

This article appeared in The Mountain Astrologer in 2000

Local Apparent Time

by

Kenneth Bowser

According to her family records, Maria Antonia Habsburg was born November 2, 1755 at 7:30 p.m. in Vienna, Austria. If a horoscope is cast for these data using 7:30 p.m. Central European Time, it will not produce the right horoscope because clocks in 1755 were not set to that time standard. Central European Time and the other time zones used today were not employed until late in the Nineteenth Century. If the local mean time of Vienna is substituted for Central European Time, Maria's horoscope will still be wrong because local mean time was not used anywhere as a civil standard until 1780 at Geneva, Switzerland, and nowhere else until London adopted local mean time in 1792; the rest of England did not follow suit at once..

In 1755 wherever a mechanical clockwork was in place in Western Civilization as a civil standard, and almost surely throughout the Islamic world as well as India, it was set to the Sun. Sun time or sundial time is more commonly known in astronomical and astrological parlance as local apparent time. The critical difference between local mean time and local apparent time is that the former keeps to a mean rate and the latter does not. The most obvious manifestation of this difference is that in local mean time reckoning, the clock usually has only an approximate relation to true noon, whereas by local apparent time reckoning, noon o'sun is always exactly noon o'clock. Local mean noon and local apparent noon coincide four times per year, yet local mean time severs the constant relationship between a clock and the Sun.

In the case of Maria Antonia, better known by the French rendering of her name, Marie-Antoinette (queen of France and wife of Louis XVI), the difference between 7:30 p.m. local apparent time and 7:30 p.m. local mean time is sixteen minutes and twelve seconds. The local mean time equivalent of 7:30 p.m. local apparent time is sixteen minutes and twelve seconds earlier, or 7:13:48 p.m. local mean time. While these are equivalent times in different systems of reckoning, the difference must be taken into account to view a horoscope from this period, as a

contemporary astrologer would have calculated it. This local mean time value, 7:13:48 p.m., is the time which will give her correct horoscope (see figure one). Since most of us use computer programs, which will not recognize an entry rendered in terms of local apparent time, one must know what to do with it. With very few exceptions, modern astrologers relegate every horoscope, which predates the modern era to local mean time status without converting it from local apparent time to local mean time. This article explains how to convert back and forth from mean time to apparent time with related information about time.

Why Bother with Local Apparent Time?

It is important to observe local apparent time (LAT) for the era during which it was in effect for the same reason that astrologers are careful to note what time standard was in effect or if daylight saving time was observed for a modern birth or event: for the sake of general accuracy. For Marie-Antoinette the difference between using the correct time standard, LAT, and the wrong one, local mean time (LMT), is four degrees and fifteen minutes of arc at the mid-heaven and three degrees and forty minutes on the ascendant. This may seem trifling until it is recognized how quickly signs of short ascension rise in high latitudes north and south. At some heavily populated latitudes all or most of a sign can rise in only sixteen minutes. Using LMT as the time convention for periods before it came into use can give the wrong rising sign, and, depending on one's preferred house system, planets may be positioned in the wrong house. Primary directions being especially time sensitive will not give the right symbolism at the right time for angles (i.e. horizon and meridian) which are only slightly wrong. Likewise, the angles of the secondary progressions will be incorrect if the wrong time standard is observed; the position of the Moon will be wrong, in the case of Marie-Antoinette, by ten minutes of arc. That doesn't sound like much, but since the Moon often takes about twenty minutes of time to move ten minutes of arc, using the wrong time standard will mean that the angles of her lunar returns will often be more than five degrees in error. Finally, the tertiary progressions will not be accurate if the wrong time is used. All of these problems can cause rectification attempts to be inflicted on charts that don't need them if the wrong system of time reckoning is applied to the

correct reading of the most accurate clock, or if no error is suspected, a horoscope will simply not be correct if LMT is used for a period when it didn't exist.

How early did Clocks Appear and when was LAT in Effect?

