

# ISP220

QUARKS, SPACETIME, AND THE BIG BANG

# Eric Clapton





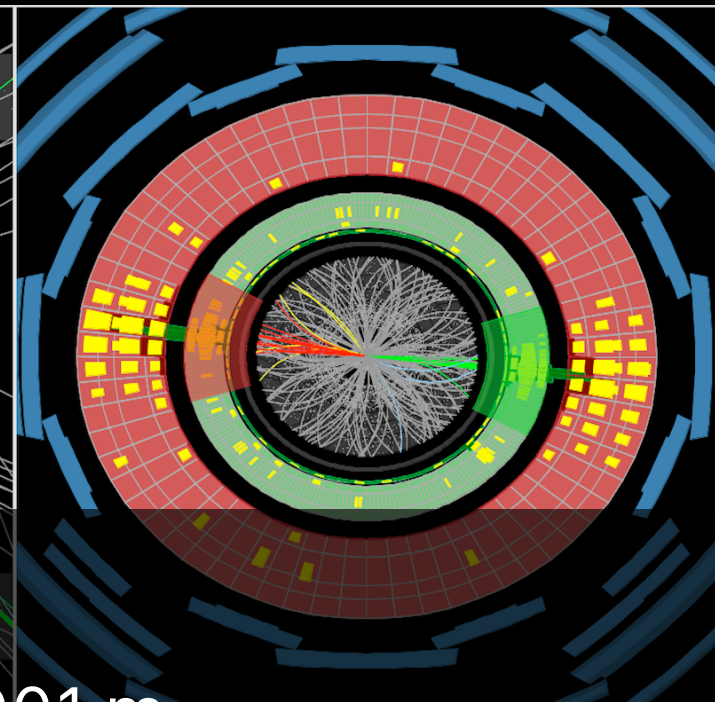
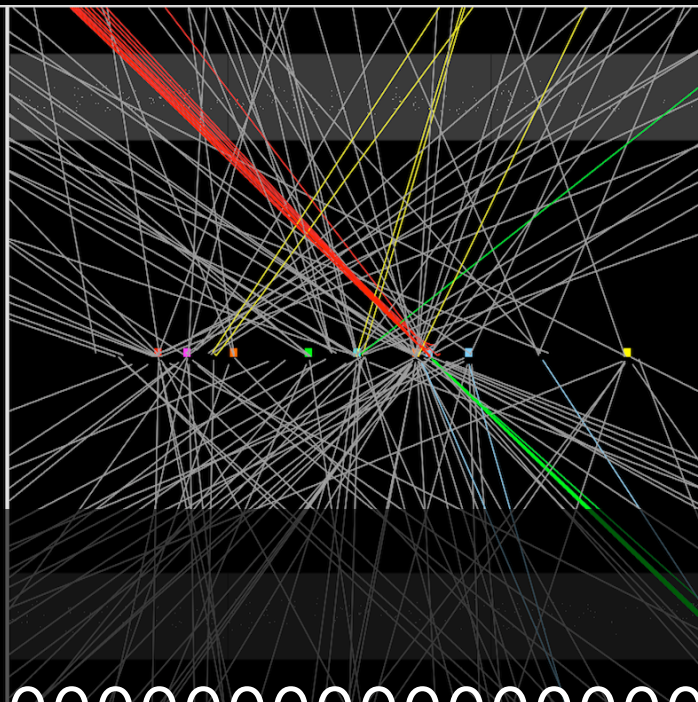
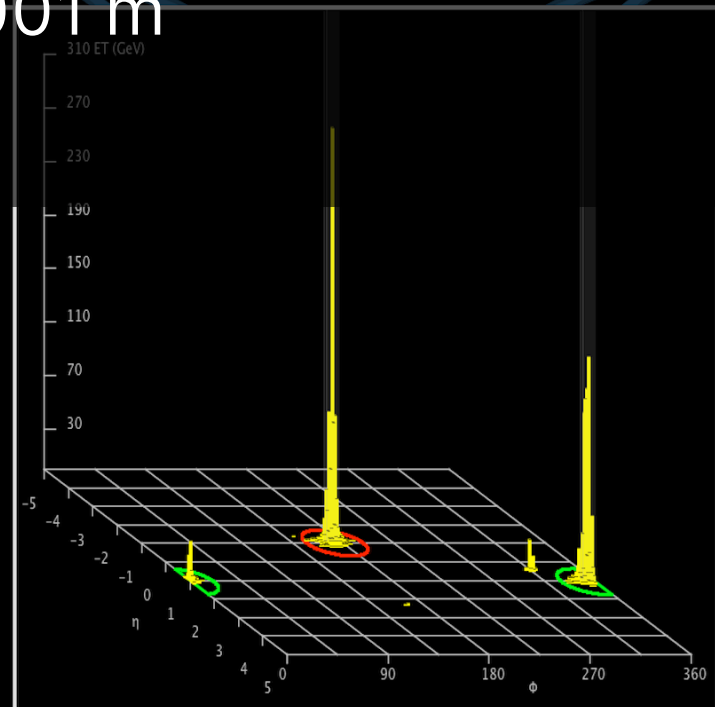
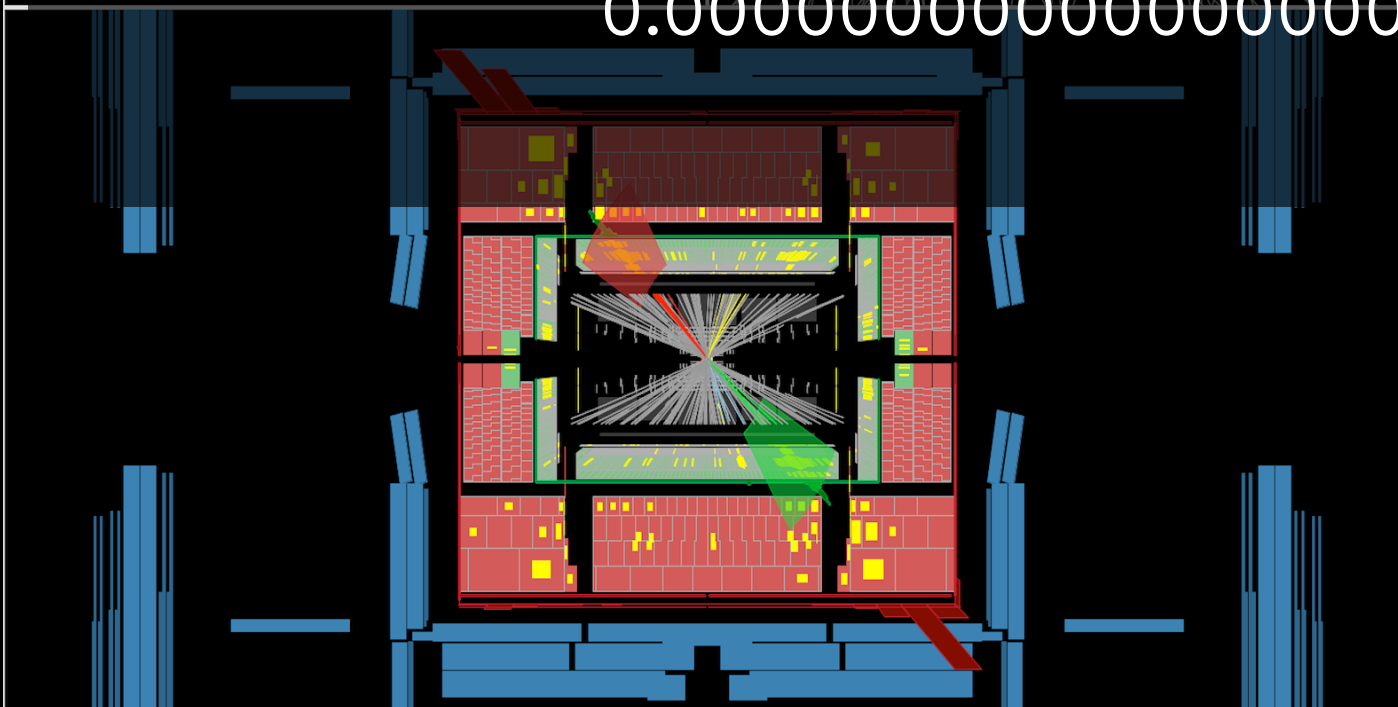
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Date: 2012-04-14 22:30:13 CEST

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welcome

to ISP220

Quarks, Spacetime, and the Big Bang





**Cnip**

**Brock**

University Extinguished Professor,  
Physics & Astronomy, MSU

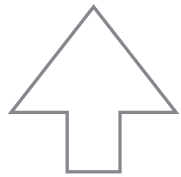
**MICHIGAN STATE**  
**UNIVERSITY**

MSU Global

# welcome

to ISP220

**Quarks**, Spacetime, and the Big Bang

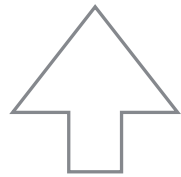


Because we'll talk  
about elementary  
particles

# welcome

to ISP220

Quarks, **Spacetime**, and the Big Bang



Because we'll spend a lot of  
time on Einstein's theories  
of Relativity

# welcome

to ISP220

Quarks, Spacetime, and the **Big Bang**



Because we'll talk about  
the beginning of the  
Universe



isp220 studies:

the **largest**

and

the smallest

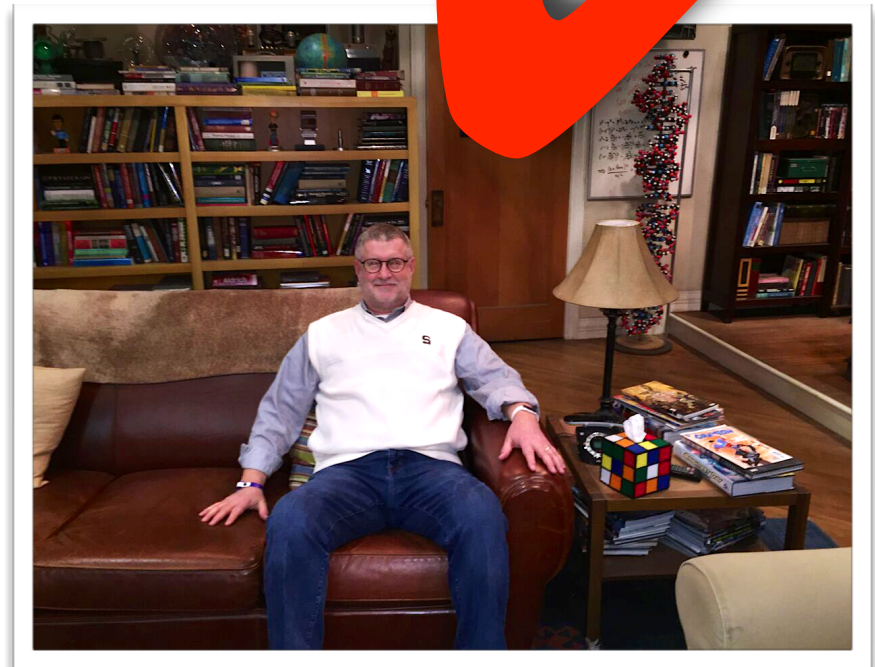
entities of all

the **largest?**

Cosmology



the smallest  
particle physics



So .

A course on particle physics?

"hmm. I think I've heard that before..."

