Astronomy Cast Episode 218 for Monday, January 31, 2011: Max Planck

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.

Fraser: Hi, Pamela how you doing?

Pamela: I'm doing well, Fraser, how are you doing?

Fraser: Good. I hope I got that right. You're the one who knows a little bit of German, right?

Pamela: I know a little bit of German, and your pronunciation is way better than how we normally say it in the American physics classroom, where it becomes Max "Pl-ayn-ck."

Fraser: So, either way: Max "Pl-ahn-ck" or Max "Pl-ayn-ck," we'll go with that. Time for another action-packed double episode, where we meet a man and his mission. This time around it's German physicist, Max Planck, considered to be the father of Planckton theory. He was later granted a Nobel Prize for just that discovery. So let's take a trip back just over 100 years to learn about the man who changed our understanding of the very small: Max Planck. So where do you want to start with this one, I mean, Einstein got all the press, but Max Planck made one of the most important discoveries in all of physics, right? I mean, he's… what an amazing series of discoveries and ideas!

Pamela: And one of the things that really brings it home is, in reading up for this episode, I found the statement, that when people are referring to classical physics, they're referring to everything discovered before Max Planck, so his career defines the turning point from classical physics to our modern era of quantum mechanics and relativity.

Fraser: So, can you go back for a second? What was the classic understanding of physics?

Pamela: Up until then people casually argued left and right about whether light was a particle or wave. We dealt with motions in a nice, linear fashion, where you had a force that accelerated something, and you figured out distances, and time worked everywhere the same way for everybody, and it was just a nice, uniform, didn't-hurt-your-head-too-much, your-stomach-was-comfortable-with-physics, kind of reality to live in.

Fraser: Right, a Newtonian reality…

Pamela: Exactly.

Fraser: Right. Motion… all of the physics made a lot of sense.

Pamela: The worst it got was when you're dealing with a circular or spherical object, you had to use non-Euclidian geometry. Boo-hoo, you could still model it!

Fraser: [laughing] But the evidence was mounting up that there was something wrong.

Pamela: Exactly. We had this problem that people were trying to understand: what's the energy coming off of light sources? What is the energy in a hot system? The realization that when you shine light of different colors on objects, different things happen, that heat and photons are related to one another…people were trying to come to terms with all of these different ideas, they were trying to map out the structure of an atom. All of these things were going on pretty much contemporary to one each other, and in trying to understand the amount of light that came from an object of a given temperature, there was this problem where if you looked at it using one set of rules, all of the theories worked perfectly well for long wavelengths; if you looked at it with another set of equations, it all worked perfectly for short wavelengths, but there was no unified understanding of "if you have a hot object, what is the distribution of light coming off of that hot object?" and without that understanding, things like stellar spectra, things like, well, something as simple as "what color is light coming off an incandescent light bulb?" -- we couldn't answer those questions, and Max Planck figured out how to answer those questions.

Fraser: And so what was his answer to the question? What discovery did he make?

Pamela: It wasn't so much a discovery as, just like Kepler, he kept trying to fit reality into his equations and make it work, and he didn't really like his answer, so Kepler discovered that things orbit on ellipses instead of circles, and Planck discovered that the only way you can really get the relationship between energy and light to work out is to say the energy is restricted to quanta, that you can go no smaller than a certain value and you have to jump up in a given increment: Planck's constant value. Now, he didn't actually think that light was confined to these given increments -- that understanding would come later. He was initially just trying to find an equation that would fit reality.

Fraser: Hmm…alright, well let's talk about his life then?

Pamela: [laughing] I love the abrupt changes! This man is doing this brilliant science, but he was a human -- he did have a life going on in the background.

Fraser: That's all I'm saying, you know, he's more than just a simple, you know, a groundbreaking idea. Sounds as if he was a pretty interesting guy, too.

