

*There is a lot more in the Universe  
than what meets the eye*

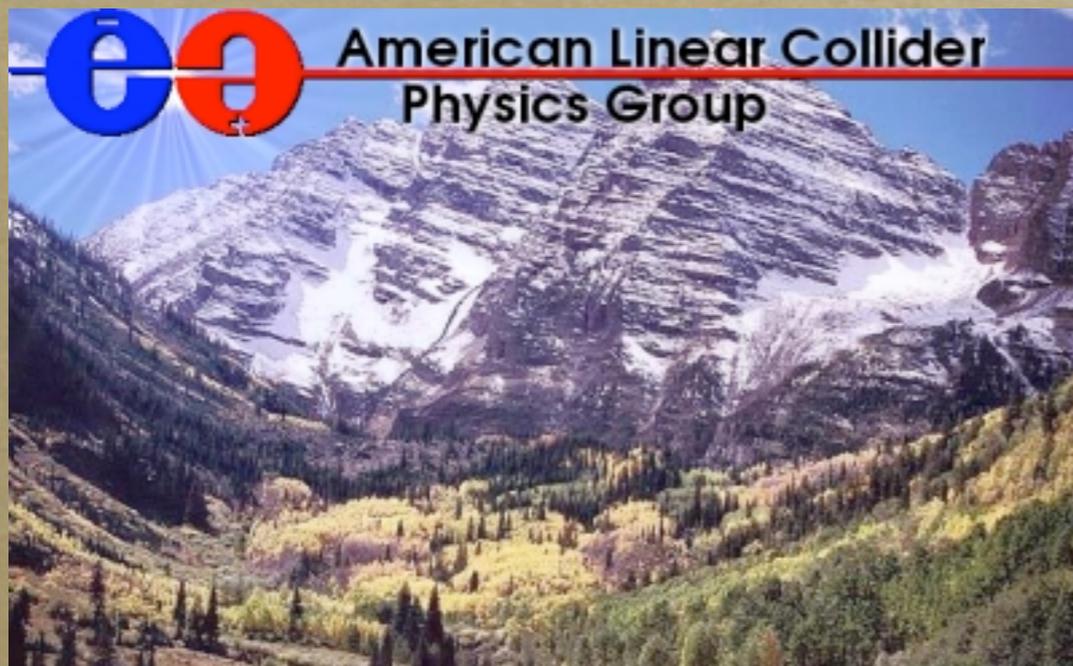


# *Seeing the invisibles*

*–Challenge to 21st century particle physics and cosmology–*

*Hitoshi Murayama (Berkeley)*

*Snowmass, August 22, 2005*



# The Invisibles

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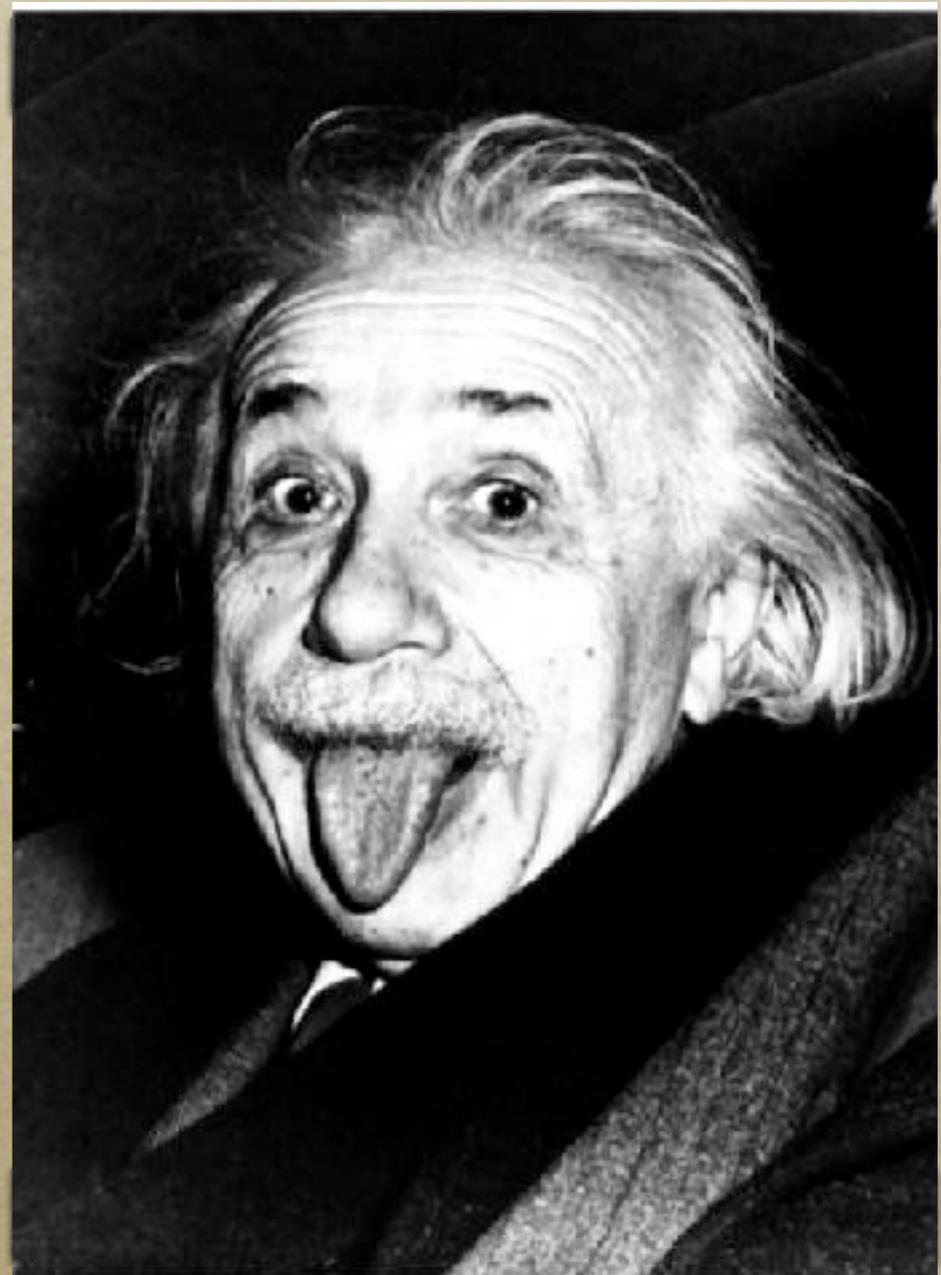
- *The Invisibles in the Universe*
  - *Dark Field*
  - *Dark Matter*
  - *Dark Energy*
- *They all have something to do with energy*

$$E=mc^2$$

- *E* stands for *energy*
- *m* stands for *mass*
- *c* stands for *speed of light*

*It says mass and energy  
are the same*

- *We understand energy  
quite well*
- *We actually don't  
understand mass*



# Outline

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- *Energy* –Kinetic and Potential–
- *Mass* –Newton to Einstein–
- *What is the Mass Energy?*
- *Mass Deficit in the Universe*
- *(Dark Energy ripping the Universe)*

# Energy

– *Kinetic and Potential* –

# Energy

*Energy is the capability to do something*

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# THE INCREDIBLES

NOW PLAYING



# Two kinds of energies

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- *Something moving fast*  
*“kinetic energy”*
- *Something raised high*  
*“potential energy”*
- *All energies observed in the laboratory are of either kind*

# Kinetic energy



IN THEATERS 11.5.04



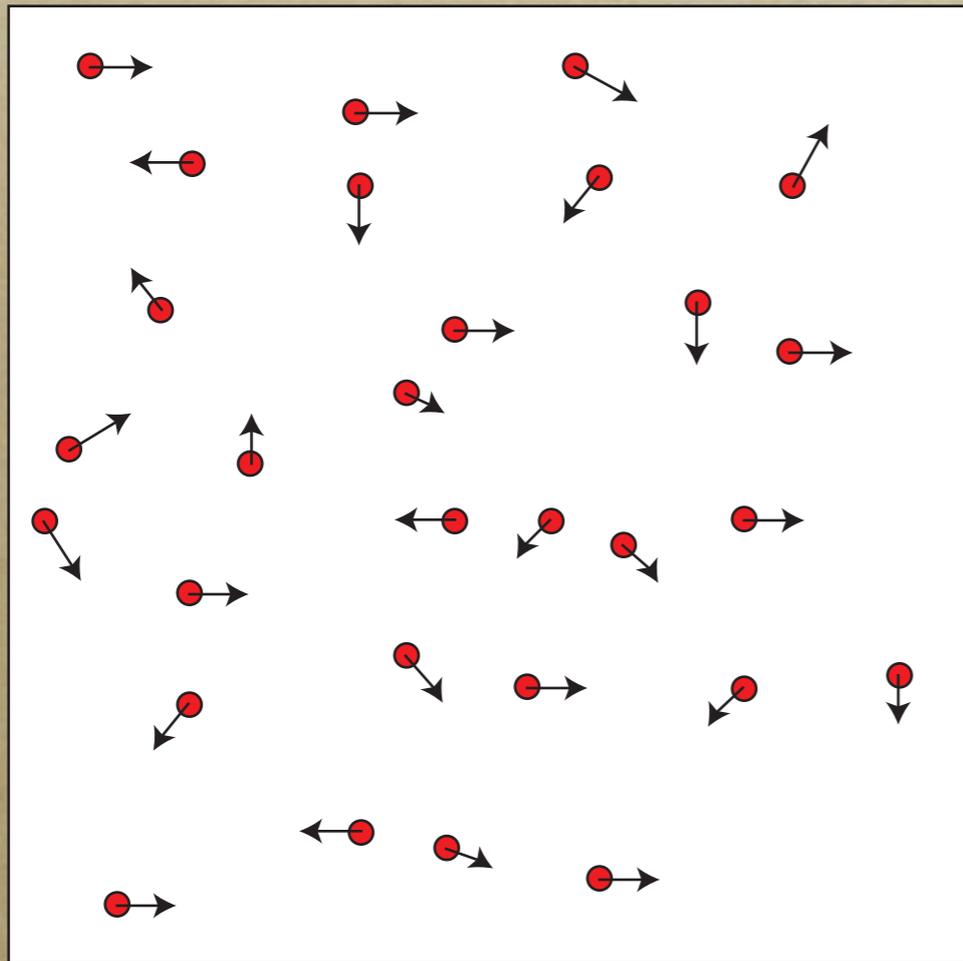
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# Thermal Energy

