

JD3 – 3D Views of the Cycling Sun in Stellar Context: Overview

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Abstract. We summarise the motivations and main results of the joint discussion “3D Views of the Cycling Sun in Stellar Context”, and give credit to contributed talks and poster presentations, as due to the limited number of pages, this proceedings could only include contributions from the keynote speakers.

Keywords. Sun: rotation, Sun: interior, Sun: activity, stars: rotation, stars: interiors, stars: activity

1. Motivation

This joint discussion meeting was marking the importance of a historical achievement in astronomy: the first instantaneous 3D view of a star, our Sun. Hence the words “3D views” in the title. This achievement has importance for both the solar and stellar activity communities. Another motivation for bringing together the solar and stellar activity communities was that presently we appear to experience the start of a lower-activity cycle of solar activity following several strong cycles as well as the longest and deepest solar cycle minimum of the space age, which accounts for the motivation to look at the “cycling Sun”. The latter phenomenon is one reason that brings solar physicists to look at other active stars and their cycles for guidance. Stellar astronomers, in turn, make use of the detailed observations of the Sun when interpreting stellar data. Moreover, both communities appreciate the breathtaking details brought by solar and inner-heliospheric observations provided by, e.g., Hinode, SDO, SoHO, and the STEREO spacecraft. Space-borne stellar observations by the Kepler mission provide unprecedented details of temporal variability in stars, fascinating both communities.

At the time of the start of the XXVIIIth IAU General Assembly, and in fact the very days JD3 took place in Beijing between 20-22 August 2012, we were in the unique position to have a full 3D view of the Sun provided by the twin STEREO spacecraft, which have been drifting away from the Earth since their launch in 2006, one of the spacecraft being 115° behind, while its twin was 123° ahead of the Earth. Their observations combined with those by other spacecraft around the Earth (SOHO, Hinode, SDO) as well as ground-based observatories, gave us instantaneous 3D view of the Sun. This is a historical achievement in stellar physics. As the STEREO spacecraft move about 22° around the Sun in opposite directions relative to the Earth, this unique 3D view will be maintained for as long as nearly six years, except for some periods in 2015 when one or the other will be out of contact because its apparent angular distance from the Sun will

be too small for efficient communication, or will be physically occulted by the Sun. The temporal overlap of these out-of-contact periods is small, only 11 days in March 2015.

Solar activity is on the increase following the unexpectedly deep and long solar minimum in 2009. This long minimum period was monitored in great detail both on the Sun and the heliosphere, revealing a wide range of activity phenomena, which were observed with no disturbance from or overlap with other events. SDO has been showing us breathtaking details of the entire active Sun as viewed from Earth with temporal cadence of 12 seconds, monitoring solar activity, which has nearly reached maximum of cycle 24, with unprecedented observing details of various activity phenomena ranging from microflares and penumbral jets through quiet-sun mini-eruptions to the largest filament eruptions and coronal mass ejections. Although longer-term forecast of solar activity does not seem to indicate that a Maunder-type Grand Minimum would start in the next (few) hundred years, looking at the number of solar-type stars in Maunder-type deep activity minima is thought-provoking and crucial until we have a validated predictive model of the dynamo action of the Sun and its peers.

New insights brought by the combinations of these novel observational views are continuously posing new questions, inspiring and advance theoretical analysis and modelling, improving our understanding of the physics underlying magnetic activity phenomena. Therefore state-of-the-art observational and modelling results were presented side-by-side at the meeting.

2. Outline of the meeting

The programme was divided into seven sessions, each led by two keynote talks on the topic, presenting solar, then stellar state-of-the-art overviews side by side. The keynote talks combined insights gained from observations and modelling. Only the last session had a single keynote presentation, addressing stellar results by focusing on Kepler observations. All 13 keynote presentations are included in this proceedings, following this Overview.

2.1. *Evolution of solar and stellar magnetic fields*

Chair: van Driel-Gesztelyi (France, Hungary, UK). After a brief introduction by the Chair, the keynote presentations by Todd Hoeksema (USA) and Manuel Güdel (Austria) gave overview of the evolution of solar and then stellar magnetic fields (see Hoeksema, 2013 and Güdel, 2013). Three contributed talks followed. First, Jingxiu Wang (China) presented a work on “Vector magnetic field characteristics of the super-active regions with major flare activity”, co-authored by Anqin Chen. This observational talk was followed by a theoretical one on the dynamo, presented by Arnab Choudhuri (India) on “Theoretical modelling of grand minima of solar activity using the flux transport dynamo model” (co-author: Bidya Karak), which invited many questions. The session ended with a lively presentation by Peng-Fei Chen (China) on “3D view of ‘EIT waves’ in the solar corona”.

