Astronomy Formulas

Radiation

Intensity Ratio	$m_B - m_A = 2.5\log\left(\frac{I_A}{I_B}\right)$ $\frac{I_A}{I_B} = 10^{0.4(m_B - m_A)}$	m = Magnitude I = Intensity
Wien's Law	$\lambda_{peak} = \frac{b}{T}$	$b = 2.898 \cdot 10^6$ nm · K T = Temperature [K]
Stefan Boltzmann Law	$F = \sigma T^4$ $L = 4\pi\sigma R^2 T^4$ $\frac{L}{L_\odot} = \left(\frac{R}{R_\odot}\right)^2 \left(\frac{T}{T_\odot}\right)^4$	F = Flux (luminosity/area) [W/m^2] $\sigma = 5.6704 \cdot 10^{-8}$ W · m^{-2} · K^{-4} T = Temperature [K] L = Luminosity [W] R = Radius [m]
Redshift	$z + 1 = \frac{\lambda_O}{\lambda_E}$	z = Redshift λ_O = Observed wavelength λ_E = Emitted wavelength
Doppler Shift	$v = cz$	v = Velocity of source [m/s] c = Speed of light [m/s] z = Redshift
Inverse Square	$I = \frac{L}{4\pi d^2}$	I = Light intensity [W/m^2] L = Luminosity [W] d = Distance [m]
Distance Modulus	$m - M = -5 + 5\log(d)$ $d = 10^{\frac{m-M+5}{5}}$	m = Apparent magnitude M = Absolute magnitude d = Distance [pc]

Telescopes and Optics

Small Angle Formula	$\theta = 206265\frac{D}{d}$	θ = Angular diameter [arcsec] D = Diameter d = Distance
Resolving Power	$\Delta\theta_{arcsec} = 251643\frac{\lambda}{d}$ $\Delta\theta_{rad} = 1.22\frac{\lambda}{d}$	$\Delta\theta$ = Angular separation [arcsec, rad] λ = Wavelength d = Optical diameter
Compare LGP	$\frac{LGP_A}{LGP_B} = \left(\frac{D_A}{D_B}\right)^2$	LGP = Light gathering power D = Optic diameter
Magnification	$M = \frac{F_O}{F_E}$	M = Magnification power F_O = Objective focal length F_E = Eyepiece focal length
F Ratio	$\frac{L_f}{D_O}$	L_f = Focal Length D_O = Objective Diameter
Parallax	$d = \frac{1}{p}$	d = Distance [pc] p = Parallax angle [arcsec]

Orbital Mechanics

Gravitation	$F_G = G\dfrac{m_1 m_2}{r^2}$	F_G = Gravitational force [N] m = Mass [kg] r = Distance [m] $G = 6.67 \cdot 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$
Vis Viva Equation	$v = \sqrt{GM\left(\dfrac{2}{r} - \dfrac{1}{a}\right)}$	v = Velocity [m/s] $G = 6.67 \cdot 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$ M = Mass [kg] r = Distance [m] a = Semimajor axis [m]
Circular Velocity	$v_{circ} = \sqrt{\dfrac{GM}{r}}$	v = Velocity [m/s] $G = 6.67 \cdot 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$ M = Mass [kg] r = Distance [m]
Escape Velocity	$v_{esc} = \sqrt{\dfrac{2GM}{r}}$	v = Velocity [m/s] $G = 6.67 \cdot 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$ M = Mass [kg] r = Distance [m]
Ellipse Equations	$r = \dfrac{a(1-e^2)}{1+e\cos(\theta)}$ $b^2 = a^2(1-e^2)$ $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$	a = semimajor axis b = semiminor axis e = eccentricity θ = angle from periapsis
Eccentricity	$e = \dfrac{c}{a}$	a = semimajor axis c = linear eccentricity = distance from foci to center
Apoapsis/Periapsis	$r_a = a(1+e)$ $r_p = a(1-e)$	r = distance a = semimajor axis e = eccentricity
Kepler's Second Law	$\dfrac{dA}{dt} = \dfrac{\pi ab}{T}$	A = area a = semimajor axis b = semiminor axis T = period
Kepler's Third Law	$\dfrac{a^3}{T^2} = \dfrac{G(M+m)}{4\pi^2}$	a = semimajor axis T = period M = larger mass m = smaller mass $G = 6.67 \cdot 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$
Virial Theorem	$\langle T \rangle = -\dfrac{1}{2}\langle U \rangle$ $\langle T \rangle = -\dfrac{1}{2}\sum_{k=1}^{N}\langle \mathbf{F}_k \cdot \mathbf{r}_k \rangle$	$\langle T \rangle$ = Time averaged kinetic energy $\langle U \rangle$ = Time averaged potential energy
Binary System	$a = r_1 + r_2$ $r_1 = a\dfrac{m_2}{m_1 + m_2}$ $\dfrac{m_1}{m_2} = \dfrac{\alpha_2}{\alpha_1} = \dfrac{r_2}{r_1} = \dfrac{v_2}{v_1}$	r = Distance from barycenter a = semimajor axis α = Angular distance from barycenter m = mass v = radial velocity

