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UNCERTAINTIES AND MISCONCEPTS ABOUT CALENDARS: A PROJECT OF A NON-HISTORICAL CALENDAR

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Abstract. A review of calendars and their properties in use is presented. The presence of a non-astronomical approach in recent times is emphasized. Here a calendar project is presented which would realize one of the main objectives: an easy historical identification and a minimal necessity for the presence of astronomy in their maintenance.

1. INTRODUCTION

Ancient observations of the Sun and Moon from many different cultures and civilizations date back about a hundred centuries, writings from ancient China and Babylon that have survived from at least 2500 years B.C. To establish an accurate **calendar**, ancient civilizations observed regularly all major celestial events, especially eclipses of the Moon and Sun, moon phases etc., and some of the observers were taught how to predict that events based on local historical observation records. The dividing lines between knowledge, belief, religion, and superstition are blurred and depend on some particular point of view. Like a puzzle, these concepts can be put together in a way that will help us understand it.

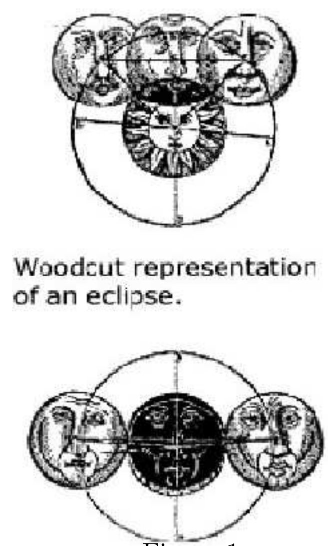

Figure 1:

Astronomers' views of astronomy in particular and of science in general often (absolutely) differ from the views of the general public. This dichotomy we will try to discuss in this article. The first part is personal view of public misconceptions of topics relevant to live calendars and, as very important, to the Julian calendar. We will see that conflicts between astronomy and political, historical and local influences can lead to misunderstandings. Finally, we hear of other conflicts between astronomers' thinking and the understanding of the listeners.

To answer the question of how we calculate years or time at all, it is necessary to describe the world view and religious background of the age when the time calculation was created. For example, let we consider the sentence: Mankind measures time using the stars. Lay people, whose knowledge is based on belief, rather than science, say: "The course of the stars determines time," and from this, religious people derive the saying that "Heaven guides everything on Earth." (Boll, 1903).

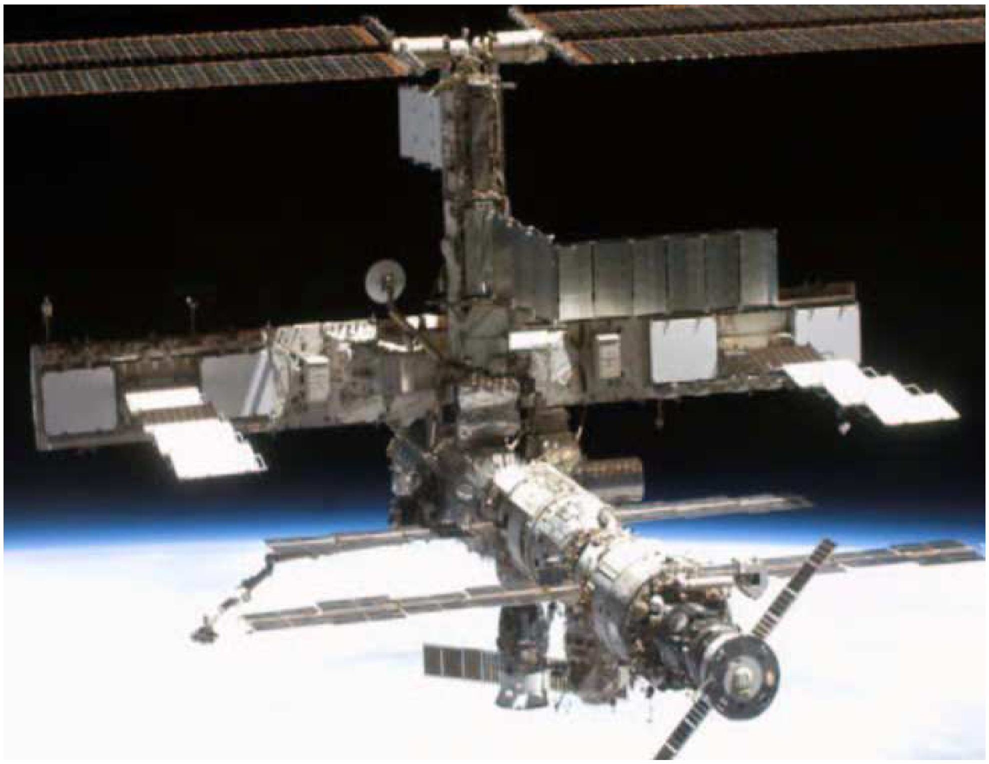

Figure 2: This is a "heaven's" object.

