How to Tell the Time

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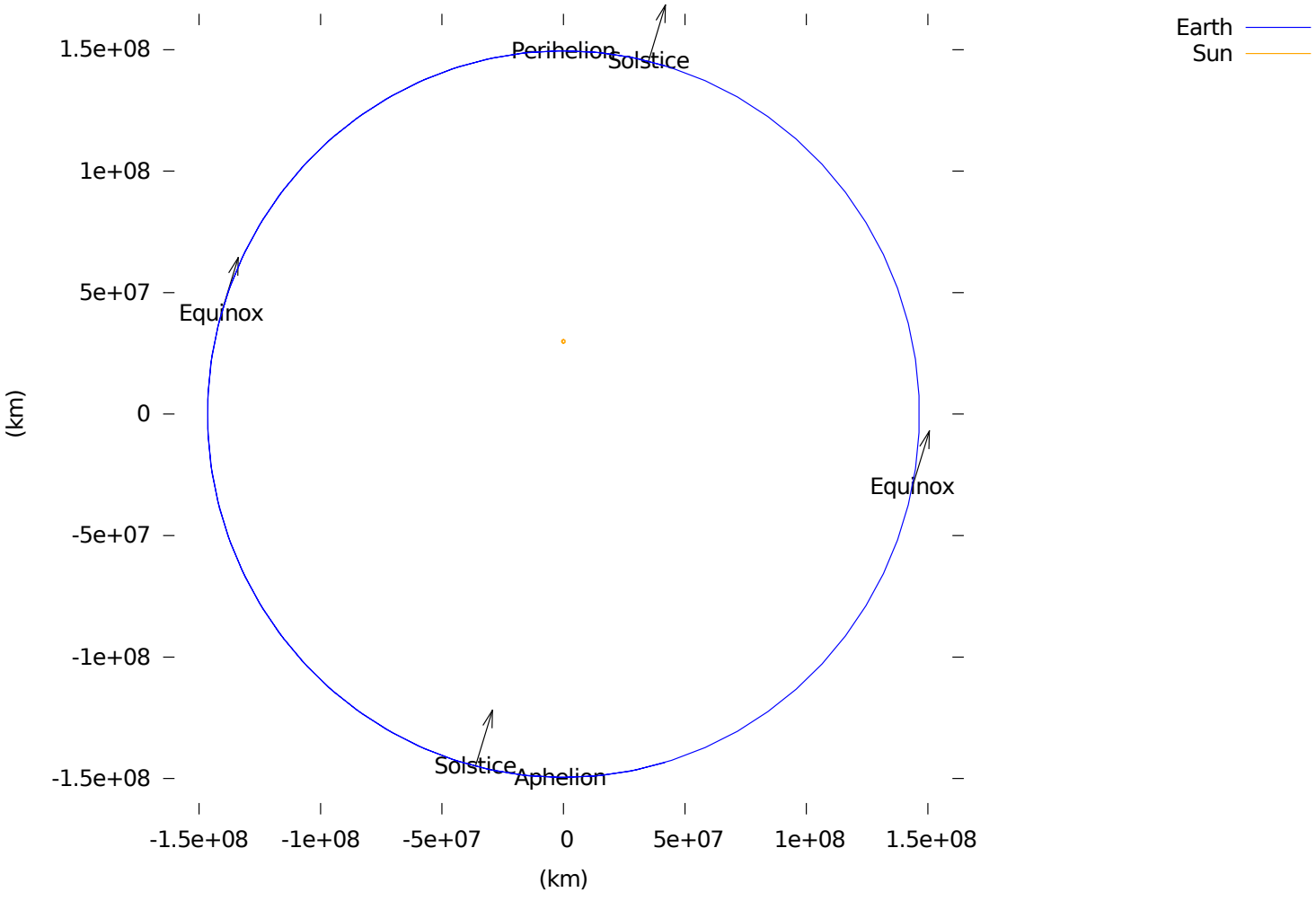
2014: The Year

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 4^{th} January 2014.


Earth
Sun
Perihelion
Solstice
Equinox
Equinox
Solstice
Aphelion
1.5e+08
1e+08
5e+07
0
-5e+07
-1e+08
-1.5e+08
(km)
-1.5e+08
-1e+08
-5e+07
0
5e+07
1e+08
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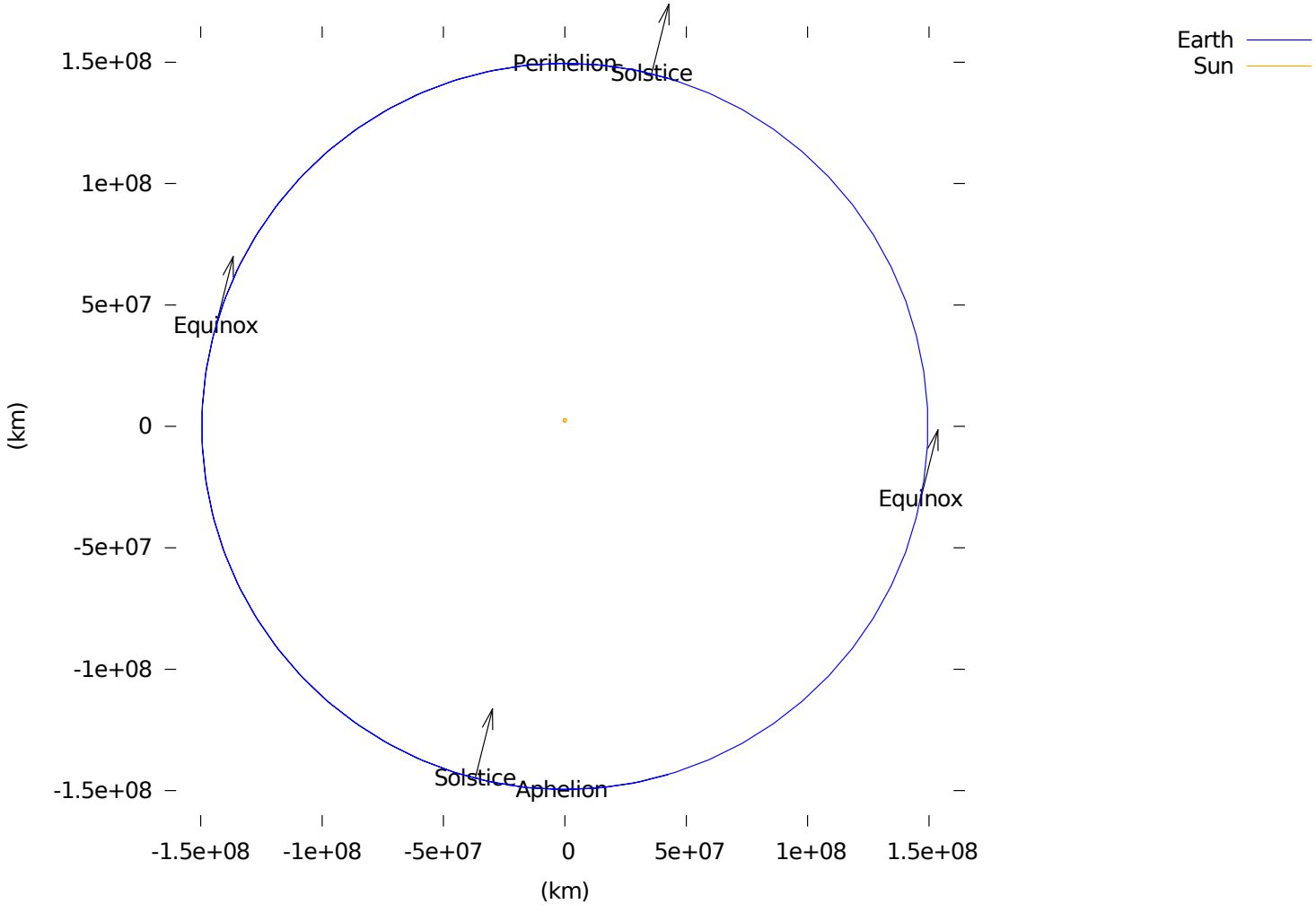
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Four Years

