３．国際ワークショップ 目次詳細
International Workshop

（所属・職名は平成31年3月現在）
(Affiliation and Department are correct as of March 2019)

Extreme solar events: How hostile can the Sun be?

Principal Investigator: Ilya Usoskin (University of Oulu)
Co-investigator and host: Fusa Miyake (ISEE)

The Sun sporadically produces energetic eruptive events, which provide an essential insight into physics of astroparticle acceleration in conditions unreachable in vitro. Moreover, they may affect Earth and form an important hazard for our technologically developed society. Space-based technologies, such as navigation, communication, remote sensing, etc. are vulnerable to the effects caused by such events, which can have dramatic consequences. Although we have quite an extensive dataset of direct data for the last decades, it is still insufficient to address open questions related to extreme solar eruptive events: what is an extreme solar event? How strong can it be? How often do they occur? What can be the worst-case scenario for such an event? These questions were addressed during an ISEE workshop "Extreme solar events: How hostile can the Sun be?" which took place at ISEE during the period of 02 – 06 October 2018 hosted by Dr. Fusa Miyake.

An international team of world-top experts from the relevant research fields (M. Baroni, France; E. Cliver, USA; C. Dyer, UK; H. Hayakawa, Japan; T. Jull, USA; K. Kusano, Japan; H. Maehara, Japan; F. Mekhaldi, Sweden; F. Miyake, Japan; M. Oinonen, Finland; D. Sokoloff, Russia; S. Poluianov, Finland; E. Rozanov, Switzerland; I. Usoskin, Finland; L. Wacker, Switzerland; F. Wang, China) were gathering for the round-table discussion and open-mind brainstorming.

Specific focus areas were:

- Statistic of direct information obtained for the space era using ground-based and space-borne detector over the last decennia.
- Historical (archival) data on extreme solar events in the past.
- Proxy-based data of cosmogenic isotopes (^{14}C recorded in tree rings, as well as ^{10}Be and ^{36}Cl measured in polar ice cores) covering the period of the Holocene (the last twelve millennia).
- Development of models of energetic particle acceleration and transport in the Heliosphere, magnetosphere and atmosphere.
- Statistical properties and probability density function of the extreme event occurrence.
- Estimate of the mean flux of solar energetic particles on the million-year using data on cosmogenic isotopes from lunar rocks.

- Possible consequences of solar extreme events for the modern technological society.

The workshop was organized as a series of review talks presenting the current state of the art, followed by discussions and brainstorming. The final day of the workshop was devoted a discussion of a planned joined publication. During the second day of the workshop, a visit to the ISEE facilities, including the AMS was organized.

As a result, a joint strategy in studying extreme solar particle events has been developed. It was noted that presently there is no overview publication related to this topic, and it was decided to write a joint edited book on the topic of extreme solar events and their consequences, where individual sections are written by experts. The book entitled “Extreme Solar Particle Storms: The hostile Sun” is in preparation now for the IOP (Institute of Physics) publisher (the book contract is signed), with the book delivery deadline in June 2019. The book will contain nine Chapters (Introduction; What can be learned from the modern data? State-of-the-art theory and modelling; Cosmogenic isotopes as proxy for solar energetic particles; Measurements of radionuclides; Characterisation of the measured events; Further search for extreme events; Possible impacts; Concluding remarks).

Overall, the workshop can be regarded as highly successful and leading to a community-wide coordination of efforts in the study of extreme solar events and their possible consequences. This has not only purely academic but also important societal and technological outputs.

International Workshop on Data-Driven Models of the Solar Progenitors of Space Weather and Space Climate

Mark Cheung (Lockheed Martin Solar & Astrophysics Laboratory)

Research Summary

The increasingly dense observational coverage of the solar atmosphere has led to many important insights into the origins of solar activity. At the same time, the increasingly sophisticated numerical models of the interaction between plasma and magnetic fields have provided important lessons on the basic physical mechanisms underlying the observed behavior. State-of-the-art magnetohydrodynamics (MHD) models are now capable of yielding observational diagnostics that are in general agreement with observations (Cheung, Rempel et al. 2019). Yet, if we wish to apply these lessons to forecasting space weather and space climate, many challenges remain. First of all, even with the aforementioned advances in MHD modeling, there remains a wide gap between numerical models and reality as revealed by observations. As observational capacity – in terms of spectral, temporal and spatial coverage – improves, so do the number of observables not explained by the current generation of models. One possible reason is the lack of certain physical ingredients in the models. In this ISEE/CICR International Workshop (November 6^{th} to 9^{th} 2018), we address the key problems remaining in using observational data to constrain and to drive MHD models of solar eruptions.

