

To get the full value of joy you must have
someone to divide it with.

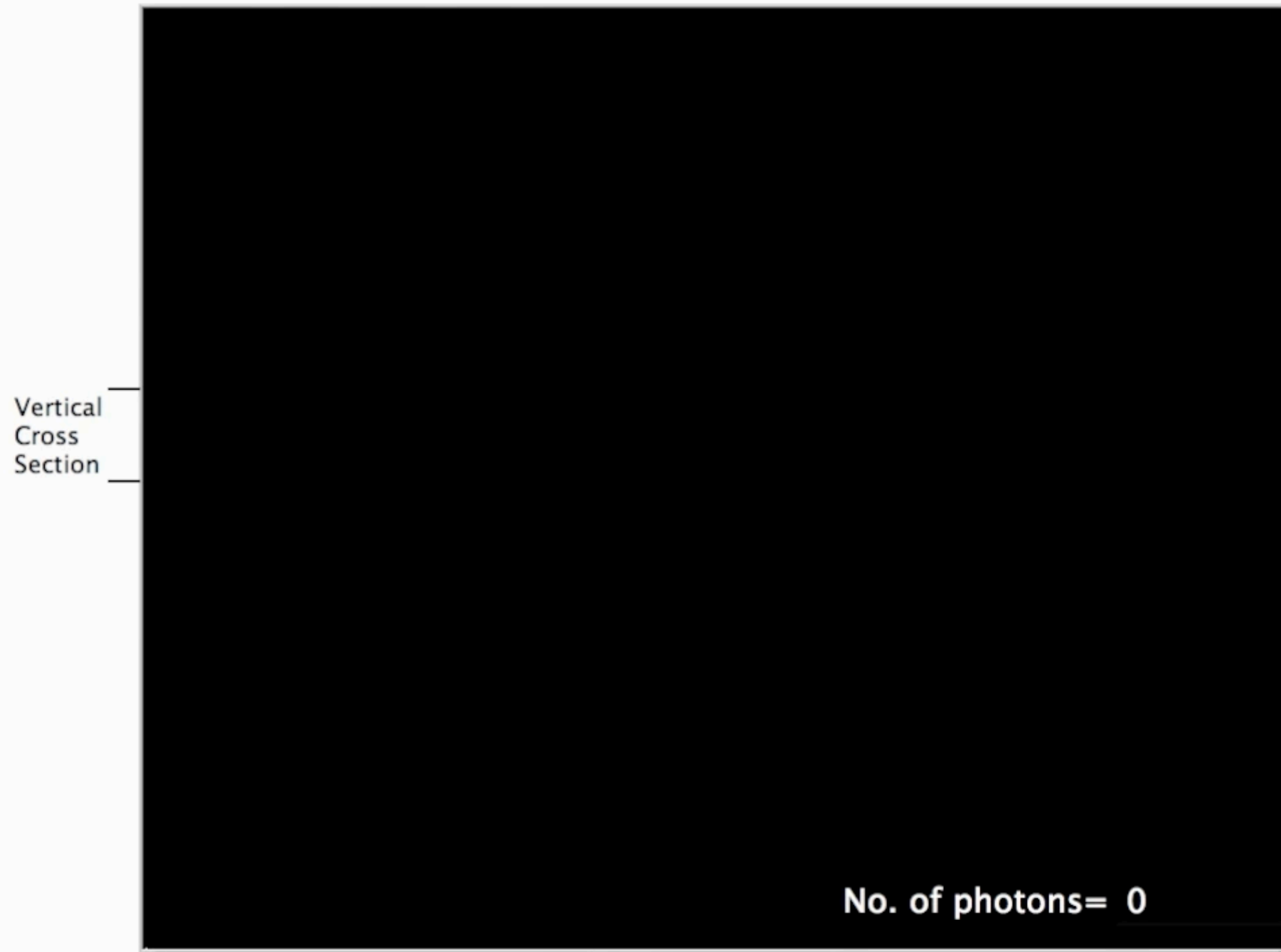
– Mark Twain

Midterm review

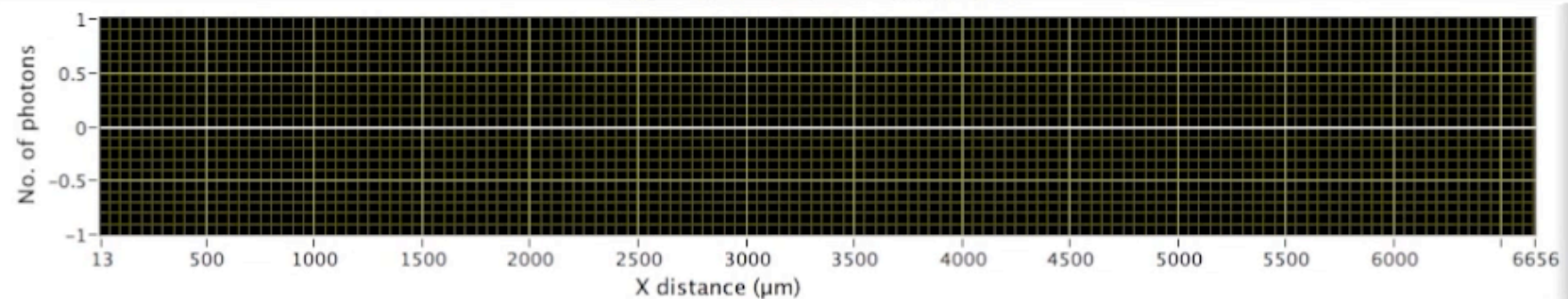
Things you'd like me to review

- ~~Two (laser) colors beating together~~
- ~~The series of questions on both example midterms regarding the laser/mirror configuration~~
- ~~Basic diffraction and interference~~
- Use of marine chronometers/early navigation
 - Trains and time zones+
- Light clocks

