Astronomy Cast Episode 219 for Monday, February 7, 2011
The Planck Mission

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, Fraser?

Fraser: I'm doing really well -- that's it. That's all I got to say about that, but I can't wait to talk about Planck so let's move right on – no chit chat! Another mission named after a famous physicist. Last week we talked about Max Planck, this time we're going to talk about the Planck Mission, designed to study the cosmic microwave background radiation across the entire sky. Like the previous WMAP mission, this will help astronomers understand the first moments after the Big Bang. Planck – now Planck wasn't its original name, was it?

Pamela: Well, none of these missions start with whatever the published name that you hear is. So Planck started with the rather horrid name of COBRAS/SAMBA, which might make a good music genre, but is a bit complicated to say for a mission.

Fraser: Right, but if you were keeping your eye on the COBRAS/SAMBA mission, it's had its name changed.

Pamela: Exactly.

Fraser: Right, and so what was Planck's goal, its purpose?

Pamela: It is one of the very few single-purpose missions that we've launched. It is an intellectual successor, you might say, to the Wilkinson Microwave Anisotropy Probe (WMAP), and it's job is to go out, look up and do nothing more and nothing less than map the cosmic microwave background radiation and nearby wavelengths of light to the highest resolution ever done for the purpose of measuring cosmological parameters.

Fraser: And this is this continuing job …what was it? The KOBE was one of the first ones and then the WMAP did another level of accuracy, and then this is just going to do the same job but do it again. It's like they're taking the same spot and they're just searching it deeper and deeper and deeper. I guess in this case it's the whole sky, but they're doing the same job, they're just doing a better job with better technology.

Pamela: Right. And WMAP did the entire sky as well and it's known for creating those weird blue and red mottled ovals that people have seen and this is -- we've talked about this before -- all good things come from the cosmic microwave background. There are so many questions that can be answered if you just get good enough data, but here from the surface of the planet we can't get that data because we have this sky that has "opaqued" the wavelengths that we're most interested in. We have all of these heat sources that are contaminating the light that we're trying to see, sort of like trying to take a picture with a thousand suns in the room. And when you put all of these things together, it means you just can't do the resolution you want, even if you're launching balloons into the upper atmosphere, so we put satellites out in awkward locations, this particular one is in the L2 Lagrange point, where it's out, if you imagine a straight line from the sun through the earth and then add a million or so miles – that's where the L-2 position is.

Fraser: Kind of like in this shadow of the Earth from the sun.

Pamela: It's not the literal shadow of the Earth, but it's 1.5 km away from the planet Earth.

Fraser: Right, right. In a bit of a bigger orbit than us. It's remaining in that position.

Pamela: Exactly.

Fraser: And we've got a whole show on the Lagrange point and why that's a nice, stable place to put a spaceship.

Pamela: And so it's hanging out there, it's already completed more than one map of the sky, and watching this mission is painful, in some ways, because with missions like Hubble, like Herschel, like all of these other beautiful imaging missions. They go up, they send down pictures, science comes out, and you can do all of these different questions, you can do them to a certain degree in a very short turnaround period, but with Planck you have to wait while it patiently paints the sky over and over and over collecting data until you can layer all of this data on top of one another to can get all of the depth all of the resolution you need to start answering fundamental questions.

Fraser: And at the time that we're recording this, we actually don't have much data yet, do we?

Pamela: No, at this point, they're getting interesting results, but the interesting results have nothing to do with the primary questions. The interesting results come from the things that they have to correct for. So when we look at the sky in the microwave, the maps that we see they've all been corrected for this "stuff" that's between us, and when the cosmic microwave background was released, and we've done entire shows on this, this is what's often referred to as the surface of last scattering. This is the light that was emitted at the moment that the universe finally became opaque, and there's all sorts of things that have interfered with this surface, and it's not that this is the edge of the universe. If I were to pick myself up and move 15 billion light years to the right, I'd still see cosmic microwave background. It would have different details than the one I see now, but it's still there. There's always this at-the-same-distance surface that's constantly moving away. So it's the same distance for the same time, but as time changes the distance changes. There's this surface that that sphere of space at a given moment released these photons in all directions, and we're just receiving the ones that had time to get to us. Now, as those photons have made that extremely long journey, there's stuff that gets in the way. So we see holes in the cosmic microwave background that are created by what's called the Sunyaev–Zel'dovich effect, which is perhaps one of the things I've most correctly pronounced on this show [laughing].

Fraser: [laughing] You can pronounce some Russian, that's right.

