

Nuclear Science and Transmutation Research Division
 Astro-Glaciology Research Group
 Summary of Research Activities

1. Abstract

Our Astro-Glaciology Research Group promotes both experimental and theoretical studies to open up the new interdisciplinary research field of astro-glaciology, which combines astrophysics, astrochemistry, glaciology, and climate science.

On the experimental side, we measure isotopic and ionic concentrations in ice cores drilled at Dome Fuji station, Antarctica, in collaboration with the National Institute of Polar Research (NIPR, Tokyo). Here, the ice cores are time capsules which preserve atmospheric information of the past. In particular, the ice cores obtained around the Dome Fuji site are very unique, because they contain much more information on the stratosphere than any other ice cores obtained from elsewhere on Earth. This means that we have significant advantages in using Dome Fuji ice cores if we wish to study the Universe, since UV photons, gamma-rays, and highenergy protons emitted by astronomical phenomena affect the stratosphere. Our principal aim is thus to acquire and interpret information preserved in ice cores regarding:

- Signatures of past volcanic eruptions and solar cycles;
- Relationships between climate change and volcanic activity, and climate change and solar activity as well;
- Traces of past supernovae in our galaxy, in order to understand better the rate of galactic supernova explosions.

Moreover, we are promoting experimental projects on:

- Development of an automated laser melting sampler for analyzing ice cores with high depth resolution;
- Development of precise analytical techniques of high sensitivity for analyzing ice cores;
- The evolution of molecules in space;
- The application of analytical methods for measuring isotopes in ice cores to archaeological artifacts.

On the theoretical side, we are simulating numerically:

- Chemical effects of giant solar flares and supernovae on the Earth's atmosphere;
- The explosive and the *r*-process nucleosynthesis in core-collapse supernovae.

Combining our experimental evidence and theoretical simulations, we are promoting the researches mentioned above. These all will contribute to understanding relationships between the Universe and Earth. In particular, climate change is the most critical issue facing the world in the 21st century. It is also emphasized that the frequency of supernova explosions in our galaxy has not yet been fully understood, and it is the key to understand the *r*-process nucleosynthesis.

Members

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List of Publications & Presentations**Publications****[Original Papers]**

- K. Takahashi, Y. V. Sahoo, Y. Nakai, H. Motoyama, and Y. Motizuki, “Annually resolved profiles of $\delta^{34}\text{S}$ and sulfate in shallow ice core DF01 (Dome Fuji, Antarctica) spanning the nineteenth century and their geochemical implications,” *J. Geophys. Res. Atmos.* **127**, 2021JD036137 (2022).
- Y. Miyake, N. Ikoma, K. Takahashi, Y. V. Sahoo, and H. Okuno, “Test of ^{107}Pd transmutation with macroscopic quantities,” *J. Nucl. Sci. Technol.*, published online (May 11, 2022). DOI: 10.1080/00223131.2022.2072012 .
- K. Kanzawa, F. Miyake, K. Horiuchi, K. Sasa, K. Takano, M. Matsumura, T. Takahashi, Y. Motizuki, K. Takahashi, Y. Nakai, K. Ohtani, Y. Tada, Y. Ochiai, H. Motoyama, H. Matsuzaki, A. Yamazaki, Y. Muramatsu, and T. Yamagata, “High-resolution ^{10}Be and ^{36}Cl data from the antarctic dome Fuji Ice core (100 years around 5480 BCE): An unusual grand solar minimum occurrence?,” *J. Geophys. Res. Space Phys.* **126**, e2021JA029378 (2021).
- S. Katsuda, H. Fujiwara, Y. Ishisaki, Y. Maeda, K. Mori, Y. Motizuki, K. Sato, M. S. Tashiro, and Y. Terada, “New measurement of the vertical atmospheric density profile from occultations of the crab nebula with X-ray astronomy satellites Suzaku and Hitomi,” *J. Geophys. Res. Space Phys.* **126**, e2020JA028886, (2021).
- K. Kitajima, Y. Nakai, W. M. C. Sameera, M. Tsuge, A. Miyazaki, H. Hidaka, A. Kouchi, and N. Watanabe, “Delivery of electrons by proton-hole transfer in ice at 10 K: Role of surface OH radicals,” *J. Phys. Chem. Lett.* **12**, 704 (2021).

[Books]

- 望月優子, 「シリーズ現代の天文学第 1 巻人類の住む宇宙第 2 版」(第 3 刷新規業績), pp. 147–149 (「第 4 章太陽系 4.1.2 節太陽の現在」), 岡村定矩他編, 日本評論社, 2021 年 11 月, ISBN 978-4-535-60751-4.
- 望月優子, 佐藤勝彦, 「シリーズ現代の天文学第 1 巻人類の住む宇宙第 2 版」(第 3 刷改訂), pp. 99–144 (「第 3 章元素の起源」), 岡村定矩他編, 日本評論社, 2021 年 11 月, ISBN 978-4-535-60751-4.

