How We Tell the Time

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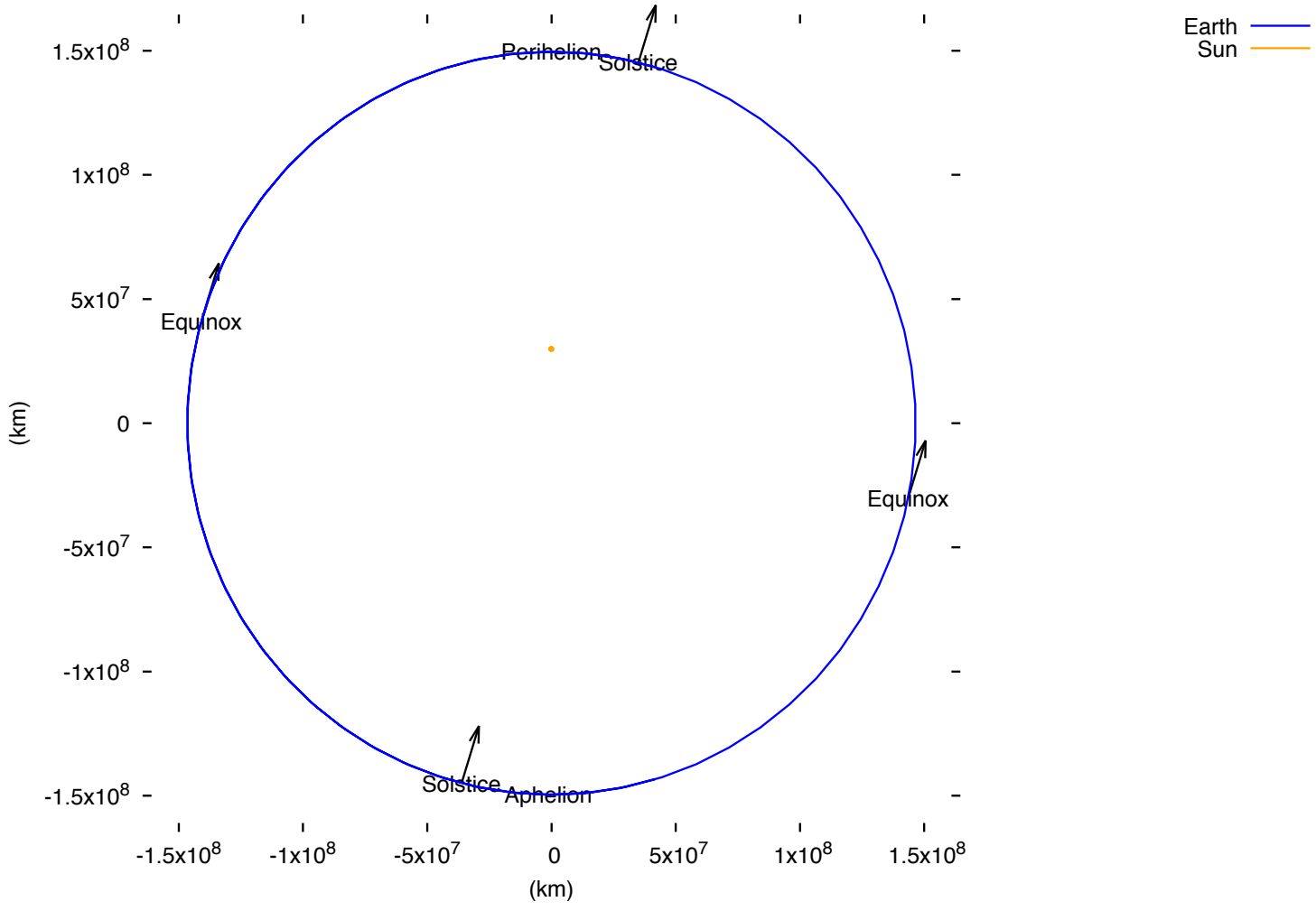
2016: The Year

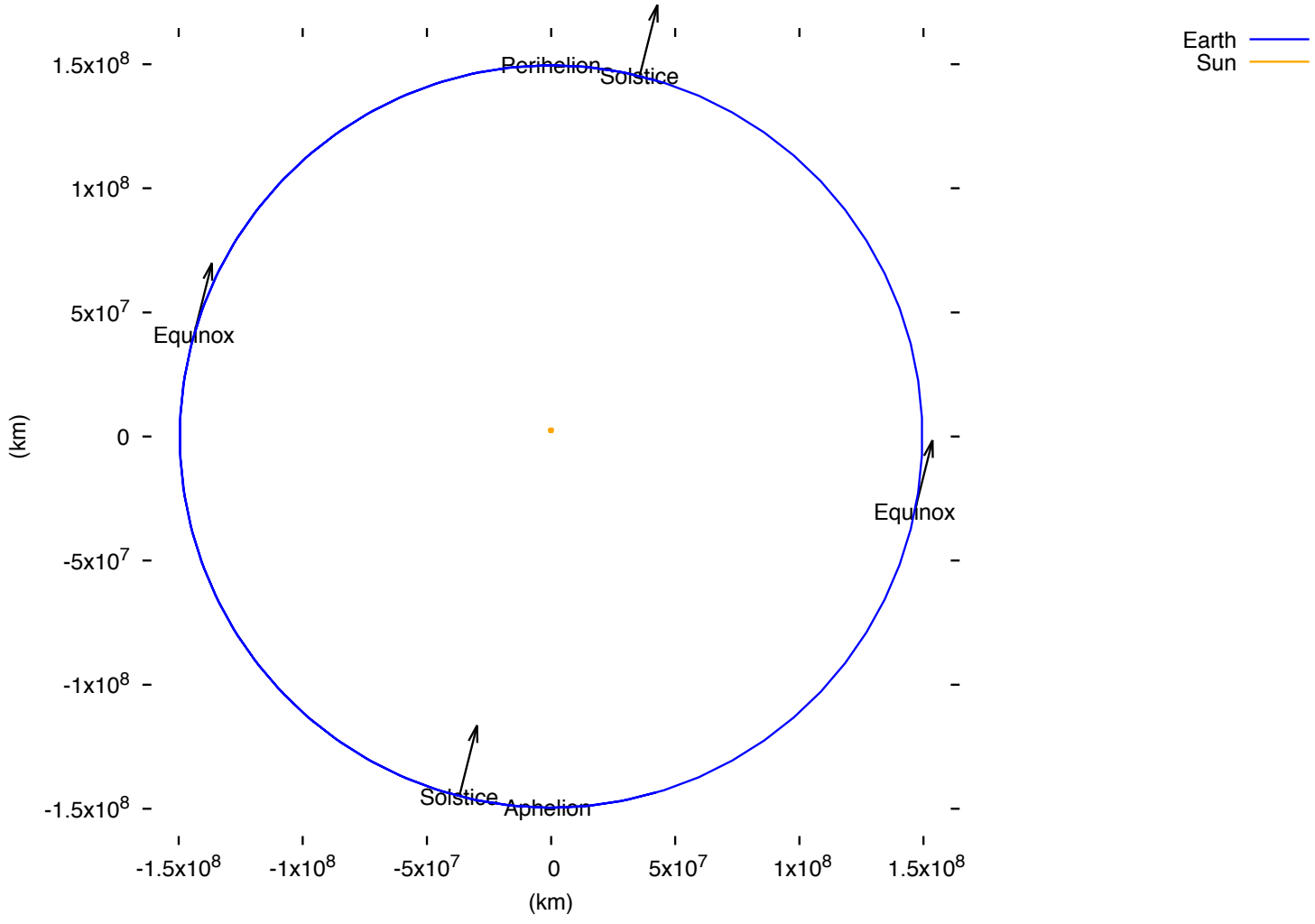
Seasons: Weather cycles, days lengthen and shorten.

