Snap! Goes the Field Line

Interview with Christine Gabrielse, graduate student researcher, UCLA

Q: Hi Christine. Just for the record, could I get you to state your name and your title here at UCLA?

A: My name is Christine Gabrielse, and I'm a graduate student researcher (GSR).

Q: How would you describe the THEMIS mission to a high school student?

Well, a lot of people think that space is cold and empty and there's nothing going on out there, but actually the opposite is true. In fact, just like we have weather here on Earth, we also have what [we call] *space weather*. And just like we're trying to understand and predict weather here on Earth, we're trying to understand and predict weather in space. So that's where the THEMIS mission comes in. THEMIS is a NASA mission of five identical space crafts, which were launched to [occupy] the space near Earth to study what kind of space weather is going on. And the thing that makes THEMIS really cool is that there are five satellites! You may wonder, "Can't you just do your work with one satellite? Why do you need five?" Well, if you just have one satellite, you only have one observation point in space. So something that is really big, you're only seeing a tiny bit of. If you were to give me, say, one piece of a puzzle, and ask me to tell you what the entire puzzle looks like, I would have no idea! I could tell you things like, "It has trees, and it's green," but that's about it. But if you give me more puzzle pieces, I could start to tell you what the picture looks like. So with THEMIS, we have five satellites, they can see the same thing going on from all different perspectives, and get an idea of what the space weather is like out in space.

Q: In order to understand the THEMIS mission, you have to understand a lot about Earth's magnetic field [and the magnetotail?]. Can you tell us a little more about the Earth's magnetic field?

A: To understand the magnetotail, we first have to understand that the Earth has what's called a magnetic field. So, if you have ever played with magnets, every magnet has what is called a magnetic field. If you have ever played with a bar magnet, which is just those straight line magnets, and iron fillings, you usually put it on a glass and sprinkle [around] the iron fillings, you'll see that around the magnet will form these invisible lines. And these invisible lines, which go from one pole to the other, are what are called magnetic field lines. So our Earth actually has is sort of like an invisible bar magnet going through it, and that's why we have our North and South Pole. Out of one pole, the field lines are coming out, and in another pole, they are going in. If you could draw all these field lines around the entire Earth, it would kind of look like a donut -- with a donut hole that is the Earth in the center. But we're talking about now a tail and there's not really a tail in a donut! In order to get this tail, we actually have another interaction going on. Our Earth is not the only body that has a magnetic field, the Sun has a magnetic field, as well. The Sun also [generates] what's called a *solar wind*. The Sun also has a magnetic field. So the Sun has a solar wind—which is a plasma, which is charged particles—which is just blowing out from the Sun in every direction. As the solar wind is blowing out from the Sun, it's actually carrying the Sun's magnetic field lines outwards towards the Earth. When this magnetic field from the Sun reach our magnetic field lines on the Earth, it crashes in, and instead of having this nice donut round shape, it pulls those magnetic field lines and blows them backwards into what we call the magnetotail. It's very similar to a windsock, if you've ever seen a windsock blowing on a high building, the wind will fill it and blow this windsock outward. That's just like our magnetotail, where we have the solar wind and its magnetic field blowing and it pulls back the Earth's magnetic field into a magnetotail.

Q: Your research has to do with electrons moving and accelerating. Can you tell me more about that?

