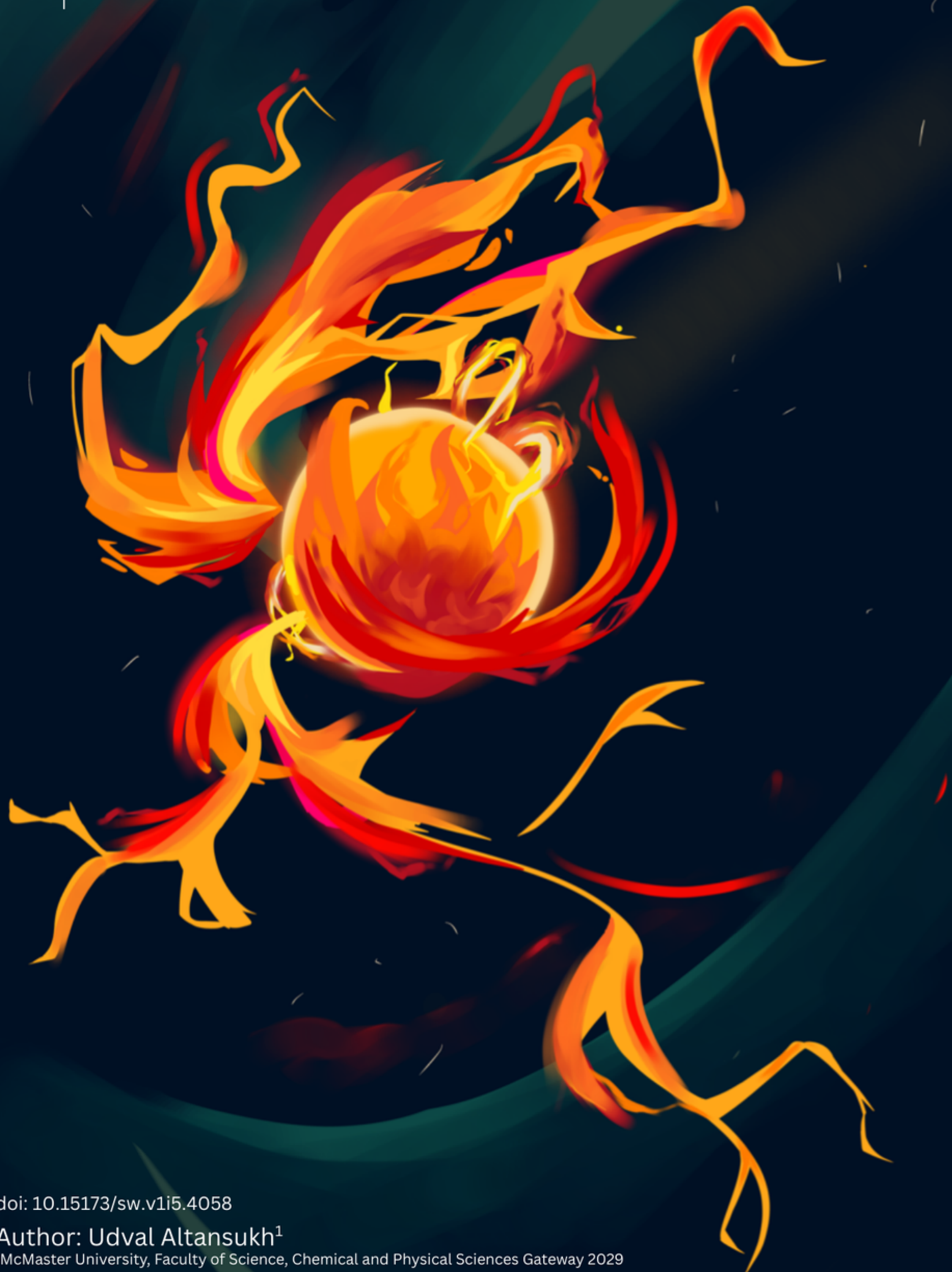

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Author: Udval Altansukh[1]
[1]McMaster University, Faculty of Science, Chemical and Physical Sciences Gateway 2029

Illustrator: Japleen Saini[2]
[2]McMaster University, Faculty of Health Sciences, Bachelor of Health Sciences (Honours Biochemistry) 2028

Solar Comeback: New Era of Space Weather

For the past half-century, we have lived through one of the Sun's calmest eras. Like all celestial objects, the Sun cycles between quiet and active phases, shaping space weather that influences Earth's radiation belts and the spacecraft and technologies on which humanity depends. A recent news story reports findings that suggest this calm period is ending, with the sun entering a new era of stronger activity.[1,2]

The solar cycle is characterized by a period of approximately 11 years. However, we might be oversimplifying this system, as there is a longer-term cycle called the Centennial Gleissberg Cycle (CGC) that is the duration of seven to eight solar cycles (approximately 80-100 years). Using earlier analyses[3] of solar activity from 1998 to 2021 as a foundation, a recent study further investigated long-term trends, revealing that we are witnessing a turnover in the Gleissberg Cycle, where solar activity is projected to rise after decades of decreasing in F10.7 flux (indicating solar activity) and increasing in proton flux.

