

Time standards

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Definition of Time

what clocks measure

- (attr. to physicists Albert Einstein, Donald Ivey, and others)

what prevents everything from happening at once

- (physicist John Wheeler and others)

a linear continuum of instants

- (philosopher Adolf Grünbaum)

a certain period during which something is done

- (Medical Dictionary)

a continuum that lacks spatial dimensions

- (Encyclopaedia Britannica)

dimension in which events can be ordered from the past through the present into the future, and also the measure of durations of events and the intervals between them

- (Wikipedia)

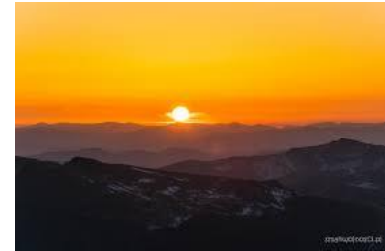
Time flow measurement



From...



Between...



Changing...

Time periods

- Sun / year

Interval of time between the same position of the Earth on the solar orbit (e.g. perihelium)

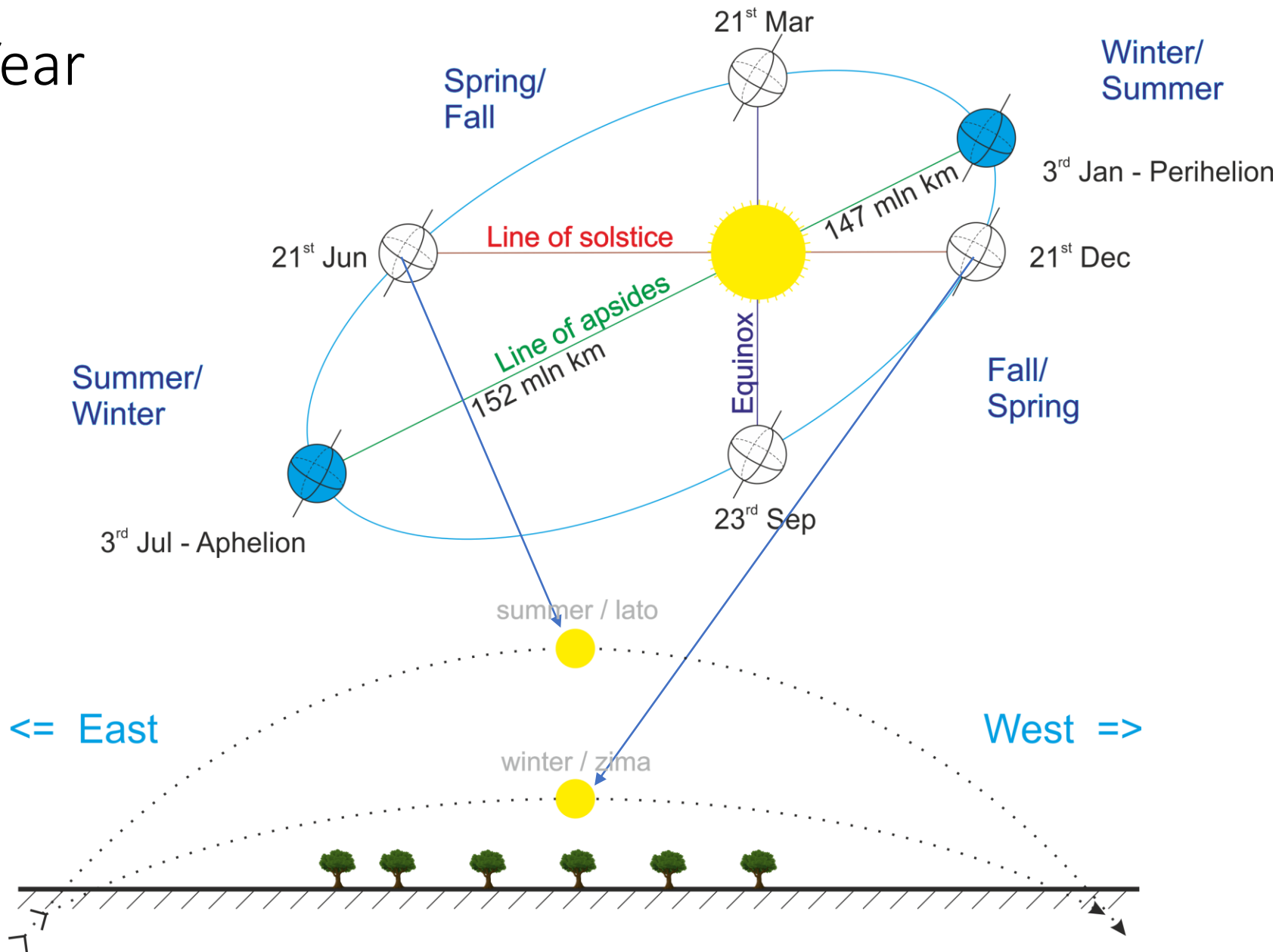
- Moon / month

Interval of time between the same phase of the Moon (e.g. new Moon).

- Earth / day