A: So when we have the solar wind blowing into our Earth and its magnetosphere, you actually get a lot of energy—think about the sun, it's very energetic— so all this energy from the sun is dumping into our Earth system. When we have that *magnetotail* that's being pulled back, if you think about it, it's kind of like a rubber band where this side is the Earth—so as more and more energy gets dumped in these field lines get stretched and stretched and stretched -- and suddenly it can't just take it anymore, and it snaps! And all that energy suddenly goes flying back towards the Earth really really fast and actually will dump itself into the North and South Pole regions which is when we get the aurora. So, my research in particular is studying just how exactly are these electrons being energized. We know that they are traveling by this snap coming back towards Earth but then we see that a lot of energization is happening in there so I'm trying to find more specifically how that all occurs. So even when you're not having that energy build up there are always electric fields and magnetic field in the Earth's magnetosphere. One relation you can remember is that whenever there's an electric field, it will move an electron. It's like a force. If I'm just a little electron here and an electric field comes and pushes me, I'm going to move in the direction of the electric field. And when a magnetic field is also there, it's also going to be pushing on that electron. So you can imagine it's like if you were a kayaker crossing a river, where the river is pushing the kayak towards the Earth slowly, but I'm also trying to cross the river at the same time. So now, when you have that energy release and big snap, it's like the river suddenly got very very fast, but I'm also crossing the river at the same time. When an electron crosses a potential drop caused by an electric field that will actually give it energy. Our idea is that as an electron is crossing this really fast flow, it's also gaining energy from this potential drop.

Q: So when that snap happens, can we see it?

A: Oh, that's a great question! This is sort of the one thing we can visually see the result of. So when we have that snap, all those really energetic particles come streaming in towards the Earth, and the thing is with these particles, they stay trapped on those magnetic field lines. If we remember our rubber band analogy, we're going to have these particles coming in, but they are going to stay on their line. So when they come in, we have to again remember that donut-shaped magnetic field [of] the Earth. All those magnetic field lines that these particles are travelling on are connected only to the North Pole and the South Pole, like that [demonstrates]. Actually, if you've ever wondered why we only see the aurora on the North and South Poles, this is why. When the particles come streaming in on these magnetic field lines they get dumped into the North Pole and dumped into the South Pole. And they start hitting our ionosphere, which is the region of the Earth's atmosphere which is kind of beyond the air we can breathe and it is up very close to outer space. When we have particles coming in from outer space, we have also have the atmosphere particles -- so when this particle comes in, it's going to hit this guy. And when he hits this guy in the atmosphere, this guy is going to share this energy. So he's really excited and he makes this guy really excited. And when that particle gets really excited, it emits light. And when that light is emitted, then we can actually see it up in the sky, as the aurora.

Q: What causes the different colors in the aurora?

A: Well, remember that we said when an energetic particle is coming in from outer space, it's going to eventually strike a molecule in the Earth's ionosphere, and that's what emits the light. So at higher altitudes, we have a lot more oxygen molecules, while at lower altitudes we have more Nitrogen molecules. A very very slow energetic particle coming from space is not going to travel very far before hitting an oxygen molecule and when it hits the oxygen molecule, the oxygen molecule will actually emit a red light. But a very fast particle coming in from space will travel fast enough to make it in from lower altitudes, and it will bypass the oxygen and hit the nitrogen instead. And the nitrogen will emit a green light. So the reason we see different colors is basically the different molecules in Earth's ionosphere that are being hit by the energetic particles coming in from outer space.

Q: Can you explain a little bit about how the solar wind is different from the wind here on Earth?

Sure. The wind on Earth is composed of dense air. I know it doesn't feel dense because you can push your hand through it, but it's actually a lot denser than outer space. Usually wind here on Earth is caused by changing pressure. You have a pressure system moving in, and suddenly you get strong winds, blowing from a higher pressure to a lower pressure, because all these particles in the air want to go to a region with less pressure. But the Sun is emitting light and radiation and energetic particles like electrons and protons. These all move radially outward in every direction, away from the ball of the Sun, so you have the solar wind going outward. It can travel very very fast, much faster than the winds you'll see on Earth's surface, and this is what's called plasma in outer space. If you hear the word "plasma" it's these charged particles that are being carried out from the Sun on the solar wind.

Q: What is your role in the THEMIS Mission?

