A 4D Superconducting MKID Camera for CFHT

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National Research Council Canada | Conseil national de recherches Canada

Canada

A Proud History of Imaging at CFHT

- HRCAM
- PUEO
- MOCAM
- CFH12K
- MegaCam
- WIRCAM

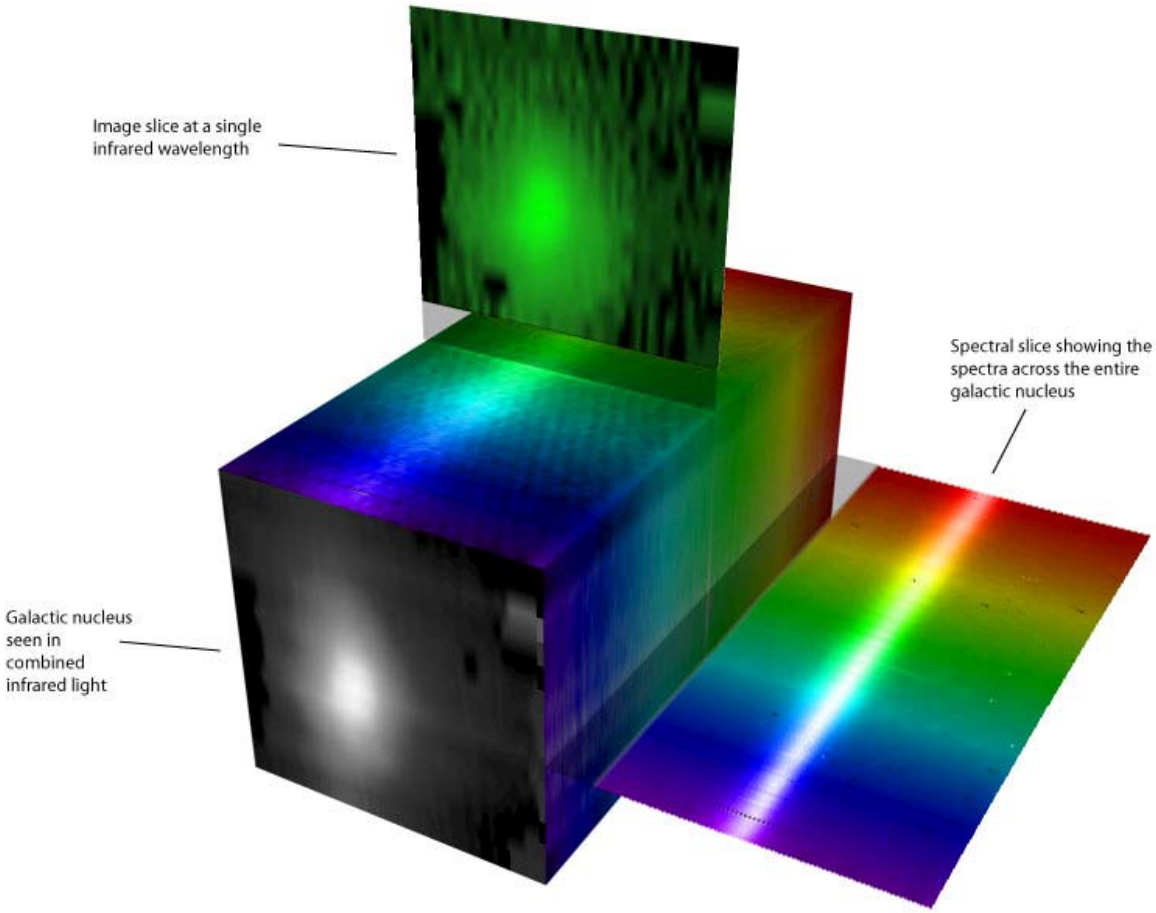
A Proud History of Imaging at CFHT

- HRCAM
- PUEO
- MOCA
- CFH12
- MegaC
- WIRC/