Pamela: So random things get pronounced correctly, and the Sunyaev–Zel'dovich effect…it's an effect that as the light passes through giant clusters, these are places where you end up with scores and scores and scores of galaxies all packed together with gas in between all the clusters, and as the light passes through, as the cosmic microwave background passes through this cluster, the photons interact with the electrons that are within the cluster. They get affected by thermal effects and kinematic effects, and all these effects add up to change the color of those photons, so that they're no longer part of this flux from the cosmic microwave background, and so where these clusters exist we see little blank spots in the cosmic microwave background. This is annoying if you're trying to study the cosmic microwave background, but it's rather awesome if you're trying to find galaxy clusters because galaxy clusters like to be invisible. They like to blend in to the mix of foreground galaxies and background galaxies and just not reveal themselves.

Fraser: Now will these galaxy clusters be pretty far away or will they be closer to us?

Pamela: The ones that they've been finding have typically been, well for galaxy clusters is commonly called red shift and if you read older papers it's actually called high red shift. They're Zs 0.3 or less. This is corresponding to about 5 billion light years away or less, so not huge, but when you're trying to find clusters of galaxies, those galaxies get faint pretty fast, so this is still very impressive results.

Fraser: No, but I could imagine if they were further away, then they would be smaller on the sky, and then they wouldn't pollute the data because they'd just be too small to see. But in this case they're just big enough for us to see them and wonder what these little blank spots are.

Pamela: Right, and one of the annoying things about trying to study galaxy clusters is the largest ones did form fairly early on, but your nice, healthy moderate cluster it got that way over time, so if we're looking at things that will become today's mid-sized galaxy clusters, in the past they were a lot smaller, and something that's smaller isn't going to have as large of an effect on the cosmic microwave background, so as you're looking back in time, you're looking at things that just haven't had the chance to get big enough to affect the cosmic microwave background yet.

So now you say they've been trying to correct, so is this like a process where they find one of these little spots and then they have to look at it with some other method, like Hubble, and see if there is indeed a galaxy cluster there, and that way they can rule it out?

Pamela: Well, so it's a two-step process. The first process is identifying all these little, "Hm, that looks like it could be a galaxy cluster -- spots in the cosmic microwave background," and so far they've identified 189 candidates at varying degrees of statistical significance, and whether or not they prove out to be a galaxy cluster, they're still defects in the map that have to be corrected for, and they're working on trying to confirm that these are all indeed clusters. And to confirm that they're clusters, you can look at them with Hubble, but these things are more distant and if you're looking in the wavelength that Hubble looks in, if you're looking in optical and infrared colors and ultraviolet colors, you're going to see everything that's in the front of the cluster, you're going to see everything that's in the back of the cluster, and unless you take a spectrum of every single galaxy in your image, you can't tell what's a cluster member or not, so there's no way to say, "I'm looking down a filament in the sky" vs. "I'm looking at a cluster of galaxies." So what generally gets done instead is all of the hot gas that sinks down into the core of the galaxy cluster wind up releasing X-rays, so instead of following up with Hubble, we actually follow up with telescopes like XMM-Newton and Chandra, and a study looking at 30 of these potential galaxy clusters has confirmed 21 out of the 25 that it's looked at so far, so the goal is to look at 30; it's looked at 21 of 25. I saw two conflicting websites on this. The paper was 21 out of 25, having confirmed with XMM-Newton, so it's working -- they're finding clusters,

Fraser: And now they weren't finding these in the WMAP data? Is it because it's so much more precise?

Pamela: It's that much more precise, and I think you just have different people publishing different results at this point, so some of these were known, some of these are newly-known, so of those 189 cluster candidates, some of those will probably correspond to things we already know about.

Fraser: OK, so we've got…I mean I know it's been there…I'm actually looking at the website right now…at the time we're recording this it's 679 days since the launch, and they've completed their fourth all-sky survey, no, they *started* their fourth all-sky survey.

Pamela: And they've published one set of data-released papers based on one [missing audio] bit of all-sky maps. So one thing that they do that's kind of terrifying, in some ways, is they don't put out a call for telescope proposals like Hubble might do. They instead put out a call for proposals to get to write papers with their data. So if you have an idea for a research study you want to do, you have to submit for permission to do the research study using the data.

Fraser: Really? Even though the data is publicly available?

Pamela: Well, it's not public yet.

Fraser: Right, so you have to request the data. That's very different from things like the Sloan Digital Sky Survey where anyone can go on and look through it and make discoveries.

Pamela: And this is a matter of where you are in the timeline of the mission. This is a young mission. It's still getting ongoing data; it's still defining new questions that can be asked with the data it's producing. Sloan does data releases, we've gone through a number of data releases, but for the first "n" months, where I think for Sloan, the "n" is six, for the first six months or so the Sloan scientists get sole access to that data and they can publish as much as they want. Now, they have media officers and things like that that coordinate when the publications come out, but there is still that proprietary period pretty much all data has a proprietary period, and we're still in that proprietary period for Planck.

