

Index

- afterglow, 1, 15, 54, 228, 273, 501
 - achromatic afterglow, 70
 - bumps and wiggles, 66
 - canonical X-ray afterglow lightcurve, 9, 18, 56, 58, 114, 343
 - normal decay phase, 18, 61, 343
 - plateau, 59
 - post-jet-break phase, 18, 61, 343
 - shallow decay phase, 18, 59, 343
 - steep decay phase, 18, 56, 343, 354, 355
 - chromatic afterglow, 18, 61, 70, 344
 - continuous energy injection, 59
 - GeV flare, 75
 - high-energy afterglow, 73
 - internal plateau, 19, 60, 61, 113, 471
 - onset of afterglow, 65, 235
 - optical afterglow, 64
 - optical flare, 66
 - plateau, 18
 - radio afterglow, 72
 - radio flare, 72
 - re-brightening feature, 66
 - spectral energy distribution, 56
 - spectral index β , 55
 - temporal decay index α , 55
 - X-ray afterglow, 56
 - X-ray flare, 9, 18, 33, 61, 66, 75, 114, 343, 471
- afterglow models, 273
 - Blandford–McKee solution, 277
 - blastwave, 165
 - closure relations, 72, 291, 292, 301, 320, 322, 324, 325, 327, 328
 - deceleration, 235
 - dynamics, 279–281
 - energy injection, 276, 296
 - forward shock model, 289
 - ISM model, 274, 289, 298, 303
 - jet model, 299
 - edge effect, 300
 - orphan afterglow, 305
 - sideways expansion, 302
 - structured jet model, 307
 - uniform jet model, 306
 - mechanical model, 168
 - microphysics parameters, 180
 - non-relativistic model, 311
 - polarization, 342
 - radiation front, 341
 - radiative fireball, 275
 - reverse shock model, 314
 - dynamics, 315, 317
 - thick shell, 326, 339
 - thin shell, 321, 337
 - self-similar regime, 274
 - SSC contribution, 313
 - synchrotron spectrum, 285
 - comoving magnetic field strength B' , 288
 - cooling Lorentz factor γ_c , 287
 - minimum injection Lorentz factor γ_m , 285
 - self-absorption frequency ν_a , 287
 - wind model, 275, 296, 298, 304
- alternative ideas, 269
 - cannonball model, 269
 - fireshell model, 270
 - precession, 271
- central engine, 14, 228, 444
 - hyper-accreting black hole, 15, 119, 445
 - $\nu\bar{\nu}$ annihilation, 446
 - Blandford–Znajek (BZ) mechanism, 446, 450
 - late central engine activity, 55, 470
 - long-lasting central engine, 61, 63
 - millisecond magnetar, 15, 19, 61, 83, 119, 455
 - accretion, 460
 - differential rotation, 459
 - spindown, 456
 - NS equation of state (EoS), 463, 464
 - NS–NS merger
 - hyper-massive NS, 463
 - prompt BH, 463
 - stable NS, 463
 - supra-massive NS, 463
 - quark star, 468
 - strange quark star, 468

- strange star, 468
- circumburst medium, 54
- classification, 108
 - amplitude f -parameter, 110
 - amplitude f_{eff} -parameter, 110
 - compact star GRBs, 114, 116, 419, 432, 454, 463
 - duration–hardness classification scheme, 108
 - high-luminosity GRBs, 10, 92, 97, 112
 - intermediate-duration GRBs, 29, 110
 - long GRBs, 6, 16, 29, 108
 - low-luminosity GRBs, 9, 12, 93, 98, 112, 431
 - massive star GRBs, 114, 116, 419, 454, 461
 - optically bright GRBs, 113
 - optically dark GRBs, 70, 113
 - phenomenological classification scheme, 108
 - physical classification schemes, 114
 - short GRBs, 6, 29, 94, 98, 108
 - short GRBs with extended emission, 113
 - SN-GRBs, 114
 - SN-less GRBs, 114
 - Type I GRBs, 80, 114, 116, 419
 - Type II GRBs, 114, 116, 419
 - ultra-long GRBs, 10, 119
