

IAU Symposium

320

11-14 August 2015
Honolulu, United States

Proceedings of the International Astronomical Union

Solar and Stellar Flares and their Effects on Planets

Edited by

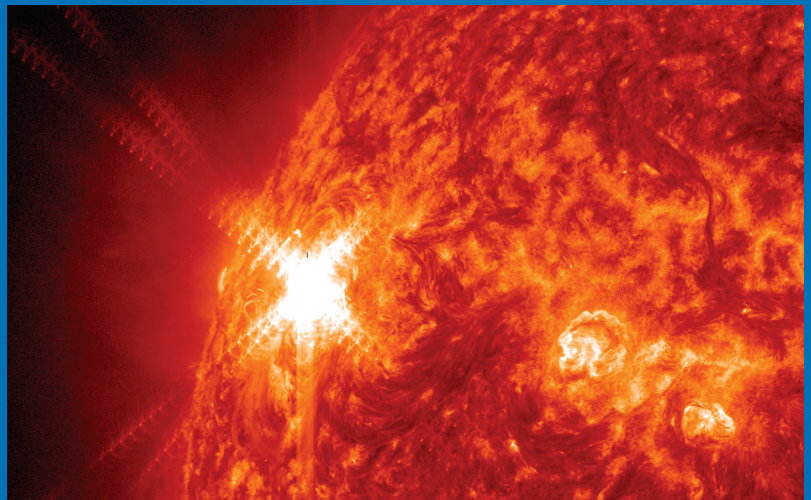
Alexander G. Kosovichev

Suzanne L. Hawley

Petr Heinzel

ISSN 1743-9213

International Astronomical Union



CAMBRIDGE
UNIVERSITY PRESS

SOLAR AND STELLAR FLARES AND THEIR EFFECTS ON PLANETS
IAU SYMPOSIUM 320

COVER ILLUSTRATION:

Image of a massive X1.9 class solar flare on the Sun on Nov. 3, 2011 at 20:27 UT, taken by the NASA's Solar Dynamics Observatory. The flare erupted from an extremely active region on the Sun called AR11339.

IAU SYMPOSIUM PROCEEDINGS SERIES

Chief Editor

THIERRY MONTMERLE, IAU General Secretary
*Institut d'Astrophysique de Paris,
98bis, Bd Arago, 75014 Paris, France
montmerle@iap.fr*

Editor

PIERO BENVENUTI, IAU Assistant General Secretary
*University of Padua, Dept of Physics and Astronomy,
Vicolo dell'Osservatorio, 3, 35122 Padova, Italy
piero.benvenuti@unipd.it*

INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

International Astronomical Union



**SOLAR AND STELLAR FLARES
AND THEIR EFFECTS ON
PLANETS**

**PROCEEDINGS OF THE 320th SYMPOSIUM
OF THE INTERNATIONAL ASTRONOMICAL
UNION HELD IN HONOLULU, UNITED STATES
AUGUST 11–14, 2015**

Edited by

ALEXANDER G. KOŠOVICHEV

New Jersey Institute of Technology, Newark, USA

SUZANNE L. HAWLEY

University of Washington, Seattle, USA

and

PETR HEINZEL

Astronomical Institute of the CAS, Ondřejov, Czech Republic



CAMBRIDGE UNIVERSITY PRESS
University Printing House, Cambridge CB2 8BS, United Kingdom
32 Avenue of the Americas, New York, NY 10013, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© International Astronomical Union 2016

This book is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of the International Astronomical Union.

First published 2016

Printed in the UK by Bell & Bain, Glasgow, UK

Typeset in System L^AT_EX 2 ϵ

A catalogue record for this book is available from the British Library Library of Congress Cataloguing in Publication data

This journal issue has been printed on FSCTM-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the world's forests. Please see www.fsc.org for information.

