"ON TIME" LOGO HERE. NOT PRESENTED FOR REDUCING FILE SIZE. SEE FIGS IN ontime DIRECTORY

Contents

Notion Of The Past & Can We Change It ?

by I. Novikov
Theoretical Astrophysics Centre, Copenhagen

At the very end of the Millennium there is a lot of discussions and speculations about the most daring dreams of physicists, about their most challenging ideas. Among them probably the most outstanding is the possibility of travelling to the past.

What can be said from the scientific point of view about the possibility of flights into the past?

First of all it is necessary to note that we ourselves cannot get younger in any 'flight' voyage. In any one of us, in any human being and any system, time can only flow forward, only from youth to old age. As Alice says to Humpty Dumpty in Lewis Caroll's *Through the Looking Glass*, 'one can't help growing older'. We know the law of increasing disorder, increasing entropy, which dictates the aging of an organism.

Nevertheless, it is possible to imagine that using specially designed machinery, a human being could get into a special 'tunnel' in which he moves backwards with respect to time in the external space, and emerges in the past when passing through the other mouth of this tunnel. Obviously, the traveler through time does not get younger at all. However, having sneaked into the past, he can find himself, for example, in the time of his youth or even in an epoch before he was born!

This journey looks, to a certain degree, like diverting a small fraction of the discharge of a powerful river, pumping this rivulet through a pipe along the bank in the direction opposite the river flow, and then returning this water to the main flow far upstream.

Pure theoreticians, mathematicians rather than physicists, have already dealt for a considerable time with bizarre fantastic worlds in which travel back through time is allowed. These worlds are generated by solving systems of equations of general relativity. It appears that the general opinion has been that these solutions have no connection whatsoever with reality, despite being of great interest for studying the structure of the theory itself.

All this looked very funny. For theorists, this solution was a veritable mathematical toy. No more than a toy, though.

Only rather recently this idea started to be treated seriously. In spite of many works on the subject the possibility (in principle!) to create a time machine remains unclear.

If time travel becomes reality (in remote future) its impact on our society would be so great that we cannot even imagine it. Thus it is very interesting to discuss whether and how the laws of physics can deal with a time machine.

The argument that is especially popular in debates of this sort is theso-called *'grandfather paradox'*. It goes roughly like this: "If I could go back into the past in which my grandfather was very young, I could kill him and thereby make my own birth impossible". Or another version of the same paradox: "I return into my own past, meet myself in my youth and kill my younger version".

In both cases this unnatural homicide generates complete nonsense. Should we infer that such an event is impossible? But why? I have my 'free will', don't I? Hence I can realize this 'free will', at least in principle.

Science fiction writers have scrutinized all possible versions of this scenario. But here we return to physics.

Does the 'grandfather paradox', or other similar paradoxes, demonstrate that travel through time is not allowed? Indeed, it seems logical that having gone back in time and eliminated the cause of a phenomenon that has already taken place in the present, we thereby violate the fundamental principle of science: causality!

But is this true? I doubt it, and suspect that the argument as given above is flawed. What has physics to say about the likely consequences of meeting oneself (or one's grandfather) in the past?

Obviously, a physicist (at least our contemporary physicist) is unable to perform an exact calculation of the actions of a human being. This is the field for psychology and sociology, not for physics. However, a physicist can give a strict calculation of what happens to simple physical objects after they pass through a time machine. Such calculations have been performed, and it was demonstrated how physics could deal with such unusual situation without any paradoxes. We will not go into details here, but restrict ourselves by a few remarks.

First of all if somebody use a time machine it means he/she makes a 'loop of time'. I wish to attract the readers attention to one totally new factor that arises here. If a 'time loop' exists, the events on this loop cannot be separated into future and past. To clarify this statement, let us consider the following example.