 - X-ray flashes (XRFs), 1, 8, 41, 112
 - X-ray rich GRBs, 1, 8, 41, 112
- collapsar, 15, 16, 85
 - cocoon, 16
 - jet, 16
- compact star mergers, 21, 86, 98, 489
 - BH–BH mergers, 11, 490, 492
 - BH–WD mergers, 442
 - NS–BH mergers, 19, 115, 433, 440, 441, 490
 - NS–NS collisions, 442
 - NS–NS mergers, 13, 14, 19, 115, 433, 434, 440, 441, 490
- correlations, 101
 - $E_{\gamma, \text{iso}}-\Gamma_0$ relation, 106
 - $L_{\gamma, \text{iso}}-E_{p, z}-\Gamma_0$ relation, 106
 - $L_{\gamma, \text{iso}}-\Gamma_0$ relation, 106
 - Amati relation, 102, 103
 - Dainotti relation, 106
 - Fenimore–Reichart relation, 105
 - Fermani relation, 104
 - Frail relation, 104
 - Ghirlanda relation, 102, 103
 - Liang–Zhang relation, 103, 104
 - luminosity–lag relation, 63, 105
 - luminosity–variability relation, 105
 - Norris relation, 105
 - Xu–Huang relation, 106
 - Yonetoku relation, 102, 103
- cosmology
 - comoving distance, 95
 - cosmography, 513
 - cosmological parameters, 95
 - damped Ly α (DLA) system, 507, 509
 - distances
 - angular distance, 514
 - comoving distance, 513
 - light-travel distance, 514
 - luminosity distance, 514
 - transverse comoving distance, 514
 - extragalactic background light (EBL), 512
 - Gunn–Peterson (GP) trough, 508, 509
 - Hubble diagram, 514, 515
 - Hubble parameter, 513
 - look back time, 96
 - luminosity distance, 91, 95
 - metal enrichment history, 506
 - Population III stars, 502
 - reionization history, 508
 - star formation history, 503
- fast radio bursts (FRBs), 73, 517
- fireball, 13, 54, 241, 360
 - acceleration, 242
 - characteristic radii, 243
 - base of fireball R_0 , 243
 - coasting radius R_c , 246
 - deceleration radius R_{dec} , 250
 - internal shock radius R_{IS} , 247
 - photosphere radius R_{ph} , 247
 - Sedov radius R_{Sedov} , 253
 - spreading radius R_s , 246
 - coasting, 243
 - deceleration, 243
 - shell width, 245
 - thick shell, 252, 318, 339
 - thin shell, 252, 318, 337
- fireball shock model, 14, 384
- fundamental physics, 519
 - CPT violation, 522
 - Einstein’s Weak Equivalence Principle (WEP), 523
 - Lorentz Invariance Violation (LIV), 519, 521
 - photon rest mass, 524
 - quantum gravity, 519
- gamma-ray burst (GRB), 1
- Gamma-Ray Coordinates Network (GCN), 8
- global properties
 - V/V_{max} , 90, 91
 - $\log N-\log P$, 89–91, 96, 98
 - beaming-corrected energy, 100
 - emission energy, 100
 - kinetic energy, 100
 - bolometric luminosity, 97
 - k -correction, 97
 - detected event rate, 92
 - event rate density, 92
 - inhomogeneous, 90
 - intrinsic event rate density, 92
 - isotropic, 89
 - isotropic energy, 99

- bolometric emission energy, 99
- kinetic energy, 99
- luminosity function, 92, 97–99, 310, 441
- non-uniform, 90
- observed event rate density, 92
- radiative efficiency, 100
- redshift distribution, 91, 92, 94, 440
- volumetric event rate, 92
- GRBs
 - GRB 021206, 52
 - GRB 030323, 506, 507
 - GRB 030329/SN 2003dh, 7, 67, 77, 78, 114, 118, 231, 311, 313
 - GRB 041017, 51
 - GRB 041219A, 51, 52
 - GRB 041219B, 51
 - GRB 050406, 63
 - GRB 050416A, 525
 - GRB 050502B, 63
 - GRB 050509B, 9
 - GRB 050607, 63
 - GRB 050709, 9, 83, 440
 - GRB 050712, 63
 - GRB 050713A, 63
 - GRB 050714B, 63
 - GRB 050724, 9, 80, 81, 83, 116, 440, 497