Aim of our calendar: Keep Equinoxes and Solstices at the right time of year, especially the vernal equinox.
Tricky: year isn't whole number of days (365.24219).

The time of year: angle between earth's axis and the line from the earth to the sun.

NB: seasons nothing to do with distance to sun. Earth is at its closest (Perihelion) about 2^{th} January 2016.


Earth
Sun
Perihelion
Solstice
Equinox
Equinox
Solstice
Aphelion
1.5x10^8
1x10^8
5x10^7
0
-5x10^7
-1x10^8
-1.5x10^8
(km)
(km)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Four Years

Tropical (Solar) Year Axis at same angle to Earth-Sun line.

Sidereal Year Earth-Sun line at some angle.

Anomalistic Year Perihelion to perihelion.

Julian Year 365.25 days.

Counting Years

Count years from the (supposed) year of Christ's birth.

Dionysius Exiguus (AD 523) produced table of Easter Dates.

Herod died in 4BC, so Dionysius probably got it wrong.

BC dating came somewhat later, with the missing year zero.

Before that dates were counted since the founding of Rome.
1AD = 754AUC (ab urbe condita).

November: The Month

Need bigger division of years than just days.
Moon's phases is next most obvious thing in the sky.

Months roughly to be in sync with the moon (29.5305889 days)?
Other calendars are better in this respect.

We've ended up with funny months.

Story says Romulus gave 10 months, a successor, Numa, added 2 more.

Julian Reform

Ianuarius	29	31	Quinctilis	31	31
Februarius	28	28/9	Sextis	29	31
Martius	31	31	September	29	30
Aprilis	29	30	October	31	31
Maius	31	31	November	29	30
Iunius	29	30	December	29	31

Old leap: Cut Feb at 23/24, *intercalarius* of 27 days, irregular.
New leap: Once in 4, double Feb 24.
Took 445 day year (46BC), and fumbling to get there (8AD).
(Astronomical events a useful retrospective!)

Aiming for 365.24219 day year.

When	Calendar	Length
????	Old Roman	$355 \pm £££$
45BC	Julian	365.25
1582AD	Gregorian	365.2425

Papal Bull of 24 Feb 1582: 4 Oct followed by 15 Oct.
Equinox back at 21 Mar.
Took a while to catch on: 1752 for us.

Wednesday: Day of Week

7 day week is very old. Ptolemaic week by Romans and biblical week by Jews.

Portuguese	English	French	Planet
segunda-feira	Monday	lundi	Moon
terça-feira	Tuesday	mardi	Mars
quarta-feira	Wednesday	mercredi	Mercury
quinta-feira	Thursday	jeudi	Jupiter
sexta-feira	Friday	vendredi	Venus
sábado	Saturday	samedi	Saturn
domingo	Sunday	dimanche	(Sun)

Possibly longest unbroken tradition. Resisted French and Communist reform.