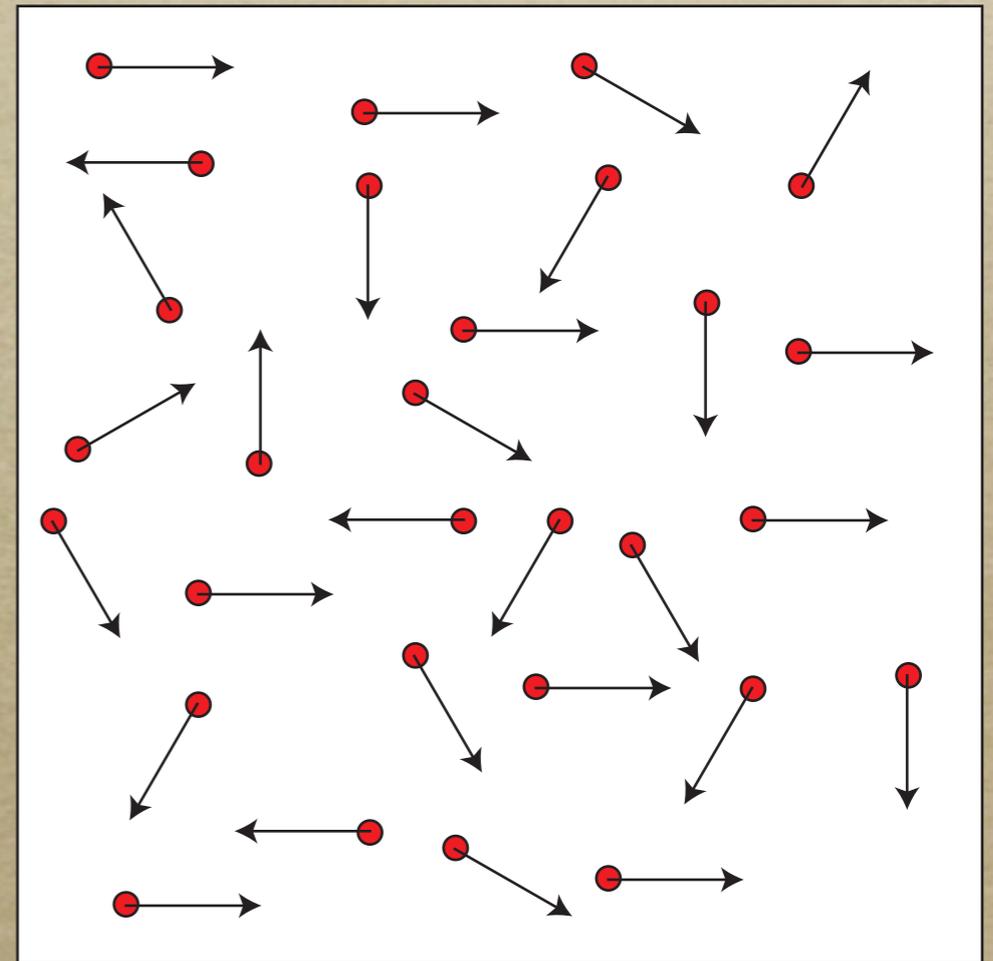


# Thermal Energy=Kinetic Energy

*cold*



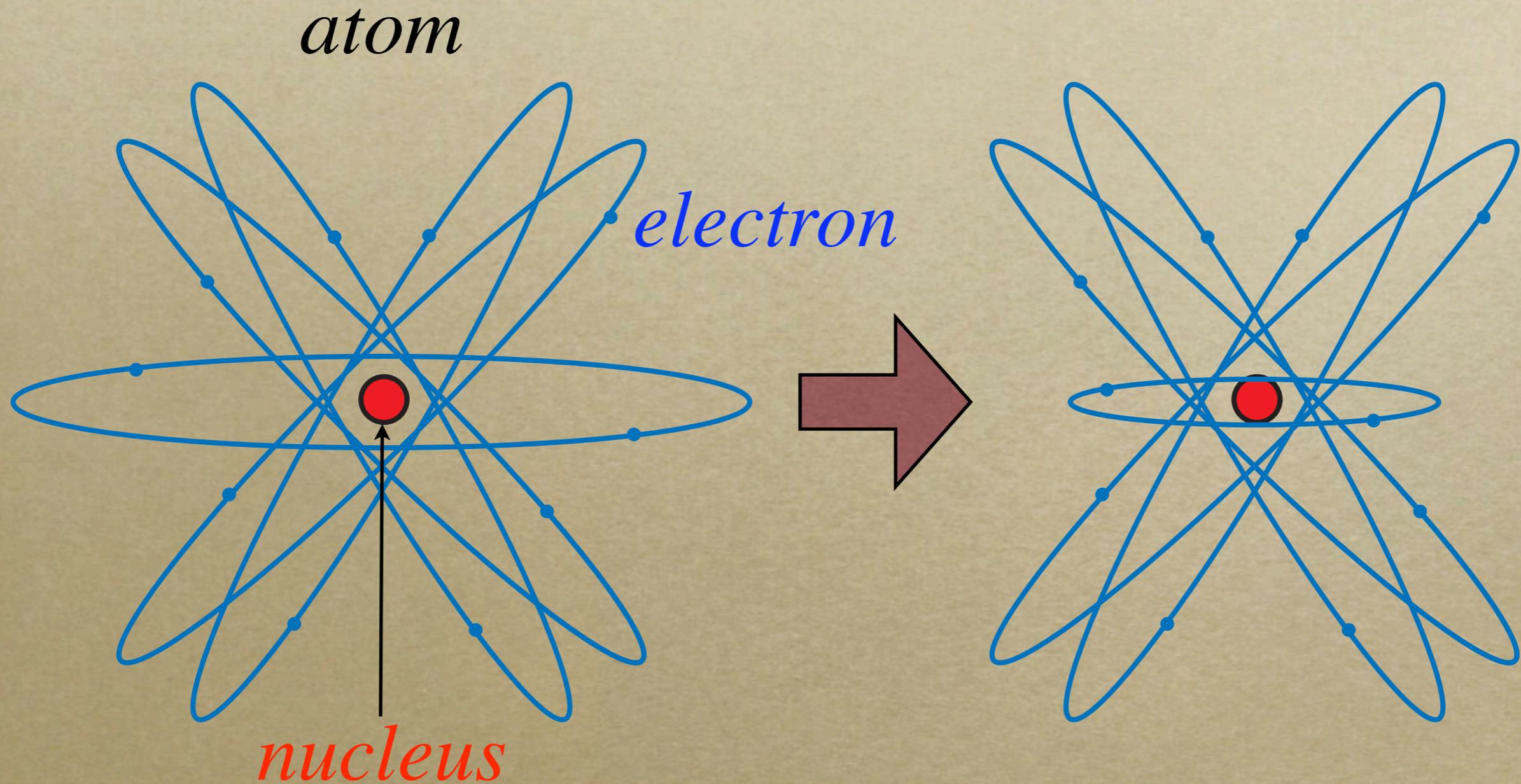
*hot*



# Chemical Energy



# Chemical Energy=Potential Energy



# Energies transform



*chemical energy in the body*  $\Rightarrow$  *potential energy of the train*

# Mass Energy = ?

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*If mass is another form of energy,*

*what is it?*

*Is it kinetic?*

*Is it potential?*

# Mass

– *Newton to Einstein* –

# Encyclopædia Britannica “*Mass*”

---

in physics, quantitative measure of *inertia*, ... the resistance that a body of matter offers to a change in its speed or position upon the application of a force. ...

# Which one has more inertia?



# Encyclopædia Britannica “*Mass*”

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in physics, quantitative measure of **inertia**, ... the resistance that a body of matter offers to a change in its speed or position upon the application of a force. ...

For years ... the theory of **conservation of mass**, held that the mass of an object or collection of objects never changes, no matter how the constituent parts rearrange themselves. ....

# Conservation Law of Mass



# Encyclopædia Britannica “*Mass*”

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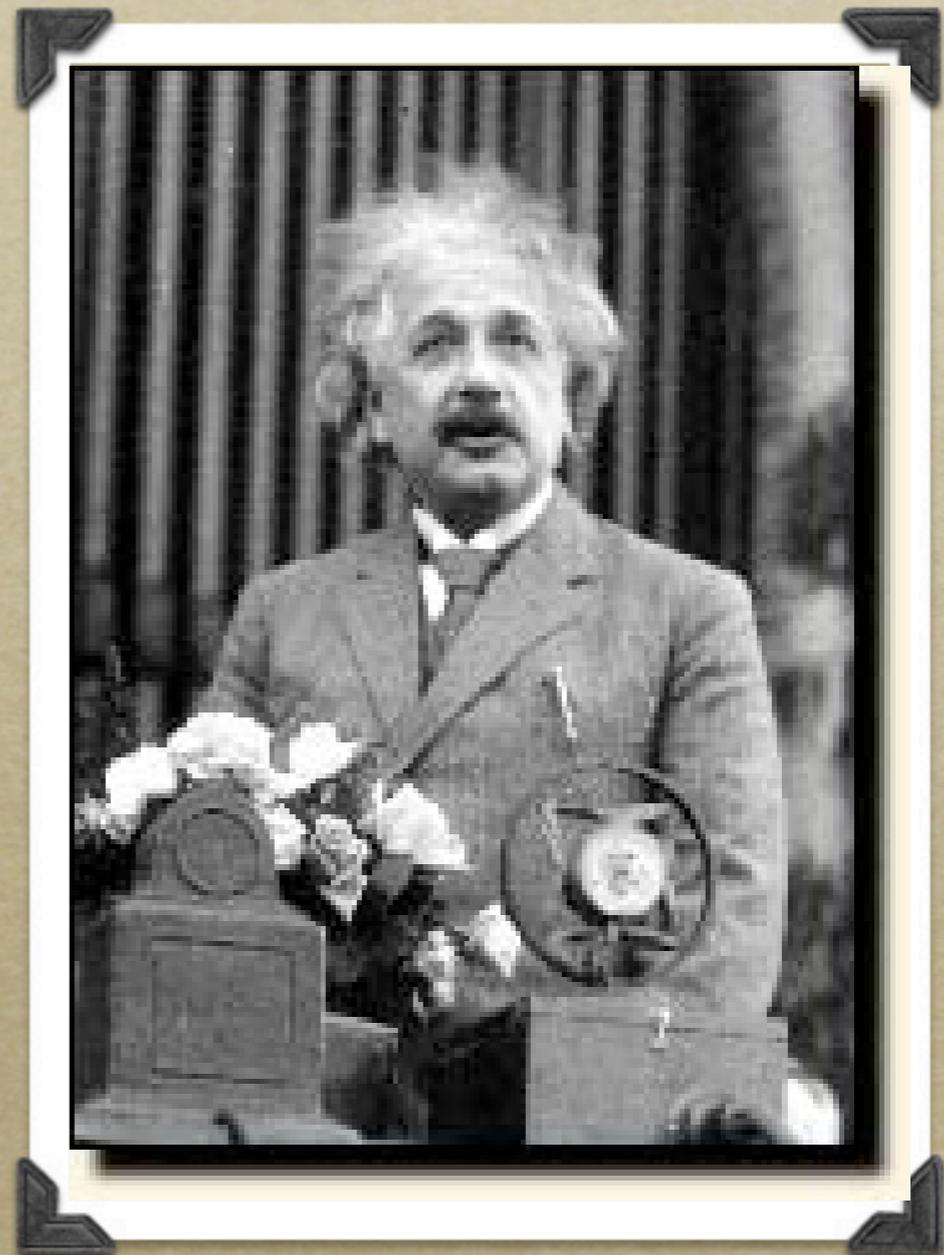
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For years ... the theory of **conservation of mass**, held that the mass of an object or collection of objects never changes, no matter how the constituent parts rearrange themselves. ...

With the advent of the **special theory of relativity** by Einstein in 1905, the notion of mass underwent a radical revision. **Mass lost its absoluteness**. The mass of an object was seen to be equivalent to energy, to be interconvertible with energy, ... Mass was no longer considered constant, or unchangeable.

$$E=mc^2$$

“It followed from the special theory of relativity that mass and energy are both but different manifestations of the same thing -- a somewhat unfamiliar conception for the average mind. Furthermore, the equation *E is equal to m c-squared*, in which energy is put equal to mass, multiplied by the square of the velocity of light, showed that very small amounts of mass may be converted into a very large amount of energy and vice versa. The *mass and energy were in fact equivalent*, according to the formula mentioned before. *This was demonstrated by Cockcroft and Walton in 1932, experimentally.*”



# First Atom Smasher

- *Cockroft and Walton “split the atom” (1932)*



*Modern alchemy!*

- *$p$  weighs 1.0078u*
- *${}^7\text{Li}$  weighs 7.0160u*
- *${}^4\text{He}$  weighs 4.0026u*  
 $1.0078\text{u} + 7.0160\text{u}$   
 $- 2 \times 4.0026\text{u} = 0.0186\text{u}$
- *Mass is converted to energy!*



