INTERVIEW OF
MADHULIKA GUHATHAKURTA
By Troy Cline

Q: Well, good morning. Could you tell us who you are and your primary area of research much right now.

A: My whole name is Madhulika Guhathakurta. But I guess I am better known as Lika because it's a daunting name. People can't pronounce it.

And for over a solar cycle now I have been the lead program scientist for NASA's Living With a Starprogram. And living with a star means living with our sun. Sometimes people forget the sun isA star simply because we get to see it in the day sky.

Q: That's right. I can't tell you how many times we run into that in education. It's a fun -- it's a good topic, though.

We have several questions to ask you. You have quite a history with space weather. And I -- talking with you earlier, you said something in the hall that I thought was really interesting and that was...

A: Yeah. You know, I mean, here I am interviewing for sort of living history of space weather. It's an appropriate term. When we use the word "history," I think it means that something is old and we are capturing the information. We are actually creating the history of space weather as we speak.

Space weather is a very new concept that has come about as our societies have evolved technologically. And so we are creating the science behind space weather which we call "Heliophysics." It's a new discipline.

And understanding the impacts of space weather itself, is still an emerging sort of area of science and understanding.

Q: So if people would like to be part of history, jump on board, because now's the time to do it especially in the area of space weather.

A: Absolutely.

Q: Now, I have quite a few questions. And we have several written down, because of your experience with space weather already. And one of them is, with what and when were you involved in space weather research? And I think this will open the flood gates of what we can talk about.

A: And then the way I would answer the question, when did my interest begin in space weather, is sort of the very beginning of my research career in Astrophysics.
I was trained as an astrophysicist in graduate school. I specialized in just one star, however, the sun. So that's the specialty.

You can also call me a "solar physicist." And in my research career, I sort of expanded this specialization to include the study of sun's effects on Earth.

And today, you know, I manage the science of this program called "Living With A Star." And then so it's at the very beginning of my research career that I started looking at the influence of sun on our society but really concentrating on the science of it, (the) sun as an astrophysical object.

You know, we -- people don't think about it, but we actually live in the outer atmosphere of our star. It's the corona. And this atmosphere is constantly expanding and losing particles, particles in the form of electrons and protons. These particles propagate through the interplanetary medium.

And so what I was studying is really understanding the propagation of solar wind, you know, what kind of energy and momentum do you need to make the corona as hot as it is and for it to actually continue -- continuously expand and produce these particles.

That was my research career almost some 15 years ago before I became a NASA bureaucrat at NASA Headquarters.

So kind of going on from there, I came to NASA's Goddard Space Flight Center actually as a research scientist 20 years ago in 1993. And during that time I actually worked, I was a co-investigator on five missions called "SPARTAN." It's an acronym, stands for Shuttle Pointed Autonomous Research Tool for Astronomy. It's a mouth full.

And what this SPARTAN spacecraft did is that this -- we could put sort of, you know, our instrument concept into this package and this would be carried by astronauts and then deployed in space. So we were actually working very closely with shuttle astronauts. That was pretty unique, you know. Many scientists at NASA don't get the opportunity to work with astronauts. And I did that for five years, as a matter of fact.

And what the experiments were was sort of, again, the beginning concept of some of missions we are flying today in Living With a Star Program. One was white-light coronagraph that actually determines the properties of the corona. And you can actually see it visually through the remote sensing images that we capture with the white-light coronagraph. These images look very much like the eclipse images that we see with unaided eyes. So it's visually dramatic. But the data provided us with information on the density of the corona, you know, how many electrons are there, temperature, the magnetic topology that shapes the corona. Very important.

And there was another instrument from Harvard-Smithsonian, SAO, ultraviolet corona spectrometer. Both of these sort of mission concept eventually get fed into our current missions like Solar Terrestrial Relations Observatory, STEREO, spacecraft or Solar Dynamics Observatory. So we were already kind of beginning to gather the scientific knowledge that was necessary to connect the sun and the interplanetary medium.