Pamela: He was! And in a lot of ways, he was your "scientist's scientist." There are certain stereotypes that you hear about: "Well, many scientists and mathematicians are gifted at music," well, Max Planck was gifted at music. In fact, for a long time growing up, it was thought, "well, maybe with his gifts at piano, his gifts at other instruments, maybe he'll be a musician." And he was supported in that, but when he was seventeen, he met a good mathematician at his gymnasium, and he fell in love with science. Then, just like your quintessential scientist, he fell into the boring classes, and complained about the boring classes, but just sort of put his nose to the grindstone, and sucked it up, and got through, and dealt with boring professors, and dealt with uninteresting professors. What's interesting reading in his bios, is point after point is made about: "He went here and was bored; he went there and the courses were dry." [laughing] As someone who's "been there, done that" -- not all my professors were not that way, but there's always that one. But he kept his nose to the grindstone and found interesting what he was doing, and found questions that intrigued him over and above the charisma that was injected into the content by the people conveying the information.

Fraser: So where did he go to University?

Pamela: He entered University at age 17. He graduated from high school quite young and studied at the University of Munich, but they didn't have a large physics department. Physics was still a beginning field in some ways at that point, and he was kind of unimpressed, but he got through, finished what he was doing, and he went on to qualify for his dissertation at Munich, finishing his PhD at the age of 21, which kind of makes me feel dumb and stupid because I was finishing my Bachelor’s degree at 22. And when he was working on his thesis, he got to work with some of the big names: Kirchoff and Hemholtz, and after finishing up his degree he went on to be a private lecturer. He went on to become an associate professor at the University of Kyle, which is where he grew up, and he actually married a woman that he was childhood friends with, and then he went on to become a full professor at the University of Berlin. So, he did many different things over his life. He studied at Berlin for a while, working with Kirchoff and Hemholtz. It was your typical (admittedly very accelerated) academic career. One of the things that impressed me about him is that he also did have this family life that is mentioned over and over in all of the discussions of him. He married in 1887 and went on to have many children. He had first a son, and then twin daughters, and then another son – all with his first wife. One of the things that he had to deal with – faced with the wars and faced with medical care as it was at the time -- was he lost one of his sons to WWI, then he lost both of his daughters to childbirth. Then during WWII, he lost his second son, who participated in an attempt to assassinate Hitler, which is one of those strange things to read in the biography of a major scientist. He lost all but one of his children. He had a third son via his second wife, but his life wasn’t an easy one -- first watching his children, and then his wife, and then another child all die before he did. And it wasn’t easy going through the wars either, and this is where a lot of the idea of the "scientific stoic" was another one of those things that he kind of lived up to.

Fraser: Right. I mean, you just think about the amount of tragedy! He lost his first wife, second wife, all of those children…I can't even imagine, and yet continued on teaching and helping with science. Unbelievable.

Pamela: And he also wasn't politically silent. During WWI, he was very a much a "OK, everyone, we're going to get through this, just put your nose to the grindstone and just work." And that's something that's very admirable -- to have Europe basically falling apart around you, and to just say, "we're scientists, we're just going to do science and get through this." Then during WWII, he was admittedly one of the 92 scientists that signed the declaration that it was a good idea to take over the rest of Europe, but he went on to admit that that probably wasn't the right thing for him to do, and he recognized what was happening to his Jewish colleagues, and throughout WWII, he publicly supported the science being done by Einstein, a Jewish scientist. He looked for ways to, within the institutions that he worked at, essentially hide German scientists and give them places to continue working. World War II wasn't an easy time for him; he was an old man at this point, and he had to flee the bombing that was going on at this point, he lost his home, and at one point he basically said, "I just want to live to see this over and see us get back to doing science again."

Fraser: I don't know…it's a hard thing to say, right? I mean, we don't know what it would be like in a totalitarian state like that, and in his mind, it was really all about doing the science, but I mean, to sign your name to such a horrible document…it's a hard thing to then take a step back and say well, you know, you've got to understand the time they were going into. It's a really interesting story. I normally have opinions about this thing, but I don't know what I would do in that situation.

