

Chapter 21: **Table of contents, appendices, index, etc.**

- table of contents
- table of potentially useful constants and equations
- tables, duplicated from various chapters
 - table 4.1: summary of orbital and physical properties of selected solar system objects
 - table 9.1: bulk properties of giant planets
 - table 5.1: densities and magnetic fields of selected terrestrial solar system objects
 - table 9.3: magnetic field strengths of giant (and comparison) planets
 - table 8.1: properties of substantial atmospheres of terrestrial objects
 - table 8.2: properties of tenuous atmospheres of terrestrial objects
 - table 9.2: atmospheres of giant planets
 - table 13.1: selected properties of the Sun
 - table 14.1: some of the principal characteristics of the spectral types
 - table 14.2: approximate properties of Pop. I main sequence stars
 - table 14.3: approximate properties of Pop. I supergiant stars
 - table 14.4: properties of a few interesting and/or well-known stars
- chapter-level index

Table of contents, briefly:

Ch 0	math review
Ch 1	introduction: history and basic physics
Ch 2	additional celestial mechanics as applied to the solar system
Ch 3	celestial coordinates
Ch 4	introduction to the solar system
Ch 5	interiors of terrestrial planets
Ch 6	volcanism and other endogenic processes, in two parts
Ch 7	cratering and meteorites
Ch 8	planetary atmospheres
Ch 9	giant planets and planetary magnetospheres
Ch 10	formation and age of the solar system
Ch 11	stellar distances and magnitudes
Ch 12	binary stars
Ch 13	the Sun, in two parts
Ch 14	stellar spectra and analysis
Ch 15	stellar evolution
Ch 16	stellar remnants
Ch 17	the Milky Way
Ch 18	other galaxies and introduction to expansion of the universe
Ch 19	cosmology
Ch 20	optics, telescopes, detectors
Ch 21	contents, appendices, index, tables, etc.

Table of potentially useful constants and a few common equations

gravitational constant	G	$6.674 \cdot 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	$4\pi^2 \text{ AU}^3 \text{ M}_\odot^{-1} \text{ yr}^{-2}$
useful in		$F = GM_1 m_2 / r^2 = gm_2 ; \quad P^2 = [4\pi^2 a^3] / [G(M_1+M_2)]$	
and in		$v = [G(M_1+M_2) \cdot (2/r - 1/a)]^{1/2}$	
speed of light	c	$2.998 \cdot 10^8 \text{ m s}^{-1}$	
useful in		$c = \lambda f;$	$\lambda = \lambda_0 [1 + (v_r/c)]$
Planck constant	h	$6.626 \cdot 10^{-34} \text{ J s}$	$4.136 \cdot 10^{-15} \text{ eV s}$
useful in		$E = hf = hc / \lambda$	
Boltzmann constant	k	$1.381 \cdot 10^{-23} \text{ J K}^{-1}$	$8.617 \cdot 10^{-5} \text{ eV K}^{-1}$
useful in		$E \sim k T;$	$v \sim [2kT/m]^{1/2};$
and in		$P = (\rho kT/m);$	$H = kT / (g m)$
Stefan-Boltzmann constant	σ	$5.670 \cdot 10^{-8} \text{ J s}^{-1} \text{ m}^{-2} \text{ K}^{-4}$	$= \frac{2\pi^5 k^4}{15h^3 c^2}$
useful in		$L = 4\pi r^2 \sigma T^4$	
Wien's law		$\lambda = [2.898 \cdot 10^{-3} \text{ m K}] / [T (\text{K})]$	
converting eV to J		$1 \text{ eV} = 1.602 \cdot 10^{-19} \text{ J}$	
converting seconds to years		$1 \text{ yr} = 3.16 \cdot 10^7 \text{ s}$	
mass of an electron	m_e	$9.109 \cdot 10^{-31} \text{ kg}$	$0.511 \text{ MeV}/c$
unified atomic mass unit	m_u or u	$1.661 \cdot 10^{-27} \text{ kg}$	
mass of a hydrogen atom	m_H	$1.67 \cdot 10^{-27} \text{ kg}$	1.008 u
mass of a proton	m_p	$938.3 \text{ MeV}/c$	1.0073 u
mass of a neutron	m_n	$939.6 \text{ MeV}/c$	1.0087 u
astronomical unit	$1 \text{ AU} =$	$1.496 \cdot 10^{11} \text{ m}$	
parsec	$1 \text{ pc} =$	$206,265 \text{ AU}$	$3.0857 \cdot 10^{16} \text{ m} = 3.26 \text{ ly}$
light year	$1 \text{ ly} =$	$63,241 \text{ AU}$	$9.4607 \cdot 10^{15} \text{ m} = 0.3066 \text{ pc}$

Table 4.1: Summary of orbital and physical properties of selected solar system objects

Object	semi-major axis (AU or km)	revolution period (days or years)	orbit eccentricity	& inclination to ecliptic or planet equator (°)	rotation period (hours or days)	obliquity (°)
Sun	—	—	—	—	25 – 34 d	7.25
Mercury	0.387	87.97 d	0.206	7.0	58.65 d	0.003
Venus	0.723	0.615	0.007	3.39	–243 d	177.4
Earth	1.0	1.0	0.017	7.2 to Sun eq.	23.93	23.44
Moon	384,400 km	27.32 d	0.055	5.15 to ecl.	27.32 d	6.69
Mars	1.52	1.88	0.094	1.85	1.026 d	25.19
Phobos	9,376 km	0.32 d	0.015	1.09	0.32 d	0
Deimos	23,463 km	1.26 d	~0	0.93	1.26 d	
4 Vesta	2.36	3.63	0.09	7.14	5.34	
Ceres	2.77	4.60	0.08	10.59	9.07	~3
2 Pallas	2.77	4.61	0.23	34.84	7.81	~78?
10 Hygiea	3.14	5.56	0.12	3.84	27.62	
Jupiter	5.20	11.86	0.05	1.31	9.93	3.13
Io	421,700 km	1.77 d	0.004	0.05	1.77 d	
Europa	670,900	3.55 d	0.009	0.47	3.55 d	0.1
Ganymede	1.070·10 ⁶ km	7.15 d	0.0013	0.20	7.15 d	
Callisto	1.883·10 ⁶ km	16.69 d	0.0074	~1	16.69 d	0
Saturn	9.58	29.46	0.056	2.49	10.55	26.73
Mimas	185,539 km	0.94 d	0.02	1.57	0.94 d	0
Enceladus	237,948 km	1.37 d	0.005	0.019	1.37 d	0
Tethys	294,619 km	1.89 d	~0	1.12	1.89 d	0
Dione	377,396 km	2.74 d	0.002	0.019	2.74 d	0
Rhea	527,108 km	4.52 d	0.001	0.345	4.52 d	0
Titan	1.222·10 ⁶ km	15.95 d	0.029	0.35	15.95 d	0
Iapetus	3.561·10 ⁶ km	79.32 d	0.029	15.47	79.32 d	0
2060 Chiron	13.71	50.76	0.38	6.93	5.92	
Uranus	19.19	84.02	0.05	0.77	–17.24	97.8
Miranda	129,390 km	1.41 d	0.0013	4.23	1.41 d	0
Ariel	191,020 km	2.52 d	0.0012	0.26	2.52 d	?
Umbriel	266,300 km	4.14 d	0.0039	0.21	4.14 d	0?
Titania	435,910 km	8.71 d	0.0011	0.34	8.71 d	?
Oberon	583,520 km	13.46 d	0.0014	0.06	13.46 d	?
5145 Pholus	20.36	91.85	0.57	24.65	9.98	?
Neptune	30.07	164.8	0.0087	1.77	16.11	28.32
Proteus	117,647 km	1.122 d	~0	0.52	1.122 d	~0
Triton	354,759 km	– 5.88 d	~0	157	5.88	0
Pluto	39.26	247.7	0.25	17.16	6.387 d	122.5
Charon	19,591 km	6.387 d	0	0	6.387 d	
Haumea	43.22	284	0.19	28.19	3.92	?
Makemake	45.72	309	0.16	29.00	7.8	?
Eris	67.78	558	0.44	44.04	25.9	?
90377 Sedna	524.4	~11,400	0.85	11.93	10.3	?