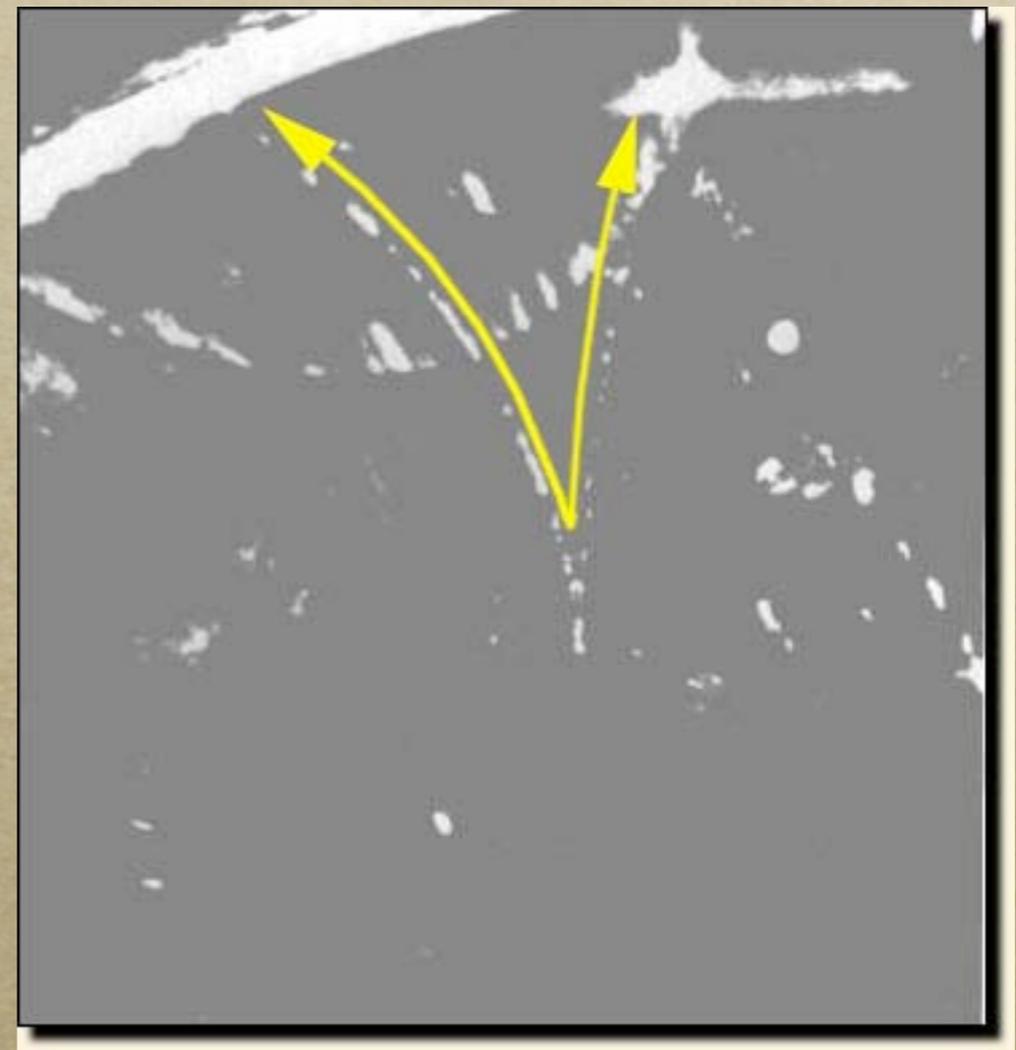
1951 Physics Nobel

# Irène and Frédéric Joliot-Curie

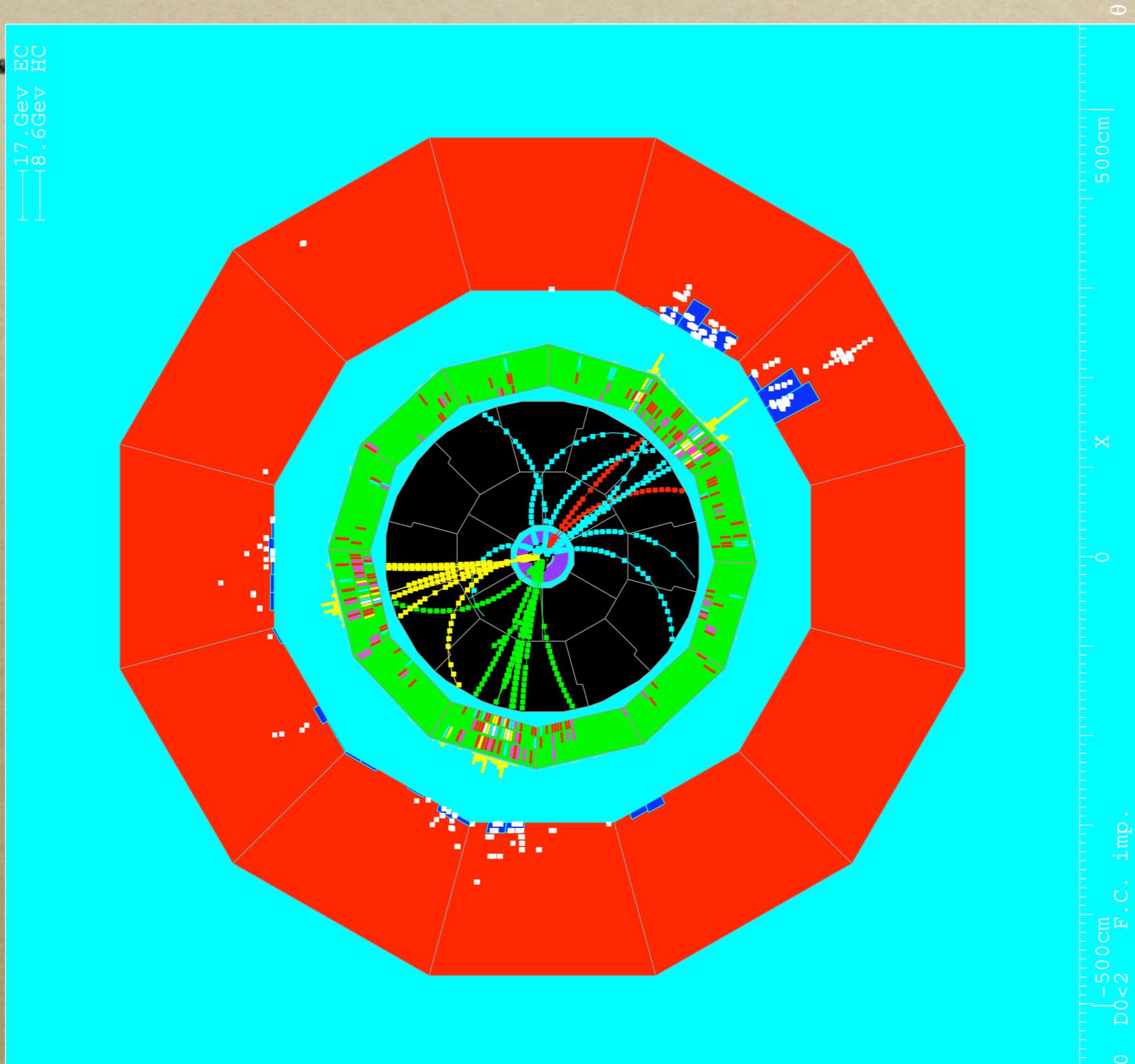
- *Picture taken in 1933*
- *Energy (photon) can convert to mass (electron and positron)*



1935 Chemistry Nobel



# *matter anti-matter annihilation*

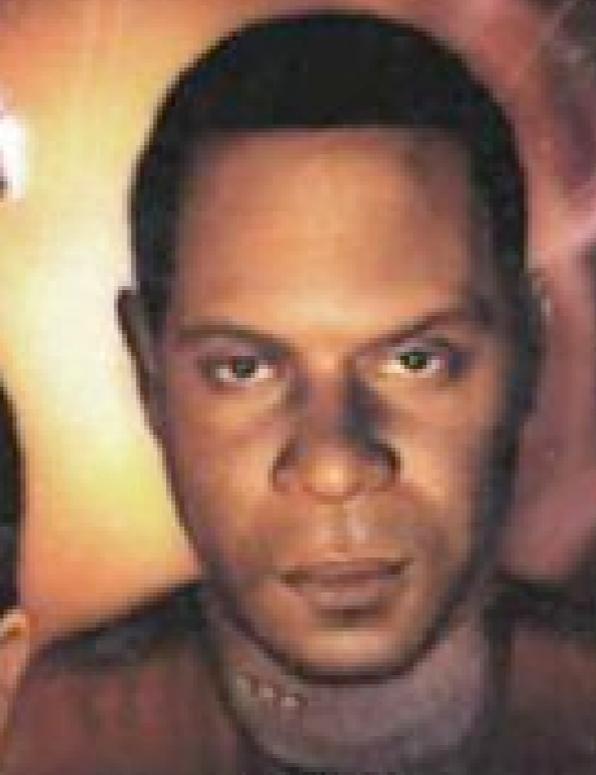
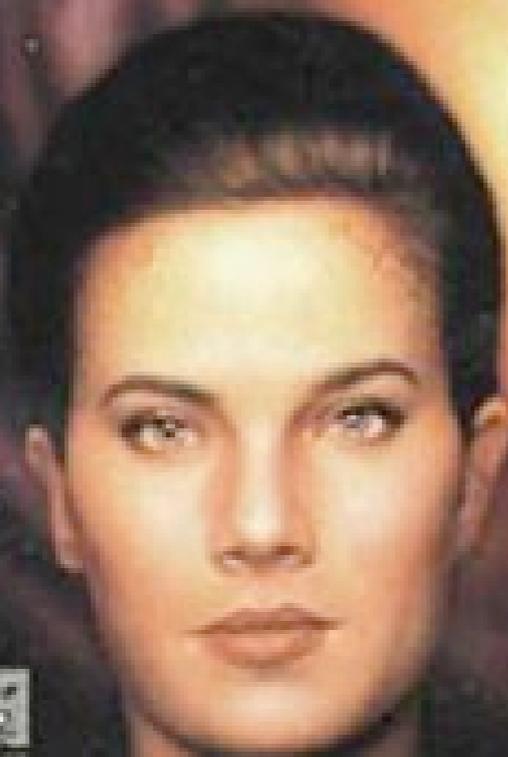


#8

# STAR TREK

## DEEP SPACE NINE

### ANTIMATTER



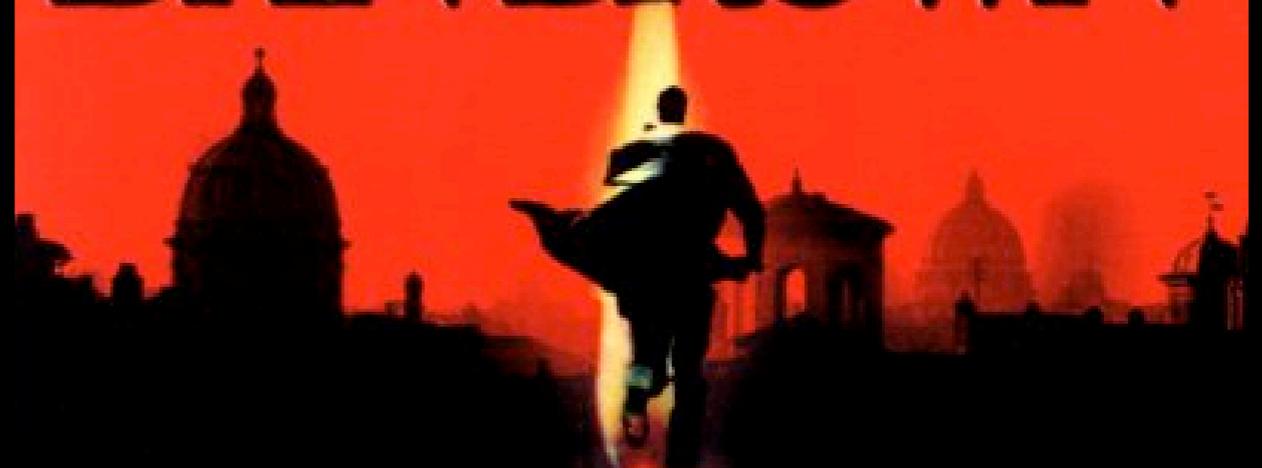
With a dangerous cargo at stake, Commander Sisko must battle a band of hijackers!