ISBN 9781107137578 hardback
ISSN 1743-9213

Table of Contents

Preface	x
Chapter 1: Introduction	
Solar and stellar flares and their impact on planets	3
<i>K. Shibata</i>	
Chapter 2: Multi-wavelength observations of solar flares	
Solar extreme ultraviolet (EUV) flare observations and findings from the Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE).....	27
<i>T. N. Woods, F. G. Eparvier & J. P. Mason</i>	
EUV irradiance observations from SDO/EVE as a diagnostic of solar flares	41
<i>R. O. Milligan</i>	
Fermi Large Area Telescope observation of high-energy solar flares: constraining emission scenarios.....	51
<i>N. Omodei, M. Pesce-Rollins, V. Petrosian, W. Liu, F. R. da Costa & A. Allafort, for the Fermi-LAT collaboration</i>	
Observations and modeling of the ultraviolet emission of solar flares	57
<i>K. Mikula, A. Berlicki & P. Heinzel</i>	
The exceptional aspects of the confined X-class flares of solar active region 2192	60
<i>J. K. Thalmann, Y. Su, M. Temmer & A. M. Veronig</i>	
Spectroscopic UV observations of M1.0 class solar flare from IRIS satellite.....	64
<i>V. M. Sadykov, A. G. Kosovichev, I. N. Sharykin & S. V. Dominguez</i>	
GREGOR observations of a small flare above a sunspot	68
<i>M. Sobotka, J. Dudík, C. Denker, H. Balthasar, J. Jurčák, W. Liu & the GREGOR Team</i>	
On the fine structure of solar flare X-ray loop top sources.....	74
<i>T. Mrozek & S. Kołomański</i>	
High-temperature solar flare plasma behaviour from crystal spectrometer observations	80
<i>B. Sylwester, J. Sylwester, K. J. H. Phillips, A. Kepa & T. Mrozek</i>	
Multitemperature analysis of solar flare observed on 2003 March 29	86
<i>A. Kepa, B. Sylwester, J. Sylwester, M. Siarkowski, T. Mrozek & M. Gryciuk</i>	
Model of flare lightcurve profile observed in soft X-rays.....	89
<i>M. Gryciuk, M. Siarkowski, S. Gburek, P. Podgorski, J. Sylwester, Anna Kepa & Tomasz Mrozek</i>	
Dark feature in EUV post-flare loops.....	95
<i>Q. Song, M. Zhang, J.-S. Wang, X.-S. Feng & X.-X. Zhang</i>	
Restricted propagation of an “EIT wave” in the low solar corona.....	98
<i>D. M. Long, D. Pérez-Suárez & G. Valori</i>	

Coronal quasi-periodic fast-propagating magnetosonic waves observed by SDO/AIA.	103
<i>Y. Shen</i>	
Multi-wavelength observations of filament oscillations induced by shock waves . .	106
<i>Y. Shen</i>	
Solar flare soft X-ray spectra from Diogenes observations	109
<i>M. Stęślicki, J. Sylwester, B. Sylwester, Ż. Szaforz, Z. Kordylewski, S. Płoceniak, M. Siarkowski & Kenneth J. H. Phillips</i>	
Thermal characteristics of a B8.3 flare observed on July 04, 2009.	112
<i>A. K. Awasthi, B. Sylwester, J. Sylwester & R. Jain</i>	
Chapter 3: Advances in observations of stellar flares	
Discovery of superflares	119
<i>D. Nogami</i>	
The shape of M dwarf flares in Kepler light curves.	128
<i>J. R. A. Davenport</i>	
The frequency of stellar X-ray flares from a large-scale XMM-Newton sample . .	134
<i>J. P. Pye & S. R. Rosen</i>	
High dispersion spectroscopy of solar-type superflare stars with Subaru/HDS. . .	138
<i>Y. Notsu, S. Honda, H. Maehara, S. Notsu, T. Shibayama, D. Nogami & K. Shibata</i>	
Statistical properties of superflares on solar-type stars based on the Kepler 1-min cadence data	144
<i>H. Maehara, T. Shibayama, Y. Notsu, S. Notsu, S. Honda, D. Nogami & K. Shibata</i>	
Flares in A-type stars?	150
<i>M. G. Pedersen, V. Antoci & H. Korhonen</i>	
Flares from ultracool L dwarfs with Kepler	153
<i>J. E. Gizis, R. Paudel, P. K. G. Williams, A. J. Burgasser & S. J. Schmidt</i>	
Characterization of X-ray flare properties of AB Dor	155
<i>S. Lalitha</i>	
Ultraviolet spectrophotometry of flares on “quiescent” M and K dwarf exoplanet hosts	161
<i>R. O. Parke Loyd, K. France & A. Youngblood</i>	
Chapter 4: Magnetic field structure and dynamics of flaring regions	
Nonlinear force-free modeling of magnetic fields in flare-productive active regions	167
<i>M. S. Wheatland & S. A. Gilchrist</i>	
Hinode magnetic-field observations of solar flares for exploring the energy storage and trigger mechanisms	175
<i>T. Shimizu, S. Inoue & Y. Kawabata</i>	

