MICROWAVE KINETIC INDUCTANCE DETECTORS

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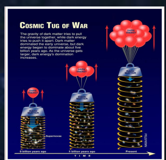
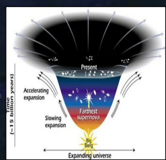
INTRODUCTION

THE DARK ENERGY SURVEY (DES)

- *DARK ENERGY:* A theoretical repulsive force that counteracts gravity and accelerates the expansion of the universe.
- The *Dark Energy Survey* uses a powerful telescope equipped with the Dark Energy Camera (DECam) to survey the skies and create a better understanding of dark energy.





ORIGINS

REDSHIFT

- *REDSHIFT:* The wavelength of light increases as it traverses the expanding universe between its point of emission and its point of detection by the same amount that space has expanded during the crossing time.
- Scientists use redshift to determine the position of galaxies. Dark energy affects the way galaxies are distributed in the universe.
- Redshift measurements of many galaxies are needed to characterize dark energy with more precision.

METHODS

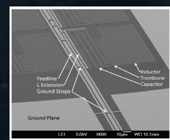
CCDs and SPECTROSCOPY

- Redshift can be determined using three different methods: *Imaging with Charge-Coupled Devices*, *Spectroscopy*, and *Microwave Kinetic Inductance Detectors.*
- *IMAGING WITH CHARGE-COUPLED DEVICE:* A CCD is able to count the number of photons that hit one of its pixels during a certain length of time. Using color filters, an image of photon intensity is created.
  - ❑ CCDs are limited by their inability to track the time at which a photon hits its pixels.
- *SPECTROSCOPY:* Spectrographs are able to accurately split the light into different wavelengths and shine it onto CCDs to create high-resolution images.
  - ❑ Spectrographs are limited by their inability to track images over large distances.

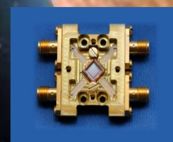
MKIDs

MICROWAVE KINETIC INDUCTANCE DETECTORS (MKID)

- *MKIDs:* Superconducting detectors developed at the California Institute of Technology.
- MKIDs consist of thousands of pixels that contain an inductor and a capacitor.



MKID Pixel – Inductor + Capacitor

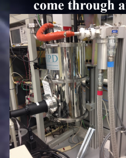


MKID Device

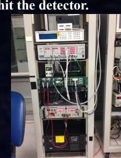
- MKIDs theoretically have the ability to execute astronomical studies with a high efficiency.
  - ❑ Because MKIDs consist of thousands of pixels, they have the ability to create images of multiple objects in the sky.
  - ❑ MKIDs measure redshift easily because they can track the time at which a photon hits each of its pixels.
  - ❑ By measuring the change in inductance at the time at which a photon hits each pixel, MKIDs have the ability to measure the energy of each photon.

ADIABATIC DEMAGNETIZATION REGRIGERATOR – MKID SETUP

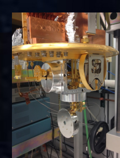
- The adiabatic demagnetization refrigerator cools the detector down to temperatures in the millikelvins.
- The MKID resides at the bottom of the refrigerator; and a small window on the front of the refrigerator allows light to come through and hit the detector.



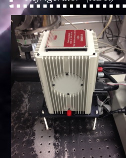
Adiabatic Demagnetization Refrigerator (ADR)



Network Analyzer, Stanford Research System Mainframe, ROACH Board

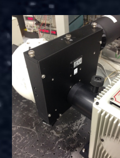


ADR Open – MKID



Lamp – Source of photons

Monochromator – Separates the light

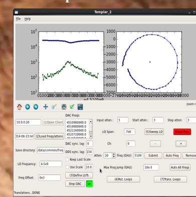


Shutter – Controls light from lamp

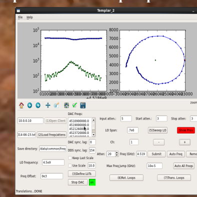
RESULTS

TESTING FOR RESONATORS

- To test for resonators, we use the *Network Analyzer* and the *ROACH* to complete a "wide sweep" of the pixels at chosen frequencies.
- Using the *Templar* GUI, each resonator is shown as a separate channel.
- Templar shows each resonator plotted in the complex plane.

