Welcome to Caltech!

and

Physics 1a: Newtonian mechanics

Lecture 1: Introduction

Basic info

Ryan Patterson, rbpatter@caltech.edu
Office: Lauritsen 339, x5753

Lectures:

Wed and **Fri**, 11am
201 E. Bridge (a.k.a. Feynman Lecture Hall)

Sections:

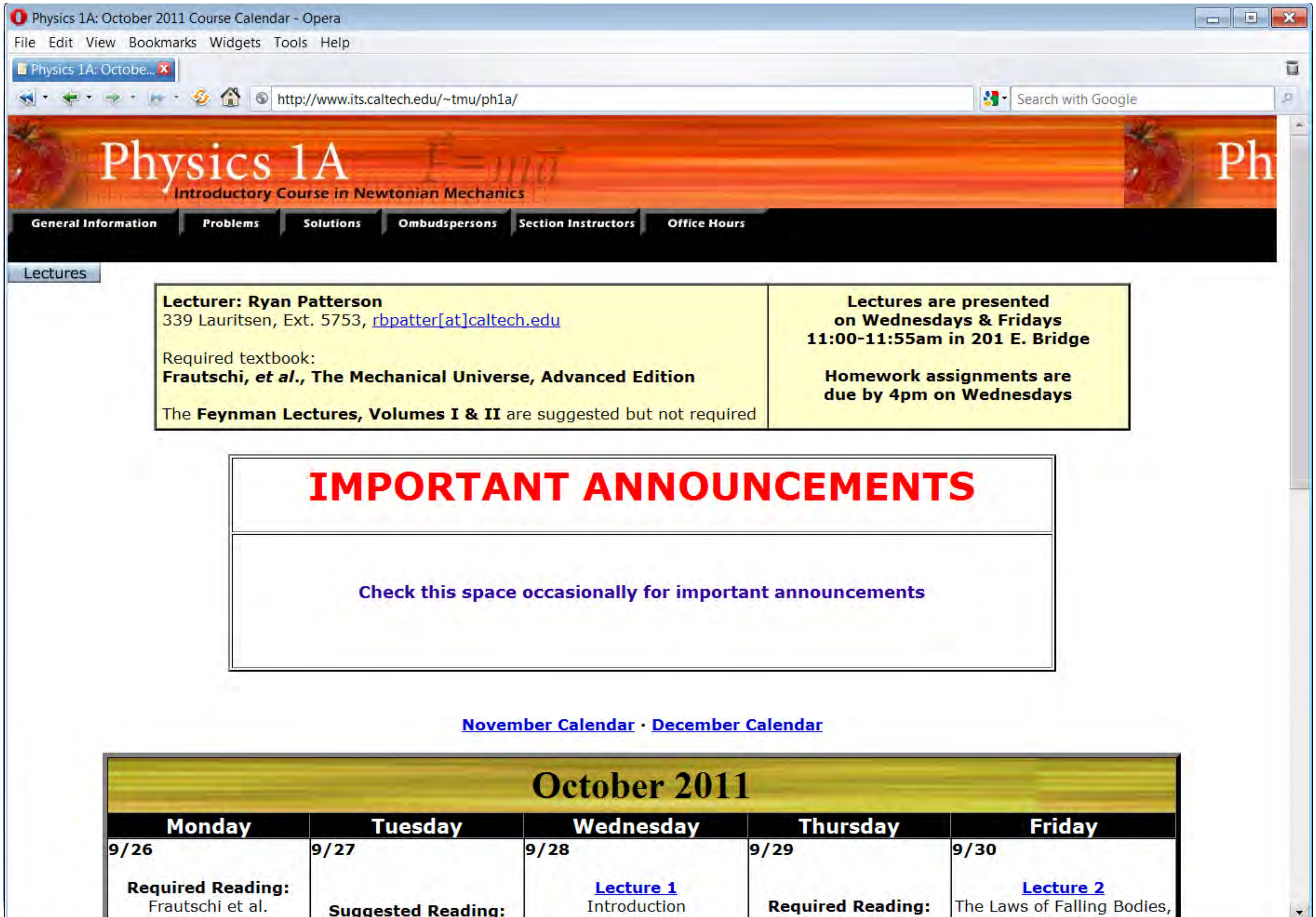
Mon and **Thu**, 1pm or 3pm, various locations and instructors.

Office hours:

Various times, locations, and instructors (see webpage)

Course webpage

http://www.its.caltech.edu/~tmu/ph1a/



Course calendar

On the course webpage…

Required reading

November Calendar · December Calendar

October 2011

Monday	Tuesday	Wednesday	Thursday	Friday
9/26 **Required Reading:** Frautschi et al. Chapter 1	9/27 **Suggested Reading:** Feynman Vol. I Chapters 1, 2, 8	9/28 Lecture 1 Introduction **Homework 1:** QP1, QP17 Frautschi, Chapter 3 Problems 10, 13	9/29 **Required Reading:** Frautschi et al. Chapter 2	9/30 Lecture 2 The Laws of Falling Bodies, Derivatives
10/3 **Required Reading:** Frautschi et al. Chapters 3, 4	4 **Suggested Reading:** Feynman Vol. I Chapter 11	5 Lecture 3 Integrals and Inertia **Homework 2:** QP9, QP43 Frautschi, Chapter 4 Problems 17, 20 ***Homework 1 Due*** **Quiz 1 handed out**	6 **Required Reading:** Frautschi et al. Chapter 5	7 Lecture 4 Vectors
10 **Required Reading:** Frautschi et al. Chapter 6 **QUIZ 1 DUE**	11 **Suggested Reading:** Feynman Vol. I Chapters 9, 7	12 Lecture 5 Newton's Laws **Homework 3:** QP3, QP4 Frautschi, Chapter 7 Problems 16, 17 ***Homework 2 Due***	13 **Required Reading:** Frautschi et al. Chapter 7	14 Lecture 6 Gravitation & Circular Motion
17 **Required Reading:** Frautschi et al. Chapter 8	18 **Suggested Reading:** Feynman Vol. I Chapter 12	19 Lecture 7 Forces of Nature **Homework 4:** QP20, QP21, QP28 Frautschi, Chapter 9 Problem 6 ***Homework 3 Due*** **Quiz 2 handed out**	20 **Required Reading:** Frautschi et al. Chapter 9	21 Lecture 8 Non-Inertial Frames
24 **Required Reading:** Frautschi et al. Chapter 10 **QUIZ 2 DUE**	25 **Suggested Reading:** Feynman Vol. I Chapters 4, 13, 14	26 Lecture 9 Energy **Homework 5:** Frautschi, Chapter 10 Problems 11, 25, 28, 32 ***Homework 4 Due***	27 **No Required Reading**	28 Lecture 10 Conservation of Momentum

Homework assignments

Quizzes

Material overview

- Introduction
- Falling bodies, derivatives
- Integrals and inertia
- Vectors
- Newton's laws
- Gravitation and circular motion
- Forces of nature
- Non-inertial frames
- Energy
- Conservation of momentum
- Oscillatory motion
- Angular Momentum
- Rotation of Rigid Bodies
- Fluid Mechanics
- Kepler's Laws
- Gyroscopes

All of this in about 9 weeks

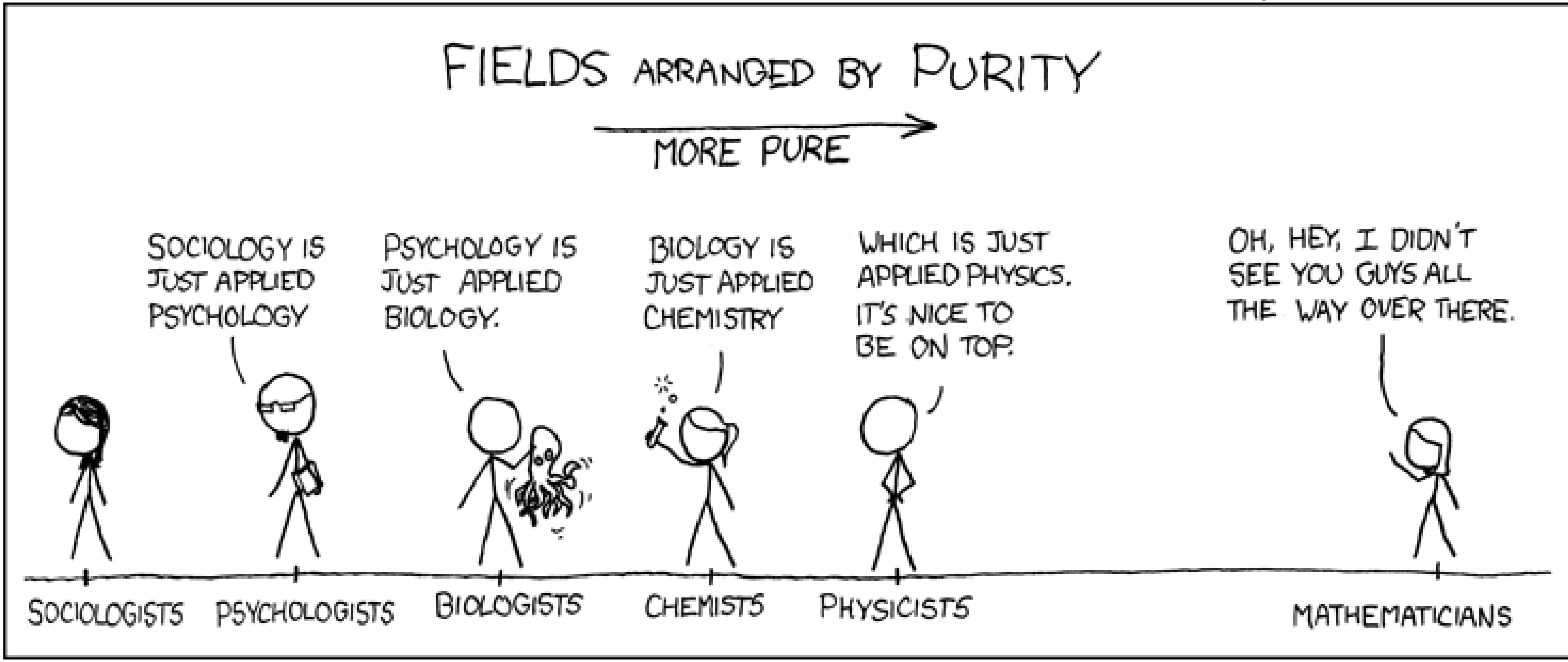
A lot will be covered in a short amount of time.

