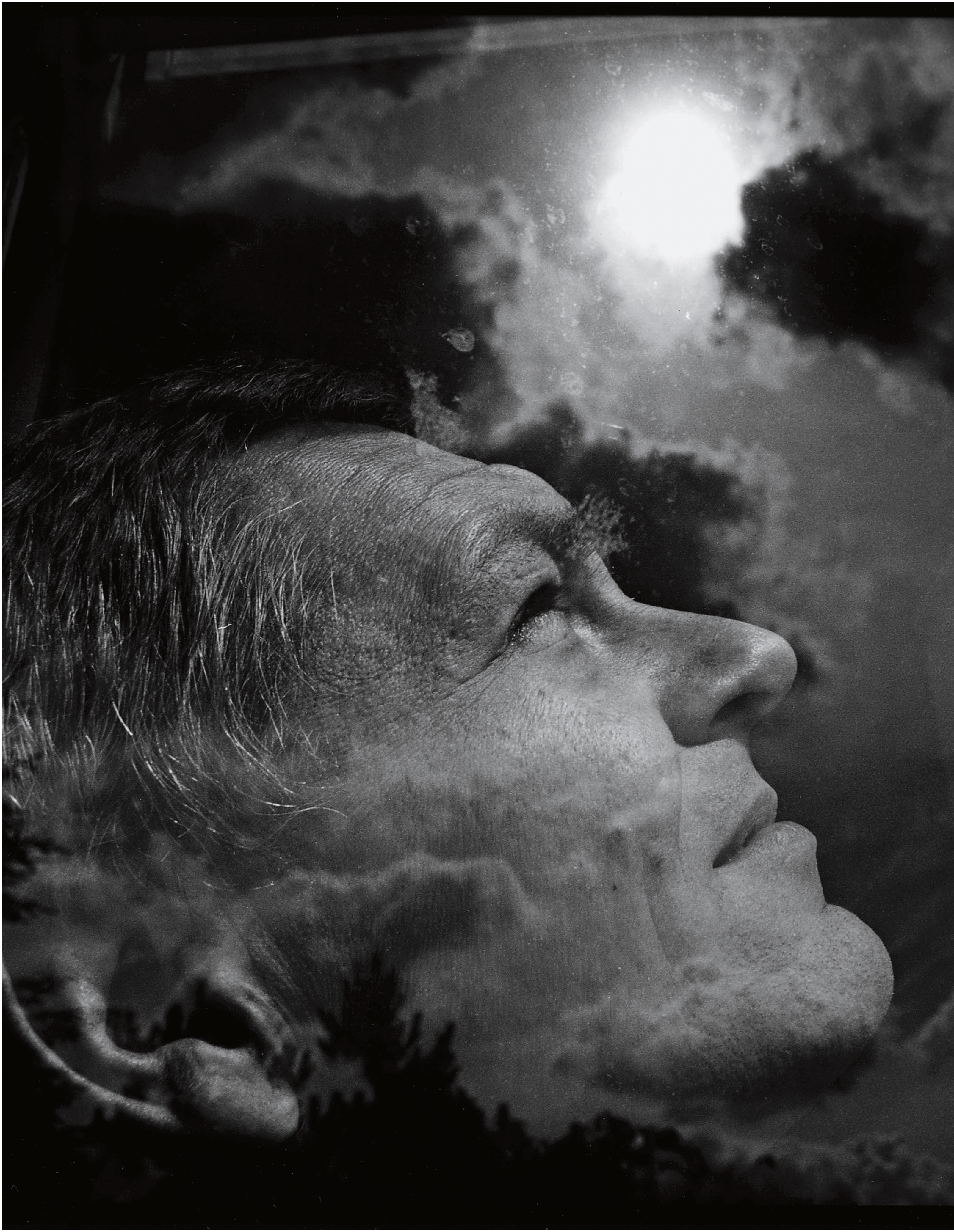


THE DISCOVER INTERVIEW
HENRIK SVENSMARK

His studies show that the sun plays a major role in global warming. So are humans off the hook? And if so, why does he use compact fluorescent lightbulbs?