Interval of time, in which the Earth turn around its axis related to a celestial body.

Year



Year

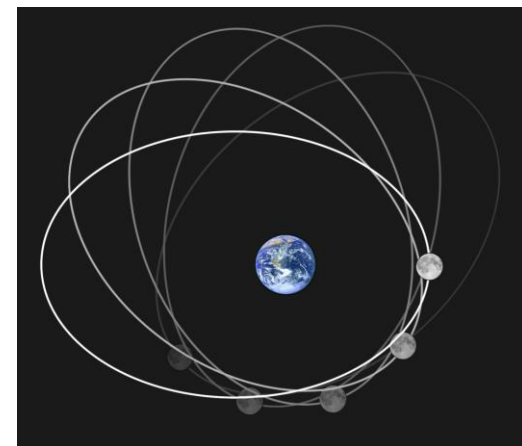
The full rotation on solar orbit takes 365.2422 days, therefore:

- Regular year lasts 365 and every 4 years leap year lasts 366 days
- The leap year fulfils one of the following conditions:
 1. is divisible by 4, but not is divisible by 100, or
 2. is divisible by 400

An example:

Year 2000:

1. $2000/4 = 500$ (the rest = 0) and $2000/100=20$ (the rest = 0)
the condition is not fulfilled
 2. $2000/400 = 5$ (the rest = 0) => the condition is fulfilled
- year 2000 is the leap year



Month

Average period in which Moon phases change equals 29.5 days,

which gives $12 \times 29.5 = 354$

While the orbital period of the Earth is 365.2422 days

The lacking almost 2 weeks are compensated by extension of the months.

Therefore, nowadays duration of the months equal 30 or 31 days except February which lasts 28 days (29 during leap years)

Moon Phases for Szczecin, Poland in 2018

Showing moon phases for:

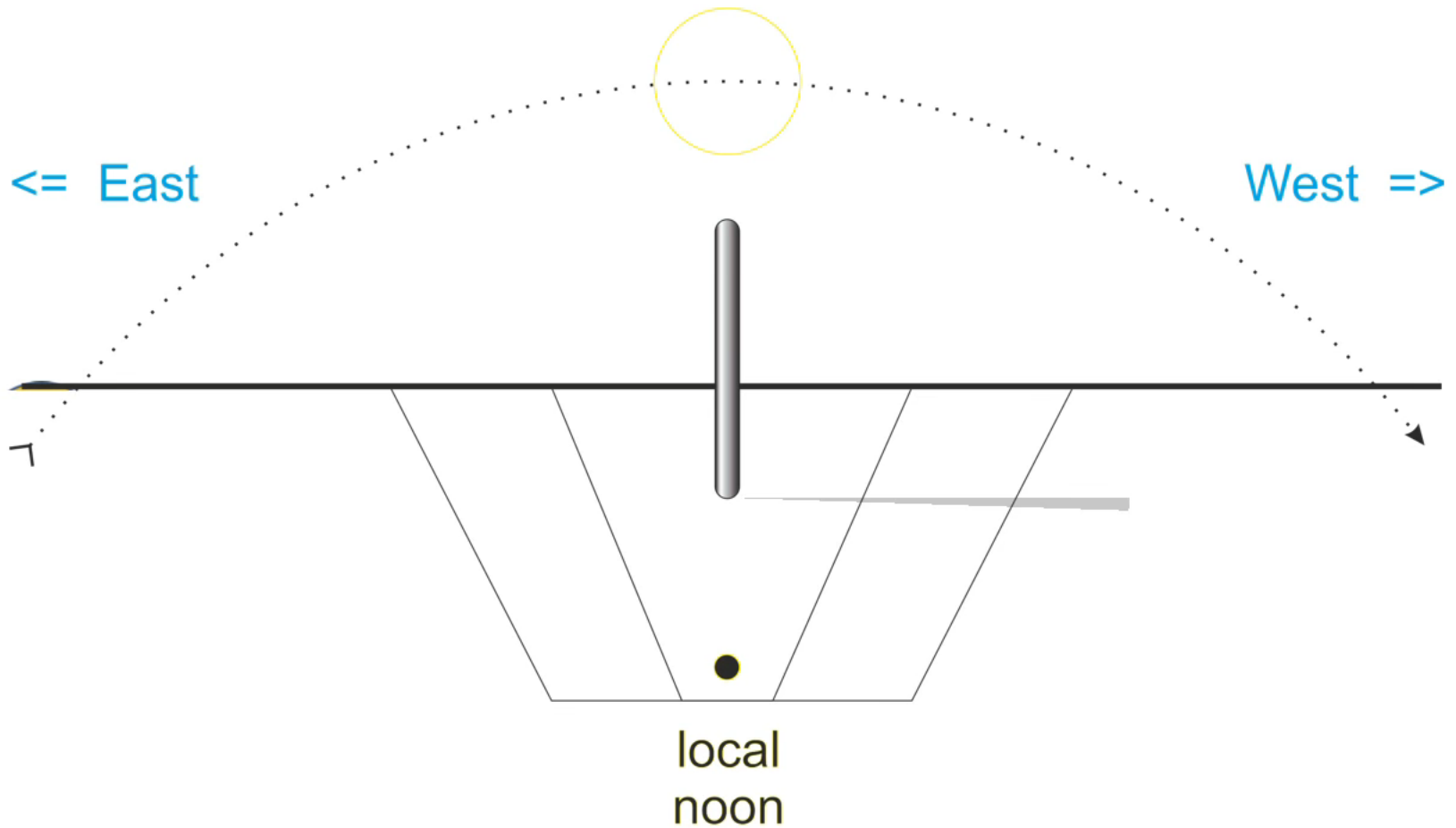
2018

Go

Lunation	New Moon		First Quarter		Full Moon		Third Quarter		Duration
1175					2 sty 03:24		8 sty 23:25		29d 19h 47m
1176	17 sty 03:17		24 sty 23:20		31 sty 14:26		7 lut 16:53		29d 18h 48m
1177	15 lut 22:05		23 lut 09:09		2 mar 01:51		9 mar 12:19		29d 16h 06m
1178	17 mar 14:11		24 mar 16:35		31 mar 14:36		8 kwi 09:17		29d 12h 46m
1179	16 kwi 03:57		22 kwi 23:45		30 kwi 02:58		8 maj 04:08		29d 9h 51m
1180	15 maj 13:47		22 maj 05:49		29 maj 16:19		6 cze 20:31		29d 7h 55m
1181	13 cze 21:43		20 cze 12:50		28 cze 06:53		6 lip 09:50		29d 7h 05m
1182	13 lip 04:47		19 lip 21:52		27 lip 22:20		4 sie 20:17		29d 7h 10m
1183	11 sie 11:57		18 sie 09:48		26 sie 13:56		3 wrz 04:37		29d 8h 04m
1184	9 wrz 20:01		17 wrz 01:14		25 wrz 04:52		2 paz 11:45		29d 9h 45m
1185	9 paz 05:46		16 paz 20:01		24 paz 18:45		31 paz 17:40		29d 12h 15m
1186	7 lis 17:01		15 lis 15:54		23 lis 06:39		30 lis 01:18		29d 15h 18m
1187	7 gru 08:20		15 gru 12:49		22 gru 18:48		29 gru 10:34		29d 18h 08m