Some things may seem hard; some easy. Stay on your toes!

Take advantage of:

- Reading
- Lectures
- Sections
- Office hours

http://xkcd.com/435/



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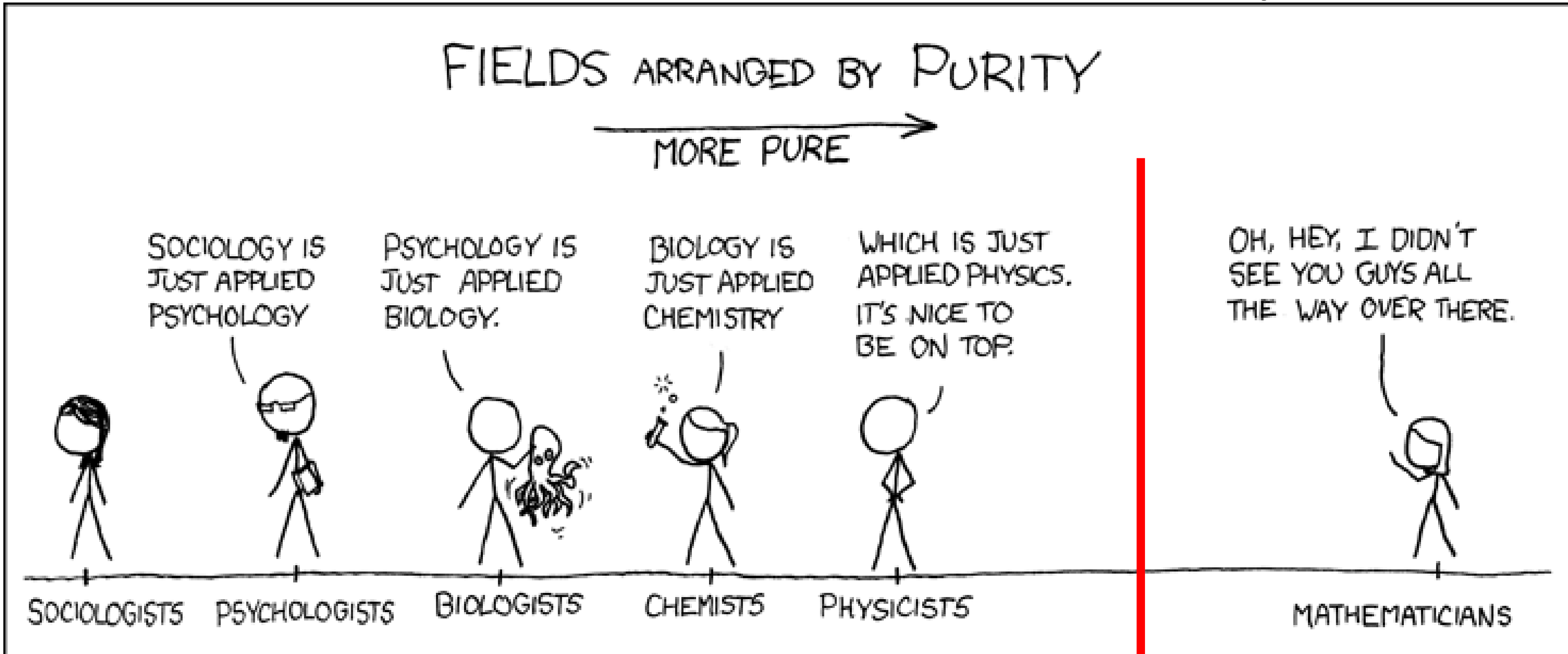
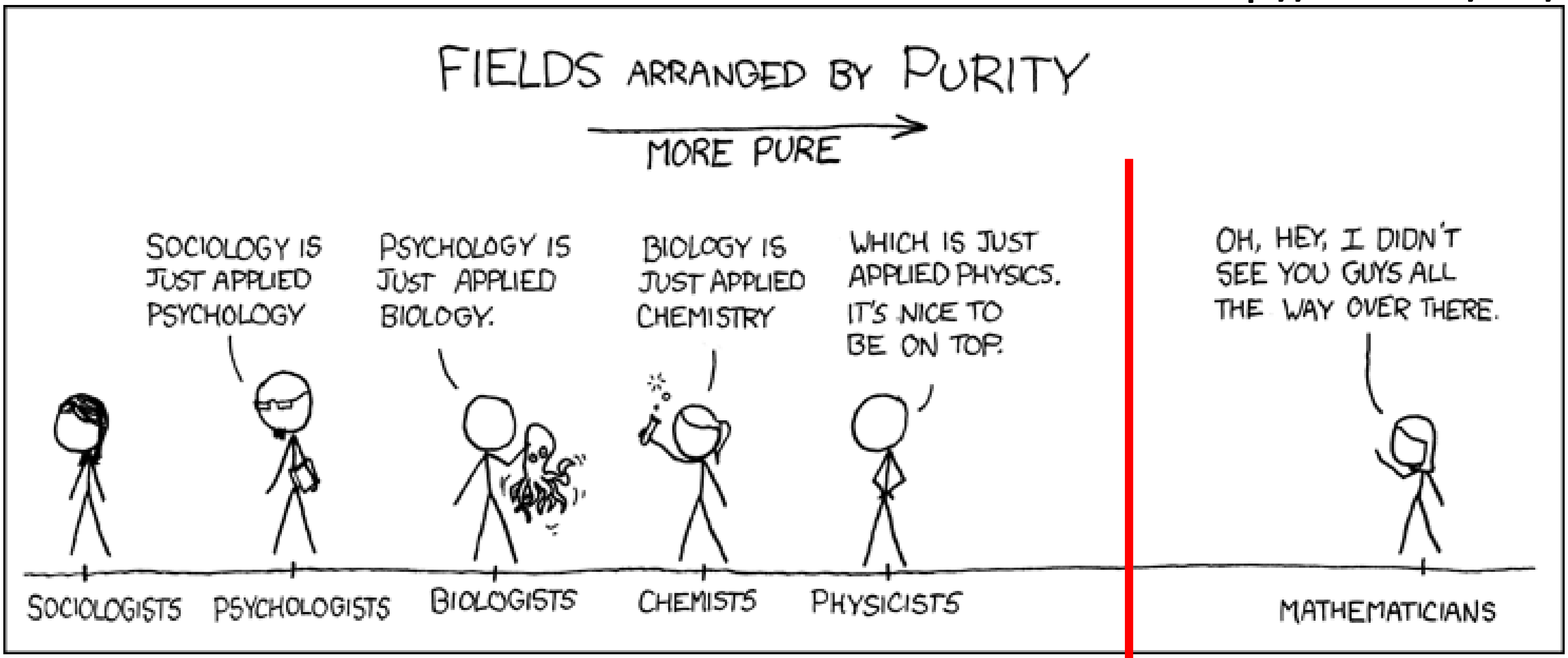