CFHT is the best site on Mauna Kea in terms of image quality

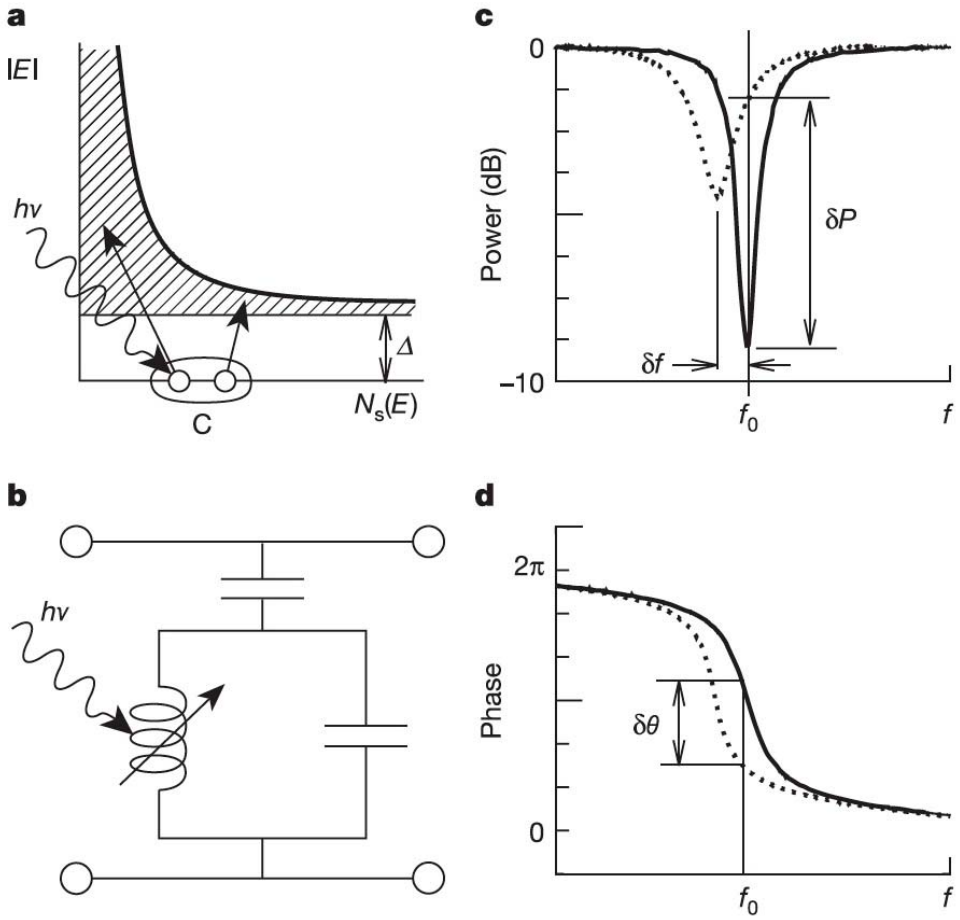
Time for another breakthrough!

“4D” Datacubes: The Ultimate Dataset



+ Time !

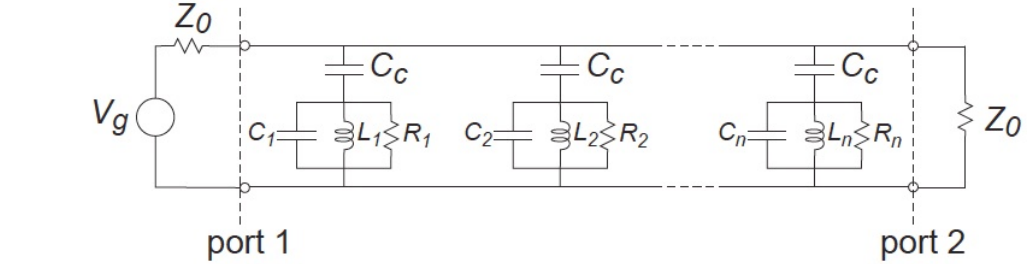
Microwave Kinetic Inductance Detector (MKID)

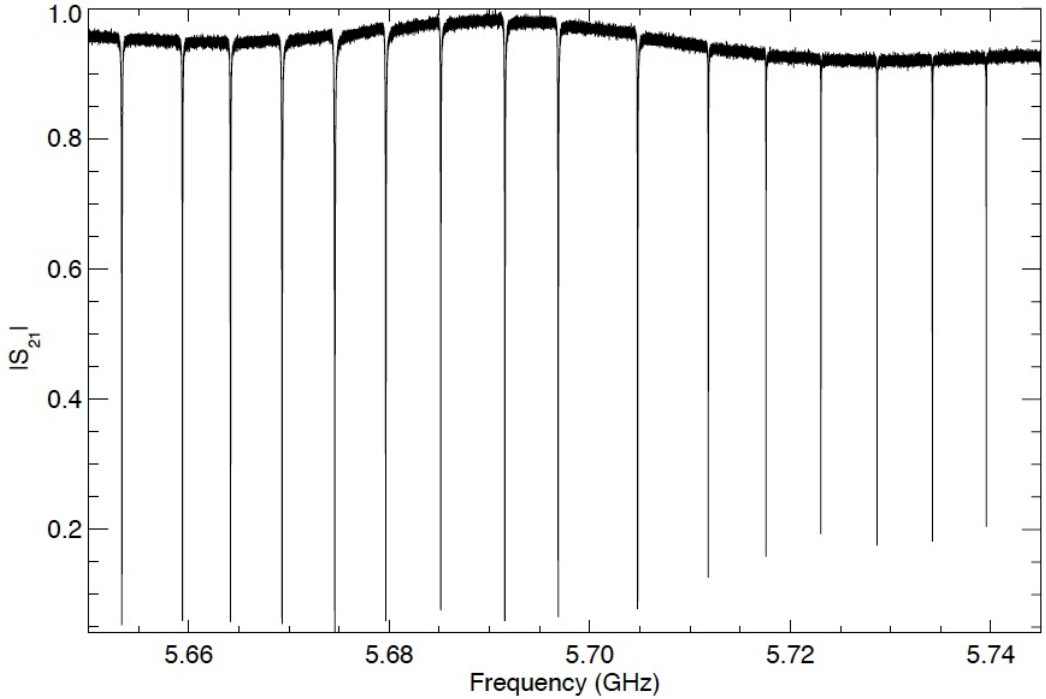


MKIDs are well-known in sub-mm astronomy

They are now ready for the UV/optical/near-IR!

