

DIVISION E / WORKING GROUP: IMPACT OF MAGNETIC ACTIVITY ON SOLAR AND STELLAR ENVIRONMENTS

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1. Summary of the Working Group

1.1. *Aims and Terms of Reference*

The aim of this Working Group (WG) is to bring together theorists, modellers and observers in the field of Solar, Stellar and Planetary Physics to coordinate and facilitate the interdisciplinary science related to understanding the impact of stellar magnetic activity on their space environments and planetary atmospheres.

1.2. *Summary*

The activity of stars, such as the Sun, modulates the environment within their astrospheres. This variable forcing is mediated via stellar magnetic fields, radiative and energetic particulate flux, stellar winds and magnetic storms. In turn this influences planetary atmospheres, climate and habitability. Studies of this intimate relationship between the parent star, its astrophere and planets that it hosts have reached a certain level of maturity within our own solar system – fueled both by advances in theoretical modeling and a host of satellites that observe the Sun-Earth system. This WG takes advantage of these recent advances in studies of the Sun and the heliosphere to explore stellar activity and its impact on astrospheres. This is achieved by enabling interdisciplinary interactions between theorists, modelers, observers and data analysts whose research is directed towards understanding the origin of stellar magnetic, radiative and particulate variability, their impact on the electromagnetic and particulate environment of planets and the consequent forcing of planetary atmospheres. The activities of the WG is expected to impact not only the field of solar and stellar astrophysics but will also be of relevance for studies of planetary habitability, and can potentially guide future searches for Earth-like planets within habitable zones. The goals of this WG are addressed through organization

of workshops and symposia across the globe and in relevant reviews and publications that highlight important advances in our understanding.

1.3. *Original Motivation*

Stellar activity cycles are produced deep in their interior by a magnetohydrodynamic (MHD) dynamo mechanism that relies on interactions between plasma flows and magnetic fields. These fields manifest as star spots on the surface and get dispersed in the surrounding space through stellar winds. Variation of this magnetic output contributes to radiative, particulate and stellar wind variability within the astrosphere. Transient events such as magnetic storms originate within stellar magnetic structures and generate extreme conditions that perturb the astrosphere. Experience with the Sun shows that long-term solar cycle variations also modulate the solar radiative output across all spectral ranges. Although this modulation is quite small over decadal solar-cycle timescale, it is still the primary natural source of energy for driving planetary climates. More extreme fluctuations in the activity of the Sun, apparent over timescales ranging to millennia such as the solar Maunder minimum are thought to result in more significant changes in the climate.

This activity causally connects the parent star to planets that reside in its astrosphere. This star-astrosphere-planet connection has been the subject of intense scrutiny in our solar system, especially in the last decade or so with the understanding that solar variability impacts the environment in the heliosphere (space weather) and is relevant for space climate. We also note that life, at least of the kind we know of, evolves under a set of well defined physical conditions which include appropriate levels of radiation governed by the parent star. Thus, exploring stellar activity cycles and their influence on their astrospheres has the potential of identifying similar conditions in other stellar systems and by extension, guiding the search for habitable, Earth-like planets.

2. Overview of Working Group Activities (2016-2018)

Below we provide a summary of activities of this WG during the period 2016-2018, which include efforts funded by the IAU as well as capacity building efforts led by WG members.

2.1. *IAU Symposium 328: Living around Active Stars*

This WG successfully proposed and organized the IAU Symposium 328 “Living around Active Stars” which was held in Maresias, Brazil from 17-21 October, 2016. This IAUS brought together scientists from diverse, interdisciplinary scientific areas such as solar, stellar and planetary physics, climate physics and astrobiology to review the current state of our understanding of solar and stellar environments. The scientific program was structured along the following themes:

- Solar and Stellar Activity
- Heliospheric and Astrospheric Environments
- Coupled Star-Planet Evolution
- Exoplanets, Habitability and Life

Invited speakers in each theme provided the general overview and background and summarized important advances and challenges, while contributed talks discussed the most recent scientific research in these topics. Following each session, an extended period was dedicated to discussions which resulted in significant exchanges between the audience

and the speakers of individual sessions. This added value to the understanding of the talks and led to discussions of outstanding questions that need to be tackled by the community.

