

# Presentation of the PHYSICS DIVISION

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**13 August 2024**



**BERKELEY LAB**

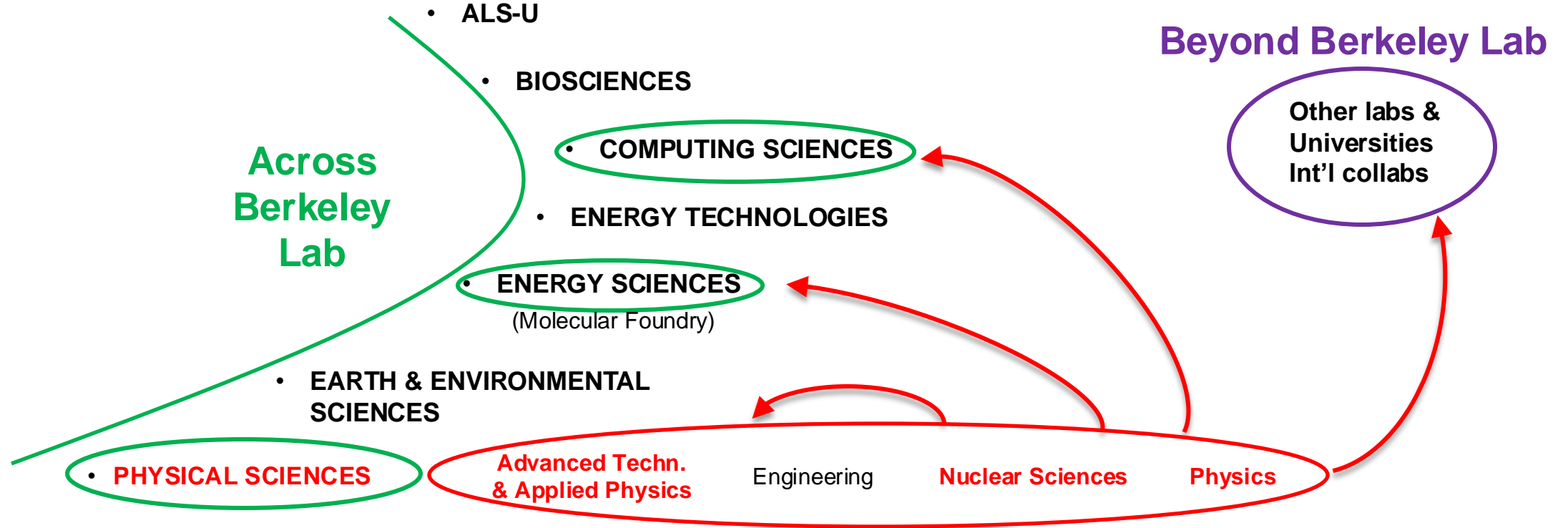


U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

# Berkeley Lab at a glance

- **LBL**: large (>\$1B) multi-purpose DOE lab, 3500 employees
- **Strong connections**



- **Physics Division**: 1 of LBNL's 22 scientific divisions, but 9/16 of its Nobel Prize awardees!

# Physics Division: particle physics & cosmology

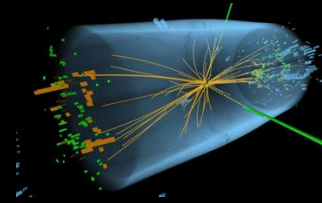
## Mission:

Explore nature of the Universe at its largest and smallest scales to understand its fundamental constituents, history and evolution

## Approach:

- Innovative instrumentation and computation
- Outstanding scientific staff, close connection with UC Berkeley
- Leading design and construction of large experiments with international collaborations

Particle physics



Neutrinos

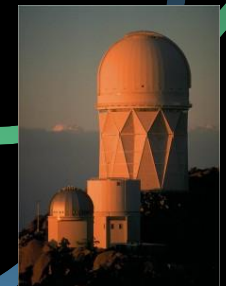
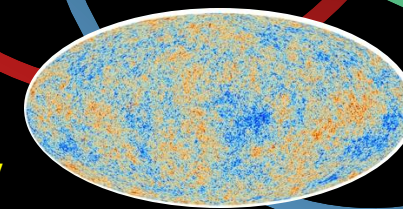
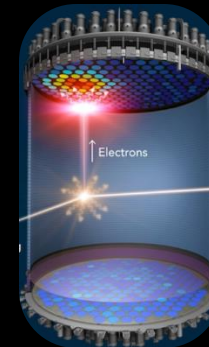