Tropical Year Axis back to same angle with Earth-Sun line.

Sidereal Year Earth-Sun line to sun 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).

January: 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 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, intercal of 27 days, irregular.
New leap: Once in 4, double Feb 24.
Took a 445 day year, and some fumbling to get there.

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

Possibly longest unbroken tradition. Resisted French and Communist reform.

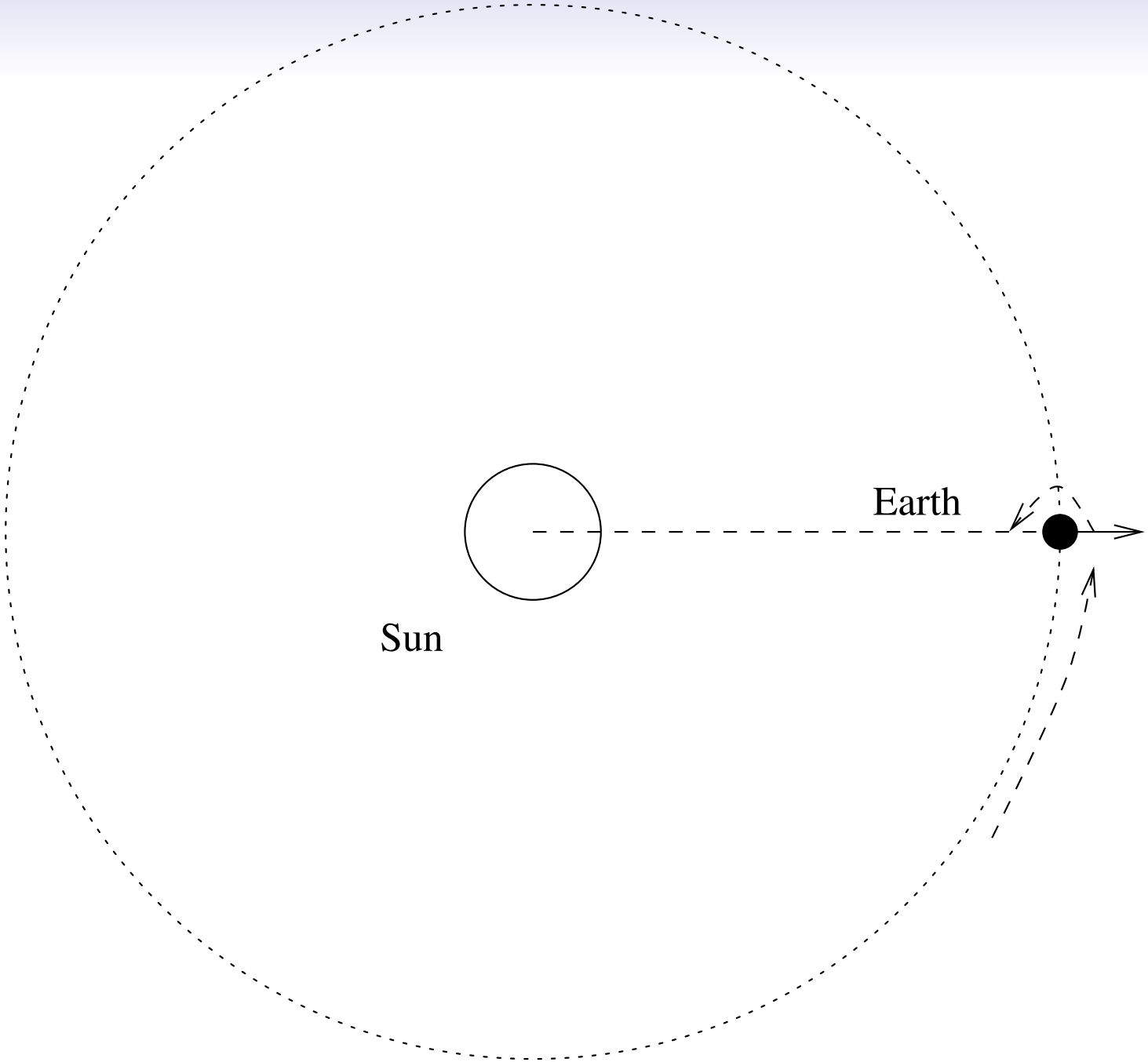
Days

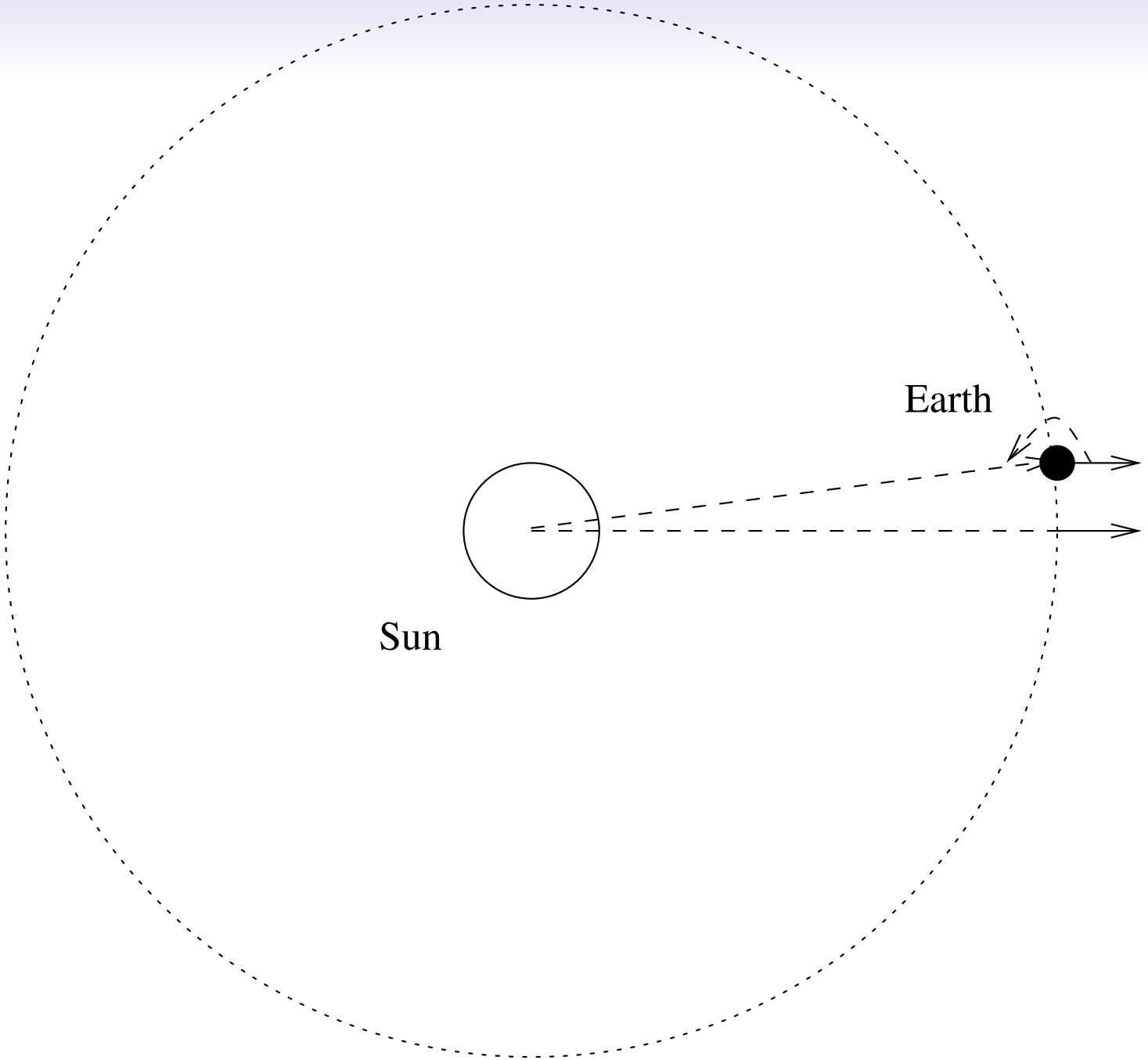
Obviously, it gets dark and bright once per day!

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

Must be something to do with Earth going around.

Solar vs. sidereal days.


Earth
Sun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Hours

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

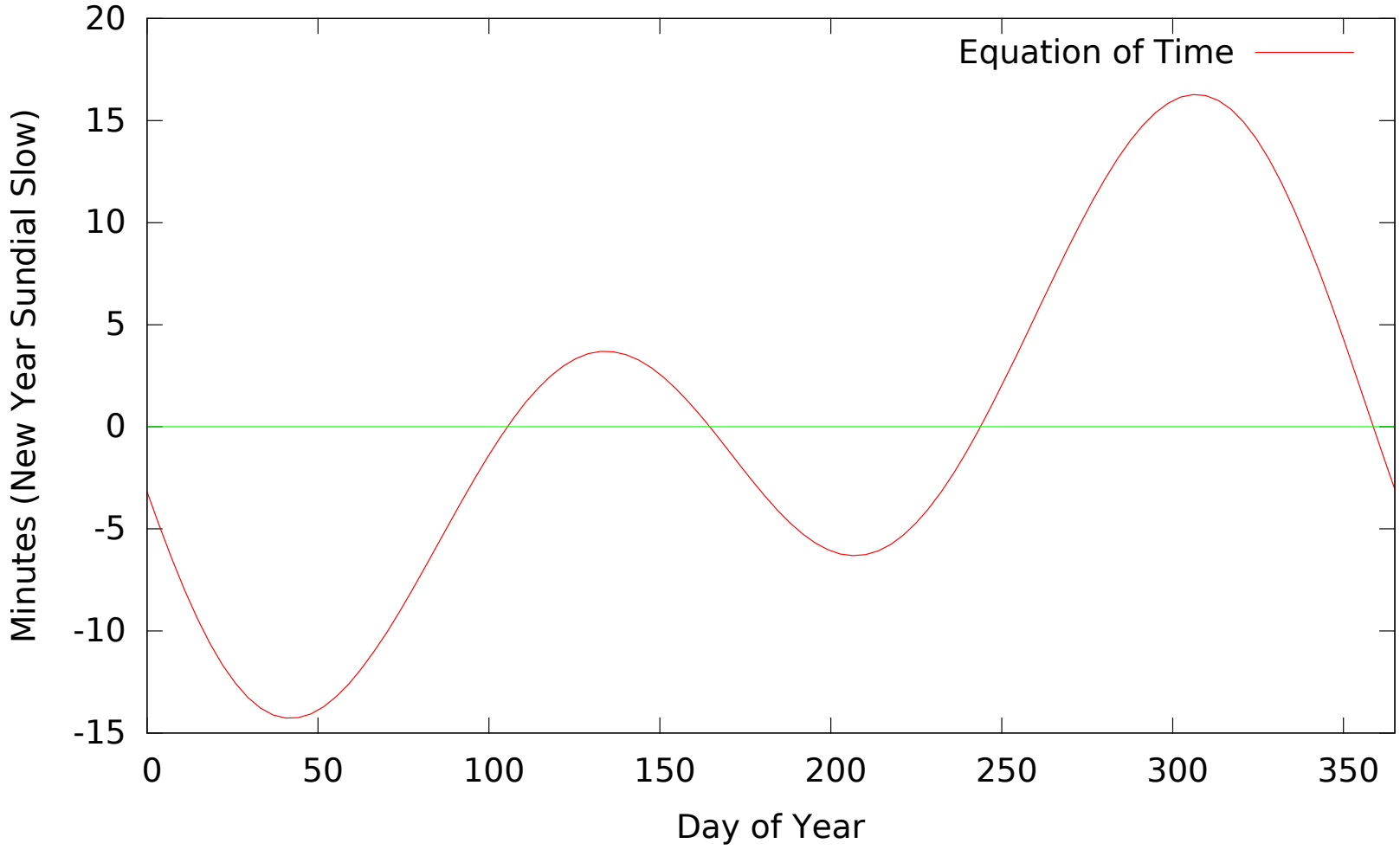
Were very uneven. Gradually fixed (14C).

