Astronomy Cast Episode 275 for Monday, October 8, 2012: Isaac Newton, Part 1

Fraser: Welcome to Astronomy Cast, our weekly facts-based journey through the Cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain; I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University – Edwardsville. Hi, Pamela. How are you doing?

Pamela: I'm doing well. How are you doing? And Happy Canadian Thanksgiving to you.

Fraser: You have a Canadian husband, and so I'm sure that you are made aware every year that this is the proper and true Thanksgiving, and not that other one. I hope you had turkey last night.

Pamela: I sadly was on a plane last night, so I had a sad ravioli.

Fraser: So I don't if we had anything…we didn't think of anything to announce, so I don't think we will. Actually you know what we should announce is just to remind people that we record every episode of Astronomy Cast now as a live Google plus hang-out, and if you want to join us and watch us record live and answer your questions, you can circle the Astronomy Cast page on Google plus, and then you'll get a notification of when we're going to record, but normally we're going to record Mondays at noon Pacific time, 3:00 Eastern, and do the math for all the different time zones. Cool. Well, alright, are you ready to go?

Pamela: I'm hoping. You always find something I'm not ready for.

Fraser: Just you wait. Alright, let's go.

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Fraser: So Isaac Newton has been called the greatest and the most influential scientist who ever lived. And that sounds about right. He unlocked our modern understanding of gravity and the laws of motion, dabbled in optics, philosophy and even alchemy. He was also known to have a bit of a difficult personality, so let's find out everything we can about Isaac Newton. So if you could pick one discovery that Isaac Newton was most famous for…gravity?

Pamela: I think it's probably a tie between gravity and Calculus because more people have to learn Calculus than remember gravity.

Fraser: That's true. So then who was this guy, and where did he come from?

Pamela: So the odd thing is that while he's most remembered as a scientist, he was a Brit who was eccentric, who was difficult to work with, who's generally believed to have Aspberger's, and who wrote far more about Christian hermeneutics and occult and alchemy than he did about science. So it's just fascinating that a lot of what he did was based on trying to use science to understand religion, and use logic to translate the Bible. He was fluent in Hebrew, but it's his writing related to science that survives to the modern day.

Fraser: I always think of him as like a Sheldon Cooper, I gotta say.

Pamela: I think that's fairly accurate, but had Sheldon listened to his mother concerning religion. Although that's to say Newton didn't believe in the holy trinity. He thought that worshipping Jesus was idolatry, so while he was a Christian hermeneutic, he was also a heretic, so he was just like a totally confusing dude.

Fraser: Yeah, and he did some pretty weird experiments. I hope we'll get to the one where he jammed a knitting needle in his eye to see how optics worked. But let's go back then…where did he come from? Where did he grow up and get his initial education?

Pamela: So he was born prematurely on Christmas Day in the old calendar, and his father died three months later. He was born in Woolsthorpe-by-Colsterworth in Lincolnshire, England, where they have long and difficult names.

Fraser: That's a good British name for a town.

Pamela: It is. It is. So according to his mother, you could basically stick the poor guy in a mug upon his birth; he was quite small, and his father died a few months after he was born, and his mother remarried and then left poor young Newton to be raised by his grandmother, and according to all accounts Newton never fully got on with his step-father, or particularly got on with his mother after that, so he had a difficult childhood. He did go to school, went to college, but then had to drop out of college when his mother's second husband passed away, and she said he needed to come back and be a farmer, except as one might imagine, academics don't make the best farmers under many situations, especially not the physically science bent ones, and eventually the university convinced his mother to let him go back to school. So he just had a very difficult beginning to his life, but he was able to complete his education. He went on to get a position at Cambridge that allowed him to both work for the university and study.

Fraser: Now, sorry, what time frame are we looking at here? He was in the 1700s?

Pamela: He was in the 17^{th} century. He was born in 1642. He died at the beginning of the 1700s, so his childhood was all during the 1600s. He actually was overlapping with the Bubonic plague, which…one interesting thing to think about is the university shut down due to the plague at various times, and it was while he was sent home to avoid dying of the plague, as one hopes to do, that he was able to accomplish a lot of his writing.