From there, after I finished these five missions, I went to NASA headquarters actually to do the STEREO mission as a program scientist for STEREO mission. And that was in December of 1998. While there, you know, I absolutely did STEREO. STEREO launched in 2006. It is still gathering fabulous observations. It's given us the full 3-D view of the sun like no other spacecraft has ever done. And it's going to come back again and going to do the full circle come back.

But while at NASA Headquarters in those years, we actually conceived of this new mission or new program line called "Living With A Star."

Now, in the Science Mission Directorate at NASA, we really concentrated on curiosity-driven science. Science for science sake. You know, the question of application did not emerge in those days. We had Earth Science, of course, very application-driven in terms of climate changes but Earth Science was a separate directorate.

So in Space Science, which is where Heliophysics Division resided, did not do application-oriented science. Living With a Star was the first and the only program in that sense in the space science area. That actually went after science with societal relevance. That was really the tag line for the Living With a Star Program. And what is the societal relevance of such a science that is space weather.

And so what we needed to do is we needed to connect essentially, you know, what the sun does and how -- what -- how does the sun vary, how does all the variability in the form of particles magnetic field propagate through the interplanetary medium, how does it influence our planetary environment as well as all the planets in the solar system, and what are the consequences on life and society.

These were essentially the fundamental questions of Living With a Star Program. And that is the beginning of addressing space weather science by NASA program.

Q: That's amazing to me because often when we're out talking to the public about Heliophysics and space weather, they're most interested in how it affects them and what impact it has on them.

And as soon as we start talking about satellites and people walking in space and our ideas of going, you know, into deep space or manned missions to various places, we're talking about space weather and how important it is because without having a better understanding of what's going on or how to predict it and how to deal with the radiation in space, there's no way we could survive a six-month journey to Mars, for instance.

A: Absolutely. You know what I find fascinating, so now I have been in this program, leading, shaping this program, as I said, over a solar cycle.

So the program actually officially started in 2001, it's 2013 now, so it's a little over one solar cycle. One solar cycle is, give or take, 11 years. And we are continuously shaping this program. When this program first began, as I said, it was science with societal relevance. Right.

Today -- and society in those early years simply meant on our planet. Right. Whatever is affected by space weather in terms of technology, in terms of, you know, robotic exploration, human exploration, was all relevant to our planet Earth.

Because, you know, space weather was kind of a very immature science. We could barely predict space weather at our own planet, let alone try to predict space weather at other planets, even though we understood it as being an important concept. Today, we have actually evolved from that state. We are doing relatively well in terms of our understanding and in terms of, you know, giving that understanding and the observations to NOAA, Space Weather Prediction Center, where they do the actual forecasting for the nation. Now, they do the forecasting for our planet.

Well, NASA's interest doesn't really stop at our planet. So I want to bring back again Living With a Star Program. It is science with societal relevance. It's that science that affects life and society. And to me, society is wherever we human beings go.

Today, you know, we have robotics, spacecraft that are found in every corner of our solar system from the very edges of the solar system in the form of Voyagers, New Horizons Pluto that will be going to Pluto. We have it on Mars, at MESSENGER, Mercury -- you know, MESSENGER is the mission.

So we want to be able to provide some level of forecasting for this robotic spacecraft, but, you know, NASA's goal is eventually to leave low earth orbit and explore the solar system with not only robotic spacecraft but with human explorer. So for that, interplanetary space weather becomes absolutely vital. So here, you are talking about space weather.

I will take you to a new birthday that emerge for interplanetary space weather. And I kind of think of that day to be the day when the two STEREO spacecraft were in opposition, I believe February 10^{th} or 11^{th}, 2011. That was the first time we were able to view both the front and the far side of the sun simultaneously.

If you think about history, you know, what could be more profound for a human species who have always, you know, kind of have grown up with the sun, admired the sun, but we cannot actually see the far side of the sun.

And with the aid of the two STEREO spacecraft and because we have down-linked data that, you know, we get small abstract of data real time every minute, we are able to see what's happening on the far side and the front side simultaneously. It's a real 360-degree view of the sun.

And that is continuing on and will continue on for a little while longer. These spacecraft are not in stable point. They're drifting at a rate of about 22 degrees per year. So eventually, they will come back.