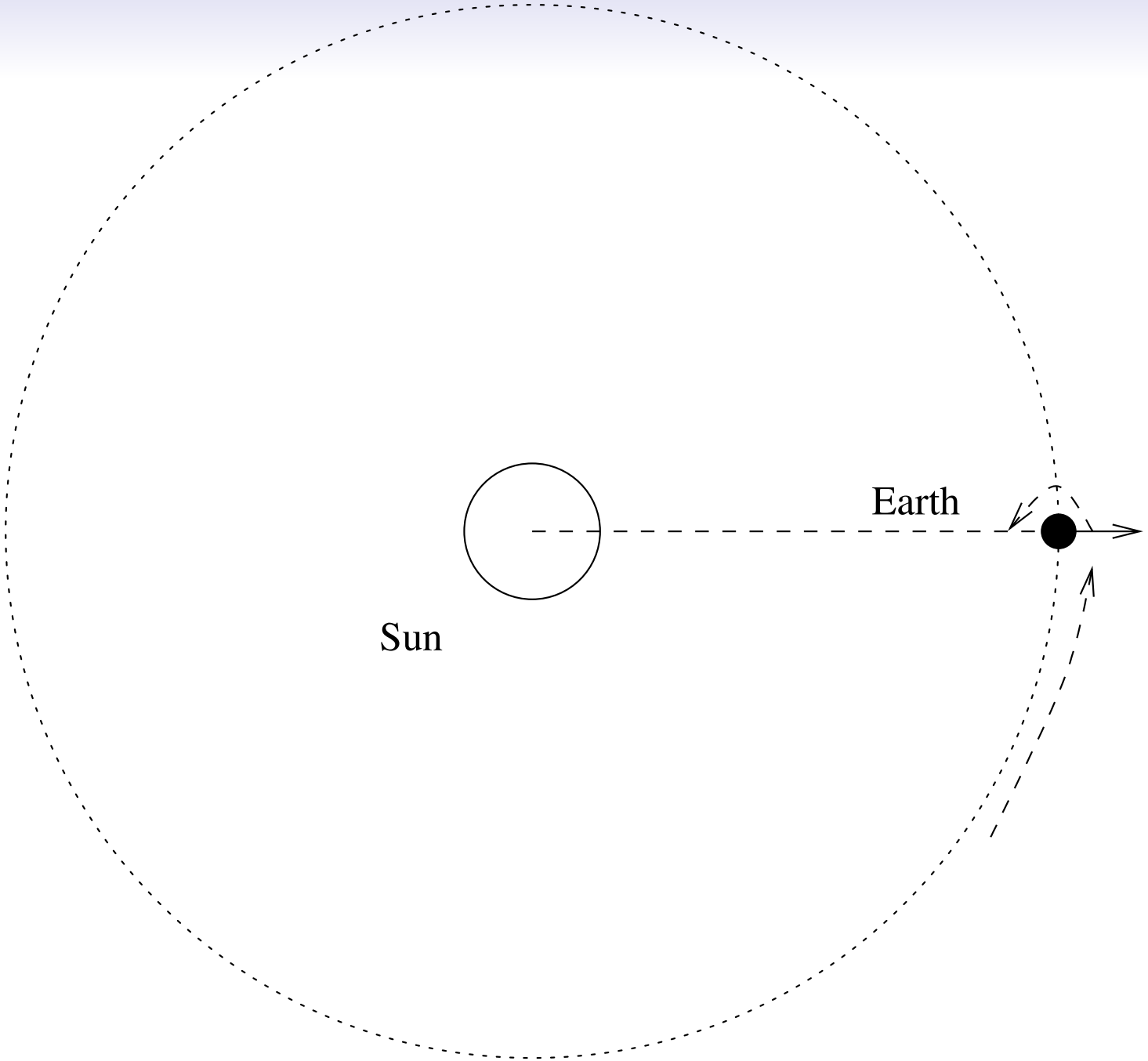
Days

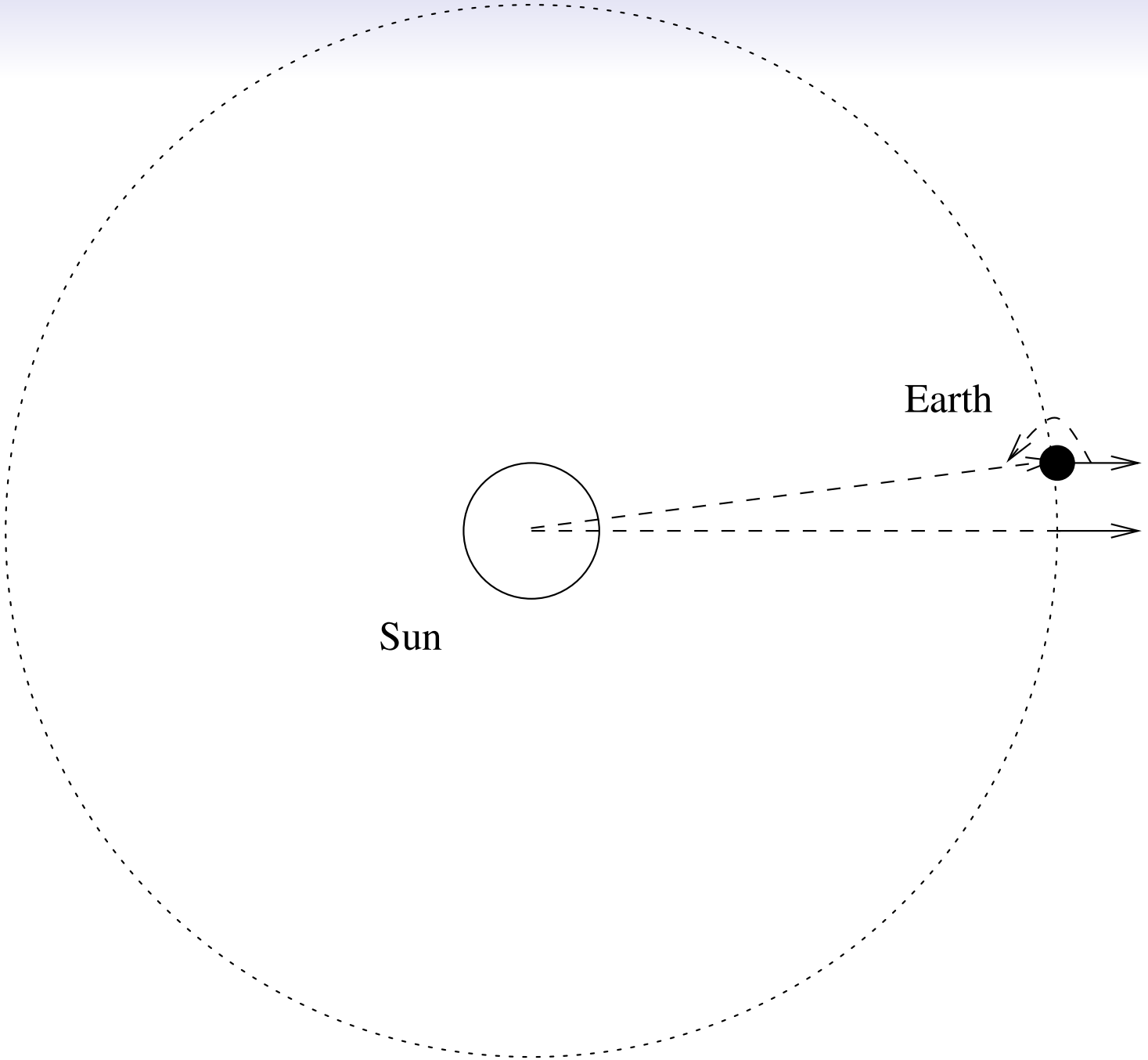
Obviously, it gets dark and bright once per day!

Different cultures start days at: sunset, sunrise, midnight, midday, ...

Must be something to do with Earth going around.

