

Microwave Kinetic Inductance Detectors (MKIDs)

Marty Navaroli, August 2011

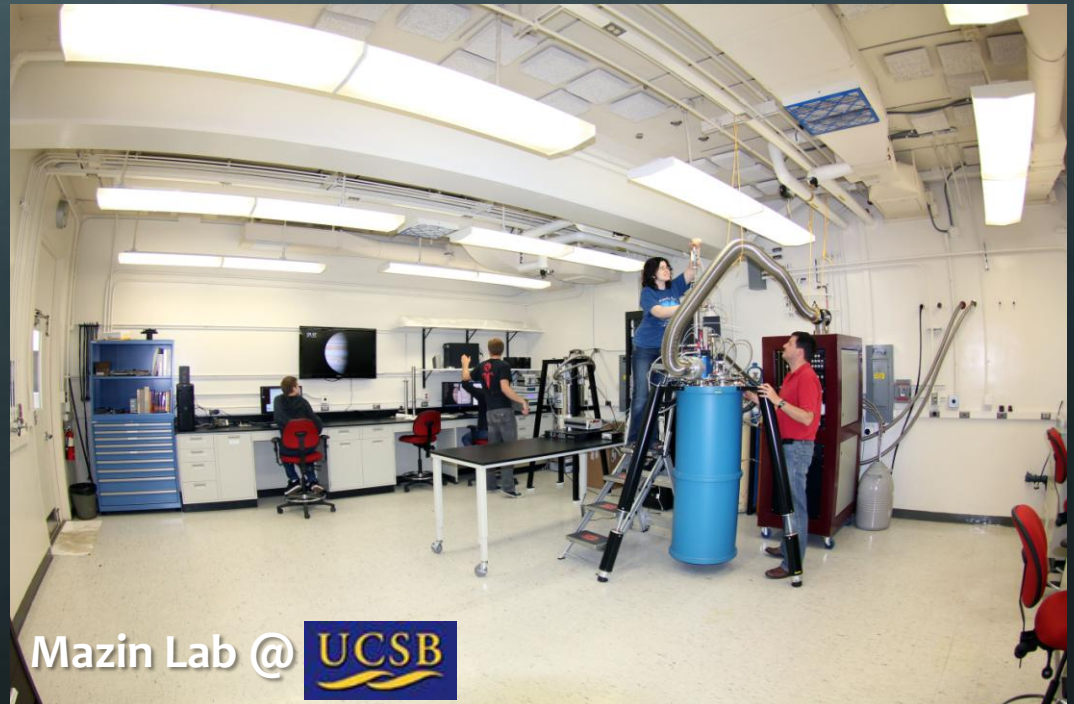
UCSB Optical/UV MKID Team:

Principle Investigator: Ben Mazin

Post-Doc: Sean McHugh, Kieran O'Brien

Graduate: Eric Langman, Seth Meeker

Undergraduate: William Spinella, Marty Navaroli

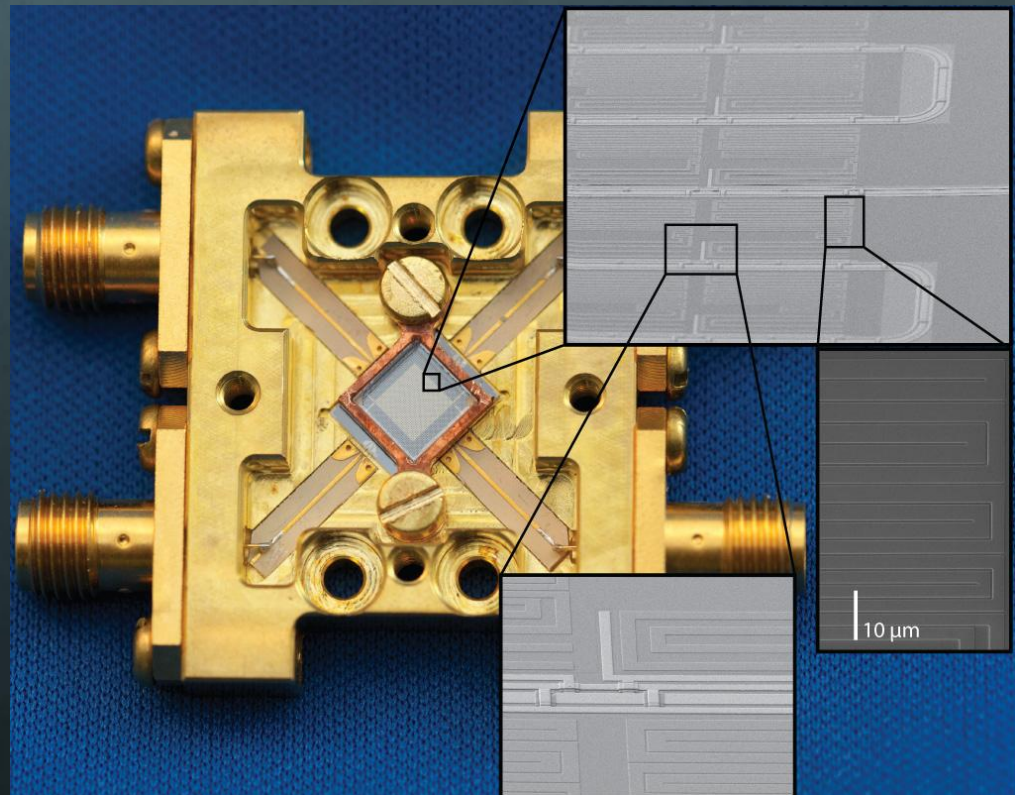


Mazin Lab @



What are MKIDs?

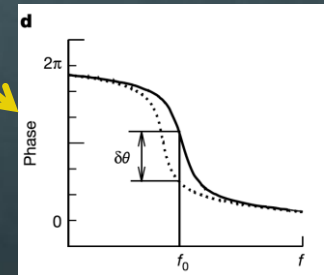
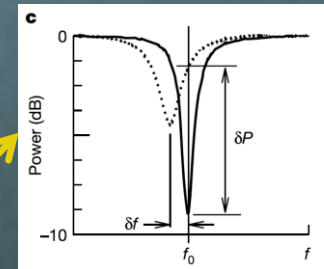
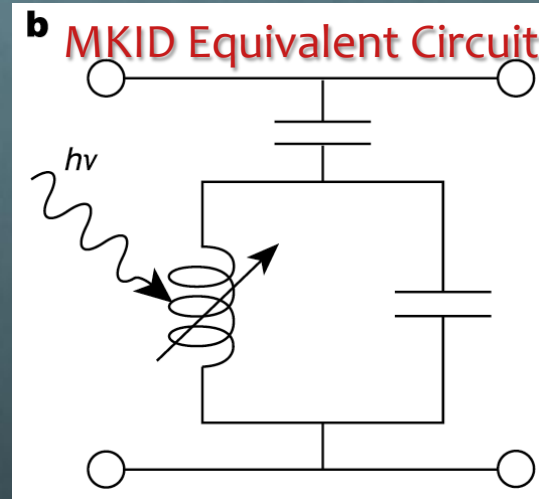
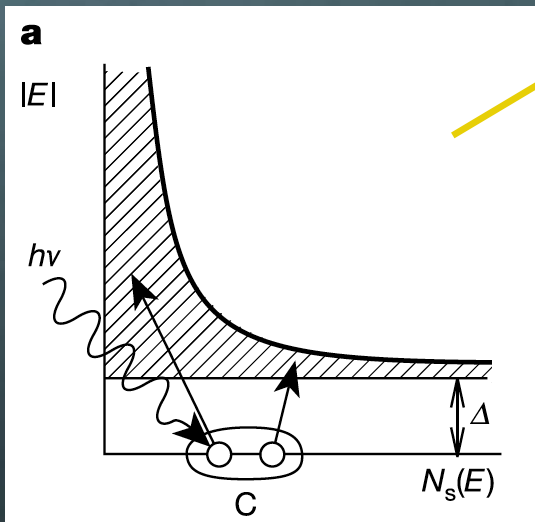
- Low temperature, superconducting photon detector
- Used for astronomy in the submillimeter, near infrared, optical, ultraviolet, and X-ray
- Can determine the energy and arrival time of individual photons
- Detect earth-like planets around nearby stars, observe time-dependent objects such as pulsars and x-ray binary systems, and measure galaxy redshifts



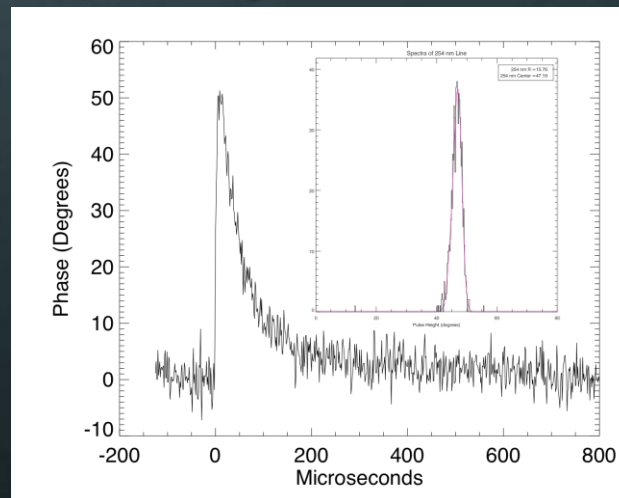
How do they work?