Young's double slit with a coherent source photon by photon

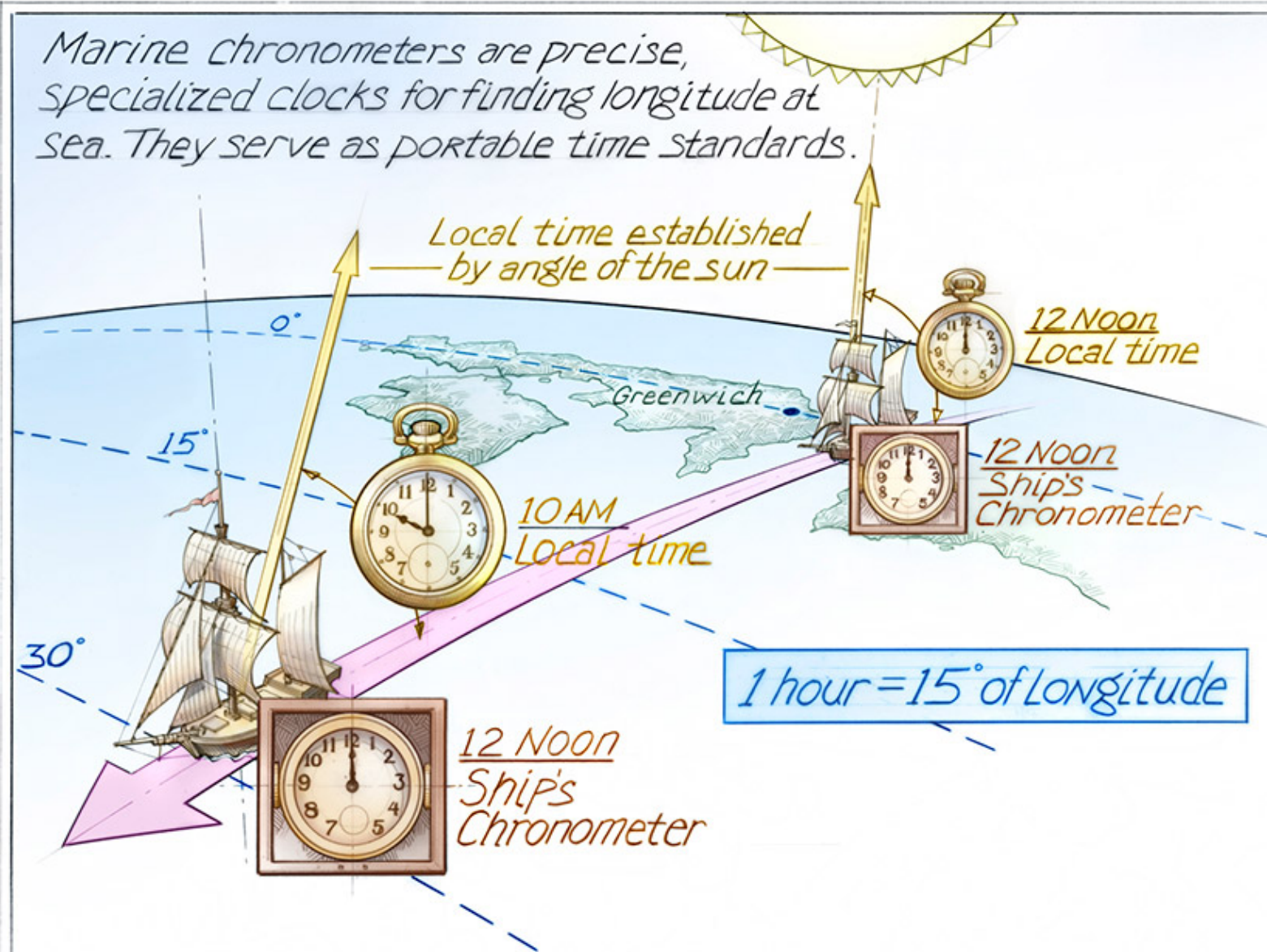


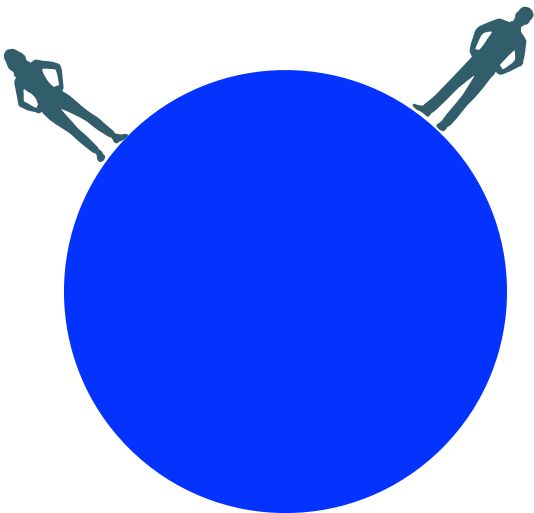
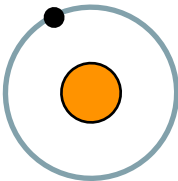
Vertical cross section



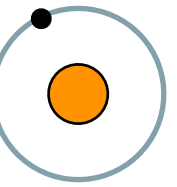
USING A MARINE CHRONOMETER

Marine chronometers are precise, specialized clocks for finding longitude at sea. They serve as portable time standards.

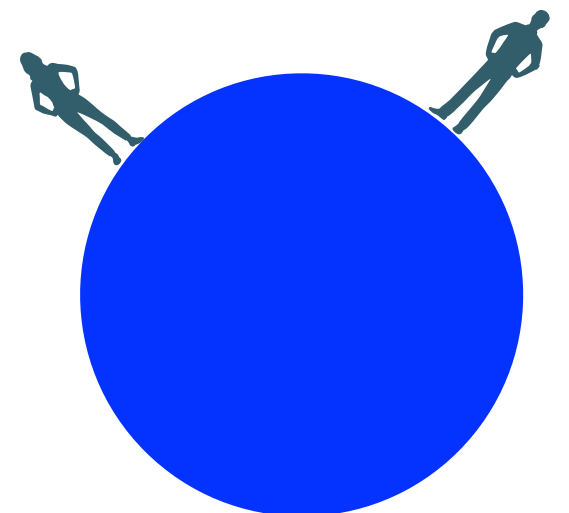




Local time & longitude



- Until recently, ‘time’ *meant* local time
- Depending on where you are east-west, stars, sun, & planets will appear at different angles above the horizon
- ‘Angle above horizon’ (east-west) is a *synonym* for ‘local time’
- Need *either* concurrent observations, or to know what time it is somewhere else



