

CONTENTS

Editor's Preface	xi
The GR11 Scientific Organising Committee	xiii
The GR11 Honorary Committee and Financial Sponsors	xiii
Contributors to this book	xiv
PLENARY LECTURES	
Accretion disks around black holes	1
<i>M.A. Abramowicz</i>	
Introduction	1
Accretion disks in astronomical objects	1
Small accretion rates: the standard model	2
Limits of validity of the standard model	12
Conclusions	16
Supergravity, Kaluza-Klein and superstrings	18
<i>M.J. Duff</i>	
1. General relativity	18
2. Particle physics	20
3. The Kaluza-Klein idea	21
4. Supersymmetry	29
5. The September 84 revolution	34
6. Strings	36
7. Kaluza-Klein approach to strings	44
8. Einstein's equations from vanishing conformal anomaly	46
9. Spontaneous compactification of the bosonic string	49
10. The heterotic and type II strings	53
11. Conclusions	56
Folklore in relativity and what is really known	61
<i>J. Ehlers</i>	
Superstring theory	72
<i>M.B. Green</i>	
The formulation of string theories	75
Quantum numbers	80
Physics from Calabi-Yau spaces	82
Other theoretical ideas	84

Gravity-wave astronomy	86
<i>L.P. Grishchuk</i>	
1. Introduction. Gravity-wave astronomy in action	86
2. Theory and some new results	86
3. Burst and periodic sources of gravitational waves	87
4. Cosmological stochastic background: the early universe	89
5. Detection	94
6. New ideas and prospects	95
7. Conclusion	97
 Quantum Gravity	99
<i>C.J. Isham</i>	
1. Introduction	99
2. Higher-derivative gravity	102
2.1 Introduction	102
2.2 Lattice gauge theory	103
2.3 Regge calculus and (Riemann) ²	105
3. Quantum spacetime structure	106
3.1 Quantum foam	106
3.2 Lorentzian spacetime effects	107
3.3 Regge calculus	110
4. Quantum cosmology	112
4.1 The Hartle-Hawking programme	112
4.2 Conceptual problems	116
5. Constraint quantization	117
5.1 Phase space tunnelling	117
5.2 New canonical variables	120
6. Conclusions	121
 Black hole uniqueness theorems	130
<i>P.O. Mazur</i>	
Introduction	130
1. The Einstein-Maxwell equations for spacetimes with one Killing vector	132
2. Black hole boundary conditions	138
3. Divergence identities for harmonic maps and no hair theorems	142
4. A global identity for nonlinear sigma-models and its applications (black hole uniqueness theorem)	148

Twistors in general relativity	158
<i>R. Penrose</i>	
1. Introduction	158
2. Twistors in flat space-time	159
3. Duality between the two definitions	161
4. The geometry and physics of twistors	162
5. Twistor concepts for curved space-time	164
6. Quasi-local mass and angular momentum	169
7. Examples of quasi-local mass	171
 Numerical relativity from gravitational radiation to cosmology	177
<i>T. Piran</i>	
Introduction	177
Relativistic stellar cluster	178
Characteristic methods, scalar field and cosmic censorship	180
Regge calculus, cosmology and inflation	184
Rotating gravitational collapse and gravitational radiation	188
Three dimensional codes	193
Conclusions	196
 How Einstein discovered general relativity: a historical tale with some contemporary morals	200
<i>J.J. Stachel</i>	
Introduction	200
The equivalence principle	201
The metric tensor	202
General covariance	203
Problems with the standard mathematical formulation	205
Fiber bundles and sheaves	207
 Astronomical and space experiments to test relativity	209
<i>J.H. Taylor</i>	
Introduction	209
Historical overview	210
Gravitational redshift	210
Perihelion advance of planetary orbits	211
Bending of light	211
Shapiro time delay	212
Pulsar timing and relativity	213
Cosmic background gravitational radiation	216
Relativity and binary pulsars	216
Quantitative test for gravitational radiation	218