Table 4.1: Summary of orbital and physical properties of selected solar system objects, continued

Object	mass (kg)	diameter (km)	ave. density (g/cm ³)	albedo (Bond or geom.)	surface temp. (K)	atmosphere or color
Sun	$1.99 \cdot 10^{30}$	$1.39 \cdot 10^6$ (eq.)	1.41	–	5780	H, He
Mercury	$3.30 \cdot 10^{23}$	4,879	5.43	0.068 Bond	80 – 700	trace
Venus	$4.87 \cdot 10^{24}$	12,104	5.24	0.90 Bond	737	CO ₂ , N ₂ , SO ₂
Earth	$5.97 \cdot 10^{24}$	12,742	5.51	0.31 Bond	184 – 330	N ₂ , O ₂ , Ar, H ₂ O
Moon	$7.35 \cdot 10^{22}$	3,474	3.35	0.12 geom.	70 – 390	trace
Mars	$6.42 \cdot 10^{23}$	6,779	3.93	0.25 Bond	130 – 308	CO ₂ , Ar, N ₂ , O ₂
Phobos	$1.07 \cdot 10^{16}$	27 x 22 x 18	1.88	0.071 geom.	~233	
Deimos	$\cdot 10^{20}$	15 x 12 x 11	1.47	0.068 geom.	~233	
4 Vesta	$2.59 \cdot 10^{20}$	~525	3.46	0.42 geom.	85 – 270	V-type
Ceres	$9.39 \cdot 10^{20}$	938	2.17	0.09 geom.	168 – 235	C-type
2 Pallas	$2.11 \cdot 10^{20}$	544	~2.8	0.16 geom.	~164	B-type
10 Hygiea	$8.67 \cdot 10^{19}$	~431	2.08	0.07 geom.	~164	C-type
Jupiter	$1.90 \cdot 10^{27}$	139,822	1.33	0.34 Bond	165 @ 1 bar	H ₂ , H ₂ , CH ₄ , NH ₃
Io	$8.93 \cdot 10^{22}$	3,643	3.53	0.63 geom.	110	trace SO ₂
Europa	$4.80 \cdot 10^{22}$	3,122	3.01	0.67 geom.	102	trace
Ganymede	$1.48 \cdot 10^{23}$	5,268	1.94	0.43 geom.	110	trace O ₂
Callisto	$1.08 \cdot 10^{23}$	4,821	1.83	0.2 geom.	134	trace O ₂ , CO ₂
Saturn	$5.68 \cdot 10^{26}$	116,464	0.69	0.34 Bond	134 @ 1 bar	H ₂ , He, CH ₄ , NH ₃
Mimas	$3.75 \cdot 10^{19}$	396	1.15	0.86 geom.	~64	
Enceladus	$1.08 \cdot 10^{20}$	504	1.61	0.99 Bond	75 (ave)	trace H ₂ O, N ₂ , CO ₂
Tethys	$6.17 \cdot 10^{20}$	1,062	0.98	0.80 Bond	86	
Dione	$1.10 \cdot 10^{21}$	1,123	1.48	0.99 geom.	87	
Rhea	$2.31 \cdot 10^{21}$	1,527	1.24	0.95 geom.	53 – 99	
Titan	$1.345 \cdot 10^{23}$	5,150	1.88	0.2 geom.	93.7	N ₂ , CH ₄ , H ₂
Iapetus	6.5×10^{19}	1,470	1.09	~0.6 geom.	90 – 130	
2060 Chiron	?	~166 km	?	~0.15 geom.	~75	
Uranus	$8.68 \cdot 10^{25}$	50,724	1.27	0.30 Bond	76 K @ 1 bar	H ₂ , He, CH ₄
Miranda	$6.59 \cdot 10^{19}$	471	1.20	0.32 geom.	~60	
Ariel	$1.35 \cdot 10^{21}$	1,158	1.59	0.23 Bond	~60	
Umbriel	$1.17 \cdot 10^{21}$	1,169	1.39	0.10 Bond	~75	
Titania	$3.53 \cdot 10^{21}$	1,577	1.71	0.17 Bond	70	
Oberon	$3.01 \cdot 10^{21}$	1,523	1.63	0.14 Bond	70-80	~0 atm
5145 Pholus	?	185	?	0.046	~62	red
Neptune	$1.02 \cdot 10^{26}$	49,244	1.64	0.29 Bond	72 K @ 1 bar	H ₂ , He, CH ₄
Proteus	$4.4 \cdot 10^{19}$	~420	~1.3	0.096 geom.	~51	
Triton	$2.14 \cdot 10^{22}$	2,706	2.06	0.719 geom.	38	N ₂
Pluto	$1.303 \cdot 10^{22}$	2,377	1.86	0.49 – 0.66 geo	33 – 55	N ₂ , CH ₄ , CO
Charon	$1.586 \cdot 10^{21}$	1,212	1.66	0.37 geom.	53	
Haumea	$4.0 \cdot 10^{21}$	~1,400	2.6	~0.8	< 50	neutral
Makemake	$< 4.4 \cdot 10^{21}$	~1,470	?	0.81	~38	reddish
Eris	$1.66 \cdot 10^{22}$	2326	2.52	0.96	~42-55	reddish
Sedna	?	~1,000	?	0.32 geom.	~12	red

Table 9.1: Bulk properties of giant planets

	Jupiter	Saturn	Uranus	Neptune
Mass (Earth masses)	318	95	14.5	17.1
Average radius (Earth radii)	11.0	9.1	4.0	3.9
Flattening ($1 - R_{\text{polar}}/R_{\text{equator}}$)	0.065	0.098	0.023	0.017
Moment of inertia factor	0.254	0.210	0.225	~0.25
Density (g/cm^3)	1.33	0.69	1.27	1.64

Table 5.1: Densities and magnetic fields of selected terrestrial solar system objects

object	average density (g/cm^3)	surface magnetic field (μT)	field source / comments	interior liquid layer?
Mercury	5.43	0.25	dynamo?	partially molten core?
Venus	5.24	$\sim 5 \cdot 10^{-4}$	induced by solar wind	Fe-Ni core?
Earth	5.51	31	dynamo	Fe-Ni outer core
Moon	3.35	~ 0.03	localized crustal field	thin outer core
Mars	3.93	$\sim 10^{-3}$	loc. crustal field + solar wind	Fe/FeS core?
Io	3.53	~ 1.3	interacts with Jupiter's field	thin outer mantle shell
Europa	3.01	~ 0.2	interacts with Jupiter's field	ocean
Ganymede	1.94	~ 0.75	intrinsic; dynamo?	ocean; possibly two
Callisto	1.83	~ 0.04		ocean? not completely differentiated
Titan	1.88	~ 0	interacts with Saturn's field	ocean
Enceladus	1.61	~ 0	interacts with Saturn's field	ocean
Pluto	1.86	no?		ocean?

Models suggest subsurface oceans are possible on Rhea, Titania & Oberon, Triton, Orcus (a plutino), Eris, Sedna (TNO; very long eccentric orbit)

Table 9.3: Magnetic fields of giant (and comparison) planets

	Surface field strength μT	Magnetic moment $\text{T} \cdot \text{m}^3$	relative to Earth
Jupiter	428	$1.6 \cdot 10^{20}$	20,000
Saturn	22	$4.8 \cdot 10^{18}$	600
Uranus	23	$3.8 \cdot 10^{17}$	50
Neptune	14	$2.2 \cdot 10^{17}$	25
Earth	31	$7.9 \cdot 10^{15}$	1
Ganymede	0.72	$1.3 \cdot 10^{13}$	$1.7 \cdot 10^{-3}$
Mercury	0.3	$2.8 \cdot 10^{12}$	$3.5 \cdot 10^{-4}$