Kinetic Inductance Effect

Incident photon changes surface impedance of a superconductor

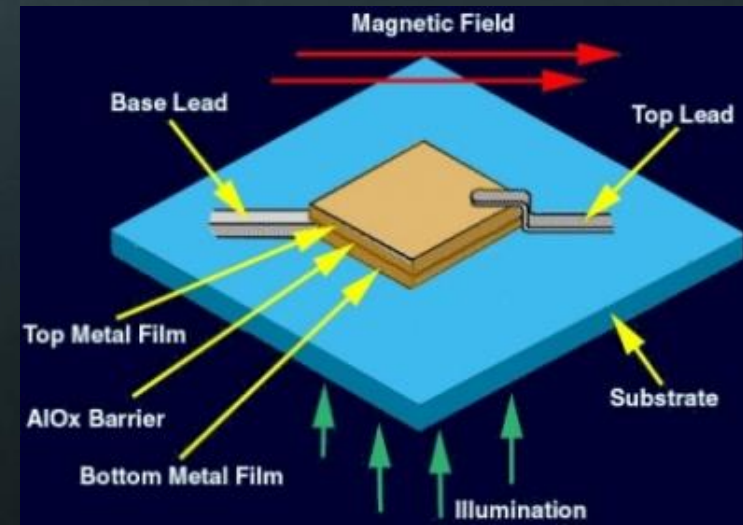
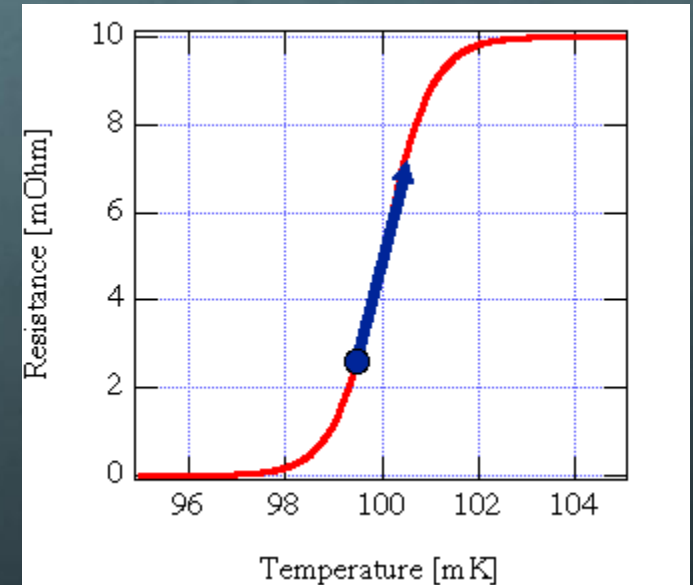


Typical Single Photon Event



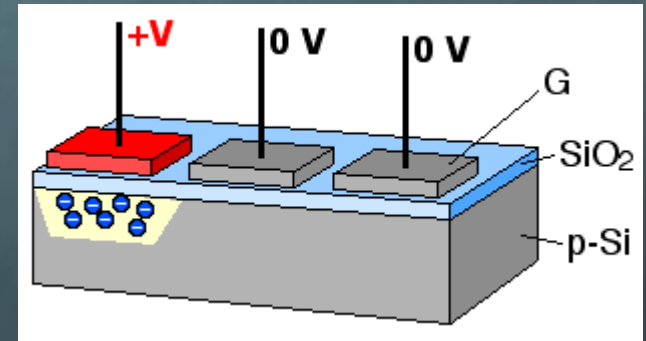
Other Low Temperature Detectors

- Transition edge sensor detectors (TESs)
 - Exploits non-instantaneous superconducting transition temperature region
 - Small energy absorption \rightarrow large resistance change
- Superconducting tunnel junction (STJs)
 - Uses superconducting-normal-superconducting (SNS) junction to measure quasiparticles created by breaking Cooper pairs
 - Magnetic field must be applied to each pixel to suppress Josephson current



Other Detectors (non-low temp)

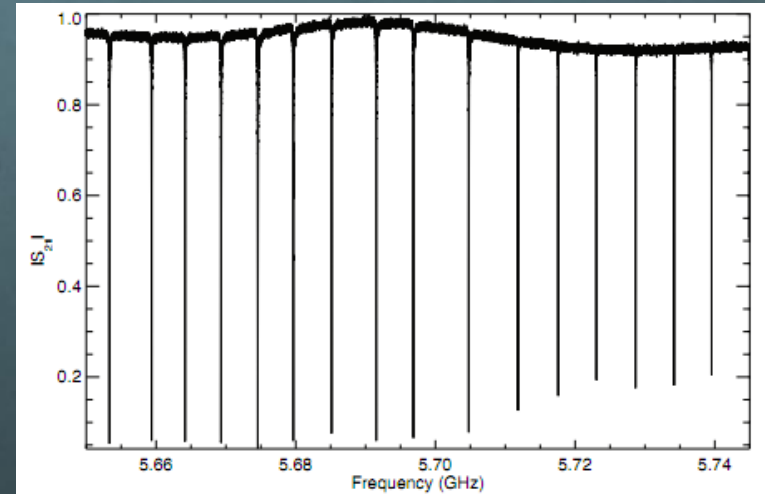
- Charged-couple devices (CCDs)
 - 2-D array of capacitors
 - Image projected onto capacitors causing capacitors to accumulate electric charge



- After the exposure, charge is transferred from capacitor to capacitor until it reaches a charge amplifier on the edge, which then converts it to a voltage and stored as digital memory
- This process takes time!