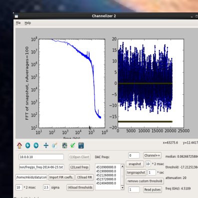


Templar – Channel Zero

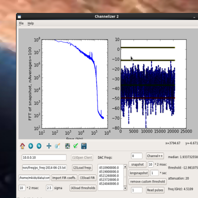


Templar – Channel One

- After finding resonators, the *Channelizer* GUI is used to observe photons making contact with the detector.
- Long and short snapshots can be taken to view the noise and light coming through the shutter and monochromator.



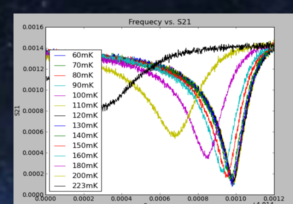
Channelizer – No light



Channelizer - Light

CHANGING TEMPERATURE

- To test the effects of temperature on the performance of the device, tests were run ranging from 60 mK through 223 mK.

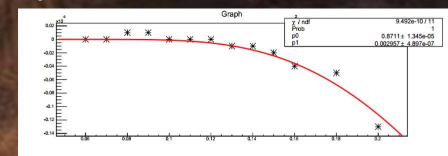


Frequency vs. S21

RESULTS (continued)

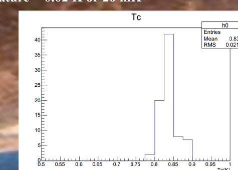
FITTING FOR CRITICAL TEMPERATURE

- Using the data from the temperature versus frequency graph, each pixel was fit for its critical temperature.
- By finding the critical temperature of each pixel, the temperature at which the pixel becomes superconducting can be found.
- In the figure below, pixel twenty-four was fitted and found to have a critical temperature of 0.87 Kelvin.



Pixel Twenty-Four – Fit for Critical Temperature

- This plot shows the distribution of the critical temperature of the ninety resonators that were observed.
- Out of ninety, seventy-nine had good critical temperature fits.
- RMS of the temperature = 0.02 K or 20 mK



Distribution of Critical Temperature

REFERENCES

Cohen, Julie. "A Cutting-Edge Detector for Astronomers." *The UCSB Current*. Web. 20 July 2014.
"A Cutting-Edge Detector for Astronomers." *The UCSB Current*. Web. 20 July 2014.
"Dark Energy, Dark Matter - NASA Science." *Dark Energy, Dark Matter - NASA Science*. Web. 18 July 2014.
"Dark Energy (Definition)." *About.com Physics*. Web. 20 July 2014.
"The Dark Energy Survey." - *Survey*. Web. 18 July 2014.
"Dark Energy." *Symmetry Magazine*. N.p., n.d. Web. 23 July 2014.
Dunbar, Brian. "Hubble Space Telescope Contributes to Nobel Prize in Physics." *NASA*. NASA, 05 Oct. 2011. Web. 22 July 2014.
"Kinetic Inductance Detector." *Wikipedia*. Wikimedia Foundation, 21 May 2014. Web. 20 July 2014.
"Kinetic Inductance Detector." *Wikipedia*. Wikimedia Foundation, 21 May 2014. Web. 20 July 2014.
Mazin, Ben. "Microwave Kinetic Inductance Detectors." (2004). Print.
"Mazin Lab." *Mazin Lab*. Web. 21 July 2014.
"Mazin Lab MKID Physics." *Mazin Lab MKID Physics*. Web. 21 July 2014.
"Physics - Overview and Resources." *About.com Physics*. Web. 21 July 2014.
"Prime Focus Spectrograph | SuMIRe Project." *Prime Focus Spectrograph | SuMIRe Project*. Web. 21 July 2014.
"Redshift." *Redshift*. Web. 21 July 2014.
"Redshift." *Wikipedia*. Wikimedia Foundation, 14 July 2014. Web. 20 July 2014.
"Southern Astrophysical Research Telescope." *Wikipedia*. Wikimedia Foundation, 17 July 2014. Web. 21 July 2014.
"What Is A CCD?" - *Charge Coupled Device*. Web. 20 July 2014.

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