Table 8.1: properties substantial atmospheres of terrestrial objects

	Venus	Mars	Earth	Titan
N ₂	0.035	0.019	0.78	0.98
O ₂	< 20 ppm*	0.0015	0.21	
O ₃		0.01 ppm	10 ppm	
Ar	70 ppm	0.019	0.0093	
H ₂ O	~30 ppm	< 100 ppm	< 0.05	
CO ₂	0.96	0.96	400 ppm	
CO	~25 ppm	< 0.001	0.2 ppm	
CH ₄			1.8 ppm	0.14
SO ₂	20 – 200 ppm		trace (& trace N ₂ O)	traces H ₂ and various hydrocarbons
H ₂ S	1 – 2 ppm			
H ₂ SO ₄	4 – 10 ppm, clouds			
Ne	7 ppm	2.5 ppm	18 ppm	
He	12 ppm		5 ppm	
surface pressure	9200 kPa	0.6 kPa	101 kPa	147 kPa

*Parts per million by volume

Table 8.2: properties of tenuous atmospheres of terrestrial objects

Object	principal gases	surface pressure
Triton	N ₂ ; CO & CH ₄ ~few 10 ⁻³ N ₂ ; Ar, Ne?	~1.6 Pa
Pluto	N ₂ ; CO & CH ₄	~0.3 – 1 Pa
Io	SO ₂ ; traces of SO, NaCl, S, O	~10 ⁻⁴ Pa
Ganymede	O, O ₂ , H	~10 ⁻⁶ Pa
Europa	O ₂	~10 ⁻⁷ Pa
Rhea	O ₂ , CO ₂	~10 ⁻⁷ Pa
Dione	O ₂	~10 ⁻⁸ Pa
Mercury	Na, Mg, O ₂ , S, H ₂ S, Ca, K, H ₂ O, He, H	~10 ⁻⁹ Pa
Moon	Ar, He, Ne, Na, K	~10 ⁻⁹ Pa

Any moon with pole caps, even very small moons, will have had some molecules of ices spending some amount of time hopping from warmer subsolar latitudes to the poles.

Table 9.2: Atmospheric properties of giant planets

	Jupiter	Saturn	Uranus	Neptune
H ₂	0.864	0.963	0.85	0.85
He	0.136	0.033	0.13	0.13
H ₂ O	$2.3 \cdot 10^{-3}$	$\sim 1.6 \cdot 10^{-3}$	$\sim 1.4 \cdot 10^{-3}$	$\sim 1.4 \cdot 10^{-3}$
CH ₄	$1.8 \cdot 10^{-3}$	$4.3 \cdot 10^{-3}$	0.020	0.030
NH ₃	$2.3 \cdot 10^{-4}$	$4.8 \cdot 10^{-4}$	$< 1.9 \cdot 10^{-4}$	$< 1.9 \cdot 10^{-4}$
H ₂ S	$1.9 \cdot 10^{-4}$	$3.8 \cdot 10^{-4}$	$\sim 3 \cdot 10^{-4}$	$\sim 8 \cdot 10^{-4}$
Ne	$2.0 \cdot 10^{-5}$			
Ar	$1.3 \cdot 10^{-5}$			
C ₂ H ₆	$\sim 3 \cdot 10^{-6}$	$\sim 3 \cdot 10^{-6}$	$< 1 \cdot 10^{-8}$	$1.7 \cdot 10^{-6}$
Traces				

Table 13.1: selected properties of the Sun

Mass	$1.99 \cdot 10^{30}$ kg
Radius	$6.96 \cdot 10^5$ km
Luminosity	$3.828 \cdot 10^{26}$ J/s
Average density	1.41 g/cm ³
Temperature — Core	$15.7 \cdot 10^6$ K
Temperature — Photosphere	5,778 K (T _{effective})
Temperature — Corona	range; several million K
Rotation period	~ 25 days near equator; ~ 35 days near poles
Magnetic field	$\sim 1 \cdot 2 \cdot 10^{-4}$ T globally; ~ 0.3 T in sunspots
absolute magnitude	M _v = 4.83
color index	B-V = 0.62
spectral type	G2V
metallicity	Z = 0.0122

Table 14.1: some of the principal characteristics of the spectral types.

O	blue	$T_{\text{eff}} > 30,000$ K	He II; multiply ionized metals; some lines in emission
B	blue-white	T_{eff} : 10,000 - 30,000 K	He I, Balmers increasing
A	blue-white - white	T_{eff} : 7,500 - 10,000 K	Balmer lines; ionized metals; Ca II strengthening
F	white - yellow-white	T_{eff} : 6,000 - 7,500 K	Balmer lines ↓; Ca II ↑; neutral metals increasing
G	yellow-white - yellow	T_{eff} : 5,200 - 6,000 K	Balmers weak; Ca II max; neutral metals ↑; CH
K	yellow - orange	T_{eff} : 3,700 - 5,200 K	Balmers very weak; Ca II; neutral metals strong; TiO
M	orange - red	T_{eff} : 2,400 - 3,700 K	Ca II ↓; neutral metals strong; molecular bands
WR	Wolf-Rayet stars; no hydrogen lines; emission lines of helium and N &/or C, sometimes O		
L	mostly brown dwarfs; some very low-mass stars; some very cool supergiants		
T	infrared brown dwarfs, $T_{\text{eff}} \sim 700 - 1,300$ K; methane present in spectra		
Y	recently created classification for very cool brown dwarfs; possibly NH ₃ , H ₂ O present in spectra		
C	Carbon stars; most are CR, CN giants similar to G/K and K/M stars but with added carbon		
S	ZrO in spectra; carbon intermediate between carbon stars and normal M stars		
wd or D	white dwarfs: degenerate remnants of solar-type stars; broad lines		

Table 14.2: approximate properties of Population I main sequence (luminosity class V) stars

	T_{eff}	B-V	M_V	B.C.*	R / R_{\odot}	M / M_{\odot}
O2	48,000	-1.0	-6.1	-4.7	15	100
O5	42,000	-0.33	-5.7	-4.40	12	60
B0	30,000	-0.3	-4.0	-3.16	7.4	17.5
B5	15,200	-0.17	-1.2	-1.46	3.9	5.9
B8	11,400	-0.11	-0.25	-0.80	3.0	3.8
A0	9,790	-0.02	0.65	-0.30	2.4	2.9
A5	8,180	0.15	2.0	-0.15	1.7	2.0
F0	7,300	0.30	2.7	-0.09	1.5	1.6
F5	6,650	0.44	3.5	-0.14	1.3	1.4
G0	5,940	0.58	4.4	-0.18	1.1	1.05
G5	5,560	0.68	5.1	-0.21	0.92	0.92
K0	5,150	0.81	5.9	-0.31	0.85	0.79

K5	4,410	1.15	7.4	-0.72	0.72	0.67
M0	3,840	1.40	8.8	-1.38	0.60	0.51
M5	3,000	1.64	12.3	-2.73	0.2	0.15
M8	2,400	2.12	18.7	-4.1	0.10	0.08

*B.C. = bolometric correction

Table 14.3: roughly, approximate properties of Population I supergiants (luminosity class I)

	T_{eff}	B-V	M_V	B.C.	R / R_{\odot}
O9	32,000	-0.27	-6.5	-3.2	25
B2	17,600	-0.17	-6.4	-1.6	40
B5	13,600	-0.10	-6.2	-0.95	50
A0	9,980	-0.01	-6.3	-0.4	60
A5	8,610	0.09	-6.6	-0.1	65
F0	7,460	0.17	-6.6	-0.01	80
F5	6,370	0.32	-6.6	-0.03	100
G0	5,370	0.76	-6.4	-0.15	120
G5	4,930	1.02	-6.2	-0.3	150
K0	4,550	1.25	-6.0	-0.5	200
K5	3,990	1.60	-5.8	-1.0	400
M0	3,620	1.67	-5.6	-1.3	500
M5	2,880	1.80	-5.6	-3.5	800

Table 14.4: properties of a few interesting and/or well-known stars.