yes, that one

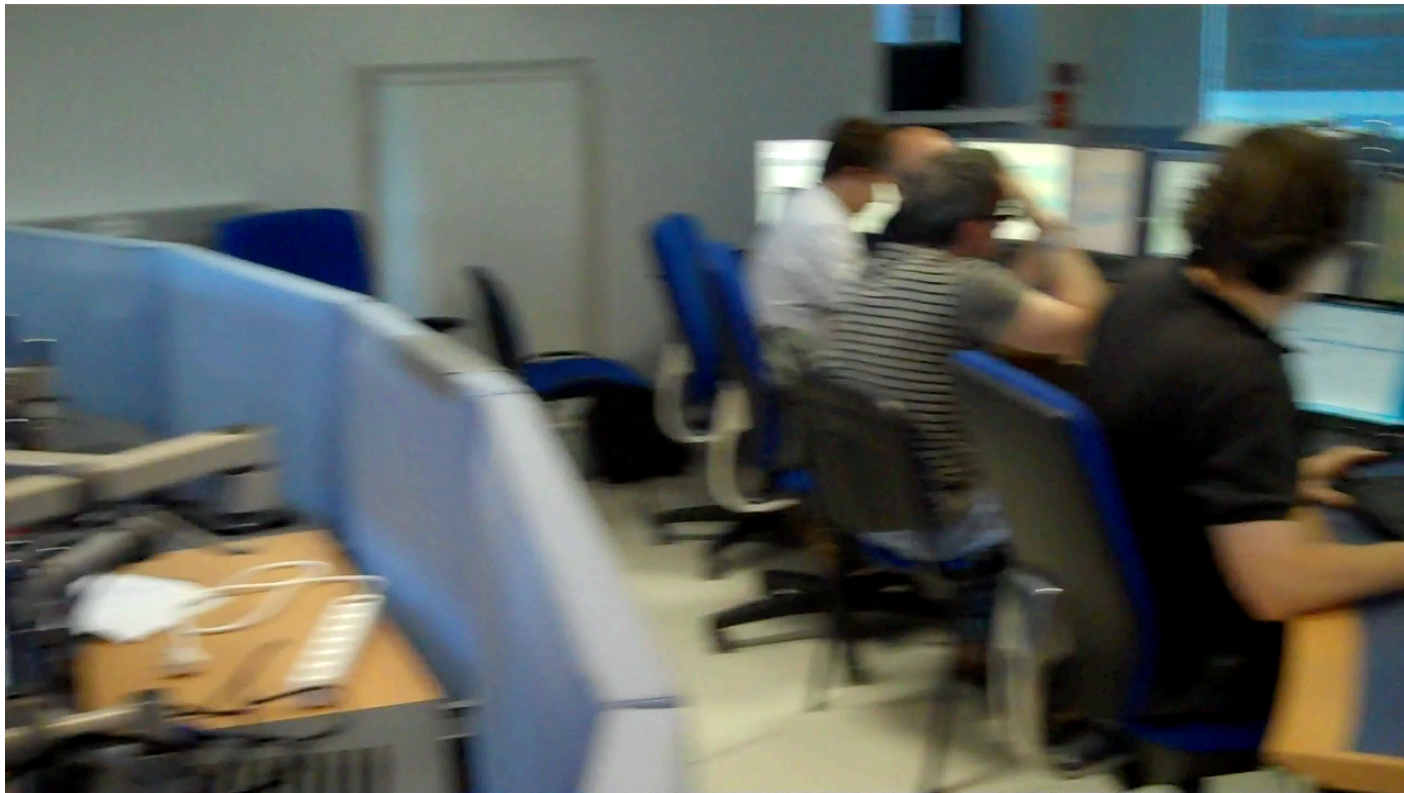


some artistic license





# the real control room



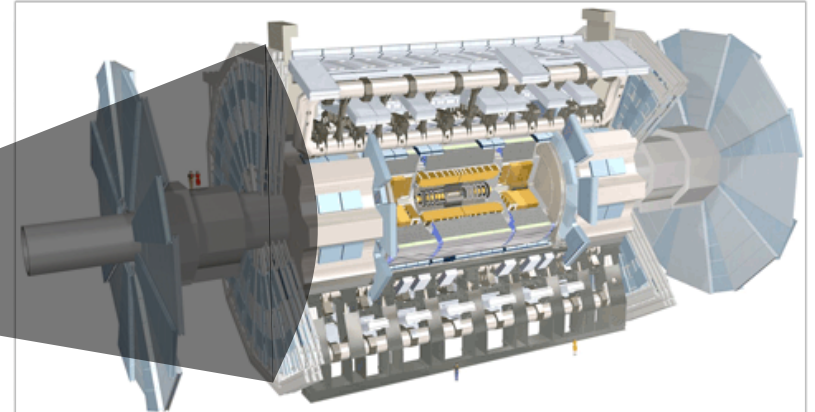
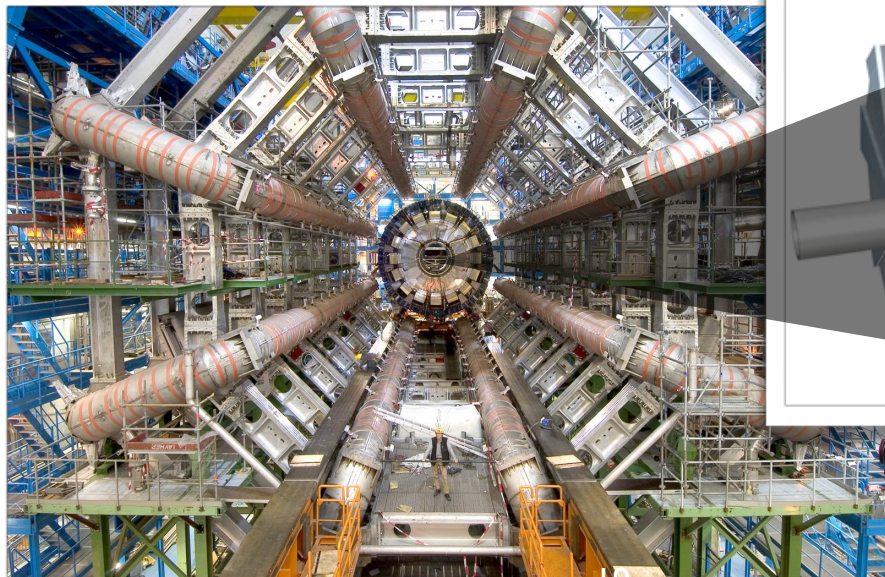
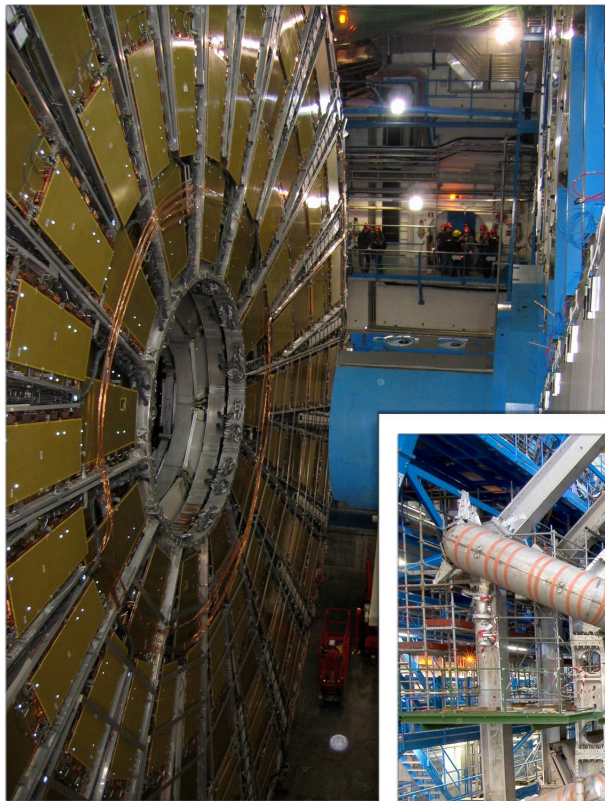
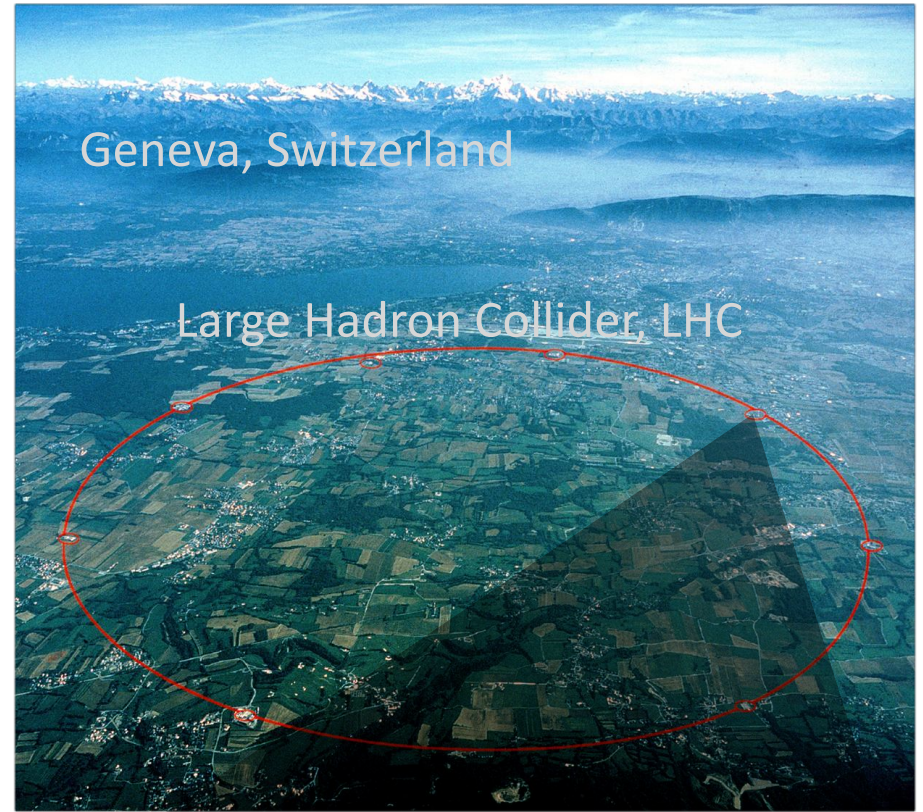






Geneva, Switzerland

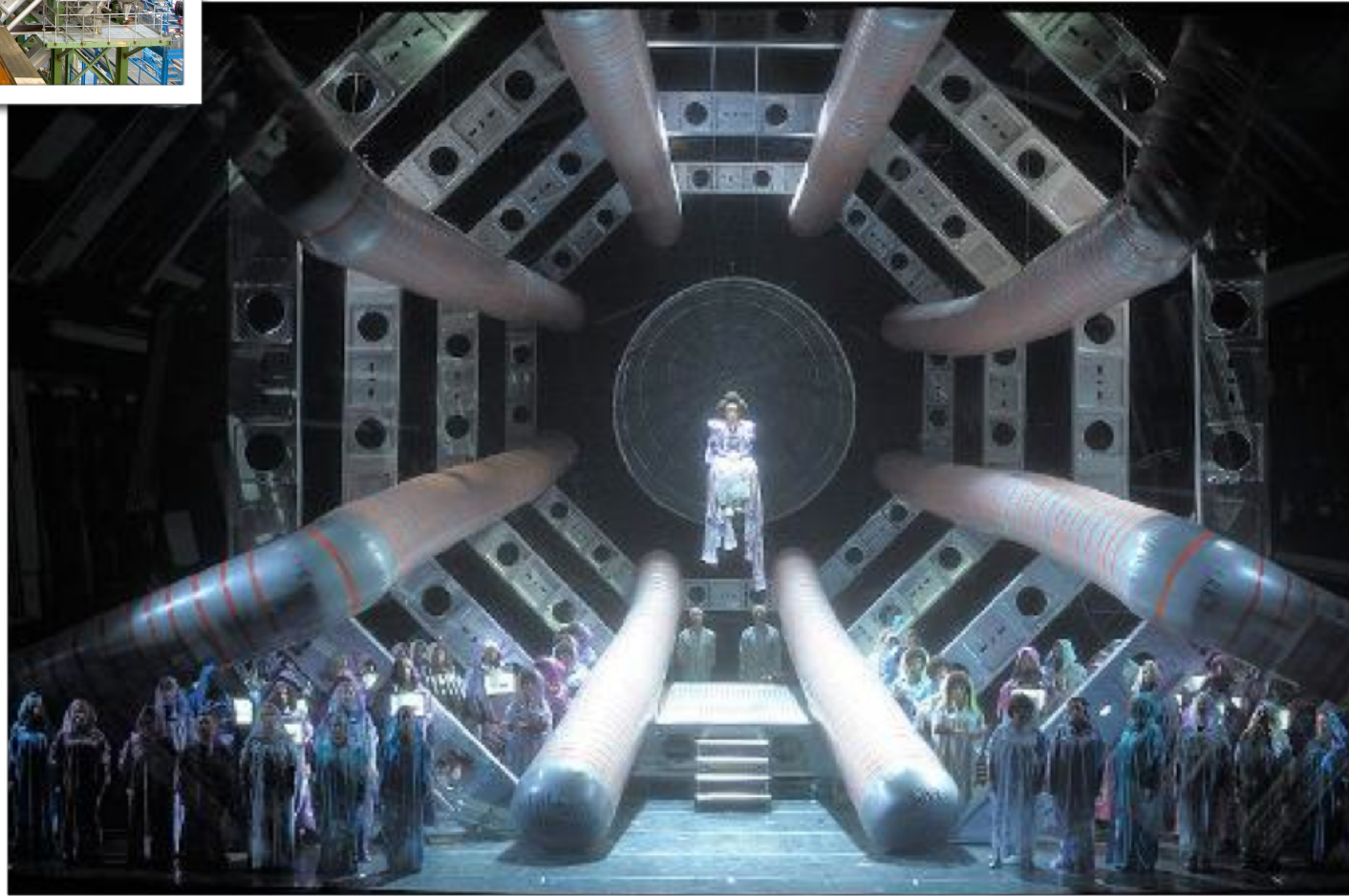
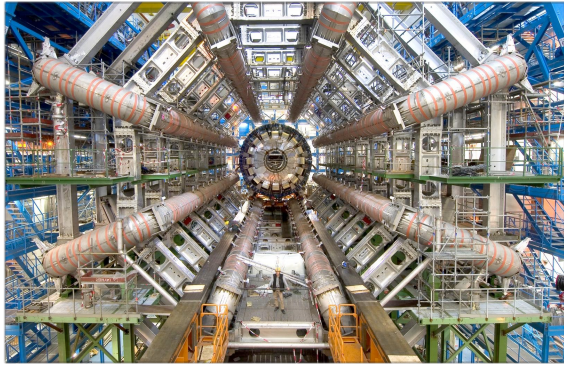
Large Hadron Collider, LHC



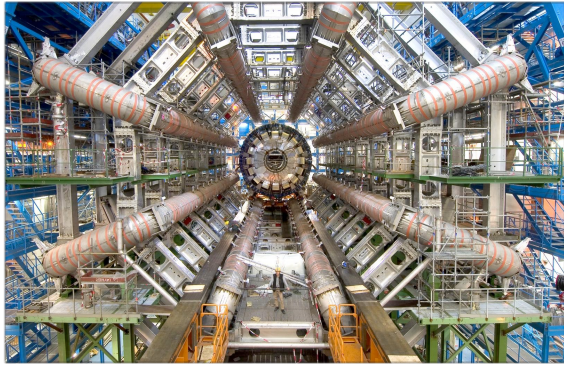


somehow our experiment

generates attention







# research university

science faculty have dual duties

teaching

research

who pays taxes?

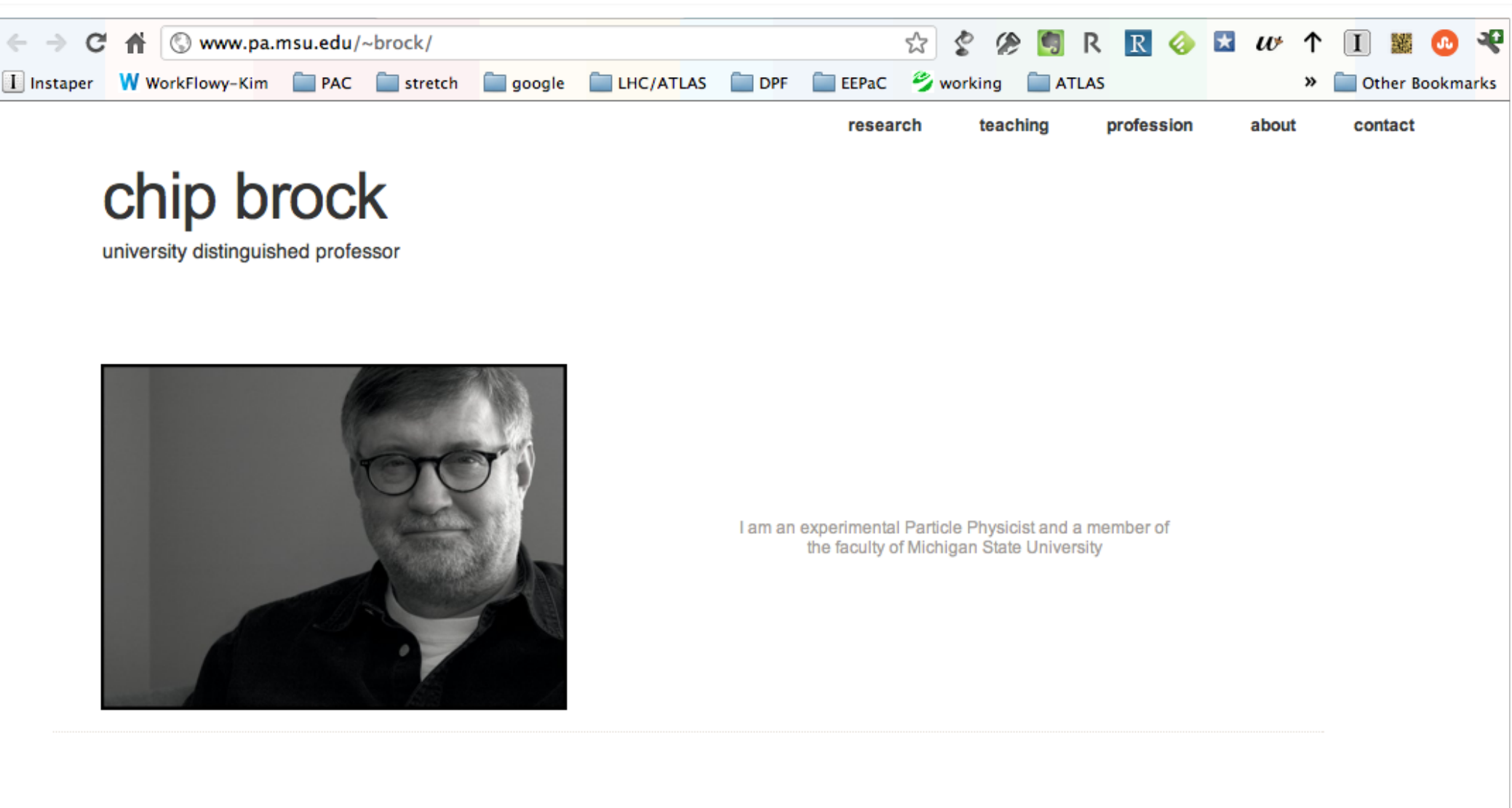
thanks.

