

Contents

<i>Preface</i>	xiii
1 Overview: Galaxies and Cosmology	
1.1 Introduction	1
1.2 Evolution of the Universe	3
1.3 Formation of Dark-Matter Halos	8
1.4 Galaxy Formation	12
1.5 Morphological Classification of Galaxies	18
1.6 The Evolution of Galaxies	26
1.7 Properties of Disk Galaxies	34
1.8 Properties of Elliptical Galaxies	41
1.9 Milky Way Galaxy	46
1.9.1 Components of the Milky Way	47
1.9.2 Metallicity	50
1.9.3 Kinematics	51
1.9.4 The Galactic Centre	54
1.10 Features of Active Galactic Nuclei	55
1.10.1 Compact Sizes, Variability, and Continuum Emission	56
1.10.2 Radio Emission and Jets	62
1.10.3 Emission Lines	63
1.10.4 Absorption Systems	64
1.11 Taxonomy of Active Galactic Nuclei	65
1.11.1 Radio Galaxies	65
1.11.2 Quasars	66
1.11.3 BL Lac Objects	67
1.11.4 Seyfert Type I Galaxies	67
1.11.5 Seyfert Type II Galaxies	67
1.11.6 Low-Ionisation Nuclear-Emission Regions	67

1.12	Luminosity Function of Galaxies and Quasars	70
1.12.1	Galaxy Counts and Luminosity Function	71
1.12.2	Quasar Counts and Luminosity Function	76
1.13	Distribution of Matter	79
1.14	Extragalactic Background Radiation	82
2	Galactic Structure and Dynamics	
2.1	Introduction	85
2.2	Models for Galaxies in Steady State	86
2.2.1	Polytropes	88
2.2.2	Isothermal Spheres	89
2.2.3	King Model	90
2.2.4	Axisymmetric Systems	92
2.3	Aspects of Stellar Orbits	94
2.3.1	Spherically Symmetric Potentials	94
2.3.2	Rotation Curves of Disk Galaxies	96
2.3.3	Epicyclic Approximation in Axisymmetric Potentials	101
2.3.4	Planar Nonaxisymmetric Potentials	104
2.3.5	Potentials in the Rotating Frame	108
2.4	Application of the Jeans Equations	112
2.4.1	Asymmetric Drift	113
2.4.2	Mass and Velocity Dispersion	115
2.4.3	Rotation of Elliptical Galaxies	117
2.5	Stellar Dynamics at Galactic Cores	121
2.6	Spiral Structure	125
2.7	Warps	137
2.8	Chemical Evolution of Galaxies	139
2.9	Galaxy Interactions and Mergers	149
2.9.1	Galactic Cannibalism	151
2.9.2	Galaxy Collisions	154
2.9.3	Numerical Simulations	156
3	Friedmann Model of the Universe	
3.1	Introduction	161
3.2	The Friedmann Model	161
3.3	Kinematics of the Friedmann Model	167
3.4	Dynamics of the Friedmann Model	176
3.5	Observational Tools in Friedmann Models	187
3.6	Gravitational Lensing	196
3.6.1	Constant Surface Density	202
3.6.2	Point Mass	203
3.6.3	Isothermal Sphere	206

