Astronomy Cast Episode 169

The Fermi Mission

Fraser: Good, now we need to do a bit of a disclaimer with today's show, which I think is like a first for us.
Pamela: It is. But that's ok.
Fraser: Yeah, so the Fermi mission, previously known as GLAST, was a sponsor of Universe Today, and by sponsor I mean they covered our costs to do a bunch of question shows with kids, and they bought us some cool audio equipment, and they paid for the postage for us to send the recorders back and forth from schools, and they also helped us get some material published all relating to that. So, now you know that we're totally in cahoots with the GLAST mission, raking in the thousands, so yeah, no, that was great. So thanks to them... and this free publicity for them has no relation... it would have happened whether or not they had sponsored our show. Do you think... is that good?
Pamela: I think that covers it. And they're our friends, we like Lynn, we like all of the people over at Fermi which used to be called GLAST.
Fraser: Yeah, yeah, so they're our GLAST friends. So that's it, yeah... there's our big disclaimer, we're friendly with them. Ok, alright, so last week we talked about Fermi the man, and now we're going to talk about Fermi the space telescope. That's right, Enrico Fermi made such an impact in the astronomy and physics community that he got a space telescope named after him. So let's take a look at what this mission will do, and it's discoveries so far. Alright so the Fermi mission, previously known as GLAST... what's the history?
Pamela: So this is a mission that's been in planning for a long, long, time. It finally launched back in June of 2008, breaking the hearts of its crew in many ways. It's not so much the crew but the scientists behind the mission... it was supposed to launch June 5, they all had tickets to be there June 5, they were all there on June 5, and the mission launches on June 11. So many of the people who had flown out to see it launch ended up having to fly home before it actually took off into space.
Fraser: Yeah, that is one of the terrible risks that you take when you try to go watch a space shuttle launch, or any mission launch. The chance of it launching all depends on the weather, and on any technical glitches on the rocket and really it's just a gamble, a lottery whether or not your mission actually launches on the day it's supposed to.
Pamela: And this was one of those wonderful times when there was a space shuttle launch on May 31 and so there were a lot of people who were like, "Ok, I'm here for the space shuttle, I'm going to hang out and stay for the GLAST launch," and then it got delayed. But that's ok because once it launched on June 11, everything's been clear skies ever since. They took off on July 2, just a couple weeks later they were confirmed as up and running and started making sure that all the instruments checked out and then in mid-August, August 26 they were able to release the first all-sky map that this little mission was able to create and they renamed the mission Fermi.
Fraser: Alright, but let's go back a bit then. What is the scientific problem that the Fermi mission is trying to solve?
Pamela: Well, most simply, they wanted to be able to look at the entire sky in fairly high resolution in gamma ray light. We have telescopes like Hubble that are up there looking

in visible light, we have Spitzer working in the infrared, we don't have anything that's extremely high energy. We don't have the gamma rays. We have Chandra, which gets us close with x-rays. But, with Fermi we're finally able to go that extra step and start mapping the entire sky, looking for things that are high energy that otherwise we'd miss.
Fraser: Ok, and so if we've got high energy gamma rays, what kinds of things are we going to be seeing when we switch our eyeballs to gamma rays?
Pamela: So, the target science objects were originally active galactic nuclei, looking at angry large black holes in the centers of galaxies that are in the process of actively consuming material. Looking for...
Fraser: Like, these are quasars, right?
Pamela: Quasars, active galactic nuclei, they all span the same category of objects... radio galaxies are another name, Seyferts...
Fraser: Right, Seyfert galaxies, so you've got a super-massive black hole actively consuming material.
Pamela: So, these objects, with their high-energy accretion disk, their high magnetic fields, they end up giving off light in the gamma rays. We're also going to be looking for gamma ray bursts themselves, exploding stars that channel energy out their magnetic poles and if we happen to be along the beam, we see this as a sudden burst of gamma ray light on the sky. Looking for neutron stars, stars that are more massive than the sun and roughly the size of Manhattan in diameter, these objects also can have extremely powerful magnetic fields that accelerate particles to high velocities and high energies. Also just looking at, well, cosmic rays and supernova remnants. These are particles that get decelerated radically as they hit various gas in our universe and in this deceleration process give off extremely high energy light. So, we're basically out there to say, ok, if it has high energy, what does it look like when we resolve it?
Fraser: And what would you say, then, is the connection between the mission and the man? Why do you think they renamed this mission after Fermi?
Pamela: Well, Fermi was the first person to really propose a mechanism for how cosmic rays might get accelerated. Cosmic rays are these high energy particles that come in through the atmosphere from well, we didn't used to know what source, and we see them in cloud chambers, you can actually see them. This is where through various means you create literally a chamber of clouds and you can watch high energy particles pass through the chamber. These are used as teaching tools, and while we generally see them with radiation that we know the source of, you also end up seeing cosmic rays passing through them. And it was Fermi who suggested what the source of these high energy particles might be.
Fraser: And the source is?
Pamela: Well, you can accelerate particles in magnetic fields, and the sudden deceleration ends up letting off high-energy light.
Fraser: And so he thought that there was some object out there that was creating a really powerful magnetic field and accelerating the particles.
Pamela: He was happy with the magnetic field explanation, I believe.
Fraser: So he did... right, but so but what was the source of the magnetic field, I guess... that's the big question, right?
Pamela: And this is something we've been working to figure out ever since then. Our universe, it turns out, is filled with high-energy magnetic fields. When Fermi was first

