

Contents

I ELEMENTARY PARTICLES IN COSMOLOGY	
A. Dolgov	1
1 Introduction.	5
2 The Minimal Standard Model (MSM) in Particle Physics.	7
3 The Standard Model of the Universe Evolution	31
4 Baryogenesis	53
5 Thermodynamics of elementary particles in the expanding Universe	71
II QUANTUM FIELD THEORY IN CURVED SPACETIME	
L. Ford	89
6 Basic Formalism. Particle Creation	93
6.1 Second Quantization in Curved Space	93
6.2 Particle Creation by Gravitational Fields	96
7 The Hawking Effect	103
8 Negative Energy Densities and Fluxes	115
9 Green's Functions and $\langle T_{\mu\nu} \rangle$ in Curved Spacetime	125
9.1 Ultraviolet Behavior	125
9.2 Infrared Behavior	129
10 Semiclassical Gravity Theory and Metric Fluctuations	135
10.1 Limits of the Semiclassical Theory	135
10.2 Metric Fluctuations and the Ultraviolet Divergence Problem	139
III MULTIDIMENSIONAL CLASSICAL AND QUANTUM COSMOLOGY AND GRAVITATION: EXACT SOLUTIONS AND VARIATIONS OF CONSTANTS	
V. Melnikov	147
11 Introduction: Fundamental Physical Constants	149
12 Classical Multidimensional Cosmology	163

12.1 Variations of G in 10-Dimensional Cosmology of Superstring Origin	163
12.2 Solutions with Perfect Fluid in (4+N)-Dimensional Cosmology	170
12.3 Perfect-Fluid Type Solution in Multidimensional Multicomponent Cosmology	176
12.4 On Reduction of Multicomponent Cosmology to Toda Lattice	181
13 Quantum Multidimensional Cosmology	187
13.1 On Wheeler-De Witt Equation in Multidimensional Cosmology	187
13.2 Exact Solutions for Models with Cosmological Constant	198
13.2.1 Model with a Perfect Fluid	206
14 Classical and Quantum Spherically-Symmetrical Solutions in Multidimensional Gravitation	213
14.1 Generalized Schwarzschild Solution in Multidimensional Gravitation	214
14.2 On Black Holes in Multidimensional Theory	219
14.3 On Charged Black Hole in Multidimensional Theory	224
14.4 Scalar-Electrovacuum Multidimensional Solutions	227
14.5 Multidimensional Model with Interaction of Scalar and Electromagnetic Fields. Stability of Solutions	236
 IV NONLOCAL ELECTRODYNAMICS	
B. Mashhoon	245
15 Physical Structure of General Relativity	249
16 Hypothesis of Locality	259
17 Duality of Absolute and Relative Motion	265
18 Nonlocality	269
19 Spin-Rotation-Gravity Coupling	277
20 Discussion	285
21 Acknowledgement	287
22 Appendix	289
 V THEORETICAL COSMOLOGY	
M. Novello	297
23 Introduction	299

24 The Cosmic Fluid	301
24.1 The Ideal Gas	302
24.2 The Conservation of Energy	306
24.3 Raychaudhuri's Equation	306
24.4 Equilibrium Thermodynamics of the Ideal Gas	309
24.5 The Deformed Friedmann Universe	311
24.6 Stokesian Fluid	311
24.7 Non-Perfect Fluids	312
24.8 The Expansion Equation	313
24.9 The Shear Equation	313
24.10 The Vorticity Equation	313
25 Light Propagation	315
25.1 Electromagnetic Waves	315
25.2 Minimal Coupling	316
25.3 Non-Minimal Coupling	316
25.4 Electromagnetic Disturbances	318
25.5 Minimal Waves	319
25.6 Non-Minimal Waves	323
25.7 Creation of Photons in an Expanding Universe	326
25.8 Thermodynamics of a Photon Gas	328
25.9 Some Mathematics	332
26 The Scalar Field	335
26.1 The Gravitational Interaction of the Scalar Field Φ	335
26.2 Minimal Coupling	336
26.3 Conformal Coupling: a Feasible Example of Non-Minimal Interaction	337
26.4 The Fundamental Solution	339
26.5 Structure of Spacetime	341

