



Detecting Dark Matter Using A Scintillating Xenon Bubble Chamber

Jason Parks, Eric Dahl, and Daniel Baxter

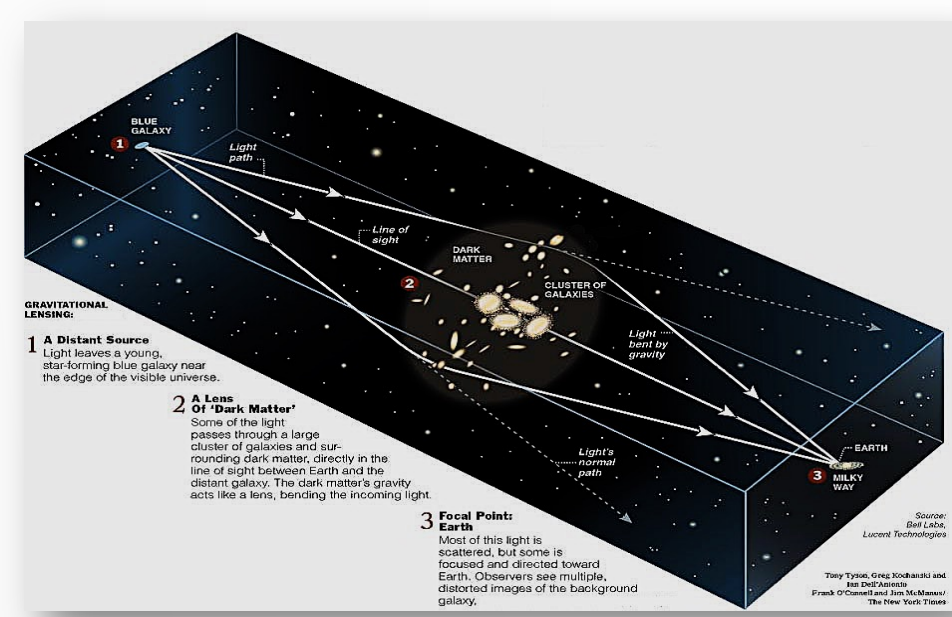
Dark Matter in the Universe

Scientists now have realized that it's not what shines in the dark, but what hides in the dark that dominates our universe. Billions of dark matter particles pass through everything and everyone they encounter by the second, and with the aid of technology we are going to find out once and for all what dark matter particles are made of and what role they play in our universe. We are developing a tool to answer these questions, the Scintillating Xenon Bubble Chamber for Dark Matter Particle Detection.

What is Dark Matter?