Fraser: OK, so he ended up at Cambridge, which was like the perfect place for somebody interested in these kinds of topics.

Pamela: Yes, so he was able to finish his education while he was at Cambridge, and this was back in the days before you got a specific degree in physics, you got a specific degree in mathematics. It was pretty much a university degree, and while he was in university, he studied DesCartes, and Copernicus, and all the great thinkers, and it was while he was working on all of his studies that he started to figure out advanced mathematical theories. In 1665, he developed the binomial theorem, so his initial work was: let's think about all of the great philosophers, let's think about all the great scientists, and let's work on building a mathematical treatise, and so he started with the binomial theorem and has been torturing math students ever since.

Fraser: I think I've been tortured by that one. So pure math…so then how…he's famous for so many different things, so how did his education take him further into that?

Pamela: Well, so the thing with being an academic back then was it wasn't like today where you said, "I want a grant to go do 'foo.' I want a grant to go do 'foo.'" It was more a matter of you sat and you thought, you worked, you exchanged letters, and so for him, he developed the binomial theory. About the time that he was done with that and he had graduated, the university temporarily closed due to the great Plague, Bubonic plague. This was its second massive sweep through England, and when he went home, it was while he was home that he started working on developing Calculus and working in optics, and thinking about the law of gravitation. So between 1665 and 1667, he was working from his house, something that I know you and I both enjoy getting to do, but in those pre-internet days, that meant you're kind of trapped and left on your own with your thoughts, but Newton was such that he died a virgin, according to all accounts, he never had a relationship with a woman, while he had some good friends who were men who he exchanged letters with, for the most part, he was a very solitary individual, so these years were highly productive for him, and when he returned to Cambridge as a fellow of Trinity University, it was a chance for him to continue working on. Although one of the things he had to deal with was the fellows of that time were required to become ordained priests, and so Newton had the fun of trying to avoid becoming a priest, who, as I said, he was a heretic, and it's kind of hard to commit yourself to becoming a priest when you recognize that you don't believe that Jesus Christ is part of the trinity, and while you're good with God, you're not good with modern views of the Church, so he had an interesting time at that point, and eventually managed to avoid becoming a priest by becoming the Lucasian Chair, which is the Chair that is now held by Steven Hawking, so he started a grand tradition at that point.

Fraser: OK, so he had quite an interesting life, as you said -- very reminiscent personality-wise of Sheldon Cooper from the "Big Bang Theory," which I think is a great model.

Pamela: Sheldon had a girlfriend; Newton did not.

Fraser: That's debatable…but during this time, very productive couple of decades, made massive improvements in all kind of sciences and math, so I think we should really break down all these different topics of study that he went through, and put them in some kind of order and really take a look at all the things that he… so you said he worked on binomial theory, what were some of the other really big and groundbreaking areas of study that he worked on, and what was the process?

Pamela: The advancement of Calculus, infinitesimal Calculus -- this is where you take the sum of all the littlest pieces and add them up to find the area under a curve, basically. He developed that in order to be able to advance his physics, and one of the interesting problems faced by people trying to put all of the pieces together is Newton didn't want to share or publish anything he didn't feel was absolutely perfect because he greatly feared being scorned or ridiculed, so while he developed Calculus, well, most likely in the late 1660s, he didn't bother to get around to publishing it until the late 1680s, and this opened the door for Leibniz to be in a position to co-discover Calculus and put his theories forward and try to claim he was the developer of it. Luckily, the book Principia, which is much of Isaac Newton's theories on physics, clearly required him to have developed Calculus…and he had other earlier books, one a manuscript on the motion of bodies in orbit that clearly also required some form of Calculus to have been present as well in order for him to have come to the conclusions he came to, so it's now generally accepted that Newton developed it first, but what's interesting is he used Leibniz's notation for it because it's considered to just be the easier way to notate Calculus.