Imagine that I walk in a long string of people moving along a straight line. I can definitely say which of them is in front of me and who is behind. If, however, we all follow a circle, I can say 'ahead of me'or 'behind me' only about my nearest neighbours but not about the entire line of people. Regarding people further and further ahead of me, I ultimately go around the entire circle and reach myself from behind. This is why people moving on a circle cannot be divided into those 'moving in front' and those 'walking behind'.

The same is true for the 'time loop'. We can say which of the nearest events belong to the future and which to the past. But this division cannot be applied to the time loop as a whole. The loop has no clearly defined future and no past, and all events affect one another on a circle. Briefly and metaphorically speaking, we are under 'double' strong influence: without the time machine events are influenced by the flow of data from the past (but not from the future! this is the gist of the causality principle), while events on the loop respond to information coming from both the past and the future.

Therefore, with the time machine, today's events must be consistent with (i.e. be determined by) not only the past but also the future! I formulated this self-consistency principle many years ago and now it appears to be accepted by everyone who works in the time machine field. Recently I and my colleagues were able to provide that this principle can be deduced from the fundamental laws of physics.

Let us recapitulate.

With the time machine becoming a reality, the future starts to affect the past. All events occur in such a way that this influence is taken into account. However, once an event has taken place (it was influenced by the events both in the past and in the future), that's the end, it cannot be altered. 'What has really happened cannot be undone'.

Still, how about the assassination of the grandparents? Could this extravagant crime be committed using the time machine? The answer is a categorically NO. The American physicist Kip Thorne puts it this way:

“ ...something has to stay your hand as you try to kill your grandmother. What? How? The answer (if there is one) is far from obvious, since it entails the free will of human beings. The compatibility between free will and physical law is a terribly muddy issue even in the absence of time machines.”

As for the constraints of ‘free will’, the reader should notice that even without a time machine, ANY LAW OF PHYSICS places limits on ‘free will’. Say, I might wish to walk on the ceiling (without special equipment): my ‘free will’ prompts me to. This, however, is forbidden. The law of universal gravitation limits my ‘free will’ and there is nothing I can do about it.

In the presence of the time machine the constraints on ‘free will’ are, of course, somewhat different, but they are not, in principle, anything extraordinary in the physics of our time.

I will conclude this brief discussion of the limitations imposed on ‘free will’ with a remark made by Einstein and which may be of interest to those readers who find time mull over problems of this type. Schopenhauer once remarked: “A man can do what he wishes but he is not free to wish what he wants” (Epilogue. A Socratic dialogue in M. Planck: Where is science going? London, 1933 p.210)

“NATURAL UNIT OF TIME” IMAGE HERE. NOT PRESENTED FOR REDUCING FILE SIZE (SEE FIG natutime.gif)

Measuring The Time

By D. Matsakis,
Time Service Department, U.S. Naval Observatory

For centuries, the most accurate way to tell time was by using the rotating Earth as a clock, and the standard for judging man-made clocks was whether they could be used to predict meridian crossings of the Sun and stars.

A theory which predicted that the Earth might be an imperfect clock was published by Sir George Darwin, son of evolutionist Charles Darwin, who showed that the tides had the effect of slowing down the rotation of the Earth and of pushing the Moon father away. The exact amount of the slow down is very difficult to calculate because it depends on the detailed geometry of the ocean floor. It is impossible to calculate this for past eons, when the continents themselves had different arrangements. Over recorded historical time, however, one can measure how much the Earth has slowed down by carefully using available information on solar eclipses and the fact that the longitude of the Moon’s shadow depends upon the rotational angle of the Earth. The oldest recorded eclipse that can be used for this was observed by the Chinese in 1825 BC, however, in order for that eclipse to have been seen by the Chinese the Earth’s rotation must have deviated by about 14 hours from its projected amount. Along with observations of other eclipses by the Greeks and others we can infer that the Earth generally slows down at a rate of about 1.7 milliseconds/day/century, which means the year gets about .62 seconds longer every century. However, this slowdown is irregular because Earth’s rotation is also related to such things as the angular momentum of the atmosphere, and the motion of the Earth’s liquid interior. The rotation of the Earth is part of the variations in Earth Orientation, which are measured by the International Earth Rotation Service (IERS), using radio observations of extragalactic objects such as quasars and observations of satellites such as those of the Global Positioning System (GPS). Links to the IERS and the U.S. Naval Observatory’s role within that, can be found starting from our web page at http://maia.usno.navy.mil.