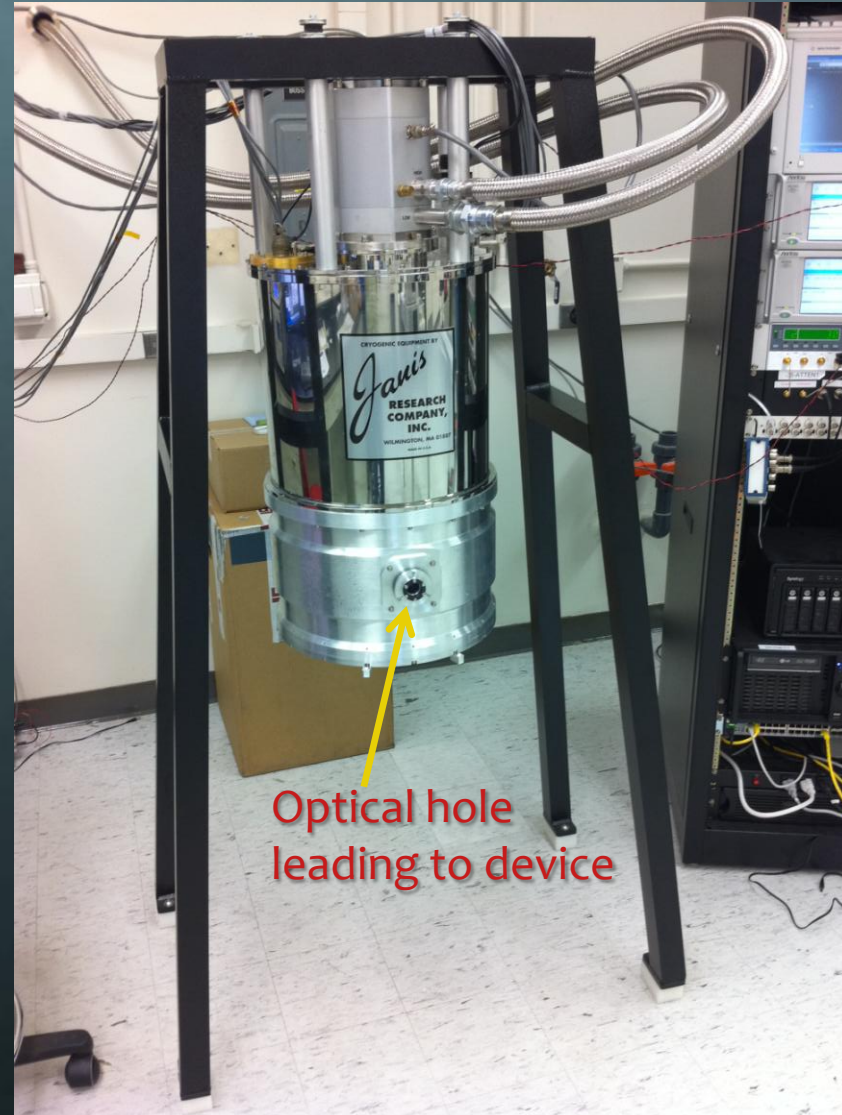
Benefits of MKIDs

- Very easy to make a large array
 - Thousands of resonators can be read out through a single coaxial cable and a single high electron mobility transistor (HEMT)
 - Like a radio station
 - TES/STJs require multiple wires per pixel
 - 32 x 32 array of pixels -> lots of wires
 - No Josephson junctions
- Time resolution up to six orders of magnitude better than a CCD
 - No read noise, dark current, or cosmic rays and ~10x the bandwidth!
- All readout electronics at room temperature