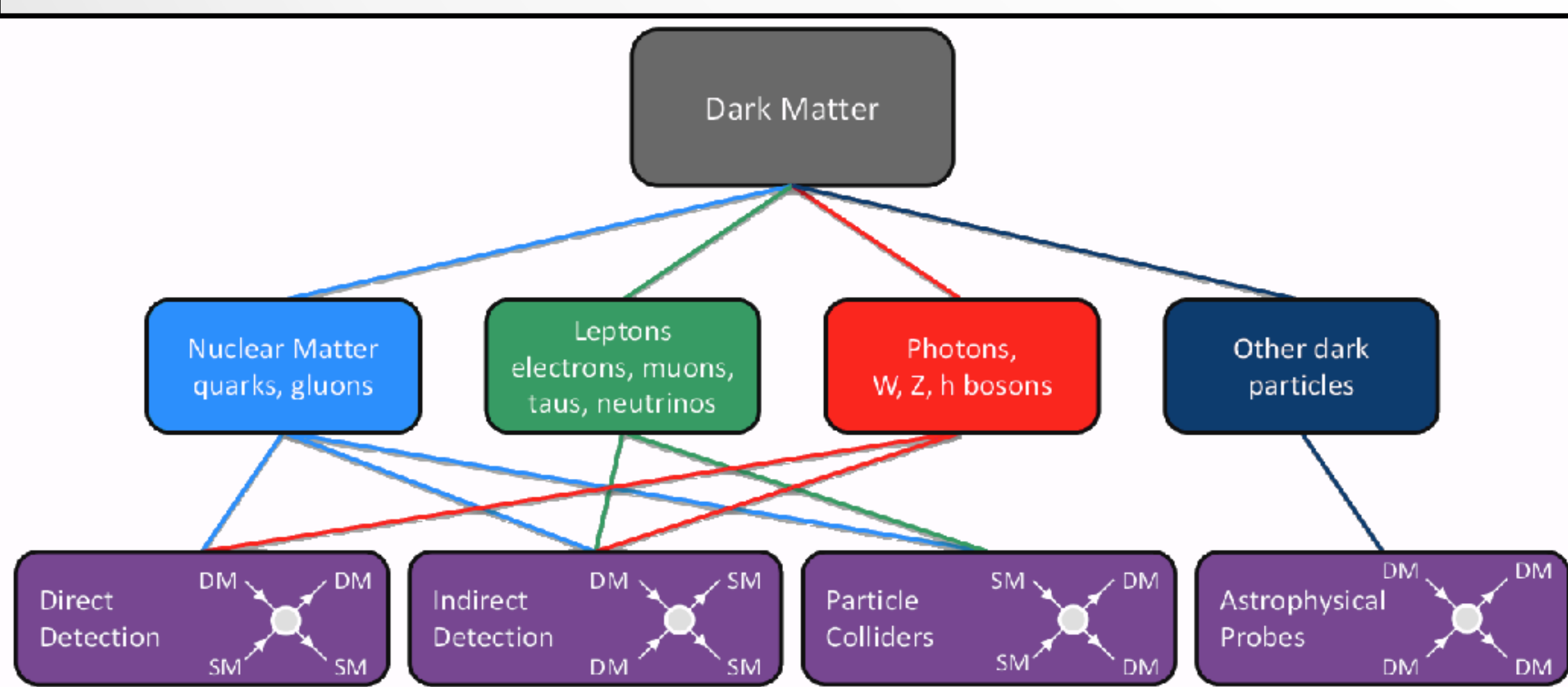
We know that dark matter exists from many different observations, which not only prove that dark matter exists but also measure how much dark matter is present in the universe. Observational evidence includes galactic clustering, velocity curves of spinning galaxies, gravitational lensing, and the cosmic microwave background.

Individual dark matter particles have yet to be observed, but there are many hypothetical particles that may make up the dark matter. The leading Dark Matter candidate is a WIMP (**Weakly Interacting Massive Particle**).