MKID: Built-in Frequency Domain Multiplexing





Up to 1000 resonators can be connected to a single feed line

Highly scalable with multiple feed lines

An Actual MKID Device

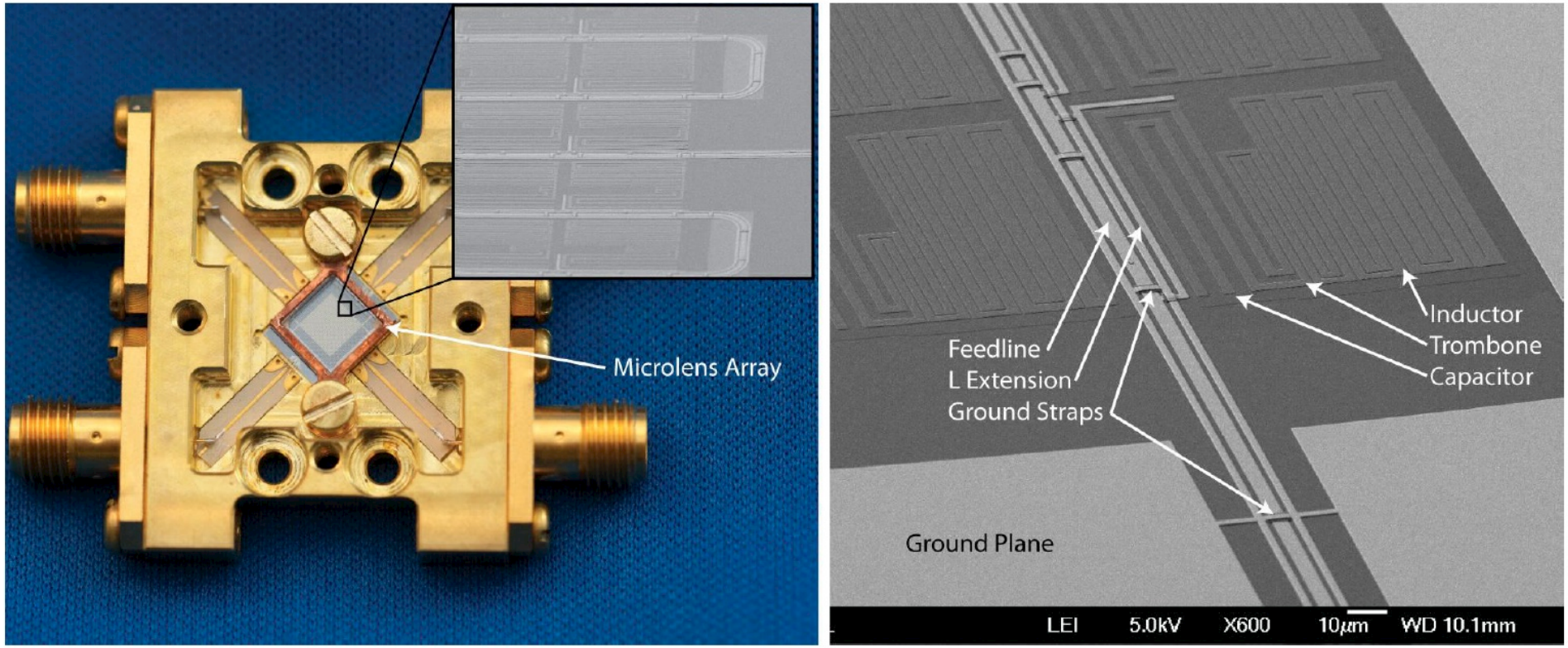
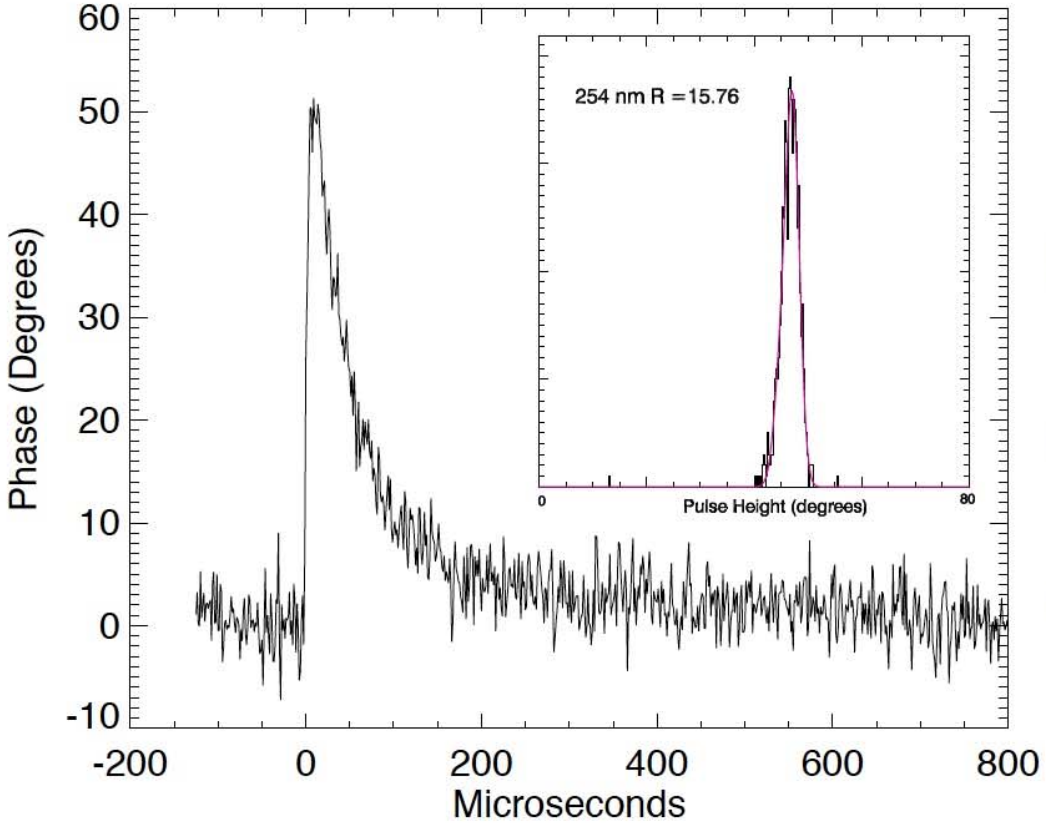


