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EDITORIAL

Editorial: Solar Wind at the Dawn of the Parker Solar Probe and Solar Orbiter Era

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Abstract Solar Wind 15 brought together almost 250 experts from all continents of the world to discuss the current trends and future perspectives of the research on the Sun and its solar wind. The present article collection recaptures some of the highlights of their contributions.

Keywords Solar wind

1. Solar Wind 15 – An Overview of the 15th International Solar Wind Conference

In the week of 18 to 22 June 2018 the international community of solar wind experts gathered in Brussels for the 15th International Solar Wind Conference. The home chosen for this

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event was the Hotel Metropole, the renowned venue of the famous 1911 Solvay Conference, which was a starting point of modern physics. Running a parallel with that historic event would be preposterous and pretentious. Nevertheless, the study of the solar wind finds itself in a revolutionary moment. The feeling of excitement in the community comes from three converging trends.

First, a few weeks after the conference was held, the Parker Solar Probe (PSP) mission launched successfully (on August 12, 2018). PSP opens a new era of in situ measurements of the solar wind at distances closer to the Sun than ever possible before. PSP has just completed on June 9th, 2020 its 5th close encounter with the Sun flying within 18.7 million kilometres from the Sun's surface, the closest distance a human-made object has ever been to the Sun. PSP was soon followed by a European-led mission, Solar Orbiter (SolO) that despite not reaching the same close distances from the Sun will provide both in situ and remote-sensing observations of the Sun with unprecedented resolution.

Second, the continuing exponential growth of computing power, the Moore's law, has led to simulations of the Sun and of the solar wind of growing complexity and accuracy, allowing a deeper understanding of the processes governing the magnetised plasma emitted by the Sun and giving us a better ability to predict the space weather at the Earth.

Third, the data provided by the two endeavours just mentioned, observations and simulations, have built over time a vast database of information that now can be the basis for a rapidly growing field of research in artificial intelligence (AI) and machine learning (ML) methods for data mining. Figure 1 illustrates the growth in observational data for solar science and compares it with the growth in transistor density in supercomputers, an indicator of how much data is produced by simulations per second. Data generated by observations and by simulations has grown by 6 – 7 orders of magnitude over the last 40 years. The promise is that using new AI methods on this data will allow us to uncover mechanisms, patterns and correlations human minds are too limited to embrace.

Solar Wind 15 serendipitously came at the perfect time when PSP was being launched, supercomputers were progressing swiftly towards the goal of breaking the exascale barrier and AI was becoming a dominant trend in society. The spirit of the venue that already witnessed the birth of modern physics brought together inspiring presentations on some of the most important achievements of recent research.

The new missions PSP, SolO, PROBA-3 and InterHelioProbe were presented in the communications by A. De Groof, A. Driesman, V.D. Kuznetsov, D.M. Hassler, D. Mueller, J. Owen, A. Zhukov and T. Zurbuchen. Keynote presentations from J.F. Lemaire, W.H. Matthaeus, M. Velli and R.F. Wimmer-Schweingruber highlighted some key aspects of current research. G. Lapenta introduced the perspectives of supercomputing applied to space science in the age of ML and AI, focusing on the new initiative AIDA (http://www.aida-space.eu/) funded by the European Commission under the Horizon 2020 project.

The program of the conference was broad, covering widely all areas of solar wind research, thanks to the efforts of the Scientific Committee:

i) Origin and acceleration of the solar wind close to the Sun:
   Lucia Abbo, Jiansen He, Pete Riley, Marco Velli.
ii) Solar wind evolution during its propagation in the heliosphere:
   Stuart Bale, Giovanni Lapenta, Yana Maneva, Sergio Servidio.
iii) Connection of CMEs and ICMEs:
   Sergio Dasso, Emilia Kilpua, Stefaan Poedts, Manuela Temmer, Yuming Wang, Andrei Zhukov.