26.6 Weyl Integrable Spacetime: WIST	344
26.7 The First and the Second Clock Effects	345
26.8 Dynamics for a WIST	347
26.9 The Cosmic Model	348
26.9.1 The Eternal Universe	350
26.9.2 The Accelerated Universe	351
26.9.3 The Hubble Parameter	353
26.9.4 The Structural Problem	353
26.9.5 WISTons and Anti-WISTons	356
26.9.6 Time Reversal	357
26.9.7 Creation of the Universe	359
26.9.8 Cosmogony	361
26.10 The Cosmic Evolution	364
27 Isotropization	367
27.1 Geometric Analysis of Isotropization	368
27.2 Thermodynamic Treatment-I	371
27.3 Changing of Observer	374
27.4 Thermodynamic Treatment II-Phase Transition	376
27.4.1 Landau's Phase Transition Theory	377
27.4.2 Phase Transition in QFT	378
27.4.3 Liquid Crystal	380
27.4.4 The Cosmic Fluid as a Liquid Crystal: the Isotropization	385
28 The Eternal Universe	389
28.1 General Comments	389
28.2 Varying Λ	391
28.3 New Short-Range Gravitational Forces	396
28.4 The Principle of Unification	396
28.5 The Interaction of Leptons	397
29 Traditional Cosmological Models	405
29.1 Einstein's Universe	406
29.2 Friedmann's Universe	408
29.3 Lemaitre-De Sitter Universe	409
29.4 Kasner's Universe	409

29.5 Gödel's Universe	409
VI PERTURBATIONS IN THE EXPANDING UNIVERSE	
S. Gottlöber	415
30 Introduction .	417
31 Cosmological models	421
32 The linear theory of gravitational instabilities in Newtonian theory	433
33 The Zeldovich approximation	443
34 The relativistic theory of perturbations	453
35 The generation of perturbations during inflation	461
36 Observing perturbations in the universe	467
37 Beyond the standard model	479
VII OBSERVING THE UNIVERSE	
B. Jones	493
Introduction	495
1 The Scope of the Present Review	495
2 Books, Reviews and Papers	496
3 Abbreviations, Prejudices etc.	497
38 A Brief History	499
38.1 Cosmic Expansion	499
38.2 Big Bang vs. Steady State	501
38.3 The Renaissance in Cosmology	503
39 Cosmology - a quick overview	507
39.1 Looking into the distance is looking into the past	507
39.2 The Universe was more Homogeneous in the Past	508
39.3 Cosmological Models	509
39.4 The Standard Model	510
39.5 The Success of the Standard Model	511
39.6 Calendar of Events	513
40 Observational Cosmology	515

40.1 Projected Sky Surveys	516
40.2 Redshift Surveys	517
40.3 Cosmography: Mapping the Universe	520
40.4 The Microwave Background Radiation	521
40.5 Telescopes and Satellites	521
41 Cosmology - the Homogeneous Model	525
41.1 The Simplest Model	525
41.1.1 Scale Factors, Redshifts and all that	525
41.1.2 Important quantities: H_0, Ω_0, ρ_c	527
41.1.3 The Hubble Parameter h	529
41.1.4 q_0, Ω_0 and Λ	531
41.1.5 Dark Matter	532
41.1.6 The Standard CDM Model	533
41.2 Photons	534
41.2.1 The redshift	534
41.2.2 Temperatures	535
41.2.3 Photon density	536
41.3 The Expansion	537
41.3.1 The FireBall Phase	538
41.3.2 Recombination	541
41.3.3 The Post Recombination Era	543
42 Classical Tests	545
42.1 Number- Redshift counts	545
42.2 Angular Diameters	547
42.2.1 The general formula	547
42.2.2 Large redshifts	547
42.2.3 Other important scales	548
42.3 The Magnitude-Redshift Relation	549
42.4 Number- Magnitude counts	551
42.5 Surface Brightness tests	552
43 Galaxy Clustering	555
43.1 The Galaxy Distribution	555
43.2 Two-Point Correlation Function	556
43.2.1 Calculating correlation functions	557
43.2.2 A couple of examples	558
43.2.3 Clustering in Projection	560

