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Say Kids, What Time Is It?

by Dr. Lew Thomas

That was the opening line in a very popular kids' TV program from 1947 to 1960. The "peanut gallery" of about 40 kids answered that line with, "It's Howdy Doody Time!" That may have been good enough in the old days, but we astronomers are much too serious and business-like to abide such frivolity nowadays. Here's Dr. Lew's answer to the question, "what time is it?"[1]

Introduction

Let us first present a partial list of the kinds of time; that is, time measured by various periodic events. We have:

1) apparent solar time
2) mean solar time
3) universal time
4) zone time
5) ephemeris time
6) atomic time
7) dynamical time
8) mean sidereal time
9) apparent sidereal time

Fig. 1 Just one of the faces of time

We will now give a general description for each of the items in this list, and indicate what periodic event is involved.

Apparent Solar Time

Apparent solar time is indicated by the hour angle of the Sun measured westward from the local meridian. The hour angle of the Sun, when on this meridian, is zero hours, Since this corresponds to noon or 12 hours, we write the equation for the Local Apparent Solar Time as

$$LASOT = 12 + HA_{sun} \quad \text{hours} \qquad (1)$$

The word "local" is used since LASOT applies to the observer's local meridian and "apparent" because the real Sun, in its apparent or observed position, is used, This is the time which would be measured by a sundial.

Mean Solar Time

Apparent solar time is fine if you plan only to use sundials. Your watch, however, operates on what is known as mean solar time.

The problem with apparent solar time is that the Sun does not move from day to day at a constant speed across the sky. This means that time intervals measured in this way vary in length. Most of us want our time intervals to be constant, so apparent solar time will not do.

The reason that the speed of the Sun varies comes from the fact that the Earth orbits the Sun in an ellipse with the Sun at one focus.

When the Earth is nearest the Sun in January, it moves faster than when it is farthest away in June.[2]

Moreover, since the Earth is tilted about 23½° with respect to the plane of its orbit (the ecliptic), the Sun appears to move at a varying rate along the ecliptic during the course of a year, Both the varying speed and the tilt of the Earth[3] cause the Sun to reach the local meridians at varying times throughout the year.

It would be inappropriate to have our watches track apparent solar time since they would then have to run at a varying speed. In earlier times, it was most difficult to make mechanical clocks behave in this manner, therefore a fictitious Sun was created. This so-called mean sun started its yearly trip at the vernal equinox along with the real sun on March 20 or 21. Thereafter, while the real sun moved at varying speeds along the ecliptic, the mean sun moved on the celestial equator at a constant rate. This rate was the average or mean of the speeds of the true sun so that the real and mean sun would again meet at the next vernal equinox.

In summary, the mean sun moves along the celestial equator in our skies and at a constant rate. It is this rate to which our timepieces are set.

Mean solar time is therefore based upon the hour angle of the mean sun. The local mean solar time is

$$\text{LMSOT} = 12 + \text{HA}_{\text{mean sun}} \quad \text{hours} \qquad (2)$$

Universal Time

Clearly mean solar time is different for every different longitude of each observer. In order to standardize the measurement of time for astronomical purposes, the mean solar time on the Greenwich meridian (zero degrees Longitude) is established as Universal Time. Astronomical measurements may be referred to this standard.

The Local Mean Solar Time may be computed from universal time and vice versa by using the formula

$$\text{LMSOT} = \text{UT} + \text{Lo}/15 \quad \text{hours} \qquad (3)$$

UT = universal time
Lo = longitude of the observer in degrees
15 = this factor changes degrees into hours
(Earth rotates at a 15°/hr rate = 360°/24 hrs)

Here it should be noted that, by convention, west longitude is considered negative (-) and east longitude positive (+).

Zone Time and the International Date Line

Examination of equation (3) indicates that the local mean solar time will change every time the observer moves to a new longitude. This is very well for astronomers, but commerce and other civil activities can not be scheduled in this manner. Therefore, by international agreement, time zones have been established within which the same clock time applies. These zones are generally 15° apart. When one travels eastward from one time zone to the next, the traveler's watch is advanced by 1 hour. In moving westward from one zone to another, the watch is set backward 1 hour.

