Astronomy Cast Episode 276 for Monday, October 15, 2012: XMM-Newton

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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: Good. I just went on a road trip and I wanted to share something with people, which is if you've never done this, you should absolutely do this. I live on Vancouver Island so we often go to the United States, down to Seattle, and when I was in Seattle, we just like on a whim went to the Boeing factory and it is a phenomenal place! It is amazing. It's the largest building in the world by volume -- they kept telling us this, but you get to see these planes being built, and it felt a bit like I was watching spacecraft get built. You see 747s getting built, and the way they crane them around and stuff, so if you're ever in the Seattle area…and if you live in the Seattle area and you haven't been to the Boeing factory – shame on you! Go check it out. It's awesome. There you go. That's news you can use… but you've actually seen rockets launched and rockets constructed.

Pamela: Yeah, I got to tour around Johnson Spaceflight Center where they were working on constructing space planes at the time. I've been down to Kennedy and seen GRAIL launch and seen the Shuttle launch, but no, I've never been inside one of the Boeing factories so that sounds mighty awesome.

Fraser: It's super cool! Well, let's get cracking then.

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Fraser: So on the plus side, the Earth's atmosphere keeps us alive, but on the down side, though, it blocks x-ray radiation from reaching the surface. OK, maybe that's still in the plus category. Still, in order to understand the universe at the higher energy levels, you need to launch a space telescope like the European Space Agency's XMM-Newton telescope, so let's learn about the telescope named for the famous scientist. Let's learn about the telescope. Now, when…what's the history of the telescope? When did the ESA decide they were going to build themselves an x-ray telescope?

Pamela: Well, the plans for this one started in the early 80s, it got built in the late 90s, started doing science in 2000, and this is the mission that just refuses to die. So it's been going since 2000, which literally means it is younger than the Hubble Space telescope and several others, but it's had its mission extended a number of different times because it's still doing very good science. It's still a work horse. And one of my favorite random mission statistics is this satellite, because it observes in the x-ray, it has to get very distant from the Earth. It has to get out far enough that it's beyond the Earth's radiation belts, and so it actually has a 48-hour orbit that brings it down fairly close to the Earth, and then whips it out into this nice, slow orbit when it's furthest from the Earth, and so it's had, as of the day that we're recording this, 2357 revolutions around the Earth, and it's had 3190 refereed papers that used its data, so it's actually producing papers at a rate that on average is greater than its orbital velocity… well, not velocity, but orbital rate.

Fraser: Yeah, and it's funny because as the publisher of Universe Today since 1999, one of the first stories that I worked on was the launch of the XMM-Newton, and have been sort of reporting stories from that non-stop for 12 years now. You know, it's a funny thing – it's going, it's going, it's going, and it's gathering tons of x-ray radiation, and many of the pictures that people have seen out there were taken by this spacecraft. They don't realize. It and Chandra are doing the heavy lifting out there.

Pamela: And it also has one of the illustrators that we end up seeing their work over and over and over, so if you've ever seen any of these gamma ray burst animations, where you see the beautiful many reds and greens, disk with the jets jetting out…

Fraser: Black holes and yeah…

Pamela: A lot of these are pieces of art that were originally commissioned to go with the FM, the XMM-Newton (not be confused the radio station), XMM-Newton spacecraft, so there's lots of little ways that this hard-to-pronounce spacecraft has snuck into our understanding of astronomy.

Fraser: Now, let's go back a bit for a second here. Why do we need to have a space telescope for x-ray radiation? And why is that important?

Pamela: Well, so the "why do we need it" boils down strictly to our atmosphere is kind enough to block high energy radiation from reaching the surface of the Earth, so we don't get x-rays, we don't get gamma rays. Superman's x-ray vision is always perplexing, because in order for x-ray vision to actually work you'd need the x-rays to be coming through the person, but there's no source of x-rays, so yeah, unless he's doing back-scattered radiation like they do at the airports, Superman's x-ray vision is missing a few scientific details there.

Fraser: He would be admitting lethal doses of x-ray radiation in all directions, and then looking for the backscatter coming back, right?

Pamela: Yeah, so Superman… it's one of those Marvel fails. So without the x-ray…

Fraser: Before you get in trouble, it's DC.

Pamela: Was it D.C.? Crap. Sorry.

Fraser: So don't send an email, please.

Pamela: Sorry, I goofed.

Fraser: Um…but, uh right. So but what do we use this x-ray radiation for? Like what will astronomers want to use it for?

