

Einstein's Physics Of Illusion

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Some of you may think from the title "Einstein's Physics of Illusion", that I'm going to talk about the physics which underlies what we think of as magic. That is not what I expect to talk about. Some of you may think that I suspect that Einstein had some special physics of illusions. If he did, I don't know anything of it. Instead, what I want to do, with Einstein's help, is to trace our physics all the way back to square one, and to find out whether, underlying it, there may possibly be something akin to magic.

George Valens has written a charming book called *The Attractive Universe*. It is subtitled "Gravity and the Shape of Space", and on the very first page he says that when a ball is thrown straight up, after a while it comes to a stop, changes its direction and comes back. He says it looks like magic, and probably it is. Now what he is taking for granted is that it should have gone off on a straight path without any change in speed or direction. But you see, that also would have been the result of magic. We do not understand in physics why the ball comes back. But we also do not understand in our physics why the ball should have continued without any change in the direction of its speed.

Now in the title, and in the remarks that I have made so far, what I mean by magic or illusion is something like what happens when, in the twilight, you mistake a rope for a snake. And this sort of thing was analyzed very carefully by some people in North India long, long ago, and they said that when you make such a mistake there are three aspects to your mistake. First, you must fail to see the rope rightly. Then, instead of seeing it as a rope, you must see it as something else. And finally, you had to see the rope in first place or you never would have mistaken it for a snake. You mistook it for a snake because the rope was three feet long, and you're accustomed to three foot long snakes.

But before I speak further about illusion, I want to say a few words about what we do understand in physics, and I also want to point out a few gaps in that understanding. When we talk about the universe, or when we look out and see it, what we see is that the universe is made out of what we call matter. It's what we call a material universe. And what we want to do, first of all, is to trace that material back, not quite to square one, but to square two at least. We want to find out whether we can think of all these things which we see as being made out of matter, as really being made out of only a few ingredients. And the answer is that we can. Long ago the chemists pointed out that all these things that we see are made out of not more than 92 ingredients. Those are the 92 chemical elements of the periodic table. It was suggested in 1815 that all those different chemical elements are probably made out of hydrogen. That was Prout's hypothesis, because in those days no one knew how to do it. But now, in modern times,

we do know how to do it, and we do know that that's what happens. All the other chemical elements are made out of hydrogen, and it happens in the stars"

The universe, even as it is today, consists mostly of hydrogen. And what it is doing is falling together in the gravitational field. It falls together to galaxies and stars, and the stars are hot. Falling together by gravity is what makes them hot. And they get hot enough inside so that the hydrogen is converted to helium. Now helium is a very strong atomic nucleus, and so the main line in building up the atoms of the atomic table goes this way: First, four hydrogens make one helium. Then three heliums make one carbon. Two heliums won't stick. That would be beryllium-8. There is no beryllium-8. It won't last. But three heliums will stick, and that's carbon. Four is oxygen. Five is neon. That's the way it goes in the stars; the other nuclei are built of helium nuclei. Six makes magnesium. Then silicon, sulfur, argon, calcium, titanium, chromium and iron.

In big stars it goes like this. But in small stars like our sun it goes only up to carbon or possibly carbon and oxygen. That's where our sun will end, at about the size of the earth, but with a density of about four concrete mixing trucks in a one pint jar. Larger stars get too hot by their own gravitational squeeze, and the carbon cannot cool off like that. They go right on to oxygen and so on, until they get, in the center, to iron. Now iron is the dumbest stuff in the universe. There is no nuclear energy available to iron -- nothing by which it can fight back against gravitational collapse; so gravity collapses it, this time to the density of a hundred thousand airplane carriers squeezed into a one pint yogurt box. One hundred thousand airplane carriers in a one pint box! And, when it collapses like that, the gravitational energy that is released to other forms blows the outer portions of the star all over the galaxy. That's the stuff out of which our bodies are made. Our bodies are all made out of star dust from such exploding stars.