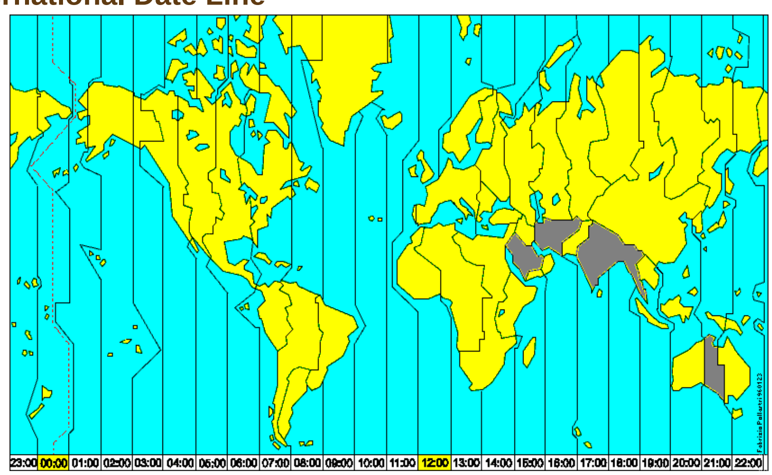

Fig. 2 Time zone boundaries.
http://toi.iriti.cnr.it/uk/timezone.html

The time within each zone is called the zone time or the standard time. It is the mean solar time on the longitude meridian that is central to the zone. The 15° width was chosen because the Earth rotates 15° each hour. The zones are diagrammed in figure 2.

Of course, it would be inconvenient if a zone boundary should cut across a city, or a state, or, in some instances, even a national boundary. Therefore when this occurs, the zone boundary is often shifted so as to match the civil boundary.

Another problem arises with zone time. Suppose we were to be at the prime meridian in Greenwich, England at noon on a Sunday. Let us now travel westward rapidly enough to keep the Sun on our local meridian. It remains noon for us all during our travels. By the time we again reach Greenwich, twenty-four hours later, it would be Monday. But the Sun is still on our meridian. It has never set. So how can the day advance?

To avoid this dilemma, an International Date Line has been established running from the North to South Pole across the middle of the Pacific Ocean and for the most part at longitude 180°. When you cross this line going from west to east, your day "backs up." For example, suppose you are west of the IDL and the day is Sunday at say 8am. When you cross this line going eastward, it immediately becomes Saturday at 8am. Later on you will have Sunday all over again! On the other hand, if you are east of the IDL and it is 8am on Sunday, when you cross the line going west, it becomes Monday at 8 AM. You would have lost the rest of Sunday!

Atomic Time

The radiation of cesium 133 is used as the standard of atomic time. Specifically, an atomic second is the duration of 9,192,631,770 cycles of the radiation from cesium which corresponds to the transition between two hyperfine energy levels[4] of the ground state of this atom. This time duration is defined in the **International System of Units** (abbreviated **SI** from the French *Le **S**ystème **I**nternational d'Unités*).

International Atomic time (TAI is derived by the analysis of atomic time standards in many countries. The fundamental unit of TAI is the SI as determined at the epoch of January 1, 1958.

Dynamic Time[5]

Dynamic time (DT) replaced ephemeris time[6] in 1984 and became the independent argument for dynamical theories of motion for celestial bodies and for the tabulation of ephemerides. (TDT) is used as the argument for all geocentric ephemerides. At 1977 January 1.00 TAI, the TDT was exactly 1977 January

1.0003725 days. The unit of TDT is 86,400 SI seconds at mean sea level. We refer to mean sea level because there is a relativistic effect upon time as a result of the Earth's gravity and rotation. In general

$$TDT = TAI + 32.184 \text{ seconds} \qquad (4)$$

Apparent and Mean Sidereal Time

Local Apparent Sidereal Time (LAST) is measured by the hour angle of the vernal equinox (HA_{ve}). This is expressed by

$$LAST = HA_{ve} \text{ hours}$$

LAST is also equal to the Right Ascension line on the observer's meridian measured in hours.

Mean sidereal time is the apparent sidereal time less the effects of the Moon on the Earth's spin. Both apparent and mean sidereal time can be related to mean solar time by simple mathematical expressions.