# the real ‘‘why’’

It's a privilege to actually receive a salary to do this work.

You graciously pay for our research and I'd like you to be able to appreciate the results and its future.

I'd like to tell you about it.



[www.pa.msu.edu/~brock/](http://www.pa.msu.edu/~brock/)





you're participating in a century-old,  
uniquely American college experience

Abbott Lawrence Lowell, Harvard President 1909:

"A discussion of the ideal college training  
would appear to lead to the conclusion that  
the best type of liberal education in our  
complex modern world aims at producing men  
who know a little of everything and  
something well."

"General Education"

...at MSU: Integrative Studies

look at the goals of the Center for  
Integrative Studies in General Science:

<http://cisgs.msu.edu/about.html>



you're not physicists, so  
I know that you're  
brave and fearless to take  
this course.



# my goals for you

To learn of discoveries, theories, and puzzles in particle physics and cosmology

To learn some visualization tools and apply them to understanding some experimental and theoretical techniques

To meet some of the historical and contemporary physicists who built both of these fields



# lots of moving parts



in ISP220

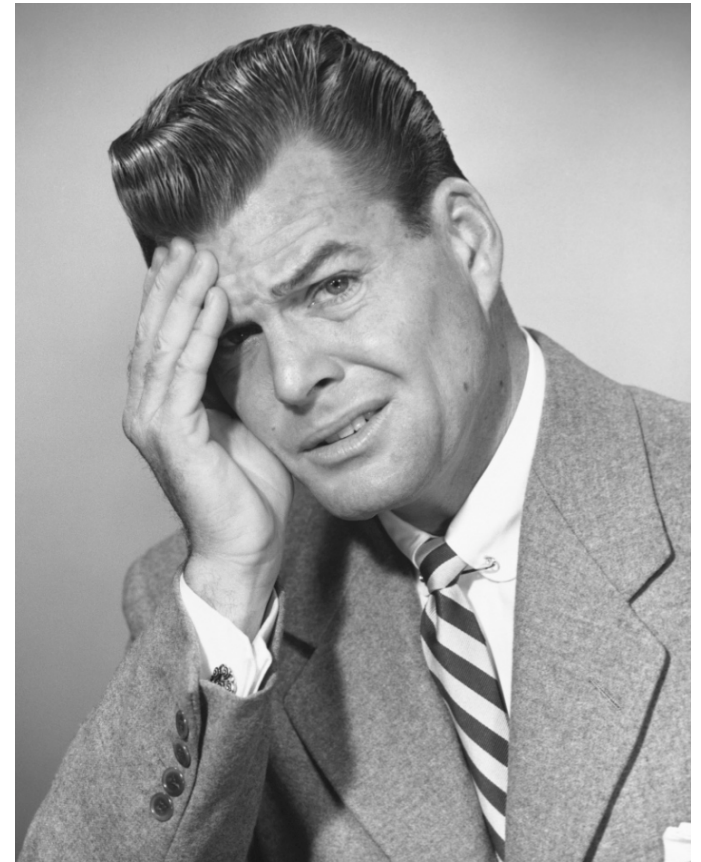
# sorry.

about those videos

still no clue what's going on

I'll take them down for now

dept and MSU IT working on it



# QS&BB in 3 parts

## Part 1

### "classical physics"

motion, forces,  
momentum,  
energy, electricity,  
magnetism,  
waves,  
electromagnetism

up until  
~mid February

## Part 2

### relativistic physics

special relativity  
general relativity  
20th century  
cosmology

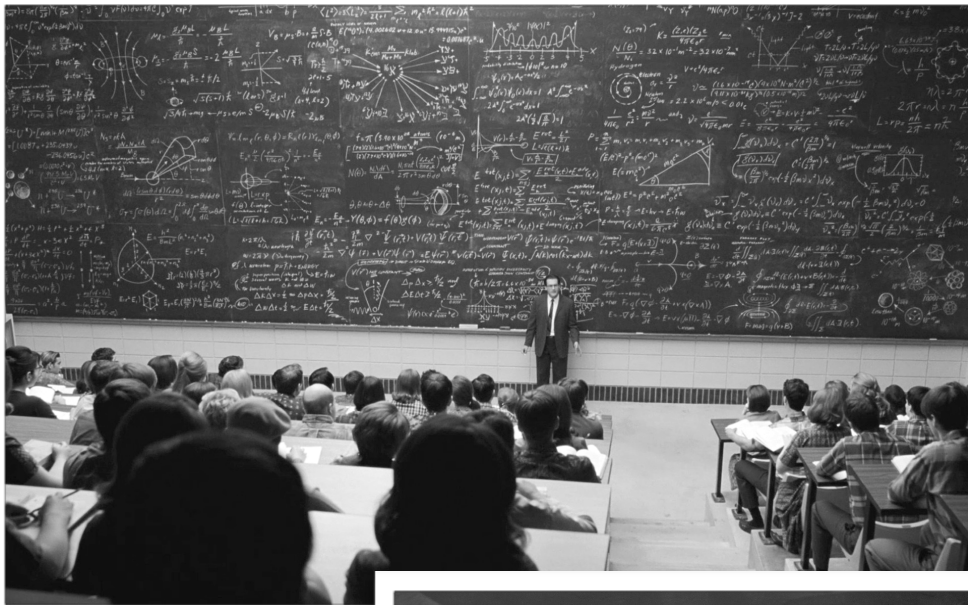


### "field theory"

quantum  
mechanics  
+ relativity  
particle physics  
current  
cosmology



# a combination of sources



I'll lecture



You'll  
read the  
texts

You'll read  
some on-line  
material

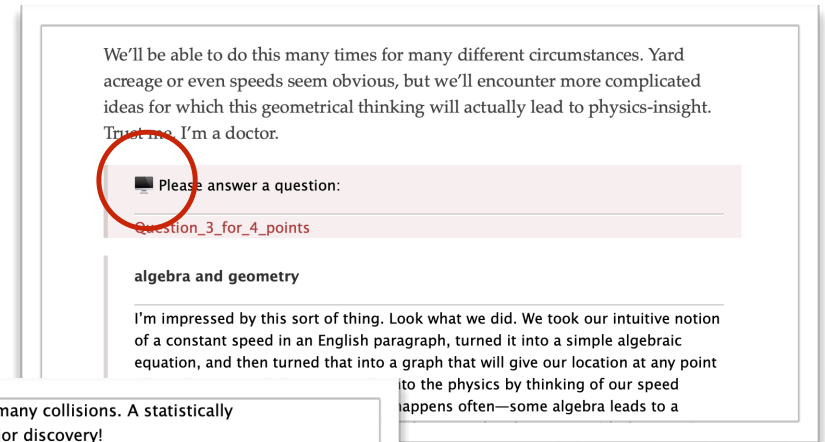


You'll  
watch  
some  
videos

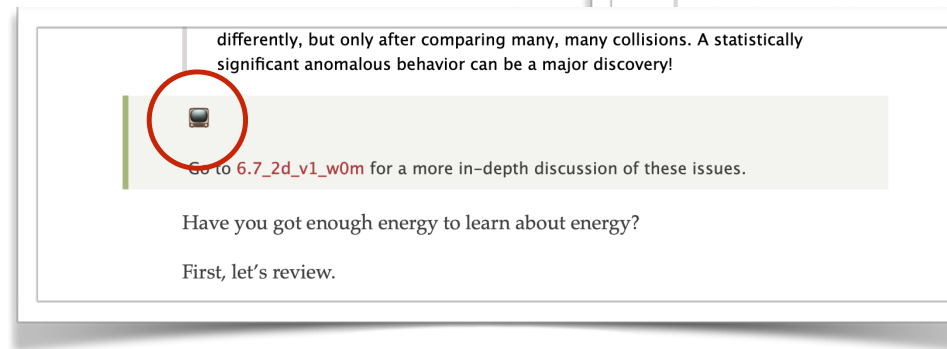


# sign posts along the way

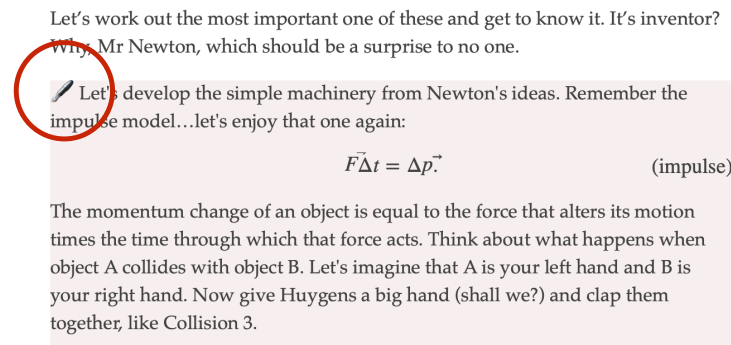
periodic, in-line questions:



some videos:



get out your pencil:



# Part 1 primary source

All of Part 1 content

## QS&BB in 3 parts

### Part 1

#### "classical physics"

motion, forces,  
momentum,  
energy, electricity,  
magnetism,  
waves,  
electromagnetism

### Part 2

#### relativistic physics

special relativity  
general relativity  
20th century  
cosmology

Part 3!

#### "field theory"

quantum  
mechanics  
+ relativity  
particle physics  
current  
cosmology

1. we'll call it: "QS&BB"

2. videos in support, section by section

## 1. Hi.

Welcome to the detailed content of Quarks, Spacetime, and the Big Bang.

The subject chunks of QS&BB are segmented into individual "lessons." Each is a topic on its own, although most lessons will assume familiarity with the previous ones. You can get back to this page by going "home" in the sidebar.

### 1.1 Outline of Lessons

#### A Little Bit About This On-line Text

Why we're doing this!

#### Lesson 1. Once Upon a Time...

...there was a tiny fluctuation in spacetime.

#### Lesson 2. What Can We Know, and How?

Science is a thing. Different from other things. How?

#### Lesson 3. Mathematics, The M Word

A tiny bit of mathematics. Really.

#### Lesson 4. Motion, Getting From Here to There

You like to move it move it. Move it.

#### Lesson 5. The Big Mo, Force and Momentum

What Newton brought

#### Lesson 6. Collisions, Banging Things Together

Collisions and Conservation of Momentum

#### Lesson 7. Energy, It Just Keeps Going and Going

Never enough. Always just enough.

#### Lesson 8. Early Cosmology

Round 1. Wrestling With the Planets

#### Lesson 9. The Astrophysics of Galileo and Newton

Cosmology of Galileo and Newton

#### Lesson 10. Charge It! Charges and Magnets

Electric charges, magnets, and currents.

#### Lesson 11. Faraday's Experiments

Electricity and Magnetism together

#### Lesson 12. Faraday's E&M Fields

The field idea

#### Lesson 13. Maxwell's Fields

Electromagnetic Waves

let's take a look at QS&BB text



# resources

text books

<http://www.chipbrock.org>

Facebook Group

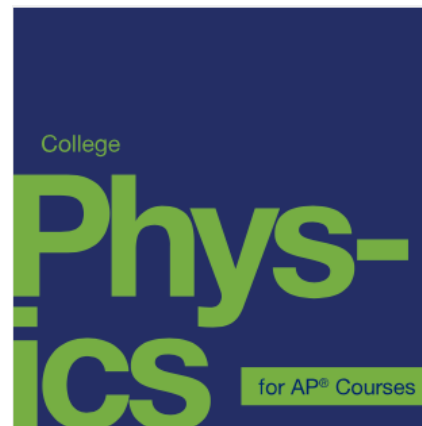
MasteringPhysics

MasteringAstronomy

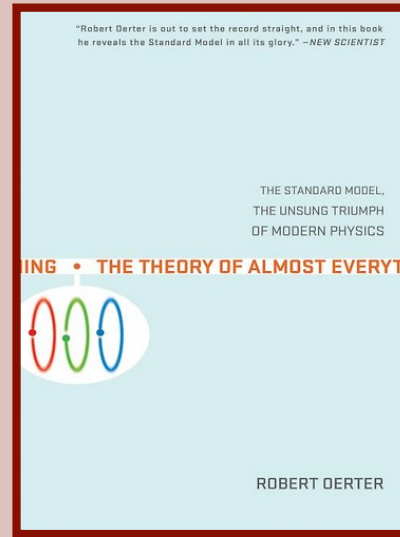
blogs and websites

other materials...

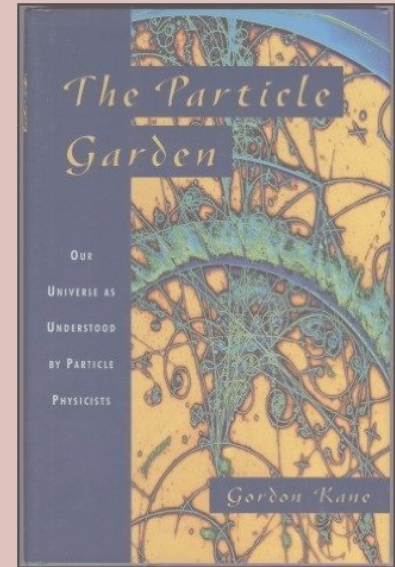
use this for free:



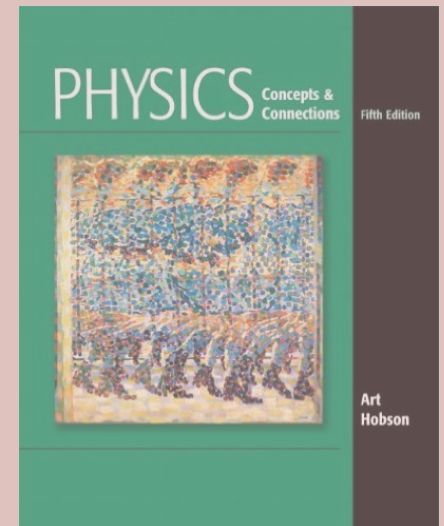
buy this:



maybe buy this:



maybe buy this:



# part 1 schedule

QS&BB in 3 parts		
Part 1	Part 2	Part 3!
"classical physics"	relativistic physics	quantum mechanics
motion, forces, momentum, energy, electricity, magnetism, waves, electromagnetism	special relativity, general relativity, 20th century cosmology	+ relativity, particle physics, current cosmology

## Part 1: By Tuesday & Thursday

You should read the Lesson assigned to that particular day. The in-line reading questions will close.