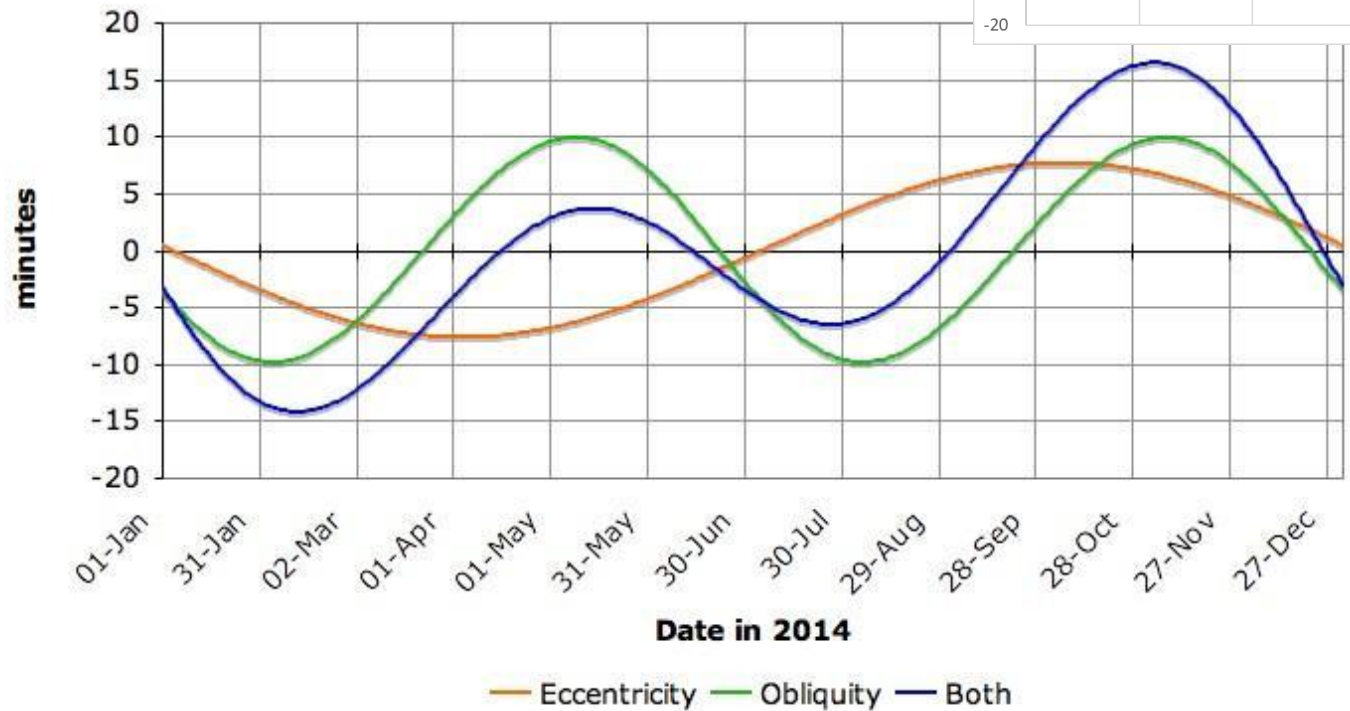
* All times are local time for Szczecin. Time is adjusted for DST when applicable. They take into account refraction. Dates are based on the [Gregorian calendar](#).

Solar day - apparent

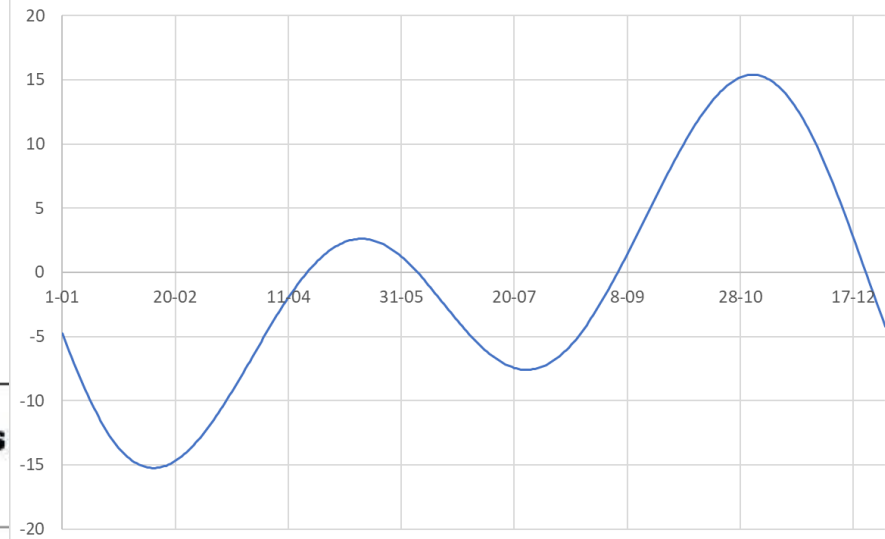


Solar day - mean

Equation of Time Components



Difference in day length in 2018, Warszawa



The difference between mean and apparent solar time is known as the equation of time

Mean solar day



- This is usually expressed as a correction, never exceeding 16 minutes, that is added to or subtracted from apparent solar time to determine mean solar time.

