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The Era of Multi-Messenger Solar Physics

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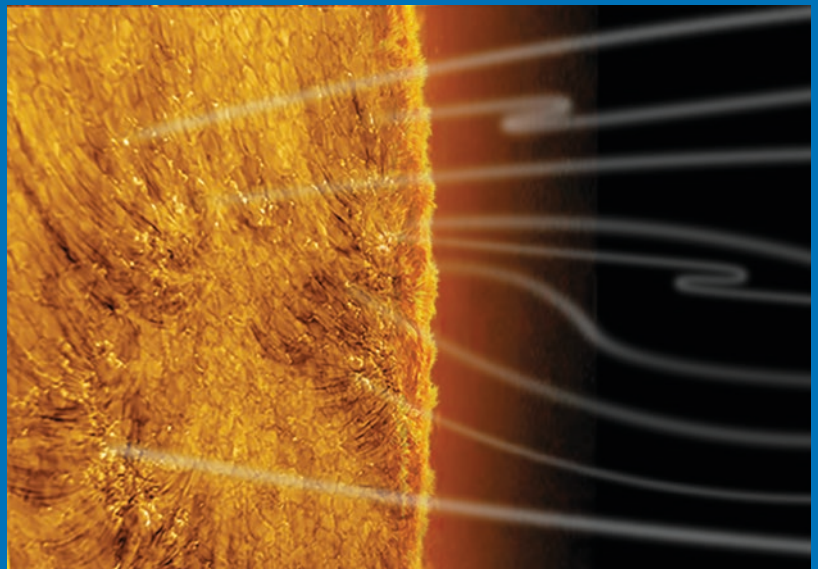
Gianna Cauzzi
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THE ERA OF MULTI-MESSENGER SOLAR PHYSICS

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COVER ILLUSTRATION:

A high resolution image of a solar plage, acquired with the VBI instrument on the Daniel K. Inouye Solar Telescope in the H- β line. The region, about 55×55 Mm in size, is the putative source region of the in-situ measurements obtained by Parker Solar Probe during Encounter #12. An artist impression depicts the magnetic switchbacks observed by PSP, which might be originating at the edges of supergranules and plage magnetic elements. The original H- β image was acquired on disk but has been rotated to make it appear as observed at the solar limb. (Credits: NSO/AURA/NSF, see <https://nso.edu/press-release/u-s-national-science-foundation-celebrates-the-inauguration-of-its-daniel-k-inouye-solar-telescope/>. Graphics by John Williams, NSO)

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**THE ERA OF
MULTI-MESSENGER SOLAR
PHYSICS**

**PROCEEDINGS OF THE 372nd SYMPOSIUM OF
THE INTERNATIONAL ASTRONOMICAL UNION
HELD IN BUSAN, REPUBLIC OF KOREA
2–5 AUGUST, 2022**

Edited by

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Preface

IAU Symposium 372, “The Era of Multi-Messenger Solar Physics” was coordinated through Division E (Sun and Heliosphere), with support from its Commissions, Division G (Stars and Stellar Physics), and the Inter-Division E-F-G Working Group on Impact of Magnetic Activity on Solar and Stellar Environments. It was held on Aug 2–5, 2022, during the first week of the XXXI IAU General Assembly in Busan, Republic of Korea. Almost 80 researchers contributed to the Symposium with invited, oral and poster presentations, representing 18 countries. Given the travel limitations due to the lingering COVID19 pandemic, over 30 contributors participated remotely in this hybrid meeting. However, as typical for GA-related Symposia, numerous other colleagues participated in selected oral and poster sessions.

Multi-messenger science has a long history in solar astronomy. For decades, direct measures of particles emanating from the Sun, like the solar wind, have been used together with electromagnetic field diagnostics as the couriers of information. This approach has shaped our understanding of how solar activity forms and relentlessly influences the heliosphere, including the planets existing within it. Several major solar facilities have recently come online, including the Parker Solar Probe (PSP), Solar Orbiter, or the Daniel K. Inouye Solar Telescope (DKIST, still in commissioning at the time of the Symposium), and they will be soon joined by others like the Chinese ASO-S or the Indian Aditya-L1. This collective, and unprecedented, observational power is now heralding an exciting new era of scientific opportunities within multi-messenger solar physics. The main goal of the Symposium was that of highlighting how these facilities can address many of the scientific questions facing contemporary Solar Physics, with a special emphasis on their synergies and the challenges and rewards of their coordinated operation.

The Symposium was structured in 7 Sessions, and included 15 invited and 24 contributed talks, as well as 36 poster and e-talk presentations. Among the many new results presented, we point out the first observations of the magnetic fields of active regions on the “hidden” face of the Sun, obtained with Solar Orbiter/PHI, and the spectacular data acquired with the Daniel K. Inouye Solar Telescope, revealing details on scales of 20–30 km at the solar surface (cf. the cover image for this book). Of note, the DKIST data were acquired during a campaign to support Parker Solar Probe encounter #12, with the main goal of providing the magnetic configuration for the source region of PSP’s in-situ measurements. This perfectly introduced the topic of the Symposium. The power of combining observations of various kinds was well illustrated by modeling efforts for multi-mission science, aimed at maximizing the likelihood of linking in-situ data to their source region at or near the Sun with careful predictions.

Solar activity at a variety of spatial and temporal scales was the focus of several talks, ranging from the working of the solar dynamo as derived from a new generation of MHD simulations of the solar interior, that incorporate enhanced helioseismology techniques, to new methods to estimate the magnetic non-potentiality of active regions, which help predicting whether they will produce eruptive flares. The resulting Coronal Mass Ejections (CMEs), their magnetic configuration and interaction, as well as the propagation of solar particles in the inner heliosphere were also discussed; results from an amazing fleet of spacecrafts at our disposal are really starting to explain how the Sun shapes its environment and help our understanding of similar phenomena at other stars. Indeed, the synergy between solar and stellar studies is an emerging field; during the Symposium we discussed the long-term evolution of the solar wind, and how the study of exoplanetary systems could improve our understanding of the evolution of the solar wind and how it affected the young Earth. Of course, the proximity of our star allows

us to obtain exquisitely resolved observations: these motivate sophisticated numerical investigations of mechanisms such as turbulence and magnetic reconnection, or the role of small scales in the creation of larger structures. One such a case is the local dynamo, the process responsible for the appearance of the magnetic fields in the quiet Sun and their variation with the cycle; other talks showed how small-scale vortex motions in the lower atmosphere could be the ultimate cause for the patchy nature of switchbacks in the solar wind as observed by PSP.

The Symposium concluded with the GA-plenary talk on August 5, presented by Valentin Martinez Pillet. His talk highlighted several science cases that will critically depend on the optimal coordination among multiple facilities, making a profound case for multi-messenger solar physics.

We would like to thank here the International Astronomical Union for their support, in particular for their generous policy of travel grants to young researchers. Very special thanks however are due to the Korean National Organizing Committee of IAUGA 2022 and the Local Organizing Committee, for their endless support in the organization of the whole GA, among the many logistical difficulties introduced by the pandemic. It has been truly a herculean effort, and they deserve our deepest, and heartfelt, gratitude.

Gianna Cauzzi and Alexandra Tritschler, co-chairs SOC
Boulder, CO
25 April 2023

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