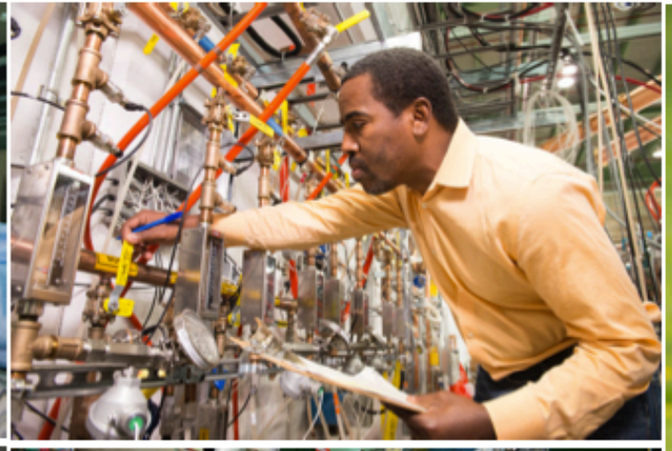
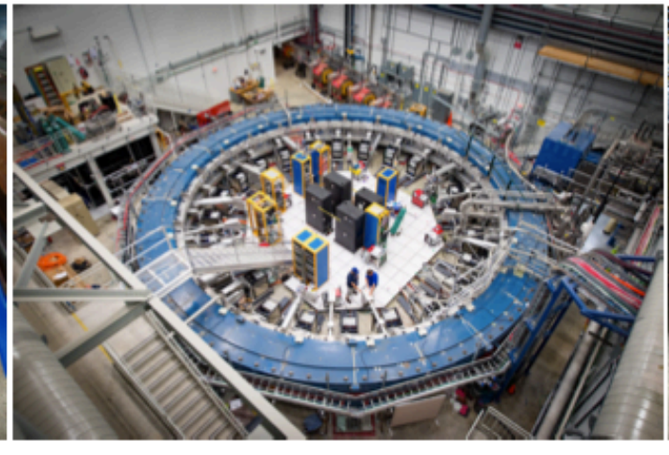
Superheores in STEM: Keynote

Juan Estrada
Scientist “senior”, Fermilab
May 1st, 2021






Fermilab is America's particle physics and accelerator laboratory.

Our vision is to solve the mysteries of matter, energy, space and time for the benefit of all. We strive to:

- **lead the world in neutrino science with particle accelerators**
- **lead the nation in the development of particle colliders and their use for scientific discovery**
- **advance particle physics through measurements of the cosmos**

Juancito

Born in Argentina. Child number 6, in a family with 8 kids.
Grew up in USA, Austria, Brazil, Chile and Argentina. Lots of different schools, lots of different languages, lots of different cultures. Could not really figure out what was going on at school until ~7th grade…

Not a star student.

University ➜ Graduate School ➜ Fermilab

Started at Universidad de Buenos Aires in Argentina. Public school, no tuition, 100% admission rate. Awesome place!

Came to the US as a graduate student to get my PhD in physics at University of Rochester.

Continued at Instituto Balserio, by the mountains in Argentina.

Worked on Fermilab science as a student in the Tevatron collider

This is what we study at Fermilab

Fermions: spin = 1/2 particles

Quarks

u up
c charm
t top
d down
s strange
b bottom

e electron
μ muon
τ tau
ν_e electron neutrino
ν_μ muon neutrino
ν_τ tau neutrino

Leptons

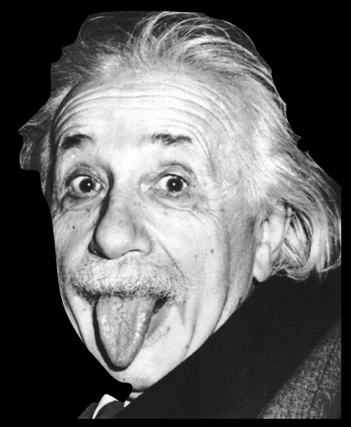
H Higgs boson

Higgs Boson: spin = 0 fundamental scalar particle

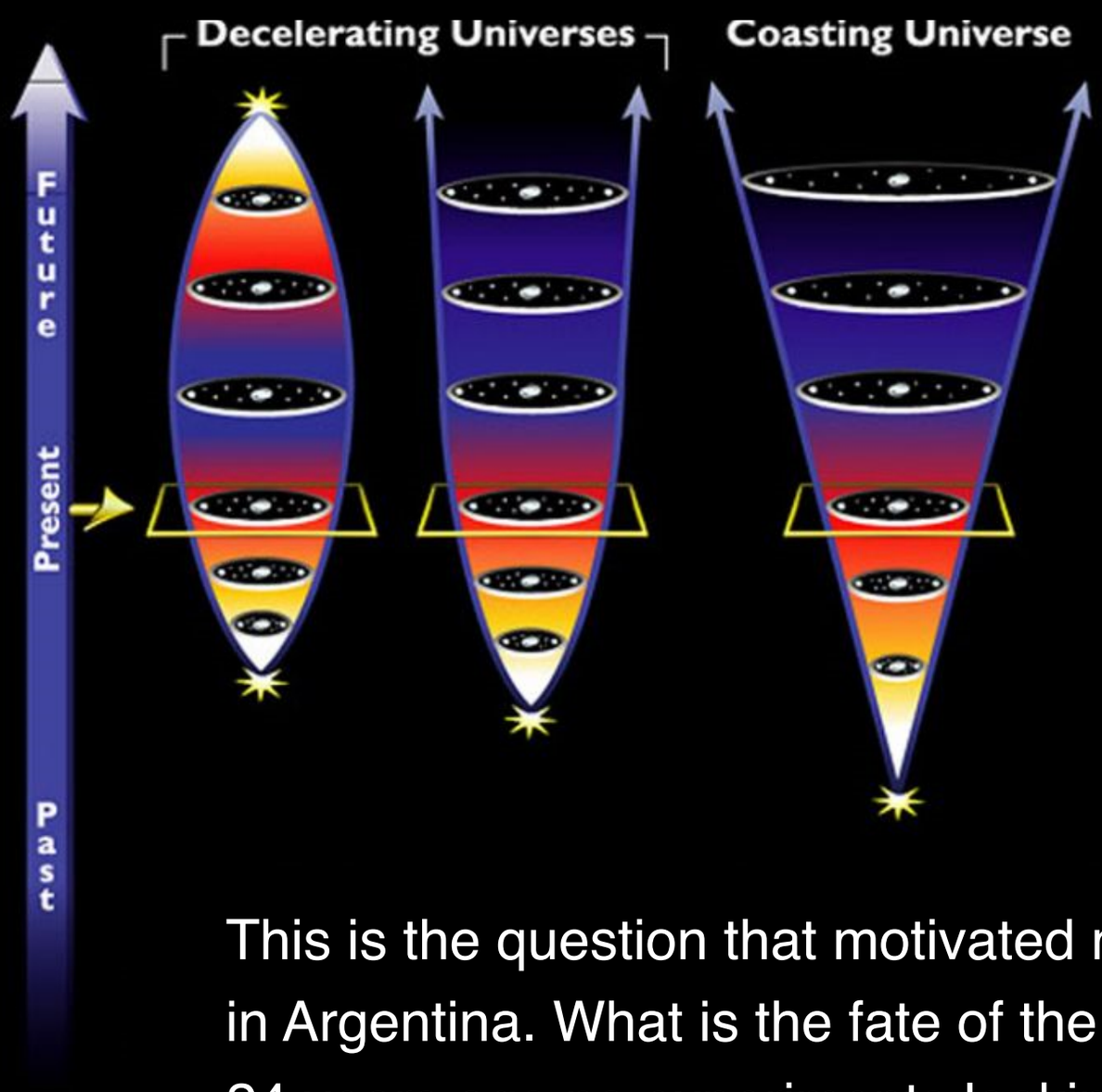
Vector Bosons: spin = 1 particles

Forces

Z Z boson
γ photon
W W boson
g gluon



+ gravity



This is the question that motivated me from very early as a student in Argentina. What is the fate of the Universe?