	RA (2000)			Dec (2000)		m_b	m_v	B-V	parallax	μ RA	μ Dec	v_{radial}	Spt& LC	notes
	h	m	s	°	'									
α Cen A	14	39	36.5	-60	50.0	0.72	0.01	0.71	754.81	-3679	474	-21.4	G2V	
α Cen B	14	39	35.1	-60	50.3	2.21	1.33	0.88	796.92	-3614	803	-20.7	K1V	
α Cen C	14	29	42.9	-62	40.8	12.95	11.13	1.82	769.8	-3776	766	-22.4	M5.5Ve	+ planet
Albireo (β Cyg) A	19	30	43.3	27	57.6	4.17	3.09	1.08	7.51	-7.2	-6.2	-24.07	K3II +B9.5V	
Albireo (β Cyg) B	19	30	45.4	27	57.9	5.01	5.11	-0.1	8.38	-0.99	-0.5	-18.80	B8Ve	
Aldebaran α Tau	4	35	55.2	16	30.6	2.4	0.86	1.54	48.94	63.5	-189	54.26	K5III	
Algol (β Per)	3	8	10.1	40	57.3	2.07	2.12	-0.05	36.27	2.99	-1.7	4.0	B8V	eclipsing binary
Altair (α Aql)	19	50	47	8	52.1	0.98	0.76	0.22	194.95	536	385	-26.6	A7Vn	
Antares (α Sco)	16	9	24.5	-26	25.9	2.75	0.91	1.84	5.89	-12	-23	-3.5	M0.5Iab +B3V	
Arcturus (α Boo)	14	15	39.7	19	10.9	1.18	-0.05	1.23	88.83	-1093	-2000	-5.19	K1.5III	

Barnard's	17	57	48.5	4	41.6	11.24	9.51	1.73	547.5	-803	10362.54	-110.51	M4V	BY Dra var
Betelgeuse (α Ori)	5	55	10.3	7	24.4	2.27	0.42	1.85	6.55	27.5	11	21.91	M1-2Ia-lab	
Canopus (α Car)	6	23	57.1	-52	41.7	-0.59	-0.74	0.15	10.55	19.9	23.2	20.3	A9II	
Capella (α Aur)	5	16	41.4	45	59.9	0.88	0.08	0.8	76.2	75.3	-427	29.19	K0+G1III	spectroscopic bin
Castor (α Gem) Aab	7	34	35.9	31	53.3	1.62	1.93	-0.31	64.12	-206.3	-148	6	A1.5IV+dM1e	spectroscopic bin
Castor (α Gem) Bab	7	34	36.1	31	53.3	1.62	2.97	-1.35	64.12	-206.3	-148	-1.2	A1IV+dM1e	spectroscopic bin
Castor (α Gem) Cab	7	34	37.6	31	52.2	10.56	9.27	1.29	64.12	-207.6	-96	2.5	2(M0.5Ve)	BY Dra & bin
τ Ceti	1	44	4.1	-15	56.2	4.22	3.5	0.72	273.96	-1721	854	-16.68	G8V	multiple planets; debris disk
61 Cygni A	21	6	53.9	38	45.0	6.39	5.21	1.18	285.95	416	32	-65.74	K5V	BY Dra var
61 Cygni B	21	6	55.3	38	44.5	7.4	6.03	1.37	286.15	4106	3156	-64.07	K7V	
Deneb (α Cygni)	20	41	25.9	45	16.8	1.34	1.25	0.09	2.31	2.0	1.9	-4.9	A2Ia	
ϵ Eri	3	32	55.8	-9	27.5	4.61	3.73	0.88	310.9	-975.2	19.5	16.43	K2 V	BY Dra var; + planet
Fomalhaut (α PsA) A	22	57	39	-29	37.3	1.25	1.16	0.09	129.8	329	-165	6.5	A4V	+planet; debris disk; angular size 0.212"
Fomalhaut B (TW PsA)	22	56	24.1	-31	33.9	7.58	6.48	1.1	131.4	330	-158	7.2	K4Ve	BY Dra var
Fomalhaut C	22	48	4.5	-24	22.1	14.3	12.624	1.676	130.3	332	-184	6.5	M4.0Ve	
ϵ Indi	22	3	21.7	-56	47.2	5.75	4.69	1.06	274.8	3967	-2536	-40	K5V	
Luten 726-8 A (BL Cet)	1	39	1.5	-17	57.0		12.7		374	3296	563	29	M5.5V	flare
Luten 726-8 B (UV Cet)	1	39	1.5	-17	57.0		13.2		374	3296	563	29	M6V	flare
Mizar (ζ 1 UMa) A	13	23	55.5	54	55.5	2.29	2.23	0.06	38	121	-22	-5.6	A1.5V	spectroscopic bin
Mizar (ζ 2 UMa) B	13	23	56.3	54	55.3	4.05	3.88	0.17	40.5	114	-26.5	-9.3	A1+A7IV-V	spectroscopic bin
Alcor (80 UMa)	13	25	13.5	54	59.3	4.18	4.01	0.17	40.5	113	-28.6	-8.9	A5+M3-4 V	binary
Polaris (α UMi) Aa	2	31	49.1	89	15.9	2.62	2.02	0.6	7.54	44.5	-11.9	-16.4	F8 Ib	Cepheid
Polaris (α UMi) Ab							9.2						F6V	
Polaris (α UMi) B	2	30	33.5	89	15.6	8.69	8.2	0.49				-8	F3V	
Pollux (β Gem)	7	45	18.95	28	1.6	2.14	1.14	1.0	94.54	-627	-45.8	3.23	K0IIIb	+ planet
Procyon (α CMi) A	7	39	18.1	5	13.5	0.79	0.37	0.4	284.6	-717	-1035	-3.2	F5 IV-V	
Procyon (α CMi) B	7	39	17.9	5	3.4	10.7	10.92	-0.2		-709	-1024		DQZ	
R136a1	5	38	42.4	-69	6.0	12.78	12.77	0.01	0.02				WN5h	LMC
Regulus (α Leo) A	10	8	22.3	11	58.0	1.24	1.4	-0.2	41.13	-249	5.6	5.9	B8IVn	
Regulus (α Leo) B/C	10	8	12.8	11	59.8	8.99	8.13	0.9	41.21	-254	8.0	6.72	K0Ve (+M4V?)	binary
Rigel (β Ori) A	5	14	32.3	-8	12.1	0.1	0.13	-0.03	3.78	1.3	0.5	17.8	B8Iae	
Rigel (β Ori) Bab	5	14	32	-8	12.2	10.4	10.4	0.00				19.1	B9+B9	spectroscopic bin
Ross 128	11	47	44.4	0	48.3	12.905	11.153	1.75	295.8	607	-1223	-31.2	M4V	flare; +planet
Sirius (α CMa) A	6	45	8.9	-16	43.0	-1.09	-1.09	0.00	379.2	-546	-1223	-5.5	A1V	spectroscopic bin
Sirius (α CMa) B	6	45	9	-16	43.1	8.41	8.44	-0.03		-547	-1207		DA1.9	
Spica (α Vir)	13	25	11.6	-11	9.7	0.74	0.97	-0.23	13.06	-42	-30.7	1	B1V	
Vega (α Lyr)	18	36	56.3	38	47.0	0.03	0.03	0.00	130.23	201	286	-20.6	A0V	
WISE 0855-0714	8	55	10.8	-7	14.7				448	-4800	500		Y2	$m_J = 25$

Chapter-level index

topic	chapter(s)
⁷ Li	16, 19
0.2 micron bump (in ISM absorption)	17
1-meter barrier	10
1420.406 MHz (or 21-cm)	17
2014 MY ₆₉ (Ultima Thule)	4
21-cm emission (or 1420.406 MHz)	17
21-cm line	15
3- α fusion	15
3C 273	18
3C 279	18
5303 Å coronal green line	13
a ^ˆ ā	6
aberration of starlight	2
ablation	7
absolute magnitude	11
absorption line	13, 14
abundant elements (in planetary lithospheres)	6
acceleration equation	19
accretion disk	18
accretion energy	9
accretion heating	5
ACE (Advanced Composition Explorer)	1
achondrite	7
active galactic nuclei (AGN)	18
active region	13
Adams, John Couch	4
aeolian processes	6
aerogel	4
aesthenosphere	5
ages of selected surfaces	7
Ahuna Mons (on Ceres)	6
air mass	11
Airy disc	20
Akrotiri (on Thera)	6
albedo	4
Algol	15
Allan Hills 84001	7
alpha decay	10
alpha process	15
alt-az mount	20
altitude (angle relative to horizon)	3
ammonia	6
amphibole	6
analemma	3
andesite	6
Andromeda galaxy (M31)	18

