●行方 宏介 特定助教

Kosuke NAMEKATA (Assistant Professor)

研 究 課 題： 太陽圏進化学の新機軸創成：
若い太陽型星の突発現象の集中的調査による太古の太陽地球環境の再現
（New Frontiers in Heliospheric Evolution: A Comprehensive Investigation of Transients on Young Sun-Like Stars to Reveal the Ancient Solar-Earth Climate）

専 門 分 野： 天文学（Astronomy）

受入先部局： 理学研究科（Graduate School of Science）

前職の機関名： 国立天文台（National Astronomical Observatory of Japan）

私の専門は天文学で、恒星の表面で発生するスーパーフレアという大爆発現象を研究対象としています。スーパーフレアからの高エネルギー放射や粒子は、周囲の惑星大気の進化に影響を及ぼします。私は、この爆発現象の調査を通し、周囲の惑星の生命生存可能性を明らかにすることを目標にしています。

白眉プロジェクトでは、若い頃の太陽に似た太陽型星に注目し研究を行います。世界中の望遠鏡や人工衛星を総動員し、発生予測が困難なスーパーフレアを多波長で観測することに挑戦し、若い太陽型星の恒星圏の擾乱を調べます。様々な年齢の若い太陽型星の観測により、年齢に伴う恒星圏の擾乱の性質変化を明らかにできれば、太陽の過去の進化の示唆が得られると考えています。本研究を通し、生命誕生の文脈で最も重要な年代における太陽と地球の関係を解明することを目指します。

I specialize in stellar astronomy, focusing on the study of stellar energetic explosions, so-called “superflares.” While superflares are frequent on young stars and possibly on the ancient Sun, superflares are quite rare on our present-day Sun. The high-energy radiation and particles from the superflares can severely influence the evolution of the atmospheres of surrounding young planets. I aim to investigate the nature of superflares on young stars to determine the potential habitability of the surrounding planets.

In the Hakubi Project, I will focus on young Sun-like stars similar to our Sun in its youth. Using telescopes and satellites around the world, I will observe these unpredictable superflares across multiple wavelengths and investigate the disturbances they cause in the stars’ astrospheres. By observing young Sun-like stars at various ages, I hope to reveal the characteristics of astrospheric disturbances and their evolution with age, providing insights into the evolution of our own Sun in its youth. This research is directed at elucidating the relationship between the Sun and the Earth during the critical epoch of the origin of life.

The history of our Sun

The Sun, our nearest star, occasionally exhibits explosive events on its surface known as “solarflares”. These flares, through the ejection of plasma and the emission of X-rays and ultraviolet radiation, exert significant influences on the terrestrial environment (Fig. 1).

From this, we empirically learn about the profound connection between the Sun and the Earth. In fact, my fascination with this field of research began when I learned of the majestic story that the beautiful auroras on the Earth, which paint the night sky, are a manifestation of the Earth's magnetosphere being influenced by solar activity. Through observing

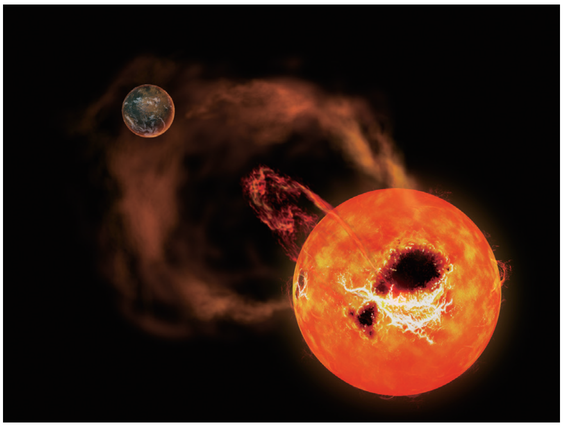

Fig. 1　An imaginary picture of a stellar superflare and plasma ejection（©National Astronomical Observatory of Japan）.

the Sun and the Earth, scholars have learned a great deal about solar flares. However, observational records of solar flares span merely 160 years, a fraction of the Sun's 4.6-billion-year lifespan. Consequently, it is questionable whether contemporary knowledge of the Sun alone suffices to comprehend the full history of the solar-terrestrial environment.

Stars as solar proxies

Recent achievements in stellar astronomy and cosmic ray studies have facilitated a paradigm shift in our understanding of solar flare activity throughout the Sun's approximate 4.6 billion-year lifespan. There is a growing consensus that there have been periods characterized by intense flare activity in the past. Notably, stellar astronomy provides a unique window into the past by allowing us to infer the conditions of the ancient Sun from observations of its counterparts, young Sun-like stars — i.e., stars similar to the Sun in temperature and mass. Stellar observations have revealed that these young Sun-like stars do produce "superflares," i.e., flares of a magnitude surpassing the largest recorded in solar observational history, at a frequency of once every few days (Fig. 1). In light of these findings, the hypothesis has been put forth that frequent superflares on the young Sun could have had profound impacts on the atmospheric formation of the young Earth and other planets, as well as on the birth of life itself. This hypothesis is garnering considerable interest from scholars in the fields of Earth planetary science and biochemistry.

Missing Information

The interstellar environment affected by a star is referred to as the "astrosphere." Over the past two decades, observational studies have progressively shed light on the "steady-state" astrosphere emanating from stars. However, the recent paradigm shift towards recognizing superflares has left the concept of a "dynamically variable" astrosphere relatively uncharted. Of particular importance is the quantitative assessment of the direct effects on planets by plasma ejections and the sudden bursts of X-rays and ultraviolet radiation (Fig. 1). Even plasma ejections, X-rays, and ultraviolet radiation from small-scale flares on our own Sun have significant implications for the Earth's environment and human civilization. Thus, the impact of superflares is expected to be considerable. What could be the possible effects of superflares on the young planets? It has been proposed that plasma ejections and X-ray/ultraviolet radiation could play a role in forming molecules crucial to the origin of life within planetary atmospheres and protoplanetary disks through processes such as ionization and chemical changes. Despite widespread recognition of the significance of these phenomena, progress in understanding them has been unsatisfactory, primarily due to the scarcity of observations. While numerical simulations and extensions of solar physics may yield plausible predictions, the limits of such laws remain unknown.

Era of multi-observatory and multi-wavelength observations

Considering this background, my research in the Hakubi Project seeks to address the question: "What are the characteristics of the astrospheres affected by the superflares, and how do they evolve with age?" I plan to leverage my global network of collaborators, along with a suite of telescopes and satellites, to facilitate multi-observatory and multi-wavelength observations of superflares on young Sun-like stars. Observations across multiple wavelengths will enable precise measurements of the stars' multi-temperature plasma states, including velocity and density. I will conduct intensive, simultaneous multi-wavelength observations of young Sun-like stars at various ages to evaluate the evolution of astrospheres affected by plasma ejections and the X-rays and ultraviolet radiation. Through this stellar research, I aim to pioneer a new frontier in heliospheric evolution, which seeks to understand the Sun during critical periods relevant to the origin of life.

[References]

- K. Namekata, et al. Discovery of a Long-duration Superflare on a Young Solar-type Star EK Draconis with Nearly Similar Time Evolution for H α and White-light Emissions, ApJL, 926, pp.5-12, 2022
- K. Namekata, et al. Probable detection of an eruptive filament from a superflare on a solar-type star, Nature Astronomy, 6, pp.241-248, 2022
- K. Namekata, et al. Optical and X-ray observations of stellar flares on an active M dwarf AD Leonis with Seimei Telescope, SCAT, NICER and OISTER, PASJ, 72, 4, id.68 pp.1-15, 2020