

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

Handbook of X-ray Astronomy

Modern X-ray data, available through online archives, are important for many astronomical topics. However, using these data requires specialized techniques and software. Written for graduate students, professional astronomers, and researchers who want to start working in this field, this book is a practical guide to X-ray astronomy.

The handbook begins with X-ray optics, basic detector physics, and charge-coupled devices, before focusing on data analysis. It introduces the reduction and calibration of X-ray data, scientific analysis, archives, statistical issues, and the particular problems of highly extended sources. The book describes the main hardware used in X-ray astronomy, emphasizing the implications for data analysis. The concepts behind common X-ray astronomy data analysis software are explained. The appendices present reference material often required during data analysis.

KEITH ARNAUD is at the Center for Research Excellence in Space Science and Technology, NASA Goddard Space Flight Center, and is an Associate Research Scientist in the Astronomy Department, University of Maryland. A veteran of X-ray astronomy, he is recognized worldwide as an expert on data analysis techniques.

RANDALL SMITH is an astrophysicist in the High Energy Astrophysics Division of the Smithsonian Astrophysical Observatory. He is internationally known for his work on spectral emission from astrophysical plasmas and the underlying issues of atomic physics.

ANETA SIEMIGINOWSKA is an astrophysicist in the High Energy Astrophysics Division of the Smithsonian Astrophysical Observatory. She has worked in both theoretical and observational aspects of X-ray astronomy with interests in extragalactic radio sources, quasars, powerful jets, and statistical methods.

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

Cambridge Observing Handbook for Research Astronomy

Today's professional astronomers must be able to adapt to use telescopes and interpret data at all wavelengths. This series is designed to provide them with a collection of concise, self-contained handbooks, which covers the basic principles peculiar to observing in a particular spectra region, or to using a special technique or type of instrument. The books can be used as an introduction to the subject and has a handy reference for use at the telescope, or in the office.

Series editors

Professor Richard Ellis, Department of Astronomy, *California Institute of Technology*

Professor Steve Kahn, Department of Physics, *Stanford University*

Professor George Rieke, Steward Observatory, *University of Arizona*, Tucson

Dr Peter B. Stetson, Herzberg Institute of Astrophysics, *Dominion Astrophysical Observatory*, Victoria, British Columbia

Books currently available in this series:

1. Handbook of Infrared Astronomy
I. S. Glass
3. Practical Statistics for Astronomers
J. V. Wall, C. R. Jenkins
4. Handbook of Pulsar Astronomy
D. R. Lorimer, M. Kramer
5. Handbook of CCD Astronomy, Second Edition
Steve B. Howell
6. Introduction to Astronomical Photometry, Second Edition
Edwin Budding, Osman Demircan
7. Handbook of X-ray Astronomy
Edited by Keith Arnaud, Randall Smith, and Aneta Siemiginowska

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

Handbook of X-ray Astronomy

Edited by

KEITH A. ARNAUD,^{1,2} RANDALL K. SMITH,³ AND
ANETA SIEMIGINOWSKA³

1. CRESST, NASA Goddard Space Flight Center

2. Astronomy Department, University of Maryland

3. Smithsonian Astrophysical Observatory



CAMBRIDGE
UNIVERSITY PRESS

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Tokyo, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9780521883733

© Cambridge University Press 2011

This publication 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 Cambridge University Press.

First published 2011

Printed in the United Kingdom at the University Press, Cambridge

A catalog record for this publication is available from the British Library

Library of Congress Cataloging in Publication data

Handbook of X-ray astronomy / edited by Keith A. Arnaud,
Randall K. Smith, Aneta Siemiginowska.

p. cm. – (Cambridge observing handbooks for research astronomers)
Includes index.

ISBN 978-0-521-88373-3 (hardback)

1. X-ray astronomy. I. Arnaud, Keith A., 1959– II. Smith, Randall K.
(Randall Knowles), 1969– III. Siemiginowska, Aneta.

IV. Title. V. Series.

QB472.H36 2011

522'.6863 – dc23 2011023034

ISBN 978-0-521-88373-3 Hardback

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party internet websites referred to in
this publication, and does not guarantee that any content on such websites is,
or will remain, accurate or appropriate.

