

## COSMIC MAGNETIC FIELDS

Magnetic fields are important in the Universe and their effects contain the key to many astrophysical phenomena that are otherwise impossible to understand. This book presents an up-to-date overview of this fast-growing topic and its interconnections to plasma processes, astroparticle physics, high energy astrophysics, and cosmic evolution. The phenomenology and impact of magnetic fields are described in diverse astrophysical contexts within the Universe, from galaxies to galaxy clusters, the filaments and voids of the intergalactic medium, and out to the largest redshifts. The presentation of mathematical formulae is accessible and is designed to add insight into the broad range of topics discussed. Written for graduate students and researchers in physics, astrophysics, and related disciplines, this volume will inspire readers to devise new ways of thinking about magnetic fields in space on galaxy scales and beyond.

PHILIPP P. KRONBERG is Research Professor Emeritus at the University of Toronto, Canada and Visiting Scholar at Los Alamos National Laboratory. He has served on or chaired advisory and management boards of many organisations and facilities and has received numerous awards and distinctions including a Humboldt Award, a Guggenheim Fellowship, and a Killiam Fellowship. For over thirty years Kronberg has pioneered both measurements and physical and mathematical analyses to deduce astrophysical magnetic fields on many scales, from our Milky Way to the most distant quasars.

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## CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

[www.cambridge.org](http://www.cambridge.org)

Information on this title: [www.cambridge.org/9780521631631](http://www.cambridge.org/9780521631631)

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First published 2016

Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

*A catalogue record for this publication is available from the British Library*

*Library of Congress Cataloging in Publication Data*

Names: Kronberg, Philipp P., 1939-

Title: Cosmic magnetic fields / Philipp P. Kronberg, University of Toronto.

Description: Cambridge : Cambridge University Press, 2016. | Series: Cambridge astrophysics series ; 53 | Includes bibliographical references and index.

Identifiers: LCCN 2016000896 | ISBN 9780521631631 (hardback : alk. paper)

Subjects: LCSH: Cosmic magnetic fields. | Magnetic fields. | Astrophysics.

Classification: LCC QB462.8 .K76 2016 | DDC 523.01/88--dc23 LC record available at <http://lcn.loc.gov/2016000896>

ISBN 978-0-521-63163-1 Hardback

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This book is dedicated to my parents Philipp Kronberg and Jean Davidson Kronberg for  
their unwavering support of my career in astrophysics and radio astronomy  
and  
to my sons Paul, Martin, and Michael Kronberg for their constant encouragement in the  
writing of this book.

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## Preface

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Recent observational advances reveal the widespread existence of magnetic fields in the Universe, and produce much firmer estimates of magnetic field *strengths* in both interstellar space and some regions of intergalactic space. Microgauss-level fields are a common component of spiral galaxy disks and halos. Current measurements can detect magnetic fields, directly or indirectly, in the late universe of galaxies as far as “observational reach” can take us. This is at least to  $z \sim 3$ , and means that they have not globally changed into the past, that covers at least 90% of the lookback time to the origin of the Universe.

They appear to pervade the intracluster medium of clusters of galaxies, and indeed well beyond the cluster core regions. Strengths of ordered magnetic fields in the intracluster medium of cool core galaxy clusters exceed what is typical for the interstellar medium of the Milky Way. This challenges us to explain how they were first generated, and then regenerated to the unexpectedly high measured levels, and to answer the related question of how such widespread magnetic fields influenced the formation of stars and galaxies.

In this book I describe how extragalactic magnetic fields on different scales and in different astrophysical systems can be probed and measured. I also discuss some new methods which could be used to indirectly infer field strengths that are otherwise beyond the reach of direct measurement.

Some basic physical processes responsible for the regeneration of fields are outlined, including mechanisms of magnetic diffusivity and dissipation that influence field amplification. Fast dynamo processes associated with galaxy halo outflow and radio jets can demonstrably magnetise large volumes of intergalactic space; nonetheless, the mechanisms are far from completely understood. Fast-acting dynamo mechanisms appear to operate in galaxies through galaxy outflow, in extragalactic jets and lobes, and possibly in cooling flow clusters. Magnetic reconnection and related magnetohydrodynamic (MHD) processes may also be important.

Whether the intergalactic fields we now observe were originally produced in stars and galaxies, or in the pre-Recombination early Universe is a question with many ramifications, and increasingly discussed. It seems clear that stars and galaxies can seed and regenerate magnetic fields in various ways, post-Recombination. But magnetic fields may have also emerged earlier during Inflation, and perhaps integral to creation of the first subatomic particles as they emerged from the primordial “soup” in the course of enormous energy transfers.

Additional or colour-enhanced illustrations can also be found at the URL [www.cambridge.org/9780521631631](http://www.cambridge.org/9780521631631).

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## Acknowledgements

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I am especially grateful to Sharon Hanna for her invaluable advice and assistance in the preparation and checking of the manuscript. For figure drawing and improvement I am also indebted to Raul Cunha for his competent and cheerful assistance with the large and diverse range of illustrations.

I am indebted to the following colleagues, students, and friends for valued suggestions, checking, and assistance, and additional material: Felix Aharonian, Harjit S. Ahluwalia, Rainer Beck, Julia Becker-Tjus, Gregory Benford, Martin Bernet, Elly Berkhuijsen, Peter Biermann, Guido Birk, Robert Braun, Alan Bridle, Jo-Anne Brown, David Clarke, Stirling Colgate, Raul Cunha, William Daughton, Rod Davies, Eric Donovan, James Drake, Quentin Dufton, Andrew Fletcher, Ernst Fürst, Bryan Gaensler, Götz Golla, Salman Habib, Sharon Hanna, George Heald, Michael Hudson, Norbert Junkes, Karl-Heinz Kampert, Ulrich Klein, Arie König, Roland Kothes, Fritz Krause, Marita Krause, Russell Kulsrud, Harald Lesch, Hui Li, Kathleen Lindeman, Richard Lovelace, Francesco Miniati, Mark Morris, Masanori Nakamura, Andrii Neronov, Phyllis Orbaugh, Frazer Owen, Eugene Parker, Phil Perillat, Rick Perley, Judith Perry, Bharat Ratra, Martin Rees, Patricia Reich, Wolfgang Reich, Brian Reville, Bob Rosner, Vera Rubin, Marcin Sawicki, Michael Scarrott, Gerd Schrade, Herta Schrade, Anwar Shukurov, Martine Simard-Normandin, Dmitry Sokoloff, Todor Stanev, Andrew S. Taylor, John R. Taylor, Chris Thompson, Serap Tilav, Ronald Tucker, Gerrit Verschuur, Heinz Völk, Ievgen Vovk, Richard Wielebinski, Hao Xu, and Ellen Zweibel. The list would be incomplete without acknowledgement of, and gratitude to many graduate students and postdocs who have contributed significantly, directly or indirectly, to my own work on magnetic fields in space.

The writing of this book was made possible with grant support from the Natural Sciences and Engineering Research Council of Canada (NSERC). In addition to NSERC, I am also grateful to the Alexander von Humboldt Foundation, the Canada Council Killam Program, the Guggenheim Foundation, and Los Alamos National Laboratory for enabling many of my own research results over several years.