24 years ago no experiments looking at this… (almost)

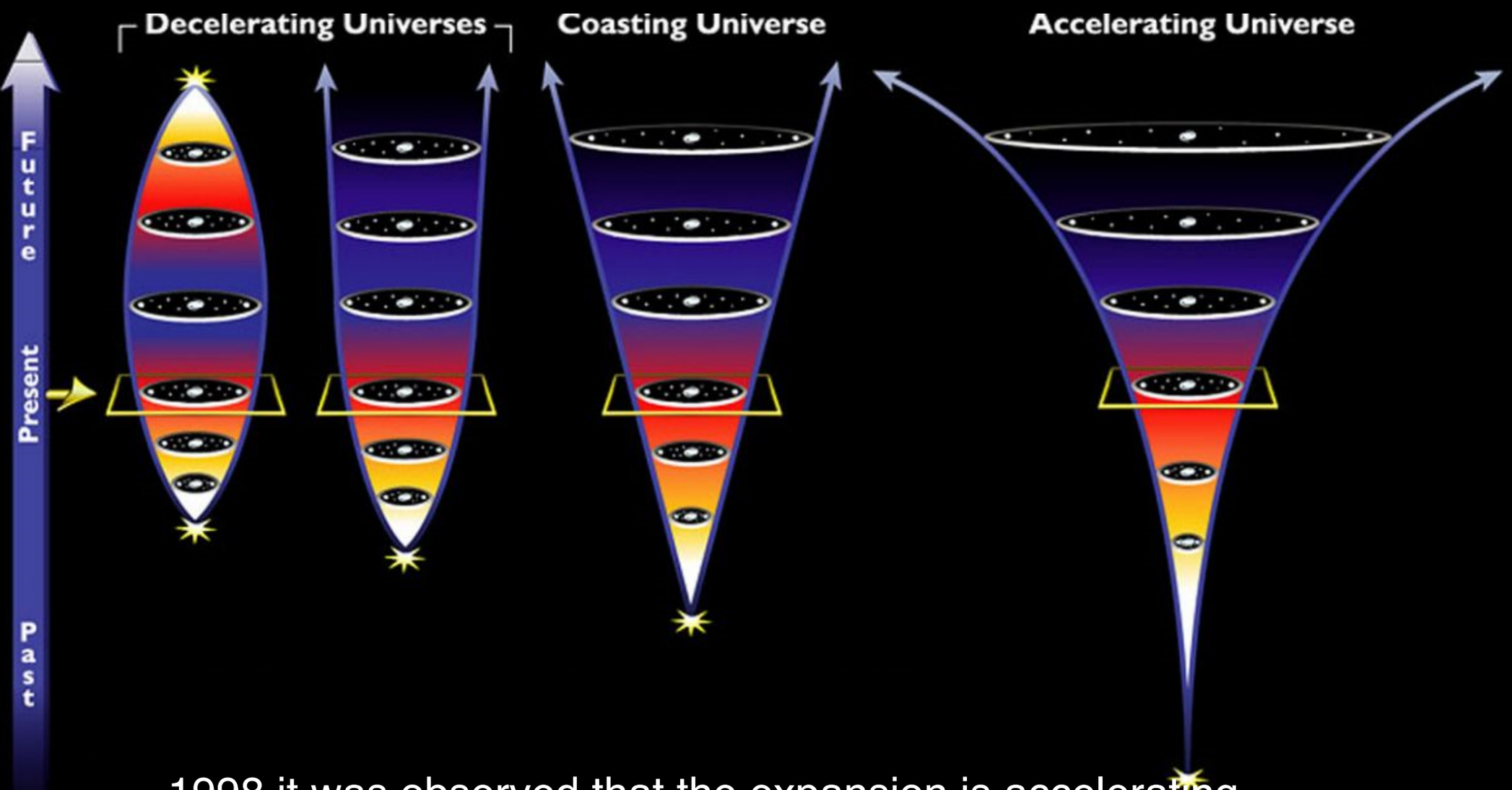
Dark Energy, big surprise!