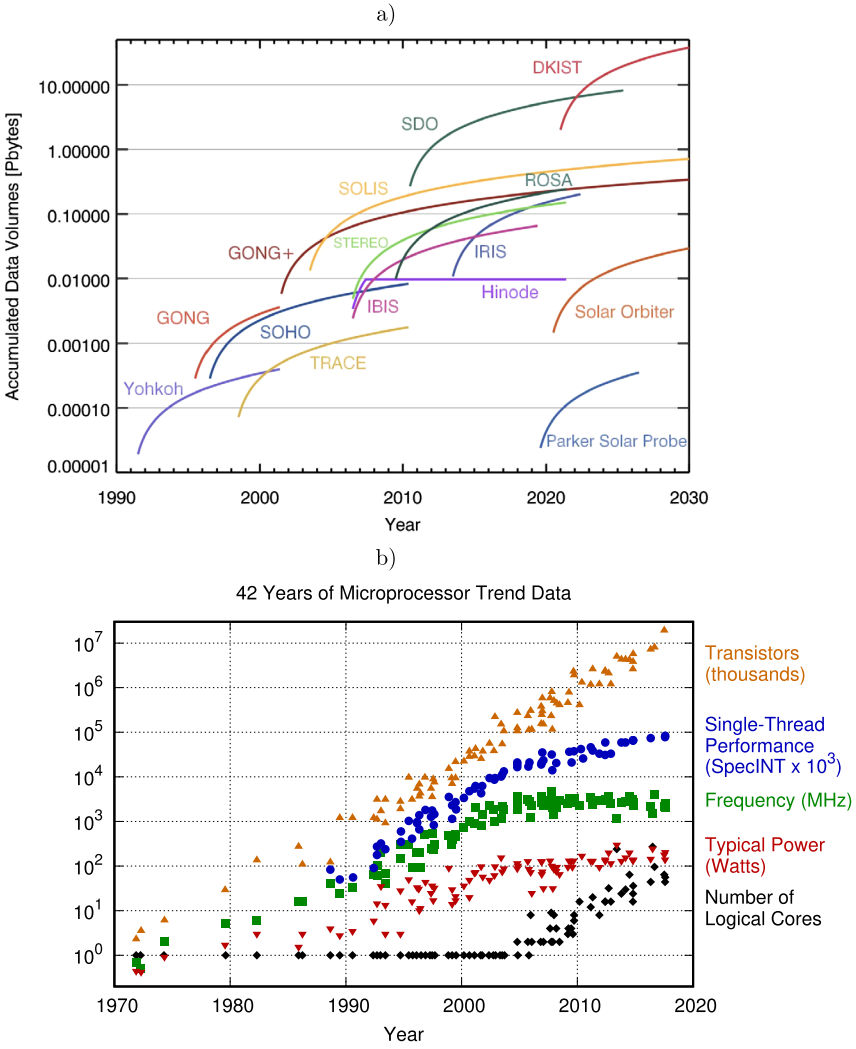

Figure 1 Big data in solar wind science: **a**) growth of the accumulated data from solar observations (courtesy of National Solar Observatory), **b**) Moore's law (data from https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data: the number of transistors per integrated circuit chip continues to grow, leading to more simulation data produced per unit time. The frequency and single thread performance has saturated but are compensated for by the growth of computing cores per chip. The typical power remains a key limit that cannot grow further for economical and environmental reasons.

iv) Suprathermal and energetic particles in the solar wind:
Ling Hua Wang, David Lario, Nicole Meyer-Vernet, Viviane Pierrard, Ian Richardson.

v) Solar wind interaction with solar system objects and dust:
Philippe Escoubet, Masaki Fujimoto, Mihaly Horanyi, Benoit Lavraud.

vi) Interaction of the solar wind with the interstellar medium:
Vlad Izmodenov, Nick Pogorelov, Nathan Schwadron.

vii) Current and future solar and heliospheric missions:
Dipankar Banerjee, Nicola Fox, Daniel Mueller, Yuri Yermolaev.

2. Topical Collection: Solar Wind at the Dawn of the Parker Solar Probe and Solar Orbiter Era

The present article collection recaptures some of the highlights of the contributions given by the more than 200 attendees (see Figure 2).

New methods to analyze available data are used to obtain new insight into the physics of solar wind. Stansby et al. (2018) describe a reprocessing of the original Helios ion distribution functions to provide reliable and reproducible data to characterise the proton core population of the solar wind in the inner heliosphere. Ďurovcová, Šafránková, and Němeček (2019) analyze with innovative methods the velocity distribution functions measured by the Helios spacecraft to find new insight on the relative drifts between three dominant components of the solar wind (proton core, proton beam, and α-particle core) at different distances from the Sun. The results of a comprehensive study of a large set of interplanetary CMEs (ICMEs) observed by the Wind mission during 20 years (1995 – 2015) are presented by Nieves-Chinchilla et al. (2019). They demonstrate that most of the ICMEs exhibit clear or possible signatures of a magnetic flux rope, although more complex configurations represent almost a quarter of all cases.