2.2. *Driving magnetic activity: differential rotation from seismology and patterns in surface activity*

Chair: John Leibacher (USA). The two keynote talks were given by Mark Miesch (USA) and Klaus Strassmeier (Germany) (see Miesch, 2013, and Strassmeier, 2013), who presented the role of convection and large-scale mean flows in the Sun and active stars and their implications for cyclic solar and stellar activity. Two solicited contributed talks were given by Krisztián Vida (Hungary) on “Activity in low-mass stars: spatial correlation and

evolution of the observed features” and by Shaolan Bi (China) on “Revised solar models with rotation and magnetic fields”. The latter talk was brilliantly presented by the PhD student of the author, Tanda Li.

2.3. *Magnetic activity from microflares to megaflares*

Chair: Mark Miesch (USA) The keynotes by Lyndsay Fletcher (UK) and Adam Kowalski (USA) introduced this exciting subject (see Fletcher, 2013, Kowalski & Hawley, 2013). Then Hugh Hudson (UK, USA) presented a thought-provoking solicited talk on “The X-ray limb of the Sun”, calling into question our understanding of the solar limb structure. This was followed by a theoretical work presented by Jun Lin (China) on “Solar Flare, CME, and the Reconnecting Current Sheet in Between” (co-authors: Zhixing Mei, Chengcai Shen). The session concluded with two talks on flare spectra by Janusz Sylwester (Poland) “Solar Flare Sulphur Abundance” (co-authors: Barbara Sylwester, Kenneth J.H. Phillips) and Barbara Sylwester “Flare Differential Emission Measure from RESIK and RHESSI Spectra” (co-authors: Janusz Sylwester, Anna Kepa, Tomasz Mrozek, Kenneth J.H. Phillips).

2.4. *3D views of the Sun and active stars surfaces and interiors*

Chair: Takashi Sakurai (Japan). From the keynotes in this session by Allan Sacha Brun (France) and Heidi Korhonen (Denmark) the audience learned about spectacular results produced by recent solar dynamo modelling (Brun & Strugarek, 2013) as did 3D reconstructions of active stars (Korhonen, 2013). Two contributed talks were presented by Debi Prasad Choudhary (USA) on “Chromospheric Properties of Sun as a Star” and Junwei Zhao (USA) on “Helioseismic Studies of Solar Far-Side Active Regions and Emerging Active Regions” (co-authors: Stathis Ilonidis, Alexander Kosovichev). The session ended with oral presentations of posters (see full list below) by Hugh Hudson (P1), Ting Li (P4), Nariman Ismailov (P9), Valery Krivodubskij (P8), Jie Jiang (P7), and van Driel-Gesztelyi (P2, P3).

2.5. *3D views of the Sun and active stars – atmospheres and astrospheres*

Chair: Peng-Fei Chen (China). The keynotes by Alexis Rouillard (France) and Moira Jardine (UK) presented STEREO results on coronal mass ejections and their propagation in the heliosphere (Rouillard, 2013) and magnetic surface and even coronal structures from active star, e.g. filaments (Jardine, 2013). These were followed by a solicited talk by Etienne Pariat (France) on “Magnetic topology of solar activity events” (co-authors: Guillaume Aulanier, Antonia Savcheva, Sophie Masson, Pascal Démoulin) and another solicited talk by Lucie M. Green (UK) on “Multi-wavelength observations of solar eruptions”. Then Dibyendu Nandy (India) spoke about a new initiative on “Solar-Stellar Cycles and their Implication on the Astrospheres” (co-authors: Allan Sacha Brun, Ed Cliver, Sarah E. Gibson, Margit Haberreiter, Andres Munoz-Jaramillo, Steven H. Saar, Adriana Silva-Valio, Ilya Usoskin). The session’s final talk was presented by Hui Li (China) on “Magnetic energy evolution and its relation to solar flares”.

