

# Solar Surface Magnetism

# NATO ASI Series

## Advanced Science Institutes Series

*A Series presenting the results of activities sponsored by the NATO Science Committee which aims at the dissemination of advanced scientific and technological knowledge, with a view to strengthening links between scientific communities.*

The Series is published by an international board of publishers in conjunction with the NATO Scientific Affairs Division

<b>A Life Sciences</b>	Plenum Publishing Corporation
<b>B Physics</b>	London and New York
<b>C Mathematical and Physical Sciences</b>	Kluwer Academic Publishers
<b>D Behavioural and Social Sciences</b>	Dordrecht, Boston and London
<b>E Applied Sciences</b>	
<b>F Computer and Systems Sciences</b>	Springer-Verlag
<b>G Ecological Sciences</b>	Berlin, Heidelberg, New York, London,
<b>H Cell Biology</b>	Paris and Tokyo
<b>I Global Environmental Change</b>	

## NATO-PCO-DATA BASE

The electronic index to the NATO ASI Series provides full bibliographical references (with keywords and/or abstracts) to more than 30000 contributions from international scientists published in all sections of the NATO ASI Series.

Access to the NATO-PCO-DATA BASE is possible in two ways:

- via online FILE 128 (NATO-PCO-DATA BASE) hosted by ESRIN, Via Galileo Galilei, I-00044 Frascati, Italy.
- via CD-ROM "NATO-PCO-DATA BASE" with user-friendly retrieval software in English, French and German (© WTV GmbH and DATAWARE Technologies Inc. 1989).

The CD-ROM can be ordered through any member of the Board of Publishers or through NATO-PCO, Overijse, Belgium.



**Series C: Mathematical and Physical Sciences - Vol. 433**

# Solar Surface Magnetism

edited by

Robert J. Rutten

and

Carolus J. Schrijver

Sterrekundig Instituut,  
Utrecht, The Netherlands



**Springer-Science+Business Media, B.V.**

Proceedings of the NATO Advanced Research Workshop on  
Solar Surface Magnetism  
Soesterberg, The Netherlands  
November 1–5, 1993

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 978-94-010-4519-3  
DOI 10.1007/978-94-011-1188-1

ISBN 978-94-011-1188-1 (eBook)

---

*Printed on acid-free paper*

---

All Rights Reserved

© 1994 Springer Science+Business Media Dordrecht

Originally published by Kluwer Academic Publishers in 1994

No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system, without written permission from the copyright owner.

# TABLE OF CONTENTS

List of participants .....	ix
Preface .....	xi

## I. Context

C. Zwaan	3
<i>The Sun among the stars</i>	

## II. Techniques

E. Landi Degl'Innocenti	29
<i>Recipes for solar polarimetry</i>	
C.U. Keller	37
<i>Some aspects of polarimetry with LEST</i>	
C.U. Keller	43
<i>Speckle techniques for spectroscopic observations</i>	
W. Schmidt, H. Balthasar, E. Wiehr	49
<i>The Fe I 10265 Å line as an excellent tool for magnetic field measurements</i>	

## III. Magnetic elements

R. Muller	55
<i>Properties of small magnetic elements</i>	
L.H. Strous	73
<i>Dynamics of small magnetic elements in a growing active region</i>	

S.K. Solanki, J.H.M.J. Bruls, O. Steiner, T. Ayres, W. Livingston, H. Uitenbroek	91
<i>The upper photosphere and lower chromosphere of small-scale magnetic features</i>	
A. Skumanich, B.W. Lites, V. Martínez Pillet	99
<i>Vector spectropolarimetry with the Advanced Stokes Polarimeter (ASP) for quantitative solar magnetometry</i>	
K. Muglach, S.K. Solanki, W.C. Livingston	127
<i>Preliminary properties of pores derived from 1.56 micron lines</i>	
V. Gaizauskas	133
<i>The magnetic chromosphere</i>	
B. Schmieder, P. Heinzel, G. Tsiropoula, C.E. Alessandrakis	151
<i>Fine structures of the solar chromosphere</i>	
F.-L. Deubner, J. Hofmann, E. Kossack, B. Fleck	155
<i>Non-linearities of chromospheric oscillations</i>	
B.W. Lites, R.J. Rutten, J.H. Thomas	159
<i>Chromospheric oscillations</i>	
G. Severino, M.-T. Gomez, B. Caccin	169
<i>Modelling umbrae</i>	
P. Maltby	179
<i>Sunspot temperatures</i>	
J. Staude	189
<i>Interpretation of sunspot oscillations</i>	
R.A. Shine, A.M. Title, T.D. Tarbell, K. Smith, Z.A. Frank, G. Scharmer	197
<i>Dynamics of the Evershed effect</i>	
J.H. Thomas	219
<i>The cause of the Evershed effect in sunspots: flows or waves?</i>	
P.C. Martens, N. Hurlburt, A.M. Title, L.A. Acton	237
<i>An analytical model for fluted sunspots and a new interpretation of Evershed flow</i>	