Theory

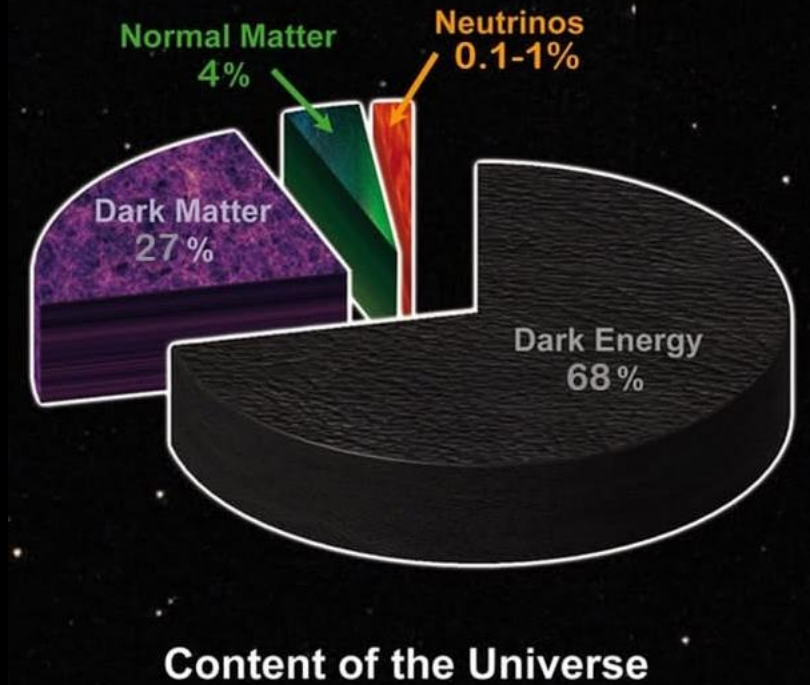
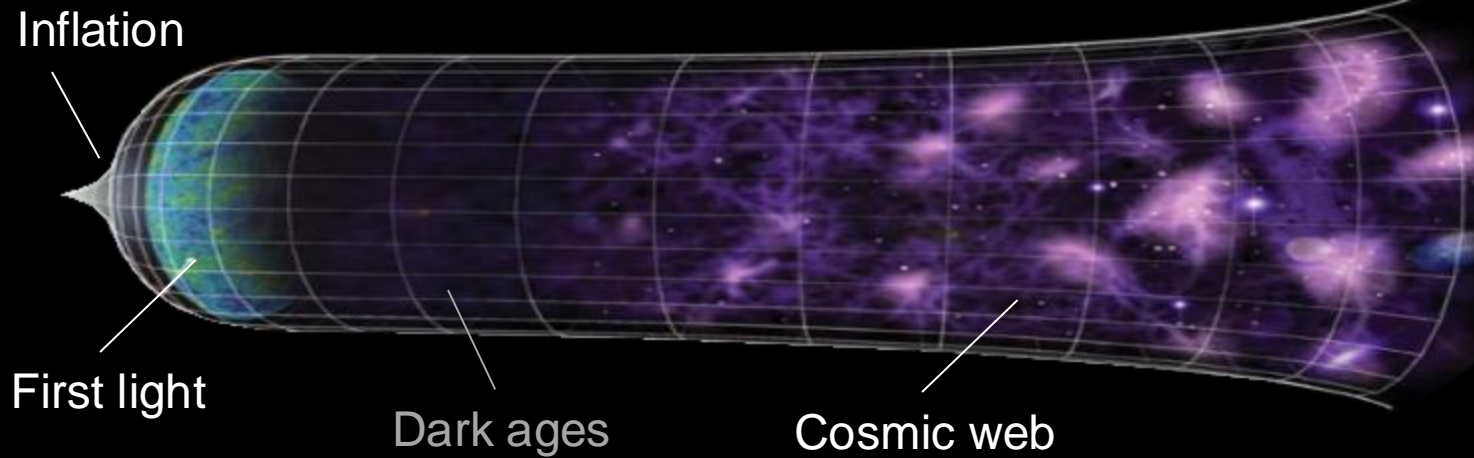
AIML  
QIS