By 1967 cesium atomic clock technology had matured to the point where it was decided to change civil time from that based upon the rotating Earth (Universal Time, which when referenced to an inertial reference frame is termed UT1) to International Atomic Time (TAI). The unit of TAI, the second, was defined as 9,192,631,770 periods of oscillation of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the undisturbed cesium atom at sea level. This definition was chosen to so that the TAI second would equal the UT1 second as the Earth turned in 1830.

Atomic clocks get time by integrating frequencies, and those frequencies are realized as microwave signals referenced to an atomic transition. In all commercial cesium clocks, cesium atoms are boiled into a vacuum and deflected by a magnetic field so that only atoms in the lower of two states are channeled to a detection system. Along the way, the atoms take about a millisecond to pass between two regions where they are exposed to microwaves at the transition frequency between their internal states. If the exciting pulses are in phase and on frequency, the atoms will undergo a transition which will be noted at the detection region. As the pulse frequency is varied, the transition probability displays a Ramsey pattern, whose shape is by no coincidence equivalent to the diffraction pattern of two finite slits. Commercial cesiums reach precisions of a few parts in 10^{14} in a day, as measured by the Allan Variance. (An extremely simple explanation of the Allan Variance is that it is related to the rms of the pairwise difference between successive clock frequency measurements separated by an interval tau.) Because averaging can help reduce noise, clocks typically show lower Allan Variances as τ increases; however, at some τ, higher-order noise processes due to systematic errors start to increase the Allan Variance.)

Recently, the Observatory of Paris and the Ecole Normale Superior created an extension of the conventional cesium atomic clock, called the cesium atomic fountain. This clock uses laser-based techniques to cool atoms to the microkelvin level and state-select them. Then atoms are pushed upwards by varying the balance of up versus down laser-light pressure, after which they pass through a microwave-exposure region and continue vertically until gravity brings them back to the same microwave-exposure region. After the second microwave exposure, the atoms then continue dropping to where the fraction of them that underwent a transition due to the microwaves can be counted. This technique, now being copied and developed by almost every major timing lab, is expected to reach a frequency stability of a few parts in 10^{16} after several days, beyond which variation of systematic errors will block further improvement. In contrast, commercial cesium standards may average down to a few parts in 10^{15} after a few months. Fountains benefit chiefly from longer sampling times, non-magnetic state selection, and passing through the same microwave exposure region twice. Efforts are also underway to develop rubidium-based atomic fountain clocks, which should prove to be more precise because their relevant transitions are much less sensitive to collisional effects.

The absolute calibration of clocks is not simple. The frequency is mostly affected by such things as electric fields, magnetic fields, collisional effects, and phase variations within or between the two (or one) microwave regions. Absolute frequency measurements are done only by a very few specialized timing laboratories.

Although not useful as absolute frequency standards, commercial hydrogen masers offer great precision. These use state-selected hydrogen atoms to generate very time-stable microwave radiation via coherent maser emission. Cavity-tuned masers use varactor diodes to keep the electrical properties of the cavity containing the hydrogen atoms and the microwaves constant. Radio astronomers use hydrogen masers for Very Long Baseline Interferometry (VLBI) because of their short-term precision, which can average down to 10^{-15} in a day. Over periods of months, systematic errors add up so that their accuracy may be somewhat worse than cesium standards, but such long-term measurements are difficult to make. Other frequency standards based upon trapped ions are also under development. The US National Institute of Standards and Technology (NIST) is able to trap individual laser-cooled mercury ions in a time-varying quadrupole electric field, while at the Jet Propulsion Laboratory (JPL) frequency standards trap a few million ions for greater short-term precision. Pulsars also have the potential to be used as clocks, as has been realized since their discovery.