But why do I call that particular moment in time the birth of interplanetary space weather? Because it is at that point, you know, modelers could begin to use observations from STEREO and actually generate model where you can take a coronal mass ejection and sort of propagate it into the solar system. And you had the data points to actually do that, to bound the model.

And now this is done routinely at Goddard's Community Coordinated Modeling Center. We generate this model every day, all the time, especially if there is a solar storm coming. And with that, they are able to actually let the spacecraft operators for NASA that, hey, there is a CME coming your way.

So a word that didn't exist in the vocabulary, or even sometimes actually in our dream, "interplanetary space weather," is a concept today has emerged as a new science, a new forecasting tool.

Q Okay. Now, what impacts will Living With a Star Program have on our understanding of space weather?

A You know, as I was mentioning before, until recently forecasters could barely predict space weather in the limited vicinity of -- we've been doing it for a while.

So interplanetary, you know, forecasting was out of the question. And that began to change with the 2006 launch of the twin STEREO probes, followed almost four years later by the Solar Dynamics Observatory. Solar Dynamics Observatory is the first mission of Living With a Star Program.

So these three spacecraft now surround the sun monitoring active regions, flares, and coronal mass ejections, around sort of the full circumference of the star.

So no matter which way a solar storm travels, a STEREO still fleet can track it. This has improved our ability to predict space weather with longer lead time. And that's very important for operators who have to take mitigating steps.

There are, you know, I should tell you what impact this forecasting have on space weather. There are about 500 active satellites that circle the Earth. We rely on them for TV, telephone, internet, GPS navigation, and weather forecasting.

The terrestrial weather forecasting, isn't that kind of ironical that terrestrial weather forecasting satellites are vulnerable to space weather. You might not get that forecasting if there is a major outbreak of space weather. So all of these are vulnerable to space weather.

Humans orbit earth, too, on board the International Space Station right now. The ISS is fortunately located inside earth's magnetic field, so it enjoys a degree of protection. But future astronauts en route to the moon and Mars will be outside this magnetic bubble. Their spaceships are going to be in direct contact with the sun's atmosphere.

So NASA's Living With a Star program, which was formed in 2001, was to deal with this reality, essentially. If we are going to live inside the sun'So s atmosphere, we need to learn more about it, especially how to predict the storms. The basic strategy is the same as weather studies on earth. We're going to launch a fleet of weather stations like space weather buoys, spacecraft that observe different aspects of sun's atmosphere and its impact on Earth.

So LWS has four missions in various states of operation and development. And together they will surround and explore the sun-Earth system in ways no spacecraft or no program has done before.

Solar Dynamics Observatory, launched in February 2010, is providing HDTV quality photographs of sunspots, solar flares, revealing the onset of storms in never before seen details. So this is fundamental science, again, that has societal relevance.

The Radiation Belt Storm Probes that just launched last year in August, and now has been renamed to honor Van Allen as "Van Allen Probes," it is actually studying Earth's radiation belt in some ways. - you know, there is no point studying the sun if you can't measure its impact on Earth. And that's what we are doing with the Radiation Belt Storm Probes or Van Allen Probes.

So little parts, whips of the sun's atmosphere, can become cracked by Earth's magnetic field inside radiation belts. But there are really high energetic particles that, in some ways, lie in wait for astronauts and satellites trying to leave or simply orbit the planet.

And so the two Van Allen Probe spacecrafts are actually exploring these regions and discovering how they are populated and energized by space weather, these particles. And there are fabulous science results coming out.

As a matter of fact, right after we launched it, we realized that there was a new, a third belt forming. You know, as a consequence of what was happening with one particular solar storm.

Q Wow.

We don't understand all the details, but we actually get to observe it and now we are doing the detailed science analysis.

Q So once again, making history.

A Making history.

And then we have two more missions that are in the development phase, Solar Orbiter Collaboration, which is a mission from the European Space Agency, which will actually put itself at an inclination of about 30 degrees from the sun's equator providing the first truly polar view of solar magnetic field.

And this measurement is crucial for most of our models. And we don't have a very good handle on this measurement yet.

