Irradiance Variations of the Sun and Sun-like Stars

December 13, 2018

Short and long-term irradiance variability on the Sun and other main sequence stars manifest in both spectroscopic and bolometric brightness variations. These can be particularly evident at shorter wavelengths, for instance in chromospheric Ca II and coronal X-ray emission, but span the entire observed spectrum. These variations are predominantly caused by magnetic-field emergence and evolution due to the complex interaction of gas dynamics and magnetic flux. Concentrations of magnetic fields on solar and stellar surfaces form various observable features, with dark spots and faculae being the most obvious such manifestations. These two features are the main drivers of solar and stellar radiative variability on timescales of about a day and longer.

The last few years have brought significant progress both in modelling and in measuring the variability of solar and stellar radiative outputs. Modeling improvements include new understandings of radiative transfer, magneto-hydrodynamic modeling, flux transport, and the solar dynamo. The recently-launched NASA Total and Spectral Solar Irradiance Sensor (TSIS-1), which began providing new total and spectral solar irradiance data in March 2018, continues the current 40-year uninterrupted space-borne solar-irradiance measurement record. NASA's Kepler mission has provided a rich, new, long-term, high-precision photometry record indicating stellar-variability amplitudes and timescales from hundreds of thousands of stars and is now being followed on by the The Transiting Exoplanet Survey Satellite (TESS), launched in April 2018. Such solar and stellar variability potentially impacts planetary-system environments and thus is of high interest not only for solar and stellar physicists but also for climate and exo-planet scientists. Furthermore, stellar activity can be a limiting factor even for the detection of exo-planets via transit observations, which rely on high-precision light curves.

The Topical Collection solicits papers aimed at observing and modelling irradiance variations of the Sun and Sun-like stars and, in particular, at understanding the links between magnetic fields and the resulting solar and stellar variability. We especially welcome papers based on synergies between solar and stellar research. Very often models originally developed for the Sun can be expanded to Sun-like stars (see e.g. Shapiro et al., 2014; Beeck et al., 2015; Borgniet et al., 2015; Meunier et al., 2015; Norris et al., 2017; Isik et al., 2018; Witzke et al., 2018), which allows constraining the more complex and detailed solar models via the much broader range of stellar parameters (whereas the Sun provides just a single example) and better understanding the common physics behind solar and stellar activity. Similarly, putting solar data in a stellar context (see, e.g. Preminger et al., 2011; Judge et al., 2012; Egeland et al., 2017; Radick et al., 2018; Karoff et al., 2018; Reinhold et al., 2018; Judge et al., 2017) is beneficial for both solar and stellar research.

The Guest Editors of the Topical Collection (co)-organized three meetings this year with a strong emphasis on studies of solar and stellar variability observations, modeling, and effects. These include:

- 2018 Sun-Climate Symposium (March 2018).
- Stellar Brightness Variations: building on the solar knowledge. Cool Stars 20 Splinter (July 2018).
- IAU XXXth Focus Meeting FM9: Solar Irradiance: Physics-Based Advances (August 2018);

Each of these meetings attracted more than 100 participants and stimulated lively discussions. Many of the participants expressed an interest in a follow-up Topical Collection in a well-established peer-reviewed journal.

We plan to solicit both modelling and observational papers on solar and stellar variability and the resulting effects on radiative output (irradiance). Modelling and observational topics include:

- Simulations of magnetic field impacts on solar and stellar atmospheres (Beeck et al., 2015; Norris et al., 2017);
- Simulations of magnetic flux emergence and transport (Isik et al., 2018);
- Modeling of solar (Yeo et al., 2017; Shapiro et al., 2017) and stellar variability (Witzke et al., 2018; Reinhold et al., 2018)
- Historical records of solar activity (Chatzistergos et al., 2018; Kopp et al., 2016);
- Observations of solar (Kopp, 2016) and stellar (Radick et al., 2018) brightness variability

With its readership including not only solar researchers but also stellar astronomers and Earth scientists using solar variability in climate models, *Solar Physics* is a prime journal for this Topical Collection, which will include a breadth of the latest observational and modeling results describing solar- and stellar-variability and their associated effects on radiative outputs.

Based on our previous experience and the feedback from participants of the aforementioned meetings, we expect about 15 contributed articles. In addition, we plan to solicit authors for three invited review articles summarizing the recent progress in a) solar irradiance measurements; b) physics-based modelling of solar and stellar irradiance; and c) understanding of the effects of solar and stellar variability on Earth climate and exoplanet environments, respectively.

The deadline for submission of statements of interest, including a tentative title, abstract, author list, and three suggestions for referees, will be February 15 2019, and the proposed deadline for manuscript submission is 30 April 2019.

For further information, and submission of statements of intent, please contact: John Leibacher (Solar Physics editor), Greg Kopp (guest editor), Alexander Shapiro (guest editor).

