Index

aberration
  chromatic, 274, 291
  spherical, 278, 281
adaptive optics, 289, 302
Airy, George, 285
Airy disk, 285, 288
Airy pattern, 286
Akhenaton, 6
al-Battani, 11
ALMA, observatory, 192, 318
Almagest, 4, 9, 19
Alpher, Ralph, 187
al-Tusi, 11, 298
Alvarez, Luis, 116
Alvarez, Walter, 115
amateur astronomers, 262–263
amateur astronomy
  finding amateur astronomy clubs, 269
  participation in research, 263
angular momentum, 216, 311
anthropic principle, 218–220
antimatter, 209–211
Apollo missions, 56, 70, 72
Apollonius’s theorem, 279
archaea, 235
Archean period, 80, 97
arcminute, definition, 16
arcsecond, definition, 16, 137
Aristarchus of Samos, 8, 87
Aristotle, 87, 199
Arrhenius, Svante, 231
Ayabhata, 9
associations, stellar, 160
asteroids, 79, 106
Itokawa, 107
  preventing collisions with Earth, 116
  probability of impact, 114
  Trojans, 111
astrology, 31
  in China, 10
astronomical numbers, how to visualize, 222–223
astronomical sites, 303
astronomical unit, AU, 91, 137
astronomy, ancient, 6–12
  astronomical phenomena in the Bible, 7
  marking time of the day, 16
  predictions of eclipses, 18
astronomy, major questions in 221
astrophysics, as a discipline, 30
astro-tourism, 269
atmospheric turbulence, 29, 286, 290, 299–300, 303
aurorae, 52, 87, 93
  on Jupiter, Saturn, and Uranus, 54
Averroes, or Ibn-Rushid, 11
axions, 206

Barbara A. Mikulski Archive for Space Telescopes, MAST, 300
baryons, 206
Bayer, Johann, 5
Becquerel, Henri, 38
Bell, Jocelyn, 154, 314
Big Bang, 130, 189–190, 199, 218
  cosmic background radiation, 187
  origin of name, 184
  source of antimatter, 210
  what was before?, 193
Big Bang theory, 179
binoculars, 253
black holes, 77, 148, 151, 191, 196, 221
  evaporation, 204, 221
  origin of concept, 202
  Schwarzschild radius, 201
blue stragglers, 155–156
Bode, Johann Elert, 98
Bode’s law, 98
Bok globule, 170
Boltzmann, Ludwig, 249
Brahe, Tycho, 88, 298
Brahmagupta, 9
brown dwarfs, 94, 221, 243
Bruce Medal, 225
Buffon, Count of, 37
Burney, Venetia, 97
calendars, 14
Julian, 21
Cambrian period, 230
Cannon, Annie Jump, 144
carbon atom (and chemistry of life), 229, 233
carbon dioxide, 47, 54
Carter, Brandon, 218
Cassini, interplanetary space probe, 109, 242
Cavendish, Henry, 36
celestial poles, 15
Central Bureau of Astronomical Telegrams, 267
Cepheids, 136, 153
as standard candles, 154
discovery of, 154
Ceres, 79, 106
discovery of, 99
Chandra, X-ray space observatory, 203, 308
Charge coupled device (CCD), 258, 296, 299
Charon, 101
chemical reactivity, 229
Chicxulub crater, 114–115
Chinese astronomy, 10
chlorophyll, 74
chemical reaction, 46
citizen science, 265–267
clusters of galaxies, 171, 173, 182
Bullet Cluster, 207
MACS J01416.1–212
MACS J0416.1–2403, 212
Virgo cluster, 137, 159
comets, 236, 260, 262
as source of meteors, 22
Churyumov–Gerasimenko/67P, 45, 120
citizen science project, 267
Comet 252P/Linear, 254
Halley, 10
Hyakutake, 119

McNaught, 120
molecular oxygen in, 45
origin of, 118
Shoemaker–Levy 9, 112–113, 264
structure and composition of, 119
tails of, 92–93, 119
water on, 240
compass, 50
Compton Gamma Ray Observatory, 308, 320
conics, 278
constellations, 1–4
appearance changing over time, 13
Big Dipper, 3, 13
Centaurus, 5, 157
Orion, 2
Sagittarius, 314
Southern Cross, 12
continental drift, 47
Cook, James, 89
Coordinated Universal Time (UTC), 21
Copernicus, Nicolaus, 88
COsmic Background Explorer, COBE, 188, 308
cosmic “dark age”, 181, 191
cosmic horizon, 199
cosmic latte, 218
cosmic microwave background, 179, 187–191, 199, 224, 314