Fraser: And this just comes back to this constant situation with the early scientists, where in order to do the kind of work they wanted to do, they would have to invent the various pieces of the puzzle to be able to do it, so you have this situation where in order to do better math for gravity, he had to invent possibly the most important mathematic invention in the last 1000 years, you know, as a tool in the same way that Galileo had to invent a new thermometer, you know what I mean? There was almost this expectation that if you were going to push the boundaries, not only were you going to have to push the boundaries in your science, you were going to have to come up with the technology and the methods and, you know…I can imagine him going, "Well, I need a computer, so it's time to sit down and invent silicon conductors because that's what I've got to do to compute how to turn lead into gold."

Pamela: Well, it wasn't quite like that, but one of the, I think, reaching things that Isaac Newton did, in a certain way, in a certain framework is he was such a perfectionist in what he did that when he finally did get around to sharing his different theories, when he finally got around to publishing his results, he did it in such a thorough manner and with such a concise language that the style with which he wrote Principia is considered to be the best possible style that a scientist can use. So well, yes, he defined the Calculus that everything we do, unfortunately, relies on (or fortunately, depending on how you feel about having to sit down and do mathematics), while he is one of the early people to sort out many different things with optics, while he sorted out why Kepler's equations work (and we'll describe all of these in a moment), the way that he described these things -- it's not just used in physical sciences, it's not just used in mathematics, it's used across all of academia as a way to discuss scientific concepts, so he defined the language with which we use as professional scientists to communicate to one another.

Fraser: Wow. That's pretty deep. OK, so we've got Calculus, what else?

Pamela: So binomial theory, Calculus -- those were really the big things for him when it comes to mathematics. He did lots of other things, but those are the big things that people walk away with. Optics is probably next. He was the first person to really put together the pieces that white light, the light that comes out of incandescent light bulbs, the light that comes from the Sun that when you focus it onto a wall, you get a nice, white circle, although we typically talk bout the Sun as being yellow, but that's a complicated discussion. White light, he realized, is actually just the combination, the additive combination of a variety of different colors, and by playing with prisms and lenses, he realized that you can use a prism to diffuse all those different colors, and he realized that lenses, in their own way, use the principles as that prism, and because of that, any telescope that's ever made that uses lenses is always going to be dividing all the white light into all of its individual colors. This is something called chromatic aberration, and in order to prove that he was right, he developed a new type of telescope that we call the Newtonian telescope that uses a reflecting mirror, and for him the idea wasn't so much to build the better telescope, but to show that lenses refract light into all of its different colors; whereas mirrors simply reflect the beams. For him, this was…he thought of, well, what we now call photons as corpuscles, so it was the Corpuscular Theory. Today, we recognize that light is both particles and waves, but he was one of the early people saying “it’s particles, and here’s how you treat it mathematically as particles, and here’s how mirrors don’t care what color those particles are,” so that was kind of a creepy awesome modern thing.

Fraser: And so what’s the darning needle in his eyeball story?

Pamela: So I have to admit that I’m completely grossed out by eyeballs, so any reference I had of that in my head had been blocked out until you brought it back up at the beginning of the show.

Fraser: Really? OK. Alright. If I recall then, he wanted to see how the eyeball distorted light, how it acted as a lens, so he took a knitting needle and he kind of jammed it…does this squeak you out?

Pamela: Yes. Google it!

Fraser: …knitting needle, squeezed his eyeball around it, and took a look at how it affected the light, and how it changed his vision and…you know.

Pamela: Yeah, yeah.

Fraser: …and nearly blinded himself. Go ahead, Google the story, but it’s the kind of thing that would occur to him. He’s just like, “Well, I gotta figure this out, and I am the closest human around, so let’s get…yeah, let’s perform the experiment.” Yeah.

Pamela: Yuck.

Fraser: OK. I learned something new about you today, and your squeakiness with eyeballs.

Pamela: Yeah, I can’t even put contacts in. I’m totally squeed out by eyeballs.

Fraser: No, I’ve never put a contact lens in. I can’t even imagine doing it. Well, let’s just move on then, so we can move past…so he figured out prisms, rainbows, light, breaking up, combining again, OK, also very important.