Came to us via monastery and Roman army.

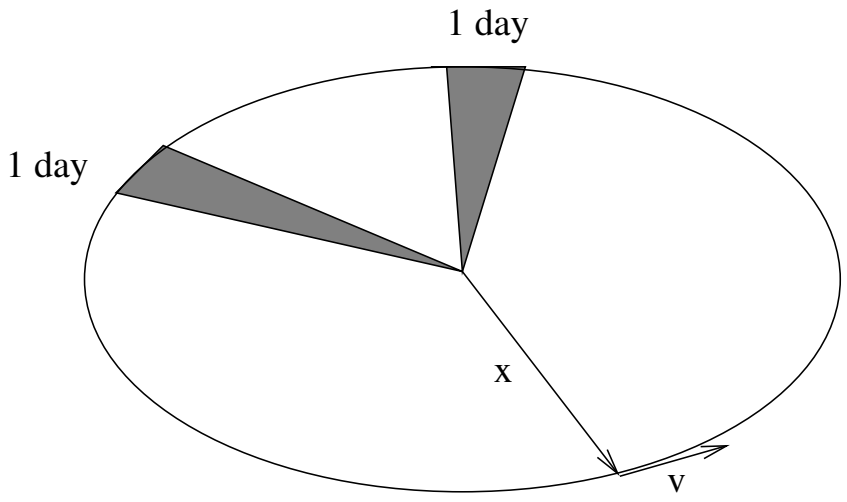
In 7C, lots of subdivisions, by middle ages we have *minutae primae* and *minutae secondae*.

Apparent vs. Mean Time

In 1792, move from apparent time to mean time.



Kepler's Second Law



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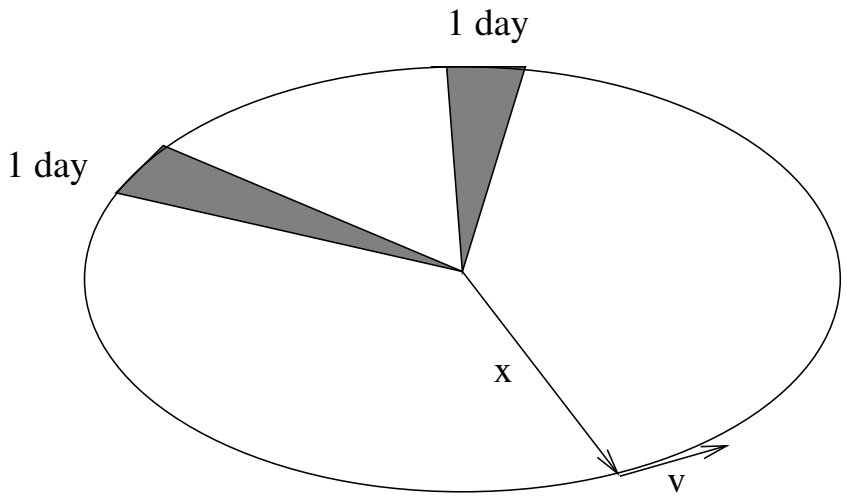

Differentiation:

$$\frac{d}{dt}\vec{x} = \vec{v}, \qquad \frac{d}{dt}\vec{v} = \vec{a}$$

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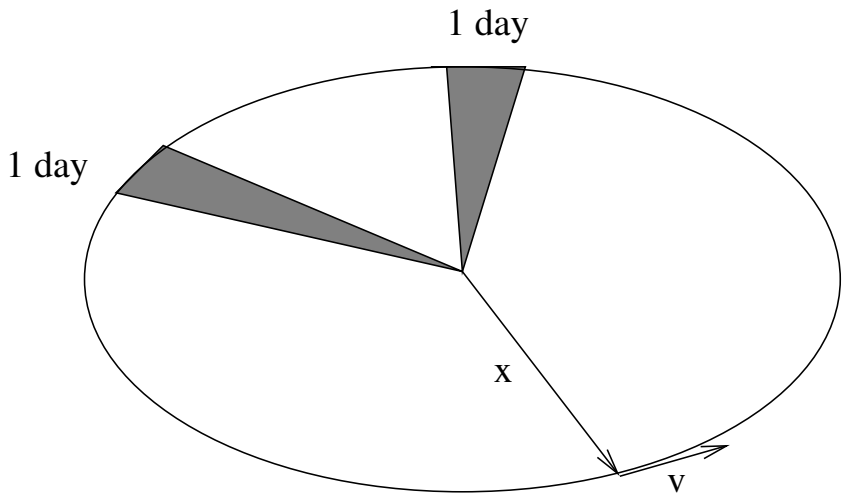