Slipping magnetic reconnection and complex evolution of a flux rope and flare ribbons	179
<i>T. Li & J. Zhang</i>	
Magnetic reconnection between an emerging active region and the quiet Sun . . .	185
<i>B. Zhang, J. Zhang, S. Yang, T. Li, Y. Zhang & L. Li</i>	
Radio spectroscopy of stellar flares: magnetic reconnection & CME shocks in stellar coronae	191
<i>J. Villadsen, G. Hallinan & S. Bourke</i>	
Stellar flares and the dark energy of CMEs	196
<i>J. J. Drake, O. Cohen, C. Garraffo & V. Kashyap</i>	
Evidence of thermal conduction suppression in hot coronal loops: supplementary results	202
<i>T. Wang, L. Ofman, X. Sun, E. Provornikova & J. M. Davila</i>	
 Chapter 5: Flares and plasma eruptions	
Mass ejections from the Sun	211
<i>L. M. Green</i>	
Conditions for the existence of Kelvin-Helmholtz instability in a CME	218
<i>A. Páez, V. Jatenco-Pereira, D. Falceta-Gonçalves & M. Opher</i>	
Searching for failed eruptions interacting with overlying magnetic field	221
<i>D. Gronkiewicz, T. Mrozek, S. Kotomański & M. Chruślińska</i>	
The estimate of hot Jupiter mass loss rate in the interaction with CME from a solar type star	224
<i>D. V. Bisikalo & A. A. Cherenkov & P. V. Kaygorodov</i>	
 Chapter 6: Particle acceleration and transport	
Numerical RHD simulations of flaring chromosphere with Flarix	233
<i>P. Heinzel, J. Kašparová, M. Varady, M. Karlický & Z. Moravec</i>	
Response of chromospheric lines to different periodic non-thermal electron beams	239
<i>J. Cheng & M. Ding</i>	
Updated calculations of the ionization equilibrium for the non-Maxwellian electron n -distributions in solar flares	243
<i>E. Džifčáková & J. Dudík</i>	
 Chapter 7: Comparison of solar and stellar flares	
Flare stars across the H-R diagram: a clue to the origin of the corona	249
<i>L. A. Balona</i>	
White-light continuum in stellar flares	259
<i>A. F. Kowalski</i>	
White-light continuum emission from a solar flare and plage	268
<i>A. Berlicki, A. K. Awasthi, P. Heinzel & M. Sobotka</i>	