anisotropy of, 189
temperature of, 188
cosmic rays, 49, 172, 210, 215
cosmological constant, 205
cosmology, 194
as a discipline, 31
cosmos, 223
craters, lunar, 58
crepuscular rays, 23
Cretaceous period, 114
Curie point, 49
Curie, Pierre and Marie, 38
cyanobacteria, 46
dark energy, 204–207
dark matter, 206–208
in Milky Way halo, 176
Darwin, Charles, 231, 238
Fraunhofer, Joseph von, 293
Friedmann, Alexander, 184
frost line, 42, 96
fundamental forces, 180, 194, 199–200
Gaia, astrometric space telescope, 309
galaxies (other than the Milky Way)
Andromeda Galaxy, 154, 173, 220, 257
BDF3299, 193
classification of, 173
CR7, 192
formation of first galaxies, 192
GN-z11, 198
Messier 31, 266
Messier 33, 203, 207
Messier 51, 172
Messier 60, 217
Messier 74, 173
Messier 81, 159
Messier 82, 159
Messier 83, 265
Messier 87, 173, 317
morphology of, 174
NGC 1300, 173
NGC 1316, 174
NGC 1427, 173
NGC 3311, 222
NGC 4647, 173
NGC 7424, 175
number of, 177
protoquagalaxies, 197
radioquagalaxies, 263
Galaxy Zoo, 264–265
Galilean telescope, 291
Galileo, Galileo, 84, 89, 165, 199, 290
gamma-ray bursts, 300, 320
gamma-ray telescope, 320
gamma rays, 82, 169, 210
Gamow, George, 187
Ganymede, 44, 104
gegenschein, 107
general relativity, 200
g eo-centric model, 9, 11, 87
g goid, 34
Giotto, space probe, 309
gnomon, 11, 17
Go, Christopher, 264
Goodricke, John, 154
Google Sky, 267
graphite, 42
grating, 286
gravitational constant, 35
gravitational lenses, citizen science project, 267
gravitational lensing, 212, 244
gravitational redshift, 211
gravitational waves, 200–201, 204, 224
detection of, 321
first detection of, 201
gravitons, 200, 223
gravity, 35, 89, 129, 200–204
center of, 138
nature of, 199
green flash, 26
greenhouse effect, 54
in primitive atmosphere, 45
molecules responsible for, 55
Guinand, Pierre-Louis, 293
Guth, Alan, 189
habitable zones, 236
Hadean period, 80
hadrons, 206
Hale, George, 299
Halley, Edmund, 13
Hawking, Stephen, 204
Hawking radiation, 204
Hayabusa, space probe, 107
heliocentric model, 8, 88–89
heliosphere, 79
helium, 41, 45, 77, 130, 180
discovery of, 31
helium-3, 73
Helmholtz, Hermann von, 231
Herschel, Caroline, 166, 262
Herschel, infrared space observatory, 42,
309–310
Herschel, William, 99, 166, 262, 291
Hertz, Heinrich, 313
Hertzspring, Ejnar, 144
Hertzspring–Russell diagram, 144, 161
Index

Hewish, Antony, 154, 314
Hey, James Stanley, 313
Hipparchus of Nicaea, 8, 13, 15, 135
Hipparcos, astrometric space telescope, 136, 309
HL Tau, protoplanetary disk, 76
Hohmann, Walter, 124
Hohmann transfer orbit, 124
Holmes, Arthur, 39
Hoyle, Fred, 185, 219
on panspermia, 231
Hubble constant, 183
Hubble deep fields, 177
Hubble law, 183
Hubble Space Telescope, 307
angular resolution of, 288
Deep Fields program, 193
Frontier Fields program, 193, 212
observations of Pluto, 100
observations of solar system planets, 121
servicing of, 305
Humason, Milton, 154, 178, 183, 196, 299
classification of galaxies, 173
Huygens, Christiaan, 285
hydrocarbon lakes, 242
hydrogen, 41, 45, 77, 129–130, 180, 220, 228
fusion of, 129
in the interstellar medium, 171
hydroxyl molecule, OH, 248
ice ages, 46, 237
on Mars, 48
IceCube Neutrino Observatory, 323
Indian astronomy, 9
inflation, cosmic, 179, 189–191, 197
inflation, 190
infrared radiation, 54, 93, 133
Infrared Space Observatory, 309
initial mass function, 161
interference of light, 284
interferometers, astronomical, 312–313, 315
Atacama Large Millimeter/submillimeter Array, 313
European VLB1 Network (EVN), 315
Fabry–Perot, 286