 - GRB 050730, 72
 - GRB 050820A, 51–53
 - GRB 050822, 63
 - GRB 050904, 9, 63, 509, 511
 - GRB 050906, 63
 - GRB 051103, 443
 - GRB 060124, 51
 - GRB 060218/SN 2006aj, 9, 10, 51, 117, 431
 - GRB 060418, 65, 69, 342
 - GRB 060505, 9, 80, 81, 114, 115
 - GRB 060526, 72
 - GRB 060607A, 72
 - GRB 060614, 9, 65, 66, 79–81, 83, 114–116, 440
 - GRB 060729, 66
 - GRB 061006, 83, 440, 497
 - GRB 061121, 51
 - GRB 070110, 60, 72
 - GRB 070714B, 83, 440, 497
 - GRB 071025, 86
 - GRB 080319B (naked-eye GRB), 10, 51, 53, 311, 377, 409, 500, 523
 - GRB 080503, 83, 497
 - GRB 080913, 9, 116, 500
 - GRB 080916C, 11, 37, 45, 46, 234
 - GRB 081029, 67
 - GRB 081125, 49
 - GRB 081207, 49
 - GRB 081221, 49
 - GRB 081222, 49
 - GRB 081224, 49
 - GRB 090102, 69, 343
 - GRB 090423, 9, 116, 500
 - GRB 090426, 9, 116
 - GRB 090429B, 9, 116, 498, 500
 - GRB 090510, 11, 45, 46, 51, 234, 520–523
 - GRB 090515, 60
 - GRB 090902B, 11, 38, 45, 46, 49, 51, 234, 378, 408
 - GRB 090926A, 11, 45, 46, 49, 51, 67, 234
 - GRB 091208B, 69
 - GRB 100316D/SN 2010bh, 9
 - GRB 100704A, 73
 - GRB 100724B, 44, 47
 - GRB 100728A, 75
 - GRB 100826A, 522
 - GRB 100828A, 53
 - GRB 101011A, 73
 - GRB 101225 (Christmas GRB), 10, 120
 - GRB 110205A, 51, 52
 - GRB 110301A, 53, 522
 - GRB 110721A, 46, 47, 53, 378, 522
 - GRB 111209A/SN 2011kl, 431
 - GRB 120308A, 69, 343
 - GRB 120323A, 46
 - GRB 120412A, 28
 - GRB 130427A, 11, 49, 51, 52, 56, 57, 72, 75, 78, 114, 118, 234, 288, 299, 314
 - GRB 130603B, 83, 440, 497
 - GRB 130606B, 378
 - GRB 160625B, 34, 54, 409, 522
 - GRB 670702, 3
 - GRB 930131, 52
 - GRB 940217, 73
 - GRB 941017, 46
 - GRB 960924, 52
 - GRB 970228, 7, 55
 - GRB 970508, 7, 55
 - GRB 980326, 79
 - GRB 980425/SN 1998bw, 7, 78, 118, 498
 - GRB 980703, 525
 - GRB 990123, 8, 42, 51, 53, 65, 66, 72, 299, 334
 - GRB 990510, 65
 - GRB 991208, 525
 - GW150914-GBM (putative), 442
 - GW170817/GRB 170817A, 12, 22, 94, 99, 433, 470, 488, 492, 495, 498, 517, 524
 - GRB detectors
 - Apollo*, 4
 - BeppoSAX*, 6, 16, 56, 114
 - CGRO*, 1, 5
 - BATSE, 1, 5, 14, 29, 52, 73, 89, 90
 - EGRET, 73
 - Fermi*, 1, 10, 19, 41, 89
 - GBM, 1, 10, 43, 73
 - LAT, 10, 73
 - Ginga*, 4

- HETE-2*, 7, 16, 114
- IKAROS* GAP, 53
- INTEGRAL*, 41
- RHESSI*, 4, 52
- Swift*, 1, 8, 18, 56, 89, 114
 - BAT, 1, 8, 63
 - UVOT, 8
 - XRT, 8, 56, 63
- UHURU*, 4
- Vela*, 3, 4
- Venera* Konus, 4
- Wind* Konus, 43
- GRB duration
 - T_{50} , 27
 - T_{90} , 27, 29, 30, 108, 110
 - t_{burst} , 64, 119
 - rest-frame duration, 111, 116
- GRB jet, 299
 - beaming correction factor f_b , 100
 - cocoon, 423
 - Gaussian jet, 308
 - jet break, 17, 61, 64, 299
 - jet breakout time, 425
 - jet head, 423
 - jet opening angle, 17, 93, 302–304
 - power-law jet, 308
 - quasi-universal structured jet, 17, 310
 - spine–sheath structure, 425
 - standard energy reservoir, 17, 308
 - structured jet, 307
 - uniform jet, 17, 306
- GRB physics
 - basic theoretical framework, 229
 - compactness problem, 229
 - energy dissipation mechanism, 228, 349
 - jet composition, 228, 349
 - cold (Poynting flux) component, 240
 - hot (fireball) component, 240
 - hybrid components, 266, 366
 - open questions, 228, 349
 - particle acceleration mechanism, 228, 349
 - photosphere, 358, 362
