IN VIDEO 14, NEIL TALKS ABOUT:

- *Trusting the instruments, not the senses, when piloting a plane*
- *The history of scientific inquiry: Aristotle through Galileo*
- *The Physics Behind an apparitional universe: trusting the equations, not commonsense*

Neil Feldman: Okay.

Judy Feldman: Okay, we're recording. The date is October 10th, 2014.

Neil: It's Friday. So this is in preparation for my book and tentative title right now is a working title, so don't worry about it, but it's Considering Einstein and the Quantum Theory. As subtitle, The Physics Behind an Apparitional Universe. We'll see how far we get in part one. I was very ambitious and I thought we'd get from the dawn of modern science to Special Relativity but I don't think so. I should also point out that a lot of the ideas you're going to hear are based on the cosmology of John Dobson who was the founder of the San Francisco Sidewalk Astronomers and the inventor of the Dobsonian telescope.

I'll just lay it out. The quantum enigma. Of all the theories that have been tested for over 85 years, no prediction by this theory has ever been shown to be wrong. But if you take this theory seriously, it says that the reality of the physical universe depends upon our observation of it. This is the quantum enigma. It seems almost impossible to comprehend. And Sir James Jeans said, "The universe begins to look more like a great thought than a great machine."

So to explore all this stuff that we're going to go into, we have to have some ground rules. The first ground rule is that we're going to employ the scientific method. This is a structured method of inquiry. It's based on gathering up observations. It's empirical, looking for measurable evidence that's subject to specific principles of reasoning. It consists of the collection of data through observation and experimentation, and then the formulation and testing of hypotheses. These steps need to be replicable by anyone. The hypotheses must dependably predict future results.

Second ground rule. We will employ what's called Occam's razor. "The simplest explanation that covers the facts is usually the best." That's a quote from him. The theory with the fewest new assumptions is usually the correct one. Entities must not be multiplied beyond necessity. That all came from Father William of Occam. I don't have the date, I should. Sir Isaac Newton put it in his Principia as, "We are to admit no more causes of natural things than such are both true and sufficient to explain their appearances. Therefore, to the same natural effects we must so far as possible assign the same causes." It will become apparent later why Occam's razor is very important.

Then the final ground rule is that we need to trust the equations of physics and science, not our commonsense.

I don't have this figured out here, but I was going to actually start the book by describing a pilot like myself who is only trained to fly in good weather. If such a pilot that is not trained to fly on instruments loses sight of the horizon by flying into a fog bank, or a cloud, or because it's dark at night, there's no moon – there's nothing to give him any sense of a horizon and he trusts his guts to keep the plane level – he will kill himself in about 30 seconds. He will put the plane into what's called a dead man's spiral, thinking all the time that the plane is perfectly level when in fact it's banked slightly and it will continue to turn that plane to that point where it will just spiral. It's a well-known phenomenon. It's very likely what happened to Robert Kennedy Jr.

But the point is that there are instruments and if you are instrument rated you've gone through training that does two things. One, you know how to interpret what the instruments are telling you about where the horizon really is. More importantly, you trust the instruments, not your guts. Otherwise you'll kill yourself.

I believe in the world of quantum physics and Einsteinian theory. If you are going to be honest you have to realize that the commonsense view is not correct. But the equations suggest a viewpoint very different that will go against your commonsense. Nonetheless, the equations are what we have to trust, not our guts.

So how do we know our universe? By observation. You need something right?

Judy: Yeah, I just want to have ideas about what you can…

Neil: There's a pen over there. Yeah, you can interrupt me anytime. Don't…

Anna: There's a pad of paper right there.

Judy: I don't want...Where?

Anna: Right under the loose paper on the top of the table.

Neil: Yeah, that's blank.

Judy: The one I...

Neil: Yeah, stop me…

Judy: The only thing I was going to say was, can you honestly use the…is it a Hindu story about the snake and the rope?

Neil: Well, we'll get to that. This is really just to kind of set the stage. I'm actually of a mind that I should stay away from the Vedanta as much as possible.

Judy: Well that doesn't necessarily…

Neil: I mean, we'll get to it at the end but I don't want to confuse the…

Judy: Yeah, but it might be more confusing if you jump. I mean we'll see.

Neil: Well now I'm going to…

Judy: But that doesn't necessarily have anything to do with the Vedanta, that story.

Anna Feldman: No, actually the West has stories like that so you might do a little research into whether…

Neil: Well, I'm not opposed to it but you see how I lay this out and then tell me if you think I should put it in here.

Judy: Yeah, that's why I'm going to do, notes instead of interjecting right now.

Neil: Yeah, that's fine.

Anna: That's good.