The full process

Observing stars
to measure local
time



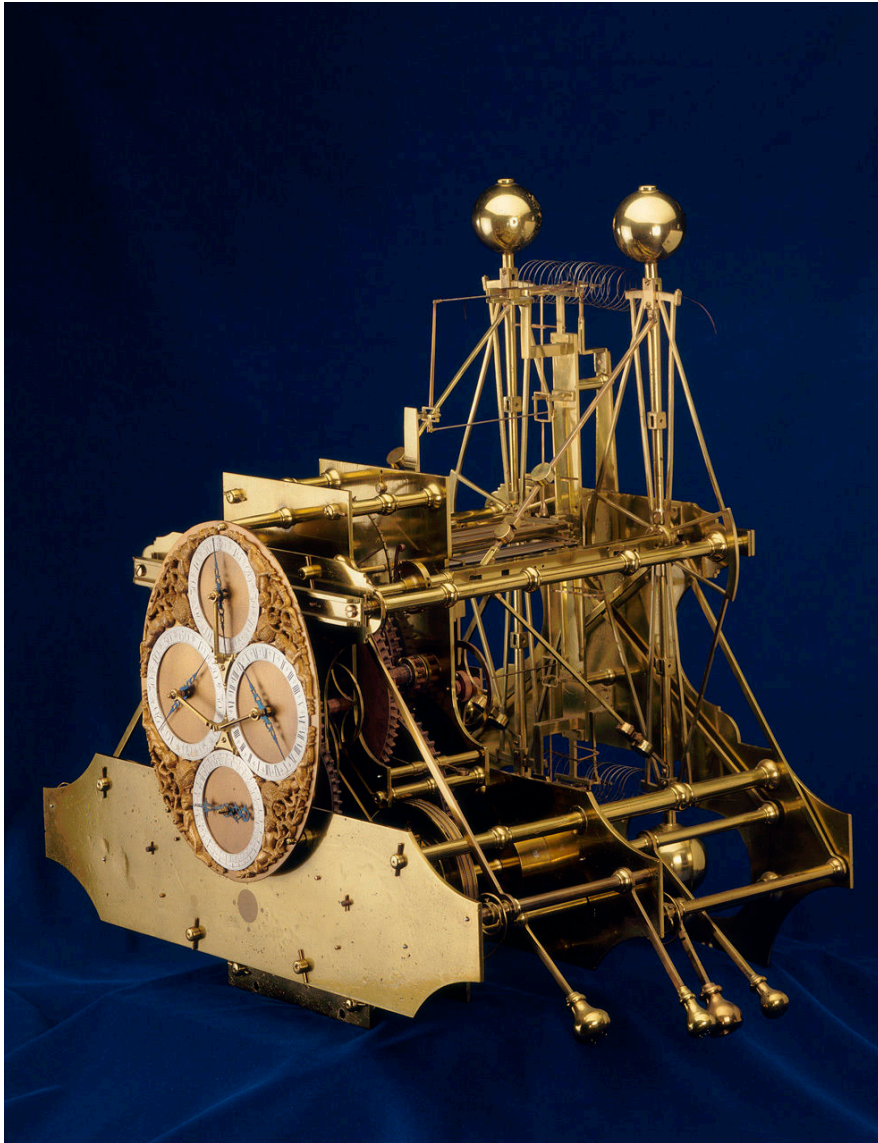
Time ball to tell ships the time



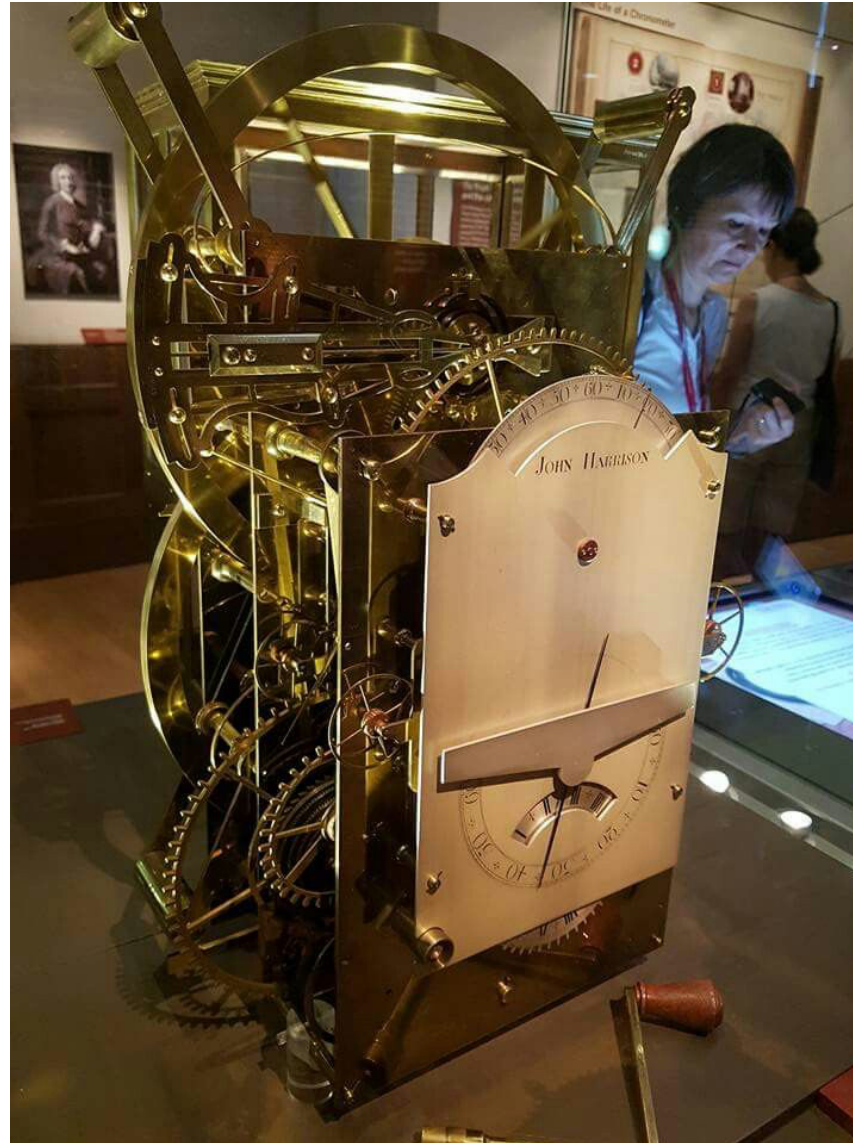
Finding local time (angle above horizon of stars or sun)



