

Index

- aberration, 236
 ABM pulse, *see* accelerated baryonic matter pulse
 accelerated baryonic matter pulse, 199–203
 accretion disc, 236–276
 absorption processes, 238, 239
 atmospheres, 243
 coronal activity, 237–239, 242, 243, 246, 254, 271
 emissivity, 242–243, 248, 249, 256–258, 262, 265,
 266, 268, 271, 275
 inclination, 241–243, 246, 247, 249, 255, 263, 265,
 268
 inner boundary, 246
 ionization, 239, 243–244
 light bending model, 254–259, 263, 264, 266, 267
 magnetic fields, 237, 242, 246, 249, 254, 255, 271
 outer boundary, 249
 photo-ionized gas, 239
 plunge region, 245, 246
 accretion processes, 163, 184
 angular momentum transfer, 184, 245, 291, 295
 spin-down, 285–287, 289–291, 300, 303
 spin-up, 245, 289
 energy transfer, 290–291, 295
 in core collapse supernovae, 286–293
 magnetized plasma, 184, 289, 290, 292, 294, 305
 suspended, 285, 290, 291, 294–296, 303
 Achúcarro, A, 319
 active galactic nuclei, 195, 215, 237–240, 260–264,
 266, 267, 271, 272, 276, 302, 304, *see also*
 quasar, *see also* Seyfert galaxies
 Adler, R, 5
 ADM constraint algebra, 318
 ADM formalism, 20
 ADM mass, 316, 319
 AdS/CFT duality, 312
 affine parameter, 9, 21, 40, 47, 100, 101, 106, 147,
 154, 155, 334
 afterglow, *see* gamma-ray burst, afterglow
 AGNs, *see* active galactic nuclei
 Alfvén waves, 291, 305
 algebraically degenerate, *see* algebraically special
 algebraically special, 39, 40, 42–46, 52, 59, 62, 63,
 66, 67, 97, 116, 117
 Andromeda, 217, 223
 angular coordinates, 337
 angular momentum, 4, 14, 56–57, 60, 82, 95,
 102–105, 110, 116, 125, 127, 128, 132, 135,
 146, 153, 155–157, 245–247, 286, 287, 311,
 316, 319, 335–341
 barrier, 287
 angular momentum transfer, *see* accretion processes,
 angular momentum transfer
 angular velocity, 25, 109–111, 122, 286, 296, 338, 339
 anti-de Sitter spacetime, 312, 316, 318, 320, 340
 antigravity, 39
 AS, *see* algebraically special
 ASCA (Advanced Satellite for Cosmology and
 Astrophysics), 247, 258, 259, 264, 265, 272
 asymptopia, 107
 asymptotic flatness, 333, 335, 337, 339
 atlas, 154
 Australasia, 61
 axion–dilaton, 97
 axisymmetric spacetime, 59, 95, 97, 98, 108–111,
 117, 124, 125, 127, 129, 130
 Bañados, M, 316
 Bardeen trajectory, 290
 baryon loading, 198, 199, 204
 BATSE (Burst and Transient Source Experiment),
 189, 191, 205, 281, 293, 302
 Bazin, M, 5
 Bekenstein, J, 128, 178, 180, 183, 311
 Bekenstein–Hawking entropy, 178, 311–313, 315,
 319, 321, 322, 326, 327, 333, 340
 Bell, J, 164
 BeppoSAX, 189, 193, 247–249, 251, 256, 264–267,
 281, 282, 302
 Bergmann, P, 39, 324
 Bethe, H, 169
 Bianchi identity, 43, 71
 bifurcation two-surface, 123
 binding energy, *see* energy, binding
 Birkhoff theorem, 3, 6
 Birmingham, D, 318
 black hole, 87–90, 92, 95, 98, 106–111

- astrophysical, 13, 119, 161–305
 atmosphere, 312
 binaries, 236, 237, 240
 candidates, 169, 264–267
 eddy currents, 185
 entropy, *see* Bekenstein–Hawking entropy
 formation, 194, 195
 in core-collapse supernovae, 284, 288–293
 growth, 226, 228
 horizon, *see* horizon
 magnetosphere, 287, 292
 mass formula, 171–175
 merger with black hole, 225–227
 merger with neutron star, 285, 290, 303, 304
 outflows in core-collapse, *see* supernova, outflows
 seed, 226
 spin, *see* angular momentum, *see* rapid spin
 spin parameter, 245, 247
 squashed, 334
 statistical mechanics, 311–313, 320
 supermassive, 213–234, 302, 304
 accretion rate, 230, 231
 formation, 225–232
 imaging, 232–233
 mass estimates, 221–225, 229
 number estimates, 218
 shadow, 233
 temperature, *see* Hawking temperature
 thermodynamics, 173, 183, 311–328
 black ring, 136, 336–337, 339–341
 black string, 333–337, 340, 341
 Blandford–Znajek process, 255, 287
 Bondi, H., 38, 40, 127, 175
 Boyer, R., 57, 59–61, 98, 106
 brane, 98, 312, 313, 332
 Brans–Dicke spacetime, 128
 Broglio, L., 181
 Brown–York microcanonical path integral, 318
 BTZ spacetime, 316–320, 326, 328
 Boyer–Lindquist form, 316
 buckling instability, 292–295
 Bunting, G., 111, 129–132, 134, 135