John Vornholt



BESTSELLING AUTHOR OF *DIGITAL FORTRESS*

# DAN BROWN

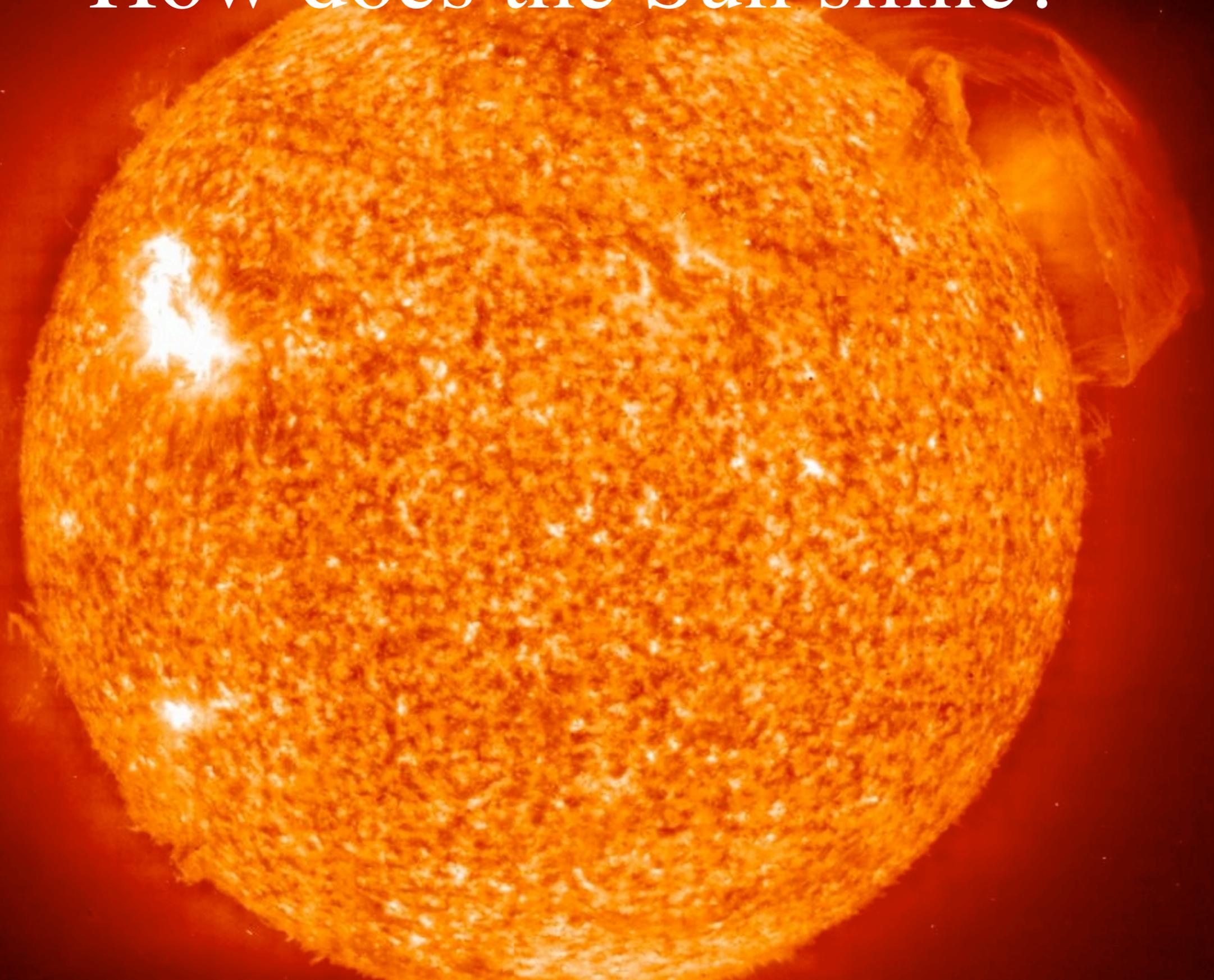


A NOVEL

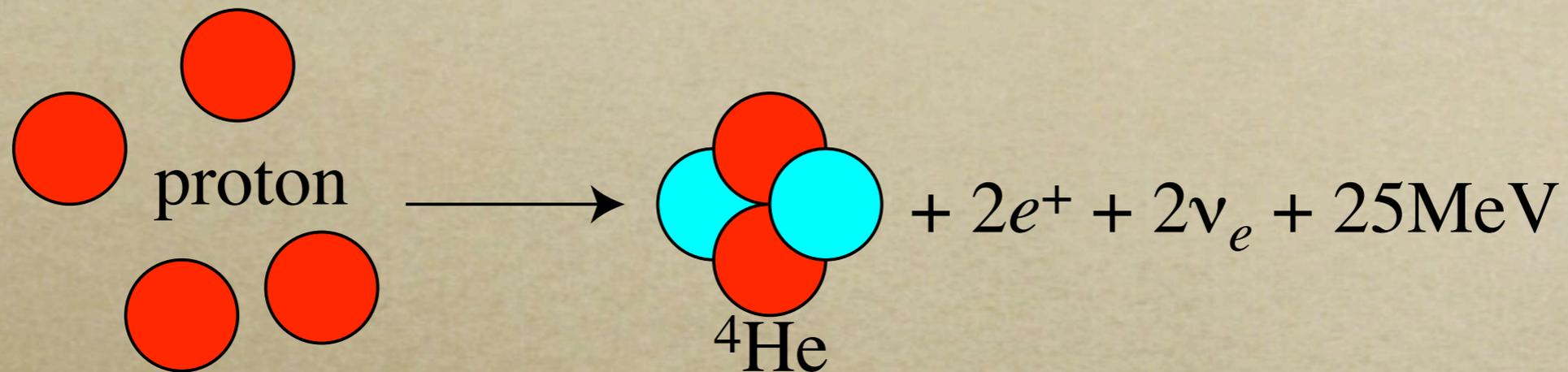
# ANGELS & DEMONS

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How does the Sun shine?



# How the Sun shines



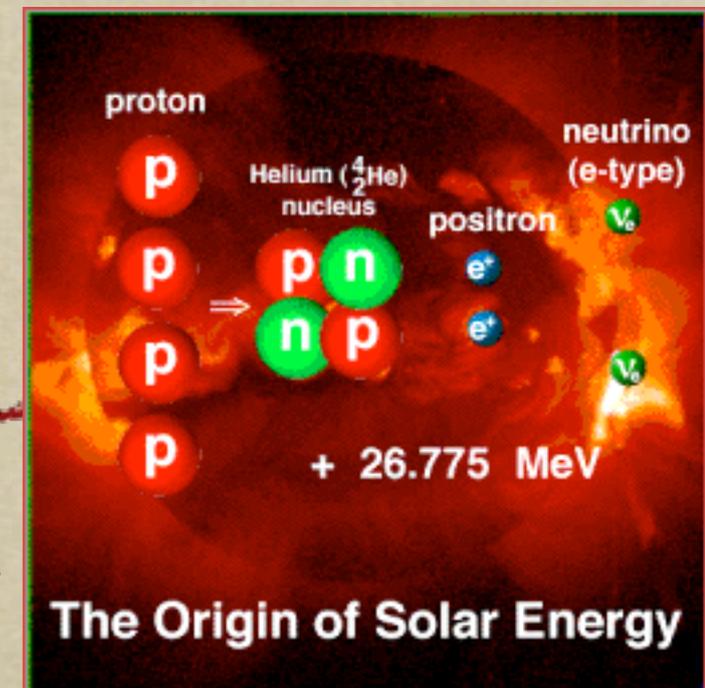
$$4p(1.0078u)$$

$$= {}^4\text{He}(4.0026u) + 2e(0.0005u) + 0.0276u$$

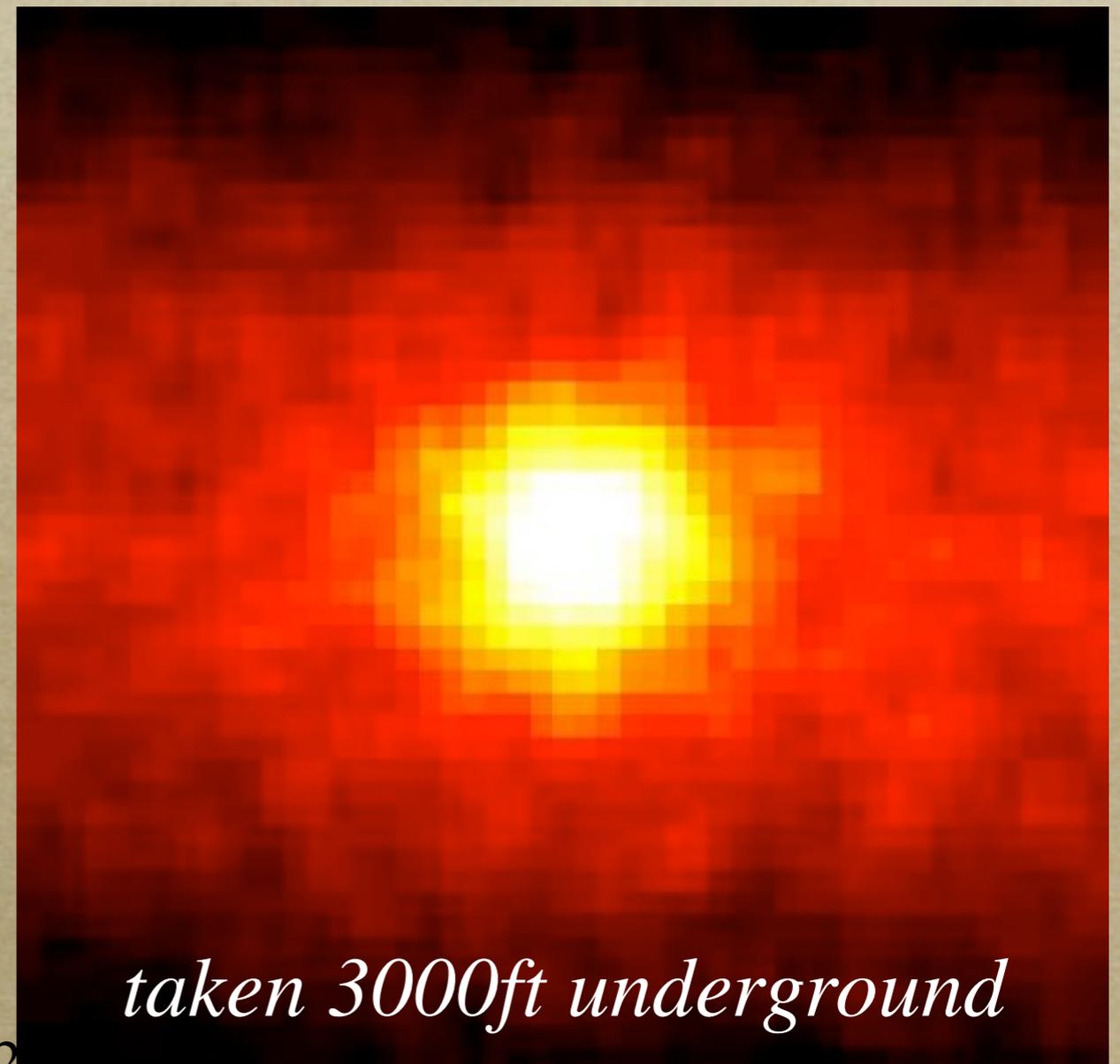
- *fusion of protons releases a lot of energy*
- *If it weren't for the  $E=mc^2$ , we can't live!*

# Seen the invisible

*Neutrinos are the fusion products in the Sun*  
*Trillions of them go through our body every second*  
*Used to be an "invisible"*



*SuperKamiokande*

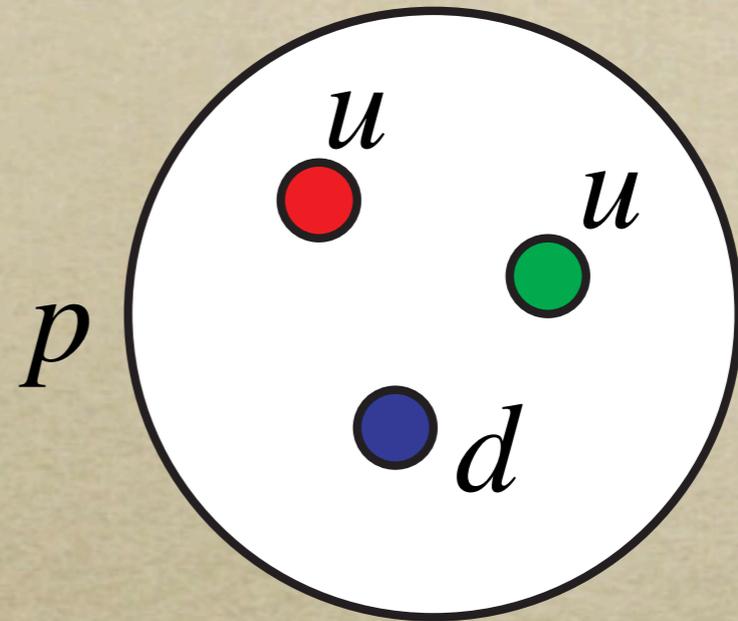


What is the Mass Energy?

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# quarks within

- *protons, neutrons are made up of three quarks eternally confined inside*
- *They move around every 0.000 000 000 000 000 000 000 001 seconds*
- *This motion gives the most of the mass energy of the proton and neutron and us!*