 - dissipative photosphere, 15, 17, 20, 360, 372, 375, 376
 - non-dissipative photosphere, 358
 - pair photosphere, 381
 - radiation mechanism, 228, 349
- GRB plasma physics, 392
 - gyrofrequency, 393
 - gyroradius, 393
 - magnetic Reynolds number, 395
 - plasma frequency, 394
 - plasma skin depth, 394
 - Reynolds number, 394
- hadronic processes, 221
 - Δ -resonance, 21, 226, 480
 - $p\gamma$ interaction, 21, 221, 226, 480
 - cross section, 226
 - pp/pn interaction, 221, 227, 481, 487
 - cross section, 227
 - neutron decay, 341, 411
 - photon–meson interaction, 226
 - proton inverse Compton scattering, 225
 - proton synchrotron radiation, 225
- host galaxy, 84
 - early-type galaxy, 86
 - elliptical, 86
 - hostless, 87
 - irregular galaxy, 84
 - long GRB host galaxy, 84
 - metallicity, 84
 - offset, 87
 - short GRB host galaxy, 86
 - specific star formation rate, 85
 - spiral galaxy, 84
 - star-forming galaxy, 84
- hydrodynamics, 149
 - equation of state, 151
 - adiabatic index, 152
 - gas pressure, 151
 - Mach number, 155
 - non-relativistic, 149
 - ram pressure, 155
 - relativistic, 150
 - enthalpy density, 150
 - sound speed, 154
 - sound wave, 154
 - supersonic, 154
- hypernova, 16
- kilonova, 82, 434, 435, 440
 - Li–Paczynski nova, 434
 - macronova, 82
 - mergernova, 83, 435
 - r-process nova, 83, 434
- magnetic field
 - acceleration, 260
 - configuration, 256
 - helical geometry, 256
 - poloidal field, 260
 - striped-wind geometry, 257
 - toroidal field, 260
 - magnetic blob, 258
 - magnetosphere
 - Goldreich–Julian density, 260
 - light cylinder, 260
- magnetic reconnection, 395
 - internal-collision-induced magnetic reconnection and turbulence (ICMART), 20, 402
 - Petschek reconnection, 398
 - Sweet–Parker reconnection, 395
 - turbulent reconnection, 398

- magnetohydrodynamics (MHD), 152
 - Alfvén speed
 - non-relativistic, 160
 - relativistic, 161
 - ideal MHD, 153
 - MHD shocks, 162
 - MHD waves, 159
 - fast magneto-sonic/fast MA waves, 160
 - magneto-sonic waves/magneto-acoustic (MA) waves, 160
 - phase velocity, 160
 - shear Alfvén waves, 160
 - slow magneto-sonic/slow MA waves, 160
 - sound waves, 160
 - relativistic, 152
- methods
 - cross-correlation function method, 38
 - stepwise low-pass filter correlation method, 35
- multi-messenger, 11, 21, 473
- cosmic rays, 2, 21, 473, 474
 - GZK cutoff, 475
 - Hillas condition, 477
 - UHECR, 2, 16, 21, 475, 477
- detectors
 - Advanced LIGO, 11, 21, 491
 - IceCube*, 11, 483, 484
- gravitational waves, 2, 11, 21, 488
 - electromagnetic counterpart, 494
 - frequency, 490
 - GW150914, 488, 491
 - GW170817, 11, 488, 492, 498
 - inspiral, 491
 - merger, 491
 - ring down, 491
 - strain, 491
- neutrinos, 2, 480
 - EeV neutrinos, 21, 486
 - GeV neutrinos, 21, 487
 - high-energy neutrinos, 2, 11, 480
 - MeV neutrinos, 487
 - PeV neutrinos, 16, 21, 481
 - TeV neutrinos, 21, 487
- pair production and annihilation, 217, 379
 - γB process, 219
 - absorption coefficient, 219
 - Bethe–Heitler process, 219
 - cross section, 219
 - one-photon pair production, 219
 - pair annihilation, 220
 - cross section, 220
 - two-photon pair production, 217
 - cross section, 218
 - kinematics, 217
- particle acceleration
 - diffusive, 170