 3C–120, 270
 3C–273, 57, 213, 214, 219
 C-metric, 336
 Canterbury, University of, ix–xi
 capture process, 171
 Cardy formula, 313–316, 319–322, 325, 326
 Cardy, J., 314
 Carroll, S., 5
 Cartan equations, 43, 46, 47, 70
 Carter constant, 102–104, 166
 Carter, B., 59, 61, 62, 67, 98, 115, 117, 124, 125, 127,
 129, 166, 168, 169, 174, 177, 236, 340
 Carter–Penrose diagram, 34, 108, 317
 causality violating region, *see* Kerr spacetime, closed
 timelike curves
 celestial sphere, 79, 147
 Centaurus A, 219, 220
 Centaurus–X3, 180, 181

 central charge, *see also* Virasoro algebra, 314–315,
 318, 327
 CGRO (Compton Gamma Ray Observatory), 189,
 191, 281
 Chandra, 189, 214, 217, 227, 247, 248, 250, 251, 265,
 267, 272
 Deep Fields, 217, 218, 261
 Chandrasekhar, S., 5, 101, 162, 332
 Chern–Simons gauge theory, 318, 319, 339
 Christodoulou, D., 169, 171, 173–176, 178
 Christoffel symbol, 145
 Chruściel, P., 109, 133, 134
 collapse
 astrophysical, 4, 33, 57, 59–61, 95, 104, 107,
 115–117, 128, 133, *see also* supernovae, core
 collapse
 gravitational, 6, 117, 118, 162, 163, 165, 178, 182,
 193, 194, 196, 197, 203, 204
 idealized, 61
 Oppenheimer–Snyder, 4, 44, 57, 116
 colliding black holes, *see* black hole, mergers
 colliding galaxies, *see* galaxy mergers
 Compton broadening, *see* relativistic broadening
 Compton scattering, 238, *see also* X-ray, spectra,
 Compton hump
 conformal boundary, 116
 conformal circle, 87
 conformal compactification, 78
 conformal coupling, 128
 conformal embedding, 121
 conformal flatness, 126, 130, 135, 139
 conformal infinity, 87, 92
 conformal motions, 87
 conformal null infinity, 136
 conformal projection, 107, 108
 conformal space, 78
 conformal spatial completion, 137
 Constellation-X, 237, 270, 275, 276
 coordinate chart, 6, 144–146, 150, 153–154
 cosmic censorship, 117, 155
 weak, 117, 128
 cosmic microwave background radiation, 218, 226
 temperature anisotropies, 225
 cosmic rays
 ultra high-energy, 196, 304, 305
 cosmological constant, 97, 98, 119, 121, 135–137,
 316, 319, 336
 Cotton tensor, 126, 130, 138
 current rings, 290, 292
 curvature singularity, *see* singularity, curvature
 Cygnus A, 185, 219–221
 Cygnus–X1, 163, 169, 181–183, 185, 186, 191, 193

 d’Alembertian, 103, 104
 D’Inverno, R., 5
 Damour, T., 185, 188, 190, 194
 dark matter, 195, 225
 Debever–Penrose vector, 59
 Debney, G., 45, 52, 53, 66, 68, 97
 Deruelle, N., 194
 differential form, 10, 40, 42, 46, 47, 70