Although the quality of pulsar timin data has improved with the discovery of millisecond pulsars and the development of improved measurement equipment including antennas, atomic clocks have always been superior. However, pulsar timing data are useful for many other reasons; even if they do not prove useful as clocks, pulsars will always be important users of clock technology. The existence of many national timing laboratories, each with its own set of atomic clocks, could lead to confusion if there were no international coordination. Fortunately the service of computing TAI is provided by the International Bureau of Weights and Measures (BIPM), located in Sevres, France, acting under the Treaty of the Meter and the United Nations. The BIPM uses data from about 200 clocks and about 50 institutions, and publishes the difference between each contributor's time and TAI in the form of a mothly bulletin, about two weeks after-the-fact. Since TAI is independent of variations in the Earth's rotation, a closely related timescale, Coordinated Universal Time (UTC), is also defined which is identical to TAI except for an integer number of seconds, termed leap seconds. Leap seconds are inserted at the midnights following Dec 31 or June 30 so as to keep —UT1-UTC— < .9 sec. Because the second was defined with respect to the shorter years of the 1800's, we must usually add a leap second every 18 months; currently TAI and UTC differ by 32 seconds exactly. Because of practical problems with the implementation of leap seconds, efforts are being made to halt the addition of leap seconds, so that UT1-UTC would be unbounded.The U.S. Naval Observatory's Time Service Department is the largest contributor to the computation of TAI, because it maintains a total of about 50 cesium clocks and 15 hydrogen masers at its sites in Washington DC and Schriever Air Force Base in Colorado. This large ensemble of well-maintained clocks has made it possible to keep the time of the U.S. Naval Observatory, termed UTC(USNO), within 10 nanoseconds of UTC for the past year. This time is made freely available to all via the GPS satellite system, and it is anticipated that improved clock technology and GPS architecture will make both UTC and UTC(USNO) even more precise in the near future. Although space does not permit proper recognition of the many important timing laboratories, links to some of them can be found from within the "Clocks of the Future" page of http://www.tycho.usno.navy.mil.

Ancient Calendars Currently in Use

By E. Theodossiou and E. Danezis
Faculty of Physics, University of Athens

In ancient times the powerful god Sun was the only king of the daylight, while the paleface Moon was the indisputable goddess of the night. Primitive peoples measured time by the passing of seasons, by the hunting period and by the blossoming of various types of trees.

Studying the remote ancient period of the first human activities, we can easily distinguish the important roles of the Moon and the Sun in their society formation. Men and women tried to commemorate important events in their lives according to the Sun's motion and by the various phases of the Moon.

The periodic alternation of day and night (light and dark) and the periodicity of the Moon phases, about every 7 days, imposed the first small time periods (day and week). These easily recognized time periods led the priests to construct a fixed time period measurement, which they called calendar. The first ancient calendrical system, because of religious causes, was based upon the mysterious lunar phase periodicity, or more precisely upon the synodic lunar month (*The length of the synodic month is 29.530589 days for the epoch 1900*).

Ancient World has not known a unique calendar. Every ancient nation had its own lunar or luni-solar calendar, characterized by month names, which were related to feasts in honor of national, local deities. Furthermore, the beginning of the civilian year coincided with the instant of realization of the new Moon phases. But, as the primitive societies became more and more sophisticated, the old calendars became more complex, because of the adoration of various deities or because of an advanced astronomical knowledge.

Since the requirements of various nations or civilizations differed dramatically, the world's ancient calendars historically have been extremely diverse. Famous calendars were in use during the ancient times in the Near, Middle and Far East areas. Some of them are still in use, as the Hebrew or the Chinese, the Japanese and the Korean calendars for both religious and civil purposes.

