TABLE OF CONTENTS

PREFACE xi

CHAPTER 16: Formation of the Sun and its Planets – WILLIAM M. KAULA 1
1. Introduction 1
2. Star Formation 2
2.1. Galactic Structure 2
2.2. Stellar Properties 3
2.3. Planetary Indications 4
2.4. Interstellar Clouds 4
2.5. Observations of Forming Stars 4
2.5.1. T-Tauri Variable Stars 5
2.5.2. Nonemission, Nonvariable Pre-Main Sequence (PMS) Stars 5
2.5.3. Herbig–Haro Objects 5
2.6. Conditions for Cloud Collapse 6
2.7. Models for Star Formation 7
2.8. Modeling of Secondary Features 10
2.9. Dynamical Evolution 11
3. Cosmochemistry 11
3.1. Chronology 12
3.2. Nuclide Variations 14
3.3. Chemical Variations Among Chondritic Meteorites 17
3.4. Chemical Variations Among Differentiated Objects 18
4. Planet Formation 19
4.1. *gd* Gas-Dust Interaction 20
4.2. *CD* Disk Dynamics 20
4.3. *Cpp* Planetesimal Swarms 22
4.4. *CPD* Planet-Disk Interactions 23
4.5. *CPP, CPPp* Planetary Systems 24
4.6. *CP(f, s)p* Terrestrial Planet Formation 25
4.7. *P, Pg* Gaseous Protoplanet Contraction 25
4.8. *WD, XD, BD* Solar and External Effects on the Nebula 26
5. Implications for the Formation of the Sun and Planets 27
Acknowledgement 27
References 28

CHAPTER 17: The Solar Neutrino Problem: Gadfly for Solar Evolution Theory – MICHAEL J. NEWMAN 33
1. Introduction 33
2. Standard Theory of Solar Evolution 34
3. The Missing Solar Neutrinos 35

4. Have We Left Something Out? 36
4.1. Microscopic Physics 36
4.2. Rotation 36
4.3. Magnetic Fields 37
4.4. Accretion 37
4.5. Star Formation 38
5. The Exotic Models 39
5.1. Mixing 39
5.2. Varying G 40
5.3. Quark Catalysis 40
5.4. Depleted Maxwell Tail 40
5.5. Immiscible H–He 41
5.6. The Central Black Hole 41
5.7. Nonconventional Energy Transport 41
6. Conclusions 42
Acknowledgements 43
References 43

CHAPTER 18: Stellar Chromospheres, Coronae, and Winds – J. P. CASSINELLI and K. B. MacGREGOR 47
1. Introduction 47
2. Late-Type Stars 50
2.1. Introduction 50
2.1.1. Overview 50
2.1.2. The Solar Case 50
2.1.3. Methodology 54
2.2. Observational Evidence for the Presence of Chromospheres in Late-Type Stellar Atmospheres 54
2.2.1. Spectral Diagnostics and Line Formation 54
2.2.2. Observational Summary and Location in the H–R Diagram 58
2.2.3. The Wilson-Bappu Effect 61
2.3. Observational Evidence for the Presence of Regions and Coronae in Late-Type Stellar Atmospheres 64
2.3.1. Transition Regions 64
2.3.2. Coronae 67
2.4. Chromospheric and Coronal Heating Mechanisms 70
2.4.1. Overview 70
2.4.2. Acoustic Wave Heating 70
2.4.3. Magnetic Heating Mechanisms 74
2.5. Observational Evidence for Mass Loss from Late-Type Stars 76
2.5.1. Main Sequence Stars 76
2.5.2. Circumstellar Absorption Lines 77
2.5.3. Chromospheric Emission Line Asymmetries 79
2.5.4. Circumstellar Dust Shells 81
2.5.5. Summary 83

2.6. Mass Loss Mechanisms for Late-Type Giants and Supergiants 84
2.6.1. Overview 84
2.6 2. Thermally Driven Winds 86
2.6.3. Radiation Driven Winds 87
2.6.4. Wave Driven Winds 88
3. The Winds and Coronae of Early-Type Stars 89
3.1. Introduction 89
3.2. The Velocity and Mass Loss Rates Derived from Line and Continuum Observations 92
3.2.1. The Formation of P Cygni Profiles 93
3.2.2. The Free-Free Continuum Energy Distribution of Hot Stars 97
3.3. Coronal Gas in Early-Type Stars 99
3.3.1. Superionization of the Winds 99
3.3.2. X-Ray Observation of Early-Type Stars 101
3.4. Wind Dynamics 104
3.4.1. Radiation Forces on Line Opacity: Momentum Deposition Considerations 105
3.4.2. Radiative Acceleration 106
3.4.3. Instability of Line Driven Winds and the Consequences 110
3.4.4. Hybrid Models with a Base Coronal Zone 112
3.4.5. Magnetically Driven Winds and Magnetically Dominated Coronae 113
Acknowledgements 115
References 115