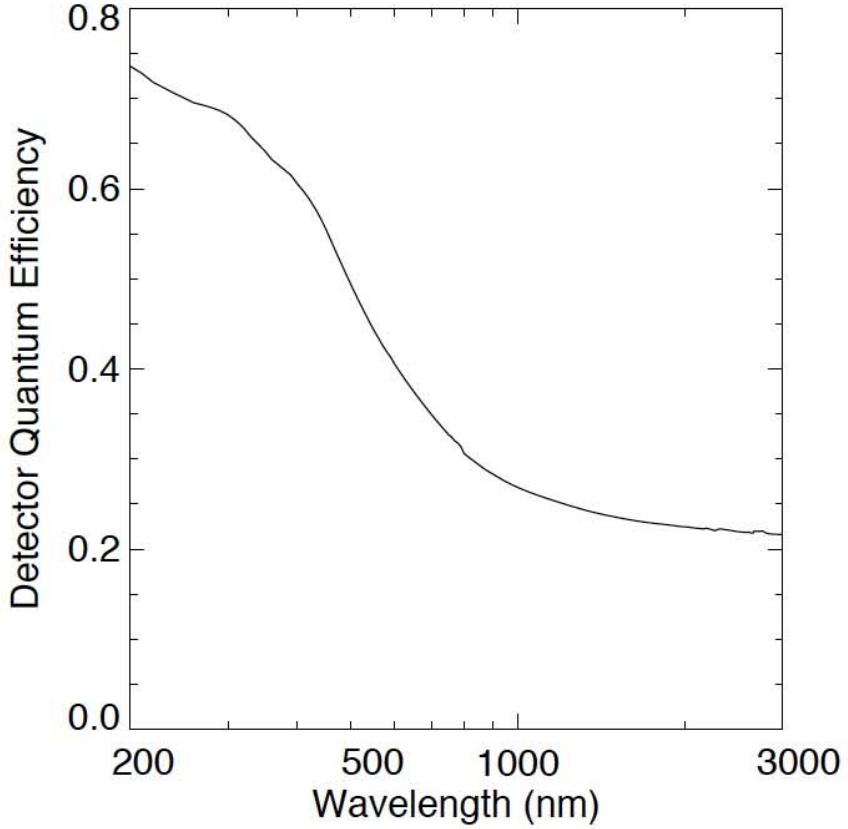
Figure 1. Left: A photograph of the ARCONS 1024 pixel MKID array with microlenses mounted into a microwave package. Right: Scanning electron microscope (SEM) images of the array highlighting the pixel design.