BY **MARION LONG**

Most leading climate experts don't agree with Henrik Svensmark, the 49-year-old director of the Center for Sun-Climate Research at the Danish National Space Center in Copenhagen. In fact, he has taken a lot of blows for proposing that solar activity and cosmic rays are instrumental in determining the warming (and cooling) of Earth. His studies show that cosmic rays trigger cloud formation, suggesting that a high level of solar activity—which suppresses the flow of cosmic rays striking the atmosphere—could result in fewer clouds and a warmer planet. This, Svensmark contends, could account for most of the warming during the last century. Does this mean that carbon dioxide is less important than we've been led to believe? Yes, he says, but how much less is impossible to know because climate models are so limited.

There is probably no greater scientific heresy today than questioning the warming role of CO_2, especially in the wake of the report issued by the United Nations Intergovernmental Panel on Climate Change (IPCC). That report warned that nations must cut back on greenhouse gas emissions, and insisted that "unless drastic action is taken . . . millions of poor people will suffer from hunger, thirst, floods, and disease." As astrophysicist Eugene Parker, the discoverer of solar wind, writes in the foreword to Svensmark's new book, *The Chilling Stars: A New Theory of Climate Change,* "Global warming has become a political issue both in government and in the scientific community. The scientific lines have been drawn by 'eminent' scientists, and an important new idea is an unwelcome intruder. It upsets the established orthodoxy."

We talked with the unexpectedly modest and soft-spoken Henrik Svensmark about his work, the criticism it has received, and truth versus hype in climate science.

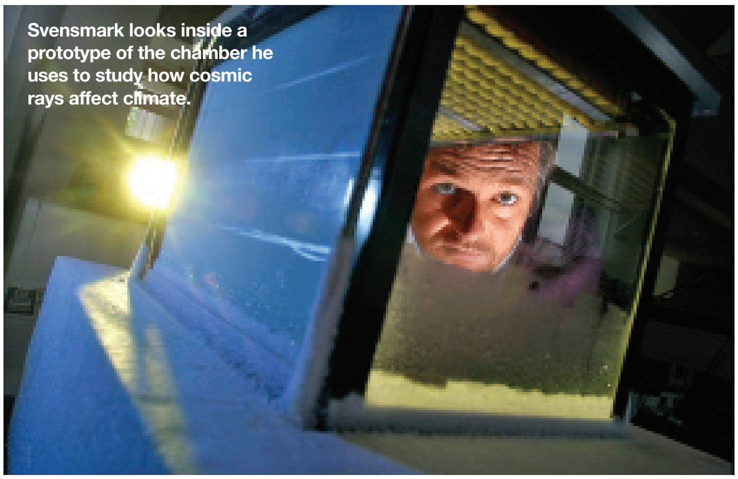
Was there something in the Danish weather when you were growing up that inspired you to study clouds and climate?

I remember being fascinated by clouds when I was young, but I never suspected that I would one day be working on these problems, trying to solve the puzzle of how clouds are actually formed. My background is in physics, not in atmospheric science. At the time when I left school and began working, it was almost impossible to get any permanent work whatsoever in science. That was why, after doing a lot of physics on short-term things at various places, I took a job at the Meteorological Society. And once I was there I thought, "Well, I had better start doing something." So I started thinking about problems that were relevant in that field, and that was how I started thinking about the sun and how it might affect Earth.

It was a purely scientific impulse. With my background in theoretical physics, I had no—well, certainly not very much—knowledge about global warming. I simply thought that if there is a connection to the sun, that would be very interesting, and I certainly had no idea it would be viewed as so controversial.

In 1996, when you reported that changes in the sun's activity could explain most or all of the recent rise in Earth's temperature, the chairman of the United Nations Intergovernmental Panel called your announcement "extremely naive and irresponsible." How did you react?