 - diffusive shocks, 172
 - first-order Fermi acceleration, 149, 170, 172
 - non-relativistic shock, 172
 - relativistic shock, 174
 - second-order Fermi acceleration, 170
 - stochastic processes, 170
- particle physics, 221
 - Δ baryon, 224
 - baryon, 224
 - Bose–Einstein statistics, 224
 - boson, 224
 - boson mediator, 224
 - W^\pm boson, 224
 - Z^0 boson, 224
 - gluon, 224
 - graviton, 224
 - photon, 224
 - Fermi–Dirac statistics, 222
 - fermion, 222
 - hadron, 224
 - Higgs field, 224
 - leptons, 222
 - electron, 223
 - muon, 223
 - neutrino, 223
 - tau, 223
 - lepton number, 223
 - mesons, 224, 225
 - π meson (pion), 225
 - kaon, 225
 - neutron, 223
 - proton, 223
 - quark, 222
 - color, 222
 - standard model, 222
 - strange particle, 224
- polarization
 - γ -ray polarization, 52
 - inverse Compton scattering, 215
 - optical polarization, 69, 342
 - synchrotron radiation, 200
 - X-ray polarization, 64
- Poynting-flux-dominated flow, 18, 20
 - characteristic radii
 - coasting radius, 265
 - deceleration radius, 265, 266
 - photosphere radius, 265
 - radius of causal disconnection, 265
- progenitor, 14, 228, 418
 - accretion-induced collapse, 119, 442
 - blue supergiant, 119, 431
 - He core–BH merger, 430
 - shock breakout, 426
 - non-relativistic, 426
 - relativistic, 429
 - trans-relativistic, 427
 - Wolf–Rayet star, 77, 421

- prompt emission, 1, 27, 349, 498
 - prompt emission lightcurve, 29, 350
 - fast component, 34
 - power density spectrum, 34
 - precursor emission, 30
 - pulses, 35
 - slow component, 34
 - spectral lag, 38, 350
 - prompt emission spectrum, 40
 - Band function, 1, 6, 41, 350
 - break energy E_0 , 41
 - Comptonized model, 43
 - cutoff power law, 42
 - elemental spectral components, 47, 48
 - GRB function, 41
 - hardness ratio, 29
 - high-energy photon index β , 41
 - high-energy spectral component, 46
 - log-parabolic model, 49
 - low-energy photon index α , 41, 351, 388
 - non-thermal spectrum, 40
 - peak energy E_p , 1, 41, 373, 387, 408
 - simple power law, 43
 - thermal component, 44
 - thermal spectrum, 40
 - prompt GeV emission, 51, 357
 - prompt optical emission, 51, 356
 - spectral evolution, 49, 350
 - hard-to-soft evolution, 49, 350
 - intensity tracking, 49, 350
- prompt emission models
 - Compton drag model, 409
 - electromagnetic model, 399
 - hadronic model, 410
 - ICMART model, 402, 403, 412
 - efficiency, 404
 - internal shock model, 383, 390, 412
 - efficiency, 385
 - magnetic dissipation models, 391
 - photosphere model
 - dissipative, 360, 372, 375, 376, 412
 - non-dissipative, 358
 - reconnection switch model, 400
 - synchrotron self-Compton model, 409
- r-process, 14
- radiation mechanisms
 - bremsstrahlung, 182, 215
 - relativistic bremsstrahlung, 215
 - Compton scattering, 201
 - free-free radiation, 215
 - inverse Compton scattering, 14, 182, 201
 - Y parameter, 205, 207
 - Compton y parameter, 212
 - Compton cross section, 203
 - Comptonization, 213
 - Comptonized spectrum, 213
 - double Compton scattering, 214
 - down-Comptonization, 213
 - emission power, 203
 - Klein–Nishina regime, 202, 207
 - multiple IC scattering, 212
 - polarization, 215
 - single IC scattering, 204
 - Thomson cross section, 184, 203
