Solar Phys (2015) 290:3091–3094
DOI 10.1007/s11207-015-0816-7

Preface: Probing the Sun Inside and Out

Louise Harra[1] · Deborah Baker[1] · Rachel Howe[2] · John Leibacher[3,4] · Lidia van Driel-Gesztelyi[1,5,6]

Published online: 17 November 2015

Keywords Flares, Dynamics · Helicity, Magnetic · Magnetic fields, Corona

The solar-activity cycle is not well understood. In 2008 – 2009 there was an unusual period of low solar activity. This extended solar minimum, although not unknown in the historical record, was the first during the space age. We are able to explore this, and the low-amplitude cycle which followed, with a diverse set of data. We have space-based helioseismic and atmospheric data available from the *Hinode* spacecraft (Kosugi *et al.*, 2007), *Solar and Heliospheric Observatory* (SOHO: Domingo, Fleck, and Poland, 1995), *Transition Region and Coronal Explorer* (TRACE: Handy *et al.*, 1999), and now the *Solar Dynamics Observatory*

Probing the Sun: Inside and Out
Guest Editors: D. Baker, L.K. Harra, and R. Howe

✉ D. Baker
deborah.baker@ucl.ac.uk

L. Harra
l.harra@ucl.ac.uk

R. Howe
rhowe@nso.edu

J. Leibacher
john.leibacher.sola@gmail.com

L. van Driel-Gesztelyi
Lidia.vanDriel@obspm.fr

1 Mullard Space Science Laboratory, University College London, Holmbury St Mary, UK

2 University of Birmingham, Birmingham, UK

3 National Solar Observatory, Tucson, AZ, USA

4 Institut d'Astrophysique Spatiale, Université Paris-Sud/C.N.R.S., 91405 Orsay Cedex, France

5 Konkoly Observatory of Hungarian Academy of Sciences, Budapest, Hungary

6 Observatoire de Paris, LESIA, FRE 2461(CNRS), 92195 Meudon Principal Cedex, France

(SDO; Pesnell, Thompson, and Chamberlin, 2012), which was launched in February 2010. In addition we have access to historical and contemporaneous data from many ground-based observatories including the *Birmingham Solar-Oscillations Network* (BiSON; Hale *et al.*, 2015) and *Global Oscillation Network Group* (GONG: Harvey *et al.*, 1996).

The Sun's activity cycle is most likely created by a dynamo located near the base of the Sun's convection zone at 0.28 $R_\odot$ depth. The solar dynamo is not well understood, and hence predicting the solar-activity cycle is extremely difficult. There have been predictions for the new cycle (Cycle 24), which range widely from a high-amplitude cycle to a period of extended solar minimum similar to the Maunder Minimum: an extreme low activity period from 1645 – 1715. This lack of understanding of the solar cycle is what has driven us to combine forces between helioseismologists and solar-atmosphere experts. The flows inside the Sun create the magnetic field that we measure on the surface and structure the corona.

We obtained funding from the Leverhulme Trust for an international network that allowed a series of workshops to occur from 2011 – 2014. This network was aimed at using the wealth of data to allow us to connect up the unusual behaviour in the interior to that of the solar atmosphere and in so doing provide a firm foundation for advances in the understanding of the cyclic behaviour of the Sun and its ensuing activity. The goals of the network were addressing fundamental processes occurring in our star that directly affect the environment in which the Earth exists. Our ultimate goal was to gain a better understanding of how magnetic fields are generated and amplified by the dynamo mechanism and how the cyclic nature of solar magnetic field is created and maintained. The results that we have obtained concentrate on this activity cycle (inside and outside the Sun) and also on solar flares. This Topical Issue highlights some of the key results from this network.

