Kinetic Inductance Detectors for X-ray Astrophysics

Ben Mazin, April 2013

The X-ray KID Team:

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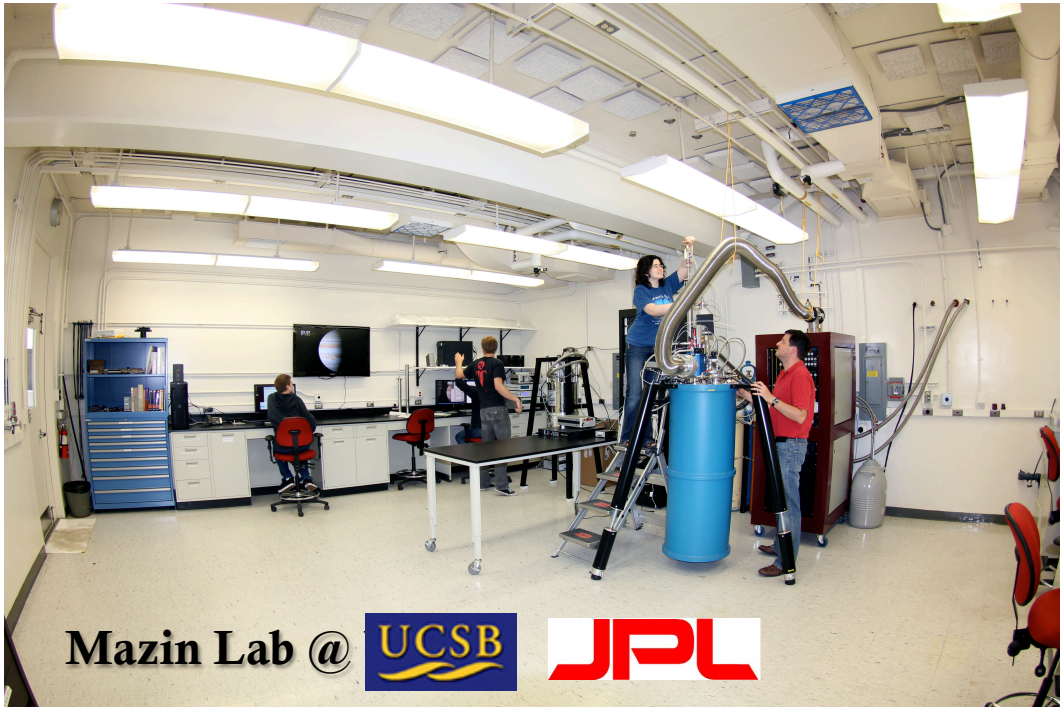
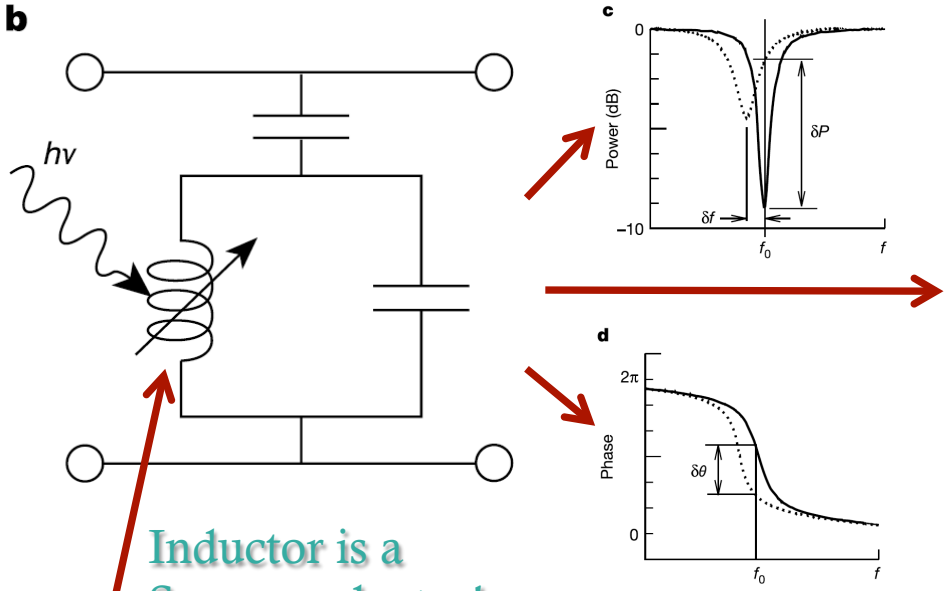
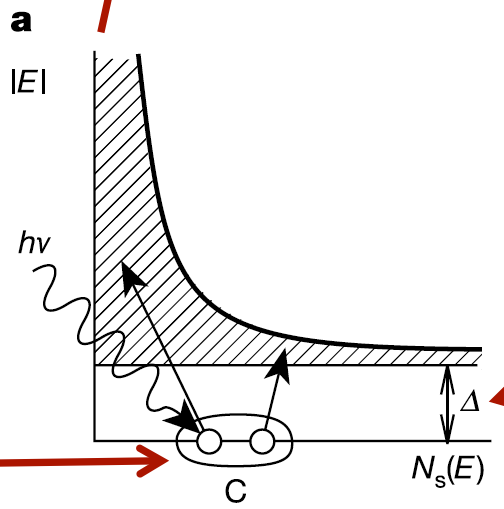


