

Index

- Λ CDM, 166, 184, 192
 σ_8 , 190
- Abell catalog, 145
 aberration, 119
 accelerating universe, 145, 165, 192
 acoustic oscillations
 damping, 198
 fundamental mode, 198
 higher harmonics, 198
 Active Galactic Nucleus, AGN, 57
 additive bias, 126
 affine parameter, 23
 anisotropy spectrum, 13
 apparent magnitude, 75
 arcsecond, 1
 astronomical unit, AU, 98, 104
 attar power spectrum, 178
- B-mode
 of shear, 135
 baryon density, Ω_b , 165
 Baryon Oscillation Spectroscopic Survey (BOSS), 170
 baryons, 165
 Bayes' Theorem, 160
 black holes, 89
 Boltzmann constant, 196, 210
 Born approximation, 31
 boson, 196
 Bremsstrahlung, 146
- Canada–France–Hawaii Telescope (CFHT), 179, 189
 Cassini spacecraft, 28
 caustics, 50
 as curves of infinite magnification, 66
 asymmetric lens, 80
 isothermal sphere, 52, 72
- center of mass
 of star and planet, 95
 Chandra satellite, 146
 Christoffel symbol, 22, 141
 circular PSF
 effect on ellipticity, 120
 cluster, *see* galaxy cluster
 clustering of matter
 using tomography, 188
 CMB, *see* Cosmic Microwave Background
 Cold Dark Matter, CDM, 166
 comoving coordinates, 163
 comoving distance, 212
 complex conjugate, 203
 Compton scattering, 197
 conditional probability, 160
 conjugate variables, 155
 l and θ , 200
 convergence, 11, 34, 64, 154, 163, 212
 as delineator of strong and weak lensing, 35
 as dilation, 65
 as element of distortion tensor, 64
 effect on acoustic peaks, 200–201
 isothermal sphere, 69
 relation to Φ , 37
 relation to Φ in Fourier space, 156, 163
 spherically symmetric, 42–44
 convolution, 203, 209
 core angular radius, 46
 core radius, 44
 correlation function, 167, 175
 Cosmic Microwave Background, CMB, 3, 12, 165, 196–199
 lensing, 196
 temperature of, 14, 204
 cosmic shear, 11, 135, 162
 E-B decomposition, 173
 B-modes, 175
 E-modes, 173

- cosmic variance, 180, 183
- cosmological constant, 159, 166
- cosmological distance
 - measured with tomography, 188
- cosmology, 164
- Coulomb scattering, 197
- covariance matrix, 124
- critical curves, 53
 - asymmetric lens, 80
 - isothermal sphere, 72
 - point mass, 66
- critical density of the universe, 149, 160, 174, 210
 - defined, 165
- critical surface density, 8, 9, 34, 42, 60, 76, 134, 154, 211
- cross shear, 135
- curvature, 141
- curved space, 23
- dark energy, 145, 165
 - equation of state w , 166, 192
- Dark Energy Survey, 159, 174, 184, 189
- dark matter, 7, 81, 87, 137, 165
 - evidence from galaxy–galaxy lensing, 139
 - halo, 89
 - in the Galaxy, 87–89
 - MACHO fraction, 94
- deceleration, 145
- deflection angle, 1, 17, 20, 31, 38, 115, 203, 211
 - experienced by CMB photons, 199
 - General relativity, 25
 - isothermal sphere, 44–46
 - Newtonian, 20
 - point mass, 39
 - spherically symmetric distribution, 41, 132
- density of states, 183
- diffraction, 119
- Diffuse Infrared Background Experiment (DIRBE), 95
- dilation
 - due to convergence, 64
- dimensional analysis, 156
- Dirac delta function, 35, 43, 130, 155, 169, 176, 178, 199, 203, 205
- distance
 - angular diameter, 144, 159
 - comoving, 142
- distances in cosmology, 142–145
- distortion tensor, 64, 108, 115, 211
 - as spin-2 field, 129
 - relation to Φ , 64
- Drake equation, 95
- dust, 88, 95
- Dyson, F., 2
- Earth mass, 210
- Eddington, A., 2
- Einstein radius, 4
 - cored isothermal sphere, 46, 48
 - of foreground star, 99, 211
 - point source, 39
 - singular isothermal sphere, 46
- Einstein ring, 4, 48
- Einstein summation convention, 21
- Einstein's equations, 164
- Einstein, A., 1, 21
- electric polarizability, 117
- electrons, 197
- ellipse, 109
- elliptical Gaussian, 124
- ellipticity, 11, 109
 - in terms of moments, 110
 - of stars, 122
 - relation to shear and convergence, 111
 - weighting in the presence of noise, 112–114
- energy density, 163
- exoplanets, 7, 87, 95–97
 - detection via microlensing, 96
 - detection via radial velocity, 95
 - detection via transits, 96
- expanding universe, 142
- extrasolar planets, *see* exoplanets
- Fermat's principle, 56
- flat rotation curve, 88, 137, 140
- flux, 62
- forward modeling, 123
- Fourier space, 155, 156, 163
- Fourier transform, 154
 - continuous, 155
 - conventions, 155
 - of CMB anisotropies, 199
 - of lensed CMB temperature, 203
 - of real function, 199
- fractional overdensity δ , 147, 163
 - RMS σ , 147, 167, 170
 - statistics of, 166–172
- Freundlich, E., 1
- Friedmann equation, 159, 164
- Galactic bulge, 93, 95
- Galactic center
 - distance to, 93
- Galactic coordinates, 93
- galaxies, 137
- Galaxy, *see* Milky Way
- galaxy cluster, 9, 44, 132, 145–149
 - abundance, 147
 - mass from shapes, 149–153
 - mass function, 149
 - radius definitions, 149
- galaxy density, 181
- galaxy surveys
 - BOSS, 170