Fraser: And so, as we discussed earlier, though, the real goal here is to do that detailed map of the cosmic microwave background radiation, so how much better will this be than WMAP, and then what will that tell us that's different from what WMAP told us? I mean, WMAP told us that the universe is 13.7 billion years, it found additional evidence for dark energy and as we keep joking, I mean, so much traces its roots back to the microwave background, so when will it find its data? How precise is it going to be? And what will this tell us that we didn't already know?

Pamela: Well, "How good is it going to be?" -- that's always a bit of a "please dear mission please keep working we really like you mission please keep working," so nominally, the mission ends at the end of 2011, but there's always that hope that the mission will still be bright and happy and working and have people engaged and that this will allow it to keep going, so the main mission with the main set of instruments is going through 2011, it looks like the satellite will keep being fine and one of the other instruments is extended through the end of 2012, and there's always the potential that it will get extended again, and all of these different extensions, when you add the data together, are what define how good your final results are.

Fraser: Now is this one of those situations where the spacecraft is going to run out of some kind of cryogenic fluid? Or is it going to be able to keep going for years and years and years beyond its expected lifespan?

Pamela: It depends instrument to instrument. This is something that the mission…you have a number of things that "age out" the number of instruments.

Fraser: OK, OK so 2012…

Pamela: And what I've been hearing is we will get results that are orders of magnitude better. Now, that's a cagey way of saying "we're not going to give you exact numbers right now." But the questions that it will be able to answer are I think where the really interesting things lie. So there's things like there's this cold spot that was spotted in the WMAP data, and this is a feature about 5 degrees across that is markedly colder than you would expect to find something that size to be, and by colder I mean how much below the average value of the cosmic microwave background that point is.

Fraser: Yeah, and it's not much, I mean the variations in temperature are so tiny.

Pamela: Right, so there are scientists that have argued that if this particular spot was located *anywhere* else on the sky, it's deviation of roughly –20 micro-kelvins, probably wouldn't have been noticed, but because it happens to be located in the middle of a deviation that's +20 micro-kelvins, it stands out and it's been noticed and there have been some really interesting things in the media. One scientist, Laura Mersini-Houghton, she said, "maybe this is where our universe and a parallel universe are coming together" -- that's not the predominant theory. The predominant theory is that there's just a gap with a red shift of about one that has nothing in it. That gap is causing that section to appear colder for a variety of effects -- but we don't know!

And this cold spot – if it is a super-void, if there is a giant empty spot, we'll be able to tell that there's a giant empty spot using the Planck data.

Fraser: So it won't be a data error anymore. We will know that it exists.

Pamela: Exactly. Exactly.

Fraser: Or it will disappear.

Pamela: Right, and that's always the possibility. We've all seen the images of the face on Mars – it looks like a fabulous face in the old Viking data. You look at it with something like High Rise, and suddenly it's like, "Oh, that's a mountain, that's very clearly a mountain."

Fraser: OK, so we're going to be able to rule out, or find intriguing new evidence about the cold spot…I'm assuming we will still know that the universe is 13.7 billion years, but maybe it will be what 13.777?

Pamela: Right so here it's the continued lockstep motion forward of using the cosmic microwave background. We look at all of those fluctuations, and this is going to sound non-intuitive, but if you measure the size of each fluctuation and make a histogram of size of fluctuation vs. number of fluctuations, you can actually get a sense of what size the universe was, and what composition the universe had at the moment that light was released. This is sort of like measuring the size of a Coke bottle by listening to the harmonics of someone blowing into it. Because the harmonics were created at different moments in time, they all add together to create basically the sounds of a Coke bottle that's 20 ounces, 1 liter, ½ liter, all resonating together. We can see, in these different size spots, all these different sound waves adding together in interesting ways that tell us the composition and the size of the universe at the moment of release, and when you add that together with our understanding of the current expansion rate of the universe, with our growing understanding of the history of the expansion rate of the universe, with our knowledge of the composition of the universe, it's by adding together our knowledge of composition now, what we're learning about composition then, our understanding of the geometry of the expansion rates, we're able to beat down all of these error terms, smaller and smaller and smaller. Now, one of the things that excites me most, though, is this also starts to put better limits on our understanding of the size of the universe.

Fraser: How does it do that?

Pamela: Well, you remember that show we did where we talked about the universe potentially being shaped like a soccer ball?

Fraser: Or a Taurus, or a saddle… Right.