High-speed streams recorded by the Wind spacecraft are analyzed by Pi et al. (2020) to investigate their long- and short-term variations. The analysis suggests that long-term variations are connected with a time evolution of the source region on the time scale of solar rotation. D'Amicis et al. (2020) report that Alfvénic slow solar wind streams seen during the maximum of solar activity are characterised by a very high correlation between velocity and magnetic field fluctuations and by higher amplitude fluctuations. These results suggest that the Alfvénic slow wind has a different origin from the slow wind found near the boundary of coronal holes.

Images obtained by Solar Dynamics Observatory's (SDO) Atmospheric Imaging Assembly (AIA) are combined by Qi et al. (2019) with observations taken by the Interface Region Imaging Spectrograph (IRIS) and with magnetograms taken by SDO's Helioseismic and Magnetic Imager (HMI) to investigate the photospheric magnetic features in the regions of coronal plumes. Tadikonda et al. (2019) confirm that EUV emission is present beyond three solar radii using coronal imaging of the Solar UltraViolet Imager (SUVI) on board the Geostationary Operational Environmental Satellite-R series spacecraft. Ho, Mason, and Allen (2019) examine several ^{3}He-rich events and discuss the lack of observable ^{4}He intensity increases and the implications for the enhancement and acceleration mechanism of this special type of SEP events.

A three-dimensional hybrid (fluid electrons but particle in cell kinetic ions) model is used by Ofman (2019) to study the onset, nonlinear evolution and dissipation of the kinetic instabilities in multi-ion plasma. Preferential heating of the α particles and dissipation of magnetic fluctuation energy are seen to affect the kinetic and global properties of the solar wind. Hybrid simulations in 2.5D are used by Roberts and Ofman (2019) to represent solar wind fluctuations as the evolution of an initial state of magnetic field and plasma.

The statistical properties of ions in two-dimensional fully developed turbulence are compared by Pecora et al. (2019) using two different numerical algorithms: Hybrid PIC, where only the ions are particles but the electrons are a fluid and full PIC where all species are

Figure 2 Group photo of the Solar Wind 15 conference.

treated as particles. The study allows the authors to investigate particle diffusion and acceleration phenomena. Perri et al. (2019) study the dependence on the intermittency of the distribution of pitch-angle scattering tracking individual test particles in a turbulence spectrum comparable to that in the solar wind. Verdini, Grappin, and Montagud-Camps (2019) investigate the standard incompressible turbulent heating in the accelerating region, showing that the large-scale phenomenology is inaccurate and overestimates the heating by a factor

Table 1 The Solar Wind Conference series.

1964	SW1	Pasadena, California, USA
1971	SW2	Pacific Grove, California, USA
1974	SW3	Pacific Grove, California, USA
1978	SW4	Burghausen, Germany
1982	SW5	Woodstock, Vermont, USA
1987	SW6	Estes Park, Colorado, USA
1991	SW7	Goslar, Germany
1995	SW8	Dana Point, California, USA
1998	SW9	Nantucket Island, Massachusetts, USA
2002	SW10	Pisa, Italy
2005	SW11	Whistler, Canada
2009	SW12	Saint-Malo, France
2012	SW13	Kauai, Hawaii, USA
2015	SW14	Weihai, China
2018	SW15	Brussels, Belgium

at least 20. The suggestion is made that realistic 1D wind models cannot be based solely on incompressible turbulence and compressible turbulence and shocks are needed to increase wave reflection and heating.

Comparison of observations and simulations were a central theme of the Solar Wind 15. Katushkina et al. (2019) show that the WSA-Enlil model confirms qualitatively the latitudinal distribution of the solar wind found from the SWAN data. Lionello et al. (2019) implement non-equilibrium ionization calculations into a 1D wave-turbulence-driven hydrodynamic solar wind model and compare modelled charge states with in situ measurements.

This collection of articles closes an adventure but prepares us for the next event. Solar Wind 15 comes at the end of a most distinguished series of conferences (Table 1).

The upcoming Solar Wind 16 conference is scheduled to return to Pacific Grove, California, USA in 2021.

In bidding everybody who attended farewell, we thank our sponsors who contributed to the success of the event: the European Space Agency and the Flemish Research Foundation (FWO). We thank also the hotel Metropole for its hospitality and the KU Leuven congresbureau and the secretariat of the Department of Mathematics of KU Leuven for their logistic effort.

On behalf of the local organising committee (Giovanni Lapenta [chair], Andrei Zhukov, Stefaan Poedts, Luciano Rodriguez, Viviane Pierrard, David Berghmans and Yana Maneva), thank you for coming!

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