Figuring out how the universe works

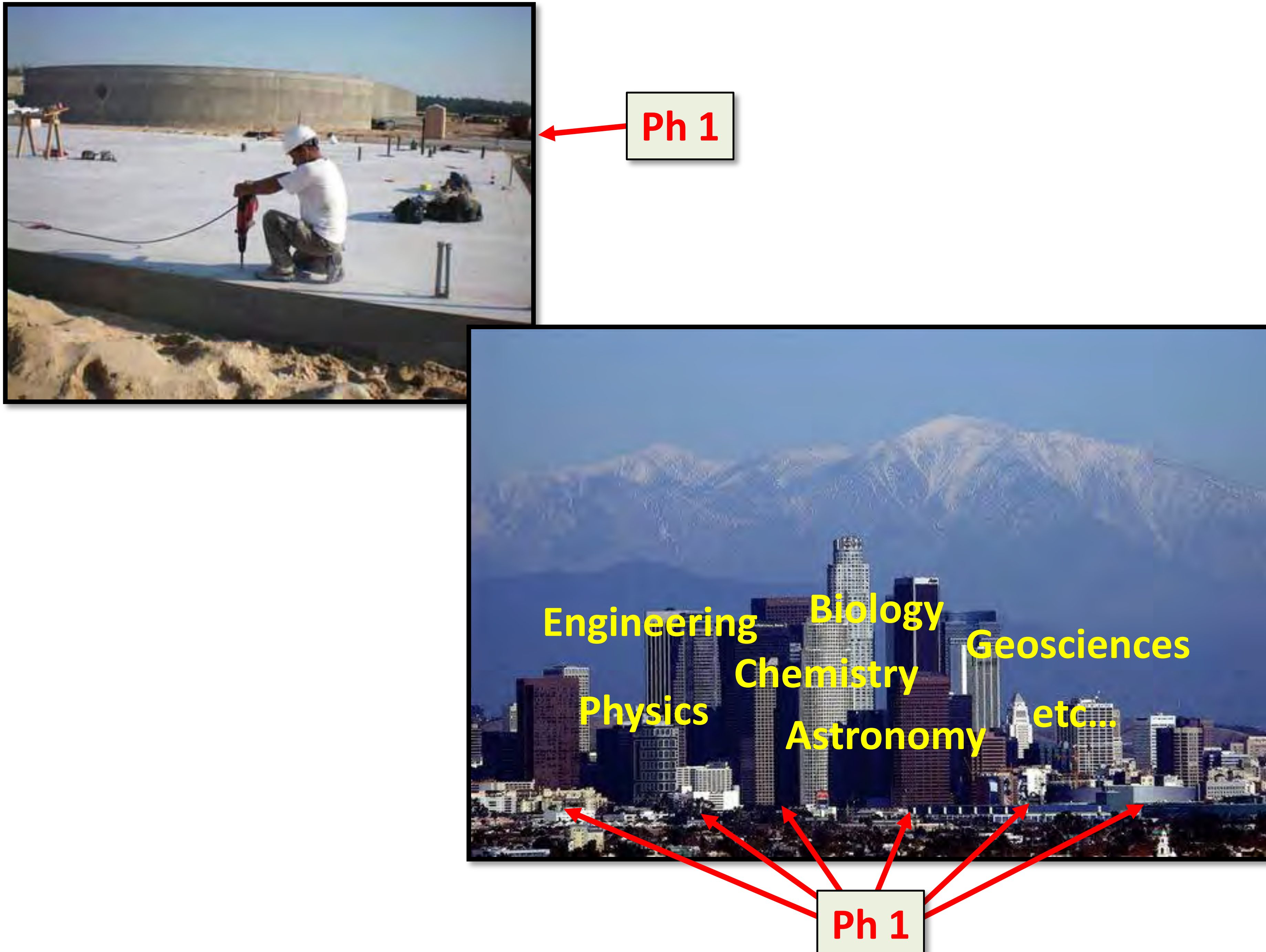
http://xkcd.com/435/



Figuring out how the universe works

- **The primary material in this course is about three centuries old.**
- **But, one has to begin at the beginning…**

Ph 1



Ph 1
Engineering
Biology
Geosciences
Chemistry
Physics
etc...
Astronomy
Ph 1

So, let's begin…

Units

Distance:

meters, inches, miles, parsecs…

Time:

seconds, years, fortnights…

Force:

newtons, pounds…

Energy:

joules, ergs, calories ≠ Calories…

Units

Distance:
meters, inches, miles, parsecs…

Time:
seconds, years, fortnights…

Force:
newtons, pounds…

Energy:
joules, ergs, calories $\neq$ Calories…

Can convert between units that measure the same thing.

For example…

Distance:
1 ft = 12 in
1 in = 2.54 cm
1 lb $\approx$ 0.454 kg
(or exactly 0.45359237 kg, since 1959)

Time:
1 year $\approx 3.16 \times 10^7$ seconds
$\approx \pi \times 10^7$ seconds

Converting units

Consider a velocity:

$$v = 88 \text{ mph} = \frac{88 \text{ mi}}{1 \text{ hr}}$$

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$$v = \frac{88 \text{ mi}}{1 \text{ hr}} \times \underbrace{\frac{1 \text{ hr}}{3600 \text{ s}}}_{=1} \times \underbrace{\frac{1609 \text{ m}}{1 \text{ mi}}}_{=1} = 39.3 \frac{\text{m}}{\text{s}}$$

SI units

Stay consistent ⇒ less work & fewer mistakes

SI units

Stay consistent ⇒ *less work & fewer mistakes*

length	:	meter (m)
time	:	second (s)
mass	:	kilogram (kg)

} **Fundamental SI units**

SI units

Stay consistent ⇒ *less work & fewer mistakes*

length	:	meter (m)	Fundamental SI units
time	:	second (s)	
mass	:	kilogram (kg)	
velocity	:	m/s	Derived SI units
accel.	:	m/s^2	
area	:	m^2	
		etc…	

SI units

Stay consistent ⇒ ***less work & fewer mistakes***

length	:	meter (m)	Fundamental SI units
time	:	second (s)	
mass	:	kilogram (kg)	
velocity	:	m/s	Derived SI units
accel.	:	m/s^2	
area	:	m^2	
		etc…	
force	:	newton (N) = $kg{\cdot}m/s^2$	Derived SI units with special names
energy	:	joule (J) = $kg{\cdot}m^2/s^2$	
		etc…	

Checking your work with units

Q: How tall is Bob?

Checking your work with units

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(work, work, algebra, algebra, …)

Checking your work with units

Q: ***How tall is Bob?***

(work, work, algebra, algebra, …)

A: ***8 kg*** ← **Clearly a bad answer! Look for the error.**

Checking your work with units

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A: 92 m ← **Right units, but physically questionable...**

Checking your work with units

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(work, work, algebra, algebra, …)

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A: 1.8 m ← **Could possibly be correct.**

Checking your work with units

Q: How tall is Bob?

↓ *(work, work, algebra, algebra, …)*

A: 8 kg ← **Clearly a bad answer! Look for the error.**

A: 92 m ← **Right units, but physically questionable...**

A: 1.8 m ← **Could possibly be correct.**

Mistakes of the first type should never survive!

Algebra gone awry?

Consider:

Distances x and y

Time t

Algebra gone awry?

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$x + t$ = nonsense [4 m + 2 s = ???]

Algebra gone awry?

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Distances x and y

Time t

$x + t$ = nonsense [$4\text{ m} + 2\text{ s}$ = ???]

$\cos(xy)$ = nonsense [$\cos(9\text{ m}^2)$ = ???]

Algebra gone awry?

Consider:

Distances x and y

Time t

$x + t$	=	nonsense	[4 m + 2 s = ???]
$\cos(xy)$	=	nonsense	[cos(9 m^2) = ???]
$\log(x/y)$	=	okay!	[log(unitless number)]

Algebra gone awry?

Consider:

Distances x and y

Time t

$x + t$	=	nonsense	[4 m + 2 s = ???]
$\cos(xy)$	=	nonsense	[$\cos(9\ \text{m}^2)$ = ???]
$\log(x/y)$	=	okay!	[log(unitless number)]

Similarly:

Consider the area of a rectangle with sides 2 m and 4 m

~~$A = 2 \times 4 = 8$~~

$A = (2\ \text{m}) \times (4\ \text{m}) = 8\ \text{m}^2$

How language can be trouble

pound: **mass or force, depending on context (!)**
ounce: **mass or volume, depending on context (!)**

Another good reason for SI units

How language can be trouble

pound: **mass or force, depending on context (!)**
ounce: **mass or volume, depending on context (!)**

Another good reason for SI units

Q : How far away is Ventura? ← **"distance" question**
A : About 1.5 hours. ← **"time" answer** *(and probably the answer the questioner wants!)*

(Start of "time" discussion, demos, etc.)

Time

We use "time" constantly ; take it as a given.

Try to define it?

Can measure it, even if we can't define it easily.

Find something that repeats at regular intervals...

Earth around sun → 1 yr

Moon around earth → ~1 month

MOON ↕ MONTH

Earth about own axis → 1 day

Shorter times?

↳ 2 pendula demo

↳ digital clock demo, part I (AC power)

Time standard

1 second ≡ period of that pendulum ?

$\rightarrow$ *not a great global standard*

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1 second ≡ (Earth's rotation period) / 86400 ?

$\rightarrow$ *rotation period varies a lot (seasons, earthquakes, long-term wobbles)*

Time standard

1 second ≡ period of that pendulum ?