The ancient Babylonian calendar, based on the Moon's phases, is the classical type of a lunar calendar. In it the year began in spring equinox with the month Nissanou. The Babylonians celebrated Akitou, the great holiday of spring, singing Enuma Elish, the Epic Poem of Creation.

The Hebrew calendar
The present luni-solar Hebrew calendar is based upon the ancient Babylonian one. The Jewish calendar in its original form was primarily lunar; the month and hence the civil year was controlled by lunar phases. Later, 7th century B.C., the priests used intercalary months to adjust the lunar to the solar year and a luni-solar Hebrew calendar was introduced. But only during the 4th century A.D. the Hebrew calendar became fixed.

The Babylonian month's names had their influence to the Hebrew ones. The year in Jewish calendar began either with the spring month Nissan or the autumn month Tishri. In our times, the Hebrew calendar is a typical example of a luni-solar calendar. It employs two cycles, a solar one of 28 years and the Metonic lunar cycle of 19 years. In Israel, the present Jewish calendar involves common years with 353, 354, 355 days and embolismic or intercalary years with 383, 384, 385 days; so there are 14 possible combinations for the Jewish civil year. The day is considered to begin at 6 p.m., but practicaly it begins at sunset.

Because of a) it's luni-solar nature, b) religious purposes, and c) practical problems, the Jewish calendar is a complicated calendrical system and rather complex rules governing its construction. The modern Jewish calendar is considered to date from the year of Creation (Anno Mundi, in Latin), which according to sacred Jewish tradition corresponds to October 7, 3761 B.C. That's why it is quite different to the dates introduced by the Gregorian calendar.

The ancient Chinese calendar
The ancient Chinese calendar is the oldest unbroken calendrical system in History. It is said that its origin was the year 2637 B.C. (Bing-zi) -according to the proleptic Gregorian calendar- during the reign of the mythical Emperor Shen Yen Huang-Ti. The emperor was the keeper of the calendar, since the calendar was considered as the sacred document, the holy symbol of the civil unity of the Empire.

From time to time the Chinese astronomers modified the calendar in order to make it more accurate (Reforms of Emperors Yao, 2357 B.C. and Chou-Chia, 1273-1241 B.C.). Finally, the astronomer Liou-Chin invented a cycle known as Chia-Shih-Chou (1st B.C. century) to adjust the lunar to the solar year. We note that the Chinese calendar is also used by Chinese communities in U.S.A. and around the world.

The influence of the Chinese calendar extended in Japan and in Korean peninsula. The Japanese created their own calendar on the same basis as the Chinese one. The beginning of the Japanese calendar is February 11, 660 B.C. (according to the proleptic Gregorian calendar). This date corresponds to the Emperor's Zimmou (Zimmou Tenno) coronation.

In Korea, the starting point of its calendar is considered to be the year 2333 B.C. (tangy), which corresponds to the establishment of the 1st national kingdom, by the mythical king Tangun. Meanwhile, in modern Korea a Buddhist year (bul-gi) exists, beginning in 544 B.C., a date considered as the year of Buddha's death (Buddhism Theravanta).

The Indian calendars
The ancient lunar and lunisolar Indian calendars were subject to the local variations. In general, there was no accordance between the calendars of different Indian cities and regions; hence between the calendrical holidays.

In India, in the mid-20th century, there were almost 30 native different calendrical systems. So, when India gained its independence, in 1952, a Committee was appointed by Prime minister, Padit Nehrou, for the Calendar reform. The so called Calendar Reform Committee recommended a new calendar for uniform use in the huge country. In 1957, in accordance with the recommendation of the Committee a new calendrical system was introduced by the government based upon the native Saka era. In this era March 22nd of the Gregorian year 1957 A.D. corresponded, in general, to Chaitra 1st 1879 of Saka's era.