[1] The first paragraph of this article was written by Ray Shapp.
[2] This was first established by Kepler who stated that a line drawn from the Sun to any planet sweeps through equal areas in equal times. When the planet is nearest the Sun, it must therefore move faster.
[3] The angle made by the ecliptic plane with the plane of the Earth's equator is called the obliquity of the ecliptic.
[4] Hyperfine radiation occurs when the spin of the electron is in the same direction as the spin of the protons in the nucleus of the atom. The movement of the electron in dropping to its lowest or ground state produces this radiation.
[5] A fine explanation of present day time scales can be found in section L1 of recent issues of *The Astronomical Almanac* published yearly by the U.S. Government Printing Office, Washington, D.C.
[6] Ephemeris time was used prior to 1984 as the standard for gravitational theories of the solar system. It was based upon the time it took the Earth to orbit the Sun in the year 1900 with all planetary perturbations removed.

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Time standards for planetary motion calculations

Ephemeris time, dynamical time and coordinate time are all intended to provide a uniform time for planetary motion calculations.

- **Ephemeris Time** (**ET**) is an obsolete time standard based on the ephemeris second, which was a fraction of the tropical year. The ephemeris second was the standard for the SI second from 1956 to 1967. Ephemeris Time was discontinued in 1984. For applications on Earth's surface, ET was replaced by TDT, which has since been redefined as TT. For the calculation of ephemerides, ET was replaced by TDB, but deficiencies in the definition of TDB led to its replacement by TCB for use in the solar system as a whole, and by TCG for use in the vicinity of Earth. In actual practice, ephemerides are calculated using T_{eph}, which is linearly related to TCB but not officially defined.
- **Terrestrial Dynamic Time** (**TDT**) replaced Ephemeris Time and maintained continuity with it. TDT is a uniform atomic time scale, whose unit is the SI second. TDT is tied to International Atomic Time (TAI) but, because the zero point of TAI was somewhat arbitrarily defined, TT was offset from TAI by a constant 32.184 seconds. The offset provided a continuity with Ephemeris Time. Terrestrial Dynamic Time has been redefined as Terrestrial Time.
- **Barycentric Dynamical Time** (**TDB**) is similar to TDT but includes relativistic corrections that move the origin to the barycenter. TDB differs from TT only in periodic terms. The difference is at most 10 milliseconds, which is negligible for many applications.

In 1991, in order to clarify the relationships between space-time coordinates, new time scales were introduced, each with a different frame of reference. Terrestrial Time is time at Earth's surface. Geocentric Coordinate Time is a coordinate time scale at Earth's center. Barycentric Coordinate Time is a coordinate time scale at the center of mass of the solar system, which is called the barycenter. Barycentric Dynamical Time is a dynamical time at the barycenter. http://en.wikipedia.org/wiki/Time_standard

Stewart's Skybox

By Stewart Meyers

The topic for this month's column is from our own multi-talented Clif Ashcraft who wanted to hear about jets. No, not those sardine cans with wings that fill the sky and sometimes ruin long exposure astrophotos. Rather, I am talking about the cosmic variety.

Starting Big

In the early 20th century, improvements in photographic technology allowed astronomers to take images of relatively faint objects through their telescopes. In 1918, Heber Curtis took a picture of M87, an elliptical galaxy in Virgo that is well known to many amateurs. When the plate was developed, he noticed what he called a "curious straight ray" sticking out of the nucleus of the galaxy.

Little progress was made toward explaining this phenomenon until the 1950s. As a result of the pioneering insights of Karl Janssky and Grote Reber in the 1930s being combined with technology derived from radar research in World War II, radio astronomy entered the astronomical mainstream. In those days, astronomers were just detecting sources of radio emission and were establishing their approximate locations. One of the brightest sources was in the constellation of Virgo and was named Virgo A. As the resolution of radio telescopes improved, the source of the emission was narrowed down to M87, then eventually to the "curious straight ray."

With the improved radio and optical data, this "ray" was shown to be a jet of gas streaming away from the nucleus at very high speeds, as is very clearly shown in this Hubble Space Telescope image from the Space Telescope Science Institute (see Figure 1).

Astronomers were puzzled and could not figure out how a confined jet of material could be shot away from a galactic nucleus. Over the years, more of these jets were found in other galaxies.

As knowledge of galactic jets was gradually improving, a clue was provided by the study of quasars. Discovered in the early days of radio astronomy, these objects were considered to be very mysterious, though by the 1960s, it had been found that they were in the centers of very distant galaxies. This news was slow to be released outside the astronomical community. The original "Star Trek" series episode "Galileo 7" maintained they were mysterious objects in our galaxy, though in defense of "Star Trek", the revisionist astronomer, Halton Arp, also believed that quasars were much smaller and closer than other astronomers thought.