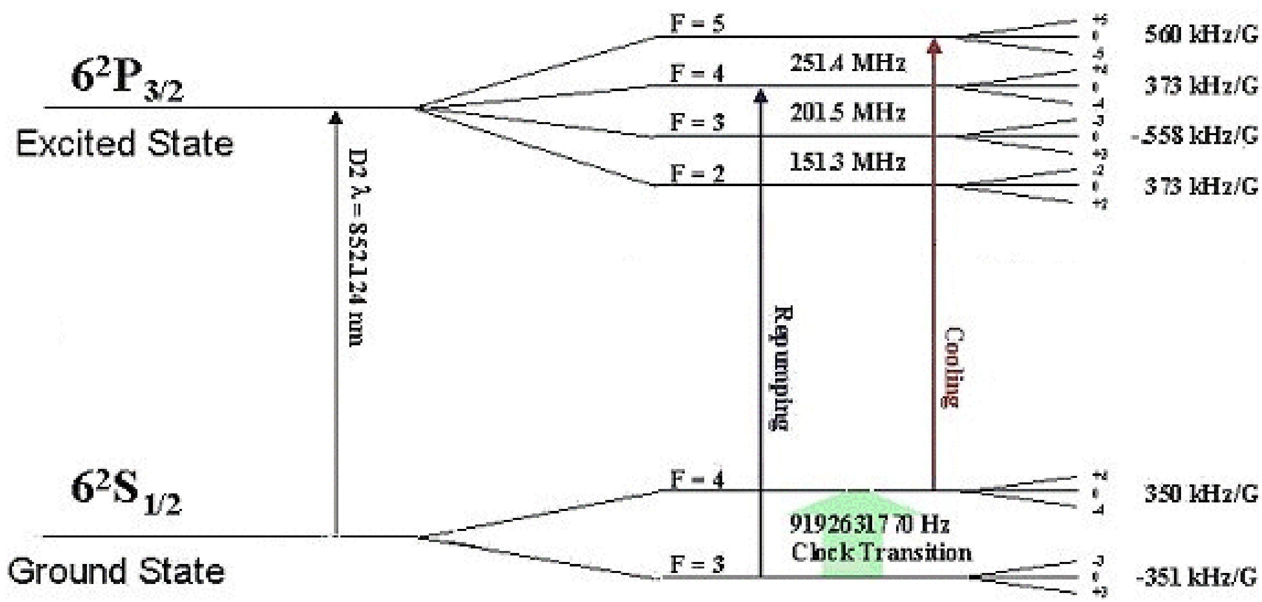
→ *not a great global standard*

1 second ≡ (Earth's rotation period) / 86400 ?

→ *rotation period varies a lot (seasons, earthquakes, long-term wobbles)*

1 second ≡ 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs.

→ *very stable, very reproducible!*



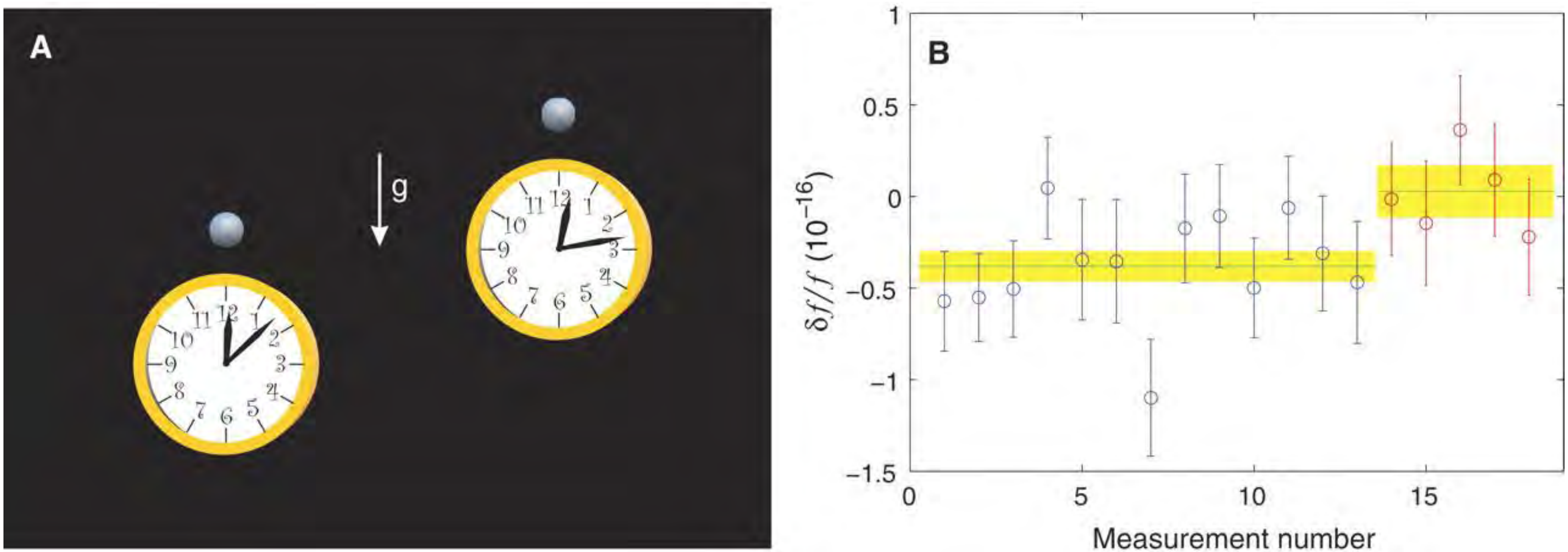
Cesium-133 energy levels

Optical Clocks and Relativity

Science AAAS

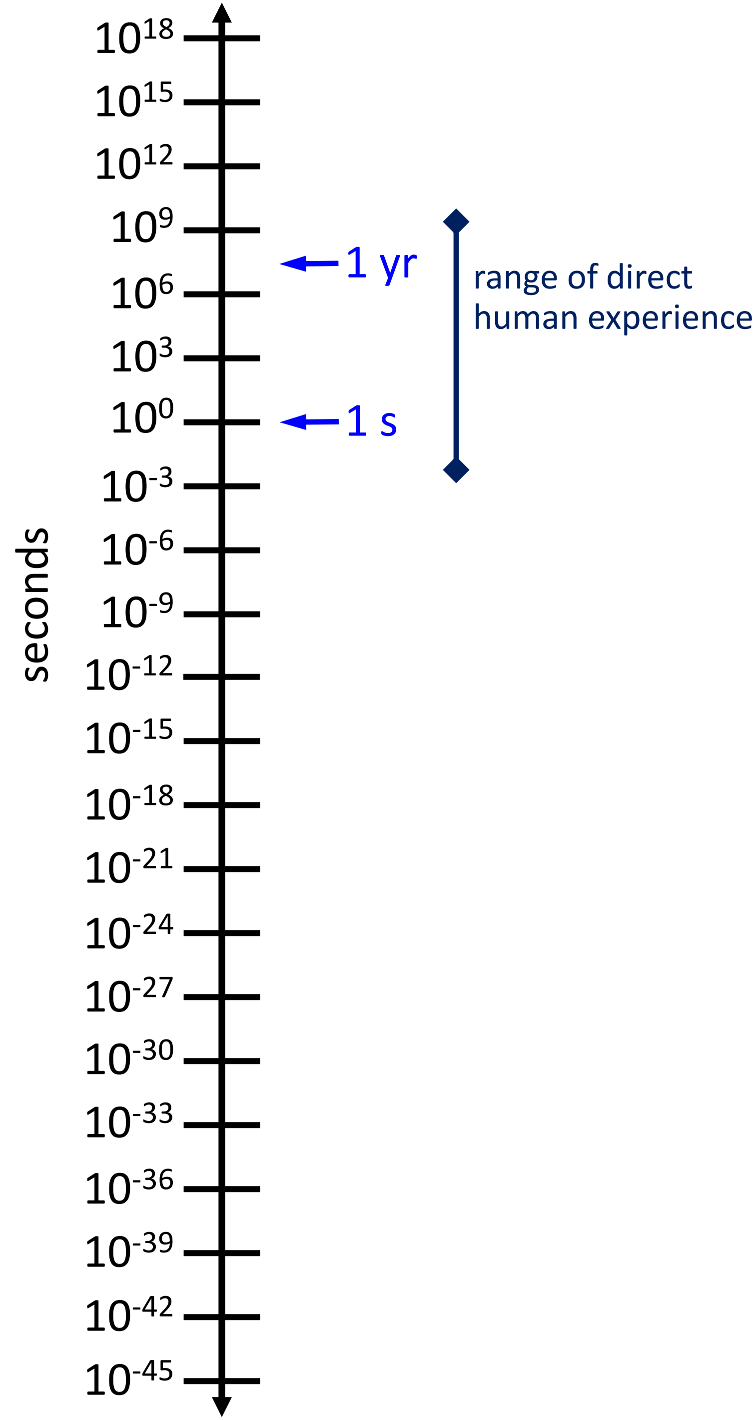
C. W. Chou,* D. B. Hume, T. Rosenband, D. J. Wineland

24 SEPTEMBER 2010 VOL 329 **SCIENCE** www.sciencemag.org

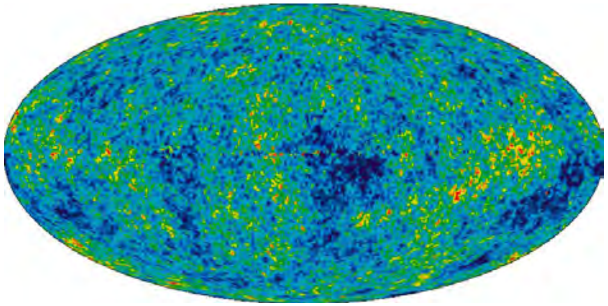


Compare clock rates at two heights differing by <u>only 33 cm</u>.

