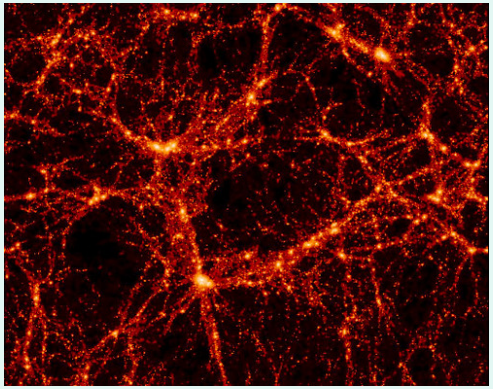
Astronomy 120

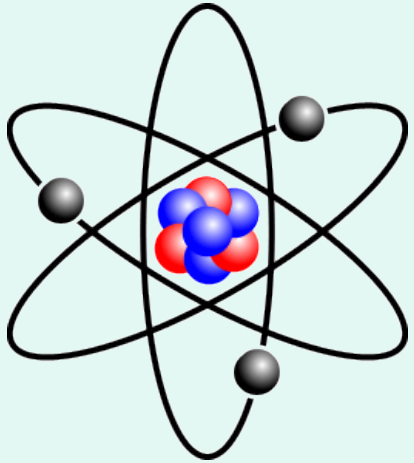
www.astro.yale.edu/astro120



Prof. Jeff Kenney

Class 1

May 28, 2018



Astronomy 120

Lec 1-5: intro, physics review

Lec 6-8: stars

Lec 9-14: galaxies, clusters & dark matter

Lec 15-18: active galaxies & black holes

Lec 19-24: cosmology & the universe

For full syllabus see website

www.astro.yale.edu/astro120

Class website

main site:
www.astro.yale.edu/astro120

but most things also on canvas

textbook

- ***Universe*** (Freedman, Geller, Kaufmann) 10th edition
- E-book recommended (LaunchPad)
- website has link
- “hardcopies” (used, looseleaf) at Yale bookstore or through Amazon (10th or 9th or 8th editions are OK)

Remote polling & peer instruction

- More discussion & learning in class

→Attendance important!

- Less material covered in class

→Important to read textbook before class!

→On-line Reading quizzes

Must complete by 12noon the day of the class!

-> Starts tomorrow

Accessed from Canvas, “Quizzes”, “RQ Lxx” is the Reading Quiz for Lecture #xx

Computers & notetaking in class

- no electronic devices in class EXCEPT if you really want laptop to take notes (must first discuss with professor)
- no phones
- I will hand out paper copies of slides at start of each class for you to take notes

Grading

40% Weekly Homework
10% Reading quizzes
10% Attendance & Class Participation*
10% Observing & Planetarium assignment
30% Final exam

*class participation – lose credit if distracted during class

Homeworks

- ~2x weekly
- 1st HW due *this Wed May 30*
- 2nd HW due *this Fri June 1*

Help!?

TUTORING:

All hours are drop in. No appointments required

QR/SC Tutoring – begins Tuesday 5/29

Tuesdays, Wednesdays, Thursdays: 4:30pm-6pm (Astr, Eng, Math, Phys, Stat)

Location: SML 116C in the Center for Teaching and Learning (301 York Street)

Professor:

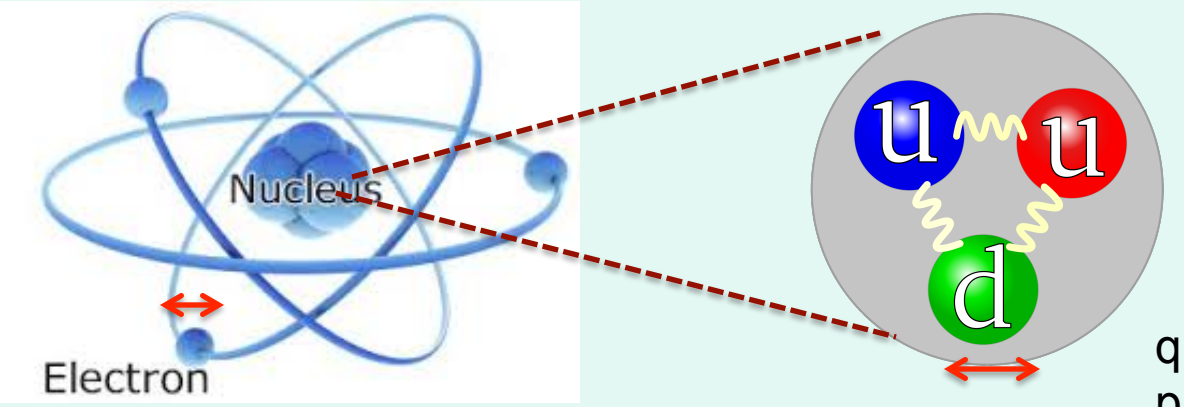
email jeff.kenney@yale.edu

Office Hours: by appt

SIZES & DISTANCES

Electron or quark 10^{-18} m

smallest things we have measured
or inferred based on physical principles

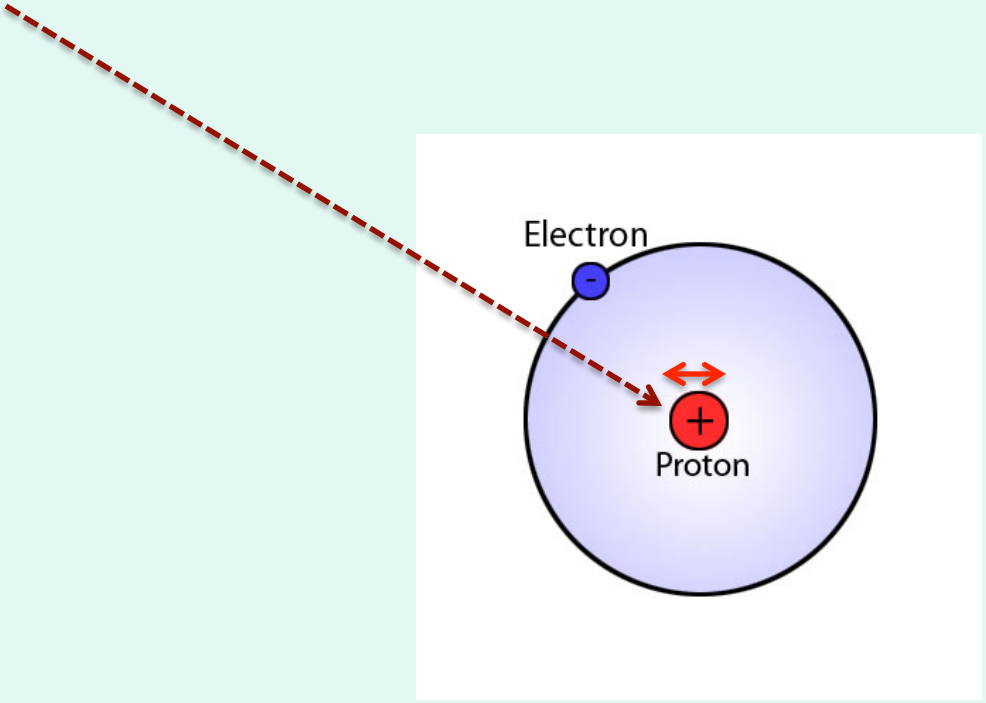


quarks inside
proton

SIZES & DISTANCES

Electron or quark 10^{-18} m

Proton = nucleus of H atom 10^{-14} m



SIZES & DISTANCES

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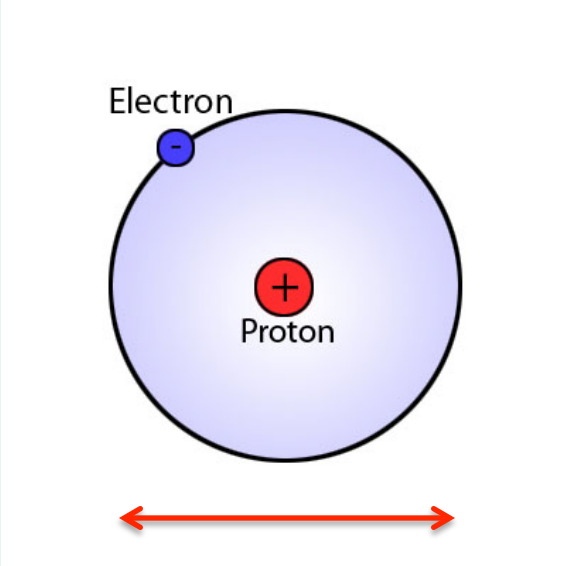

