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INTERVIEW OF

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DR. THOMAS J. BOGDAN

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UCAR

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Conducted by Troy Cline

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1 P R O C E E D I N G S

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

11 DR. BOGDAN: My name is Tom Bogdan, and I am
12 the President of the University Corporation for
13 Atmospheric Research, also known as UCAR. UCAR is a
14 501(c)(3) not for profit that is a consortium of 104
15 universities from across the U.S. and Canada. Most of
16 those universities are involved in research related to
17 weather, water, climate, air quality, and, of course,
18 space weather is part of what we do as well.

19 We operate the National Center for
20 Atmospheric Research in Boulder, Colorado, which
21 includes the High Altitude Observatory that was
22 founded by Walter Orr Roberts back in 1940, whose work

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1 was to look at the corona and was really some of the
2 initial studies of space weather before and during
3 World War II that was used for the capacity to predict
4 radio interference and blackouts for the Allied
5 Forces.

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

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

17 (Off the record.)

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

22 DR. BOGDAN: My research interest has always

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1 involved sunspots, the dark blemishes on the face of
2 the Sun that Galileo first discovered, quote, unquote,
3 for us when he turned the telescope towards the Sun,
4 but which the ancient Chinese and others had known
5 about well, well before that time.

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

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

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

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

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

18 DR. BOGDAN: They do. Some of them have
19 very long lifetimes and can travel around the Sun
20 many, many times, the ones that have the longer
21 wavelengths, but the ones that are shorter actually
22 get either absorbed on sunspots or magnetic structures

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1 or potentially get reabsorbed by the sound -- by the
2 convection later on. So there's a variety of types of
3 sound. And we used all of them because they have
4 different penetration depths.

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

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

17 I got involved in space weather research, I
18 think like most people, in a very roundabout way. I
19 did not intend to go into the subject. In graduate
20 school, I very much wanted to follow Einstein and do
21 general relativity, black holes, you know, all those
22 amazing things that sit out in the cosmos that appear

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1 to be so much less pedestrian than the Sun, although
2 today we realize through space weather that the Sun is
3 hardly a pedestrian star, by any stretch of the
4 imagination.

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

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

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

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

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

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1 tubes come together --

2 (Off the record.)

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

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

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

17 So I worked this out in detail, and one of
18 the predictions that came from that was that the
19 distribution of sizes of sunspots should follow a
20 certain law, a certain distribution with size, the
21 relative number of large to small, and, moreover, that
22 that should vary with the solar cycle, because when

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1 there's more magnetic flux around during solar max,
2 it's easier for these little tubes to find each other
3 and coalesce and make big things than during solar
4 minimum, when there's very few of them. And so the
5 last thing to do is, of course, go look at the size
6 distribution and hopefully show that that confirmed my
7 thesis and become famous.

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

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

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

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1 something like 300,000 areas of sunspots.

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

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

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

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

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

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

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

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

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

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1 affected.

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

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

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