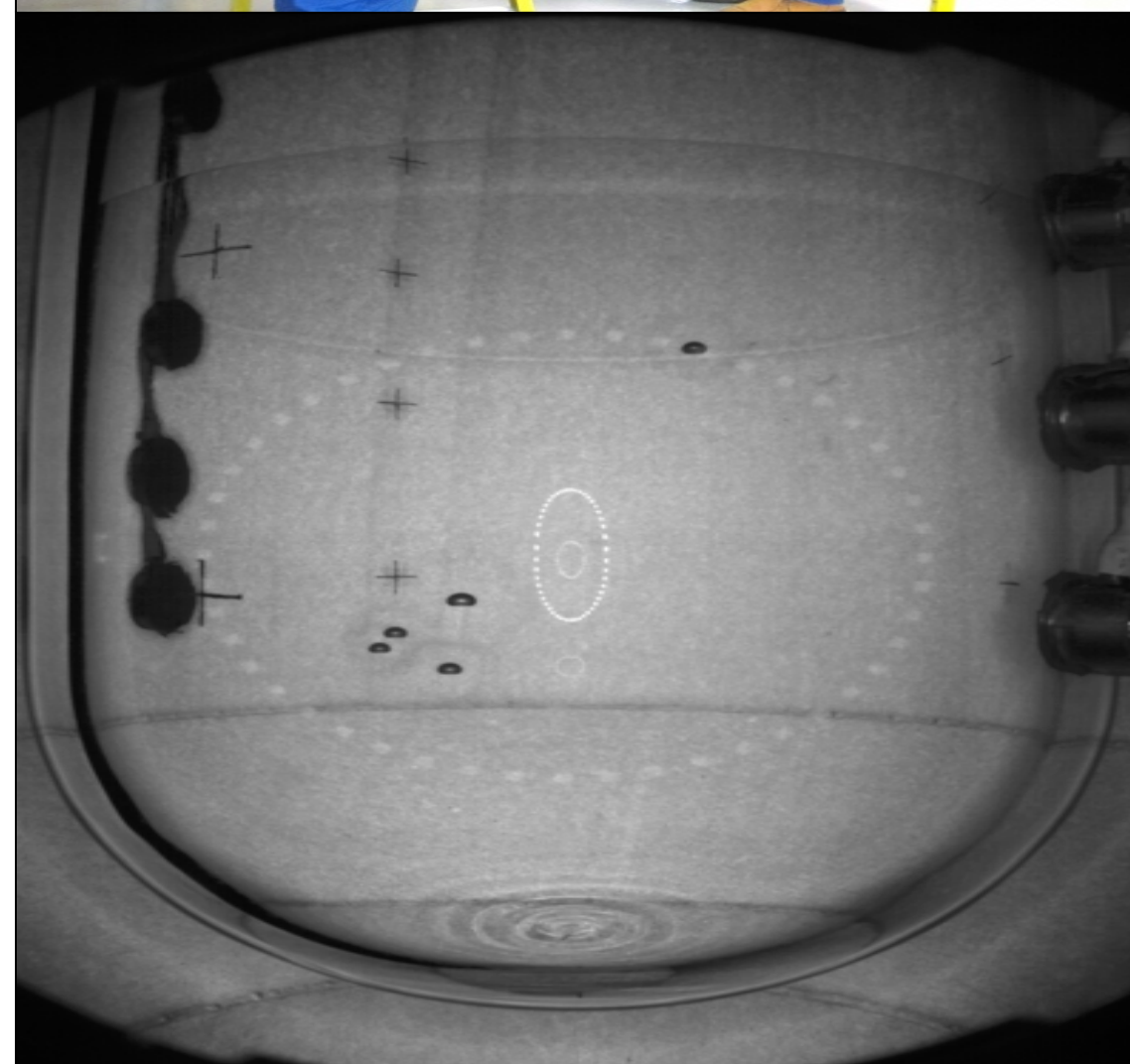
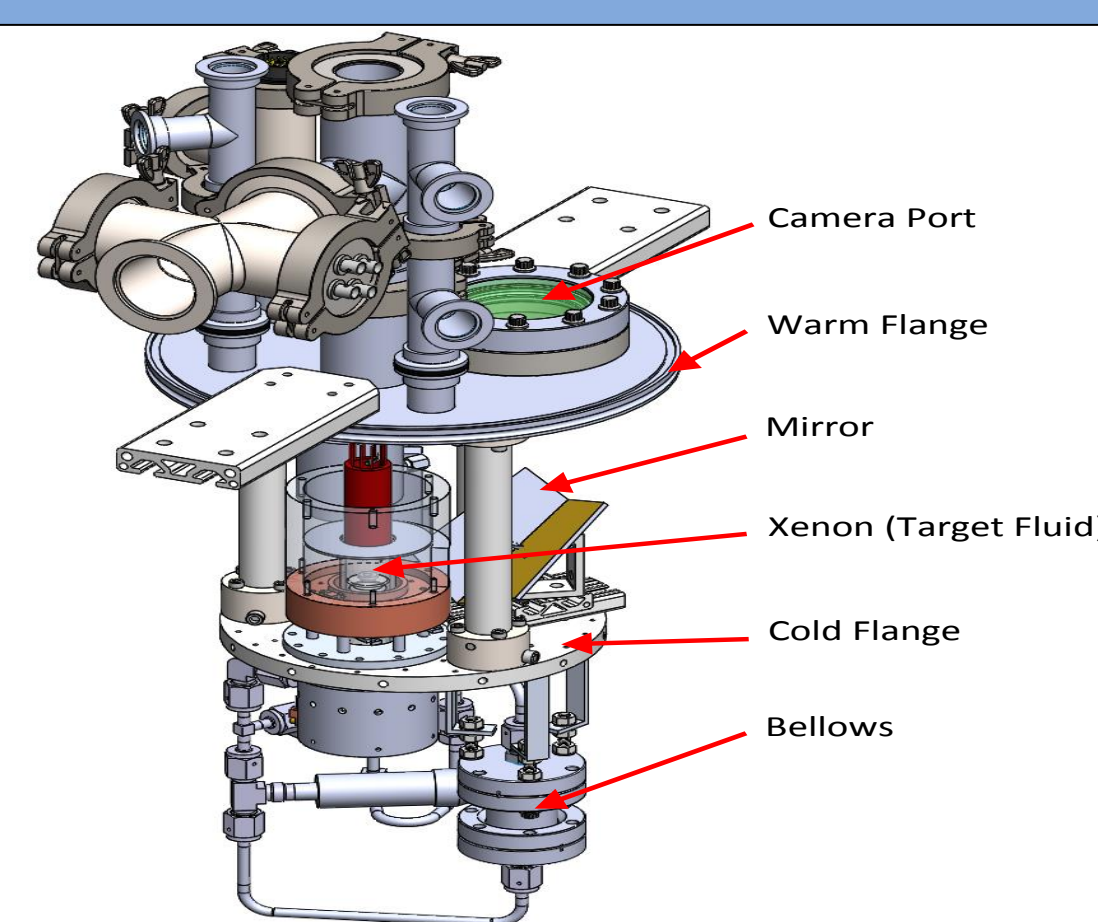


