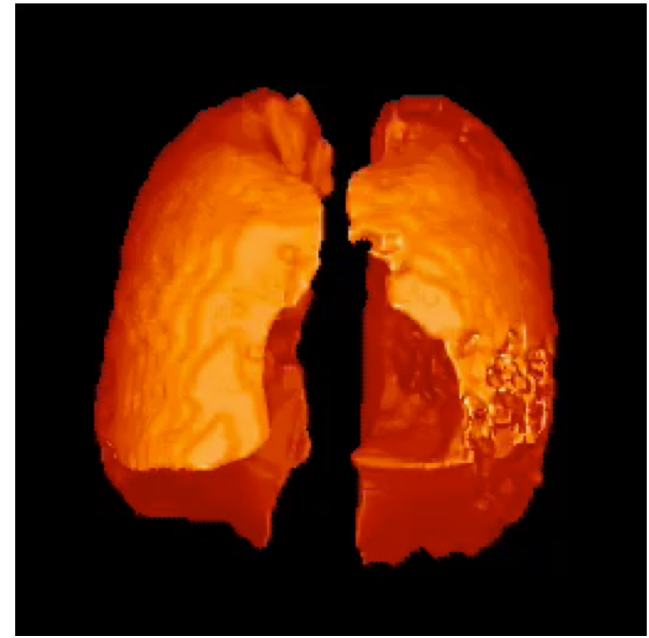
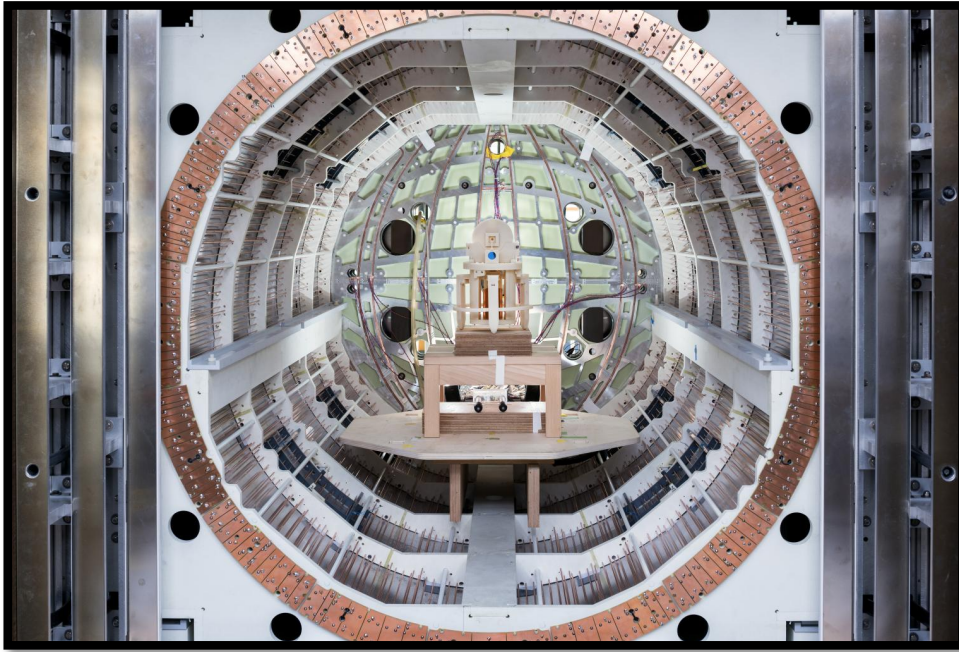


Why Is There Something Rather Than Nothing?



FRIB

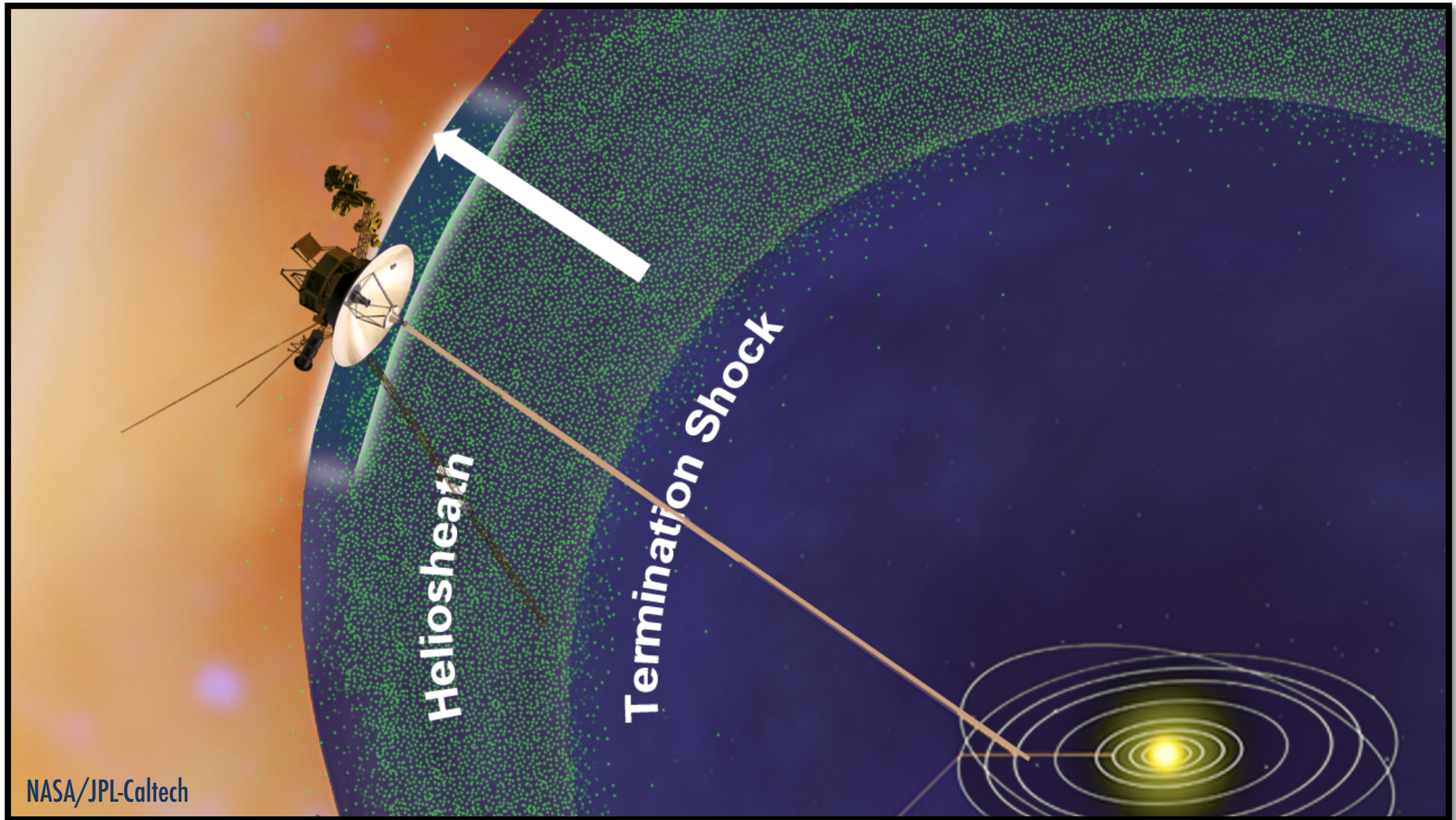


Jaideep Taggart Singh
Michigan State University

PAN 2018

2018-07-26

Voyager has not blown up...yet!

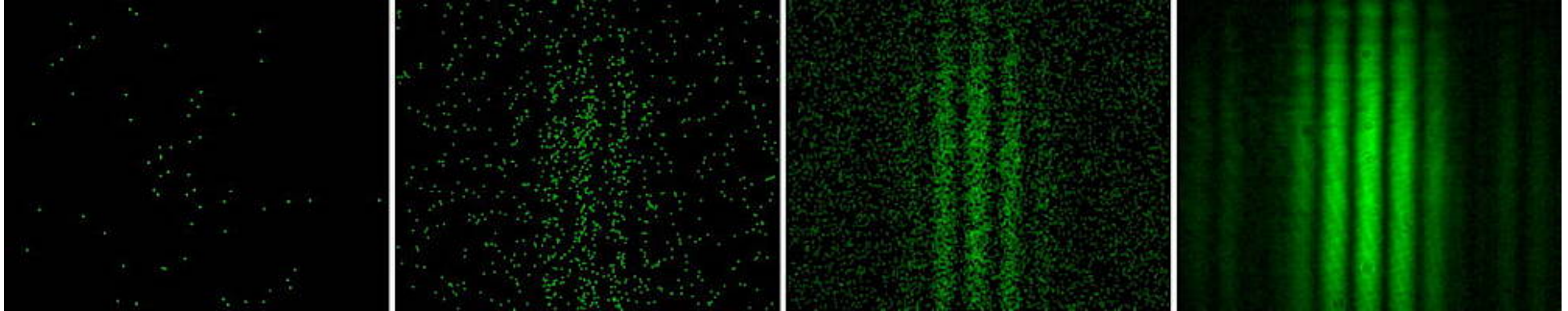


NASA/JPL-Caltech

Everything that you can see is made of Matter.



Light is different, it is particles of Energy called Photons.



dim



BRIGHT



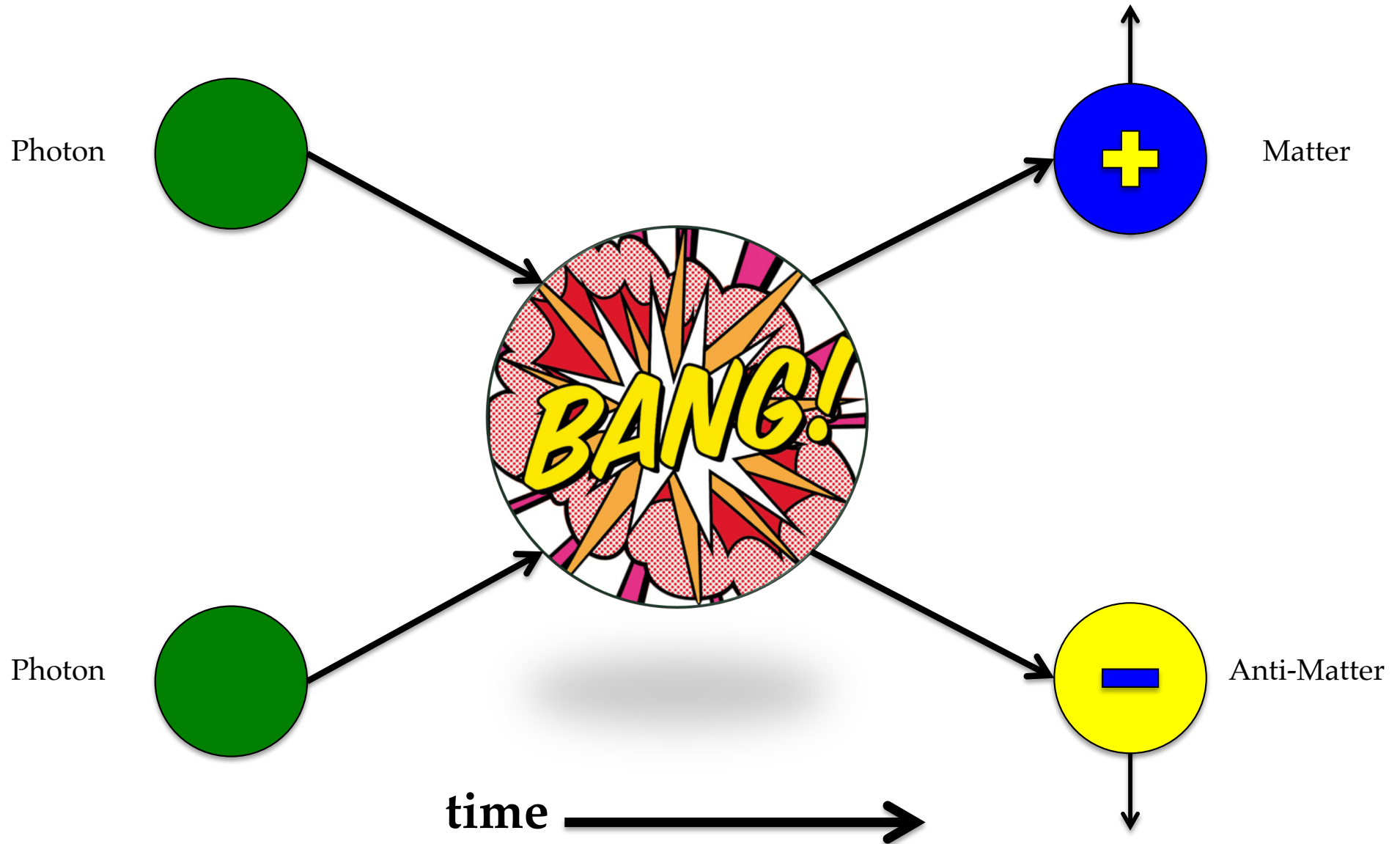
<http://www.sps.ch/artikel/progresses/wave-particle-duality-of-light-for-the-classroom-13/>
<http://www.zacsky.com/blog/2011/03/attitude-dimmer-switch>
<http://www.feit.com>