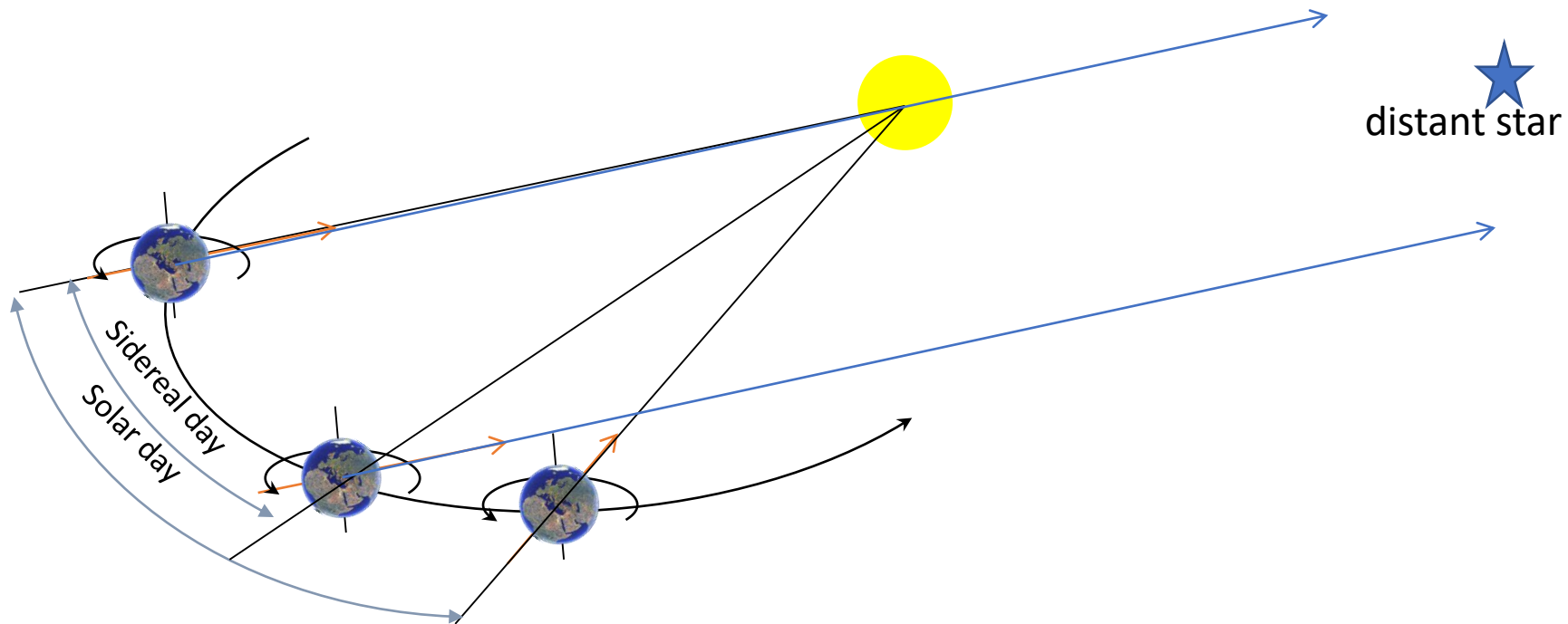
Mean solar day



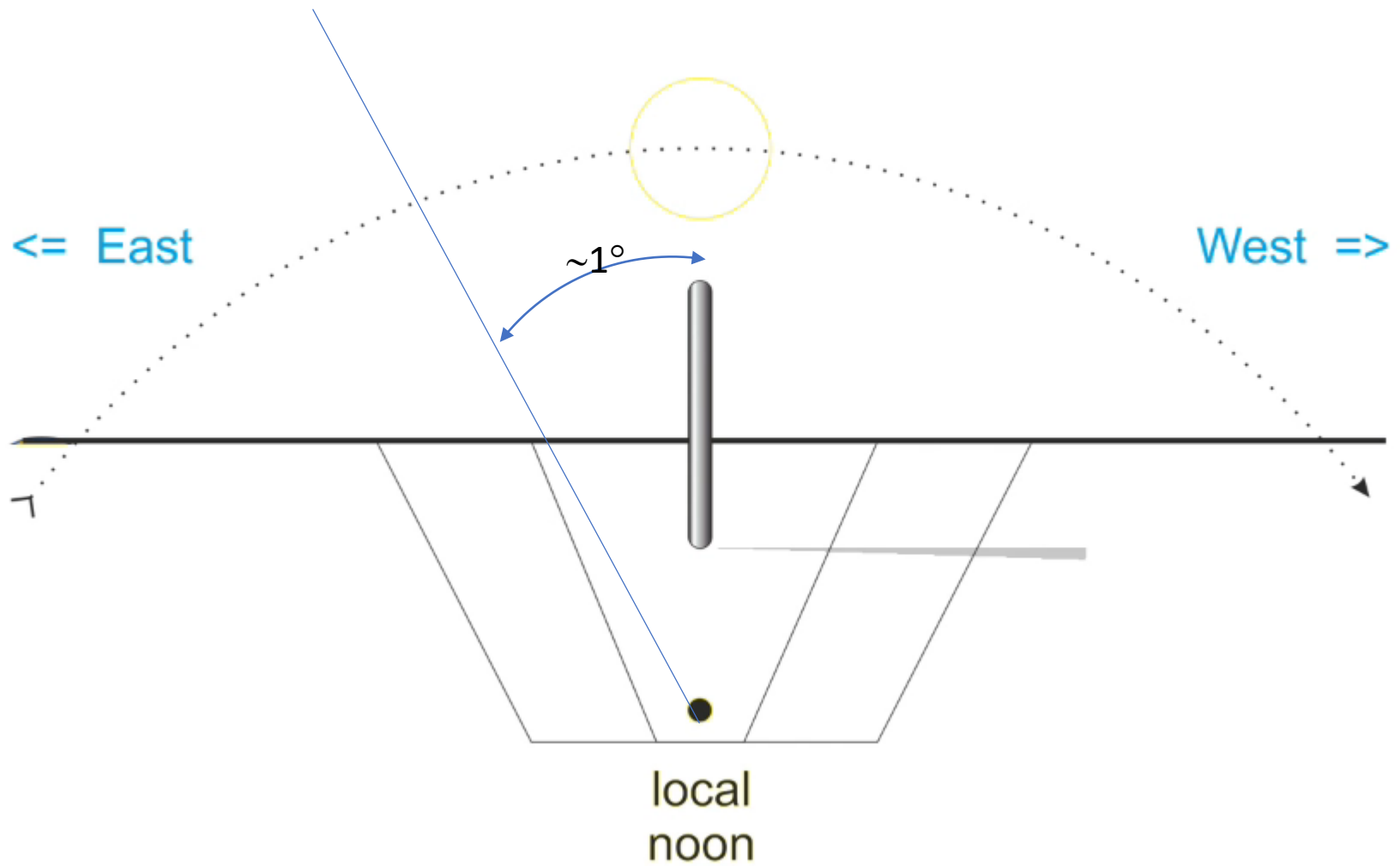
- The previous time standard with mean solar day – GMT
- Now UT = GMT
- UT1 – UT corrected for the pole movement (ab. 0.035 s)
- UT2 – UT1 additionally corrected for seasonal variation of rotation speed of the Earth
- The unit of time, the second, was at one time considered to be the fraction $\frac{1}{86\,400}$ of the mean solar day ($24\text{h} \times 60\text{min} \times 60\text{sec}$).

Sidereal day

- 1 turn for 1 year $\Rightarrow 360^\circ/365 \text{ days} \approx 1^\circ \approx 4 \text{ minutes}$



Sideral day



Time measurement

However measurements showed that irregularities in the rotation of the Earth made this an unsatisfactory definition.

