



Astronomy needs statistical methods to interpret data, but statistics is a many-faceted subject that is difficult for non-specialists to access. This handbook helps astronomers analyze the complex data and models of modern astronomy.

This Second Edition has been revised to feature many more examples using Monte Carlo simulations, and now also includes Bayesian inference, Bayes factors and Markov chain Monte Carlo integration. Chapters cover basic probability, correlation analysis, hypothesis testing, Bayesian modelling, time series analysis, luminosity functions and clustering. Exercises at the end of each chapter guide readers through the techniques and tests necessary for most observational investigations. The data tables, solutions to problems, and other resources are available online at [www.cambridge.org/9780521732499](http://www.cambridge.org/9780521732499).

Bringing together the most relevant statistical and probabilistic techniques for use in observational astronomy, this handbook is a practical manual for advanced undergraduate and graduate students and professional astronomers.

#### Reviews from the First Edition:

"The book is unusual for its application to astronomy and outstanding for its explanation of basic statistical concepts. Highly recommended." *Choice*

"Interesting and informative if read cover-to-cover; can be easily dipped into for that single must-have piece of information; and is comprehensive within its well-defined remit...The result is a neat little book that's a pleasure to read and a blessing to have handy for reference." *Ian D. Howarth, The Observatory*

Cover illustration: the background image shows the Gemini North telescope, courtesy of Larry Stepp, Gemini Observatory, AURA, NSF and NOAO. Cover insets courtesy of D. Clowe *et al.* and the AAS; ESA and the Planck Mission Team; N. Suzuki *et al.*, the Supernova Cosmology Project Team and the AAS; E. Komatsu *et al.*, the WMAP team, the NASA GSFC public archive and the AAS.

**CAMBRIDGE**  
UNIVERSITY PRESS  
[www.cambridge.org](http://www.cambridge.org)

ISBN 978-0-521-73249-9



9 780521 732499 >

<i>Foreword to first edition</i>	<i>page</i> xiii
<i>Foreword to second edition</i>	xv
<i>Note on notation</i>	xvii
<b>1 Decision</b>	<b>1</b>
1.1 How is science done?	4
1.2 Probability; probability distributions	6
1.3 Bolt-on statistics?	7
1.4 Probability and statistics in inference: an overview of this book	8
1.5 How to use this book	17
<b>2 Probability</b>	<b>20</b>
2.1 What is probability?	21
2.2 Conditionality and independence	24
2.3 ... and Bayes' theorem	26
2.4 Probability distributions	33
2.5 Bayesian inferences with probability	46
2.6 Monte Carlo generators	48
<b>3 Statistics and expectations</b>	<b>55</b>
3.1 Statistics	55
3.2 What should we expect of our statistics?	59
3.3 Simple error analysis	61
3.4 Some useful statistics, and their distributions	66
3.5 Uses of statistics	68
<b>4 Correlation and association</b>	<b>71</b>
4.1 The fishing trip	71

4.2	Testing for correlation	74
4.3	Partial correlation	83
4.4	But what next?	84
4.5	Principal component analysis	86
<b>5</b>	<b>Hypothesis testing</b>	<b>92</b>
5.1	Methodology of classical hypothesis testing	94
5.2	Parametric tests: means and variances, $t$ and $F$ tests	96
5.3	Non-parametric tests: single samples	106
5.4	Non-parametric tests: two independent samples	113
5.5	Summary, one- and two-sample non-parametric tests	119
5.6	Statistical ritual	121
<b>6</b>	<b>Data modelling and parameter estimation: basics</b>	<b>126</b>
6.1	The maximum-likelihood method	128
6.2	The method of least squares: regression analysis	134
6.3	The minimum chi-square method	138
6.4	Weighting combinations of data	141
6.5	Bayesian likelihood analysis	142
6.6	Bootstrap and jackknife	147
<b>7</b>	<b>Data modelling and parameter estimation: advanced topics</b>	<b>151</b>
7.1	Model choice and Bayesian evidence	151
7.2	Model simplicity and the Ockham factor	153
7.3	The integration problem	154
7.4	Pitfalls in model choice	157
7.5	The Akaike and Bayesian information criteria	159
7.6	Monte Carlo integration: doing the Bayesian integrals	160
7.7	The Metropolis–Hastings algorithm	161
7.8	Computation of the evidence by MCMC	166
7.9	Models of models, and the combination of data sets	170
7.10	Broadening the range of models, and weights	173
7.11	Press and Kochanek’s method	176
7.12	Median statistics	180
<b>8</b>	<b>Detection and surveys</b>	<b>182</b>
8.1	Detection	183
8.2	Catalogues and selection effects	189
8.3	Luminosity functions	196
8.4	Tests on luminosity functions	208
8.5	Survival analysis	211
8.6	The confusion limit	224

<b>9</b>	<b>Sequential data – 1D statistics</b>	<b>230</b>
9.1	Data transformations, the Karhunen–Loeve transform, and others	231
9.2	Fourier analysis	234
9.3	Filtering	241
9.4	Correlating	247
9.5	Unevenly sampled data	252
9.6	Wavelets	254
9.7	Detection difficulties: $1/f$ noise	257
<b>10</b>	<b>Statistics of large-scale structure</b>	<b>262</b>
10.1	Statistics on a spherical surface	262
10.2	Sky representation: projection and contouring	265
10.3	The sky distribution	268
10.4	Two-point angular correlation function	269
10.5	Counts in cells	275
10.6	The angular power spectrum	281
10.7	Galaxy distribution statistics: interpretation	287
<b>11</b>	<b>Epilogue: statistics and our Universe</b>	<b>291</b>
11.1	The galaxy universe	291
11.2	The weak lensing universe	301
11.3	The cosmic microwave background universe	307
	<i>Appendix A The literature</i>	316
	<i>Appendix B Statistical tables</i>	321
	<i>References</i>	335
	<i>Index</i>	347