Local apparent time has been in effect since people began to break up the day into sections demarcated by sunrise, noon and sunset. Since the times of sunrise, noon and sunset continuously vary throughout the year at all locations, a time standard tied to any of these events must also be variable. A shadow clock or a sundial is necessarily tied to noon marked by when the Sun's shadow is shortest or absent altogether for locales in the tropics. After sunset one must know the sky very well to keep track of time by the stars, and in bad weather one must make do with hourglasses or slow-burning fuses or knots which can only offer an approximation of elapsed time, not local apparent time.

Water clocks or *klepsydra* came into use well before the Christian Era and have the advantage that they can keep time after the Sun has set, but they corrode, they're messy and they freeze in European winters. Water clocks, since they were kept to local apparent time, were set to noon, usually (sometimes to sunrise or sunset) and adjusted regularly to take into account the changing times of noon which are a consequence of the Sun-Earth geometry. Waterclocks eventually became quite accurate especially within the borders of Islam. They were much more accurate than early mechanical clocks and remained so for more than three and a half centuries.

The entirely mechanical clock, i.e. one with a mechanical escapement, driven by suspended weights, and later, by springs, was invented late in the thirteenth century A.D. No one knows for sure by whom or exactly when; the evidence, such as it is, suggests that mechanical clocks were invented in Western Europe. Exeter cathedral in England had a clock in 1284. Early mechanical clocks could have a daily error of as much as one thousand seconds per day, and therefore needed to be reset often to get rid of their accumulated error. The most dependable standard with the least variation was the Sun, so clocks were usually reset by a gnomon (the index or style of a sundial which projects a shadow) to local apparent noon; yet in the medieval world not only the hours, but the days were often reckoned from sunrise, sunset, noon or

midnight depending on custom, region, religion and politics. Worse, hours were often seasonal, i.e. deliberately of uneven duration such that hours of daylight were divided into twelve and the hours of night likewise into twelve. The length of the hours changed every few weeks at regular step intervals to correspond to the changes in the duration of daylight. This often presents serious problems to those who would set up horoscopes for fourteenth, fifteenth and sixteenth century figures in the absence of a marker like "morning," or "two hours after sunset" or "three and a half hours after the beginning of the day" (if it is known when the calendar day began). The only thing that can be assumed about time standards during this early era of mechanical clocks is that mean time was never used.

Occasionally the argument is advanced that early clocks were so inaccurate or that time consciousness was so loose, that it doesn't matter whether apparent time is employed or not for the period when it was in vogue, because the stated times are not likely to be accurate. This is particularly true for periods before the seventeenth century because very few clocks or watches had minute hands then, although public clocks, even with only an hour hand, generally chimed the half and quarter hours. Horological improvements had whittled away daily errors in the best clocks for three centuries to a modest degree, but in the absence of gear cutting and other machine tools, even well regulated clocks often gained or lost as much as fifteen minutes per day as they aged and finally wore out. It must be admitted, however, that the very best clock of its day had reached the one-minute daily error level shortly before the end of the sixteenth century.

In 1656, Christiaan Huygens, a Dutch physicist, made a spectacular breakthrough by applying a pendulum to regulate a clockwork. Huygens' first pendulum clock had a daily error of only fifteen *seconds*. Shortly afterward, Jean Picard, who founded the *Connaissance des Temps* in 1679, the first national ephemeris, had a long duration pendulum clock set up at the Paris Observatory which was accurate to within a minute for a period of two months. From the next decade, the 1660's onward, local apparent time can be considered for most practical purposes—certainly astrological ones—to be as accurate as mean time standards were in the nineteenth century. While minute hands were beginning to become more common on clocks (but not

watches) by mid-century, the pendulum clock hastened the adoption of the minute hand as a standard in clockmaking, and most clocks soon had one, not merely clocks built to the highest standard. The horoscopes of royalty, or those whose parents could afford a good clock for periods before the mid seventeenth century, are less suspect than those less well born.

