From *Astrophysical Formulae*, Kenneth R. Lang, 1980, pp. 499-500:

5.1.3. Precession, Nutation, Aberration, and Refraction

The earth's flattening, combined with the obliquity of the ecliptic, results in a slow turning of the celestial equator on the ecliptic due to the differential gravitational effect of the moon and the Sun. This effect causes the equinox to move westward along the ecliptic at the rate of about 50″ per year. The gravitational couples between the center of mass of the earth and the other planets cause an additional motion of the equinox eastward of about 0.12″ per year as well as a diminution of the obliquity of the ecliptic of about 0.47″ per year. The net result of both the luni-solar and planetary effects is a general precession in right ascension, m, declination, n, and longitude, χ, which was first observed by HIPPARCHUS (125 B.C.). The theoretical values are (NEWCOMB, 1892, 1906)

$$\begin{aligned} m &= 3.07234 + 0.00186\,T \quad \text{seconds of time per year} \\ m &= 46.0851 + 0.0279\,T \quad \text{seconds of arc per year} \\ n &= 20.0468 - 0.0085\,T \quad \text{seconds of arc per year} \\ \chi &= 50.2564 + 0.0222\,T \quad \text{seconds of arc per year,} \end{aligned} \tag{5-25}$$

where T is the number of tropical centuries since 1900.0. The obliquity of the ecliptic for the reference epoch 1900.0 is 23°27′08.26″. The increase in right ascension, $\Delta\alpha$, and declination, $\Delta\delta$, are given by

$$\Delta\alpha = [m + n \sin\alpha \tan\delta]\,N$$

and

$$\Delta\delta = [n \cos\alpha]\,N, \tag{5-26}$$

where α and δ are, respectively, the right ascension and declination for the reference epoch, and N is the number of years between the desired date and the reference date. From Eq. (5-25), for example, the values of m and n for the reference epoch 1950.0 are $m = 3.07327$ seconds of time per year and $n = 20.0426$ seconds of arc per year.

BRADLEY (1748) first observed periodic nutation terms in the precession which are caused by the periodic motions of the moon in orbit around the earth and the earth in orbit around the Sun. The principal term depends on the longitude of the node of the moon's orbit and had a period of 18.6 years and an amplitude $N = 9.210''$ in 1900.0. The constant N is known as the constant of nutation. The nutation may be resolved into a correction, $\Delta\psi$, to the Sun's longitude, and a correction, $\Delta\varepsilon$, to the mean obliquity of the ecliptic by using the theory given by WOOLARD (1953). The nutation in longitude is given in the ephemeris, and the nutation in the obliquity, $\Delta\varepsilon$, is $-B$, where the Besselian day number, B, is tabulated in the ephemeris. The first-order nutation corrections to the right ascension and declination are given by

$$\Delta\alpha = (\cos\varepsilon + \sin\varepsilon \sin\alpha \tan\delta)\,\Delta\psi - \cos\alpha \tan\delta\,\Delta\varepsilon$$

and

$$\Delta\delta = \sin\varepsilon \cos\alpha\,\Delta\psi + \sin\alpha\,\Delta\varepsilon, \tag{5-27}$$

where α and δ are, respectively, the right ascension and declination for the reference epoch, and ε is the obliquity of the ecliptic which is tabulated in the ephemeris.

BRADLEY (1728) first observed aberration, which is a tilting of the apparent direction of a celestial object toward the direction of motion of the observer. Its