The equatorial view from Earth limits studies of polar magnetic field. And so Solar Orbiter that's going to launch in 2017 is going to address this area.

And finally, the mission that is closest to my heart, Solar Probe Plus. I've worked on this for longer than 11 years. This is the most exciting mission of all. It is a heat resistant spacecraft designed to plunge deep in the sun's atmosphere, the corona, where it can sample solar wind and magnetic fields in situ.

This is the environment that is the very genesis of space weather. That's where space weather is created. No spacecraft has ever been as close to the sun as Solar Probe Plus. It will go to within 7 million kilometers from the surface. And this is unexplored territory, and we are going to learn a lot about it.

You know, the way I say that we have visited pretty much every corner of the solar system except the very center. This is the first time, you know, humanity will go to a star.

Q Well, it's pretty evident that there are many, many different aspects to Living With a Star and the program.

Are there international efforts that you can tell us about, because we know that NASA and within the country, there's so much going on in the area of space weather, but we also know about international efforts that you have been part of. And could you expand on that for us?

A Absolutely. So Living With a Star was created in 2001. Soon after that, was the end of 2002 and early 2003, we created actually an initiative called International Living With a Star Program. And what this is is essentially a group of space-faring nations, any nation that does space science is part of this program.

And what we do in this program is come together, describe our plans for research, for space observations, and figure out ways of cooperating and collaborating. We have a steering group of six individual nations. And now China is very much part of the -- that steering group having kind of demonstrated its capability and excellence in the area of space program.

So this is an ongoing effort where we meet as a group every year, typically twice a year. We host workshop in developing work where scientists are not able to, you know, travel to big meetings but we take the understanding and the content of sort of Heliophysics Science, Living With a Star effort in those areas.

And as I gave you examples, you know, STEREO, Solar Orbiter Collaboration, and many other NASA missions, these are missions in partnership with other nations.

And something that I haven't talked about yet and that is sort of the research frontier that Living With a Star Program has created. Living With a Star essentially became -- you know, it took four desperate separate sciences which are very old traditional science of solar physics, magnetospheric physics, heliospheric science, ionospheric science – combine them one entity end to end.

What happens on the sun and what are the consequences in these various elements of space. So it was no longer one area of study in isolation, but a system science of this environment.

And we begin -- eventually began to call this system science "Heliophysics." Heliophysics is a new word that we came up, but Heliophysics is a discipline today. It, in some ways, it is much like Earth Science. Okay.

So before "Meteorology" became a word, what we were doing? We were studying the ocean currents, the, you know, precipitation measurements, temperature, et cetera. Eventually all of these studies whole list into the study of Meteorology which describes terrestrial weather.

In the same way, I think the study of the sun-Earth system or sun-planet system really is the study of Heliophysics as a system.

But this -- so this is, in some ways, an environmental science which has both Meteorology and Astrophysics. That's what makes it so unique and rich because two very different kinds of fields that came together to describe the phenomenon.

And clearly, there were never any textbooks written for this subject because the discipline didn't exist.

And so as part of being the Living With A Star Program scientist, I actually commissioned the creation of Heliophysics textbooks. And this was really more for advanced graduate students or postdocs. You know, these are reference documents that describes the complexity of the science and the connectiveness of the science.

So there are three volumes – Heliophysics volume I, II, and III. And now we actually have Heliophysics textbooks that some professors are utilizing in creating curriculum for their schools, for their graduate school, and (inaudible).

And so I've run the summer school now, this is my seventh year. And what I have embarked upon, you know, having done the reference level textbooks, is really looking at teaching Heliophysics at four year degree college level so we have teachers from four year degree colleges attending summer school and developing curriculum for their students.

Q Wow.

Now, given the history and current status of space weather and everything we've been talking about, what do you envision your legacy being?

A I think I got so drawn into Heliophysics because I see such a tremendous potential in this science because it characterizes the outer space environment that we are immersed in.

And in way -- in some ways, I think the science of Heliophysics is going to be essential for us human species to go from being Earth dwellers to space dwellers. And I think that's inevitable.