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

Contents

	<i>List of contributors</i>	<i>page viii</i>
	Introduction	1
1	Optics	6
	<i>Schwartz</i>	
	1.1 Introduction	6
	1.2 X-ray reflection	7
	1.3 X-ray mirrors	10
	1.4 Diffraction gratings	18
	1.5 The future of X-ray optics	21
2	Detectors	23
	<i>Edgar</i>	
	2.1 X-ray detectors	23
	2.2 Proportional counters	24
	2.3 Gas scintillation proportional counters	33
	2.4 Scintillators	34
	2.5 Microchannel plates	35
	2.6 CZT detectors	37
	2.7 Microcalorimeters	37
3	Charge-coupled devices	39
	<i>Grant</i>	
	3.1 Introduction	39
	3.2 Basic principles and operation	40
	3.3 Performance	48
	3.4 Detector features	53
	3.5 Future X-ray imaging detectors	58

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

vi

Contents

4	Data reduction and calibration	59
	<i>Arnaud and Smith</i>	
4.1	The event file	59
4.2	Looking at the data	66
4.3	Selecting events of interest	68
4.4	Extracting analysis products	75
4.5	Calibration	78
5	Data analysis	86
	<i>Smith, Arnaud, and Siemiginowska</i>	
5.1	Introduction	86
5.2	Low-resolution spectral analysis	86
5.3	High-resolution spectral analysis	99
5.4	Imaging analysis	105
5.5	Timing analysis	108
6	Archives, surveys, catalogs, and software	114
	<i>Arnaud</i>	
6.1	Archives	114
6.2	Surveys and catalogs	117
6.3	Software	125
6.4	Calibration data	129
7	Statistics	131
	<i>Siemiginowska</i>	
7.1	Introduction	131
7.2	The statistical underpinning of X-ray data analysis	132
7.3	Probability distributions	133
7.4	Parameter estimation and maximum likelihood	134
7.5	Confidence bounds	137
7.6	Hypothesis testing and model selection	138
7.7	Statistical issues	141
8	Extended emission	146
	<i>Kuntz</i>	
8.1	Introduction	146
8.2	Backgrounds and foregrounds	148
8.3	Initial analysis	155
8.4	Spectral analysis	156
8.5	Image analysis	158
8.6	Mosaics	162

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)*Contents*

vii

Appendices

1	X-ray lines and edges <i>Smith</i>	163
2	Conversion tables <i>Smith</i>	170
3	Typical X-ray sources <i>Smith</i>	175
4	Major X-ray satellites <i>Smith</i>	178
5	Astrostatistics <i>Siemiginowska</i>	182
6	Acronyms	186
	<i>References</i>	190
	<i>Index</i>	195

Cambridge University Press

978-0-521-88373-3 - Handbook of X-ray Astronomy

Edited by Keith A. Arnaud, Randall K. Smith and Aneta Siemiginowska

Frontmatter

[More information](#)

Contributors

Daniel A. Schwartz, Harvard-Smithsonian Center for Astrophysics,
60 Garden Street, Cambridge, USA, MA 02138

Richard J. Edgar, Harvard-Smithsonian Center for Astrophysics, 60 Garden
Street, Cambridge, USA, MA 02138

Catherine E. Grant, MIT Kavli Institute for Astrophysics and Space
Research, 77 Massachusetts Avenue, Cambridge, USA, MA 02139

Keith A. Arnaud, NASA Goddard Space Flight Center, Code 662, Greenbelt,
USA, MD 20771

Randall K. Smith, Harvard-Smithsonian Center for Astrophysics, 60 Garden
Street, Cambridge, USA, MA 02138

Aneta Siemiginowska, Harvard-Smithsonian Center for Astrophysics,
60 Garden Street, Cambridge, USA, MA 02138

K. D. Kuntz, JHU Department of Physics & Astronomy, 3400 N. Charles
Street, Baltimore, USA, MD 21218