Pamela: And it's one of those things where you have to look at, in some ways, what is the difference between what someone says and what someone does? Yes, he signed a piece of paper that was probably not (it definitely wasn't) a good document, but beyond signing that document, he was then at the risk of his own life, someone who spoke out to say "OK, those of you who are scientists and not German, stop applying for jobs in foreign countries. We need to let the German scientists who can't be German Jewish scientists, who can't work in this nation anymore take those jobs." That's one of the philosophies he talked about. I mean, can you imagine, your whole country's falling down around you, and it's an easy thing to think, "OK I'm just going to take that job my buddy has in America right now, or that job my buddy has in ______"… well, pretty much everywhere else was getting bombed pretty badly right then….but to say, "OK look, we at least are German nationals, we have options if we stay in this country, but look at our Jewish colleagues -- if they stay they have no options." I have the utmost respect for that single action.

Fraser: Right. So, then I think it's really important for us now to take a look at the discoveries -- his actual academic contributions to science. So, when did he really start to produce some science that was some of the groundbreaking stuff? I mean, he had his thesis…I'm not sure, was it better than your thesis?

Pamela: [laughing] Yes.

Fraser: Well, what is the timeline of some of the really big discoveries?

Pamela: His work from the beginning was extremely fundamental. That's the thing about him is: even when he wasn't doing cutting-edge, changing-the-laws-of-everything type science, he was always working to innovate things. Before going into his great discoveries, I think there's one interesting tidbit that has to be noted to contextualize all of this: he was told when he looked into going into physics that it was a waste of time.

Fraser: Dead end…

Pamela: Philipp von Jolly actually said to him: "In this field, almost everything is already discovered, and all that remains is to fill in a few holes," so can you imagine? You're starting your whole career, you're young, you're excited, you're interested, and you're told, "Dude, you're wasting your time – we've already done it!"

Fraser: Yeah, you're in typewriter repair right now…

Pamela: His response was: "That's OK, I'm interested in just filling in the details." So Planck wasn't one of these upstart scientists who want to *change the world forever and win the Nobel Prize!* That wasn't his goal. I know people who start out with that goal -- that wasn't him. He just wanted to be the one going in and saying, "Huh, we haven't figured this little detail out. Let's do that. Let's figure out this little detail over here and figure out that," and he kind of filled in quantum mechanics [laughing].

Fraser: [laughing] Yeah, that little detail…

Pamela: Right, so while he was studying he got introduced to the concepts of thermodynamics, and he ended up doing his dissertation work on the Second Law of Thermodynamics. This is the law that basically states: "Everything is devolving to chaos." It's the law that says that entropy basically takes over in isolated (the fancy words are: entropy of an isolated macroscopic system never decreases)… perpetual motion machines -- they just can't exist because there's always going to be something breaking down the order within a system. This is the idea that all systems tend to disorder over time.

Fraser: Right. And so the whole universe is moving towards a state of higher entropy, and so then came from a place of lower entropy in the past.

Pamela: And this was one of those ideas that…well, the philosophical implications of this are great. I don't know a physicist who hasn't blamed the surface of their desk on entropy at least once in their life.

Fraser: [laughing] Right, right. Come on, I'm just going the same direction as the universe!

Pamela: Exactly! I don't think entropy defines the accruement of paperwork -- but it seems to apply!

Fraser: Second Law of Thermodynamics and Paperwork…

Pamela: Yes, and Planck was someone who just fundamentally saw entropy as just something in his gut that made sense and contextualized the universe. And so that was where he started, but while he continued doing work on thermodynamics, and doing work on entropy, he picked up on these ideas of [missing audio] trying to understand the energy distribution of light, and that's where he jumped in and he tried all sorts of different models before finally settling on the "energy equals some constant (now called Planck's constant) times the frequency of light." And when he came up with this, it was just a theory, just a pretty theory that happened to work. He actually, like Einstein, spent the entirety of his life struggling with the concept that our universe is governed by statistical principles, that idea of quantum isn't just a property of transitions – how light is admitted and absorbed – but it's a fundamental property of the waves themselves. The philosophical ideas, the things that still make people's stomachs upset in our post-classic realm of physics – he struggled with those the same way. He eventually came to terms with, "Yes, you need to do statistical thermodynamics these days," but he didn't like it. And I love the idea that he was the one who looked at science and recognized, "Well, this is the way it is, this is how it works, and I don't like it."