MKID Advantages

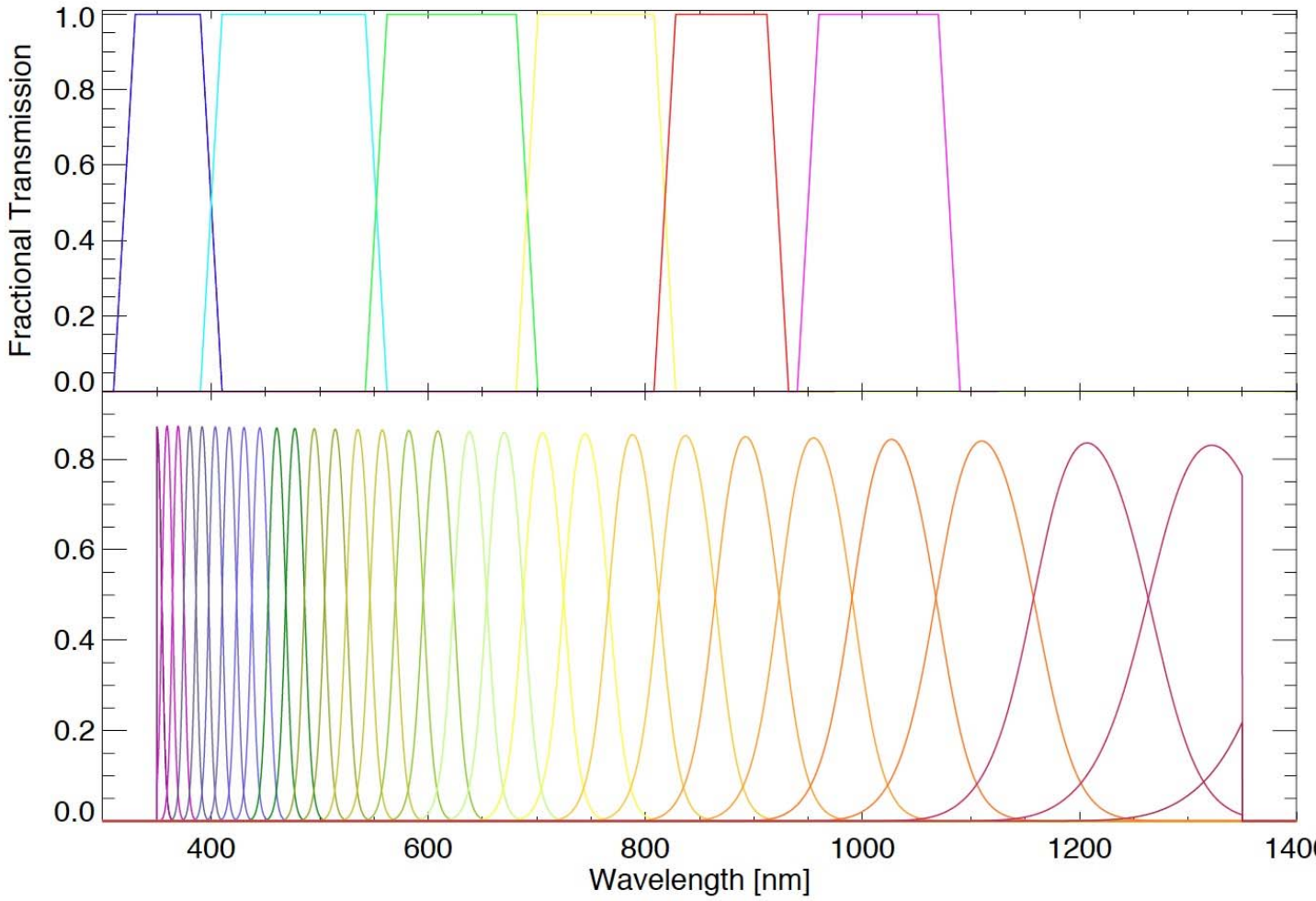
- Provide individual photon x-y position, energy and arrival time
- Time resolution up to six orders of magnitude better than a CCD
- Extremely broad intrinsic bandwidth with good quantum efficiency from 0.1 – 6 μm; nearly 10 times the bandwidth of a CCD
- No read noise or dark current and nearly perfect cosmic ray rejection
- Time domain information allows use of calibration star for dynamic apertures and tip-tilt corrections
- Photon arrival time, energy resolution and large number of pixels allow monitoring and removal of sky emission

MKID Resolution and Efficiency





MKID Bandpasses



LSST
u, g, r, i, z, y

R = 50
30 “filters”

MKID as a SuperMOS

Giga-Z (100,000 pixels):

- Observe ~ 2 billion galaxies in 3 years on dedicated 4-m class telescope
- Low-resolution SED spanning 350-1350nm
- 1000 times number of galaxies that could be measured on any currently proposed LSST spectroscopic follow-up facility
- Redshifts for galaxies up to z~6 down to i=25 with accuracy $\sigma(\Delta z)/(1+z) = 0.03$ for the whole sample

