9.3 Coordinate transformations (astronomical)

Time in astronomy

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)
Modified Julian day number	$MJD = JD - 2400000.5$	(9.2)
Day of week	$W = (JD + 1) \quad \mathrm{mod}\, 7$	(9.3)
Local civil time	$\mathrm{LCT} = \mathrm{UTC} + \mathrm{TZC} + \mathrm{DSC}$	(9.4)
Julian centuries	$T = \dfrac{JD - 2451545.5}{36525}$	(9.5)
Greenwich sidereal time	$\mathrm{GMST} = 6^{\mathrm{h}}41^{\mathrm{m}}50^{\mathrm{s}}.54841$ $+ 8640184^{\mathrm{s}}.812866\,T$ $+ 0^{\mathrm{s}}.093104\,T^2$ $- 0^{\mathrm{s}}.0000062\,T^3$	(9.6)
Local sidereal time	$\mathrm{LST} = \mathrm{GMST} + \dfrac{\lambda^\circ}{15^\circ}$	(9.7)

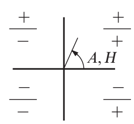
JD	Julian day number
D	day of month number
Y	calendar year, e.g., 1963
M	calendar month (Jan=1)
$*$	integer multiply
$/$	integer divide
MJD	modified Julian day number
W	day of week (0=Sunday, 1=Monday, ...)
LCT	local civil time
UTC	coordinated universal time
TZC	time zone correction
DSC	daylight saving correction
T	Julian centuries between 12^{h} UTC 1 Jan 2000 and 0^{h} UTC $D/M/Y$
GMST	Greenwich mean sidereal time at 0^{h} UTC $D/M/Y$ (for later times use $1\,\mathrm{s} = 1.002738$ sidereal seconds)
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]

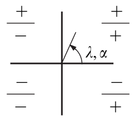
Hour angle	$H = \mathrm{LST} - \alpha$	(9.8)
Equatorial to horizon	$\sin a = \sin\delta \sin\phi + \cos\delta \cos\phi \cos H$	(9.9)
	$\tan A \equiv \dfrac{-\cos\delta \sin H}{\sin\delta \cos\phi - \sin\phi \cos\delta \cos H}$	(9.10)
Horizon to equatorial	$\sin\delta = \sin a \sin\phi + \cos a \cos\phi \cos A$	(9.11)
	$\tan H \equiv \dfrac{-\cos a \sin A}{\sin a \cos\phi - \sin\phi \cos a \cos A}$	(9.12)

LST	local sidereal time
H	(local) hour angle
α	right ascension
δ	declination
a	altitude
A	azimuth (E from N)
ϕ	observer's latitude



[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	$\varepsilon = 23^\circ 26' 21''.45 - 46''.815\,T - 0''.0006\,T^2 + 0''.00181\,T^3$	(9.13)	ε mean ecliptic obliquity T Julian centuries since J2000.0[b]
Equatorial to ecliptic	$\sin\beta = \sin\delta\cos\varepsilon - \cos\delta\sin\varepsilon\sin\alpha$	(9.14)	α right ascension δ declination λ ecliptic longitude β ecliptic latitude
	$\tan\lambda \equiv \dfrac{\sin\alpha\cos\varepsilon + \tan\delta\sin\varepsilon}{\cos\alpha}$	(9.15)	
Ecliptic to equatorial	$\sin\delta = \sin\beta\cos\varepsilon + \cos\beta\sin\varepsilon\sin\lambda$	(9.16)	
	$\tan\alpha \equiv \dfrac{\sin\lambda\cos\varepsilon - \tan\beta\sin\varepsilon}{\cos\lambda}$	(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	$\alpha_g = 192^\circ 15'$	(9.18)	α_g right ascension of north galactic pole δ_g declination of north galactic pole
	$\delta_g = 27^\circ 24'$	(9.19)	
	$l_g = 33^\circ$	(9.20)	
Equatorial to galactic	$\sin b = \cos\delta\cos\delta_g\cos(\alpha-\alpha_g) + \sin\delta\sin\delta_g$	(9.21)	l_g ascending node of galactic plane on equator
	$\tan(l - l_g) \equiv \dfrac{\tan\delta\cos\delta_g - \cos(\alpha-\alpha_g)\sin\delta_g}{\sin(\alpha-\alpha_g)}$	(9.22)	
Galactic to equatorial	$\sin\delta = \cos b\cos\delta_g\sin(l-l_g) + \sin b\sin\delta_g$	(9.23)	δ declination α right ascension b galactic latitude l galactic longitude
	$\tan(\alpha-\alpha_g) \equiv \dfrac{\cos(l-l_g)}{\tan b\cos\delta_g - \sin\delta_g\sin(l-l_g)}$	(9.24)	

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