INTERVIEW OF

DR. THOMAS J. BOGDAN

UCAR

Conducted by Troy Cline

P R O C E E D I N G S

MR. CLINE: Well, thank you so much for your time. I know that it's hard to get together with some people, especially on a busy schedule in the middle of Washington, D.C., let alone finding a quiet space to conduct an interview, but I'm glad we were able to move ourselves off of the hotel lobby and -- so that I could capture a few words with you in an interview. Could you tell us who you are and a little bit of what you're doing right now?

DR. BOGDAN: My name is Tom Bogdan, and I am the President of the University Corporation for Atmospheric Research, also known as UCAR. UCAR is a 501(c)(3) not for profit that is a consortium of 104 universities from across the U.S. and Canada. Most of those universities are involved in research related to weather, water, climate, air quality, and, of course, space weather is part of what we do as well.

We operate the National Center for Atmospheric Research in Boulder, Colorado, which includes the High Altitude Observatory that was founded by Walter Orr Roberts back in 1940, whose work was to look at the corona and was really some of the initial studies of space weather before and during World War II that was used for the capacity to predict radio interference and blackouts for the Allied Forces.

So my organization has a long history that leads back to really some of the early beginnings of space weather in the U.S. But today, I am an unrepentant bureaucrat, and I try to advocate for our science and our research, and that's what brings me to Washington this week.

But the research that I did before I became an administrator involved sunspots, the dark blemishes that appear on the Sun that we discovered in the West, when Galileo first turned the telescope on the Sun in the --

(Off the record.)

MR. CLINE: Hey, Brian, this is Troy. We just had to stop for a quick conversation in the hallway, so we're picking up just a few sentences back. Okay?

DR. BOGDAN: My research interest has always involved sunspots, the dark blemishes on the face of the Sun that Galileo first discovered, quote, unquote, for us when he turned the telescope towards the Sun, but which the ancient Chinese and others had known about well, well before that time.

And my research involved trying to understand what sunspots really were. We know a lot from their surface manifestation. But what I tried to do was use sound that is created by the convection that surrounds the sunspots. The outer 30 percent of the Sun convects, the solar convection zone, and a byproduct of that convection is noise, or sound, and that sound traverses sunspots. It runs over them. It passes through them.

And what was observed in the 1980s by Doug Brown and Tom Duvall and some of their collaborators was that that sound is absorbed by sunspots. And that was a very intriguing question as to why sunspots wanted to absorb that sound and scatter it. And so my work was to try to determine what we could learn about the sunspots by watching that scattering process, kind of a very classical physics problem.

And for me, it was intriguing because what we could find is the nature of the spot below the solar surface, where we can't see it. So it was a very interesting mathematical problem and also one that related to the observations.

The -- in the end, the mystery was solved by noting that when the sound passes across the sunspot, it creates waves within the sunspot that then propagate up into the atmosphere or down into the interior of the Sun, and that's where that energy goes. It isn't actually absorbed so much as it is converted to another type of wave mode that we then did not observe on the surface.

MR. CLINE: I would like to ask one question. Does -- the sound waves that propagate from these areas, do those travel all the way through or around the Sun to the other side?

DR. BOGDAN: They do. Some of them have very long lifetimes and can travel around the Sun many, many times, the ones that have the longer wavelengths, but the ones that are shorter actually get either absorbed on sunspots or magnetic structures or potentially get reabsorbed by the sound -- by the convection later on. So there's a variety of types of sound. And we used all of them because they have different penetration depths.

MR. CLINE: Were you able to gather evidence -- before we could see what was happening on the far side of the Sun, away from Earth, were you able to gather evidence and get an idea of what was happening on the opposite side of the Sun from us because of these sound waves?

DR. BOGDAN: Yes. These sound waves have been used by a number of investigators because they store the information on their travels in terms of their phase, shifts, and time delays. So, indeed, the longer-lived sound waves have been used for what's called far-side imaging, which is very exciting.

I got involved in space weather research, I think like most people, in a very roundabout way. I did not intend to go into the subject. In graduate school, I very much wanted to follow Einstein and do general relativity, black holes, you know, all those amazing things that sit out in the cosmos that appear to be so much less pedestrian than the Sun, although today we realize through space weather that the Sun is hardly a pedestrian star, by any stretch of the imagination.

And when I went to work with a gentleman named Ian Lurch (ph), who was a professor at the University of Chicago, he said, "I don't have any money to support any grad students on the work I'm doing, and anyway, if I were you, I would go next door and work with the gentleman in the next office who, by the way, is quite a bit smarter than I am anyway."

That gentleman turned out to be Eugene Newman Parker, who is well-known in the space weather community for having predicted the existence of the solar wind and the impacts of that solar wind and who also spent a great amount of time wrestling with the question of why the Sun's corona is so hot and has come up with, I think, is probably the definitive theory that it is really due to topological impacts of the magnetic field through reconnection, the so-called nanoflares that were recently discovered by several NASA missions over the last few years.