After the introduction of the pendulum clock, local apparent time continued on its long run as the only standard in the West and almost surely, the rest of the world, even though the new accuracy of clocks made inroads against the rationale of LAT in theory, if not practice. After London went onto mean time in 1792, it was made the civil standard at Berlin in 1810, but not in the other German states immediately. Paris went onto a mean time standard in 1816, after twenty years' effort on the part of French horologists, but not the whole of France. In the United States adoption of mean time was later still, most likely due to religious opposition. Sun time was regarded as "God's time" and deviation from it was considered a modest sin in a less secular age than our own. There is some evidence that LAT hung on in the United States far into the nineteenth century, e.g., in the Congressional Record of the Twenty-Ninth Congress, it is recorded that on December 1, 1845:

"At 12 o'clock meridian, Benjamin B. French Esq. the Clerk of the House at the last session of Congress rose and said, that as the hour of twelve o'clock had arrived, he would, in pursuance of usage, if not objected to, call over the list of members by States for the purpose of ascertaining the names of those present, and whether a quorum was present."

The Sun was in the meridian, that is, local apparent noon occurred at Washington on December 1, 1845 at 11:49:24 a.m. local mean time. While it is not conclusive, one must wonder why Mr. French would otherwise specify 12 o'clock *meridian*, that is local apparent noon, since at local mean time noon the Sun would be more than ten and a half minutes beyond the meridian.

The question of when mean time was adopted in the United States is a troublesome matter that extends back to the transition from apparent time to mean time everywhere, namely, what kind of time was in effect when and where? The answer is that it varied from community to community and region to region; but as a benchmark, one should never use local mean time for a

horoscope that pre-dates 1780 for a Genevan, 1792 for a Londoner, 1810 for a Berliner, 1816 for a Parisian and probably much later than that for an American, especially in the western states.

Once the capital city of a state or country adopted mean time, its environs slowly took on the local mean time of the capital at the expense of their own. Places more remote from the capital slowly adopted their own LMT, and places still farther out stayed longer on LAT. The example of England is typical: the rate at which communities dropped LAT and adopted their own LMT, and the rate at which the LMT of London slowly absorbed the local times of neighboring communities, until the entire country observed it, is buried in civic records. By 1855 the overwhelming majority of English clocks were set to the local mean time of the Greenwich Observatory, or GMT, but it wasn't the legal time in England until 1880.

What is the Astronomical Rationale of LAT?

Local apparent time is a variable rate because the Sun's apparent daily motion is variable, and this for two reasons: first, the obliquity of the ecliptic, and second, the ellipticity of the Earth's orbit. The ecliptic is the plane of the Earth's revolution about the Sun. The celestial equator, which is the Earth's equator extended out into space, is the plane of the Earth's rotation. The angle between these two planes, currently $23^{\circ} 26' 16''$, is the obliquity of the ecliptic. As the planes of rotation and revolution are not the same, it follows that since the Sun moves in the ecliptic, equal changes in celestial longitude, which is reckoned along the ecliptic will not produce equal changes in right ascension which is reckoned along the equator. Additionally, the Earth's orbit is an ellipse, not a circle, which requires that the Earth move faster at perihelion, slower at aphelion and at other speeds between these two extremes. Seen in another way, if the Earth's spin axis was not inclined to the plane of its orbit but straight up, perpendicular to the ecliptic, and the Earth's orbit was a circle instead of an ellipse, there would no seasons and no such condition as apparent time, only one unvarying climate state and one unvarying time state.

The consequence then of the Earth's elliptical orbit and the obliquity of the celestial equator to the ecliptic is that the Sun's daily motion is variable. A clock set to a mean time standard, because such a standard is not synchronized to the Sun, demonstrates that variability,

but until the going of any clock was accurate enough to demonstrate it, there was no reason to think about invoking a mean time standard, even though use of a such a standard facilitates astronomical computations. The central issue is that there was no more reliable standard with less variation than the Sun until clocks became consistently less variable than the Sun.*

The Rules for Coverting Apparent to Mean Time and Vice Versa

The difference between LAT reckoning and LMT reckoning is called the equation of time. The value of the equation of time must be found in order to convert apparent time to its mean time equivalent. In the example of Marie-Antoinette given earlier, the equation of time is 16 minutes and 12 seconds. For the current era, since the equation of time changes slowly over a period of decades, one could simply go to a table with the values of the equation of time throughout the course of the year and take out an approximation that would not be far wrong; but because the equation of time changes substantially over centuries as the date of perihelion and other orbital factors change, recourse to a modern table will not do for an earlier period.