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Newton's Second Law:

$$\vec{F} = m\vec{a}$$

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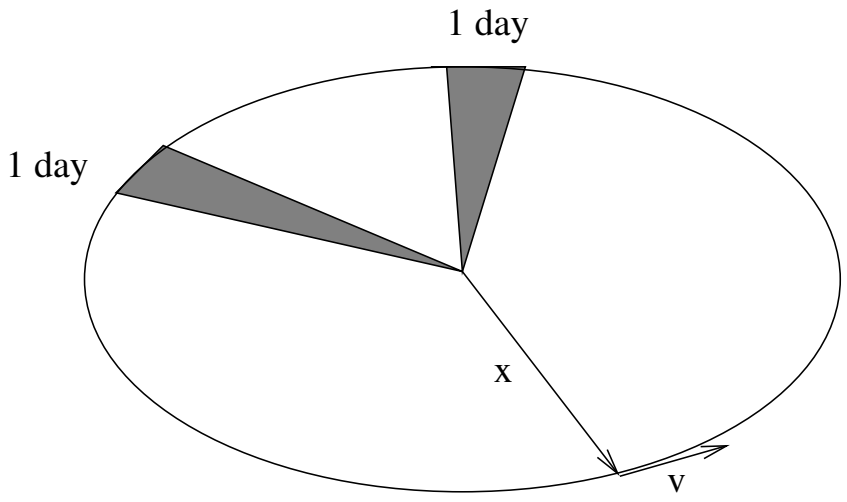

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Cross product gives area:

$$\text{Area} \quad = \quad \vec{v} \times \vec{x}$$

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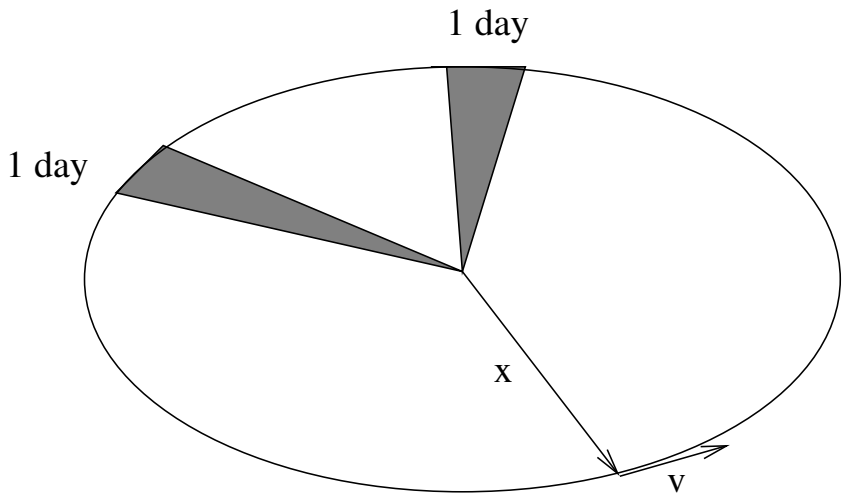

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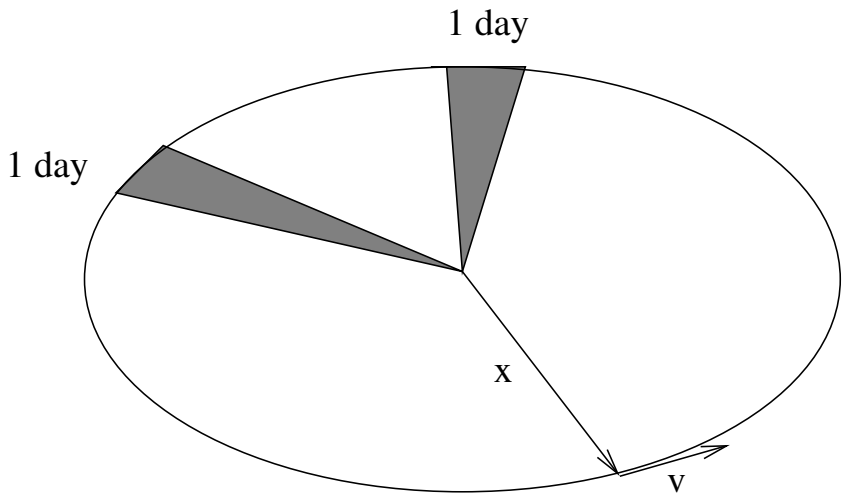

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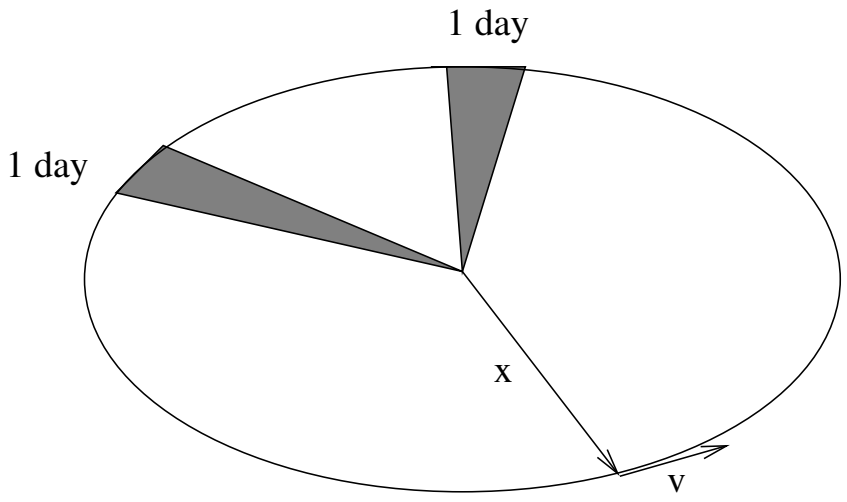

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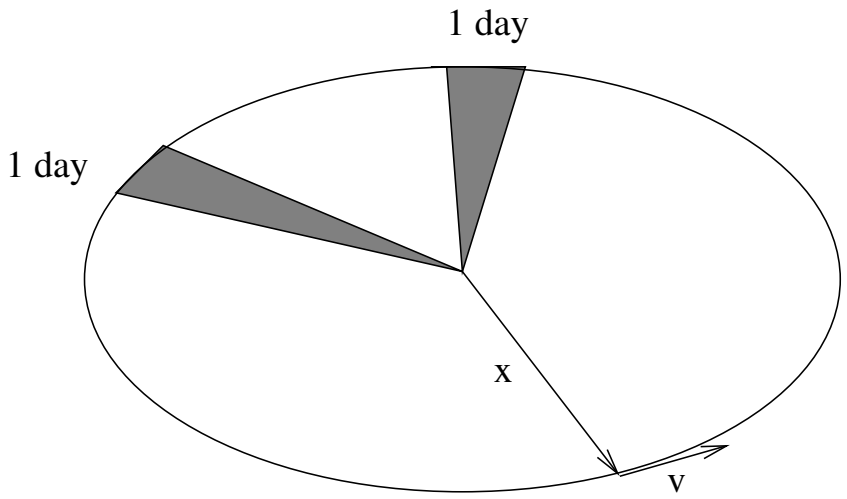