topic	chapter(s)
angle of repose	6
angular momentum	2
angular momentum (exchange among particles or planets)	10
angular resolution	20
anisotropy	18
anomalous month	2
antenna (dish)	20
Antennae galaxies (NGC 4038 + 4039)	17, 18
anti-cyclonic storm	9
anti-greenhouse effect	8
anti-particle	1, 19
aperture	20
aperture synthesis	20
apoapse or apocenter (apogee, aphelion, etc.)	1
Apophis	4
apparent magnitude	11
apparent solar time	3
arcsecond (or second of arc)	11
Ariel (Uranus)	4
Aristarchus; relative scale Earth - Moon - Sun	1
array	20
asteroid belt	4
astrometric binary	12
astronomical unit	1, 2, 4
asymptotic giant branch	15
AT2018cow	20
Atacama Large Millimeter Array (ALMA)	20
atmospheric circulation	8
atmospheric extinction	11
atmospheric loss	8
atomic spectra	1
AU Microscopium	10
aurorae	8, 9, 13
azimuth	3
Balmer lines	13
Balmer series, transitions	1, 14
banded-iron formation	6
bar magnet	13
barred spiral	17, 18
baryon	1, 19
baryon-to-photon ratio	19
baryonic matter	19
basalt	6
Bayeux Tapestry	4
Bekenstein, Jacob	19
Bell Burnell, Jocelyn	16

Chapter-level index, cont.

topic	chapter(s)
belts (Jupiter)	9
beta decay	10
Big Bang	19
Big Crunch	19
Big Rip	19
binding energy	1
biotite	6
bipolar outflow	10
BL Lacertae objects (blazars)	18
black body	14
black hole	16, 18, 19
blackbody radiation	1
blackbody spectrum	11
blazar (BL Lac object)	1
blue stragglers	15
body waves	5
Bohr, Niels	1
Bok globule	15
bolide	4
bolide	7
bolometric albedo	4
bolometric correction	11
bolometric magnitude	11
Bond albedo	4
boson	1, 19
bow shock	9
Bowen reaction series	6
brane	19
breccia	7
bremsstrahlung, thermal (free-free emission)	19
Bretz (Spokane-Missoula) floods	6
Broad Line Region	18
brown dwarf	14, 15
Bullet Cluster	18
butterfly diagram	13
C-type asteroid	4
Ca II H+K lines	13
calcium-aluminum inclusion (CAI)	7, 10
calendars	1
Callisto	4
Callisto	7
Cannon, Annie Jump	14
cantaloupe terrain	4
carbonaceous chondrite	7
carbonate-silicate cycle	8
carbonate	6

topic	chapter(s)
Casimir Effect	19
Cassegrain reflector	20
Cassini (spacecraft)	9
CCD camera	20
cD galaxy	18
celestial equator	3, 11
celestial meridian	3
celestial pole	3, 11
celestial sphere	3
CEMP (carbon-enhanced metal poor) stars	14, 18
Centaurus	4
Centaurus A (NGC 5128)	18
center of mass	2, 4, 12
central eclipse	12
central peak (in crater)	7
centripetal acceleration	8
Cepheid(s)	15, 18
Čerenkov radiation	1, 20
Ceres	4, 5, 6
Chandra X-ray Space Telescope	17, 20
Chandrasekhar limit	15, 16, 19
channeled scablands	6
characteristic expansion time	19
Chariklo	4
Charon	4, 7
chassignites	7
Chelyabinsk event	7
Chicxulub impact	7
Chinese, ancient observation records	1
Chiron	4
chondrite	6, 7
chondrule	7, 10
chromatic aberration	20
chromosphere	13
Churyumov-Gerasimenko (comet 67P)	4
cinder cone	6
circumpolar	3
circumstellar disk	10
clathrate	6
clay	6
climate change	8
cluster (of galaxies)	18
CMD (color-magnitude diagram)	14
CNO cycle	1, 13, 15
CO emission	18
CO molecules, emission	17
coagulation	10

Chapter-level index, cont.

topic	chapter(s)
cold dark matter	19
Cold Spot (in the CMB)	19
collapsar	15, 16
collision (of galaxies)	18
color (charge)	1, 19
color excess	11
color index (e.g., B - V)	11
Columbia River basalts	6
coma (comet)	4
Coma Cluster	18
comet(s)	4, 10
common minerals	6
compactified (extra dimensions)	19
complex crater	7
concave lens	20
condensation	10
condensation temperatures (for various minerals)	5
conduction	5, 16
conjunction	2
contact binary	12
continuous opacity	13
continuum	14
convection	5, 13
convective cells (in atmosphere)	8
convective transport	15
convective zone	13
convex lens	20
Copernican model	2
Copernicus	1
core (of giant planet)	9
core (of rocky planet)	5
core (of Sun)	13
core accretion (giant planets)	10
core sizes (rocky planets)	5
core-collapse supernova	15, 16
Coriolis effect	8
corona	13
corona (volcanic feature)	6
coronagraph	13
coronal hole	13
coronal mass ejection	2, 13
Cosmic Microwave Background (CMB)	18, 19
cosmic ray	1
cosmic ray exposure age	7
cosmic spherule	7
cosmological constant	19
Cosmological Principle	19

topic	chapter(s)
Crab Nebula	16
Crater Lake (Mount Mazama)	6
crater rays	7
critical density	19
cross-bedding	6
cryovolcanism	6
cryovolcano	6
Curie temperature	5
curvature of Earth	1
curvature of space	19
cyclic model	19
Cygnus A	18
dark energy	19
dark energy-dominated universe	19
dark image	20
dark matter	17, 18, 19
dark matter mini-halo	18
Davis, Ray (solar neutrino detection)	13
Dawn (spacecraft)	4
decay constant	10
declination	3, 11, 20
decompression melting	6
decouple	19
deferent	2
degeneracy pressure	16
degenerate (stellar core)	15
degree	1
Deimos	4
density	1
density (of solar system materials)	5
density (of various planetary materials)	4
density perturbation	19
density variation (in early universe)	19
detached binary	12
deuterium	19
differential rotation	13
differentiate	5
differentiated	9
differentiation	4, 10
diffraction grating	20
diffraction pattern	20
diffraction, single-slit	20
diogenites	7
Dione	4
diorite	6
dipole term (in the CMB)	19

Chapter-level index, cont.

topic	chapter(s)
disequilibrium chemistry (CHON)	10
dish (antenna)	20
disk instability	10
dispersion	20
distance modulus	11, 17
distance-velocity relation (or Hubble's law)	18
diurnal motion	3
dolomite	6
Doppler broadening	14
Doppler effect	11
Doppler shift	1, 12, 17
draconic month	2
Dragonfly 44	18
dune	6
dust (in galaxies of various types)	18
dust grain(s)	15, 17
dust storm (Mars, global)	6
dust tail (comet)	4
dwarf elliptical	18
dwarf planet	4
dwarf spheroids	18
dynamical timescale	19
Eagle Nebula (M16)	10, 15
Earth	4, 5, 6, 7, 8, 9, 10
earthquake	5
eccentricity	1
eccentricity (orbital)	12
Echelle spectrograph	20
eclipse	2
eclipsing binary	12
ecliptic	2, 11
Eddington limit	15, 18
effective temperature	9, 11, 14
Einstein ring	19
ejecta blanket	7
ekpyrotic	19
electromagnetic radiation	1, 20
electron	1
electron capture	10
electron volt (eV)	1
electroweak epoch	19
ellipses	1
elliptical galaxy	18
Enceladus	4, 5, 6, 7
endogenic process	6
energy level	14

topic	chapter(s)
energy level diagrams	1
enstatite chondrite	7
entropy	19
epicenter (of earthquake)	5
epicycle	2
equation of state	5, 16, 19
equation of time	3
equatorial coordinates	3, 11
equatorial mount	20
equilibrium temperature	9
equipartition of energy	8
equivalent width	14
Eratosthenes; size of Earth	1
Eris	4
escape speed	1, 8
ESO-510-G13 (galaxy)	17
Eta Carinae	15
eucrites	7
Eugene Shoemaker	7
Europa	4, 5, 6
eutectic point	6
evaporites	6
event horizon	16, 19
Event Horizon Telescope	17
evolutionary track	15
excess infrared emission	9
exogenic process	7
exoplanets	10
exosphere	8
extinction	11
extrusive (or volcanic igneous rock)	6
Faber-Jackson relation	18
falls (meteorites)	7
false vacuum	19
Fast Radio Burst (FRB)	19
fault	6
Fe/H	14
feldspar	6
Fermi bubbles	17
Fermi Gamma-Ray Space Telescope	17, 20
fermion(s)	1, 19
field of view	20
filament (solar)	13
filament (of galaxies)	18
finds (meteorites)	7
fireball	7