## Part 1: During Tuesday & Thursday

gentle quiz on reading

demonstrations relevant to the lesson

some in-class guided questions to work together

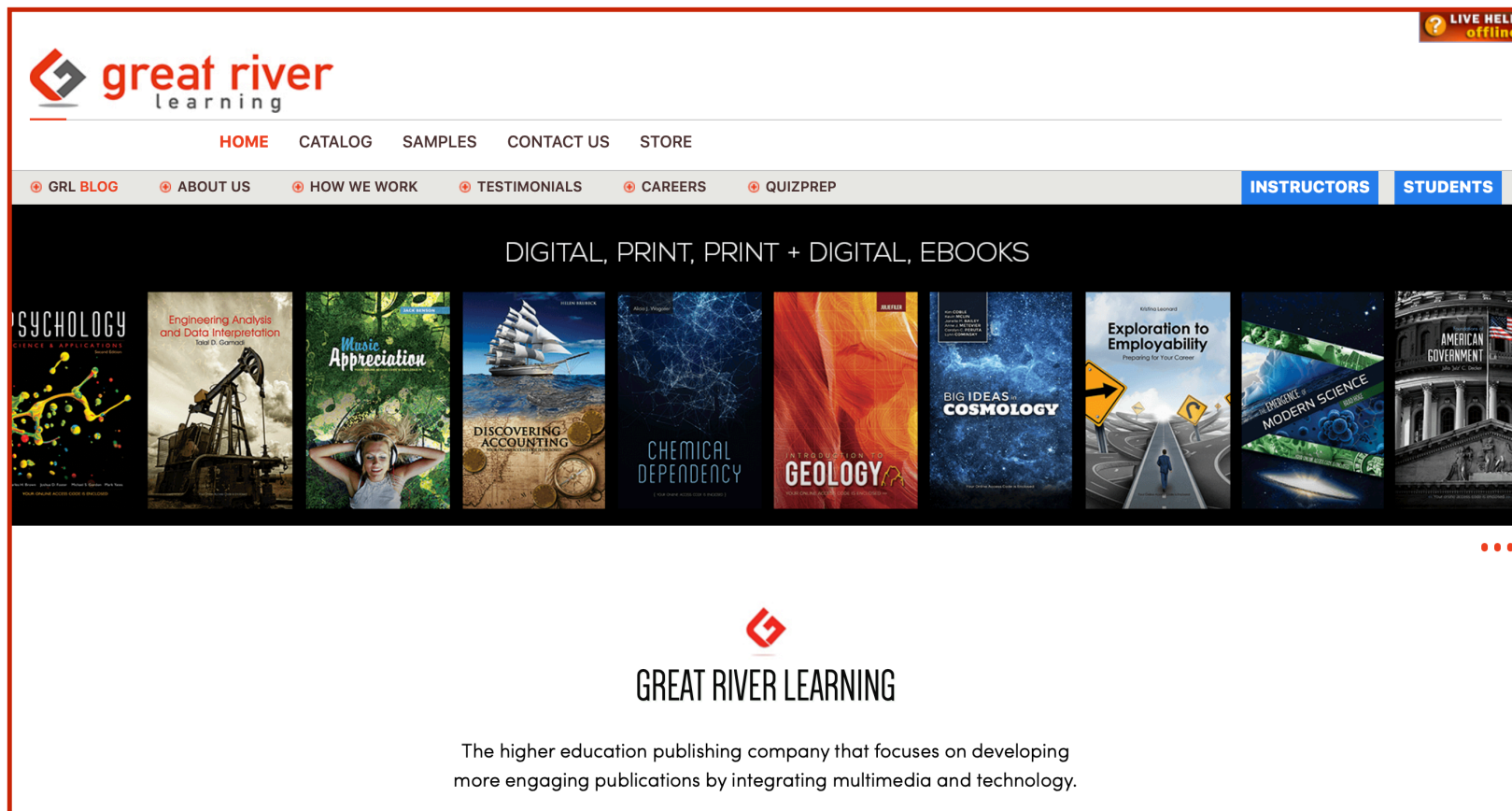
an in-class exercise that you can work out together

Homework: every 2 weeks

# one caveat

GreatRiverLearning

approached me about writing an on-line textbook



let's look




# beta test 1 lesson



GreatRiverLearning

<https://www.grtep.com>



Welcome Student Brock | [Account](#) | [Logout](#)

[Home](#) | [Internal Messages](#)

Login

Username \*

This is your e-mail address

Password \*

[Forgot Password?](#)

Login

First Time User (with access code)

Access Code \*

For help with access codes, please [click here](#).

Next

First Time User (without access code)

No access code from the book? Purchase access here.

Click Here To Purchase

For questions or concerns please contact [web support](#).  
Having troubles viewing something on the page? Make sure you have the correct [plug-ins](#).  
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View the Great River Learning [Privacy Statement](#).

# one lesson

Lesson 5, for next Tuesday

try it

*your homework will be absorbed into their system  
and I'll retrieve it as a spreadsheet*

evaluate it at the end of the lesson

*and I'll give you some spartycash or a new car or  
something*

I have codes for you to get in for free...

Student_Name	Access Code
Ahmed, Zachary Mohamed	CSXXH-CPT9G-P4XZH-23BGF
Allen, Ryan Herrick	CSC47-TFTHT-3RGM-C66V
Chapman, Lauren Michelle	CSSR2-V42FK-3RXXR-PXM76
Christensen, Connor James	CS7SN-PPF9R-3492F-MZXBB
Clemons, Alexis Taylor	CSKZZ-Z4T2R-36RVH-FNF98
Contreras, Armando	CSDFX-C3FT3-BSCCK-NVGMM
Coombs, Louis William	CSKCD-FCD6V-DV6H2-4R3HB
Coulter, Holly Lane	CS7KX-D9S76-3T988-ZBCXV
Dekoning, Case Hendrik	CSZBX-XKGKS-3B8DR-R8PTF
Derozier, Clea Marie	CSMVK-4DTGS-87FS9-DTDFK
Deschenes, Eric James	CSSHM-4FXN7-4VXVC-TRPNR
Dickens, Brady Dean	CSFG9-Z2B82-ZRB36-NGC78
Do, Sara	CSHK3-VDP8T-FBVT-KS8PS6
Erben, Hannah Marie	CSCH7-66T8G-H6M36-PZPVH
Farrell, Alayna Nicole	CSGHT-7MB4F-9NX33-V62D3
Fineout, Kael Hu	CSHK3-R8TMR-BRGV8-7242P
Finneran, Tommy	CSTDB-M289C-F3DG4-G4BPB
Fitzgerald, Patrick Robert	CSS66-XHRB8-K3XHM-6M8XD
Francis, Tyler Thomas	CSKZD-NPPGR-C4K4C-S8FD3
Freitag, Christian Alexander	CS9TP-7MRM7-64FM9-GD6ZH
Gagnon, Lauren Marielle	CS2SP-KDFBH-DH3R6-KBKRP
Gilaj, Alton	CSBPS-RN2BX-S429H-GKMSS
Graham, Heather Marie	CSMDK-4MP3M-SVHCC-HB3BZ
Hartley, Nate	CS6SF-HXS32-3R6T7-PCHRH
Haywood, Kayla Marie	CSPFT-CRSDD-KHKFF-3S9RZ
Howard, Jack	CSS6Z-3S3VN-4RP94-FNS6H
Irwin, Avery Eib	CS677-M4S7F-BS8BN-PPXGG
Jenkins, Brendan Alan	CS82P-648HK-NKKBV-FNZV8
Johnson, Marcus Wheland	CS3DK-2HPXR-9RB62-7RMK4
Judd, Monica Rene	CSNMN-MD2Z9-2CN2Z-24ZP7
Koretz, Sam	CS7G4-ZS4C4-DN5S4-PGRR3
Kramer, Eli Bernard	CSFSC-P2BGR-NNMVV-24RMD
Lim, Nick	CSTNM-K27ZH-KXFMS-73KRZ
Lozano, Gabe	CS63B-NG7CG-F43XF-MMF8H
Manchester, Ian Ronald	CSXR7-Z4T66-FK6TT-DM4P9
Mastroianni, Lia Marie	CSX26-P3NSF-V9RRN-RCSNX
Moloughney, Ryan Joseph	CSZ8R-862RS-4DCD3-79SVR
Montroy, Katie	CSTRP-CNR3S-34N3T-KCMXB
Morello, Caden Michael	CSSC8-F9PGP-TKZ2X-B7T3R
Murden, Brenden	CSPFD-SGM2B-6K7D2-TG2VX
Oconnell, Emma Kay	CS6MP-T6S4D-KHN9M-ZH7DS
Orr, Nick	CSNB2-TT2CB-M7PF3-PGZCM
Quiazon, Carlo	CSP7X-TX3TS-6KSTT-43RSV
Reynolds, Dana Lynn	CSN23-ZBVH3-6TB44-D29XF
Ritter, Blake Mcleod	CSR8Z-6C2T6-G3N96-D9HHV

Ross, Chyna Alexis	CSMR8-7VN9X-KTK86-Z2SD9
Saunders, Lorie Ella	CSB94-6CMV8-C447Z-H8N3M
Schubert, Alyssa Marie	CS74D-MPMNB-C74HK-BMK26
Shipp, Leah Mason	CSSRV-KDNCK-K3GKF-S3B84
Steenland, Julia Bove	CSPV6-363VB-Z972P-TFGNM
Sun, Zhiwei	CSHBF-K6K7B-64GGP-9XDN3
Tate, Jalen Davis	CSDGP-HMT9M-SSNT8-44HMC
Thakur, Sidharth	CSH8K-7VH3N-36DHZ-M3ZHH
Thomas, Tim	CSR4K-BBZ2C-ZND3K-ZRGFK
Torres, Ashley Ciera	CS7BM-978ZX-FB3TK-DG3RN
Trinh, Belinda Ngoc	CSZRC-HC437-VXXDT-NF93D
Varady, Brad	CSSDR-VBTDG-4333X-9S3HT
Watson, Daryn Nicole	CSVFF-CXDVB-HR7RC-VNTDN
Weinstein, David Joshua	CSD72-6DK8C-Z2VP8-P8XGP
Wells, Kayla Elizabeth Marie	CSS4T-VBKPR-BZX87-7N2RD
Wu, Cindy	CS8KP-G9286-4ZM8N-C2642
Xiong, Jiaxuan	CS2SV-4XX28-T4X99-P3994
Zhang, Yifei	CSM98-73BN4-9BH8C-KZ346
Andrews, Benjamin	CSBCG-C2PH6-9B79R-RK64F
Bassett, Mark Francis	CSTG7-6TF8C-6SZXR-KZ38N
Burdick, Caroline N	CSNRR-7V8G2-9GDNN-HZTC2
Cismesia, Nadia R	CS3TD-8DD4G-TFZ46-C4RTM
Crosser, Madison Marie	CSGNX-74XM8-BMSB6-GMZHD
Czajka, Brenden Michael	CSDMZ-RGFXX-MXP62-ZGGZN
Delgado, Antonio Christopher	CSDGZ-KCPRG-46K2G-FZRBM
Eberle, Alison Reine	CSCNH-6M3HF-27VCD-K9XG2
Feldman, Jacob Matthew	CSMB6-268PB-VCXMG-2S9Z2
Garcia, Matt	CSZNP-KFG4F-CBBX8-TVBVZ
Gettel, Justin Andrew	CSSMG-4FGHR-TBCK6-SMX9P

Hix, Natalie Violet	CS3TH-3KF29-HZCBH-4K7XK
Hobson, Alyssa Jordan	CS47M-DKPSF-FMNZ8-3FPN2
Huang, Qi	CS2BP-2F4MH-SHTCV-6X9RZ
Kada, Myrna Mahir	CSGGX-SKG2F-S7VTX-PMZS2
Lintol, Sydney Marie	CSFN8-82FDT-HXGFG-MKR4H
Maceri, Tommy	CSNNV-M6BDC-P39SZ-MDDKS
Mccallum, Erin Margaret	CS2HZ-T6DGV-4D44N-FSV4H
Mezaache, Kristin Nicole	CST49-9DT6P-SRN3R-NBTH8
Olweean, Danny	CS7RF-DK7R2-XPGNT-KBHM3
Poe, Jeralyn Megan	CS3B9-7S2MD-XZ9XV-6CR2D
Richard, Bre	CSN89-Z2CPP-M3V78-HV397
Rodas-Mazariegos, Paulo Gerardin	CS8BB-7XXZ7-RVBF6-PBS39
Stallings, Peyton Christine	CSC6X-PNCCF-PZF6C-FVNFY
Steffke, Madeline May	CST3P-GSRB3-KXF44-P8NPG
Warner, Mikayla Erin	CS43X-HXKN9-R78ZG-B62F2
	CS8N6-M3HNC-G2DF3-6VF64

I've also uploaded it to:

[https://qstbb.pa.msu.edu/storage/QS&BB2019/Homework\\_Projects/](https://qstbb.pa.msu.edu/storage/QS&BB2019/Homework_Projects/)

