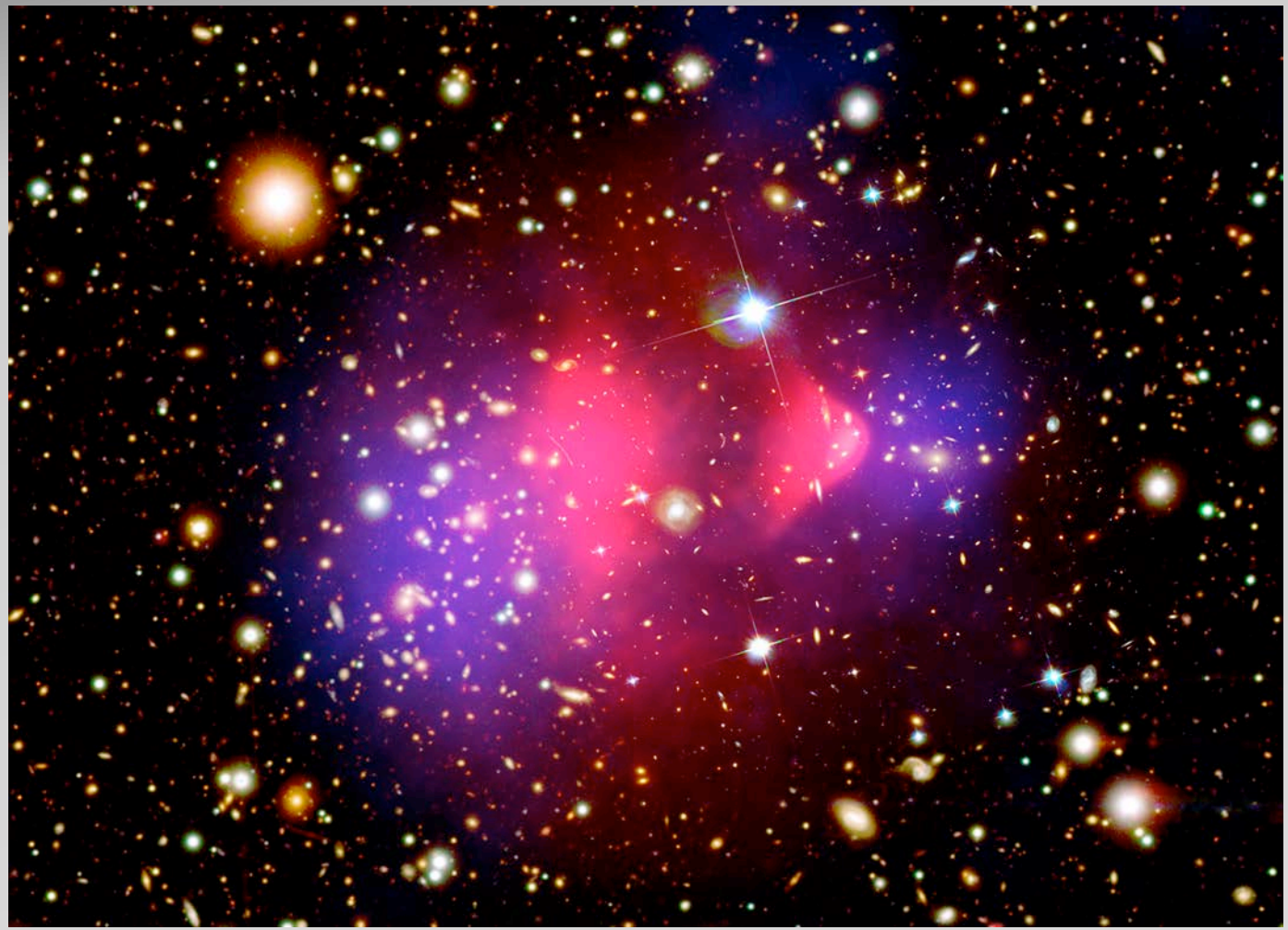


DARK MATTER

Evan Shockley
University of Chicago

Question: What's dark matter?

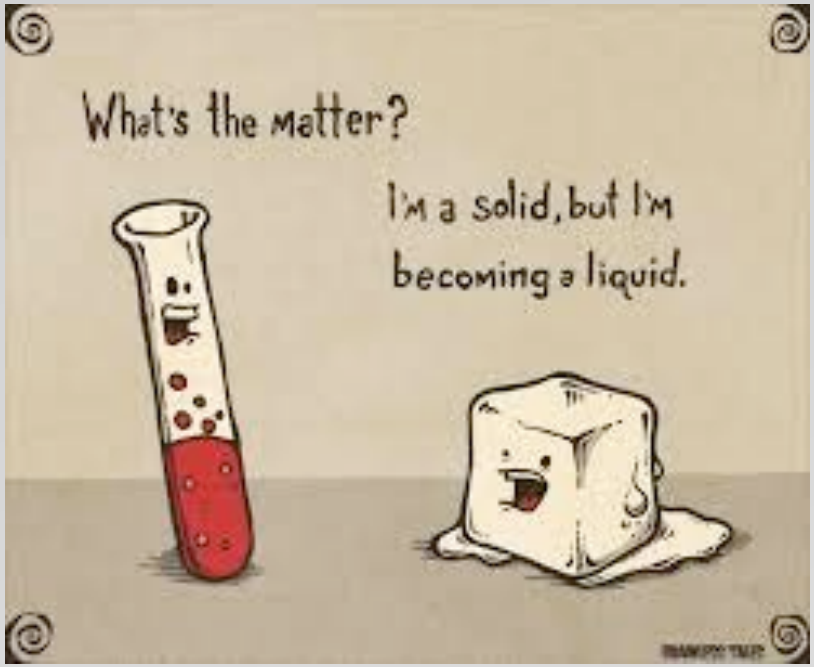
Short Answer: We don't know.

Longer answer…

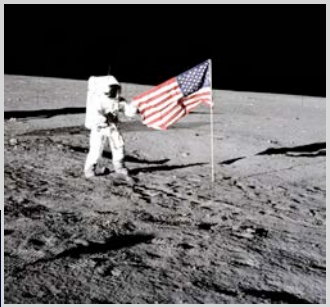
Let’s start with a different question

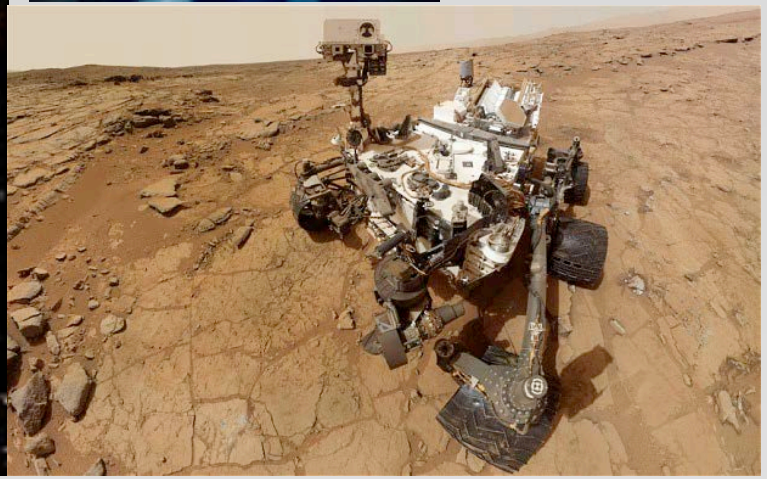
What is matter?