Chapter-level index, cont.

topic	chapter(s)
first contact (eclipse geometry)	2, 12
fission	10
flare	13
flat field	20
flat spacetime	19
flatness problem	19
Fleming, Williamina	14
flux	1, 4, 11, 14, 20
focal length	20
focus (of earthquake)	5
forbidden transition	17, 18
force-carrying boson	1
forces, fundamental	1
Fourier transform	20
fractionation	6
frame dragging	16
Fraunhofer lines	13
free-free emission (thermal bremsstrahlung)	19
frequency	1, 20
Friedmann equation	19
fundamental forces	19
fundamental plane	18
fusion	13
fusion crust	7
gabbro	6
galactic coordinates; latitude, longitude (b, l)	17
galactic pole	17
Galilean satellites	4
Galilean telescope	20
Galileo	1, 17
Galileo (spacecraft)	4, 9
Galle, Johann Gottfried	4
Gamma Ray Burst (GRB)	15, 19
Ganymede	4, 7
Ganymede (interior model)	5
Ganymede (magnetic field)	5
gas chromatography	8
gas giant	4, 9
general theory of relativity	1, 19
geocentric models	1
geostrophic wind	8
geosynchronous satellite orbits	2
geyser	6
giant (star)	14
giant elliptical	18
giant molecular cloud	15

topic	chapter(s)
giant-impact hypothesis	10
Giotto	4
globular cluster	14, 17
gluon	1, 19
GN-z11	18
gnieiss	6
googol (number)	19
gradient wind	8
GRAIL	6
grand unification	19
granite	6
granulation	13
grating equation	20
grating, diffraction	20
gravitational collapse	10
gravitational compression	5
gravitational lens	1, 18
gravitational lensing	19
gravitational potential energy	5, 18
gravitational radiation	19
gravitational redshift	16
gravity field anomalies	2
grazing incidence mirror	20
GRB (gamma Ray Burst)	15, 16, 19
Great Attractor	18
Great Red Spot	4, 9
greatest elongation	2
green flash	8
greenhouse effect	8
Gunn-Peterson trough	19
GW170817 (neutron star merger)	16, 18, 19
H-R (Hertzsprung-Russell) diagram	14, 17
H II region (or Strömgren sphere)	15, 17
H-	13
H ₀ (or Hubble constant)	18, 19
habitable zone	10
Hadley cell	8
hadron epoch	19
Hale-Bopp	4
half life	10
halides	6
Halley's comet	4
halo	17
Haumea (dwarf plnaet)	4
Hawking radiation	16, 19
Hawking, Stephen	16

Chapter-level index, cont.

topic	chapter(s)
Hayashi track	15
haze	9
HED meteorites	7
height (of volcano)	6
Heisenberg Uncertainty Principle	1, 14, 19
helioseismology	13
heliosphere	13
helium flash	15
helium rain	9
hematite	6
Herschel, William	4, 17
Higgs boson	1, 19
Hohmann transfer orbit (least-energy orbit)	2
Hokusai (crater on Mercury)	7
Holmberg radius	18
hologram	19
homogeneous	19
horizon	3
horizon problem	19
horizontal branch	15
horseshoe orbits	2
hot Jupiters	10
hot spot	5
hour angle	3
hour circle	3
howardites	7
Hubble constant (or H_0)	18
Hubble parameter	19
Hubble relation (or distance velocity relation)	18, 19
Hubble type	18
Hubble, Edwin	18
Hubble's tuning fork	18
Hurricane Ivan	8
Huygens probe	6
Hydra-Centaurus Supercluster	18
hydrogen cloud (comet)	4
hydrostatic equilibrium	1, 5, 10, 15, 19
Hypatia of Alexandria	1
hypernovae	15
I Zwicky 18	19
Iapetus	4, 6
ice giants (or slush giants)	4, 9
ice XVIII	5, 9
ices	6
ideal gas	8
Ideal Gas Law	1

topic	chapter(s)
IGM (intergalactic medium)	18
igneous rocks	6
image scale (or plate scale)	20
image, real or virtual	20
impact basin	4
inclination (of orbit)	4, 12
index of refraction	20
index of refraction of ISM	16
inflation	19
initial mass function	15
Instability Strip	15
interactions, fundamental	1
intergalactic medium (IGM)	18
interior models of giant planets	9
intermediate mass black hole	18
interplanetary dust grains	7
interstellar medium	13, 15
interstellar wind	9
intrusive (or plutonic igneous rock)	6
Io	4, 6
Io plasma torus	9
ionization energy	14
ionization stage	14
ionosphere	8
iron oxide	6
irons (meteorites)	7
irregular galaxy	18
isobar	8
isochron	10
isochrone	15
isostatic compensation	5
isotope ratio (for meteorites)	7
isotropic	4, 19
Jack Hills (Western Australia)	10
Jeans' length	15, 19
jets (from AGNs)	18
Johnson - Cousins filters	11
Joule	1
Jupiter	4, 9
K correction	18
kamacite	7
kelvins	1
Kepler's rules for orbits	1, 2, 12
Kepler's supernova remnant	16
Keplerian telescope	20

Chapter-level index, cont.

topic	chapter(s)
Kilauea	6
Kirchhoff's rules (for spectra)	1
Kirkwood gaps	4
komatiite	6
KREEP basalts	6
Kuiper Belt	4, 10
Lagrange points	1
Lake Manicouagan (Quebec)	7
Lake Vostok	6
landslide	6
Laniakea Supercluster	18
Large Hadron Collider	19
large-scale structure	18
Laser Interferometer Gravitational wave Observatory (LIGO)	1, 19
late heavy bombardment	6, 7
latitude	3
lava tube	6
Le Verrier, Urbain	4
least-energy orbit (Hohmann transfer orbit)	2
Leavitt, Henrietta Swan	18
Leavitt's law (or Period-Luminosity relation)	18
lens	20
lenticular (S0) galaxy	18
lenticular island	6
Leonids	4
lepton	1, 19
lepton epoch	19
librate	2
light cone	19
light curve (for eclipse)	12
light curve (galaxy)	18
light curve (of supernova)	16
light echo	15
light element nucleosynthesis	19
light year	11
light-gathering power	20
lightning	9
LIGO; detection of gravitational radiation	1
limb darkening	13
limestone	6
line broadening	14
line profile	14
Lippershey, Hans	20
liquid metallic hydrogen	4, 9
lithosphere	5
Little Ice Age	13

topic	chapter(s)
Local Group	18
local solar time	3
Local Standard of Rest (LSR)	11, 17
Loki (Io volcano)	4
longitude	3
longitudinal waves (seismic body waves)	5
Love waves (seismic surface waves)	5
low-surface-brightness (LSB) galaxy	18
luminosity	1, 4, 11
luminosity class	14
Luminous Blue Variable	15
lunar dust	7
lunar occultation diffraction pattern	12
lunar samples	10
Lyman series transitions	1
Lyman- α forest	19
M 77 (NGC 1068)	18
M-type asteroid	4
M104 (NGC 4594)	18
M16 (Eagle Nebula)	10, 15
M31 (in Andromeda)	18
M51 (NGC 5194)	18
M80 (NGC 6093)	17
M81 (NGC 3031)	18
M82 (NGC 3034)	18
M87 (Virgo A; NGC 4486)	18
MACHO (MAssive Compact Halo Object)	17
Magellanic Clouds	17
Magellanic Stream	17
magma	6
magnetar	16, 19
magnetic activity, stellar	13
magnetic braking	10, 13, 115
magnetic dipole	9
magnetic field	4, 13
magnetic field (of MW)	17
magnetic field orientation	5
magnetic monopole	19
magnetic reconnection	13
magnetic reversal (planetary)	5
magnetic reversal (solar)	1
magnetite	6
magnetogram	13
magnetohydrodynamics	5
magnetopause	9
magnetosphere	4, 9