Photo: U. Montan
Saul Perlmutter

Photo: U. Montan
Brian P. Schmidt

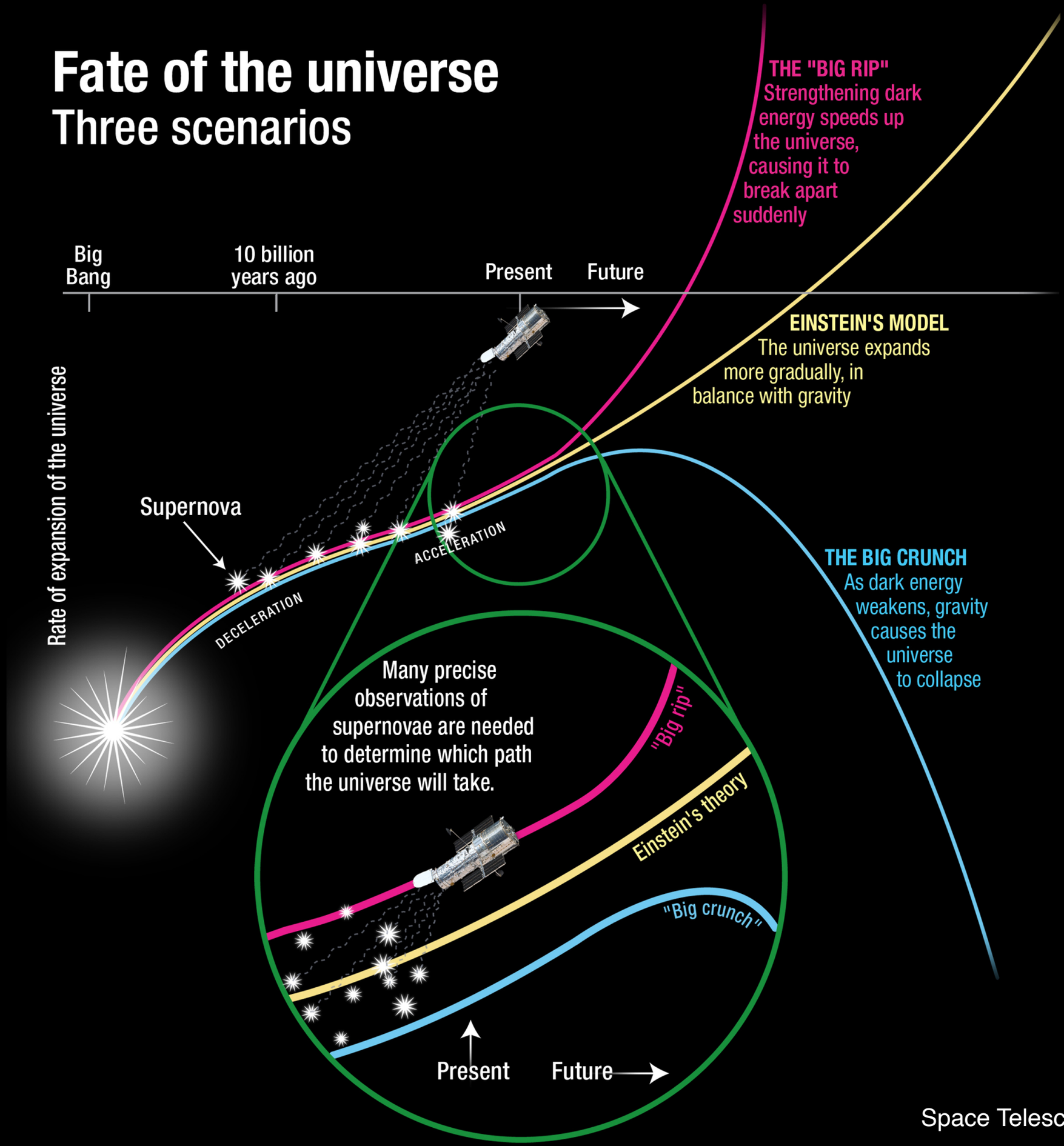
Photo: U. Montan
Adam G. Riess

measurement in 1998
Nobel in 2011



1998 it was observed that the expansion is accelerating

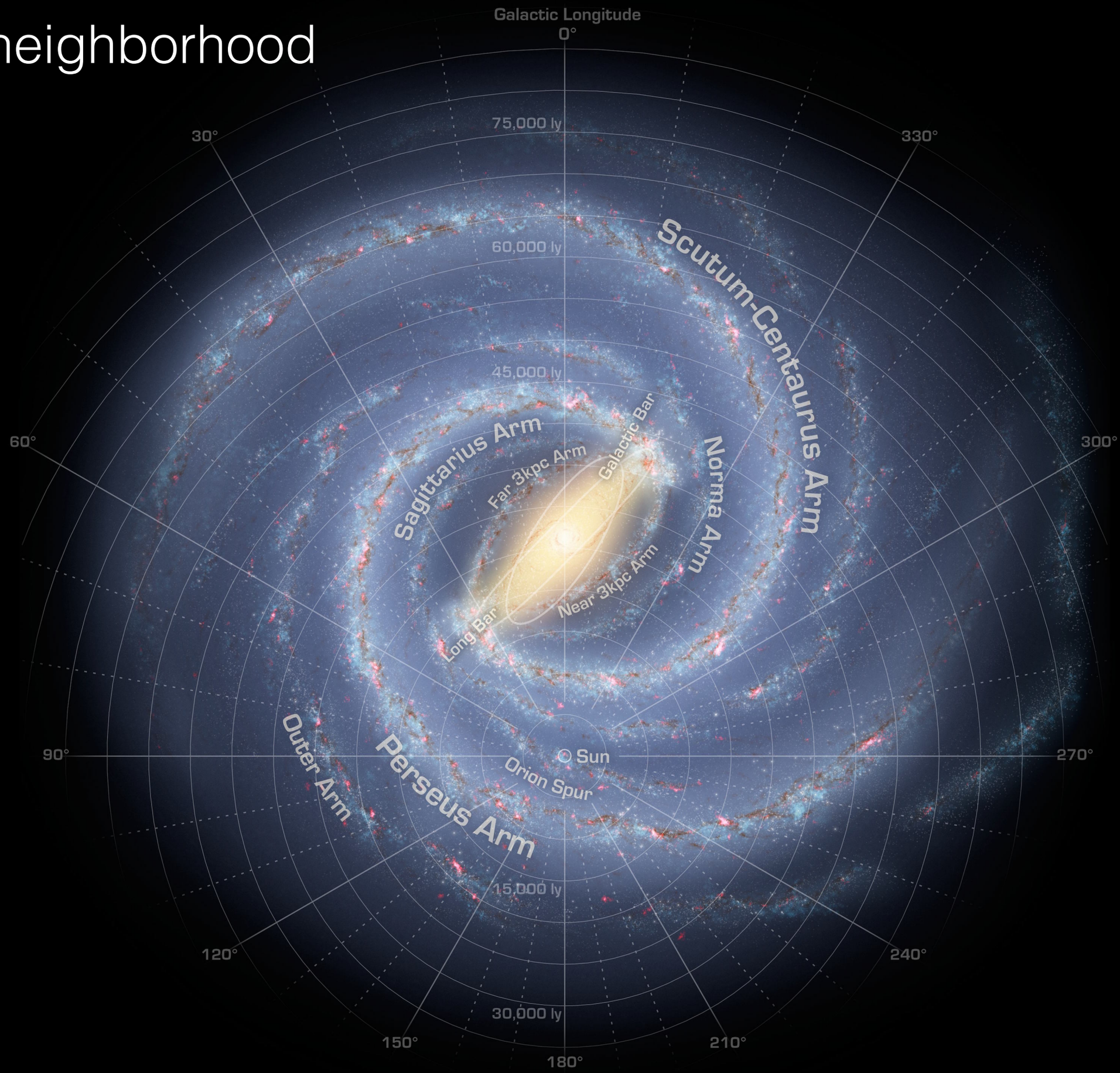
Fate of the universe
Three scenarios



Space Telescope Science Institute

How much matter in a galaxy?

your neighborhood



its really a kids game

1980: Rotation curves points to Dark Matter

Vera Rubin

(1928 -2016)