*The first major by-product of accurate clocks that ultimately benefited astrologers was the determination of sidereal time in 1678 by John Flamsteed, the first *Astronomer Royale* at the Greenwich Observatory, which had been established in 1675. The clocks Flamsteed commissioned for the observatory were the most accurate in the world at the time, and the first to be set to Greenwich Mean Time; also the adoption of the local mean time of the Greenwich Observatory in 1676 is probably the first official application of a mean time standard anywhere. It remained, however, an astronomical, not a civil standard, until 1792. Ephemerides for the sixteenth, seventeenth and generally the eighteenth centuries did not have a tabular entry for sidereal time (see figure 2, a typical 17th century English ephemeris) because until Flamsteed determined the rate, it was not known that the Earth's daily rotation is uniform as there had not been clocks available heretofore that were accurate enough to demonstrate it.

Sidereal time is a measure of rotation. The Earth rotates on its spin axis in 23 hours 56 minutes and 04.09054 seconds of mean solar time which equals 24:00:00 hours of mean sidereal time, a faster rate; therefore 24 hours of mean solar time takes 24 hours 03 minutes and 56.55535 seconds of mean sidereal time, so when you add the "acceleration on the interval" (9.856 seconds per hour) if you do your charts by hand, you're taking into account the acceleration of mean sidereal time on mean solar time. Actually the Earth's rate of rotation is not uniform due to tidal and atmospheric friction, the effect of the seasons and changes in the mantle and molten core; but the variation from an unvarying rate is so minuscule that Flamsteed's 1678 value was good enough to last well into the nineteenth century for navigational and most other purposes.

The equation of time can be seen in several equivalent forms, first as the difference between apparent and mean time; second, as the difference between the hour angle of the true Sun and the hour angle of the mean Sun; and also, as the difference between the right ascension of the apparent Sun (RAAS) and the right ascension of the mean Sun (RAMS). Most computer programs will generate right ascension (RA) and declination coordinates. RA should be in time, not arc. If your program gives RA only in arc, divide the value it gives you for any particular time by 15 because the Earth rotates 15° in one hour. For example, $350^\circ 17' 29'' \div 15 = 23\text{h } 21\text{m } 10\text{s}$. If your program cannot produce RA, it can be derived in the following way:

The RAAS can be calculated from this modest equation: $\tan \alpha = (\cos \varepsilon) (\tan \lambda)$ where α = the RAAS, ε = the obliquity of the ecliptic, and λ = the tropical longitude of the Sun in 360° notation, i.e. $0^\circ \Upsilon = 0$, $0^\circ \text{ } \text{♊} = 30$, $0^\circ \text{ } \text{♋} = 60$ etc. Since the obliquity of the ecliptic varies by more than two degrees over several tens of millennia, the values for the last several thousand years at one hundred-year intervals are included in figure 3.

The RAMS is the same as the RA of the MC (or local sidereal time) at local mean time noon (**not** zone time noon). Then multiply the difference between the previous local mean time noon and the birthtime by 9.856 seconds per hour and add those seconds to the RAMS at noon.

Table 1.

Determine the values of the right ascension of the apparent Sun (RAAS) and the right ascension of the mean Sun (RAMS) for the birth data.

If the RAMS is greater than the RAAS, the equation of time (E of T) is positive (+).

If the RAAS is greater than the RAMS, the equation of time (E of T) is negative (-).

Then, having arrived at the value of the E of T, apply it to one of the following four rules:

- 1) If the birthtime was reckoned in apparent time and the E of T is +, SUBTRACT the E of T from the apparent time to get the mean time equivalent.
- 2) If the birthtime was reckoned in apparent time and the E of T is -, ADD the E of T to the apparent time to get the mean time equivalent.
- 3) If the birthtime was reckoned in mean time and the E of T is +, ADD the E of T to the mean time to get the apparent time equivalent.

4) If the birthtime was reckoned in mean time and the E of T is -, SUBTRACT the E of T from the mean time to get the apparent time equivalent.

The following worked example illustrates how accurately a horoscope could be set up more than four hundred years ago, if attention is paid to the time standard in place then, instead of applying LMT to every old horoscope no matter what its date.