The Islamic Calendar
The Islamic or Moslem calendar, is a typical lunar calendar, without intercalation, used by a billion of Moslems. The Islamic calendar is used today in Moslem countries, for all civil and religious purposes. Its beginning is the Hejira or Hegira (Mohammed's flight from Mecca to Medina) considered to be the sunset of July 16, 622 A.D.

Mohammedan era reckoned from this date.

Moslem calendar is a purely lunar one; this means that the year contains only 354 days. Because of it, this calendar does not take into account the solar motion and every civil year moves back 11 days! So, there is no accordance between the Islamic months and the seasons of the year (tropical year) (*The length of the tropical year is 365.242199 days for the epoch 1900*). That's why the Moslems New Year makes a circuit of seasons every 33 years.

Ancient Egyptian calendar
Finally, the most famous ancient calendar used, is the ancient Egyptian calendar; the only purely solar calendar in ancient times. This old, practical, solar calendar influenced the Roman calendar (The reform of Julius Caesar, with the advice of the Greek astronomer Sosigenes, 46 B.C.). Therefore, the ancient Egyptian calendrical system provided the basis for the Julian calendar (old style) and consequently for the Gregorian Reform (new style), which is more or less a universal civil calendrical system.

In Upper Egypt, the Copts and in Ethiopia, the Christians, today use a modified Egyptian calendar based upon the so called Alexandrian era. The Copts in Egypt dated their epoch from August 284 A.D., known as Diocletian era (date of Roman Emperor's Diocletian coronation), while the Ethiopians from August 29, 7 A.D., because -as they claim- seven years after Christ's birth they knew all the miracles about it in Ethiopia.

In all these countries ancient calendars and the Gregorian calendar -which is an almost universal calendar- are used simultaneously. This means that the Gregorian calendar is an official calendar used by the authorities (trade, international communication, education etc.), while the people -the farmers, the housekeepers- use their own traditional native ancient calendar.

Chronological eras still in use
In conclusion the much advertising Millennium for the Christian era is not a universal Holiday. Hebrews, Copts, Moslems, Chinese, Japanese, Koreans and many others use today various types of lunar or luni-solar calendars, both for civil and religious purposes.

This means that they celebrate New Year's Eve the first day of Tishri, Tout, Mouhrram etc. at different dates of New Year's Christian Eve, 1st January of the Gregorian calendar. Thus, January 1st, 2000 A.D. of the Julian calendar (January 14th of the Gregorian calendar) corresponds to:

Era	**Date**	**Era**	**Date**
Chinese	February 5th, 4637	Hegira (Moslems)	April 5th, 1421
Diocletian (Copts)	September 11th, 1717	Indian-Saka	March 21st, 1922
Japanese	January 1st, 2660	Korean	January 1st, 4333
Hebrew	September 29th, 5761 A.M.		

Bibliography
1. Explanatory Supplement to the Astronomical Ephemeris and the American Ephemeris and Nautical Almanac. Issued by H.M. Nautical Almanac Office by Orders of the Lords Commissioners of the Admiralty. London, 1961.
2. Parise, F. (Ed.): The Book of Calendars. Facts On File, Inc. 1982.
3. Theodossiou, E. and Danezis, E.: The Odyssey of the Calendars, Vol. I.: Searching for the Roots of Knowledge. Diavlos Pub. Athens, 1995.
4. Theodossiou, E. and Danezis, E.: The Odyssey of the Calendars, Vol. II.: Astronomy and Tradition. Diavlos Pub. Athens, 1995.
5. The Astronomical Almanac for the year 2000. London. Issued by by H.M. Nautical Almanac Office Rutherford Appleton Laboratory on behalf of the Council for the Central Laboratory of the Research Council.
6. http://astro.nmsu.edu/~lhuber/leaphist.html.

by L. E. Doggett
(excerpt from http://astro.nmsu.edu/~lhuber/leaphist.html)

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. 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.

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.

This special section was edited by M. Kontizas & D. Gouliermis.