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Chasing Solar Eclipses Around the World

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by Martina B. Arndt

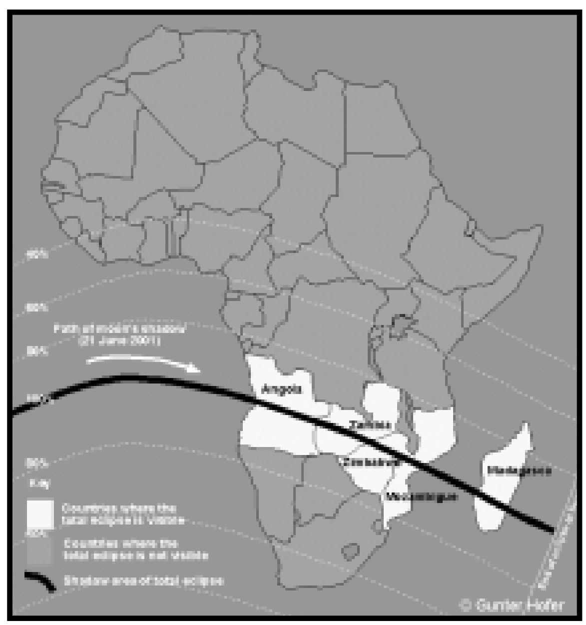
Solar eclipses are rare, beautiful, frustrating, and provide great excuses to explore places in the world you may not ordinarily go. The last time a total solar eclipse was visible from Massachusetts was off Cape Cod on March 7, 1970. Fortunately, the next eclipse visible from Massachusetts will be visible *everywhere* in the state—but you have to be around on May 1, 2079 to see it. I was a year old for the last one so I don't expect to see the next.

Perhaps you have been lucky enough to see a total eclipse. The probability is higher that you have seen a partial or annular eclipse of the Sun, or even a lunar eclipse. In fact, on Christmas Day 2000 there was a partial solar eclipse visible from many locations in New England. Ever the science enthusiast, I built a pinhole camera with an empty box, a piece of tinfoil, a pin, and lots of tape. I coerced (nearly) all of my family celebrating together in Maine to stand in the middle of the street with the box on their head so they could observe the moon "taking a bite out of the Sun." Thankfully my family is used to my idiosyncrasies and is very tolerant of my effervescent enthusiasm for events like this.

Eclipses have brought me to Mongolia (1997), Antigua (1998), and most recently to Africa (2001). Total solar eclipses are rare because the moon needs to be perfectly aligned with the Sun so that it blocks out most of the sunlight. This alignment occurs only once a year or so, and, in order to see the Sun fully eclipsed, you need to be situated in the moon's shadow, which is a very small area with respect to the size of the earth. The map on the right shows the path of the moon's shadow across southern Africa. Not only do you have to be in the right place, you have to be there at the right time, since eclipses only last between seconds to a few minutes. I was able to attend the 2001 eclipse in Africa with funding from two grants from Bridgewater's Center for the Advancement of Research and Teaching (CART). From our location in Zambia, the eclipse was visible for over 3 minutes.

Eclipse chasers are traditionally a motley crew. Cities in the path of total eclipses are often overrun with scientists, amateur astronomers, and interested tourists. Our group of eleven included five scientists and two engineers from the US and Europe, a filmmaker, two students, and a manager at a networking firm. Everyone came to help with the science, and everyone had the experience of a lifetime.

Eclipses are beautiful because with the bright Sun blocked out we get a glimpse of the tenuous, delicate structure of the Sun's upper atmosphere. The world that is in the path of the eclipse darkens and shadows fade—everything gets a cold hue to it. Animals often become quiet, and the weather seems to still. It's no wonder that people who do not understand eclipses think the world is coming to an end. One story from eclipse lore claims that in 1504, Christopher Columbus was marooned on the coast of Jamaica. To manipulate the locals, he arranged a meeting with them when he knew an eclipse was going to begin. He announced that unless they gave him what he wanted, God would show displeasure by taking away the Sun. Needless to



The path of the moon's shadow across southern Africa

say, when the eclipse started, Columbus got everything he asked for.

Eclipse chasing can also be incredibly frustrating. We work hard to find the right place; we struggle to be there at the right time—and often clouds, rain, or snow foil all plans. (Did I mention it snowed in Mongolia during the eclipse of 1997?) Not only do we depend on Mother Nature for this event, we have to have her permission to see it.

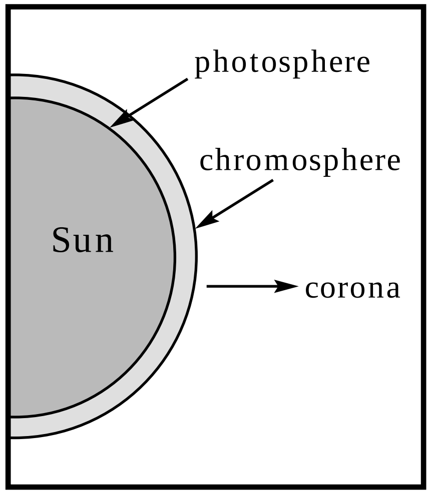
I don't enjoy chasing eclipses just for the experience—I also do it to learn more about the Sun. My research is in solar physics, a field I discovered while doing research in the time between undergraduate and graduate school. I worked with Dr. Shadia Habbal at the Center for Astrophysics in Cambridge, Massachusetts for two years on projects in solar physics using data from the Skylab satellite. I still collaborate with Dr. Habbal—in fact she is the principal scientific investigator on all the eclipse expeditions.