- "stuff"
- made of atoms
- people, planets, stars… pretty much everything

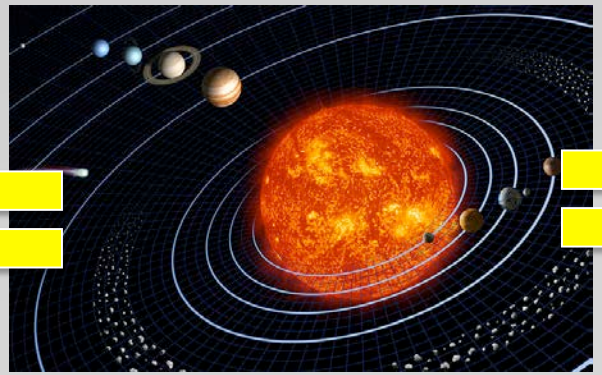


We've learned a lot about matter over the years





We've learned that matter causes gravity



"If matter thus draws matter; it must be proportion of its quantity. Therefore the apple draws the Earth, as well as the Earth draws the apple."

-account from William Stuckley, one of Newton's contemporaries

Mass (amount of matter)

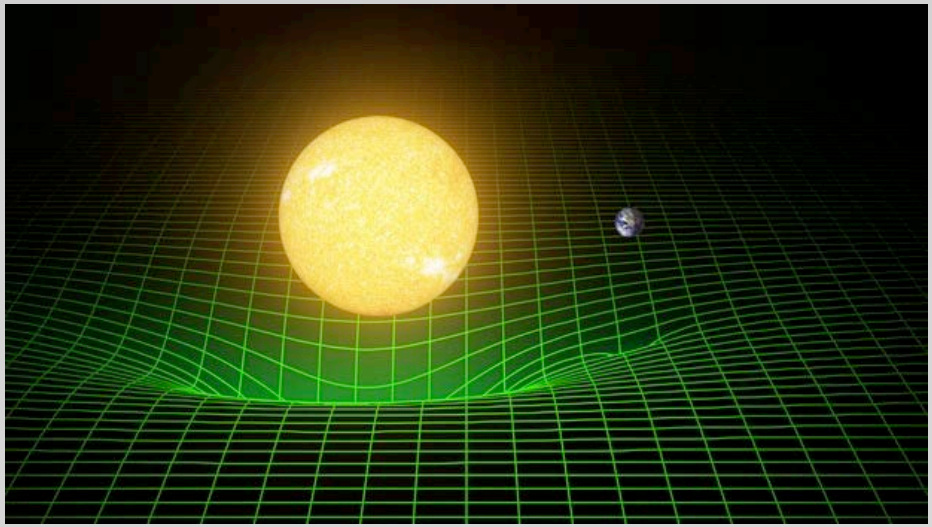
$$F = \frac{GMm}{r^2}$$

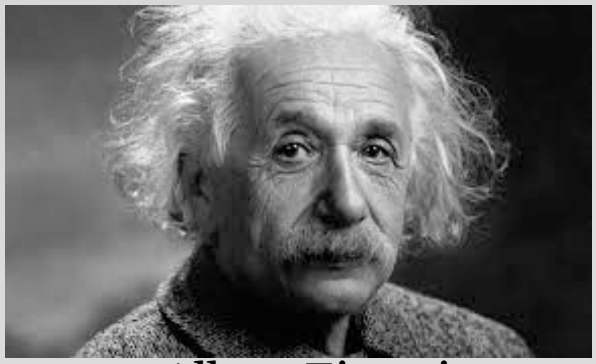
Force

