

**Lawrence Berkeley National Laboratory
Annual Report 2019
July 3, 2019
Mentor: Tony Spadafora
Workshop Coordinator: Laurie Kerrigan
Co- Organizer: Ken Cecire (QuarkNet)**

The LBNL Physics Division hosted its thirteenth “Physics in and Through Cosmology” workshop for QuarkNet Leadership teachers and high school students. The five-day workshop from June 24 to June 28, 2019 was held at the Lawrence Berkeley National Lab. Twelve physics teachers participated. Six of the teachers have been active members of QuarkNet for five or more years. Three new teachers joined the group this year and three from previous years returned. There was one retired teacher also, who has been active in QuarkNet throughout his career. 38 students participated. The teachers & students represented public and private high schools in the greater San Francisco Bay Area.

The first day was a Masterclass workshop just for the teachers lead by Ken Cecire. This included a Neutrino Physics Tutorial, MINERvA Masterclass Measurement, Introduction to World Wide Data Day and a Fermilab Virtual Visit.



The second day was also lead by Ken. The day started with Particle Cards, continuing with a MINERvA Masterclass, Introduction to World Wide Data Day ATLAS Masterclass and ATLAS World Wide Data Day Measurement. There were also talks by Berkeley Lab scientists.

The other days consisted of morning & afternoon scientist talks and tours of the ALS (Advanced Light Source), Molecular Foundry, and the 88” cyclotron research facilities at LBNL. Small groups of 3-4 students & one teacher also discussed the lectures and designed & carried out experiments with Cosmic Ray Detectors.

On the last day we had a Panel Discussion with the following researchers from LBL: Ben Nachman, Chris Marshall, Quentin Riffard, Stephen Bailey, and Vanessa Boehm

Formal presentations by LBNL scientists (unless noted otherwise), included:

Tony Spadafora – LBNL Safety Briefing

Ingrid Peterson - “Safety Presentation”

Haichen Wang - “Particle Physics: An Introduction”

Ben Nachman - “The LHC as a gluon factory: the strong force in action with the ATLAS detector”

Nikki Apadula - “Heavy Ion Collisions”

Larry Phair “The 88-Inch Cyclotron” part of the colloquium series

Natalie Roe -”LBNL 101”

Saul Perlmutter - Q&A

Kara Ponder - “Exploring Dark Energy through Supernova Cosmology”

Brian Marten –“ Life Cycle of Stars & production of elements” (QuarkNet teacher)

Chris Marshall - "Neutrinos: Ghosts of the Universe"

Quentin Riffard - “Dark matter: how to search for the invisible.”

Stephen Bailey - “How to make a 3D map of the universe”

Vanessa Boehm -”Machine Learning in Cosmology”



On the last day students completed a self- evaluation of how much they learned about science concepts during the workshop. They used a scale of 1 (nothing) to 5 (a lot).

The overall average was 4.07.

The concepts with the highest rated learning gain were:

The nucleus is held together by nuclear forces that overcome the electromagnetic repulsion between the protons 4.50

Both matter & antimatter exist but the Universe is mainly matter. 4.53

The Universe's expansion is accelerating due to Dark Energy. 4.56

Higgs bosons allow fundamental particles to have mass. 4.65

Neutrinos are produced by radioactive decay, in stars, accelerators, reactors. 4.68

The Universe is approximately 5% atomic matter, 20% dark matter, and 75% dark energy. 4.71

The Red Shift is the stretching of wavelengths revealing time and distance. 4.71

There are four fundamental forces, most interact through carrier particles shaping the Universe. 4.82

Some comments by the students and teachers include:

“I gained so much knowledge about Cosmology and Physics that I wouldn't have been able to acquire anywhere else.”

“Getting the chance to talk with Saul Perlmutter, Nobel Prize winner was amazing.”

“The stories of the paths that led them (scientists) to be where they are today were very inspiring because they showed that many non-linear career paths still work out spectacularly. I also made many new friends; the other students were fantastic.”

“What I liked about the workshop was being able to tour the 88” Cyclotron, the Molecular Foundry, and the ALS.”

“I really value the connections I make with other teachers during the workshop.”

“This workshop was easily the best professional development workshop I have ever attended (and I do not say that lightly; I have attended many truly excellent professional development workshops). It was *so* cool to be doing these activities and learning about all of this mind-blowing physics together with students!!”

Participating Teachers:

Philip	Becker
Erin	Galloway
Virgil	Jackson
Jessica	Kellar
Laurie	Kerrigan
Justin	Louie
Bryan	Marten
Glen	Melnik
Richard	Piccioni
Valerie	Risk
Jennifer	Tetler
Kalee	Tock