SOLAR ACTIVITY AND THE EARTH

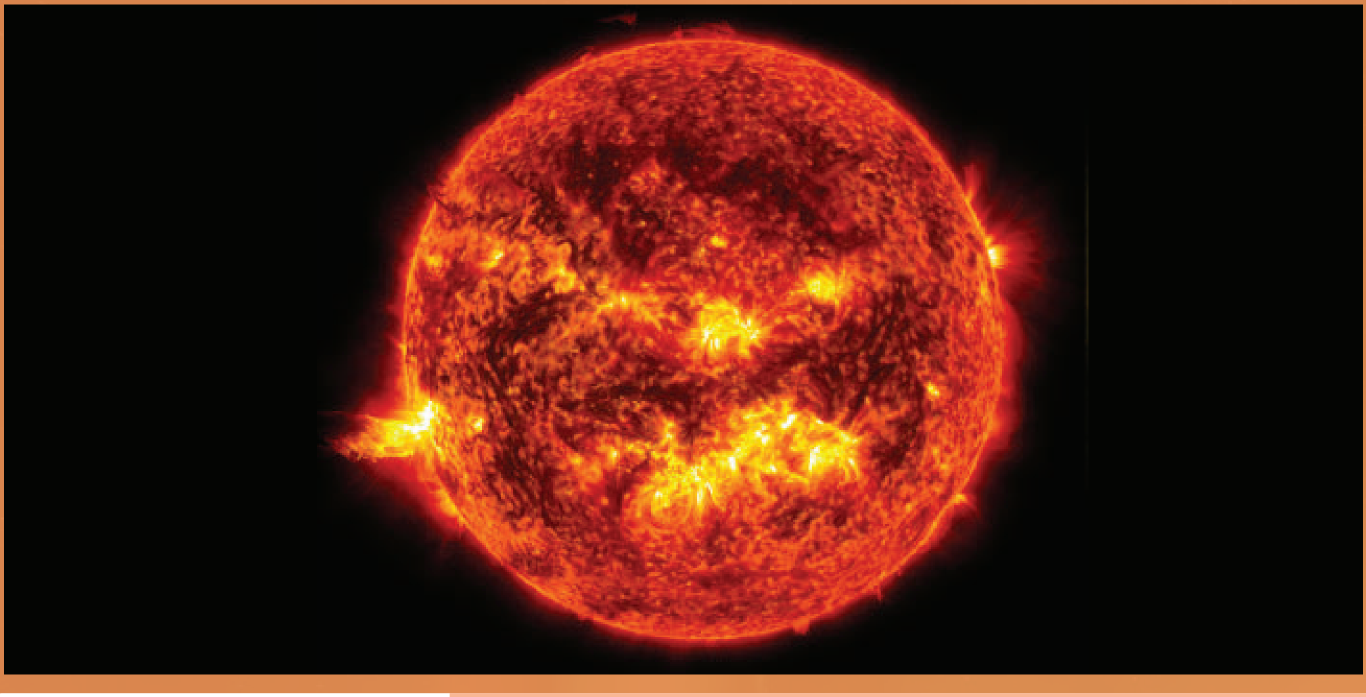

Fig. 1. Our sun is a gigantic nuclear fusion reactor in which hydrogen atoms combine to form helium, giving off energy in the process. It is so huge that 1.3 million Earths would fit inside it! And despite being mostly 'electrified gas' (plasma), its mass is 330,000 times that of Earth. In this image from 20 June 2013, at left is a bright solar flare and an eruption of solar material shooting through the sun's atmosphere. A few minutes later, this same region of the sun sent billions of tonnes of charged particles into space, an Earth-directed *coronal mass ejection* (CME). Such particles reach us in 1–3 days, but do not penetrate the atmosphere thanks to Earth's designed protection system. Credit: NASA

Donna Mullenax

THE SUN has been making headline news in this year of 2024—and not just the spectacular solar eclipse in North America. Solar flares. Coronal mass ejections. Solar prominences.[1] Sunspots. Longer than normal solar maximum.[2] Words and phrases like these have been prominent in the media and social media. Then there was the powerful X5 solar flare on New Year's Eve 2023.[3] What are these solar phenomena (also known as solar weather), and how do they impact you?