Inflation in the universe, circa 1986	223
<i>M.S. Turner</i>	
Successes of the standard cosmology	223
Shortcomings of the standard model	224
Basic mechanics of new inflation	228
Successfully implementing inflation	233
Specific models	235
Open (or semi-open) questions	236
Inflation confronts observation	239
Epilogue	243
Some recent developments in general relativity	247
<i>S.-T. Yau</i>	
REPORTS ON SYMPOSIA	
Algebraic computing	253
<i>I. Frick</i>	
Summary of papers and computer demonstrations	253
General programs	253
The classification project	255
Homothetic Killing tensors	256
Kaluza-Klein and supergravity	256
Algebraic computing. Developments since 1983	257
Alternative theories of gravity	262
<i>H.F.M. Goenner</i>	
Astronomical and space experiments	274
<i>R.D. Reasenberg</i>	
Preferred frames	276
Pulsar models	276
Active-passive mass ratio	277
Stanford gyro	277
Alternative frame-dragging test	279
Points	279
Mercury orbiter	280
Discussion	281

Astrophysical cosmology	283
<i>J. Bardeen</i>	
Overview	283
Introduction	283
The inflation paradigm	283
Alternative paradigms	286
Contributed papers	287
Multiple weak gravitational lensing	287
Cosmic microwave anisotropy	287
Multiply-connected universes	288
Panel discussion	288
Summary	288
Asymptotia, singularities and global structure	291
<i>C.J.S. Clarke</i>	
1. Foundational issues	291
2. Global structure and conjugate point theory	291
3. Singularities	292
3.1 Particular examples	292
3.2 Cosmic censorship	293
3.3 Singularity theorems	293
4. Asymptotically flat space-times	294
4.1 The existence problem	294
4.2 Energy, momentum, angular momentum and moments	294
4.3 Conformal Killing fields	295
4.4 Examples	296
Early universe	298
<i>D.V. Nanopoulos</i>	
Exact solutions	302
<i>D. Kramer</i>	
1. The procedure	302
2. First session: vacuum and electrovacuum solutions	303
2.1 Generation methods	303
2.2 Other methods	304
2.3 Special solutions	305
2.4 Non-empty solutions from vacuum	307
3. Second session: perfect fluid solutions	307
3.1 Solutions with special slices	307
3.2 Spherical symmetry	308
3.3 Petrov type D solutions (with electromagnetic field)	309
3.4 Special solutions	310
4. Other topics	310
5. Commentary	311

Gravitational wave detectors	313
<i>W.M. Fairbank</i>	
Bar detectors	314
Laser detectors	318
 Kaluza-Klein theories	320
<i>D. Brill</i>	
Introduction	320
Quantum effects	321
Cosmology	321
Black holes	323
Alternate theories	323
Other classical topics	324
 Mathematical cosmology	326
<i>G.F.R. Ellis</i>	
Homogeneous and isotropic universe models	326
Homogeneous but anisotropic cosmologies	327
Inhomogeneous cosmological models	327
The decay of anisotropy and inhomogeneity	327
The growth of inhomogeneities	327
Self-similar inhomogeneities	328
Approximate homogeneity and smoothing	329
Observational relations	329
Further work	330
 Mathematical problems	331
<i>Y. Choquet-Bruhat</i>	
 Numerical Relativity	336
<i>T. Nakamura</i>	
1. Ten years old numerical relativity	336
2. Summary of symposium	338
3. Numerical relativity after ten years	343
 Particle motion and continua in general relativity	347
<i>J.N. Goldberg</i>	

Quantum field theory on curved space	358
<i>P. Hajicek</i>	
The main stimuli in the development of the theory	358
Semiclassical approximation	359
The tree stage	361
Exact classical solutions	361
Linear theory of small disturbances	361
Tree scattering of small disturbances off each other	364
The one-loop stage	364
The back reaction	365
Effects on small disturbances	365
Higher loop corrections	367
Conclusions	367
 Radiative spacetimes and approximation methods	369
<i>B.F. Schutz</i>	
Introduction	369
The quadrupole formula	369
Gravitational radiation	372
Approximation methods	375
 Superstrings	377
<i>L. Brink</i>	
1. Introduction	377
2. Problems which should be solved	379
2.1 Geometry	379
2.2 Consistent perturbation expansion	381
2.3 Non-perturbative effects	382
2.4 Compactifications to four dimensions	382
2.5 Gravitational collapse and singularities	383
2.6 Planck-time cosmology	384
3. Conclusions	384

Terrestrial experiments to test theories of gravitation	387
<i>H.J. Paik</i>	
Introduction	387
Equivalence principle	389
Inverse square law	391
Other experiments	392
Conclusion	394
Twistors, spinors and complex methods	397
<i>K.P. Tod</i>	