Before the workshop, participants were briefed on a preliminary set of scientific and technical questions on the topic. Case studies (e.g. NOAA Active Regions 12017 and 12673) were chosen and data sets pertaining to the case studies were curated and shared with the participants. The workshop was scheduled such that mornings were reserved for presentations, and afternoons reserved for data analysis, coding and discussion among small teams. Participants were required to discuss their findings from the previous afternoon of work.

Several new projects resulted from the discussions at this ISEE/CICR Workshop. One example project is led by participant Toriumi, who provided horizontal slices of MHD data to several modelers (Cheung, Inoue, Jiang) for setting boundary conditions of their models. This “hares and hounds” exercise allowed the team to assess the reliability of the models. Dr. Toriumi presented his preliminary findings at the Annual Meeting of the Astronomical Society of Japan in March 2019.

Another new project started between Prof. Kusano with Cheung, Sun and Chintzoglou. Cheung, Sun and Chintzoglou provided a sequence of 3D coronal field models to Prof. Kusano in order for him to test his theory of the double-arc instability (Kusano & Ishiguro 2017). They had a follow-up meeting about this work in December at the American Geophysical Union meeting in Washington DC. Results from this collaboration were presented at the Flux Emergence Workshop held at the University of Tokyo in March 2019.

Park and Sun compared estimates of the (cumulative) helicity flux in the flare productive Active Region 12673 and found discrepancies between estimates from different methods. As a result, Sun has started a collaboration with Pete Schuck (NASA, not at this workshop) to include Doppler velocity measurements in the DAVE4VM algorithm, which is expected to make a difference for regions such as AR 12673, which fast Doppler flows near the polarity inversion line.

Sun and Danilovic started a collaboration to examine ground-based observations of Active Region 12673 taken by the Swedish Solar Telescope. They will study the magnetic field and Doppler velocity flows near the polarity inversion line before the X9 flare on Sep 9th 2017.

As a result of the discussions between participants Rempel, Fan, Cheung, and Sun, they have a proposed a new multi-year project to the NASA DRIVE Initiative. The proposed work tackles some of the challenges of data-driven modeling recognized at the ISEE/CICR Workshop.

One stated intended outcome of this ISEE/CICR Workshop is to train early space weather researchers at Nagoya University in the techniques of data-driven MHD simulations. Judging by the active participation by Prof. Kusano and Drs. Inoue, Kaneko, Iijima and Park and Takasao, this goal has been provisionally archieved.

Finally, it is worth pointing out our workshop took place in November 2018, which is relatively late in the Japanese fiscal year. We foresee more publications resulting from this effort appearing in late 2019 and in 2020. The participants and co-Chair Cheung thank ISEE and Professor Kusano for supporting this workshop. Participants acknowledge travel support from the ISEE. Due to the relatively large size of this team, Cheung’s NASA grant “Physics and Diagnostics of the Drivers of Solar Eruptions” partially funded travel support for some US-based team members.

International workshop on relations between solar evolution and atmospheric escape from terrestrial planets

Kanako Seki (Graduate School of Science, University of Tokyo)

Venue: Higashiyama Campus of the Nagoya University
http://en.nagoya-u.ac.jp/access/

Dates: March 26 (Tue) – 29 (Fri), 2019

Scope of the Workshop:

Solar radiation and solar wind, which are energy sources of various phenomena occurring in the Sun-Earth system, are thought to have changed with the evolution of the Sun. It is predicted from the evolution model of the solar-type stars that the solar radiation in the visible band was fainter in the past than in the present day, as is known in the so-called "faint young sun paradox". On the other hand, it is inferred that the solar radiation in the higher wavelength bands such as UV, EUV, and X-ray, which greatly influence the upper atmosphere and the space environment around planets was stronger than in the present. For example, it is pointed out that EUV radiation of 4 billion years ago was about ten times as much as present [e.g., Ribas et al, 2005]. As for the solar wind, which is the mass release from the sun, there is an estimate that the mass release rate was higher until about 3.8 billion years ago, and the mass release rate before that was about 100 times larger than in the present [eg., Wood et al., 2005]. However, uncertainty is not small in these estimates.