 - Thomson optical depth, 204
 - Thomson regime, 202
 - up-Comptonization, 213
 - jitter radiation, 187
 - characteristic angular frequency, 187
 - emission power, 187
 - synchrotron radiation, 14, 55, 75, 182, 285, 351
 - characteristic angular frequency, 183
 - cooling, 188
 - cooling frequency ν_c , 190
 - cooling time scale, 188
 - emission power, 183
 - fast cooling, 189–191, 388
 - maximum injection frequency ν_M , 190
 - minimum injection frequency ν_m , 190
 - peak specific emission power, 197
 - polarization, 200
 - self absorption, 193
 - self-absorption, 192
 - self-absorption frequency ν_a , 193
 - slow cooling, 189, 190
 - spectrum, 183
 - synchrotron self-Compton, 55, 75, 205, 313
 - Thomson scattering, 201
- relativity
 - curvature effect, 139
 - dimensionless speed, 123
 - equal-arrival-time surface (EATS), 136
 - event, 122
 - general relativity, 142
 - contravariant, 144
 - covariant, 144
 - Einstein field equations, 142
 - energy–momentum tensor, 143
 - equivalence principle, 142
 - general principle of relativity, 142
 - gravitational redshift, 146
 - Kerr metric, 146
 - Kerr–Newman metric, 148
 - metric tensor, 144
 - proper time, 145
 - Reissner–Nordström metric, 148
 - Schwarzschild metric, 145
 - Schwarzschild radius, 146
 - inertial frame, 122
 - cosmic proper frame, 127
 - laboratory frame, 127
 - observer frame, 127

- Lorentz factor, 123
- space-time interval, 124
- special relativity, 122
 - aberration of light, 126
 - apparent “superluminal” motion, 130, 231
 - Doppler factor, 131
 - Doppler transformations, 132
 - intrinsic length, 124, 132
 - invariance of c , 122
 - inverse Lorentz transformation, 124
 - length contraction, 124
 - Lorentz transformation, 123
 - observed length, 125, 132
 - relative Lorentz factor, 141
 - relativistic velocity transformation, 125
 - special principle of relativity, 122
 - time dilation, 125
- time interval
 - angular spreading time scale, 354
 - comoving-frame emission time interval, 131
 - ejecta emission time interval, 128
 - engine-time interval, 128
 - observer-time interval, 128, 131
- shocks, 149
 - external shock, 14, 61
 - forward shock, 15, 54, 59, 64, 69, 75, 149, 289, 352
 - reverse shock, 14, 15, 54, 59, 69, 75, 149, 314, 315, 317
- FS/RS system
 - blastwave, 165
 - contact discontinuity (CD), 165
 - forward shock (FS), 165
 - reverse shock (RS), 165
- internal shocks, 14, 20, 149, 352, 374, 383
- MHD shocks, 162
- microphysics parameters, 180, 342, 345, 347
- plasma instability, 149
 - two-stream instability, 178
 - Weibel instability, 178
- Rankine–Hugoniot conditions, 154, 155, 157
- relativistic shocks, 149, 156
- shock front, 154
- shock jump conditions, 149, 154
 - non-relativistic, 154
 - relativistic, 157
- turbulence-excited fluid instability, 179
- soft gamma-ray repeaters (SGRs), 120, 442
 - SGR 1806-20, 443
- supernova, 76, 429
 - broad-line Type Ic, 76
 - core collapse, 77
 - GRB-associated SN, 76
 - narrow-line Type Ic, 76
 - red bump, 78
 - thermonuclear burning, 77
 - Type I, 76
 - Type Ia, 76
 - Type Ib, 76
 - Type Ic, 76, 114
 - Type II, 76
- Swift* sources
 - Sw J1644+57, 10, 120, 443
 - Sw J2058+05, 120, 443
 - XRO 080109/SN 2008D, 10, 427
- tidal disruption event, 120