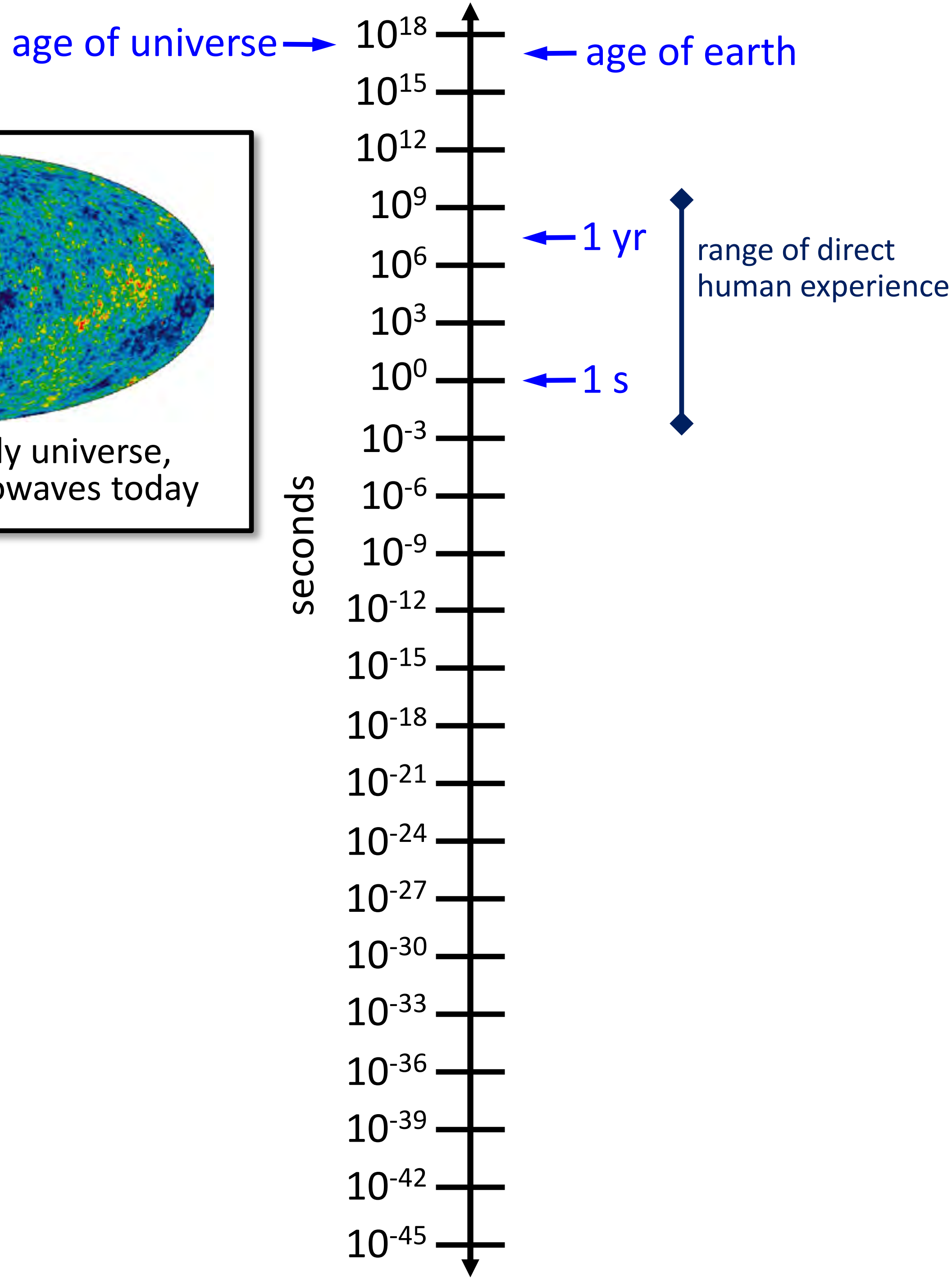
At the <u>higher position</u>, the observed <u>rate is higher</u> by a factor of 1.0000000000000004.

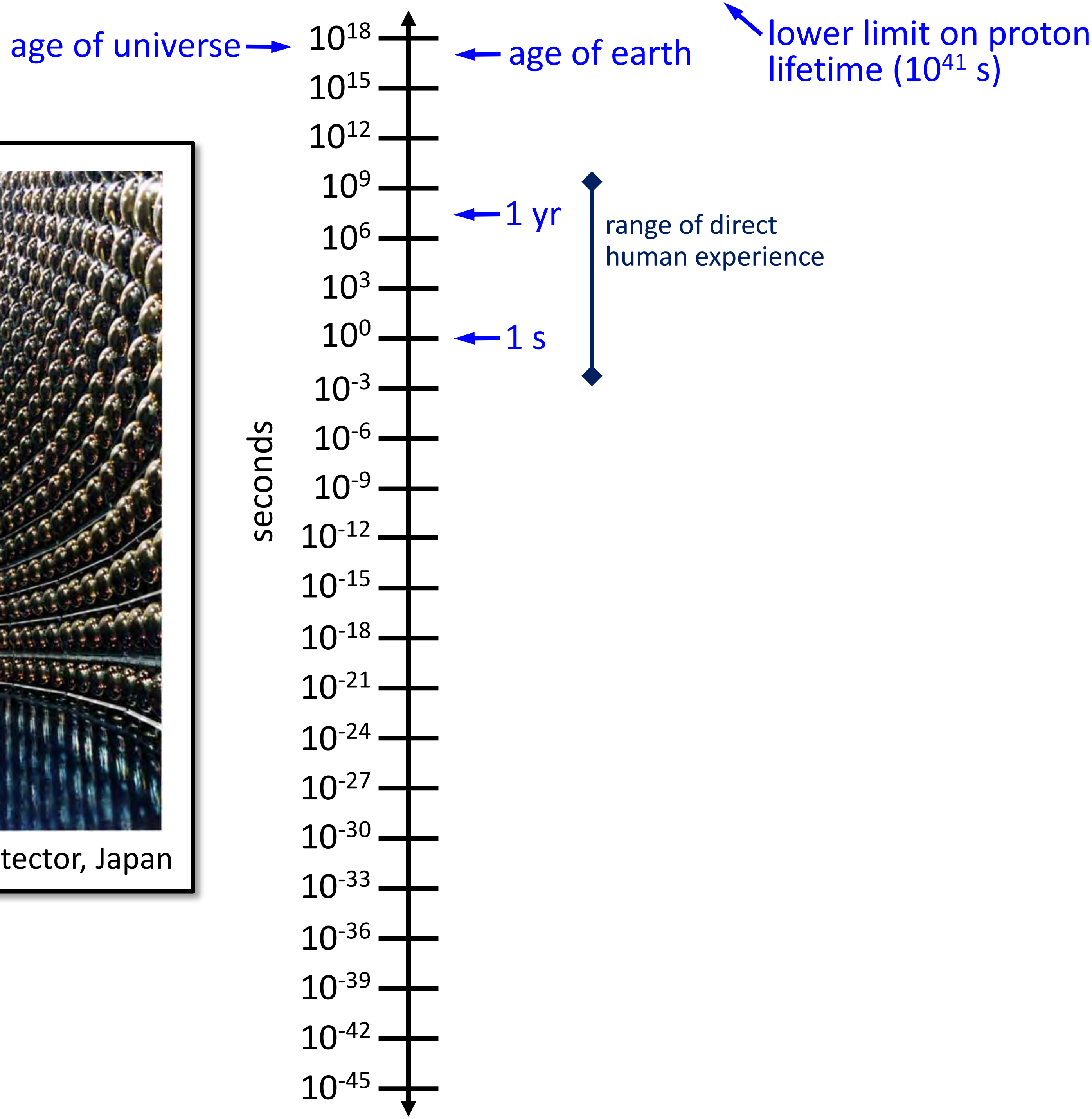


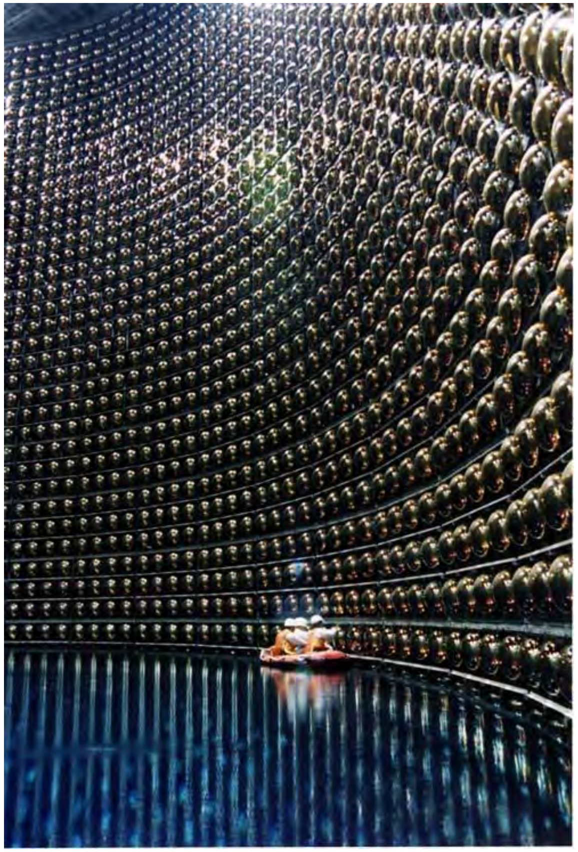
seconds
10^18
10^15
10^12
10^9
10^6
10^3
10^0
10^-3
10^-6
10^-9
10^-12
10^-15
10^-18
10^-21
10^-24
10^-27
10^-30
10^-33
10^-36
10^-39
10^-42
10^-45
1 yr
1 s
range of direct
human experience