43.2.4 Limber's Formula and Depth Scaling	562
43.2.5 Clustering from redshift surveys	563
43.2.6 Cluster-cluster correlation function	564
43.2.7 The two-power-law model	565
43.3 High Order Correlations	566
43.3.1 Some definitions	566
43.3.2 Scaling Relations	567
43.4 Counts in Cells	568
43.4.1 Counts and Moments	569
43.4.2 Scaling the variance	571
43.4.3 Higher Moments	572
43.4.4 The lognormal and other distributions	573
44 Deviations from the Standard Model	575
44.1 Modelling the Universe	575
44.1.1 Gravitation as the Dominant Force	575
44.1.2 N-Body Simulations	576
44.2 Small Deviations	579
44.2.1 Linear Perturbations	579
44.2.2 Peculiar Velocity Fields	580
44.2.3 Shear and Vorticity	581
44.3 Random Fields	582
44.3.1 Specifying the Fluctuations	582
44.3.2 Fourier representation	584
44.3.3 The Power Spectrum	585
44.3.4 $\xi(r)$, $P(k)$, variances and so on	587
44.3.5 Normalization	587
44.4 The Spectrum of Fluctuations	588
44.4.1 Windows and Spectra	588
44.4.2 The Harrison-Zel'dovich Spectrum	590
44.4.3 The observed power spectrum	591
44.4.4 Evolution of the spectrum	592
44.5 Biasing	593
44.5.1 Relating Mass and Light	593
44.5.2 Biasing mechanisms	594
44.5.3 Measuring b (or $b/\Omega^{0.6}$)	596
45 Peculiar Velocity Fields	599
45.1 The Velocity-Density relationship	600
45.2 IRAS and other redshift surveys	601
45.3 Surveys with independent distance estimates	602
45.4 The problem and the POTENT solution	603

45.5 Reconstructing the 3-d Flow	604
45.5.1 The comoving coordinate q-space	604
45.5.2 The three-dimensional velocity field	605
45.5.3 Getting to grips with physical space	605
45.5.4 Real Data: sparseness and noise problems	606
45.6 Dipole Motion	607
46 The Microwave Background Spectrum	609
46.1 The Spectrum	609
46.2 The μ parameter	610
46.3 They parameter	612
46.4 COBE constraints on y and μ	613
47 The Microwave Background Fluctuations	615
47.1 Measuring Multipoles etc.	616
47.2 The Sachs-Wolfe Effect	617
47.3 Comparing with theory	619
47.3.1 What a theory can predict	620
47.3.2 Expressing it in terms of angles	620
47.3.3 The instrumental response	621
47.3.4 Relating density and temperature fluctuations	622
47.4 Simple theoretical models	622
47.5 Cosmic Dipole	623
47.6 The Quadrupole Component	624
47.7 Degree scale anisotropies	627
47.8 The Future of Cosmology?	627
A Magnitudes and all that.	629
B Peculiar velocities- homogeneous background	630
VIII GENERALIZED QUANTIZATIONS OF GAUGE THEORIES I. Tyutin	639
IX QUANTUM EFFECTS IN COSMOLOGY L. Grishchuk	667
48 Introduction. The Current State of the Universe	669

49 A Complete Cosmological Theory	673
50 An Overview of Quantum Effects in Cosmology	675
51 Parametric (Superadiabatic) Amplification of Classical Gravitational Waves	677
52 Graviton Creation in an Inflationary Universe	681
53 Quantum States of a Harmonic Oscillator	687
54 Squeezed Quantum State of Relic Gravitons. Theory and Experimental Prospects	691
55 Quantum Cosmology, Minisuperspace Models and Inflation	697
56 Form the Space of Classical Solutions to the Space of Wave Functions	703
57 On the Probability of Quantum Tunneling from “Nothing”	707
58 Relic Gravitons and the Birth of the Universe	711
Acknowledgements	714
FIGURE CAPTIONS	719
Figure 1	720
Figure 2	721
Figure 3	722
Figure 4	723
Figure 5	724
Figure 6	725
Figure 7	726
Figure 8	727
Figure 9	728