Microwave Kinetic Inductance Detectors

MKID Equivalent Circuit



Inductor is a Superconductor!



Cooper Pair

Energy Gap

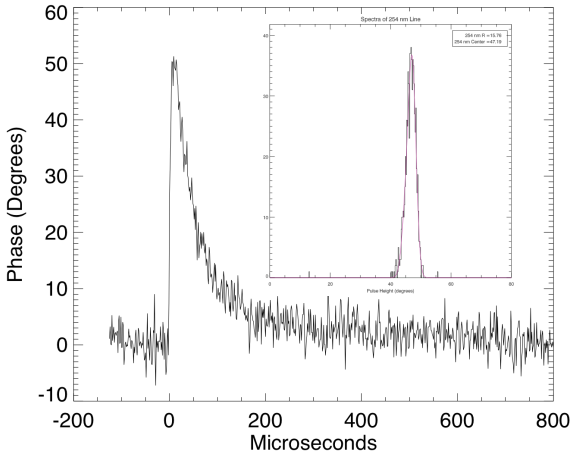
Silicon – 1.10000 eV

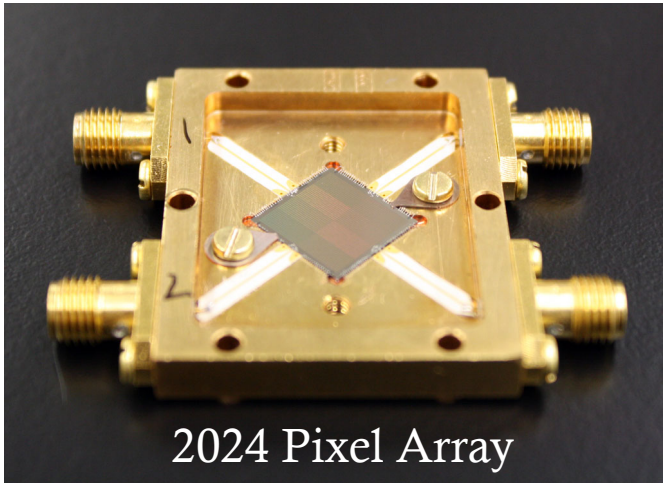
Aluminum – 0.00018 eV

Energy resolution:

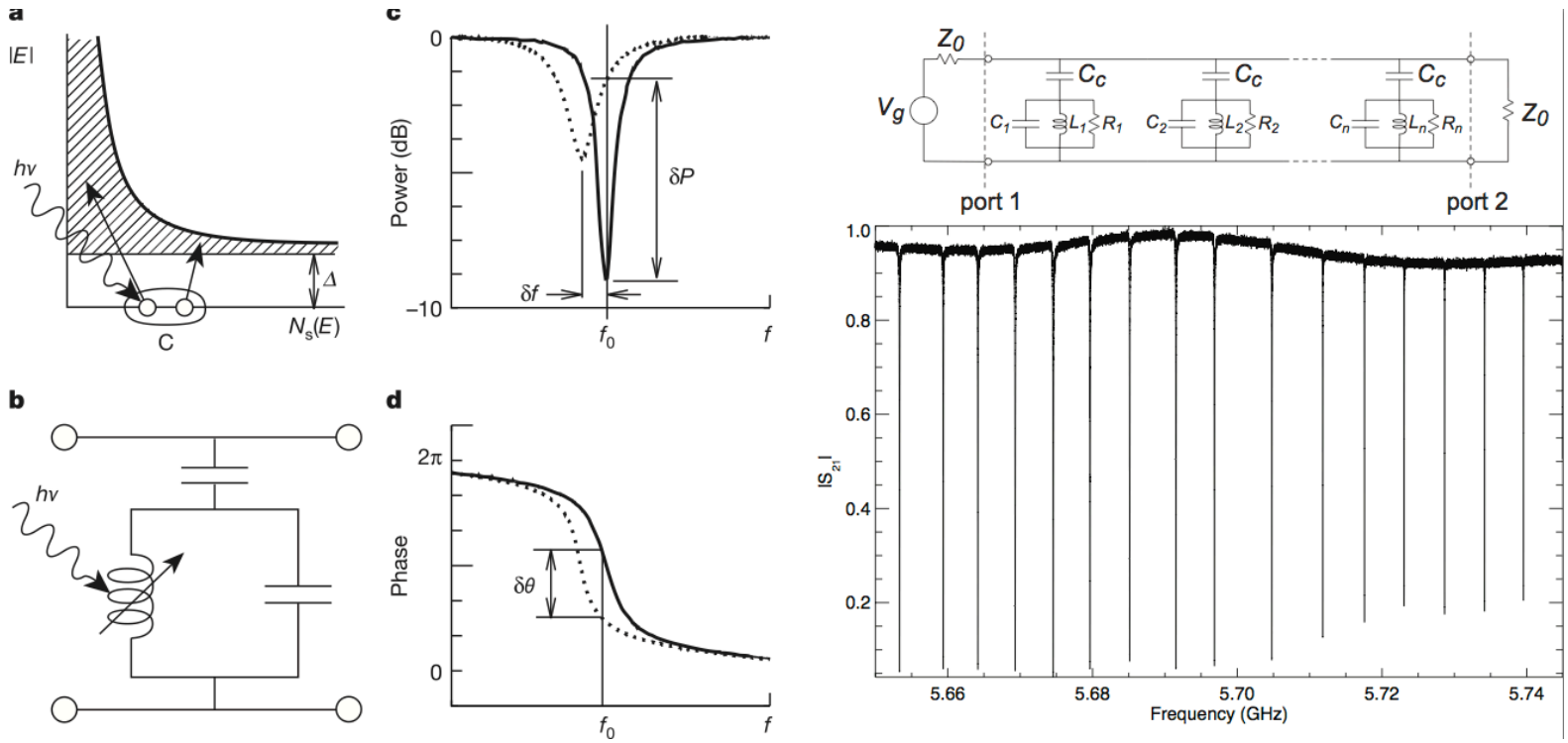
$$R = \frac{1}{2.355}\sqrt{\frac{\eta h\nu}{F\Delta}}$$