The recent discovery of a horoscope at the University of California at Santa Cruz attributed to the hand of Johannes Kepler (1571-1629) is typical of the horoscopes of the day. It is cast in terms of the tropical zodiac for 5:00 p.m. local apparent time on September 10, 1586 in the Old Style, that is, Julian calendar reckoning (the Gregorian or New Style dates from October 15, 1582 but not all countries and regions in Europe adopted it immediately). Because Kepler gave no minutes for the angles or the lights, the horoscope could be set up for a fairly wide swath of longitude between approximately Munich, Germany to Vienna, Austria which are both on 48° North. The house system used was Regiomontanus, the standard of the day. For 5:00 p.m. (*LMT* since we don't know yet what the LMT equivalent is that corresponds to 5:00 p.m. LAT), September 10, 1586 in the Old Style (Julian calendar), the following values obtain:

$$\begin{array}{r} 11\text{h } 56\text{m } 35\text{s} = \text{RAMS} \\ -11\text{h } 49\text{m } 50\text{s} = \text{RAAS} \\ \hline 6\text{m } 45\text{s} = \text{E of T} \end{array}$$

As the RAMS is greater than the RAAS, the equation of time is positive. Since the time in the document is rendered in terms of apparent time and the equation of time is positive, we subtract the equation of time from the apparent time to get the mean time equivalent; and since the E of T will not change over the course of six minutes of mean solar time, the same value applies to both the E of T at 5:00 p.m. LAT and 5:00 p.m. LMT.

$$\begin{array}{r} 5:00:00 \text{ p.m. LAT} \\ -0:06:45 \text{ E of T} \\ \hline 4:53:15 \\ +0:00:01 \text{ mean time-sidereal time interval} \\ \hline 4:53:16 \text{ p.m. LMT} \end{array}$$

The equation of time at 5:00 p.m. LMT was +6minutes 45seconds, but this value of the E of T is in terms of right ascension, which is reckoned in mean sidereal time. To go from sidereal to

mean time requires that the acceleration be subtracted, but we can account for the difference between sidereal time and mean time by adding 1 second to 4:53:15 for the acceleration on 6m 45s. The result gives the value of the equation of time in terms of mean solar time: 6m 44s. The angles and positions of the planets answer to 4:53:16 PM LMT, and are a best fit for Munich (48° N 08' and 11° E 35').

Positions as per Kepler

Sun: 27° ♍
Moon: 7 ½° ♊
Mercury: 22° ♊
Venus: 0° ♍
Mars: 5 ½° ♈
Jupiter: 12° ♎
Saturn: 1° ♏ 30' Rx
Node: 18° ♊
10th: 14° ♎
11th: 29° ♎
12th: 18° ♊
1st: 25° ♎
2nd: 23° ♎
3rd: 26° ♏

Positions for Munich at 5:00 p.m. LAT = 4:53:16 p.m. LMT

Sun: 27° ♍ 13'
Moon: 7° ♊ 23'
Mercury: 22° ♊ 03'
Venus: 0° ♍ 08'
Mars: 5° ♈ 58'
Jupiter: 12° ♎ 31'
Saturn: 1° ♏ 26' Rx
node: 17° ♊ 34'
10th: 13° ♎ 50'
11th: 28° ♎ 33'
12th: 17° ♊ 35'
1st: 24° ♎ 57'
2nd: 22° ♎ 55'
3rd: 26° ♏ 04'

The use of apparent time is particularly helpful in rectifying charts when the equation of time is large. For example, George Washington's birth was written in the family bible as having occurred "about 10 in the morning" of February 11, 1731/32. England and the American colonies used the Annunciation Style* in those days according to which the year turned not on January 1 but on March 25, so it was still 1731 according to the Annunciation Style in February of what we now call 1732. In addition, Washington's birth was recorded in the Julian Style of calendar reckoning (England and the American colonies did not adopt the Gregorian calendar until 1752). The Gregorian equivalent is February 22, 1732. At ten in the morning on that day near what is now Wakefield, Virginia, where Washington was born, the equation of time was -14 minutes and 1 second; so before the first test has been applied to that time, a base chart of 10:14:01 a.m. LMT has to be set up (see figure 4) to avoid the fundamental error of assuming

* The Annunciation Style refers to the announcement by the angel Gabriel to Mary that she was carrying the Christ child, as described in Luke 1:28-35. The date of the Annunciation is March 25, which Christian churches still commemorate as the day of the announcement of the Incarnation.

that LMT was the time standard during an era when it didn't exist. The best angular fits in his solar and lunar returns and his neo-solar quotidian progressions for his marriage, victory at Yorktown, swearing in as first president and his death suggest a birthtime of 9:58 a.m. LAT (10:12:01 a.m. LMT) which is certainly still "about 10 in the morning."