# part 2 schedule

Part 2: During Tuesday & Thursday

lectures: just like the 13th century

random quizzes on reading/attendance

demonstrations

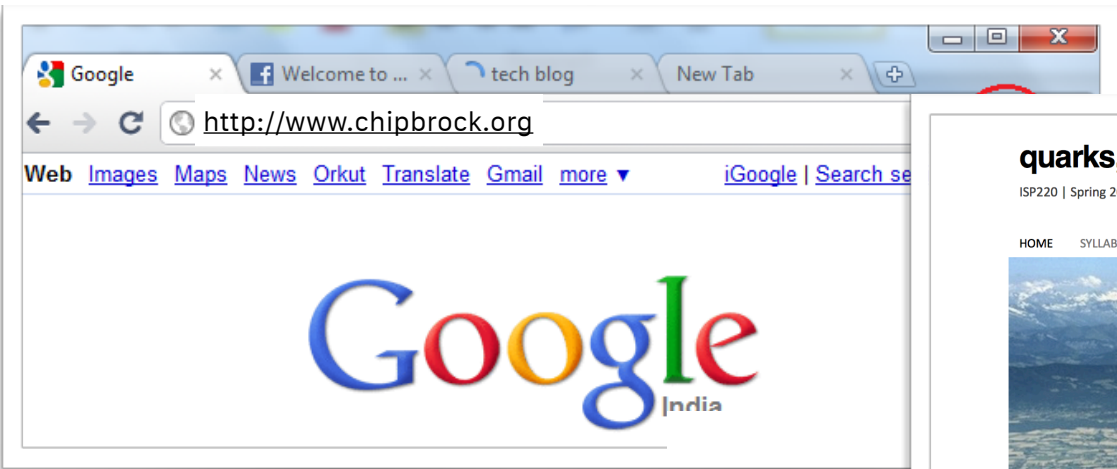
Homework every week

*released on Saturday, due the following Friday*

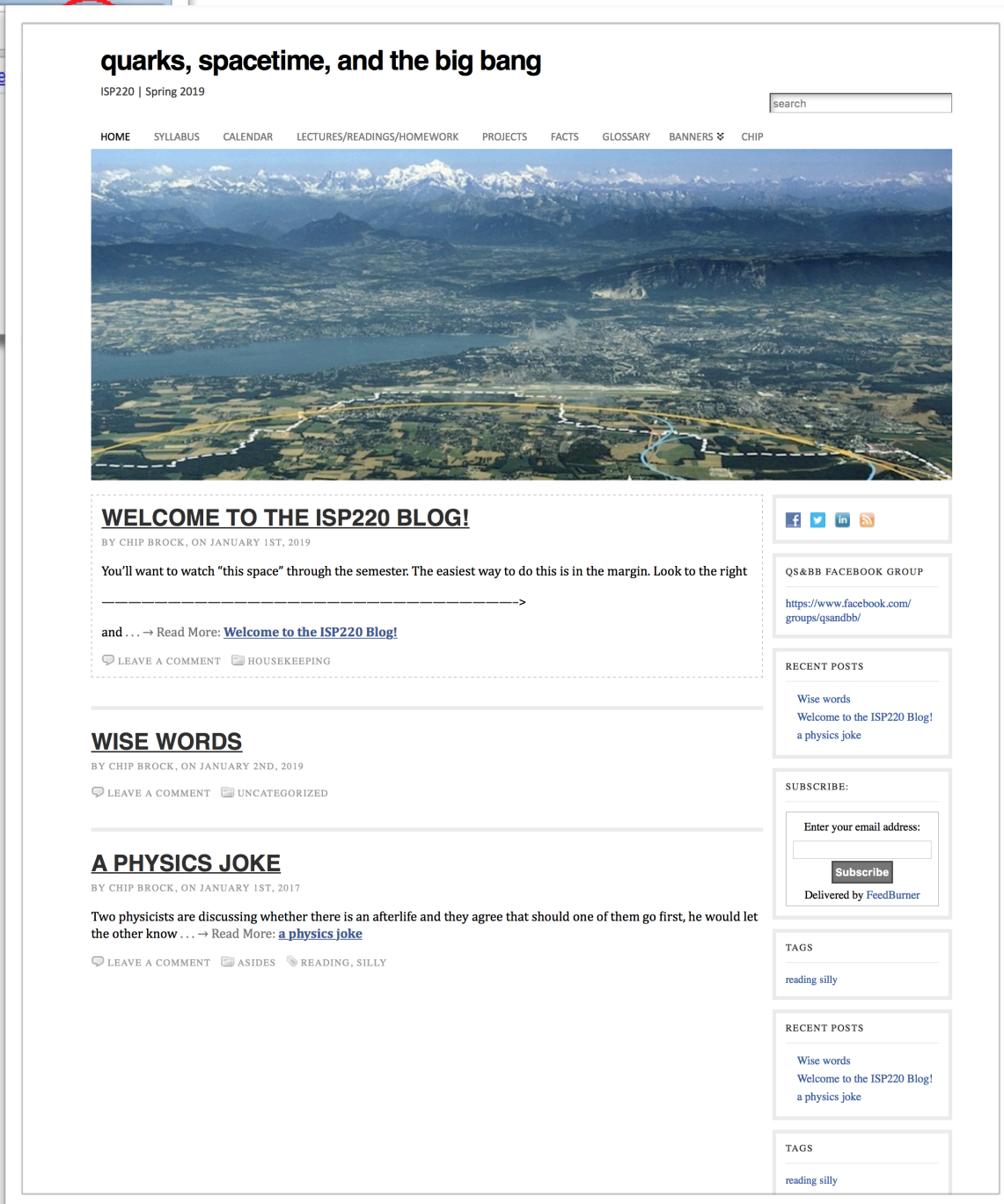
QS&BB in 3 ~		
Part 1	Part 2	Part 3!
"classical physics"	relativistic physics	quantum mechanics
motion, forces, momentum, energy, electricity, magnetism, waves, electromagnetism	special relativity general relativity 20th century cosmology	+ relativity particle physics current cosmology







let's go there



# your contributions

simple in-line reading questions from Part 1 QS&BB

simple on-line homework

2 on-line exams, like homework

readabook: from a list, choose a book to carefully read and review

a final-exam project done in groups

announced and unannounced quizzes

some extra stuff you can do for points

# read the syllabus carefully

two kinds of points:

## Core Base Points

Source	max #	pts per	total possible
homework: during Part 1	3	30	90
homework: rest of semester	10	30	300
exams	2	60	120
reading questions: during Part 1	9	30	270
book review	1	20	20
Feynman Diagram Final	1	20	20
in-class projects: during Part 1	5	15	75
early quizzes: during Part 1	5	5	25
random quizzes	4	10	40
random attendance	2	5	10
Total			970

## Extra Credit Points Available

Source	max #	pts per	total possible
another book review	1	20	20
reading notes	5	10	50
Big Questions	2	10	20
fakefacebook bio	1	20	20
final day poster	1	20	20
Total extra			130

# read the syllabus carefully

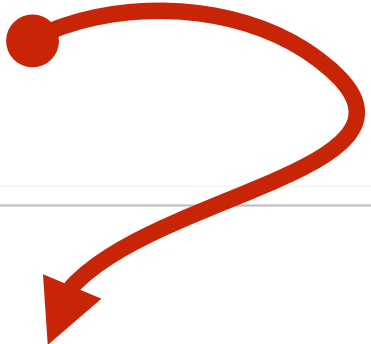
grades

notice that it's based on the core points:

projects add

## Grades

This is approximate:



Total Points	Grade	% of total core
850	4.0	about 90%
780	3.5	about 80%
700	3.0	about 70%
630	2.5	about 65%
540	2.0	about 55%!
480	1.5	about 50%!!
430	1.0	about 45%!!!

These are created in order to make it hard to badly in ISP220.



# bookmark:

<http://www.chipbrock.org>

course website

<https://qstbb.pa.msu.edu/ed/>

"the book" "QS&BB"

[https://qstbb.pa.msu.edu/storage/QS&BB2019/videos\\_2019/](https://qstbb.pa.msu.edu/storage/QS&BB2019/videos_2019/)

the videos

[https://qstbb.pa.msu.edu/storage/QS&BB2019/isp220\\_slides\\_2019/](https://qstbb.pa.msu.edu/storage/QS&BB2019/isp220_slides_2019/)

the ftp site where I'll store all lecture slides

[https://qstbb.pa.msu.edu/storage/QS&BB2019/Homework\\_Projects/](https://qstbb.pa.msu.edu/storage/QS&BB2019/Homework_Projects/)

periodic homework and project materials

<http://www.pearsonmylabandmastering.com/northamerica/masteringphysics/>

MasteringPhysics

<https://www.pearsonmylabandmastering.com/northamerica/masteringastronomy/>

MasteringAstronomy

<https://loncapa.msu.edu>

LON-CAPA, reading questions in Part 1 and repository of projects throughout

<http://www.facebook.com/groups/qsandbb/>

QS&BB Facebook Group...by invitation only

# the M word

When I took high school Latin

I was not required to write original works in Latin

but I was required to be able to read Latin

That's how we'll use mathematics in QS&BB

read an algebraic "sentence" or "paragraph" in order to gain  
**insight**

# I assume

that you went to high school

and that you can manage simple algebra and scientific notation

remember:  $4,000,000 = 4 \times 10^6$ ?  $0.000004 = 4 \times 10^{-6}$ ?

can you solve for  $x$ :  $y = mx$        $y = a\sqrt{b+x}$        $y = ax^2$ ?

you're good

*see QS&BB, Lesson 3 for review*

and that you'll always ask if you don't understand something

# how to get ahead

come to class

do the work

use your hands.



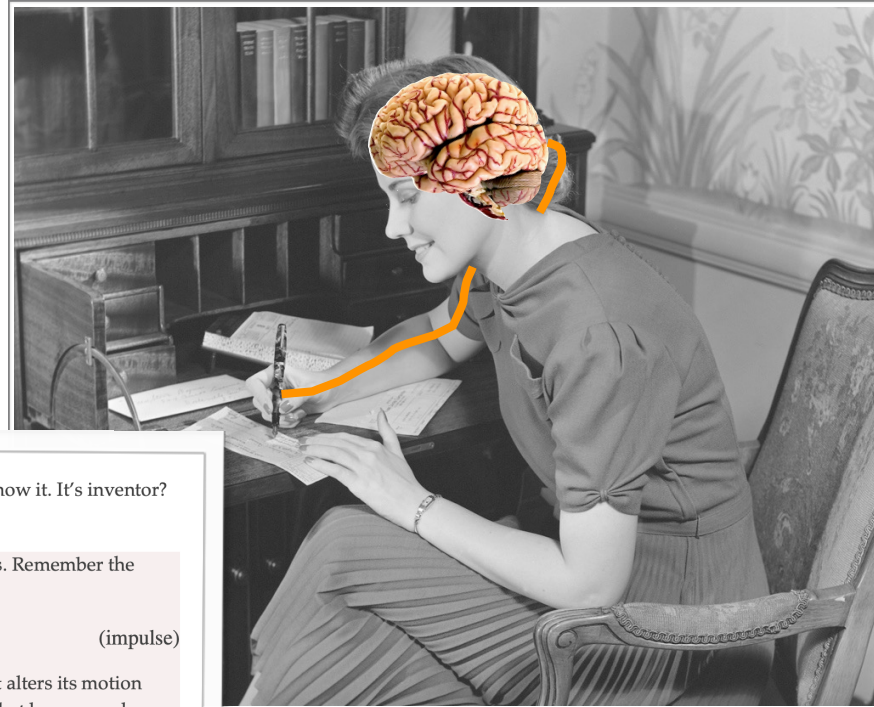
# my experience

about learning anything involving logical reasoning

how I do it, even today

you can't "read" mathematics

remember?



you must  
copy it.  
with your  
fingers

Let's work out the most important one of these and get to know it. It's inventor?  
Why, Mr Newton, which should be a surprise to no one.

Let's develop the simple machinery from Newton's ideas. Remember the  
impulse model...let's enjoy that one again:

$$\vec{F}\Delta t = \Delta\vec{p} \quad (\text{impulse})$$

The momentum change of an object is equal to the force that alters its motion  
times the time through which that force acts. Think about what happens when  
object A collides with object B. Let's imagine that A is your left hand and B is

SO

bring a notebook to class



no computers, phones, iPads, or fraternity brothers

# how I'd do your job

come to class

watch and listen to lectures and demonstrations

take brief notes

*if something goes by quickly—jot the slide # and look later*

*if it still bothers you, **ask** and maybe I'll make a movie*

when I go to the tablet...write with me

you've got friends

check the website for my office hours

in-person and virtual (Skype and Facebook)

and for those of our TA:

Katie Schram

in-person and virtual (Facebook)



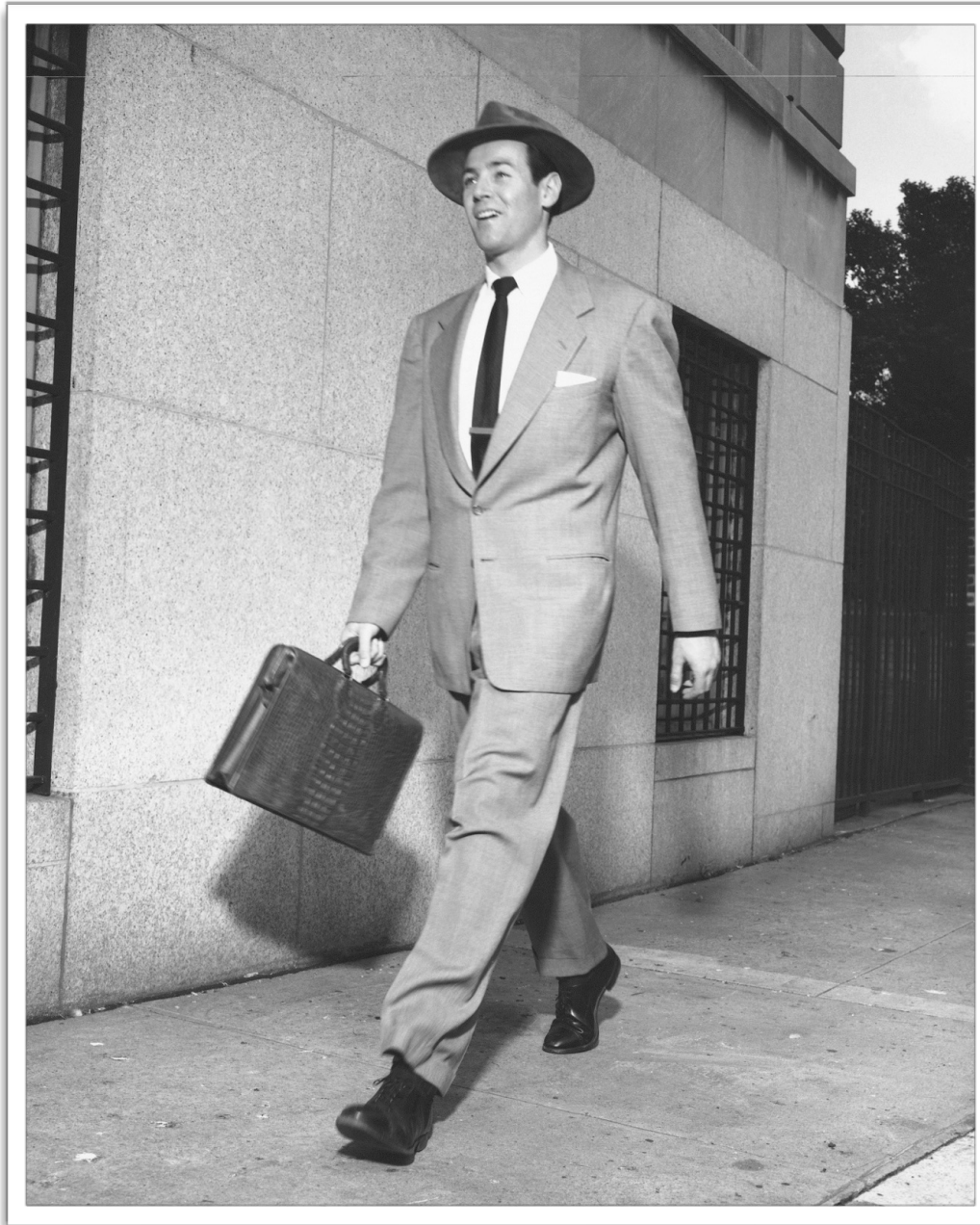
# how to get ahead

come to class

do the work

use your hands.