2018-07-26

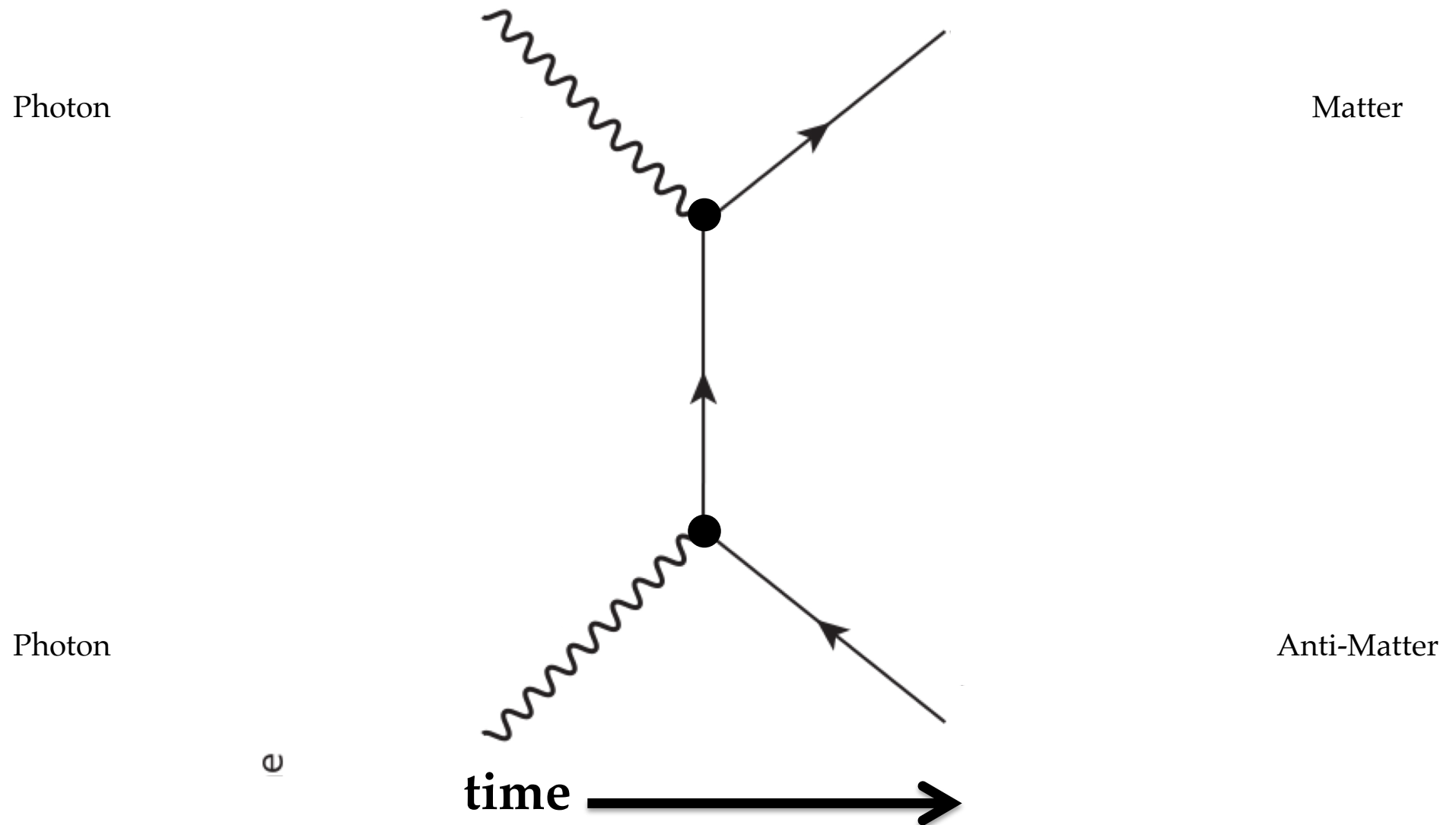
PAN 2018

4

Light can be converted into Matter and Antimatter.



Feynman Diagram of Pair Production

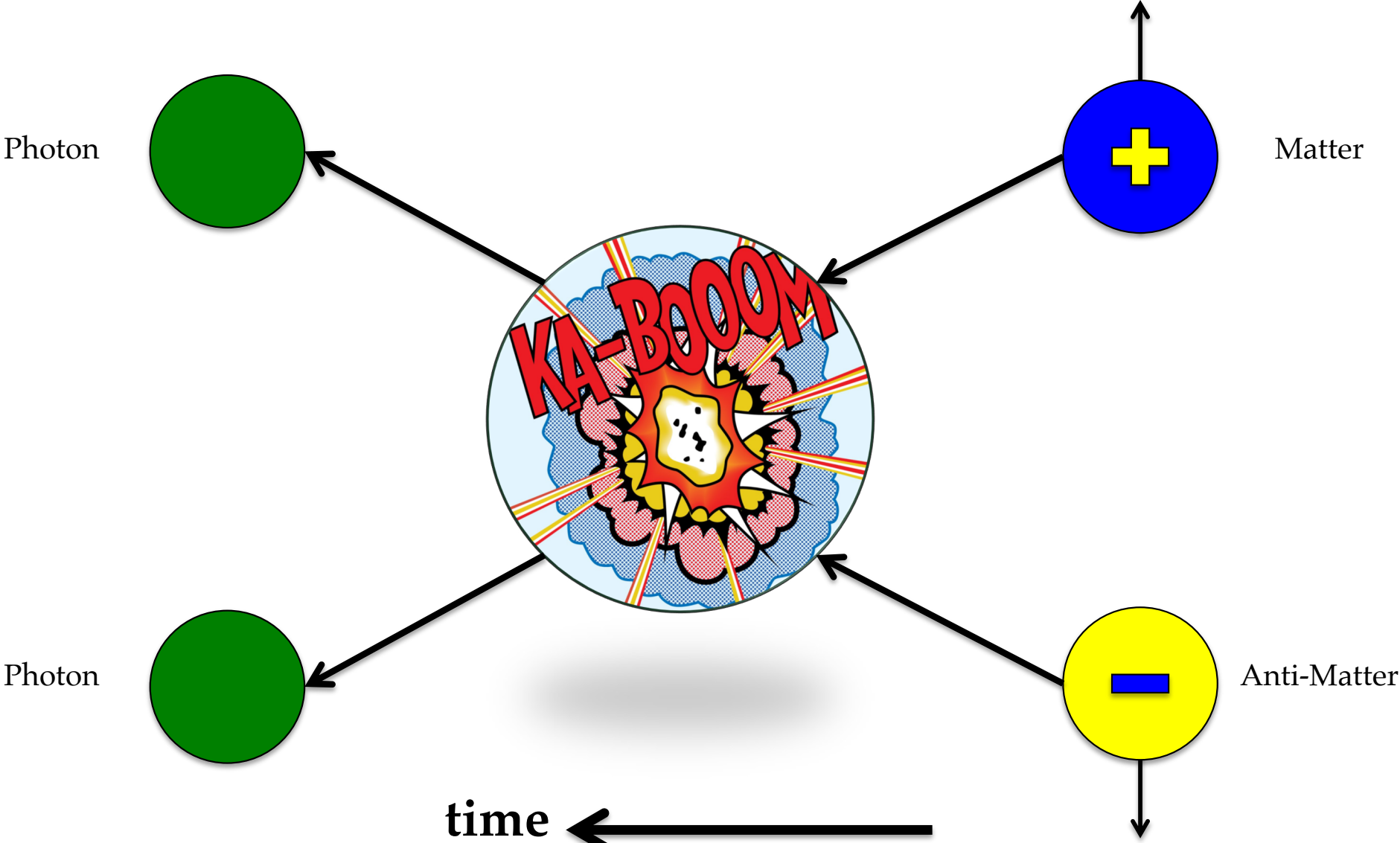


https://commons.wikimedia.org/wiki/File:Mutual_Annihilation_of_a_Positron_Electron_pair.svg

2018-07-26

PAN 2018

Matter and Antimatter disappears into Light.

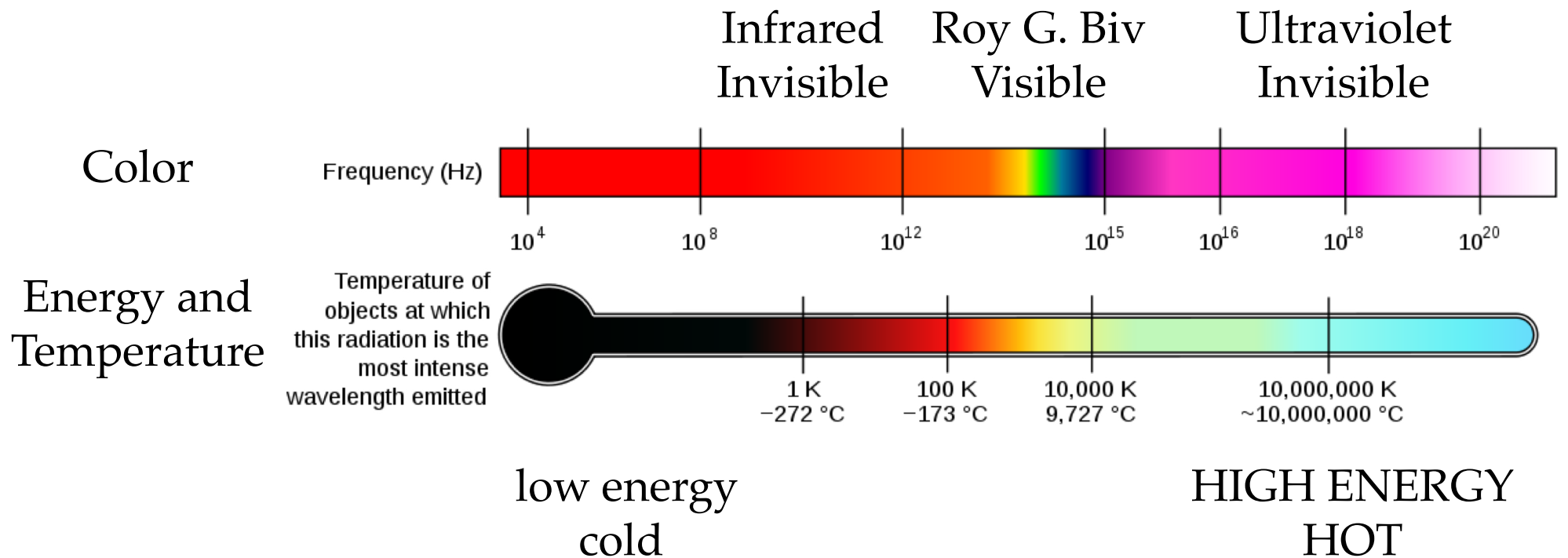


<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

2018-07-26

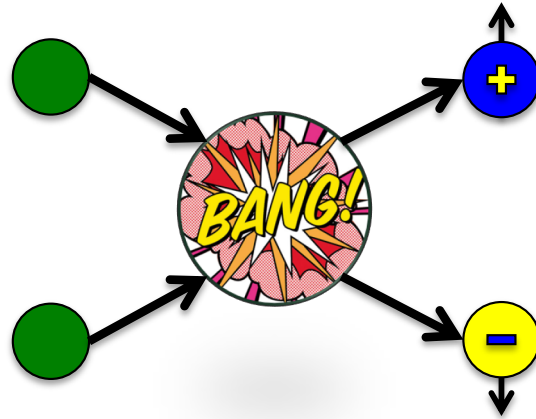
PAN 2018

The Color of the Light tells you the Energy of its Photons.