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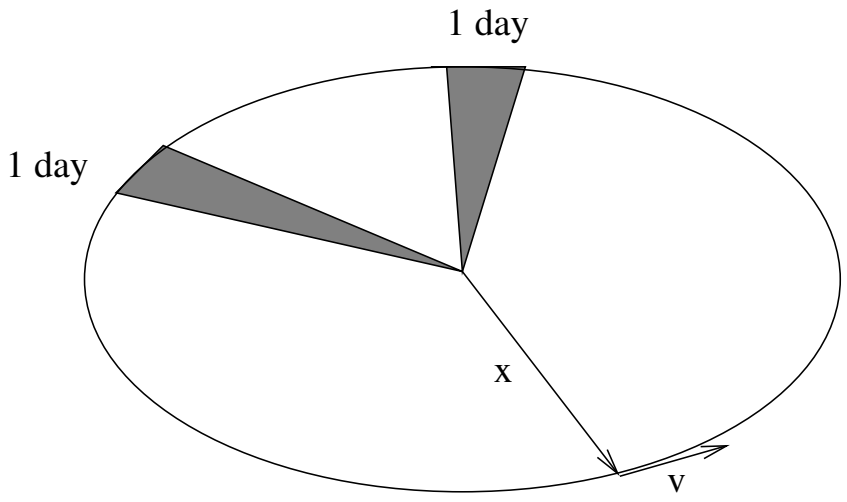

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Actually Conservation of Angular Momentum!

Irish Legal time

Problem with midnight — it depends where you live.

In 1858, case law chooses local time.

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

Dunsink Observatory made measurements.
Usher: 25m7–48s (1787).
Brinkley: 25m22s (1832).
Romney-
Robinson: 25m21s (1838).

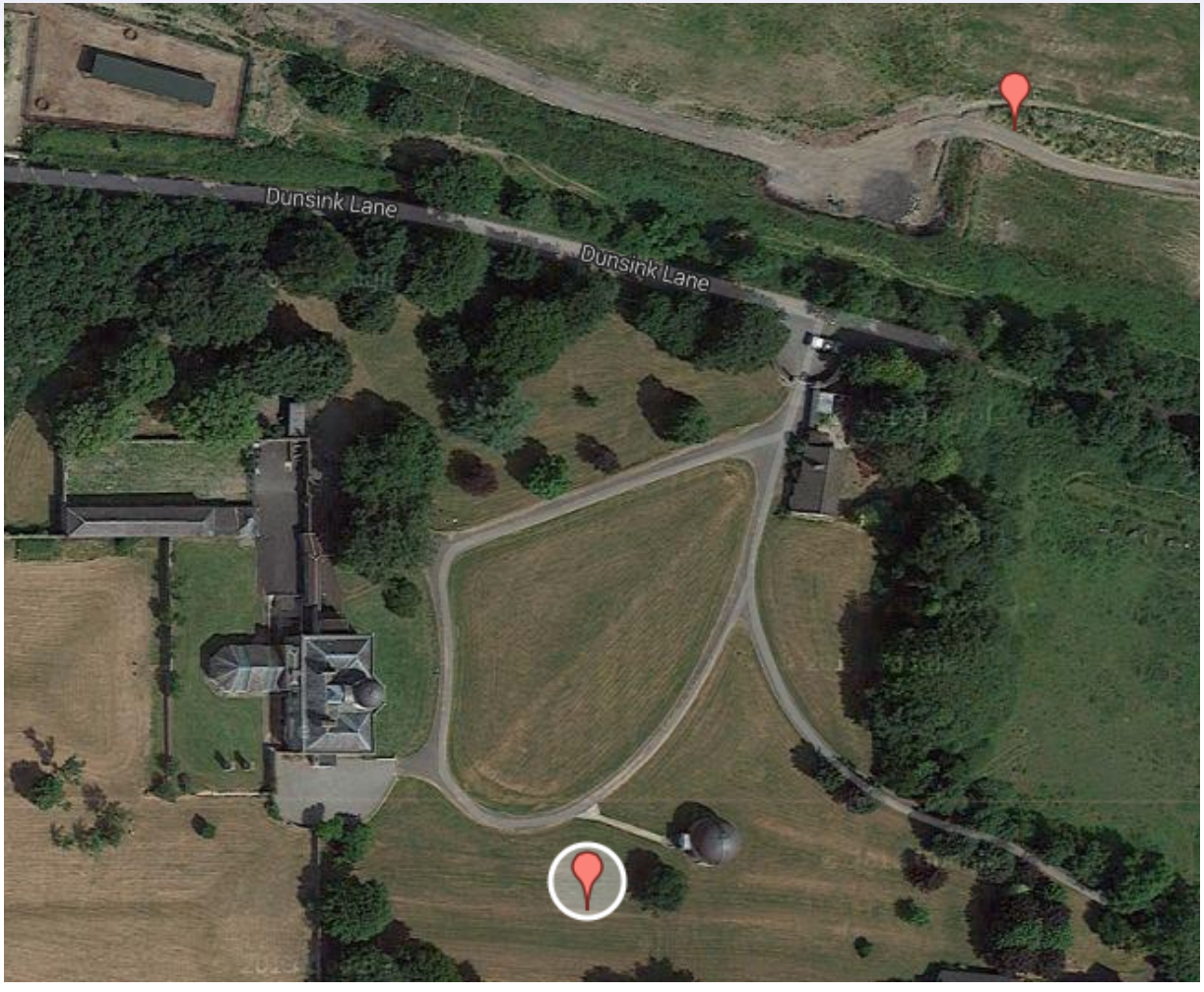


Image: Google Maps

$6°20.3′,53°23.2′$ vs $6°20.2′,53°23.3′$

Legal Time Since

1916	Move to GMT with GB
1916	Daylight saving
1923	Western-European Time
1941–5	No double Summer Time
1947	No double Summer Time
1968	Standard Time (GMT+1)
1971	Changed mind?
1986	Order giving effect to EEC directive
2001	2000/84/EU directive currently in force (from 2002 last Sun in March/October)

