Tuesday, 5 Feb

brought to you by the letters ELECTRIC AND MAGNETIC FIELDS

pitchers and catchers report in 8 days

AC/DC week

housekeeping

A mistake

the Kepler's Law answer in L8 was wrong

everyone gets credit. Those who told me about it get 3xcredit

MasteringAstronomy! Free. Go there & register:

Course ID: MABROCK41459

Access code: WSSPCT-BLIDA-INANE-TOGUE-RIGOT-UNRWA

free e-text, *The Cosmic Perspective*

reading assignments and homework, mixed with Mastering Physics

During Part 1:

you're doing a great job keeping up!

I sure hope ~~you're keeping up~~

Lectures begin **next tuesday, 2/12**

Lesson 13 is up

Content: a mixture of text and video

Status of the server is:

February 2019

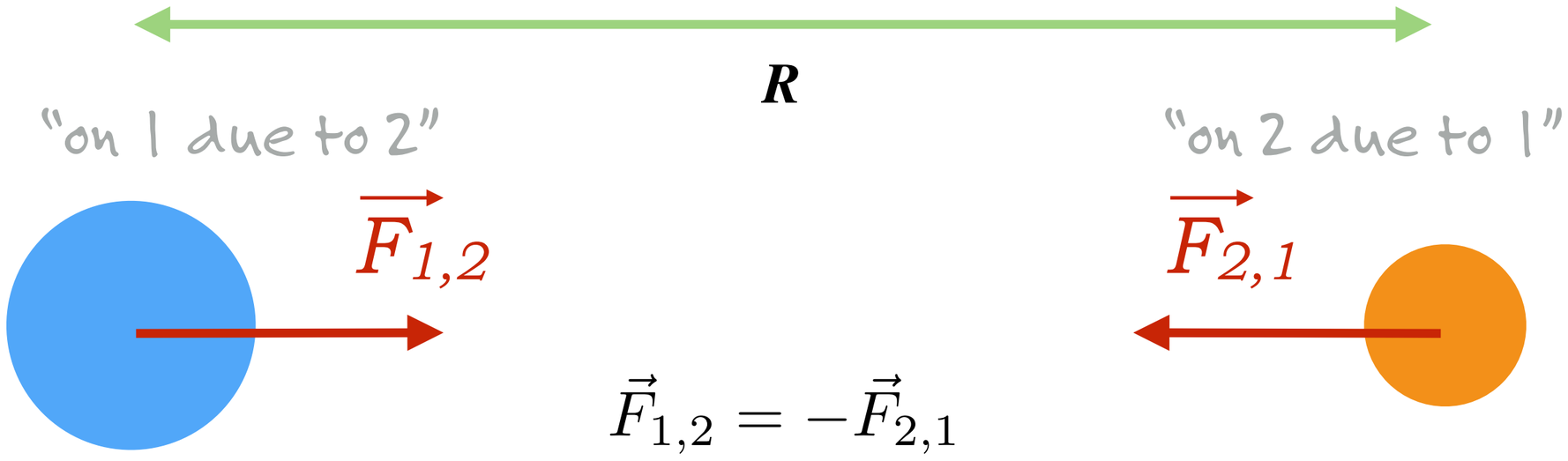
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	31	1	2
		yadda yadda yadda				HW2
3	4	5	6	7	8	9
		lessons 10,11,12		lesson 13	HW2 due	HW3
10	11	12	13	14	15	16
		lecture		lecture	HW3 due	HW4
17	18	19	20	21	22	23
		lecture		lecture	HW4 due	HW5
24	25	26	27	28	1	2
←	midterm?	→ lecture		lecture	HW5 due	

Eastern Time Time Zone

quiz

when we left off….way…back

this changed everything



$$\vec{F}_{1,2} = -\vec{F}_{2,1}$$

m_1 m_2

$$|\vec{F}_{1,2}| = |\vec{F}_{2,1}| = F$$

$$F = G\frac{m_1 m_2}{R^2}$$

$G = 6.67300 \times 10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$

"Gravitational Constant"

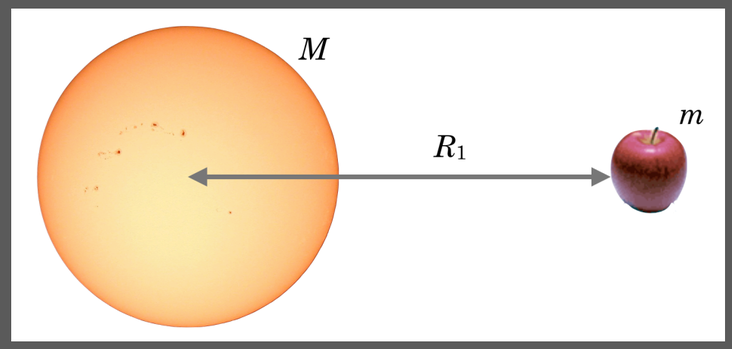
energy conservation still good

$$F_{A,S} = G\frac{M_A M_S}{R^2}$$

$$U(R) = -G\frac{Mm}{R}$$

So, $E_T = 0$ when KE=0

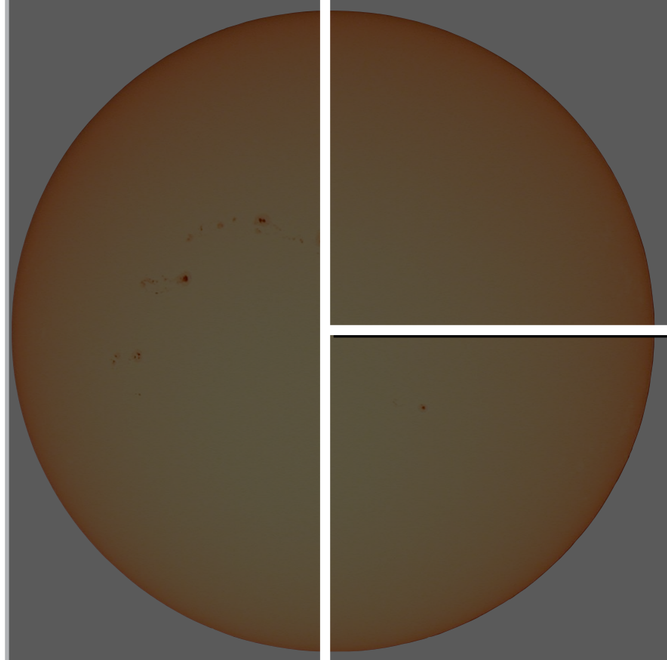
Where is PE = 0? not so obvious



E

$KE + PE =$ constant

Where is KE = 0? when v = 0



$K(R)$

we define PE = 0 at $R = \infty$

R

nudge it a smidgen toward the Sun...

R

$U(R)$

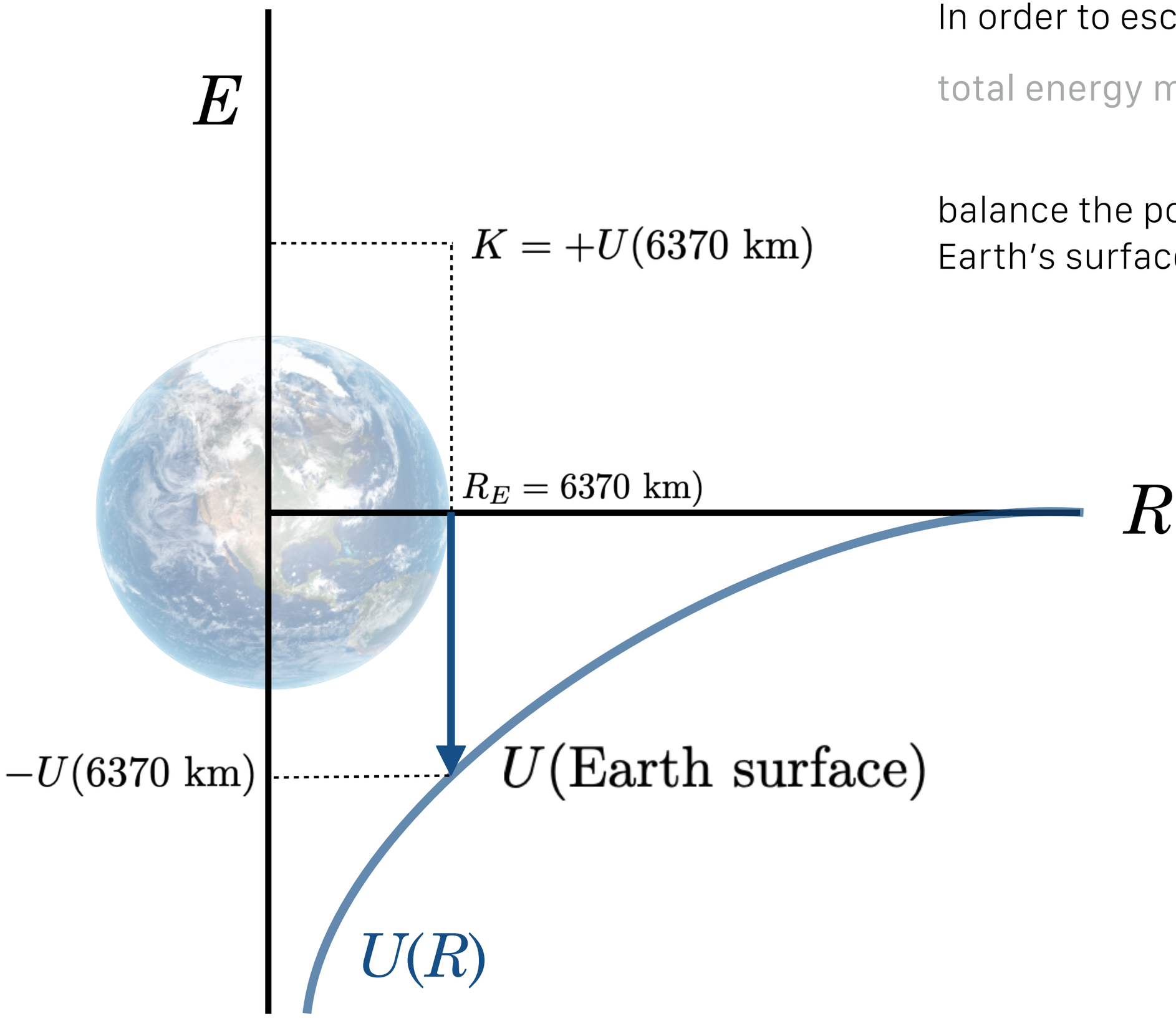
it starts to accelerate

$$K(R) + U(R) = KE + PE = \text{ constant}$$

so this *decreases* as apple approaches

this increases as apple approaches

Escape Velocity.