Distinguishing between coronal cloud prominences and channel prominences and their associations with solar and stellar flares	278
<i>S. F. Martin, O. Engvold, Y. Lin & J. A. da Silva</i>	
On the origin of solar and stellar flares	288
<i>S. Ibadov & F. S. Ibadov</i>	
Chapter 8: Solar and stellar magnetic activity	
The role of complex magnetic topologies on stellar spin-down.	297
<i>V. Réville, A. S. Brun, A. Strugarek, S. P. Matt, J. Bouvier, C. P. Folsom & P. Petit</i>	
Synthetic activity indicators for M-type dwarf stars.	303
<i>S. Wedemeyer & H.-G. Ludwig</i>	
Super-active regions in solar cycle 24.	309
<i>A. Chen & J. Wang</i>	
Solar activities observed with the New Vacuum Solar Telescope.	315
<i>S. Yang & J. Zhang</i>	
Lightcurve studies and magnetic activities of several eclipsing binaries	321
<i>X. L. Han, L. Zhang, Q. Pi & D. Wang</i>	
The design of solar synoptic chart for space weather forecast	324
<i>Q. Song, J.-S. Wang, X.-S. Feng & X.-X. Zhang</i>	
Descriptive study of X-class flares released in the year 2014, during the double peak of SC-24.	330
<i>A. A. Hady, M. H. Mostafa & S. W. Samuel</i>	
Temporal solar irradiance variability analysis using neural networks	333
<i>A. Tebabal, B. Damtie & M. Nigussie</i>	
The Reflecting Heliometer of Rio de Janeiro after 6 years of activity	339
<i>S. C. Boscardin, C. Sigismondi, J. L. Penna, V. D'Avila, E. Reis-Neto & A. H. Andrei</i>	
Solar radius variations: new look on the wavelength dependence.	342
<i>J.-P. Rozelot, A. Kosovichev & A. Kilcik</i>	
Solar diameter measurements from eclipses as a solar variability proxy	351
<i>D. W. Dunham, S. Sofia, K. Guhl & D. Herald</i>	
Chapter 9: Flares and star-planet interaction	
Magnetism and activity of planet hosting stars.	357
<i>J. T. Wright & B. P. Miller</i>	
Stellar wind – magnetosphere interactions in hot Jupiters.	367
<i>D. L. Buzasi</i>	
Ultraviolet and X-ray irradiance and flares from low-mass exoplanet host stars	370
<i>K. France, R. O. P. Loyd & A. Brown</i>	

Optical hydrogen absorption consistent with a bow shock around the hot Jupiter HD 189733 b	376
<i>P. W. Cauley, S. Redfield, A. G. Jensen, T. Barman, M. Endl & W. D. Cochran</i>	
Observed effects of star-planet interaction	382
<i>S. J. Wolk & I. Pillitteri & K. Poppenhaeger</i>	
CARMENES: M dwarfs and their planets	388
<i>A. Quirrenbach, P. J. Amado, J. A. Caballero, H. Mandel, R. Mundt, A. Reiners, I. Ribas, W. Seifert, M. Azzaro, D. Galadí & the CARMENES Consortium</i>	
Quiescent and flaring Lyman- α radiation of host stars and effects on exoplanets	391
<i>J. L. Linsky, K. France, Y. Miguel & L. Kaltenegger</i>	
The particle and magnetic environments surrounding close-in exoplanets	397
<i>A. A. Vidotto, R. Fares, M. Jardine, C. Moutou & J.-F. Donati</i>	
Magnetic energy fluxes in close-in star-planet systems	403
<i>A. Strugarek, A. S. Brun, S. P. Matt & V. Réville</i>	
The early Earth under a superflare and super-CME attack: prospects for life . . .	409
<i>V. Airapetian, A. Gloer & G. Gronoff</i>	
Chapter 10: New frontiers in solar and stellar flares and research programs	
Synergy between solar and stellar flares: challenges and perspectives	419
<i>S. L. Hawley</i>	
First radio burst imaging observation from Mingantu Ultrawide Spectral Radioheliograph	427
<i>Y. Yan, L. Chen, S. Yu & CSRH Team</i>	
The Lyman- α Solar Telescope (LST) for the ASO-S mission	436
<i>H. Li</i>	
Geant4 simulations of STIX Caliste-SO detector's response to solar X-ray radiation	439
<i>J. Barylak, A. Barylak, T. Mrozek, M. Steślicki, P. Podgórski & H. Netzel</i>	
Solar X-rays from 0.3 A.U.: The ChemiX Bragg Spectrometer on Interhelioprobe	442
<i>J. Sylwester, M. Siarkowski, J. Bakala, Ż. Szaforz, M. Kowaliński, M. Steślicki, B. Sylwester, Z. Kordylewski, O. Dudnik, V. D. Kuznetsov, V. Polansky, S. Kuzin & K. J. H. Phillips</i>	
Progress of site survey for large solar telescopes in western China	447
<i>Y. Liu, T. Song, X. Zhang, S. Liu, M. Zhao, Z. Tian, Y. Miao, H. Li, J. Huang, B. Su, Y. Lu, X. Li & Q. Song</i>	
Soft X-ray polarimeter-spectrometer SOLPEX	450
<i>M. Steślicki, J. Sylwester, S. Płoceniak, J. Bakala, Ż. Szaforz, D. Ścisłowski, M. Kowaliński, J. Hernandez, S. Kuzin & S. Shestov</i>	
Author index	456