Typical Single Photon Event





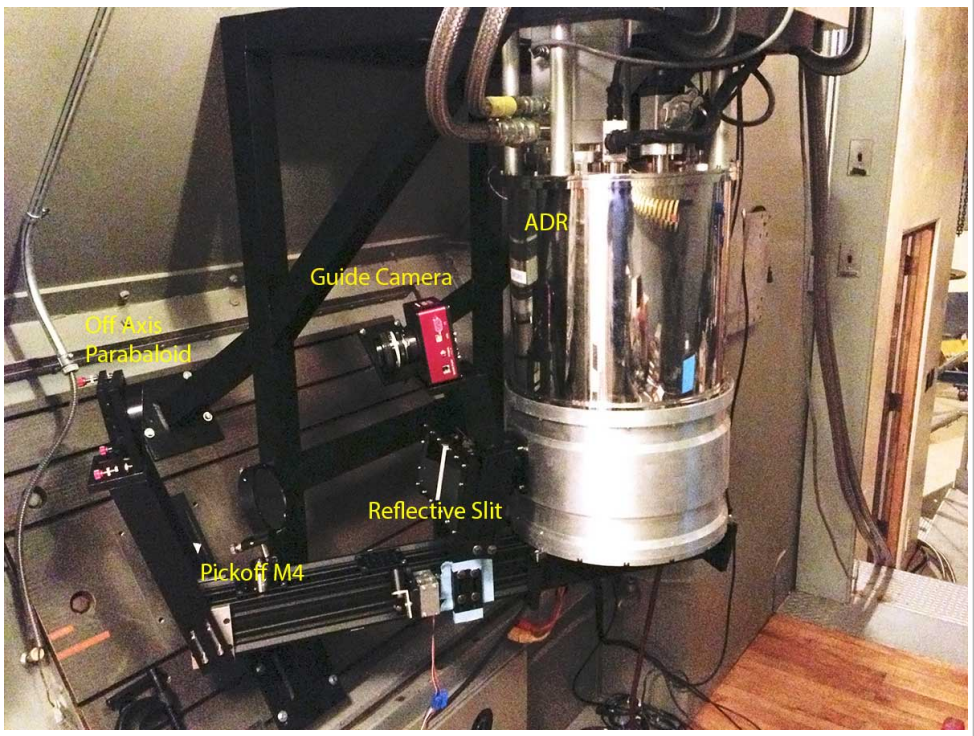
Frequency Domain Multiplexing



- Each resonator (pixel) has a unique resonant frequency in the GHz range
- A comb of sine waves is generated and sent through the device
- Thousands of resonators can be read out on a single microwave transmission line (FDM)