Skylab images are beautiful, and I have to admit they drew me into the field. At some point I realized the significance of the fact that we have a star very, very close to us. How close? The light from the closest star we can see in the night sky takes a few years to reach us. The light from the Sun only takes 8 minutes. The Sun is the heart of the solar system. Without it we would not have life on Earth. Since the Sun is a star, it is completely different from the planets. It produces incredible amounts of energy and has no solid surface on which to stand. The "big ball of fire" is a plasma laboratory in the sky—a resource that provides incredible amounts of data. But we still don't understand everything about it. I study the Sun because I want to solve one or two small parts of the unsolved solar puzzles. So, before I tell you more about our trip to Africa, let me give you an overview of some of the science we were trying to do with this eclipse.

SOLAR ECLIPSE SCIENCE

The two aspects of the Sun we are trying to better understand are related to the Sun's atmosphere. More specifically, we are trying to determine the mechanisms behind coronal heating and the origin of the fast and slow solar wind.

The Sun has many layers and is made entirely of plasma (essentially charged particles such as electrons and protons.) The visible "surface" of the Sun is the *photosphere*. Above the photosphere the *chromosphere* and *corona* make up the Sun's upper atmosphere (shown above). The chromosphere is hot, but cooler than the photosphere, as might be expected. (Well, okay, maybe you



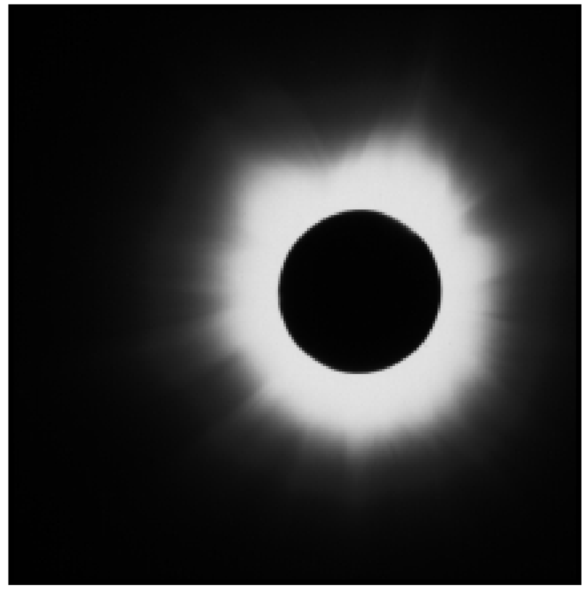
Schematic diagram of the Sun and its upper atmosphere

don't expect it. Here is an analogy—when your hand is close to a flame, the temperature decreases as you move your hand away.) However, the corona is many times hotter than both the chromosphere and photosphere, presenting a major enigma for solar physicists: what is the mechanism behind coronal heating?

Solar plasma escapes the Sun via the solar wind. These charged particles often interact with the earth, affecting orbiting satellites, disturbing power grids, and generating the beautiful northern lights (*aurora borealis*). The solar wind can be characterized by two speeds: fast (> 600 kilometers/second or 1,317,600 mph) and slow (~400 kilometers/second or 878,400 mph). The origin (e.g. location on the Sun) of these two types of winds is still unknown.

To begin solving enigmas like coronal heating and solar wind origin, one needs to test potential theories with data representing actual physical conditions on the Sun. It is especially important to determine physical conditions at the boundaries between the photosphere and upper atmospheric layers. Relevant physical parameters include local magnetic field strength, plasma density, and plasma temperature.

Unfortunately, the chromosphere and corona are very dim compared to the photosphere, in part because they are less dense. Therefore, we are not able to observe these layers unless the entire photosphere is blocked out. The best way to block the photosphere is with the moon during a total solar eclipse. Therefore, nature provides us with the optimal opportunity to observe the solar atmosphere close to the solar "surface" as well as the boundaries between atmospheric layers.



Eclipses can also help us expand our understanding in other scientific disciplines. For example, observations during the May 29, 1919 solar eclipse were used to confirm Einstein's general theory of relativity for the first time. In addition, Helium (from *Helios*, the Greek name for the Sun) was discovered during an eclipse in 1868 before it was found on Earth.

THE ECLIPSE IN AFRICA

After consulting weather maps, eclipse bulletins, and the level of political unrest in several countries, we decided to observe the eclipse from Zambia. So now the trick was to get there. Before we could leave, we needed visas and vaccinations. As a US citizen, I only needed a visa into Zambia even though we had plans to travel through Zimbabwe and Botswana. To visit these places, I needed vaccinations for hepatitis A and B, polio, typhoid, malaria, tetanus, diphtheria, measles, mumps, and rubella. I took many pills and became an expert at receiving shots.