Pamela: Different colors map to different temperatures of processes going on throughout the universe. Really, really hot processes, very, very high-energy processes, end up producing high-energy light, high-energy photons that we end up detecting in the x-ray. So when we see the shockwaves of exploding stars compressing surrounding gas, those shocks can emit x-rays. When we look into the hearts of galaxy clusters, where gravity is compressing all the inner cluster material, we see x-rays getting emitted, so there's a whole variety of different processes ranging from explosions to extremely dense environments that all end up releasing x-rays, and we can't understand those processes if we can't see those processes, so by launching these space telescopes, we're able to tap into part of the data that we can't see from the surface of the Earth and build a more spectrally-varied picture of our universe.

Fraser: Right. OK, so it's sort of like certain kinds of processes in the universe are going to give off this radiation, and that can then tell you that certain things are happening, like merging galaxy clusters and…yeah.

Pamela: A good way to think of this is here on Earth: imagine if suddenly you couldn't see anything that was yellow, orange or red -- just suddenly all of that information is gone. There's lots of things that suddenly would be harder to understand. Well, there's lots of colors in astronomy…

Fraser: Street lights…

Pamela: Yeah! So there's lots of colors in astronomy that we can't generally see, certain bands in the infrared that don't make it through our atmosphere, certain bands in the radio that there's just too much molecular stuff in the atmosphere, but then all the high-energy stuff gets blocked and so it's…we're trying to build a data-based understanding of our universe, so we need all the data, and that includes all the x-rays.

Fraser: And so, OK, so let's talk about the observatory itself then. You said it was launched in 1999. How was it launched?

Pamela: It was a regular, everyday rocket -- one of the Ariane 504 rockets, so nothing exciting about how it was launched. No space shuttle missions were involved. This is a European mission.

Fraser: Right, they probably launched it from their South American facility, right?

Pamela: They did. They launched it from French Guinea, and if you've never watched any of the videos or seen a launch down there, one of the awesome things about the videos (and I'm guessing if you're there in person you'll see this too), there are giant birds on this island, and so as you're watching the launch it looks occasionally like a pterodactyl has just flown through the image.

Fraser: You see that a bit in Florida too though – great big birds flying past.

Pamela: Yeah, I missed them there, but so this is a great facility. One of the reasons it is such a great facility is it's close to the equator, so you get the extra velocity from the Earth's orbital rotation. It was launched into an extremely elliptical orbit as I said earlier. It actually gets to about a third the distance to the Moon at its furthest away. Nearest -- it's still many times further away than the International Space Station. Its close point is still 7000 miles up.

Fraser: Now you mentioned, sorry, that it's trying to avoid the radiation belts. Is that right?

Pamela: Well, it's trying to get out of them for the majority of its orbit, so it spends about 8 hours of its 48-hour orbit inside the radiation belts, which gets it closer, and it's easier to transmit data back down to the Earth, but that's not the primary reason to do this. But the advantage of having this highly elliptical orbit is one of the things that Kepler figured out is that when you're close to your thing that you're orbiting – the Sun, the planet, whatever it is that you're orbiting, you move much faster than when you're further away. This is the "equal area and equal time" part of the planetary laws, and with this highly elliptical orbit, it spends 8 hours whipping past the Earth, going through the Earth's shadow, but then it lingers for long periods of time much further away, and it can get 10, 12 straight hours on one source without any difficulty. Now, compare that to other objects, other space craft that are orbiting every hour and a half or so around the planet, they're constantly getting a change in view, so with this longer period orbit, you can get longer observations. X-rays are a bear to detect; objects that are giving them off aren't giving off a lot of them most of the time, so you're able to get long, long period exposures and count each of those little individual photons that are coming into the telescopes.

Fraser: And so the other sort of main telescope for this is the Chandra x-ray observatory. So how do they compare and contrast as two observatories?

Pamela: So XMM-Newton – it has 3 different major instruments and it was designed originally to do spectroscopy to measure what are the wavelengths of the different photons that are coming in and are hitting it, so it's trying to figure out what sorts of oxygen, iron, heavily ionized systems are out there, and it's specially designed, in fact, its original name tied into its spectral capabilities. It's designed to go out and count the photons coming in at the specific wavelengths, allowing it to…it's hard to explain if you're not a Spectroscopist why this is cool. So the way to think about it is…sorry I just hit this wall of I don't know how to make counting iron-ionized photons cool!

Fraser: Well, I mean cooler than it already is…I mean it's inherently a very cool thing, but I mean, you know, specifically as it relates to this telescope…no, I understand.

Pamela: So there's basically gas out there that you can measure its composition, you can measure its temperature, you can measure all sorts of cool things just by knowing the iron is doing this, the oxygen is doing this, the background continuum is this, and you get this through spectroscopy. We've done episodes on spectroscopy before. There's no easier way to make people's eyes glaze over than to show them spectra.