Neil: Anyway, so we know our universe by observation. How do we observe the universe? We see things away from us. We do that via radiation, light energy. We hear things away from us via sound energy. We touch, feel things separate from us, and that's really based on electrical energy. And we taste and smell things separate from us. That's actually based on our sensing of magnetic bonds. The interesting thing about all of these observations, these five sense phenomena are all electromagnetically based.

So the five senses that we have respond to, five different kinds of energies. The inner ear or the saccule responds to gravitation. That's how we get oriented in the gravitational field and it is, by the way, what gets confused when you're in that airplane without a reference to the horizon. Our skin responds to kinetic energy. Temperature is kinetic energy. When you rub your hands together, they get hot. That's kinetic energy being turned into heat. The eyes respond to radiation energy, but only in a very select band of frequencies. The tongue responds to electrical energy. Protons, single protons, taste sour. And the nose is a very complicated mechanism, responds to magnetic energy in the sensing of molecular bonds of various smells.

So what can we observe about the universe? Well, it appears as made up of really itsy-bitsy teeny-tiny electrically charged particles of matter that always want to fall together by gravity. Our universe and everything in it appears to be bound by laws of gravity, inertia and electricity. But those particles of matter also appear as waves.

How can we explain this? Well actually we can't. We don't know why all the bits of matter exhibit gravity, electricity and inertia. And we still don't know what gravity, inertia and electricity really are.

So, how do these concepts of gravity and inertia first arise? We're going to go through the quick history starting with Aristotle and the Greeks. Jump ahead to Nicolaus Copernicus and Galileo, Tycho Brahe, I don't know. Go on to Kepler and Sir Isaac Newton.

So, if we start with the philosophers of ancient Greece, they actually set the stage for modern science because they saw nature as explicable. They saw nature as governed by laws. They actually defined the laws of logic and they saw explanations based on fundamental principles. Aristotle chose some fundamental principles. First, the Earth is the center of the universe. All heavenly bodies move in perfect circles. Objects fall because of their desire for the cosmic center. Heavier objects will fall faster than lighter ones. The stuff of the universe is made of five elements. Actually, four plus one element: earth, water, air, fire, and ether. The first four elements were earthly. The last one, ether, was not.

So Aristotle's commonsense view was, he said, "Matter cannot act where it is not." Which is to say, matter can't interact with any other matter unless it is somehow in direct contact with it. It's interesting to note that Einstein felt exactly the same way. He had an unyielding bias that matter had to be touched by something in order to move.

Anna: Can you explain that? What did Aristotle mean?

Neil: Well if you think...He meant that if you saw an arrow moving, it was being propelled along somehow by something pushing on it. Any movement you saw had to be as the result of a direct contact. If you think about mechanics, or anything, initially with the arrow you have the bow and it launched it but it was a direct…

Judy: Action.

Neil: Direct action, direct contact. Matter is not going to move or stop moving unless something acts on it that touches it somehow.

So Aristotle's major mistake was that he assumed these fundamental principles could be intuitively perceived as self-evident. So his science had no mechanism to compel consensus. In other words, these things were not to be tested. They were just obvious. Later, the Catholic Church made a mistake, too, because they picked up Aristotle's view and it became the official dogma of the Catholic Church in the late middle ages, and it was primarily through the efforts of Thomas Aquinas. Aquinas took Aristotle's cosmology and his physics and he fit it together with the Church's moral and spiritual doctrine. For example, Earth, where things fell, was also the realm of the morally fallen man. And the heavens, where things moved in perfect circles, was the realm of God and his angels.

Now Pythagoras felt that the universe was a flawed reflection of perfection, and of course we have the Pythagorean theorem as a way of measuring the distance between two points. Everybody's learned this.

Judy: When?

Neil: Middle school?

Judy: Yeah.

Anna: Grade school.

Judy: I don't think so. We did it in high school.

Neil: Right, something like that. High school or middle school.

Ptolemy of Alexandria was trying to solve problems for astrologers. The astrologists needed to track and predict the five bright objects, which we now know as the planets. They were called the wanderers that wandered through the sky. These were, you had fixed stars and you had these five objects that were moving. And then they would watch them very closely because that's how they would make their astrological predictions.

So it would be helpful to have a way of doing this mathematically. Ptolemy's mathematics, his model of the universe worked beautifully but it required that the planets moved on epicycles. These were really complicated loopy curves and circles within circles. Stationary Earth was at the cosmic center, but it worked. It at least tracked and predicted the motion of all the objects including the Sun, and it was accepted as true and then later this became religious doctrine.

Excuse me.

Judy: You all right? You need water?

Neil: No, that's okay.