We do know that the main ingredient of the universe is hydrogen and that the main usable energy in the universe is gravitational. We know that the name of the game is falling together by gravity (hydrogen, falling together by gravity), but what we don't know is why things fall together by gravity. We do know that the stuff out of which this universe is made is hydrogen, but we do not know from where we get the hydrogen. We know that the hydrogen is made of electrical particles, protons and electrons, and we know that the total electrical charge of the universe is zero, but we do not know, you see, why it is made of electricity. We do not know why it falls together. And we do not know why, when things are moving, they should coast. There are these gaps in our understanding. We know how things coast. We know how things fall. We know how the electrical particles behave, but we don't know any of the why questions. We don't have any answers to the why questions.

What I want to talk about next is a discovery made by Albert Einstein when he was 26 years old and working in the patent office in Bern. Then I want to talk about the consequences of that discovery and, through that, I want to trace our physics back, if possible, to answer those why questions.

Einstein noticed that we cannot have an objective universe in three dimensions. We all talk about 3-D. Hardly anybody talks about 4-D. But the universe is 4-D. It is not possible to have a universe of space without a universe of time. It is not possible to have space without time, or time without space, because space and time are opposites. I don't know that Einstein ever used the language that space and time are opposites, but if you look at his equations, it is very, very clear that that's exactly what they are. If, between two events, the space separation between them is the same as the time separation between them, then the total separation between them is zero. That's what we mean by opposites in this case. In electricity if we have the same amount of plus charges as we have of minus charges, say in the same

atom or the same molecule, then that atom or that molecule is neutral. There is no charge seen from outside. Likewise here. If the space separation between, two events is just the same as the time separation between those two events, then the total separation between those two events is zero.

I'll give you an example. Suppose we see an exploding star, say in the Andromeda galaxy. There's one going on there right now. It's been visible for about a month or so. Now the Andromeda galaxy is two and a quarter million light years away, and when we see the explosion now, we see it as it was two and a quarter million years ago. You see, the space separation and the time separation are the same, which means that the total separation between you and what you see is zero. The total separation, the real separation, the objective separation, that is, the separation as seen by anybody, between the event which you see and the event of your seeing it -- the separation between those two events is always zero. What we mean when we say that the space and time separations between two events are equal is that light could get from one of those events to the other in vacuum.

We see things out there, and we think they're really out there. But, you see, we cannot see them when they happen. We can't see anything when it happens. We see everything in the past. We see everything a little while ago, and always in such a way that the while ago just balances the distance away, and the separation between the perceiver and the perceived remains always at zero.

As soon as Einstein noticed that we cannot have a universe of space without a universe of time and vice versa, and that they are connected in this way, and that the only way to have an objective universe is in four dimensions, and not in two or three or one -- as soon as he noticed that, he had to redo our physics.

Now relativity theory is a geometry theory. It's not something else. It's a geometry theory. It's about the geometry of the real world. I'm sure that most if not all of you have been exposed, somewhere along your educational careers, to the geometry of Euclid. His geometry is in two dimensions and in three, but he didn't have any idea about introducing the fourth dimension. His geometry - is a theoretical geometry about a theoretical space which does not, in fact, exist. Newton based his understanding of physics also on that understanding of geometry, and Newton's physics is a theoretical physics about a theoretical universe which does not, in fact, exist. We know now, you see, that Euclid was wrong in his understanding of geometry, and that Newton was likewise wrong in his understanding of physics. And we had to correct our physics in terms of Einstein's re-understanding of geometry. It was when Einstein went through our physics with his new understanding of geometry that he saw that what we had been calling matter or mass or inertia is really just energy. It is just potential energy. It had been suggested a few years earlier by Swami Vivekananda that what we call matter could be reduced to potential energy. In about 1895 he writes in a letter that he is to go the following week to see Mr. Nikola Tesla who thinks he can demonstrate it mathematically. Without Einstein's understanding of geometry, however, Tesla apparently failed.