A calendar is a system of organizing units of time for the purpose of reckoning time over extended periods. By convention, the day is the smallest calendrical unit of time; the measurement of fractions of a day is classified as timekeeping. The generality of this definition is due to the diversity of methods that have been used in creating calendars. Although some calendars replicate astronomical cycles according to fixed rules, others are based on abstract, perpetually repeating cycles of no astronomical significance. Some calendars are regulated by astronomical observations, some carefully and redundantly enumerate every unit, and some contain ambiguities and discontinuities. Some calendars are codified in written laws; others are transmitted by oral tradition.

Whatever their scientific sophistication, calendars must ultimately be judged as social contracts, not as scientific treatises.

Figure 3: China.

The common theme of calendar making is the desire to organize units of time to satisfy the needs and preoccupations of society. In addition to serving practical purposes, the process of organization provides a sense, however illusory, of understanding and controlling time itself. Thus calendars serve as a link between mankind and the cosmos. It is little wonder that calendars have held a sacred status and have served as a source of social order and cultural identity. Calendars have provided the basis for maintaining cycles of religious and civil events.

Figure 4: The Second Tample.

According to a recent estimate (Fraser, 1987), there are about forty calendars used in the world today. This article is limited to the some principal calendars in current use. The fundamental bases of the calendars are given, along with brief historical summaries. Although algorithms are given for correlating these systems, close examination reveals that even the standard calendars are subject to local variations. With the exception of the Julian calendar, this article does not deal with extinct systems. Inclusion of the Julian calendar is justified by its everyday use in historical studies.

2. ASTRONOMICAL BASES OF CALENDARS

The principal astronomical cycles are the day (based on the rotation of the Earth on its axis), the year (based on the revolution of the Earth around the Sun), and the month (based on the revolution of the Moon around the Earth). The complexity of calendars arises because these cycles of revolution do not comprise an integral number of days, and because astronomical cycles are neither constant nor perfectly commensurable with each other.

The **tropical year** is defined as the mean interval between vernal equinoxes; it corresponds to the cycle of the seasons. The following expression, based on the orbital elements of Laskar (1986), is used for calculating the length of the tropical year:

$$TY = 365.^{d}2421896698 - 0.00000615359T - 7.29 \times 10^{-10}T^2 + 2.64 \times 10^{-10}T^3 \quad (1)$$

where $T = (JD - 2451545.0)/36525$ and JD is the Julian day number (see next section). However, the interval from a particular vernal equinox to the next may vary from this mean by several minutes.

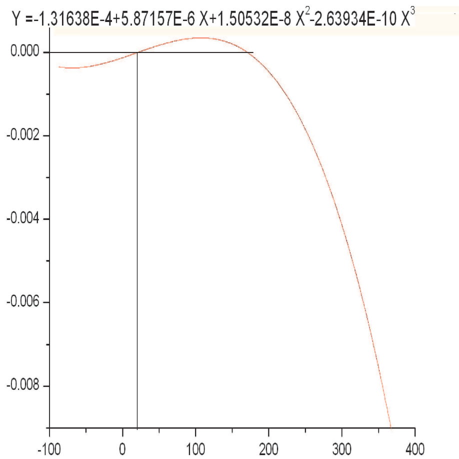

Figure 5: Polynomial Y=TY-365.2422.