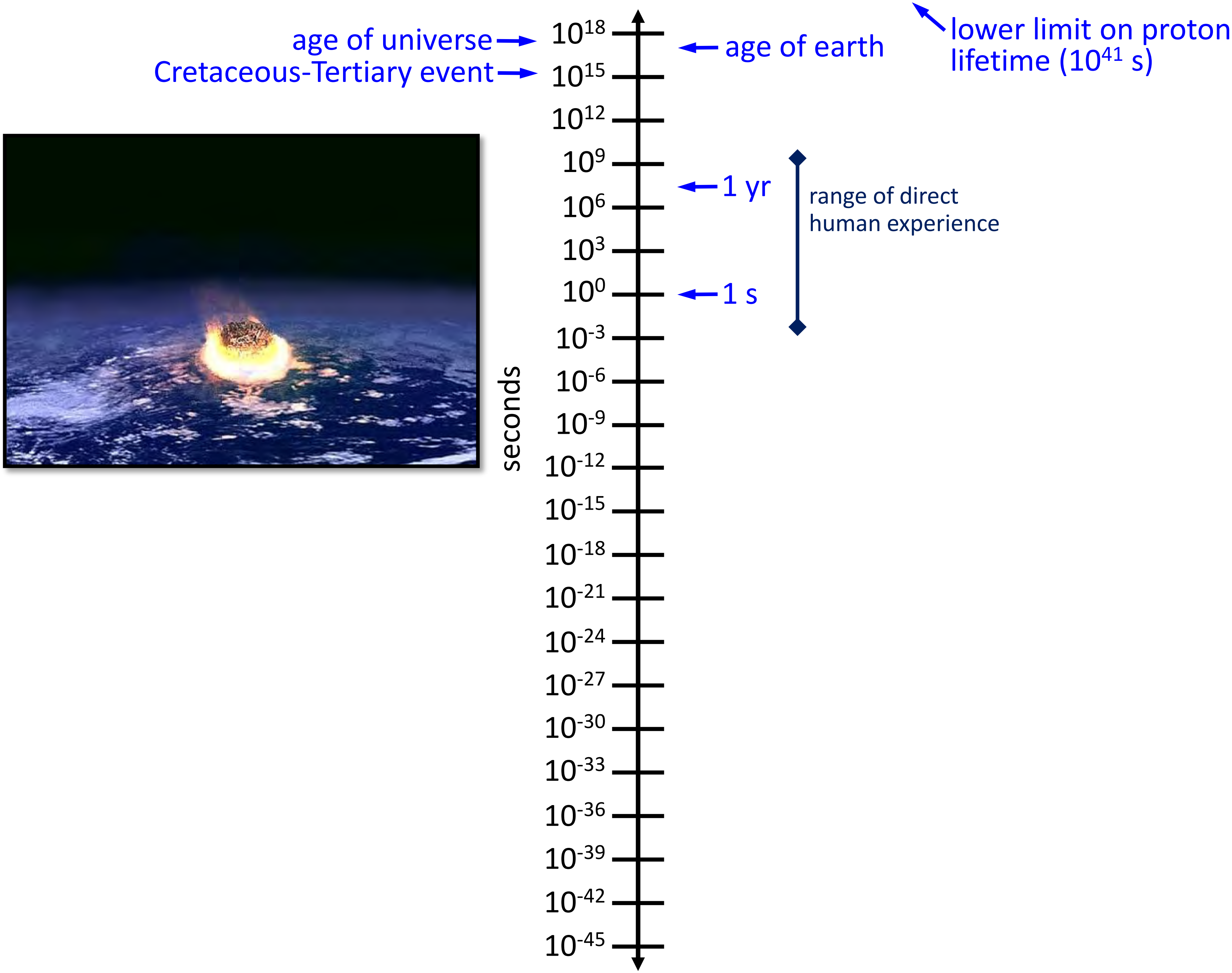
Light from the early universe,
showing up as microwaves today



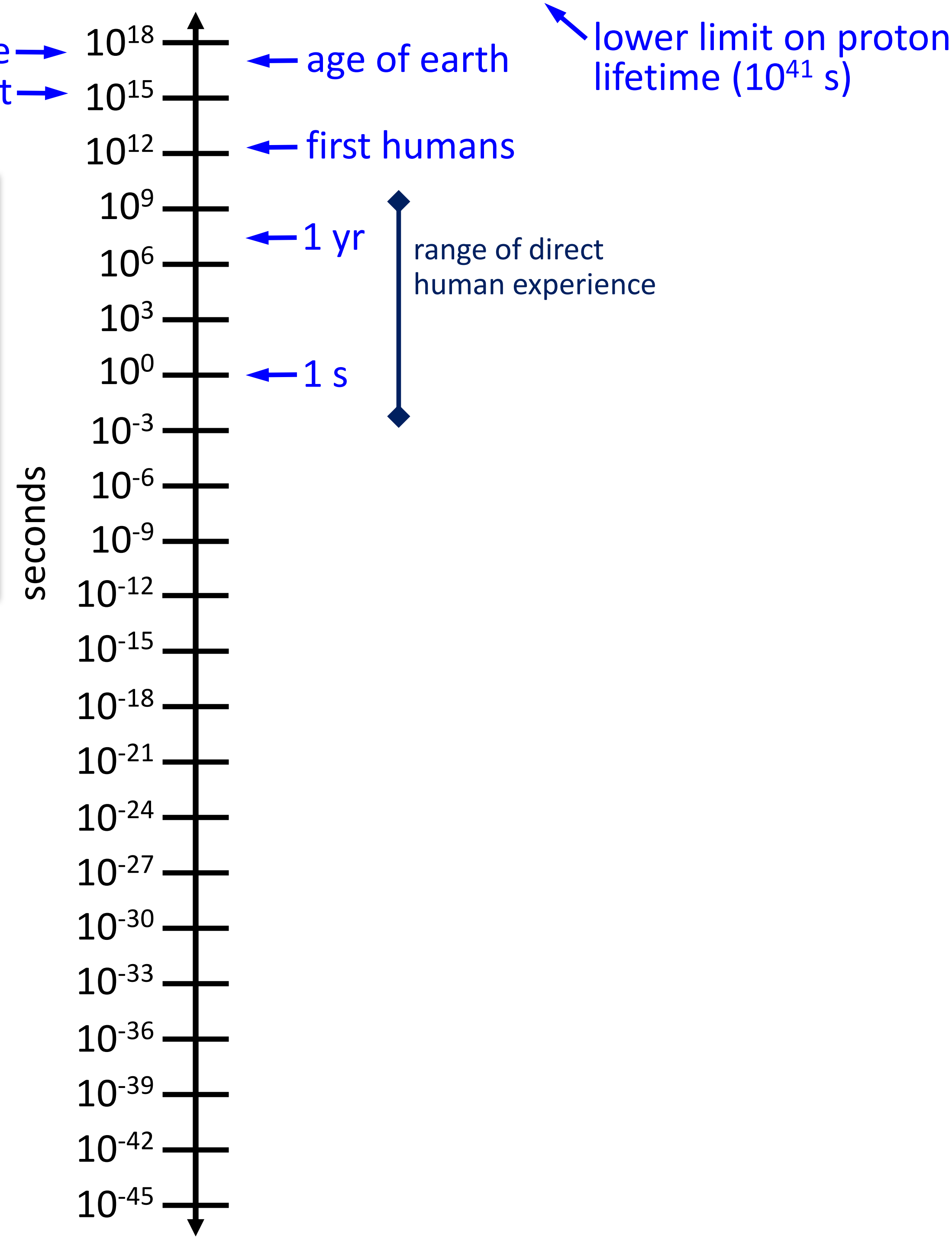




Super Kamiokande detector, Japan



age of universe
Cretaceous-Tertiary event
age of earth
lower limit on proton lifetime (10^{41} s)
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}
1 yr
1 s
range of direct human experience
seconds