Fraser: [laughing] Right, but that's "too bad for me," not "the universe is wrong."

Pamela: Exactly, and one of his most famous quotes is: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." And this is so entirely true…

Fraser: Still the case...

Pamela: Still the case...

Fraser: Right, so we've got here quantum, and I mean, we've got a whole episode just on -- not just quantum theory -- we've got one just on spectrum and quanta. So you know, there's really specific…exactly how this works…how light is bundled up in these discreet packages of energy and what that tells you about the universe, but then where did his discovery go next?

Pamela: That basically changed everything about how we look at physics, and he spent a lot of the rest of his life trying to figure out all of the consequences of this one simple "quantization" of energy. He was also someone that was a great fan of the work being done by Einstein, and again, this is where I pointed out: he was a German scientist working in less-than-friendly conditions for Jewish scientists, and he was able to publicly say, "Look, Einstein's stuff is good!" and then he worked to build on it.

Fraser: He made significant contributions to special relativity when that theory was developed and published, so you see his work going through and he did physical chemistry with his thermodynamics work. He got into electromechanics, he got into special relativity, and what he ended up doing, actually, is building a center, and this is one of the most important legacies, in some ways, for Max Planck is throughout much of his life, he was the director of his own center. He selected the people who worked for him. He used that position as president of the Kaiser Wilhelm Society to essentially hide people occasionally. He used it derive science that was scientist-focused vs. university-focused. Any of you listening to this who are at universities know there are times when you are simply told, "We don't care what you do, but you have to bring in money," or you're told "No, sorry. We fully recognize that you need x, y, or z or your research won't work, but we're bringing in this new hire and so we're going to take away your lab space now" -- all these sort of things that happen in a large, institutional setting, he kind of got rid of, and he said, “OK, we’re going to put the scientist at the center, build the institution around the scientist, and give them freedom to do what’s best.” And today, that notion has evolved into the Max Planck Society, which creates institutes all over Germany that are some of the most well-regarded science research centers in the world, where you take the leading person in mathematics, the leading person in electrostatics, the leading person in relativity and you give them a center that they can populate with people they know are good, with people they know they want to work with, with people they hand pick, and just let them go free with a good budget. This is an amazing way to let the best scientists in the world be the best scientists they can be.

Fraser: Yeah, at *Universe Today*, we get a lot of great science news coming out of the Max Planck Institute for Astrophysics.

Pamela: Yeah.

Fraser: Yeah, and so a lot of them…and they’re all translated into English, and we’re able to access them and talk to the researchers, and it’s great! A huge amount of the research that you see is coming out of these people.

Pamela: So you see this person over the course of his life: he was that kid interested in music who did well, who got lured into mathematics, who said “Physics is fun! I don’t care if I discover anything, I’m just going to do this,” who got curious and saw entropy as a driving force in the universe, and then caught this neat little problem which was termed the “Ultraviolet Catastrophe” (which was just a good name) and decided to solve it, and got the Nobel Prize for it, and then fought for his friends during the War, and fought for his colleagues, and who signed this stupid document he shouldn’t have, but then spoke out and lost a son who tried to kill Hitler (or was part of an assassination plot, rather).

Fraser: Yeah, and he didn’t live too much longer after the Second World War.

Pamela: No, he died in 1947 at 89. He lived through what was perhaps the most turbulent time in German history, and he just got stuff done; in the face of personal tragedy, national tragedy, losing his home -- he just got stuff done.

Fraser: And so next week, then, we’re going to be talking about the Mission…

Pamela: Yes.

Fraser: …and its big goals, and some other really cool things. It’s going to be… it’s already launched hasn’t it?

Pamela: And it just gets stuff done, kind of like the man.

Fraser: That’ll be great. So we’ll talk to you next week about the Planck Mission.

Pamela: That sounds great! Cool!

Fraser: Alright, talk to you later, Pamela.

Pamela: OK, bye-bye.