

Index

- active galactic nucleus, 149–50, 161
 - radio jets, 149
- Albrecht, Andreas, 81
- Alpher, Ralph, 49
- Andromeda galaxy, Messier 31, 10, 22, 28, 31, 36, 98, 148–9, 193, 236
- Augustine, St, 2, 6
- Baade, Walter, 22, 31
- Barnes, Bishop, Ernest, 5
- baryon genesis, 90–1, 185
 - and charge conjugation, 90–1
 - and parity violation, 90–1
 - and proton decay, 91–2
- baryon number, 89–91, 185
- biasing, of galaxy distribution, 197–8, 207
- Big Bang, *see* Friedmann-Lemaître equation
- Big Crunch, 238, 240–1
- Bondi, Herman, 42
- blackbody radiation, cosmic, 50–8, 88–9
- black hole, 10, 60, 69, 140–52
 - massive, 69
 - mini, 60, 69–71, 145–6
 - stellar, in X-ray binary systems, 146
 - supermassive, 143–4, 146–50, 210, 240
- Bolton, John, 45
- branes, 74–5, 184, 213–14, 217, 237
- brown dwarfs, 139–40
- Casimir effect, 62–3, 77, 129
- Chandrasekhar mass, maximum mass of
 - white dwarfs, 38, 134
- Chandrasekhar, Subrahmanyan, 38
- chemical evolution of the galactic spheroid, 231
- chemical evolution of the galaxy, 230–3
- comoving distance, 98
- Compton wavelength, 10, 68, 70–1
- Cosmic Background Explorer (COBE)
 - satellite, 51, 56–8, 189–90
- cosmic microwave background, 40, 45–6, 48–58, 88–9, 237
- angular peaks, 191, 204
- Comptonisation, 168
- decoupling, 177, 238
- dipole anisotropy, 53, 58, 108, 201
- fluctuations, 131, 178, 187–92, 205, 238–9
 - adiabatic, 177–8, 181, 184, 205
 - entropy, 185–6
 - isothermal, 177
- foregrounds, 190, 239
- last scattering epoch, 54–5, 191
- last scattering surface, 109
- polarisation, 207
- recombination, 158–9
- reionisation, 207, 210
- thermalisation, 53–4
 - via bremsstrahlung, 54
- cosmic ray particles, 88
- cosmic strings, 73–4
 - and gravitational lensing of the cosmic microwave background, 216
 - and monopoles, 215
 - and pulsar timing, 215–16
 - and textures, 214–16
 - and walls, 215
 - as topological defects, 214
- cosmological constant, 63, 203–8
- cosmological principle, 7, 32, 47, 104
 - anthropic, 8
 - perfect, 7
- cosmological tests, and curvature of space, 108–10, 112, 131
 - galaxy counts, 106–7
- critical density, in Friedmann-Lemaître universe, 101–2, 120–1, 152, 165, 168, 178, 184, 186, 202, 207
- Cronin, James, 91
- dark matter, 113–57
 - baryonic, 122–5, 132–57, 160, 165–9
 - MACHOs (Massive Astrophysical Compact Halo Objects), 132–3, 154–7, 172

- cold, 172–6, 180, 189, 196–8, 202–12
 - fluctuations, 175
- hot, 176–81, 211
- in galaxy clusters, 165
 - nonbaryonic, 122–9, 152–3, 157
 - neutrinos, 125–6, 212
 - WIMPs (Weakly Interacting Massive Particles), 125–9, 172
 - and photinos, 126–9, 211
 - annihilation, 128–9
 - and supersymmetry (SUSY), 127
 - warm, 210–12
- de Laplace, Pierre-Simon, 69
- de Sitter, Willem, 48
- Dicke, Robert, 49
- diffuse gamma ray background, in steady state universe, 43, 44
- Doppler effect, 25–7, 32, 36, 88
- Doroshkevich, Andrei, 49
- Dyson, Freeman, 240
- Eddington, Arthur, 3, 4
- Einstein, Albert, 5, 47, 48, 140, 142
 - static universe, 206
- energy
 - dark, 121, 129–31, 203–8
 - as quintessence, 239
 - gravitational potential, 99–102, 105–6, 175, 186, 195, 202
 - kinetic, 99–102, 105–6, 175, 186, 195
- Fermi, Enrico, 50
- Fisher, Richard, 37
- Fitch, Val, 91
- Friedmann, Alexander, 47, 97, 100
- Friedmann–Lemaître equation, 97–102
 - and closed universe, 105, 109
 - and flat universe, 192, 204
 - and hyperboloidal space, 106
 - and open universe, 104–6, 109, 184–6, 205
 - and spherical space, 106
- fundamental forces, 64–6, 73, 92
 - and W boson, 65, 93
 - and Z boson, 65, 93
 - electromagnetic, 64
 - grand unification of, 65, 72, 75, 89–90, 127–8, 214
 - gravitational, 64
 - symmetry breaking, 76–7, 214
 - phase transition, 212–13
 - topological defects, 213
- strong nuclear, 65, 75
- weak nuclear, 65
- galaxies
 - barred, 23, 153–4
 - clusters of, 30, 56, 118, 165–9, 171–2, 177, 180–1, 186, 193, 196, 202–3, 207–8, 235
 - ‘fingers of God’, 199
 - dwarf, 23, 171–2, 175, 196, 208–9, 236
 - rotation curve, 116
 - elliptical, 23, 35, 36, 153, 223
 - fundamental plane, 200–1
 - irregular, 33
 - groups of, 118
 - halos of, 117, 152–7, 195–6, 208–9
 - flattening, 153
 - large-scale bulk flows of, 119–20, 198–202
 - and the Great Attractor, 120
 - large-scale distribution of, 196–202
 - lenticular or S0, 23
 - Local Group of, 52–3, 98, 236
 - local supercluster of, Virgo supercluster, 33, 52–3, 118, 193
 - pairs of, 118
 - peculiar, 24
 - peculiar velocities of, 119, 202
 - radio, 44, 45, 160
 - Seyfert, 146
 - spiral, 22, 36–7, 117
 - superclusters of, 118, 177, 186, 193, 196, 235
- galaxy formation, 219–36
 - and temperature fluctuations in microwave background, 56
 - bottom-up, 172–6
 - ellipticals, 232–5
 - mergers of protogalaxies, 233–5
 - spirals, 232–3
 - top-down, 176–81
- gamma ray burst sources, 151
- Gamow, George, 49
- general relativity and curvature of space, 82, 102, 184, 192
 - theory of, 47, 59, 82, 141–2, 145
- gravitational redshift, 143
- no hair theorem, 145
- Gold, Thomas, 42, 43
- gravitational collapse of interstellar cloud, 14, 15