While studying quasars, some astronomers noticed evidence of gas moving at very high speeds away from a few quasars. In fact, the speeds were too high - faster than light. It was soon realized that this superluminal speed was just an illusion caused by relativistic effects when the galactic jet from the quasar is almost pointed at Earth and is moving at a substantial fraction of the speed of light.

For some time, it was thought that jets were found only within galactic nuclei. But that would change.

Fig. 1 "curious straight ray" in M87
http://hubblesite.org/gallery/album/entire_collection/pr2000020a

SS433 and SNL

In 1969, it was found that some X-ray sources in our galaxy were highly variable. But there was a surprise in store. Bruce Margon, in 1978, studied the spectra of an X-ray source in a supernova remnant known as W50 in Aquila. He noticed that the Doppler shift of the signal changed over time. It was red shifted, normal, then blue shifted. This cycle would repeat. Further investigation found that the source was a binary system with a 13-day orbital period and also that the jets had a precession cycle of 160 days. The mainstream media misinterpreted the information and reported that a star that was both coming and going at the same time.

In what was a first in the history of astronomy, this X-ray source, now known as SS433, was featured in a brief segment on the "Weekend Update" skit on "Saturday Night Live" where Don Novello (as his famous character Father Guido Sarducci) claimed that study by the astronomers at the Vatican Observatory revealed that everything in that star system went forwards, then backwards, including the aging process.

When studied by real astronomers, it was determined that SS433 is an X-ray binary. That is, a normal star, usually in the red giant phase, has a compact object (in the case of SS433, a neutron star) as a companion. The neutron star pulls gases from the outer atmosphere of the normal star, and forms an accretion disk.

Around this time, astronomers were starting to accept that very massive black holes exist in the centers of galaxies. It was also realized that a young galaxy would have large quantities of gas in its central region, which would eventually fall into the central black hole and form an accretion disk. So SS433 offered a link between the jets emitted by galaxies and quasars and those emitted by neutron stars and black holes in X-ray binaries.

Small Scale Version

Back in 1890, S.W. Burnham discovered a small nebula in Taurus, near a variable star that would be known as T Tauri. At the time, it was considered to be a small example of a reflection nebula, and it became known as Burnham's Nebula. Then, in 1946, two astronomers, George Herbig and the late Guillermo Haro, were independently studying NGC 1999 and Burnham's Nebula when they noticed some bright objects in their images. These bright objects were soon known as Herbig-Haro objects and were considered somehow connected to the process of star birth. Based on the evidence of early spectroscopic work, it was thought for a time that these objects contained newborn stars being flung out of the nebula where they were born. But the actual truth was much different.

With improved resolution, the Herbig-Haro objects were revealed to be the results of jets shooting out of the nebula where stars were forming and hitting a dense part of the outer nebula. The resulting shock causes the gases to ionize and glow. At first, astronomers were not sure why newborn stars should be emitting jets, since the prevailing theories indicated that star birth was a gradual and relatively sedate process. However, it has been learned that is not the case. The disk surrounding newborn stars is not a simple, peacefully rotating object that gradually accretes onto the star. But rather it is a place where gas and dust are in constant motion, with some of the material spiraling in toward the star.

Three Common Ingredients

Seeing jets shoot out of active galaxies is one thing, but when jets are seen associated with other kinds of astronomical objects, that is significant and it can tell us something about how the universe works.

It seems that all cosmic jets have a few things in common. First, they all involve objects (black holes, neutron stars, or protostars) that are surrounded by much larger disks of material. Secondly, the material is falling towards the object. Finally, the central object has a magnetic field. These common elements are the crucial clues to how jets form.

The current view is that matter is spiraling in towards the central object. As a result, it forms a flattened disk and it heats up, becoming hottest close to the central object. Some of this heated, rapidly moving matter becomes ionized and interacts with the central object's magnetic field and is carried away from the disk in a magnetically contained jet.

Close But Not Quite

In recent years, a new jet-like phenomenon has been discovered. When red giants approach the end of their lives, they shed the outer layers of their atmosphere, which then forms what are known as planetary nebulae. It was thought that this process was spherical, and that the shape of planetary nebulae such as M57 (the Ring Nebula) as seen in this image below taken by our own Hank Adams were presented as evidence of this. But, when telescopes

Fig. 2 Planetary nebula, M57 Credit Hank Adams

like the Hubble Space Telescope took images of planetary nebulae, some had shapes like butterflies. Others had shapes suggesting two lobes.