- **Rozporządzenie Rady Ministrów z dnia 30 listopada 2006 r. w sprawie legalnych jednostek miar**
 - sekunda — czas równy 9 192 631 770 okresom promieniowania odpowiadającego przejściu między dwoma nadsubtelnymi poziomami stanu podstawowego atomu cezu 133
- **SI Brochure: The International System of Units (SI) [8th edition, 2006; updated in 2014]**
 - The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

TAI – International Atomic Time

IERS – International Earth Rotation and Reference Systems Service
(before: International Earth Rotation Service)

– the institution responsible for atomic scale

On 01/01/1950 TAI was fixed to agree with UT1:

$$\text{TAI} - \text{UT1} = 0 \text{ [s]}$$

TAI constantly deviate from UTA due to variation of the Earth rotation,
in 2015:

$$\text{TAI} - \text{UT1} = 36 \text{ [s]}$$

UTC – Universal Time Coordinated

- Compromise – seconds are a constant interval of time (SI seconds) but the scale is coordinated to agree with UT1 using leap seconds
- It is a weighted average of approximately 420 atomic clocks around the world:

$$\text{UTC} = \text{TAI} - n \text{ [s]}$$

- The n number is a whole number of leap seconds which changes to keep deviation between UTC and UT1 within 0.9 [s] (IERS)

$$|\text{UTC} - \text{UT1}| < 0.9 \text{ [s]}$$

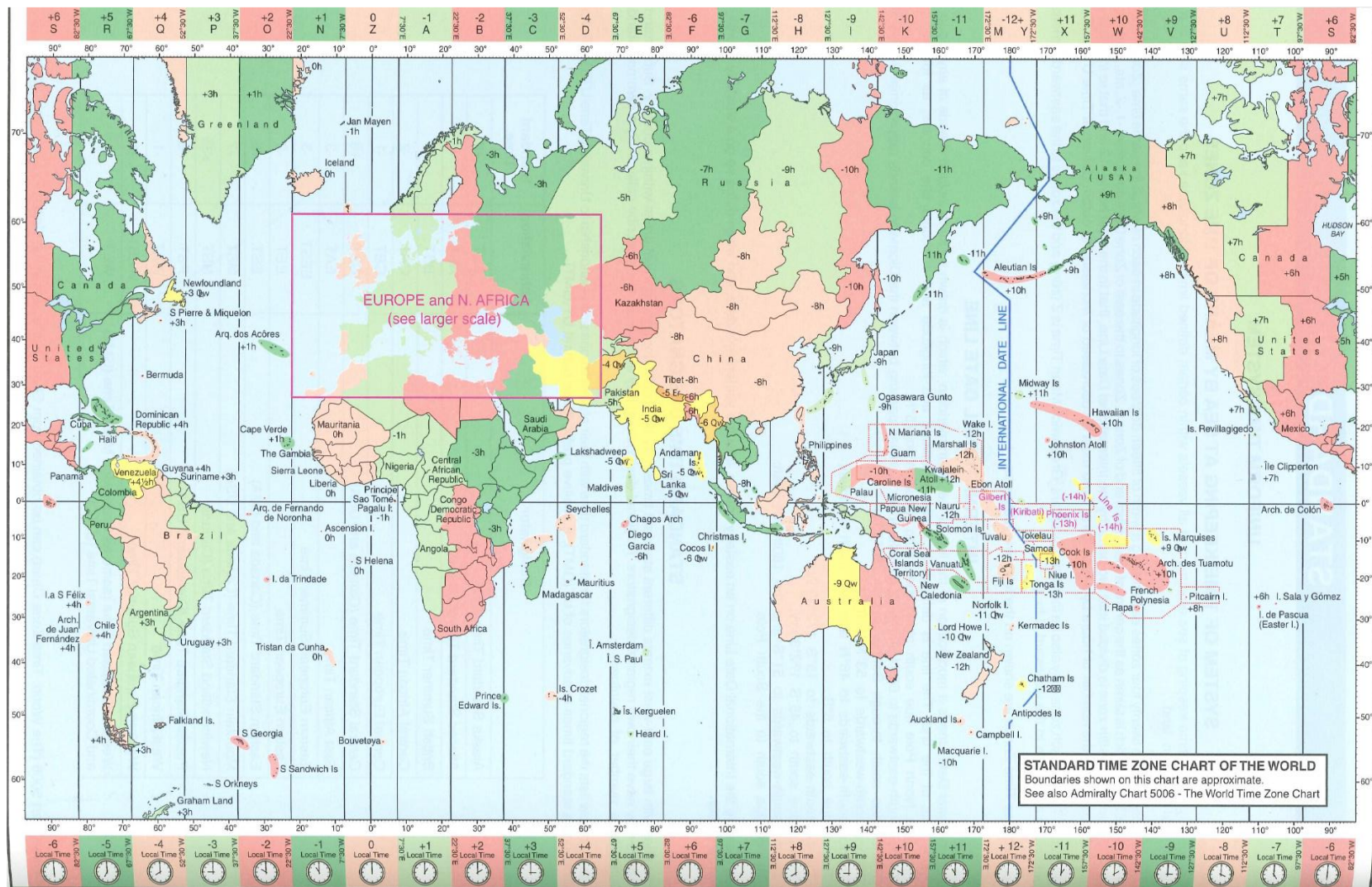
Positive leap second	TAI - UTC
30/06/1985	23
31/12/1987	24
31/12/1989	25
31/12/1990	26
30/06/1992	27
30/06/1993	28
30/06/1994	29
31/12/1995	30
30/06/1997	31
31/12/1998	32
31/12/2005	33
31/12/2008	34
30/06/2012	35
30/06/2015	36
31/12/2016	37