Observations

from 21 cm hydrogen

from starlight

100

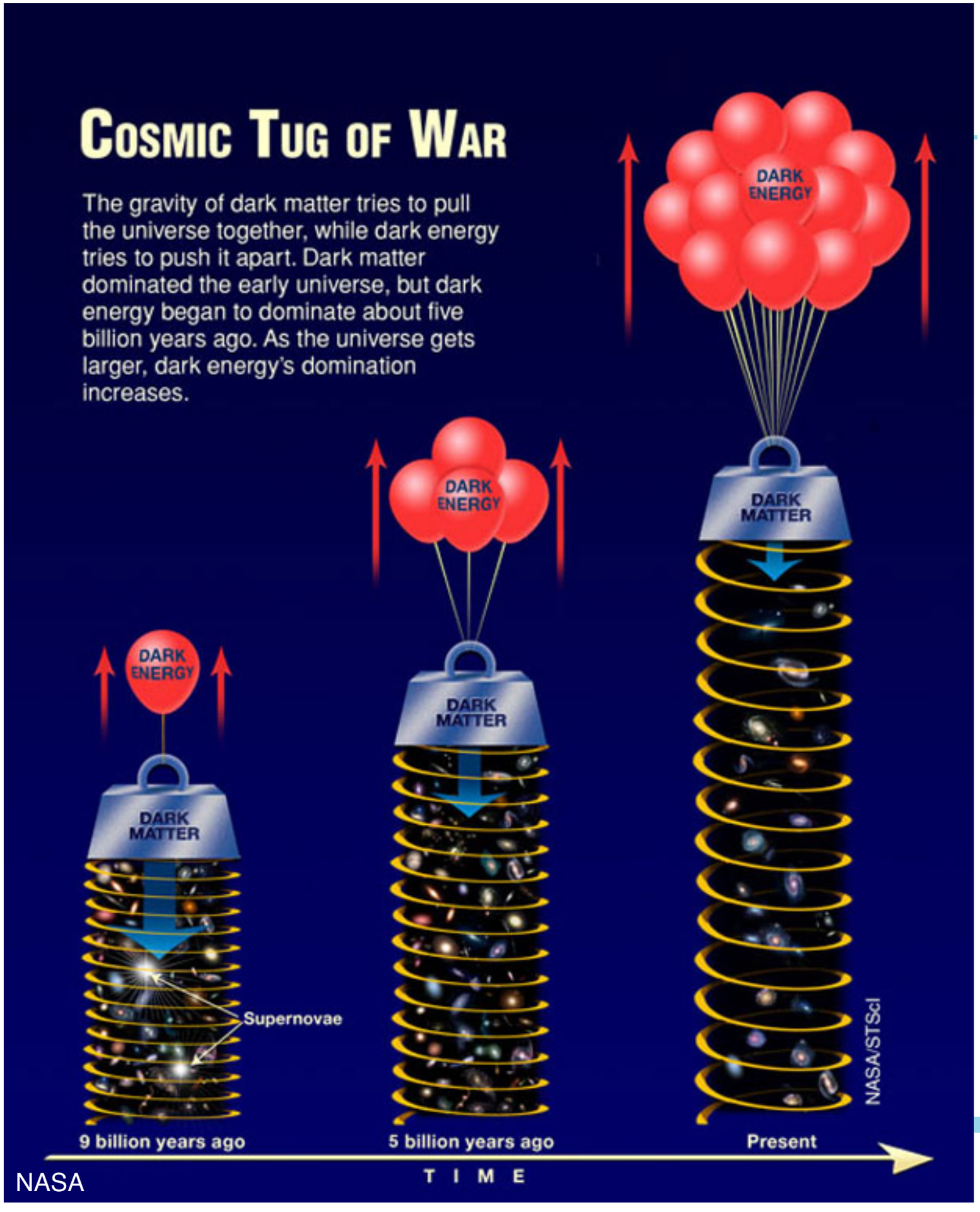
50

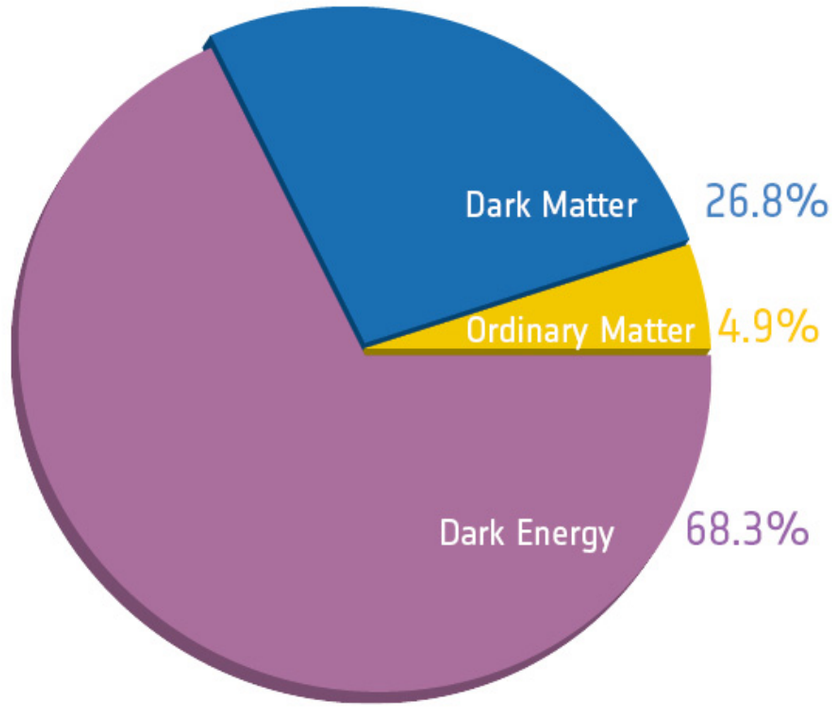
V (km/s)

Expected from visible disk

10 20 30 40 50

R (× 1000 ly)

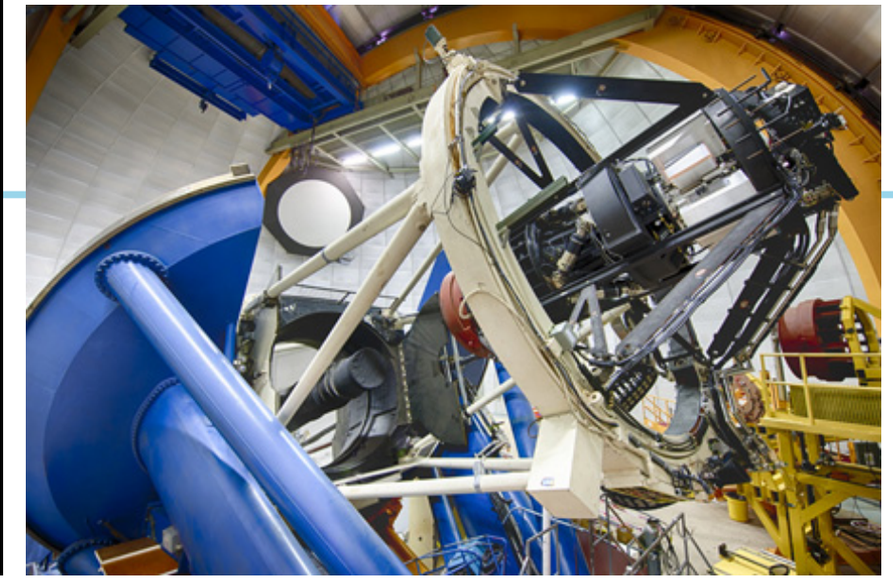




The dynamics of the universe is dominated by a repulsive force we do not understand , Dark Energy.

The part we do understand (gravity) is coming from a particle that is not part of our standard model, Dark Matter.

Fermilab

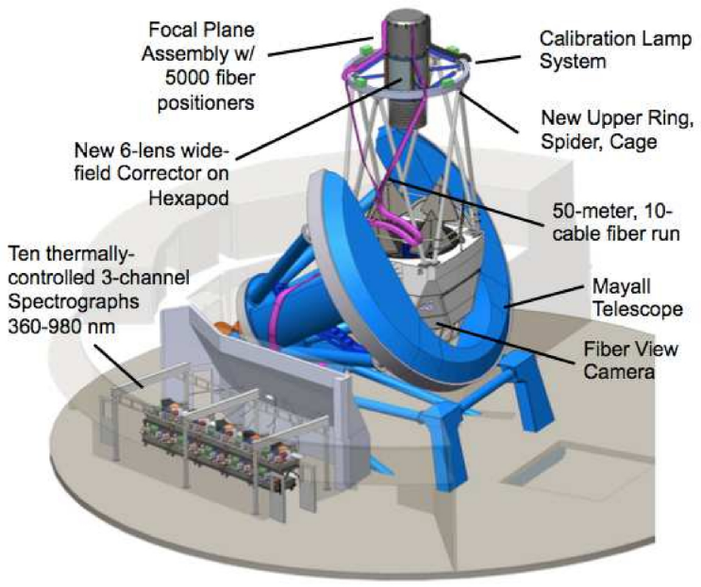


2012

At Fermilab we build instruments to measure the effects of dark matter and dark energy. Dark Energy Camera in Chile. Images of 300 million galaxies.

Fermilab

Dark Energy Spectroscopic Instrument (Arizona, Kitt Peak)



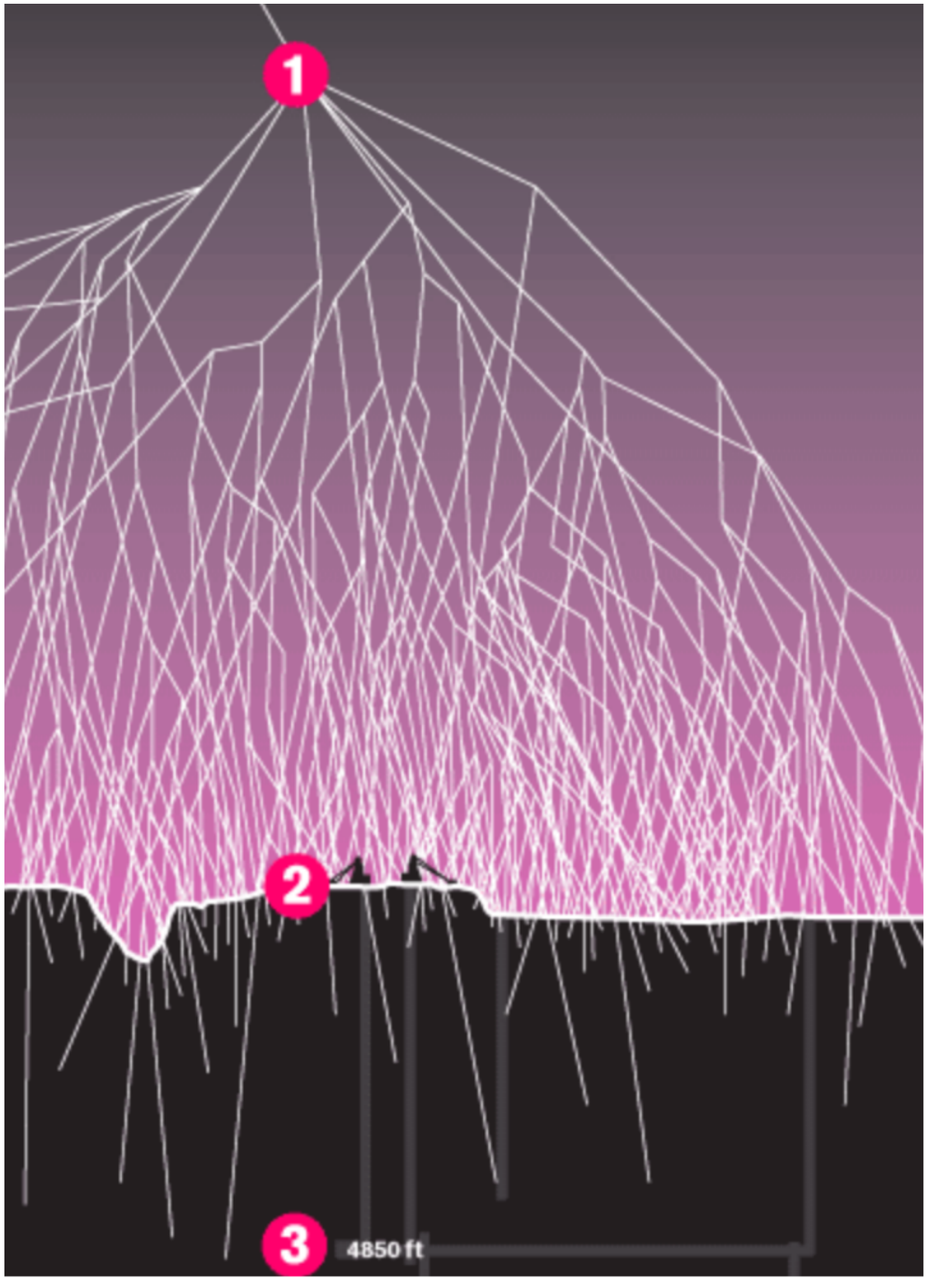
Measure the spectrum for 35 million galaxies