It was from the geometry that Einstein saw that what we call rest mass, that which is responsible for the heaviness of things and for their resistance to being shaken, is really just energy. Einstein's famous equation is $E = mc^2$. Probably most of you have seen that equation. It says that for a particle at rest, its mass is equal to its energy. Those of you who read Einstein know that there is no "c" in that equation. The c^2 is just in case your units of space and time don't match. If you've chosen to measure space in an arbitrary unit and time in another arbitrary unit, and if you have not taken the trouble to connect the two units, then, for your system you have to put in the c^2 . If you're going to measure space in centimeters, then time must not be measured in seconds. It must be measured in jiffies. A jiffy is the length of time it

takes light to go one centimeter. Astronomers are rather broad minded people, and they have noticed that the universe is quite a bit too big to be measured conveniently in centimeters, and quite a bit too old to be measured conveniently in seconds; so they measure the time in years and the distance in light-years, and the units correspond. That "c" in the equation is the speed of light in your system of units, and if you've chosen years and light-years then the speed of light in your system is one. And if you square it, it's still one, and the equation doesn't change. The equation simply says that energy and mass are the same thing.

Our problem now is that if we're going to trace this matter back, and find out what it is, we have first of all to find out what kind of energy makes it massive. Now we have only a few kinds of energy to choose from. Fortunately there are only a few: gravitational energy, kinetic energy, radiation, electricity, magnetism and nuclear energy. But I must allay your suspicion that nuclear energy might be very important. It is not. The nuclear energy available in this universe is very small. If all the matter in the universe began as hydrogen gas and ended as iron, then the nuclear energy released in that change (and that is the maximum nuclear energy available) is only one per cent of what you can get by letting that hydrogen fall together by gravity. So nuclear energy is not a big thing, and we have only five kinds of energy to choose from in order to find out what kind of energy makes the primordial hydrogen hard to shake. That, you remember, was our problem.

What we want is potential energy, because the hydrogen is hard to shake even when it's not doing a thing. So what we're after is potential energy, and that restricts it quite a bit more. Radiation has nothing to do with that. Radiation never stands still. And kinetic energy never stands still. And even magnetic energy never stands still. So we are left with electricity and gravity. There are only two. We don't have any choice at all. There is just the gravitational energy and the electrical energy of this universe available to make this universe as heavy or as massive as we find it.

Now I should remind you that the amount of energy we're talking about is very large. It's five hundred atom bombs per pound. One quart of yogurt, on the open market, is worth one thousand atom bombs. It just happens that we're not in the open market place. We live where we have no way to get the energy of that yogurt to change form to kinetic energy or radiation so that we can do anything with it. It's tied up in there in such a way that we can't get it out. But right now we're going to talk about the possibility of getting it out. We want to talk about how this tremendous energy is tied up in there. We want to talk about how this matter is "wound up".

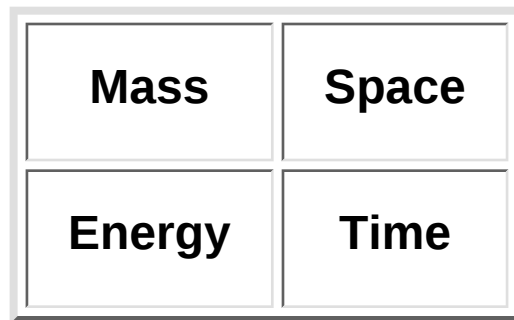
First let's talk about watches. We know how they're wound up. They're wound up against a spring. Now when we wind up a watch, what I want to know is whether it gets heavier or lighter. If we have a watch, and if we wind it up, does it get harder to shake or easier? It gets harder to shake because when we wind it up we put more potential energy into it, and energy is the only thing in the universe that's hard to shake. So now we want to know in what way the whole universe is wound up to make it heavy and hard to shake. We know that it must be wound up against electricity and gravity. The question is: How?