Very Large Array (VLA), 313
Very Large Baseline Array (VLBA), 315
Very Large Telescope Interferometer (VLTI), 313
very long base line interferometry, 204
International Astronomical Union, 100, 267
membership, 268
International Gamma-Ray Astrophysics Laboratory, 320
International Space Station, 210
International Thermonuclear Experimental Reactor (ITER), 163
interstellar clouds
temperature of, 187
interstellar communications, 247
interstellar dust, 169, 171, 175
interstellar grains, 42
interstellar medium, 171
molecules in, 234
inversion layer, 304
iridium, 115
Islamic astronomy, 11, 298
isotopic ratios, 47
Jansky, Karl, 262, 313–314
Janssen, Pierre, 30
Janssen, Zachery, 290
jets of radio emission, 174
Jones, Albert, 264
Julian Day, 21
Jupiter, 289
"Red Spot Jr.", 264
aurorae on, 53
Great Red Spot, 108
magnetic field of, 49
Kant, Immanuel, 75, 166
Kepler, Johannes, 88, 199
laws of planetary motion, 35, 88, 138, 153, 243
Kepler, space mission, 239, 244, 265, 312
Kuduru of Meli-shipak II, 7
Kuiper belt, 118–119
Kuiper, Gerard, 118
Kuiper belt objects, 76, 99, 101, 107
2014 $\mu$69, 78
water on, 240
LaCourse, Darryll, 265
Lagrange points, 111, 305, 309–310
Lambert, Jean-Henri, 166
Laplace, Pierre Simon de, 75, 202
Laser Interferometer Gravitational-Wave
Observatory (LIGO), 201, 321
Laser Interferometer Space Antenna (LISA), 322
Le Verrier, Urbain, 99
Leavitt, Henrietta Swan, 154
Lemaître, Georges, 182–183, 185
lens, oldest known, 290
Levy, David, 264
life
coming from outer space, 231
conditions for life, 235
definition of, 227
existence in the solar system, 240
in the universe, 219
intelligent forms of, 238
non-carbon based, 233
origin of, 228–230
planetary conditions for, 237
search for intelligent life, 239
light
absorption of sunlight, 28
atmospheric phenomena, 23
diffraction of, 284
diffusion of, 284
dispersion of, 255
infrared, 133, 175
pressure of, 91
reflection of, 284
refraction of, 284
scattering of, 82
scattering of sunlight, 25
ultraviolet, 191
light curve, 153
light-year, definition, 137
Lippershey, Hans, 290
living matter
composition of, 228
Lockyer, Joseph, 30
Lord Kelvin, see Thomson, William
Lowell, Percival, 99
L7 neutrino experiment, 208
luminosity vs. brightness (of stars), 136
lunacy, 74
lunar rocks, 72
Magellan, Ferdinand, 166
Magellanic Clouds, 166, 173, 220
Large Magellanic Cloud, 150
Small Magellanic Cloud, 128
magnetic declination, 50
magnetic fields, 155, 174, 237
lines of force of, 52
movement of Earth’s magnetic poles, 51
of Earth, 48
of Moon and planets, 49
magnetic shielding, 50
magnetosphere, 52
magnitude scale, definition, 134
main asteroid belt, 43
water in, 44
main sequence of stars, 139, 144, 148
Marconi, Guglielmo, 313
Mars, 44
atmosphere of, 123
citizen science project, 267
color of the sky, 26
discovery with robotic rovers, 121
Gale crater, 235
human exploration of, 123
ice age on, 48
life on, 240
orbital trajectories to, 124
water on, 44, 237, 240
weather on, 123
mass, derivation of, 133, 138
Maunder minimum (of sunspots), 86
McKellar, Andrew, 187
Méchain, Pierre, 34, 260
Mercury, 43, 104
phases of, 105
water on, 43, 105
meridian, 19
arc of, 33
MESSENGER, interplanetary probe, 105
Messier, Charles, 260
Messier objects, 254, 260
metals, 161, 191
meteorites, 22, 39, 226
composition of, 78
finding of, 267
meteoroids, 22, 231
meteors, 22
of Chelyabinsk, 22
Perseids, 22
showers, 22
meter, definition, 34
methane, 55, 233, 245
Milankovitch, Milutin, 48
Milky Way, 1, 165
as a barred spiral galaxy, 175
central black hole, 176, 203