Distance

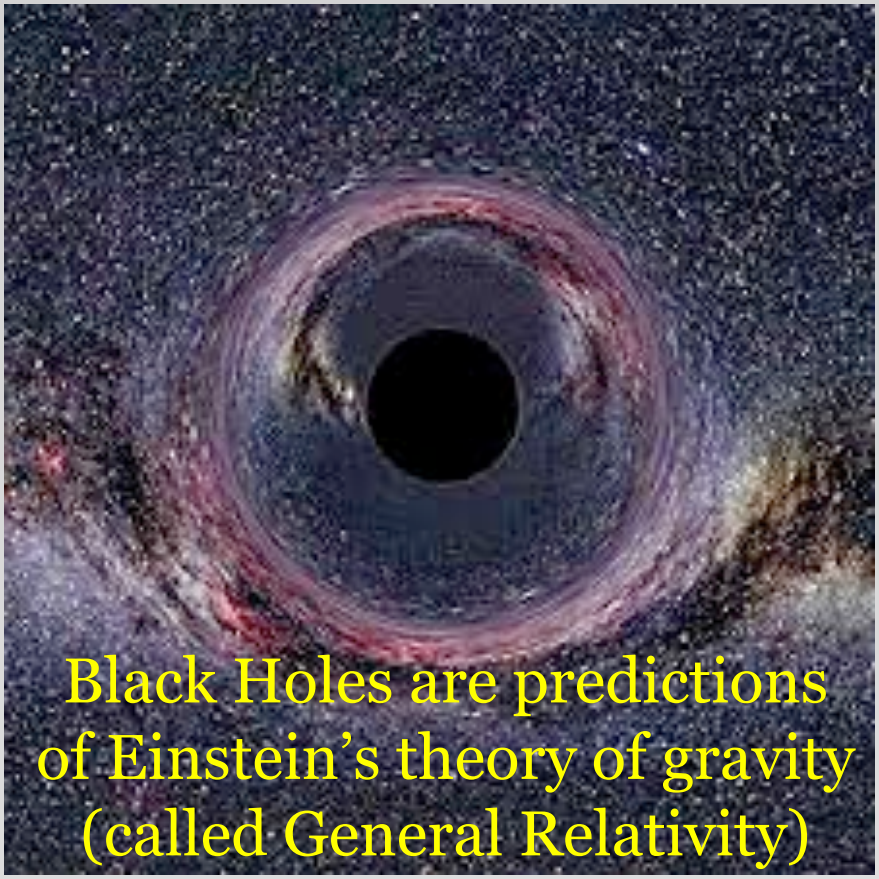
Isaac Newton

Additionally, we've learned that matter distorts space and time itself

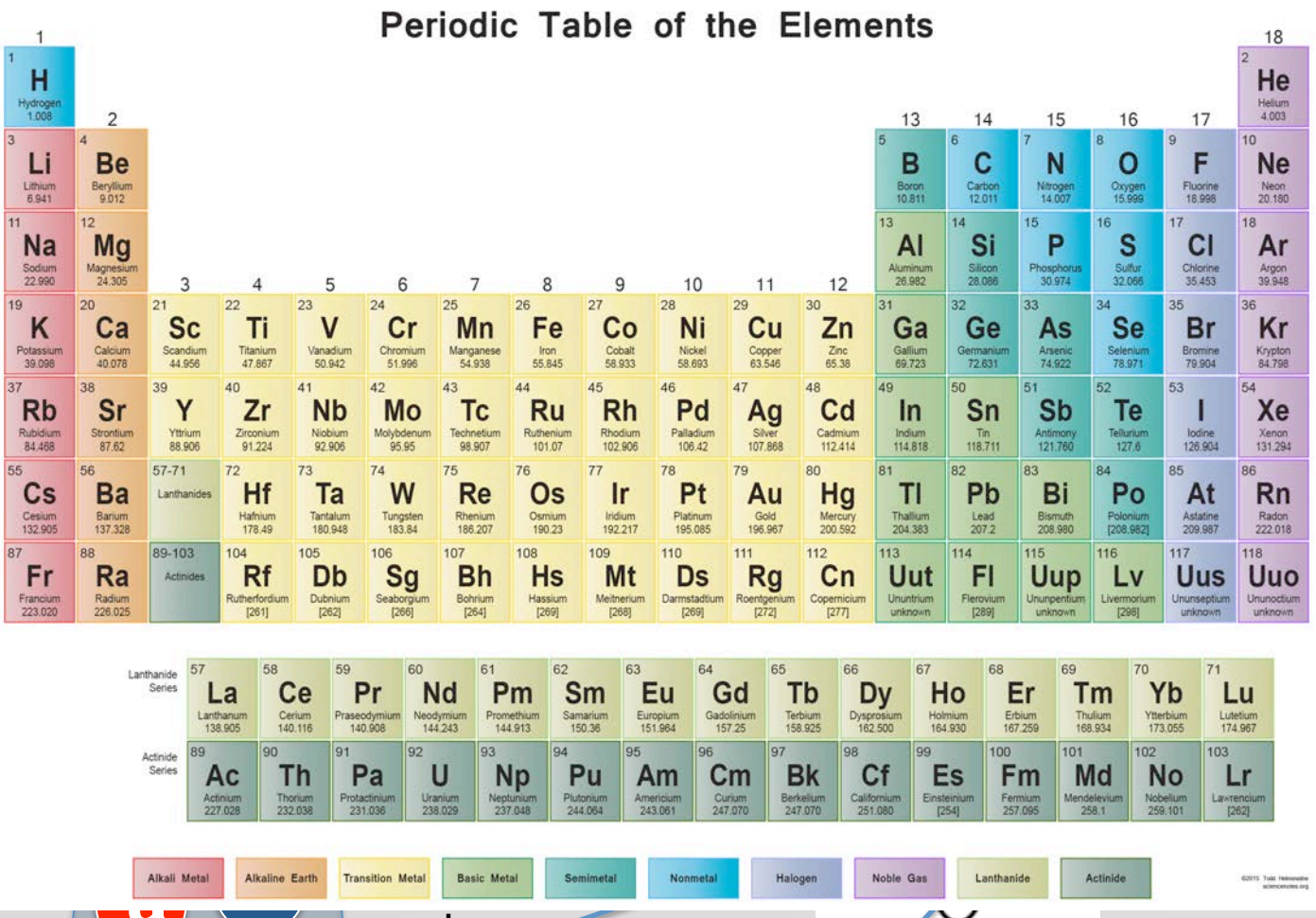




Albert Einstein



We know what matter is made of



"up quark"

"down quark"

neutrons

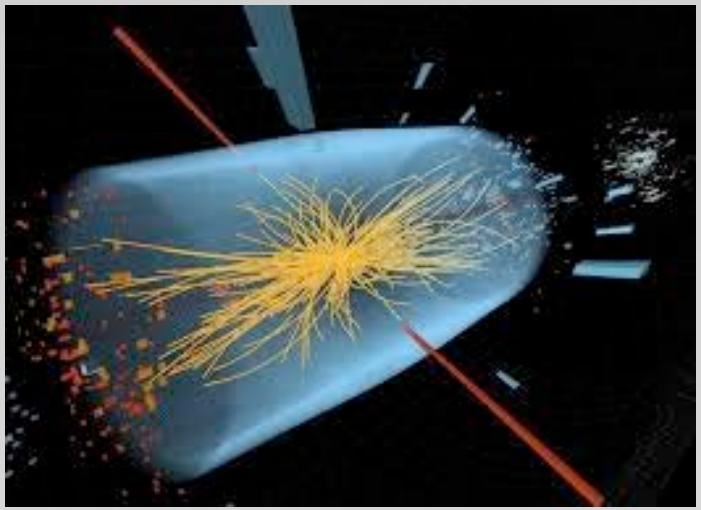
electrons

We can even *create* matter in a (big) laboratory

Accelerate protons to EXTREMELY high speeds.

$E = mc^2$

Collide the protons to create other particles



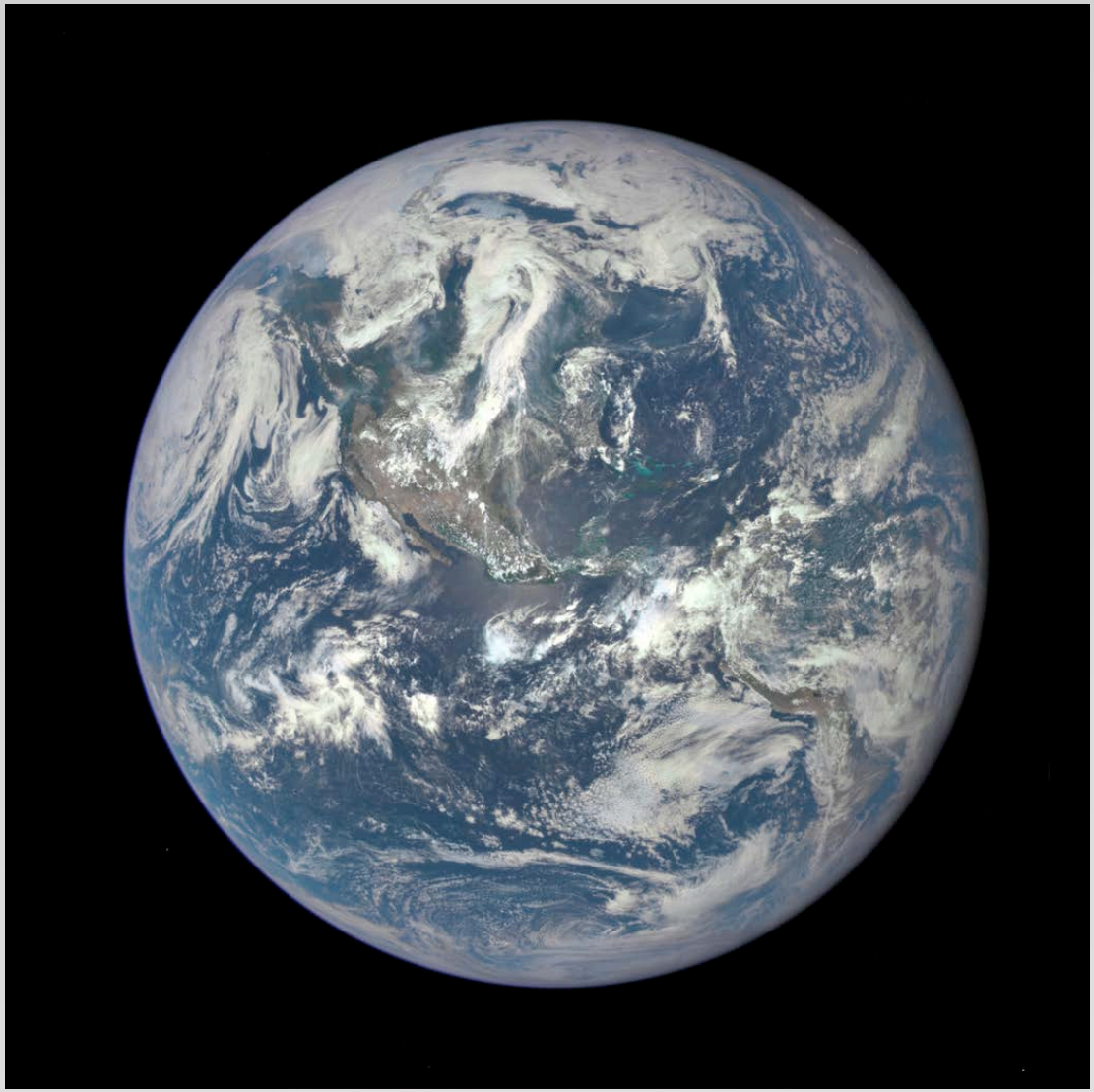
Detect these particles with a massive detector

