

【Grant-in-Aid for Scientific Research (S)】

Broad Section B



Title of Project : Solar activity over the past 10,000 years

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Keyword : Sun, Cosmic ray, Cosmogenic nuclide, tree ring, ice core

【Purpose and Background of the Research】

Solar flares and coronal mass ejections emit very high-energy particles called “Solar Energetic Particles (SEPs).” Satellites often observe rapid increases in SEP flux, a phenomenon known as a SEP event. Large-scale SEP events pose a major threat in the current space exploration era as they can damage artificial satellites, harm astronauts exposed to flux, and cause communication failures. Therefore, an understanding of SEPs is necessary. However, the long-term occurrence characteristics of SEP events, such as their occurrence rate and upper limit are poorly understood because SEP events are not directly observed and recorded before the 1940s.

Cosmogenic nuclides such as the ^{14}C of tree rings and the ^{10}Be and ^{36}Cl of ice cores are known as excellent proxy data of past extreme SEP events (tens of times larger than the largest SEP events in direct observations). We discovered signatures of extreme SEP events such as 775 CE and 994 CE from the data of cosmogenic nuclides (Figure 1). These findings indicate not only the possibility of superflares in our sun, but also indicate the possibility of extreme solar phenomena in the future, which can profoundly affect the modern society.

The purpose of this study is to identify the largest SEP event during the past 10,000 years by analyzing the ^{14}C in annual rings and ^{10}Be and ^{36}Cl in ice cores and to clarify the frequency and characteristics of extreme SEP events. To evaluate the universality and peculiarity of the Sun among the sun-like stars, we will compare the data of our sun and the stellar flares of the sun-like stars.

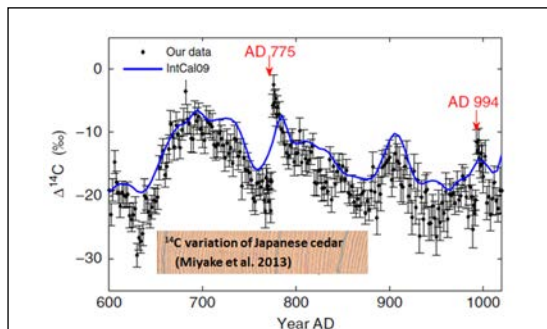


Figure 1 SEP events shown in ^{14}C data

【Research Methods】

To comprehensively detect the signatures of extreme SEP events, we will conduct a one-year resolution ^{14}C analysis of tree rings over the past 10,000 years (Figure 2). In

addition, the detected events will be characterized through ^{10}Be and ^{36}Cl analyses of ice cores.

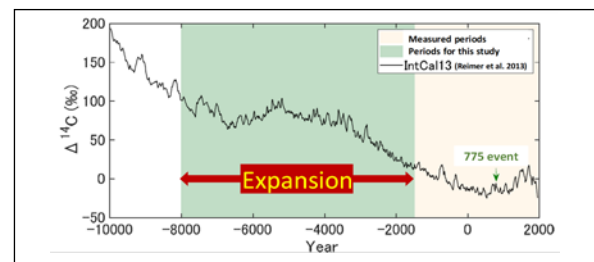


Figure 2 Measurement periods for this study

【Expected Research Achievements and Scientific Significance】

This research will provide long-term ^{14}C data over the past 10,000 years, revealing the occurrence rate of extreme SEP events and the largest SEP event during that period. Furthermore, as various solar activities have been observed during the past 10,000 years, we expect to clarify the relationship between the occurrences of extreme SEP events and solar activities.

The obtained data are not only important for investigating past solar activity, but are also potentially available for other investigations. For example, this study provides basic ^{14}C dating data. The ^{14}C spikes can be used as a one-year dating point, enabling the ultra-high-precision ^{14}C dating and one-year synchronization of ice cores and sediment cores. Such an unrestricted age indicator of regional and natural sample types is unprecedented and groundbreaking.

【Publications Relevant to the Project】

- F. Miyake, I. Usoskin, S. Poluianov (Editors), “Extreme Solar Particle Storms: The hostile Sun”, Institute of Physics Publishing (2019).
- F. Miyake, K. Nagaya, K. Masuda, T. Nakamura, A signature of cosmic-ray increase in AD 774-775 from tree rings in Japan, *Nature*, 486, 240-242 (2012).

【Term of Project】 FY2020-2024

【Budget Allocation】 152,400 Thousand Yen

【Homepage Address and Other Contact Information】

<http://www.isee.nagoya-u.ac.jp/en/index.html>