Solar vs. sidereal days.


Earth
Sun


Earth
Sun

Hours

Arbitrary divisions of a day. They arise by dividing things into 12.

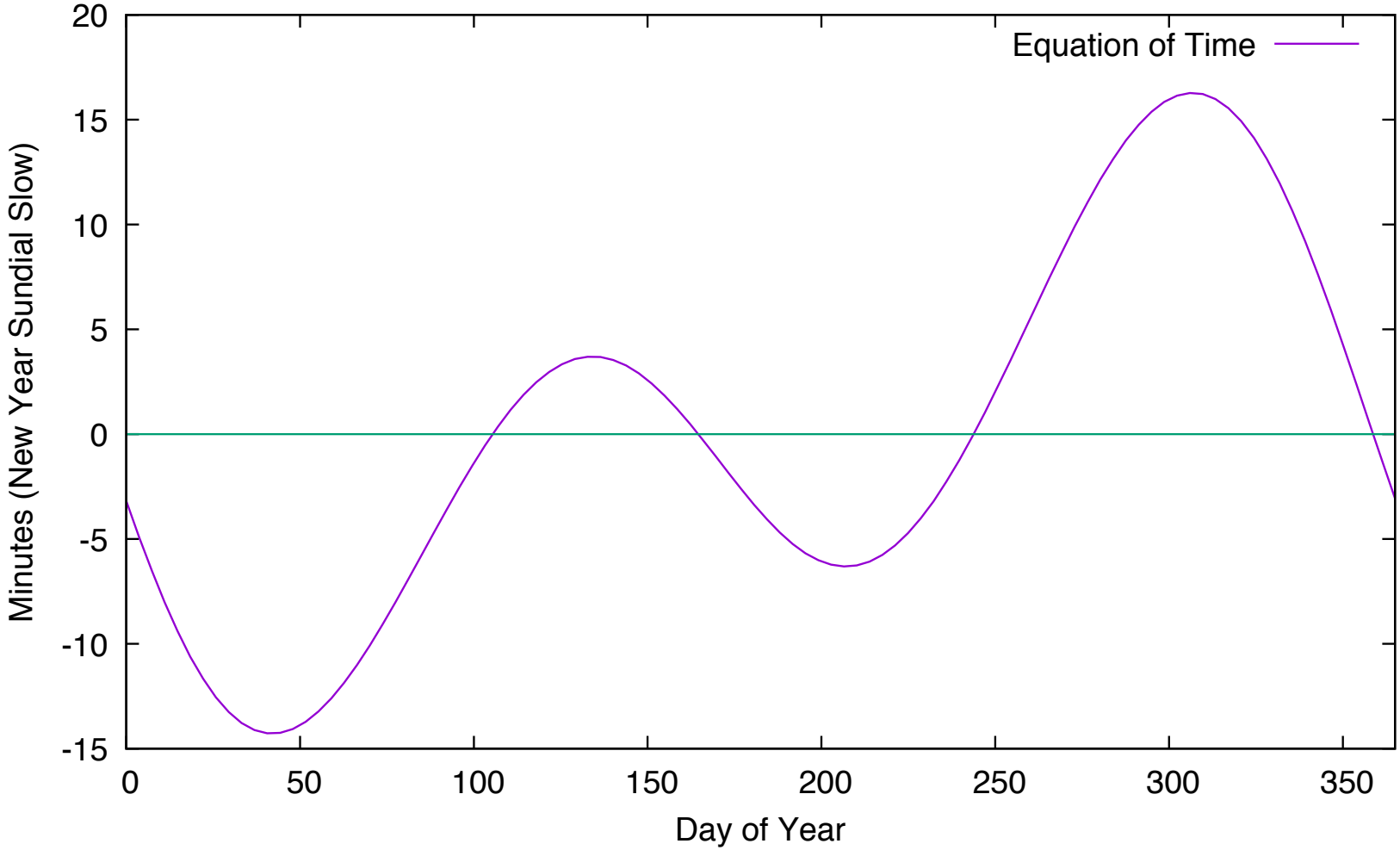
Were very uneven. Gradually fixed (14C).

Came to us via monastery and Roman army.

In 7C, lots of subdivisions, by middle ages we have *minutae primae* and *minutae secondae*.

Apparent vs. Mean Time

In 1792, move from apparent time to mean time.



Irish Legal time

Problem with midnight — it depends where you live.

In 1858, case law chooses local time.

(Maybe the Albert Memorial Clock meridian?)

In 1880, legislation fixes GMT in England, DMT in Ireland.

Dunsink Observatory

Usher:	25m7–48s (1787).
Brinkley:	25m22s (1832).
Romney-Robinson:	25m21s (1838).
Elliott-(Ray-Drury-Malone):	25m21.02s (2017).

Albert Memorial Clock: 23m41s.