So Nicolaus Copernicus, late 1400s - early 1500s, was a Polish monk. He was born 1400 years after Ptolemy. That's how long Ptolemy's ideas held sway. In 1543, his treatise called *The Revolution of Heavenly Orbs* was published, right after his death. That was by design. He did not want to take on the Church or any authority. But in his treatise the Sun, not the Earth, was the center of the universe. All the other five planets orbited the Sun. He also points out that the Earth spins on its axis and that it was the third planet from the Sun. The heavenly bodies still traveled in circular orbits but this was a much simpler explanation of the observations. He'd been using Occam's razor.

The simplicity of what he came up with was not sufficient to win over the authorities. One of the ways that he was ignored is that they would say, "Look, the Earth obviously stands still. We don't feel any motion. If it's in motion we would feel it." It was also perfectly obvious that if you took a stone and you dropped it, it obviously would be left behind if we were dropping it on a moving Earth. The Earth would move away – stone, boom!. Since air occupied all space, a great wind should be blowing if we're on a moving Earth. So these were the kinds of arguments to justify keeping the status quo. But most importantly, the Copernican viewpoint conflicted with the 'wisdom of the Golden age.' They contradicted the Bible and they put salvation at risk.

Johannes Kepler came a little later. He was the first to coin the term inertia, from inert. He came to the conclusion that the Sun and the Earth attract each other. And so do the Earth and the Moon. He incorrectly attributed the attraction initially to angels, and then later to magnetism, which also was wrong. He had the idea of a mutual attraction across empty space and that, too, was contrary to Aristotle.

Tycho Brahe was a contemporary of Kepler, died before him, but he made very, very accurate observations. And Kepler got his hands on these observations after Brahe died. That allowed him to resolve his thinking into three basic laws. First, the orbits of the planets were elliptical, not circular, and the Sun was off-centered in the elliptical orbit. That lent to the idea that the closer a planet was to the Sun, the faster it would move in its orbit. And the larger the orbit, the longer it would take for a planet to go around the Sun.

So it was a brilliant analysis of hard observations. But Kepler couldn't explain these rules. He didn't like them because now he had these imperfect circles. But he accepted what he saw. He accepted the observations.

There was a fellow named Giovanni Benedetti in the early 1500s, Italian obviously, who studied the flight of cannonballs. So he set out to test one of Aristotle's thoughts without obvious facts. He tied two objects of equal weight together with a thin thread. He expected them to fall twice as fast. That's what Aristotle would have expected in his idea, because heavier objects fall faster to the Earth. So you take two objects, now you connect, they should fall twice as fast. But he discovered that was not the case. He confirmed that all objects fall to the Earth at the same rate regardless of their weight.

Now I point out that it's Benedetti who did this because Galileo got credit for it. Galileo observed the same fact but Benedetti came up with the discovery before Galileo. Still, Galileo was the first to truly employ the scientific method. He really is the father of the scientific method. He was the first to conceive and carry out experiments to prove his theories.

At this point I have to go into a description of what Galileo observed about pendulums. He studied them, I think, while he was getting bored sitting through service in Church. I think that's the story. He would watch the chandelier go back and forth, something like that. But anyway, he found that the period of one oscillation, one cycle, was constant. It didn't matter how large or small the amplitude of the swing. It didn't matter how much it moved. It was a constant. He got the same result with pendulums of equal length but unequal weights attached to them. And actually these experiments were excellent demonstrations of the force of inertia.

So he came up with this law of falling bodies and he said, "In a vacuum, all bodies fall at the same acceleration." Not the Aristotelian concept at all…

Anna: But he didn't have a vacuum.

Neil: That's right. Neither do you.

Anna: So it wasn't observational. It was hypothetical.

Neil: He extrapolated from the observation. But the reason that he said in a vacuum, he wanted to eliminate the effect of air.

Anna: Wind.

Neil: So to get over that, when he did his famous experiment at the tower of Pisa, he had objects that were heavy enough to overcome any air resistance, so he could prove the point.

Anna: But they were different weights.

Neil: Yes.

Anna: Okay.

Neil: But the best example of this, you can find it on YouTube, was when we went up to the moon and we repeated the same experiment but this time they did it with a – I think it was a lead ball and a feather. Now they have a vacuum. They both hit at the same time. So that really illustrates the point better than anything else because...But that's the brilliance of Galileo and Newton. They extrapolated into seeing these forces operate in a vacuum. They didn't have a vacuum to confirm the experiment, but they based it on the observation of experiments that they could perform that weren't limited by the fact they didn't have a vacuum.

So, in a vacuum all bodies fall at the same acceleration. The effect of gravity is the same regardless of the mass of the body. The distance that it falls is proportional to time squared and the question is why do bodies fall to Earth rather…