*Murray Gell-Mann  
1969 Nobel*

# Life in Prison

2004 Physics Nobel

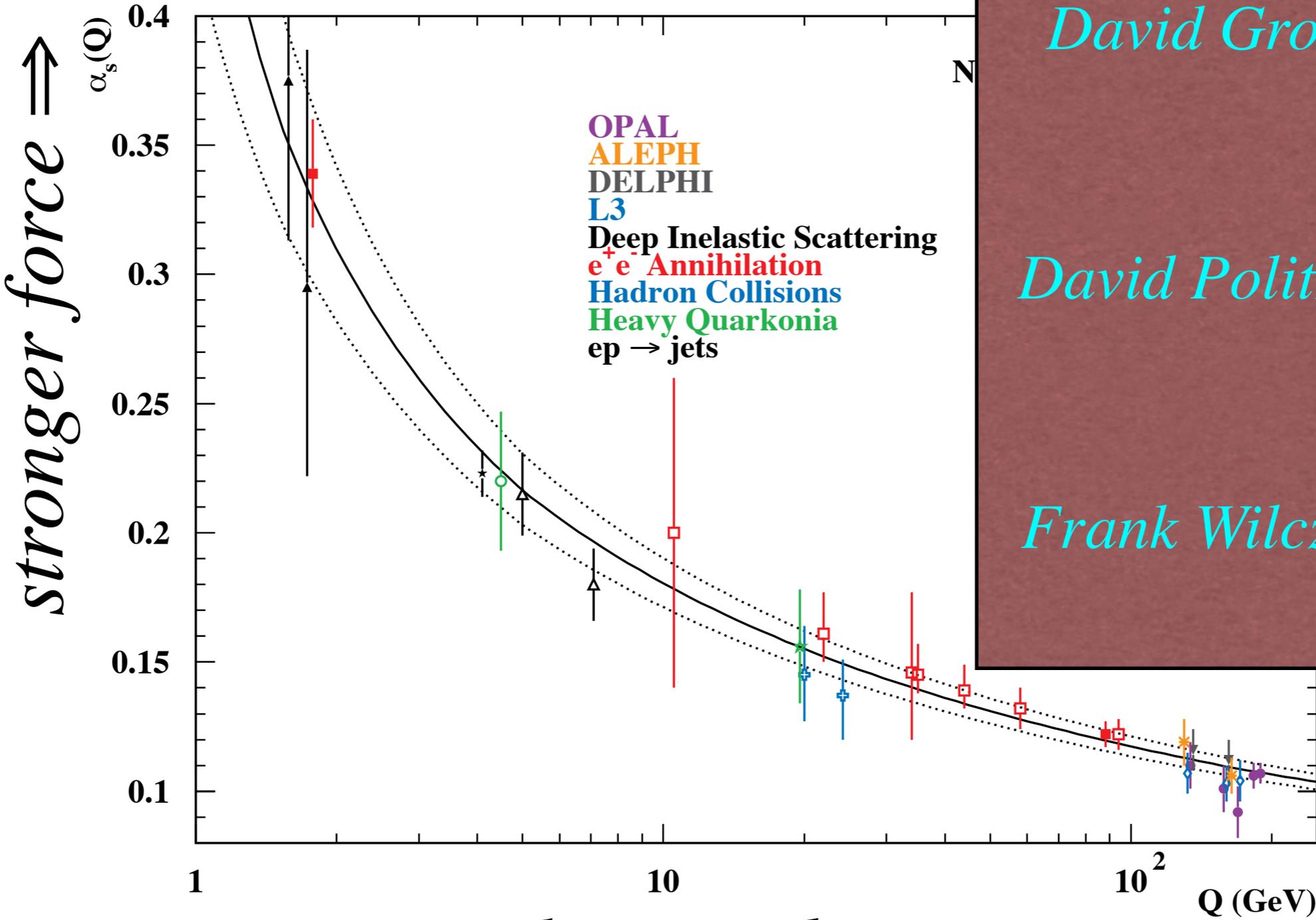
David Gross



David Politzer



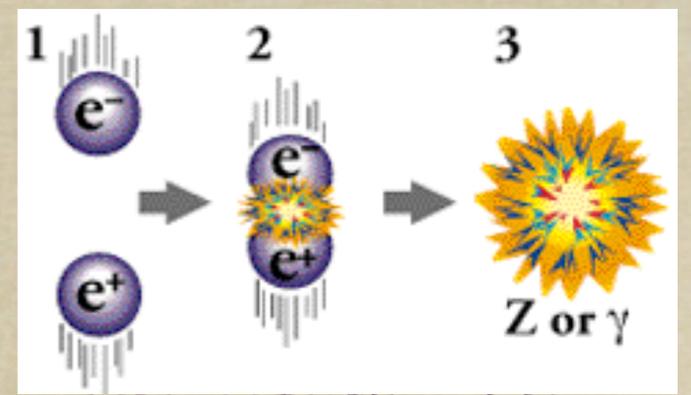
Frank Wilczek



*stronger force*  $\Rightarrow$

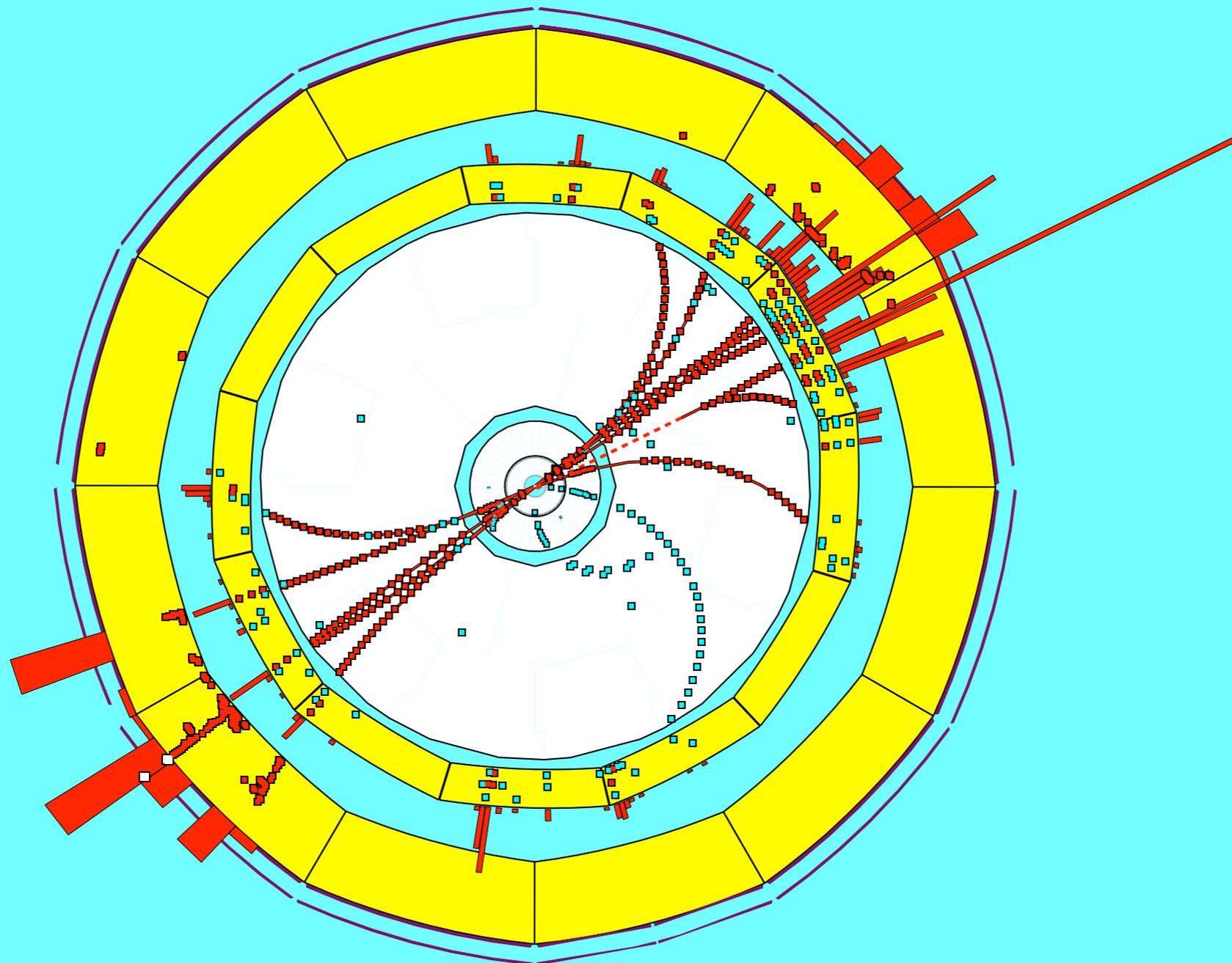
$\Leftarrow$  *longer distance*

$$e^+e^- \rightarrow \bar{q}q$$



 **ALEPH** DALI

Run=15768 Evt=5906



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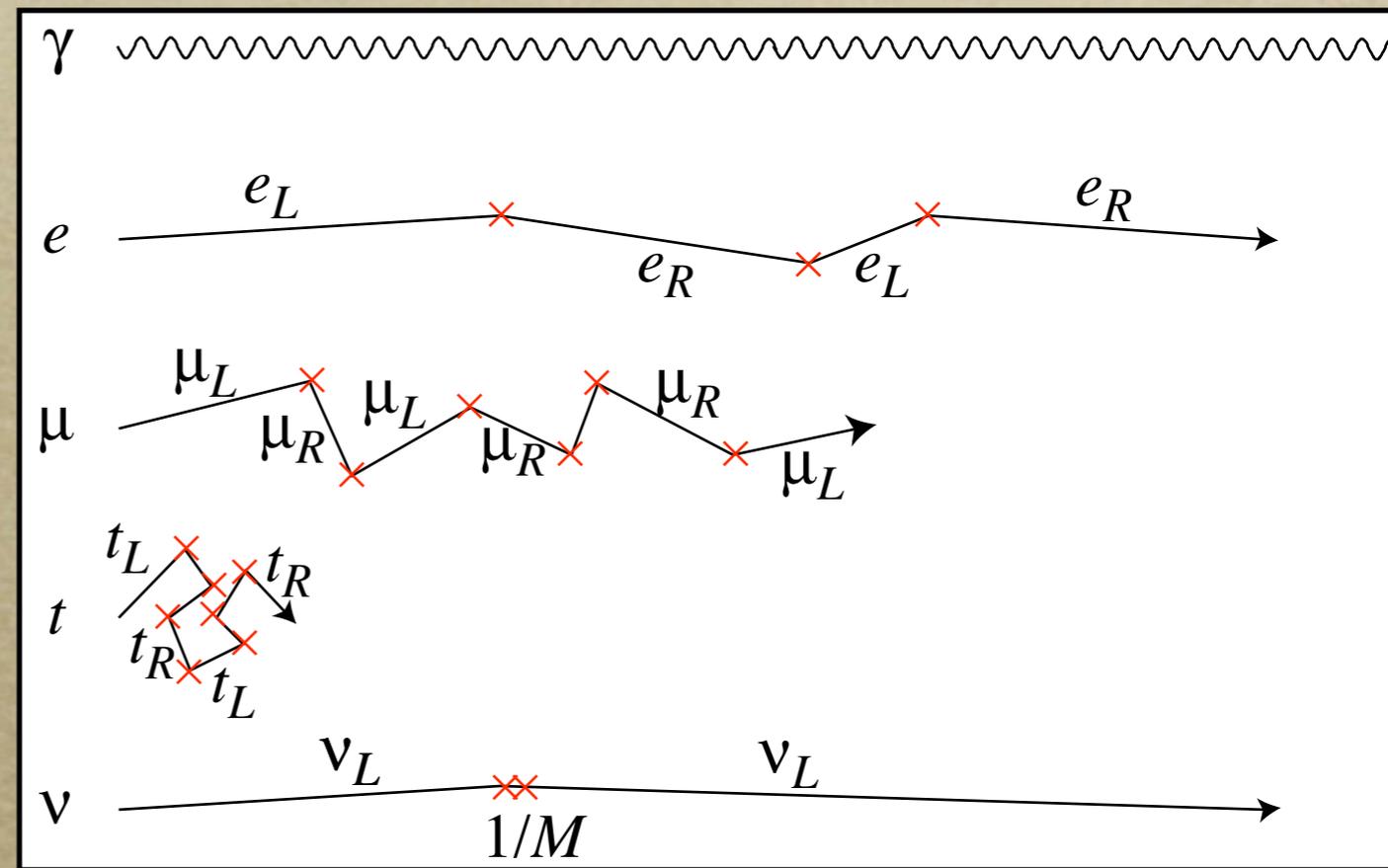
# Mystery

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- *There is a reason why protons and neutrons have energy when they are at rest because of quarks inside*
- *But quarks themselves do have a small mass energy, so does the electron without anything inside*
- *Why do have particles energies when they are just sitting around??*
- *If electron doesn't have a mass, atoms would disintegrate in nanoseconds*

# Something is in the Universe

- There is *something* filling our Universe: *Dark Field*
- It doesn't disturb light and is invisible
- *other particles bump on the Dark Field and pick up energy*
- *What is it??*



# Large Hadron Collider (LHC)

*Pump enough energy into space*





# Deeper Questions

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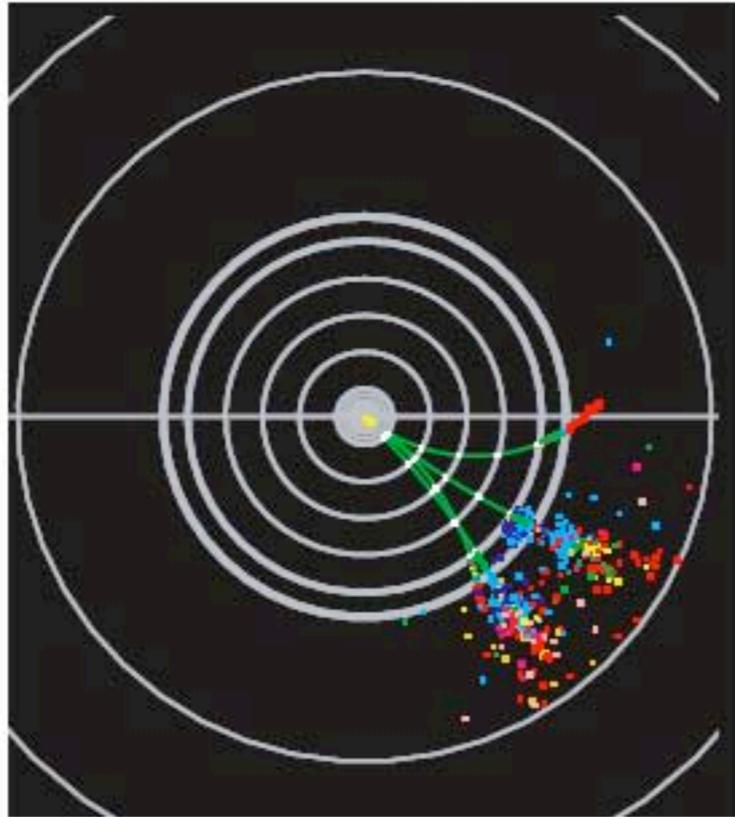
*Having seen “what” makes up the Dark Field, it opens up even more questions.*