1916

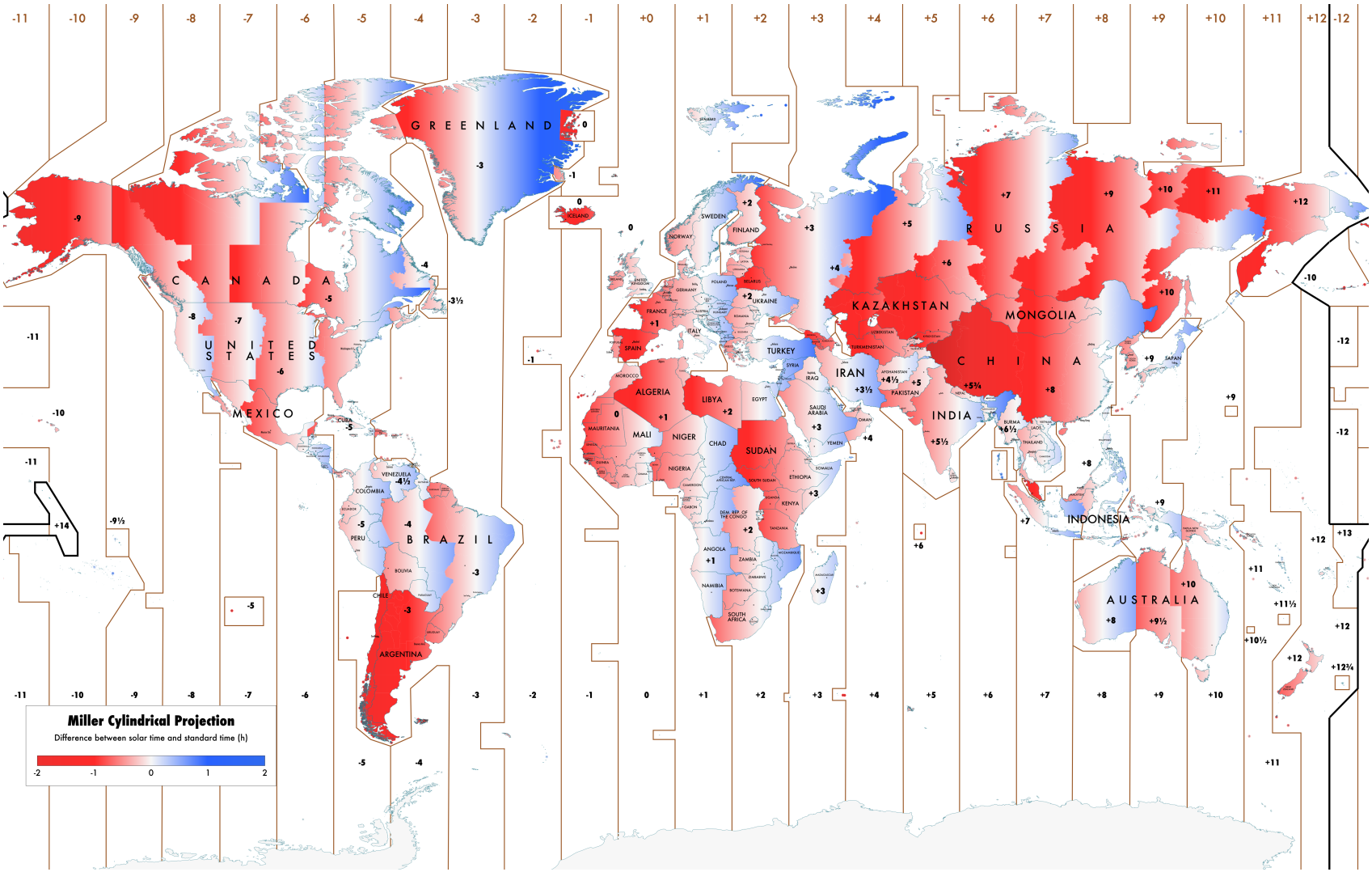
The Meridian Conference (1884): Greenwich as prime meridian.
By 1911, even France has moved to GMT, but Ireland hadn't.

31 Mar	Germany adopts Summer Time.
24–29 April	Easter Rising in Dublin.
10 May	Summer time bill read.
14 May	John Lonsdale: unification efforts.
17 May	Summer time act gets royal assent.
21 May	Clocks put forward at 2am.
1 Aug	Uniform Time bill (Herbert Samuel), concerns (John Dillon).
4 Aug	Dublin Mercantile Association support
7 Aug	Edward Carson comments in Parliament.
17 Aug	Deal on Dublin Bill mentioned in Parliament.
23 Aug	Uniform Time Bill gets royal assent.
Sep	Planning train/mail/boat/clocks/...
1 Oct	Irish clocks put back 35 min at 3am.

Highlights Since

1925	Western-European Time
1939	End of watch on mail to Dublin.
1941–5	UK has Double Summer Time
1947	UK has Double Summer Time
1968	Standard Summer Time (GMT+1)
1971	Changed mind.
1973	UK and Ireland join EU.
1997	UK and Ireland use EU DST rules.
2001	2000/84/EU directive currently in force (from 2002 last Sun in March/October)

Local Mean Time vs. Civil Time



http://blog.poormansmath.net/the-time-it-takes-to-change-the-time/

Seconds: Universal Time

All in terms of GMT. There's a problem...

...GMT is dead!

Universal Time is calculated from sidereal time (now ERA) using a formula like this:

$$86636.55536790872 + 0.000005098097\,T + 0.000000000509\,T^2$$

(A day is usually 86400 long).

Atomic Seconds

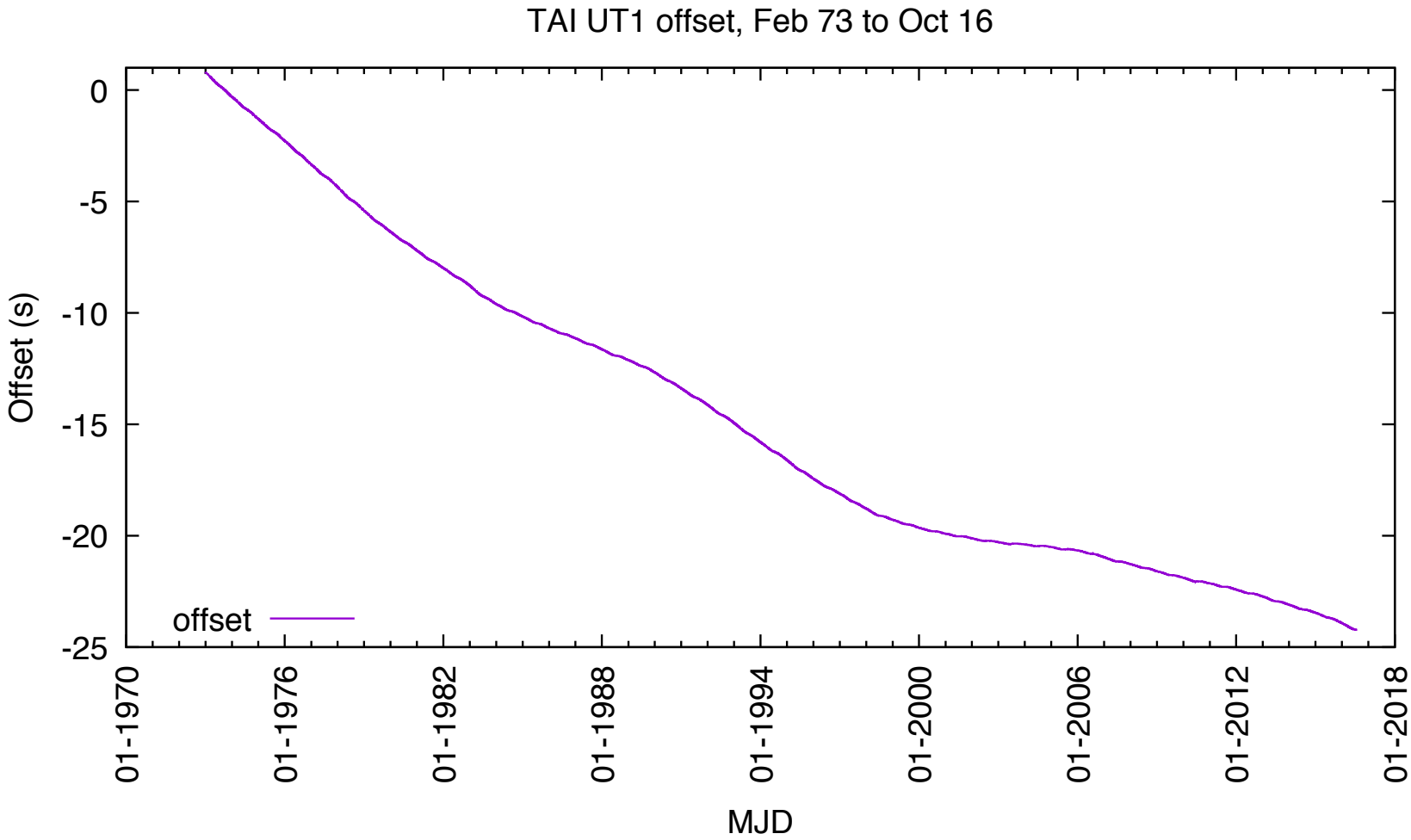
International Atomic Time has been available since 1955 (officially since 1972). Uses SI second.