Presentations**[International Conferences/Workshops]**

- Y. Motizuki (iPoster paper), Y. Nakai, K. Takahashi, J. Hirose, Y. V. Sahoo, Y. Yano, M. Yumoto, M. Maruyama, M. Sakasita, K. Kase, S. Wada, and H. Motoyama, “A novel, ultra-high-resolution laser-melting sampler with resolution controllability for discrete analyses of ion concentrations and stable water isotopic compositions in ice cores,” AGU Fall Meeting 2021, New Orleans & Online, December 13–17, 2021.
- K. Kitajima (poster), Y. Nakai, W. M. C. Sameera, M. Tsuge, A. Miyazaki, H. Hidaka, A. Kouchi, and N. Watanabe, “A new electrochemical property of ice: negative charge transport triggered by reactions of surface OH radicals with electrons,” Workshop on Interstellar Matter 2021, Sapporo, November 17–19, 2021.
- Y. Nakai (poster), H. Hidaka, and N. Watanabe, “Methanol production via interactions of low-energy CH_3^+ ions with ASW surface: experimental investigation of ion-surface reaction,” Workshop on Interstellar Matter 2021, Sapporo, November 17–19, 2021.
- Y. Motizuki, Y. Nakai, K. Takahashi, T. Imamura, and H. Motoyama, “A proxy for decadal solar cycles from AD 1600 to 1900 based on nitrate concentrations in a Dome Fuji (Antarctica) ice core,” The 6th Workshop of the Astronomy & Astrophysics from Antarctica (SCAR AAA 2021), Virtual meeting, September 8–10, 2021.
- K. Kitajima, Y. Nakai, M. Tsuge, A. Miyazaki, H. Hidaka, A. Kouchi, and N. Watanabe, “Verification of proton-hole transfer in ice at 10 K via detection of surface OH radicals,” 36th Symposium on Chemical Kinetics and Dynamics, Online, Jun 2–4, 2021.
- Y. Motizuki, Y. Nakai, K. Takahashi, J. Hirose, Y. V. Sahoo, Y. Yano, M. Yumoto, M. Maruyama, M. Sakasita, K. Kase, S. Wada, and H. Motoyama, “A novel high-resolution laser-melting sampler for discrete analyses of ion concentrations and stable water isotopic compositions in firn and ice cores,” virtual EGU General Assembly 2021 (vEGU21), April 19–30, 2021.
- Y. Motizuki (invited), “Astro-glaciology sciences using antarctic ice cores—A key project of RNC for the origin of elements and climate change,” Workshop3 on Climate Change and Geoscience, OIST-RIKEN Joint Symposium, Series 1: Green and blue planet—How can ecological research shape our future?, Onna-Son, Okinawa, April 6–7, 2021. (With organizing and serving as a Discussion Leader of Workshop3)
- Y. Motizuki (invited), “Some topics on gender issues related to nuclear astrophysics calendar - based on a keynote talk at the IAU symposium on equality, equity, and inclusion in astronomy, celebrating the 100-year of IAU,” UKAKUREN Seminar, Online, March 7, 2022.

[Domestic Conferences/Workshops]

- 望月優子 (招待講演), 「地球アーカイブからさぐる, 宇宙と地球の歴史」, 朝日カルチャーセンター中之島教室 「宇宙と地球と元素」シリーズ講座, オンライン, 2022 年 3 月 26 日.
- 勝田哲, 藤原均, 石崎欣尚, 前田良知, 森浩二, 望月優子, 佐藤浩介, 田代信, 寺田幸功, 安井良輔, 「X 線天文衛星を用いた地球超高層大気および太陽コロナの観測的研究」, 第 21 回高宇速研究会, 豊中, オンライン, 2022 年 3 月 9–11 日.
- 望月優子, 中井陽一, 高橋和也, 今村隆史, 本山秀明, 「南極ドームふじアイスコアを用いた 10 年スケール太陽周期の同時検出」, 日本天文学会 2022 年春季年会, オンライン, 2022 年 3 月 2–5 日.

渡部直樹 (ポスター), 北島謙生, 中井陽一, 柘植雅士, 日高宏, 香内晃, 「極低温の氷と NH_3 , H_2S 固体の界面における負電荷移動機構」, 原子衝突学会第 46 回年会, オンライン, 2021 年 10 月 26–28 日.

勝田哲, 藤原均, 石崎欣尚, 前田良知, 森浩二, 望月優子, 佐藤浩介, 田代信, 寺田幸功, 「X線天文衛星『すざく』と『ひとみ』が捉えたカニ星雲の地球大気遮蔽による大気密度鉛直プロファイルの測定」, 令和 3 年 (2021 年) 度・第 1 回 STE (太陽地球環境) 現象報告会 (合同研究集会), 2021 年 9 月 28–30 日.

望月優子 (招待トーク), “A new-type, innovative automated ice-core sampler using laser melting method”, Online seminar “How to give an impressive pitch presentation in global situation”, JST 世界で活躍できる研究者育成プログラム総合支援事業, オンライン, 2021 年 8 月 13 日.

望月優子 (招待講演), 「南極の水からひもとく宇宙と地球の歴史」, 早稲田大学高等学院理工学特論, オンライン, 2021 年 4 月 20 日.