UTC – Universal Time Coordinated

- DUT1 – predicted difference between UTC and UT1 (0.1 s precision)

Start Date	Time	DUT1 Correction
2017-11-30	0000 UTC	+0.2 s
2017-06-29	0000 UTC	+0.3 s
2017-03-30	0000 UTC	+0.4 s
2017-01-26	0000 UTC	+0.5 s
2017-01-01	0000 UTC	+0.6 s
2016-11-17	0000 UTC	-0.4 s
2016-09-01	0000 UTC	-0.3 s
2016-05-19	0000 UTC	-0.2 s
2016-03-24	0000 UTC	-0.1 s
2016-01-31	0000 UTC	0.0 s
2015-11-26	0000 UTC	+0.1 s
2015-09-11	0000 UTC	+0.2 s
2015-07-01	0000 UTC	+0.3 s
2015-05-28	0000 UTC	- 0.7 s
2015-03-19	0000 UTC	- 0.6 s
2014-12-25	0000 UTC	- 0.5 s
2014-09-25	0000 UTC	- 0.4 s

Standard Times



Standard times

LEGAL TIME

The following list gives the decreed Legal Time in each territory. A negative prefix denotes Legal Times in advance of UT(GMT); a positive prefix, those behind UT(GMT).

Where there is a seasonal change from the Standard Time normally in force to Daylight Saving Time (DST) or Summer Time, details are given. An asterisk indicates that a territory is not expected to observe DST in the current year. DST dates followed by the letter E are estimates. Certain Islamic countries that observe DST may revert to their standard time during the 29 day period of Ramadan.

The list is amended in Section VI of the Weekly Edition of Admiralty Notices to Mariners as changes become known.

Standard Time Zone Charts of the World and of Europe & N. Africa are published on the preceding pages. See also Admiralty Chart 5006.

Territory	Standard Time	Daylight Saving Time		
			Begins (LT)	Ends (LT)
Açôres, Arquipélago dos (Portugal)	+1	0	Last Sunday in March 0000h	Last Sunday in October 0100h
Afghanistan	-4½	*		
Albania	-1	-2	Last Sunday in March 0200h	Last Sunday in October 0300h
Algeria	-1	*		
American Samoa	+11	*		
Amirantes, Les	-4	*		
Amsterdam, Île (France)	-5	*		
Andaman Islands (India)	-5½	*		
Andorra	-1	-2	Last Sunday in March 0200h	Last Sunday in October 0300h
Angola	-1	*		
Anguilla (UK)	+4	*		
Antigua	+4	*		
Argentina	+3	*		

ADMIRALTY List of Radio Signals vol. 2

GPS time

- GPS has its own time scale
- It differs from UTC by an almost whole number of seconds:

$$GPS_{time} - UTC = n \cdot s - C_t$$

where:

n – whole number of seconds

C_t – correction which equals a few nanoseconds

GPS time

- GPS time doesn't use leap seconds to agree with UT1, like UTC does
- On 05.01.1980, when the system has been launched, the GPS time was synchronised with UTC, and difference to TAI equaled 19 seconds

local	2018-02-26 11:52:52	Monday	day 057	timezone UTC+1
UTC	2018-02-26 10:52:52	Monday	day 057	MJD 58175.45337
GPS	2018-02-26 10:53:10	week 1990	125590 s	cycle 1 week 0966 day 1
Loran	2018-02-26 10:53:19	GRI 9940	146 s until	next TOC 10:55:18 UTC
TAI	2018-02-26 10:53:29	Monday	day 057	37 leap seconds

<http://leapsecond.com/java/gpsclock.htm>

The end