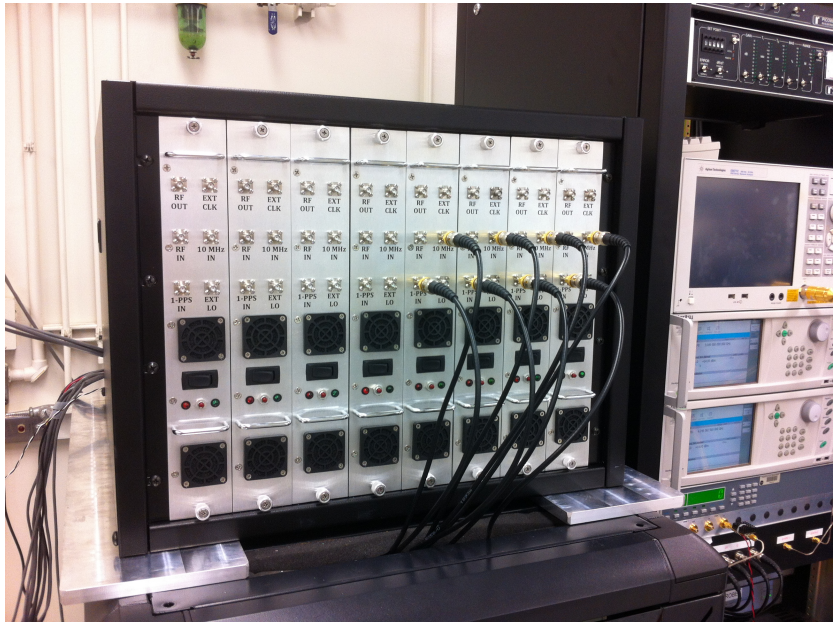
Proven at the Telescope with ARCONS

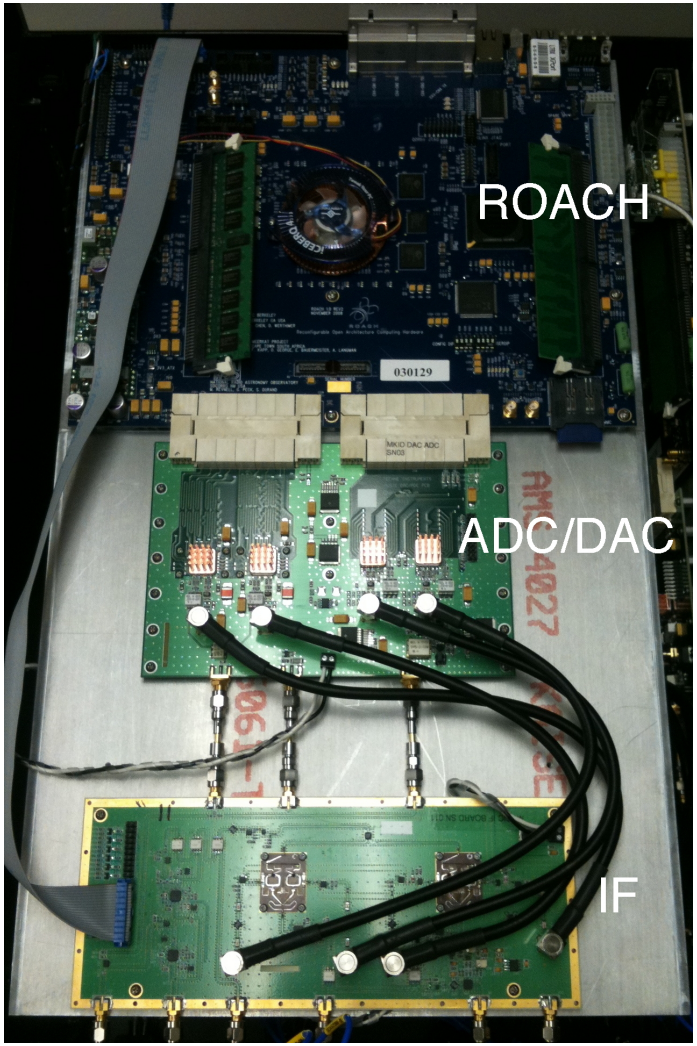
- Array Camera for Optical to Near-IR Spectrophotometery (ARCONS)
- First Light: July 28, 2011, Palomar 200” Coudé
- Now 24 observing nights (Palomar+Lick)
- Lens coupled 2024 (44x46) pixel array in cryogen-free ADR
- 0.5” pixels yields 22”x23” FOV
- 400 nm to 1100 nm simultaneous bandwidth with maximum count rate of ~2000 cts/pixel/sec
- 350-1350 nm soon
- Energy resolution R~10 at 400 nm



Current System (Gen 1)

- Dual 1 GSPS 16-bit DACs
- Dual 550 MSPS 12-bit ADCs
- ROACH with Virtex 5 SX95T
- Complete readout for 256 resonators in 550 MHz of bandwidth
- 8 ROACH boards read out 2048 pix
- ~$25/pixel (Gen2 - $3/pixel)