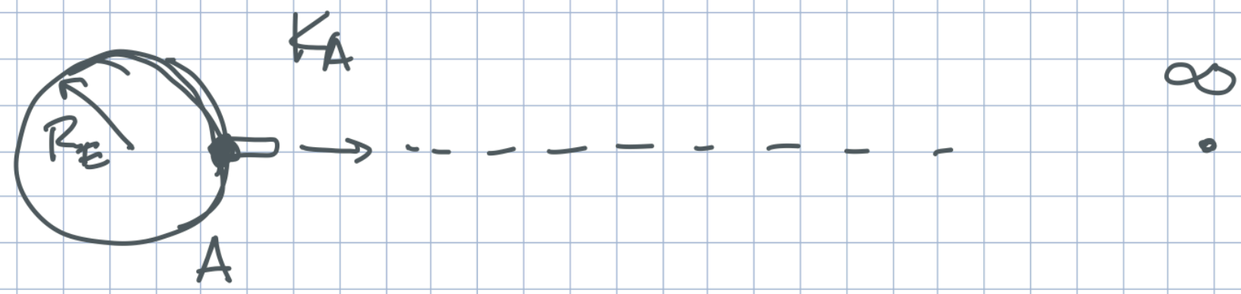


In order to escape Earth’s pull

total energy must be >0 for all R

balance the potential energy at the Earth’s surface

"escape velocity"



$$E_T = K_\infty + U_\infty = 0$$

$$0 = K_A + U_A$$

engineering nature

$$\tfrac{1}{2} m v^2 - \frac{G M_E m}{R_E} = 0$$

$$\tfrac{1}{2} m v^2 = \frac{G M_E m}{R_E}$$

$$v^2 = \frac{2 G M_E}{R_E}$$

$$v = \sqrt{\frac{2 G M_E}{R_E}}$$

$v = 11{,}200$ m/s $\rightarrow$ 25,000 mph

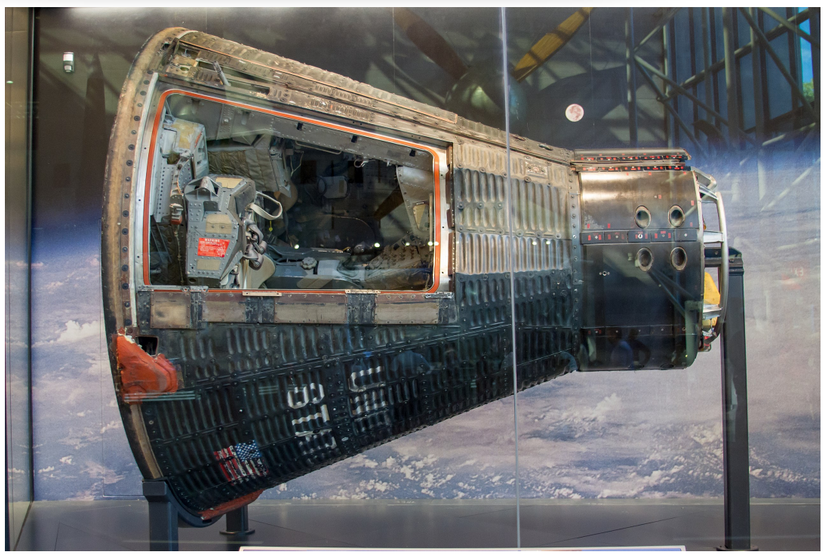
Newton had 3 issues:

1. “Action at a distance”
2. Stability of the Universe
3. Absolute Space and Time

now go back to yesteryear of NASA

DOCKING!!

$$v^2 = G\frac{M_E}{R}$$



Gemini V

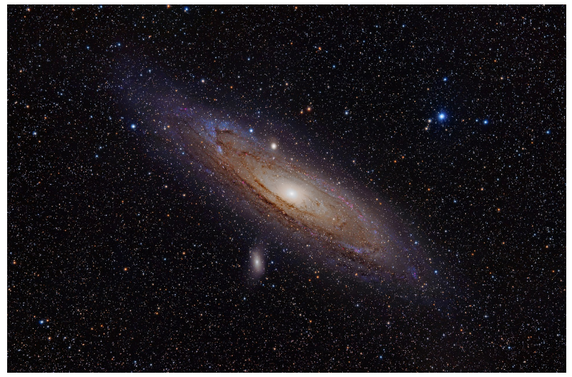
June 1965

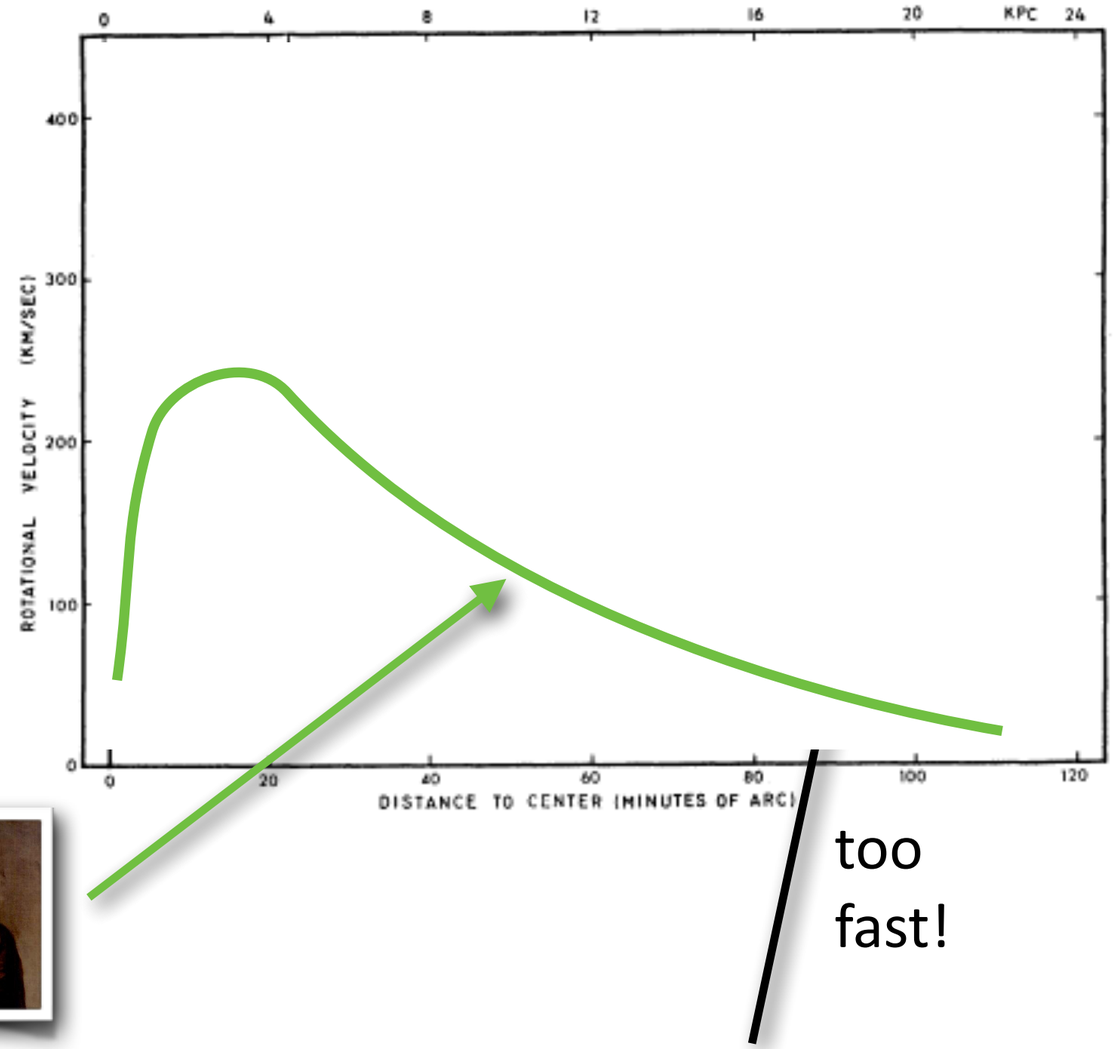
James McDivitt and Ed White

something's there

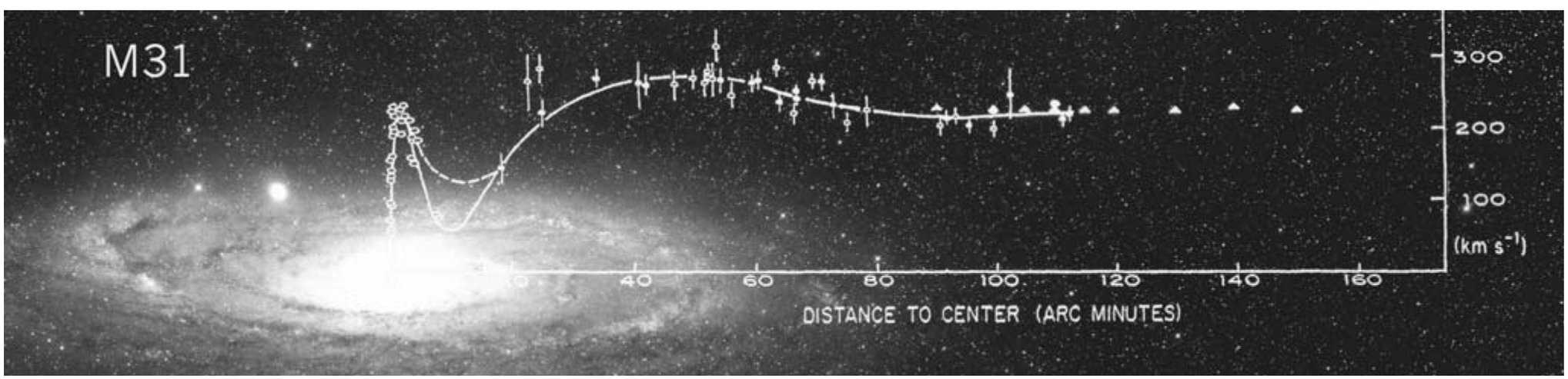
$$v = \sqrt{G\frac{M_{\text{galaxy center}}}{R}}$$

Vera Rubin, w/ Kent Ford, 1970: Andromeda



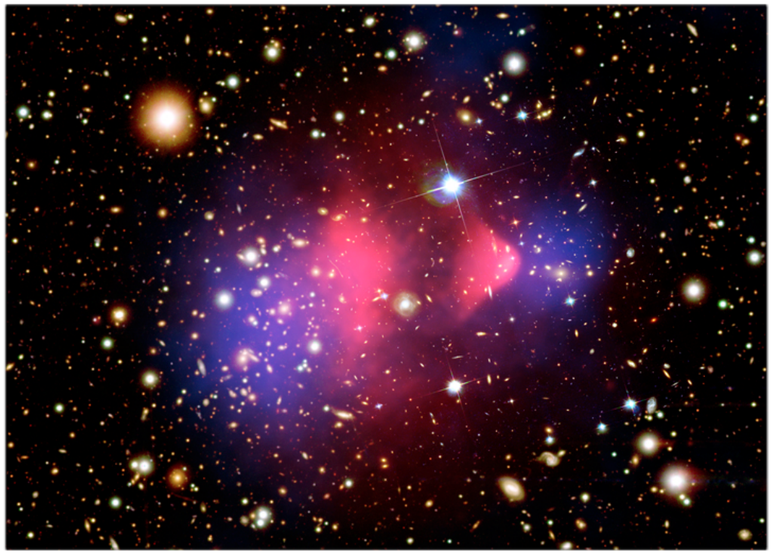


too fast!