Pamela: So there's all kinds of crazy things people come up with for the shape of the universe, and in many of these different models, as you put them together you realize, well, if the universe is this size, the light from over here that's coming directly toward us should also have enough time to wrap around the other side of the sky. And we can start looking for smaller features that reflect that "wrapping around the sky." At WMAP resolutions we're able to start putting constraints with some models it was saying the visible universe, what you see when you look left, right, up, down and measure the distances of the cosmic microwave background. What we see is no more than 4% of the universe. Now, this will start to be able to put better constraints on well, how big is the universe? And potentially answer the question if we see light wrapping around.

Fraser: Now could we still come back with the answer that it's possibly infinite?

Pamela: That's unfortunately one of the cases that we end up in. It's either we see the light wrapping around and we know how big the universe is, or we place a limit on it and say, we are no more than X% of the universe, in which case we could be 4% or we could be .00004%. In one case we're a lot smaller a part than the other part.

Fraser: Or 1 divided by infinity, unless I got my math wrong. We're "one-infinitith" of the universe. Right, so OK we'll get then a sense further ideally I mean wouldn't that blow your mind, right? If we actually see the back of our spacecraft, which we're not going to see, but we're going to see the evidence that light behaves or that the universe behaves in this way that we've talked about, that if you look in one direction long enough, you'll see the back of your own head.

Pamela: And there's other random science (that to the scientist doing it, it's not random), but when you start talking about the cosmic microwave background, it feels that way. People who do star forming can actually use the cosmic microwave background; people studying the Oort cloud can use the cosmic microwave background, so this is where "all good things come from the cosmic microwave background" come into play. They've already released a catalog of what are called "cold cores." These are the cocoons in which stars are forming in dark, cold regions of dust…dark molecular clouds. As we look out across the galaxy in microwave eyes, you see all these "cold cores" sitting there blocking your way to the cosmic microwave background, and these represent all the places we should go in and start studying star formation.

Fraser: I mean it's funny how we have a spacecraft that's designed to do one thing, but that one thing is so useful in so many branches of astronomy that it's going to keep astronomers busy for decades.

Pamela: And this is where you're able to now and then justify funding single-purpose telescopes. There's not many of them. There's the Planck Mission, there's Kepler, which is single-purpose: it's going to find planets. And it's finding planets and it's doing such an amazing job. And there is ancillary science with variable stars, and you have Gravity Probe B that is studying -- was studying gravity. These single purpose mission are either answering fundamental questions we just can't answer any other way, or doing things that the science is just so good that you say, "OK, we're going to commit a major portion of the very-limited resources we have to answering this one fundamental question with this one mission."

Fraser: Right. It's going to be amazing. So then if people wanted to keep their eyes peeled in the news for the big announcements, when should we expect to see them?

Pamela: I'm kind of expecting that we'll see the first round of pretty cool things coming out…scientists like to save things for big conferences, and I suspect that they will either have their own big conference sometime in the beginning of 2012, or they'll be presenting things at the American Astronomical Society meeting. So one of those places is probably a pretty good bet. So look for things the beginning of 2012. The big, big results are likely to start coming out a year after that. It takes time to go through all of the data, but if you want to follow things day to day, you can actually follow them on Twitter, and I don't think I've ever promoted a mission on Twitter before, but their Twitter feed actually promotes some pretty interesting stuff now and then. They're just "@ Planck." One of the things they've recently promoted is they have a neat-looking mission, and on their website they have a cardboard cut-out model that allows you to put together the mission, and there's some videos posted up on how to follow the videos to put the model together -- and it's just silly, but it's fun, so you can learn how to do this and the Planck model is actually designed by Stuart Lowe who we've worked with who does the "Jodcast" and "Astronomy Blog" and helps with the "365 of Astronomy," and who's responsible for all of the ending credits.

Fraser: Go, Stuart!

Pamela: So Stuart built this model and it's on their Twitter feed, and it's just a great way to engage a little bored child in building a spacecraft.

Fraser: They've actually got a bunch of these models for a lot of these missions. My kid sand I built one that came out a few years ago. It was like a dodecahedron, and it was the entire sky. It was really neat.

Fraser: OK good, well thanks a lot, Pamela. So look for that in 2012, probably 2013, titles like: "Age of the Universe Further Refined," "Astronomers Have a New Estimate for the Size of the Universe," "Astronomers Find Where Our Universe is Colliding with Another Universe," or "The Cold Spot..."

Pamela: "Cold Spot Solved and Erased!"

Fraser: "Cold Spot Solved," yeah… that'd be great! OK cool, well thanks a lot Pamela.

Pamela: Sounds good, talk to you later, Fraser.