I was just stunned. I remember being shocked by how many thought what I was doing was terrible. I couldn't understand it because when you are a physicist, you are trained that when you find something that cannot be explained, something that doesn't fit, that is what you are excited about. If there is a possibility that you might have an explanation, that is something that everybody thinks is what you should pursue. Here was exactly the opposite reaction. It was as though people were saying to me, "This is something that you should not have done." That was very strange for me, and it has been more or less like that ever since.


Svensmark looks inside a prototype of the chamber he uses to study how cosmic rays affect climate.

So it's difficult to do climate research without being suspected of having a hidden agenda?

Yes, it is frustrating. People can use this however they want, and I can't stop them. Some are accusing me of doing it for political reasons; some are saying I'm doing it for the oil companies. This is just ridiculous. I think there's a huge interest in discrediting what I'm doing, but I've sort of gotten used to this. I've convinced myself the only thing I can do is just to continue doing good science. And I think time will show that we are on the right track.

Do you ever worry that people will take your findings and use them to support unwarranted or even harmful conclusions?

I would be happy to kill the project if I could find out that there was something that didn't fit or that I no longer believed in it. When we started, it was just a simple hypothesis based on a correlation, and correlations are, of course, something that could be quite dubious, and they could go away if you get better data. But this work has only strengthened itself over the years.

What first made you suspect that changes in the sun are having a significant impact on global warming?

I began my investigations by studying work done in 1991 by Eigil Fiin-Christensen and Knud Lassen Fiin-Christensen. They had looked at solar activity over the last 100 years and found a remarkable correlation to temperatures. I knew that many people dismissed that result, but I thought the correlation was so good that I could not help but start speculating—what could be the relation? Then I heard a suggestion that it might be cosmic rays, changing the chemistry high up in the atmosphere. I immediately thought, "Well, if that is going to work, it has to be through the clouds."

That was the initial idea. Then I remembered seeing a science experiment at my high school in Elsinore, in which our teacher showed us what is called a cloud chamber, and seeing tracks of radioactive particles, which look like small droplets. So I thought to myself, "That would be the way to do it." I started to obtain data from satellites, which actually was quite a detective work at that time, but I did start to find data, and to my surprise there seems to be a correlation between changes in cosmic rays and changes in clouds. And I think in early January 1996, I finally got a curve, which was very impressive with respect to the correlation. It was only over a short period of time, because the data were covering just seven years or something like that. So it was almost nothing, but it was a nice correlation.

How exactly does the mechanism work, linking changes in the sun with climate change on Earth?

The basic idea is that solar activity can turn the cloudiness up and down, which has an effect on the warming or cooling of Earth's surface temperature. The key agents in this are cosmic rays, which are energetic particles coming from the interstellar media—they come from remnants of supernova explosions mainly. These energetic particles have to enter into what we call the heliosphere, which is the large volume of space that is dominated by our sun, through the solar wind, which is a plasma of electrons, atomic nuclei, and associated magnetic fields that are streaming nonstop from the sun. Cosmic-ray particles have to penetrate the sun's magnetic field. And if the sun and the solar wind are very active—as they are right now—they will not allow so many cosmic rays to reach Earth. Fewer cosmic rays mean fewer clouds will be formed, and so there will be a warmer Earth. If the sun and the solar wind are not so active, then more cosmic rays can come in. That means more clouds [reflecting away more sunlight] and a cooler Earth.

Now it's well known that solar activity can turn up and down the amount of cosmic rays that come to Earth. But the next question was a complete unknown: Why should cosmic rays affect clouds? Because at that time, when we began this work, there was no mechanism that could explain this. Meteorologists denied that cosmic rays could be involved in cloud formation.

You and a half-dozen colleagues carried out a landmark study of cosmic rays and clouds while working in the basement of the Danish National Space Center. How did you do it?