John Harrison & Longitude



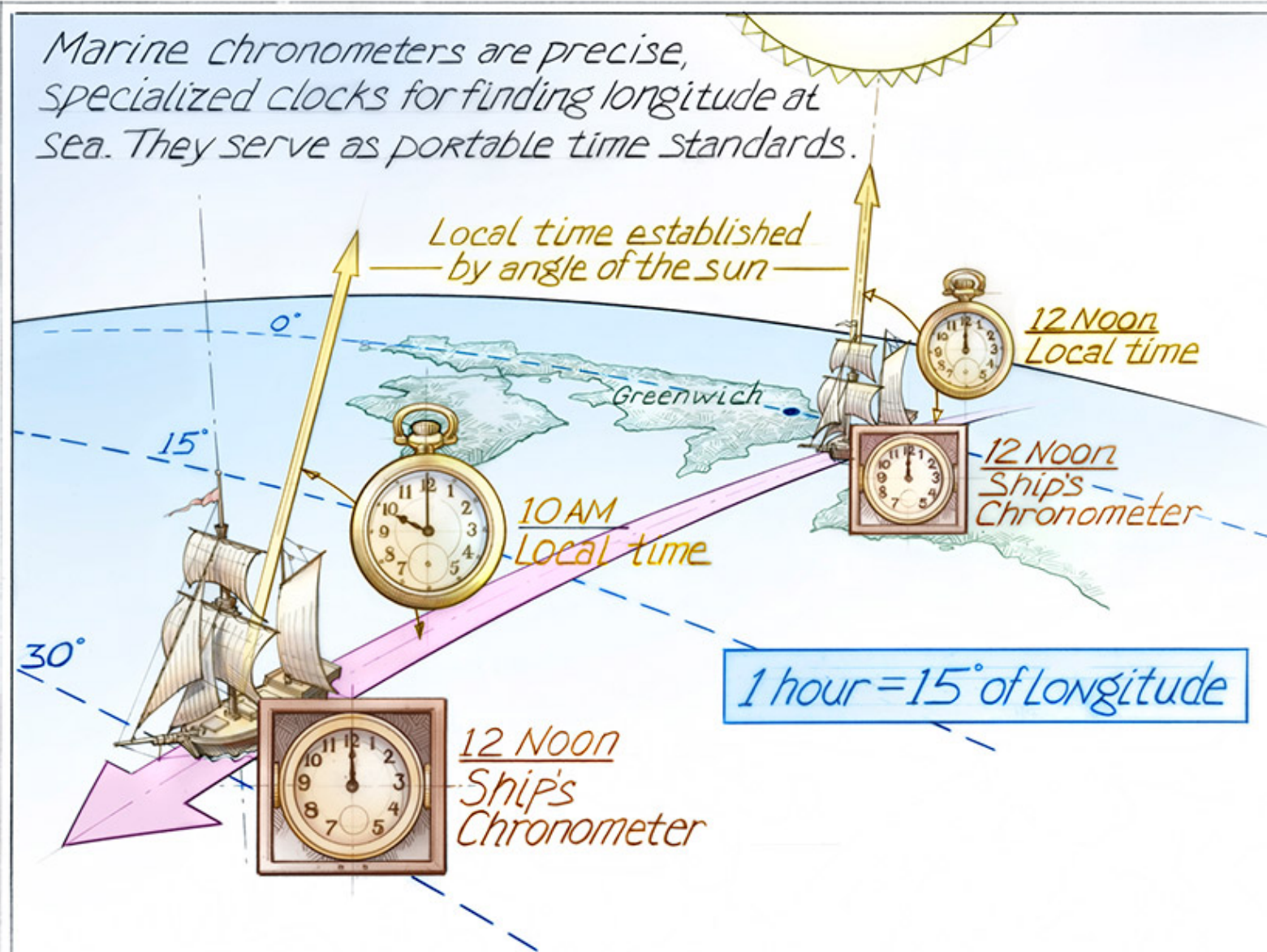
H1



Arnold chronometer

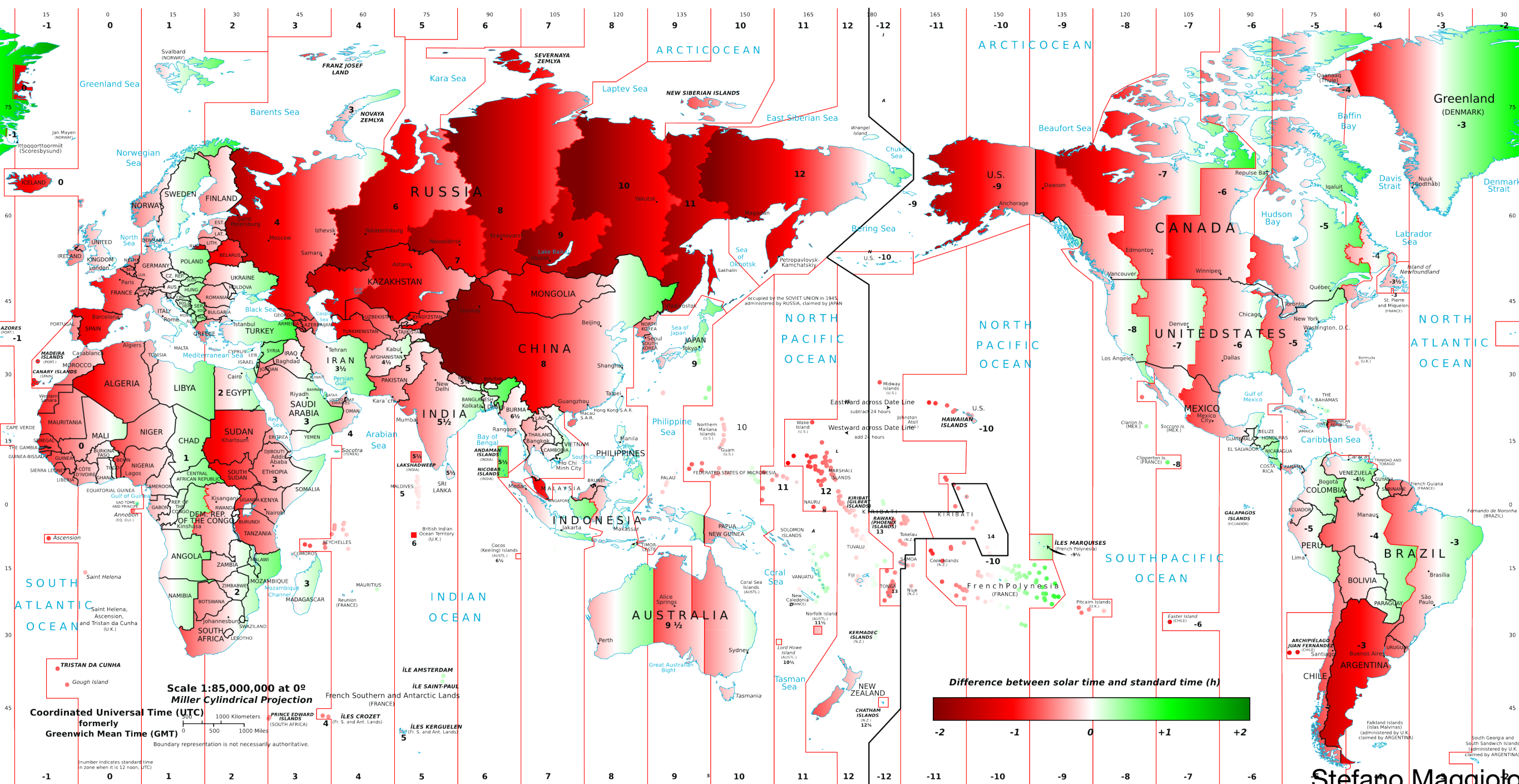
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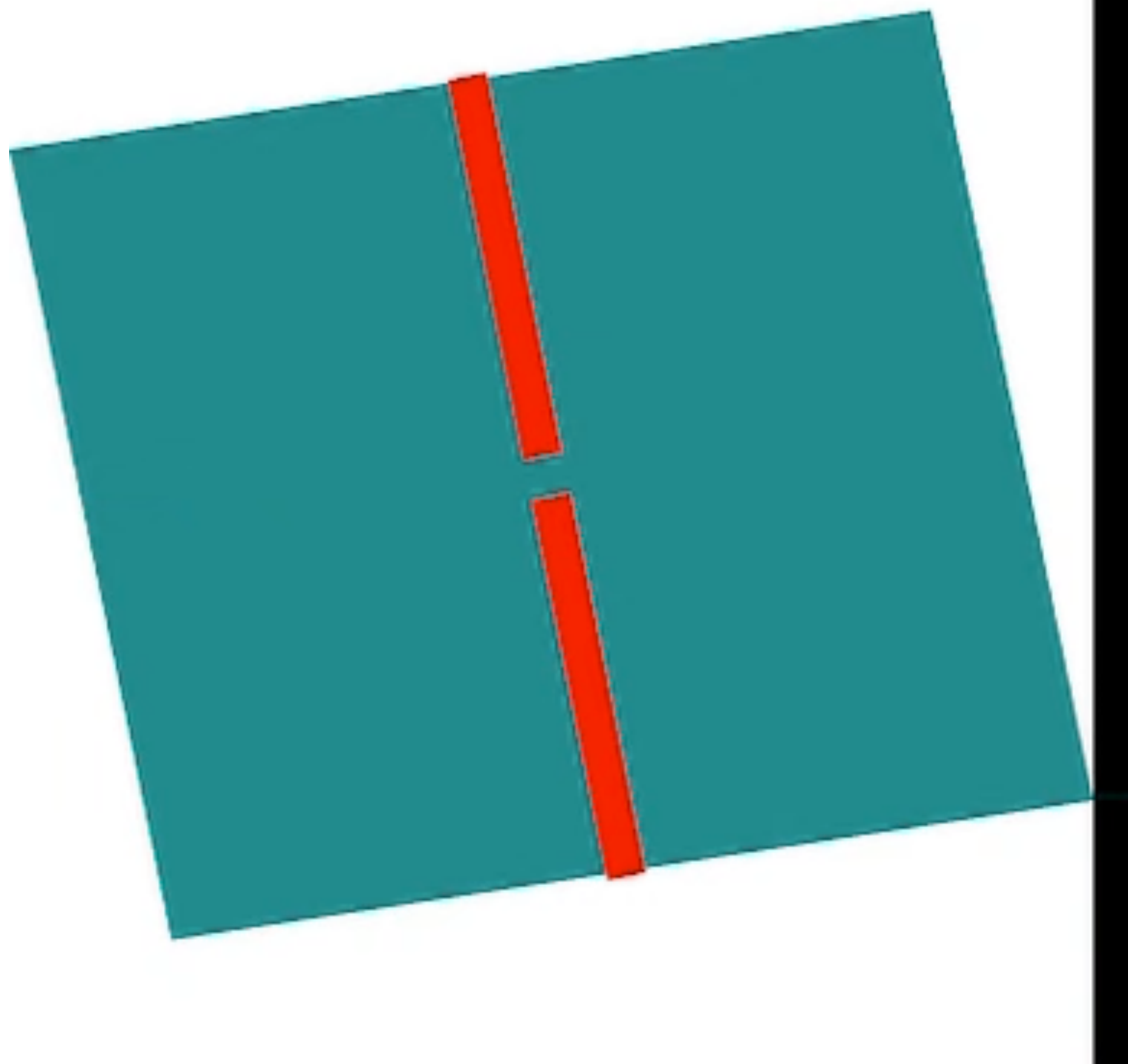