Solar activity refers to various phenomena on the Sun, including sunspots, solar flares, coronal mass ejections, solar Extreme Ultraviolet irradiance (EUV), and auroral activity. However, this study focuses on F10.7 flux as the main indicator, a proxy of Extreme Ultraviolet irradiance (EUV) which is a type of very energetic short-wavelength light from the Sun. Proton flux, on the other hand, is the high-energy proton population trapped in Earth's inner radiation belt caused by the magnetic field, which is measured by NOAA POES satellites. When EUV irradiance increases, it heats up and expands the volume of the atmosphere, causing particle collisions at higher altitudes and thus inner zone proton loss. This creates an inverse relationship between solar activity and proton flux as a trend of solar cycles[3,4].

Previous proton flux measurements[3], along with annual sunspot number records[5] spanning 1700–2012, show a long-term rise in the proton flux approaching a maximum and an extended solar activity minimum between cycles 24 and 25 (11-year cycles), indicating the recent CGC minimum that we now expect to increase. This can be seen in **Figure 1.**

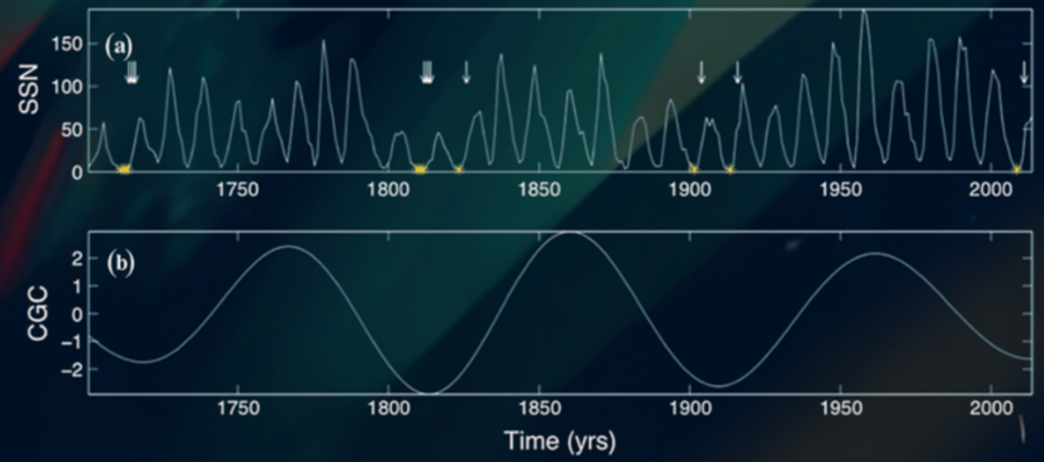

Figure 1. *Shows (a) the annual sunspot number (SSN) record from 1700 to 2012*[5] *and (b) time series of the Centennial Gleissberg Cycle (CGC) in sunspot number on a log scale. Each arrow and asterisk included in (a) specifies a time when the annual sunspot number was less than 3*[2].

This analysis has been extended by recent research, three years to 2024, using a similar method to inspect the predictions of previous studies, which show the signs of the CGC minimum and proton flux maximum passing. The solar activity increase, alongside comparison of results from a theoretical simulated model[6] is shown in Figure 2, which clearly shows an inversely proportional relationship (lower proton flux corresponding to higher solar activity represented by the F10.7 flux, and vice versa).

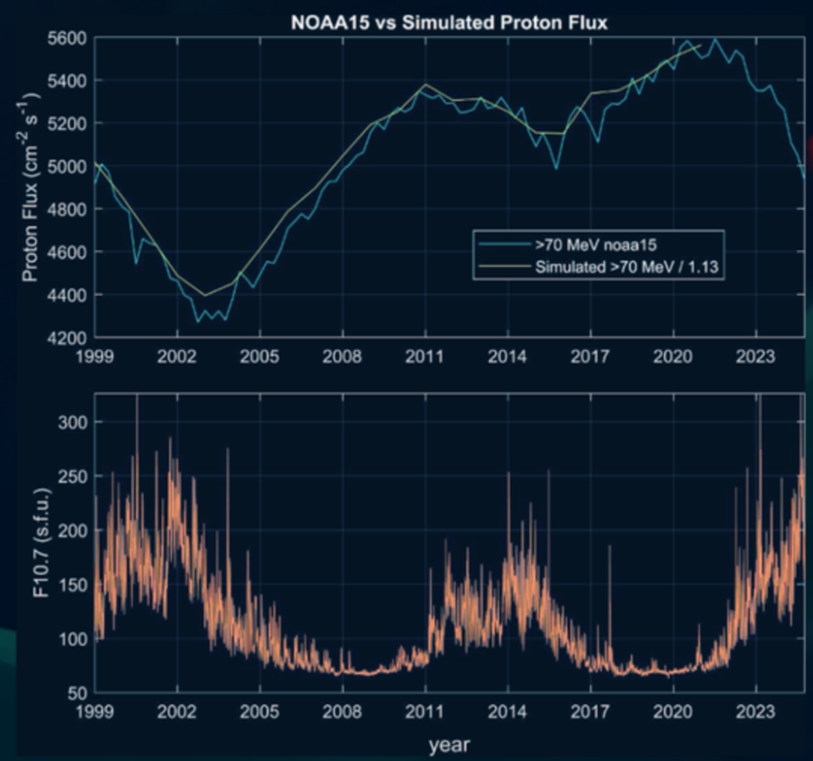

Figure 2. *NOAA-15's average data of proton flux (red) with Selesnick's simulated model of the inner zone radiation belt (blue)*[6]*. (Bottom): F10.7 data directly showing solar activity*[2].

