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

**Broad Section B**

# Title of Project : Solar activities from pre-main-sequence stage to present

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## 【Purpose and Background of the Research】

The Sun occupies more than 99% of total mass of the solar system and the intense radiations impact thermo and electromagnetic environments of planets. Astronomical observations reveal that pre-main-sequence stars frequently generate violent super-flares which emit high-energy particles from the stars. The violent star activities often occur coronal mass ejections (CMEs). The CMEs may impact evolution of grain and planet formations and other processes in the protoplanetary disk. However, the violent solar activities have not been clarified from material evidence in the primitive chondrites. On the other hand, main-sequence stars would generate super-flares with once per several thousand years. The frequencies decrease with increasing ages of stars. However, it is not clear whether the Sun generated super-flares through the main-sequence period.

In this study, we focus energy distribution of stellar winds and the intensity of the pre-main-sequence Sun and how the stellar wind emissions changed between pre-main- to main-sequence stages of the Sun. In order to analyze it, we will measure energy distributions of solar wind from extraterrestrial materials known solar irradiation ages. The purpose of this study is to determine secular change of solar activities from pre-main-sequence stage to present.

## 【Research Methods】

In this study, we will measure 3-dimensional distributions of noble gas contents and their isotope compositions by an isotope nanoscope. We analyze solar wind fluences and the energy distributions from the measurements and infer solar activities at the solar irradiation age. The isotope nanoscope has been developed by our group and has an unique characteristics to detect noble gases in nano-scale volume in solids. We will develop new apparatuses of inductive charge detection system and wide-area imaging system and install to the isotope nanoscope in order to measure Ne and possibly Ar in addition to He and enlarge measurement area.

We will measure asteroid Itokawa particles to determine solar winds at about 1 million years ago; the lunar regolith particles at about 0.1, 1, 2 and 4 billion years ago; and gas-rich chondrites at 4.6 billion years ago corresponding to pre-main-sequence stage of the Sun (Figure 1).

On the basis of these measurements, we analyze kinetic energy distribution of solar winds from low-speed keV level to high-speed MeV levels. The higher ends correspond to super-flare phenomena. The differences of analytical results between samples correspond to secular change of the solar activities from birth of Sun to present.

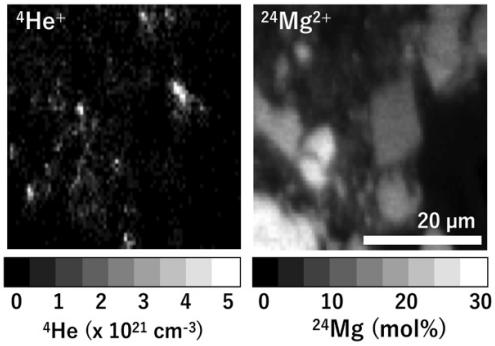


Figure 1. Two-dimensional distribution of solar wind He (left) and mineral particles (right) in matrix of gas-rich chondrite NWA 801.

## 【Expected Research Achievements and Scientific Significance】

Following outcomes would be expected:

Secular changes of solar activity from birth of the Sun would be derived by sampling of solar winds from extra terrestrial materials of every 1 billion years from the solar system formation.

The solar activity of pre-main-sequence Sun will be clarified by solar wind record in chondrites. Kinetic energies and frequencies of CMEs associated with super-flares of the pre-main-sequence Sun would be higher than those of the main-sequence Sun.

These outcomes are useful to further understanding not only for stellar evolution, but also evolution of protoplanetary disk and planets, space weathering and space weather.

## 【Publications Relevant to the Project】

- Bajo, K., Olinger, C.T., Jurewicz, A.J.G., Burnett, D.S., Sakaguchi, I., Suzuki, T., Itose, S., Ishihara, M., Uchino, K., Wieler, R. and Yurimoto, H. (2015) Depth profiling analysis of solar wind helium collected in diamond-like carbon film from Genesis. *Geochem. J.* **49,** 559-566.
- Nagata, K., Bajo, K.-i., Itose, S., Matsuya, M., Ishihara, M., Uchino, K. and Yurimoto, H. (2019) Aberration-corrected focused ion beam for time-of-flight secondary neutral mass spectrometry. *Applied Physics Express* **12,** 085005.

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