Most of the solar phenomena are 'invisible' to the unaided eye. One exception concerns the largest sunspots (fig. 2; caution: *never* look directly at the sun without proper eclipse glasses). In addition, we can detect the way in which some of these phenomena affect the earth, even without specialized instruments. For example, we can see the auroras (northern and southern lights, fig. 3), which become much more intense as the result of a solar flare. And we can notice the disruptive impact of solar weather on modern communications.

Spots and flares on the sun

Before the advent of telescopes designed to view the sun, the sun was thought to

Fig. 2. Sunspots visible during the 8 April 2024 total solar eclipse Photo: **Donna Mullenax**

Fig. 3. The aurora borealis (northern lights) just outside of Vancouver, Canada. The various colours depend on the specific type of gas molecule impacted, its energy state, concentration, and altitude.

be an unchanging calm star. It was not until sunspots were studied over time that many started to realize the sun was constantly changing. Galileo is considered the first to study and document the sun over 400 years ago, though some debate exists over this. Some ancient records from before Christ discuss possible sunspots.[4,5]

The sun is a high energy plasma sphere comprised mostly of hydrogen (73% by mass) and helium (25%); the remainder (2%) is trace elements. *Plasma*, sometimes called the 'fourth state of matter' (in addition to solid, liquid, gas) is formed when a gas is superheated to such a high temperature that the electrons are ripped away from their atoms to make an ionized gas. The plasma rotates at different speeds on different parts of the sun, and plasma flow with its charged particles produces a strong, active magnetic field.

Sunspots, the largest of them visible without instruments, are areas where the magnetic field is particularly strong. They appear darker (fig. 2) because they are somewhat cooler than the surrounding areas, i.e., ~3,500° C (6,300° F) compared to ~5,500° C (9,900° F).

This magnetic field sometimes becomes twisted. When it violently straightens out, it releases various sorts of powerful electromagnetic radiation, and causes charged particles (mostly protons and electrons) to be propelled at high speed into the solar system. These high-energy, bright 'explosions' are known as *solar flares*. They typically occur near the sunspots. The radiation takes eight minutes to reach the earth. Since the particles travel more slowly, they take about 20 minutes.

A *coronal mass ejection* (CME) often goes hand in hand with a solar flare. It, too, is the result of magnetic field realignment. A CME is a huge cloud of solar plasma with its embedded magnetic fields hurled from the sun; it takes days to reach the earth (fig. 1).

Solar prominences (called *solar filaments* when viewed from a different angle) are not eruptions and do not impact the earth. They are plasma loops associated with the sunspots. Good online summaries of the differences and connections between the prominences/filaments, flares, and CMEs are readily accessible.[6]

Magnetic reversals and the solar cycle

It has been known for a long time that the sun goes through what is known as a *solar cycle* which repeats every 11 years or so (fig. 4). At the end of each cycle (which is the beginning of the next one), the magnetic poles of the sun literally