- dilaton gravity, 322–327
 Dirac electron, 67, 97
 Dirac equation, 101, 103
 Dirac operator, 104
 domain of outer communication, 107, 122–124, 126, 128, 133
 Doppler effect, 201, 229, *see also* redshift, Doppler
 Doran, C, 19
 dyad, 323
 dyado-torus, 196
 dyadosphere, 163, 195–198, 204, 206
 formation, 196
 over-critical, 196, 197
 under-critical, 196
 Dyson, F, 165
- Eddington limit, 261
 Eddington, A, 168
 effective potential, 166, 167, 169, 170
 Einstein equations, 4, 7, 32, 40, 42, 44, 95, 103, 108, 110, 144, 153, 157, 332
 exact solutions, 5, 40, 116, 131
 Einstein rings, 152, 155, 156
 Einstein spacetime, 38–42, 59
 Einstein tensor, 5
 Einstein’s unified field theory, 39
 Einstein–dilaton–Yang–Mills, 129
 Einstein–Hilbert action, 312, 322
 Einstein–Maxwell equations, 66, 68, 97, 127, 131, 134, 337–339
 Einstein–Maxwell spacetimes, 124, 127
 Einstein–Maxwell uniqueness theorem, 124
 Einstein–Maxwell-dilaton spacetimes, 131, 132
 Einstein–Skyrme spacetimes, 135
 Einstein–Yang–Mills spacetimes, 131, 135
 electron, *see also* Dirac electron
 Dirac theory, 191–193
 electron–positron
 pair creation, 188, 192, 193, 197
 plasma, 197–199
 Ellis, G, 5
 emission lines
 optical, 275
 X-ray, 238–240, *see also* iron lines
 emission spectra
 optically thick, 233
 optically thin, 196, 233
 Empanan, R, 136
 Empanan–Reall spacetime, 136
 energy
 accretion, 236
 binding
 gravitational, 168, 169
 nuclear, 168, 169
 blackholic, 169, 184, 187, 189, 193, 197
 Coulomb, 173, 175
 electromagnetic, 163, 173, 175, 184, 185, 187, 282
 extraction, 170, 171, 178, 185, 187, 287, 288
 radiated in gravitational waves, *see* gravitational waves, energy radiated
 rotational, 163, 165, 173, 175, 181, 184, 185, 187, 285–287
 EPIC (European Photon Imaging Camera), 250, 251, 260, 272
 EPP, *see* electron–positron, plasma
 EQTSs, *see* equitemporal surfaces
 equitemporal surfaces, 201, 202
 ergoregion, *see also* ergosphere, 109, 122, 146
 ergosphere, 28–33, 169–171
 inner, 32
 outer, 29, 32
 ergosurface, 23, 110, *see also* stationary limit surface
 Ernst potential, 125
 Ernst, F, 110
 Euclidean path integral, 312, 318, 328
 Everitt, F, 175
- Faraday induction, 305
 Fe lines, *see* iron lines
 Fermi, E, 169, 201
First Texas Symposium on Relativistic Astrophysics, *see* Texas Symposium
 fisheye, 150
 fission, 168, 169
 flagpole, 75, 84, 85
 Floyd, R, 175
 fluorescent line emission, 238, *see also* iron lines
 fractal, 152
 frame dragging, 57, 110, 152, 154, 156, 157, 184, 221, 286, 297–300
frozen star, 165
 fusion, 168, 169
 fuzzball, 312
- galaxy formation, 213
 galaxy mergers, 216, 231
 gamma-ray burst, 163, 187–191, 193–197, 201, 203–206, 281–305
 afterglow, 189, 193, 196, 200, 201, 204, 281–283, 285
 core-collapse supernova association, 204, 282
 distances, 281
 event rate, 282–284
 interpretation, 203–206
 long duration, 189, 204, 281, 283–286, 289, 293, 299, 300
 luminosity, 190, 281, 283, 300
 proper, 198, 199, 204
 short duration, 189, 281, 285, 286, 289, 300, 303
 sources, 190, 199, 200, 203, 205, 206, 282, 283, 285, 297, 302–304
 structure, 204
 supernova time sequence, 204
 Gamow, G, 164, 168
 Gauss–Bonnet theorem, 122, 135, 138
 GEO, 300
 geodesic, 40, 46, 58, 59, 61, 62, 66, 105, *see also*
 orbits
 null, *see* null geodesic
 spacelike, 106
 timelike, 105

- Geroch, R, 121
 Giacconi, R, 178, 180–182
 Gibbons, G, 98, 127, 131, 132
 Ginzburg, V, 187
 Gödel, K, 165
 Goldberg, J, 39–41
 Goldberg–Sachs theorem, 40
 Goldstone mechanism, 319
 GR-tensor, 5
 gravitational
 collapse, *see* collapse, gravitational
 light bending, *see* light bending
 radiation, *see* gravitational waves
 redshift, *see* redshift, gravitational
 gravitational waves, 303
 chirp signal, 288, 303, 304
 emission by supernovae, 284, 296
 energy radiated, 282, 294, 296, 303
 high frequency, 284
 linearized, 287–288
 long duration bursts, 300–302
 low frequency, 284
 stochastic background, 300, 302
Gravity Probe B, 161
 GRB, *see* gamma-ray burst
 GRB 011211, 297
 GRB 030329, 206, 282, 283
 GRB 031203, 206
 GRB 050315, 206
 GRB 050509, 285, 303
 GRB 050709, 285, 303
 GRB 050904, 282
 GRB 060614, 303, 304
 GRB 670702, 302
 GRB 970228, 190, 282
 GRB 980425, 206, 283, 297
 GRB 991216, 199, 200, 203, 205, 206
 Gregory, R, 333, 334
 Gregory–Laflamme instability, 333, 334, 336, 337
 Greisen–Zatsepin–Kuzmin cutoff, *see* GZK cutoff
 GRS 1915+105, 265
 GRworkbench, 146, 147, 157
 Gubser, S, 334
 Gullstrand, A, 19–20
 GX 339–4, 237, 265, 271
 gyromagnetic ratio, 67, 97
 gyroscope motion, 161
 GZK cutoff, 304