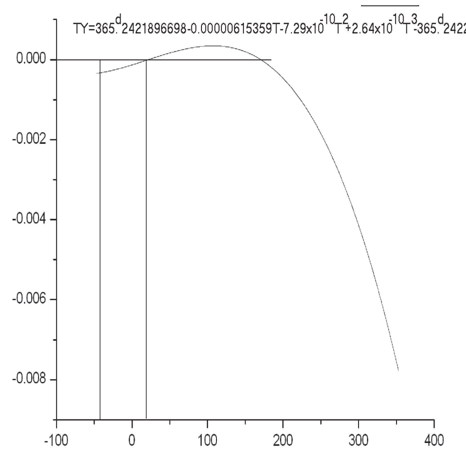

Figure 6: "Real" Y' = TY - 365.2422.

The **synodic month**, the mean interval between conjunctions of the Moon and Sun, corresponds to the cycle of lunar phases. The following expression for the synodic month is based on the lunar theory of Chapront-Touze and Chapront (1988):

$$29.^{d}5305888531 + 0.00000021621T - 3.64 \times 10^{-10}T^{2}. \tag{2}$$

Again $T = (JD - 2451545.0)/36525$ and JD is the Julian day number. Any particular phase cycle may vary from the mean by up to seven hours.

In the preceding formulas, T is measured in Julian centuries of Terrestrial Dynamical Time (TDT), which is independent of the variable rotation of the Earth. Thus, the lengths of the tropical year and synodic month are here defined in days of 86400 seconds of International Atomic Time (TAI).

From these formulas we see that the cycles change slowly with time. Furthermore, the formulas should not be considered to be absolute facts; they are the **best approximations possible today**. Therefore, a calendar year of an integral number of days cannot be perfectly synchronized to the tropical year. Approximate synchronization of calendar months with the lunar phases requires a complex sequence of months of 29 and 30 days. For convenience it is common to speak of a lunar year of twelve synodic months, or 354.36707 days.

Three distinct types of calendars have resulted from this situation. A **solar calendar**, of which the Gregorian calendar in its civil usage is an example, is designed to maintain synchrony with the tropical year. To do so, days are intercalated (forming leap years) to increase the average length of the calendar year. A **lunar calendar**, such as the Islamic calendar, follows the lunar phase cycle without regard for the tropical year. Thus the months of the Islamic calendar systematically shift with respect to the months of the Gregorian calendar. The third type of calendar , the **lunisolar** calendar, has a sequence of months based on the lunar phase cycle; but every few years a whole month is intercalated to bring the calendar back in phase with the tropical year. The Hebrew and Chinese calendars are examples of this type of calendar.

3. NON ASTRONOMICAL BASES OF CALENDARS: THE WEEK

In the concept of Africanus, the biblical seven-day creation plays a major role, and in this time frame, 6000 years (relating to the six days of creation of the world in Genesis) would elapse between the creation of the world, and the seventh day would be the Day of the Lord or the Day of Judgment.

In addition, a time concept has been developed describing the whole history of the world within one single day of 12 hours, a kind of doomsday. Please consider that modern cosmology also uses a similar concept to explain cosmic development, and this view has mankind appearing in the last seconds of the day.

Calendars also incorporate non astronomical elements, such as numerical cycles, local environmental observations, or decisions by societal authorities. In the Gregorian calendar, the week and month are non astronomical units, though the month can be traced back to calendars that counted the phase cycle of the Moon.

The origin of the seven-day week is uncertain. As a continuously running, uninterrupted cycle, it comes to us as part of Jewish tradition. However, Biblical and Talmudic texts indicate a variety of conflicting calendrical practices. Systematic observance of the Sabbath every seventh day may have developed as late as the Babylonian Exile in the sixth century B.C., followed by a period of gradual acceptance.

The number seven had mystical and cosmological significance throughout the Semitic cultures. It was used in the Babylonian and Assyrian calendars, though not as a continuous cycle. Although the seven-day week may have its origin in number mysticism, astronomy may have contributed to the mysticism. The Sun, Moon, and naked-eye planets comprise the seven "wandering stars," Seven is a useful, if inexact, count of days between the four Moon phases, and four times seven is a useful, if inexact, estimate of days from first to last visibility of the Moon in its phase cycle.

In Jewish practice, the days of the week were designated by numbers rather than by names, except that day 7 was known as the Sabbath. Recognition of the week and the observance of the Sabbath as a rest day gradually spread to the Roman world. The use of names to designate the days of the week developed in the Roman culture of the second and first centuries B.C. These names come from the astrological practice of naming each day after the planet that governed the day. At that time, the Sun and Moon were included among the planets. "Saturn's day" coincided with the Jewish Sabbath. The planetary names were gradually, if reluctantly, accepted by the Jewish and Christian cultures (Gandz, 1949).