Fraser: Light stuff on fire, you can figure out what it's made of.

Pamela: Exactly, and the universe conveniently sets itself, well, not on fire but ionizes itself, which causes the same side effects.

Fraser: It does various things to itself…yeah, yeah, exactly. And then it tells you what it's made of. As it's destroying itself, you can tell what it's made of. It's perfect.

Pamela: Yeah, and one of the other side things that XMM-Newton has that makes it novel in some ways for the time that it was built (this has been repeated since then) is it actually had an optical mission on board as well, so it was possible to monitor in optical and ultraviolet wavelengths where it was pointed, and to try to match the x- ray sky and the optical sky. One of the things we really struggle with in astronomy is how do we align all these wavelength maps. In day to day life, we look for a signpost, and we say this signpost is the corner of Main Street and St. Louis Street -- I live near that corner, but when you look out at the cosmos, you don't have signposts that necessarily give off light across the entire electromagnetic spectrum. Here's a signpost I can see in the optical, here's a signpost I can see in the x-ray -- are those the same signposts? And so trying to take simultaneous observations, it helps, and over time we're trying to work and find more and more signposts that we can use to unify our maps.

Fraser: And there's a lot of great images that come out both from NASA and also from the European Space Agency, where they do these combined photos where they use blue for x-ray, red for infrared, some other color for visible, and then they merge them together so you can see these are the parts that are the dust that's…the warm dust or the cool dust, and these are the parts that are giving off x-ray radiation, it's by seeing those things all at the same time you can really get a sense of what's going on in the pictures, and I know for scientists, they want to do that all the time. They want to look at the same thing in as many different wavelengths at the same time because each of those wavelengths is telling a story and by putting them together, you get the full story.

Pamela: Yeah, and some of the pictures…I think Centaurus A is one of the ones that I think gets abused in multiple wavelengths the most often. Andromeda is another one, but Centaurus A …it's a system that has gone through recent interaction, so when you look at it in the visible, you see this mutant dust lane cutting through a big elliptical core, and as you look across multiple wavelengths of it, you start to see "Wow! This thing in Herschel's images…" you see this beautiful disk bent through the system, so there you're starting to pick up the far infrared. As you look at it in the x-rays, you see this core is giving off a jet and there's bubbles of shock waves interacting with the materials, and so you're getting different physics out of these different colors. Where in the infrared you see the warm dust; in the x-ray you see the shock waves and the jets, and it's through putting all of these different pictures together that we're able to understand all of the different science that's going on in this recently interacting system in this active galactic nuclei.

Fraser: Yeah. Now you…do you know what the capabilities are compared to Chandra? Do they use one instrument for a certain kind of work and a different one for a different kind of work?

Pamela: Well, so both of them have similar scattering mirrors, so the way these types of telescopes work is in order to collect photons, you use grazing mirrors, so it's not like a single mirror like you see in the visible. Instead you essentially have a cone of mirrors that scatter the x-rays down onto your detector. With XMM-Newton they actually have two different telescopes side by side for collecting the x-rays. Each of them has their own instrument. Where you see the biggest difference between the two systems is Chandra does have greater sensitivity. They also have very different orbits, which allow them to take different observations. They're different systems.

Fraser: But if you were a scientist, and you were going to work on some part of x-ray radiation, would you submit for time on both devices, and then if you got one you'd be fine with it?

Pamela: No. You do use them for slightly different things. There's times when you need that one-degree field of view that you can get off a Schmidt telescope that has a 30-inch mirror, and you can do some great survey work. There's other times when you need that 10-meter mirror and a one-minute field of view, so the two telescopes have different sensitivities. They see slightly different parts of the x-ray spectrum. XMM-Newton's a little bit easier to get time on, Chandra's more competitive. It's a slightly more sensitive telescope, or somewhat more sensitive telescope. They just have different purposes.

Fraser: OK. So now, do you know what the original life span was supposed to be for this telescope? Like, as we said, it's one of those that just keeps going and going.

Pamela: It just keeps getting extended and extended and extended. It was…I want to say they were originally planning for it to go into the early 2000s. It's currently extended. They're in the process of reviewing it into 2012, but it's looking like it's going to keep going probably until 2015. They're thinking that it probably has enough fuel on board, and all of the stuff that you need to keep it pointing, keep it going. They think that the spacecraft has the ability to keep going potentially as far as 2018, so this is one of those great things where you build a telescope planning for it to last for a few years that you have the budget for, but you engineer it to last as long as possible, and you keep using it to get science as long as possible.