doing his work, we didn't know about neutron stars yet, we didn't know about pulsars yet, white dwarfs had only been theorized and were just starting to be discovered. So, science has changed radically since Fermi was around, but he was one of the pioneers of high-energy astrophysics or in his case, high energy physics.
Fraser: Right, alright well let's fast-forward then to the mission then, so, so they released an all-sky survey of the sky in gamma rays...
Pamela: Yes.
Fraser: And what did they see?
Pamela: Well, in that first image they were basically showing the flickering of pulsars that we knew existed, the variability of active galactic nuclei that we know existed but it was a proof of concept, it was showing that the mission exists. The Fermi satellite actually is able to map out the entire sky every three hours, or at least the part of the sky that's not hidden by the planet earth and hidden by the sun. Now, since then we've continued to constantly map and remap the sky, and the first really interesting discovery made by Fermi came out in October of 2008, the October after its launch. It had only been up for a few months at this point. That discovery was a pulsar that only gave off light in gamma rays. We're used to detecting pulsars in radio, where we see pulsars as this beacon of sometimes as many as 100 or 1000 pulses of radio light a second.
Fraser: Now that's the opposite end of the electromagnetic spectrum...
Pamela: The exact opposite...
Fraser: Those are the longest wavelengths, right?
Pamela: And so what we're finding now is that in a few cases we end up with objects that we only see emitting light in the gamma rays. Now, with the radio pulsars, we do see gamma rays associated with some of those as well. What we hadn't previously seen was strictly gamma ray pulsation.
Fraser: Right. And so this pulsar was giving off gamma rays but not anything else.
Pamela: Not anything else we could perceive, so what we think is happening, and at this point, by January of 2009 they were up to 12 of these, and by July they were up to 17. We're still finding these more and more as we look around the sky and what scientists think is happening is you have a tightly focused beam of radio light, and this is what we see with your quintessential radio pulsar. But there's also probably created much higher above the surface of the star a gamma ray beam that's not as tightly focused, and since it's not as tightly focused, you can see it at a wider angle. So while you have to be in a very particular place to see the radio beam, you can be slightly off-center of the beam in order to see the gamma rays.
Fraser: So does this maybe change estimations about how many pulsars are out there? Because this might be turning up pulsars that people didn't know about before.
Pamela: Well, since we already had a fairly good feel for... well, pulsars... we only see them if we're in this... within this very narrow angle of the beam. We're able to statistically figure out how many there should be out there. And what we're seeing now are the ones we'd already accounted for as these are things we can't see, except now we have a wider beam so we're able to sort of get at, oh, yeah, there is something there. What this is answering for us is earlier gamma ray missions, EGRET in particular, had picked up all these transient gamma ray sources, just a random flickering here, a random flickering there, and we weren't sure what these gamma ray sources were. And we're now

able to start matching up some of these different formerly known but not really understood gamma ray sources as being these pulsars.