age of universe
Cretaceous-Tertiary event
age of earth
lower limit on proton lifetime (10^{41} s)
first humans
1 yr
range of direct human experience
1 s
seconds
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
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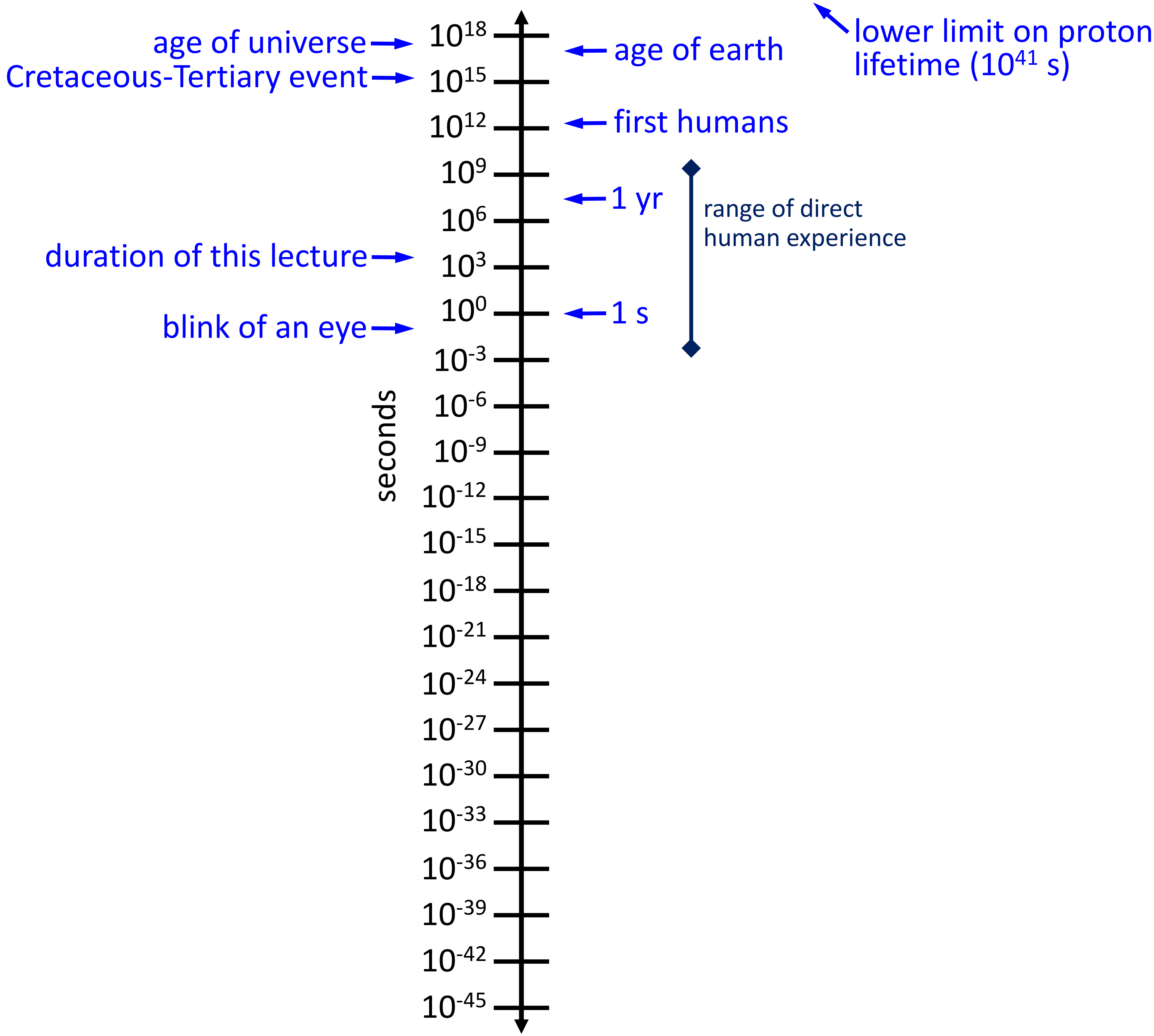
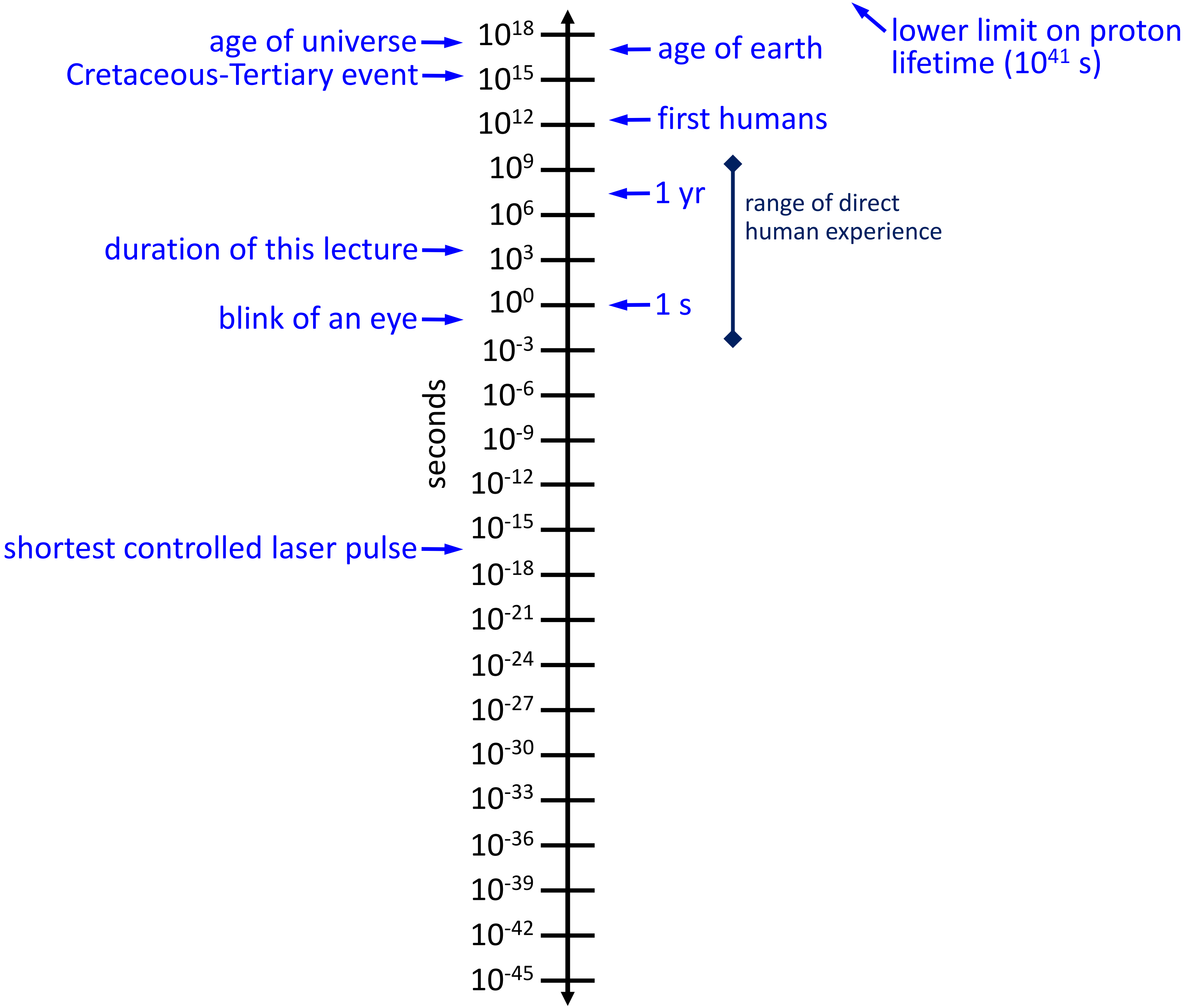
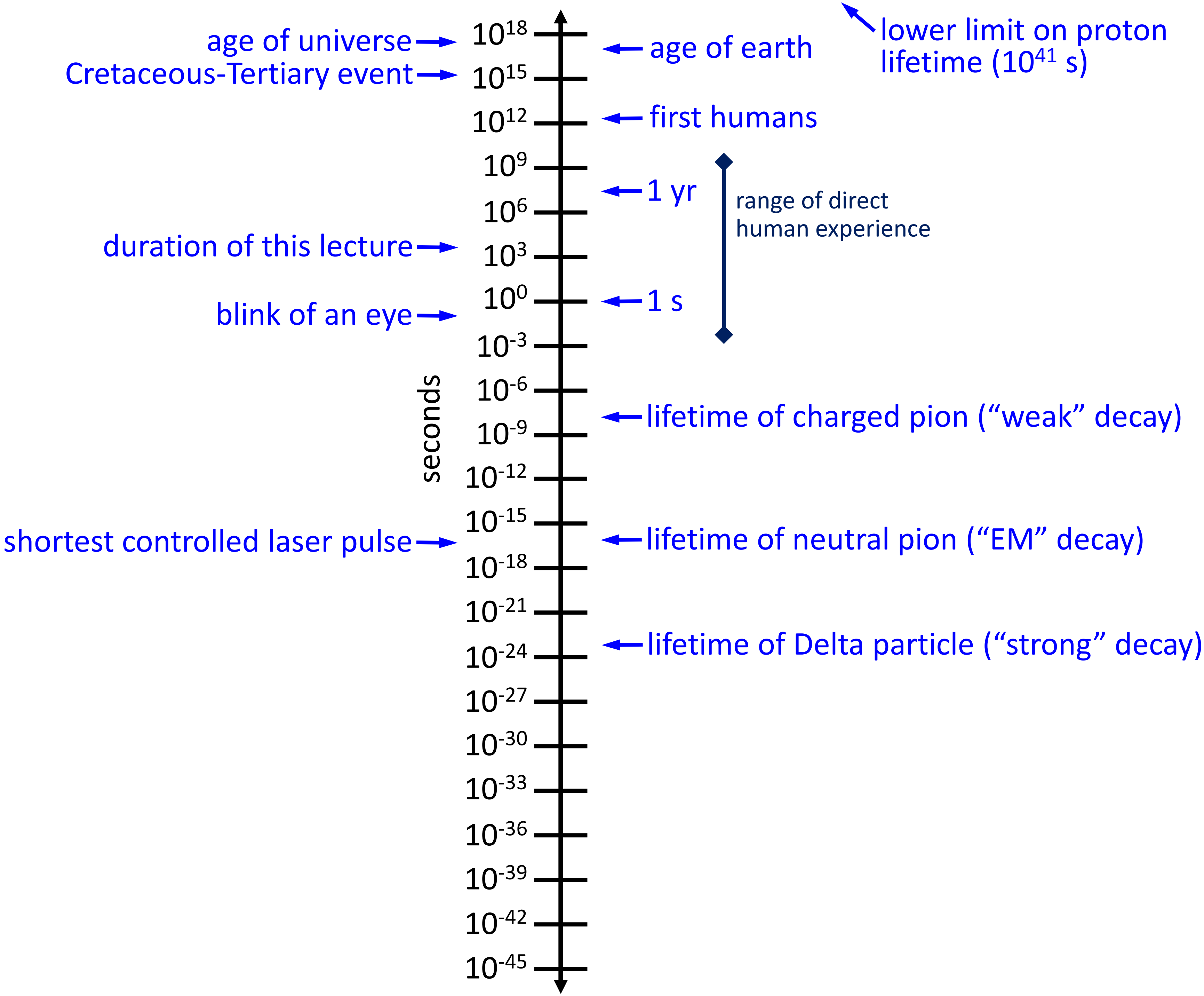
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}