evolution of conceptions, 165
future of, 220
nucleus, 176
position of the Sun in, 166
radio map of, 262
viewed at different wavelengths, 169
Miller, Stanley, 229
Miller–Urey experiment, 229
Mitchell, John, 202
molecules, formation in interstellar medium, 233
momentum, definition of, 92
Moon
albedo of, 61
angular size illusion, 29
base for astronomical observations, 72, 310
boulder trails on, 59
composition of, 61
discovery of, 99
earthshine, 73
exploration of, 70
far side of, 60
formation of, 42, 56
gravity on, 63
humans returning to, 72
interior of, 62
lack of atmosphere, 63
magnetic field of, 49
maria, 59
permanent lunar base, 72
phases of, 69
regolith, 61
rotation of, 63
tides, 64
waning and waxing of, 69
multiverse concept, 219
natural selection, 228
near-Earth objects, 116
nebulae, 169–171
30 Doradus, 141
Barnard 68, 170
Crab Nebula, 152
Helix Nebula, 170
Messier 16, 77
NGC 1299, 170
NGC 6559, 170
Orion Nebula, 303
planetary, 150
Tarantula, 141
Veil Nebula, 157
Neptune, 78, 99
New Horizons interplanetary space probe, 78, 101, 121
Newton, Isaac, 89, 178, 199, 291
noctilucent clouds, 24
North, John, 314
northern lights, see aurorae
novae, 149
nuclear binding energy, 162
nuclear fusion, 162
in stars, 95, 129, 146, 150
Index

nucleosynthesis, 78, 151, 156
numeral systems, origin of, 16
obliquity, or tilt of Earth’s axis, 48, 238
observatories
ALMA, 318
earliest, 298
ESO Paranal Observatory, 300, 313
evolution of, 299
Greenwich, 299
IceCube Neutrino Observatory, 323
in Antarctica, 318
Istanbul, 298
Jaipur Observatory, 9
Laser Interferometer Gravitational-Wave
Observatory (LIGO), 321
Maragha, 298
Mauna Kea, 304, 318
Paris, 299
Samarkand, 298
Sudbury Neutrino Observatory, 323
Uraniborg, 88, 298
US Naval, 299
Yerkes, 274
occultation, 139
Olbers, Heinrich Wilhelm, 217
Olbers’s paradox, 217–218
Oort, Jan, 79, 118
opacity, 82
Öpik, Ernst, 79, 118
Öpik–Oort cloud, 79, 118
oxygen, evolution of Earth’s atmosphere, 45
ozone, 245

periodic table, 78
Perlmutter, Saul, 205
Permian period, 114
Perry, John, 37
Perseids, 23
photosynthesis, 46
physical constants of nature, 208
Picard, Jean, 33
Planck, space observatory, 188, 310
Planck temperature, 193
Planck time, 189, 193, 223
Planet X, 99
planetary differentiation (of interiors), 97
planetary nebulae, 81
Cat’s Eye Nebula, 147
Helix Nebula, 147
planetesimals, 76, 118
planets
alignments of, 113
atmospheres of, 95
Bode’s law, 98
composition of, 95
definition of, 100
differences from stars, 93
Greek and Roman gods associated with, 7
in the night sky, 5
interiors of, 96
moons of, 102
names of, 97
orbits and axis of rotation, 110
ring systems of, 109
rocky or gaseous, 95
structure of, 95
Sumarian names, 7
tidal effects between, 113
plasmas, 129, 169
plate tectonics, 97, 237
Plato, 87
Pluto, 78, 118
discovery of, 99, 264
moons of, 102
Pluto controversy, 100
Pogson, Norman Robert, 134
Pogson’s ratio, 134
polycyclic aromatic hydrocarbons (PAHs), 226
Index

Ponzo illusion, 30
pre-biotic material, 234
Precambrian period, 230
precession of the equinoxes, 15, 48
discovery of, 9
prism, 23, 286
prokaryotes, 46, 235
proper motion, 13
protons, decay of, 221
protoplanetary disk, 39
Ptolemy, Claudius, 4, 9, 16, 19, 87
pulsars, 154, 314
citizen science project, 267
Pyrex, 280
quasars, 172, 197, 209, 212, 317
3C279, 215
radiation pressure, 91
solar sail, 124
radio astronomy, 176, 313–318
birth of, 262
Jansky (unit of flux), 135
sites for, 317
radio isotopic generator, 123
radio telescopes
Allen Telescope Array, 248
Arecibo, 315
Effelsberg, 315