Detecting Dark Matter

- 1. Direct Detection-** Experiments look for WIMPs scattering off of normal matter in detectors, which are operated in deep underground laboratories to reduce the background from cosmic rays.
- 2. Indirect Detection-** Experiments search for the products of Dark Matter particles (WIMPs) annihilating in the galactic neighborhood.
- 3. Accelerator Production-** Dark matter is produced in an accelerator such as a Large Hadron Collider (LHC) allowing two particle beams to collide converting energy into mass in the form of dark matter.



Bubble Chambers



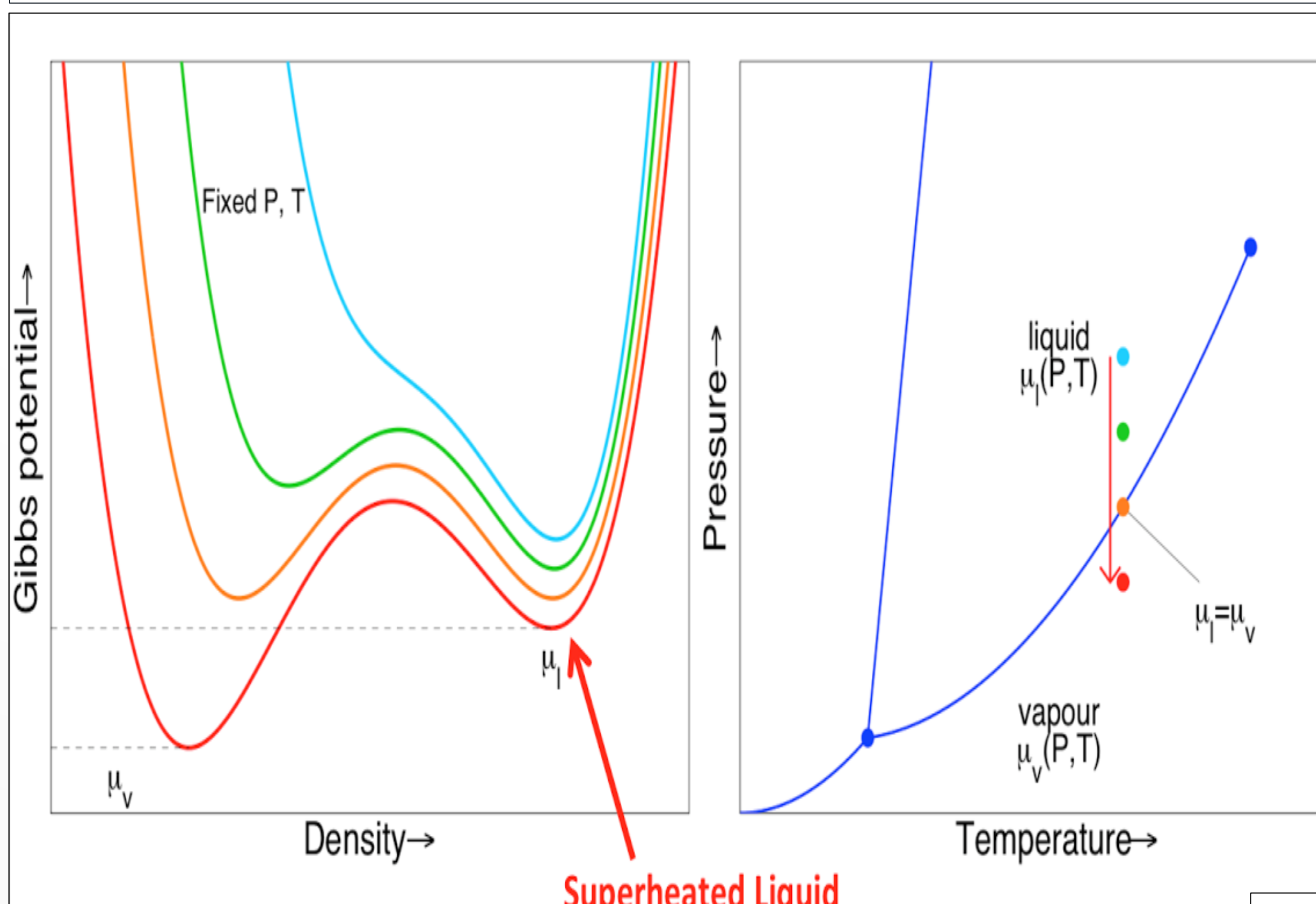
PICO-60

Scintillating Xenon Bubble Chamber

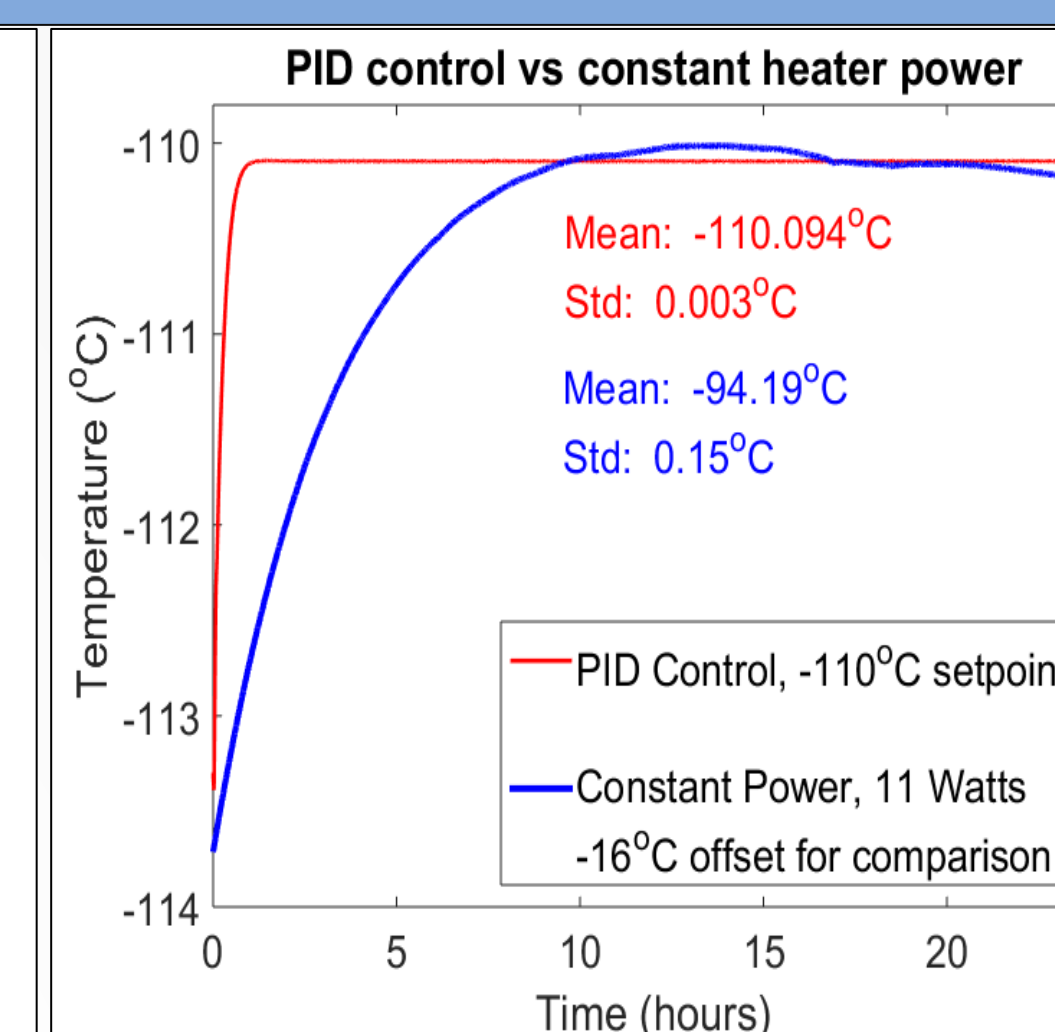
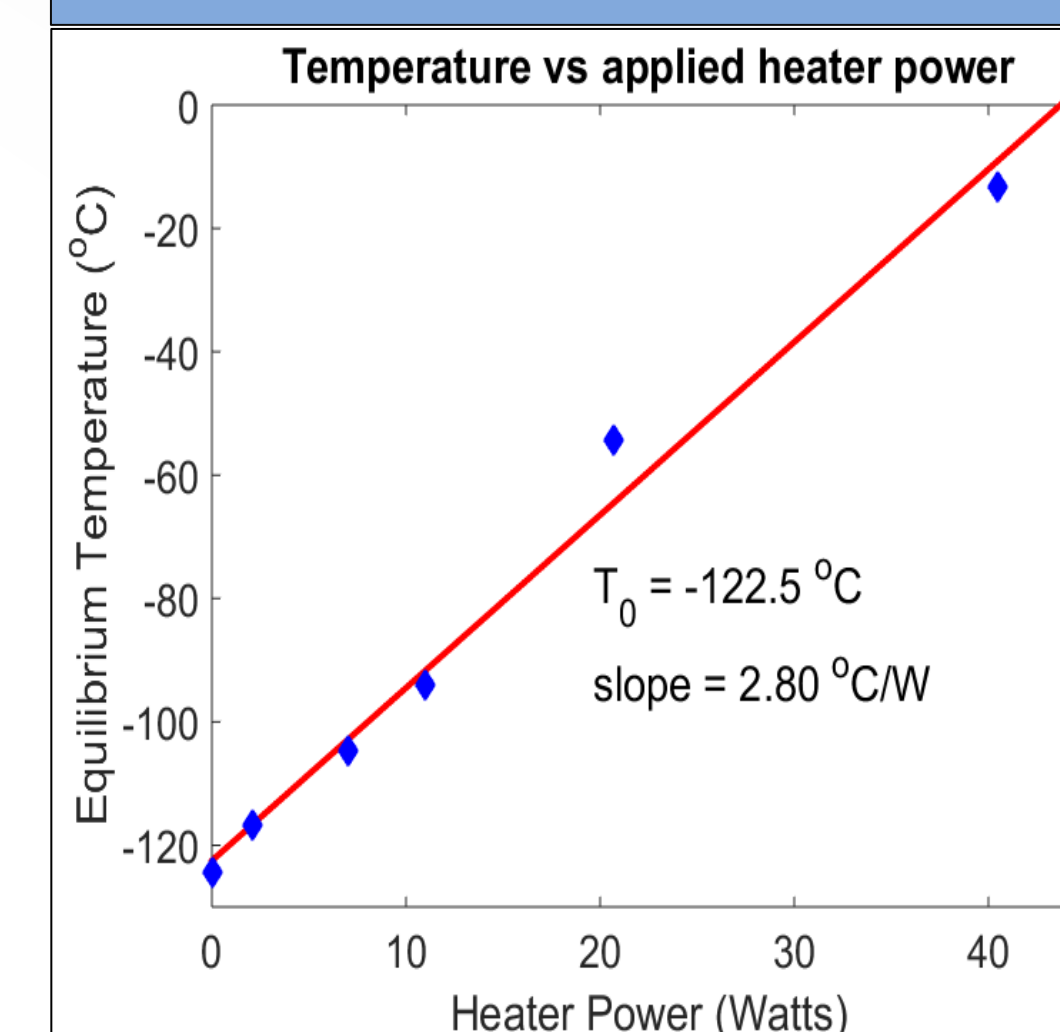
PICO consist of about 17 groups internationally and are funded for the Generation 1 experiment named PICO-60, shown above and operating 6800 feet underground in SNOLAB. The PICO Project aims to detect dark matter particles with the bubble chambers, which look for bubbles nucleated by particle interactions in a superheated liquid target (see below). We are exploring the use of a liquid xenon as a target, which will both bubble and produce scintillation light in response to particle interactions.