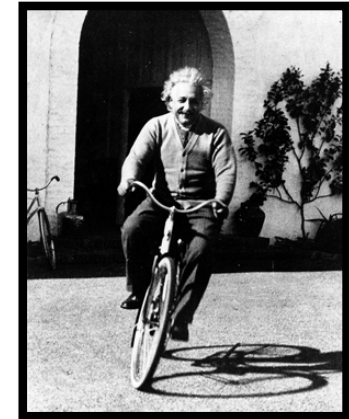
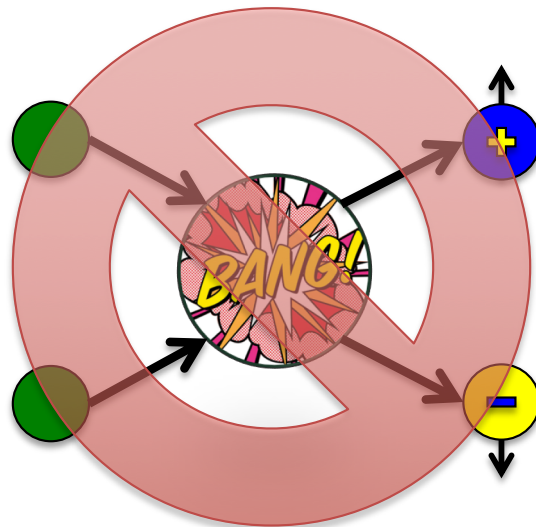


The Light has to have enough Energy to create the mass of the Stuff/Anti-Stuff ($E=mc^2$).

Energy is greater than mass.

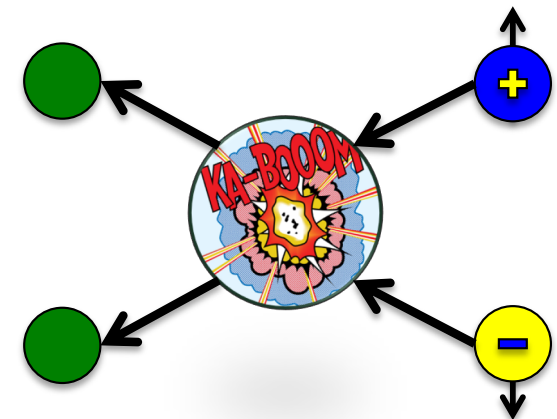


Energy is less than mass.



NASA

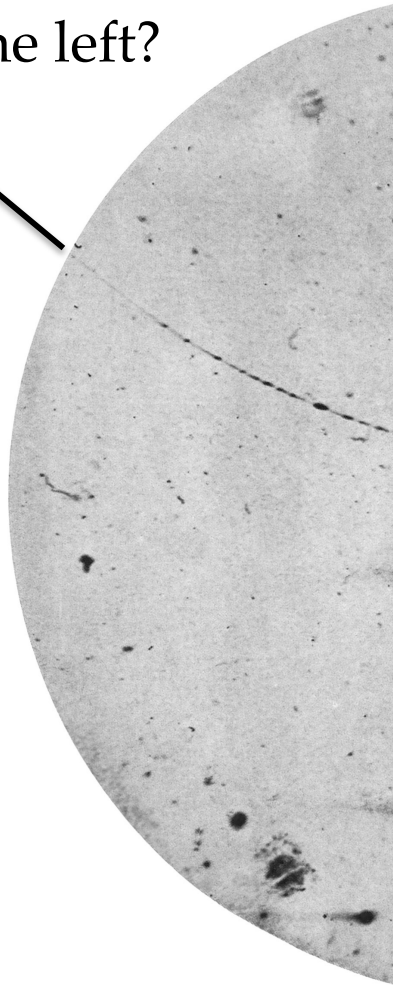
Light can be any Color, so this is always okay. Color of Light can tell you mass of Stuff / Anti-Stuff.



Does Anti-Matter Even Exist?

electron to the left?

e^-



anti-electron
to the right?

e^+



Carl Anderson
Nobel Prize 1936

<http://dx.doi.org/10.1103/PhysRev.43.491>

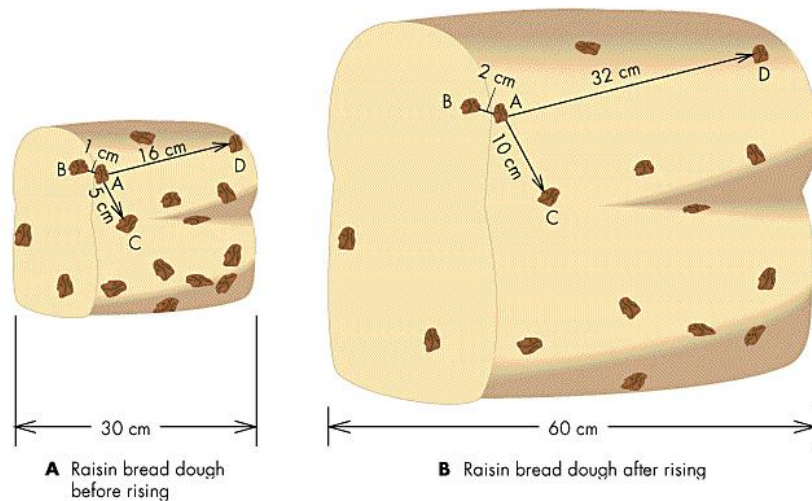
Nobel Foundation

2018-07-26

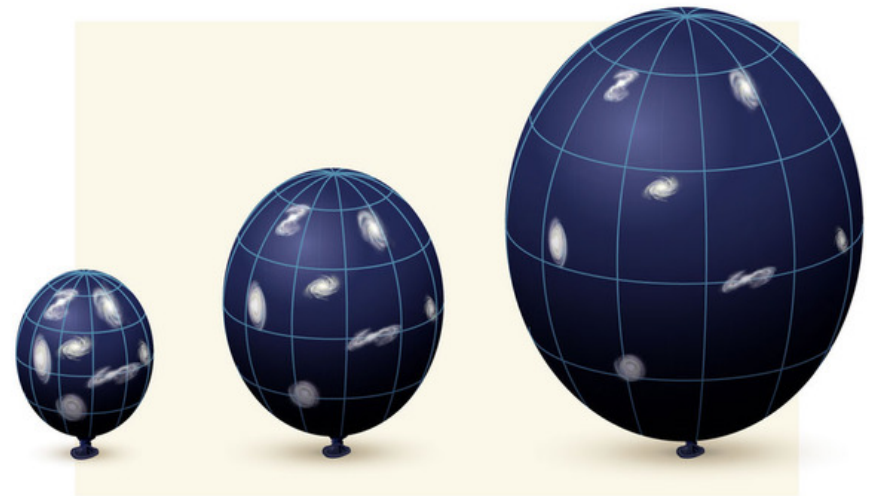
PAN 2018

10

The Universe is expanding.



The Raisin Bread Analogy

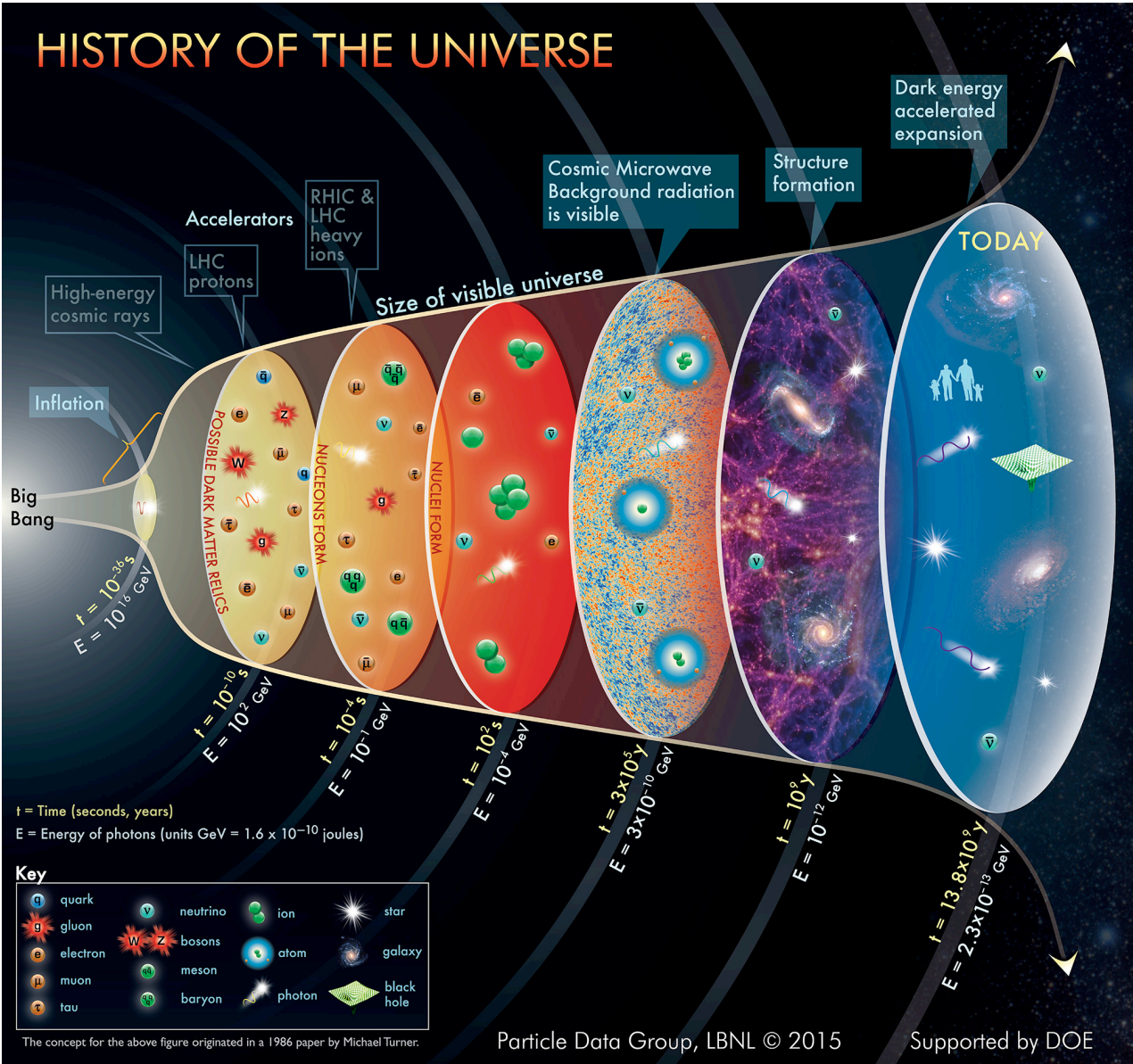


The Balloon Analogy

<http://www.mhhe.com/physsci/astronomy/fix/student/chapter23/23f26.html>
Eugenio Bianchi, Carlo Rovelli & Rocky Kolb

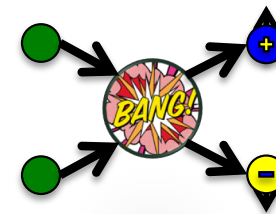
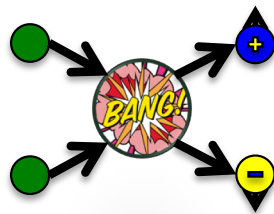
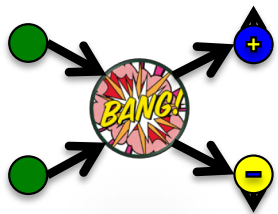
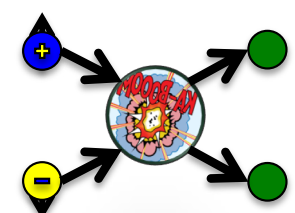
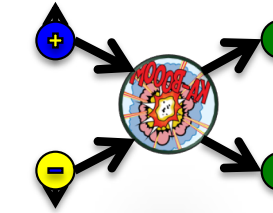
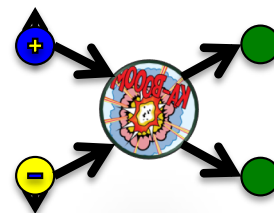
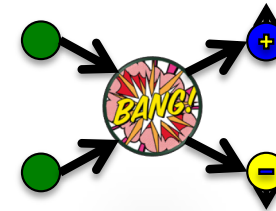
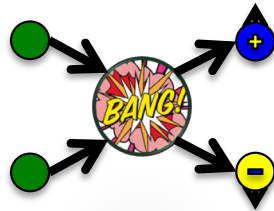
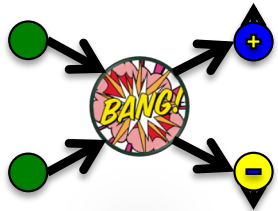
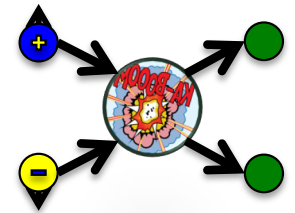
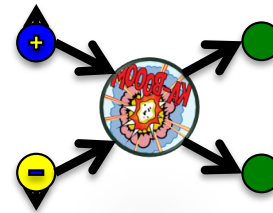
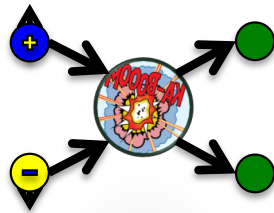
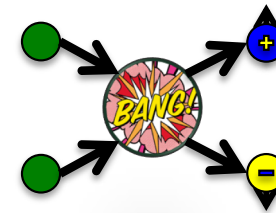
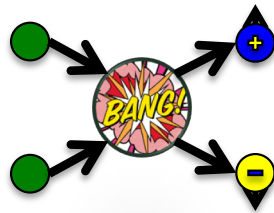
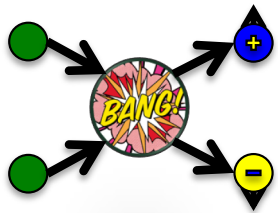
Big Bang...expanding Universe