 1H 0707–495, 261–264
 Hamilton–Jacobi equation, 100, 102, 166, 169
 Hans Lewy problem, 85
 Hartle, J, 5, 127
 Hawking area theorem, 334
 Hawking radiation, 183
 Hawking temperature, 183, 311, 313, 327, 328
 Hawking, S, 5, 62, 98, 109, 121–124, 126–128, 175, 180, 183, 311
 Hazard, C, 213

 helicity, 83
 Hercules–X1, 180, 181
 HETE (High Energy Transient Explorer), 189, 285, 302
 Heusler, M, 118
 Hewish, A, 164
 hidden symmetry, 98, 99
 higher dimensions, 115, 118, 119, 129, 131, 135–137, 312, 332–341
 Hlavaty, V, 39
 holomorphic extension, 73
 horizon, 23, 60, 95, 98, 99, 122, 123
 absolute, 25
 analytic, 133
 bifurcate, 123, 133
 Cauchy, 32, 317
 connected, 123, 126, 132, 134, 138
 constraints, 320–322
 degenerate, 124, 127, 133, 134, 338
 disconnected, 127, 132, 134
 event, 25, 61, 115, 117, 119, 121–123, 128, 146, 165, 311, 317, 321, 333–338
 extremal, 338
 future, 137
 high spin, 132
 inner, 24–29, 32, 59, 61, 107, 146, 337, 338
 isolated, 321, 328
 Killing, 122, 123, 133, 136
 local, 321
 non-connected, 124
 non-degenerate, 123, 126, 127, 130–132, 135–138
 outer, 24–29, 32, 59, 61, 146, 338
 past, 137
 regular, 125, 137
 singular, 128
 squashed, 334
 stretched, 322, 324, 327, 328
 topology, 126, 133, 135, 136, 333, 336
 unstable, 32, 333
 Houtermans, F, 168
 HST (Hubble Space Telescope), 189, 215, 216, 219, 222
 Hubble sequence, 231
 Hulse–Taylor pulsar, 288

 IC 2163, 216
 IMB (Irvine Michigan Brookhaven), 283
 innermost stable circular orbit, 237, 245–249, 254, 261, 265
 Kerr, 245
 maximal Kerr, 245, 265
 Schwarzschild, 245, 265
 spin relation, 248
 INTEGRAL (International Gamma-Ray Astrophysics Laboratory), 203
 interior solution, 61, 95, 116
 interstellar medium, 199–204, 233
 IPN (Interplanetary Network), 302
 IRAS 18325–5926, 237, 260
 iron lines, 236–259, 262, 265, 267, 272, 276
 irreducible mass, 173, 174, 180