We need to know some details on how to wind things up. How, for instance, do you wind up against gravity? You wind against gravity by pulling things apart in the gravitational field. They all want to go back together again. And if the entire universe were to fall together to a single blob, the gravitational energies that would be released to other forms would be five hundred atom bombs per pound. The universe is wound up on gravitational energy just by being spaced away from itself against the gravitational pull inward. And it turns out to be just the right amount. It really does account for the fact that it's five hundred atom bombs per pound.

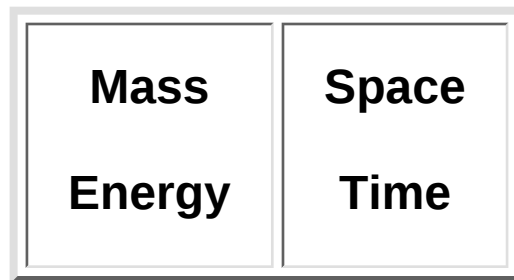
How do we wind up against electricity? We push like charges toward each other. If you push two electrons toward each other you have to do work, and it gets heavier or more massive. If you push two protons toward each other it gets more massive. And if you take a single electrical charge and make it very small, since you're pushing like charge toward itself, it too becomes more massive. Now it turns out that the work that's represented by a smallness of all the teeny-weeny particles that make up the hydrogen atoms and all the rest of this stuff is, once again, five hundred atom bombs per pound. Some of you might think that it should come out to a total of ten hundred atom bombs per pound -- five hundred gravitational and five hundred electrical. No, it's only five hundred atom bombs per pound because winding it up one way is exactly the same thing as winding it up the other way. Coins have two sides, heads and tails. You cannot make coins with only one side. For every heads there is a tails. Plus and minus charges are like heads and tails. Space and time are like heads and tails. And electricity and gravity are like heads and tails. You cannot space things away from each other in the gravitational field without making them small in the electrical field.

I think that we're ready now to attack the consequences of this new understanding of physics. We want to find out whether, through this understanding, we can trace our physics all the way back to square one, to see whether, underlying it, there may be something akin to magic. We want to know why things fall. We want the answers to our why questions.

I'm going to draw you a quick map. This is a picture of the physics before Einstein:

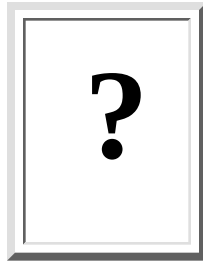


In the last century we thought that mass was one thing; energy was another. Space was one thing; time was another. In our present understanding of physics that won't work. Space and time are just two sides of the same coin. Mass and energy are just two sides of the same coin. And there is no line through there:



There is no line between mass and energy or between space and time. And we just talked about the way in which the universe is wound up in order to make the particles massive. They're wound up against space. They're spaced in against the electrical field, and they're spaced out against the gravitational field, which means that what we call matter and energy are also nothing but geometry, and the line down the middle goes too. But when the lines go, the picture goes. When the lines of demarcation between mass and energy and space and time are obliterated, we do not have a model of a physical universe. Every definition in our physics, every concept in our physics. requires measurements of length. or of

time, or of mass one or more of these measurements. And without the discrimination between length, time and mass we have no way to measure anything in physics, no way to define anything in physics. Our model of the universe does not hold up when we examine it from the standpoint of Einstein's equations. And what we are left with I shall indicate here by a question mark:

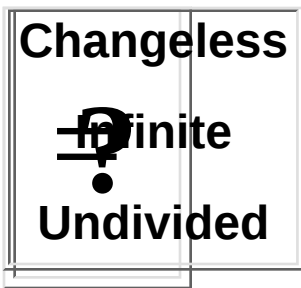


What is it that exists behind our physics? Relativity theory does not say exactly what it is, and our task is to find it out, if we can.