Something's wrong! The amount of mass required in order to match the motion is about 1/6 of what is observable.

silver bullet(s)

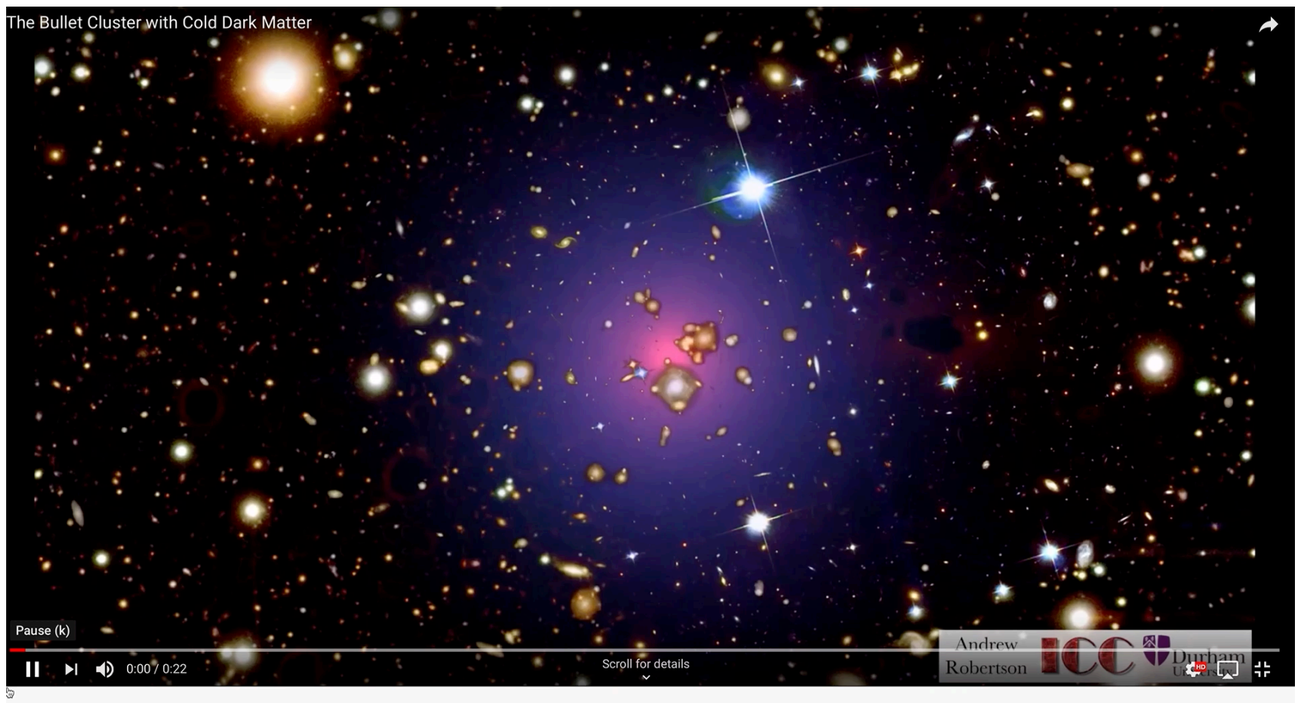


Bullet Cluster

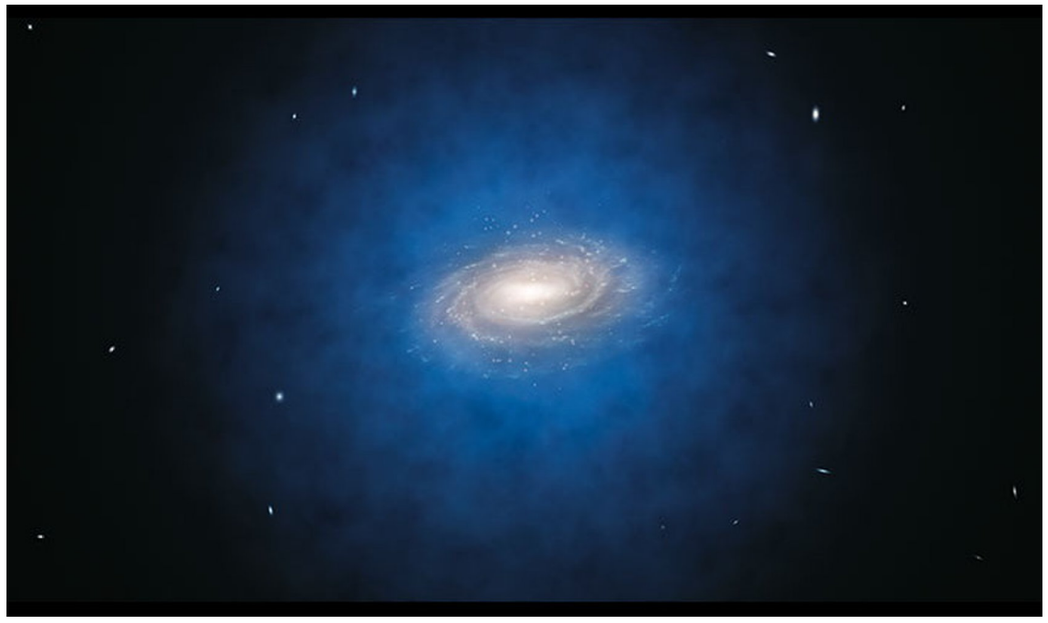
Abel 1689 composite image from Hubble Space Telescope and the Chandra X-ray Observatory

Simulation…

https://www.youtube.com/watch?v=rLx_TXhTXbs



simulation-inspired artistic view of milky way…blue is the amount of dark matter required



if it’s not a particle

then, we’re completely lost

which would be…you know…kind of cool

hypothetical

Dark Matter

=:-o

? - but perhaps 30% of the universe

?

something entirely new

did the Universe have a beginning?

Newton said, “No.”

You can do an experiment to show him to be wrong.

"Olbers' Paradox"

Heinrich Wilhelm Olbers…in 1823 and 1824 asked:

"Why is the sky dark at night?"

MSU-UNC-Brazil SOAR Telescope on Cerro Pachon, Chile

"Olbers' Paradox"

let Hubble look at a tiny patch of sky

Hubble eXtreme Deep Field:

23 days of exposure in

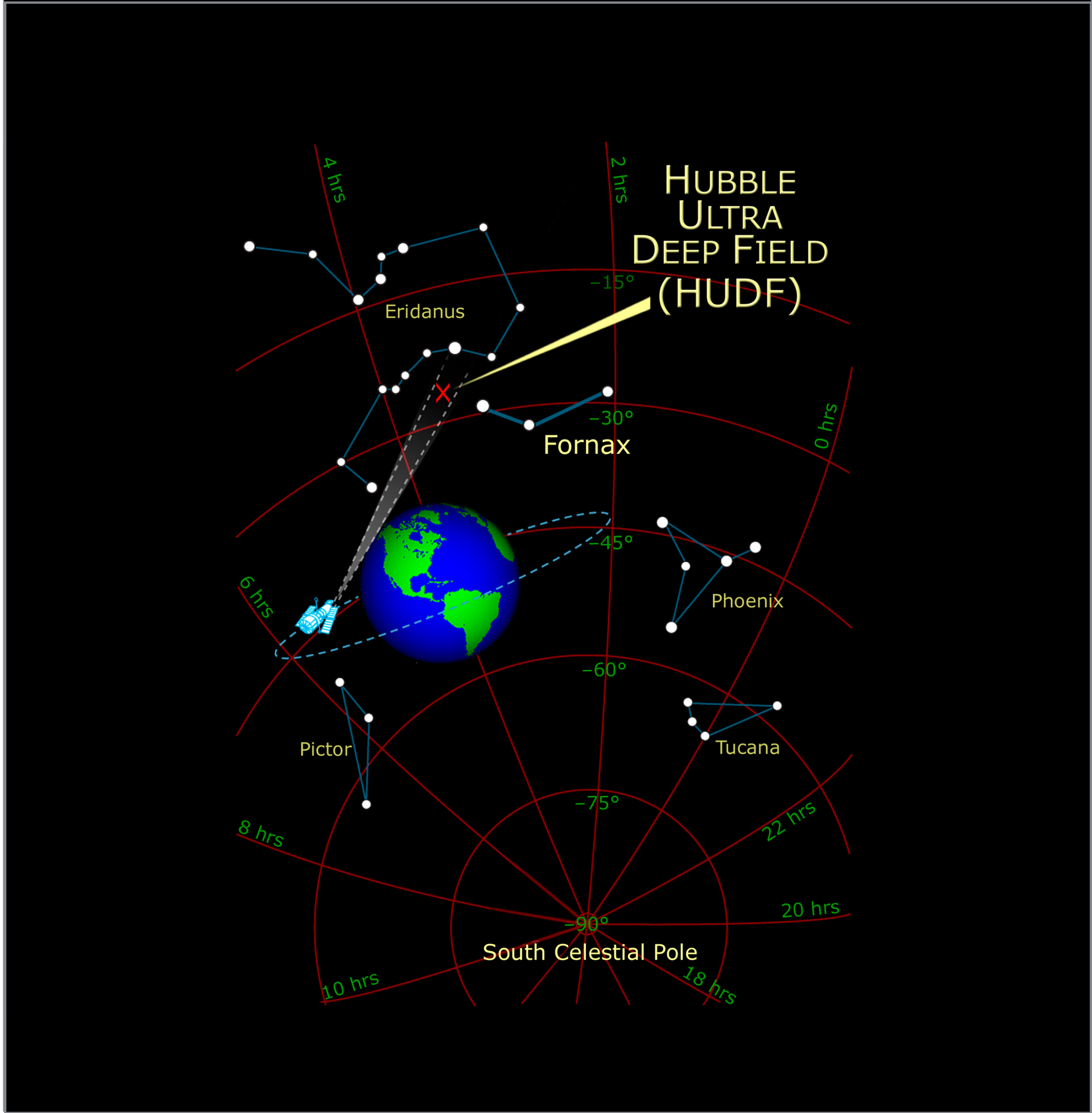
1/13,000,000th of sky

10,000 galaxies

as they were when 600M years old

or 13.2B years ago

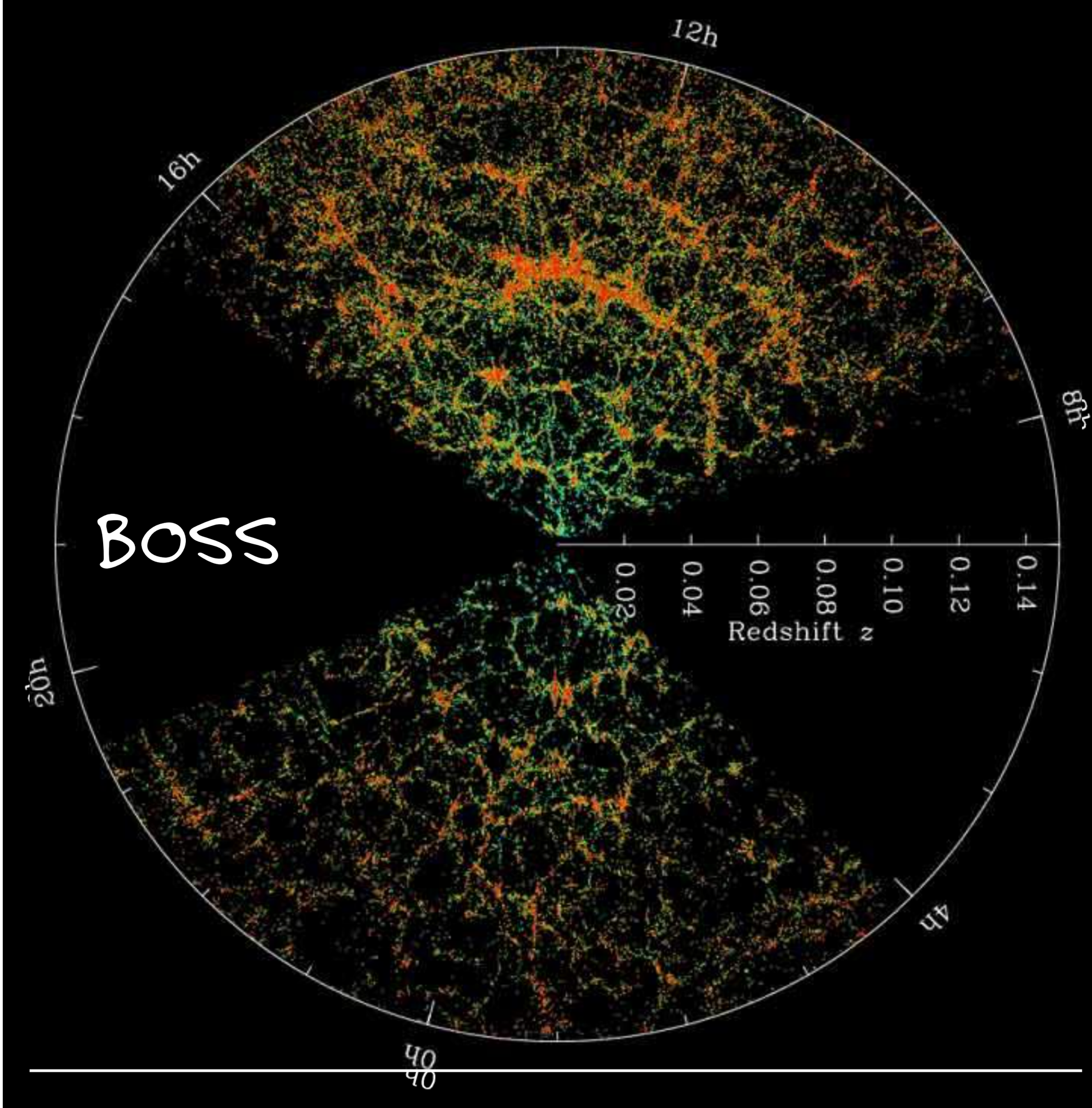
last year: 200,000,000,000 galaxies



Sloan Digital Sky Survey

Apache Point, New Mexico

equivalent of an **8Bly** large box

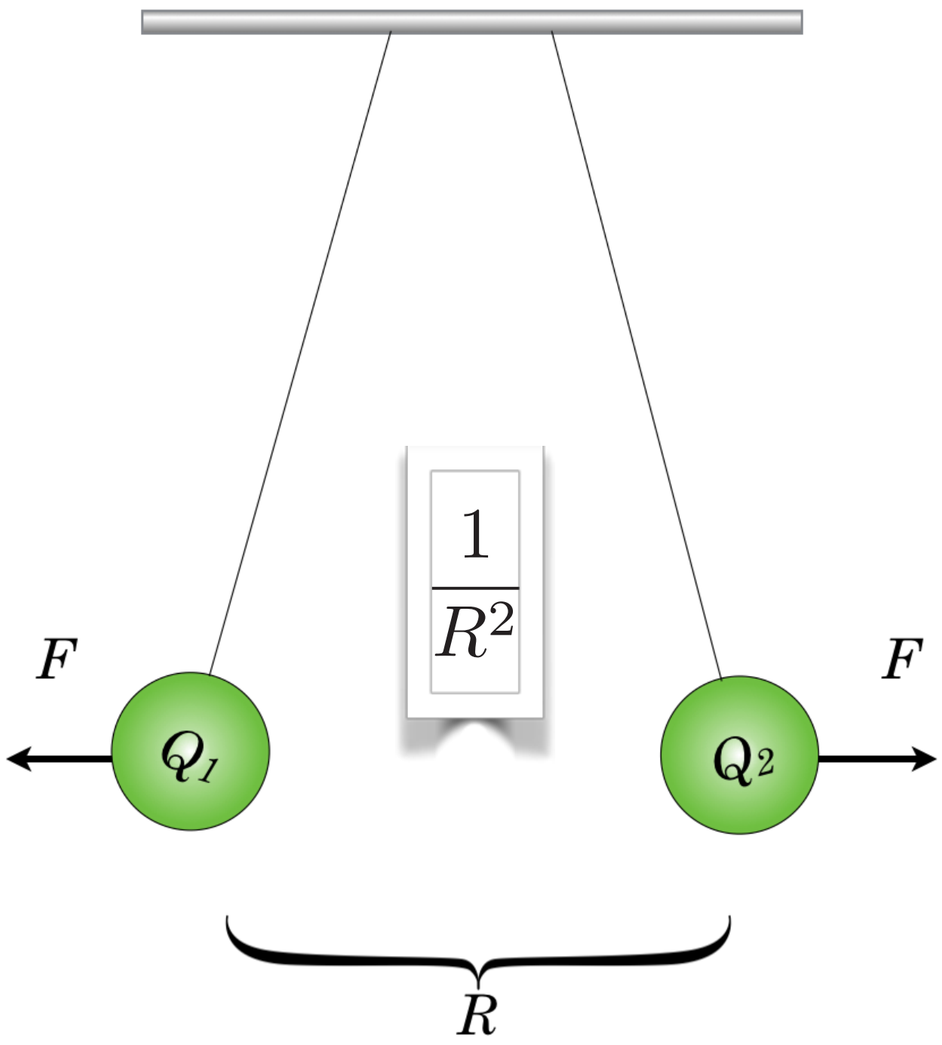


because there have not always been stars
our visible universe had a beginning

electricity and magnetism

just the facts, Ma’am

> 100 years of study



“natural” electric shocks

late 1700’s people started to carefully investigate electricity

The rules of electrostatic force of attraction/ repulsion

strange Henry Cavendish (1731 - 1810)
did it first

Charles Coulomb (1736 - 1806)
did it better

protons, neutrons, electrons

we'll care a lot about their properties:

- mass
- electric charge
- "spin"

$$m_{\text{proton}} = 1.672621637(83)\times10^{-27}\ \text{kg}$$

$$m_{\text{neutron}} = 1.67492729(28)\times10^{-27}\ \text{kg}$$

$$m_{\text{neutron}} = 1.001402 \times m_{\text{proton}}$$

$$m_{\text{electron}} = 9.10938215(45)\times10^{-31}\ \text{kg}$$

$$m_{\text{electron}} = 0.000545 \times m_{\text{proton}}$$

I don't know!

I'll sometimes approximate:

$$m_{\text{proton}} \approx m_{\text{neutron}}$$

those numbers!!

no fun.

seriously. 10^{-27}’s??

there’s a way out

our units

"p" has almost the same mass as

I'll sometimes refer to masses as:

"175 p"

"2 p"

"1/3 p"

So the mass of a Helium nucleus I might call

" ~4 p "

"about 4 p"*

* This is called the "mass number" in the context of atomic physics or chemistry

electric charge, Q or q

three kinds

positive

negative

neutral

attraction & repulsion

likes repel

opposites attract

the electron

“–”

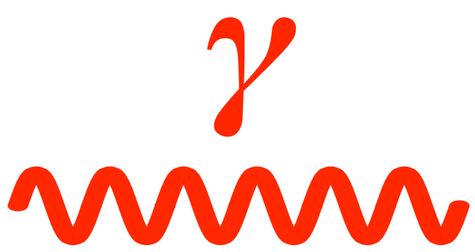
the proton

“+”

and neutron

and “photon”

“0”



more numbers

please simplify!