- *Is this it? Are there more?*
- *Why is there such a thing filling up the Universe?*
- *It is a kind of particle nobody has seen yet. Does it have relatives? Siblings?*

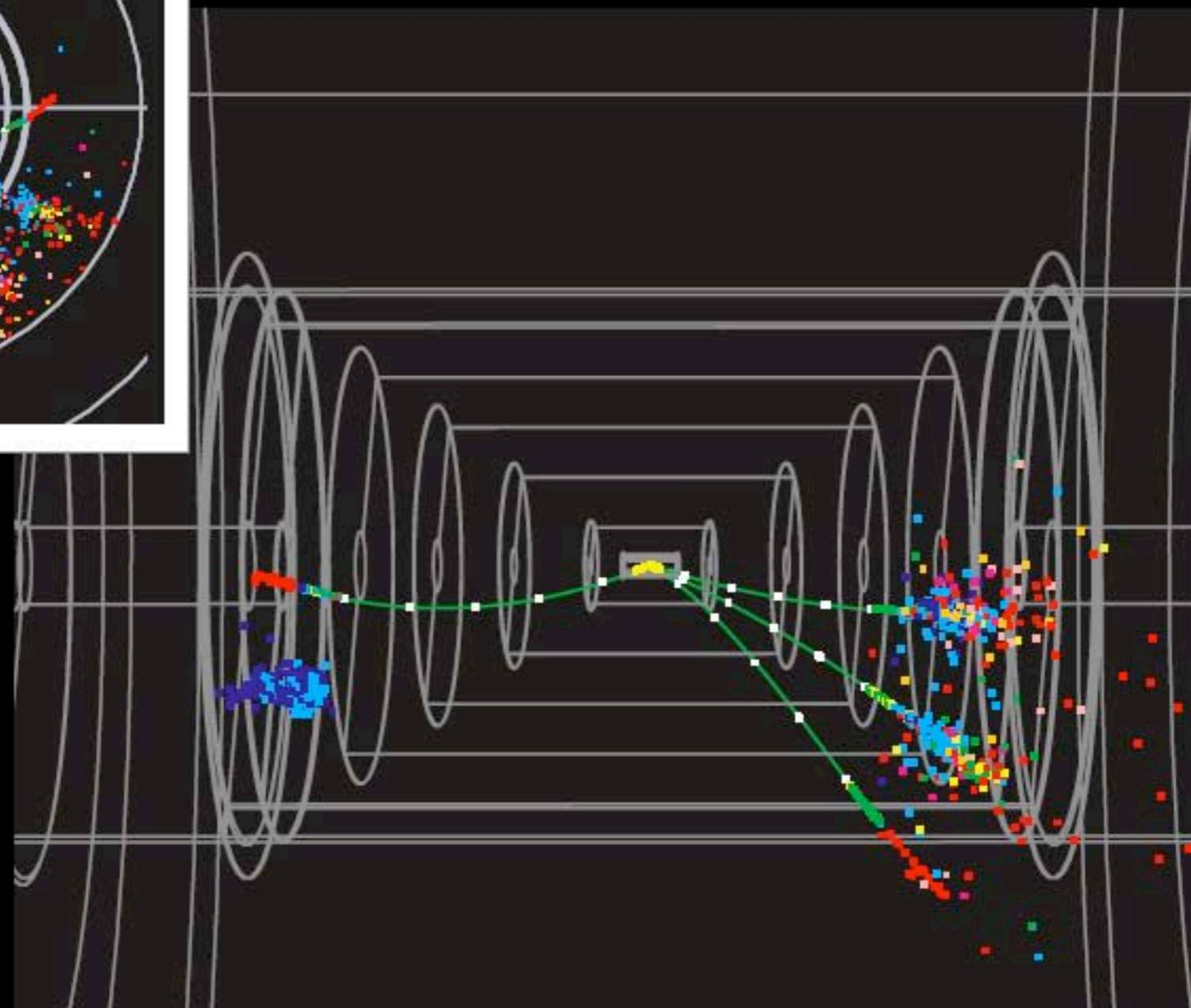
# International Linear Collider (ILC)