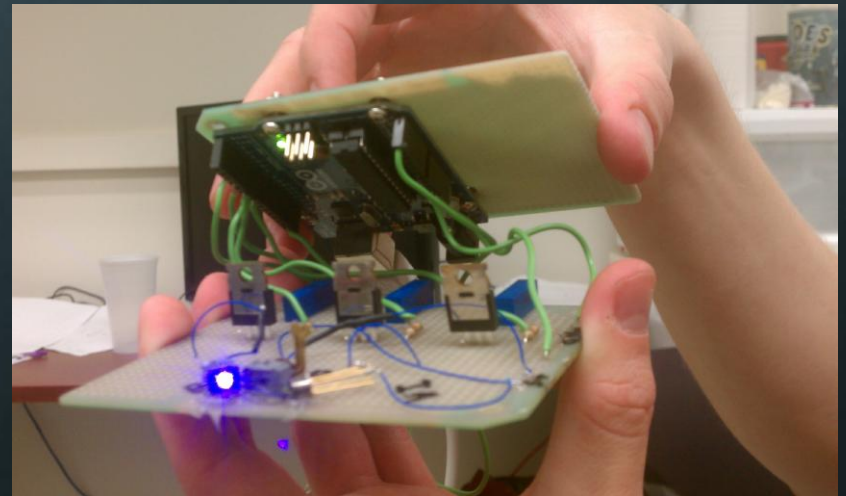
ARCONS Overview

- **AR**ray **C**amera for **O**ptical to **N**ear-IR Spectrophotometry (ARCONS)
- 1024 (32 x 32) pixel array in cryogen-free Adiabatic Demagnetization Refrigerator (ADR)
- About 10 x 10 arcsecond field of view
- Base temperature of 70 mK
- Bandwidth: 400-1100 nm
- Maximum count rate about 1000 counts/pixel/second
 - But still microsecond precision for individual photons!
- First light took place at Palomar Observatory between July and August of 2011



Over the Summer

- 🌐 Light calibration box
 - 🌐 Machine box and make circuit with red, blue, and IR lasers
 - 🌐 Wavelength and timing calibration
 - 🌐 Program arduino for steady output and to delay 1 PPS input signal by a pre-determined amount of microseconds
- 🌐 Learn Python to analyze Palomar data
- 🌐 And of course...