Other signs of the CGC turnover following cycle 24 to cycle 25 (our current cycle) can be found with sunspot numbers shown in **Figure 3**, as it is an indicator of solar activity.

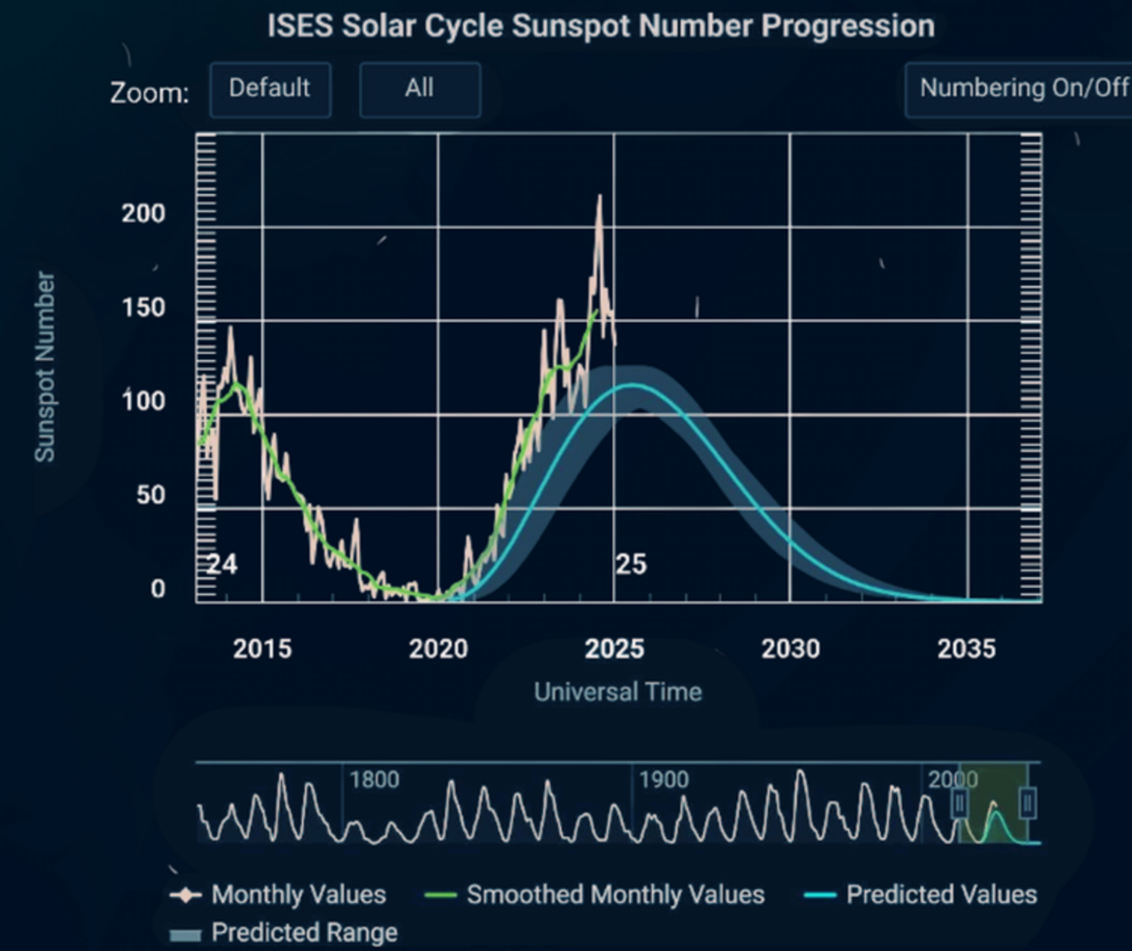

Figure 3. *NOAA's International Space Environmental Services Solar Cycle Sunspot Number and Model predictions as of July 2024*[2].

These results suggest that a new CGC cycle is underway, starting with our current solar cycle 25. Increased and unpredictable solar activity (solar flares, coronal mass ejections, geomagnetic storms, etc) can pose disruptions to both satellites and power grids and communication systems on Earth, while also producing more vivid auroras. In any case, the study emphasizes the importance of considering often overlooked longer-term factors like the Centennial Gleissberg Cycle (CGC), when planning future space missions and managing technological infrastructure, as it will become of higher significance in the coming decades.

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