Electrical charge units are archaic:
the "Coulomb," C

1 C ~ 6×10^{18} protons
= 6,000,000,000,000,000,000 protons

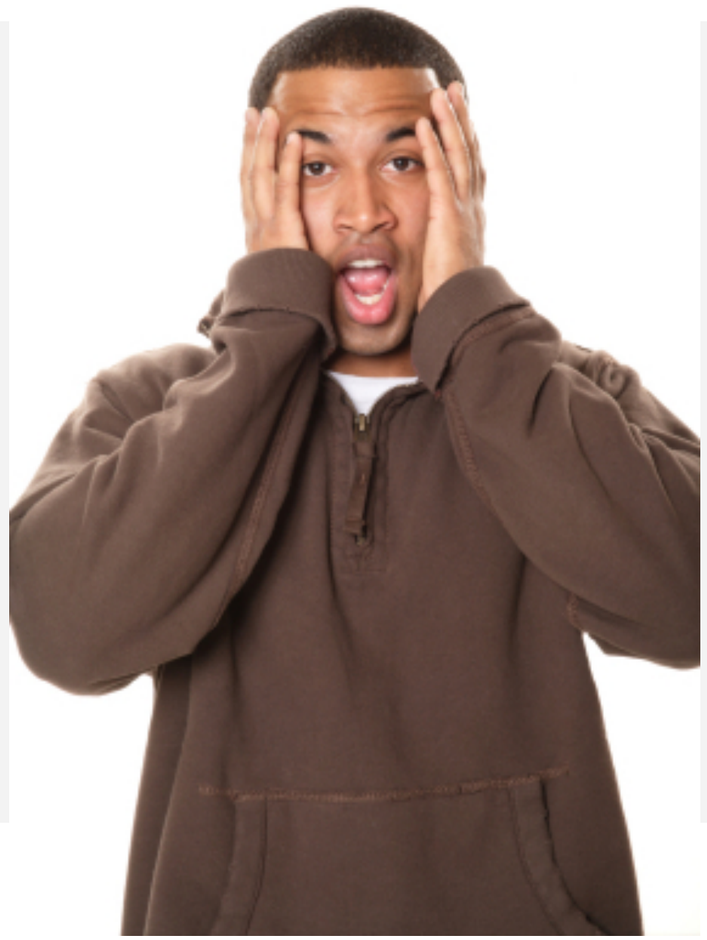
Electrical charge comes in a special package:
charge of electron = -1.6×10^{-19} C
charge of proton = $+1.6 \times 10^{-19}$ C
charge of electron = 0 C

more horrible numbers!!

still no fun.

seriously. 10^{-19} 's??

there's a way out



more numbers

simplify

Standard notation:

"e": = 1.6 x 10^{-19} C

Electrical charge comes in a special package:

charge of electron = — 1.6 x 10^{-19} C

charge of proton = + 1.6 x 10^{-19} C

charge of electron = 0 C

I don't know!

"+e"

"+2/3 e"

"–e"

"–1/3 e"

I don't know!

constant of nature:

Elementary unit of electric charge

value: $e = 1.602176565(35) \times 10^{-19}$

units: C (Coulombs)

usage: magnitude of charge of a proton (+) and electron (-)

You might want to remember this:

nature never loses electric charges

count charges

something happens!

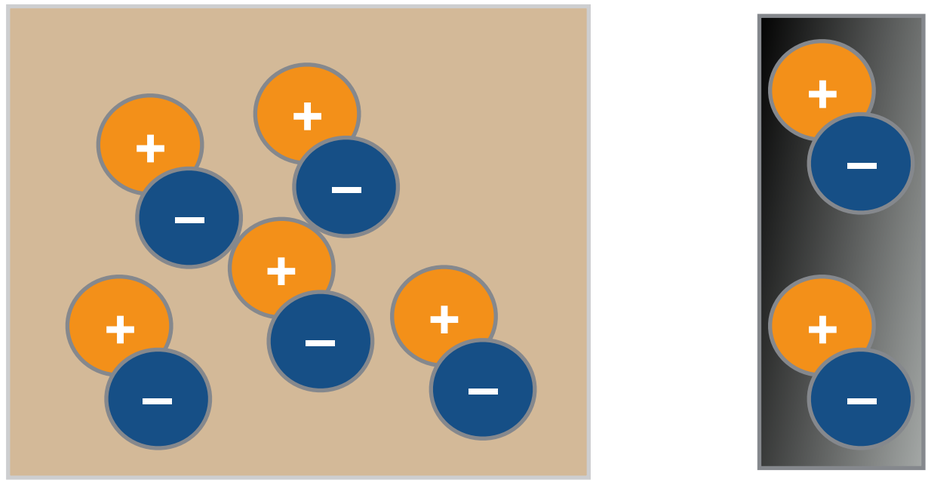
count charges again

no change: ***Electrical Charge is "Conserved"***

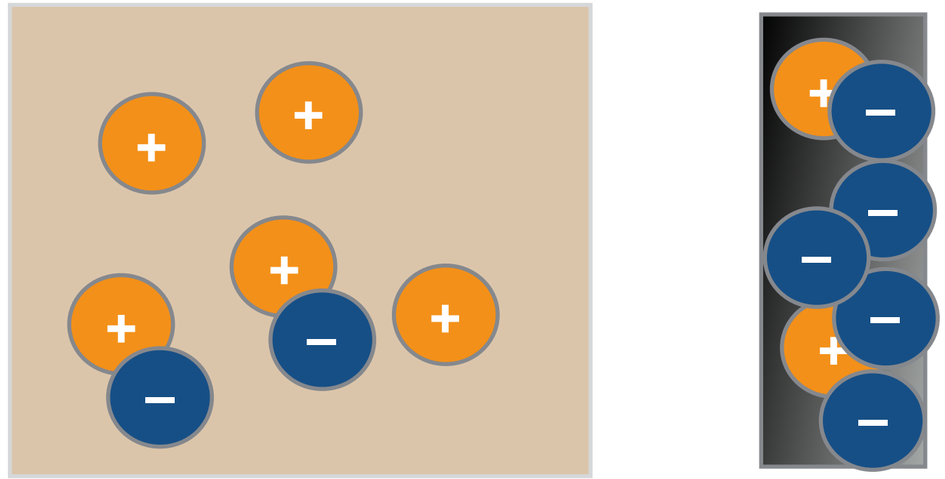
Electric Charge Conservation

electrostatic transfer by contact

before



after



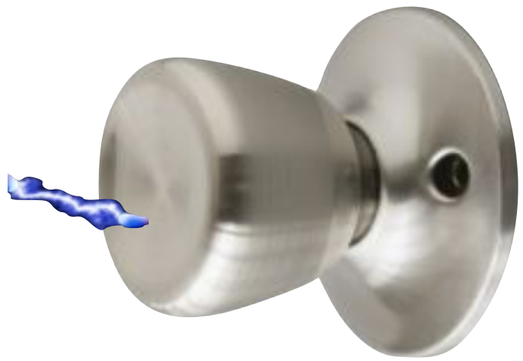
classically: fur

classically: amber

Greek: "elektron"

electrons move

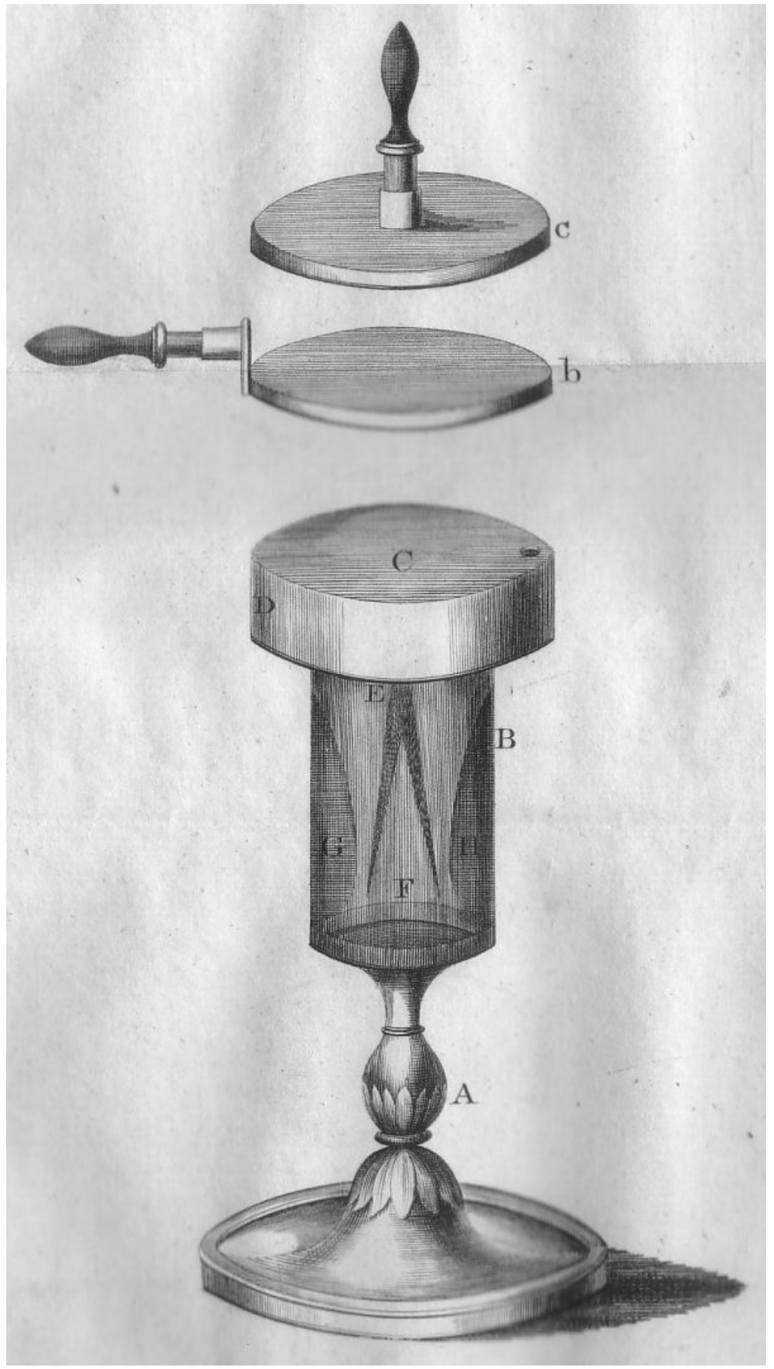
electricity…in the midwest winter?



shocking.