Well, I'm a graduate student, so, in a few words, I would consider myself a "scientist-in-training." What that means is when I first came in, I didn't know too much about the field. But I learned a lot through hands-on experience, where I am actually doing real research just like a real researcher or a professor, but as a student I have the benefit of getting a lot of advice and direction from those who have more experience than me, like my advisor. It starts out I get some research projects where they're interested in finding out different answers to questions and then I look at the data and I try to answer those questions. Now that I'm a little farther along towards getting my degree, I have, with the help of my advisor, honed in a research topic that's interesting to me—which is all about, essentially, how you will transport these energetic particles from the Sun that have got trapped in our Earth's magnetotail, and how those particles come streaming back towards the Earth. Which is actually quite interesting for us to know, because when these particles come streaming back towards Earth, that's usually when we get this *space weather* and we can end up having some dangerous situations when we have higher radiation levels in outer space. It can actually harm our spacecraft and our satellites, so we can actually lose our GPS satellites or our communications satellites can go down. For instance recently, there was what we call a *substorm* – it's a type of space weather that occurred – and one of the Blackberry satellites went down, so all these people with their Blackberries couldn't call anybody! And it's also actually dangerous for astronauts who are living in space. So the more we can understand about how space weather is going on, what causes it – the more we'll be able to protect our satellites and our humans in space.

Q: You recently published an article that describes a model you built that describes how particles are energized and transported towards the Earth from the magnetotail. When many people hear the word model, they think of a physical thing such as a model airplane, a model ship, what do you mean when you use the word model?

A: Actually when you think about a model airplane, you know that it's not the real thing. But you try to build it to be as close to the real thing as possible and if you have lots and lots of information about the airplane, you can probably make the model airplane more realistic. So when I'm talking about a model, I'm not building a model airplane, but I'm talking about a computer model. So instead of trying to replicate an airplane, I'm trying to replicate what is going on in our space. So instead of using wood and glue to build an airplane, I'm using physics equations and computer programming to build a model that will try to tell me what is happening in outer space. Instead of using pictures of your model airplane to try to make it look exactly alike, I'm using satellites to compare. I'm actually using real data to try and find out if the equations I'm putting into my computer program are actually telling me what is happening in outer space. So if my satellite says, "oh, I saw a sudden increase in the magnetic field" and my model says the same thing, it predicts, "oh, there should be an increase in the magnetic field" I have a better chance that my model is correct. So the more satellites I have to compare with my model, the better chance I have that my model is correct. You might ask, "so why don't you just use satellites?" Well, the reason why models are so helpful is that a satellite is just one piece of a puzzle. If you have five satellites, you may have 5 pieces of the puzzle, but if you have a model, you have every piece of the puzzle, I can tell you what is going on in a place where we don't even have a spacecraft to tell you what's happening. So that's the benefit of having a computer model.

Q: Right now you are a doctoral student pursuing your PhD... What are some of the options for someone in your position after you graduate?

A: Usually after a doctoral student graduates, they look for post-doc positions. Post-doc positions are short-term research positions [that are] usually only a couple years long. It gives you a chance to go to other institutions, meet with other people and enhance your understanding by hearing from different people different perspectives, and practice doing research before you go for more permanent positions. What permanent positions you may look for are usually in industry, where you can go into research but you're not really interacting with students at all. Or you can go the academic route, which is after you go through some post-docs, you may apply to be faculty at an institution and work and try to be a professor. So as far as an industry, that also may include, say, NASA, JPL, or something like that where you get involved maybe with some government labs, so there's lots of different cool things you can do.

Q: What would you like to do after you graduate with your doctoral degree?

A: I have really enjoyed looking at data and analyzing it, trying to figure out what's going on in outer space, so I probably want to try to stay in some sort of research position. and then more recently I realized just how much I enjoy interacting with people and teaching. I really enjoy trying to convey ideas to other people and even try entering some sort of mentoring relationship. So that has kept me interested in staying in academia, and going towards a professorship, but I think it's always wise to have a really open mind. So I'll keep every door open. Oftentimes it seems like you may have one idea but something else just drops in your lap and is a great opportunity, so you should take it.

Q: Have you ever encountered a challenge in your work, and if so, how did you deal with it?