Five-hundred meter Aperture Spherical Telescope (FAST), 315
Green Bank, 315
Jodrell Bank, 315
mirrors of, 315
Nançay, 315
submillimeter, 318
working of, 314
radioactivity, as source of heat, 38
radiometric dating, 39, 78, 80
Rayleigh criterion, 288
Rayleigh, 3rd Baron, 288
reaction wheels, 311
Reber, Grote, 262, 314–315
redshift, 195, 197
cosmological, 196
definition of z, 197–199
gravitational, 196
reflection of light, 284
refraction of light, 26, 29, 284, 300
regolith, see Moon
relativity, theory of, 211–213
resolution (optical), of a telescope, 278
Riess, Adam, 205
Roberts, Isaac, 262
Roche, Edouard, 112
Roche limit, 112
Rosetta mission, 45, 119
Philae, 119
rotation of cosmic bodies, 216
Rubin, Vera, 206
runaway stars, 159
Russell, Henry Norris, 144
Rutherford, Ernest, 39
Sagan, Carl, 156, 235
Saros cycle, 18
Saturn, rings of, 109, 112
Schmidt, Bernhard, 281
Schmidt, Brian, 205
Schwarzschild, Karl, 202
Schwarzschild radius, definition, 202
seasons, 13–15
length of, 15
seismic waves, 40
SETI program, 240, 247, 264–265
Shapley, Harlow, 166
shooting stars, 21
Siberian Traps, 115
silane, 233
silicates, 42, 76
sky
color of, 26
colors of sunrise, sunset, 26
sites with dark sky, 261
viewed at different wavelengths, 168
why is it dark at night?, 217
Slipher, Vesto, 154, 183–184, 196
Sloan Digital Sky Survey, 264–265
Sloan’s Great Wall, 182
sodium layer, 303
SOHO, space solar observatory, 112
solar activity, 84–86
solar halos, 24
Index

solar nebula, 42, 75
collisions of, 155
colors of, 143
composition of, 130
definition of, 146
distance to, 135
Eta Carinae, 152
evolution as a function of mass, 144
evolution of, 146
formation of, 129
formation of first stars, 191
HE 1523-0901, 142
HR 8799, 243
in intergalactic space, 158
Kappa Cassiopeiae, 160
lifetimes of, 148
luminosity of, 140
main sequence, 144
motion of, 13
names of, 4
nearest star, Proxima Centauri, 157
number of (in the Milky Way), 132
number of (visible), 1
oldest stars, 178
Pistol star, 142
Polaris, 12, 134
Population III, 191
protostars, 146
red giants, 81
R136a1, 141
RS Ophiuchi, 149
runaway, 159
70 Ophiuchi, 138
shape of, 132
Sigma Octantis, 12
size of, 139
spectral classes, 143
T Pyxidis, 149
transport of energy in, 130
UY Scuti, 140
variable, 153
steady-state theory, 185
Steinhardt, Paul J., 182
Stonehenge, 6
string theory, 182, 194, 206, 209, 214, 219, 222

solar pillars, 24
solar sails, 92, 124
solar system
boundaries of, 78
formation of, 42, 75–78
future of planets, 82
location in the Milky Way, 133
water in, 43
solar wind, 45, 52, 79, 92, 105, 210
solstices, 13
space observatories, 305–308
advantages for astronomical observing, 305
great observatories, 307
orbits of, 309
pointing of telescopes in space, 311
Space Shuttle, 308
spectroscopy, 131, 143, 286–287
detection of life signatures, 245
Fourier transform technique, 287
spectrum of the Sun, 131
speed of light (as a limit), 214
spiral arms, 136
Spitzer, infrared space observatory, 42, 197, 308
standard candles, 136, 152, 154
standard model, 194
star clusters, 78, 160
globular clusters, 161, 166, 176, 222
Messier 13, 248
Messier 80, 155
NGC 2070, 141
Omega Centauri, 161, 179
open clusters, 161
Pleiades, 78
stars
age of, 142
Alpha Centauri, 5, 137, 157
artificial, 303
Barnard’s Star, 13
biggest stars, 140
binaries, 138, 149, 153, 238
visual, spectroscopic, eclipsing, 153
brightness of, 134
catalogs of, 5

strong interaction, 200
stylus, 17
Sudbury Neutrino Observatory, 323
Sun
age of, 80
changing of, 91
chromosphere, 83
color of, 25