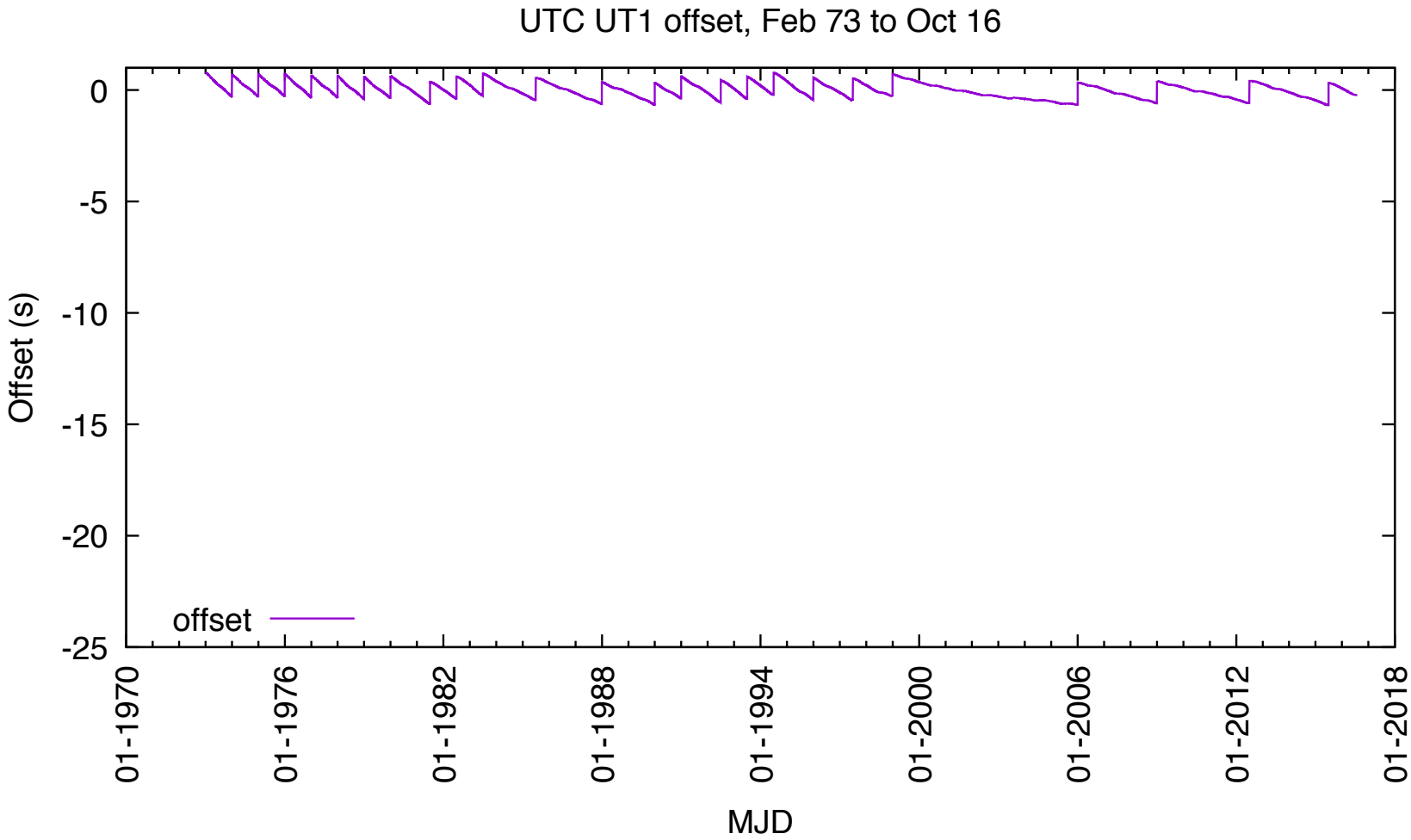
> *second:* In the International System of Units (SI), the time interval equal to 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

Problem is that UT seconds and SI seconds are different.

Coordinated Universal Time is a compromise. It ticks once per SI second, in sync with TAI.

If UTC is more than one second from UT1 then UTC is adjusted.