Super Heated Liquid

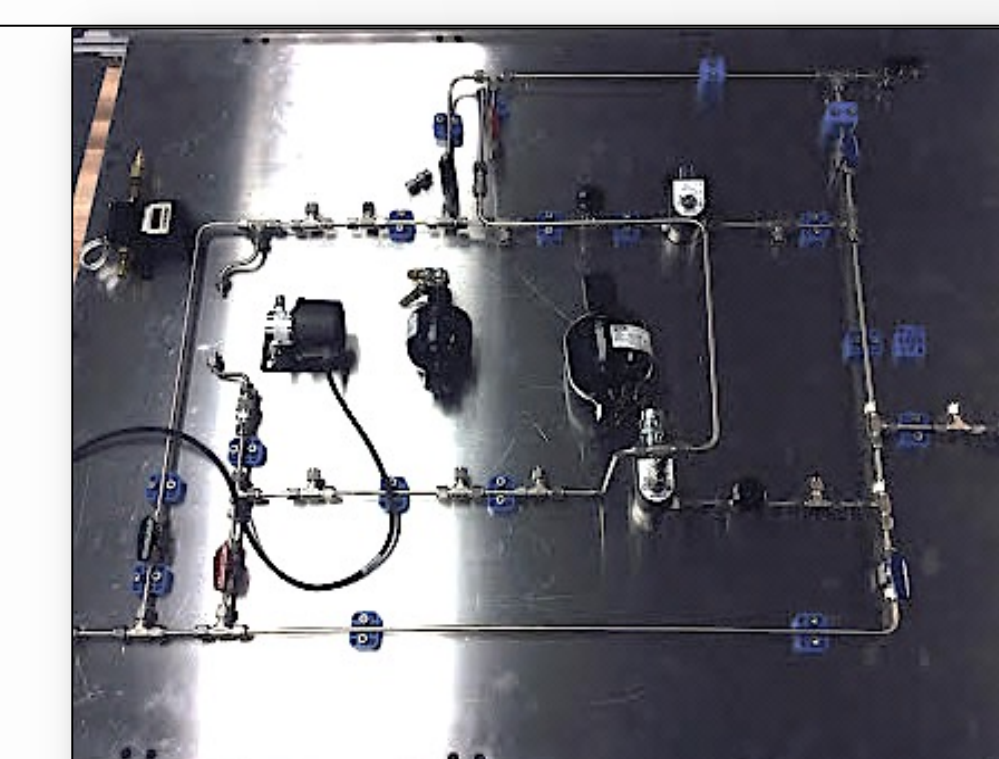
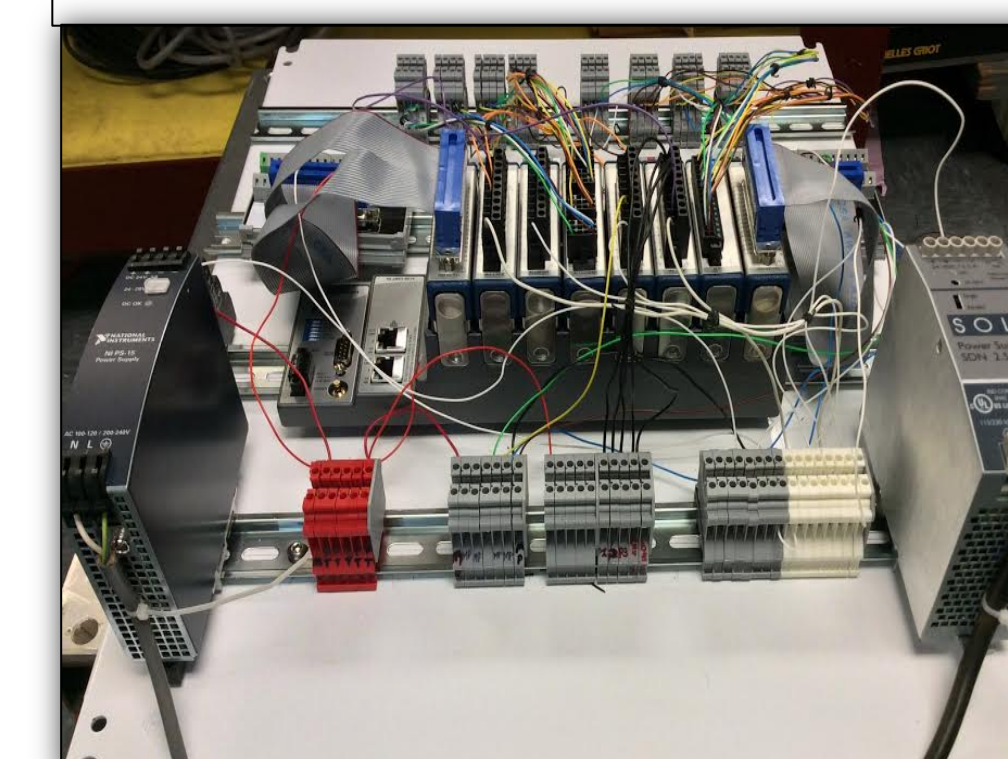
A superheated liquid is a liquid taken slightly beyond its boiling point without boiling, as in the red point in the phase diagram below. For dark matter detection, the degree of superheat must be strictly regulated at a level where WIMP interactions can nucleate bubbles. This requires precise control of the temperature and pressure of the target fluid.