So he, in many ways, laid out the framework of what space weather looked like from a theoretical perspective, though I daresay he probably didn't realize what he was doing with space weather. For him, it was fundamentally understanding how rotation, convection, and magnetic fields come together in astrophysical bodies like the Sun to create myriad interesting effects, a lot of variability, the sunspot cycle, solar flares, and these, I think, intrigued Parker all his life.

And so I was fortunate to join him as a graduate student, and, naturally, he assigned me a problem for a thesis, which was how to construct a sunspot by coalescence of many small flux tubes, smaller magnetic elements.

My thesis looked at the explanation that small tubes come together and coalesce through magnetic reconnection to make a big sunspot. And I investigated it mathematically and made many predictions. And when I got done, it turned out no one had actually measured the size distribution of sunspots, because the process by which the little tubes come together --

(Off the record.)

MR. CLINE: Hey, Brian, this is Troy. We just paused for a second as a group of people, Chatty Cathys, just walked by. So we'll pick up right now.

DR. BOGDAN: The thesis project that Professor Parker assigned to me was one of trying to understand how sunspots might form by the coalescence or coagulation of smaller units of magnetic flux. Knots, pores are the technical terms for these things.

And I worked out the mathematical theory of that based on some I would say elementary deductions about how tubes would come together. And, indeed, when we see sunspots form and decay, there is observational evidence that smaller units come together and aggregate and then disperse.

So I worked this out in detail, and one of the predictions that came from that was that the distribution of sizes of sunspots should follow a certain law, a certain distribution with size, the relative number of large to small, and, moreover, that that should vary with the solar cycle, because when there's more magnetic flux around during solar max, it's easier for these little tubes to find each other and coalesce and make big things than during solar minimum, when there's very few of them. And so the last thing to do is, of course, go look at the size distribution and hopefully show that that confirmed my thesis and become famous.

Indeed, no one had actually measured the size distribution of sunspots. People had counted them for decades, going back to Schwabe, who understood the solar cycle in the 1840s, but the actual size distribution was not known.

So after my thesis work, I took a postdoctoral appointment at the High Altitude Observatory in Boulder, Colorado, and working with Peter Gilman there, we analyzed data from the Mt. Wilson white-light plate collection at Mt. Wilson from Hale's time onward.

Every day, they took a picture of the Sun, and from those pictures, you could not just count the number of sunspots. You could also measure their areas. And the staff there had painstakingly measured something like 300,000 areas of sunspots.

And from those data, we were able to construct the size distribution, and two horrible things happened. Number one, it was not the distribution I had predicted in my thesis, and, number two, it did not vary with solar cycle. It was the same at solar maximum as it was at solar minimum. And that size distribution is called a log-normal distribution. The log rhythm of the area or the size of the sunspot is normally or Gaussianly distributed.

And it turned out such distributions are ubiquitous around us. The dust in the air that you're breathing is log-normally distributed. People's income is log-normally distributed. And it turns out a log-normal distribution is quite the opposite. It points to a process of fragmentation. So, in fact, my thesis had gotten it completely wrong.

I think for me, looking at space science over the last couple of decades, the huge turning point has been the variety of missions that NASA has flown to observe our Sun in tremendous detail and various wavelengths.

And I have to really commend Dick Fisher, who was the head of the Heliophysics Division at NASA for many years, and his predecessor, George Withbroe, for having the vision and the capacity to go forward and sell the importance of looking at our Sun in tremendous detail.

You think of missions like Solar Dynamics Observatory, RHESSI, Yoko (ph), all of which -- TRACE -- revealed amazing things about the complexity in the Sun around us and, in a sense, helped us as theorists to focus in on some of those key activities that are there. So in a real sense, NASA has opened up so much of what we know.

And later in my life, I came to use that when I was the Director of the Space Weather Prediction Center in Boulder, Colorado, a NOAA organization, the National Oceanic and Atmospheric Administration, part of the National Weather Service. And in that capacity, I was in charge of space weather for the planet, so to speak, because the U.S., through NOAA, had the premier and longest-running forecast office.

We operated 24/7 around the clock. We had space weather forecasters on shift, and we relied very heavily on data from NASA's satellites to give us that awareness of what the Sun was doing that we then pushed out to our customers, and they were in three basic areas.

The first were people who operate power grids and are susceptible to geomagnetic storms that accompany the aurora, but are fluctuating magnetic fields that drive currents and long conductors, like power lines; satellite operators, who live out at geostationary orbit and are subject to serious energetic particle storms that come in and can cause single-event upsets on their electronics and loss of pointing (ph) or control, and then, finally, people who use geo-positioning -- or geo-positioning system.

GPS is ubiquitous in everything we do. Precision GPS is even more important for construction landing airplanes. And space weather is the largest single source of GPS positioning error on the planet; always has been, always will be. And so there's a huge industry that wants to know when their GPS is affected.

So it's interesting to have started with Professor Parker back in the '80s, thinking about sunspots and the theory of the Sun and how it works and have ended up much later in life talking to power grid operators and using that same information to protect transformers in our way of life.

(Whereupon, the interview of Dr. Thomas Bogdan was concluded.)

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