The network consisted of the following members: UCL-MSSL (L.K. Harra, D. Baker, D. Long, L. van Driel-Gesztelyi, L.M. Green, S. Zharkov, S.A. Matthews), University of Birmingham (Y. Elsworth, W. Chaplin, A. Broomhall G. Davies, and R. Howe), Glasgow University (H.S. Hudson, L. Fletcher), Institut d'Astrophysique Spatiale, France (T. Appourchaux, F. Baudin), National Astronomical Observatory of Japan, Japan (T. Sekii, H. Hara), National Solar Observatory, US (I. González-Hernández, R. Komm), Max Planck Institute for Solar System Research (K. Nagashima). These workshops were held at UCL-MSSL where the lead group was based.

The following articles are included in this Topical Issue:

i) Broomhall and Nakariakov (2015): Comparisons are made between different global measures of the Sun's magnetic activity in order to investigate how they are responding to the unusually deep and long period of weak activity during 2008 – 2009. Measures of the magnetic field from the photosphere, chromosphere, corona, interplanetary space, and helioseismic data from the solar interior are considered.
ii) Komm *et al.* (2015): The solar-cycle variation of the meridional flow in the near-surface layers of the solar convection zone from the surface to a depth of 16 Mm are studied using full-disk Doppler data obtained by GONG and HMI. The meridional flow, which is a precursor of magnetic activity, varies with the solar cycle at every depth, and bands of fast meridional flow appear at mid-latitudes about three years before magnetic activity of Cycle 24.
iii) Howe *et al.* (2015): Near-surface flows show structures that persist over multiple rotations, as seen in longitude–time plots of the zonal and meridional flows from ring-diagram analysis of data from GONG and SDO/*Helioseismic and Magnetic Imager* (HMI). A correlation analysis of the structures is used to estimate the rotation rate as a function of latitude and at latitudes of above 60° the flow data reveal a strong signature of a two-sided zonal-flow structure.

iv) Buitrago Casas *et al.* (2015): Standard helioseismic techniques were applied to a large sample of flares with HXR emission above 50 keV in Solar Cycle 24 to determine whether a sunquake occurred in each event. For the identified sunquakes, a statistical study is then carried out to analyse possible correlations between acoustically active flares and continuum emission.
v) Zharkova and Zharkov (2015): Possible sources for the production of seismic response in the form of hydrodynamic shocks caused by the injection of electron-rich and proton-rich beams and the depths where these shocks deposit the bulk of their energy and momentum are investigated. It is found that the depth of energy deposition near the surface strongly affects the velocity of propagation inside the interior and the locations of the first bounce of these waves on the solar surface in the vicinity of a flare seen as ripples, or sunquakes.
vi) Yeates, Baker, and van Driel-Gesztelyi (2015): Using a new technique for assimilating individual active regions of strong magnetic flux into a surface-flux-transport model, the origin of a prominent poleward surge of leading polarity, visible in the magnetic-butterfly diagram during Solar Cycle 24 is considered. The model shows the surge to originate primarily in a single high-latitude activity group consisting of a bipolar active region present in Carrington Rotations 2104 – 2105 and a multipolar active region in rotations 2107 – 2108.
vii) Harra *et al.* (2015): The temporal changes and locations of enhancements in polar coronal non-thermal velocity measurements during the rise-phase of Cycle 24 are compared with the locations of magnetic nulls associated with unipolar magnetic streams slowly progressing towards the poles.

Acknowledgments We would like to thank the Leverhulme Trust for their support under the Leverhulme International Networks grant program, which financed the series of workshops entitled Probing the Sun Inside and Out. Irene Gonázlez-Hernández, a key member of the network, sadly passed away in February 2014. Her professional career was focused on helioseismology, and her open-mindedness and flexibility made her central to the work that we carried out in our workshops. She was unwell for much of the project, but her determination to contribute was strong. We dedicate this topical issue to Irene. She is missed by friends and colleagues across the world.

Disclosure of Potential Conflicts of Interest The authors declare that they have no conflicts of interest.