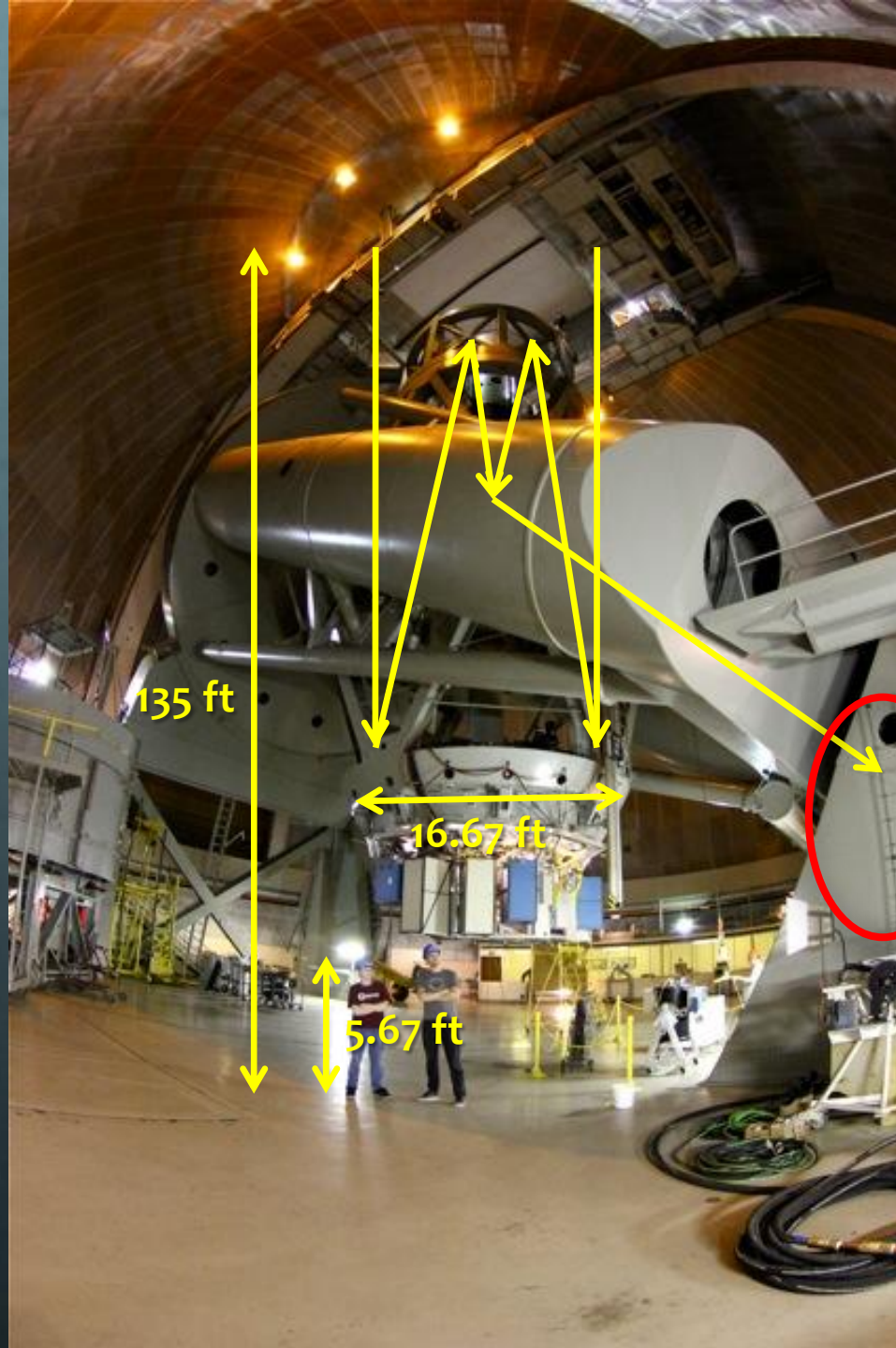
Palomar observatory



200" Hale Telescope

- 🌐 Built in 1948
 - 🌐 Remained the world's largest telescope until 1993
- 🌐 ARCONS tested on four nights in late July/early August, 2011