In this Act the expression 'West-European time' means Greenwich mean 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

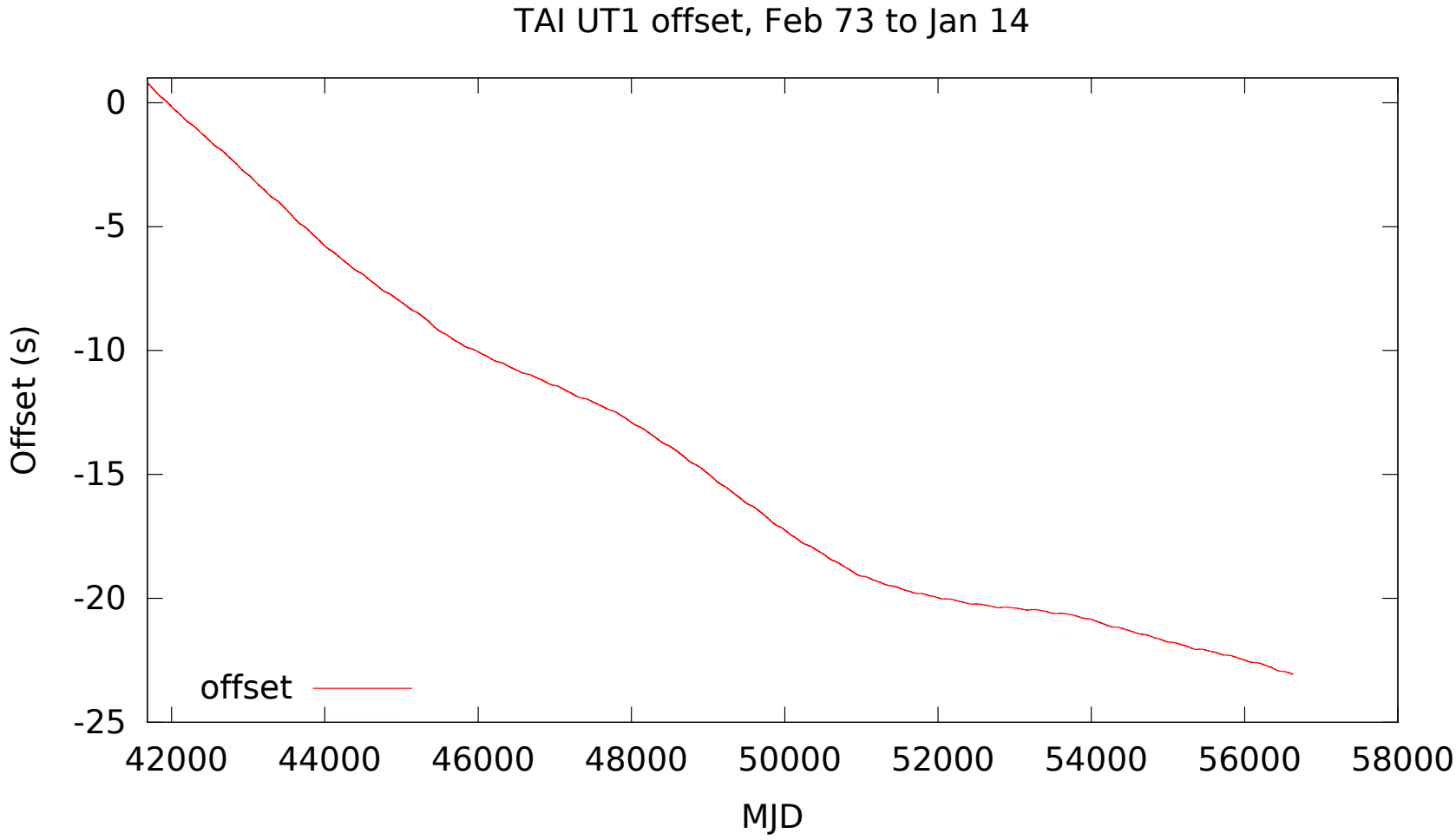
International Atomic Time has been available since 1955 (officially since 1972). Uses SI second.

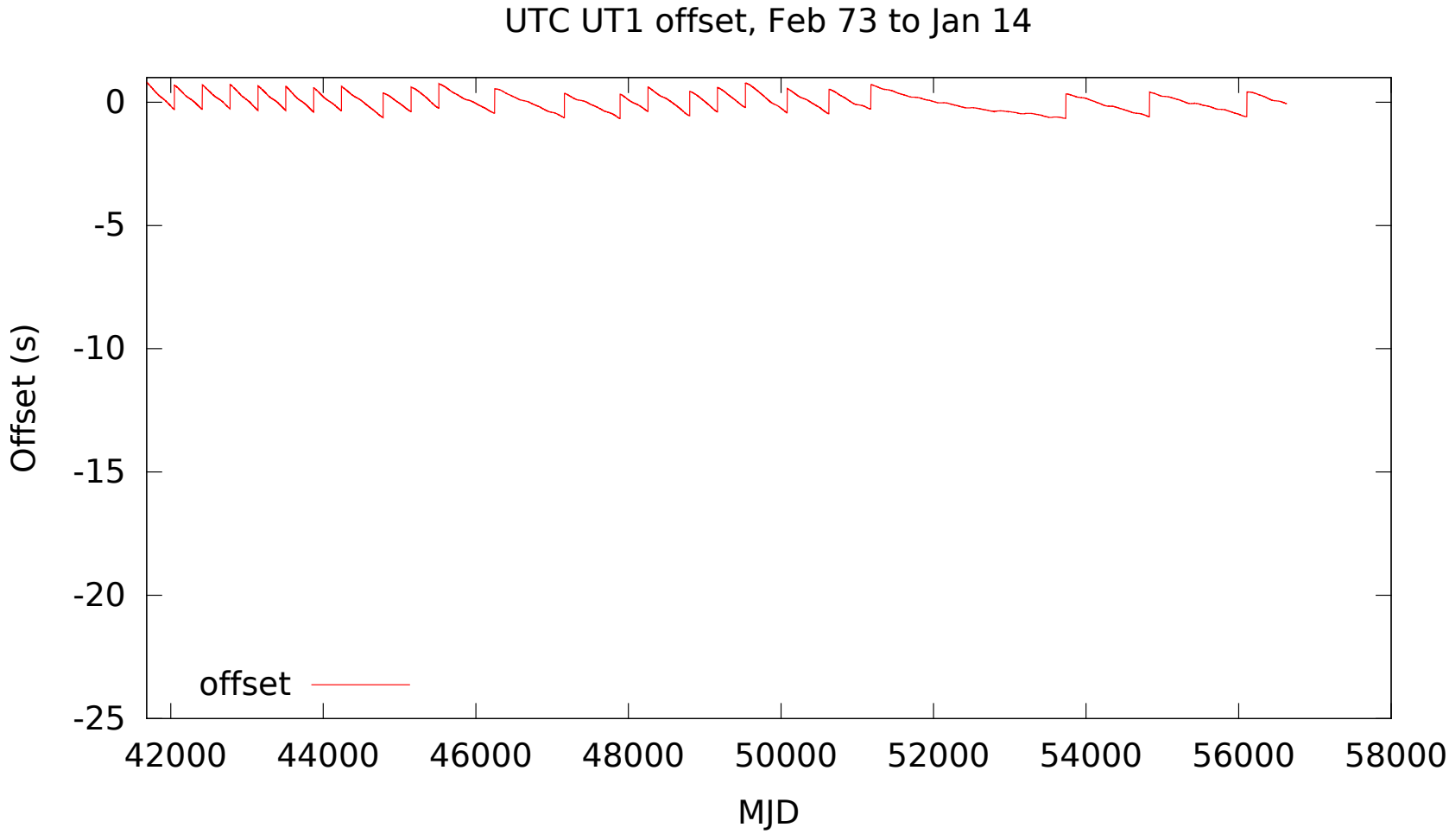
> *second:* In the International System of Units (SI), the time interval equal to 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