- ISCO, *see* innermost stable circular orbit
 ISM, *see* interstellar medium
 Israel's theorem, 109, 119–121, 126–128
 Israel, W, 33, 108, 115, 117–122, 126, 128, 139, 174, 177
- Jacobson, T, 316
 Janis, A, 68, 69
 jets, 185, 187, 219, 221, 222
 formation in supernovae, *see* supernova, jet formation
 luminosity in supernovae, 299
 morphology, 220
 orientation, 220
- Jordan, P, 164
- Kaluza–Klein techniques, 322, 333–336
Kamiokanda, 283
 Kang, G, 316
Keck, 189
Kerr Fest, ix, xi
 Kerr spacetime, 87–89, 92, 95, 97, 98, 103–108, 110, 111, 119, 332
 advanced null form, 6–10
 axis, 19
 Boyer–Lindquist form, 13–17, 59–60, 98–99, 126, 298
 classical spinning particle, 97
 closed timelike curves, 13, 21, 32–34, 107, 109
 discovery, 44–49
 Doran form, 19–22
 Eddington–Finkelstein form, 6–10
 equator, 19
 ergospheres, 28–33
 extreme, 133, 340
 higher dimensions, 97, 332, 335, 340
 history, 3–6, 38–44
 horizons, 22–28
 Kerr–Schild form, 10–13, 55–57, 96–98
 Killing vectors, 33–34
 maximally extended, 107
 original papers, 353
 rational polynomial form, 17–19
 separable form, 99–101
 survey, 3–35
 visualized, 146
- Kerr variables, 86
 Kerr's theorem, 83–86
 Kerr, R, ix–x, 73, 75, 83, 85, 86, 91, 95–98, 106, 116, 119, 161, 213, 236, 332
 Kerr–AdS spacetime, 316, 317
 Kerr–Newman spacetime, 34, 66–69, 117, 119, 122, 123, 127–130, 137, 153–157, 166, 170, 174, 175, 185, 188, 191, 192, 194–196
 Boyer–Lindquist form, 153, 154
 extreme, 133
 gyromagnetic ratio, 193
 higher dimensions, 337
 naked, 339
 visualized, 156
- Kerr–Schild metric, 5, 8, 9, 14–16, 27, 32, 45, 49, 62–68, 87, 88, 97, 117, 154, 335
 generalized, 52
 kick velocity, 287–289, 303
 Killing horizon, *see* horizon, Killing
 Killing tensor, 62, 101–104
 Killing vector, 7, 12–13, 16, 33–34, 48–53, 62, 63, 97, 99, 102, 103, 107, 109, 110, 119, 120, 122, 123, 132, 134, 136, 137, 339, 341
 Killing–Yano tensor, *see* Killing tensor
 Kol, B, 334
 Komar, A, 324
Konus, 281
 Krasinski, A, 5, 8, 19
 Kristian, J, 73
 Kruskal coordinates, 58
 Kruskal extension, 57, 59
 Kruskal–Szekeres coordinates, 316
 Kruskal–Szekeres extension, 61
 KV, *see* Killing vector
- Laflamme, R, 333, 334
 Laor, A, 248, 268
 lapse, 20, 21
 Large Hadron Collider (LHC), 119
 le Chatelier principle, 179
 Leach, R, 182
 Lense–Thirring weak-field, 4, 57
 Levi–Civita density, 323
 Lewandowski, P, 92
 Lifshitz, E, 167, 187
 light bending, 236, *see also* accretion discs, light bending model, 241, 276
 light cone, 58, 76, 79, 81, 82, 85
 LIGO (Laser Interferometer Gravitational-Wave Observatory), 284, 286, 300–304
 Lindquist, R, 59, 98
 Liouville field theory, 319
 Liouville's theorem, 149
 Lockman Hole, 260, 261
- M81, 234
 M82, 217
 M87, 222
 MacCallum, M, 92
 magnetic charge, 67, 117, 127, 128, 338, 340
 magnetic flux tubes, 183–187, 297–300, 305
 magnetic moment, 67, 338, 339
 magnetic winds, 285, 296, 303
 Majumdar–Papapetrou spacetime, 127, 131, 134
 Maple, 5, 60
 odd sign conventions, 5
 Marcel Grossmann award, 161, 206
 Marck, J, 100, 101, 104–106
 Mars, M, 97
 maser emission, 221
 Masood-ul-Alam, A, 130–132, 134, 135
 mass infall, 216, *see also* black hole, supermassive, accretion rate
 Mathematica, 5