WORLD

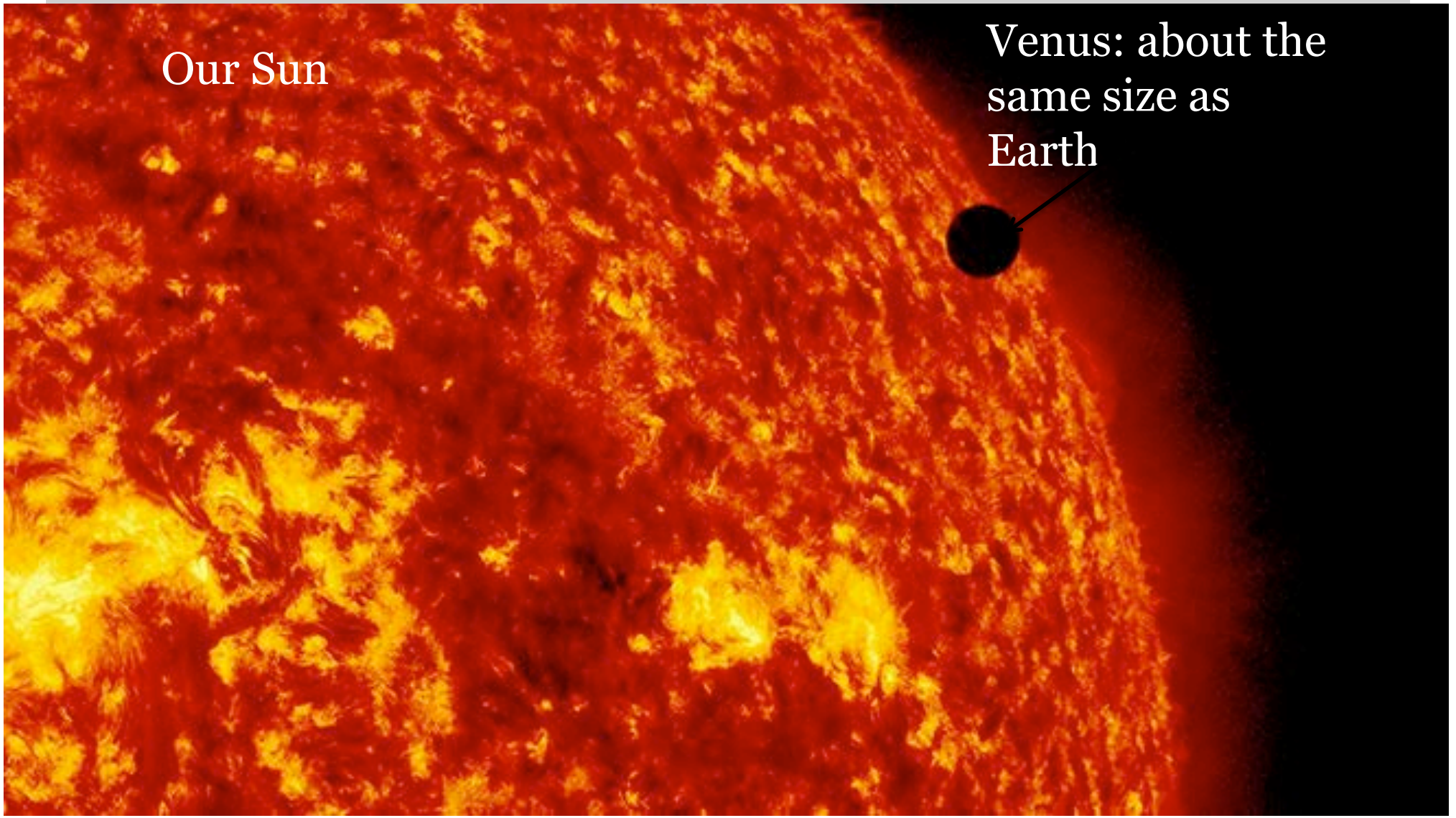
Physicists Celebrate Evidence Of 'God Particle'

A particle called the Higgs boson was detected this way in 2012, about 50 years after being *predicted* to exist!

We know there is A LOT of matter in the universe



We know there is A LOT of matter in the universe

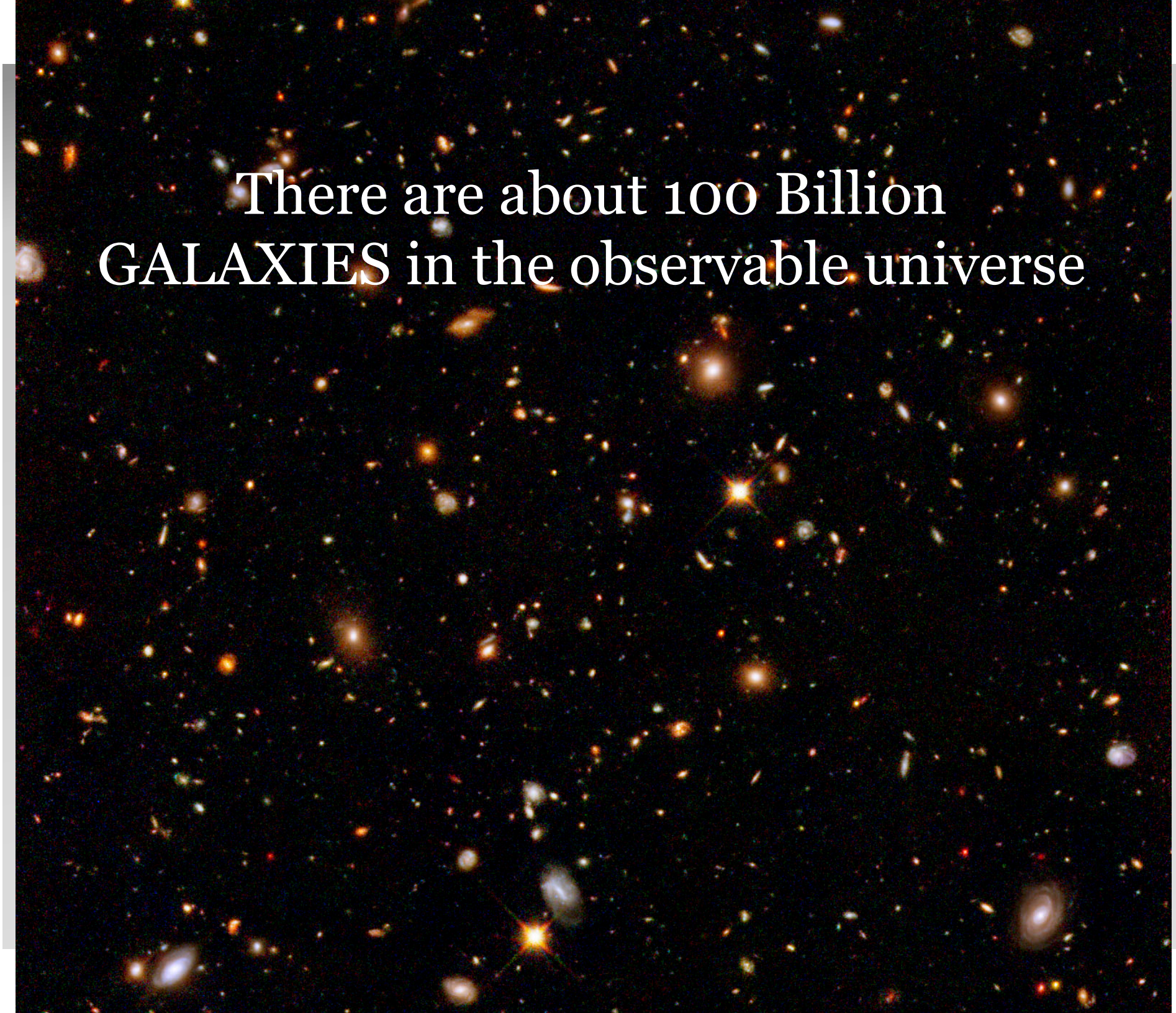


We know there is A LOT of matter in the universe

The Milky Way galaxy consists of about 100 Billion stars

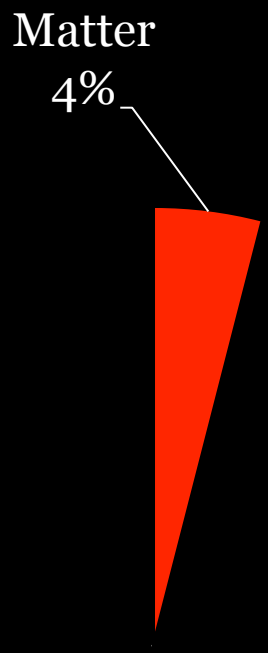
Our Milky Way galaxy as seen from Earth.