Chapter-level index, cont.

topic	chapter(s)
magnetotail	9
magnification, angular	20
magnitude (apparent and absolute)	11
magnitude (of star)	20
main sequence	14, 15
Makemake (dwarf planet)	4
mantle	5
marble	6
Mare Orientale (lunar multi-ring basin)	7
maria	4, 6
Mars	4, 5, 6, 7, 8, 10
Mars (polar caps)	6
Mars (water)	4, 6, 8
Mars methane	8
mass	1
mass spectroscopy	8
mass transfer	15
mass-luminosity relation	12
math review	0
matter-dominated universe	19
Maunder Minimum	13
Maxwell-Boltzmann distribution	1, 8, 15
mean free path	13
mean molecular weight	15
mean Sun	3
medicine wheel	1
Mercury	4, 6
Mercury, overdensity	10
meson	19
mesosphere	8
Messier, Charles	17
metallicity	11, 14, 15, 17
metamorphic rocks	6
Meteor Crater (Arizona)	7
meteor shower	4
meteorite(s)	4, 7
meteoroid	4
methane	6
metric	19
mica	6
micrometeorite crater (or zap pit)	7
Mid-Atlantic Ridge	5
migration (of young planets)	10
Milky Way structure	17
Millennium simulation	18
Mimas	4
mineral	6

topic	chapter(s)
Mira	15
Miranda (Uranus)	4
molecular cloud	15
molecular spectroscopy	1
moment of inertia	2
moment of inertia factor	9
monochromatic light	20
Moon	4, 6
Moon, formation	10
most probable speed	1, 8
Mount Mazama (Crater Lake)	6
Mount St. Helens	6
moving cluster method (of finding distance)	11
multi-ring basin	4, 7
multiverse	19
muon	1, 19
nadir	3
nakhlites	7
Narrow Line Region	18
natural broadening	14
NGC 1052-DF2	18
Near-Earth Asteroids	4
negative curvature	19
Neptune	4, 9
neutrino(s)	1, 13
neutrino (detection)	20
neutrino flavor oscillation	13
neutron star	16
neutron, mean lifetime	19
New Horizons	2, 4
Newton's law of motion	1
Newtonian telescope	20
NGC 1068 (M77)	18
NGC 1132	18
NGC 1265	18
NGC 1+D733275 (Perseus A)	18
NGC 1300	18
NGC 1376	18
NGC 1672	18
NGC 3031 (M81)	18
NGC 3034 (M82)	18
NGC 4038 + 4039 (the Antennae)	17, 18
NGC 4151	18
NGC 4202	17
NGC 4298	17
NGC 4319	18

Chapter-level index, cont.

topic	chapter(s)
NGC 4486 (Virgo A; M87)	18
NGC 4594 (M81)	18
NGC 5128 (Centaurus A)	18
NGC 5194 (M51)	18
NGC 5866	18
NGC 602	17
NGC 6093 (M80)	17
NGC 7023	17
NGC 891	18
node (of orbit)	2
noise	20
notation, atoms, molecules	1
nova	16
nuclear binding energy curve	1
nucleosynthesis	1, 13, 15
OBAFGKMLTY	14
Oberon (Uranus)	4
objective	20
oblate spheroid	2
obliquity	4, 10
observable universe	19
obsidian	6
occultation	2
Oceanus Procellarum	6
octahedrite	7
Ohmic dissipation (or resistive heating)	5
Ole Rømer measuring speed of light	1
olivine	6
Olympus Mons	4, 6
Omega (Ω)	19
Oort cloud	4, 10
Oort coefficients	17
opacity	13, 14, 15
open (or galactic) cluster	14, 17
opposition effect (at Full Moon)	4
optical double	12
orbital elements	2
orbital phase	12
orbital resonance	2
Orion nebula	15
orthoclase	6
Oumuamua (1I / 2017U1)	4
outflow channel (Mars)	6
oxidizing	8, 9
oxygen (over time in Earth atmosphere)	6, 8
ozone	8

topic	chapter(s)
P Cygni	15
P-waves (longitudinal pressure waves)	5
pā hoehoe	6
palimpsest	7
pallasite	7
pancake domes	6
parabolic mirror	20
parallax	11, 12
parsec	11
partial melting	6
particles, elementary	1
pascal (atmospheric pressure unit)	4
Pauli Exclusion Principle	1, 15, 19
Pavo-Indus Supercluster	18
Payne-Gaposchkin, Cecelia	14
peak wavelength (Wien's law)	4
Pele (Io volcano)	4
penumbra (eclipse)	2
penumbra (of sunspot)	13
periapse / pericenter (e.g., perigee, perihelion)	1
peridotite	6
Period-Luminosity relation (or Leavitt's law)	18
Perseids	4
Perseus A (NGC 1275)	18
Phaethon	4
phase change	6
phase diagram	5
phases of the Moon	2
Phobos	4
Phoebe	7
Pholus	4
photodisintegration (of nuclei)	15
photoelectric effect	20
photography	20
photometric (or spectroscopic) parallax	14
photometric filter system	11
photometry	20
photon	1, 20
photosphere	13
Pickering, Edward	14
pillars of creation (in the Eagle Nebula)	10
pion	19
pixel	20
plage	13
plagioclase	6
Planck length	19
Planck spacecraft	19

Chapter-level index, cont.

topic	chapter(s)
Planck spectrum	1
Planck time	19
Planck's constant	1
Planet Nine	4
planetary nebula	15, 16
planetary rings	2
planetesimal	4, 10
plasma	13
plasma or ion tail (comet)	4
plasma sheet	9
plate boundary	5
plate scale (or image scale)	20
plate tectonics	5
Pluto	4, 5, 6
Pluto, moons	10
plutonic (or intrusive igneous rock)	6
polar distance	3
polar storms (Jupiter, Saturn)	9
polarization	20
polarization (by dust in ISM)	17
polarization (in CMB)	19
Population I, II, III	14, 15, 17
Population III	18
pore	13
position angle	12
positive curvature	19
positron	19
positron emission	10
post-impact modification (of crater)	7
post-main sequence star	15
Poynting-Robertson effect	2
pre-main sequence star	15
pre-solar grain	7
Preliminary Reference Earth Model	5
pressure (units)	5
pressure broadening	14
pressure gradient	8
primary optical element	20
primitive atmosphere	8
primitive chondrite	10
primordial nucleosynthesis	19
prism	20
Prometheus (on Io)	6
prominence	13
proper distance	19
proper motion	11
proper motion	12

topic	chapter(s)
Proteus (Neptune)	4
proton-proton chain	1, 13, 15
protoplanet	1
protoplanetary disk	4
protostar	10
PSR 1913+16	19
Ptolemy	1
pulsar	16
pupil diameter	20
pyroclastic (eruptions)	6
pyroxene	6
QSO (quasi-stellar object)	18
quadrature	2
quantum efficiency	20
quantum fluctuation	19
quantum mechanics	19
quark(s)	1, 19
quark epoch	19
quartz	6
quartzite	6
Quasar	18
quintessence	19
r-process (fusion)	15
radial velocity	11
radian	1
radiation	13
radiation pressure	2
radiation-dominated universe	19
radiative transport	15
radiative zone	13
radio galaxies	18
radio telescope	20
radioactive isotopes (decay as heat source)	5
radioisotopic dating	10
rain	8
rampart crater (or splash crater)	7
Rayleigh criterion	20
Rayleigh scattering	8, 11
Rayleigh waves (seismic surface waves)	5
rays (crater)	7
recombination	19
recurrent novae	16
red giant	14
red giant branch	15
reddening	11

Chapter-level index, cont.