**HOT &
DENSE**



**cold &
dilute**

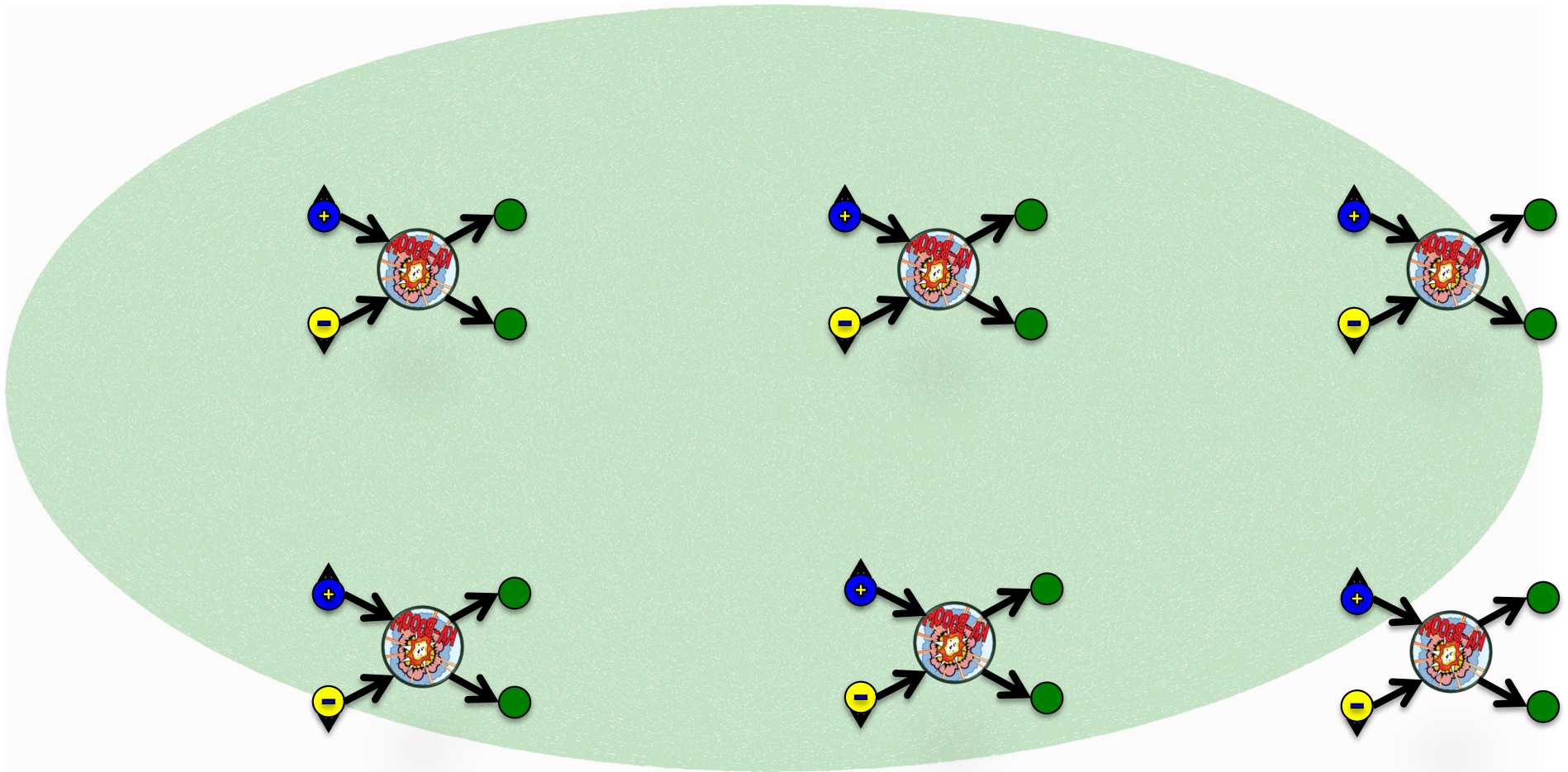
All the things happening all the time everywhere



<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

<http://www.bing-bang-mag.com/Le-premier-Comic-street-dijonnais.html>

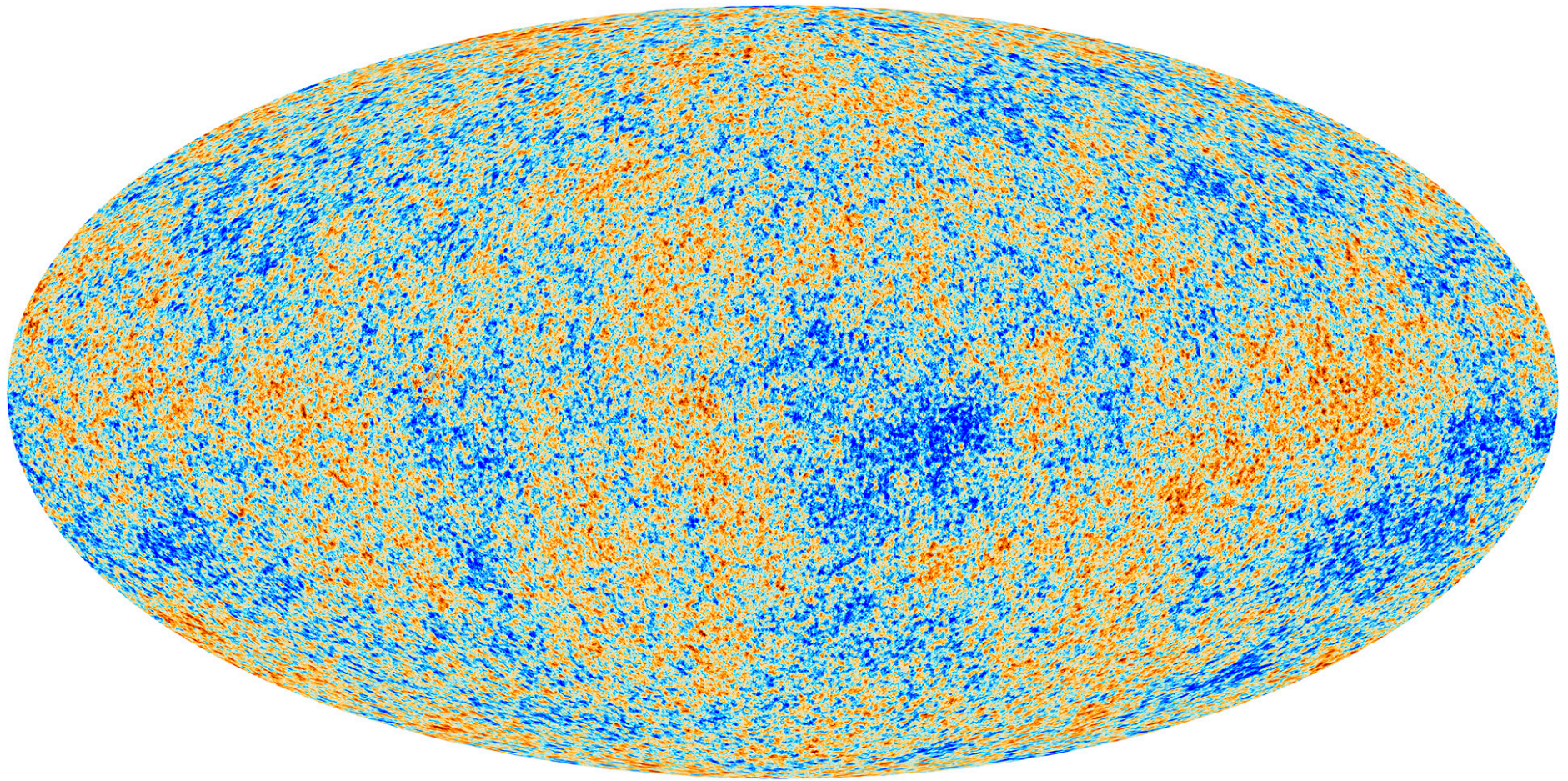
Expansion means cooling: 2.73 K everywhere



<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

<http://www.particleadventure.org/history-universe.html>

The Leftover Light: “Cosmic Microwave Background” (Baby Picture of the Universe)



Planck 2013 http://www.esa.int/spaceinimages/Images/2013/03/Planck_CMB

How much matter, anti-matter, and light is there?

Average size of “spots”



Blah blah blah some complicated math...

$$\frac{[\text{amount of MATTER}] - [\text{amount of anti-matter}]}{[\text{amount of Light}]}$$



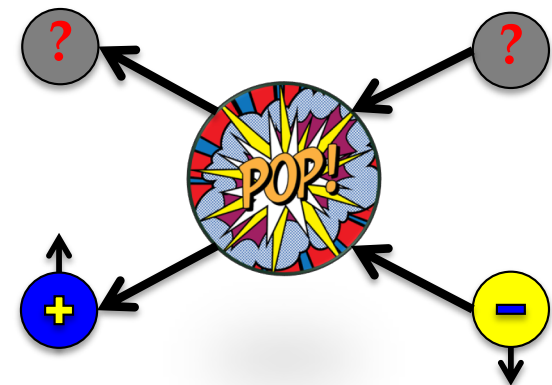
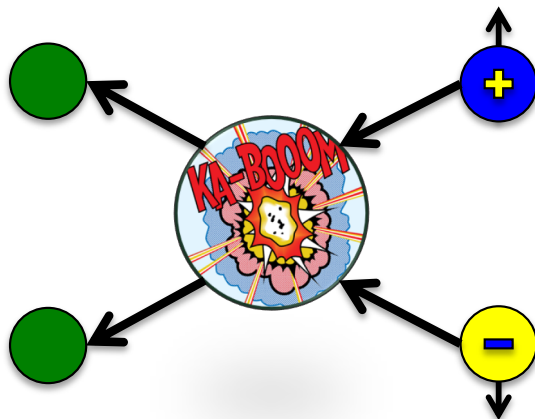
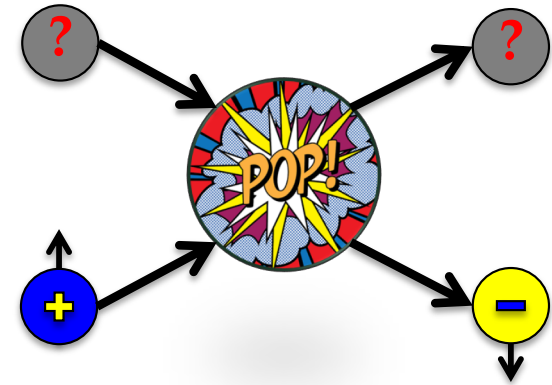
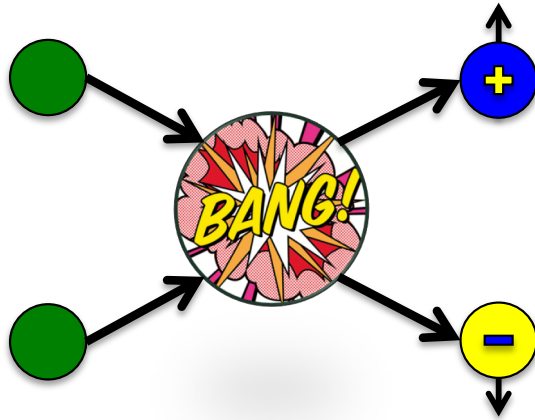
If > 0 , then more MATTER than antimatter

If < 0 , then more antimatter than matter

If > 1 , then more MATTER / antimatter than Light

If < 1 , then more Light than MATTER / antimatter

Why? Because science...