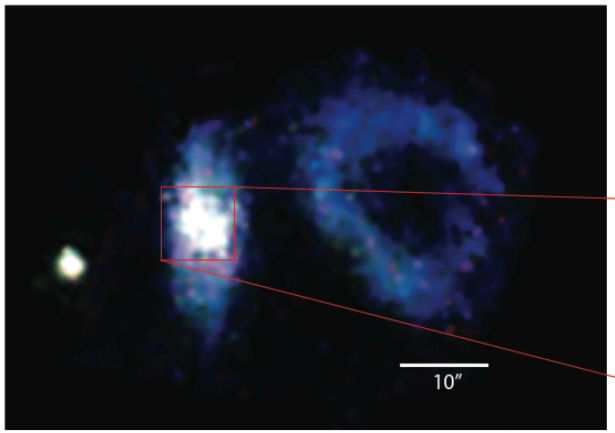


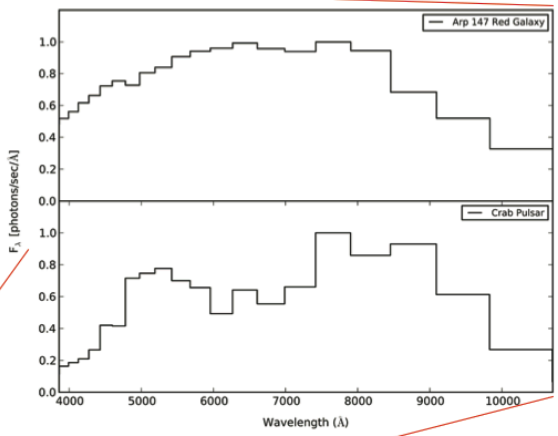
Crab Pulsar

First UVOIR Science Results

First Science Data

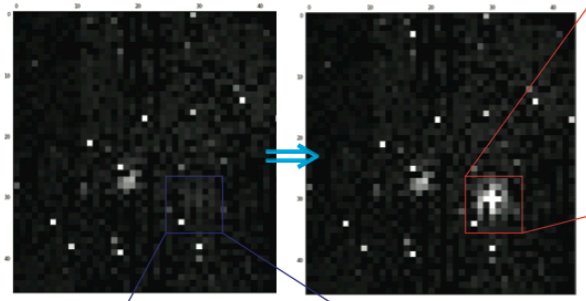
Left: ARCONS mosaic of interacting galaxy system, Arp 147. Composite of red, green, and blue images.
Below: Spectrum of central Arp 147 galaxy taken from 40 seconds of data