SIZES & DISTANCES

Electron or quark		10^{-18} m
Proton = nucleus of H atom		10^{-14} m
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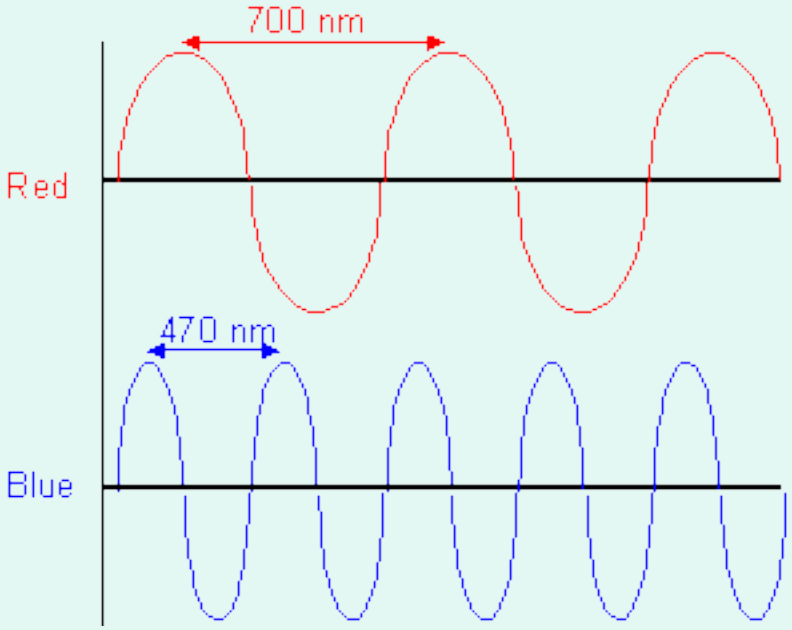

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what is smallest thing visible to naked eye?

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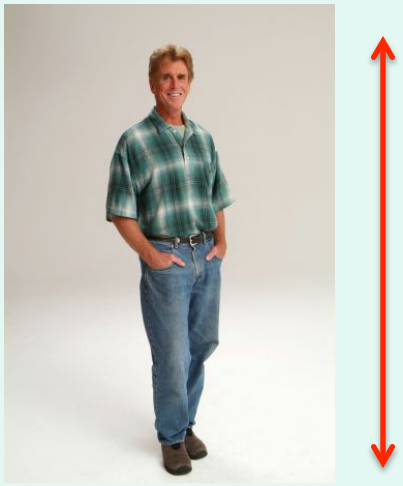

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Earth-moon distance	384,000 km	3.8×10^{8} m

to scale!

SIZES & DISTANCES

Earth's diameter	12,756 km	1.3×10^7 m
Earth-moon distance	384,000 km	3.8×10^8 m
Earth-sun distance	150,000,000 km	1.5×10^{11} m

= 93,000,000 miles

= 8.3 light-minutes

= 1 Astronomical Unit

= 1 AU

not to scale!

SIZES & DISTANCES

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nearest star		

what is nearest star?

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nearest star	4 light years (LY)	3.8×10^{16} m

what is nearest star?

Proxima Centauri, a companion to Alpha & Beta Centauri

SIZES & DISTANCES

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most distant star seen with naked eye

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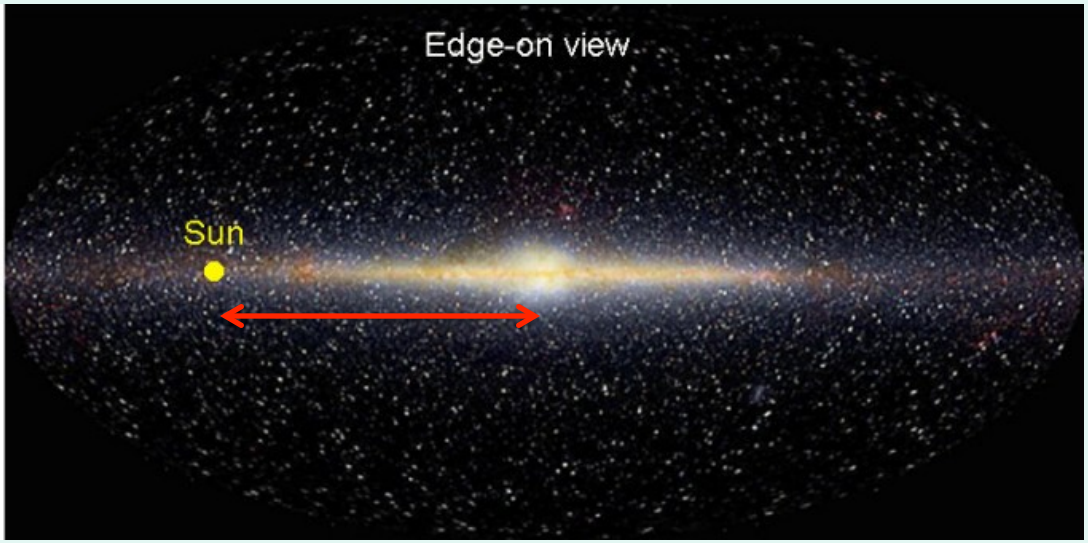
center of galaxy	30,000 LY	2.8×10^{20} m

in Sagittarius ; obscured by dust



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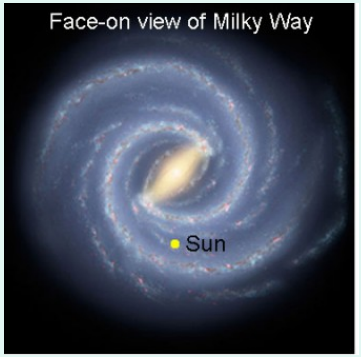
center of galaxy	30,000 LY	2.8×10^{20} m
nearest spiral galaxy	2,000,000 LY	1.9×10^{22} m