First let us understand a little bit about what we call causation in physics. What do we mean in our physics when we say that one thing causes another? We mean that there is a transformation of energy from one form to another. For instance, if the hydrogen falls together to galaxies and stars, the gravitational energy is first converted to kinetic energy in the falling; and then the kinetic energy is converted to radiation when the hydrogen falls together into stars. When radiation from stars like our sun is picked up by all these green leafy things which we call plants and trees, it's converted to electrical and magnetic forms. So all these things happen by changes in energy, by changes in the form of the energy. The amount of energy does not change. There is no such animal as the generation of energy. The amount of energy, whatever it is, seems to be completely unchangeable. It's one of our most basic observations in physics. And what we mean by causation is changes in the form of this energy. Matter itself is energy, and what we mean is that when something happens, whether it's hydrogen being converted to helium, or whatever it is, there's some change in the form of the energy. Now the universe cannot arise by this kind of causation simply because in any such change the amount of energy at the end is never any greater than the amount at the start. You cannot manufacture gold by remolding gold. You never finish with more than you started with.

With this understanding of causation in mind, I want to go back to our question mark. We want to see whether we can get some idea of the nature of what the equations of relativity theory say must exist behind the universe of our observations. And we want to see how, from that nature, we come to the world of our perception.

When we look at this question mark, what we see is that it has to be beyond space and time. Our physics is on our side of space and time, if you like, but Einstein's equations say that behind our physics there is this question, "What is it?". We know that it has to be beyond space and time. And for that reason we can get a negative statement about what it is. If it's beyond time, it must be changeless, because only in time could we have change. If it's beyond space, it must be both undivided and infinite, because only within space could we have things finite and divided. Without space you couldn't break a cookie in two. Without space you couldn't have cookie crumbs. And without time you couldn't do anything, because you couldn't have any kind of change. So whatever exists behind this universe must be changeless, infinite and undivided:



The curious thing is this, that what we see is apparently not changeless, not undivided and not infinite. It is obviously finite. The teeny-weeny particles that make up the hydrogen atoms and all the rest of these atoms and molecules are really minuscule. The number of hydrogen atoms required to make a single drop of water is equal to the number of drops of water in a million cubic miles of ocean. They are certainly finite. And this matter is divided up into atoms. Why should it be so divided? And it's continually changing. You can look anywhere.

So what we see is changing, finite and divided, and now comes the question: By what kind of causation could we get from the changeless to the changing? From the infinite to the finite? And from the undivided to the divided?

We haven't proved that we can get there by magic, but we have proved that we can't get there any other way. We cannot get there by the causation of our physics, because that would require that we change the changeless to the changing, that we divide the undivided, and that we make the infinite finite. As I say, we can prove that we cannot get there any other way, but we have not yet proved that we can get there by magic. So now I want to ask: What happens if we look at this problem from the standpoint of what I'll call apparitional causation? My favorite word for this is not quite magic. It's not quite illusion. It's apparitional causation. It's the kind of thing you do when you mistake a rope for a snake.

Could we have mistaken the changeless for the changing? Could we have mistaken the infinite for the finite? Could we have mistaken the undivided for the divided? That's the question.

So let's go back to that old analysis of apparitional causation to see if such a mistake could give rise to our physics. We want to know whether apparitional causation can answer our why questions. When we mistake one thing for another, you remember, there are three aspects to our mistakes -- three consequences, if you like. First, we must fail to see it rightly. In this case, we must fail to see the changeless, the infinite and the undivided. That's fine; we've failed. Then we must see something else in its stead, and that else must be different. And so it is. What we see is changing, finite and divided. Finally, you remember, we had to see the thing to start with. If we had not seen a three foot rope we would not have mistaken it for a three foot snake. When you mistake your friend for a ghost, if your friend is tall and thin then the ghost will be tall and thin. But if your friend is roly-poly you'll see a roly-poly ghost. Had you not seen your roly-poly friend you would not have seen a roly-poly ghost.