you'll be fine



let's get to work

# some random notions

How I think of you and me

Laws, Theories, and Models

A fly-over of QS&BB

How I think of you and me



you

you're not likely going to be a professional scientist

I'd like you to become a knowledgeable spectator

"You can observe a lot by just watching."  
Yogi Berra



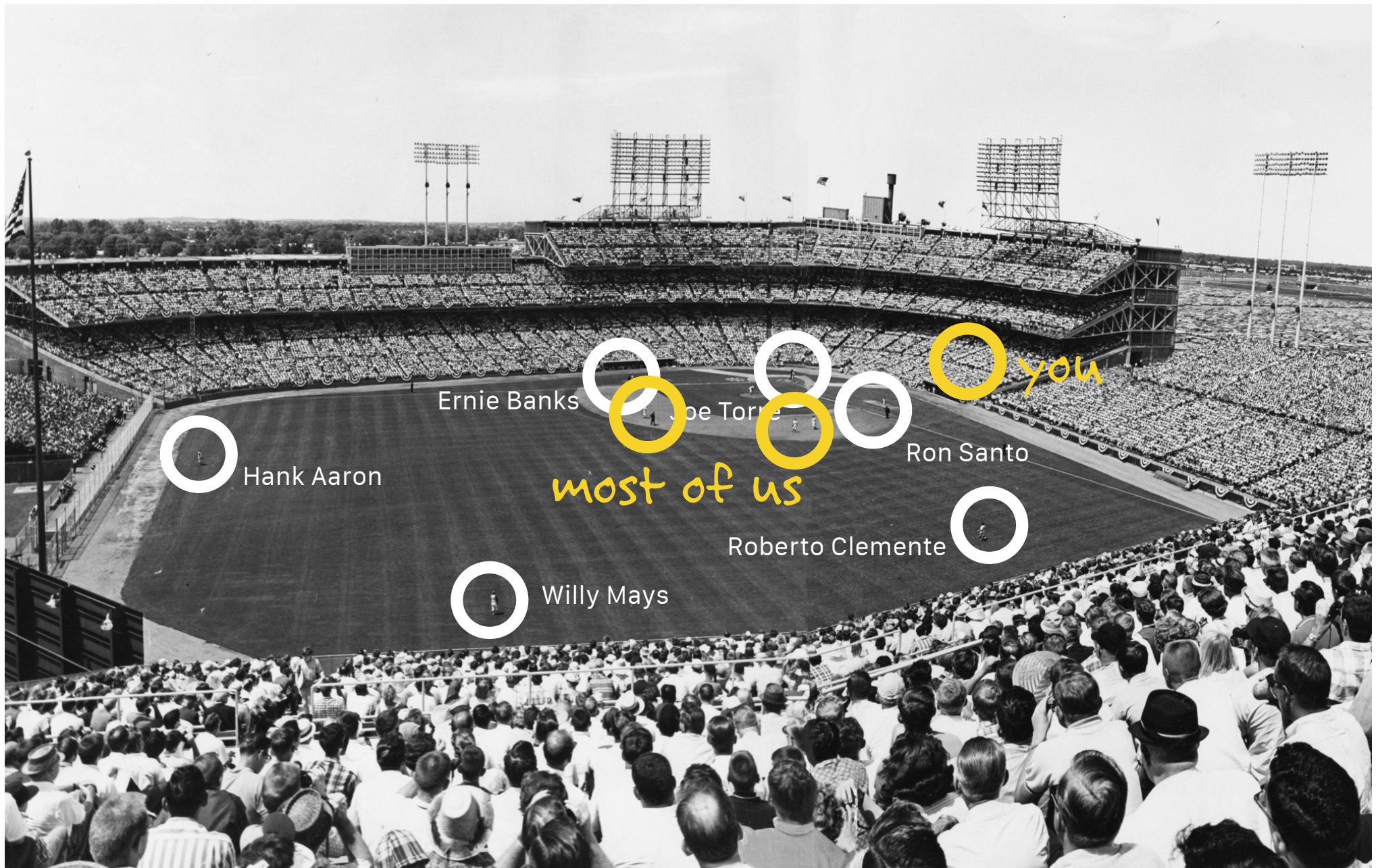
July 13, 1965 MLB All Star Game

me

some hate the "great man" history of science

I understand it perfectly





July 13, 1965 MLB All Star Game: 19/500 future Hall of Fame



## Laws, Theories, and Models



ask me

about Florida

# The L word

"Law"

don't like it.

there are no "Laws" of nature

Florida's example of a Law of Nature was:

Newton's Law of Gravitation:

Newton's **theory** of Gravitation

Newton's **law** of Gravitation

$$F_{12} = G \frac{M_1 M_2}{R_{12}^2}$$

# Theories

It's all theories, all the way down

better word: "framework"

*The Theory of Relativity is ...a theory*

Acceptable theory

highly trusted

we don't "believe" in theories of nature

*we test them and we question them*

# models

Mother Nature seems to be a mathematician

we have no idea why

it just is

A model is a mathematical "algorithm" built within the confines of one or more theories

not mean to be perfect

Goldilocks-acceptable

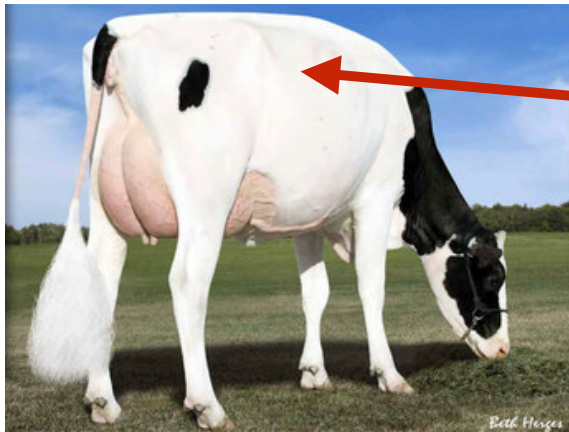
matched to need and testability



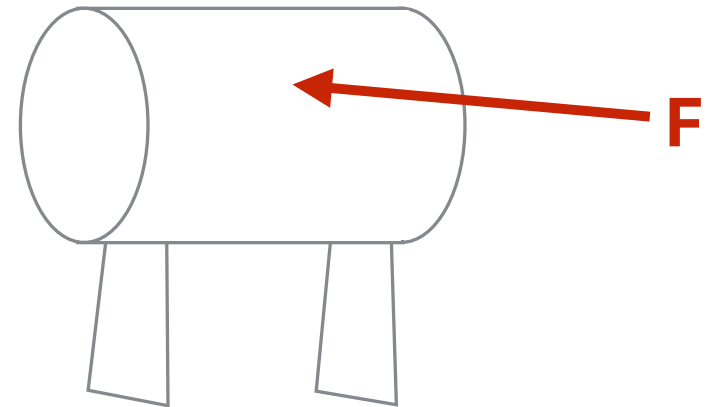
# a well-know problem

Cow Tipping...what's it take for high school boys to tip a cow?

Go tip cows? Make a model.



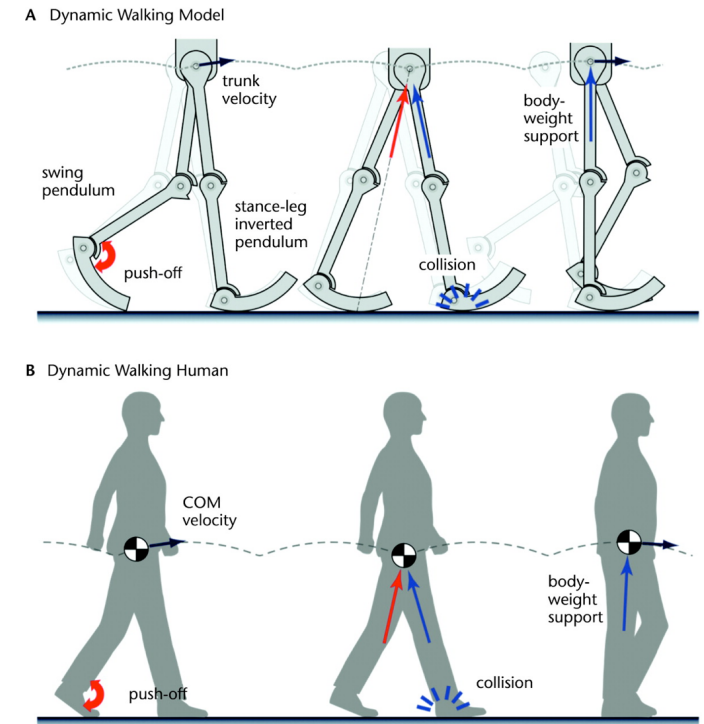
**F**



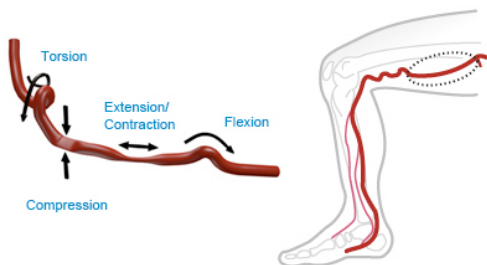
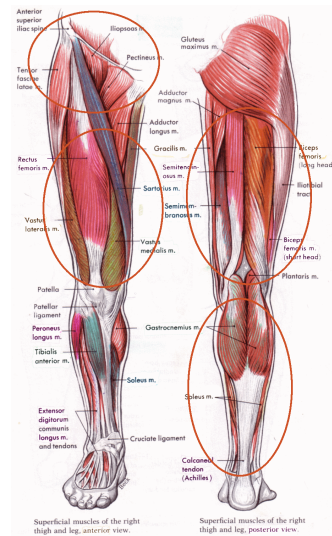
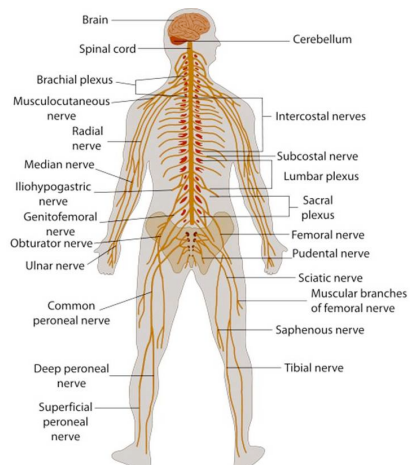
**F**

a model

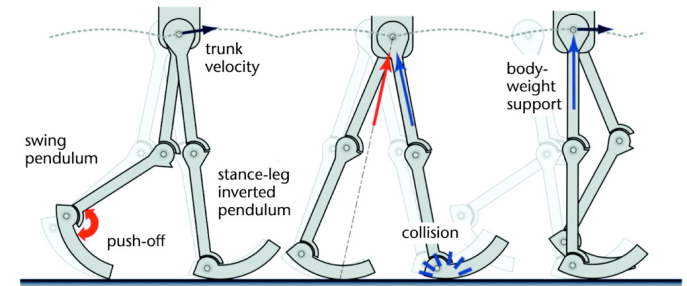
I can draw free-body diagrams and make a model of walking



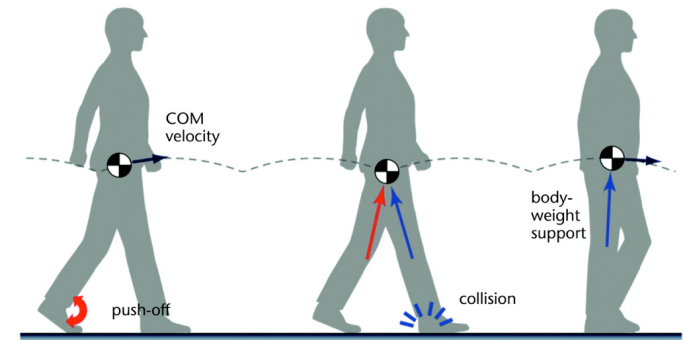
I can draw free-body diagrams and make a model of walking



A Dynamic Walking Model



B Dynamic Walking Human



But it's not the actual physiology of walking!





# 20th century physics

was interesting

3 theories developed



- Special Relativity
- General Relativity
- Quantum Mechanics

many, many models of phenomena

"Standard Model of Particle Physics"

"Standard Model of Cosmology"



# QS&BB

is all about them

the 3 theories

the 2 big models



**COMING  
ATTRACTIONS**

# what we don't know

Lots.

what banged?

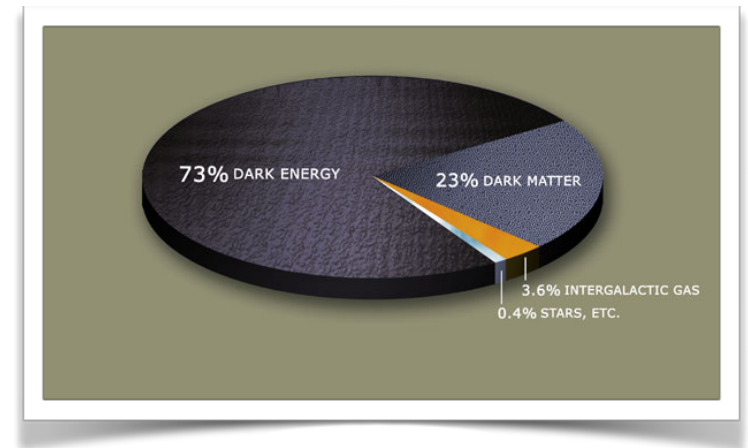
gravity and quantum mechanics don't mix

much of the universe is missing

neutrinos behave very strangely

where is all of the antimatter?

do the forces unify?



# idiosyncratic

introduction alert

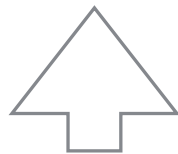


# you're asking yourself

So, self. How is this relevant to my life?

after all, you're happy being a collection of

*protons, neutrons, and electrons*



*(or just up and down quarks)*

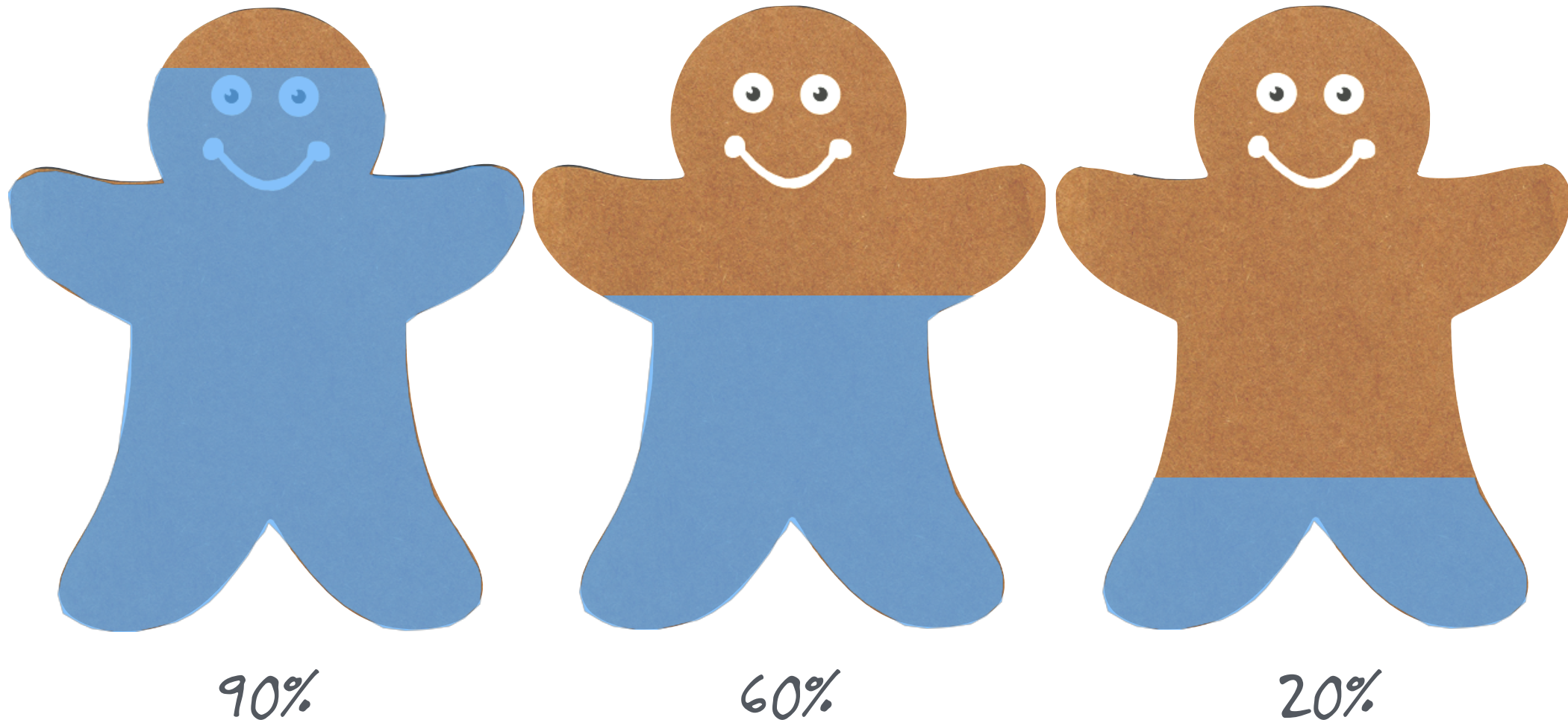


let's make this

all about you

# your-self

intricately bonded to particles and the cosmos



Made from nuclear fusion in stars.