R&D

Cosmology



# Unveiling the nature of our Universe



# The standard model of particle physics and beyond

## Standard Model of Elementary Particles

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III		
$\approx 2.2 \text{ MeV}/c^2$ $\frac{2}{3}$ <b>u</b> up	$\approx 1.28 \text{ GeV}/c^2$ $\frac{2}{3}$ <b>c</b> charm	$\approx 173.1 \text{ GeV}/c^2$ $\frac{2}{3}$ <b>t</b> top	$0$ $1$ <b>g</b> gluon	$\approx 124.97 \text{ GeV}/c^2$ $0$ <b>H</b> higgs
$\approx 4.7 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>d</b> down	$\approx 96 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>s</b> strange	$\approx 4.18 \text{ GeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>b</b> bottom	$0$ $1$ <b><math>\gamma</math></b> photon	
$\approx 0.511 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$ <b>e</b> electron	$\approx 105.66 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$ <b><math>\mu</math></b> muon	$\approx 1.7768 \text{ GeV}/c^2$ $-1$ $\frac{1}{2}$ <b><math>\tau</math></b> tau	$\approx 91.19 \text{ GeV}/c^2$ $0$ $1$ <b>Z</b> Z boson	
$< 2.2 \text{ eV}/c^2$ $0$ $\frac{1}{2}$ <b><math>\nu_e</math></b> electron neutrino	$< 0.17 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$ <b><math>\nu_\mu</math></b> muon neutrino	$< 18.2 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$ <b><math>\nu_\tau</math></b> tau neutrino	$\approx 80.360 \text{ GeV}/c^2$ $0$ $1$ <b>W</b> W boson	

**QUARKS** (left side)  
**LEPTONS** (left side)  
**SCALAR BOSONS** (right side)  
**GAUGE BOSONS VECTOR BOSONS** (right side)

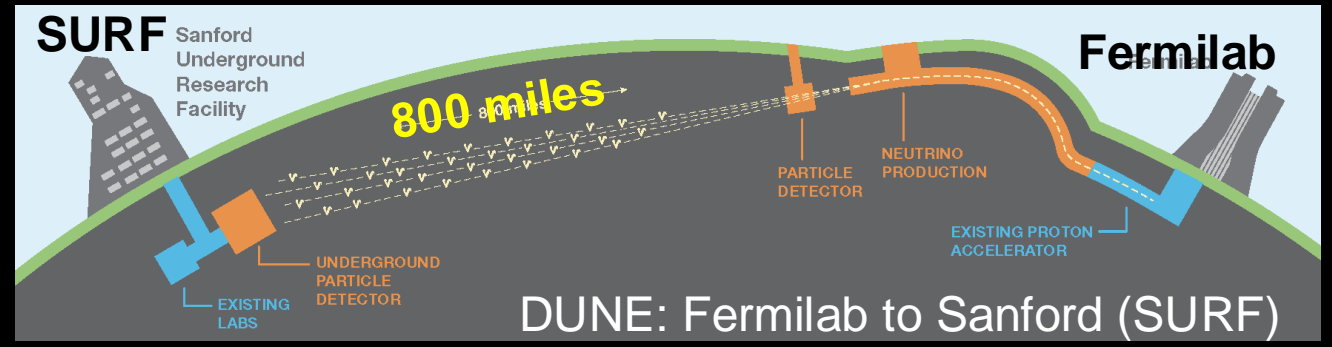
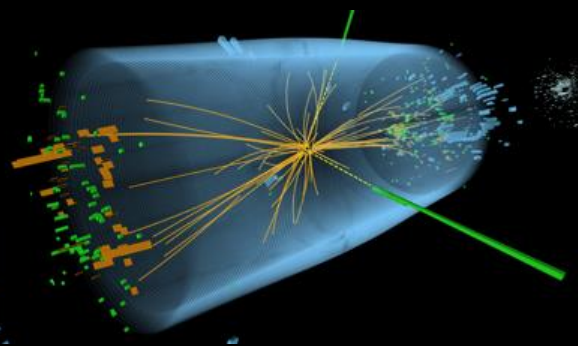
Contributing to

- international collider experiment at CERN – **ATLAS**
- Flagship US neutrino experiment – **DUNE**

⇒ understand **Standard Model of Particle Physics** ... and missing parts ...