It has been pointed out that such strong EUV radiation from the sun and solar wind caused heating and expansion of the upper atmosphere and massive atmospheric escape from the early planets [e.g., Terada et al., 2009]. However, dependence on solar radiation and solar wind parameters are significant, and it is necessary to reduce the uncertainty of parameters of solar evolution when actually applied to a planet in the solar system including Earth. For example, recent research indicates that ancient Mars had a humid climate and a habitable environment about 4 billion years ago, but now it has only a thin atmosphere and a cold dry climate. The idea that such drastic climate change is caused by atmospheric escape to outer space is considered promising, but its concrete mechanism is far from well understood.

In this workshop, we invited researchers from the fields of solar evolution and the solar-planet interaction system (“planetosphere”) to discuss thoroughly for 4 days on the latest research results on the evolution of the sun and the atmospheric escape from terrestrial planets. The objective of the workshop is to clarify the fluctuation range of atmospheric escape and its influence on planetospheric environment due to the uncertainty of understanding of solar evolution. Here we particularly focus on Mars, where new atmospheric escape observations are accumulated by MAVEN and other satellites.

In order to achieve the above objective, this workshop invited experts in evolution of stellar magnetic fields closely related to EUV radiation and stellar wind evolution. Based on the latest understanding of the solar evolution research, we will select several patterns of possible 4 and 3.5 billion years ago EUV radiation and solar wind conditions. For planetosphere researchers, we invited experts from three research groups that conduct studies of atmospheric escape, especially by global simulations of the solar wind-Mars interaction. We will conduct global simulations of Martian atmospheric escape using different methods (multi-species MHD, multi-fluid MHD, and hybrid). Based on comparison with the simulation results, we will investigate the range of atmospheric escape in light of uncertainties in our understanding of solar evolution, and its influence on Martian environment. In the workshop, we defined the input parameters including solar conditions to the simulations in details based on interdisciplinary discussions. We will summarize the results in a joint research paper on relations between solar evolution and atmospheric ion escape from Mars, to be submitted to Astrobiology. In the workshop, we also invited three graduate students for the sake of education of young researchers.

Participants (Affiliation) and presented topics:

A. Vidotto* (Trinity College Dublin) --- Evolution of the Solar-type star wind & radiation (with emphasis on EUV/XUV)

Y. Masada (Aichi University of Education) --- Evolution of the Solar/Steller magnetism

T. Suzuki (University of Tokyo) --- Evolution of the Solar/Steller wind

H. Iijima (ISEE, Nagoya University) --- Solar/Steller radiation form the viewpoint of radiative MHD simulation

S. Imada# (ISEE, Nagoya University) --- Solar Terrestrial Environment 3.5 billion years ago: Faint Young Sun Paradox

D. Brain# (LASP, University of Colorado, Boulder) --- Atmospheric escape processes from Mars

K. Seki# (University of Tokyo) --- Effects of intrinsic magnetic fields on atmospheric escape from Mars

S. Sakai (University of Tokyo) --- Effects of the IMF direction on atmospheric escape under a weak intrinsic magnetic field at Mars

H. Shinagawa (NICT) --- Simulation of the ionosphere (with emphasis on solar and other input parameters)

H. Nakagawa (Tohoku University) --- Habitability of Mars: Implication from Martian atmosphere observations

N. Terada# (Tohoku University) --- Multi-species simulation of the atmospheric escape from early Mars

Y. Ma* (UCLA) --- Multi-fluid simulation of the atmospheric escape from Mars

S. Ledvina* (SSL, UC Berkeley) --- Hybrid simulation of the atmospheric escape from Mars

R. Sakata (University of Tokyo) --- Effects of the intrinsic magnetic field on the ion loss from ancient Mars

N. Yoshida (Tohoku University) --- Seasonal variation of the dayside N2/CO2 at 140 km altitude derived from MAVEN/IUVS

Y. Nakamura (Tohoku University) --- Axisymmetric conductivities of Jupiter's middle- and low-latitude ionosphere: Implication for early Mars magnetosphere

* invited speakers, # SOC members