# Chapter 15

## Ephemerides of the Sun

The sun is probably the most frequently observed body in celestial navigation. Greenwich hour angle and declination of the sun as well as $GHA_{Aries}$ and EoT can be calculated using the algorithms listed below. The formulas are relatively simple and useful for navigational calculations with programmable pocket calculators (10 digits recommended).

First, the time variable, T, has to be calculated from year, month, and day. T is the number of days before or after Jan 1, 2000, 12:00:00 GMT:

$$T = 367 \cdot y - \text{int}\left\{1.75 \cdot \left[y + \text{int}\left(\frac{m+9}{12}\right)\right]\right\} + \text{int}\left(275 \cdot \frac{m}{9}\right) + d + \frac{GMT}{24} - 730531.5$$

y is the number of the year (4 digits), m is the number of the month, and d the number of the day of the respective month. GMT (UT) is Greenwich mean time in decimal format (e.g., 12h 30m 45s = 12.5125). For May 17, 1999, 12:30:45 GMT, for example, T is -228.978646. The equation is valid from March 1, 1900 through February 28, 2100.

Mean anomaly of the sun*:

$$g[°] = 0.9856003 \cdot T - 2.472$$

Mean longitude of the sun*:

$$L_M[°] = 0.9856474 \cdot T - 79.53938$$

True longitude of the sun*:

$$L_T[°] = L_M[°] + 1.915 \cdot \sin g + 0.02 \cdot \sin(2 \cdot g)$$

Obliquity of the ecliptic:

$$\varepsilon[°] = 23.439 - 4 \cdot 10^{-7} \cdot T$$

**Declination of the sun:**

$$Dec[°] = \arcsin(\sin L_T \cdot \sin \varepsilon)$$

Right ascension of the sun (in degrees)*:

$$RA[°] = 2 \cdot \arctan\left(\frac{\cos \varepsilon \cdot \sin L_T}{\cos Dec + \cos L_T}\right)$$

**$GHA_{Aries}$*:**

$$GHA_{Aries}[°] = 0.9856474 \cdot T + 15 \cdot GMT + 100.46062$$

**Greenwich hour angle of the sun*:**

$$GHA[°] = GHA_{Aries} - RA[°]$$

**Equation of time:**

$$EoT[m] = 4 \cdot (L_M[°] - RA[°])$$

*These quantities have to be within the range from 0° through 360°. If necessary, add or subtract 360° or multiples thereof. This can be achieved using the following algorithm which is particularly useful for programmable calculators:

$$y = 360 \cdot \left[ \frac{x}{360} - \text{int}\left( \frac{x}{360} \right) \right]$$

int(x) is the greatest integer smaller than x. For example, int(3.8) = 3, int(-2.2) = -3. The ***int*** function is called ***floor*** in some programming languages, e.g., JavaScript.

## Accuracy

Unfortunately, no information on accuracy is given in the original literature [8]. Therefore, results have been cross-checked with *Interactive Computer Ephemeris 0.51* (accurate to approx. 0.1'). Between the years 1900 and 2049, no difference greater than ±0.5' for GHA and Dec was found with 100 dates chosen at random. In most cases, the error was less than ±0.3'. EoT was accurate to approx. ±2s. In comparison, the maximum error in GHA and Dec extracted from the Nautical Almanac is approx. ±0.25' when using the interpolation tables.

## Semidiameter and Horizontal Parallax

Due to the excentricity of the earth's orbit, semidiameter and horizontal parallax of the sun change periodically during the course of a year. The SD of the sun is calculated using the following formula:

$$SD['] = 16 + 0.27 \cdot \cos \frac{30.4 \cdot (m-1) + d - 3}{1.015}$$

The argument of the cosine is stated in degrees.

The mean HP of the sun is 8.8 arcseconds. The periodic variation of HP is too small to be of practical significance.