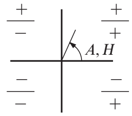
9.3 Coordinate transformations (astronomical)

Time in astronomy

Quantity	Equation	No.	Symbols
Julian day number[a]	$JD = D - 32075 + 1461 * (Y + 4800 + (M-14)/12)/4$ $+ 367 * (M - 2 - (M-14)/12 * 12)/12$ $- 3 * ((Y + 4900 + (M-14)/12)/100)/4$	(9.1)	JD Julian day number; D day of month number; Y calendar year, e.g., 1963; M calendar month (Jan=1); $*$ integer multiply; $/$ integer divide
Modified Julian day number	$MJD = JD - 2400000.5$	(9.2)	MJD modified Julian day number
Day of week	$W = (JD + 1) \quad \bmod 7$	(9.3)	W day of week (0=Sunday, 1=Monday, ...)
Local civil time	$\mathrm{LCT} = \mathrm{UTC} + \mathrm{TZC} + \mathrm{DSC}$	(9.4)	LCT local civil time; UTC coordinated universal time; TZC time zone correction; DSC daylight saving correction
Julian centuries	$T = \dfrac{JD - 2451545.5}{36525}$	(9.5)	T Julian centuries between 12^{h} UTC 1 Jan 2000 and 0^{h} UTC $D/M/Y$
Greenwich sidereal time	$\mathrm{GMST} = 6^{\mathrm{h}}41^{\mathrm{m}}50^{\mathrm{s}}.54841$ $+ 8640184^{\mathrm{s}}.812866T$ $+ 0^{\mathrm{s}}.093104T^2$ $- 0^{\mathrm{s}}.0000062T^3$	(9.6)	GMST Greenwich mean sidereal time at 0^{h} UTC $D/M/Y$ (for later times use $1\,\mathrm{s} = 1.002738$ sidereal seconds)
Local sidereal time	$\mathrm{LST} = \mathrm{GMST} + \dfrac{\lambda^\circ}{15^\circ}$	(9.7)	LST local sidereal time; λ° geographic longitude, degrees east of Greenwich

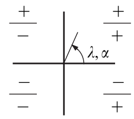
[a]For the Julian day starting at noon on the calendar day in question. The routine is designed around integer arithmetic with "truncation towards zero" (so that $-5/3 = -1$) and is valid for dates from the onset of the Gregorian calendar, 15 October 1582. JD represents the number of days since Greenwich mean noon 1 Jan 4713 BC. For reference, noon, 1 Jan 2000 $= JD2451545$ and was a Saturday ($W = 6$).

Horizon coordinates[a]

Quantity	Equation	No.	Symbols
Hour angle	$H = \mathrm{LST} - \alpha$	(9.8)	LST local sidereal time; H (local) hour angle
Equatorial to horizon	$\sin a = \sin\delta \sin\phi + \cos\delta \cos\phi \cos H$	(9.9)	α right ascension; δ declination
	$\tan A \equiv \dfrac{-\cos\delta \sin H}{\sin\delta \cos\phi - \sin\phi \cos\delta \cos H}$	(9.10)	a altitude; A azimuth (E from N); ϕ observer's latitude
Horizon to equatorial	$\sin\delta = \sin a \sin\phi + \cos a \cos\phi \cos A$	(9.11)	
	$\tan H \equiv \dfrac{-\cos a \sin A}{\sin a \cos\phi - \sin\phi \cos a \cos A}$	(9.12)	

[a]Conversions between horizon or alt–azimuth coordinates, (a, A), and celestial equatorial coordinates, (δ, α). There are a number of conventions for defining azimuth. For example, it is sometimes taken as the angle west from south rather than east from north. The quadrants for A and H can be obtained from the signs of the numerators and denominators in Equations (9.10) and (9.12) (see diagram).

Ecliptic coordinates[a]

Obliquity of the ecliptic	$$\varepsilon = 23°26'21''.45 - 46''.815\,T - 0''.0006\,T^2 + 0''.00181\,T^3 \quad (9.13)$$	ε mean ecliptic obliquity T Julian centuries since J2000.0[b]
Equatorial to ecliptic	$$\sin\beta = \sin\delta\cos\varepsilon - \cos\delta\sin\varepsilon\sin\alpha \quad (9.14)$$ $$\tan\lambda \equiv \frac{\sin\alpha\cos\varepsilon + \tan\delta\sin\varepsilon}{\cos\alpha} \quad (9.15)$$	α right ascension δ declination λ ecliptic longitude β ecliptic latitude
Ecliptic to equatorial	$$\sin\delta = \sin\beta\cos\varepsilon + \cos\beta\sin\varepsilon\sin\lambda \quad (9.16)$$ $$\tan\alpha \equiv \frac{\sin\lambda\cos\varepsilon - \tan\beta\sin\varepsilon}{\cos\lambda} \quad (9.17)$$	

[a]Conversions between ecliptic, (β,λ), and celestial equatorial, (δ,α), coordinates. β is positive above the ecliptic and λ increases eastwards. The quadrants for λ and α can be obtained from the signs of the numerators and denominators in Equations (9.15) and (9.17) (see diagram).
[b]See Equation (9.5).

Galactic coordinates[a]

Galactic frame	$$\alpha_g = 192°15' \quad (9.18)$$ $$\delta_g = 27°24' \quad (9.19)$$ $$l_g = 33° \quad (9.20)$$	α_g right ascension of north galactic pole δ_g declination of north galactic pole
Equatorial to galactic	$$\sin b = \cos\delta\cos\delta_g\cos(\alpha-\alpha_g) + \sin\delta\sin\delta_g \quad (9.21)$$ $$\tan(l-l_g) \equiv \frac{\tan\delta\cos\delta_g - \cos(\alpha-\alpha_g)\sin\delta_g}{\sin(\alpha-\alpha_g)} \quad (9.22)$$	l_g ascending node of galactic plane on equator
Galactic to equatorial	$$\sin\delta = \cos b\cos\delta_g\sin(l-l_g) + \sin b\sin\delta_g \quad (9.23)$$ $$\tan(\alpha-\alpha_g) \equiv \frac{\cos(l-l_g)}{\tan b\cos\delta_g - \sin\delta_g\sin(l-l_g)} \quad (9.24)$$	δ declination α right ascension b galactic latitude l galactic longitude

[a]Conversions between galactic, (b,l), and celestial equatorial, (δ,α), coordinates. The galactic frame is defined at epoch B1950.0. The quadrants of l and α can be obtained from the signs of the numerators and denominators in Equations (9.22) and (9.24).

Precession of equinoxes[a]

In right ascension	$$\alpha \simeq \alpha_0 + (3^s.075 + 1^s.336\sin\alpha_0\tan\delta_0)N \quad (9.25)$$	α right ascension of date α_0 right ascension at J2000.0 N number of years since J2000.0
In declination	$$\delta \simeq \delta_0 + (20''.043\cos\alpha_0)N \quad (9.26)$$	δ declination of date δ_0 declination at J2000.0

[a]Right ascension in hours, minutes, and seconds; declination in degrees, arcminutes, and arcseconds. These equations are valid for several hundred years each side of J2000.0.