Andromeda galaxy

= M31



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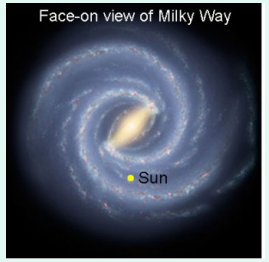
nearest galaxy cluster	50,000,000 LY	4.7×10^{23} m

Virgo Cluster



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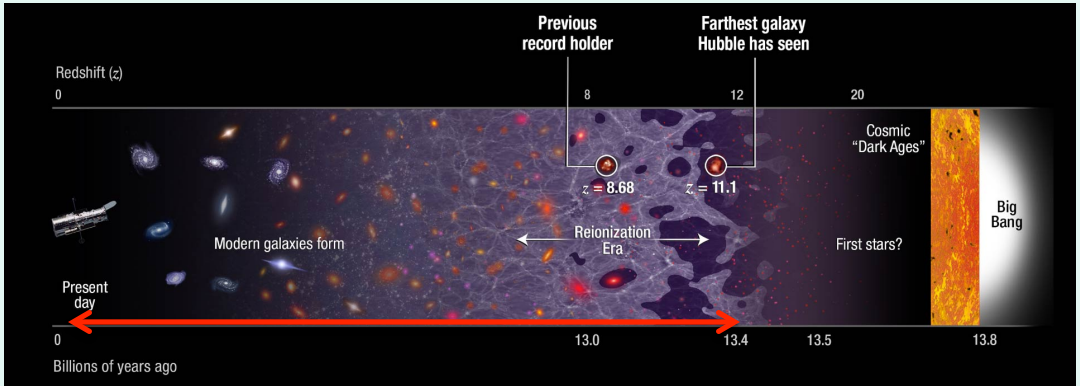
most distant galaxies known	13,000,000,000 LY	1.23×10^{26} m

redshift z~11, young galaxies



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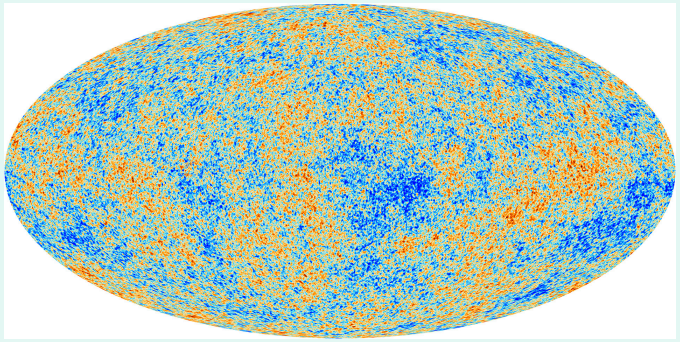
"edge" of observable universe	13,700,000,000 LY	1.30×10^{26} m



map of cosmic microwave background radiation, almost to edge of observable universe

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whole universe is probably much bigger than this…

but we can't observe it!

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to nearest galaxy cluster (Virgo cluster)	50,000,000 LY	4.7×10^{23} m
to most distant galaxies known (z=10)	13,000,000,000 LY	1.23×10^{26} m
to "edge" of observable universe	13,700,000,000 LY	1.30×10^{26} m

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range of human perception
factor of 10^{12} in size

Humans can directly perceive ~12 orders of magnitude in size

Human perception ~10^{12}

But we have so far explored ~44 orders of magnitude in size, by using technology and our intelligence

Human discovery ~10^{44}

Much of existence is beyond our direct experience!