We spent five or six years building an experiment here in Copenhagen, to see if we could find a connection. We named the experiment SKY, which means "cloud" in Danish. Natural cosmic rays came through the ceiling, and ultraviolet lamps played the part of the sun. We had a huge chamber, with about eight cubic meters of air, and the whole idea was to have air that is as clean as you have over the Pacific, and then of course, to be able to control what's in the chamber. So we had minute trace gases as you have in the real atmosphere, of sulfur dioxide and ozone and water vapor, and then by keeping these things constant and just changing the ionization [the abundance of electrically charged atoms] in the chamber a little bit, we could see that we could produce these small aerosols, which are the basic building blocks for cloud condensation nuclei.

PAGE 46-47: NICOLAI FUGLSIG/POLFOTO. OPPOSITE PAGE: COURTESY OF THE DANISH NATIONAL SPACE CENTER.

So the idea is that in the atmosphere, the ionization is helping produce cloud condensation nuclei, and that changes the amount and type of clouds. If you change the clouds, of course, you change the amount of energy that reaches Earth's surface. So it's a very effective way, with almost no energy input, to change the energy balance of Earth and therefore the temperature.

There were so many strange surprises, and many times we were busy just trying to understand what was going on. The mechanism we seemed to be finding was very different from any theoretical ideas about how it should work. It seemed to be much more effective than we had ever imagined. It seems as if an electron is able to help form a small particle—a molecular cluster, as we call it—and then the electron can jump off and help another one. So it's like a catalytic process. It was a big surprise that it is so effective.

These types of experiments had not really been done before, and we had to find new techniques in order to do them. Once we had the results, it was necessary to understand completely what was going on. So it was a very intense period of work, almost hypnotic.

Now there are other experiments, like the CLOUD project, also designed to investigate the effects of cosmic rays. How will this build on your work?
CLOUD is an international collaboration [sponsored by the European Organization for Nuclear Research, or CERN] that is taking place in Geneva, but it's going to take a while before any results come out of that. It was approved last year, and building the machine will take at least three years. That's a problem with science: You have to have a lot of patience because results are very slow to come.

If the scientists at CLOUD are able to prove that cosmic rays can change Earth's cloud cover, would that force climate scientists to reevaluate their ideas about global warming?
Definitely, because in the standard view of climate change, you think of clouds as a result of the climate that you have. Our idea reverses that, turns things completely upside down, saying that the climate is a result of how the clouds are.

Fewer cosmic rays mean fewer clouds will be formed, and so there will be a warmer Earth.

How do you see your work fitting into the grand debates about the causes of global warming and the considerations of what ought to be done about it?
I think—no, I believe—that the sun has had an influence in the past and is changing climate at the present, and it most certainly will do so in the future. We live in a unique time in history, because this period has the highest solar activity we have had in 1,000 years, and maybe even in 8,000 years. And we know that changes in solar activity have made significant changes in climate. For instance, we had the little ice age about 300 years ago. You had very few sunspots [markings on the face of the sun that indicate heightened solar activity] between 1650 and 1715, and for example, in Sweden in 1696, it caused the harvest to go wrong. People were starving—100,000 people died—and it was very desperate times, all coinciding with this very low solar activity. The last time we had high solar activity was during the medieval warming, which was when all of the cathedrals were built in Europe. And if you go 1,000 years back, you also had high solar activity, and that was when Rome was at its height. So I think there's good evidence that these are significant changes that are happening naturally. If we are talking about the next century, there might be a human effect on climate change on top of that, but the natural effect from solar effect will be important. This should be recognized in the models and calculations that are being used to make predictions.

Why is there such resistance to doing that? Is the science that conflicted or confusing? Or is politics intervening?
I think it's the latter, and I think it's both. And I think there's a fear that it will turn out, or that it would be suggested, that the man-made contribution is smaller than what you would expect if you look at CO_2 alone.