Dark Matter

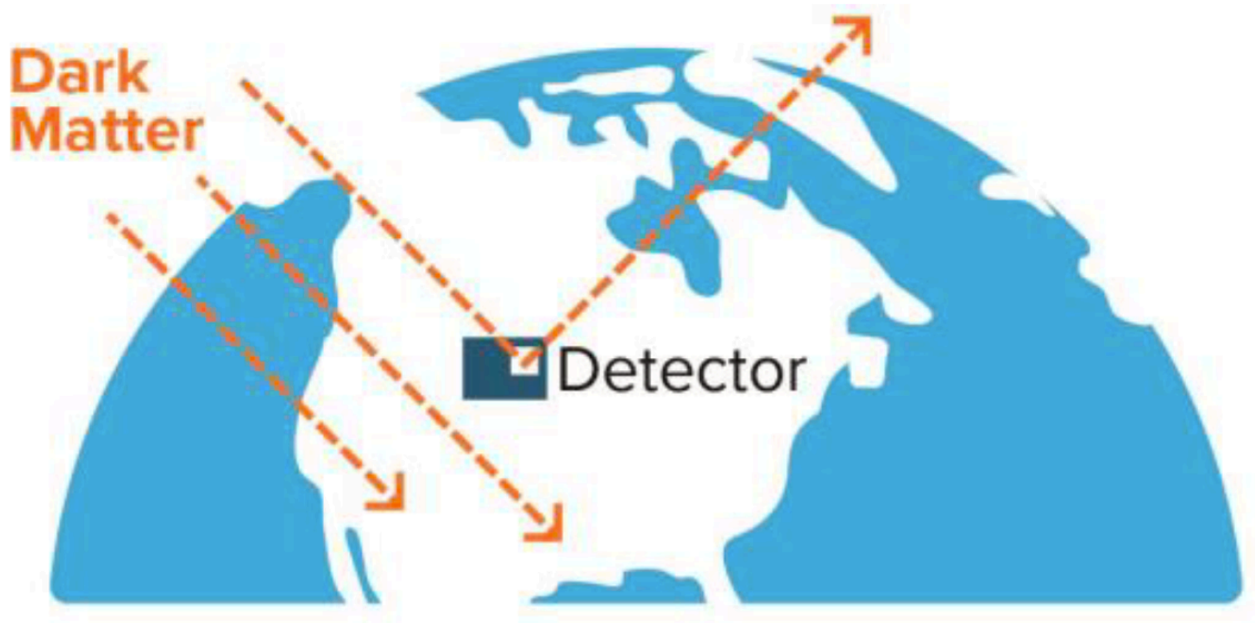
density: 6×10^{-28} kg/cm^{-3}

let's assume that it is formed by particles with the mass of a proton (1.7×10^{-27} kg)

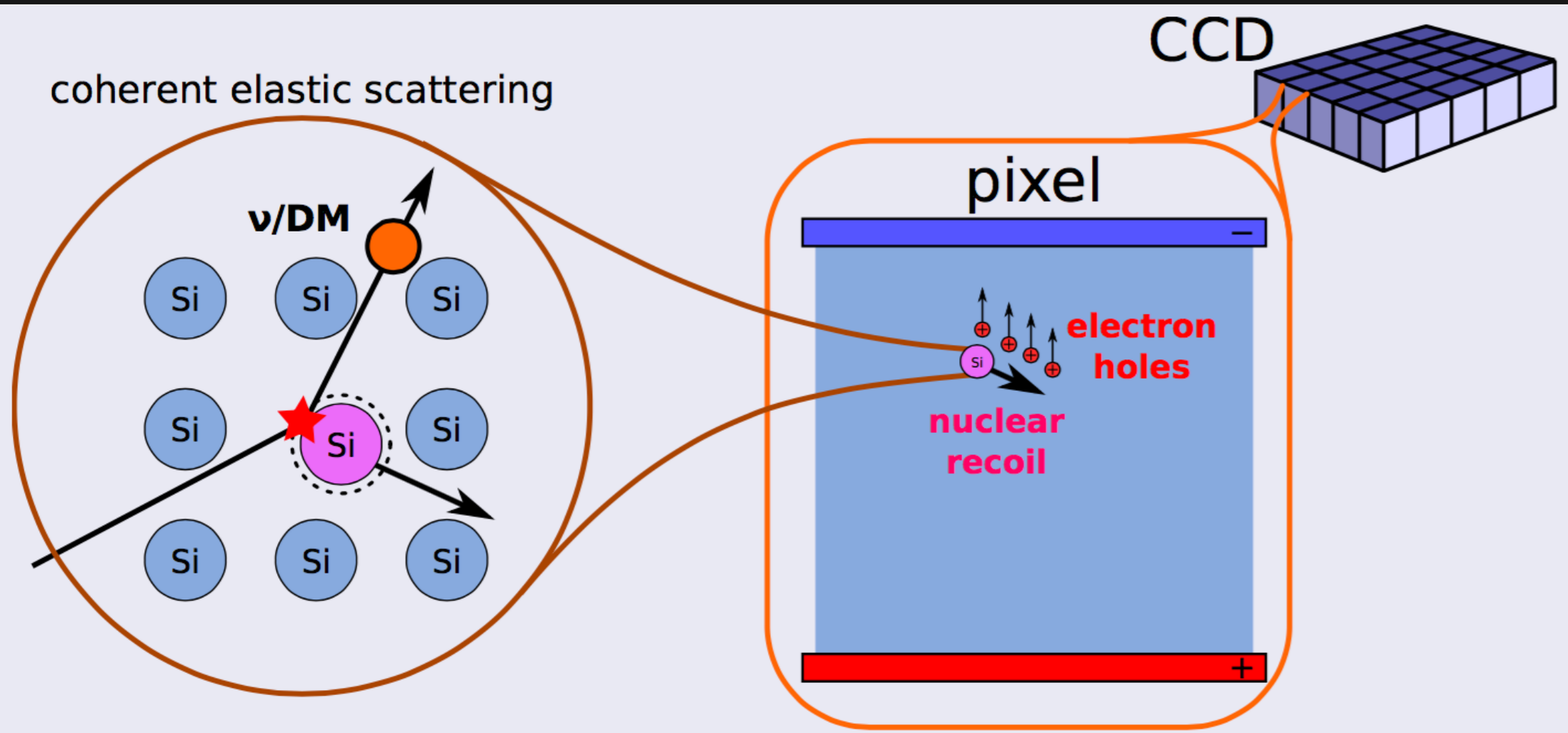
It should be everywhere…, but moving fast, velocities ~ 200 km/sec.