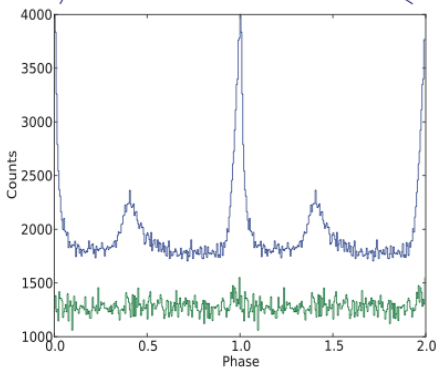


SPECTRA

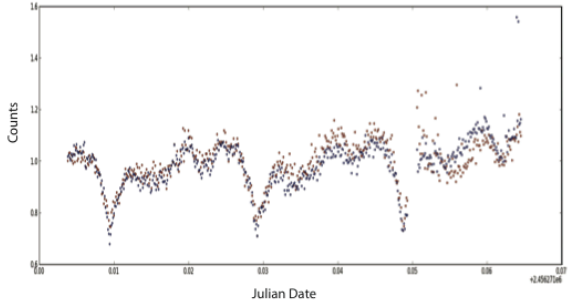
IMAGING



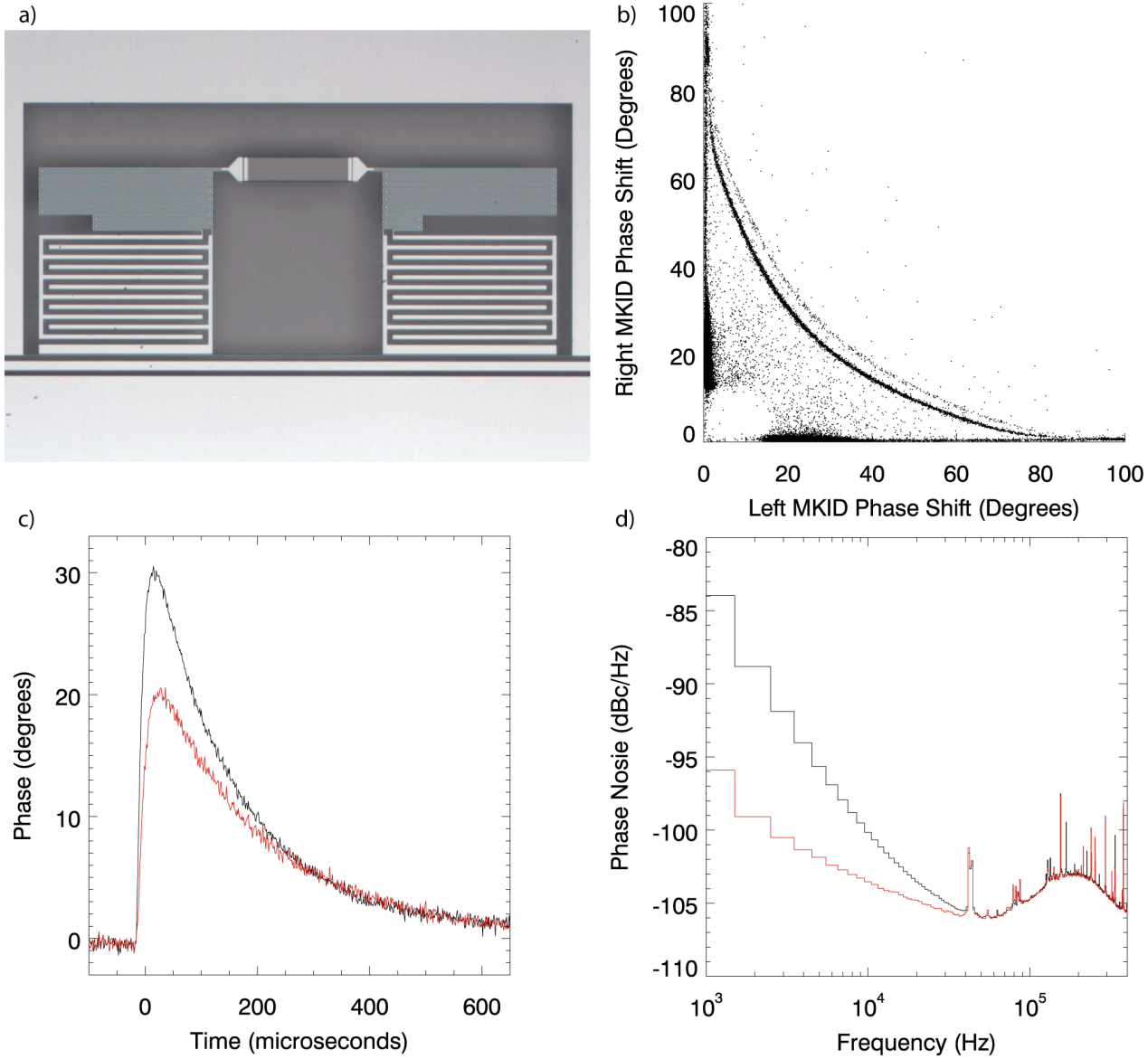
Left: Completely unprocessed images of Crab pulsar and neighboring star.
Bottom Left : 33 millisecond optical pulse profile of Crab pulsar.
Above: Optical/near-IR spectrum of Crab pulsar
Below: Optical light curve of SDSS-J0926 eclipsing cataclysmic binary system