It is a reasonable, but ultimately unprovable, assumption that the cyclic continuity of the week was maintained without interruption by religious authorities from its origin in Biblical times to the present day. Although ten days were dropped from the Christian calendar in the Gregorian Reform of 1582, the cycle of weekdays was not disturbed. Thus, in 1582, Thursday, October 4, of the Julian calendar, was followed by Friday, October 15, of the Gregorian calendar.

4. CALENDAR REFORM AND ACCURACY

In most societies a calendar reform is an extraordinary event. Adoption of a calendar depends on the forcefulness with which it is introduced and on the willingness of society to accept it. For example, the acceptance of the Gregorian calendar as a worldwide standard spanned more than three centuries.

Figure 7:

It is unbelievable that the legal code of the United States does not specify an official national calendar . Use of the Gregorian calendar in the United States stems from an Act of Parliament of the United Kingdom in 1751, which specified use of the Gregorian calendar in England and its colonies. However, its adoption in the United Kingdom and other countries was fraught with confusion, controversy, and even violence. It also had a deeper cultural impact through the disruption of traditional festivals and calendrical practices.

Because calendars are created to serve societal needs, the question of a calendar's accuracy is usually misleading or misguided. A calendar that is based on a **fixed set of rules** is accurate if the rules are **consistently applied**. For calendars that attempt to replicate astronomical cycles, one can ask how accurately the cycles are replicated. However, astronomical cycles are not absolutely constant, and they are not known exactly (see Section 2). In the long term, only a purely observational calendar maintains synchrony with astronomical phenomena. However, an observational calendar exhibits short-term uncertainty, because the natural phenomena are complex and the observations are subject to error.

5. HISTORICAL ERAS AND CHRONOLOGY

The calendars treated in this article, except for the Chinese calendar, have counts of years from initial epochs. In the case of the Chinese calendar and some calendars not included here, years are counted in cycles, with no particular cycle specified as the first cycle. Some cultures eschew year counts altogether but name each year after an event that characterized the year. However, a count of years from an initial epoch is the most successful way of maintaining a consistent chronology. Whether this epoch is associated with an historical or legendary event, it must be tied to a sequence of recorded historical events.

This is illustrated by the adoption of the birth of Christ as the initial epoch of the Christian calendar. This epoch was established by the sixth-century scholar Dionysius Exiguus, who was compiling a table of dates of Easter. An existing table covered the nineteen-year period denoted 228-247, where years were counted from the beginning of the reign of the Roman emperor Diocletian. Dionysius continued the table for a nineteen-year period, which he designated Anni Domini Nostri Jesu Christi 532-550. Thus, Dionysius' Anno Domini 532 is equivalent to Anno Diocletiani 248. In this way a correspondence was established between the new Christian Era and an existing system associated with historical records. What Dionysius did not do is establish an accurate date for the birth of Christ. Although scholars generally believe that Christ was born some years before A.D. 1, the historical evidence is too sketchy to allow a definitive dating.

In this point we must to pay attention to the viewpoint that is outside the realm of probability that the Dionysian yearly counting Anno Domini (A.D.), was determined randomly. It is probable that the adjustment of this yearly count had the aim eliciting the coincidence of a conjunction of all planets with the second millennium in order to mark the end of an assumed religious age. With the alignment of 531 CE (A.D.) as the astronomical basis for calculation, stimulated by the end-of-world fear resulting from the Anno Mundi chronology (AM), Dionysius Exiguus, with his adjustment of 1 A.D., killed two birds with one stone: calculating a Greatest Year and letting it coincide with the assumed end of a Platonic age, with the result that the conjunction occurred at the millennium (the conjunction of all planets in May 2000).

Anno Domini (A.D.) or Christian or Common Era (CE) counts the years after the adjusted date of Christ's incarnation, which traditionally is celebrated annually at 25th March during the former Northward Spring Equinox. To this count, introduced in sixth century by Dionysius Exiguus, we owe the calendrical numbering of the current years as well as the jubilee with the second millennium.