222

CFHT, 179
 DES, 128, 159, 174, 184, 213
 LSST, 159
 QDOT, 168
 SDSS, 137, 159
 galaxy–galaxy lensing, 137–139
 as evidence for dark matter, 139
 Gaussian distribution, 169, 182, 194
 general relativity, 1, 17, 20–25, 140, 141, 164
 geodesic equation, 20, 22
 geodesics, 141
 GG spectrum, 187
 GI spectrum, 187
 gradient in Fourier space, 199
 GRavitational lEnsing Accuracy Testing (GREAT),
 126
 gravitational potential, 6, 162, 173
 3D ϕ , 186
 projected, 31, 108, 162, 186, 196, 203, 211
 gravitational waves, 173
 gravity
 Newtonian, 17, 18, 140
 scalar–tensor theory, 141
 growth function, 148, 164, 187, 192

Hale, G., 1
 Heavyside step function, Θ , 114, 179
 Heliocentric Julian Date, 104
 homogeneity, 167
 impact of correlations, 170, 199
 homogeneous early universe, 197
 Hubble constant, 143, 165, 210
 Hubble rate, 164
 definition in terms of scale factor, 143
 low redshift limit, 144
 Hubble Space Telescope, 41, 77, 123
 Hubble, E., 144
 hydrogen, 197

II spectrum, 187
 im2shape, 123
 im3shape, 184
 image plane, 38, 53
 impact parameter, 1, 18
 inhomogeneity
 impact on correlations, 203
 intensity
 of radiation, 196
 intrinsic alignment, 184–188
 intrinsic ellipticity, 114, 136
 invariant distance, 21, 25
 ionization, 197
 ionization energy of hydrogen, 197
 isothermal density profile, 9, 16
 isothermal sphere, 44
 isotropy, 167

Index

Jupiter, 104
 Jupiter mass, 210

Kepler satellite, 96
 Keplerian velocity fall-off, 88, 140
 Kitt Peak, 41
 Kronecker delta, 24, 116, 158

Large Magellanic Cloud, 91
 large scale modes, 155
 large scale structure, 127, 199
 Large Synoptic Sky Telescope (LSST), 159
 length contraction, 24
 lens, 1
 lens equation, 17, 31, 38, 63, 115, 211
 isothermal sphere, 46
 multiple point masses, 97
 likelihood, 160
 likelihood function, 150
 Limber approximation, 175–179, 192
 luminosity, 137