S.K. Solanki, C.A.P. Montavon	239
<i>Some consequences of an uncombed and inhomogeneous penumbra</i>	

#### IV. Magnetic patterns

P.N. Brandt, R.J. Rutten, R.A. Shine, J. Trujillo Bueno	251
<i>On photospheric flows and chromospheric corks</i>	
G.W. Simon, P.N. Brandt, L. J. November, G. B. Scharmer, R. A. Shine	261
<i>Large-scale photospheric motions: first results from an extraordinary eleven-hour granulation observation</i>	
C.J. Schrijver	271
<i>Solar magnetic fields and percolation theory</i>	
J.K. Lawrence, A.C. Cadavid, A.A. Ruzmaikin	279
<i>Scaling properties of photospheric magnetic fields</i>	
N.O. Weiss	287
<i>Magnetoconvective patterns</i>	
R.F. Howard	297
<i>Average east-west inclinations of surface magnetic field lines</i>	
S.F. Martin, R. Bilimoria, P.W. Tracadas	303
<i>Magnetic field configurations basic to filament channels and filaments</i>	
S.F. Martin, Ch.R. Echols	339
<i>An observational and conceptual model of the magnetic field of a filament</i>	
K.L. Harvey	347
<i>The solar magnetic cycle</i>	
J.O. Stenflo	365
<i>Cycle patterns of the axisymmetric magnetic field</i>	
N.R. Sheeley Jr., Y.-M. Wang	379
<i>Returning to the random walk</i>	

## V. Theory of magnetoconvection

P. Hoyng <i>The solar dynamo</i>	387
F. Moreno-Insertis, M. Schüssler, P. Caligari <i>Dynamics of erupting magnetic flux tubes</i>	407
K. Petrovay <i>Theory of passive magnetic field transport</i>	415
O. Steiner, M. Knölker, M. Schüssler <i>Dynamic interaction of convection with magnetic flux sheets: first results of a new MHD code</i>	441
Å. Nordlund, K. Galsgaard, R.F. Stein <i>Magnetoconvection and magnetoturbulence</i>	471

## VI. Prospects

J.M. Beckers <i>Solar surface magnetism: quests for observations</i>	501
J. Rayrole, P. Mein, F. Cavallini <i>The THEMIS telescope</i>	507
M. Semel <i>THEMIS polarimetry</i>	509
B. Fleck, V. Domingo, A.I. Poland <i>SOHO: science objectives and capabilities</i>	517
Author index .....	525
Citation index .....	527
Subject index .....	535



## LIST OF PARTICIPANTS

Australia	
C.J. Durrant	Dept. of Applied Mathematics, University of Sydney
Canada	
V. Gaizauskas	Herzberg Institute of Astrophysics, Ottawa
Denmark	
Å. Nordlund	University Observatory, Copenhagen
France	
P. Mein	Observatoire de Paris, Meudon
R. Muller	Observatoire du Pic du Midi, Bagnères de Bigorre
B. Schmieder	Observatoire de Paris, Meudon
M. Semel	Observatoire de Paris, Meudon
Germany	
P. Caligari	Kiepenheuer-Institut für Sonnenphysik, Freiburg
F.-L. Deubner	Inst. für Astronomie und Astrophysik, Würzburg
A. Hofmann	Sonnenobservatorium Einsteinurm, Potsdam
W. Schmidt	Kiepenheuer-Institut für Sonnenphysik, Freiburg
M. Schüssler	Kiepenheuer-Institut für Sonnenphysik, Freiburg
H.C. Spruit	MPI für Physik und Astrophysik, Garching
J. Staude	Sonnenobservatorium Einsteinurm, Potsdam
Hungary	
K. Petrovay	Dept. Astronomy, Eötvös Loránd University, Budapest
Italy	
R. Falciani	Astronomy Department, University of Florence
E. Landi degl' Innocenti	Astronomy Department, University of Florence
G. Severino	Osservatorio Astronomico di Capodimonte, Napoli
The Netherlands	
B. Fleck	Space Science Department, ESTEC, Noordwijk
N.M. Hoekzema	Sterrekundig Instituut, Utrecht University
P. Hoyng	SRON Space Research Laboratory, Utrecht
P.C. Martens	Space Science Department, ESTEC, Noordwijk
R.J. Rutten	Sterrekundig Instituut, Utrecht University
C.J. Schrijver	Sterrekundig Instituut, Utrecht University
L.H. Strous	Sterrekundig Instituut, Utrecht University

