



Introduction to
**High-Energy
Astrophysics**

Stephan Rosswog
and **Marcus Brüggen**

CAMBRIDGE

Contents

<i>Preface</i>	<i>page</i>	<i>ix</i>
1 Special relativity		1
1.1 Introduction		1
1.2 Lorentz transformations		2
1.3 Special relativistic effects		3
1.4 Basics of tensor calculus		8
1.5 Invariance of the phase space volume		20
1.6 Relativistic electrodynamics		21
1.7 Exercises		23
1.8 Further reading		26
2 Gas processes		27
2.1 Collisions		27
2.2 Ionization		34
2.3 Transport processes		38
2.4 Equations of fluid dynamics		40
2.5 Equation of state		43
2.6 Bernoulli's equation		46
2.7 Shock waves		46
2.8 Shock acceleration		51
2.9 Fluid instabilities		56
2.10 Exercises		60
2.11 Further reading		63
3 Radiation processes		64
3.1 Introduction		64
3.2 Basic photon properties and spectrum		65
3.3 Basic definitions		67
3.4 Basics of radiative transfer		72
3.5 Summary of blackbody radiation		76

3.6	Radiative transitions	82
3.7	Radiation from moving charges	84
3.8	Individual radiation processes	96
3.9	Exercises	111
3.10	Further reading	113
4	Supernovae	115
4.1	Observational overview and classification of supernovae	115
4.2	Type II supernovae	122
4.3	Type Ia supernovae	135
4.4	Supernova remnants	142
4.5	Exercises	157
4.6	Further reading	159
5	Neutron stars, pulsars, and magnetars	161
5.1	History	161
5.2	Observational properties of pulsars	162
5.3	Why rotating neutron stars?	167
5.4	The magnetic dipole model	169
5.5	The stellar structure equations	173
5.6	The equation of state of neutron stars	177
5.7	Realistic neutron stars	184
5.8	Observational tests of the neutron star structure	188
5.9	Magnetars	194
5.10	Exercises	200
5.11	Further reading	202
6	Compact binary systems	204
6.1	Introduction	204
6.2	Dynamics in a binary system	204
6.3	X-ray binary systems	219
6.4	Double neutron star systems	232
6.5	Exercises	240
6.6	Further reading	241
7	Gamma-ray bursts	243
7.1	Introduction	243
7.2	Observed properties	244
7.3	Constraints on the central engine	258
7.4	The fireball model	265
7.5	The central engine	268
7.6	Exercises	277
7.7	Further reading	278
8	Active galactic nuclei	280

8.1	Introduction	280
8.2	Observational facts	283
8.3	What powers active galactic nuclei?	291
8.4	Basic ingredients of an AGN	300
8.5	Cosmological significance of AGN	332
8.6	Exercises	333
8.7	Further reading	336
Appendix A	Some recent high-energy astrophysics instruments	337
A.1	AMANDA and IceCube	337
A.2	ASCA	338
A.3	BEPPoSAX	338
A.4	CGRO	339
A.5	CHANDRA	339
A.6	H.E.S.S.	340
A.7	HETE-2	340
A.8	INTEGRAL	341
A.9	Pierre Auger Observatory	341
A.10	RXTE	342
A.11	SUZAKU	342
A.12	SWIFT	343
A.13	VLA	343
A.14	Very Long Baseline Interferometry	343
A.15	XMM-NEWTON	344
Appendix B	Physical constants	345
Appendix C	Distances	347
Appendix D	Luminosity, brightness, magnitude, color	348
<i>Index</i>		351