Photo credit: ESO/ S. Brunier

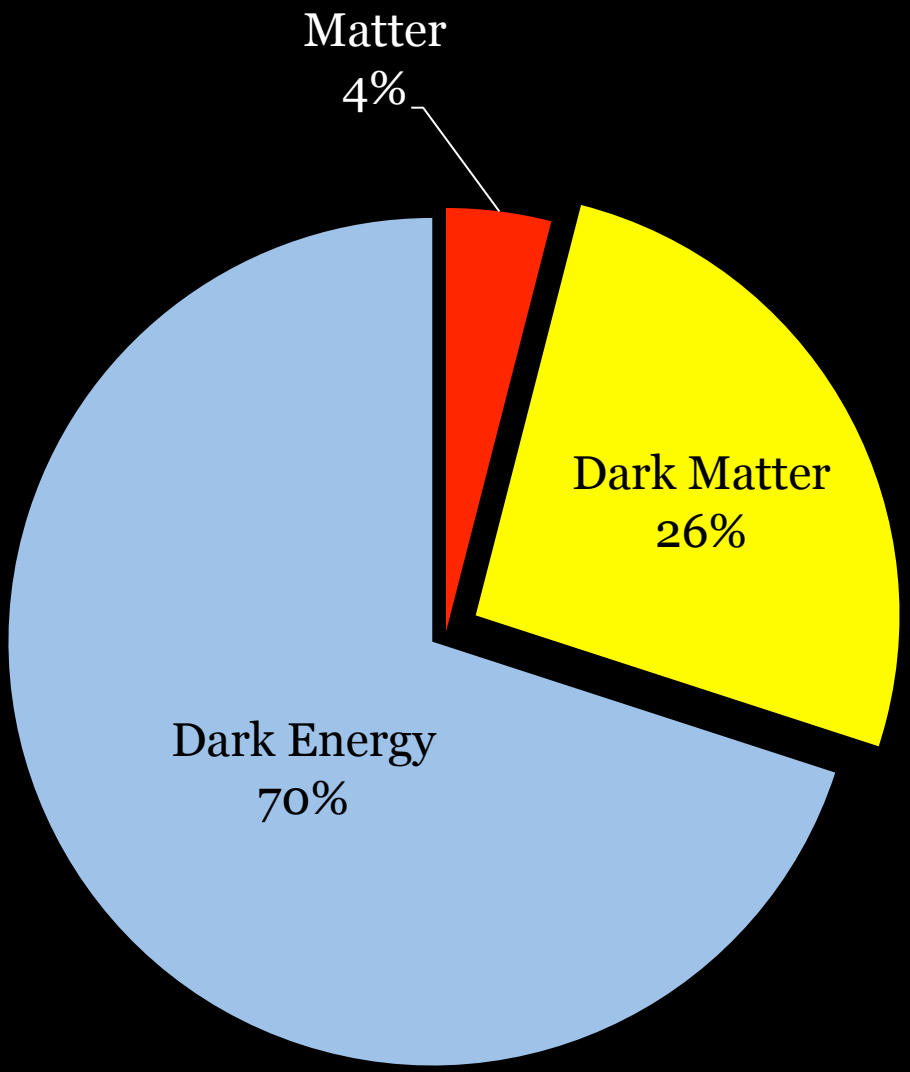

There are about 100 Billion
GALAXIES in the observable universe

The Universe

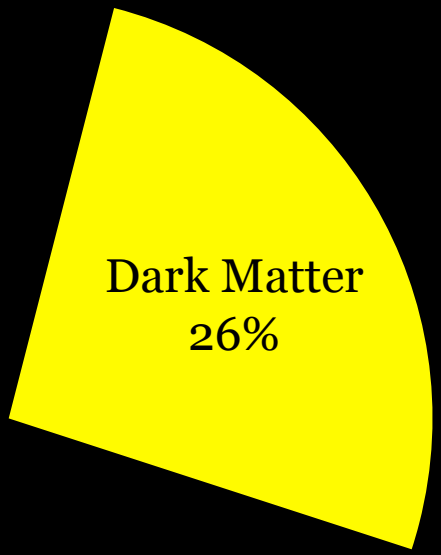
The Universe



The Universe



The Universe



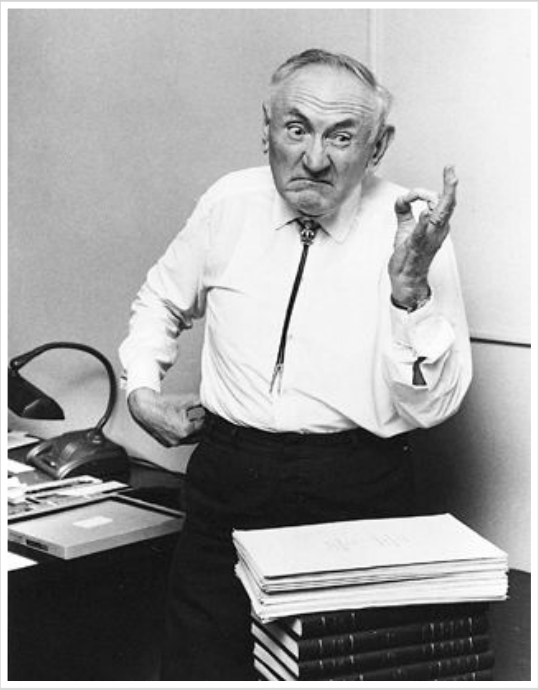
There is 5 times more Dark Matter than regular matter!

- More questions
  - How do we know dark matter exists?
  - What might dark matter be?
  - What are we doing to “find it”

Evidence for Dark Matter #1

1. Stars and galaxies are moving too fast

Jan Oort
(1932)



Fritz Zwicky
(1933)

Vera Rubin
(1970)

Remember our gravity equation?

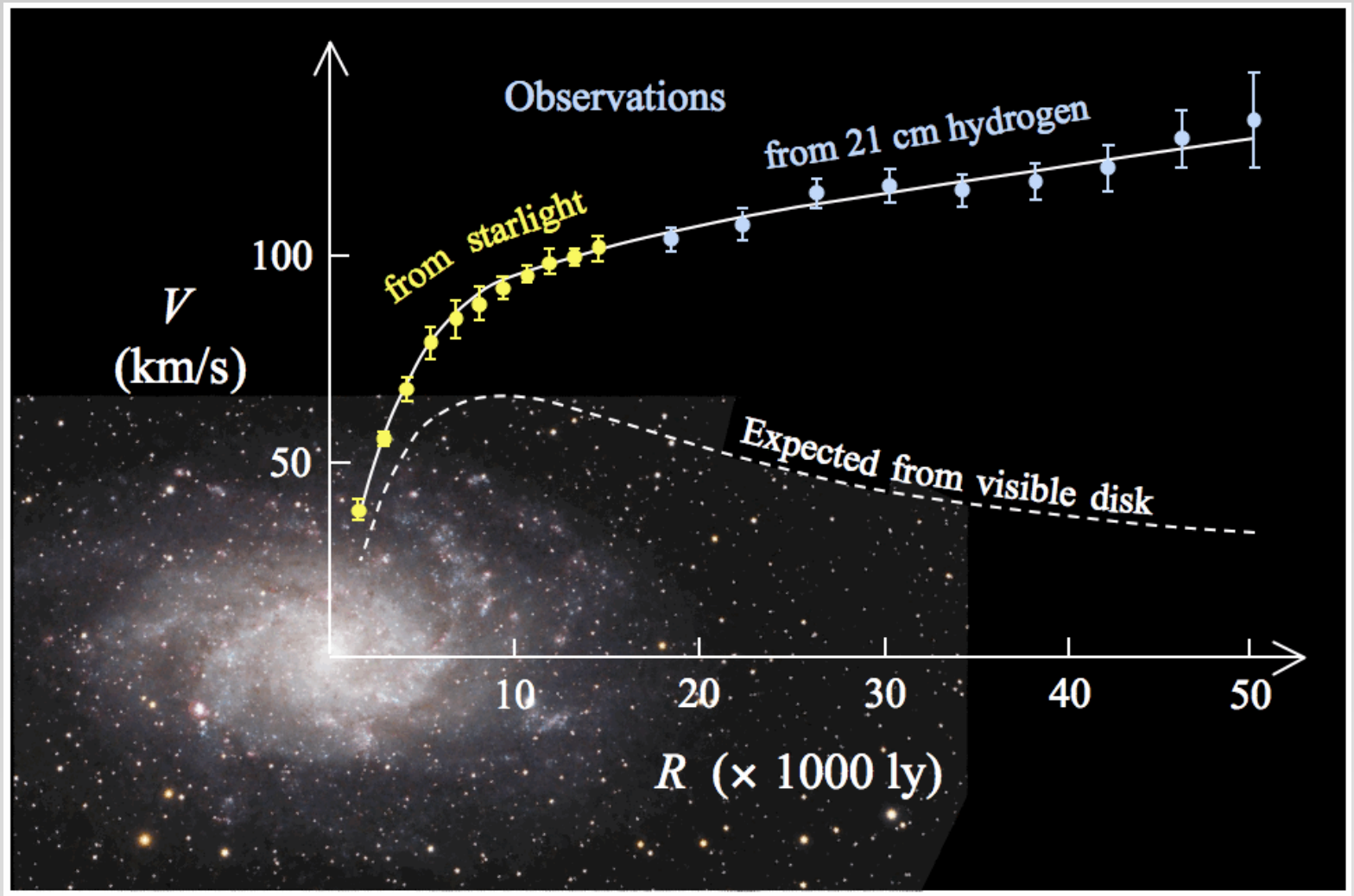
Mass (amount of matter)