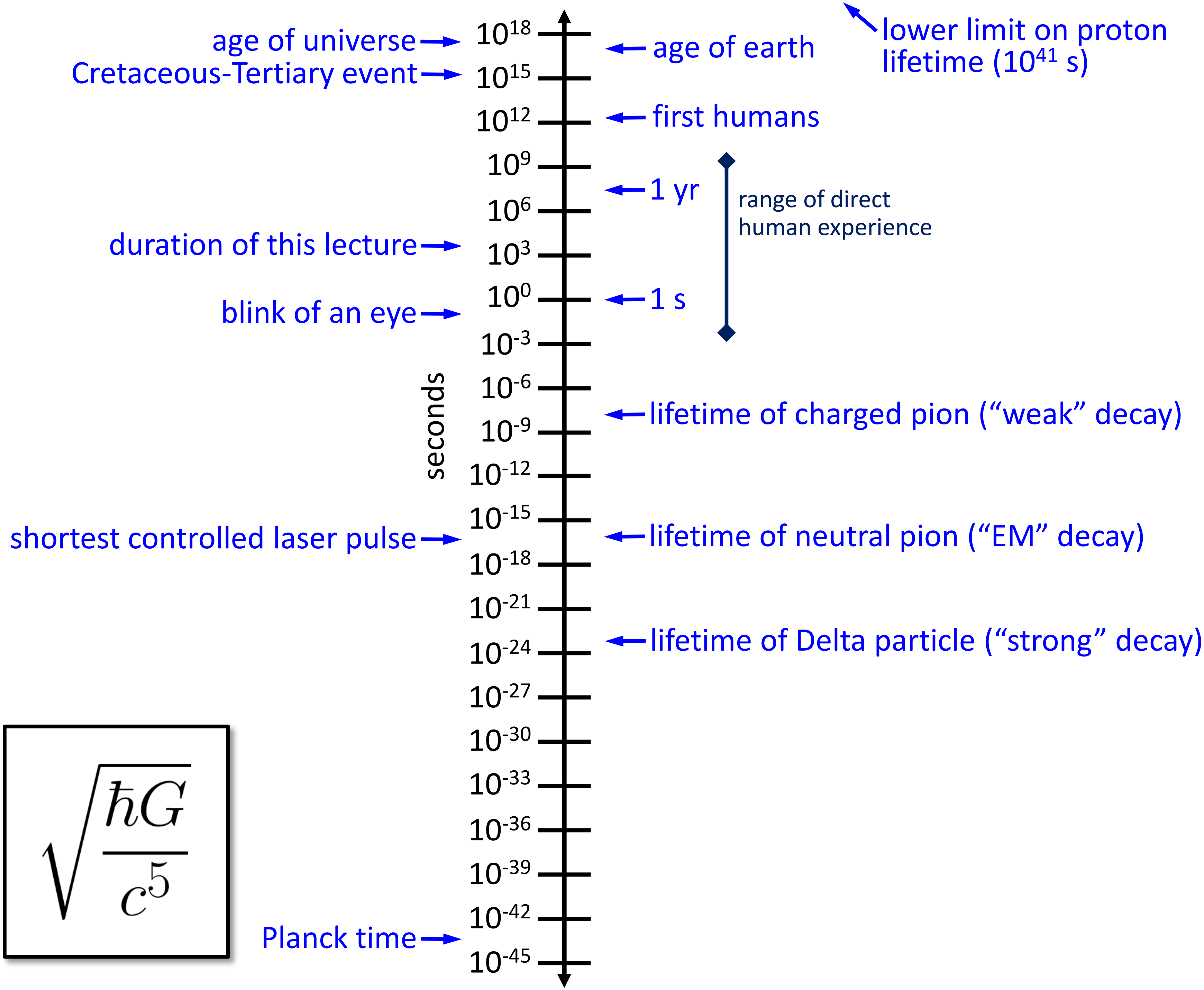
age of universe
Cretaceous-Tertiary event
duration of this lecture
blink of an eye
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}
seconds
age of earth
first humans
1 yr
1 s
range of direct human experience
lower limit on proton lifetime (10^{41} s)



age of universe
Cretaceous-Tertiary event
duration of this lecture
blink of an eye
shortest controlled laser pulse
seconds
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}
age of earth
first humans
1 yr
1 s
range of direct human experience
lower limit on proton lifetime (10^{41} s)



age of universe
Cretaceous-Tertiary event
duration of this lecture
blink of an eye
shortest controlled laser pulse
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}
seconds
age of earth
first humans
1 yr
1 s
range of direct human experience
lower limit on proton lifetime (10^{41} s)
lifetime of charged pion (“weak” decay)
lifetime of neutral pion (“EM” decay)
lifetime of Delta particle (“strong” decay)



age of universe
Cretaceous-Tertiary event
duration of this lecture
blink of an eye
shortest controlled laser pulse
Planck time
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
10^{-42}
10^{-45}
seconds
age of earth
lower limit on proton lifetime (10^{41} s)
first humans
1 yr
range of direct human experience
1 s
lifetime of charged pion (“weak” decay)
lifetime of neutral pion (“EM” decay)
lifetime of Delta particle (“strong” decay)
$\sqrt{\frac{\hbar G}{c^5}}$

Distance standard

1 meter ≡ the distance that light travels in 1/(299,792,458) seconds *(in a vacuum)*

Means that the speed of light is given exactly by:

c = 299,792,458 m/s

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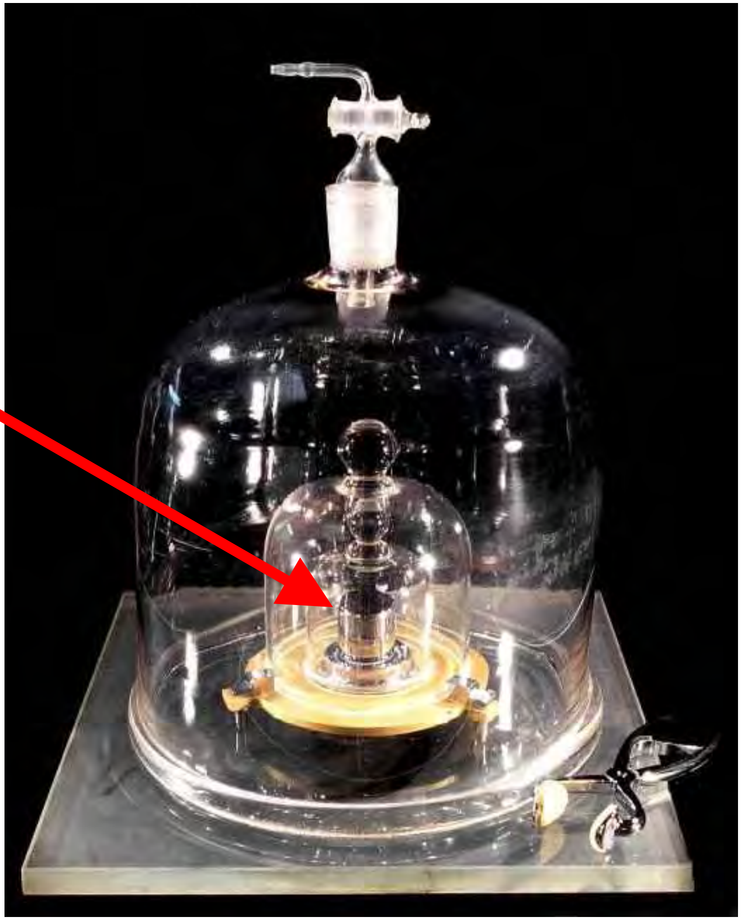
1 meter ≡ the distance that light travels in 1/(299,792,458) seconds *(in a vacuum)*

Means that the speed of light is given exactly by:

c = 299,792,458 m/s

Mass standard

1 kilogram ≡ the mass of this thing



Work is ongoing to replace this standard with something more "natural", perhaps based on Planck's constant $\hbar$.

(digital clock demo, part 2…)

Next time

We'll cover more "mainstream" topics:

- ***Position, velocity, acceleration***
- ***Derivatives (and a whiff of antiderivatives)***
- ***Constant acceleration***
- ***Objects in freefall***