corona, 83, 92
coronal holes, 92
cycle of activity, 85–86
differential rotation, 85
distance to, 89
distance to, 91
future of, 81
interior of, 82
luminosity of, 80
magnetic fields, 83
mass of, 91
mean density of, 91
photosphere, 83
position in the Milky Way, 175
prominences, 85
radio waves from, 313
rotation of, 85, 132
temperature of, 82
young Sun paradox, 80
sundials, 16–17, 19
sundogs, 24
sunspots, 10, 84
Maunder minimum, 86
suntan and ultraviolet sunlight, 27
supernova, 77, 142, 148
as source of elements, 41
as standard candles, 152
of 1054 in Crab Nebula, 10, 151
remnants of, 171
SN 1987A, 150, 264
types of, 152
synchrotron radiation, 155, 174
tachyons, 215
telescope mirrors, 278–281, 293
coating of, 293
for radio telescopes, 316
for X-rays, 318
how they are made, 280
polishing of, 280
shapes of, 278
telescopes
8-m Gemini North, 295
10-m Keck, 295
altitude-azimuth mount, 275
design of, 274
E-ELT, 295
equatorial mount, 275
ESO VLT, 274
GMT, 298
invention of, 290
list of largest, 295–297
optical configurations, 276
Cassegrain combination, 319
foci, 276
optical magnification, 289
performance criteria, 277
refracting, reflecting, 273
resolution of, 288, 290, 312
robotic telescopes, 300
Schmidt telescope, 281
the Leviathan, 292
TMT, 295
Yerkes, 292
telescopes, amateur, 254–259
Dobsonian, 258
Maksutov-Cassegrain, 259
mounts of, 256
refractor vs. reflector, 254
Schmidt-Cassegrain, 259
what can be viewed with, 1, 254–259
Thela, 42, 57
thermodynamics, laws of, 249
Thomson, William, 37, 231
tidal effect, 63, 113
tidal interaction, 109, 112
tides, 17, 64–66, 238
time
civil, 18
Coordinated Universal Time (UTC), 21
Greenwich Mean Time (GMT), 20
hour, origin of name, 16
time (cont.)
  length of day, 16–17
  local, 18
  sidereal, 19
  time zone system, 20
  Titan, 104, 121, 242
discovery of, 291
  lakes on, 242
  Titius, Johann Daniel, 98
  Tombaugh, Clyde, 99, 264
  transit, 244
  transit of Venus, 89, 244
  trans-neptunians, 78, 99, 102
  names of, 98
  triangulation method, 8, 34, 90, 135
  Turok, Neil, 182
twinkling of stars, 28
ultraviolet rays from the Sun, 27
  Voyager spacecraft, 119
universe
  age of, 177
  radiometric dating, 178
  color of, 218
  cosmological content, 205
  expansion of, 182
  future of, 220–221
  geometry of, 185
  laws of physics changing over time, 208
  mass of, 205
  notion of, 223
  origin of, 179
  size of, 190, 197–199, 218
Uranus
  discovery of, 99, 262
  rotation of, 110
  Urey, Harold, 229
vacuum energy, 205
  valence shell, 229
Venus, 44
  greenhouse effect, 55
  phases of, 105
  rotation of, 110
  volcanic activity on, 105
  water ice on, 44
  Verbiest, Ferdinand, 11
  Vesta, 106
  Voyagers, interplanetary probes, 79, 99, 109, 126
  water, 236
    as a biomarker, 245
    as a solvent, 230
    for life, 231
    formation of water, 42
    in comets, 120
    isotopic composition, 47
    on Ganymede and Enceladus, 121, 241
    origin of, 41–43
    physical properties of, 232
    polarity of molecule, 231
    presence on giant planets, 43
    presence on Mercury, Venus, and Mars, 43
  waterhole, 248
  weak interaction, 200
  Weber, Joseph, 200
  Wheeler, John Archibald, 200, 202
  white dwarfs, 81, 147, 149, 196, 211, 220
  Wilson, Robert, 187, 314
  WIMPs (weakly interacting particles), 208
  WMAP, space mission, 188
  Woltjer, Hans, 319
  Worldwide Telescope, 267
  Wright, Thomas, 166
  X-ray astronomy, 169, 224, 287, 318
  X-ray telescopes, 318
  zircons, 39
  zodiacal light, 107
  Zooniverse project, 265
  Zwicky, Fritz, 206, 212