Observations/Data



My chief responsibility this summer was testing the temperature and pressure control systems for the xenon bubble chamber. This required maintaining a temperature of -100 degrees Celsius in a liquid nitrogen-cooled cryostat.



Summary

We were to establish a stable temperature at which the temperature of xenon could be maintained at the desired superheated level (-100° Celsius), in order to establish an environment in which we could observe WIMP interactions occurring via bubble nucleation. In this process, if dark matter particles were to hit an atom, the interaction would nucleate bubbles.

References

- Akerib, D.S. "An Ultra-low Background PMT for Liquid Xenon Detectors." An Ultra-low Background PMT for Liquid Xenon Detectors. November 6, 2012. Accessed August 3, 2015.
- Aprile, E., and M. Alfonsi. "ArXiv.org Astro-ph ArXiv:1301.6620." [1301.6620] Limits on Spin-dependent WIMP-nucleon Cross Sections from 225 Live Days of XENON100 Data. Phys. Rev. Lett. 111, 021301, 9 July 2013. Web. 3 Aug. 2015.
- Amole, C, et al. "Dark Matter Search Results from the PICO-2L C3F8 Bubble Chamber." Phys. Rev. Lett. 114, 231302, Jun 2015.
- Aubin, F., and M. Auger. "Discrimination of Nuclear Recoils from Alpha Particles with Superheated Liquids." New Journal of Physics 10 (2008) 103017 (11pp), 16 Oct. 2008.
- Kudryavtsev, Vitaly A. Kudryavtsev. "Expected Background in the LZ Experiment." Department of Physics and Astronomy, University of Sheeld, Sheeld S3 7RH, UK. Web. 3 Aug. 2015.
- Savage, Don, Nancy Neal, and Ray Villard. "Blast from the Past: Farthest Supernova Ever Seen Sheds Light on Dark Universe." HubbleSite. 2 Apr. 2001. Web. 3 Aug. 2015.

Acknowledgements

"This material is based upon work supported by the National Science Foundation under Grant No. AST-1359462, a Research Experiences for Undergraduates (REU) grant awarded to CIERA at Northwestern University. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