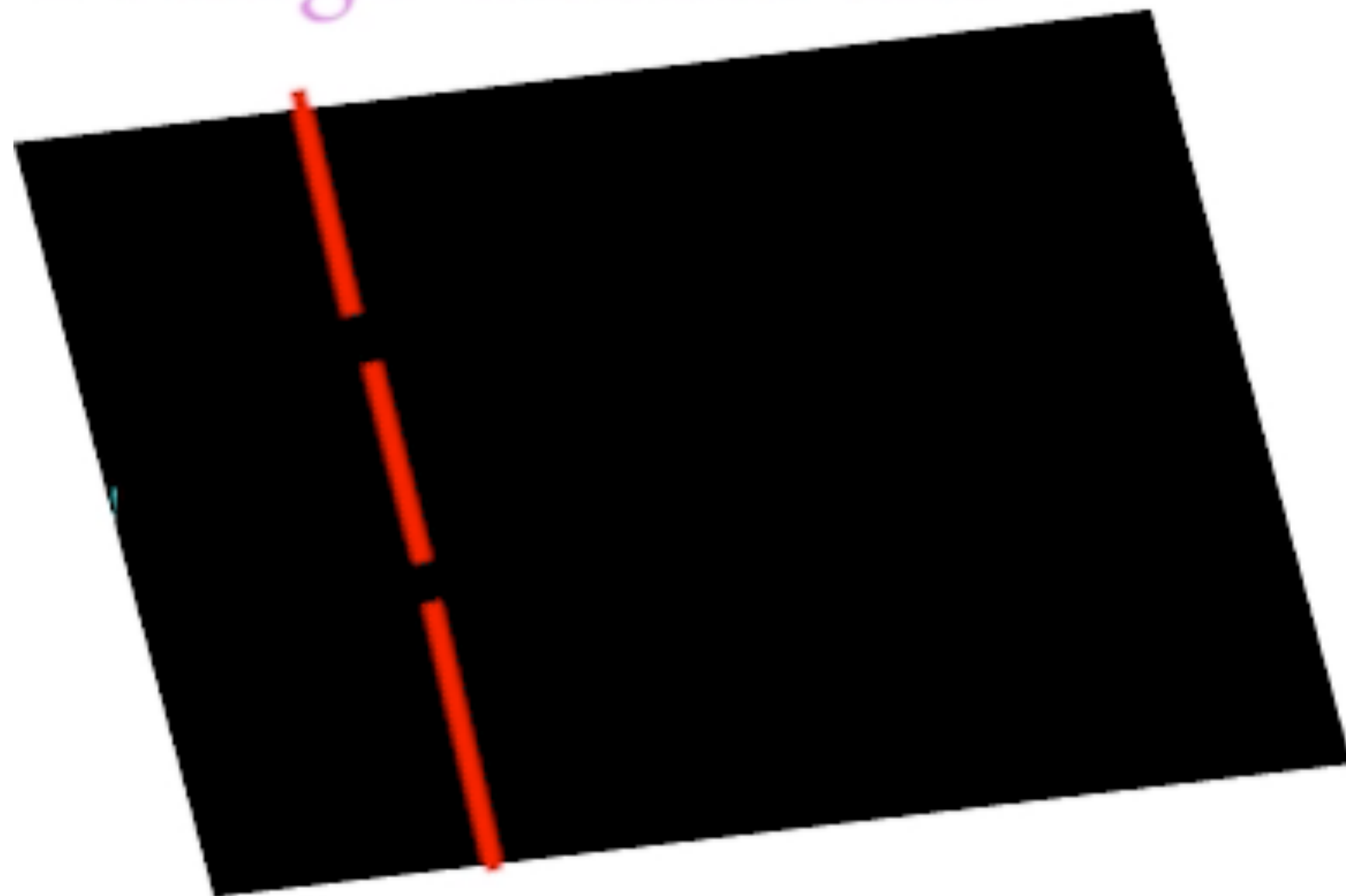
Charlie Loyd
Himawari-8



Stefano Maggiolo

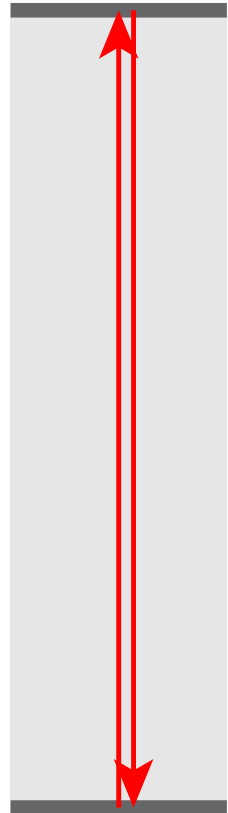


Young's double slit

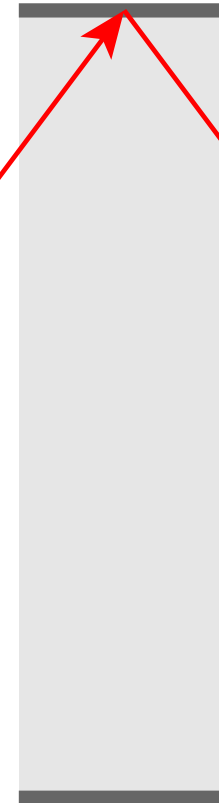
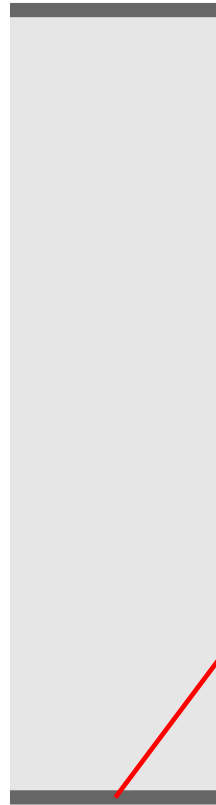


Relativity and light clocks

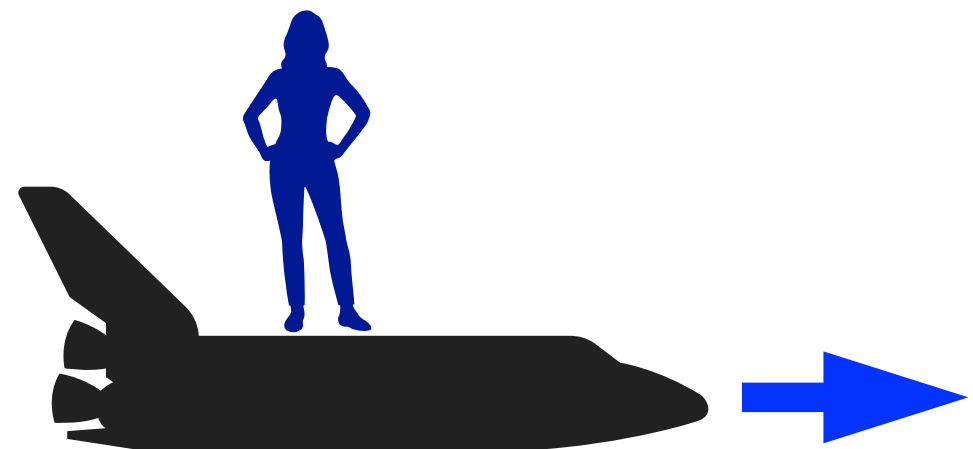
Light clock (student A homework)



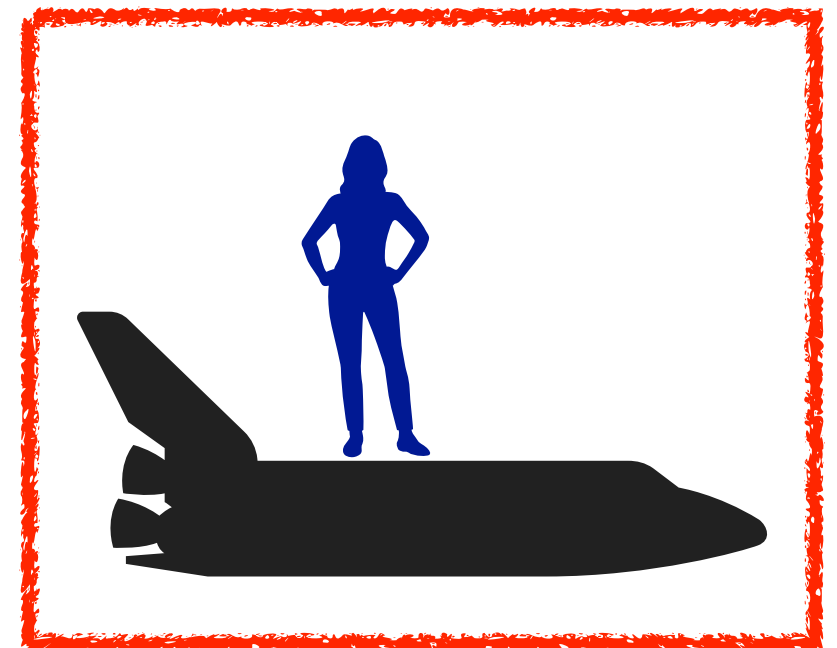
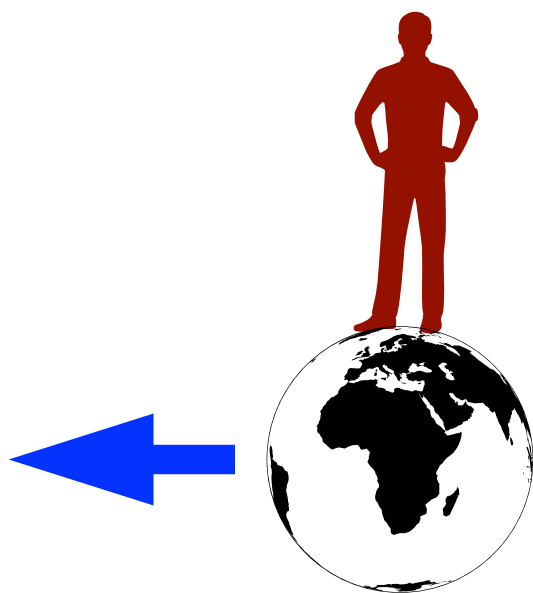
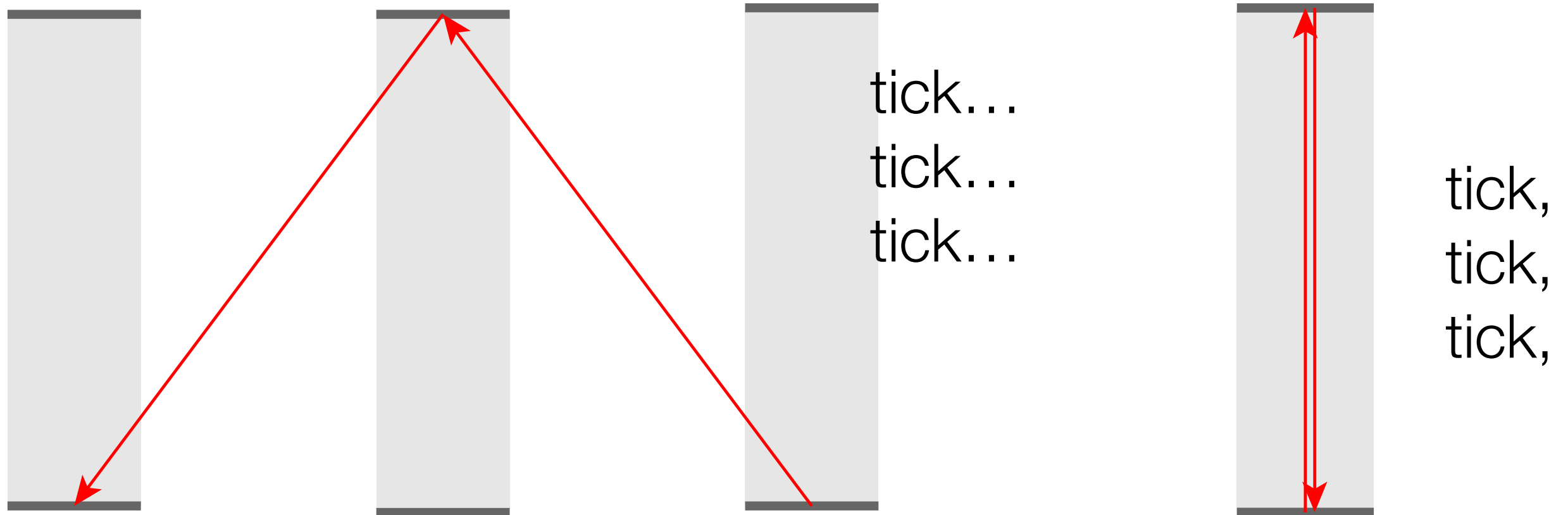
tick,
tick,
tick,