big numbers…

- number of atoms in universe ~ 10^{80}

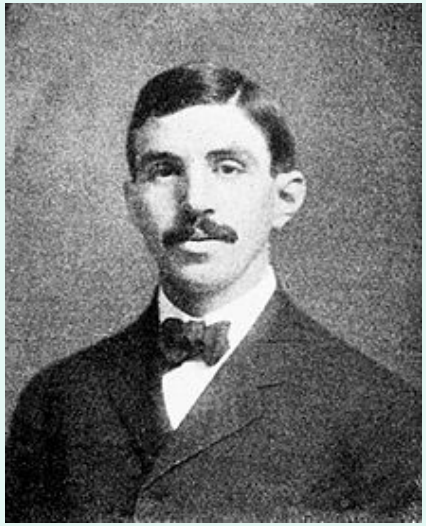
big numbers…

- number of atoms in universe ~ 10^{80}

- googol = 10^{100}

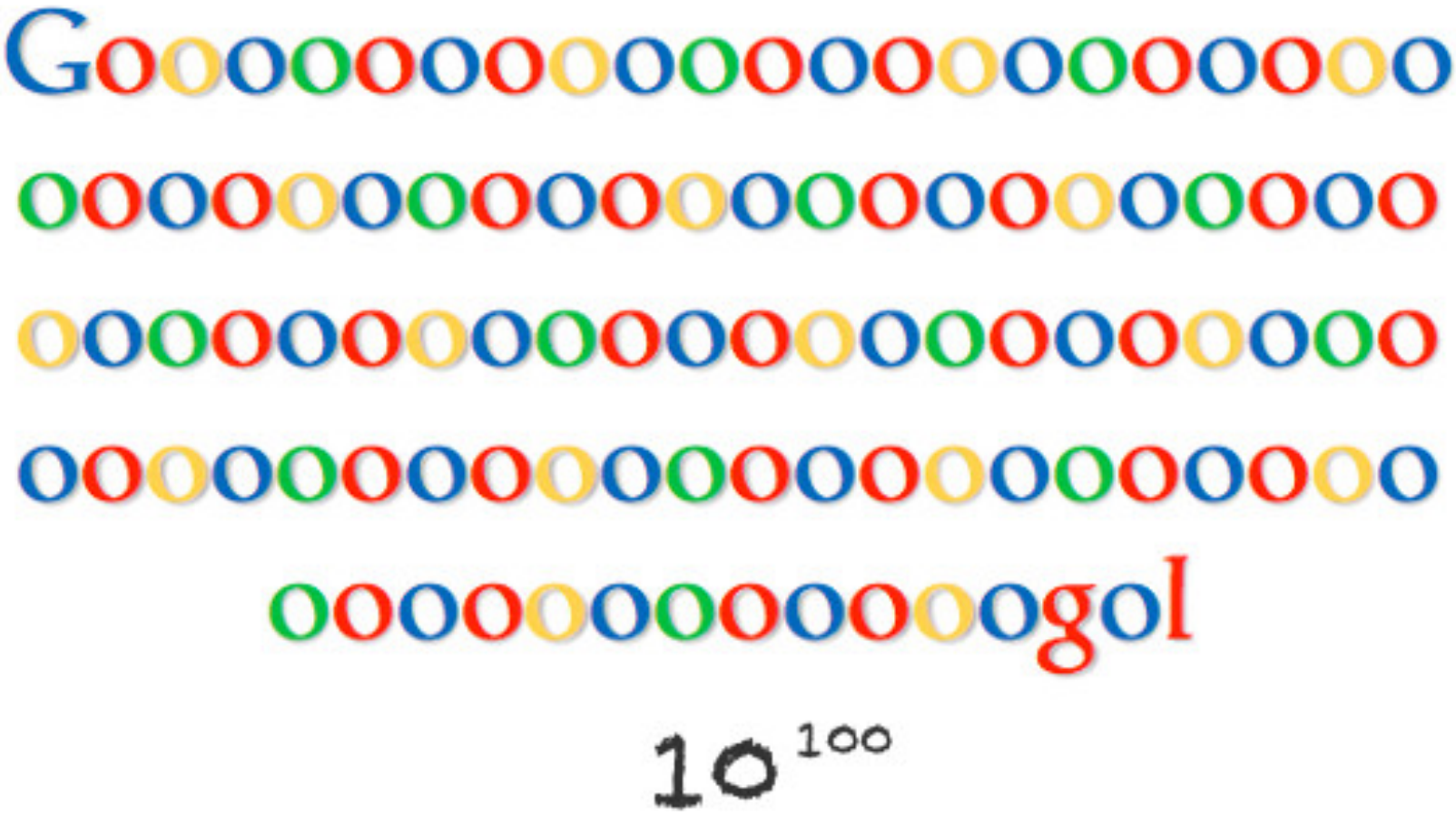
  spelled differently than the internet company