All of our observing equipment had to be carried with us—cameras, computers, monitors, tripods, electric generators, a dewar for liquid nitrogen, tents—all in addition to our own personal luggage. We were able to bring the more delicate equipment onboard with us (something we will no longer be able to do after the events of September 11th). We had hundreds of pounds of equipment, and we had to lug it all ourselves. That's why we decided to call ourselves "The Solar Wind Sherpas."

To get to Zambia, we flew from Boston to London, from London to Johannesburg (Joberg to those in the know), and from Joberg to Lusaka, the capital of Zambia. We were met by Ken, our fearless tour guide, and Eddie, our talented cook. We strapped our equipment to the roofs of two trucks and packed ourselves inside. We hit one of the few roads and headed toward Kafue National Park, where our eclipse site was located. The roads were poorly kept—I liken it to a road of potholes surrounded by token pavement. We were visiting during Zambia's winter months, so the temperature was similar to early summer in New England—sometimes cool, sometimes blistering hot. The bugs were dormant, which was good for me since mosquitoes adore me.

Away from the cities, folks live in clay houses with thatched roofs clustered in small communities. Most people walk or ride their bikes to get around. Everyone was incredibly friendly, waving at us as we drove by. The women were usually dressed in bright colored cloths, and were often spotted balancing 10-gallon drums of water on their heads as they walked.

We would eat lunch on the side of the road. Eddie was very good at pulling together meals out of cheese, bread, tomatoes, cucumbers, baked beans, and tuna. We stayed at a hotel in Lusaka for one evening and stayed at "Hippo Camp" for another. A couple of days after arriving in Lusaka, and a few adventures later (one of our trailer wheels bouncing by us as we were driving being one of them), we finally reached our camp. Some locals cut the camp out of the brush—though most of it was burned, since fire is more efficient than a sickle. We set up camp and prepared for the eclipse for six days. Most of this time was spent erecting special tents and a canopy to protect the equipment (and us) from the Sun. We balanced and aligned the tripods, got the computers connected, and practiced as a team to prepare for taking data during the 3.5-minute eclipse.

We worked during the daylight hours, and at night we feasted on great meals around the campfire. I looked forward to these gatherings—it was a great way to relax after our intense work. We spent this time getting to know each other, sharing stories of other eclipse trips, thinking about our friends and family who could not join us on the trip, and sharing our cultures. One of the more entertaining conversations was regarding *South Park*. Apparently, the television show is about one year behind the US on the South African stations. Ken and Eddie got a preview of the episodes to come.

At night, the hippos that were located 100 yards into the river that bordered our camp would become very active. Their guffawing entertained us as we sat in safety near our campfire, and in the morning we were often able to trace their evening activities by following their tracks close to camp. The night skies were beautiful—a sight not lost on the avid astronomers in the group. I was able to see stars and constellations I have never seen before—in part because the skies were so dark and in part because this was my first excursion below the earth's equator.

The day of the eclipse was full of anticipation and tension. The first hour or so before totality is spent getting into position, checking last minute notes, and quizzing each other—all while the moon appeared to take a bite out of the Sun. One person was assigned the job of announcing when totality started. At that moment all of the camera shutters started firing. These three-plus minutes during totality took intense concentration—it was dark, so we needed to recall all of our memorized exposure times as well as any filter and polarizer positions (it's kind of hard to see the exposure times on a camera in the dark). We needed to listen to our cameras to make sure our exposures were finished—and that was challenging with 8 camera shutters going off at the same time. I found it terribly stressful—this was what we had been preparing for since the last eclipse. But we did it! We got data from all our instruments, and afterward, we jumped up and down, hugged, and cried with relief. One of our photographs of the eclipse (facing page) is a white light image, and the halo around the dark moon is the corona. The filamentary structure visible in the corona is due to plasma interacting with the sun's magnetic field. Those structures that appear to extend far into space are magnetic field lines along which the solar wind travels. That evening by the campfire, we opened two bottles of champagne to celebrate.

The next morning, we packed up the camp and made our way back. Now that the eclipse was over we were able to be tourists for a couple of days—we saw Victoria Falls, the largest waterfall in the world. We also went on a game drive and saw wild animals in their natural habitat—elephants, giraffes, hippos, crocodiles, various hoofed animals, lions eating aforementioned hoofed animals, monkeys, beautiful birds, mongooses (it is not mongeese, come to find out) and lots of other animals.

After the eclipse, wearing protective glasses

The trip was a success. Not only were we able to get excellent data (Mother Nature was very accommodating), we had the adventure of a lifetime. Along the way we saw three different countries and were able to experience a new culture. I am trying my best to visit Africa again. Mother Nature is cooperating: on December 4th, 2002, there will be an eclipse visible from the southern half of Africa. I am doing all I can to go. As far as the data we have collected, we are slowing analyzing it and beginning to understand it. Perhaps we will be able to find the small piece that will help complete a solar puzzle.

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