

9.4 Observational astrophysics

Astronomical magnitudes

Apparent magnitude	$m_1 - m_2 = -2.5 \log_{10} \frac{F_1}{F_2}$	(9.27)	m_i	apparent magnitude of object i
			F_i	energy flux from object i
Distance modulus ^a	$m - M = 5 \log_{10} D - 5$	(9.28)	M	absolute magnitude
	$= -5 \log_{10} p - 5$	(9.29)	$m - M$	distance modulus
			D	distance to object (parsec)
			p	annual parallax (arcsec)
Luminosity–magnitude relation	$M_{\text{bol}} = 4.75 - 2.5 \log_{10} \frac{L}{L_{\odot}}$	(9.30)	M_{bol}	bolometric absolute magnitude
	$L \simeq 3.04 \times 10^{(28 - 0.4 M_{\text{bol}})}$	(9.31)	L	luminosity (W)
			$L_{\odot}$	solar luminosity (3.826×10^{26} W)
Flux–magnitude relation	$F_{\text{bol}} \simeq 2.559 \times 10^{-(8 + 0.4 m_{\text{bol}})}$	(9.32)	F_{bol}	bolometric flux (W m^{-2})
			m_{bol}	bolometric apparent magnitude
Bolometric correction	$BC = m_{\text{bol}} - m_V$	(9.33)	BC	bolometric correction
	$= M_{\text{bol}} - M_V$	(9.34)	m_V	V -band apparent magnitude
			M_V	V -band absolute magnitude
Colour index ^b	$B - V = m_B - m_V$	(9.35)	$B - V$	observed $B - V$ colour index
	$U - B = m_U - m_B$	(9.36)	$U - B$	observed $U - B$ colour index
Colour excess ^c	$E = (B - V) - (B - V)_0$	(9.37)	E	$B - V$ colour excess
			$(B - V)_0$	intrinsic $B - V$ colour index

^aNeglecting extinction.

^bUsing the UBV magnitude system. The bands are centred around 365 nm (U), 440 nm (B), and 550 nm (V).

^cThe $U - B$ colour excess is defined similarly.

Photometric wavelengths

Mean wavelength	$\lambda_0 = \frac{\int \lambda R(\lambda) d\lambda}{\int R(\lambda) d\lambda}$	(9.38)	λ_0	mean wavelength
			λ	wavelength
			R	system spectral response
Isophotal wavelength	$F(\lambda_i) = \frac{\int F(\lambda) R(\lambda) d\lambda}{\int R(\lambda) d\lambda}$	(9.39)	$F(\lambda)$	flux density of source (in terms of wavelength)
			λ_i	isophotal wavelength
Effective wavelength	$\lambda_{\text{eff}} = \frac{\int \lambda F(\lambda) R(\lambda) d\lambda}{\int F(\lambda) R(\lambda) d\lambda}$	(9.40)	λ_{eff}	effective wavelength



Planetary bodies

Bode's law ^a	$D_{\text{AU}} = \frac{4 + 3 \times 2^n}{10}$	(9.41)	D_{AU}	planetary orbital radius (AU)
			n	index: Mercury = $-\infty$, Venus = 0, Earth = 1, Mars = 2, Ceres = 3, Jupiter = 4, ...
Roche limit	$R \gtrsim \left(\frac{100M}{9\pi\rho} \right)^{1/3}$	(9.42)	R	satellite orbital radius
	$\gtrsim 2.46R_0$ (if densities equal)	(9.43)	M	central mass
			ρ	satellite density
			R_0	central body radius
Synodic period ^b	$\frac{1}{S} = \left \frac{1}{P} - \frac{1}{P_{\oplus}} \right $	(9.44)	S	synodic period
			P	planetary orbital period
			$P_{\oplus}$	Earth's orbital period

^aAlso known as the "Titius–Bode rule." Note that the asteroid Ceres is counted as a planet in this scheme. The relationship breaks down for Neptune and Pluto.

^bOf a planet.

Distance indicators

Hubble law	$v = H_0 d$	(9.45)	v	cosmological recession velocity
			H_0	Hubble parameter (present epoch)
			d	(proper) distance
Annual parallax	$D_{\text{pc}} = p^{-1}$	(9.46)	D_{pc}	distance (parsec)
			p	annual parallax ($\pm p$ arcsec from mean)
Cepheid variables ^a	$\log_{10} \frac{\langle L \rangle}{L_{\odot}} \simeq 1.15 \log_{10} P_d + 2.47$	(9.47)	$\langle L \rangle$	mean cepheid luminosity
	$M_V \simeq -2.76 \log_{10} P_d - 1.40$	(9.48)	$L_{\odot}$	Solar luminosity
			P_d	pulsation period (days)
			M_V	absolute visual magnitude
Tully–Fisher relation ^b	$M_I \simeq -7.68 \log_{10} \left(\frac{2v_{\text{rot}}}{\sin i} \right) - 2.58$	(9.49)	M_I	I -band absolute magnitude
			v_{rot}	observed maximum rotation velocity (kms^{-1})
			i	galactic inclination (90° when edge-on)
Einstein rings	$\theta^2 = \frac{4GM}{c^2} \left(\frac{d_s - d_l}{d_s d_l} \right)$	(9.50)	θ	ring angular radius
			M	lens mass
			d_s	distance from observer to source
			d_l	distance from observer to lens
Sunyaev–Zel'dovich effect ^c	$\frac{\Delta T}{T} = -2 \int \frac{n_e k T_e \sigma_T}{m_e c^2} dl$	(9.51)	T	apparent CMBR temperature
			dl	path element through cloud
			R	cloud radius
			n_e	electron number density
			k	Boltzmann constant
			T_e	electron temperature
... for a homogeneous sphere	$\frac{\Delta T}{T} = -\frac{4Rn_e k T_e \sigma_T}{m_e c^2}$	(9.52)	σ_T	Thomson cross section
			m_e	electron mass
			c	speed of light

^aPeriod–luminosity relation for classical Cepheids. Uncertainty in M_V is ± 0.27 (Madore & Freedman, 1991, Publications of the Astronomical Society of the Pacific, **103**, 933).

^bGalaxy rotation velocity–magnitude relation in the infrared I waveband, centred at $0.90 \mu\text{m}$. The coefficients depend on waveband and galaxy type (see Giovanelli *et al.*, 1997, The Astronomical Journal, **113**, 1).

^cScattering of the cosmic microwave background radiation (CMBR) by a cloud of electrons, seen as a temperature decrement, ΔT , in the Rayleigh–Jeans limit ($\lambda \gg 1 \text{ mm}$).