything else is made.

Recently, a theory by Dr. Juan Maldacena of Harvard University, has been the source of much excitement. Maldacena used D-branes to construct a quantum field theory in the ordinary four space-time dimensions. He also used D-branes to build a 10-dimensional string theory (with five of the dimensions compactified). By their nature, string theories include gravity. Thus Maldacena was able to show that quantum theory, string theory, and gravity were all intimately related.

An interesting aspect of Maldacena's new theory is the notion that the universe is holographic. In laser holography, a three dimensional object is projected onto a two-dimensional plane. In the Maldacena model, the four-dimensional field theory can be thought of as a holographic projection of the five dimensional string theory (the other five dimensions having been compactified). "In a holographic universe," says George Johnson, "the information about everything in a volume of space would be displayed somehow on its surface." The implications of this notion are only beginning to unfold.

So is string theory the final answer, the super-unified theory that solves the discrepancy between relativity and quantum theory and explains all the forces of nature in the same terms? Understandably, there is much skepticism in the scientific world. The main problem is that no theory can be considered valid until it has produced predictions that can be tested. Up to now, string theory has been entirely conceptual, as there have been no means of testing it.

In principle, an extremely powerful particle accelerator could test string theory, but such a machine would have to be a million billion times more powerful than the Superconducting Super Collider that was to be built in Texas before Congress killed its funding. A new accelerator, the Large Hadron Collider, being built in Europe, may offer some means of testing string theory, but not for several years. String theory predicts that the electroweak force, the strong force, and gravity have the same strength at 10^19 GeV, so the accelerator would have to be very powerful, to say the least. Even so, a direct testing of string theory seems impossible and this has led many scientists to claim that string theory is mere speculation and does not deserve the lofty term theory. For all the conceptual revolutions in string theory, many physicists maintain that there is little to show but a lot of beautiful mathematics.

"We've made an enormous amount of progress in the last few years", says Dr. Steven Giddings of the University of Santa Barbara, "but now we realize the greater depth of our ignorance."

Note (PhL): the notation 10^19 means 10 to the 19th power, which is 10 billion billion. The string length quoted earlier was 10^-33 cm which is the size of one part of 1 cm that has been divided into 1 million billion billion billion equal parts. This is very small even compared to the radius of a proton which is about 10^-13 cm. You could place 10^20 or 100 billion billion of these "strings" end to end and the result would stretch about 1 proton radius.

The book *Flatland* can be read on-line at this location: http://www.geom.umn.edu/~banchoff/Flatland/