References

B. Beeck, M. Schüssler, R. H. Cameron, and A. Reiners. Three-dimensional simulations of near-surface convection in main-sequence stars. III. The structure of small-scale magnetic flux concentrations. *Astron. Astrophys.*, 581:A42, Sept. 2015.

S. Borgniet, N. Meunier, and A.-M. Lagrange. Using the Sun to estimate Earth-like planets detection capabilities. V. Parameterizing the impact of solar activity components on radial velocities. *Astron. Astrophys.*, 581:A133, Sept. 2015.

T. Chatzistergos, I. Ermolli, N. A. Krivova, and S. K. Solanki. Ca II K spectroheliograms for studies of long-term changes in solar irradiance. *ArXiv e-prints*, May 2018.

R. Egeland, W. Soon, S. Baliunas, J. C. Hall, A. A. Pevtsov, and L. Bertello. The Mount Wilson Observatory S-index of the Sun. *Astrophys. J.*, 835:25, Jan. 2017.

E. Isik, S. K. Solanki, N. A. Krivova, and A. I. Shapiro. Forward modelling of brightness variations in Sun-like stars I. Emergence and surface transport of magnetic flux. *ArXiv e-prints*, Oct. 2018.

P. G. Judge, G. W. Lockwood, R. R. Radick, G. W. Henry, A. I. Shapiro, W. Schmutz, and C. Lindsey. Confronting a solar irradiance reconstruction with solar and stellar data. *Astron. Astrophys.*, 544:A88, Aug. 2012.

P. G. Judge, R. Egeland, T. S. Metcalfe, E. Guinan, and S. Engle. The Magnetic Future of the Sun. *Astrophys. J.*, 848:43, Oct. 2017.

C. Karoff, T. S. Metcalfe, Â. R. G. Santos, B. T. Montet, H. Isaacson, V. Witzke, A. I. Shapiro, S. Mathur, G. R. Davies, M. N. Lund, R. A. Garcia, A. S. Brun, D. Salabert, P. P. Avelino, J. van Saders, R. Egeland, M. S. Cunha, T. L. Campante, W. J. Chaplin, N. Krivova, S. K. Solanki, M. Stritzinger, and M. F. Knudsen. The Influence of Metallicity on Stellar Differential Rotation and Magnetic Activity. *Astrophys. J.*, 852:46, Jan. 2018.

G. Kopp. Magnitudes and timescales of total solar irradiance variability. *Journal of Space Weather and Space Climate*, 6(27):A30, July 2016.

G. Kopp, N. Krivova, C. J. Wu, and J. Lean. The Impact of the Revised Sunspot Record on Solar Irradiance Reconstructions. *Sol. Phys.*, 291:2951–2965, Nov. 2016.

N. Meunier, A.-M. Lagrange, S. Borgniet, and M. Rieutord. Using the Sun to estimate Earth-like planet detection capabilities. VI. Simulation of granulation and supergranulation radial velocity and photometric time series. *Astron. Astrophys.*, 583:A118, Nov. 2015.

C. M. Norris, B. Beeck, Y. C. Unruh, S. K. Solanki, N. A. Krivova, and K. L. Yeo. Spectral variability of photospheric radiation due to faculae. I. The Sun and Sun-like stars. *Astron. Astrophys.*, 605:A45, Sept. 2017.

D. G. Preminger, G. A. Chapman, and A. M. Cookson. Activity-brightness Correlations for the Sun and Sun-like Stars. *ApJ*, 739:L45, Oct. 2011.

R. R. Radick, G. W. Lockwood, G. W. Henry, J. C. Hall, and A. A. Pevtsov. Patterns of Variation for the Sun and Sun-like Stars. *Astrophys. J.*, 855:75, Mar. 2018.

T. Reinhold, K. J. Bell, J. Kuszlewicz, S. Hekker, and A. I. Shapiro. Transition from spot to faculae domination – An alternate explanation for the dearth of intermediate Kepler rotation periods. *ArXiv e-prints*, Oct. 2018.

A. I. Shapiro, S. K. Solanki, N. A. Krivova, W. K. Schmutz, W. T. Ball, R. Knaack, E. V. Rozanov, and Y. C. Unruh. Variability of Sun-like stars: reproducing observed photometric trends. *Astron. Astrophys.*, 569:A38, Sept. 2014.

A. I. Shapiro, S. K. Solanki, N. A. Krivova, R. H. Cameron, K. L. Yeo, and W. K. Schmutz. The nature of solar brightness variations. *Nature Astronomy*, 1:612–616, Aug. 2017.

V. Witzke, A. I. Shapiro, S. K. Solanki, N. A. Krivova, and W. Schmutz. From Solar to Stellar Brightness Variations: The Effect of Metallicity. *ArXiv e-prints*, Sept. 2018.

K. L. Yeo, S. K. Solanki, C. M. Norris, B. Beeck, Y. C. Unruh, and N. A. Krivova. Solar Irradiance Variability is Caused by the Magnetic Activity on the Solar Surface. *Physical Review Letters*, 119(9), Sept. 2017.