$$F = \frac{GMm}{r^2}$$

Force

- From this equation we can predict how fast objects *should* move around each other.
- Using telescopes, we can test whether these predictions agree with what we observe

Predictions and measurements don't agree!



Predictions and measurements don't agree!

Mass (amount of matter)

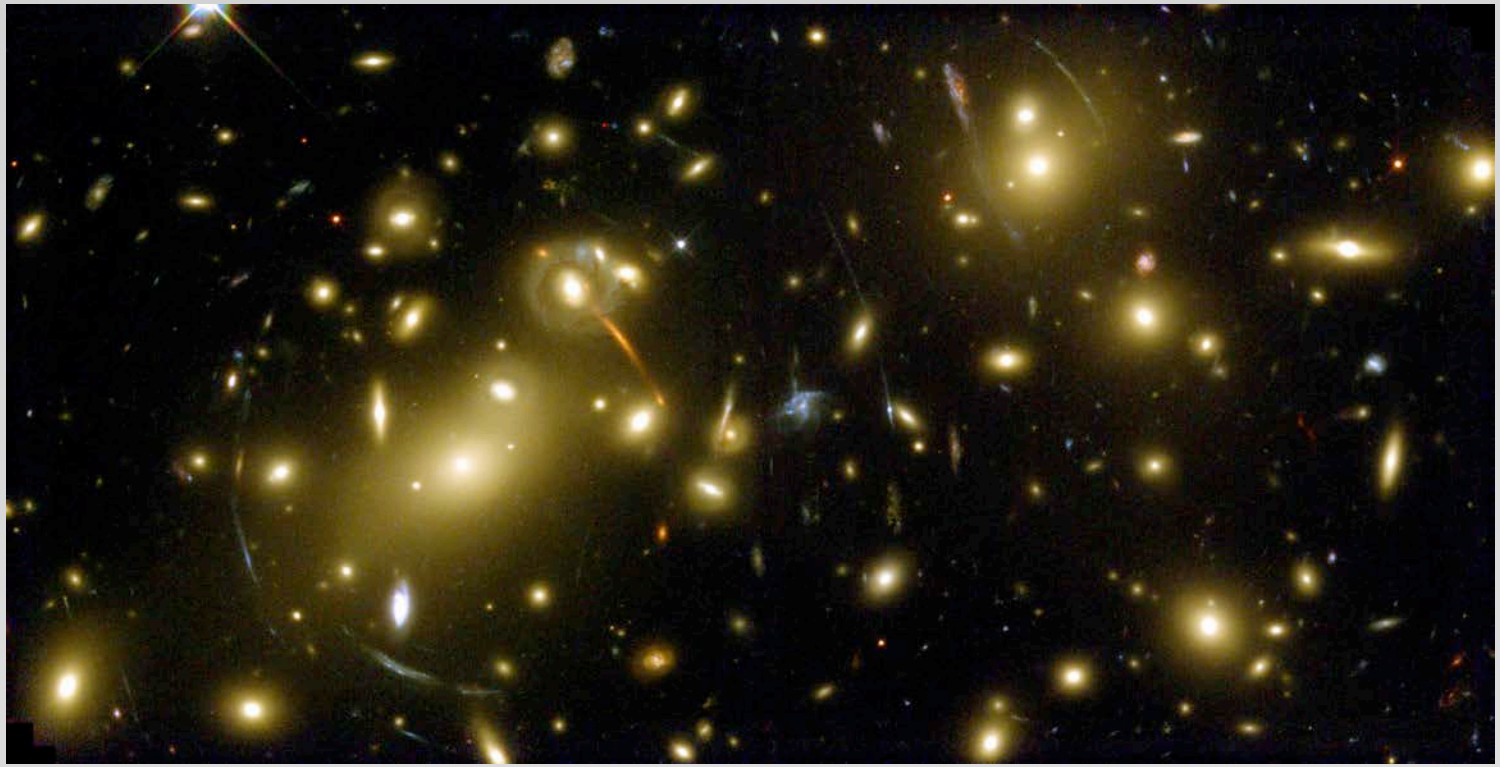
$$F = \frac{GMm}{r^2}$$

Force

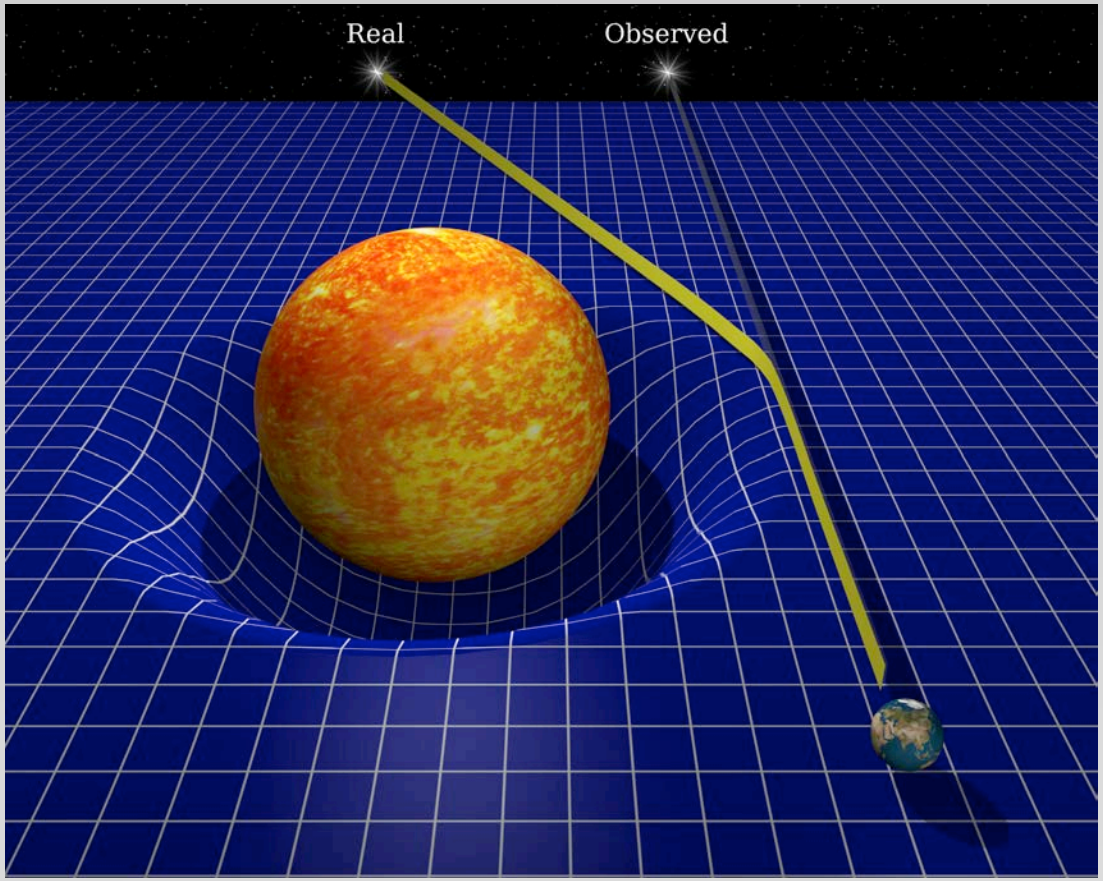
If galaxies and stars are moving too fast, maybe there's more mass (matter) than we can see!