CHAPTER 19: Solar and Stellar Magnetic Activity – ROBERT W. NOYES 125
1. Introduction 125
2. Solar and Stellar Magnetic Activity: A Phenomenological Comparison 127
2.1. Surface Magnetic Fields and their Effects on Stellar Radiative Flux 127
2.2. Direct Detection of Magnetic Fields on Stars Like the Sun 132
2.3. Ca II H and K Emission as Indicators of Stellar Magnetic Fields 133
2.4. Coronal Active Regions 136
2.5. Magnetic Activity Cycles 138
3. The Rotation/Activity/Age Connection 140
3.1. The Aging of Magnetic Activity and Rotation 140
3.2. Rotation as the Fundamental Determinant of Magnetic Activity 141
3.3. The Influence of Convection Zone Properties 143
3.4. The Vaughan-Preston Gap 144
3.5. The Evolution of Rotation and Magnetic Activity on the Sun 146
4. Avenues for Future Research 147
4.1. Observational Studies of Solar Magnetic Activity 148
4.2. Observational Studies of Stellar Magnetic Activity 149
4.3. Theoretical Studies 150
Acknowledgements 150
References 150

CHAPTER 20: Effects of Solar Electromagnetic Radiation on the Terrestrial Environment – ROBERT E. DICKINSON 155
1. Introduction 155
2. Atmospheric Structure and Composition 158
2.1. Thermosphere 158
2.2. Stratosphere and Mesosphere Structure 160
2.3. Stratosphere and Mesosphere Chemistry 162
2.4. Tropospheric Chemistry 164
3. The Climate System 167
3.1. Current Questions 167
3.2. Introduction to Simple Climate Models 167
3.3. Tapping of Thermal Radiation by Atmospheric Constituents 170
3.4. Thermal Feedback by Clouds and Water Vapor 172
3.5. Anthropogenic Modulation of Trace Gases Important for Climate 175
3.6. Atmospheric and Oceanic Circulation and the Seasons 177
3.7. Primitive Climate, the Carbon Cycle and the Faint-Early-Sun 178
4. Solar Radiation Drives the Biosphere 178
4.1. Origins of Photosynthesis 178
4.2. Photosynthesis in Action 181
4.3. Harvesting the Sunlight, Net Primary Productivity 184
5. Concluding Remarks 187
Acknowledgements 189
References 189

CHAPTER 21: The Effect of the Solar Wind on the Terrestrial Environment – N. U. CROOKER and G. L. SISCOE 193
1. Introduction 193
2. General Morphology 194
3. Solar Wind and Geomagnetic Activity 195
3.1. Solar Wind Streams 195
3.2. Geomagnetic Response to Streams 201
3.3. Periodic Geomagnetic Activity 207
3.3.1. Geomagnetic Pulsations 207
3.3.2. Diurnal and Annual Variations 208
3.3.3. Solar Cycle and Longer Period Variations 211
4. Transfer Mechanisms at the Magnetopause 212
4.1. Magnetic Merging 213
4.2. Other Mechanisms 220
4.3. Composite Model 220
5. Magnetospheric Convection 222
5.1. Convection Morphology 222
5.2. Birkeland Currents, Alfvén Layers, and Shielding 224
5.3. The Plasmasphere: a Convection/Corotation Forbidden Zone 226
5.4. Time Dependent Convection – The Substorm Cycle 227
5.5. Computer Modeling of Convection 228
5.6. Convection and Magnetic Merging in the Magnetotail 232

6. Magnetosphere Effects on the Ionosphere and Thermosphere 238
6.1. Low-Latitude Electric Fields and Currents 238
6.2. Parallel Electric Fields 239
6.3. Ionospheric Outflow 241
6.4. Effects on Thermosphere 242
7. Middle and Lower Atmosphere 243
Acknowledgements 244
References 244

CHAPTER 22: Solar Energetic Particles and their Effects on the Terrestrial Environment – GEORGE C. REID 251
1. Introduction 251
2. Solar Energetic Particles and the Magnetosphere 252
3. Energy Loss Processes 254
3.1. Polar Cap Absorption 254
3.2. Ion Chemistry of the Middle Atmosphere: Influence of Solar Energetic Particles 255
3.3. Polar Glow Aurora: Optical Effects of Solar Energetic Particle Precipitation 260
4. Atmospheric Alterations and Nuclear Interactions 261
4.1. Alterations in Middle-Atmospheric Composition 261
4.2. Nuclear Interactions and C^{14} Production 267
5. Effects of Solar Particle Events 268
5.1. Effects on Radio Communication and Navigation 268
5.2. Effects on Global Atmospheric Electricity 271
5.3. Potential Impact on Climate 273
5.4. Solar Energetic Particles and the Evolution of the Atmosphere and Biosphere 274
6. Conclusion 275
References 276

INDEX 279