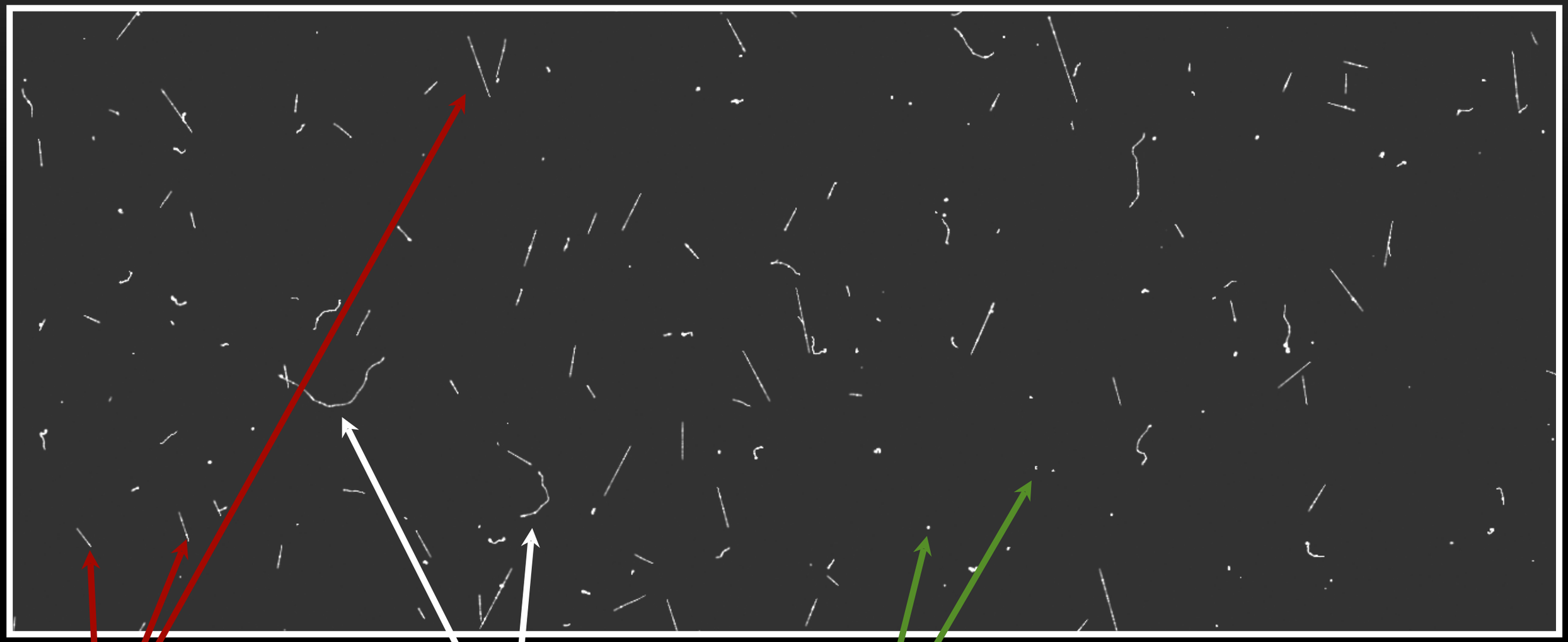
At Fermilab build very sensitive detectors and install them underground to search for dark matter particles.



Direct Dark Matter search in Collaboration with digital cameras

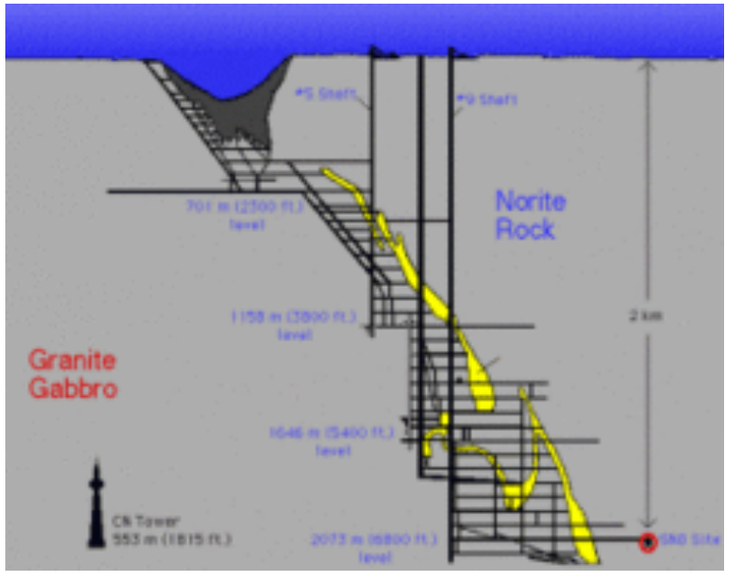


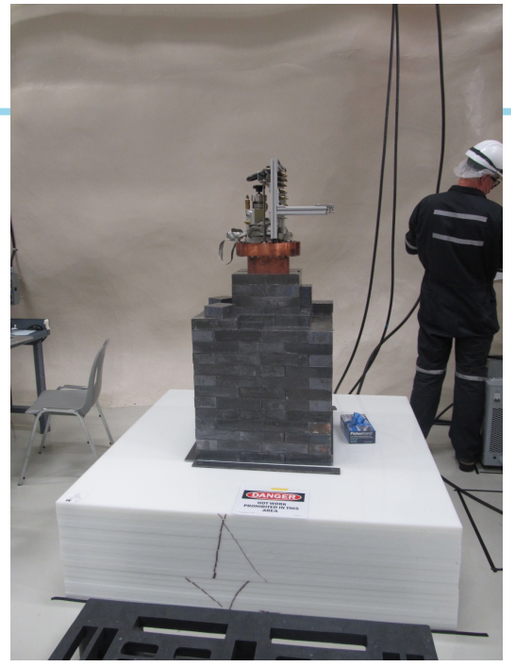
Particle identification in a CCD image



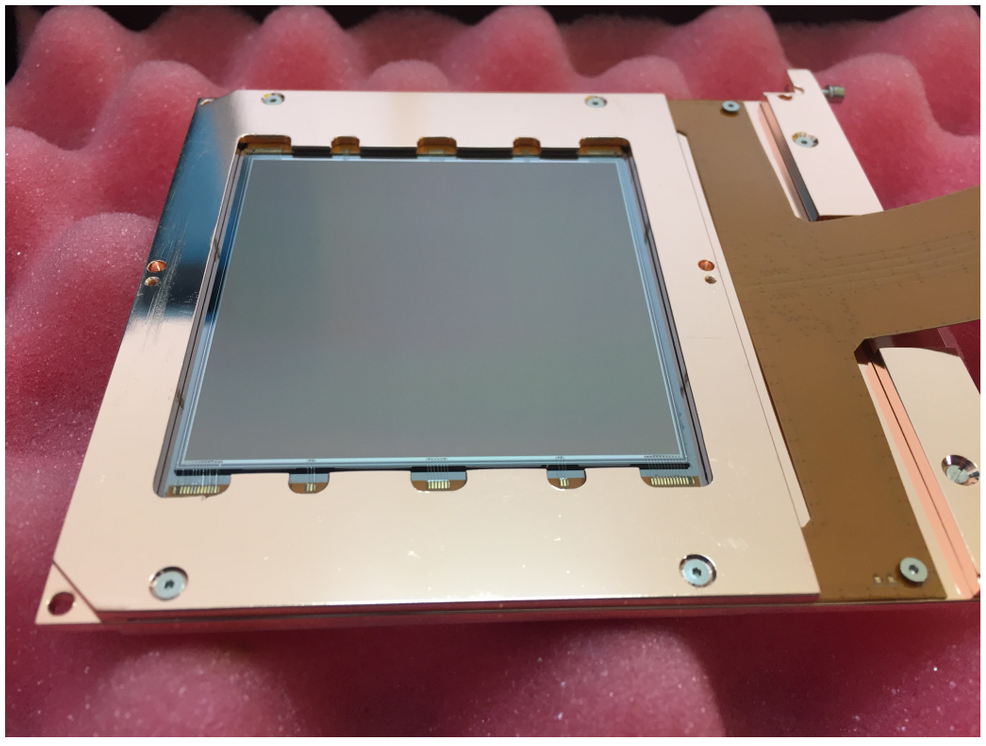
muons, electrons and diffusion limited hits.