Preface

Recent advances in observations and modelling of solar and stellar flares have opened new perspectives for understanding of the fundamental physical mechanisms of magnetic energy storage and release, particle acceleration, and radiative and dynamical processes in solar and stellar flares. The new interest in this topic is stimulated by Kepler observations which have led to the discovery that stellar flares occur not only in M-type dwarfs (UV Ceti-type variables) but also in a wide range of A-F type stars. Previously, it was believed that the F- and A-type stars do not have flaring activity. The discovery of super-flares on solar-type stars has raised questions about the possibility of such flares on the Sun, and led to hot debates about the potential effects of such super-flares on terrestrial and extra-terrestrial planets, including their impact on the origin and evolution of life. These results triggered new interest in the physical mechanism of solar and stellar flares, and their connection with the dynamo mechanism and stellar properties.

Recent observations of solar flares from the Solar Dynamics Observatory (SDO), IRIS, RHESSI, STEREO, Hinode and Fermi space observatories and large ground-based telescopes have revealed details of the magnetic topology of flaring active regions, obtained important insight into the processes of magnetic reconnection and particle acceleration, and led to new understanding of the importance of local response and global-scale coupling of the flare dynamics. Among the new observations, the Fermi detection of extremely long gamma-ray emission in many solar flares is particularly surprising. These and other new results challenge the current theories of solar and stellar flares, and even cause to reconsider the whole, once well-established, paradigm about the common physical origin and properties of the solar and stellar flares.

Previously, stellar flares associated with active M-type stars were thought to be similar to solar flares representing a sudden release of magnetic energy accumulated in the coronal part of sunspot region, in the form of high-energy particles which heat the atmosphere and corona. Stellar flares can be four orders of magnitude more powerful, which is thought to be due to bigger starspot regions generated by a more efficient dynamo process, because many of the flaring stars rotate faster than the Sun. However, the new observations have raised an alternative point of view that such powerful flares may be due to the interaction with close companions - 'hot Jupiters'. The discovery of flares on hot A-type stars with a very shallow outer convection zone and without strong magnetic field causes additional problems with the dynamo origin of the flare energy on these stars.

The IAU Symposium 320 had been a forum for discussing the recent advances in observations and theories of solar and stellar flares, focused on the understanding of their phenomenological and physical aspects, as well as consequences for terrestrial planets and exoplanets. It covered a broad range of phenomena, from the magnetic topology of flares and mechanisms of impulsive energy release to high-energy flare emission and potential impacts on planets.

The papers presented in the Proceedings are focused on recent advances in multi-wavelength observations with new space and ground-based telescopes, as well as in theory and numerical simulations. This includes discussions of similarity and differences in magnetism of the Sun and flaring stars, links to the interior dynamics and surface magnetism, physical mechanisms of magnetic energy storage and release, particle acceleration, properties of impulsive radio, optical, EUV, X-ray and gamma-ray emissions, shocks and mass ejections, origin of superflares on solar-type stars, and impact of flares

on planetary atmospheres. We hope that this volume will be useful to senior and new researchers in this fascinating and rapidly developing field of astronomy.

Alexander G. Kosovichev, Suzanne Hawley, and Petr Heinzel, co-chairs SOC