Have you had a hard time getting funding?
For an eternity, I would say. But there are no oil companies funding my work, not at all. It sounds funny, but the Danish Carlsberg Foundation—you know, the one who makes beer—they have been of real support to me. They have a big foundation; in Denmark it's one of the biggest resources for science. It's because the founder of Carlsberg wanted to use scientific methods to make the best beer. It's probably the best beer in the world, because of science.

If cosmic radiation is in fact the principal cause of global warming, is that good or bad news for human beings?
That's a good question because you would have to say that we cannot predict the sun. And, of course, that would mean that we couldn't do anything about it.

But if humans, through carbon dioxide emissions, are affecting climate less than we think, would that mean we may have more time to reduce the harmful effects?
Yes, that could of course be a consequence. But I don't know how to get to such a conclusion because right now everything is set up that CO_2 is a major disaster in society.

Do you agree that carbon dioxide is having at least some impact on Earth's current warming?
Yes, but you have to give the sun a role. If you include the sun in the right way, the effect of CO_2 must be smaller. The question is, how much smaller? All we know about the effect of CO_2 is really based on climate models that predict how climate should be in 50 to 100 years, and these climate models cannot actually model clouds at all, so they are really poor. When you look at them, the models are off by many hundreds percent. It's a well-known fact that clouds are the major uncertainty in any climate model. So the tools that we are using to make these predictions are not actually very good.

What do you hope to do next in pursuit of your theory?
I'm extremely excited about our next experiment, which will happen in the next couple months. We are planning to go one kilometer below Earth's surface because when we do an experiment in the basement we cannot get rid of the radiation. Cosmic rays are so penetrating that there's always ionization in our chamber and we

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Are cloudy skies protecting us from global warming?

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cannot get to zero ionization. I think it will be the first time that people are attempting an experiment where there is no ionization present. I think it will be quite fascinating because it will tell us something about the details in the mechanism.

Do you think then that individuals and societies as a whole need to try to conserve energy? Do you use compact fluorescent lightbulbs, for instance?
Yes, yes, we use those. And I ride a bicycle. There are good reasons to conserve our resources and find a more economical way of using energy, but the argumentation is not linked necessarily to climate.

At this stage in your work, how confident are you that your basic theories are correct?
I think it is almost certain that cosmic rays are responsible for changes in climate. I think now I have very good evidence, and I think I've come up with some very good evidence that it is clouds. Of course, we cannot discuss the exact mechanism, but I think we have some very important fragments of these ideas. One extrapolation we could make, for instance: Would this mechanism work in an ancient atmosphere? Would these processes still happen? That is something I don't know.

You discuss your work as part of an emerging field that you call "cosmoclimatology." What is that?
It is the idea that processes in space and what is happening here on Earth are connected. It is this idea that when Earth is in a certain spiral arm of the Milky Way, you can associate that with a certain geological period. Previously, the idea was of Earth as a sort of isolated system on which processes evolved. Now all of a sudden it seems as if our position in the galaxy is important for what has happened and is happening here on Earth. It is this connection between Earth and space that's exciting and why I have given it this name. Most of this research has taken place just within the last 10 years, and it is truly multidisciplinary, ranging from solar physics and atmospheric chemistry to geology and meteorology—even high-particle physicists are involved. The people who are doing space-related observations are very happy that there could be a connection from space to Earth because it makes a good argumentation for understanding processes out there.

These connections, which combine such a variety of disciplines and create opportunities for many lines of work, are surprising and wonderful. It has been a real challenge for me, though, because I have to look at so many different fields in order to work.

You've faced more than a few hard knocks in pursuing your scientific career. What keeps you going?
From the beginning, I have found this to be a really interesting problem, and now, I think, it is the potential of it that draws me on. It is something which started as a simple idea and seems to be continually extending, or expanding. That has really been the most important thing. I mean, for instance, I would never have thought that we would find these correlations between the cosmic rays and the evolution of the Milky Way and life on Earth. I never expected that all of these things are connected in a beautiful way. ■