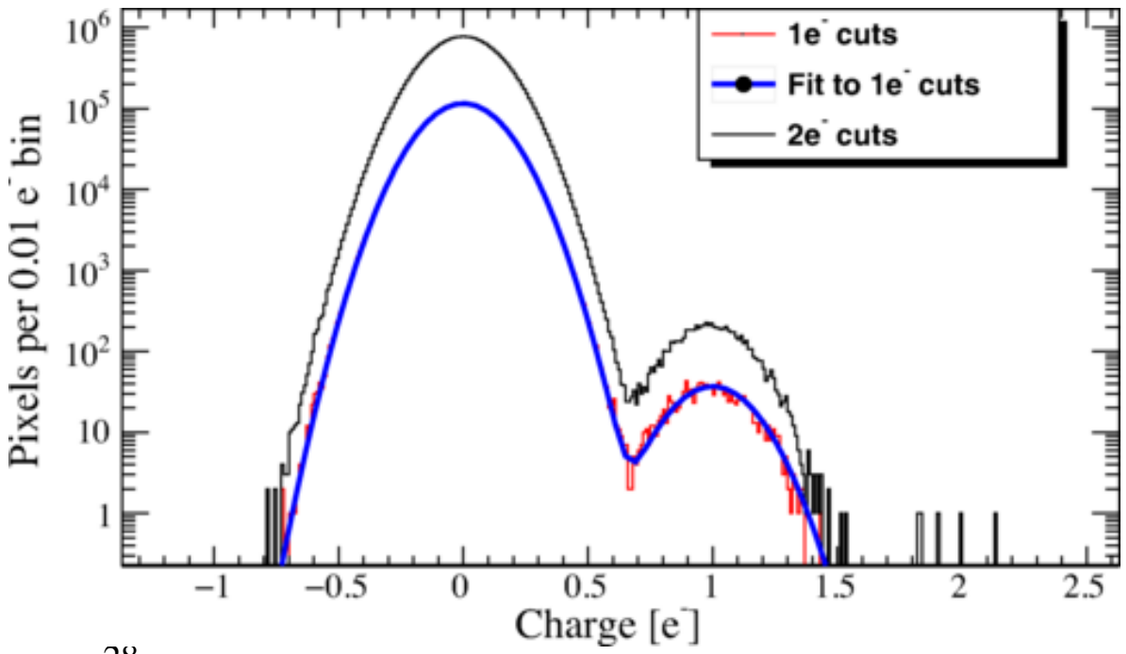
we also build and operate detectors 1 mile deep underground to look for Dark Matter particles.