Given an initial epoch, one must consider how to record preceding dates. Bede, the eighth-century English historian, began the practice of counting years backward from A.D. 1. In this system, the year A.D. 1 is preceded by the year 1 B.C., without an intervening year 0. Because of the numerical discontinuity, this "historical" system is cumbersome for comparing ancient and modern dates. Today, astronomers use +1 to designate A.D. 1. Then +1 is naturally preceded by year 0, which is preceded by year -1. Since the use of negative numbers developed slowly in Europe, this "astronomical" system of dating was delayed until the eighteenth century, when it was introduced by the astronomer Jacques Cassini (Cassini, 1740).

Even as use of Dionysius' Christian Era become **Common** in ecclesiastical writings of the Middle Ages, traditional dating from regnal years continued in civil use. In the sixteenth century, Joseph Justus Scaliger tried to resolve the patchwork of historical eras by placing everything on a single system (Scaliger, 1583). Instead of introducing negative year counts, he sought an initial epoch in advance of any historical record. His numerological approach utilized three calendrical cycles: the 28-year solar cycle, the nineteen-year cycle of Golden Numbers, and the fifteen-year indiction cycle. The solar cycle is the period after which weekdays and calendar dates repeat in the Julian calendar. The cycle of Golden Numbers is the period after which moon phases repeat (approximately) on the same calendar dates. The indiction cycle was a Roman tax cycle. Scaliger could therefore characterize a year by the combination of numbers (S, G, I), where S runs from 1 through 28, G from 1 through 19, and I from 1 through 15. Scaliger noted that a given combination would recur after $7980 (= 28 \times 19 \times 15)$ years. He called this a Julian Period, because it was based on the Julian calendar year. For his initial epoch Scaliger chose the year in which S, G, and I were all equal to 1. He knew that the year 1 B.C. was characterized by the number 9 of the solar cycle, by the Golden Number 1, and by the number 3 of the indiction cycle, i.e., (9,1,3). He found that the combination (1,1,1) occurred in 4713 B.C. or, as astronomers now say, -4712. This serves as year 1 of Scaliger's Julian Period. It was later adopted as the initial epoch for the Julian day numbers.

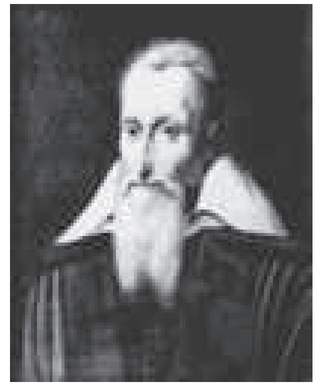

Figure 8: J. J. Scaliger.

6. THE CIRCUMSTANCES OF THE CREATION OF THE A.D. COUNT

Early Christianity used several other calendar systems before introducing the A.D. count, such as counting the years of the rule of the Roman emperor Diocletian, and the Anno Mundi (A.M.), an era counting years beginning at the assumed creation of Adam (world). The AM yearly counting system was the base of the five-volume Chronography of Sextus Julius Africanus, which he published during the consulate of Gratus and Seleucus (A.D. 221). Although it has since been lost, there are many other authors who mention or give excerpts describing his A.M. (creation of the world) count, which became very popular. The A.M. count is based on a teleological concept that would provide history with God's plan of salvation and thus is constructed on a time frame that depends on the words of the Bible.

Consequently, in the A.M. count, the date of Christ's birth was adjusted in the middle of sixth millennium to the year A.M. 5500, because it corresponded with the 11th hour of the available 12. (6000 : 12 * 11 = 5500)

The A.M. method profoundly influenced early Byzantine and Roman Christian chronology, as shown in the chronicles of Hippolytus in Rome, Sulpicius Severus, Panodoros, and others. Out of this concept arose the Alexandrian method of Annianos, who lived in the year that the patriarch Theophilus died (A.D. 412), and later the Byzantine yearly count, which is still in use by some Orthodox groups. The six-day time frame was in harmony with the six-ages-of-man doctrine of St. Augustine of Hippo, who paralleled the moment of Christ's coming with the step from the fifth to the sixth and last age in the life of a man, which takes place between maturity and senility.

The world eras of these authors, and therefore the date of creation, differ from each other by several years, being adjusted to lunar cycles and best-fitting Easter rules. The year 1 AD, for example, corresponds in the Alexandrian count to A.M. 5493, in the Byzantine count to A.M. 5509, and in the basic count of Africanus, to A.M. 5502. In this article, from comparison different origins we have adopted Byzantine count.