Binary Mass Function	$K = v_1 \sin i = \omega_{orb} r_1 \sin i$ $f = \frac{M_2^3 \sin^3 i}{(M_1+M_2)^2} = \frac{P_{orb}K^3}{2\pi G}$ $\omega_{orb} = \frac{2\pi}{P_{orb}}$	i = orbital inclination = degrees from face-on f = Mass function [kg] M = mass [kg] P_{orb} = Orbital period [s] K = peak radial velocity [rad/s] = semiamplitude of rad. vel. curve ω_{orb} = orbital frequency $G = 6.67 \cdot 10^{-11}$ $\mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$

Stars

Stellar Lifetime	$\tau \approx 10^{10} M^{-2.5}$	M = Mass (solar masses) τ = Stellar lifetime (years)
Mass-Luminosity Relation	$L \approx M^{3.5}$	M = Mass (solar masses) L = Luminosity (solar luminosity)
RR Lyrae P-L Rel.	$M_k = -2.34 \log(P) - 0.88$	M_K = Absolute K-band IR magnitude P = Period [days]
RV Tau P-L Rel.	$M = 7.36 \log(P) + 10.21$	M_v = Absolute magnitude P = Period [days]
Type I Ceph. P-L Rel.	$M_v = -2.43(\log_{10}(P) - 1) - 4.05$	M_v = Absolute visual magnitude P = Period [days]
Type II Ceph. P-L Rel.	$M_v = -2.43(\log_{10}(P) - 1) - 2.45$	M_v = Absolute visual magnitude P = Period [days]

Cosmology and Relativity

Relativistic Doppler Shift	$z + 1 = \sqrt{\frac{1+(v/c)}{1-(v/c)}}$	v = Velocity of source [m/s] c = Speed of light [m/s] z = Redshift
Hubble's Law	$v = H_0 d$	v = Recessional Velocity $H_0 \approx 70$ km/s/Mpc d = distance
Hubble Time	$T_U = \frac{9.778 \cdot 10^{11}}{H_0}$	T_U = Age of universe $H_0 \approx 70$ km/s/Mpc
Schwarzschild Radius	$r_s = \frac{2GM}{c^2}$	r_s = Schwarzchild radius G = gravitational constant M = mass c = speed of light
Time Dilation	$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$	
Length contraction	$L = L_0\sqrt{1-\frac{v^2}{c^2}}$	

Climate and Exoplanets

Planetary Equilibrium Temperature	$T_{eq} = \left(\frac{I_0(1-A_B)}{4\sigma}\right)^{1/4}$ $I_x = \frac{L}{4\pi a^2}$ $T_{eq} = T_{star}\sqrt{\frac{R}{2a}}(1-A_B)^{1/4}$	A_B = bond albedo $\sigma = 5.6704 \cdot 10^{-8}$ $\mathrm{W} \cdot \mathrm{m}^{-2} \cdot \mathrm{K}^{-4}$ a = semimajor axis [m] L = luminosity [$\mathrm{W/m^2}$]

Radiation Balance	$ASR = (1 - A_B) \cdot 340 \approx 240W/m^2$ $OLR \approx \varepsilon\sigma T_{atm}^4 + (1-\varepsilon)\sigma T_{surf}^4$	ε = emissivity ASR = absorbed solar radiation OLR = outgoing longwave radiation $\sigma = 5.6704 \cdot 10^{-8}$ W $\cdot$ m^{-2} $\cdot$ K^{-4}
Radiative Forcing	$\Delta F = I_0 \cdot (1-R) \cdot \Delta\tau = 238 \cdot \Delta\tau$ $\Delta F = -I_0 \cdot R \cdot \Delta A_B = -102 \cdot \Delta A_B$ $\Delta F_{CO2} = 5.35 \cdot \ln \frac{C_0 + \Delta C}{C_0}$ $\Delta T_s = \lambda \Delta F$	ΔF = radiative forcing [W m^2] $\Delta\tau$ = Δ solar irradiance [W/m^2] λ = climate sens. param. [K m/W^2]
Emissivity	$\varepsilon = \frac{M_e}{M_e^\circ}$	ε = emissivity M_e = Radiant exitance [W $\cdot$ m^{-2}] M_e° = Radiant exitance of blackbody
Extinction	$\Delta F = \left(\frac{R_p}{R_s}\right)^2$	
Albedo		
Habitable Zone	$r = \sqrt{\frac{(1-A)L}{16\pi\sigma T^4}}$ $T_s^4 = \frac{Q(1-A)}{2\sigma(2-\epsilon}$	$T = 273 - 373K$