10’s of thousands of volts

natural or on purpose



Abraham Bennet FRS (1749 -1799)

gold leaf electroscope

electrical currents

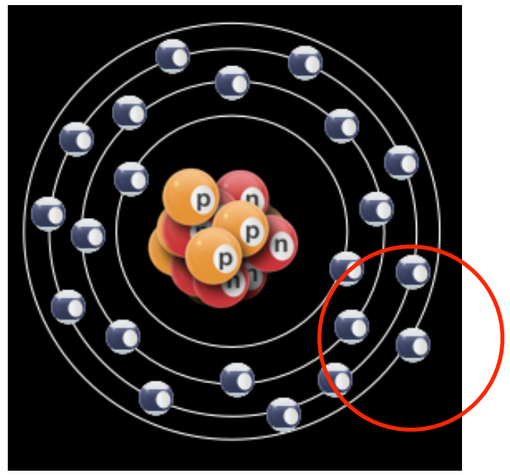
moving charges

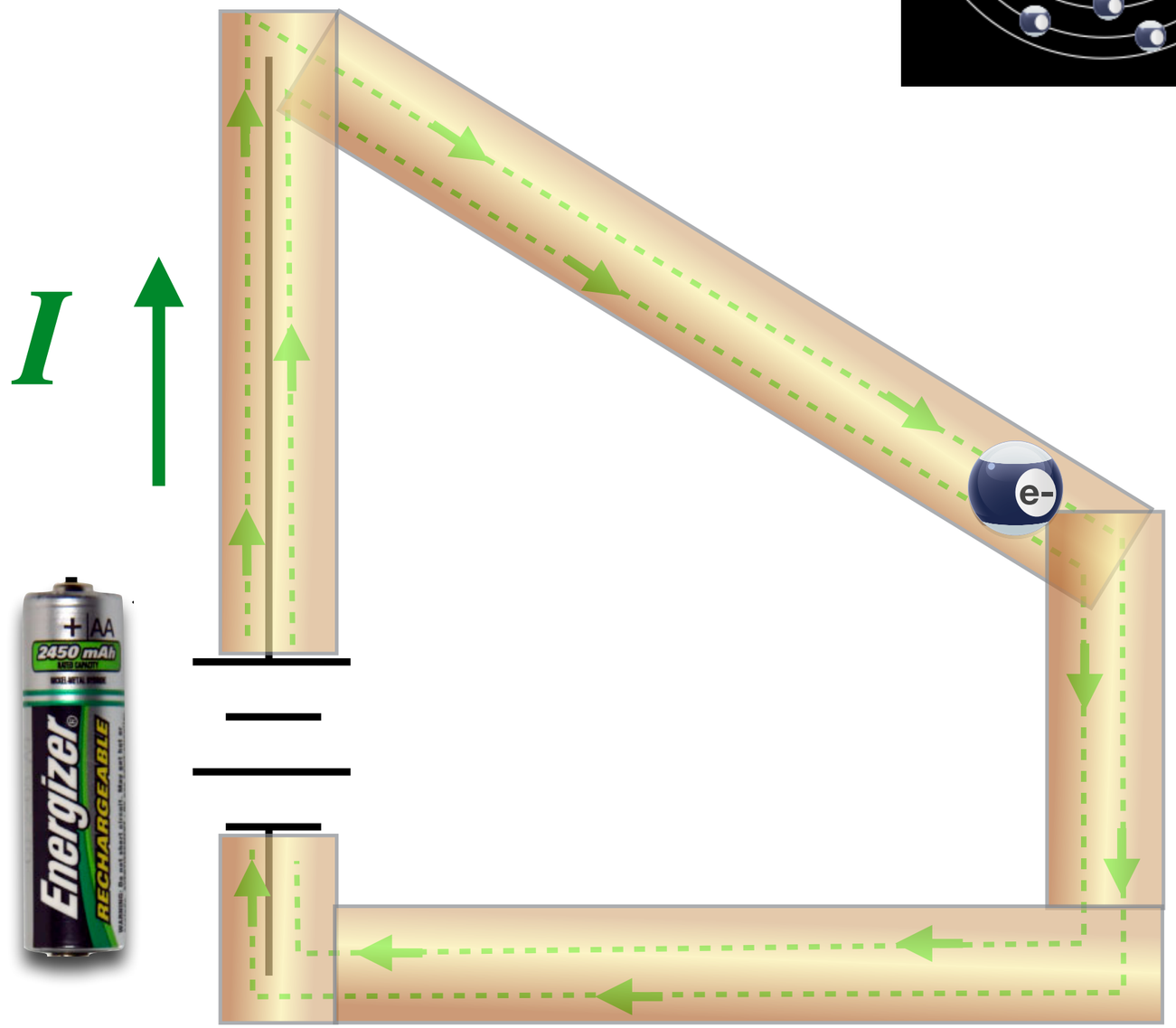
in materials with promiscuous electrons

that get around

Copper: 29 protons, electrons
34 neutrons

$1s^2 2s^2 2p^6 2d^{10} 4s^1$





electrical charges in motion

a “current”

whether in a wire or not

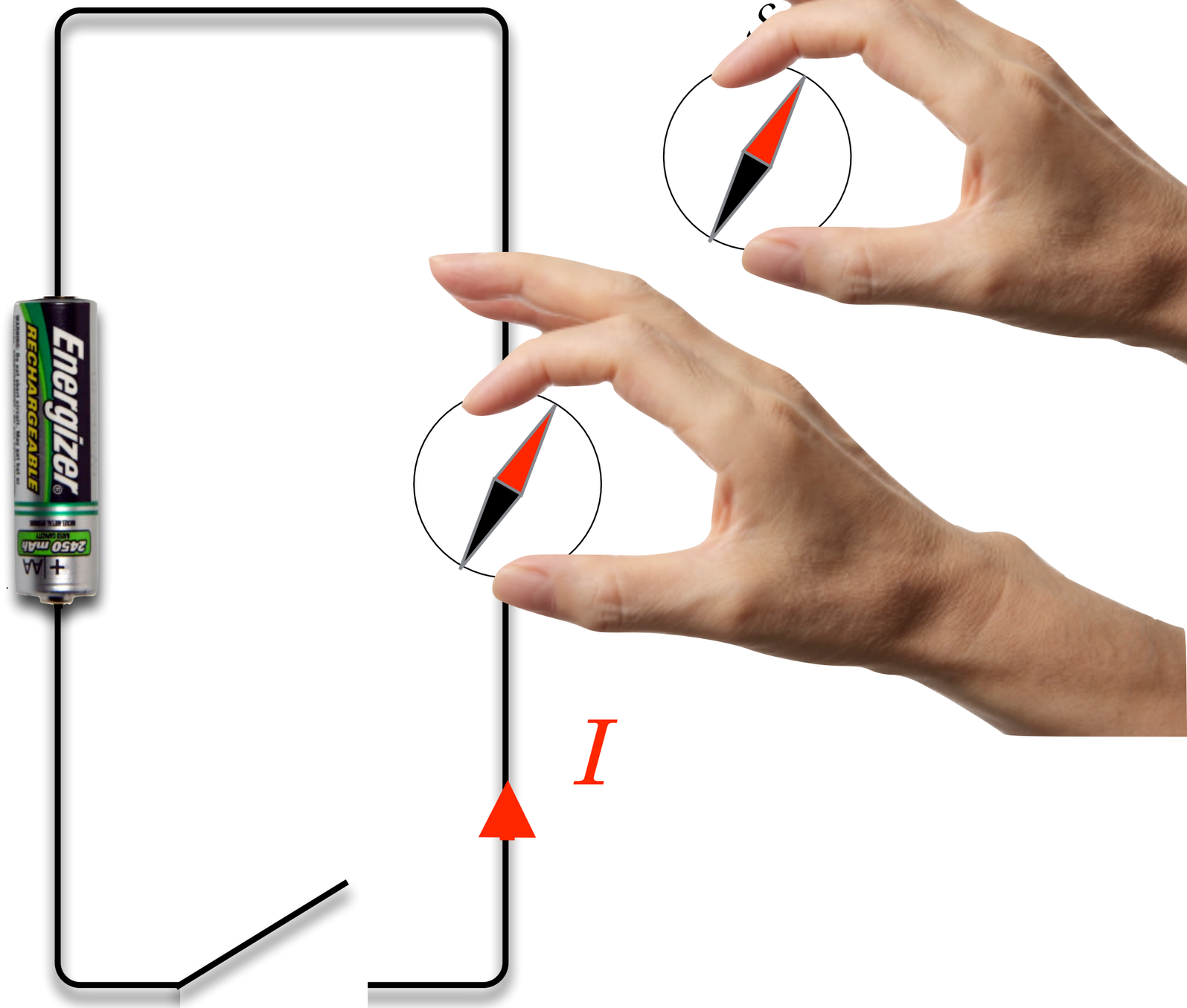
projects

sketch what you see in your sheets.