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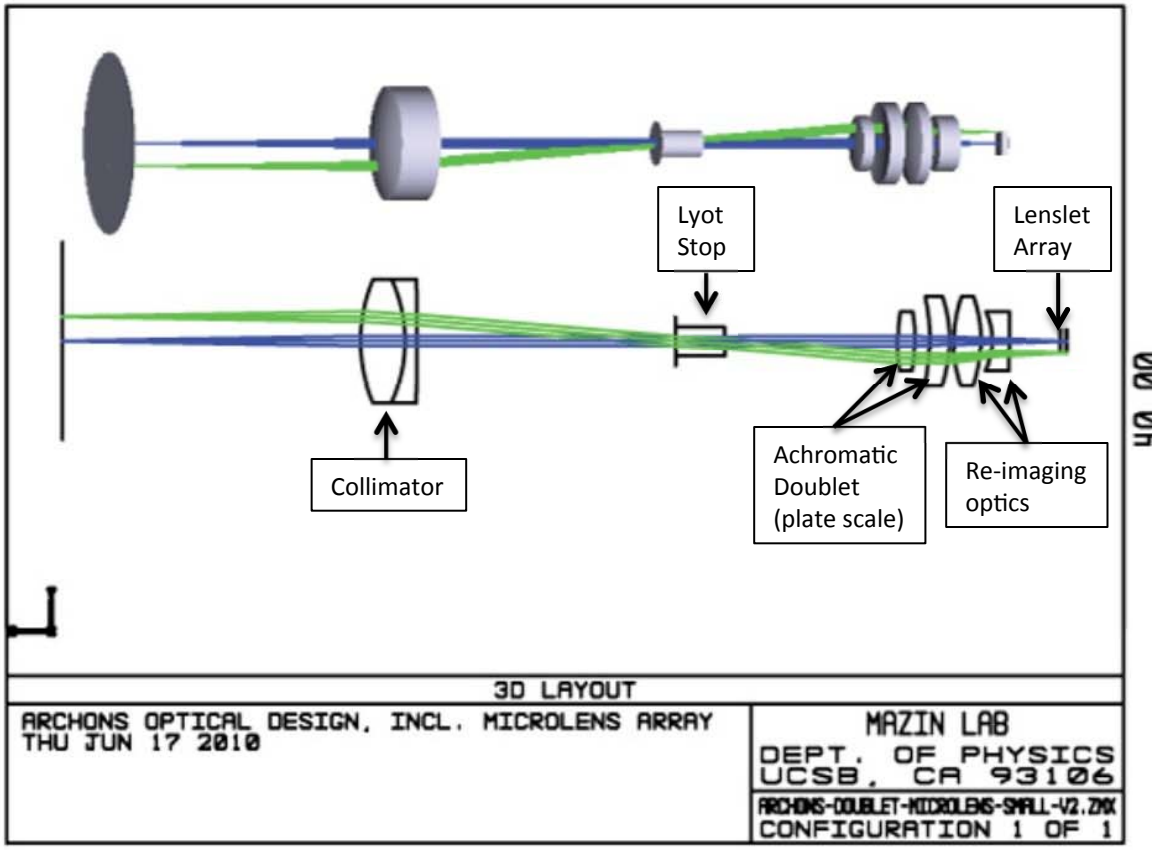
Preliminary estimate suggests that a smaller-scale, MKID-based SuperMOS at CFHT could observe around 45 million galaxies down to r~24 in the CFHTLS fields in 150 nights!