Pamela: So in 1675, he published his hypothesis on light, putting forward his ideas in written form, and talked about the idea of the ether being something that transmitted it. Luckily, it turns out that light doesn't need any such thing. It's quite happy to go through a vacuum, and what's interesting is he worked with so many other scientists over the years. He worked with Hooke, with Henry Moore, and he started thinking about light in terms of alchemy, and at one point, he actually replaced the ether in his ideas with occult forces, and so occasionally, he wandered away from mathematical reality and tried to use science to prove occult ideas, which is kind of something that most people don't learn about.

Fraser: That's hilarious. I wonder how much…but I guess the question is back in that time, you think about their line of thinking, was the occult just…the occult was absolutely true, alchemy was true, and so it was perfectly reasonable to use your logic and your reason and your experiments to try and understand these…but that the occult, or that alchemy was all just the same, you know what I mean?

Pamela: He actually took it further than others. This is why he was so afraid of being accused of being a heretic, and he never talked to people about his beliefs. He did have a lot of writing that went unpublished and so he…this wasn't mainstream. John Maynard Keynes actually wrote that Newton was the first of the Age of Reason, but the last of the magicians, and so here you have this man of science, but he wasn't actually a man of science. He…in his head, it was the occult, it was religion, it was alchemy, and he was simply trying to prove it with reason as the Age of Reason was getting started. This wasn't mainstream. He was the guy on the radio in the middle of the night, except he had the math to back up what he said.

Fraser: But I wonder if he, like, putting it into the context of the time…

Pamela: No. He was still a crazy dude.

Fraser: He was still crazy? OK, so it's not like the things that he was talking about, and the topics that he wanted to go into were well accepted and regarded and a lot of people shared his beliefs. He put people off, and they were wondering why that was all he wanted to talk about…and they had already moved on, right?

Pamela: It was more a matter of he did all this work, all of this writing, he even traveled around trying to find meaning in the architecture of buildings in the Old World, going down to Greece and Rome and studying the Tomb of Solomon, and this, for the most part, was all kept secret because he knew it wasn't normal. It's sort of like he worked so hard to avoid becoming a priest because he knew his ideas weren't normal, so he's the crazy person who's self-aware that he's crazy, and didn't publish most of his work. It was kept in letters and documents that came out after his death. For the most part, he refrained in what he published to completed ideas, so this is where his Principia of physics, his optics…optics were complete ideas that he published as a whole, but he could never reach completion on his occult ideas, so those didn't get released on the public luckily. It might have had devastating effects on his career, and he knew that.

Fraser: OK, so we've got all his work into the optics and stuff, but I guess we're missing the next logical step here is the thing we talked about right at the beginning, which is his incredible work on gravity. So what was the concept of gravity before Newton had a think about it?

Pamela: It wasn't so much that it existed. We had Kepler's laws, but the idea that forces didn't exist -- that came about from Newton's work, so starting in 1679, he started thinking about celestial mechanics, he started trying to understand what called Kepler's laws, and while he was working on all of this, the ideas started to build. He started putting together his theories of motion, equations of motion, kinematic equations as we refer to them today depending on what book you pick up, and it all started to come together as a whole, and this is where his book Principia came together, and was published in 1687. So he finally pulled all of the pieces together in this one – it's still considered to be perhaps the best-written science book of all time. He basically sat down and put all of the pieces together into a whole that we now call "Physics I" in the University, where you start with, "Well, here are the equations of Motion. OK, where do the equations of motion come from? Well, you have forces acting. Well, what are the forces acting on the Moon, on objects that are falling? Well, that's gravity." And it's this beautiful crystal-clear notion once you add force and once you're willing to admit that maybe there's this invisible force pulling objects together, and well, since things fall, it was easy to follow this through to its end, and it's this beautiful clean-cut theory that people angst over far too much.

Fraser: Now what about this whole concept of the apple falling?

Pamela: See, that one's argued about whether it's apocryphal or just an analogy he told. So people think it probably never happened, and it was just a convenient way to explain things.