244 INDEX

- gravitational instability
 - and primordial fluctuations in the
 - cosmic microwave background, 170–1, 183
 - and structure formation, 170–192
- gravity wave background
 - and polarisation of the cosmic microwave
 - background fluctuations, 217–18
 - and space detection, 217
 - and temperature fluctuations, 216–18
- relic, 216–18
- Green, Michael, 74
- Guth, Alan, 80
- hadron, 86, 93, 128
- Hawking, Stephen, 3, 60, 70
- Hawking radiation, 70
- Heisenberg, Werner, 61
 - uncertainty principle, 61–3, 68, 129, 134
- Herman, Robert, 49
- Hertzprung, Ejnar, 21
- Higgs, Peter, 214
- Higgs field, 214–15
- Hooke, Thomas, 180
- Hoyle, Fred, 19, 42, 48
- Hubble, Edwin, 22, 26, 30, 31, 47
- Hubble constant, 32–4, 39–41, 45, 200
- Hubble flow, 33, 119, 200
- Hubble law, 32, 40, 48, 119, 197, 199–200
- hydrogen
 - atomic, 11, 12, 13, 97
 - and 21 cm emission or absorption, 12, 36, 115–16
 - ionised, 11, 34
 - HII regions, 34
 - molecular, 11, 13, 14
- inflation
 - and Euclidian space, 82, 206
 - and magnetic monopoles, 213
 - and quantum fluctuations, 172, 181–4, 237
 - epoch of, 63
 - theory of, 75–84, 106, 120–1, 127, 172, 181–5, 187–9, 211, 213, 216–7, 239
- intergalactic matter, 158–69
 - clouds, 161–4
 - Lyman alpha forest, 163, 166
 - intracluster gas, 164–5, 235
 - interstellar clouds, 11, 12, 115–16, 220
 - dust, 13, 231
 - medium, 225–7
 - molecules, 13, 14
- Jaki, Stanley, 43
- Jastrow, Robert, 3
- Jeans, James, 176
- Jeans mass, 176, 221, 229
- Lamb, Willis, 62
- Laser Interferometer Space Antenna (LISA), 217, 240
- Leavitt, Henrietta, 31
- Lemaître, Georges, 2, 47, 97, 100
- lensing, gravitational, 203–4
 - and the cosmological constant, 203
 - of quasars, 203
- lepton, 86, 93, 214
- Linde, Andrei, 81
- Magellanic Clouds, 23, 31, 220
- Malmquist bias, 33–4, 37
- Mather, John, 51
- Messier 87, 148–50
- Michell, John, 69
- microlensing, gravitational, of Large
 - Magellanic Cloud, 154–7
- Milky Way galaxy, 9, 10, 28, 236
 - and Population I, 113–14
 - and Population II, 113–14, 228
 - and Population III, 228
 - disk, 113–14
 - halo, 113–14
 - rotation, 115–17
 - spiral arms as density waves, 220–2
- Milne, E. A., 3
- Muller, Richard, 53
- Narlikar, Jayant, 44
- neutrinos
 - and dark matter, 125–6
 - and weak nuclear force, 65, 92–3
 - electron, 16, 18, 126
 - muon, 16, 18, 126
 - oscillation, 126
 - solar, 15–16
 - Homestake experiment, 16
 - Sudbury Neutrino Observatory, 17–18
 - Super Kamiokande experiment, 17–18