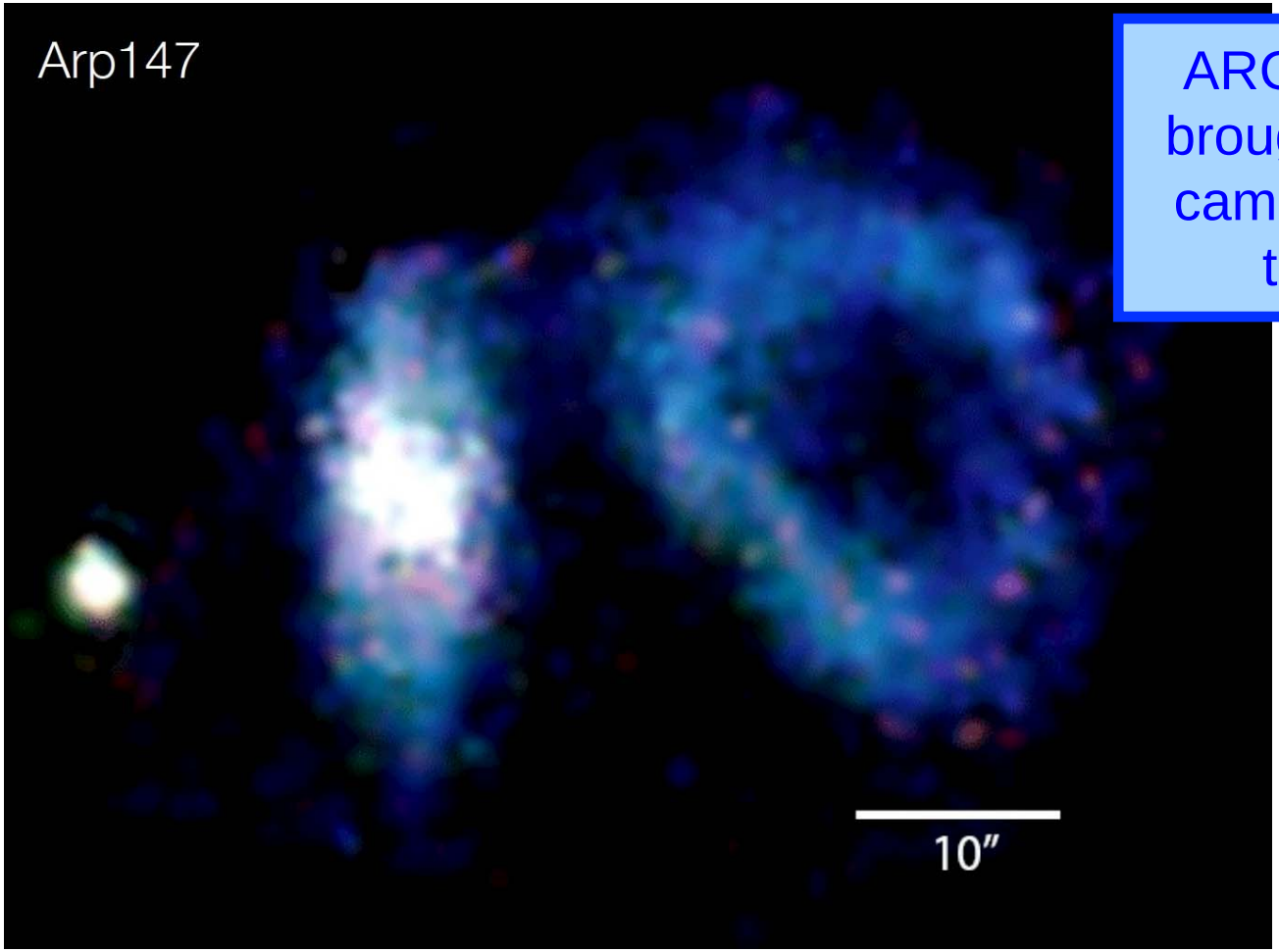
ARCONS-I: A Contiguous Imager

- Array Camera for Optical to Near-IR Spectrophotometry (ARCONS)
- Lens coupled 2024-pixel array
- 20” x 20” FoV with 0”.33 per pixel
- 350nm to 1350 nm simultaneous bandwidth
- Energy resolution R~20 at 400nm
- High, on-sky QE (detectors ~50%)
- Commissioned at Palomar Coudé focus during four nights in 2011
- Compact Object and Extragalactic Science

ARCONS-I Cryostat and Optical Design



ARCONS-I Palomar Data



ARCONS-I could be brought to CFHT as a campaign instrument this fall/winter

CFHT/ARCONS: A Proposal

- 30,000-pixel contiguous imaging camera
- 350nm – 1350 nm
- R = 20
- 49”.8 x 49”.8 FoV at Coudé focus, 0”.28 per pixel
- Excellent tip-tilt corrections in post-processing
- 4D photon stream data explorer
- Cost: $1.2M
- Timescale: 2 years