Astronomy Constants and Conversions

Constants

Fundamental Constants

Speed of light $= c = 3 \cdot 10^8$ m/s

Gravitational constant $= G = 6.67 \cdot 10^{-11}$ $\text{m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$

Mass of a proton $= m_p = 1.6726 \cdot 10^{-27}$ kg

Mass of an electron $= m_{e^-} = 9.109 \cdot 10^{-31}$kg

Charge of an electron $= e = 1.6022 \cdot 10^{-19}$ C

Hubble's Constant $= H_0 = 70$ km/s/Mpc

Stefan-Boltzmann Constant $= \sigma = 5.67 \cdot 10^{-8}$ $\text{W/m}^2\text{K}^4$

Planck's Constant $= h = 6.626 \cdot 10^{-34}$ J s

Reduced Planck's Constant $= \hbar = h/(2\pi) = 1.05457 \cdot 10^{-34}$ J s

Boltzmann Constant $= k = k_B = 1.380 \cdot 10^{-23}$ m^2 $\text{kg/s}^2\text{K}$

Wein's Displacement Constant $= b = 2.898 \cdot 10^{-3}\text{m} \cdot \text{K}$

Molar gas constant $= R = 8.315$ J/mol/K

Rhydberg constant $= R_H = 1.0968 \cdot 10^7$ m^{-1}

Solar System

Mass of Earth $= M_\oplus = 5.97 \cdot 10^{24}$ kg

Radius of Earth $= R_\oplus = 6378$ km

Mass of the Moon $= M_☾ = 7.346 \cdot 10^{22}$ kg

Radius of the Moon $= R_☾ = 1738.1$ km

Mass of Jupiter

Radius of Jupiter

Mass of Sun $= M_\odot = 1.99 \cdot 10^{30}$kg

Radius of Sun $= R_\odot = 6.96 \cdot 10^5$ km

Temperature of Sun $= T_\odot = 5778$ K

Luminosity of Sun $= L_\odot = 3.9 \cdot 10^{26}$ W

Absolute magnitude of Sun $= M_\odot = 4.83$

SGP of Sun $= \mu_\odot = GM_\odot = 1.327 \cdot 10^{20}$ $\text{m}^3 \cdot \text{s}^{-2}$

Solar metallicity $= Z_\odot = 0.0134$

Miscellaneous

Hα spectral line $= 656.28$ nm

Type Ia supernova absolute magnitude $= -19.3$

Chandrasekhar limit $= M_{\text{limit}} \approx 1.4\text{M}_\odot$

TOV limit $= M_{\text{limit}} \approx 2.1$ $\text{M}_\odot$

Conversions

Distance/Area

1 AU $= 1.5 \cdot 10^8$ km

1 pc $= 3.09 \cdot 10^{16}$ m $= 3.26$ ly

1 ly $= 9.46 \cdot 10^{15}$ m

1 m $= 3.28$ ft

1 in $= 2.54$ cm

1 mi $= 5280$ ft

1 Å $= 0.1$ nm

1 fermi $= 1$ $fm = 10^{-15}$m

1 barn $= 1$ $b = 10^{-28}$ m^2

1 acre $= 4046.86$ m^2

Angles

1 arcmin = 1' $= (\frac{1}{60})^\circ$

1 arcsec = 1" $= (\frac{1}{60})' = (\frac{1}{3600})^\circ$

Time

1 year = 31557600 s

Energy

1 Megaton of TNT $= 4.184 \cdot 10^{15}$ J

1 electron volt = 1 eV $= 1.6 \cdot 10^{-19}$ J

Temperature

°C = K − 273.15

°F $= \frac{9}{5}$°C + 32

CGS Units

1 gal $= 10^{-2}$ m/s^2

1 dyne $= 10^{-5}$ N

1 erg $= 10^{-7}$ J

1 barye $= 10^{-1}$ Pa

Planck Units

Planck temperature $= T_p = \sqrt{\frac{\hbar c^5}{G k_B^2}} = 1.4168 \cdot 10^{32}$ K

Planck time $= t_p = \sqrt{\frac{\hbar G}{c^5}} = 5.391 \cdot 10^{44}$s

Planck length $= \sqrt{\frac{\hbar G}{c^3}} = 1.61626 \cdot 10^{-35} m$

Yotta (Y)	10^{24}	Deci (d)	10^{-1}
Zetta (Z)	10^{21}	Centi (c)	10^{-2}
Exa (E)	10^{18}	Milli (m)	10^{-3}
Peta (P)	10^{15}	Micro (μ)	10^{-6}
Tera (T)	10^{12}	Nano (n)	10^{-9}
Giga (G)	10^{9}	Pico (p)	10^{-12}
Mega (M)	10^{6}	Femto (f)	10^{-15}
Kilo (k)	10^{3}	Atto (a)	10^{-18}
Hecto (h)	10^{2}	Zepto (z)	10^{-21}
Deca (da)	10^{1}	Yocto (y)	10^{-24}