



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 extra-galactic radio sources, quasars, powerful jets, and statistical methods.

Cover illustration (front inset): Perseus A. Credit: X-ray: NASA/CXC/IoA/A. Fabian *et al.*; radio: NRAO/VLA/G. Taylor; optical: NASA/ESA/Hubble Heritage (STScI/AURA) and University of Cambridge/IoA/A. Fabian; (back insets): M87. Credit: NASA/CXC/W. Forman *et al.*; Zeta Orionis. Credit: NASA/EIT/W. Waldron, J. Cassinelli; launch of the Suzaku X-ray astronomy satellite. Credit F. S. Porter.

CAMBRIDGE
UNIVERSITY PRESS
www.cambridge.org

ISBN 978-0-521-88373-3



9 780521 883733 >

	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

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

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