While this phenomenon is not totally understood, it is thought that some of the outflow from the star is somehow channeled so that much of it goes out perpendicular to its equatorial plane. While not a true jet like the others mentioned in this article, it is another case where gas flow is directed along an axis.

Bringing It All Together

What is amazing is how this process works in a wide variety of environments, from the large scale of active galactic nuclei with multi-million solar mass black holes all the way down to protostars at the beginning of their lives, and even dying red giant stars.

Isn't it something how nature likes to use the same rules over and over again?

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DR. LEW'S SEMINARS

Some of the topics for upcoming seminars include:

- Rotation of the Milky Way
- Ways to enhance your telescope viewing

(Choice of topic at Dr. Lew's seminars is determined by participants' interest)

FRIDAYS AT SPERRY

August 17, 2007
Building OTA for Schupmann Medial Refractor Clif Ashcraft

August 24, 2007
The Solar System From the Sun to the Oort Cloud Dr. Tony Passannante

September 7, 2007
What's Up: A Down-to-Earth Sky Guide Kathy Vaccari

September 14, 2007
Video - "Apollo 15: In The Mountains of the Moon" & "Apollo 16: Nothing So Hidden"

DOME DUTY SCHEDULE

August 24	Team D
August 31	Team E
September 7	Team A
September 14	Team B

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All schedules above were accurate at time of publication. Please check www.asterism.org for latest information (click on "Club Activities")

Theater In The Sky

by Ron Ruemmler

September 2007 is frustrating for New Jersey observers. The most interesting events require binoculars, a predawn wake-up call, or are simply on the wrong side of the Earth.

A pleasant exception is **Jupiter**, which dominates the southwestern sky after sunset. For the first time this year, Jupiter sets before **Mars** rises. That means that for about an hour just before midnight the brightest planet above the horizon is **Uranus**! The faint Green Gas Planet takes full advantage of this opportunity by reaching opposition from the Sun this month and staying within binocular visibility all night.

If you're up after midnight, look for Mars in the southeast. The Red Planet passes between the horns of Taurus, the Bull. Aldebaran, the eye of Taurus, is off to its upper right. Mars reaches negative magnitude status this month heading toward a magnificent opposition on Christmas Eve.

Venus is now a spectacular morning object and will remain so for the rest of the year. Far to the lower left of Venus, **Saturn** and Regulus are having a spectacular conjunction. No first magnitude star ever comes closer to Saturn than Regulus, and that will not happen again until October 2036. Unfortunately, the true conjunction is probably too close to the Sun to be observed, but the star and planet move apart very slowly and are still within three degrees by the end of the month as they close in on Venus.

Mercury is part of the year's closest conjunction between a planet and a first magnitude star. Spica, the alpha star in Virgo, the Virgin, will pass just 0.1 degree from Mercury. This event occurs over Australia and, unlike the slow conjunction of Saturn and Regulus, the Mercury-Spica conjunction is over so fast that we can only see these two objects switch places with about half a degree between them each evening.

September Sky Calendar

2 Sun 6:00am Saturn less than 1° above Regulus
3 Mon 10:34pm Last Quarter Moon
4 Tue 6:00am Mars lower right of fat crescent Moon
9 Sun 5:30am Thin crescent Moon lower left of Venus and upper right of Saturn and Regulus
9 Sun 3:00pm Uranus at opposition from the Sun
11 Tue 8:44am New Moon
12 Wed 7:12pm Sunset; start of Ramadan and Jewish year 5768 (Rosh Hashanah)
13 Thu 7:30pm Thin crescent Moon directly left of Mercury and lower right of Spica
18 Tue 8:00pm Jupiter above fat crescent Moon
19 Wed 12:48pm First Quarter Moon
21 Fri 7:40pm Mercury 0.5° lower right of Spica
22 Sat 5:00am Mercury 0.1° from Spica
22 Sat 7:40pm Mercury 0.8° upper left of Spica
23 Sun 5:51am Autumnal Equinox; Fall begins
24 Mon 5:00am Venus at maximum brightness
26 Wed 3:46pm Full Moon