Fraser: It's neat when that starts to happen, you get these little flashes, these little momentary insights that there's some other phenomenon out there, and then the astronomers put together a brand new mission and it goes out and conclusively finds them and builds a catalog and directory of them. And it's like each time you're like, oh, what's that? And then along comes the mission a few months later and searches for it... a good example just... I'm on a tangent, I apologize, is the possible discovery of methane on Mars. Right? There was like hints and sniffs of methane turned up by Mars Express and now the plans are in the works to develop a very comprehensive mission that might search for methane and really map it and track it and find it on Mars because, you know, the theory going that if there's life on Mars, and that's what the source of the methane, then maybe you can actually pinpoint the sources of where this methane is being produced. So it's the same kind of thing, where you get this little sniff and it's like, what's that? And then later on you come back with a mission and do a really good job of finding these new situations, these new phenomenon. I love it.

Pamela: And what's particularly amazing about this discovery is first of all, it's following on a sister mission, so yeah, that's really cool, problem solved, fill that checkbox out, we now know what these random little things are. But, the ability to sort out the photons from these, you can only get with a mission like Fermi that's sweeping over the entire sky over and over and over again because each time it detects these pulsars, it's only detecting a handful, a countable number, sometimes as few as 4 photons per detection. That's not that much light. So, they're able to make these amazing discoveries on so few photons that you could count them on their hands, but because they're sweeping over the objects over and over and over again, you're able to statistically say, ok, swept by it at this time... saw nothing. Swept over it at this time... 4 photons. Swept over it this time, nothing. Swept over it this time, nothing. You add up the nothings and you add up the somethings and they're able to start measuring, ah... this object pulses 3 times a second.

Fraser: But these are also very special photons, these are the freight trains of photons...

Pamela: That's true.

Fraser: These are the super-tankers of photons, so, you know, these are pretty high-energy photons moving along. So, alright we've got one big discovery, but that's not it... let's not retire that telescope and call it a day. So, what else has it found?

Pamela: Well, we've also started to be able to better understand the science down in the hearts of active galactic nuclei, where again we're tying the radio observations and the gamma ray observations together. There's a lot of radio jet galaxies out there. These beautiful systems that often when you look at them in optical light you see a nice pretty disk galaxy, look at them in radio you see these amazing jets that completely dwarf the little tiny spiral disk down in the center and they end up creating these huge lobes where the jets end up colliding with the intergalactic media. We knew that these galaxies flickered in the gamma rays. We knew that they were gamma ray emitters. What we didn't have was a good understanding of can you tie together jet activity and the activity at the gamma ray level as well, and with Fermi out there constantly looking, constantly every three hours mapping out the entire sky, you start to be able to get very good time resolution on the flickerings of that active galactic nuclei, and then to see that in the radio as well, to be able to essentially measure how the gamma ray emission and the radio

emission are coupled, and how the entire galaxy's light basically changes at both the highest temperatures and lowest temperatures in lockstep.
Fraser: And so what does the flickering mean?
Pamela: Well, what ends up happening is that you have material that's spiraling in and it's not an entirely smooth process. Just like when you're eating you don't have--unless you're very good with a straw--continuous caloric intake slurping food, rather things come in chunks. And with active galactic nuclei, when those chunks fall in, you get a flash. And when you have less falling in, you get, well, less light, less energy.
Fraser: And so they can actually now track the lumps and bumps of material being consumed?
Pamela: They can track all of that, and what's even more interesting is as they track it, as you look across multiple wavelengths, as you start looking at different scale sizes, you can start to see how the entire system interacts, you can even start to map the system because the rate at which something flickers tells you how big it is. A really large object, well the light from its furthest corner is going to take a long time to get to you compared to the light at the nearest corner. So if you have an object that is 100 light years across, well it can only flicker at time scales that allow the light to get from one side to the other, 100 years. So we can start to measure small things as we measure the flickerings very carefully.
Fraser: Whoa... that almost blows my mind because you're looking at something that is, you know, in the case of the core of a galaxy, they can be, I'm sure, the part that's putting out the high-energy particles could be, as you say, hundreds of light years across, right? So, if various things are being consumed and gobbled up, that would be happening sort of along part of the whole disk around that black hole, and so you would see different light coming at us at different times, right, as it's being consumed...
Pamela: Right.
Fraser: Whoa... and they can determine that?
Pamela: Well, and you can start to actually map things out in extremely small scales. In our own galaxy we're able to see stars whipping around the very core of the galaxy. And some of these stars are solar system scale distances away from that central super-massive black hole. So in our own galaxy we can see reasonably-imagined scale sizes. Well, we can't resolve things at that fine a scale in other galaxies, but by looking at the flickering, we start to be able to see things that are light minutes across, light hours across, light days across. And we can start to map out the central parts of the galaxy in some ways.
Fraser: Hmmm.... wow.... and so you can see just over time them building up a better and better map of really what it looks like, the environment around an actively feeding black hole.
Pamela: And it takes combining information from all the different wavelengths to do this accurately. And what's neat is while this works for the giant active galactic nuclei, the giant classic quasars, they also were able to do this for a microquasar--a system involving either a neutron star or a black hole or a giant Wolf-Rayet star, and they found that the physics there works the same. So, we're able to now take stellar-sized systems and galaxy-sized systems that we've been saying all along that, yeah, the physics is the same in these two different scenarios, but now we're able to say with certainty, yes, the physics is the same from the gamma ray radiation all the way out to the radio radiation in these two different types of systems.