TAI UT1 offset, Feb 73 to Oct 16
Offset (s)
0
-5
-10
-15
-20
-25
offset
01-1970
01-1976
01-1982
01-1988
01-1994
01-2000
01-2006
01-2012
01-2018
MJD


UTC UT1 offset, Feb 73 to Oct 16
Offset (s)
0
-5
-10
-15
-20
-25
offset
01-1970
01-1976
01-1982
01-1988
01-1994
01-2000
01-2006
01-2012
01-2018
MJD

Pros and Cons

- Keeps UTC in sync with mean day.
- Preserves legal status-quo.
- Needed by astronomers and navigators.

- Subtracting dates is hard or impossible.
- Makes software more complex.
- Misapplication could be dangerous.

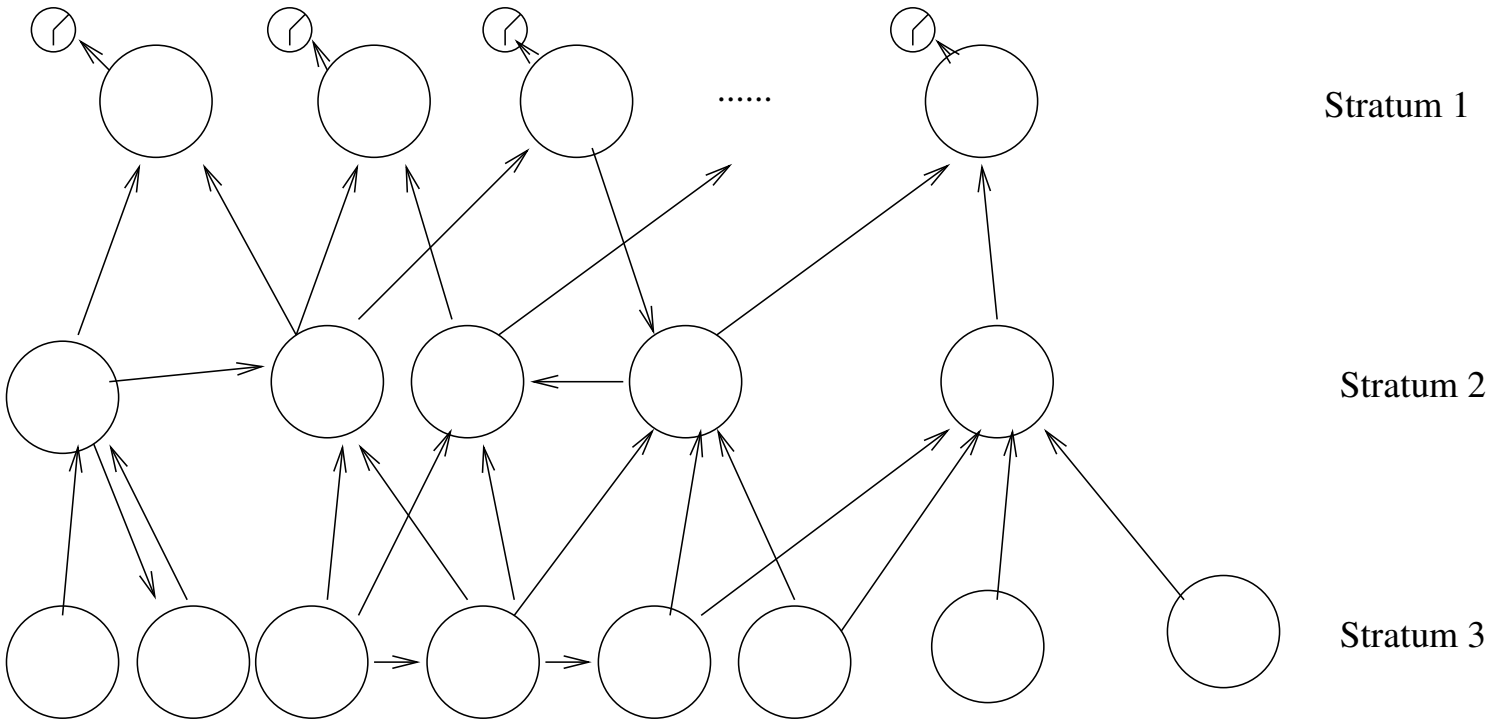
Particularly tricky for computers.
Debating since about 1999 — WRC-15 punted until WRC-23.

Thanks!

Enjoy your leap second on December 31st!

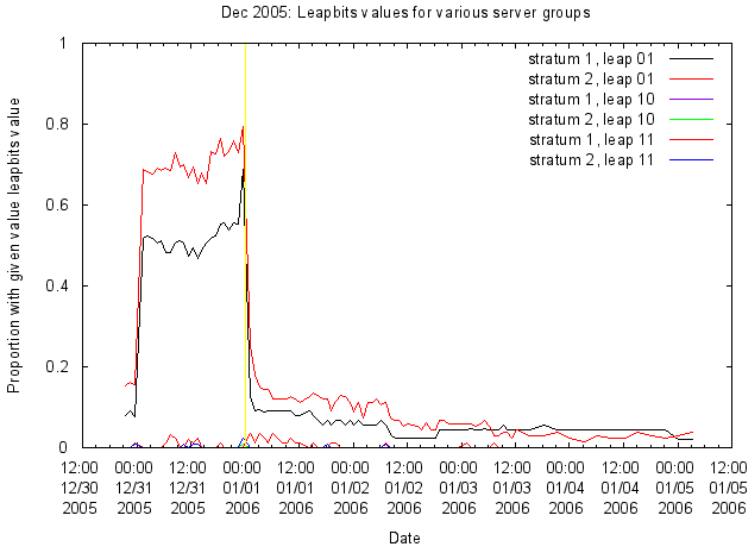
NTP: Network Time Protocol

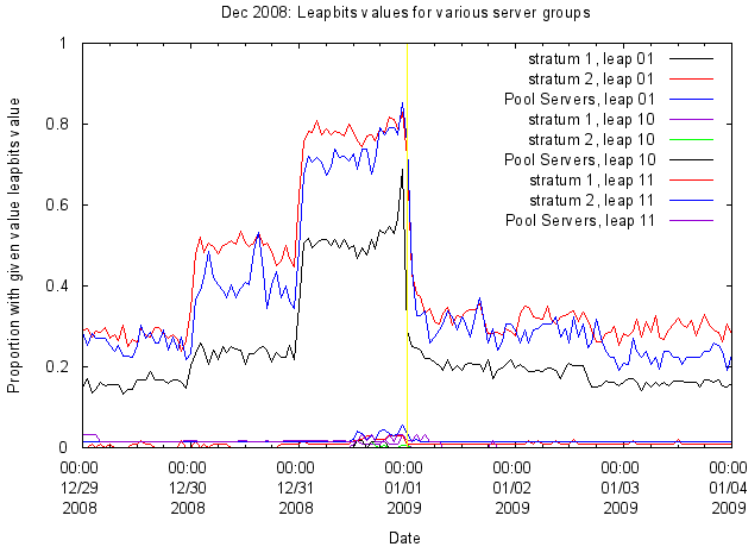
Computers exchange packets to synchronise to UTC.