- Mazur, P, 111, 129, 130, 136
 MCG-6-30-15, 237, 246–249, 251–253, 255–263,
 266–268, 271, 272, 276
 Medved, A, 316
 Mercator projection, 152
 Metzner, A, 38
 Minkowski spacetime, 7, 11, 14–16, 20, 22, 27–28,
 55, 63, 73–76, 79–83, 85, 87, 88, 96, 148
 Misner, C, 5
 Moiré pattern, 151
 MOS (Multi-Object Spectrometer), 260
 Müller zum Hagen, H, 123, 126, 127
 multipole moments, 6, 116
 formation of, 293–295
 Myers, R, 97, 131, 335
 Myers–Perry spacetime, 132, 135, 136, 337,
 340
 Boyer–Lindquist form, 335
 near-horizon geometry, 312, 315, 316, 320, 327, 328,
 339, 340
 neutron star, 164, 165, 178–182, 188, 196–198, 204,
 282, 283, 288
 critical mass, 178–180
 merger with black hole, *see* black hole, merger with
 neutron star
 merger with neutron star, 286, 304
 New Zealand, xi, 62, 332
 Newman, E, 42–44, 68, 69, 92, 97
 Newman, Unti, Tambourino, *see* NUT
 Newman–Penrose spinor formalism, 42, 43, 70,
 116
 Newton’s constant, 311
Next Generation Space Telescope, 217
 NGC 2207, 216
 NGC 3516, 272–275
 NGC 3783, 270
 NGC 4051, 239, 264
 NGC 4258, 221, 223
 NGC 6240, 227
 no-bifurcation theorem, 127–129, 333
 no-hair theorem, 108, 110, 111, 117, 118, 127–128,
 131, 134, 137, 177, 311, 340
 Noether charge, 318
 nuclear test-ban monitoring satellites, 188, 281, *see*
also Konus, see also Vela
 null congruence, 22, 39, 40, 74–80, 83–92
 null geodesic, 9, 74, 80, 90, 100, 106, 116, 121,
 144–155, 334
 Nurowski, J, 92
 NUT, 42, 59
 O’Neill, B, 5
 one-form, 10, 69, 70
 Oppenheimer, R, x, 162, 164, 179
 optical geometry, 92
 optical scalar, 45
 orbits, *see also* innermost stable circular orbit
 co-rotating, 167, 171, 172
 counter-rotating, 167, 171
 Ozsváth, I, 73
 P-GRB, *see* gamma-ray burst, proper
 Page, D, 98
 Painlevé, P, 19–20
 pair creation, *see* electron–positron, pair creation
 pair electro-magnetic pulse, 198
 with baryons, 198, 199
 Papapetrou, A, 56, 59, 60, 98, 109, 124, 169
 parallax, 147
 parallel propagation, 101, 103–106
 particles, *see also* orbits
 Pauli–Lubański vector, 83
 PEM pulse, *see* pair electro-magnetic pulse
 Penrose process, 170, 171 *see also* energy, extraction
 Penrose, R, 41, 92, 101, 102, 105, 117, 121, 170, 171,
 174, 175
 Perjés, Z, xi, 97
 Perrin, J, 168
 Perry, M, 97, 131, 335
 Petrov classification, 38, 39, 44, 117
 Petrov, A, 38
 photoelectric absorption, 238
Physics Today, 176
 Pierelli, A, 207
 Pierre Auger Collaboration, 304
 Pirani, F, 38
 pixel, 151–153
 Planck scale, 332
 Planck’s constant, 311
 Plebański, J, 5, 8, 19
 plenoptic function, 149
 PNV, *see* principal null vector
 Poisson brackets, 314, 325
 Poisson, E, 33
 Pope, C, 98
 Press, W, 104
 Price, R, 128
 principal null congruence, *see also* Robinson
 congruence, *see* null congruence
 principal null vector, 39, 40, 42, 45, 47, 66,
 101
 Proca field, 128
 projective geometry, 39, 73–91
 PSR 1913+16, 288
 pulsar, 164, 165, 181, 283, 288, 291, 296
 magnetosphere, 291
 Punsley, B, 185
 quantum field theory, 73, 313
 quantum gravity, 129, 132, 311–313, 320, 326, 332,
 333
 quasar, 57, 115, 163, 213, 214, 216, 267–269
 energy conversion, 216
 energy outflow, 231
 formation rate, 217, 225
 microquasar, 303
 number counts, 217
 supermassive black hole association, 217
 type 2, 219
 quasars, 57
 mass estimates, 217
 quasi-stationary spacetime, 49

- Rácz, I, 133
 radio jets, *see* jets
 radio lobes, 185, 221
 rapid spin, 246, 286
 duration, 291–293
 observational evidence, 245, 247–249
 ray, 40, 41, 47, 74–92, *see also* null geodesic
 ray tracing, 144–157, 233, 234
 Rayleigh stability criterion, 287, 294, 295
 Reall, H, 136
 redshift
 cosmological, 214, 217
 Doppler, 241, 242, 268
 gravitational, 165, 236, 241–243, 246, 247, 259,
 262, 268, 272, 276
 Rees, M, 175, 176
 Regge, T, 165
 Reissner–Nordström spacetime, 17, 68, 116, 117, 119,
 126, 127, 131, 132, 134, 195, 339
 relativistic beaming, 240, 241, 283
 relativistic broadening, 240, 243, 244, 249, 250, 271,
 276
 relativistic Lorentz factor, 164, 198, 200
 Rhoades, C, 178–180
 Ricci rotation coefficients, 69
 Ricci scalar, 5, 26, 30, 31
 Ricci tensor, 5, 7, 12, 20, 97, 99, 103, 120, 138
 Riemann sphere, 73, 74, 79
 Riemann tensor, 5, 7, 8, 16, 19, 97, 99, 120
 rigidity theorem, 25, 34, 122, 123, 126, 133, 136
 Rindler, W, 73, 92
 ring singularity, 19, 21, 27, 57, 58, 61, 65, 68, 69, 90,
 107–109
 Robinson congruence, 74–80, 82, 87
 Robinson, D, 62, 109–111
 Robinson, I, 40–44, 48, 73, 74, 80, 92
 Robinson–Trautman metric, 40, 44
 rotating spacetime, 3–4, 6, 26, 42, 44, 55–57, 59, 61,
 87, 98, 109, 110, 117, 119, 122, 136, 153,
 335–336, 339, 340
 Ruffini, R, 176, 187
 Ruffini–Wilson process, 184, 287
 RXTE (Rossi X-ray Timing Explorer), 247, 251, 253,
 264–267