7. GREGORIAN CALENDAR

The Gregorian calendar today serves as an international standard for civil use. In addition, it regulates the ceremonial cycle of the Roman Catholic and Protestant churches. In fact, its original purpose was ecclesiastical. Although a variety of other calendars are in use today, they are restricted to particular religions or cultures.

Years are counted from the initial epoch defined by Dionysius Exiguus, and are divided into two classes: common years and leap years. A common year is 365 days in length; a leap year is 366 days, with an intercalary day, designated February 29, preceding March 1. Leap years are determined according to the following rule:

Every year that is exactly divisible by 4 is a leap year, except for years that are exactly divisible by 100; these centurial years are leap years only if they are exactly divisible by 400.

As a result the year 2000 is a leap year, whereas 1900 and 2100 are not leap years. These rules can be applied to times prior to the Gregorian reform to create a proleptic Gregorian calendar. In this case, year 0 (1 B.C.) is considered to be exactly divisible by 4, 100, and 400; hence it is a leap year.

The Gregorian calendar is thus based on a cycle of 400 years, which comprises 146097 days. Since 146097 is evenly divisible by 7, the Gregorian civil calendar exactly repeats after 400 years. Dividing 146097 by 400 yields an average length of 365.2425 days per calendar year, which is a close approximation to the length of the tropical year. Comparison with Equation 1 reveals that the Gregorian calendar accumulates an error of one day in about 2500 years. Although various adjustments to the leap-year system have been proposed, none has been instituted.

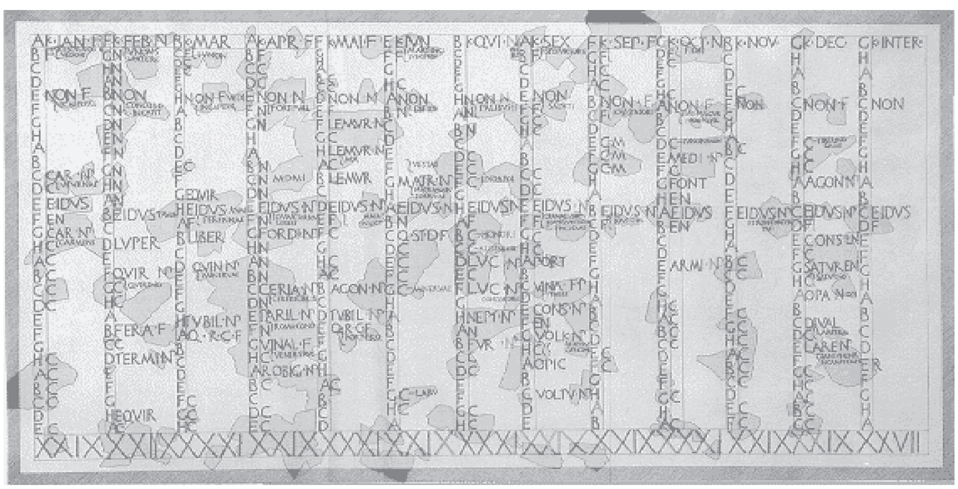

Figure 9: Roman Calendar.

Table 1: Months of the Gregorian Calendar

1.	January	31	7.	July	31
2.	February	28*	8.	August	31
3.	March	31	9.	September	30
4.	April	30	10.	October	31
5.	May	31	11.	November	30
6.	June	30	12.	December	31

* In leap year, February has 29 days

Within each year, dates are specified according to the count of days from the beginning of the month. The order of months and number of days per month were adopted from the Julian calendar.

8. ECCLESIASTICAL RULES

The ecclesiastical calendars of Christian churches are based on cycles of movable and immovable feasts. Christmas is the principal immovable feast, with its date set at December 25. Easter is the principal movable feast, and dates of most other movable feasts are determined with respect to Easter. However, the movable feasts of the Advent and Epiphany seasons are Sundays reckoned from Christmas and the Feast of the Epiphany, respectively.