2.6. *Solar and stellar cycles*

Chair: Hugh Hudson (UK, USA). This important session was expertly introduced by keynote talks by Robert Cameron (Germany) who emphasised that understanding non-linearities in the solar dynamo is the way forward in cycle forecast, and Emre Işık (Turkey) who gave a taste how multiple stellar cycles can be modelled and understood (see Cameron, 2013, and Işık, 2013). Contributed talks were presented by David Webb (USA) on “Solar Cycle variations of Coronal Mass Ejections”, and Aline Vidotto (UK)

on “The stellar wind cycles and planetary radio emission of the Tau Boo system” (co-authors: Rim Fares, Moira Jardine, Jean-Francois Donati, Merav Opher, Claire Moutou, Claude Catala, Tamas Gombosi).

2.7. *New results from SDO and Kepler*

Chair: Karel Schrijver (USA). In the final session of JD3 in Jon M. Jenkins’s (USA) keynote exciting new results on stellar variability from the Kepler mission were presented (Jenkins *et al.* 2013). SDO results were shown in contributed talks by Marcelo Emilio (Brasil) on “P and R modes in solar limb shape HMI-SDO observations” (co-authors: Jeff Kuhn, Rock Bush, Isabelle Scholl) and Jie Chen (China) on “An analysis of a Transequatorial Loop”, Yingna Su (USA) Observations and magnetic field modelling of a solar polar crown prominence (co-author: Aad van Ballegooien). Then Kiyoto Shibasaki (Japan) gave a talk on “Relation between solar activities at low and high latitudes inferred from microwave observations”, and Yuzong Zhang (China) presented “Revision of solar spicule classification”. Finally, the Chair summarised the main results of the meeting.

3. Conclusions

Bringing the solar and stellar activity communities together in this JD provided us with an opportunity to share our excitement and new insights with colleagues outside of the usual circles. At the JD solar and stellar talks were presented side by side, which kept both the solar and stellar communities together and led to lively discussions. The talks were outstanding, inspirational not only to one, but both communities, as stellar talks received many questions from the solar community and vice versa. For the three days of JD3 the lecture room was filled and buzzing. We conclude that the attempt has worked and it is a worthy path to follow in the future within the broad international context of the IAU.

Scientific Organising Committee

Lidia van Driel-Gesztelyi (France, Hungary, UK; Chair), Carolus J. Schrijver (USA, co-chair), Gianna Cauzzi (Italy), Peng-Fei Chen (China), John Leibacher (USA), Katalin Oláh (Hungary), Rachel Osten (USA).

Poster presentations

P1 Hugh Hudson: First Flare Results from EVE.

P2 L. van Driel-Gesztelyi, D. Baker, T. Trk, E. Pariat, L.M. Green, D.R. Williams, G. Valori, P. Démoulin, S.A. Matthews, E. Pedram, B. Kliem, P.F. Chen: Observations and modeling of a massive filament eruption, CME, and coronal wave.

P3 L. van Driel-Gesztelyi, J. L. Culhane, D. Baker, P. Démoulin, C.H. Mandrini, M.L. DeRosa, A.P. Rouillard, A. Opitz, G. Stenborg, A. Vourlidas, D.H. Brooks: Plasma outflows from active regions: are they sources of the slow solar wind?

P4 Ting Li: Interaction of solar global EUV wave with coronal structures.

P5 Zhi’e Liu: Solar-like oscillation in KIC 10516096, KIC 10644253 and KIC 11771760.

P6t Li Feng, Bernd Inhester, Yong Wei, Marilena Mierla, Weiqun Gan, Tielong Zhang, Mingyuan Wang: Morphological evolution of a 3D CME cloud reconstructed from three viewpoints and its comparison with other four reconstruction methods.

P7 Jie Jiang, Emre Işık, Robert Cameron, Dieter Schmitt, Manfred Schüssler: The Effect of Activity-related Meridional Flow Modulation on the Strength of the Solar Polar Magnetic Field.

P8 Valery Krivodubskij, Alexej Loginov, Oleg Cheremnykh, Nikolaj Salnikov: Hydrodynamic model of spatial and temporal variations of poloidal and toroidal components of 3D Sun flows.

P9 Nariman Ismailov, Peter Shustarev, Fekhrende Alimardanova, Gunel Bahaddinova: Planet formation processes in young solar-type stars.

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Rouillard, A. P. 2013, *Highlights of Astron.* 16, in this issue
Strassmeier, K. G. 2013, *Highlights of Astron.* 16, in this issue