 Sachs, I, 318
 Sachs, R, 40, 41, 45, 59, 73, 75
 Sagittarius A*, 223, 225, 232–234
 imaging, 232
 mass estimate, 225
 Sakharov, A, 169, 187, 312
 Salmonson, J, 198
 Schell, J, 39
 Schiff, L, 175
 Schiffer, M, 5
 Schild, A, 41, 45, 66, 67, 73, 96, 97
 Schmidt, M, 213
 Schücking, E, 73
 Schwarzschild spacetime, x, 3–5, 7, 11–12, 14, 19, 20,
 42, 44, 51, 53, 54, 57, 59, 61, 65, 68, 87, 88,
 95, 97, 105, 108, 115, 116, 119, 120, 126, 128,
 130, 131, 134, 135, 139, 144, 145, 149, 155,
 333, 335
 Schwarzschild, K, 236
 Schwarzschild, M, 165
 Schwarzschild–AdS spacetime, 137
 Schwarzschild–Tangherlini spacetime, 135, 333
 Seifert, H, 126, 127
 self-dual bivector, 42
 Sen, A, 97, 318
 Senovilla, J, 97
 separability, 97, 98, 101–104
 Seyfert galaxies, 237, 269
 Seyfert 1, 239, 240, 247, 267
 Narrow Line, 237, 260–264, 267
 Seyfert 2, 238–240
 shear, 334
 shearfree, 10, 40, 41, 46, 61, 66, 74–80, 83–92, 97
 shocks, 254, 281, 282, 299
 shot noise, 304
 Simon, W, 97
 singularity, 155, 157
 coordinate, 7, 22–23, 57–62, 99
 curvature, 7–9, 12, 22–23, 29, 33, 57–62, 90, 337
 naked, 23, 26, 58, 117, 122, 339
 physical, 31
 ring, *see* ring singularity
 Sloan Digital Sky Survey (SDSS), 217
 Smarr formula, 126, 138
 Smarr, L, 25
 SN1987, 283
 SN1998bw, 283, 297
 SN2003dh, 283
 Snyder, H, x
 spin, *see* angular momentum, *see* rapid spin
 spin energy, *see* energy, rotational
 spin–orbit coupling, 303
 spinor, 44, 45, 63, 64, 74–77, 81, 83, 86, 87, 104, 316
 stable causality, 21
 star formation, 213, 226
 rate, 283, 300, 302
 static spacetime, 44, 108, 109, 115–139, 333, 334
 staticity theorem, 123, 133
 stationary limit surface, 28, 29, *see also* ergosurface
 inner, 29
 outer, 29
 stationary spacetime, 4, 6, 34, 44, 49, 51–52, 57, 59,
 62, 63, 87, 95, 115–139, 316, 337, 340, 341
 string history, 89–92
 Strominger, A, 318
 structure formation, 213
 Sudarsky, D, 109, 133
 Sunyaev, R, 189
 supergravity, 131
 supermassive black holes, *see* black hole,
 supermassive
 supernova
 core collapse, 283, 284
 aspherical, 285, 288, 291, 296, 297
 bar–mode instabilities, 284
 fireball model, 281, 282
 cosmological event rate, 283

