

Contents

Magnetic Fields in the Early Universe

<i>Martin J. Rees</i>	1
1 Introduction	1
2 Magnetic Fields from the Ultra-Early Universe?	2
3 Protogalactic Batteries	4
4 Magnetic Fields from the First Stars	5
5 AGNs and Radio Lobes	6
6 Summary	7
References	7

Magnetic Fields in Galaxy Systems, Clusters and Beyond

<i>Philipp P. Kronberg</i>	9
1 Introduction and Background	9
2 Stellar Sources of Extragalactic Magnetic Fields	10
3 Early Plasma-driven Seeding Scenarios	14
4 The Galactic Large-scale $\alpha - \Omega$ Dynamo Theory	14
5 Proxy Measurements for Cosmologically Early, Star-ejected Magnetic Fields	15
6 Post-amplification of Initially Weak Intergalactic Seed Fields of All Kinds	16
7 Massive Black Hole Seeding of Intergalactic Magnetic Fields	17
8 Gravitational Collapse and Black Hole Electromagnetic Energy Generators	21
9 Radio Galaxies as ‘Calorimeters’ of BH-injected Magnetic Fields and CR’s	24
10 Magnetic Fields in Clusters of Galaxies	26
11 Probes of Magnetic Fields at Larger Redshifts, Beyond Galaxies and Clusters	32
12 Summary	37
References	37

Magnetic Fields in Galaxies

Rainer Beck 41

1 Introduction 41

2 Observing Extragalactic Magnetic Fields 41

3 Measuring Magnetic Field Strengths 43

4 Magnetic Fields and Gas Clouds 45

5 Magnetic Field Structure 47

6 Dynamos 53

7 Magnetic Fields in Flocculent and Irregular Galaxies 55

8 Magnetic Fields in Barred Galaxies 56

9 Halos 59

10 Interacting Galaxies 61

11 Spiral Galaxies with Jets 63

12 Outlook 64

References 65

The Origin of Galactic Magnetic Fields

Russel M. Kulsrud 69

1 Introduction 69

2 The Alpha–Omega Disc Dynamo 70

3 Evolution of a Primordial Magnetic Field 75

4 The Protogalactic Dynamo 82

5 Conclusion 87

References 88

**Magnetic Fields in the Milky Way, Derived
from Radio Continuum Observations
and Faraday Rotation Studies**

Richard Wielebinski 89

1 Introduction 89

2 Observational Rationale 90

3 The Earliest Observations 93

4 Radio Continuum Surveys of the Milky Way 94

5 Surveys of Rotation Measure
of Extragalactic Radio Sources (EGRS) 102

6 Pulsars as Probes
of the Magnetic Fields of the Galaxy 104

7 The Magnetic Fields of the Milky Way 105

References 108

**Mesoscale Magnetic Structures
in Spiral Galaxies**

Anvar Shukurov 113

1 Introduction 113

2 Observational Evidence for Magnetic Reversals 114

3 Global Reversals 117

4 Localized Reversals 123

5 Magnetic Arms 125

6 Conclusions 133

References 133

**Magnetic Fields in Diffuse H I
and Molecular Clouds**

Carl Heiles, Richard Crutcher 137

1 Introduction 137

2 Measuring the Magnetic Field
in Diffuse H I and Molecular Clouds 139

3 Observed vs. Intrinsic Probability Density Functions 146

4 $B_{||}$ from H I Absorption Lines 153

5 $B_{||}$ from H I Emission Lines 157

6 Importance of Magnetic Fields in Molecular Clouds 163

7 Molecular Cloud Observational Results 164

8 Model Predictions and Observational Tests 170

9 Magnetic Field Observations, Present and Future 176

References 179

Stellar Magnetic Fields

Leon Mestel, John D. Landstreet 183

1 Stellar Magnetism 183

2 Magnetism and Star Formation 188

3 Pre-main Sequence Stars: Observation and Theory 191

4 The Main-sequence: Late-type Stars 193

5 The Main Sequence: Early-type Stars 200

6 The Early-type Magnetic Stars:
Basic Theoretical Questions 207

7 Giant Stars 211

8 Degenerate Stars 212

References 213

Importance of Magnetic Helicity in Dynamos

Axel Brandenburg 219

1 Introduction 219

2 Dynamos in a Periodic Box 221

3 Magnetic Helicity Evolution 223

4 What Do Stars and Galaxies Do Differently? 228

5 Connection with the α Effect 235

6 What about η Quenching? 244

7 Conclusions 250

References 251

**Numerical Magnetohydrodynamics
in Astrophysics**

Max Camenzind 255

1 Introduction 255

2 The Classical MHD Model in Computer Simulation 256

3 Progress in Understanding Fundamental
MHD Processes 263

4 Special Relativistic MHD (SRMHD) Limits
of the Classical MHD 270

5 Relativistic MHD
for Rotating Black Holes (GRMHD) 273

6 Future Prospects 277

References 278