Fraser: And vice versa... right, I mean you can look then maybe make some discoveries in the Wolf-Rayet systems and then maybe scale that back up after seeing something interesting, go I wonder...
Pamela: Well, it's the accretion disks around the neutron stars, the black holes, it's when you get these jets and the magnetic fields, these are the really interesting high-energy systems that allow us to basically span all the different size scales, so from Cygnus X-3 our stellar-massed black hole out to active galactic nuclei and blazars, we're able to span all the different sizes in between.
Fraser: What about supernovae?
Pamela: Well, they have been looking at supernovae as well, and they're also looking at star-forming regions. Supernovae--there it's extending a lot of old science, but where it gets interesting is the new science of looking at systems where you have admittedly active supernovae going off but right now what they're able to do is look at things like the Doradus star-forming region, the Large Magellanic Cloud star-forming region, and nearby star-bursting galaxies, and discover that all of these systems are rich with gamma rays. And what they're finding is apparently it's the strong magnetic fields in all of these systems that get the cosmic rays completely tangled together and this is part of what's causing the soft gamma ray emission or diffuse gamma ray emission to be coming from these systems. So, what's happening is you have these areas that are rich with star formation for a variety of reasons, and there's high-energy particles being emitted as young stars are very quickly burning through their fuel, and the most massive ones are exploding as supernovae, the areas are tangled with magnetic fields and when these massive short-lived stars explode and die, the high-energy particles that get shot through get tangled up in the magnetic fields and with the deceleration they end up giving off gamma rays.
Fraser: Very cool. So, any other discoveries?
Pamela: Well, the biggest one that I think people are going to look at the longest is the pulsar discoveries. But there's been a whole steady slew of building on old science, building on our understanding of the universe, and refining and refining at higher resolutions. What's most amazing about this mission is its ability to over long periods of time keep looking fainter and fainter into the universe. By mapping the entire sky every three hours, we can just keep stacking this data, one image on top of another on top of another, and slowly pull out... well, look there's more star formation over here, well look there's more distant pulsars over there. And we're able to start getting longer and longer time duration where we can start to watch pulsar periods decay, we can start to measure long-term variability in active galactic nuclei...
Fraser: Right, and maybe, you know, set the stage for the next "huh... that's interesting" moment, right, where you're doing really long-term surveys of the sky, after awhile you're going to notice that there's some interesting trends going on, and then that's something for an all new investigation and maybe another mission.
Pamela: And Fermi still has a bunch of good years ahead of it. It, as I said, was launched in 2008, and its initial mission is for 5 years with an operational goal of going out to 10 years. So we're not really even at the half-way mark.
Fraser: Yeah, we're not even 2 years into it.
Pamela: And, so it's already made some pretty great discoveries. And I think it's going to be a fun job trying to understand these pulsars, just the fact that these things are emitting

light, not from the surface of the star, but from perhaps a few hundred miles away from the surface, and these things are only the size of Manhattan... That image alone is enough to keep me watching this mission.

Fraser: That sounds good. Well, thanks Pamela, and we'll talk to you next time.

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