- energy radiation processes, 295–297
 gravitational wave emission, *see* gravitational waves
 hydrodynamic instabilities, 293, 295, *see also*
 buckling instability, *see also* tilt instability
 jet formation, 285, 297–300
 neutrino emission, 282, 283, 285, 296
 outflows
 baryon-poor, 282, 289, 297, 298
 baryon-rich, 296, 297
 ultra-relativistic, 281, 282, 285, 297–300, 303
 type Ib, 282, 284, 285
 type Ic, 282–285
 type II, 283, 284
 supernovae
 neutrino emission, 296, 297
 superradiant scattering, 287
 superstring, 98, 115, 118–120, 132, 134, 135, 312,
 313, 320, 327, 328, 332
 supersymmetry, 118, 136, 312, 339–340
 surface gravity, 123, 134, 138, 183, 291, 311, 316,
 323, 324, 338, 339
 suspended accretion, *see* accretion processes,
 suspended
Suzaku, 237, 276
Swift, 189, 203, 282, 285, 302, 303
- Tafel, J, 92
 TAMA, 300
 Tambourino, L, 42
 Teitelboim, C, 316
 TEST sculpture, 207
 tetrad, 18, 39, 42, 44, 45, 49, 63, 69, 99–101, 105,
 116
 Teukolsky, S, 101, 104
 Texas Symposium, 57, 62
 Texas, University of, ix, 41
 thin shell approximation, 199
 Thompson, A, 42, 43
 Thorne, K, 5, 115, 180
 tilt instability, 292
 “time machine”, *see* Kerr spacetime, closed timelike
 curves
 topological censorship theorem, 133, 135
 topological field theory, 319
 Townsend, P, 319
 Trautman, A, 38, 40–44, 92
 turbulence, 231, 290
 twistor, 73–92
 twistor space, 74, 78, 86, 88
 two-form, 70, 99, 101, 338
 type D, 59, 61, 95, 97, 117
 type III, 40
 type N, 38, 40
- Uhuru*, 180–183
 ultra-relativistic approximation, 200
 uniqueness theorem, 3, 6, 108, 109, 111, 115–139,
 337, 340
 limitations, 136, 338, 340
 University of Canterbury, Christchurch, ix–xi
 University of Texas, Austin, ix, 41
- Unruh, W, 101
 Unti, T, 42
- vacuum polarization, 192, 193, 195–197
 van der Burg, M, 38
Vela, 188, 281, 302
 VIMOS (Visible Multi-Object Spectrograph), 228
 Virasoro algebra, 314, 315, 318
 central charge, 318, 321, 322, 325, 326
 generator, 314, 325
Virgo, 284, 286, 300, 302–304
 Vishveshwara, C, 108
 Vlasov–Boltzmann equation, 197
 VLBA/VLA (Very Long Baseline Array), 221, 222,
 227
 VLT (Very Large Telescope) array, 189, 224
 Melipal, 228
 Yepun, 223
 von Weizsäcker, C, 169
- Wahlquist, H, 97
 Wald, R, 109, 133, 318, 334
 Wess–Zumino–Witten model, 319
 Weyl equation, 103
 Weyl scalar, 58
 Weyl spacetime, 127
 Weyl spinor invariant, 64
 Weyl tensor, 5, 38, 97, 99, 117
 Wheeler, J, x, 5, 57, 117, 128, 162, 164, 165,
 168–170, 173–178, 180, 182, 311
 white dwarfs, 162, 163, 178, 179
 white hole, 107, 122
 Wigner, E, 165, 175, 176
 Wilkinson, D, 165, 175, 176
 Wilson, J, 184, 185, 198
 Wimmer, H, 176
 Witten, E, 319
 Woosley, S, 283
 worldsheet, 89–92
 Wybourne, B, ix
- X-ray
 background, 218
 flares, 254, 259
 luminosity, 185, 255
 variability, 271
 outbursts, 264, 265, 267
 reflection spectra, 237–240, 243–244, 246, 248,
 249, 251–253, 262, 266, 268, 270, 272,
 274
 sources, 163, 237, 246, 260, 261, 264, 265, 267,
 271, 272
 spectra, 236, 276
 absorption, 239, 240, 244, 246, 248, 250, 251,
 261, 262, 271, 272
 Compton hump, 238, 239, 249, 261
 emission, 237–241, 243–247, 249–252, 261, 262,
 267–275
 emission lines, 238–240, *see also* iron lines
 flux states, 239, 251, 257–259, 264
 hard, 237–239, 242, 246, 253, 268, 271

362

X-ray (*cont.*)

power law component (PLC), 252, 254–260, 262, 263

reflection dominated component (RDC), 252, 254–258, 260, 262, 263, 268, 270

soft, 237–239, 244, 250, 253, 261, 266–272

soft excess, 239, 262, 267–272

thermal emission, 237, 250, 267, 272

time variability, 272–275

variability, 251–253

XEUS (X-ray Evolving Universe Spectroscopy), 237, 270, 275, 276

Index

XMM-Newton, 189, 239, 247–253, 255–265, 267, 268, 270, 272, 275, 276

XTE J1650–500, 237, 264–267, 271

Yang–Mills charges, 131

Yang–Mills potential, 131

ZAMOs, *see* zero angular momentum observers

Zanelli, J, 316

Zel'dovich, Ya, 169, 187

Zerilli, F, 165

zero angular momentum observers, 286, 299