due to Edward Kasner,
American mathematician



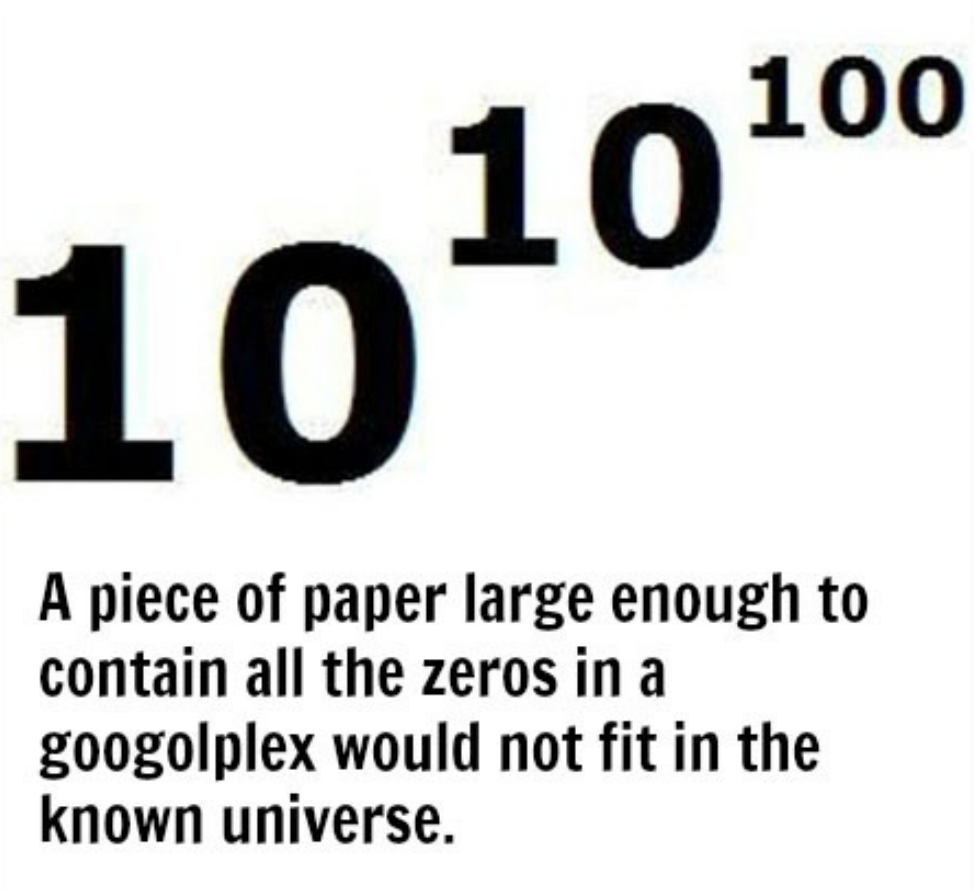
10,000,000,000,000,000,
000,000,000,000,000,000,
000,000,000,000,000,000,
000,000,000,000,000,000,
000,000,000,000,000,000,
000,000,000,000 = 1 googol