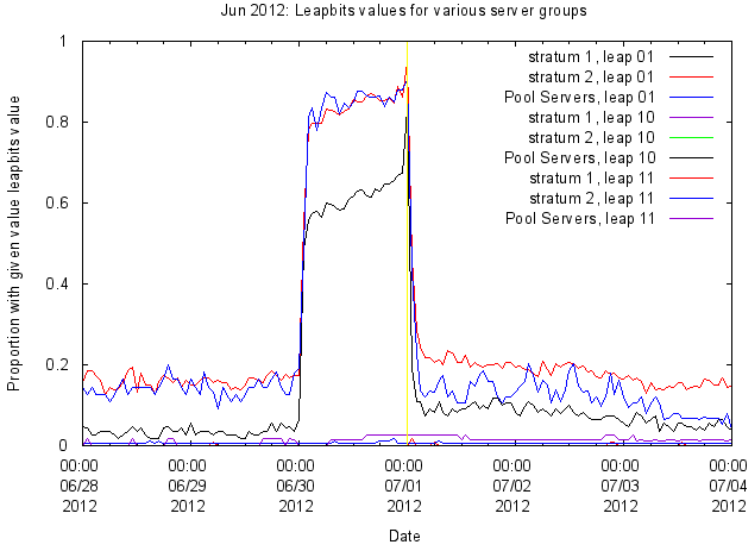


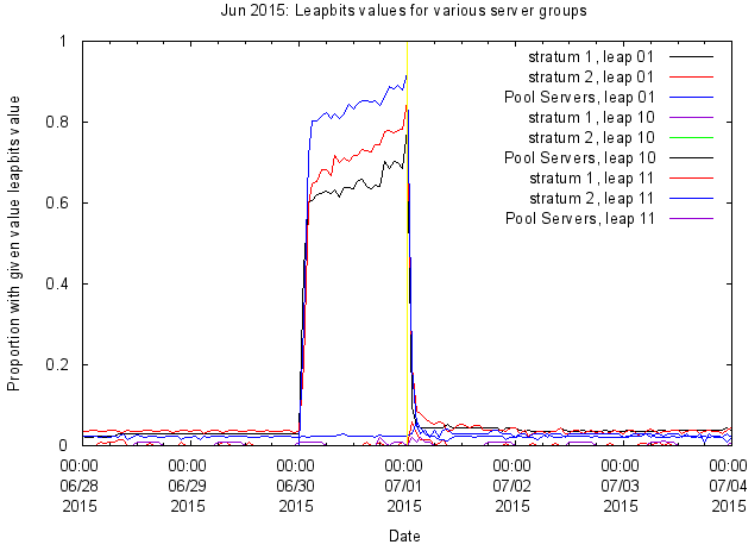
Upcoming leap second indicated in packets.

Watching NTP Leap









US GPS

Spotted on Civil GPS Service Interface Committee:

GPS.GOV

Official U.S. Government information about the Global Positioning System (GPS) and related topics

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CGSIC opinion on the redefinition of UTC now under consideration by the International Telecommunications Union (ITU)

Prepared by CGSIC Timing Subcommittee and endorsed by the CGSIC Executive Committee on 8-9 September 2014

The Civil GPS Interface Committee,

Considering that

- In 1971, the ITU-R (formerly CCIR, International Consultative Committee for Radiocommunications) proposed the present form of Coordinated Universal Time (UTC), which is based upon the SI second but remains linked to the variable rotation of the Earth through the introduction of leap seconds, which are inserted preferentially at the end of December 31 or June 30 in such a manner that |UT1-UTC| will always be less than 0.9 second.
- This proposal was accepted after discussions with BIH (Bureau International de l'Heure), URSI, IAU, IUGG, and other bodies active in positioning and navigation.
- At the time of introduction, the future implementation of satellite and other systems which cannot easily incorporate the leap second was not foreseeable.
- A proposal on the redefinition of UTC is under consideration by ITU, about which the ITU has solicited the opinion of several international bodies.

Interesting...

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And further considering that,

- leap second insertions have increasingly been associated with failures of navigational as well as timing systems, among them the ground, transmission, or accounting systems of GPS, LORAN, and commercial air travel,
- in one instance uncorrected mis-programming of a GPS receiver was responsible for a failure in mid-month, at a time when no leap second would have been expected,
- approximately 10% of the world's Network Time Protocol (NTP) servers, which provides an internet-based timing structure upon which many navigational systems depend, failed to correctly handle the leap second insertion of 2012,
- never as long as NTP servers have been monitored has every one correctly predicted the presence or absence of leap second on a December 31 or June 30,
- some systems have been mis-programmed to insert leap seconds after 23:59:59 local time instead of 23:59:59 UTC,
- many corporations, governments, providers of navigational systems, and other groups do not report failures as a matter of policy,
- and in the interests of safety some systems cease operations at the time a leap second is to be introduced,
- although navigational systems must and do continue operating through leap second insertions.

NTP leap second failures are a *known known*

- If correctly configured, NTP and PTP can handle leap seconds
- Never has every NTP server monitored been known to handle a December 31 or June 30 correctly
  - At least since serious monitoring began, January 2008
  - http://www.maths.tcd.ie/~dwmalone/time/leaps/
- 10% of the servers in the "NTP pool" got it wrong in 2012
  - Most were fixed within an hour of the insertion
  - Others, not in pool, took up to a day
  - Some added a leap second on July 31, 2012
    - https://groups.google.com/forum/#!topic/comp.protocols.time.ntp/vhVlH4ENsJQ
  - Hackers have been accused of exploiting/causing this