Made in nuclear fusion in exploding stars.

Made in the big bang.

1.5% inorganic  
1% RNA  
0.4% organics  
0.1% DNA



60-70%

P, S, Na, K, Cl, Mg, Si, F,  
Fe, Zn, Rb, Sr, Br, Al,  
Cu, Pb, Cd, B, Mn, Ni, Li,  
Ba, I, Sn, Au, Zr, Co, Cs,  
Hg, As, Cr, Mo, Se, Be, V,  
U, Ra



60-70%

The body: about  $7 \times 10^{27}$  atoms

65% of that is H: 13.772By old

assume 70kg:

$4.2 \times 10^{28}$  protons

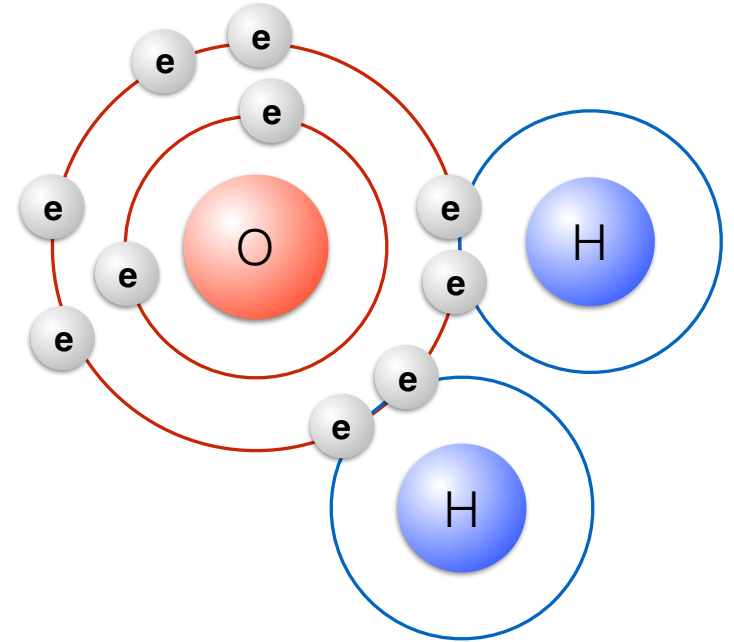
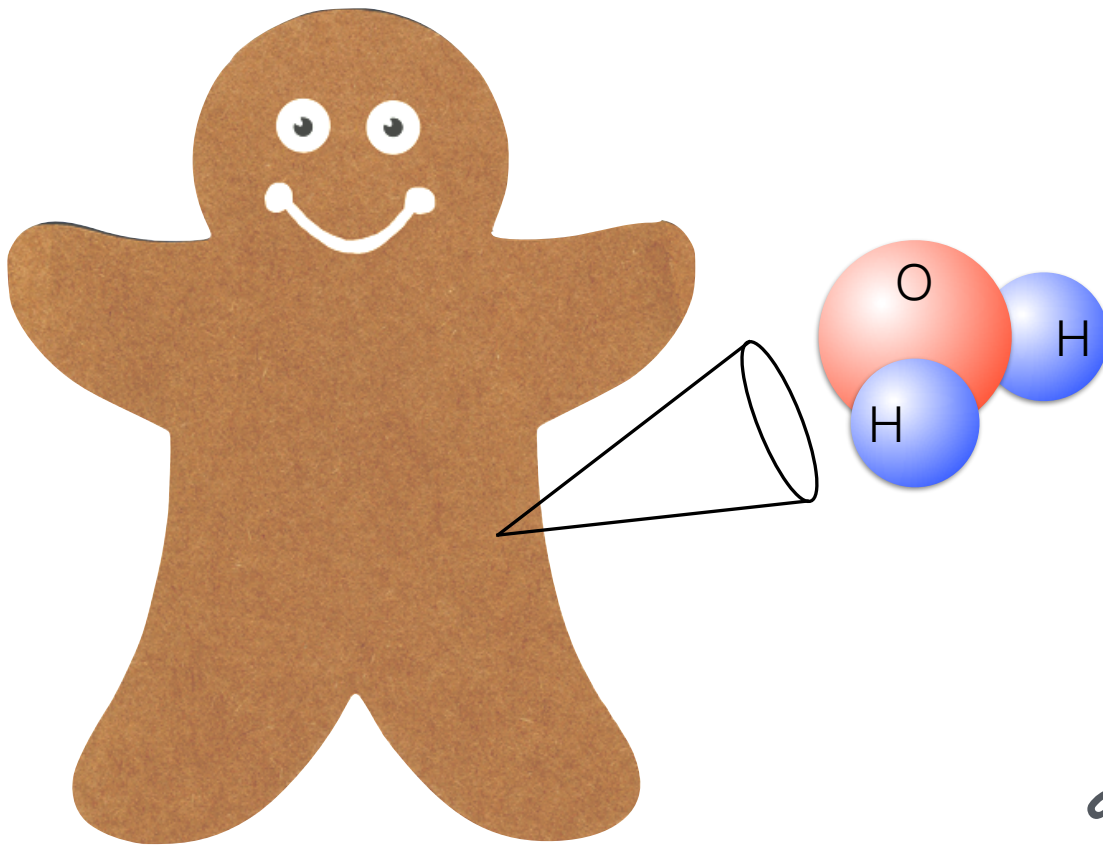
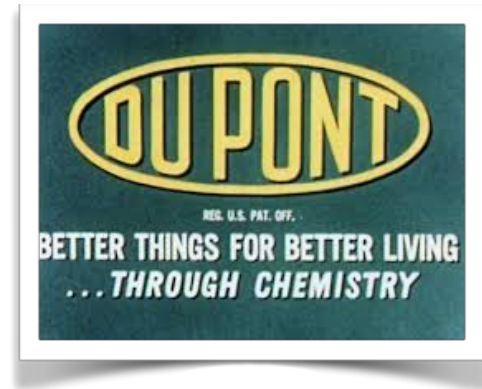
$1.4 \times 10^{28}$  neutrons

$4.2 \times 10^{28}$  electrons

} water alone

a little chemistry factory

think about water.

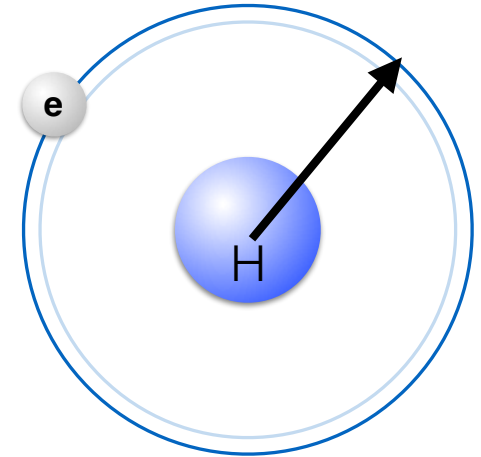
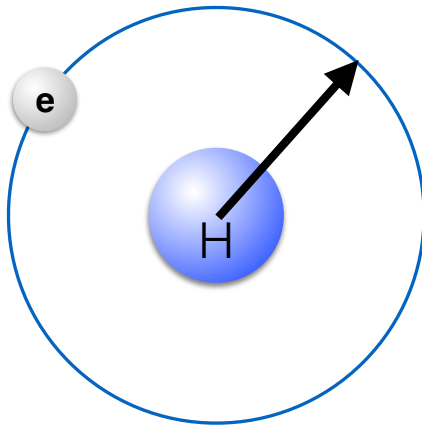


a precise, little machine



# suppose

the electron mass was few % *lighter*?



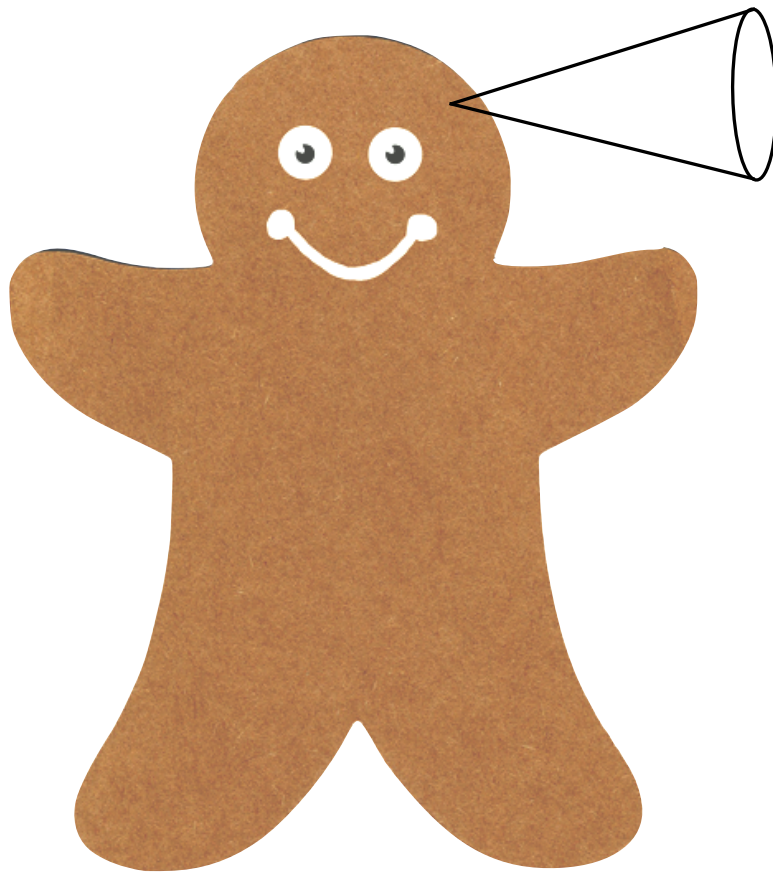
all of chemistry changes

the BB's production of H changes

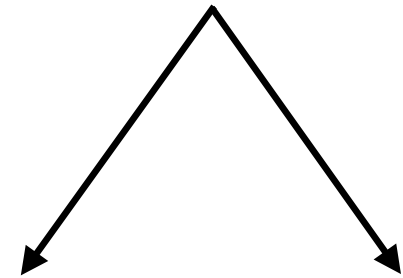
formation of stars changes

# a little radioactivity factory

those trace inorganics?



potassium includes  $^{40}\text{K}$



$^{40}\text{Ar}$

$^{40}\text{Ca}$

+ anti electron

+ electron

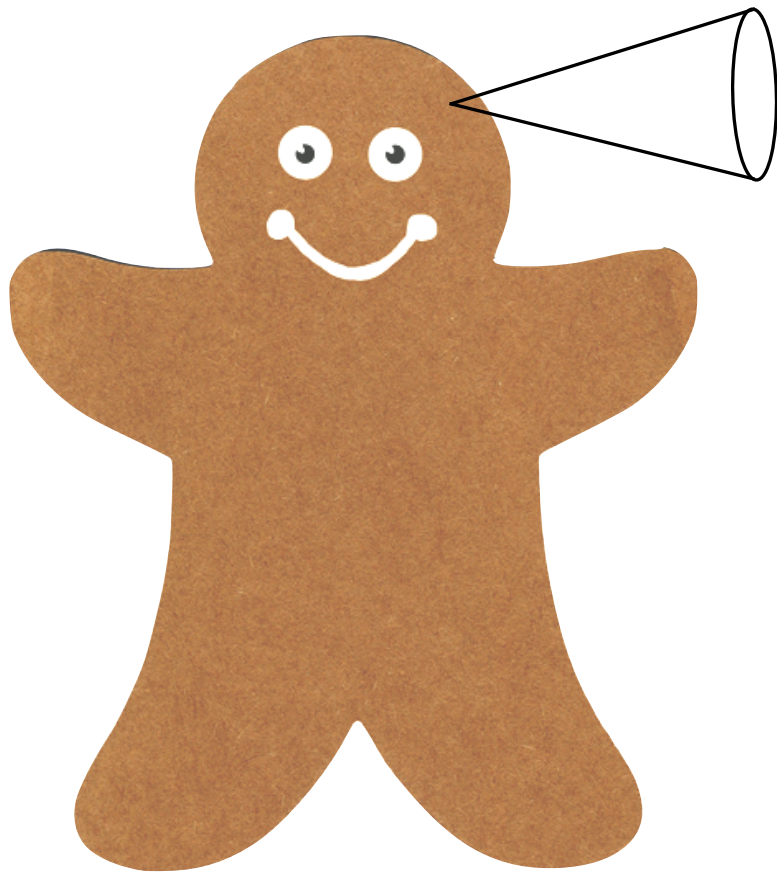
+ neutrino

+ neutrino

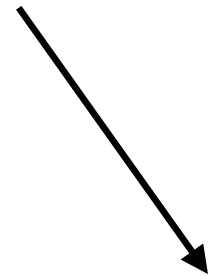
$e^+ + e^- \rightarrow 2 \text{ gamma rays}$

# a little radioactivity factory

those trace inorganics?