- supernova detection experiments, 137
- tau, 16, 126
- neutron
 - and nucleosynthesis of light elements in the early universe, 85–9, 93–6
 - and weak nuclear force, 65
- NGC 4258, 148–9
- Newton, Isaac, 180
- Novikov, Igor, 49
- nucleosynthesis, primordial, 92–6, 165
- Ohm, Ed, 49
- Olbers' Heinrich, 24
- Olbers' paradox, 24, 25
- parallax, 28, 29
- Penrose, Roger, 60
- Penzias, Arno, 48
- pion, 66
- Pius XII, Pope, 2, 4
- Planck scale, 72–3, 75
- Planck time, 71, 81, 105, 183, 212
- Poe, Edgar Allan, 25
- protogalaxy, 229–31
- protostar, 14, 18, 221–2, 230–1
- Proxima Centauri, 5, 28
- pulsar, 138–9
 - binary, 142
- quantum gravity, 61, 65, 70–1, 73, 74, 145, 212–14
 - and anthropic principle, 82–4
- quantum vacuum, 62, 77, 85, 129–30
 - and electron–positron pairs, 67
 - and proton–antiproton pairs, 67
 - and virtual particles, 66–68, 88
 - and zero point fluctuations, 62
 - false, 77–9, 81
 - true, 77–9
- quark, 10, 66, 72, 85, 90, 92–3, 214
 - and colour force, 66
 - and gluons, 66, 72
- quasar, 44, 45, 147–50, 160–4, 207, 236
- radioactive dating of long-lived isotopes, 42
- Russell, Henry Norris, 21
- Ryle, Martin, 45
- Sakharov, Andrei, 90
- Salpeter, Edwin, 19
- Sandage, Allan, 30
- Schwartz, John, 74
- Schwarzschild, Karl, 141
- Schwarzschild radius, 70–1, 141, 147, 155, 237
- Seyfert, Carl, 146
- singularity
 - Big Bang, 55, 59–60
 - naked, 60
- Slipher, Vesto, 28
- Smoot, George, 53
- spectroscopy, 11
 - and absorption lines, 12
 - and emission lines, 11
 - and Lyman alpha absorption, 14, 160–4
- steady state cosmology, 7, 41–6, 48
- stars
 - and stellar evolution, 22, 29
 - binaries, 20, 224
 - black dwarfs, 115, 135
 - blue giants, 20, 22
 - Cepheid variables, 28–31
 - first, 227–30
 - formation of, 209–10, 220–3, 234–5
 - globular clusters, 42, 113, 139, 227–8
 - Hertzsprung–Russell diagram, 21, 113, 133, 227
 - main sequence, 21, 22, 140, 223, 227
 - masses, 20
 - neutron, 37, 38, 135–9, 223
 - in Crab nebula, 138
 - planetary nebulae, 34, 35, 115, 134, 224
 - red dwarfs, 22
 - red giants, 20, 22, 224
 - red supergiants, 134, 139
 - supergiants, 33, 35, 41
 - T-Tauri, 222
 - white dwarfs 20, 22, 34, 35, 115, 130, 133–5, 155–6, 224–5, 240
- Steinhardt, Paul, 81
- Sunyaev, Rashid, 40
- Sunyaev–Zel'dovich effect, 39, 40
- supernova, 37–9, 41, 136–7, 151, 160, 210, 230
 - in Crab nebula, in AD 1054, 137–8
 - remnant, 137–8
 - SN 1987A, in Large Magellanic Cloud, 137
 - Type I, 38, 39, 41, 130, 204, 208, 224–7
 - Type II, 38, 41, 223–7

246 INDEX

- superstrings
 - and higher dimensions, 73–5
 - and superspace, 75
 - and Theory of Everything, 72
 - theory of, 59, 74–5, 83
- textures, three-dimensional topological
 - defects, 214–15
 - Goldstone bosons, 215
- thermonuclear energy
 - in stars, 18
 - solar fusion, 18, 128
 - and nucleosynthesis, 19
 - in early universe, 49, 85–96
 - of deuterium, 94–6, 122–4, 167
 - of helium, 94–6
 - of lithium, 94–6, 124–5
 - triple alpha process, 19, 224
- topology of universe, 105
- Tully, Brent, 37
- Tully–Fisher correlation, 36, 37, 119, 200
- Virgo cluster of galaxies, 33, 35, 118
- Wheeler, John Archibald, 5, 69
- Weinberg, Steven, 3, 240
- Wien's law, 50, 52
- Wilkinson Microwave Anisotropy Probe (WMAP), 191–2, 211, 239
- Wilson, Robert, 48
- wormholes, 60, 145
- Zel'dovich, Yaakov, 40
- Zwicky, Fritz, 113