4 Thermal History of the Universe	
4.1 Introduction	210
4.2 Distribution Functions in the Early Universe	210
4.3 Relic Background of Relativistic Particles	218
4.4 Relic Background of Wimps	226
4.5 Synthesis of Light Nuclei	230
4.6 A Simplified Model for Primordial Nucleosynthesis	243
4.7 Decoupling of Matter and Radiation	248
4.8 Very Early Universe and Cosmological Scalar Fields	263
5 Structure Formation	
5.1 Introduction	272
5.2 Growth of Inhomogeneities	273
5.3 Linear Growth in the General Relativistic Regime	276
5.4 Gauge Dependence of Perturbations: An Illustration	279
5.4.1 Synchronous Gauge	281
5.4.2 Poisson Gauge	282
5.5 Gravitational Clustering in the Newtonian Limit	289
5.6 Linear Perturbations in the Newtonian Limit	292
5.7 Origin of Density Perturbations	304
5.8 Transfer Functions and Statistical Indicators	315
5.9 Zeldovich Approximation	326
5.10 Spherical Approximation	329
5.11 Scaling Laws	335
5.12 Nonlinear Scaling Relations	338
6 Cosmic Microwave Background Radiation	
6.1 Introduction	349
6.2 Processes Leading to Distortions in CMBR	349
6.3 Angular Pattern of CMBR Anisotropies	352
6.4 CMBR Anisotropies: Simplified Derivation	360
6.5 CMBR Anisotropies: A More Rigorous Derivation	366
6.6 Comparison with Observations	379
6.6.1 Dipolar Anisotropy	379
6.6.2 Anisotropies at Large Angular Scales	382
6.6.3 Anisotropies at Small Angular Scales	385
6.7 Spectral Distortions of CMBR	388
6.7.1 Distortions Due to Global-Energy Injection	388
6.7.2 Sunyaev–Zeldovich Effect	395
7 Formation of Baryonic Structures	
7.1 Introduction	397
7.2 Linear Perturbations in Baryons	398

x	<i>Contents</i>	
7.3	Nonlinear Collapse of Baryons	404
7.4	Mass Functions and Abundances	415
7.5	Angular Momentum of Galaxies	424
7.6	Galaxy Formation and Evolution	427
7.7	Galaxy Distributions in Projection	439
7.8	Magnetic Fields in the Universe	443
8	Active Galactic Nuclei	
8.1	Introduction	447
8.2	The Black Hole Paradigm	447
8.3	Optical and UV Continua from AGN	451
8.4	High-Energy Spectra: X Rays and Gamma Rays	462
	8.4.1 Comptonisation	462
	8.4.2 Pair Production	468
	8.4.3 Line Emission from Iron	473
8.5	Radio Emission from Quasars	475
8.6	Radio Jets	481
8.7	Effects of Bulk Relativistic Motion	490
8.8	The Broad-Line and Narrow-Line Regions	495
	8.8.1 Broad-Line Regions	495
	8.8.2 Narrow-Line Regions	505
8.9	Intrinsic Absorbers in AGN	508
8.10	Quasar Luminosity Function	510
9	Intergalactic Medium and Absorption Systems	
9.1	Introduction	518
9.2	Gunn–Peterson Effect	518
9.3	Ionisation of the IGM	523
	9.3.1 Photoionisation Equilibrium of the IGM	523
	9.3.2 Photoionisation of the IGM by Discrete Sources	527
	9.3.3 Collisional Ionisation	532
9.4	Background Radiation from High-Redshift Sources	534
9.5	Lyman- α Absorption by a Diffuse IGM	541
	9.5.1 Classification of Lyman- α Absorption Lines	541
	9.5.2 Lyman- α Forest and a Diffuse IGM	544
9.6	Damped Lyman- α Clouds	547
10	Cosmological Observations	
10.1	Introduction	552
10.2	Cosmic Distance Scale	552
	10.2.1 Examples of Direct Distance Estimates	553
	10.2.2 Development of a Cosmic Distance Ladder	555
10.3	Age of the Universe	562

<i>Contents</i>		xi
10.4	Observational Evidence for Dark Matter	564
10.4.1	Solar Neighbourhood	566
10.4.2	Rotation Curves of Other Disk Galaxies	571
10.4.3	Cores of Spiral Galaxies and Dwarf Spheroidals	571
10.4.4	Dark-Matter Estimates from the Dynamics of the Local Group	573
10.4.5	Groups of Galaxies	575
10.4.6	Clusters of Galaxies	577
10.4.7	Virgo-Centric Flow and Velocity Fields	579
10.5	Nature of Dark Matter	581
10.5.1	Baryonic Dark Matter	582
10.5.2	Nonbaryonic Dark Matter	586
10.6	Axions	592
10.7	Cosmological Constant	595
	<i>Notes and References</i>	599
	<i>Index</i>	609