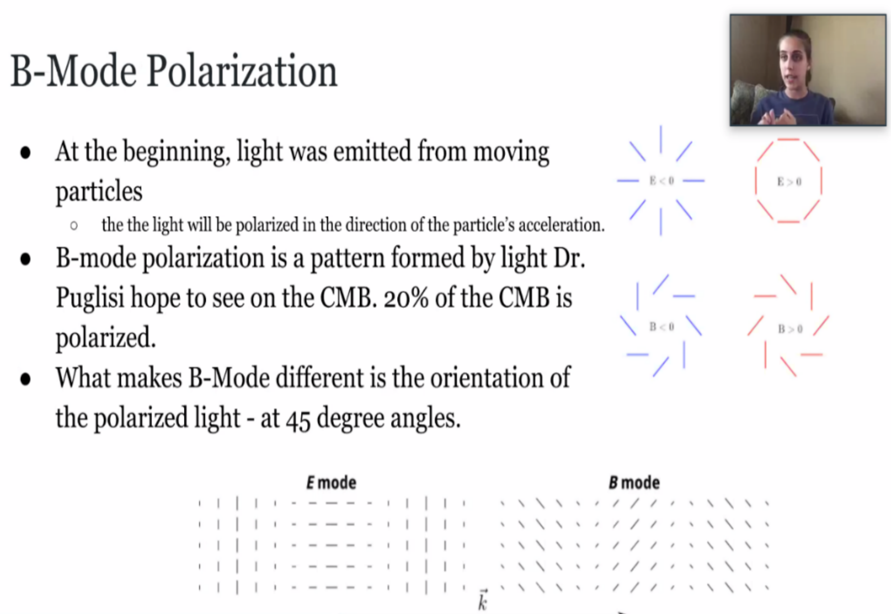
Lawrence Berkeley National Laboratory
Annual Report 2020
Aug. 1, 2020
Mentor: Tony Spadafora
Workshop Coordinator: Laurie Kerrigan
Co- Organizer: Ken Cecire (QuarkNet)

The LBNL Physics Division hosted its fourteenth "Physics in and Through Cosmology" workshop for QuarkNet Leadership teachers and high school students. This four week virtual workshop from June 29 to July 24, 2020 was held via Zoom. Twelve physics teachers participated. Five of the teachers have been active members of QuarkNet. Six new teachers joined the group this year. There was one retired teacher also, who has been active in QuarkNet throughout his career. 67 students participated. Most of the teachers & students joined from public and private high schools in the greater San Francisco Bay Area, although a few joined from throughout the U.S. and one from England.

This year we meet about 3 times a week for 3 hours. Most meetings started with Jeopardy while everyone was joining the Zoom. Then there was a talk by a LBL scientist and either small group work, a virtual activity, or a virtual tour. The small group work included creating a 60 second History of the Universe, a Scientist Interview Project, and QuarkNet activities including analyzing data from ATLAS led by Ken Cecire. We had a virtual tour of the ALS lead by Ina Reichel. The first couple of meetings included some Physics basics led by the teachers and we had a cosmic ray detector demonstration.

Highlights of the program were a drop in visit by Nobel Prize winner, Saul Perlmutter, and a round table panel discussion with the Scientists on the last day. Each small group also presented a short video or power point about the work the Scientist they interviewed was doing.

Scientist interviewed by students:
Peter Madigan
Giuseppe Puglisi
Maurice Garcia-Sciveres
Karol Krizka
Patrick McCormack
Ryan Roberts
Elodie Resseguie
Cesar Gonzalez Renteria
Neha Sai Santpur
Ben Nachman
Vincent R. Pascuzzi
Michael Wilson
Rongpu Zhou
ChangHoon Hahn



Formal presentations by LBNL scientists included:

Natalie Roe	***Welcome to the Lab***
Andrea Herman	***Mu2e & Conservation Laws***
Brooke Morrison	***The Nu Frontier***
Scott Kravitz	***Dark Matter & Machine Learning***
Haichen Wang	***High Energy Physics - ATLAS***
Ben Nachman	***Deep Learning for Particle Physics***
Elodie Resseguie	***Searching for New Physics with the ATLAS Detector***
Anthony Kremin	***Understanding a Mystery of the Cosmos: Dark Energy***
Giuseppe Puglisi	***Looking for Ripples in the Universe***

Comments from overall evaluations of workshop by teacher & students:

I learned so much about the universe that I was surprised by how little I had known before the Workshop. I loved that we got to ask questions. I had loads of fun and looked forward to learning more every day!

The topics were incredibly interesting and nothing like school curriculum.