Evidence for Dark Matter #2

2. Something called “gravitational lensing”

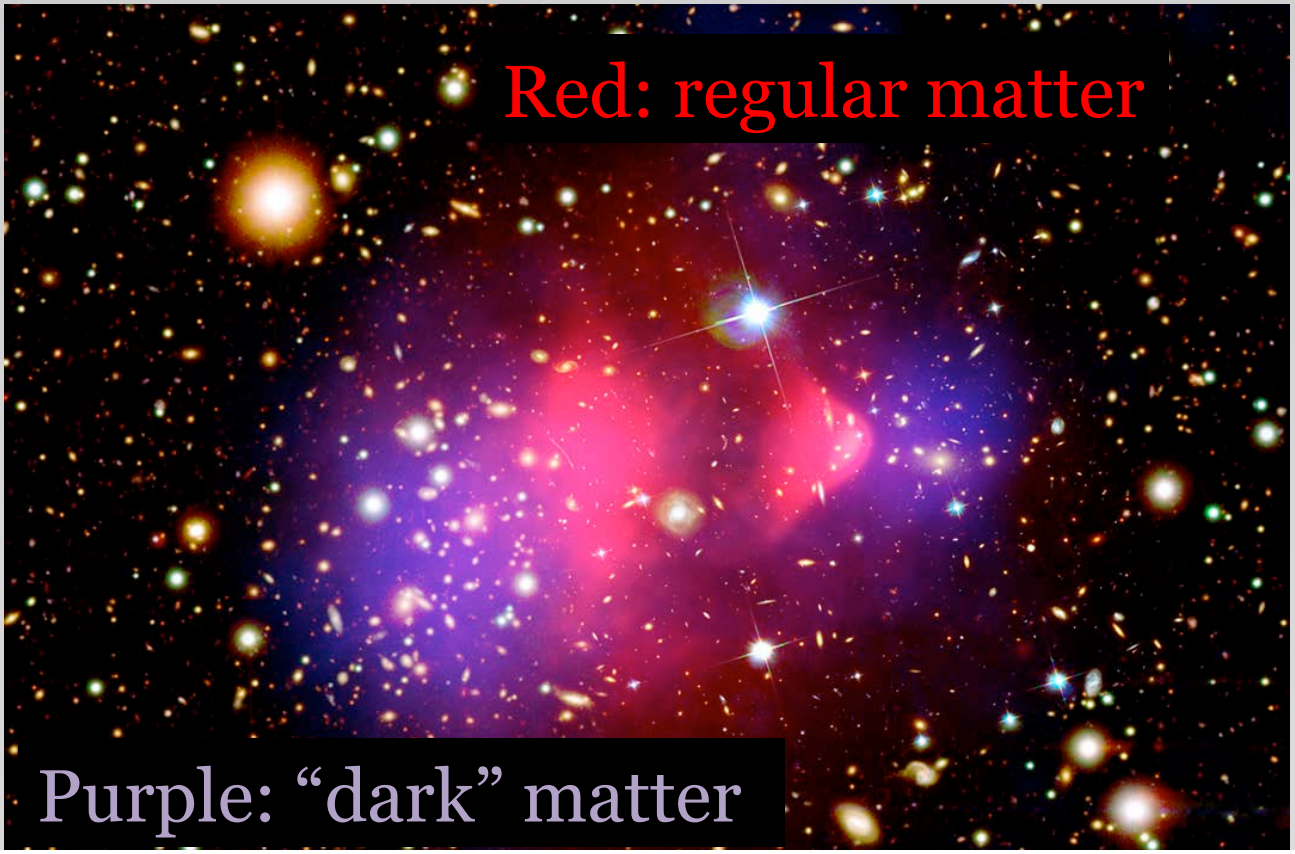


Remember the space distortions?



We can use this effect to determine how much matter is in a particular system

“Proof of Dark Matter” – The Bullet Cluster



A DIRECT EMPIRICAL PROOF OF THE EXISTENCE OF DARK MATTER *

Douglas Clowe[1], Maruša Bradač[2], Anthony H. Gonzalez[3], Maxim Markevitch[4,5], Scott W. Randall[4], Christine Jones[4], and Dennis Zaritsky[1]

ApJ Letters in press

ABSTRACT

We present new weak lensing observations of 1E0657−558 ($z = 0.296$), a unique cluster merger, that enable a direct detection of dark matter, independent of assumptions regarding the nature of the

Evidence for Dark Matter #3,4,5,…

- No time to discuss the others here, but the evidence is truly overwhelming

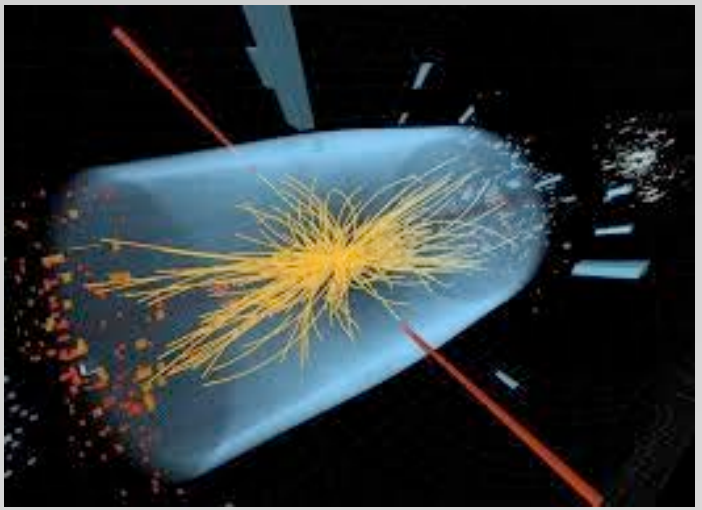
- The evidence all points to a new type of matter that:
  - causes gravity similarly to ordinary matter
  - does not interact with light: it is “dark”

So, what could dark matter be?

- We've been able to predict the existence of new particles for decades…
- Maybe dark matter is made of a new type of particle!

There are a lot of ideas

Can we create dark matter like we have made other particles?



Not yet – but we're trying.

The collider recently turned back on after a large update, so stay tuned!

