

X-RAY BINARIES

Edited by

WALTER H. G. LEWIN

Department of Physics, Massachusetts Institute of Technology

JAN VAN PARADIJS

*Astronomical Institute 'Anton Pannekoek', University of Amsterdam,
Center for High-Energy Astrophysics, Amsterdam, and
Physics Department, University of Alabama in Huntsville*

and

EDWARD P. J. VANDEN HEUVEL

*Astronomical Institute 'Anton Pannekoek', University of Amsterdam,
Center for High-Energy Astrophysics, Amsterdam*



CAMBRIDGE
UNIVERSITY PRESS

Contents

<i>Preface</i>	<i>page xi</i>
1 The properties of X-ray binaries	
<i>N. E. White, F. Nagase and A. N. Parmar</i>	
1.1 Introduction	1
1.2 Orbital periods	3
1.3 Pulse periods	18
1.4 Third periods and other modulations	25
1.5 The emission region	27
1.6 Environmental radiative processes	38
References	49
2 Optical and ultraviolet observations of X-ray binaries	
<i>J. van Paradijs and J. E. McClintock</i>	
2.1 Introduction	58
2.2 High-mass X-ray binaries	59
2.3 Low-mass X-ray binaries	73
2.4 Neutron star and black-hole masses	107
2.5 The Magellanic Cloud sources	113
2.6 Triple-star systems	117
References	121
3 Black-hole binaries	
<i>Y. Tanaka and W.H.G. Lewin</i>	
3.1 Some historic notes	126
3.2 Introduction	127
3.3 Description of the individual black-hole candidates	134
3.4 X-ray spectra – interpretations	159
3.5 BHC diagnostics	164
3.6 How many black-hole binaries are there?	167
References	168
4 X-ray bursts	
<i>Walter H. G. Lewin, Jan Van Paradijs and Ronald E. Taam</i>	
4.1 Introduction	175

4.2 Characteristics of burst sources	177
4.3 Type I X-ray bursts	178
4.4 Mass–radius relation of neutron stars	199
4.5 Theory of type I X-ray bursts	201
4.6 The Rapid Burster (1730–335)	211
4.7 Models for the Rapid Burster	222
References	228
5 Millisecond pulsars	
<i>D. Bhattacharya</i>	233
5.1 Overview	233
5.2 The general characteristics of millisecond pulsars	234
5.3 Spin-up of neutron stars and the origin of millisecond pulsars	236
5.4 Evolution of LMXBs: the standard model	238
5.5 Statistics	240
5.6 Evolution of LMXBs: beyond the standard model	243
5.7 Pulsars in globular clusters	245
5.8 Future prospects	248
References	249
6 Rapid aperiodic variability in X-ray binaries	
<i>M. van der Klis</i>	252
6.1 Introduction	252
6.2 Black-hole candidates	259
6.3 Z and atoll sources	274
6.4 Other sources	289
6.5 Overview and outlook	295
References	300
7 Radio properties of X-ray binaries	
<i>R. M. Hjellming and X. Han</i>	308
7.1 Introduction	308
7.2 Transient radio emission	313
7.3 Coupled radio–optical–UV–X-ray state changes	315
7.4 Radio jets and extended radio emission	320
7.5 Other models of compact radio emission from X-ray binaries	324
7.6 Acceleration of relativistic electrons	326
7.7 Conclusions	328
References	329
8 Cataclysmic variable stars	
<i>France Anne-Dominic Córdova</i>	331
8.1 Introduction	331
8.2 What multiwavelength observations reveal	337
8.3 The variability of CVs and its origins	360
8.4 The importance of magnetic fields in CVs	373

8.5 CV evolution	378
8.6 Endpiece: areas for future studies	381
References	384
9 Normal galaxies and their X-ray binary populations	
<i>G. Fabbiano</i>	390
9.1 Introduction	390
9.2 X-ray sources in Local Group galaxies	391
9.3 Other spiral galaxies: detecting the upper end of the luminosity distribution of X-ray sources	398
9.4 The X-ray emission of galaxies: a very brief summary	404
9.5 Recent spectral results	405
9.6 The future	410
References	416
10 Accretion in close binaries	
<i>Andrew King</i>	419
10.1 Introduction	419
10.2 Summary of accretion disc theory	419
10.3 Disc structure in LMXBs	423
10.4 Disc instabilities	427
10.5 Tides, resonances and superhumps	430
10.6 Spiral shocks	437
10.7 Coronae and winds in discs	438
10.8 Boundary layers	438
10.9 Accretion from a wind	441
10.10 Accretion on to a magnetic star	444
References	453
11 Formation and evolution of neutron stars and black holes in binaries	
<i>F. Verbunt and E. P. J. van den Heuvel</i>	457
11.1 Introduction and brief observational overview	457
11.2 Origin and evolution of high-mass X-ray binaries	464
11.3 Origin and evolution of low-mass X-ray binaries	476
11.4 X-ray sources in globular clusters	486
11.5 Statistical considerations	488
References	492
12 The magnetic fields of neutron stars and their evolution	
<i>D. Bhattacharya and G. Srinivasan</i>	495
12.1 Introduction	495
12.2 Estimation of the magnetic field	496
12.3 The origin and structure of the magnetic field	499
12.4 Evolution of the magnetic field	503
12.5 Possible mechanisms for field decay	513
12.6 Some consequences of field evolution	518

Appendix. Interaction between fluxoids and vortices	520
References	521
13 Cosmic gamma-ray bursts	
<i>K. Hurley</i>	523
13.1 Foreword	523
13.2 Introduction	523
13.3 Time histories	524
13.4 X- and gamma-ray energy spectra	526
13.5 Counterparts and lack thereof	528
13.6 Statistical properties of gamma-ray bursters	529
13.7 The great debate redux	532
References	533
14 A catalogue of X-ray binaries	
<i>Jan van Paradijs</i>	536
15 A compilation of cataclysmic binaries with known or suspected orbital periods	
<i>Hans Ritter and Ulrich Kolb</i>	578
References	579
<i>Index</i>	639