topic	chapter(s)
redshift (z)	18, 19
reduced mass	1
reduced orbit	12
reducing	8, 9
reflection nebula	17
refraction of light	1
refractor	20
refractory	4, 10
regolith	4, 6, 7
reionization	19
relative orbit	12
resistive heating (or Ohmic dissipation)	5
resolution, angular	20
resonance (orbital)	4
rest mass	1
retrograde motion	2, 4
Rhea	4
rhyolite	6
right ascension	3, 11, 20
rille	6
ring of fire	5
Robertson-Walker metric	19
Roche limit	1
Roche lobe	12, 15
rock	6
rocky planet relative core sizes	5
Rosetta (spacecraft)	4
Rosse (lunar crater)	7
rotation curve (of Milky Way)	17
RR Lyrae gap	17
RR Lyrae stars	15
Rubin, Vera	17
s-process (fusion)	15
S-type asteroid	4
S-waves (transverse shear waves)	5
Sachs-Wolfe Effect	19
saltation	6
sandstone	6
Santorini (Thera)	6
saros	2
saturated surface	7
Saturn	4, 9
scale factor	19
scale height (planetary atmosphere)	8
scale height (plane of the Milky Way)	17
scarp	6

topic	chapter(s)
scattered disk objects	4
scattering (forward scattering of light by dust)	2
scattering (of planetesimals)	10
Schwarzschild radius	16, 19
scintillation (of point source)	18
Secchi, Angelo	14
second of arc (or arcsecond)	11
secondary atmosphere	8
secondary crater	7
secondary mirror	20
secular parallax	11
sedimentary rocks	6
Sedna	4
seismic wave reflection	5
seismic wave refraction	5
seismic wave velocities	5
seismogram	5
seismology	5
semi-detached binary	12
separation	12
Sérsic index	18
Seyfert galaxies	18
Sgr A*	17
shadow zone	5
shale	6
Shapley, Harlow	17
shepherd moons	2
shergottites	7
shield volcano	6
side-aperture radar	4
sidereal period	2, 4
sidereal time	3
siderophilic (elements)	7
silica	6
silicate	6
simple crater	7
singularity	16, 19
sinuous rille	6
size-frequency distribution (for impact craters)	7
slate	6
Slipher, Vesto	18
Sloan Digital Sky Survey (SDSS)	18
slush giants (or ice giants)	4, 9
small-angle approximation	11
SN1987A	16
SNC meteorites	7
Snell's law	20

Chapter-level index, cont.

topic	chapter(s)
snow line	9, 10
snowball Earth	8
Soft Gamma Repeater (SGR)	19
solar apex	11, 17
solar motion	17
solar nebula	8, 10
solar structure	13
solar system, components of	4
solar wind	8, 13
solar-type star	15
solstice	3
spacetime	19
special theory of relativity	1
spectral energy distribution (SED)	19
spectral type	14
spectroscopic (or photometric) parallax	14
spectroscopic binary	12
spectroscopy	20
spectrum binary	12
speed of light	20
spherical aberration	20
spicule	13
spiral arms	17
spiral galaxy	18
splosh crater (or rampart crater)	7
Spokane-Missoula (Bretz) floods	6
spreading ridge	5
sputtering	8
standard candle	19
standard model of physics (particles, forces)	1
standard ruler	19
standard siren	19
starburst galaxy	18
statistical parallax	11
Stefan-Boltzmann law	1
stellar diameter	12
stellar interferometry	12
stellar luminosity	12
stellar temperature	12
STEVE	8
stones (stony meteorites)	7
stony-irons (meteorites)	7
stratosphere	8
stratovolcano	6
strewn field	7

topic	chapter(s)
string theory	1, 19
Strömgren sphere (or H II region)	17
strong nuclear force	1
structure formation	19
subduction	4, 5
subdwarf	14
sublimation	4
sulfur	6
sunspot	13
sunspot cycle	13
Sunyaev-Zel'dovich Effect	19
super giant	14
Super Kamiokande	19
supercluster	19
superluminal motion, apparent	18
supermassive black hole (SMBH)	18
supernova remnant	16
supernovae	15
surface age	7
surface gravity	14
surface waves	5
symmetry breaking	19
synchrotron emission	1, 17, 18
synodic period	2, 4
T Tauri star	15
table of atmospheric compositions of giant planets	9
table of atmospheric constituents for selected solar system objects	8
table of bulk properties of giant planets	9
table of magnetic field properties - terrestrial	5
table of magnetic field properties - giant planets	9
table of properties of interesting and/or well-known stars	14
table of properties of main sequence stars	14
table of properties of supergiant stars	14
table of selected solar system object properties	4
table of solar properties	13
table of spectral types	4
tachocline	13
taenite	7
Tagish Lake meteoroid	7
tangential (or transverse) velocity	11
Tarantula Nebula	15
tau component (of proper motion)	11
tectonic activity	4
tektite	7

Chapter-level index, cont.

topic	chapter(s)
telescope	20
temperature gradient	15
Temperature minimum (Sun)	13
temperature, planetary surface	4
terrestrial planets	4
Tethys	4, 7
Theia	10
Theophilus (lunar crater)	7
Thera (Santorini)	6
thermal escape	8
thermal evolution	9
thermal profile	9
thermal wind	8
thermosphere	8
thick disk	17
thin disk	17
tholin	6
Thorne, Kip	16
three-body problem	2
tidal heating	4, 5
tidally locked	4
tides	1
time zones	3
Tip of the Red Giant Branch (TRGB)	18
Titan	4, 5, 6, 8
Titania (Uranus)	4
Titius-Bode rule	4
Tombaugh, Clyde	4
Touchet beds	6
Trans-Neptunian Objects	4
transit (of meridian)	3
transit (of one object across disk of another)	2
Transition Region	13
transverse (or tangential) velocity	11
transverse waves (seismic body waves)	5
trench	5
trigonometric parallax	11
triple point	5
triple- α process	1
Triton	4, 6, 10
troilite	6
Trojan asteroids	2
troposphere	8
Trumpler, Robert	17
Tully-Fisher relation	18
Tunguska event	7
turn-off point	15

topic	chapter(s)
Tvashtar Catena (on Io)	4, 6
TW Hydrae	10
Tycho (lunar crater)	7
Tycho Brahe	1, 2
Tycho's supernova remnant	16
Type I (Ia, Ib, Ic) supernova	15
Type Ia supernova	16, 18, 19
Type II supernova	15
UBVRI bandpasses	11
UGC 1382	18
ULAS J1120+0641	18
Ultima Thule (2014 MY ₆₉)	4, 10
ultramafic	6
umbra (eclipse)	2
umbra (of sunspot)	13
Umbriel (Uranus)	4
units of length	1
upsilon component (of proper motion)	11
Uranus	4, 9
Urey reaction	8
vacuum, energy of	19
Valhalla (impact basin on Callisto)	7
Van Allen belts	9
variable stars	15
velocity curve	12
velocity dispersion	18
ventifact	6
Venus	4, 6, 8
Venus transits	2
vernal equinox	2, 3
Very Large Array (VLA)	20
very long baseline interferometer (VLBI)	17
Vesta	4, 7
virga	8
Virgo A (M87; NGC 4486)	18
Virgo Cluster	18
Virgo Supercluster	18
virial theorem	1, 4, 5, 15, 18
virialized	18
virtual particle	19
vis viva equation for orbital speed	1, 2
visual binary	12
void	18, 19
volatile	4, 8, 10
volcanic (or extrusive igneous rock)	6

Chapter-level index, cont.

topic	chapter(s)
Voyager (spacecraft)	9, 13
Vredefort crater (South Africa)	7
warm-hot IGM (WHIM)	18
warping the fabric of spacetime	16
water on Earth	4
wave	20
wavelength	1, 20
weak force	1
weak interaction bosons	19
weathering	6
web site recommendations	1
white dwarf	14, 15, 16
Widmannstätten pattern	7
Wien's law	1
Wilkinson Microwave Anisotropy Probe (WMAP)	19
Wilson-Bappu Effect	13
Wilson, Olin	13
WIMPs (weakly interacting massive particles)	17
wind	8
wind speeds	9
Wolf-Rayet star	15
world line	19
wormhole	16
wrinkle ridge	6
xenolith	5
Yarkovsky effect	2
Yellowstone hotspot	6
YORP effect	2
Yuty (Martian rampart crater)	7
z (redshift)	18, 19
zap pit (or micro crater)	7
zenith	3
zero-age main sequence (ZAMS)	15
zircon	10
zodiacal light	4
zonal winds	4
zone (Jupiter)	9
zone of avoidance	18
Ω (Omega)	19