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 Jan 14
Offset (s)
0
-5
-10
-15
-20
-25
offset
42000
44000
46000
48000
50000
52000
54000
56000
58000
MJD


UTC UT1 offset, Feb 73 to Jan 14
Offset (s)
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-5
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50000
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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.

Check Your Watch

Image: Unknown, via Dublin Down Memory Lane

How do you set yours?

- TV or radio.
- Your computer.
- The speaking clock.
- Radio controlled clock.
- From other clock.
- GPS!

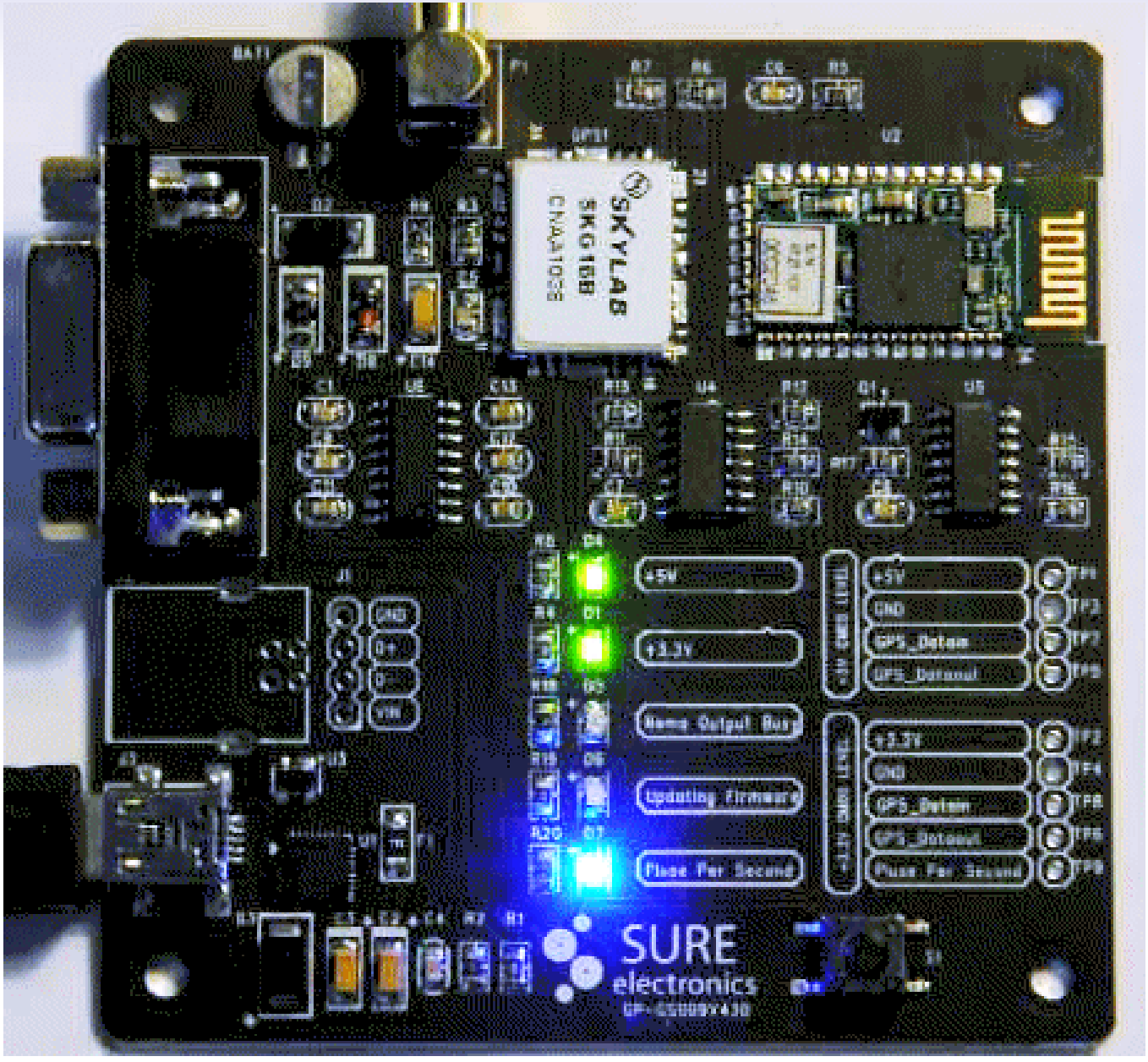

Image: David J Taylor