A: I would actually say that every day has challenges in it. First at a very broad scale there is the challenge of my thesis topic. It's one big or a couple questions that I'm trying to answer but then there are actually more tedious challenges that we face every day such as: why is my computer program crashing! I thought I wrote it perfectly! Why is it not working! I get that a lot actually. And what I find I typically do to try to overcome these challenges is to think: Okay, [what] could be the source of this problem? So if it's a code problem, I look at my code and say "Okay, it's crashing here. What could cause my code to crash in this particular place?" And I find that once you can determine what the source of the problem is, that's the hardest part and then you can work towards a solution. But sometimes, you just get stuck and you feel like there's nothing you can do. So at that point, I've learned I really need to let go of my pride and be willing to go seek help from the programmers who work on our team, or my advisor, or other researchers on our team who may have a lot more experience than I, so something that seems very challenging to me they may have a whole other perspective that I hadn't even thought about! And usually people are very welcoming and very glad to help you out.

Q: Looking back at your educational and personal background, what would you say were the key decisions, opportunities, influences, etc, that got you to where you are today?

A: Well, I was always a pretty well-rounded kid, so I liked a lot of different stuff. I think it was my dad had a real passion for airplanes and for science fiction and for amateur astronomy and I think that his passion just kind of seeped into me and I got really interested. I loved to just print out maps of the stars and try and find constellations in the freezing Wisconsin winter nights. So, then when it came time for me to graduate high school, I also had the really strong feeling that I wanted to do something that would really impact the world on a mankind scale. I wanted to do something I felt was moving mankind forward. So I thought that studying outer space and discovering things that we don't even know yet is a really great way to do that. So, I went to college in Florida, which is great for the space program, I had a lot of chances and opportunities to meet people who are really passionate about outer space, I met astronauts, I got to see some shuttle launches, [and] it just kind of fueled my desire to really want to see us grow in that area. Definitely when I was an undergrad I had some internship opportunities over the summer I worked and did research and learned a bit what it was like to plan a mission. And then, as a senior, I had a chance to work as an undergrad researcher where a faculty member actually took me in, and, along with a bunch of other undergrad and graduate students, formed a team to train us and also [teach us] how to do research, so that's where I got introduced to the topic of space physics. So then when I realized, "If I want to be a researcher I've got to go to grad school," when I applied around, I think my background and my interest in space physics is what made me and UCLA a good fit. So that's where I am today.

Q: What advice do you have for a high school student who's interested in studying physics or astronomy?

A: I would definitely recommend [taking] as much math and physics courses as possible in high school, which shouldn't scare you off if you're not the biggest math fan. Because, actually, to tell you the truth, I could never say that I actually enjoyed math. I enjoyed physics because I felt I was problem-solving, but [regarding] math I thought, "How could I ever be good at that?" But the thing that really drew me to physics and astronomy were concepts and learning "Oh this is so cool, there are black holes, that seems awesome, and other galaxies; what's going on in outer space?" So that's what drew my passion. But the thing about anything that you're learning, you need to be able to speak the language. So if you want to learn French literature, you need to learn French. If you want to learn about astronomy and physics and the really exciting area of outer space, you need to learn the language of that, which is math. Let me just tell you that the more you learn, the more passionate you become about something. So I really encourage students, don't be afraid of math, just take the classes, get involved, and learn about it.

Q: So when you're not studying and working, what kinds of things do you like to do?

A: Well, when I'm not studying and working, I also like to be really involved in my church. My husband and I enjoy having people over in our apartment, leading a bible study and just hanging out. I also like to be involved in our youth program, so it's sort of an outlet to get away from the math and the science, and interact with the other people, younger people, and talk to them and teach them. Then, also I'm a real outdoorsy person, and California's a really great place for that, we have mountains that I love to go hiking in and we have the ocean which I love to go to the beach and hang out. Another thing I really love doing is reading, so on the bus coming into work, I love to read books. (I don't know how far I should go -- I love snowboarding, I love trying new food…[laughs]).

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