we should all have lectures like this

Hans Christian Oersted

April 21, 1820



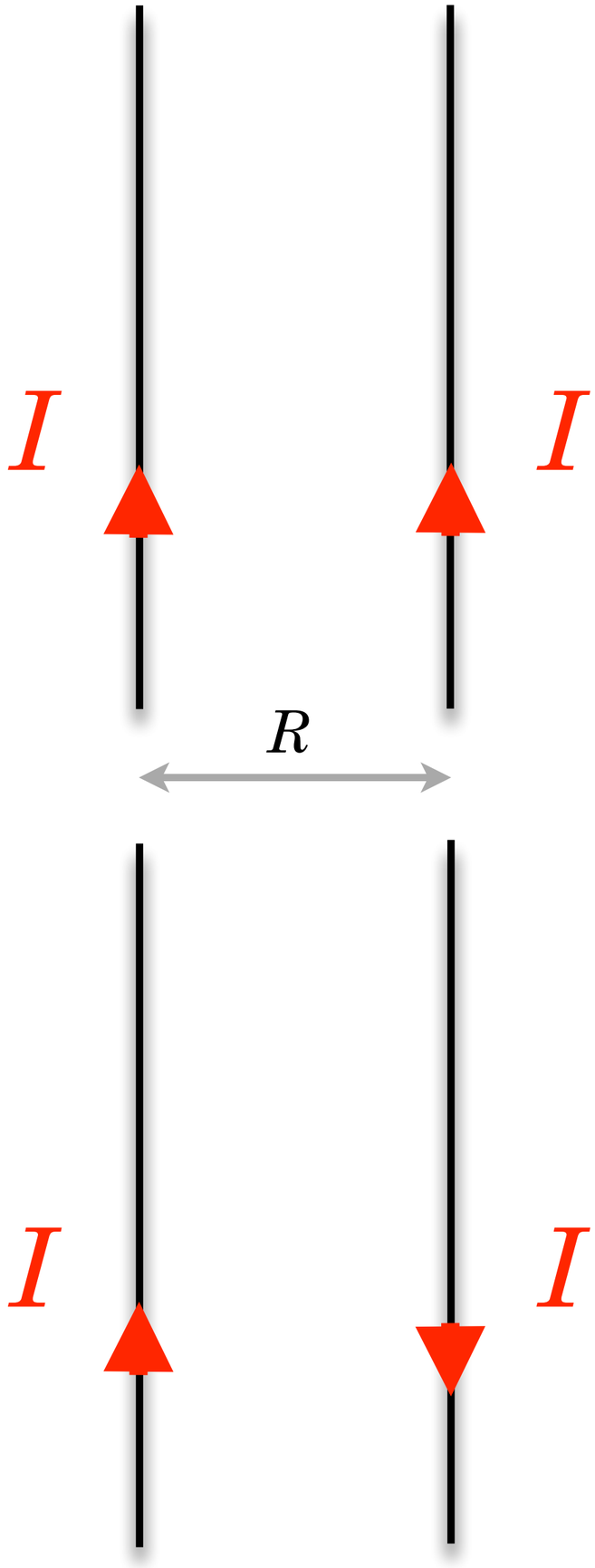
we shou

Hans Chris

April 21, 18

Ampere's Law

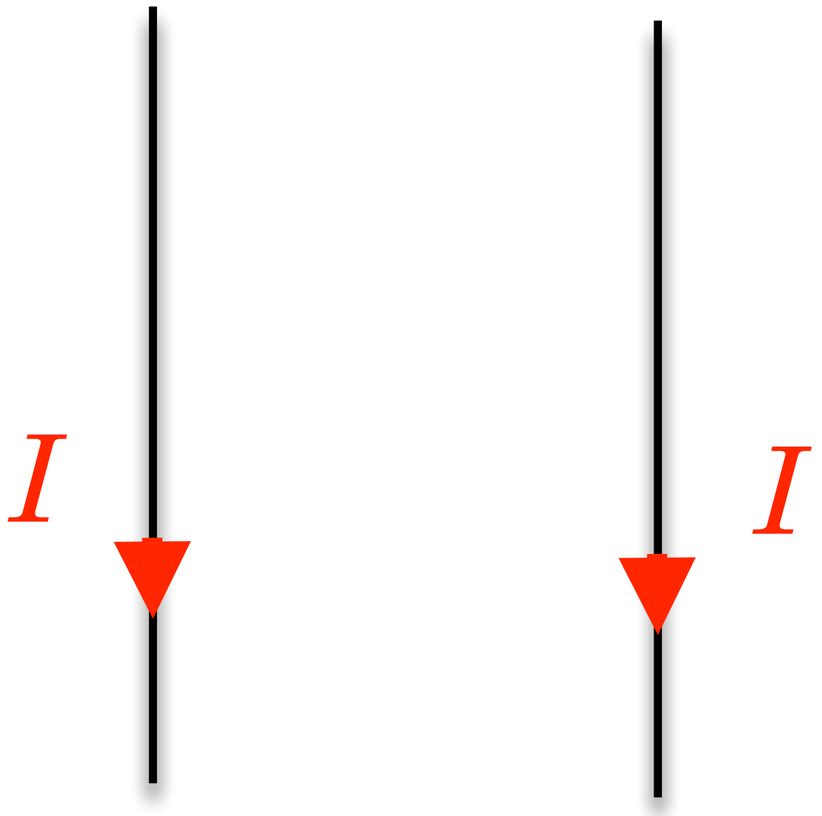
forces between wires carrying current

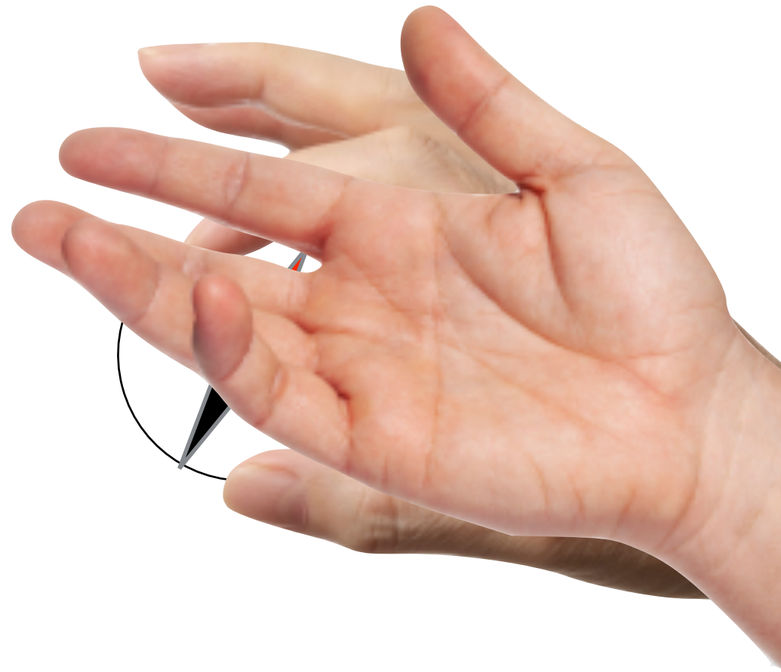


$$F \sim \frac{I_L I_R}{R}$$

Oersted’s compass?

could cancel out the effects





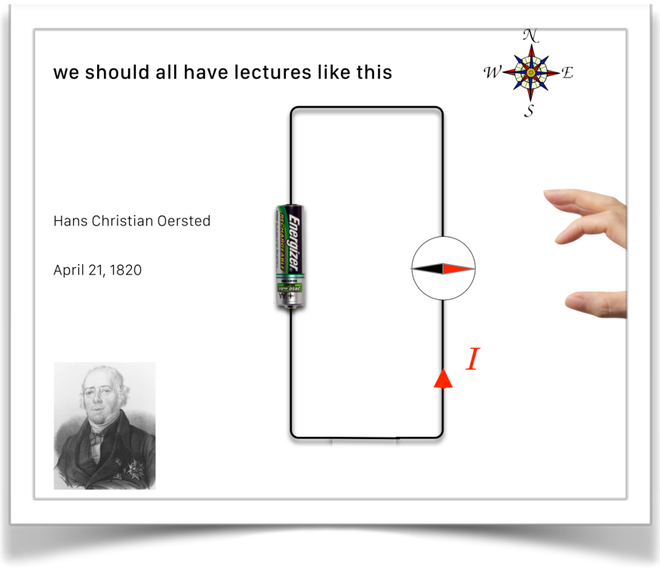
wait, wait, wait ...nothing!

You might want to think about this:

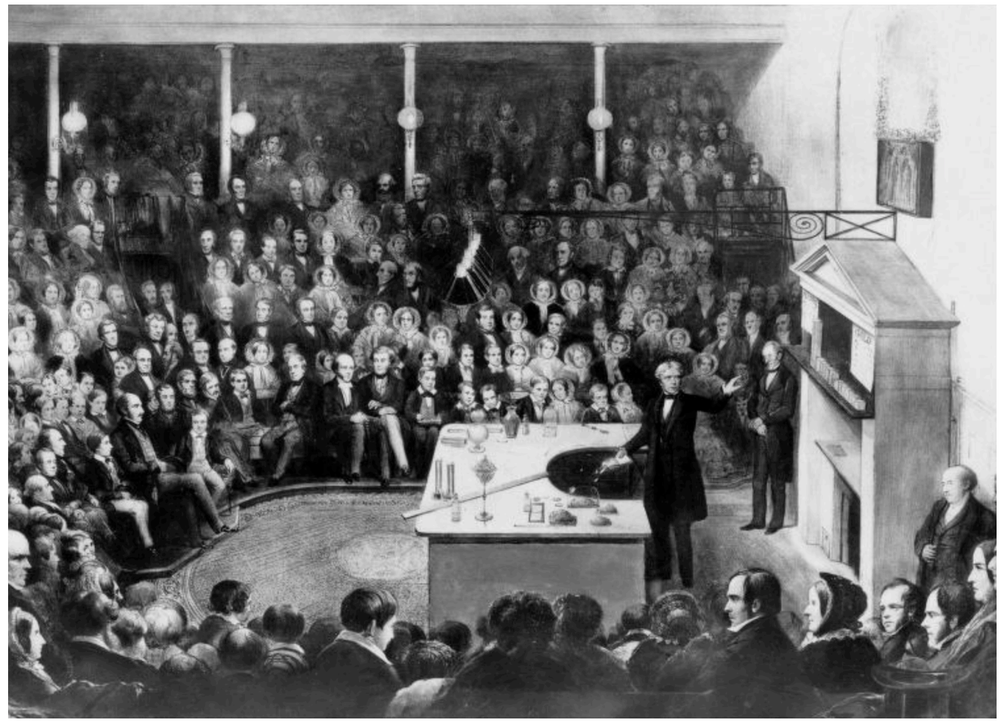
If currents cause magnetism

shouldn’t magnetism create currents?

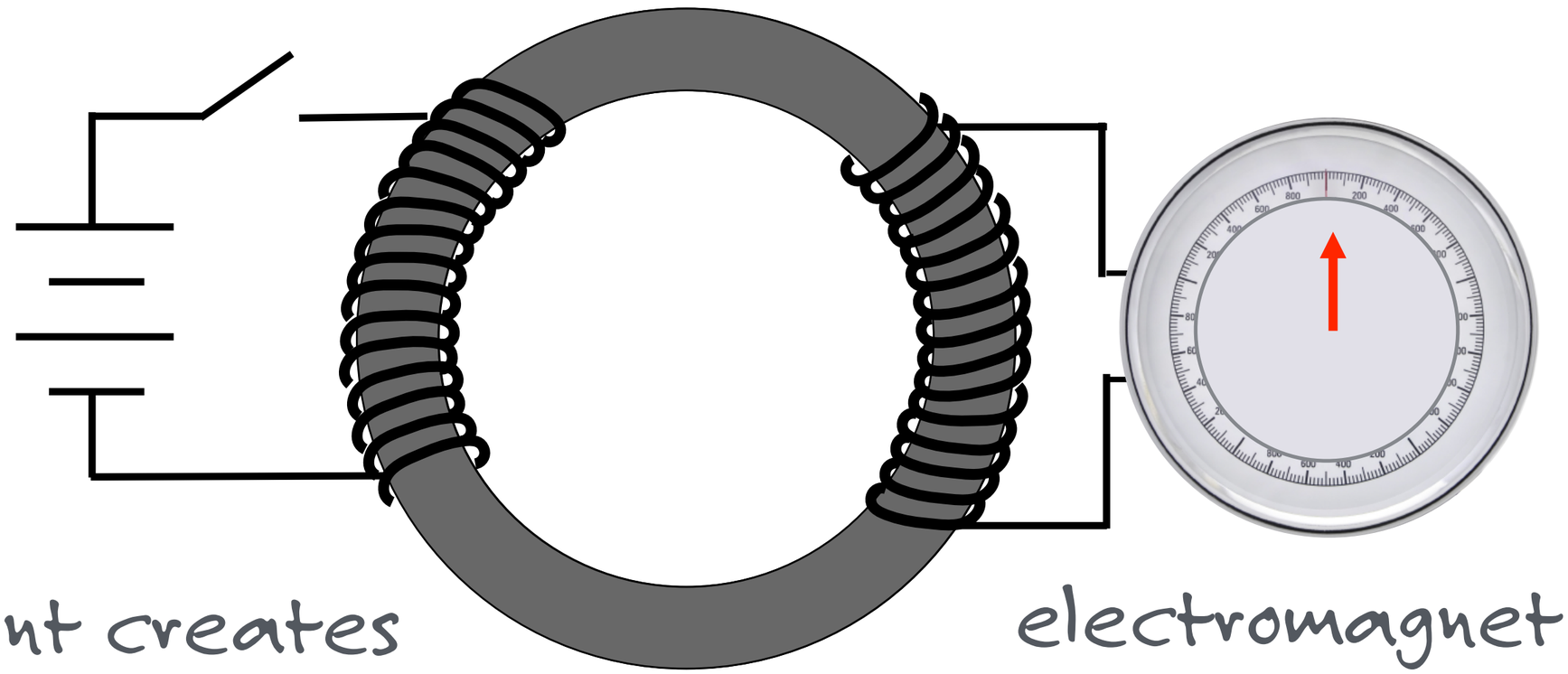
there’s a story there.