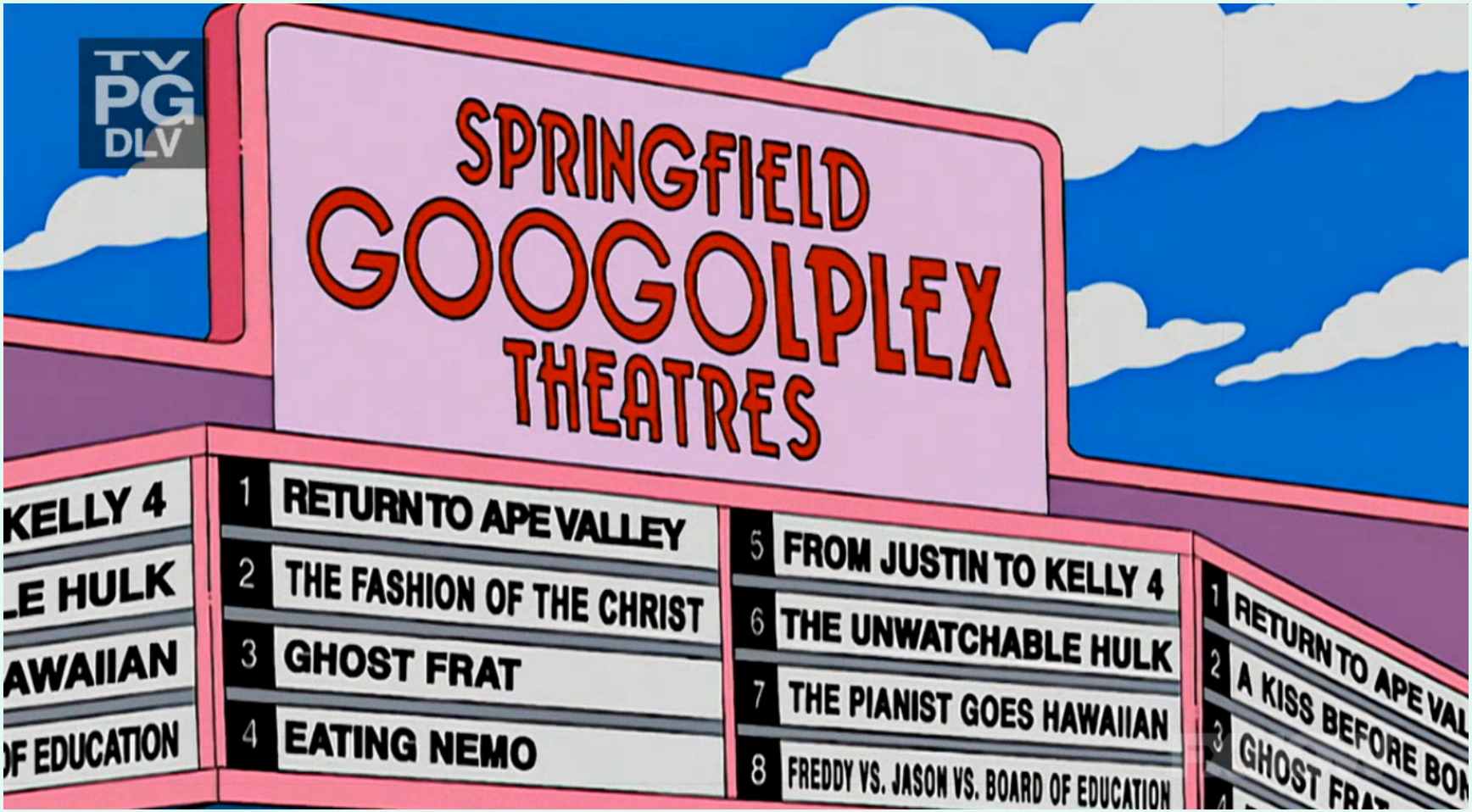
$= 10^{100}$


Gooooooooooooooooooooooo
oooooooooooooooooooooooo
oooooooooooooooooooooooo
oooooooooooooooooooooooo
ooooooooooogol
10^100

big numbers…

$10^{\text{googol}} = 10^{10^{100}}$ = ***googolplex***




TV
PG
DLV
SPRINGFIELD
GOOGOLPLEX
THEATRES
KELLY 4
LE HULK
AWAIIAN
OF EDUCATION
1 RETURN TO APE VALLEY
2 THE FASHION OF THE CHRIST
3 GHOST FRAT
4 EATING NEMO
5 FROM JUSTIN TO KELLY 4
6 THE UNWATCHABLE HULK
7 THE PIANIST GOES HAWAIIAN
8 FREDDY VS. JASON VS. BOARD OF EDUCATION
1 RETURN TO APE VAL
2 A KISS BEFORE BO
3 GHOST FRAT

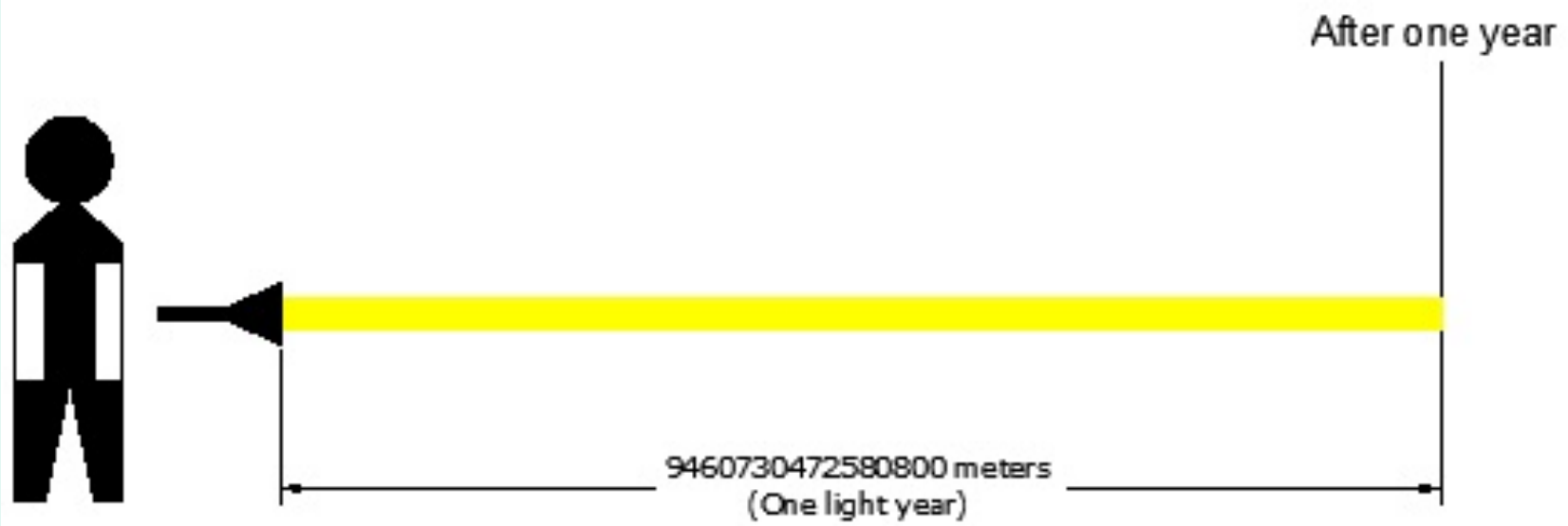
$$\text{Googol} = 10^{100} = 10^{10^{10}}$$

$$\text{Googolplex} = 10^{\text{googol}} = 10^{10^{100}} = 10^{10^{10^{10}}}$$

$$\text{Googolplexian} = 10^{\text{googolplex}} = 10^{10^{10^{100}}} = 10^{10^{10^{10^{10}}}}$$

LIGHT YEAR IS A DISTANCE!!