135 ft

16.67 ft

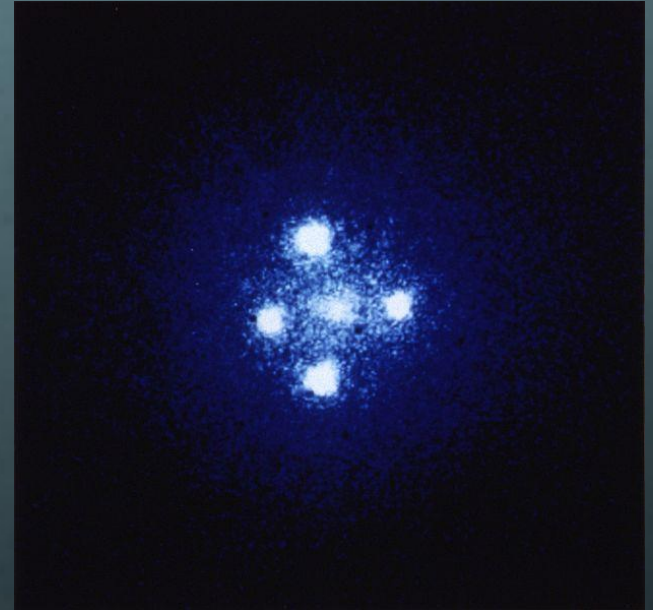
5.67 ft

ARCONS

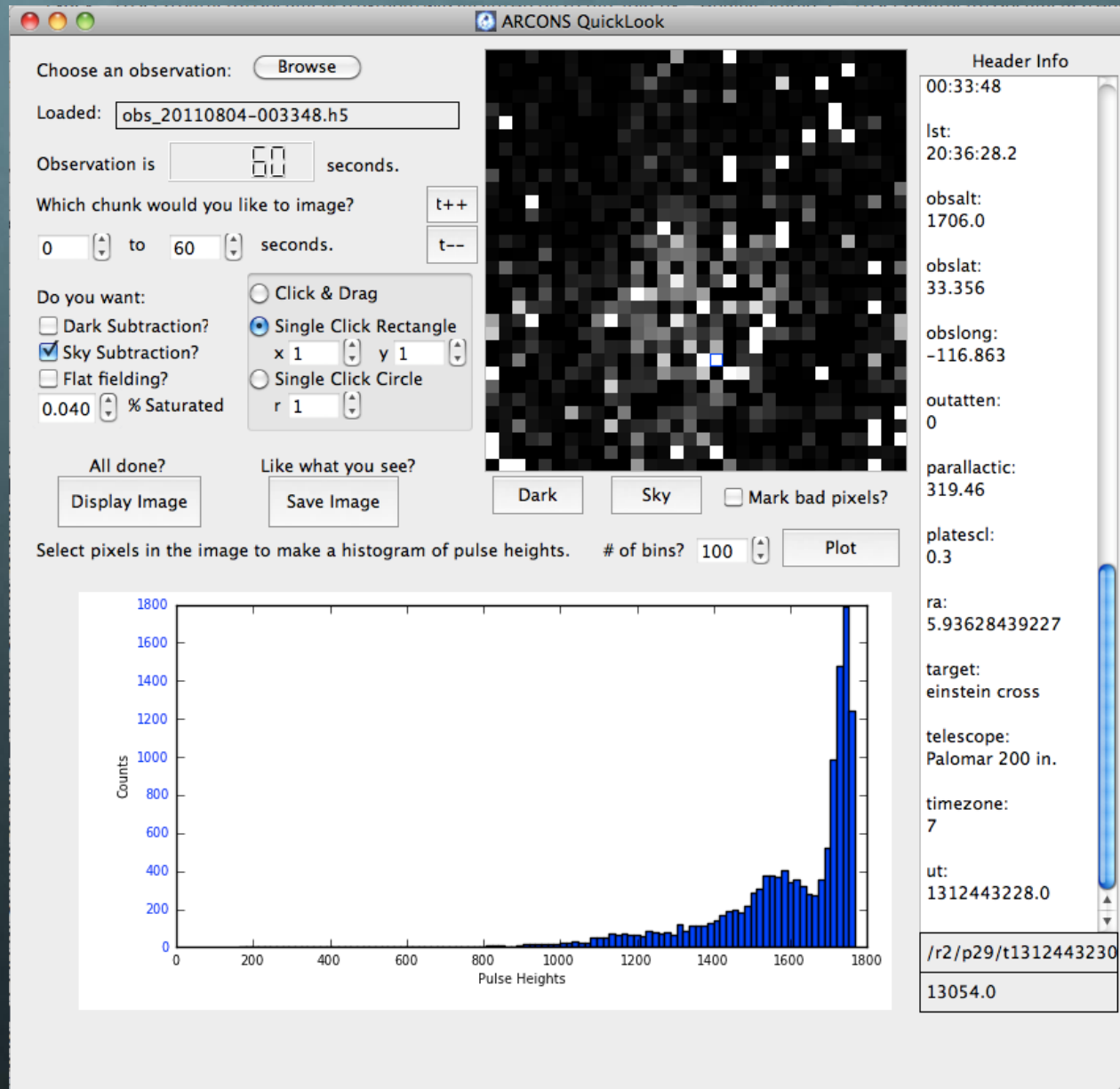


Einstein's Cross

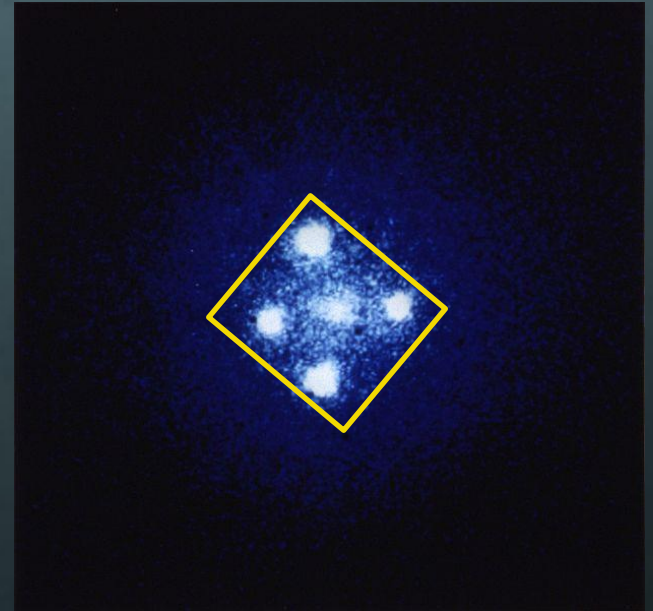
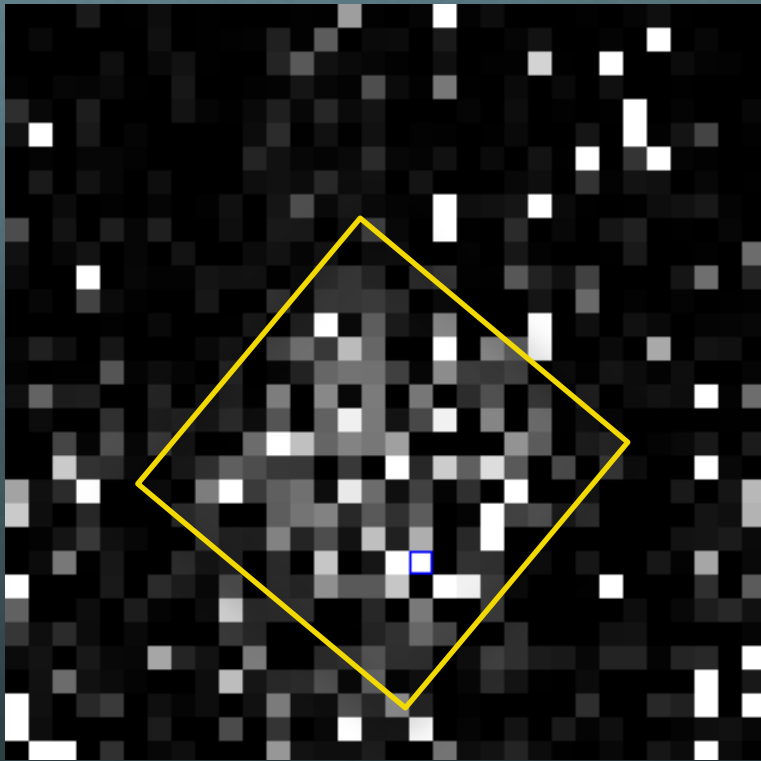
- 🌐 Gravitationally lensed quasar
- 🌐 Quasar 8 billion light years
- 🌐 Lensing galaxy 400 million light years