If, then, our physics has arisen by apparition, the changeless, the infinite and the undivided must show in that physics. But isn't that exactly what we see? The changeless shows as inertia, the infinite as electricity, and the undivided as gravity. Had we not seen the changeless, it would not have shown up in our physics. It is the changeless which we see, and, as a consequence, that changeless shows in what we see. That is why things coast. That is what we see as inertia. That is what we call mass. Likewise in order to see the undivided as the divided we had to see the undivided, and that is what we see as gravity. It is a consequence of having seen the undivided. You cannot see a universe of particles, all spaced out, without

having them fall together again. You cannot make the mistake of seeing it as divided without having the undividedness show. And, finally, you cannot make the mistake of seeing the infinite broken up into teeny-weeny particles without the consequence of seeing those particles as electrical. Probably some of you don't know quite enough physics to understand what I mean by that, but every electrical particle has energy just because of its smallness, and if you let it get bigger, its electrical energy would go down. If it could get infinitely big, its electrical energy would go to zero. So you can think that electrical energy is just the tendency to go back to the infinite, just as the gravitational energy is just the tendency to go back to the undivided.

Now these two things are really the same thing. The wind up against gravity by being spaced out is exactly the same thing as the wind up against electricity by being spaced in. And these two things make up the rest mass. They make up the thing called inertia. It's the electro-gravitational energy of the particles which we see as their rest mass. It is that energy which is hard to shake.

It's impossible to see an apparition of this sort without having it wound up. It is not possible to see this universe except wound up. The infinite and the undivided must necessarily show as the electrical and gravitational energy. There is no such thing as matter. There is only this energy, and the energy is five hundred atom bombs per pound. The energy is the consequence of the apparition. It is the yearning for liberation in the apparently finite. It is the yearning for the undivided in the apparently divided. And it is the yearning for the changeless in the apparently changing.

With the help of this notion of apparitional causation suggested by Einstein's equations, we are able, you see, to trace our physics all the way back to square one to answer those why questions. With Einstein's help we are able at last to understand why matter falls, why it coasts, and why it is made of discrete electrical particles.

We have to look at it very carefully. We have completely to change our understanding of geometry. Our native understanding of geometry, or rather our native misunderstanding of geometry, is a genetic mistake. We make the mistake because it was never necessary not to. It was never necessary, in the long past history of our race, for us to see space and time correctly. It never was. It was definitely necessary that we have at least a dog's understanding of a three dimensional space, otherwise we wouldn't have had offspring, and the species would all have died out. But it was never necessary to understand that space and time are opposites. It was never necessary to understand the origin of gravity, or the origin of inertia, or even the -fact that the atoms are made of electricity, or the fact there are 92 chemical elements. It's not necessary to understand any of these things in order to have offspring and have the perpetuation of the species go on. It works all right through many, many mistakes.

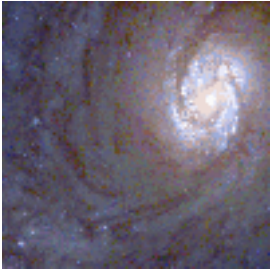
You must not think that just because it's a native perception on your part that it's true. That has nothing to do with it. Just look back and see how you got the way you are. You have to think that it's all a mistake, and you have to notice that our genetic misunderstanding of space and time is at the root of it. That's where the root is. It is with, in our mistaken notions of space and time that we see this universe the way we do. So what we have to do is to straighten out our misunderstanding.

Space is not really that which separates the many. It's that which seems to separate the one. There's only one. And in that space that oneness shines. Therefore falls whatever falls. Space is not that in which we see the finite. There is no finite. Space is that in which the infinite appears as small, and in that space that vastness shines. Therefore bursts whatever bursts. Therefore every electrical particles wants to become infinite. And therefore shines whatever shines. And time is not that in which we see change,

but that in which the changeless seems to change, and in that time that changeless shines. Therefore rests whatever rests; therefore coasts whatever coasts.

Our problem is to discriminate between what's behind this notion of space and time and what's within it. Our problem is to discriminate between the real and the make believe.

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