Despite the confusing fact that a unit of time is part of the name



light year = how far light travels in 1 year

Light goes far in a year since light is fast!

Speed of light = 3×10^5 km/s

1 light-year = 1 LY = 9.5×10^{12} km

light year (still a distance…)

distance = speed x time

$$
\begin{aligned}
1 \text{ light-year} &= (\text{speed of light}) \times (1 \text{ yr}) \\
&= \left(300{,}000 \frac{\text{km}}{\cancel{\text{s}}}\right) \times \left(1 \cancel{\text{yr}} \times \frac{365 \cancel{\text{days}}}{1 \cancel{\text{yr}}}\right. \\
&\quad \left. \times \frac{24 \cancel{\text{hr}}}{1 \cancel{\text{day}}} \times \frac{60 \cancel{\text{min}}}{1 \cancel{\text{hr}}} \times \frac{60 \cancel{\text{s}}}{1 \cancel{\text{min}}}\right) \\
&= 9{,}460{,}000{,}000{,}000 \text{ km}
\end{aligned}
$$

1 light-year = 1 LY = 9.5×10^{12} km

= 5.7×10^{12} miles (trillion)

= 6×10^{4} AU

“light year” is bad name

“light-year-distance-unit” is better name

timescales

Nuclear events (fusion, fission) 10^{-23}-10^{-10} sec

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)	10^{-16}-10^{-9} sec

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)	10^{-16}-10^{-9} sec
Chemical events	10^{-9}-10^{-6} sec

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)	10^{-16}-10^{-9} sec
Chemical events	10^{-9}-10^{-6} sec

Shortest interval perceptible to humans ????

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)	10^{-16}-10^{-9} sec
Chemical events	10^{-9}-10^{-6} sec
Shortest interval perceptible to humans	0.01 sec = 10^{-2} sec

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)	10^{-16}-10^{-9} sec
Chemical events	10^{-9}-10^{-6} sec
Shortest interval perceptible to humans	0.01 sec = 10^{-2} sec
Light travel time around earth	1/7 sec = 0.14 sec

timescales

Nuclear events (fusion, fission)	10^{-23}-10^{-10} sec
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Rotation of earth	1 day 8.6×10^{4} sec

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Shortest interval perceptible to humans		0.01 sec = 10^{-2} sec
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Rotation of earth	1 day	8.6×10^4 sec
Revolution of moon around earth	29.5 days ~1 month	

timescales

Nuclear events (fusion, fission) 10^{-23}-10^{-10} sec

Atomic events (e.g. light absorption) 10^{-16}-10^{-9} sec

Chemical events 10^{-9}-10^{-6} sec

Shortest interval perceptible to humans 0.01 sec = 10^{-2} sec

Light travel time around earth 1/7 sec = 0.14 sec

Rotation of earth 1 day 8.6×10^4 sec

Revolution of moon around earth 29.5 days ~1 month

Revolution of earth around sun 365.244 days = 1 year 3.1×10^7 sec

timescales

Nuclear events (fusion, fission)		10^{-23}-10^{-10} sec
Atomic events (e.g. light absorption)		10^{-16}-10^{-9} sec
Chemical events		10^{-9}-10^{-6} sec
Shortest interval perceptible to humans		0.01 sec = 10^{-2} sec
Light travel time around earth		1/7 sec = 0.14 sec
Rotation of earth	1 day	8.6×10^{4} sec
Revolution of moon around earth	29.5 days ~1 month	
Revolution of earth around sun	365.244 days = 1 year	3.1×10^{7} sec
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Rev. of solar system around galactic center 2×10^8 yr

= “galactic year”

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astronomical cycles give us our most important units of time

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range of human perception in time ~10^{11}

At 100 mph it takes about 10 days to drive around the earth. How long would it take to drive to the Sun?

A. 1 year
B. 10 years
C. 100 years
D. 1000 years
E. 100^{100} googillion years

If you started right now to count to 1 billion you would be finished

A. The end of the semester
B. 2027
C. Your 90th birthday
D. Yale's 1st millennial
E. End of 3rd Zombie-Clone War