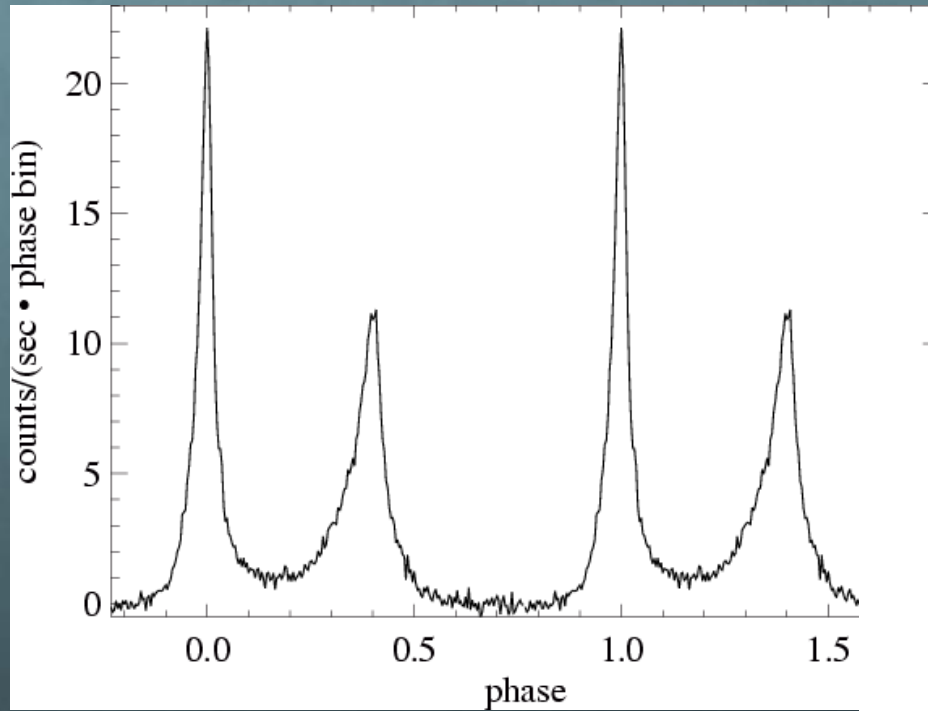
Our image of Einstein's Cross



Our image of Einstein's Cross

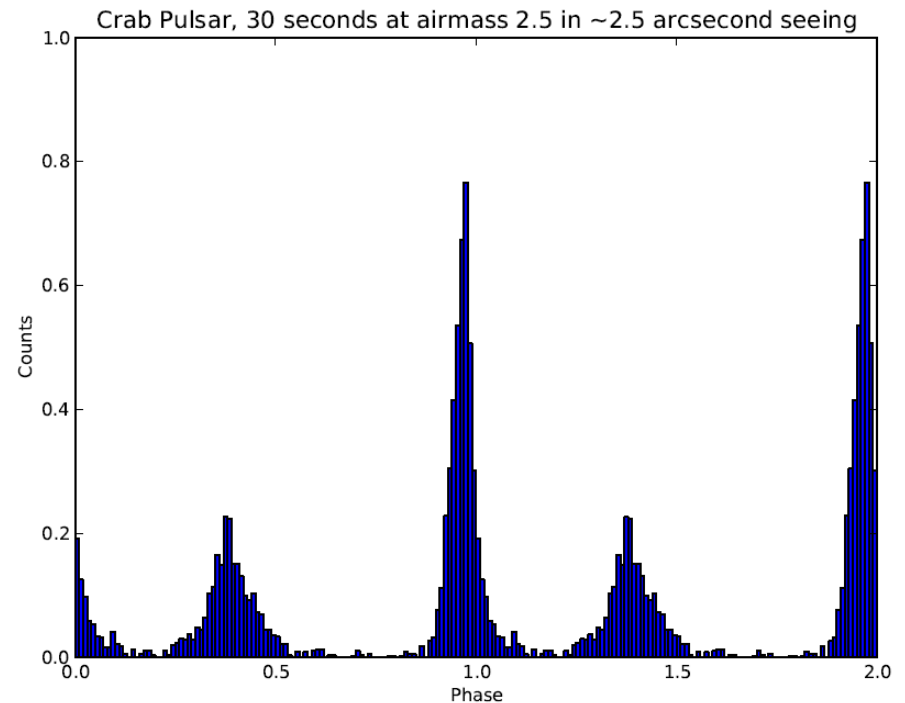


Crab Pulsar



**Pulse profile
measured with
ARCONS**

**Pulse profile for
Crab measured with
other instruments**



Conclusions

- 🌐 Palomar run very successful!
 - 🌐 Confirmed viability of MKIDs as a low temperature, individual photon detector in the optical and near-IR
- 🌐 Future goals
 - 🌐 Analyze Palomar data and extract science
 - 🌐 Obtain a better fill factor for the array
 - 🌐 Increase energy and time resolution of the pixels
 - 🌐 Fabricate larger arrays and adjust GUI/code to accommodate a larger field of view
 - 🌐 Return trip to Palomar in the spring and/or Keck next year