Grant-in-Aid for Scientific Research (S)

Broad Section B



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

MIYAKE Fusa

(Nagoya University, Institute for Space-Earth Environmental Research, Associate Professor)

Research Project Number: 20H05643 Researcher Number: 90738569

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

[Purpose and Background of the Research]

Solar flares and coronal mass ejections emit very highenergy 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 ¹⁴C of tree rings and the ¹⁰Be and ³⁶Cl 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 ¹⁴C in annual rings and ¹⁰Be and ³⁶Cl 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.

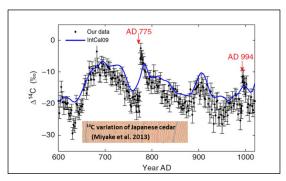


Figure 1 SEP events shown in ¹⁴C data

[Research Methods]

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

addition, the detected events will be characterized throuh ¹⁰Be and ³⁶Cl analyses of ice coress.

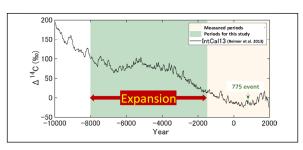


Figure 2 Measurement periods for this study

[Expected Research Achievements and Scientific Significance]

This research will provide long-term ¹⁴C 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 ¹⁴C dating data. The ¹⁴C spikes can be used as a one-year dating point, enabling the ultra-high-precision ¹⁴C 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