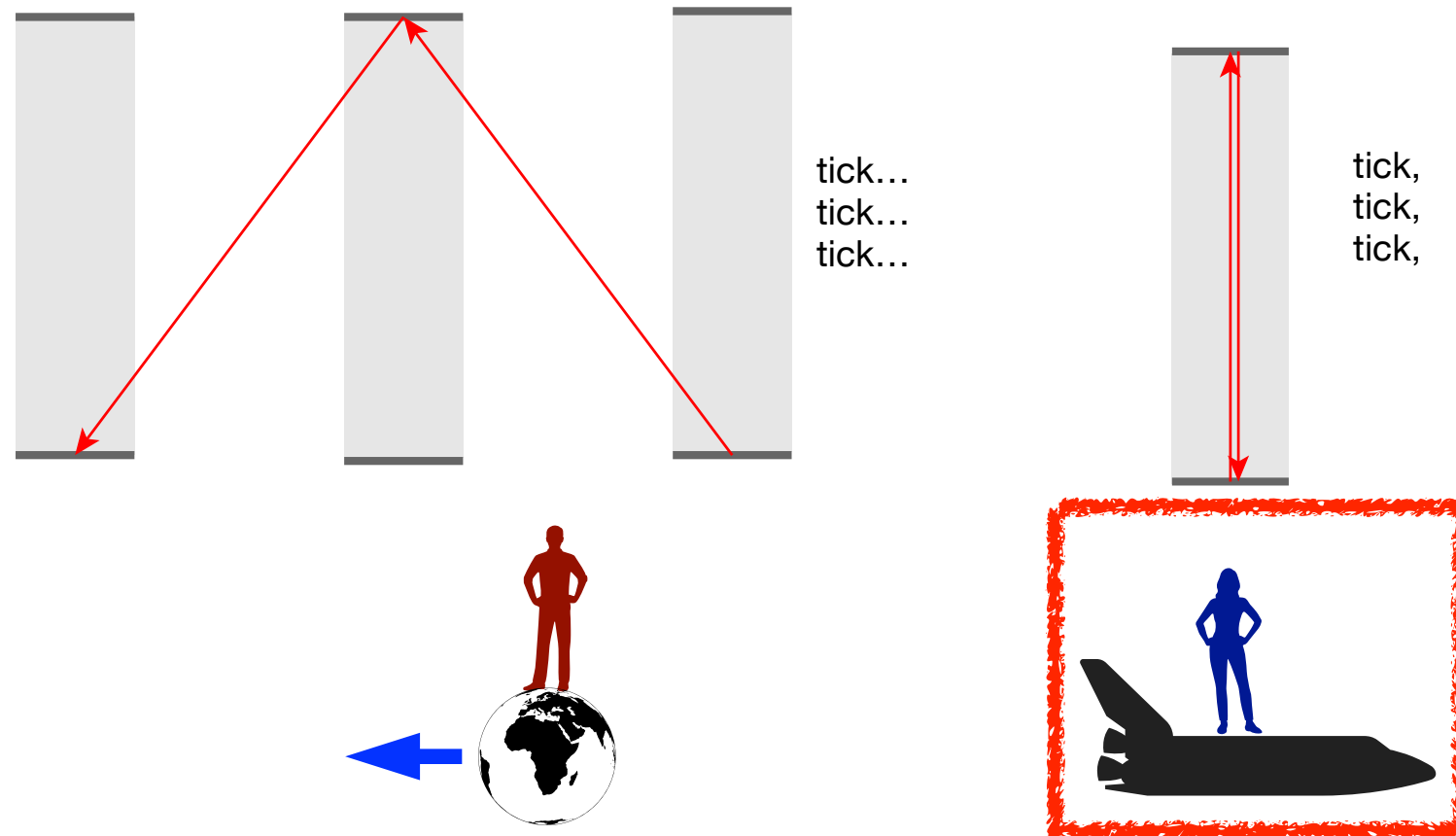
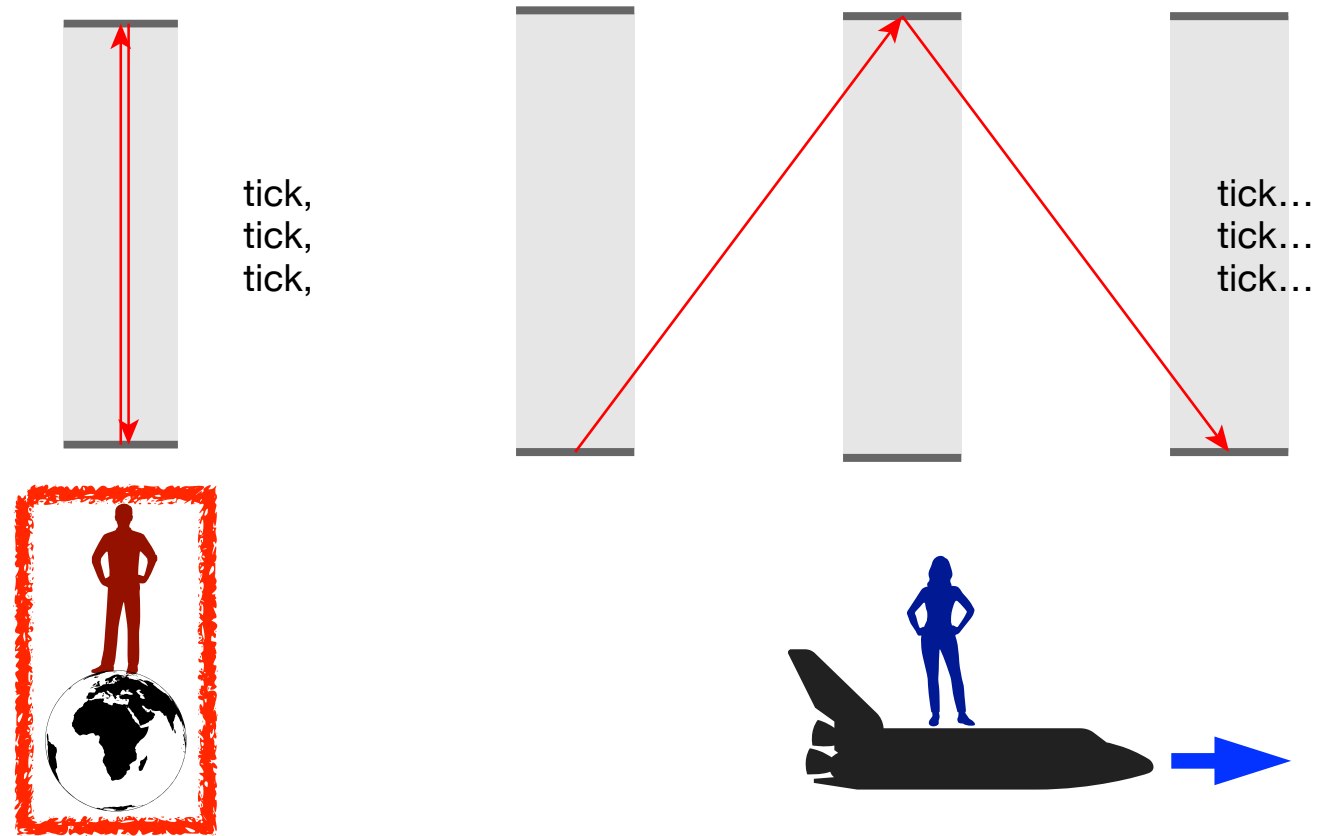


tick...
tick...
tick...