Note that Marie-Antoinette's equation of time was +16 minutes and 12 seconds, so in her case the equation of time had to be subtracted from the LAT value. The best fits for her marriage, ascension to the throne, births of her children and death by guillotine, respond to 7:29 p.m. LAT (7:12:48 p.m. LMT). Rectification is easier if the right base time is used.

Finally, to reiterate, all birthtimes until late in the eighteenth century at the earliest, are in terms of local apparent time. The tendency to ignore local apparent time should be seen for what it is: a gross oversight, which can be easily remedied by recourse to the determination of the equation of time for horoscopes, which pre-date the modern period.

The following table of the Equation of Time shows the difference between mean time and apparent time in 1999 at ten-day intervals. Minutes and seconds preceded by + means that the Sun is fast of the clock by the amount shown in the table; i.e. the Sun comes to the M.C. before local mean time noon, so that at mean time noon, the Sun will be in the 9th house. Minutes and seconds preceded by - means that the Sun is slow of the clock by the amount shown in the table; i.e. at mean time noon the Sun will not have reached the M.C. and will appear in the 10th house. The low precision maximum values are - 14m 13s on February 12 and +16m 26s on November 3. The Equation of Time is zero in 1999 on April 16, June 12, September 1 and December 25.

Jan 1	- 2m 40s	Mar 22	-7m 09s	June 10	+0m 46s	Aug 29	- 1m 11s	Nov 17	+15m 12s
Jan 11	- 7m 34s	Apr 1	-4m 08s	June 20	-1m 21s	Sept 8	+ 2m 02s	Nov 27	+12m 40s
Jan 21	- 11m 04s	Apr 11	-1m 17s	June 30	-3m 28s	Sept 18	+ 5m 32s	Dec 7	+ 8m 56s
Jan 31	- 13m 18s	Apr 21	+1m 07s	July 10	-5m 13s	Sept 28	+ 9m 04s	Dec 17	+ 4m 19s
Feb 10	- 14m 11s	May 1	+2m 48s	July 20	-6m 18s	Oct 8	+12m 12s	Dec 27	- 0m 37s
Feb 20	- 13m 49s	May 11	+3m 38s	July 30	-6m 27s	Oct 18	+14m 40s		
Mar 2	-12m 19s	May 21	+3m 29s	Aug 9	-5m 36s	Oct 28	+16m 08s		
Mar 12	- 9m 59s	May 31	+2m 29s	Aug 19	-3m 49s	Nov 7	+16m 22s		

Works Consulted

- Ahnert, Paul. Astronomische-chronologische Tafeln für Sonne, Mond und Planeten. Leipzig: Johann Ambrosius Barth Verlag, 1960.
- Andrewes, William J. H. "Time for the Astronomer." Vistas in Astronomy 28 (1995).
- The Astronomical Almanac for the Year 1999. Washington D.C.: U.S. Government Printing Office, 1998.
- Barbault, André. Traité Pratique D'Astrologie. Paris: Éditions du Seuil, 1961.
- Bartky, Ian R. "Inventing, Introducing and Objecting to Standard Time." Vistas in Astronomy 28 (1985).
- Chapman, Allan. "Christiaan Huygens (1629-95): astronomer and mechanician." Endeavour n.s. 19 (1995).
- Chauvenet, William. Spherical and Practical Astronomy. 5th ed. Philadelphia: J. B. Lippincott, 1887.
- Congressional Globe. Twenty-Ninth Congress, First Session, December 1, 1845-August 10, 1846. Washington D.C.: Blair & Rives, 1846.
- Covey, Curt. "The Earth's Orbit and the Ice Ages." Scientific American, February 1984, 250.
- Daumas, Maurice. "Le faux échappement de Villard de Honnecourt." Revue D'Histoire Des Sciences 35 (1982).
- Dohrn-van Rossum, Gerhard. History of the Hour. Chicago: University of Chicago Press, 1996.
- Explanatory Supplement to the Astronomical Ephemeris and the American Ephemeris and Nautical Almanac. London: Her Majesty's Stationery Office, 1961; reprint, London: Her Majesty's Stationery Office, 1974; 4th impression, 1977.
- Fraser, J. T., ed. The Voices of Time. 2nd ed. Amherst: University of Massachusetts Press, 1981.
- Freeman, Douglas Southall. George Washington. vol. 1. New York: Charles Scribner's Sons, 1948.
- Guye, Samuel and Henri Michel. Time and Space. New York: Praeger Press, 1971.
- Howse, Derek. Greenwich Time. Oxford: Oxford University Press, 1980.
- Hutchinson, Beresford. "Guardians of Greenwich Time." Vistas in Astronomy 28 (1985).