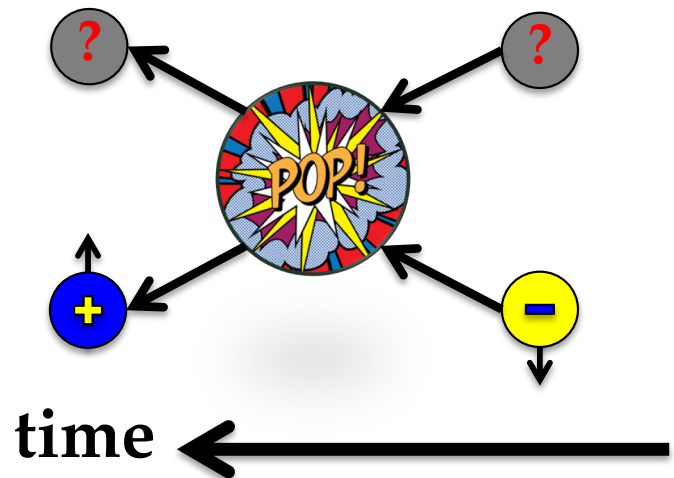
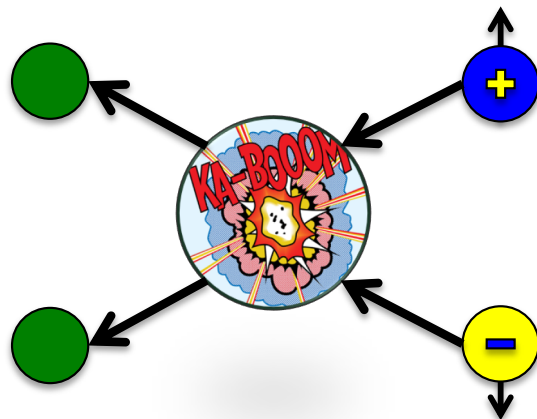
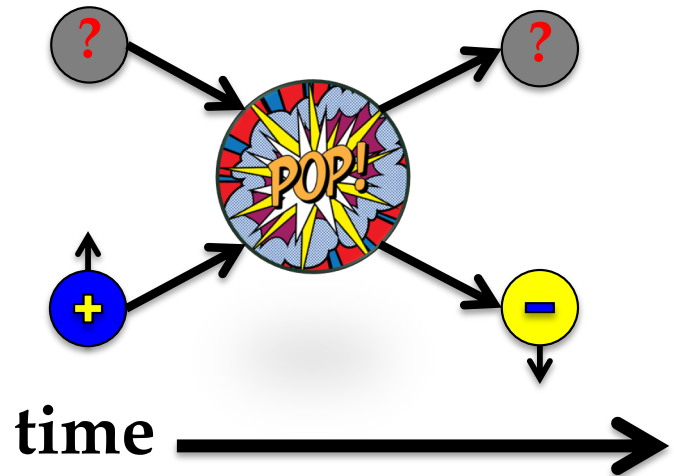
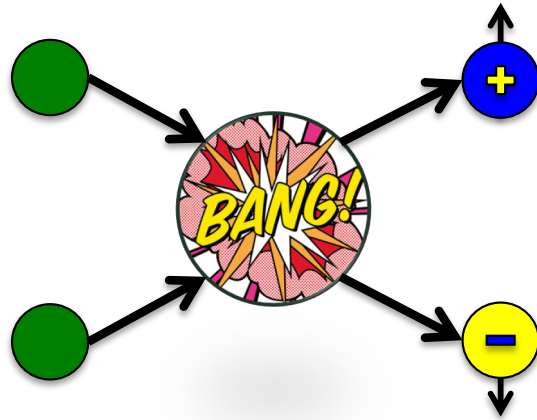


<http://www.bing-bang-mag.com/Le-premier-Comic-street-dijonnais.htm>

<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

<https://www.poparta.com/blog/the-art-is-now-pop-art-movement/>

“Time-Reversal Symmetry Violation”

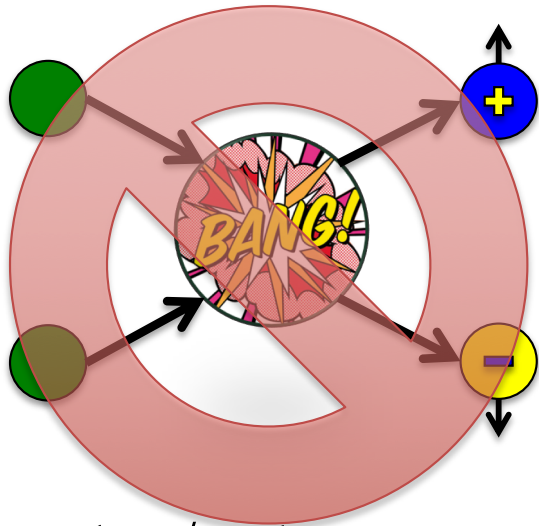


<http://www.bing-bang-mag.com/Le-premier-Comic-street-dijonnais.htm>

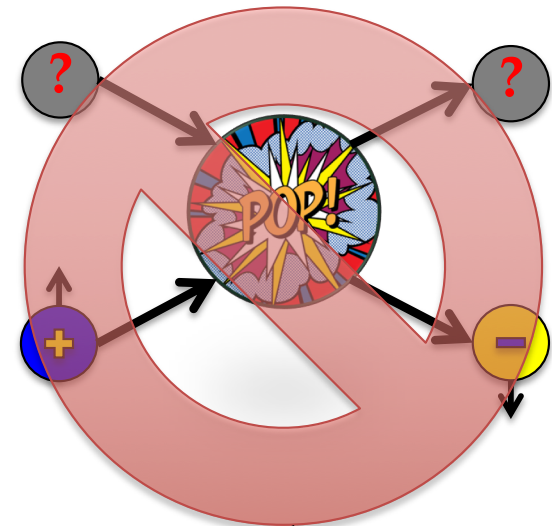
<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

<https://www.poparta.com/blog/the-art-is-now-pop-art-movement/>

You're left with only Light and Matter.

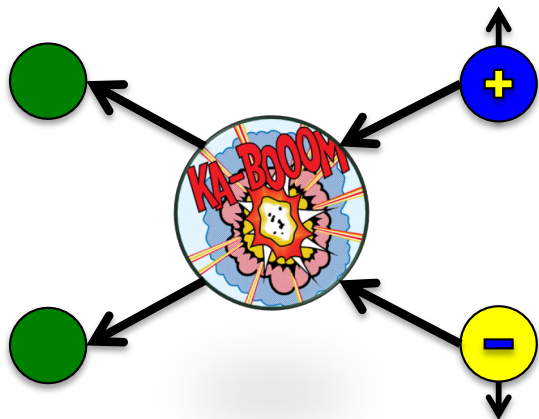


expanding/cooling Universe

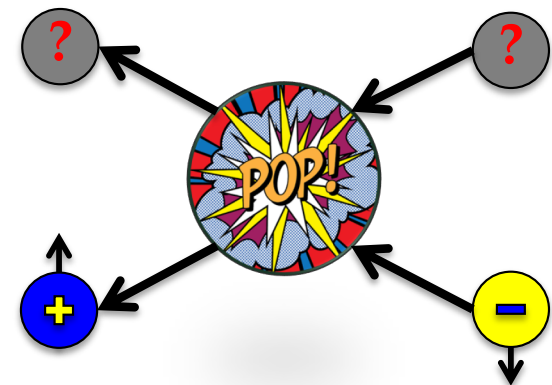


T-violation!

Light



Matter



<http://www.bing-bang-mag.com/Le-premier-Comic-street-dijonnais.htm>

<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

<https://www.poparta.com/blog/the-art-is-now-pop-art-movement/>

How to find T-violation? What kind of clock?



Measure the speed clockwise.



Measure the speed counter-clockwise.

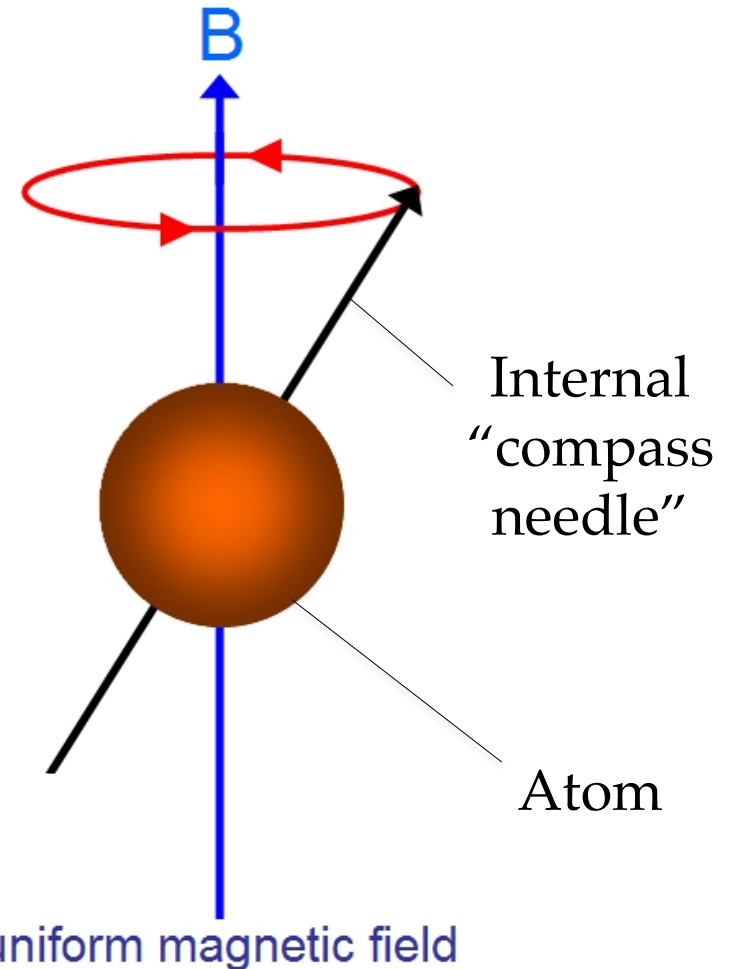
Are they different?

By JuergenG, modified by Rainer Z - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=5512303>

Atomic Clocks!



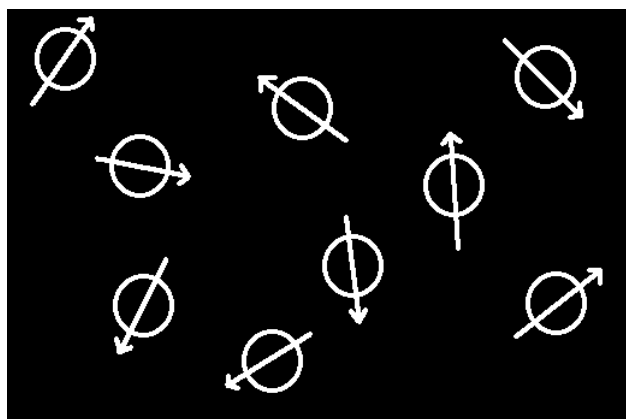
Friction added on purpose
Needle aligns to magnetic field



No friction! Needle "precesses"
Around the magnetic (B) field

CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=342457>
http://cronodon.com/Atomic/quantum_angular_momentum.html

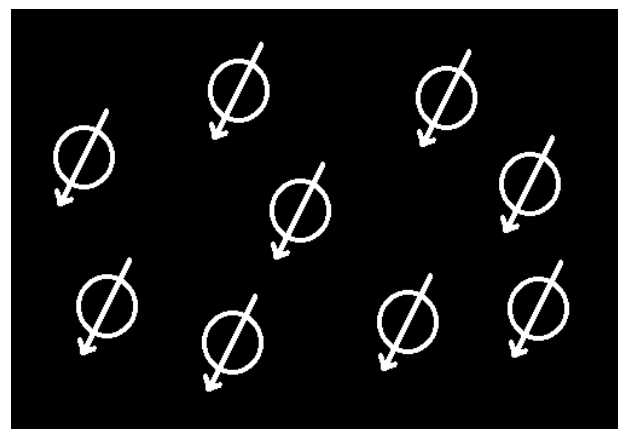
Atoms have to be magnetized first!