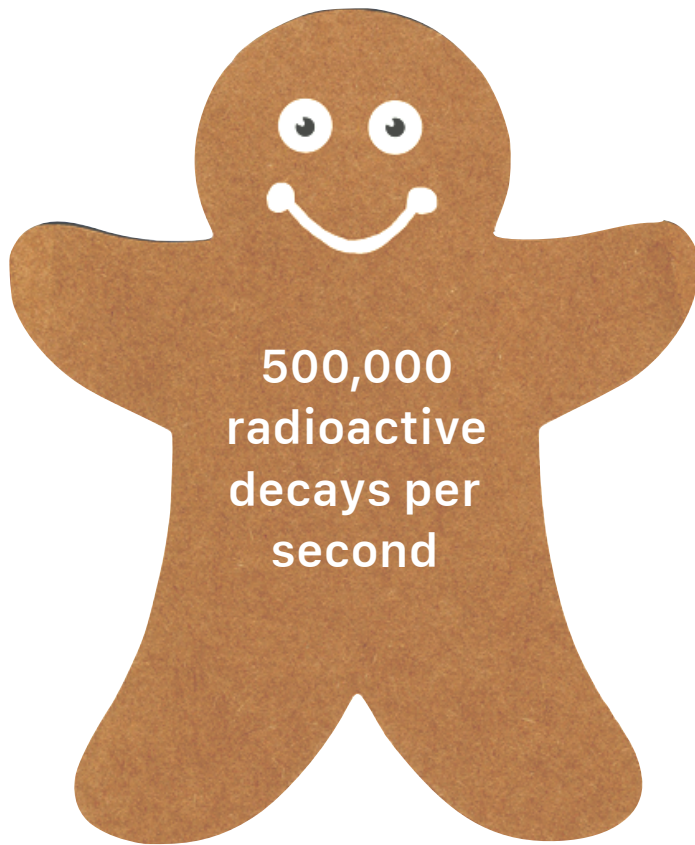
carbon includes  $^{14}\text{C}$



$^{14}\text{N}$   
+ electron  
+ neutrino

# a little radioactivity factory

you internally expose yourself about 4 X-rays' worth per week



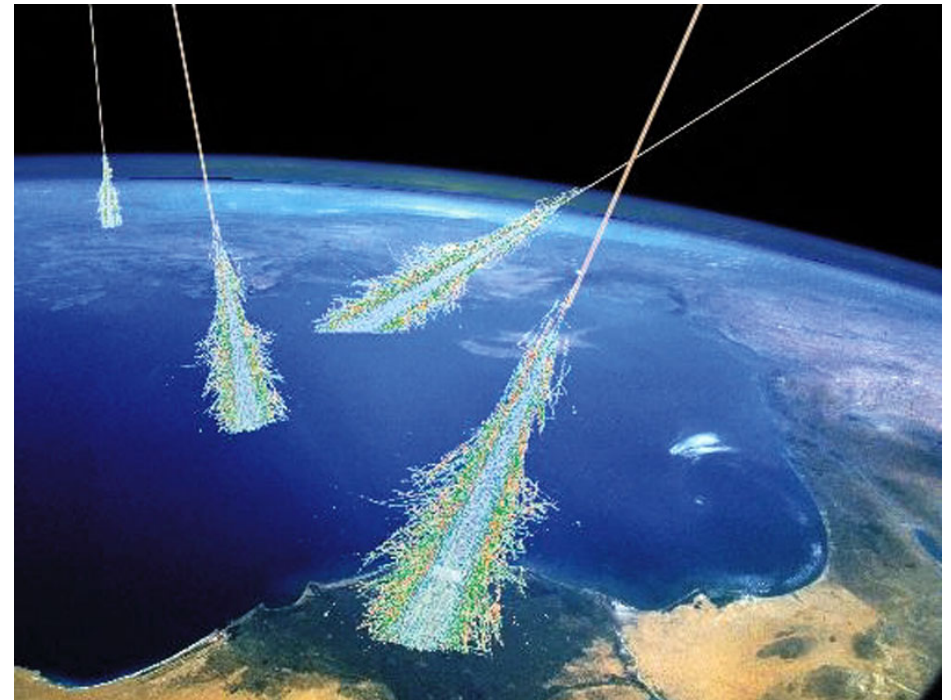
*about an X-ray per week*

# attack from above

constantly bathed

in cosmic rays

10,000  
"muons"  
per minute





that's not all

constantly bathed

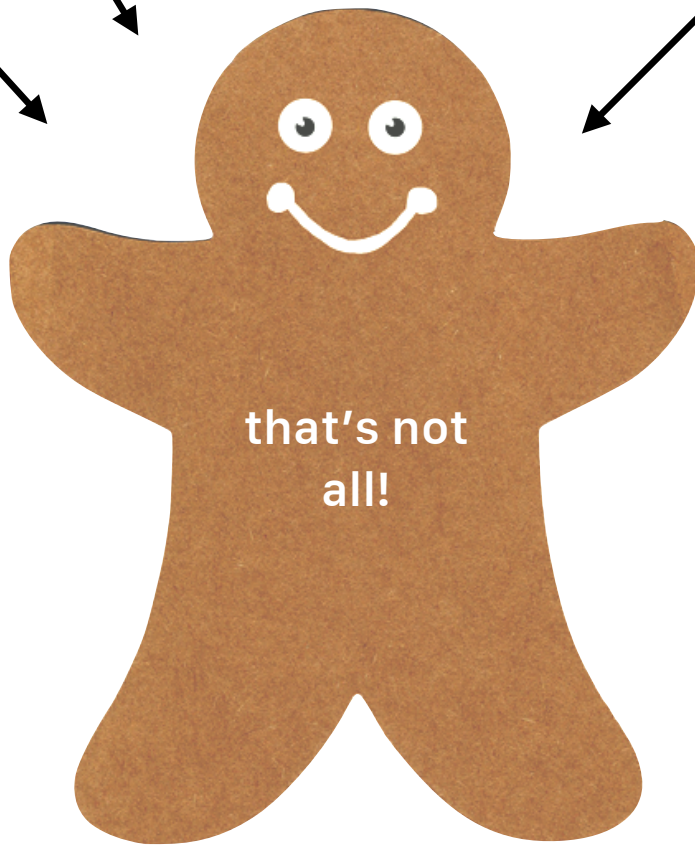
in microwaves from the big bang

galactic dark matter particles

neutrinos from the big bang

Higgs field from the first  
picosecond of the universe

vacuum  $\Lambda$  energy





# so just sitting there

You're experiencing much of particle physics:

*antimatter*

*neutrinos*

*muons*

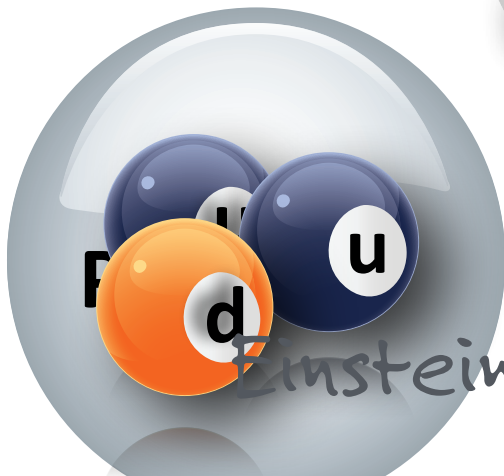
*fine tuning of masses\* so that chemistry works*

*dark matter*

*relic big bang radiation*

# take a proton

made of 3 particles: "quarks," 2 "up" and 1 "down"



Einstein's Special Relativity solved that

# so just sitting there

You're experiencing much of particle physics:

*antimatter*

*neutrinos*

*muons*

*vacuum particle production*

*dark matter*

*relic big bang radiation*

*Higgs Field*

*gluons*

*Einstein's special theory of relativity*

did you dry your hands

in the fancy air-driers?

it turned on because of Quantum Mechanics

# existing so just ~~sitting~~ there

You're experiencing much of particle physics:

*antimatter*

*neutrinos*

*muons*

*vacuum particle production*

*dark matter*

*relic big bang radiation*

*Higgs Field*

*gluons*

*Einstein's special theory of relativity*

*quantum mechanics*



did you use GPS?

works because of General Relativity

# existing so just ~~sitting~~ there

You're experiencing much of particle physics:

*antimatter*

*neutrinos*

*muons*

*fine tuning of masses\* so that chemistry works*

*dark matter*

*relic big bang radiation*

*\*Higgs Field*

*\*gluons*

*Einstein's special theory of relativity*

*quantum mechanics*

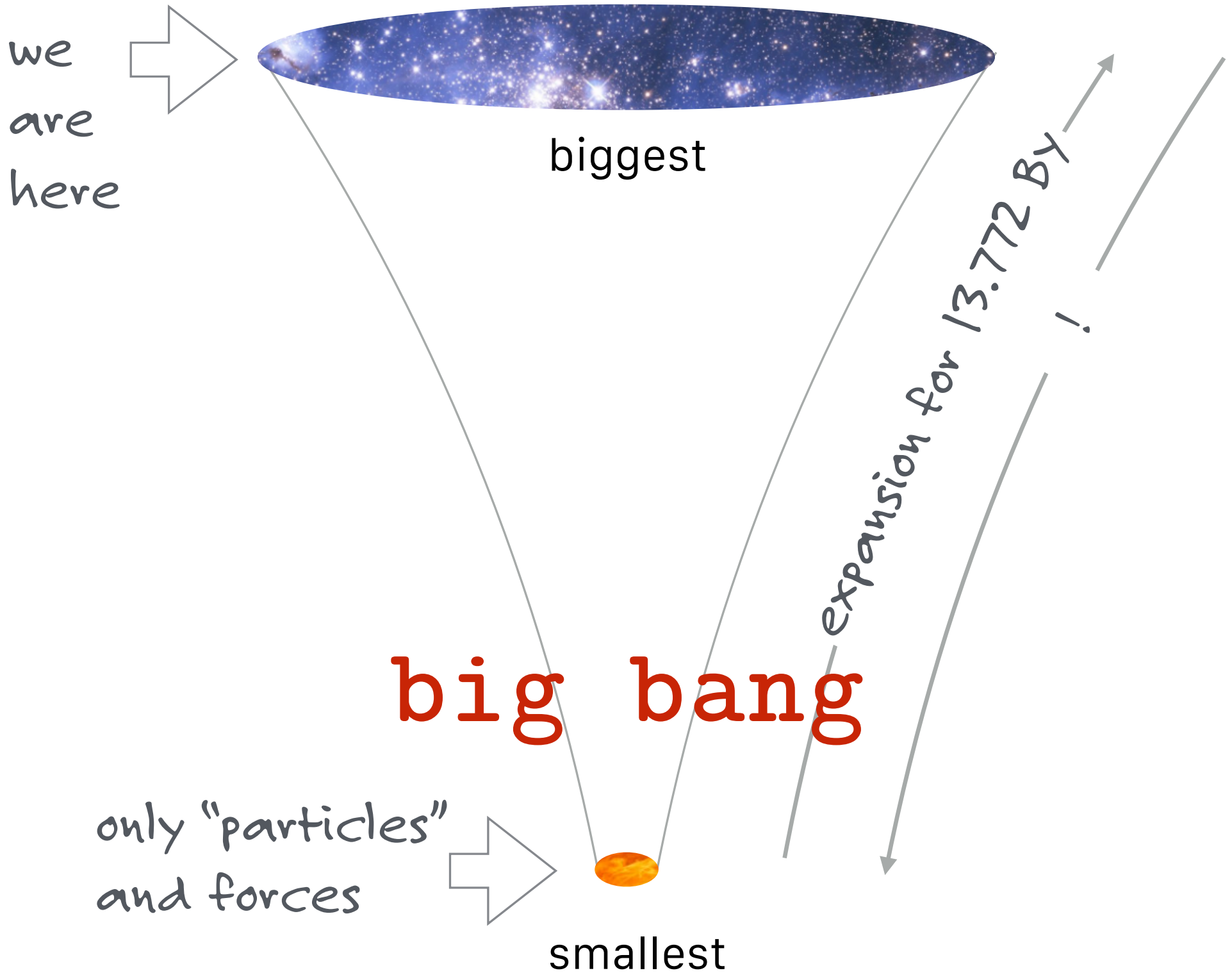
*Einstein's general theory of relativity*

# the big bang

connected these two fields

of cosmology and particle physics

ISP220 is a course about our Origins



# ISP220

leads you to  
understand, appreciate, and become familiar with  
all of this  
and more



this is a

**Big Questions** course

# The Big Questions

key:

blue: a particle physics question

green: a cosmology question

yellow: a bigger question than only cosmology or particle physics!

1. What is the Nature of Space and Time?
2. Did the Universe have a Beginning?
3. Will the Universe end?
4. Is there only one Universe?
5. What was the nature of the Early Universe, just after the Big Bang?
6. Was there anything before the Big Bang?
7. Why are galaxies clumped into filament structures?
8. Do Gravitational Waves exist?
9. Do Black Holes radiate?
10. What is the origin of ultra-high-energy Cosmic Rays?
11. What is the nature of Nothing?
12. What is the nature of Something! What is Mass in general?
13. What is the nature of the Higgs Boson(s)?
14. What new physics does the 2012 Higgs Boson-like particle point to?

15. What is the nature of Gravity and is there a Quantum Theory of Gravity?

16. What are the masses and nature of Neutrinos?

17. What is Dark Energy?

18. How many Fundamental Forces of Nature are there?

19. Why is Gravity so weak?

20. Is there a single, Theory of Everything?

21. How many Fundamental Particles are there?

22. Why do the particles have the masses that they do?

23. Are Quarks and Leptons made of other particles?

24. Are elementary particles strings?

25. What is the nature of Dark Matter?

26. Where is all of the Antimatter?

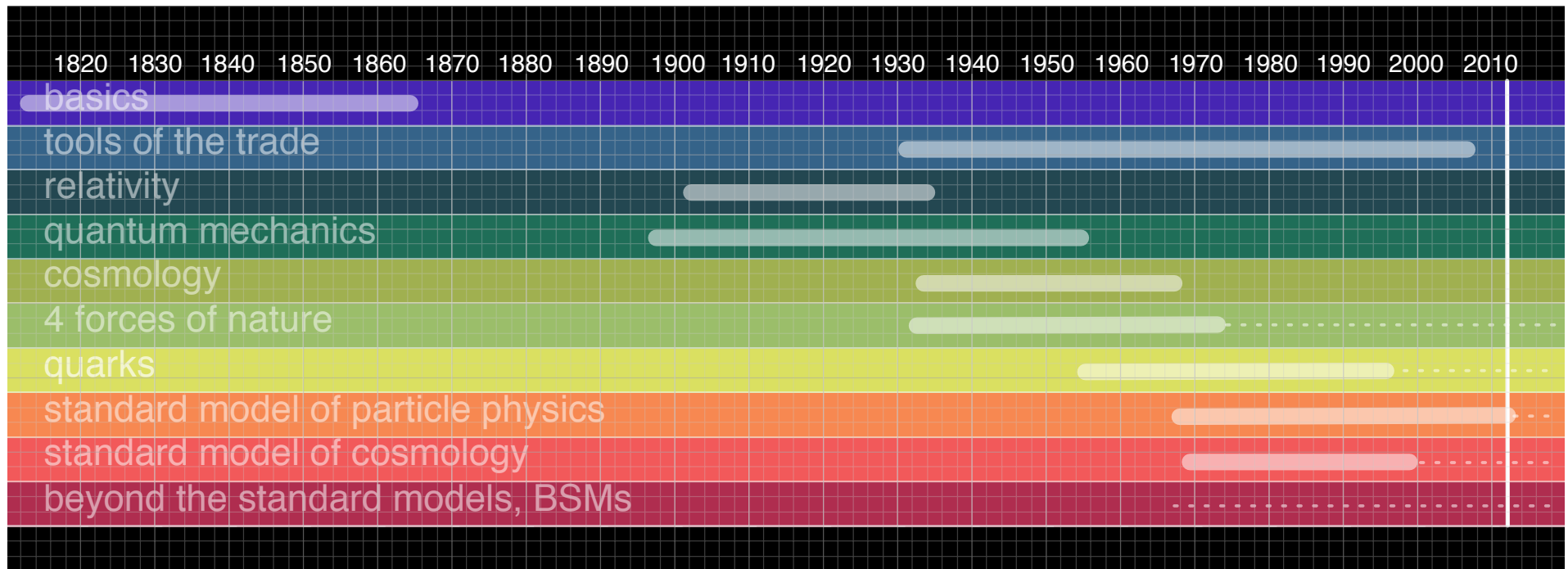
27. Is the Proton "forever" or can it decay?

key:

blue: a particle physics question

green: a cosmology question

yellow: a bigger question than only cosmology or particle physics!



### Three distinct themes

- "Foundations" ..."regular physics"...bare minimum

*very brief and gentle.*

- Einstein's Relativity

*Special and General Theories, including the beginning of quantitative cosmology*

- Field theories

particle physics and the early universe

*Current - right now - challenges*

with that

start reading and watching

questions?