Light clock (student B homework)





Takeaways

- Everyone see's their clock (time) as normal
- Everyone else's clock is running slow (if there is relative motion)
- They're **both** right

What time is it?

- Prior to ~1850 time meant local time
- 1850-1918 transition
- 1918+ timezones are firmly established, time now means a universal time (with timezones), set by local time in Greenwich London
- 1960, atomic time more accurate than earth's spin
- 1970+

Bristol Corn Exchange Clock

- Bristol time (main red minute hand)
- Greenwich mean time added (pink)
- 11 minute difference (approx)



What time is it?

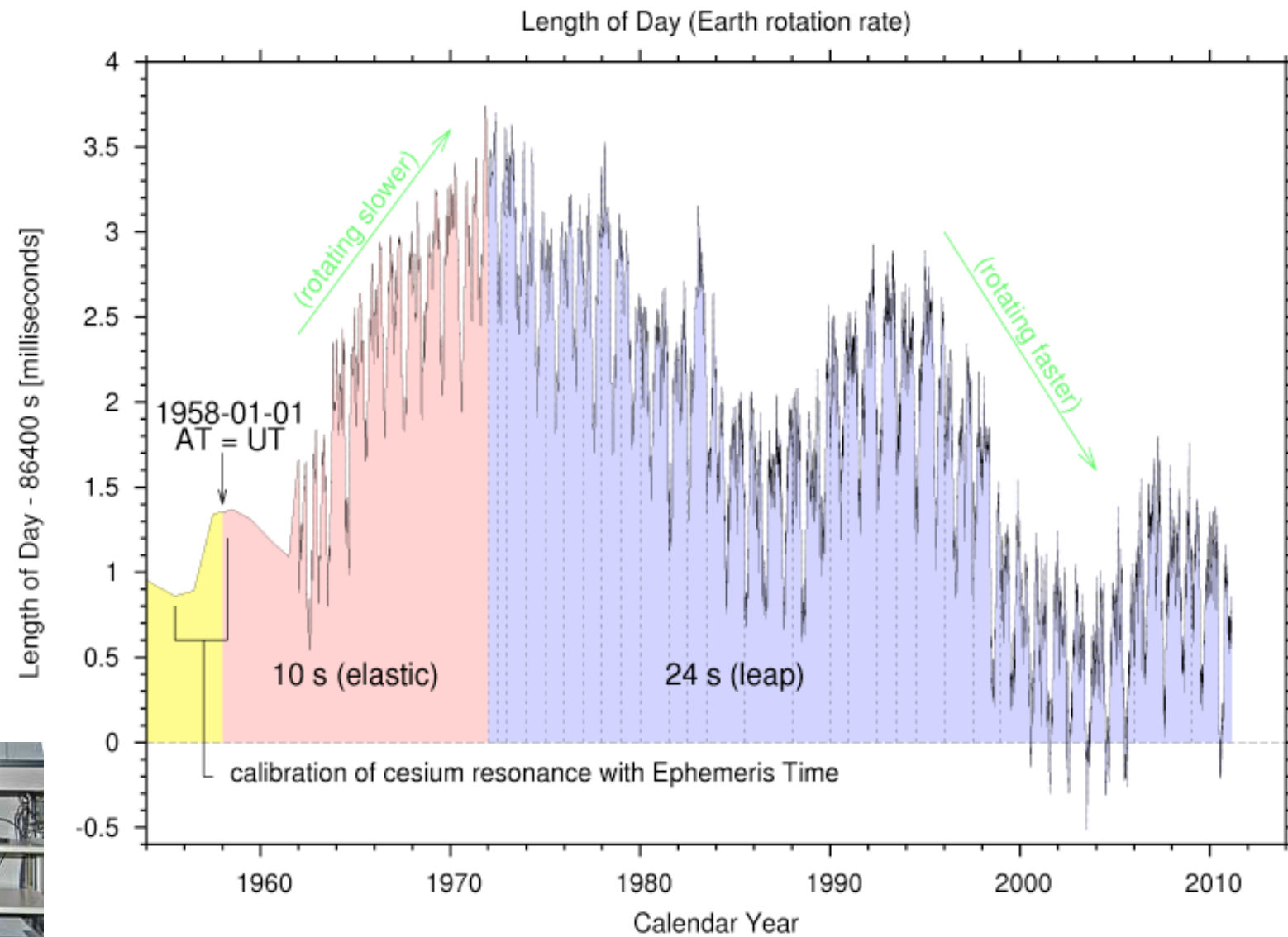
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What time is it?

- International Atomic Time (TAI)
- Universal Time (UT1)
- UTC (Coordinated Universal Time)

International Atomic Time (TAI)

- Is determined using atomic clocks
- Is very accurate
- The time of noon wanders



UT1

- Is the rotation of the Earth
- The Earth's rotation speeds up and slows down
- Time of a second wanders





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IERS Rapid Service/Prediction Centre

Mission:

The IERS Rapid Service/Prediction Centre is responsible for providing [earth orientation parameters](#) on a rapid turnaround basis, primarily for real-time users and others needing the highest quality EOP information sooner than that available in the final series published by the IERS Earth Orientation Center.

Web site:

<http://usno.navy.mil/USNO/earth-orientation>

Main products:

[Rapid data and predictions:](#)

BULLETIN A

Standard EOP data files:

FINALS.ALL (IAU1980)
FINALS.ALL (IAU2000)
FINALS.DATA (IAU1980)
FINALS.DATA (IAU2000)
GPSRAPID.OUT

Daily EOP data files:

FINALS.DAILY (IAU1980)
FINALS.DAILY (IAU2000)
GPSRAPID.DAILY

Primary scientist and representative to the IERS Directing Board: [Christine Hackman](#)

Production director and lead project scientist: [Nick Stamatakos](#)

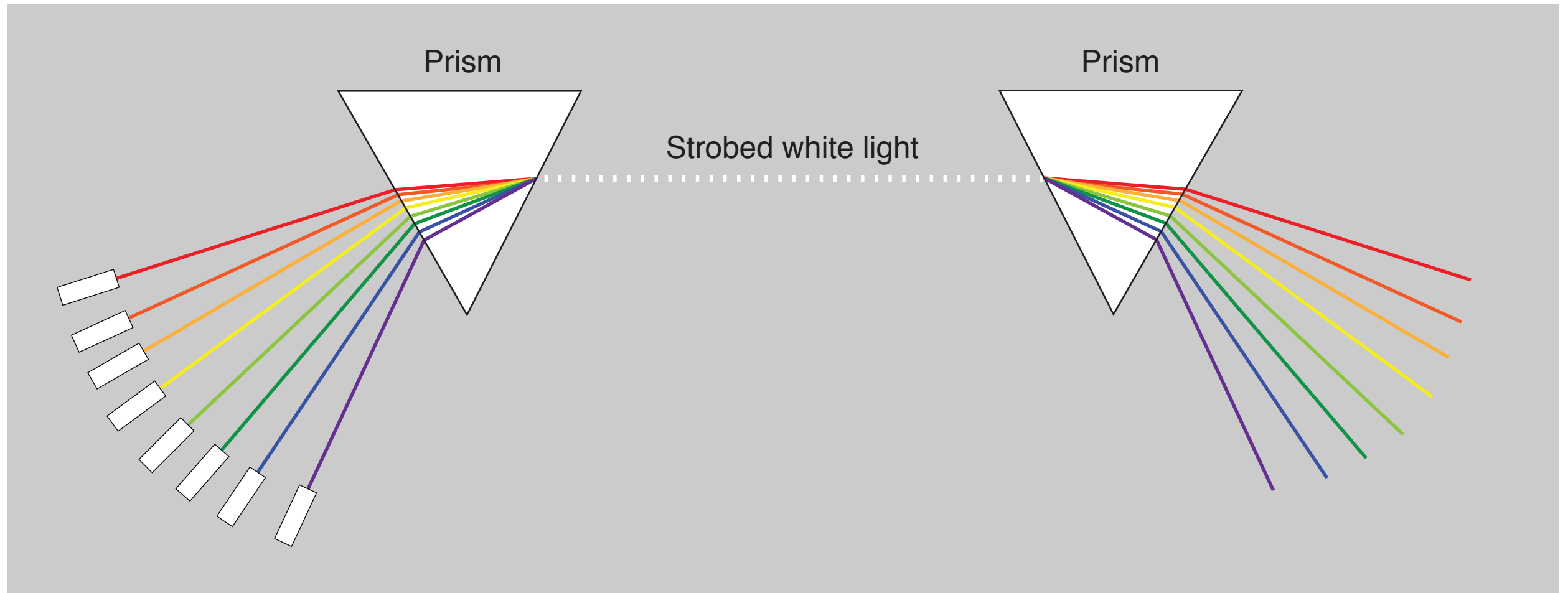
Coordinated Universal Time (UTC)