TIMING

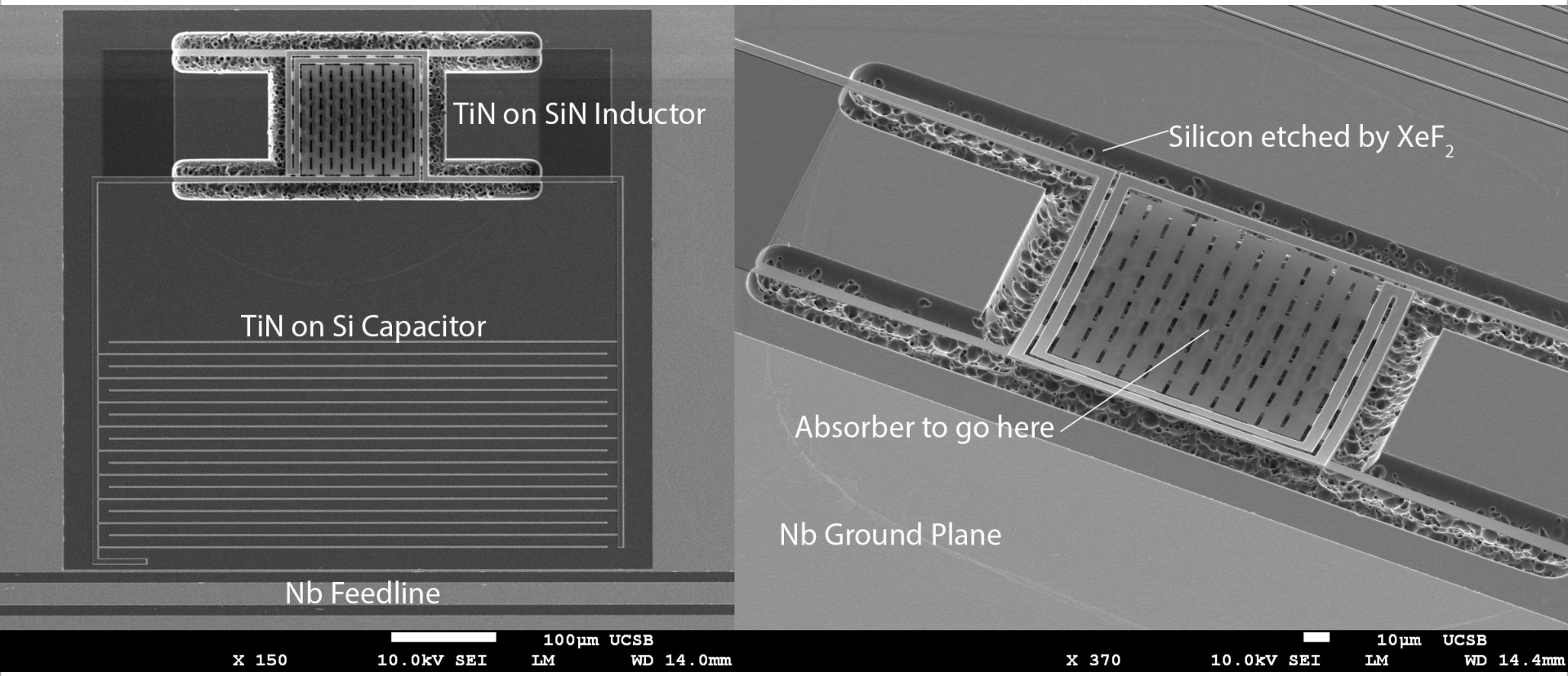


- MKIDs: Equilibrium Strip Detectors.



Thermal KIDs

- We can get better energy resolution by taking a page from the TES playbook!
  - Thermal Kinetic Inductance Detectors (TKIDs)
    - KID inductor on SiN Membrane, capacitor on bulk Si
    - X-ray hits absorber on island, heats island, breaks qps, changes surface imped.
    - Eventually superconducting mushroom absorbers (W_3Si_5? TiN? TaN? PtSi?)
    - Made at UCSB!



First TKID Results

- Pulse lifetimes up to 1.6 ms with TiN!
- Saturated, but noise and pulse shape imply <10 eV at 6 keV
- Devices with absorbers coming very soon!