C. Zwaan	Sterrekundig Instituut, Utrecht University
Norway	
P.E. Maltby	Inst. of Theoretical Astrophysics, University of Oslo
Spain	
F. Moreno Inertis	Instituto de Astrofisica de Canarias, La Laguna
J. Sanchez Almeida	Instituto de Astrofisica de Canarias, La Laguna
Switzerland	
C.U. Keller	Institut für Astronomie, ETH Zürich
S.K. Solanki	Institut für Astronomie, ETH Zürich
J.O. Stenflo	Institut für Astronomie, ETH Zürich
Ukraine	
E.A. Gurtovenko (deceased January 20, 1994)	Main Astronomical Observatory, Kiev
United Kingdom	
N.O. Weiss	Dept. Applied Math. Theor. Physics, Cambridge
USA	
A.A. van Ballegooijen	Center for Astrophysics, Cambridge MA
J.M. Beckers	National Solar Observatory, Tucson AZ
J.W. Harvey	National Solar Observatory, Tucson AZ
K.L. Harvey	Solar Physics Research Corp., Tucson AZ
R.F. Howard	National Solar Observatory, Tucson AZ
J.K. Lawrence	Dept. Physics & Astronomy, CSU, Northridge CA
S.F. Martin	Solar Astronomy, Caltech, Pasadena CA
E.N. Parker	Laboratory for Astrophysics, University of Chicago IL
D. Rabin	National Solar Observatory, Tucson AZ
N.R. Sheeley	Naval Research Laboratory, Washington DC
R.A. Shine	Lockheed Palo Alto Research Labs., Palo Alto CA
G.W. Simon	Phillips Lab., National Solar Observatory, Sunspot NM
A. Skumanich	High Altitude Observatory, NCAR, Boulder CO
J.H. Thomas	Dept. Physics and Astronomy, University of Rochester,
A.M. Title	Lockheed Palo Alto Research Labs., Palo Alto CA
H. Uitenbroek	Center for Astrophysics, Cambridge MA

Electronic mail addresses for these and for hundreds of other solar physicists are furnished by the Stanford SolarMail forwarding service. Information is obtained by sending an empty message to [solarmail@stanford.solar.edu](mailto:solarmail@stanford.solar.edu). An address list is obtained by sending an empty message to [maildir@solar.stanford.edu](mailto:maildir@solar.stanford.edu).

## Preface

Observations of the solar magnetic field are largely confined to the radiation emitted from the photosphere, the thin layer of the solar atmosphere which we call “the solar surface”. It is from solar surface observations that we must infer the internal structure and the internal magnetohydrodynamic processes that lead to the multitude of fascinating phenomena of solar magnetic activity, and from solar surface observations we must also infer the interplay of convection and magnetism that regulates field dispersal, drives the heating of the outer-atmospheric plasma, and generates the solar wind.

There is much to be learned from solar surface magnetism in physics and astrophysics; currently, there are rapid developments in this exciting field. The workshop of which this volume contains the proceedings aimed at a synthesis between observers and theorists, both with regard to the discrete elements that are the building blocks of solar magnetism and with regard to the larger-scale spatial and temporal patterns in which the magnetic elements emerge and disappear.

The workshop was held during November 1–5, 1993 in Soesterberg, The Netherlands. The fifty participants took a very active part in making the workshop quite a lively one. The articles in these proceedings cover most of the oral and poster presentations, excepting a dozen soon to be published elsewhere.

The organisation of this workshop and the editing of this volume has been a pleasure, thanks to wholehearted cooperation of many colleagues. Specifically, we thank our mentor in solar astrophysics, C. Zwaan, whose retirement shortly before the workshop, while an incentive to us, has fortunately not kept him from active research. J.W. Harvey and N.O. Weiss were valued members of the scientific organising committee. N.M.H. Hoekzema, L.H. Strous, E.B.J. van der Zalm and particularly Mrs. M. Wijburg have helped with the local organization, while Mrs. B. Gaizauskas, F.-L. Deubner, P. Mein, C. de Jager, M. Kuperus, R.H. Hammerschlag, C. Zwaan and (last but not least) Mrs. P.H.D. Zwaan-van Diggelen have provided entertainment of various sorts.

Finally, we are very grateful to NATO for funding this workshop. Its success demonstrates that NATO’s decision to terminate the general ARW programme, making this workshop its swansong in solar physics, is to be deplored indeed.

Robert J. Rutten and Carolus J. Schrijver  
Sterrekundig Instituut Utrecht, February 1994