- Most common time
- The second is given by atomic time
- Leap seconds are occasionally inserted to keep noon from being more than a second off
- Pro: lines up more or less with both atomic and celestial time
- Used for almost all common usages of time
- Not actually useful for precision work

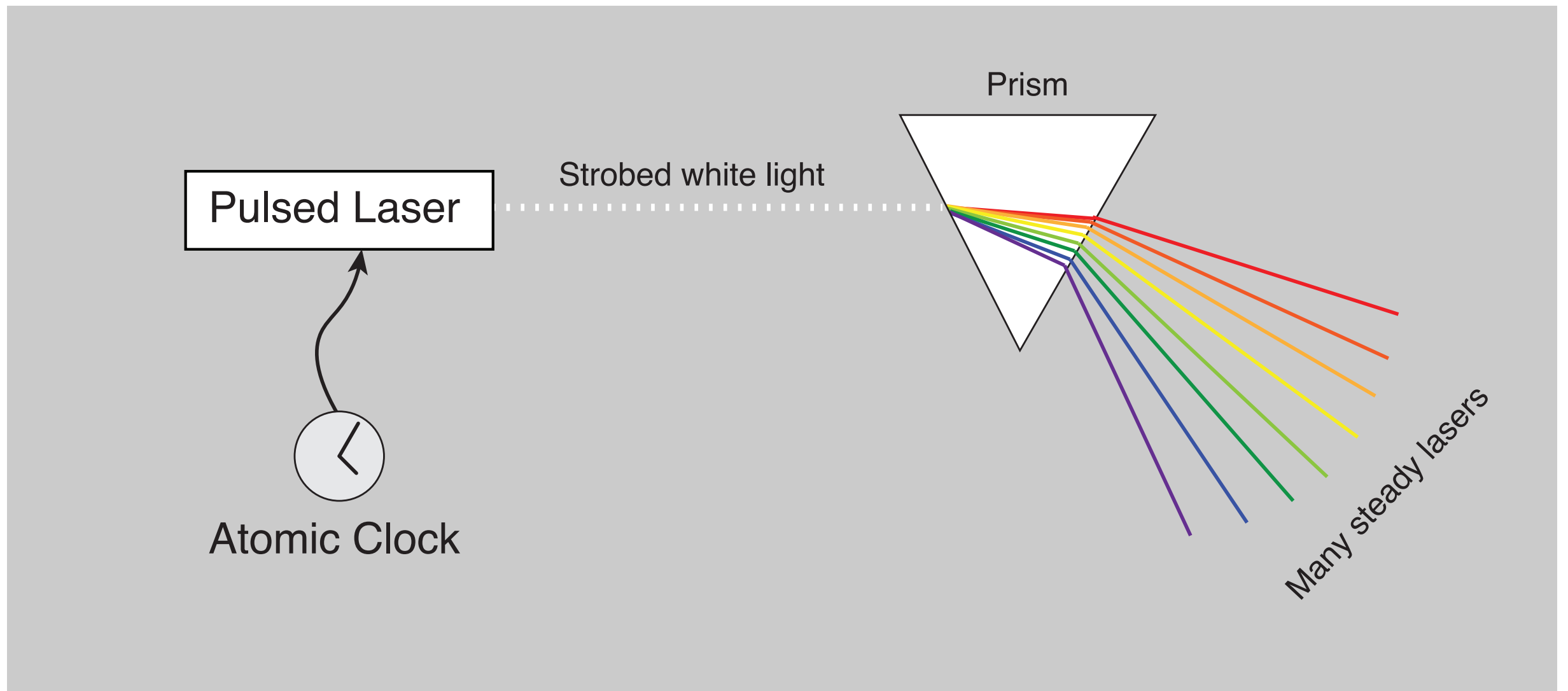
Optical clocks

Counting very fast (~100 trillion times per second)

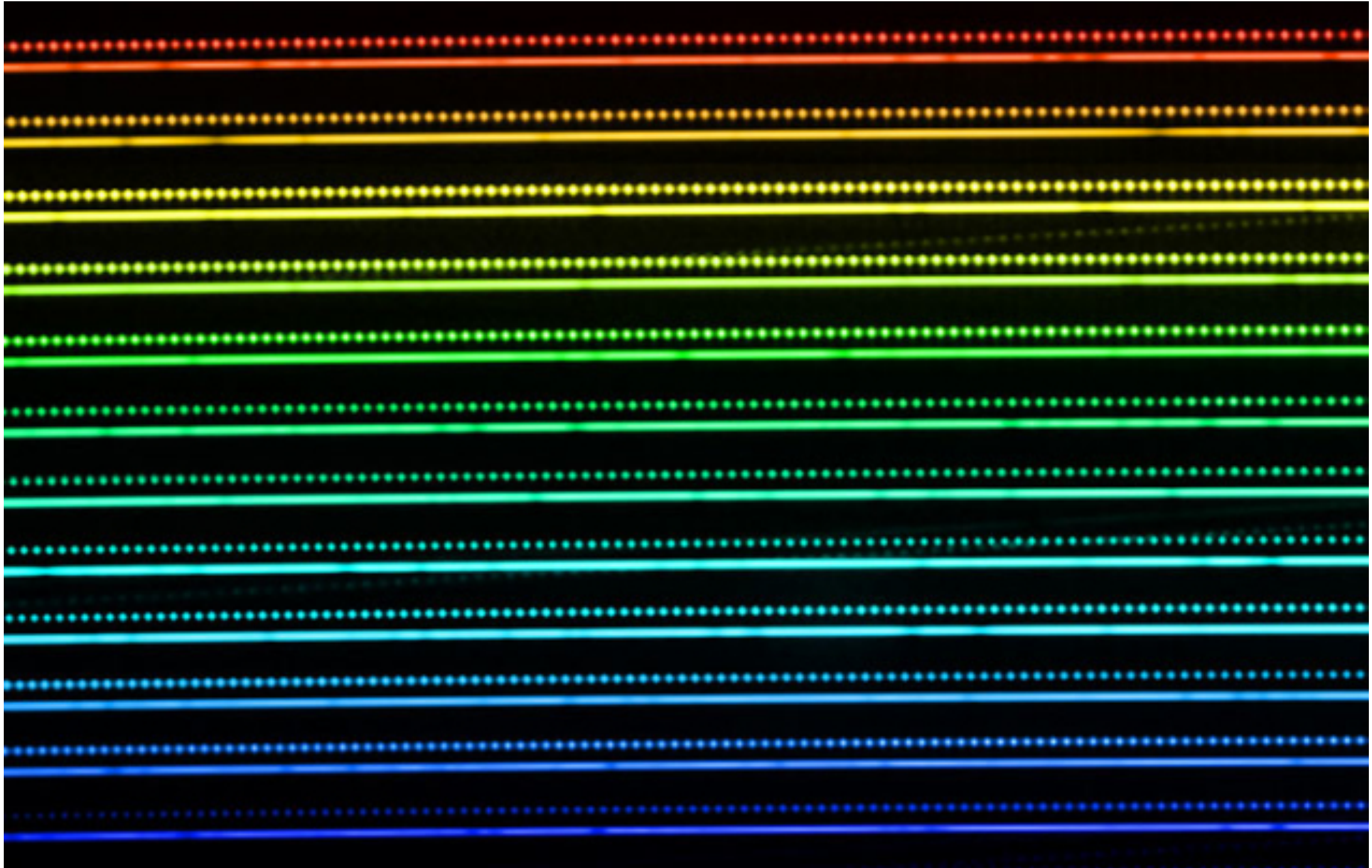
Many fancy lasers



Optical Frequency Comb



Optical Frequency Comb



Optical clock