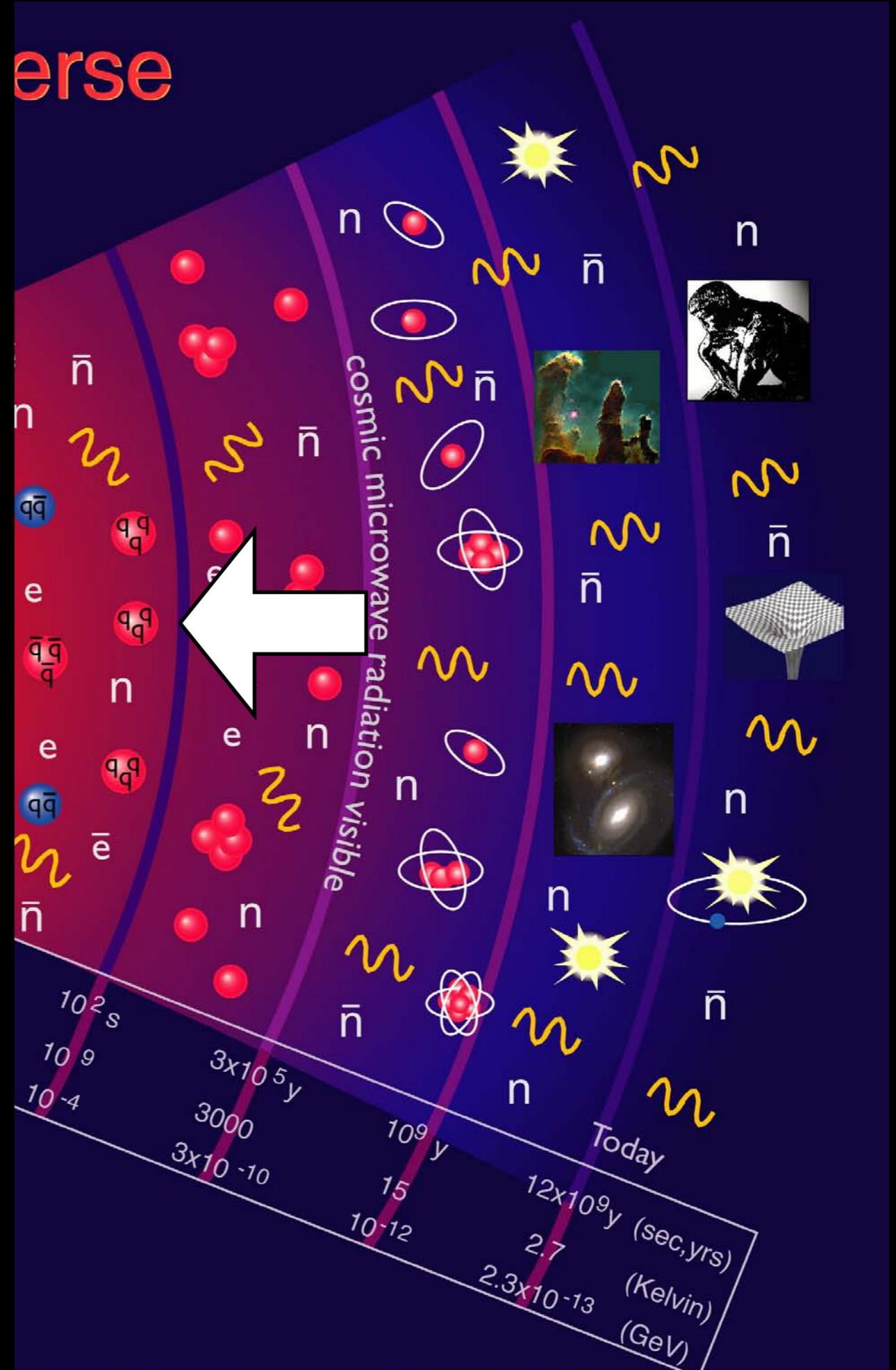
# Siblings of the Dark Field



$$e^+e^- \rightarrow \tilde{\tau}^+\tilde{\tau}^-$$



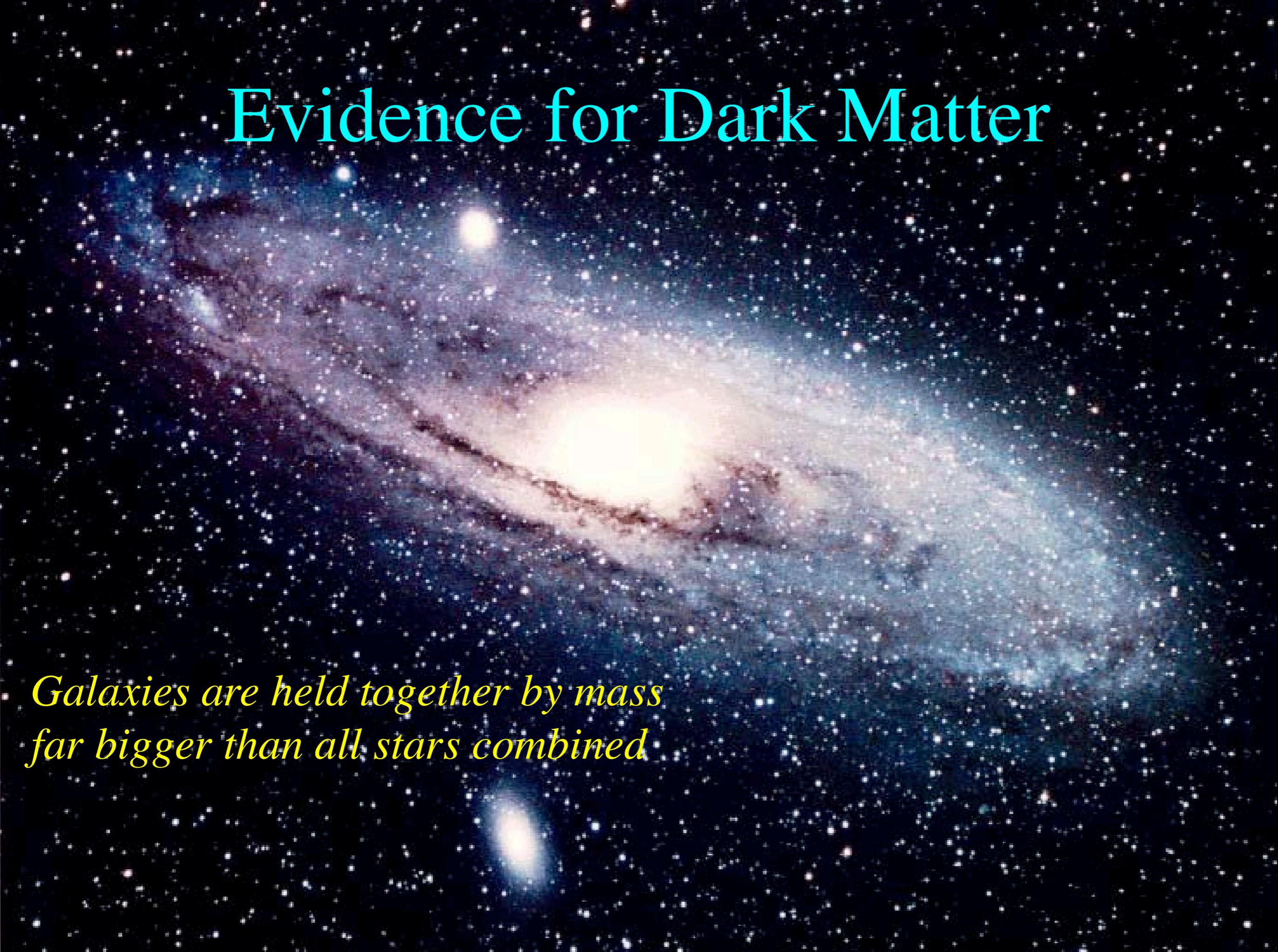
# Dark Field



# Mass Deficit in the Universe

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# Evidence for Dark Matter

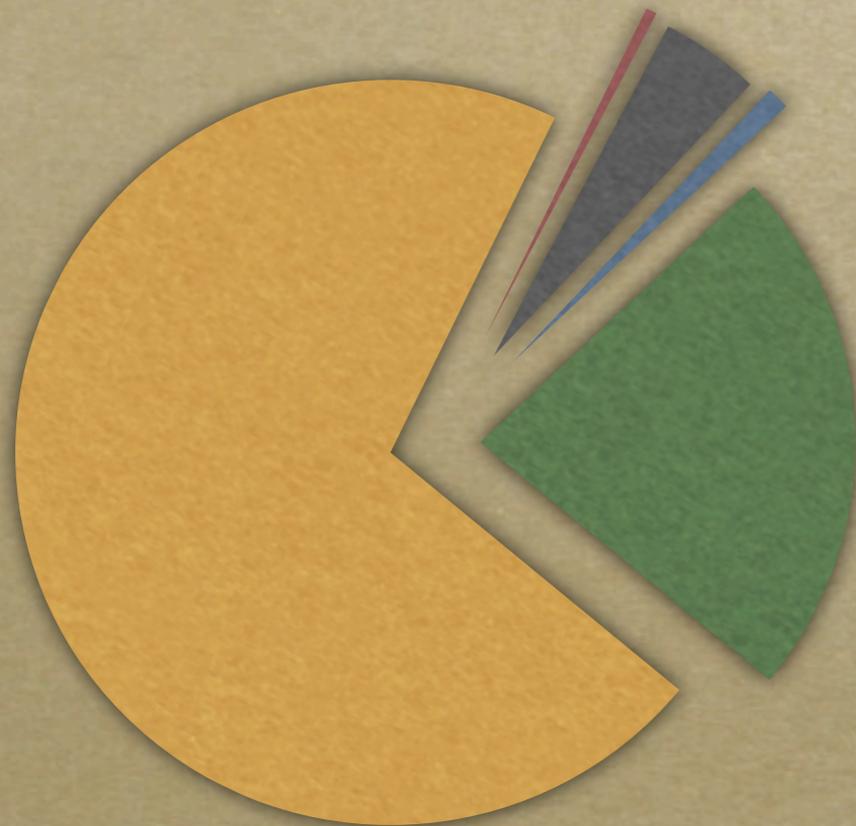
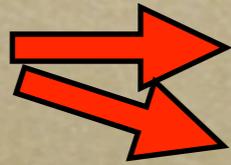


*Galaxies are held together by mass  
far bigger than all stars combined*

# Mass Deficit

- stars 0.5%
- atoms 4.4%
- neutrinos 0.1-1.5%
- dark matter 24%
- dark energy 73%

*not accounted  
for*



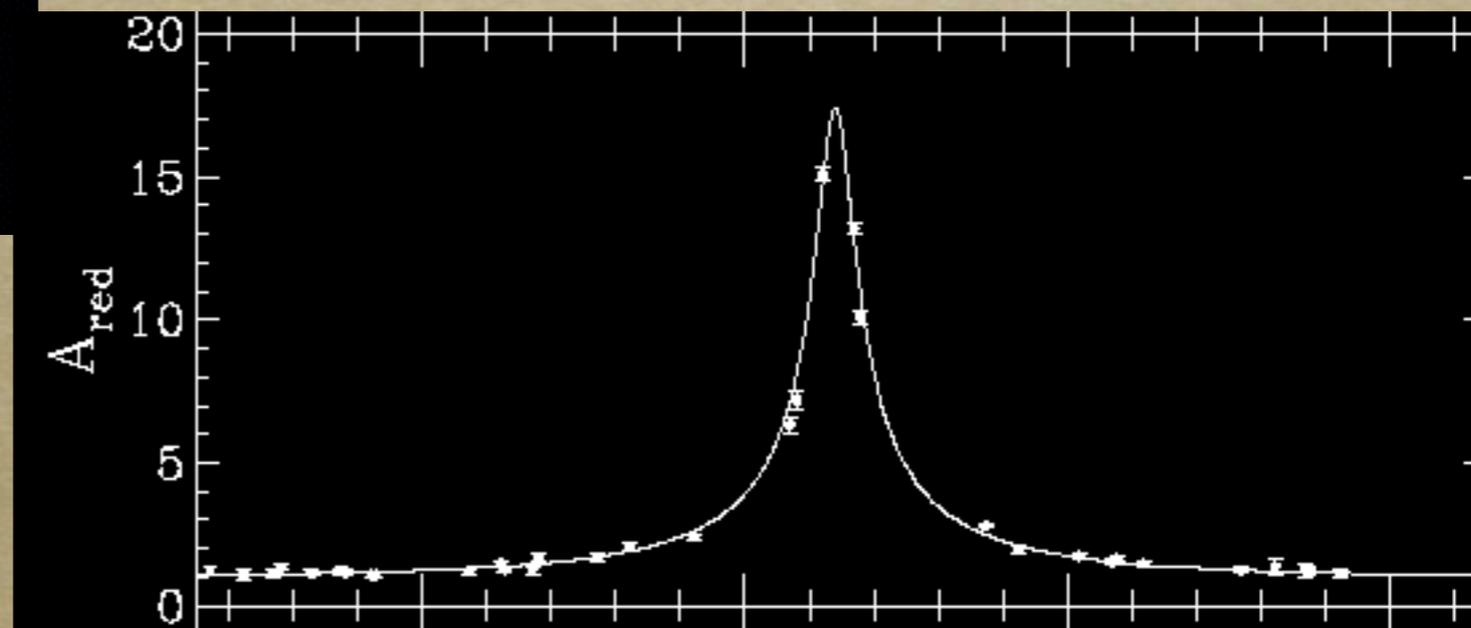
“The deficit poses a significant obstacle to long-term stability”

# Dim Stars?

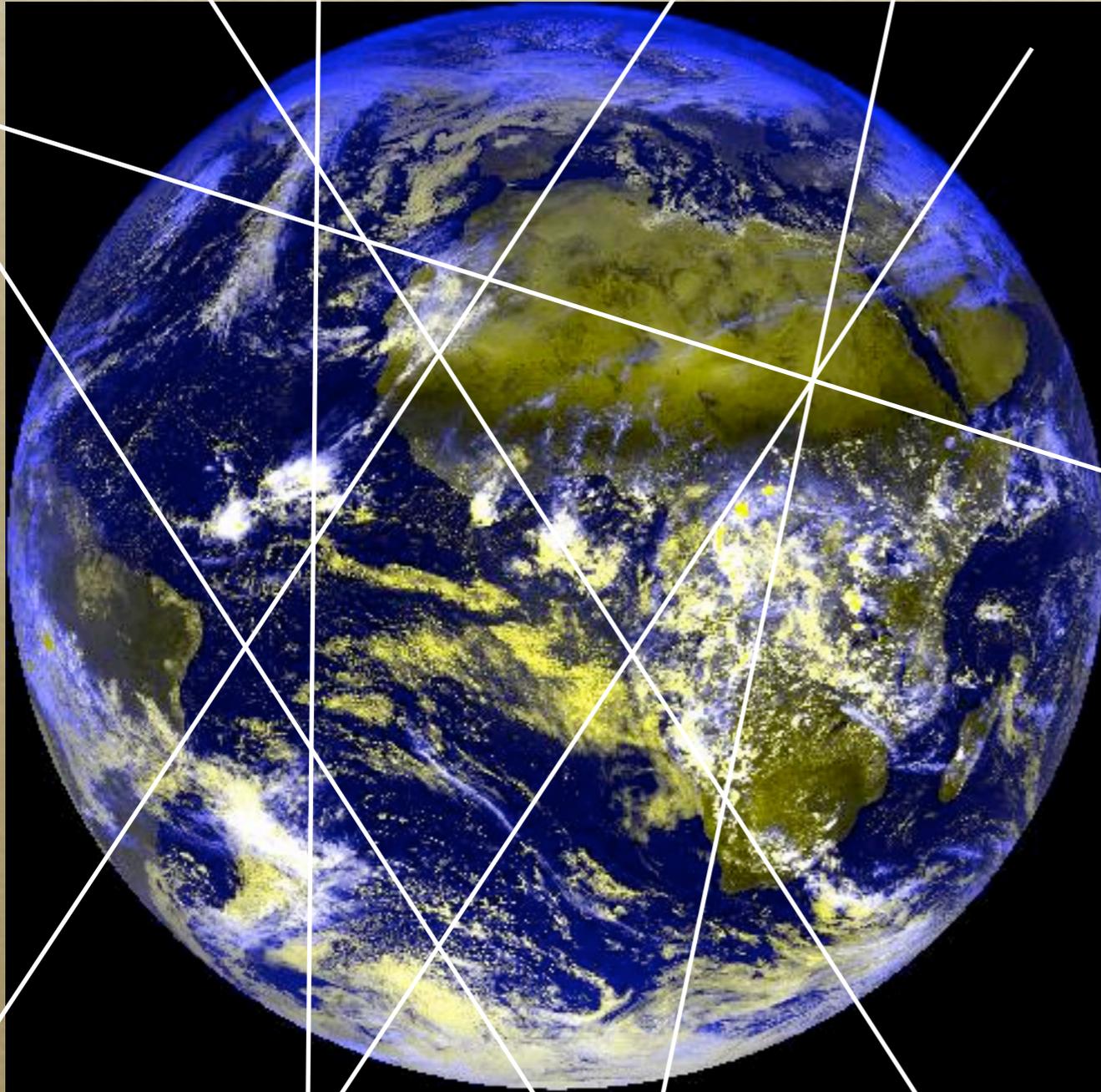
Search for *MACHOs*  
(Massive Compact Halo Objects)



*Not enough of them!*



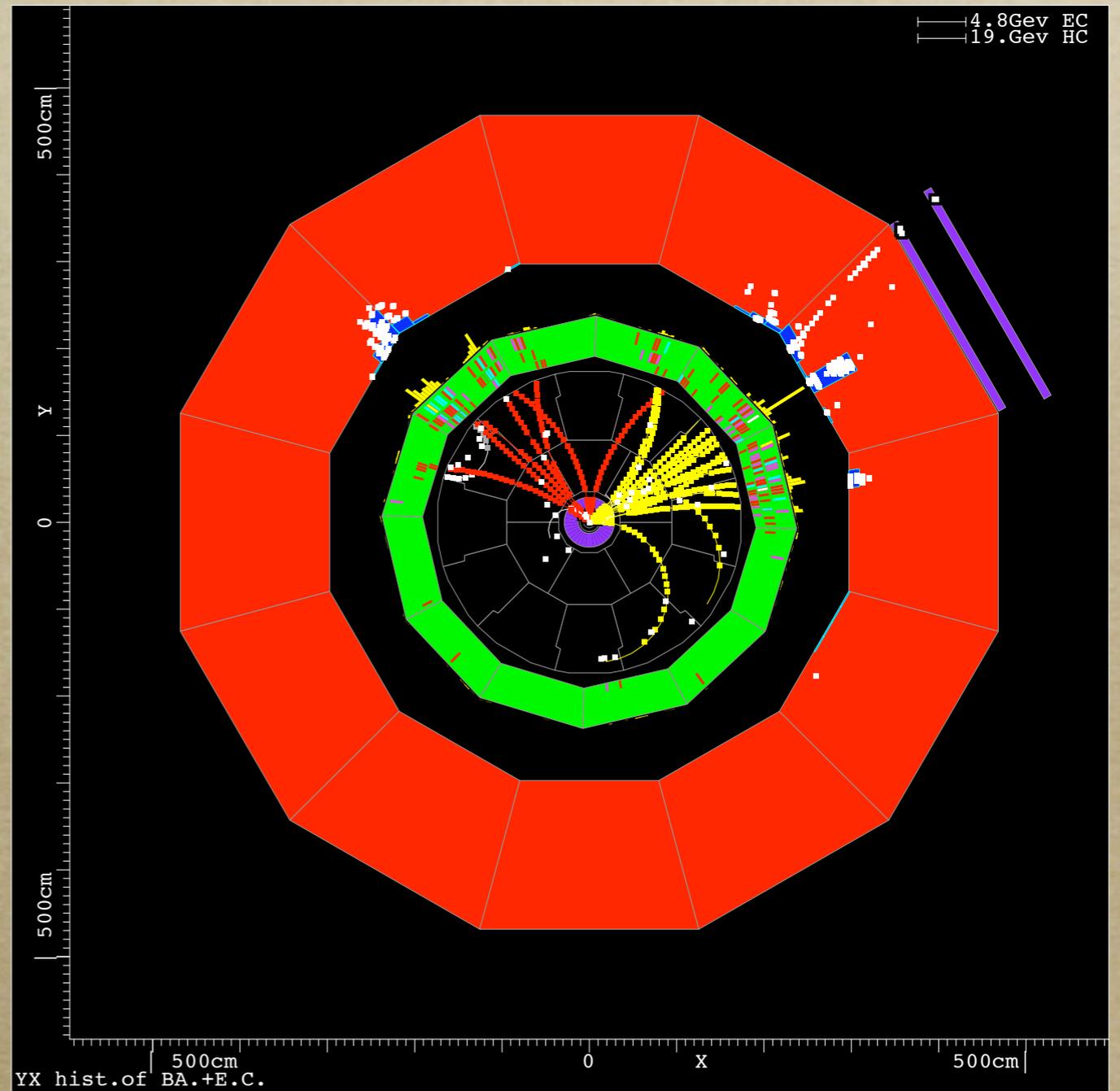
# MACHO $\Rightarrow$ WIMP



- It must be *WIMP* (Weakly Interacting Massive Particle)
- Stable heavy particle produced in early Universe, *left-over from near-complete annihilation*