- Jaquet, Eugène and Alfred Chapuis. The Technique and History of the Swiss Watch. London, Spring Press, 1970.
- Kibre, Pearl. Studies in Medieval Science, Alchemy, Astrology, Mathematics and Medecine. London: Hambledon Press, 1984.
- Landes, David S. Revolution in Time. Cambridge: Belknap Press of Harvard University Press, 1983.
- Mayr, Otto. Authority, Liberty and Automatic Machinery in Early Modern Europe. Baltimore: Johns Hopkins University Press, 1986.
- Meeus, Jean. Mathematical Astronomy Morsels. Richmond: Willman-Bell, 1997.
- Merzbach, Uta C. "Calendars and Reckoning of Time." Dictionary of the Middle Ages, vol. 3. New York: Charles Scribner's Sons, 1983.
- Mueller, Ivan I. Spherical and Practical Astronomy. New York: Frederick Ungar, 1969; reprint, New York: Frederick Ungar, 1977.
- Quinlan-McGrath, Mary. "The Villa Farnesina, Time-Telling Conventions and Renaissance Astrological Practice." Journal of the Warburg and Courtauld Institutes 58 (1995).
- Quinones, Ricardo J. The Renaissance Discovery of Time. Cambridge: Harvard University Press, 1972.
- Sherman, Stuart. Telling Time. Chicago: University of Chicago Press, 1996.
- Thompson, E. P. Customs in Common. New York: New Press, 1991.
- Turner, A.J. Of Time and Measurement. Aldershot: Variorum, 1993.

Figure 3. The Obliquity of the Ecliptic in increments of 100 years.

Jahr = year

E = ecliptic

Jahr	E	Jahr	E	Jahr	E
-3000	24° 1'6	-1000	23° 49'0	1000	23° 34'1
-2900	1'0	-900	48'3	1100	33'4
-2800	0'5	-800	47'6	1200	32'6
-2700	23 59'9	-700	46'8	1300	31'8
-2600	59'3	-600	46'1	1400	31'0
-2500	23 58'7	-500	23 45'4	1500	23 30'3
-2400	58'1	-400	44'7	1600	29'5
-2300	57'5	-300	43'9	1700	28'7
-2200	56'9	-200	43'2	1800	27'9
-2100	56'3	-100	42'5	1900	27'1
-2000	23 55'6	0	23 41'7	2000	23 26'4
-1900	55'0	100	40'9	2100	25'6
-1800	54'4	200	40'2	2200	24'8
-1700	53'7	300	39'5	2300	24'0
-1600	53'1	400	38'7	2400	23'2
-1500	23 52'4	500	23 38'0	2500	23 22'5
-1400	51'7	600	37'2		
-1300	51'0	700	36'4		
-1200	50'3	800	35'7		
-1100	49'7	900	34'9		
-1000	23 49'0	1000	23 34'1		

George Washington
Natal Chart
 Feb 22 1732
 10:14:01 AM LMT +5:07:44
 near Wakefield, VA
 38N12 076W56
Geocentric
Fagan-Allen
Campanus
True Node

Figure 4