Unmagnetized atoms

Random directions

Clocks are unsynchronized



Magnetized atoms

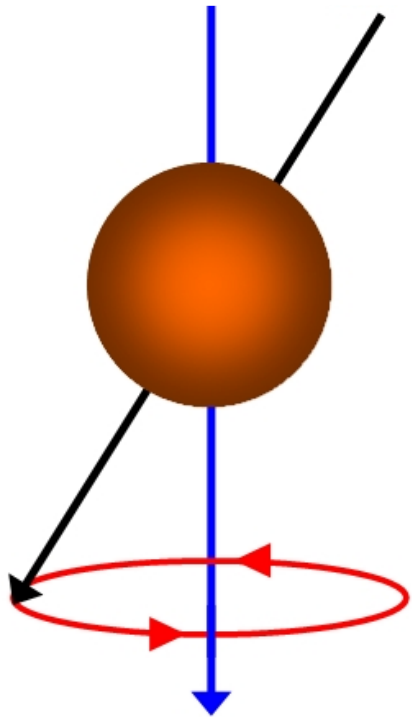
Aligned directions

Clocks are synchronized

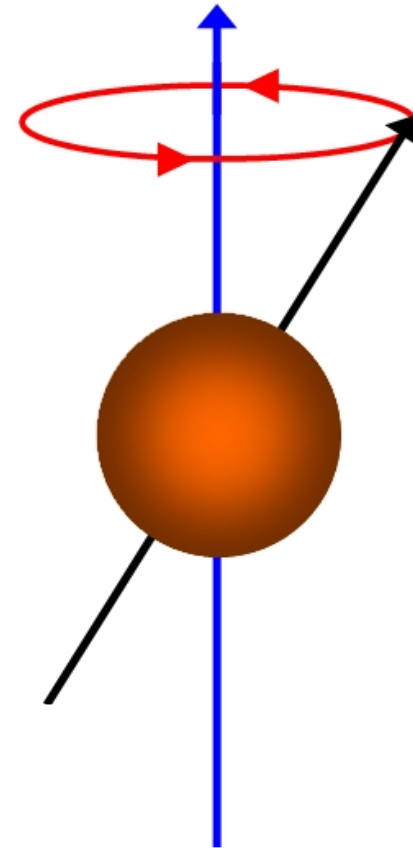
<http://uhavax.hartford.edu/chemistry/pdb/nmr/theory1.htm>

Atomic clock speed & direction depends on the magnetic field!

Need a very stable and uniform magnetic field!



Magnetic field down
Clockwise



Magnetic field up
Counter-Clockwise

CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=342457>

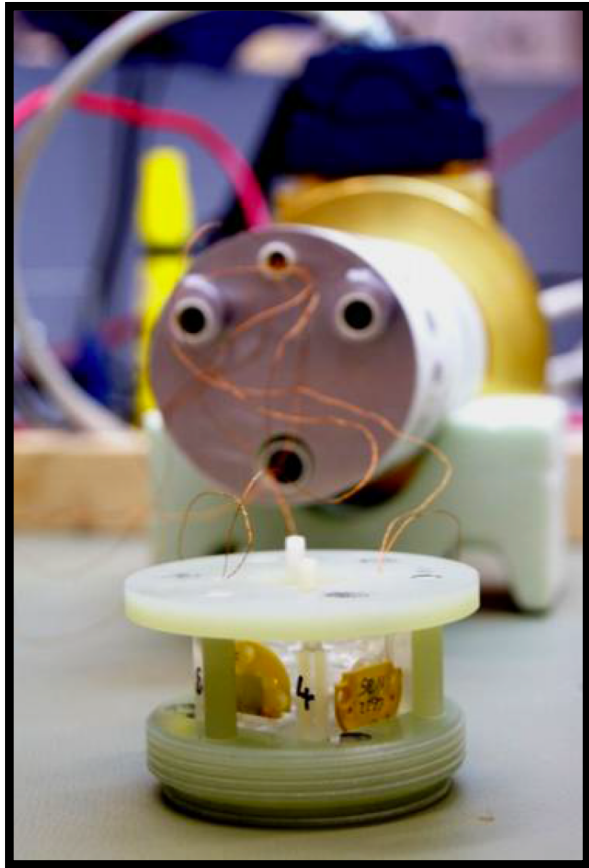
Magnetic field sizes

Object	Strength of Magnetic Field
MRI Machine	60000
Computer hard drive	40000
Loudspeaker	20000
Sun spots	3000
Refrigerator magnet	100
Earth's magnetic field	1
Cassette tape	0.4
Magnetic shielded room	0.00002
Human Brain	0.0000002
"SQUID" magnetometer	0.00000000002

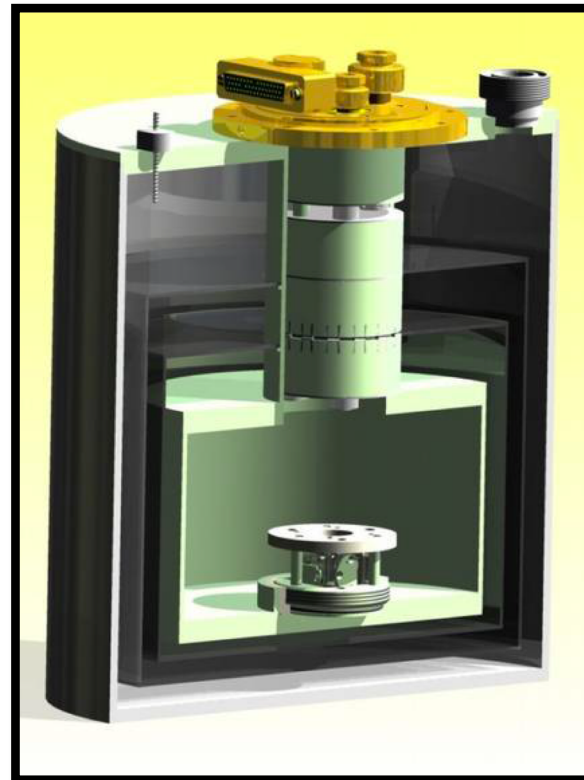
“Magic room” in Munich, Germany



“SQUID” Magnetometers: Detectors



Sensors

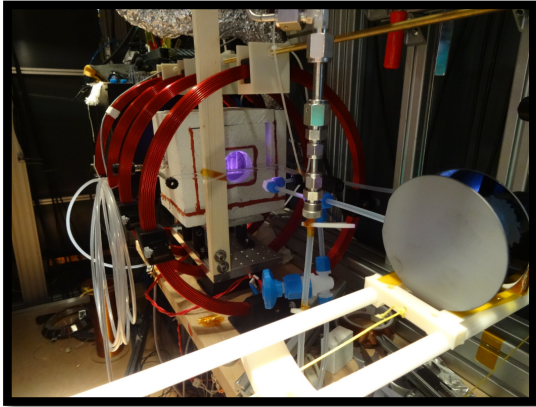


Operate at -452 °F

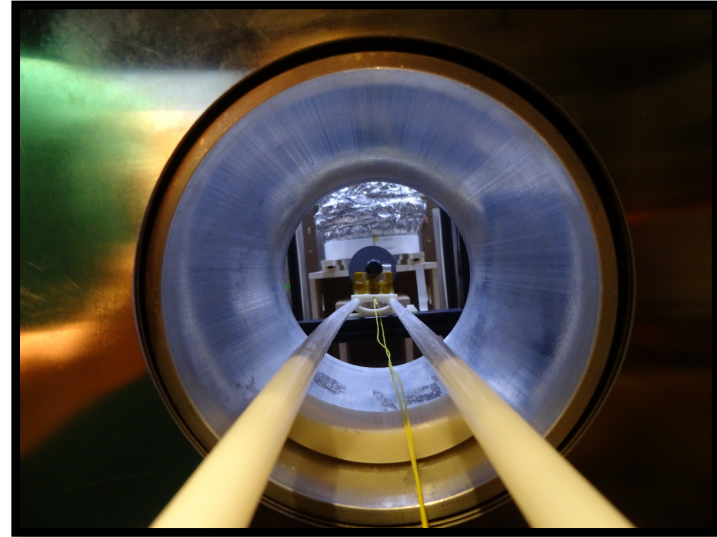
Nonmagnetic
wooden components



Real Atomic Clocks



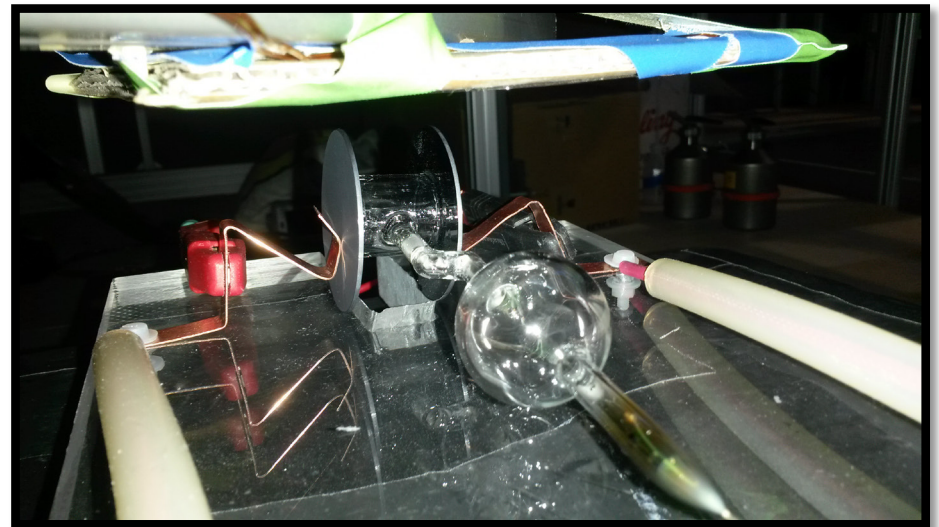
Non-human
Transport



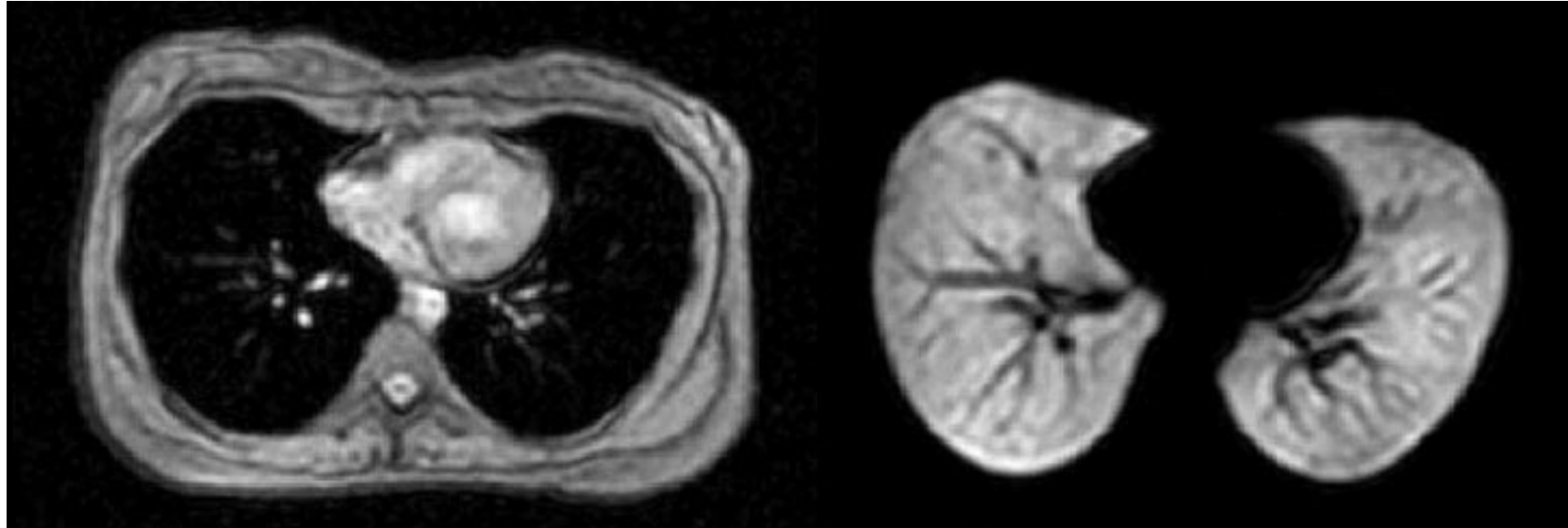
Atomic clocks are Helium & Xenon gas inside of a glass container.

Lasers magnetize the gas outside the room.