The country of Brazil was chosen to make the meeting accessible to the Latin American scientific community, and easy connectivity ensured participation from other continents. A total of 81 scientists from 19 countries attended the Symposium, out of which 23 were graduate students. Of the total participants 38% were women. It is also encouraging to note that 59% of the selected contributed talks were by women.

While the IAU funding was utilized for supporting few participants, additional funding was leveraged from the American Astronomical Society Solar Physics Division (AAS-SPD) and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) to support the meeting. The Brazilian agencies SAB, FAPESP, CAPES and CNPQ co-sponsored the meeting, with SAB extending logistical support through its web-hosting and payment services. The proceeding of IAUS 328 is discussed in the publications section (Section 2.4).

2.2. Other IAU Meetings Supported by WG

The WG also supported IAU meetings that were proposed independently through support letters and advice on the proposed programs. Support was extended to the following meetings (including up-coming ones):

- IAU Symposium 340: Long-term datasets for the understanding of solar and stellar magnetic cycles, Jaipur, India, 19-23 February, 2018
- IAU Focus Meeting FM9: Solar Irradiance: Physics-Based Advances, Vienna, Austria, 22-23 August, 2018

2.3. Organizing Committee Member led Capacity Building Activities

The following activities, including workshop and meeting organization are being facilitated by WG Organizing Committee members through independent (non-IAU) support.

- Steering of the Solar Evolution and Extrema (SEE) Group of the VarSITI (Variability of the Sun and its Terrestrial Impact) Program of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)
 - First VarSITI Symposium, Bulgaria, 6-10 June, 2016
 - European Week of Astronomy and Space Science, Special Session 7, “The effects of solar and stellar magnetic activity on planets”, Athens, Greece, 5 July 2016
 - BCool 2018 Meeting, Dublin, Ireland, 7-11 April, 2018

2.4. Highlight of Major Publications

Since the last IAU General Assembly, the follow major publications were led by WG Organizing Committee members. Only reviews, reports and books are highlighted here.

- A major review on solar-stellar connection led by members of this WG was published in Space Science Reviews (Sacha-Brun et al. 2015).
- A major review on the response of the Earths climate to a changing Sun was put together with one member of this WG being involved as an editor (Lilensten et al. 2015).
- A book chapter reviewing the current state of understanding of the impact of stellar winds on exoplanets was contributed by a member of this WG to the Handbook on Exoplanets (Vidotto 2018).
- The Proceedings of the IAU Symposium 328 was edited by three members of this WG and published by Cambridge University Press in 2017 (Nandy et al. 2017).

3. Future

Bridging the disciplines of solar-stellar astrophysics, planetary physics and climate sciences will bring about transformative progress in understanding habitability and how astrophysical environments determine the origins and sustainability of life. With major space- and ground-based instrumentation development and missions in the offing, and concurrent progress in modeling star-planet interactions, our community is poised for major advances in this interdisciplinary field. The continued efforts of this WG are therefore both desirable and necessary.

The WG on “Impact of Magnetic Activity on Solar-Stellar Environments” has been very active over the last several years and organized capacity building exercises both within the IAU community, as well as outside, with support of other international organizations. We envisage to continue this activity over the next several years. Additionally, we will also maintain an online repository of relevant publications and meetings related to this field.

We expect to have new leadership to take this WG forward as well as a restructuring of the Organizing Committee, accompanied by induction of new members. This will be achieved during or before the next IAU General Assembly in Vienna.

Dibyendu Nandi
Chair of Working Group

References

- “The Solar-Stellar Connection”, Brun, A. S., Garcia, R. A., Houdek, G., Nandy, D., and Pinsonneault, M. 2015, Space Science Reviews, Volume 196, Page 303 (doi: 10.1007/s11214-014-0117-8)
- “Earths climate response to a changing Sun”, Editors: Lilensten, J., et al. 2015, EDP Sciences (ISBN 978-2-7598-1733-7)
- “Living around Active Stars”, Proceedings of the International Astronomical Union Symposium 328, Editors: Nandy, D., Valio, A., and Petit, P., 2017, Cambridge University Press (ISBN 978-1107170056)
- “Stellar Coronal and Wind Models: Impact on Exoplanets” in Handbook of Exoplanets, Editors: Deeg H., and Belmonte J., Vidotto, A. 2018, Springer (ISBN: 978-3-319-30648-3)