Chen-Ju Lin

Simon Pagan Griso  
Nikki Apadula

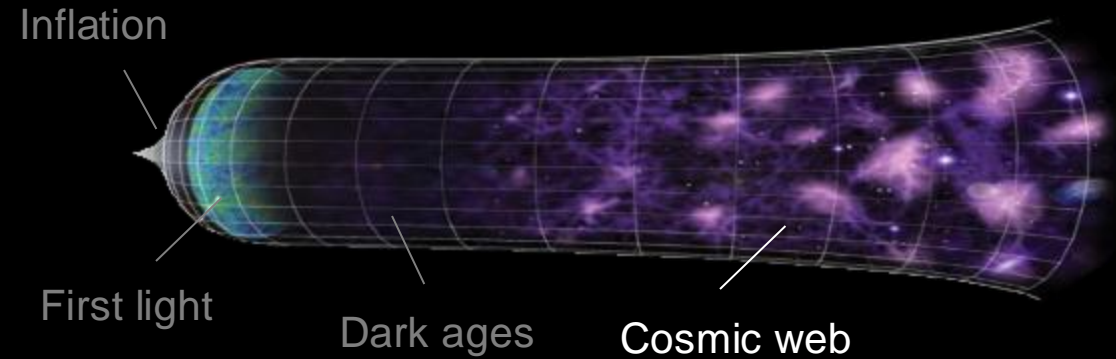
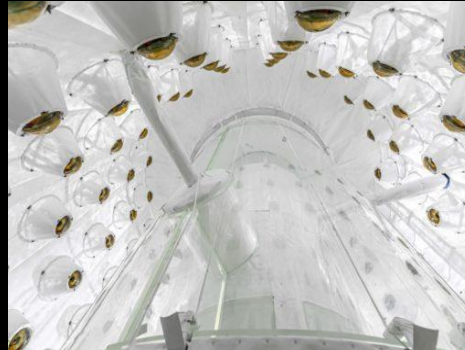


# Leading research on Dark Matter

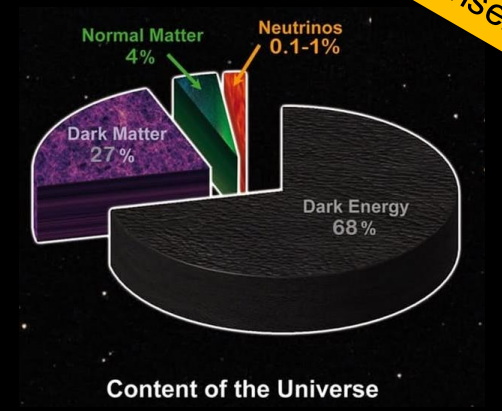
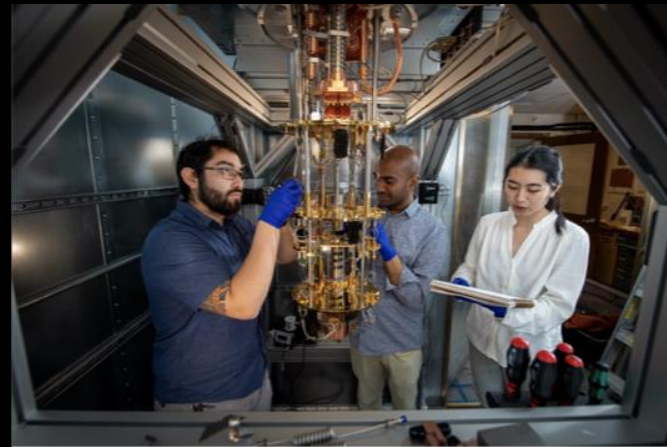
## Lead Lab for Lux-Zeplin (LZ) experiment

Searching for extremely rare interactions of **dark matter particles** in detector

- 7-tonne liquid Xenon detector
- 1 mile deep underground in South Dakota mine!
- World-leading exclusion limits



Developing new detection techniques for **light-mass dark matter particles** (use of **quantum detectors**)