MACHO, 7, 89
 MACHO collaboration, 91
 magnification, 6, 11, 62
 as Jacobian, 62
 isothermal sphere, 68–72
 point mass, 66–68
 relation to κ and shear, 65
 weak lensing, 75
 magnification threshold
 MACHO detection, 92
 planet detection, 103
 map
 of projected gravitational potential, 204
 Markov Chain Monte-Carlo, 126, 128
 mass maps, 77, 153, 173, 174
 mass sheet degeneracy, 157
 matter density Ω_m , 159, 165, 190, 195
 matter power spectrum, 187
 mean matter density $\bar{\rho}_m$, 163
 mean surface density, 134
 metric, 20, 21, 141
 microlensing, 6, 85
 by MACHOs, 89–95
 by star in distant galaxy, 85
 event duration, 90
 peak magnification, 91
 towards Galactic bulge, 94
 microwave region of electromagnetic spectrum, 196
 Milky Way, 87
 multi-wavelength image, 87, 218
 Minkowski metric, 24, 37
 modified gravity, 140
 MOND, 140
 multiple images, 4
 multiplicative bias, 126

- negative parity, 73
- neutrinos, 165
- neutron stars, 89
- Newton's constant, 1, 210
- Newton's law, 140
- noise
 - on convergence power spectrum, 180
- OGLE collaboration, 104
- optical depth, 92
- orbital radius a , 95
- ordinary differential equation, 19
- parametric analysis, 153
- parity, 72
- parsec, 210
- peculiar velocity, 142
- photons, 141
- Planck's constant, 196, 210
- point spread function (PSF), 119
 - moments of, 120
- Poisson's equation, 32, 163, 173
- post-Newtonian parameter, γ , 28
- power spectrum, 168, 175, 178
 - angular, 161
 - as Fourier transform of correlation function, 169
 - of convergence, 178
 - of deflection angle, 200
- pressure, 198
- prior, 160
- protons, 197
- QDOT survey, 168, 170
- quadratic estimator, 203
- radian
 - in degrees, arcminutes, arcseconds, 210
- recombination, 197
- redshift, 55, 79, 164
 - as distance indicator, 77
 - photometric, 153
 - relation to scale factor, 143
- redshift distribution of background galaxies, 179
- reduced shear, 112, 126, 129
- responsivity, 119
- restoring force, 198
- root mean square (RMS), 12, 118, 137, 149, 200
 - of CMB fluctuations, 198
 - of deflection angle α , 199
 - of density fluctuations, σ , 147, 170, 190
- scale factor, 142, 164, 197
 - in terms of redshift, 143
- Schwarzschild radius, 37
- shape noise, 136, 150, 157, 180
- shapes, 11
- Shapiro, I., 26
- shear, 64, 108, 163
 - as elements of the distortion tensor, 64
 - effect on galaxy shapes, 108
 - in terms of Φ , 211
 - relation to Φ in Fourier space, 163
 - tangential, 8
- shear catalog, 181
- shear polarizability, 117
- signal-to-noise
 - cluster lensing, 132
 - estimating, 159
 - of mass maps, 204
 - of weak lensing by an isothermal sphere, 135–136
- sky fraction f_{sky} , 183
- Sloan Digital Sky Survey (SDSS), 137, 159
- small scale modes, 155
- smear polarizability, 121
- smoothed CMB spectrum, 206
- SN Refsdal, 38
- solar mass, 210
- solar radius, 26
- source plane, 38, 53
- speed of light, 23
- spherically symmetric lens, 41
- stacking, 139
- statistical errors, 127
- strong lensing, 3, 35
- supernova, 38
- surface brightness, 6, 15, 62, 110
 - effect of PSF, 120
- surface density, 8, 15, 33, 154, 212
- surface of last scattering, 197, 204
- systematic errors, 127, 153, 158, 175
- tangential shear, 133, 173
 - in terms of surface density, 134
 - isothermal sphere lens, 150
- thin lens approximation, 32–35
- tidal force
 - as source of intrinsic alignment, 185
- time delay, 5, 53
 - geometric, 53
 - Shapiro, 6, 17, 25
- time dilation, 24
- tomography, 188–191
- Twin Quasar, 42
- University of Hawaii Telescope, 146
- unlensed CMB spectrum, 199
- velocity dispersion, 44
- Venus, 26
- Very Large Array, 80
- virial theorem, 160
- Warsaw University Telescope, 104

wavelength, 197	WIMP, 7, 89
weak lensing, 3, 35, 112, 132, 136	window function
Weighing the Giants program, 154	for the convergence power spectrum, 179
weighting function	
for ellipticity, 114	
Widefield Infrared Survey Telescope (WFIRST), 97	X-ray emission, 146