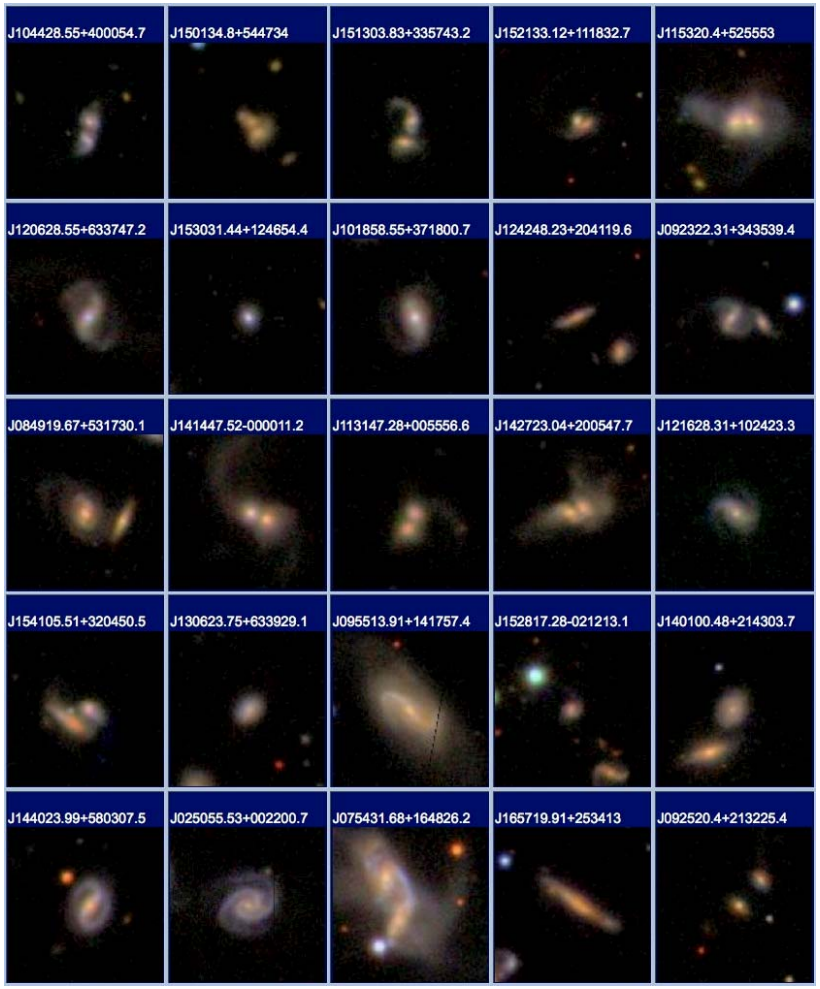
CFHT/ARCONS Science

- Compact objects:
  - Optical pulsars and magnetars
  - X-ray binaries
  - White dwarfs

- Stellar populations

- Formation and evolution of galaxies:
  - High-spatial resolution maps of stellar mass, star formation rate and history, dust, central AGNs

CFHT/ARCONS Science: SDSS AGNs



50’’ x 50’’ postage stamps of SDSS close galaxy pairs with dual AGNs

SDSS FWHM = 1’’.5

CFHT/ARCONS would provide high-spatial resolution datacubes for maps of M_*, τ, Z, dust, and age and show impact of AGNs on their host galaxies

CFHT/ARCONS Preliminary Project Structure

1. PSC: Project Science [**UVic**, UCSB]
2. MGT: Management [UCBS, HIA]
3. SYS: Systems Engineering [HIA]
4. INST: Instrument
    - INST.OIWFS: On-instrument wavefront sensor [**UVic**, HIA]
    - INST.OPT: All optics including parts, mounts and activities such as integration, alignment and testing [**UVic**, HIA]
    - INST.STR: Instrument support structure [**UVic**, HIA]
    - INST.DEW: All parts, mounts and activities associated with the Dewar
    - INST.DEW.DEW: dewar [**UVic**]
    - INST.DEW.CRYO: dewar cryogenics [UCSB, HIA]
    - INST.DEW.DET: dewar detector i.e., the MKIDs [UCSB]
    - INST.ELE: Electrical and electronics [UCSB, HIA]
5. SW: System software [UCSB, HIA]
6. DAT: Data products
    - DAT.HANDLING: getting data to archive [HIA]
    - DAT.ARCHIVE: storage, providing data to users including visualization and exploration [**UVic**, UCSB]
    - DAT.ANALYSIS: analysis of data, for both instrumentation performance checks and early science [**UVic**, UCSB]
7. INT: Assembly & Integration and Test [**UVic**, HIA, UCSB]
8. COMM: Instrument Commissioning at Telescope [**UVic**, HIA, UCSB]

CFHT/ARCONS Next Steps

- Assemble science team, study trade-offs and establish instrument top-level requirements
  - **If interested, please contact us!**
- Initiate work on optical design and post-processing algorithms
- CFHT AO in August
- ARCONS-I at CFHT in Fall/Winter?
- Start building CFHT/ARCONS in January 2014?

Summary

- Powerful 4D instrument equivalent to a 15-filter system with unique access to a new domain of time-resolved observations

- Exciting science from exotic compact objects in the Milky Way to distant galaxies

- CFHT/ARCONS will attract observers that may not have used CFHT previously

Summary

- Powerful 4D instrument equivalent to a 15-filter system with u ed obser
- Excitin Milky Way t
- CFHT/ARCONS will attract observers that may not have used CFHT previously

Building upon its proud history of imaging breakthroughs, CFHT now has an opportunity to usher in science with the next-generation of astronomical detectors!

Useful References

- O'Brien, K. et al. 2012, "ARCONS: a 1024 pixel superconducting integral field spectrograph", SPIE, 8446
  - http://dx.doi.org/10.1117/12.924920

- Mazin et al. 2012, "SuperMOS: a new class of low resolution multiobject spectrograph", SPIE, 8446
  - http://dx.doi.org/10.1117/12.926398

- Mazin et al. 2010, "ARCONS: A highly multiplexed superconducting optical to near-IR camera", SPIE, 7735
  - http://dx.doi.org/10.1117/12.856440