Peter Sorensen

# Leading research on the first instants of our Universe

## Lead Lab for CMB-S4 experiment

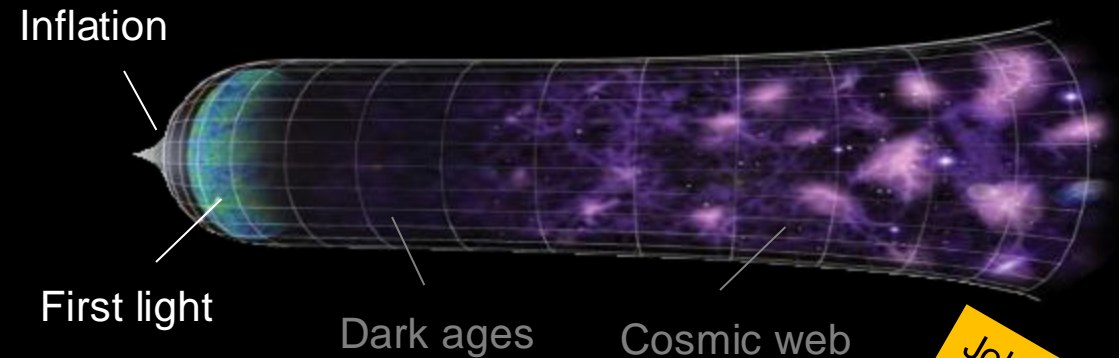
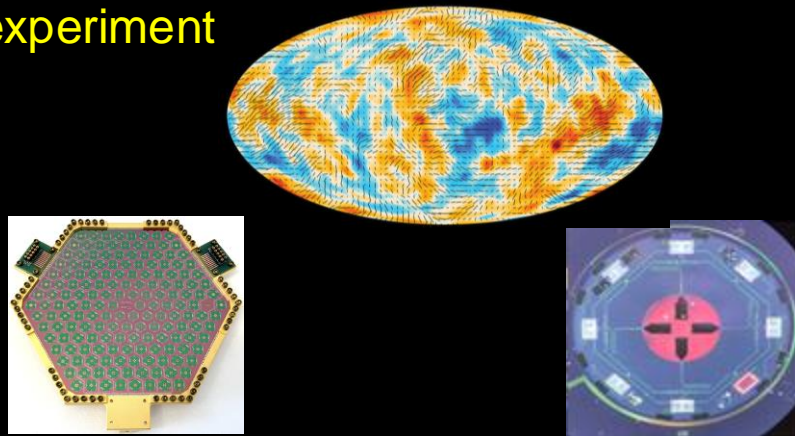
Expertise on

- Simulations
- Survey design
- Detectors

Experiments in

- South Pole & Atacama desert

⇒ study **inflation** and history of the **early Universe**



John Groh

South Pole Observatory

Atacama desert (Chile)



# Leading research on Dark Energy

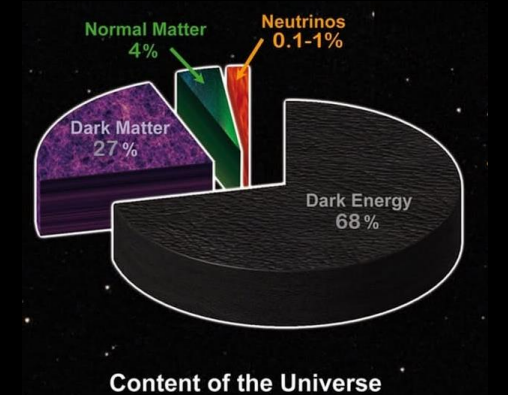
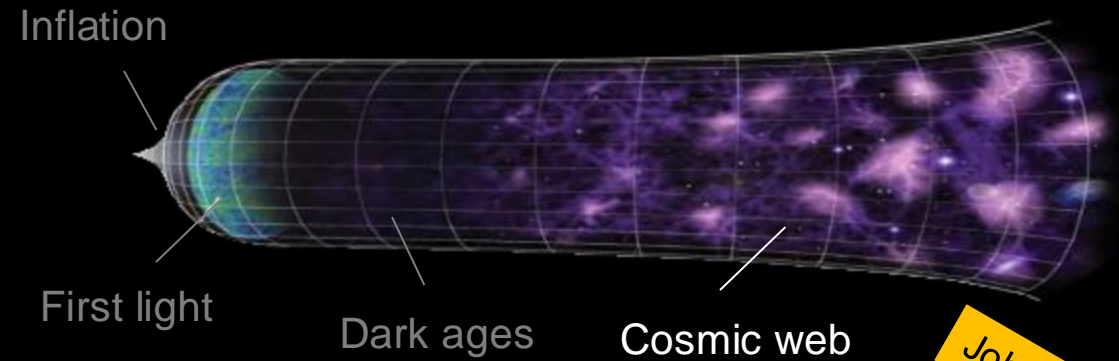
## Lead Lab for DESI – Dark Energy Spectroscopic Instrument

Mapping the Universe in 3D

- With 40 millions galaxies and quasars
- Using 5000 robots

To measure imprint of early Universe on galaxy distribution

⇒ **Dark energy**





# Enjoy your visit!

Building 50 patio

Theory-Dark Matter  
lunch  
discussion



# Thank you!