Magnetized glass container
under detector inside room



Detailed Images Of Lung Structure

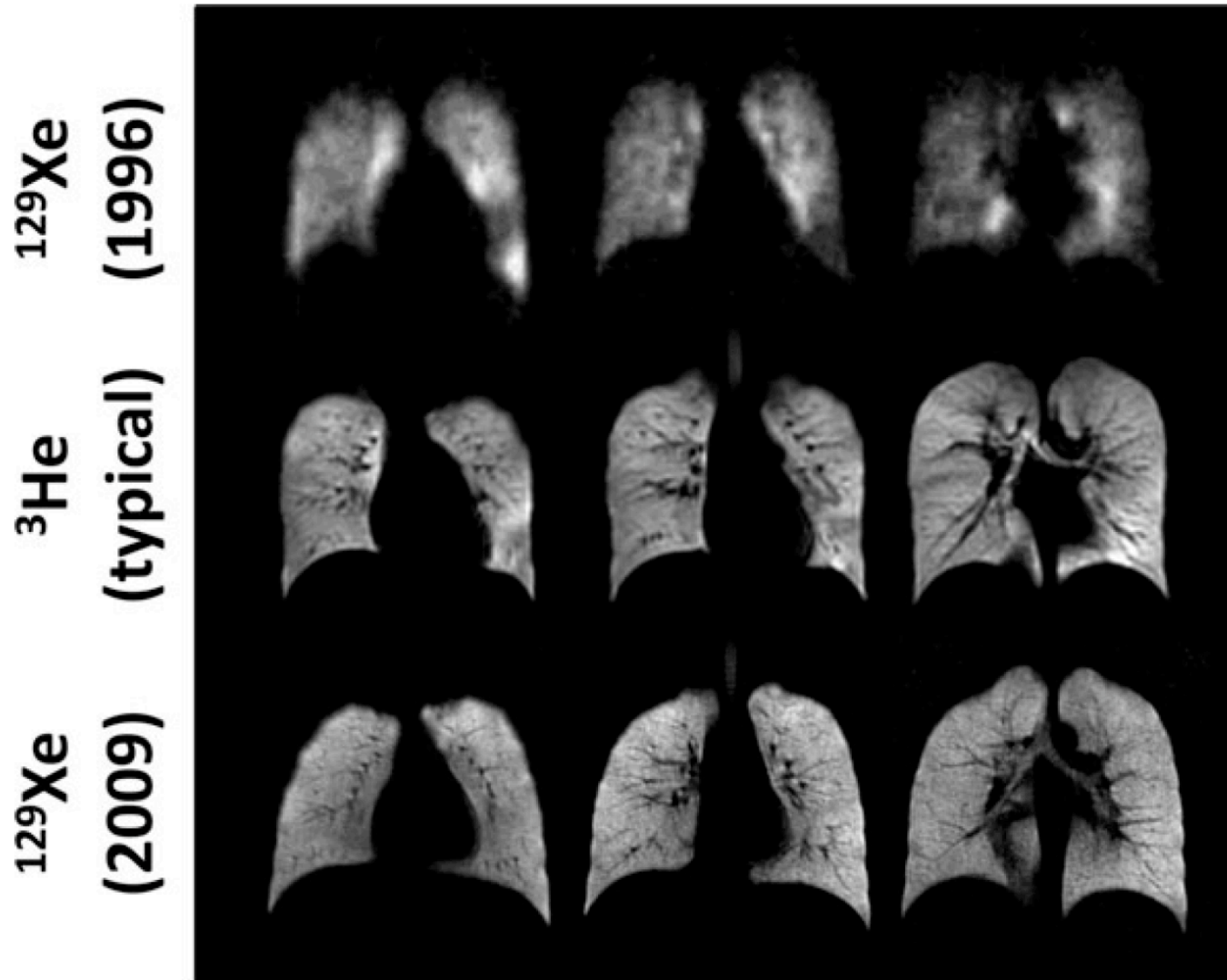


Conventional Axial ^1H MRI

Axial ^3He MRI

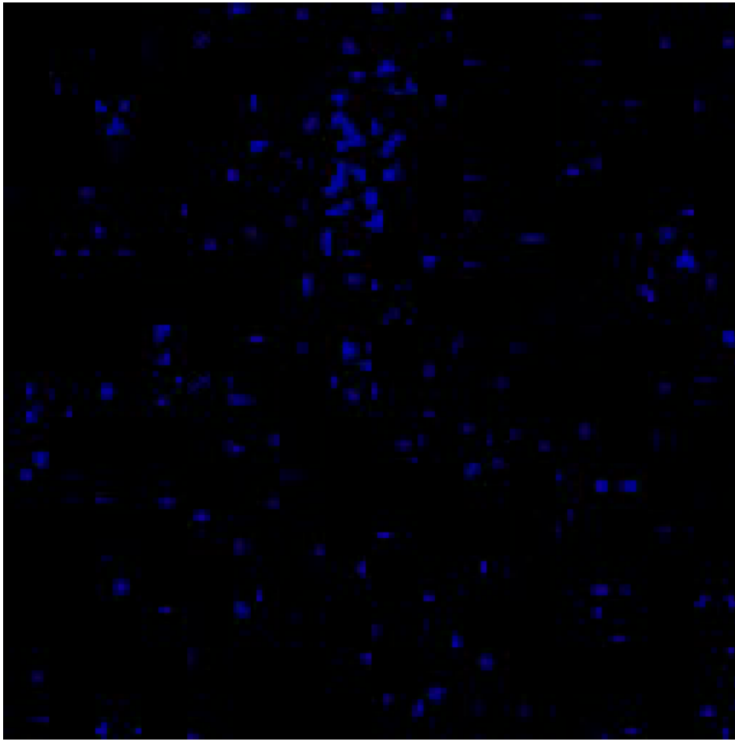
EE de Lange EE et al. Chest 130:1055-1062 (2006).

Big Improvements In Imaging

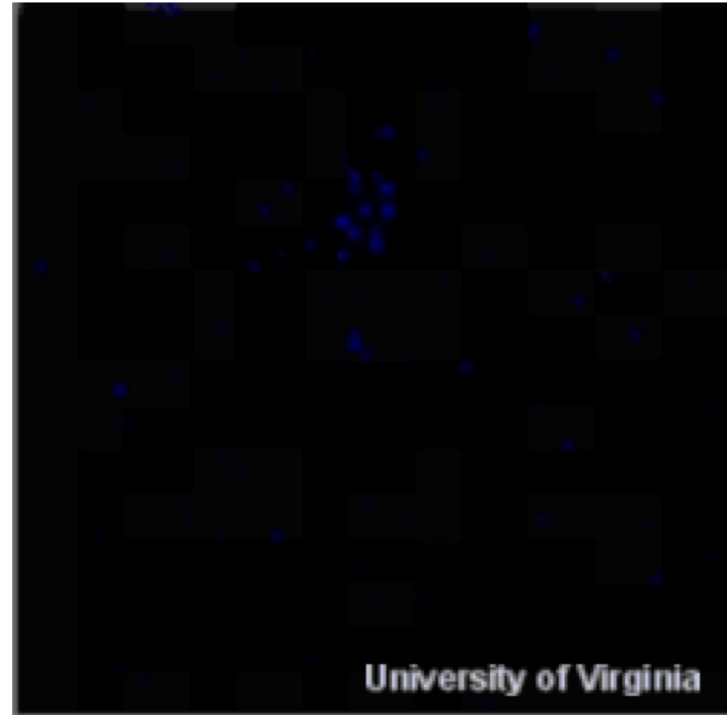


Mugler & Altes, JMRI 37 313 (2013)

Dynamic Visualizations



Healthy

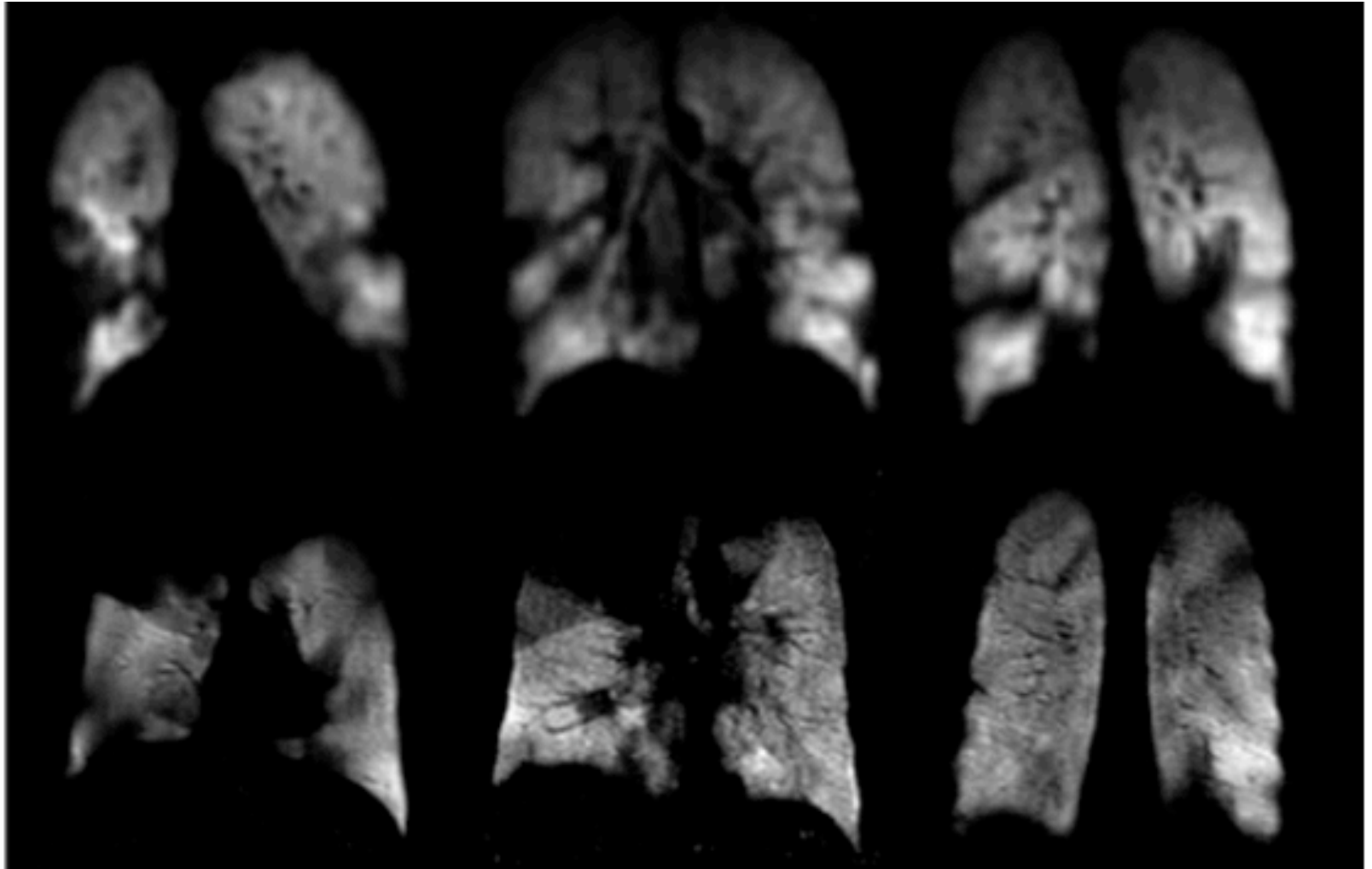


Unhealthy

Problems Areas Clearly Visible

Asthma

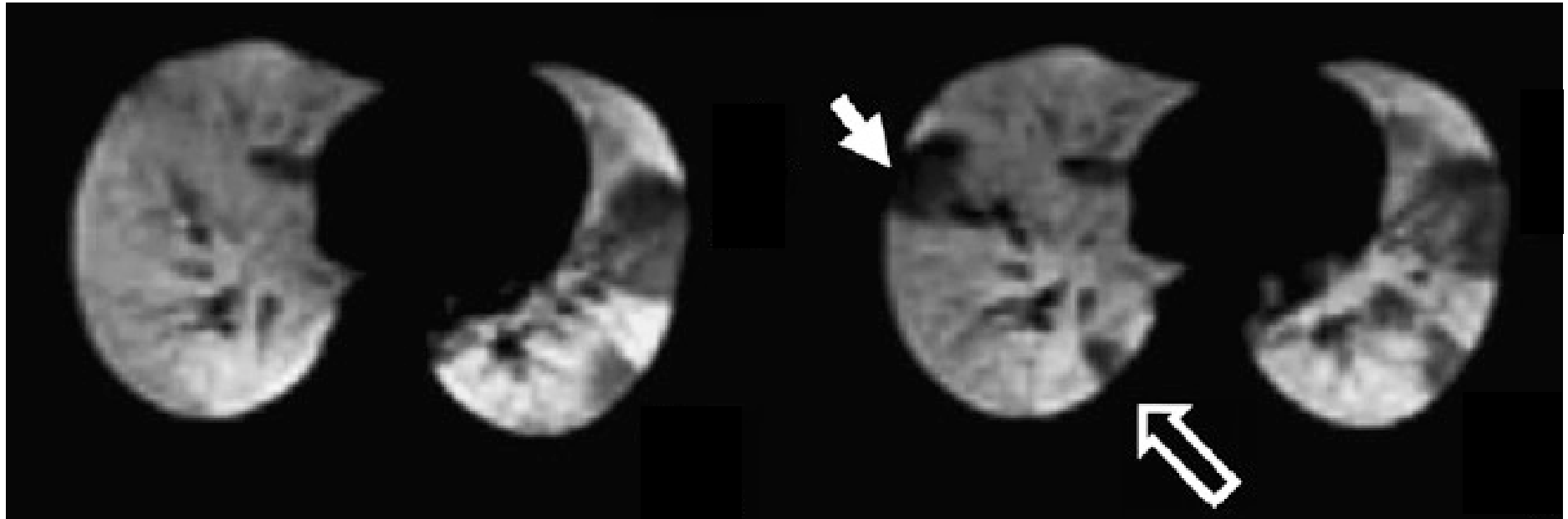
COPD



Mugler & Altes, JMRI 37 313 (2013)

How Sensitive Is the Subject?