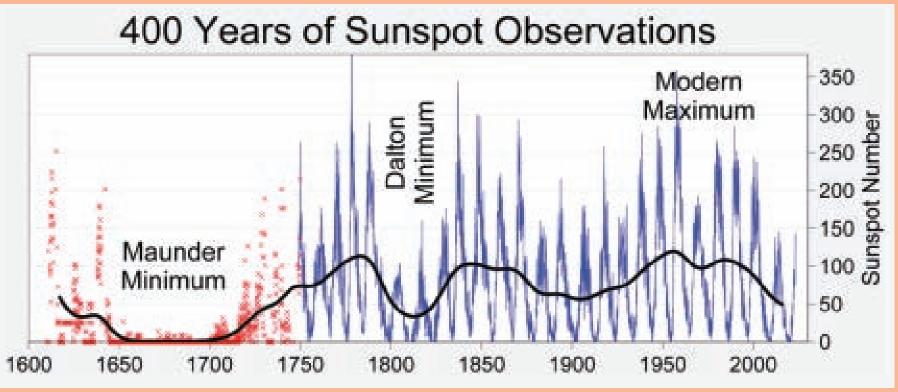

Fig. 4. Sunspot numbers show the c. 11-year cycle plus longer-term variations. The lower solar activity seen in the 'Maunder Minimum' is likely a major cause of the 'Little Ice Age' (1350–1850 AD). The 'Modern Maximum' may be relevant to the warming trend noticed over the last century or so. **Image:** © Robert A. Rohde | Wikimedia cc3.0

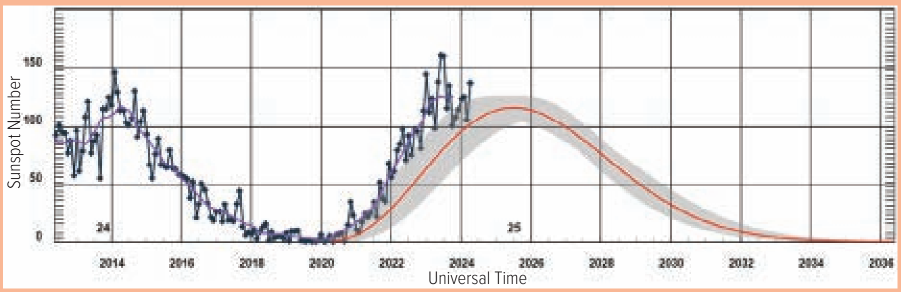

Fig. 5. ISES solar cycle sunspot number progression. We are currently in cycle number 25, the previous cycle number is also shown. **Image:** Space Weather Prediction Center, National Oceanic and Atmospheric Administration

'flip'—the north magnetic pole and south magnetic pole change places.

The reason for such a massive change is unknown, but the pattern and timing is quite consistent. At the beginning of the solar cycle, there are few to no sunspots—this is known as *solar minimum*. The number of sunspots increases as the overall solar activity increases, until it reaches *solar maximum* towards the middle of the cycle. It then gradually fades back to the solar minimum and then a new cycle begins, with the field reversing. The current cycle (solar cycle 25—fig. 5) began in December 2019. When this article is published in September 2024, we will be close to the predicted solar maximum—we might even be in it, but we won't know for sure until it's over. Solar cycle 26 should begin in 2030.

Solar wind: design feature

In addition to emitting electromagnetic radiation at many different wavelengths (not just visible light), the sun constantly sends out a stream of high-speed, high-energy charged particles—the *solar wind*, which reaches the earth. The *Voyager* space probes showed that it actually 'blows' way past all the planets, forming a huge 'bubble', the *heliosphere*. As *Voyager 2* found, outside of its limit, the *heliopause*, there was far more energetic radiation. Thus the solar wind is a design feature—a radiation shield. Even the evolutionary *National Geographic* admits: "The protective heliosphere shields everything inside it, including our fragile DNA, from most of the galaxy's highest-energy radiation."[7]

Auroras

However, the solar wind would be dangerous to life too, were it not deflected by Earth's magnetic field and atmosphere. Auroras are produced, usually near Earth's magnetic poles, when these particles interact with the atmosphere, which absorbs some of their energy. Favouring lower energy states, the electrons release photons at different wavelengths. The sky starts to dance with an array of colours (fig. 3).

Our magnetic field (the *magnetosphere*) and *ionosphere* (a layer in the upper atmosphere where the sun's radiation interacts with gases to form charged particles called ions) reflect God's design to protect the planet from the effects of the solar wind. The magnetosphere channels these particles towards the poles, which is why auroras are most often seen in high latitudes, i.e. closer to the poles. The ionosphere helps dissipate some of the particles' energy, radiating it back to space as heat.