Fraser: But the idea was he saw an apple falling, and then…

Pamela: So the story goes that he saw an apple falling, he looked up saw the Moon, realized that the Moon is falling as well, but the way it's falling is it's constantly missing the Earth, and just curving around our planet, and this is something we've talked about in our own Astronomy Cast on gravity.

Fraser: Right, it's this concept that if you had a cannon, and you shot it sideways fast enough, it would eventually just go into orbit around the Earth, that it would just keep falling further and further from where it was shot until…if you shot it fast enough it would go into orbit. It was still falling, but it was falling at the same amount of speed that it's moving around the Earth as well, so it just keeps going into orbit. I mean, that's a stunning recognition to kind of see the apple fall, and kind of go "Huh. The apple and the Moon – that's the same thing." Well, you say it's apocryphal, that's the way he described it in, I think it's the Principia, but that's the way he described it, right, was to say that they're all just falling, they're all forces, and it's all the same thing.

Pamela: And he did this when he was in his 40s, so he accomplished mathematics, geometry, binomial theorem (he did binomial theorem while still in university), gravity -- all before his 40s. And he went on to have still a more diverse career. He went on to head up the Royal Mint, where he was responsible for investigating a large number of forged coins and doing all the detailed investigations. And he was someone who just couldn't leave a mystery uninvestigated, whether that mystery be "what is it that causes a prism to break up light" to "what is it that, well, how was it that all of these coins were forged?" He estimated at one point that 20% of the coins that were swapped out in the Great Recoinage of 1696 were actually counterfeit coins, and counterfeiting was high treason, so yeah, he had a lot of investigating to do that led to people being drawn and quartered, so his heritage also includes causing people to be killed.

Fraser: Right, so we've got gravity, we've got his work on the Royal Mint, we've got his Chair at Cambridge, right?

Pamela: Yeah, Cambridge.

Fraser: Yeah. Isn't this the Chair that Steven Hawking holds?

Pamela: Yeah, we said that at the beginning.

Fraser: Right, so a long history after this. So, OK, so he does his work in gravity, he does his work in the Mint…anything left?

Pamela: Well, he lived into his 80s, and what's interesting is he lived this long and fruitful life where he was… once he reached adulthood, he lived the academic's life, where you stay in the Fellows' Halls in the University, and you exchange letters with others, and he moved in amazing circles, knowing Locke and Voltaire. And interestingly enough, he had a niece who was stunningly beautiful, and is one of the ones who ended up with all his papers later, and there's letters exchanged that he wasn't always a cold-hearted Aspberger-y scientist, but he actually wrote of his love to her (in friendly uncle love, nothing scheezy or anything like that), but it's because of this relationship with his niece that so many of his papers were able to be carried into the future.

Fraser: And so he lived into his 80s. Where did he die?

Pamela: He died in England; he died while still working at the University.

Fraser: And I'm trying to think -- wasn't his grave part of that awful Dan Brown book?

Pamela: Yeah, that's true, but I don't know if any of that was at all betrayed in truth.

Fraser: Yeah. Yeah. Cool, well, what a great story, and what a great man -- and what a weird man!

Pamela: Yeah, exactly. You have to keep in context the weirdness. Occasionally, you do have to listen to the crazy crackpot people who are making their own shit up because if they use math they could be right, but if they don't use math, just ignore them.

Fraser: I sort of think about it like our forum. He's the kind of person who we would give him 30 days in our forum, and then we wouldn't let him propose his ideas any more -- and then he turned out to be right.

Pamela: And so what Fraser's talking about is the Bad Astronomy Universe Today forums that are hosted on Cosmoquest.org, and there's a part of the forum where people can present their own alternative theories of reality, and they have 30 days to be interrogated by the community and if they can match all of the questions, well, then they're allowed to continue talking about their theory, and hopefully moving it forward and changing science. So far, no one's succeeded.

Fraser: Hasn't happened yet. No, and then that's it. Thirty days, and then the conversation is closed, and they don't get to talk about it again. Well, cool. Well, thank you very much, Pamela, and I think we were hoping to do this as a two-parter. Next week we were going to talk about the XMM Newton telescope, which was based on his name. So that's the way we roll, so we'll see you all next week.