Galaxies (including our own) are floating in a cloud of dark matter

So maybe we can detect dark matter directly

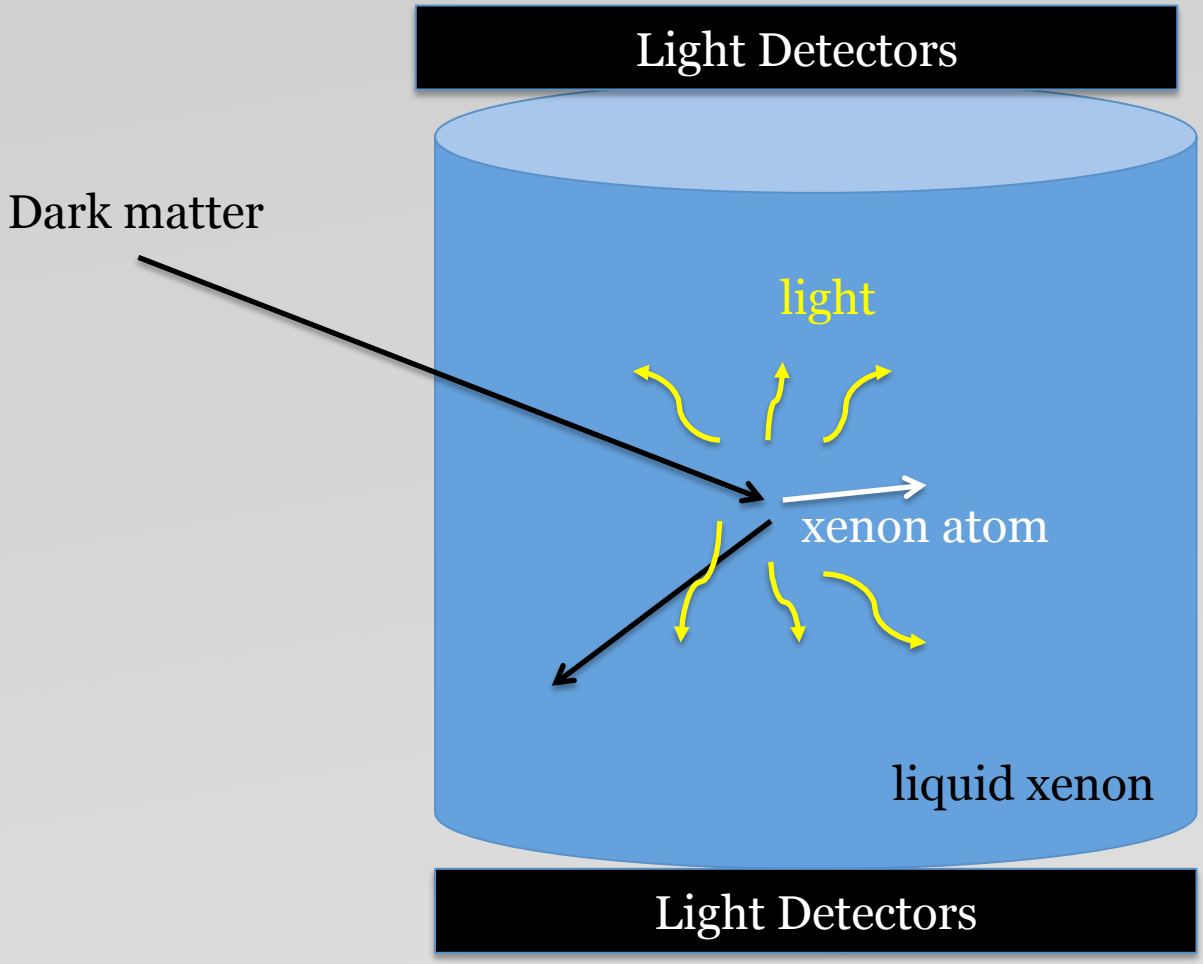
- Dark matter is passing through us right now

- Occasionally, these particles should interact with ordinary matter
- Let's look for those interactions!


My experiment: XENON1T


Columbia
RPI
Nikhef
Mainz
Stockholm
Muenster
Chicago
MPIK
UCLA
Bern
UCSD
Zurich
Rice
NYUAD
Purdue
Coimbra
Subatech
Bologna
LNGS
Torino
Weizmann

XENON1T searches for WIMPs (weakly interacting massive particles) using liquid xenon

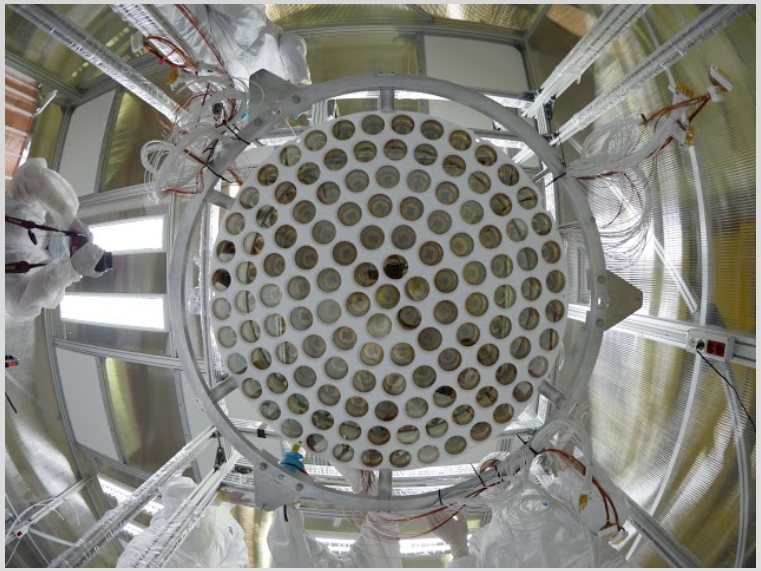


We place the detector deep underground to get away from other kinds of interactions

XENON1T is located at Gran Sasso National Laboratory in central Italy

I was able to travel to Italy last fall!

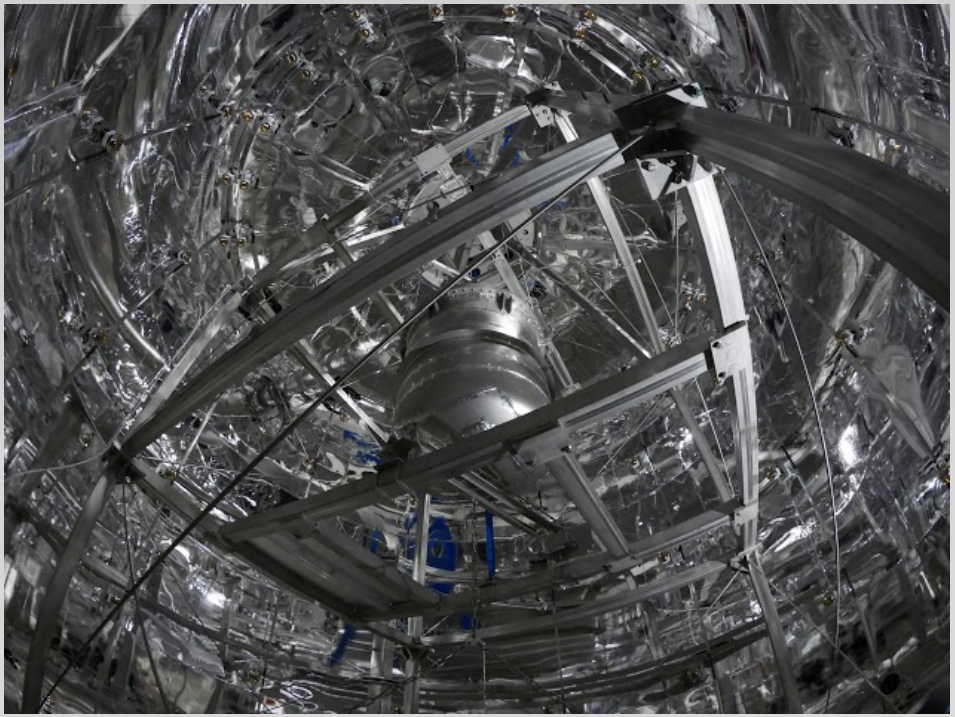
Assembling XENON1T



Assembling XENON1T

Assembling XENON1T

Assembling XENON1T



Exciting times!

- XENON1T is now filled with 3.5 tons of liquid xenon and in the commissioning stage

- After about 10 days of science data, XENON1T will be among the most sensitive WIMP detectors in the world

Thank you!