When the concentration of the high-speed particles and the extra-powerful radiation increases during solar flares and CMEs, it can greatly increase aurora activity. Auroras can then be seen at much lower latitudes—for example, as low as Georgia, USA. Humans may have been able to view auroras since the creation of Adam and Eve.

Concerns for modern society

Flares and CMEs can impact communication and navigation on the earth. They can disrupt radio and cell phone communications, disable GPS satellites, and even knock out electrical grids. In 1989, a solar storm destroyed Quebec's grid and caused a massive blackout affecting millions.[8] NASA and other space agencies around the world are watching the sun 24/7.[9] NASA regularly works with power and communications companies, hoping to guard against similar events.

Flares on other stars

Not surprisingly, other stars also have flares. A solar flare has been observed on Proxima Centauri, at 4¼ light-years away the closest star to our solar system. Estimates have this flare 100 times more powerful than anything our sun has produced. Viewed at ultraviolet wavelengths, the star became 14,000 times brighter within seconds![10] But Proxima Centauri is a red dwarf star, dimmer than the sun, and about ⅛ as big. Yet, its magnetic field is so violent as to produce such massive flares, probably around five times a year.

Why does this matter? There is a planet orbiting Proxima Centauri, called Proxima Centauri B. When first discovered, there was great excitement in evolutionary circles. This 'exoplanet' is just 1.3 times Earth's mass, and orbiting the nearest star to us. Its distance from its star is also in the so-called 'Goldilocks zone', just right for liquid water to exist on its surface. All this fuelled the speculation that life maybe evolved there—despite the impossibly small scientific chance of unaided chemicals becoming alive anywhere.[11]

However, repeated solar flares of such intensity would seem to eliminate any possibility of this exoplanet being able to *sustain* life.[12] Over time, any atmosphere or ocean would be stripped away. And the UV light from the flare reaching the surface is estimated at about 100 times the intensity needed to destroy 'UV-hardy' bacteria on Earth. Red dwarfs are the most common type of star, but invisible to the naked eye. Many of them are 'flare stars' like Proxima.[13] Our sun is remarkably quiescent compared to red dwarfs, and even compared to other stars like the sun. It is another example of the many ways in which our Creator God has designed and made a 'Goldilocks' earth and solar system for us. Our place in the universe is wonderfully suited for humans to inhabit![14]

God created our solar system for His glory, and the earth within it to be inhabited by mankind, in order to worship and have fellowship with Him. The sun and its ever-changing activity are an example of His power and wisdom, and the relative lack of our own power and understanding.

Solar flares are the most violent events in our solar system. Their observed strength is recorded by a letter followed by a number. The five classes are the letters A, B, C, M, and X (weakest to strongest). Within each class, there are nine numerical subdivisions, 1 to 9—also by strength, and in powers of 10. So, the weakest is an A1; an A2 is 10 times stronger, A3 is 10 times that again, etc. After A9, the next strongest is a B1, 10 times stronger again. The only category class which is not limited to 9 is X.

Even the weakest flares release energy equivalent to millions of hydrogen bombs (though spread out more in area and time). Therefore, the X5 solar flare on New Year's Eve 2023 was a *very* strong solar flare. The 4 November 2003 flare was a staggering X28! Such super flares are rare compared to our nearest star which, despite being *much* smaller than the sun, appears to emit flares at a much greater frequency and generally many times stronger than typical ones on our sun. This has strong design implications for life on Earth (see main text).

References and notes

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Postscript: As I was working on this article, the sun put on quite a show, with multiple solar storms. Not just one, but several X-flares caused a massive geomagnetic storm, producing auroras on 10 May 2024 at latitudes as low as Florida in the US. This made the power of the sun and its impact on the earth very evident to many in this country.

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