In the Gregorian calendar, the date of Easter is defined to occur on the Sunday following the ecclesiastical Full Moon that falls on or next after March 21. This should not be confused with the popular notion that Easter is the first Sunday after the first Full Moon following the vernal equinox. In the first place, the vernal equinox does not necessarily occur on March 21. In addition, the ecclesiastical Full Moon is not the astronomical Full Moon-it is based on tables that do not take into account the full complexity of lunar motion. As a result, the date of an ecclesiastical Full Moon may differ from that of the true Full Moon. However, the Gregorian system of leap years and lunar tables does prevent progressive departure of the tabulated data from the astronomical phenomena.

The ecclesiastical Full Moon is defined as the fourteenth day of a tabular lunation, where day 1 corresponds to the ecclesiastical New Moon. The tables are based on the Metonic cycle, in which 235 mean synodic months occur in 6939.688 days. Since nineteen Gregorian years is 6939.6075 days, the dates of Moon phases in a given year will recur on nearly the same dates nineteen years later.

9. JULIAN DAY NUMBERS AND JULIAN DATE

The system of Julian day numbers is a continuous count of days elapsed since the beginning of the Julian period as defined by the sixteenth-century chronologist J.J. Scaliger . Although Scaliger's original idea was to introduce a count of years, nineteenth-century astronomers adapted this system to create a - count of days. John Herschel (1849) thoroughly explained the system and provided a table of "Intervals in Days between the Commencement of the Julian Period, and that of some other remarkable chronological and astronomical Eras.

Julian day 0 commenced at Greenwich noon on -4712 January 1, Julian proleptic calendar. The Julian day number, expressed as an integer, denotes the number of complete days elapsed since the initial epoch. The Julian date (JD) specifies a particular instant of a day by ending the Julian day number with a decimal fraction. For example, the Julian day number of 1990 June 25 is 244 8068, whereas the Julian date at noon is 2448068.0. The midnight that begins the civil day is specified by subtracting 0.5 from the Julian date at noon.

A count of days (1-365) from the beginning of the year is sometimes a useful tool for record-keeping. However, the dubious practice of calling this a Julian date merely causes confusion with Julian day numbers.

10. THE JULIAN CALENDAR

The Julian calendar, introduced by Julius Caesar in -45, was a solar calendar with months of fixed lengths. Every fourth year an intercalary day was added to maintain synchrony between the calendar year and the tropical year. It served as a standard for European civilization until the Gregorian Reform of + 1582.

Today the principles of the Julian calendar continue to be used by chronologists. The Julian proleptic calendar is formed by applying the rules of the Julian calendar to times before Caesar's reform. This provides a simple chronological system for correlating other calendars and serves as the basis for the Julian day numbers.

Years are classified as normal years of 365 days and leap years of 366 days. Leap years occur in years that are evenly divisible by 4. For this purpose, year 0 (or 1 B.C.) is considered evenly divisible by 4. The year is divided into twelve formalized months that were eventually adopted for the Gregorian calendar .

11. HISTORY OF THE JULIAN CALENDAR

The year -45 has been called the "year of confusion," Because in that year Julius Caesar inserted 90 days to bring the months of the Roman calendar back to their traditional place with respect to the seasons. This was Caesar's first step in replacing a calendar that had gone badly awry. Although the pre-Julian calendar was lunisolar in inspiration, its months no longer followed the lunar phases and its year had lost step with the cycle of seasons (see Michels, 1967; Bickerman, 1974). Following the advice of Sosigenes, an Alexandrine astronomer, Caesar created a solar calendar with twelve months of fixed lengths and a provision for an intercalary day to be added every fourth year. As a result, the average length of the Julian calendar year was 365.25 days. This is consistent with the length of the tropical year as it was known at the time.

Following Caesar's death, the Roman calendrical authorities misapplied the leap-year rule, with the result that every third, rather than every fourth, year was intercalary. Although detailed evidence is lacking, it is generally believed that Emperor Augustus corrected the situation by omitting intercalation from the Julian years -8 through +4. After this the Julian calendar finally began to function as planned.

Through the Middle Ages the use of the Julian calendar evolved and acquired local peculiarities that continue to snare the unwary historian. There were variations in the initial epoch for counting years, the date for beginning the year, and the method of specifying the day of the month. Not only did these vary with time and place, but also with purpose. Different conventions were sometimes used for dating ecclesiastical records, fiscal transactions, and personal correspondence.

Caesar designated January 1 as the beginning of the year. However, other conventions flourished at different times and places. The most popular alternatives were March 1, March 25, and December 25. This continues to cause problems for historians.

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