STELLAR COLLAPSE

Edited by

CHRIS L. FRYER
Los Alamos National Laboratory,
Los Alamos, NM, U.S.A.
and
University of Arizona
Tucson, AZ, U.S.A.

KLUWER ACADEMIC PUBLISHERS
DORDRECHT / BOSTON / LONDON
Dedication

List of Figures xiii
List of Tables xvii
Contributing Authors xix
Preface xxiii
Foreword xxv
1. The light Problem xxvii
2. How I view the Present Problem xxviii
3. Justification of this View xxviii
Acknowledgments xxxi

Part I Core-Collapse Supernovae

Introduction 3

Chris Fryer

1 Massive Star Evolution 5

Patrick A. Young and David Arnett

1. Introduction 5
2. Useful Concepts 7
3. Formation and IMF 8
4. Hydrogen Burning 11
5. He Burning 16
6. LBVs and Wolf-Rayets 18
7. C and Ne Burning 22
8. O and Si Burning 24
9. Pop III stars 26
10. Supermassive Stars and Pair Instability 29
11. Pre-supernova State 30
12. Modelling Issues 32
13. Current Work 35
References 35
Contents

8. Nucleon–Nucleon Bremsstrahlung 166
9. Conclusion 170

Acknowledgments
References 171

6
Protoneutron Star Winds 175

Todd A. Thompson

1. Introduction 175
2. Hydrodynamics 181
3. Particulars of Protoneutron Star Winds 185
4. Results: Spherical Models 188
5. Magnetic Protoneutron Star Winds 192
6. Summary, Conclusions, & Implications 198

Acknowledgments
References 198

Part II Asymmetries in Collapse, Beyond the Basic Supernova Mechanism

Introduction 205

Chris Fryer

7
Radioactive Decay in Core-Collapse Supernovae 207

Aimee L. Hungerford

1. Supernova 1987A 209
2. Cassiopeia A Supernova Remnant 210
3. 3D γ-Ray Simulations 215
4. Conclusions 233
References 234

8
Asymmetric Supernova Explosions 237

P. H"oflich, L. Wang, A. Khokhlov

1. Introduction 238
2. Models for Collapse Supernova 238
3. Observational Evidence for Asymmetry 241
4. Numerical Methods 242
5. Results for Jet-Induced Supernovae 249
6. Conclusions 254
References 256

9
Magnetic Fields in Supernovae 259

Shizuka Akiyama, J. Craig Wheeler
1. The Magneto-Rotational Instability  
2. Discussion and Conclusions 

Acknowledgments  
References

10  
Hypernovae and Other Black-Hole-Forming Supernovae 

Ken'ichi Nomoto, 1,2 Keiichi Maeda, 1 Paolo A. Mazzali, 2,3 Hideyuki Umeda, 1 Jinsong Deng, 1,2 Koichi Iwamoto, 4 

1. Introduction  278 
2. SN 1998bw and GRB980425  
3. SN 1997ef  
4. SN 2002ap  
5. SN 1999as  
6. Type IIn Hypernova: SN 1997cy and SN 1999E  
7. Properties of Hypernovae  
8. Possible Evolutionary Scenarios to Hypernovae  
9. Explosive Nucleosynthesis in Hypernovae  
10. Extremely Metal-Poor (EMP) Stars and Faint Supernovae  
11. The First Stars  
12. Concluding Remarks  

Acknowledgments  320 
References  321

11  
Collapsars 

Weiqun Zhang and, Chris L. Fryer 

1. Introduction  327 
2. Collapsar Progenitor Models  
3. Disk Formation and Accretion Energy  
4. Jets  

Acknowledgments  353 
References  353

12  
Gamma-Ray Bursts from Supernovae 

Christopher D. Matzner 

1. Introduction: Brief review of GRB properties  357 
2. Hydrodynamic shock acceleration and weak GRBs  
3. Baryon removal  
4. Conclusions  

References  371

13  
Stellar collapse and gravitational waves 

Chris L. Fryer, Daniel E. Holz, Scott A. Hughes and, Michael S. Warren
# Contents

1. Introduction 373  
2. GWs and detectors: overview 375  
3. GW emission mechanisms 385  
4. Results for GW emission 392  
5. Summary & concluding thoughts 398  

Acknowledgments 400  
References 400  

Index 403