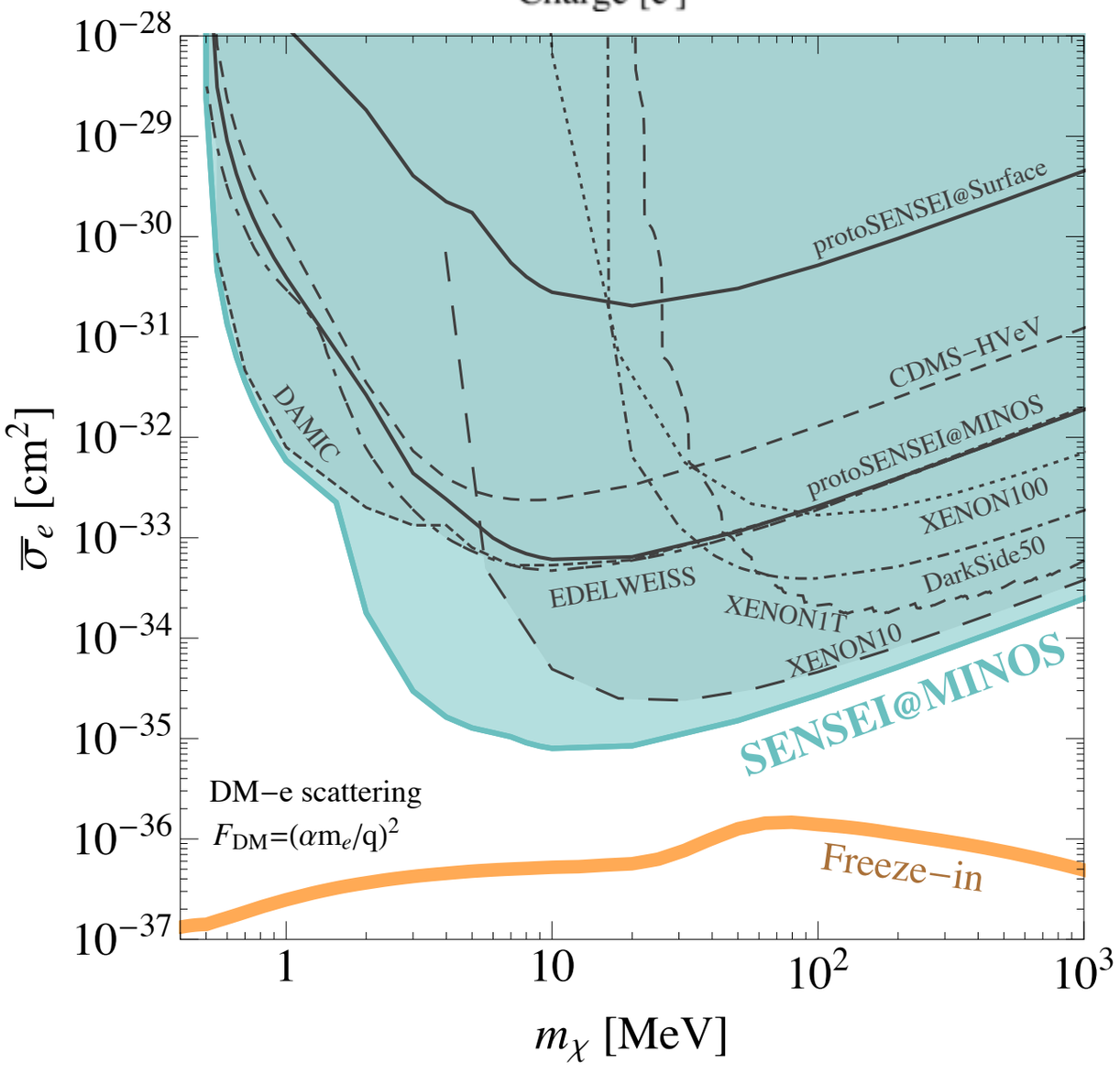




DAMIC experiment







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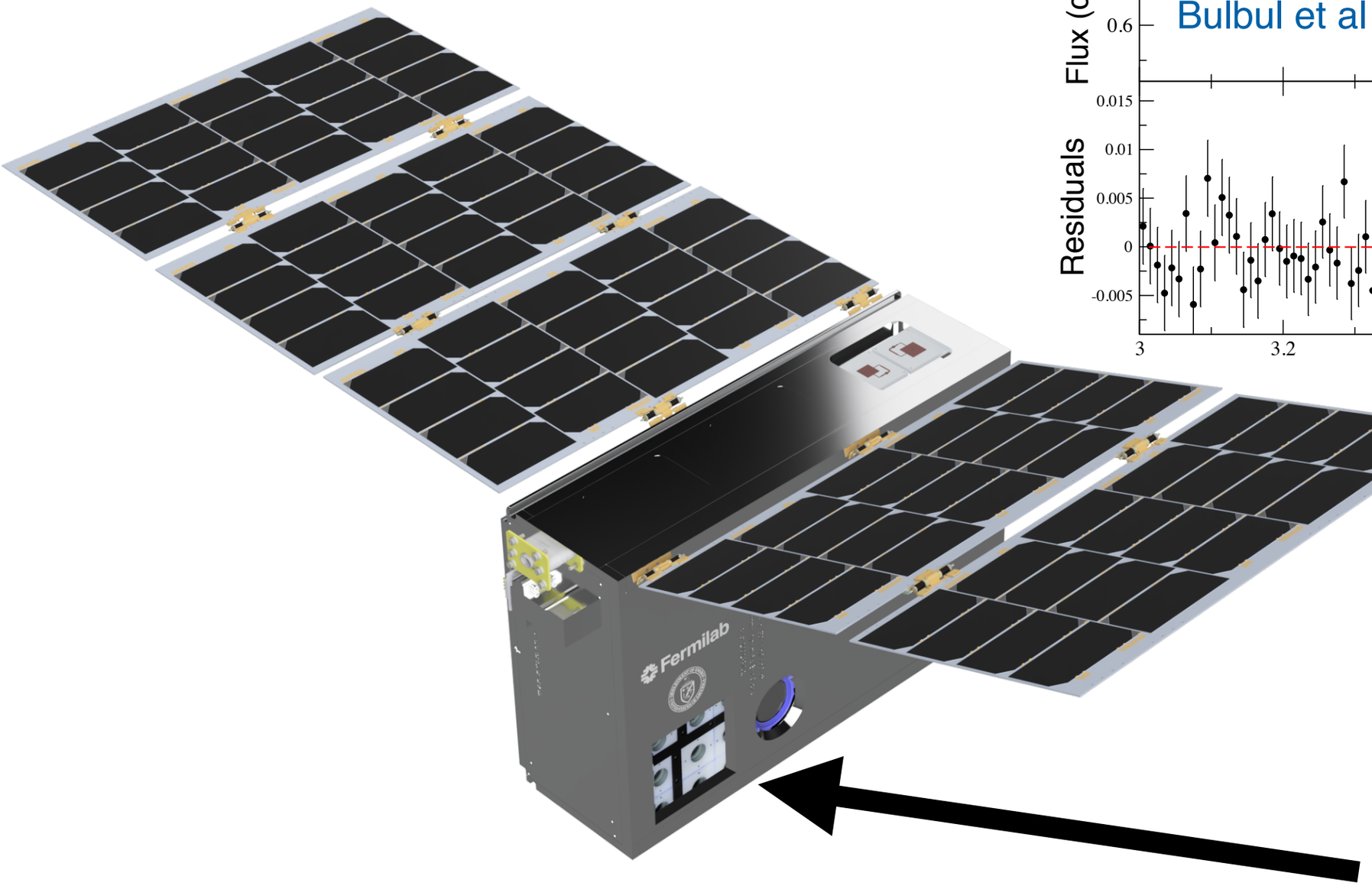
New results of the SENSEI experiment. Leading the search for low mass dark matter particles.

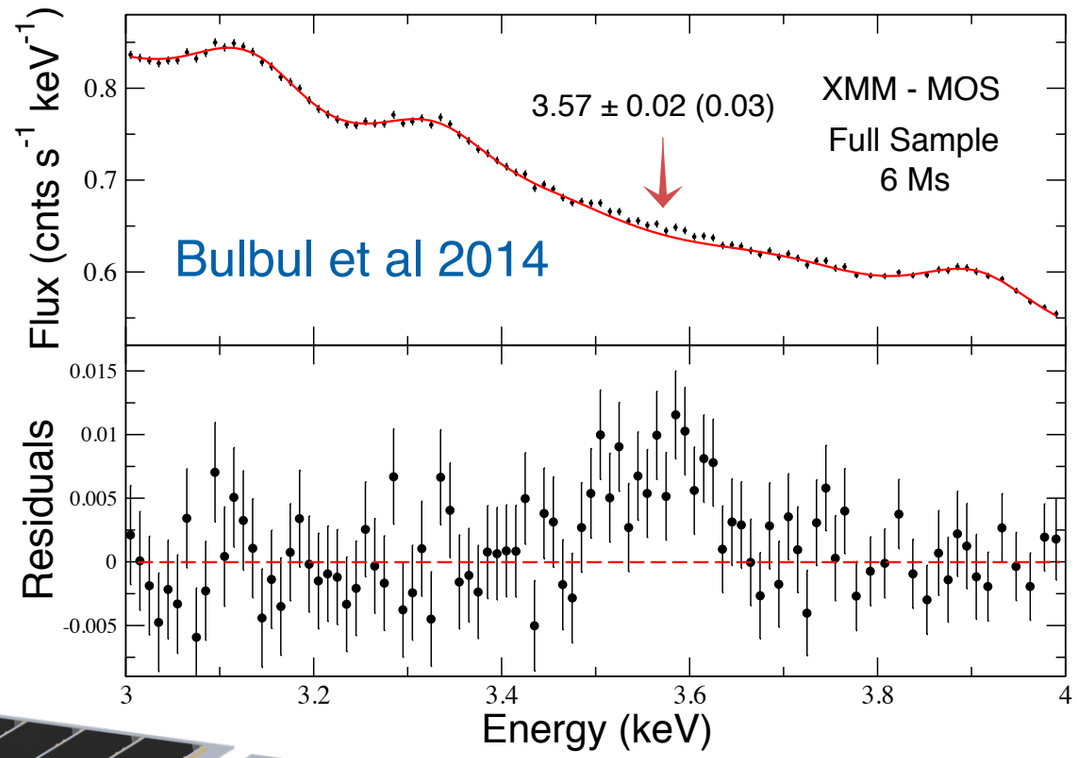
Have not been able to find dark matter yet, but we are building more powerful tools year after year.

We find a one-electron event rate of (1.6±0.10)×10⁻⁴ events/pixel/day, less than 1 gram of active mass.

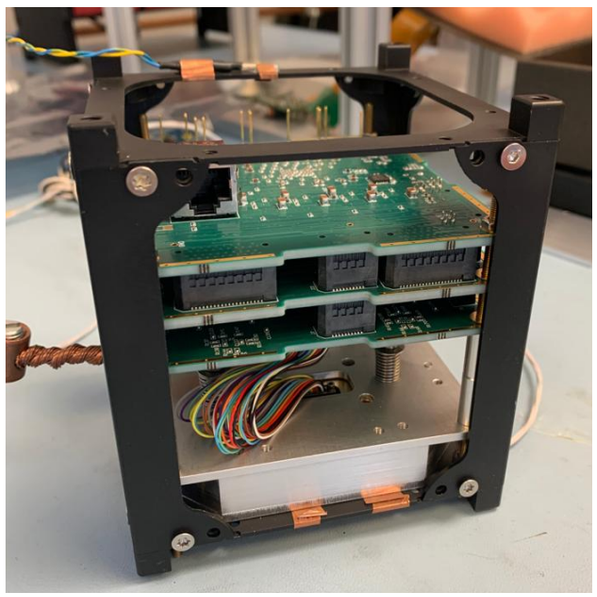
Darkness satellite to mount CCDs in space for direct dark matter search (FNAL, JPL, UIUC, SBU)

looking for potential signature of DM decay in our galaxy

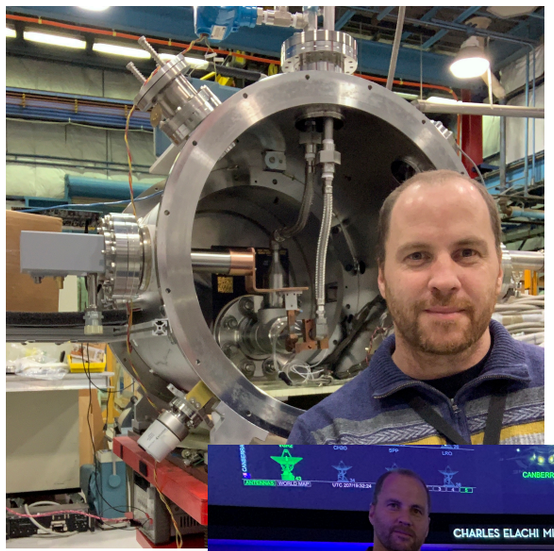




FNAL payload



it has been great fun… every day a new challenge



Fermilab

STEM at FNAL:

A true privilege to work on the mysteries of the Universe, and to build tools to go after the most important questions in physics.

Fermilab is one of the few places in the world where this science is done, it is great that you have access to it as a young student.

There are many ways to join the STEM fun at Fermilab… ask as about this during the conference