Michael Faraday (1791 - 1867)



Electromagnetic Induction



current creates
an electromagnet

electromagnet
creates a current

BUT:

only magnetism **CHANGING** in time creates a current

important example

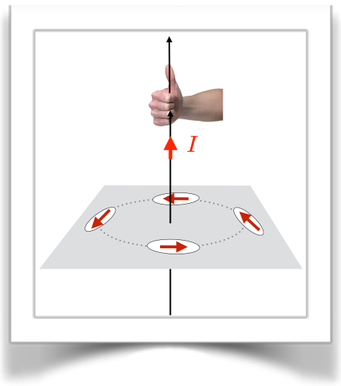
with evolving explanations

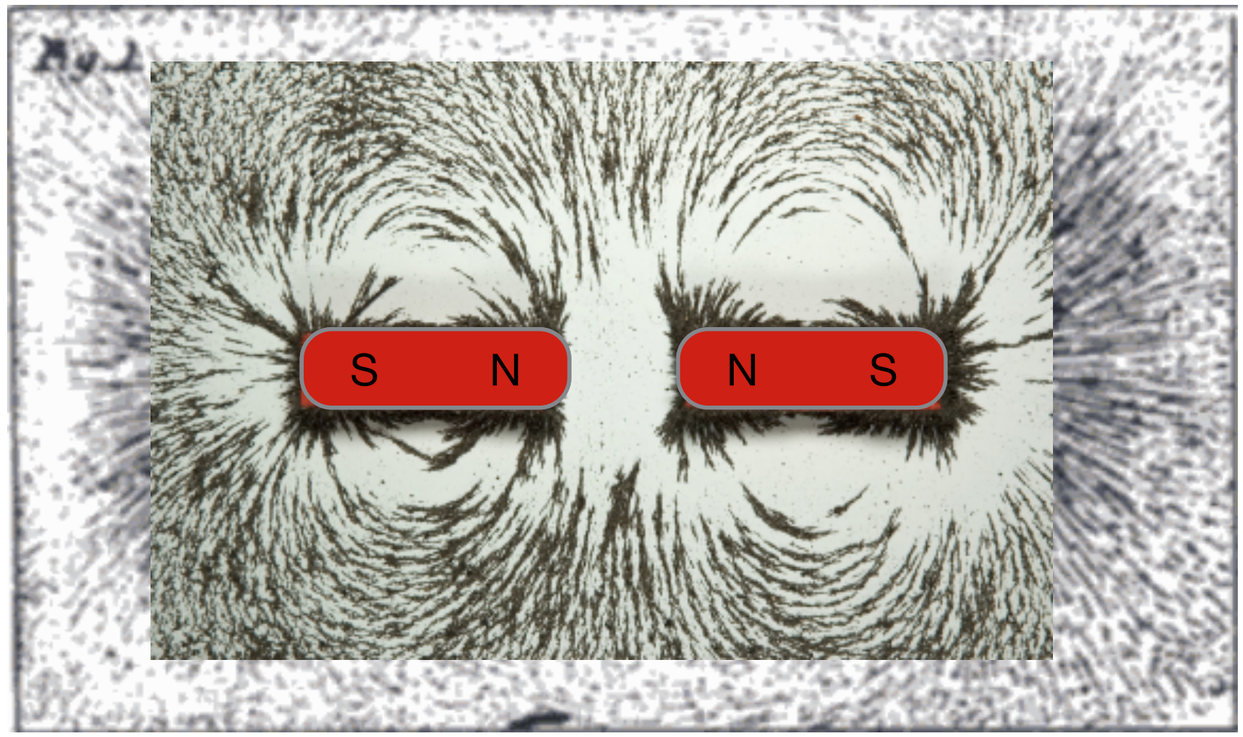
important

when magnetic lines of force **change in time**

a current flows: "**Faraday's Law**"

Faraday saw things





that weren't there for most

He saw:

"**lines of force**" exerting a physical force on little bits of iron

worse...

circular "lines of force"

Faraday's "model"

the lines of force were real features of space

he called this feature of space a "**field**"

"action at a distance"? no!

the field idea

“Action at a Distance”

a no-no

What about Electrostatic Forces?

understanding a field

it's tough

it has a quantum mechanical explanation

meaning that classical explanations leave one gasping and uncertain

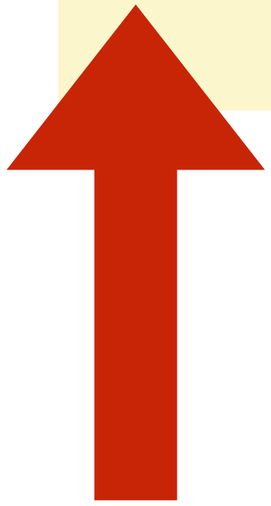
the electric force

depends on both charges

$$F = k\frac{Q}{R^2}(q)$$

depends only on Q

$$E = k\frac{Q}{R^2}$$

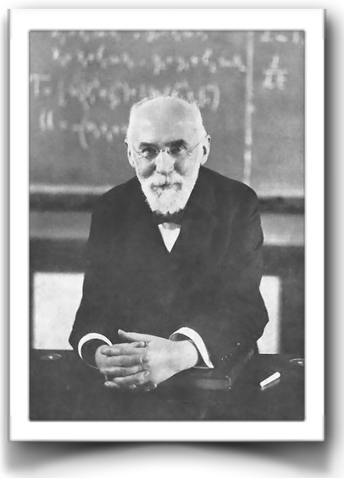


called the Electric Field for a point charge, Q

1/2 of "Lorentz Force"

Forces due to Electric Fields:

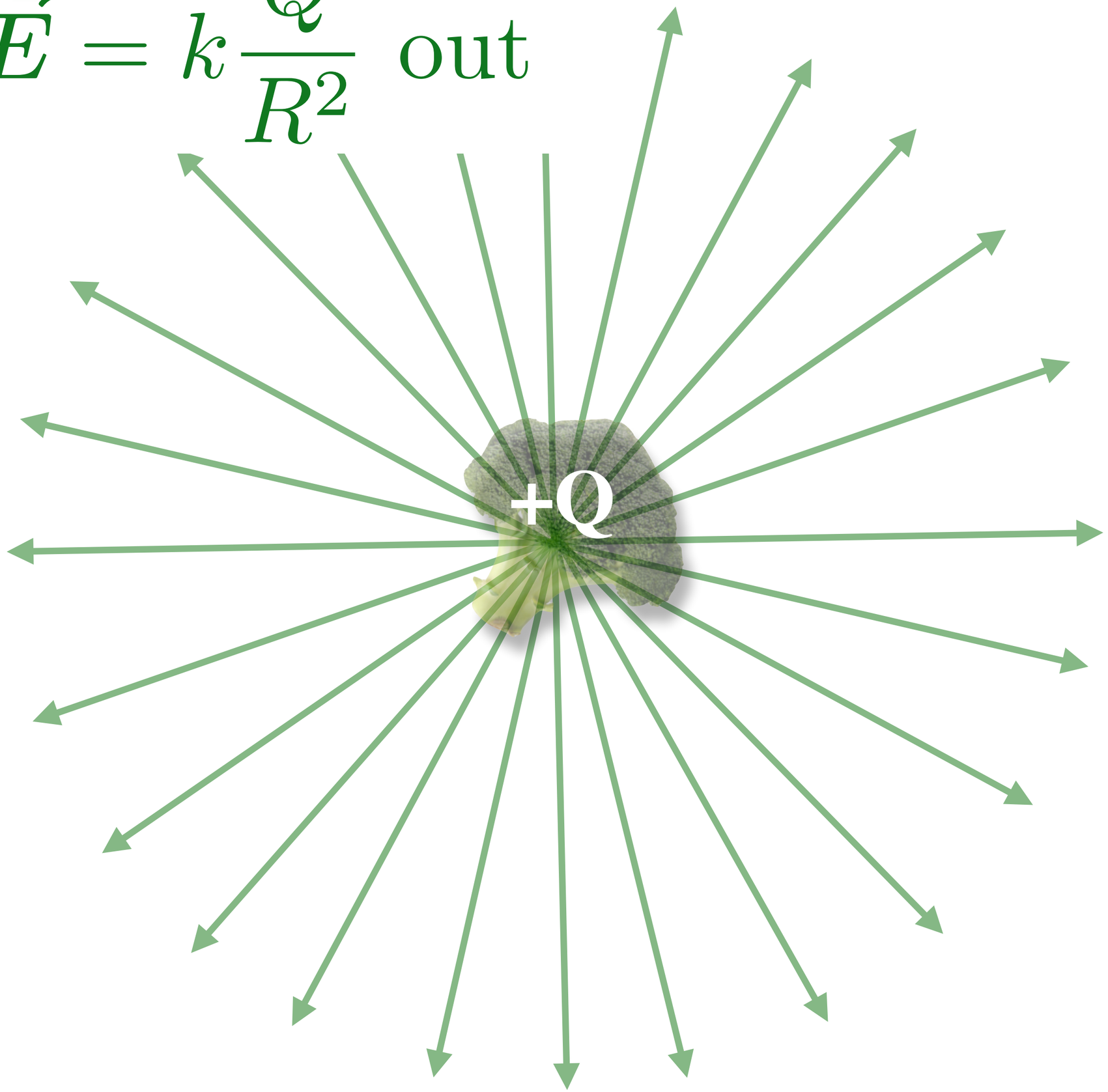
$$\vec{F} = \vec{E}q$$



the Electric Field

for a point, **POSITIVE** charge

$$\vec{E} = k\frac{Q}{R^2} \text{ out}$$



projects, continued

we'll look at a number of fields

you sketch on your sheets