This workshop proved to me how versatile and open particle physics is. There is so much to be discovered, and maybe I'll want to be a part of it! I really appreciate this team of teachers and researchers who made this possible. It is a perfect opportunity and it's amazing to see the passion from all of you.

I loved being able to learn from real scientists.

I loved the Scientist Interview Project. Being able to have a direct interaction with an actual scientist and learn about real life research was fascinating, and it was really inspiring to see their passion for science.

Awesome opportunity to learn so much! I learned so many things beyond just physics and cosmology, many things about science I didn't even know existed before.

I found it inspiring to see how excited the scientists were to talk about their research.

This is one of the best summer workshops I have ever attended! I learned a lot about current research in both particle physics and cosmology. The scientists did an excellent job presenting about their research, and the students asked insightful questions. I also enjoyed having the opportunity to interview a scientist with a small group of students. It was great to be able to learn about a particular scientist's research in depth. As a physics teacher, I plan to incorporate many things I learned about current research in particle physics and cosmology into both my AP Physics and Honors Physics classes next year.

I also found it refreshing to see the scientists' open-minded and humility about what they do not yet understand. That's such an important part of the scientific process and something I am reminded that I should emulate in my classroom.

Comments by students on what they learned according to NGSS major areas in Physics:

Structure and Properties of Matter

I learned more about many particles, including some I've never encountered! It was nice to dive deeper than the simplifications usually presented to us, especially when talking about quarks.

Fermions ½ spin. Force carriers / bosons whole spin. Quarks +2/3 or -1/3. Leptons -1 or 0 charge . The entire chart of forces, carriers and generations.

I learned that there is actually more dark matter in our universe than matter itself. Before this workshop, I knew little to nothing about dark matter, but now I know that dark matter doesn't reflect light, but it bends light, so that is proof of its existence.

Forces and Interactions

Most of my prior knowledge of forces came from AP Physics 1, so I knew how to add up net forces, but not much about what their roles really are in how particles interact. I don't think I have a full understanding of forces yet, but I do have a better understanding of what the strong and weak forces actually are.

Bosons are the force-carriers - Photons = EM force, infinite range, weaker over larger distances - Gluons = Strong Force, tiny range, the harder you pull 2 quarks apart, the stronger it gets (like a rubber band) - W/Z Bosons = Weak force, even tinier range, responsible for decay of particles - Higgs Boson = Mass, field that permeates all space, particles interaction with this field, gives mass

Energy

I now have a clearer understanding of how a particle's energy can translate to its mass.

I learned that when matter and anti-matter collide, they form pure energy. I learned that separating two quarks requires so much energy that it creates another two quarks by the mass energy equivalence.

The two things that fascinated me the most were energy production/carrying from photons and antimatter, and the all elusive dark energy (might not even be energy).

I learned a lot about the masses / energies that different detectors operate at – especially the LHC and ALS. I also learned that decay follows an energetic pathway, as particles decay into less massive pieces.

Waves and Electromagnetic Radiation

Scientists use waves to understand the history of the universe.

Two types of waves are transverse and longitudinal. Electromagnetic radiation is an example of a transverse wave. On the spectrum of visible light, violet has the shortest wavelength where red has the longest wavelength. When we observe stars, we can see that the light emitted from them is shifted to the red side of the spectrum. This is the Doppler effect, and we can infer that the expansion of the universe is accelerating.

Engineering Design
Most scientists talked about the engineering behind their experiments, so I'd say this standard is covered.

Learned that programs such as CERN require huge construction projects, building sensitive detectors is important.

I learned that if is crucial to limit the amount of noise in an experiment to ensure the best results. There are tons of different procedures and aspects of an experiment in order to do this.

Lots of clever + creative engineering used to study physics and cosmology like:
- ionization of Silicon/Argon to detect particles' paths - Cosmic
Ray Detectors - Machine Learning

Statistics are an integral part of engineering design.

Earth's Place in the Universe
We are very small and insignificant on the scales of the universe

I learned that while the earth isn't centered in the universe, the fact that light travels at a constant rate means that we can only perceive a section of the universe that is a perfect sphere surrounding earth. I learned that in looking at far away objects, we are effectively looking back in time because space will have changed massively but the light hasn't had the time to reach earth.

Expansion dictates we will only see what we see now, nothing more.

I got the chance to delve further into the formation of galaxies and stars. Also we covered the Big Bang and how the world formed. We also covered the composition of the universe, including dark matter and energy, and how physical and antimatter come to be.

List of Teachers:
Phil Becker
Kevin Doyle
Sean Fottrell
Felix Gandara-Guzman
Virgil Jackson
Sarah Kayler
Jessica Kellar
Laurie Kerrigan
Glen Melnik
Nicholas Sigmon
Kathryn Stafford
Shannon Wong