Mild-intermittent asthmatic:



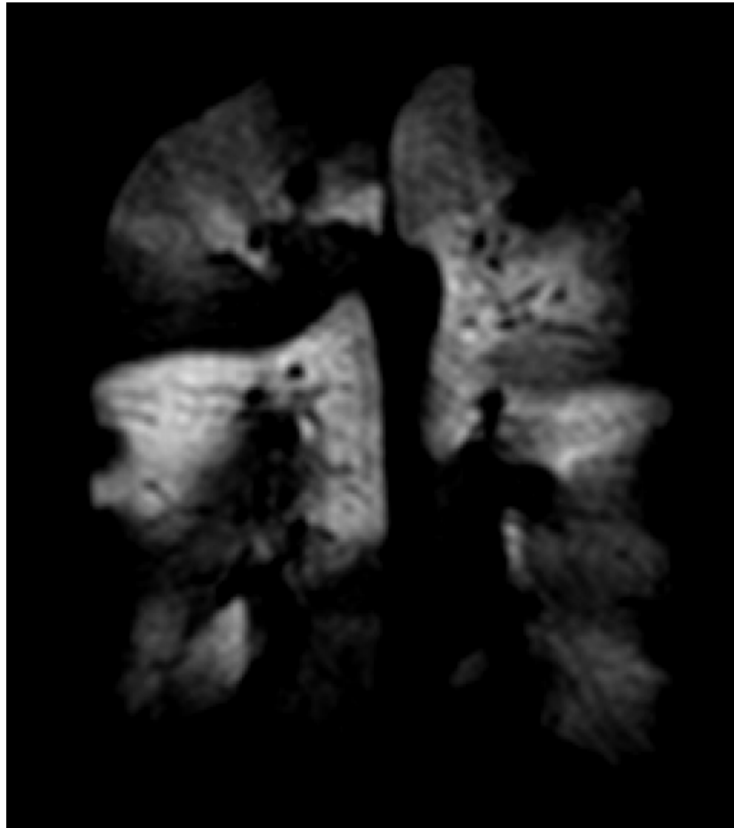
Pre Methacholine

Post Methacholine

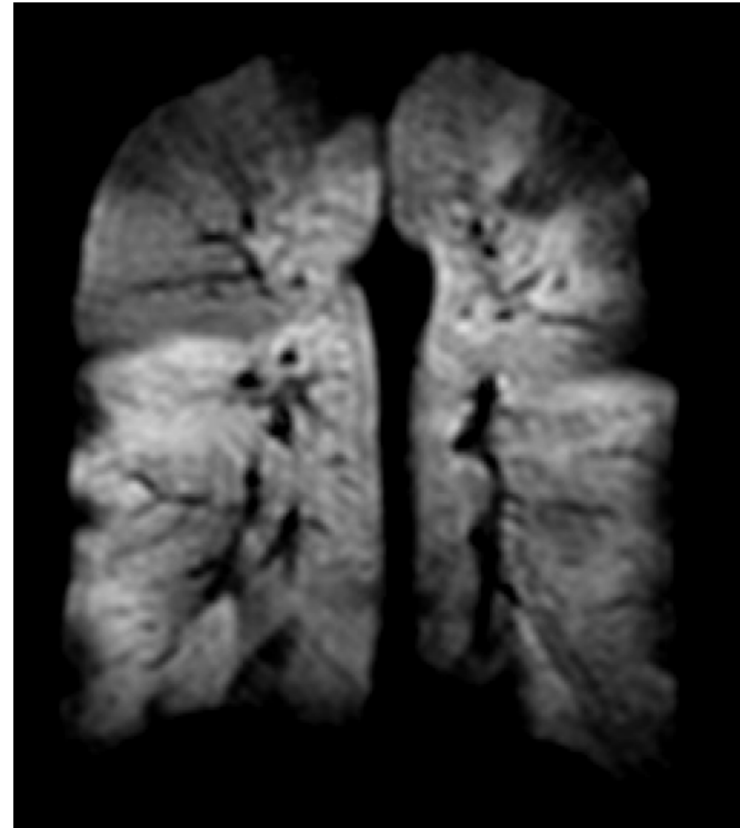
EE de Lange et al. *J. Allergy Clin Immunol* 119:1072-1078 (2007).

How Effective is the Treatment?

Severe-persistent asthmatic:



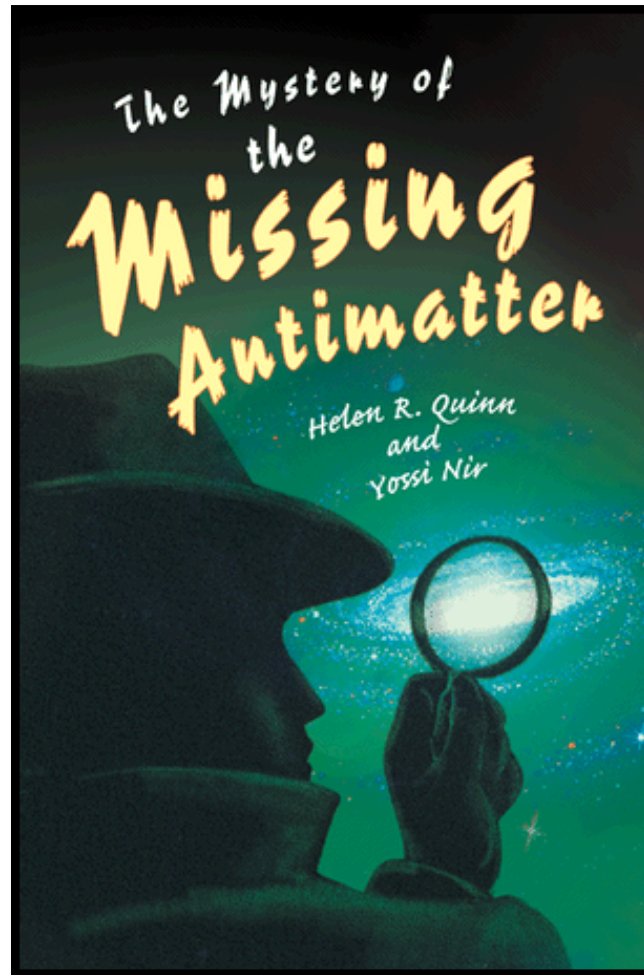
Pre Albuterol



Post Albuterol

TA Altes et al. JMRI 2001;13:378-84

For more information...



The Mystery of the Missing Antimatter
by: Helen R. Quinn and Yossi Nir
Princeton University Press (2014)

Noether's Theorem

If the laws of physics are
symmetric with respect to a
[blah blah blah] transformation,

then...

...wait for it...



<https://commons.wikimedia.org/wiki/File:Noether.jpg>

Noether's Theorem

If the laws of physics are
symmetric with respect to a
[blah blah blah] transformation,

then...

...wait for it...

[something something]
must be conserved!



<https://commons.wikimedia.org/wiki/File:Noether.jpg>

Noether's Theorem

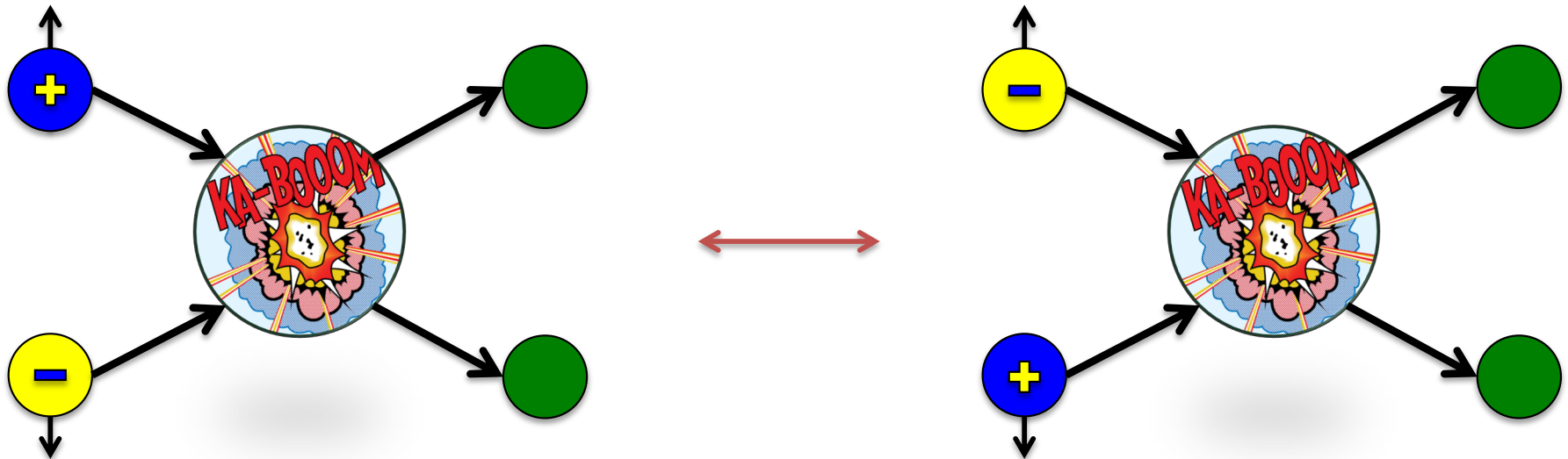


<https://commons.wikimedia.org/wiki/File:Noether.jpg>

Symmetry Transformation	Conserved Quantity
Spatial translation	?
Rotational translation	?
?	Energy
?	Charge
Change in spacetime coordinate system	?

C: Charge Conjugation

Replace particle with antiparticle



P: Parity (Spatial Inversion)

*Mirror
reflection*

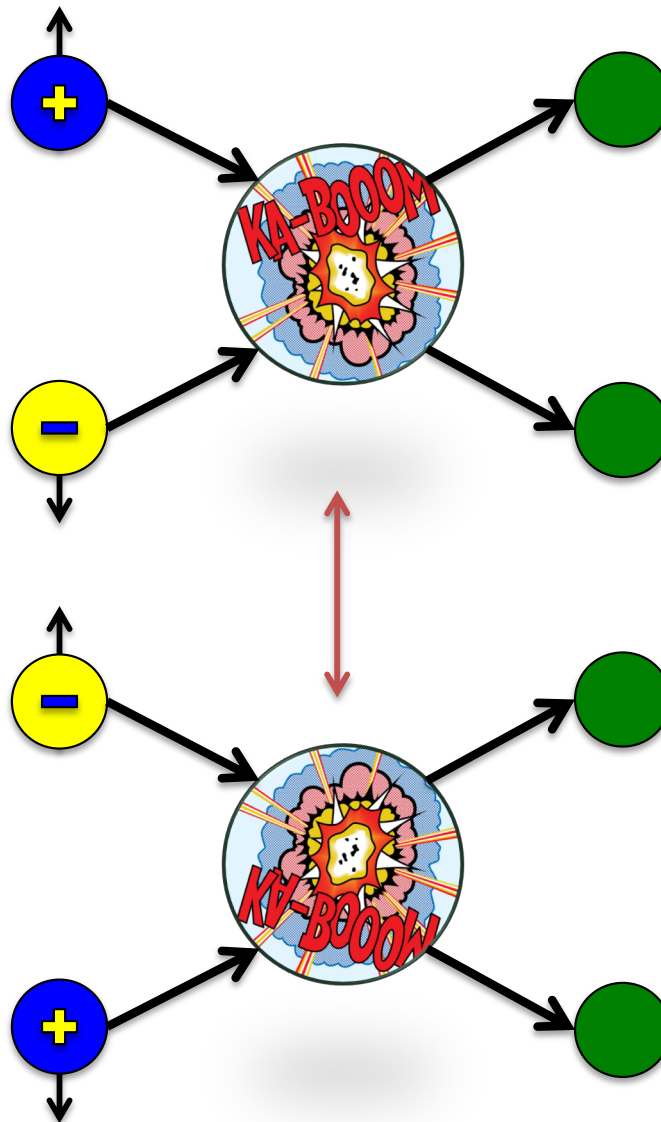
+

*180°
rotation*

+x to -x

+y to -y

+z to -z



<http://strangesounds.org/2013/08/mysterious-booms-in-the-usa-new-york-california-alaska-mississippi-utah-michigan.html>

T: Time Reversal

Reverse the arrow of time, $+t$ to $-t$