References

Broomhall, A.-M., Nakariakov, N.: 2015, A comparison between global proxies of the Sun's magnetic activity cycle: Inferences from helioseismology. *Solar Phys.* **290**. DOI.
Buitrago Casas, J.C., Lindsey, C., Calvo Mozo, B., Krucker, S., Glesener, L., Zharkov, S.: 2015, A statistical correlation of sunquakes based on their seismic, white light, and X-ray emission. *Solar Phys.* **290**. DOI.
Domingo, V., Fleck, B., Poland, A.I.: 1995, The SOHO mission: An overview. *Solar Phys.* **162**, 1. DOI. ADS.
Hale, S.J., Howe, R., Chaplin, W., Davies, G., Elsworth, Y.: 2015, Performance of the Birmingham Solar-Oscillations Network (B iSON). *Solar Phys.* **290**. DOI.
Handy, B.N., Acton, L.W., Kankelborg, C.C., Wolfson, C.J., Akin, D.J., Bruner, M.E., Caravalho, R., Catura, R.C., Chevalier, R., Duncan, D.W., Edwards, C.G., Feinstein, C.N., Freeland, S.L., Friedlaender, F.M., Hoffmann, C.H., Hurlburt, N.E., Jurcevich, B.K., Katz, N.L., Kelly, G.A., Lemen, J.R., Levay, M., Lindgren, R.W., Mathur, D.P., Meyer, S.B., Morrison, S.J., Morrison, M.D., Nightingale, R.W., Pope, T.P., Rehse, R.A., Schrijver, C.J., Shine, R.A., Shing, L., Strong, K.T., Tarbell, T.D., Title, A.M., Torgerson, D.D., Golub, L., Bookbinder, J.A., Caldwell, D., Cheimets, P.N., Davis, W.N., Deluca, E.E., McMullen, R.A., Warren, H.P., Amato, D., Fisher, R., Maldonado, H., Parkinson, C.: 1999, The transition region and coronal explorer. *Solar Phys.* **187**, 229. DOI. ADS.
Harra, L., Baker, D., Edwards, S., Hara, H., Howe, R., van Driel-Gesztelyi, L.: 2015, A Study of the coronal non-thermal velocity in polar regions during the rise from solar minimum to solar maximum in cycle 24. *Solar Phys.* **290**. DOI.

Harvey, J.W., Hill, F., Hubbard, R.P., Kennedy, J.R., Leibacher, J.W., Pintar, J.A., Gilman, P.A., Noyes, R.W., Title, A.M., Toomre, J., Ulrich, R.K., Bhatnagar, A., Kennewell, J.A., Marquette, W., Patrón, J., Saa, O., Yasukawa, E.: 1996, The Global Oscillation Network Group (GONG) project. *Science* **272**, 1284. DOI. ADS.

Howe, R., Komm, R., Baker, D., Harra, L.K., van Driel-Gesztelyi, L., Bogart, R.S.: 2015, Persistent near-surface flow structures from local helioseismology. *Solar Phys.* **290**. DOI.

Komm, R., González-Hernández, I., Howe, R., Hill, F.: 2015, Solar-cycle variation of subsurface meridional flow derived with ring-diagram analysis. *Solar Phys.* **290**. DOI.

Kosugi, T., Matsuzaki, K., Sakao, T., Shimizu, T., Sone, Y., Tachikawa, S., Hashimoto, T., Minesugi, K., Ohnishi, A., Yamada, T., Tsuneta, S., Hara, H., Ichimoto, K., Suematsu, Y., Shimojo, M., Watanabe, T., Shimada, S., Davis, J.M., Hill, L.D., Owens, J.K., Title, A.M., Culhane, J.L., Harra, L.K., Doschek, G.A., Golub, L.: 2007, The Hinode (SOLAR-B) mission: An overview. *Solar Phys.* **243**, 3. DOI.

Pesnell, W.D., Thompson, B.J., Chamberlin, P.C.: 2012, The Solar Dynamics Observatory (SDO). *Solar Phys.* **275**, 3. DOI.

Yeates, A.R., Baker, D., van Driel-Gesztelyi, L.: 2015, Source of a prominent poleward surge during solar cycle 24. *Solar Phys.* **290**. DOI.

Zharkova, V., Zharkov, S.: 2015, On generation of hydrodynamic shocks by mixed beams and occurrence of sunquakes in flares. *Solar Phys.* **290**. DOI.