Fraser: But this is different from some of the other telescopes out there, like I know with Spitzer, they had only so much coolant, and they knew pretty much down to the day when they were going to run out of coolant for the cold operations, and then they moved to the warm operations, right?

Pamela: Well, so the nice thing about x-rays is because they're already high-energy photons, it's not like you really need to cool anything.

Fraser: Right. Right.

Pamela: When you're looking in the infrared, when you're looking in these wavelengths that correspond to nice, warm surface, you have to worry about your nice warm instrument generating the color of light that you're trying to detect from the outer parts of our solar system of our galaxy, of our universe, so you have to cool your entire system down so it's not generating light that creates background noise in all of your images. Imagine if inside your camera were little lights that were shining on your camera and detector at the same time that you're trying to take a picture of the outside world. With x-rays, you know if the telescope is hot enough that it's generating its own x-rays, you probably don't want to be using it.

Fraser: Yeah, the temperature of the telescope doesn't matter for catching bullets in it, you know?

Pamela: Right. Right, so you don't have to worry about cooling at all, so these issues that affect Spitzer don't affect x-ray telescopes. So it's strictly the types of problems of…well, we've seen Hubble. Hubble periodically loses gyroscopes and it can't point as effectively. You have to worry how long can the system keep pointing. We've seen past missions fused There was one of them where NASA kept hacking new ways to keep the spacecraft pointed.

Fraser: Yeah, It's quite amazing. They're like, "We thought we needed 3 gyroscopes, we figured out how to do it with 2," and then "Oh, no, we figured out how to do it with one."

Pamela: Yeah.

Fraser: And it's, like, really clever.

Pamela: So this mission seems to be going fine as long as they keep getting renewal to keep listening to it, and keep steering it, and operating it. It's I just like I said at the beginning of the show -- I love the fact that the number of referee papers is greater than the number of revolutions around the planet.

Fraser: Right, and then you've talked about the lifetime. Is there a potential successor out there? Do you know of…I mean, you know, either from NASA or from the European Space Agency?

Pamela: I think given the current budget climate around the planet, it's… Are there scientists who have plans for potential successors who if budgets are released can step in and suddenly have great things ready to go? Yes. I know there's a group of people working on instrumentation of x-rays at Harvard, for instance.

That said, there aren't any new, big, giant, awesome x-ray missions planned for the future to supplant XMM-Newton and Chandra.

Fraser: What would they do if they did? I'm trying to think…would it just be a bigger version of the instrument, or…?

Pamela: Well, the two different problems we have with x-rays are: 1) they're hard to detect, so being able to increase the sensitivity, see fainter and fainter x-rays, that's one direction we'd go in, the other is -- the suckers are hard to focus, so these are the individual x-ray photons, and some of the things they've been working very hard on in the past few years is how do you build detectors that have greater and greater resolution so that you can see, well, what are the details of the jets, what are the details of the shocks. So we have the potential moving into the future to both increase the resolution and increase the light-gathering capability and to basically see fainter, higher-resolution objects out in the not-so-distant stars with jets, and in the very-distant galaxies with jets.

Fraser: And what would be a future objective that maybe astronomers are hoping for because I know, like, you remember when… I'm trying to remember -- was it Spitzer?

Pamela: Well, when Hubble went up it had the definitive goals of: We want to figure out what the heck is up with these planetary nebulae that have these funky shapes.

Fraser: And how fast is the universe is expanding?

Pamela: And the Hubble constant – those were the two big things. In x-rays, we're constantly getting surprised at all the different things that we're finding, so we're discovering magnetic stars that give off x-rays when their magnetic fields rearrange, we're discovering fast-moving pulsars, in some cases perhaps shot off during supernova explosions, we're discovering…one of my favorite more recent results was in the Spring it was found that the supermassive black hole in our own galaxy it periodically, essentially burps x-rays and these x-rays have reflected off of ionized atoms, and we can map the location of that ionized gas by looking at the differences in how we're seeing the light come back to us as it gets reflected from this echo. So just like you can in some ways map out a room from the way the sound echoes, we find that we're able to map out the cores of galaxies based on how the x-rays echo through the cores of galaxies.

Fraser: That would be really cool.

Pamela: And it's not a "will," it's an "is," and our ability to do this will only increase as our technology increases in the future.

Fraser: Right. Right. Very cool. OK, well, so I guess we need more funding.

Pamela: Yes. Always.

Fraser: More funding please! Yeah. Always…well, cool! Thanks a lot, Pamela. That was great, and we will see you next week.

Pamela: Sounds good…my pleasure.