# Creating Dark Matter

- Look for reactions where energy and momenta are unbalanced
- “missing energy”  $E_{miss}$
- *Something* is escaping the detector
- electrically neutral, weakly interacting
- ⇒ *Dark Matter!?*



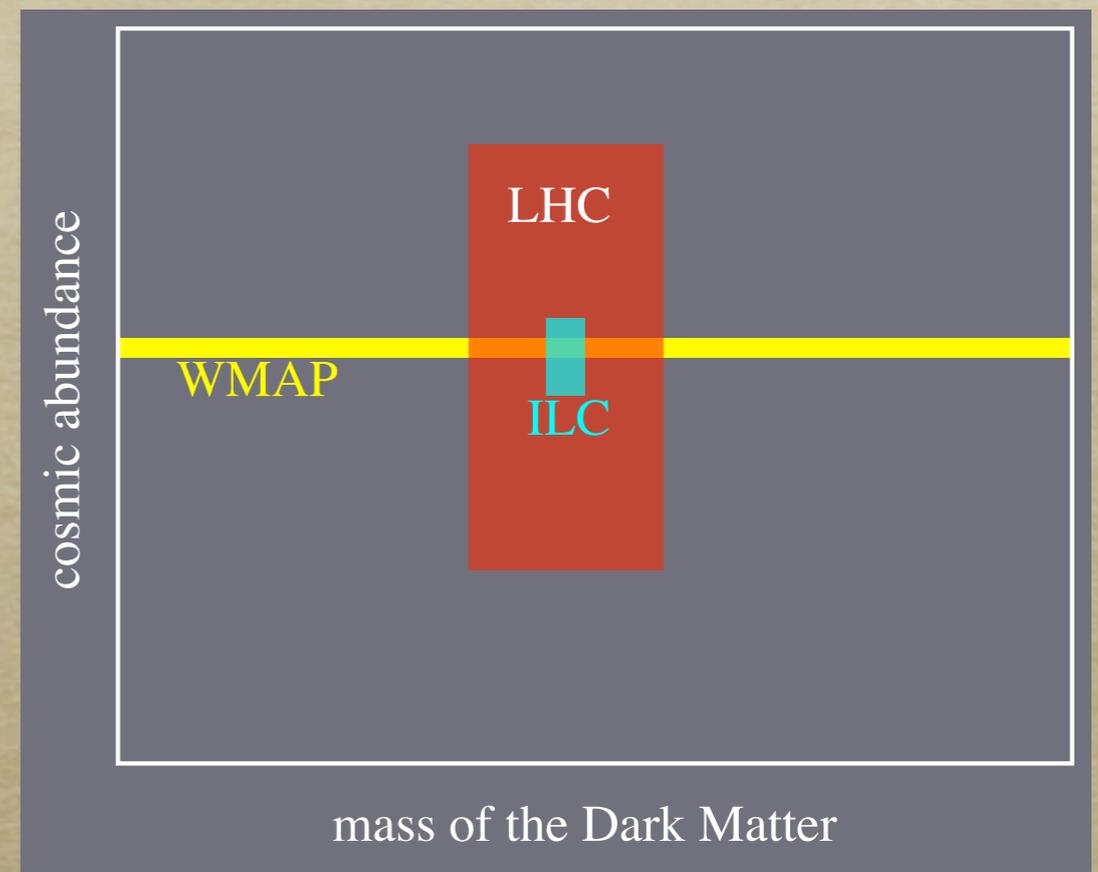
# How do we know what Dark Matter *is*?

- *cosmological measurement of dark matter*
- *detection experiments*
- *production at accelerators*

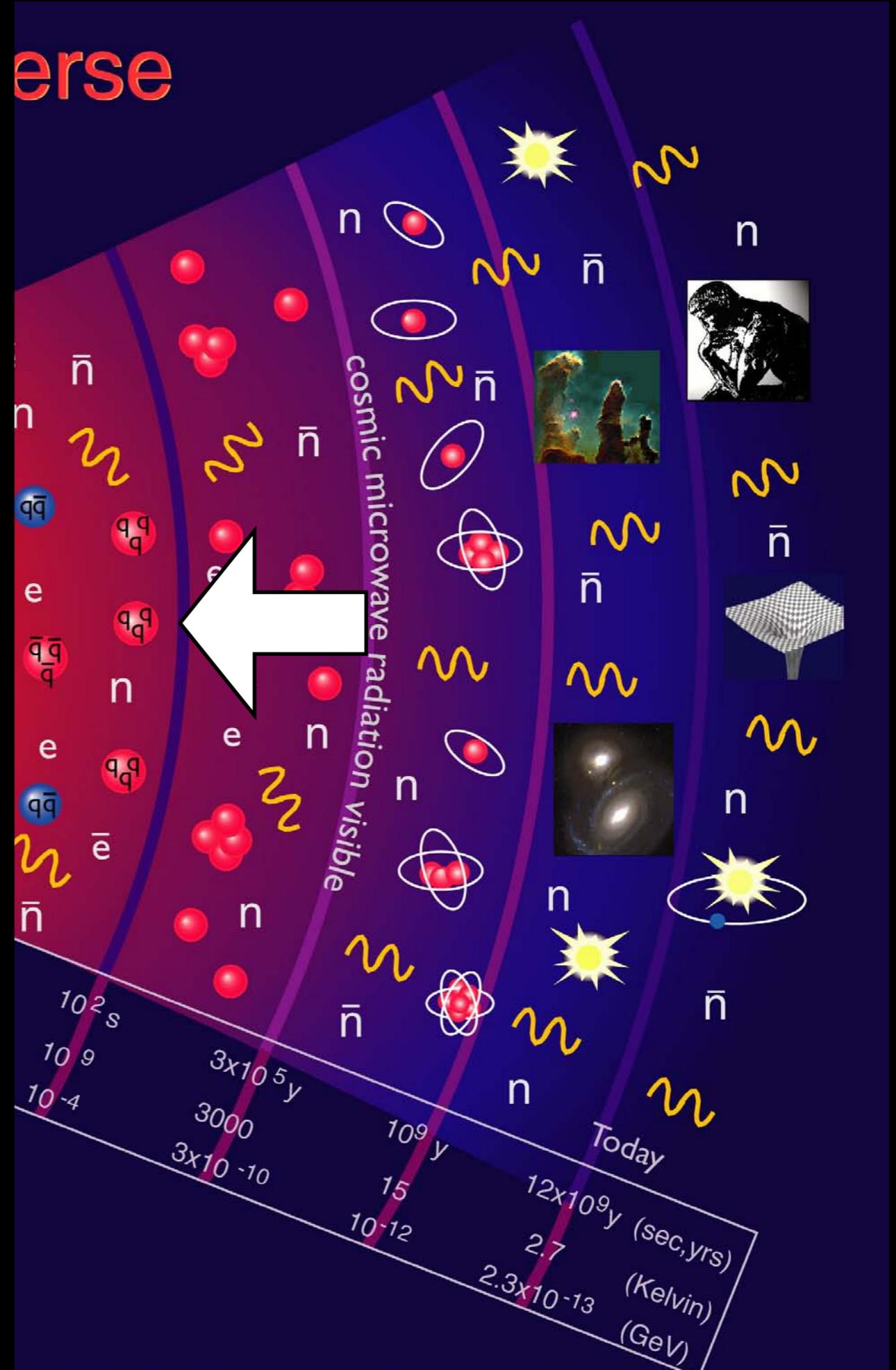
*If they agree with each other:*

⇒ *Will know what Dark Matter is*

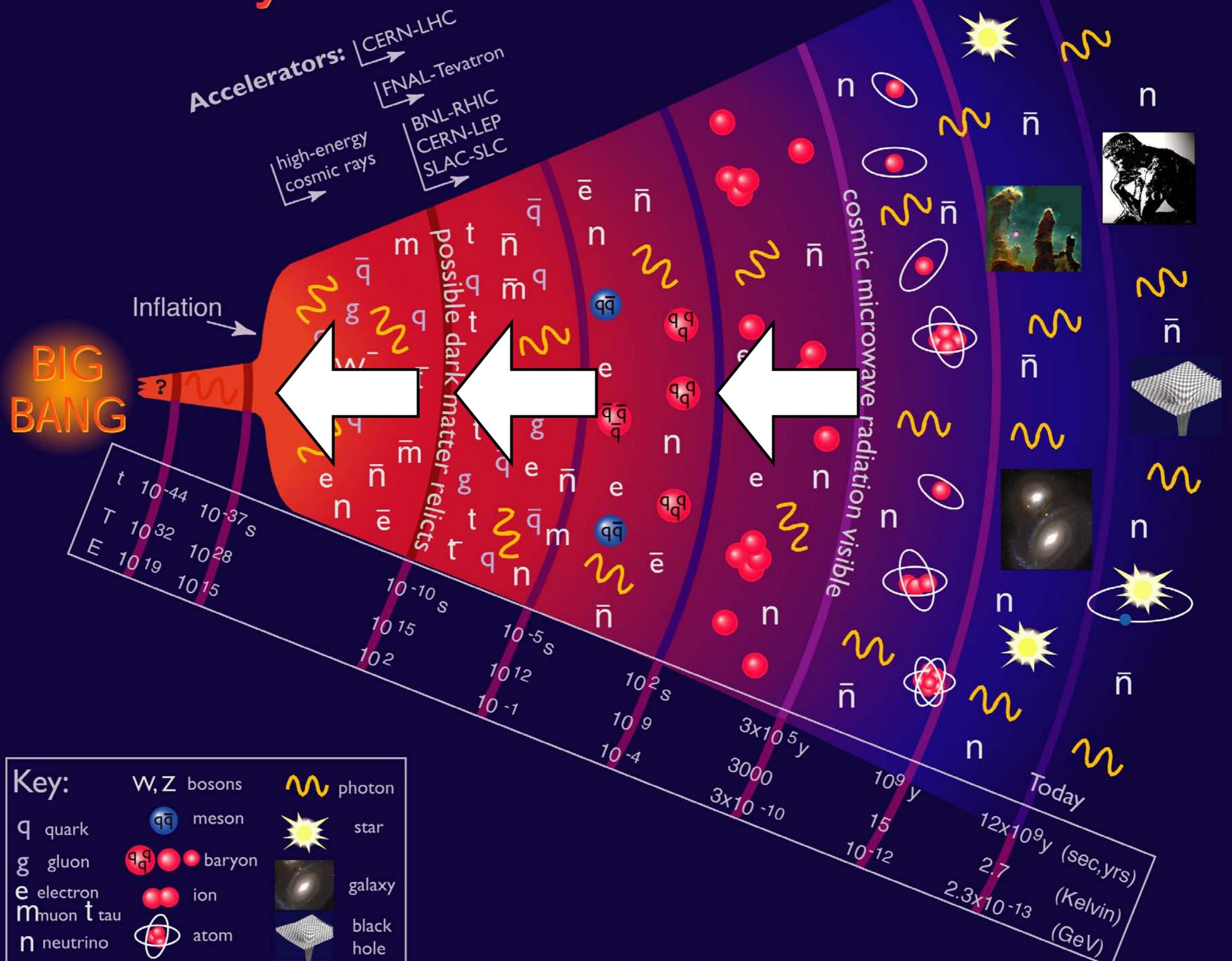
⇒ *Will understand universe back to  $t \sim 10^{-10}$  sec*



# Dark Field



# History of the Universe



# *Seeing the Invisibles*

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- *Our Universe is full of “Invisibles”*
- *Particles get energy from the **Dark Field***
- *Most mass in the universe is **Dark Matter***
- *Most energy in the universe is **Dark Energy***
- *We don't know what they are yet*
- *But we have strategies to figure that out*  
*We will see the invisibles!*

V

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# THE INCREDIBLES

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*I feel lucky to live in this era*

