MEC Prime

MKID Exoplanet Camera Next Generation of High-Contrast Exoplanet Imaging with SCExAO

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Specific Acknowledgements: Olivier Guyon, Julien Lozi, Subaru Day Crew

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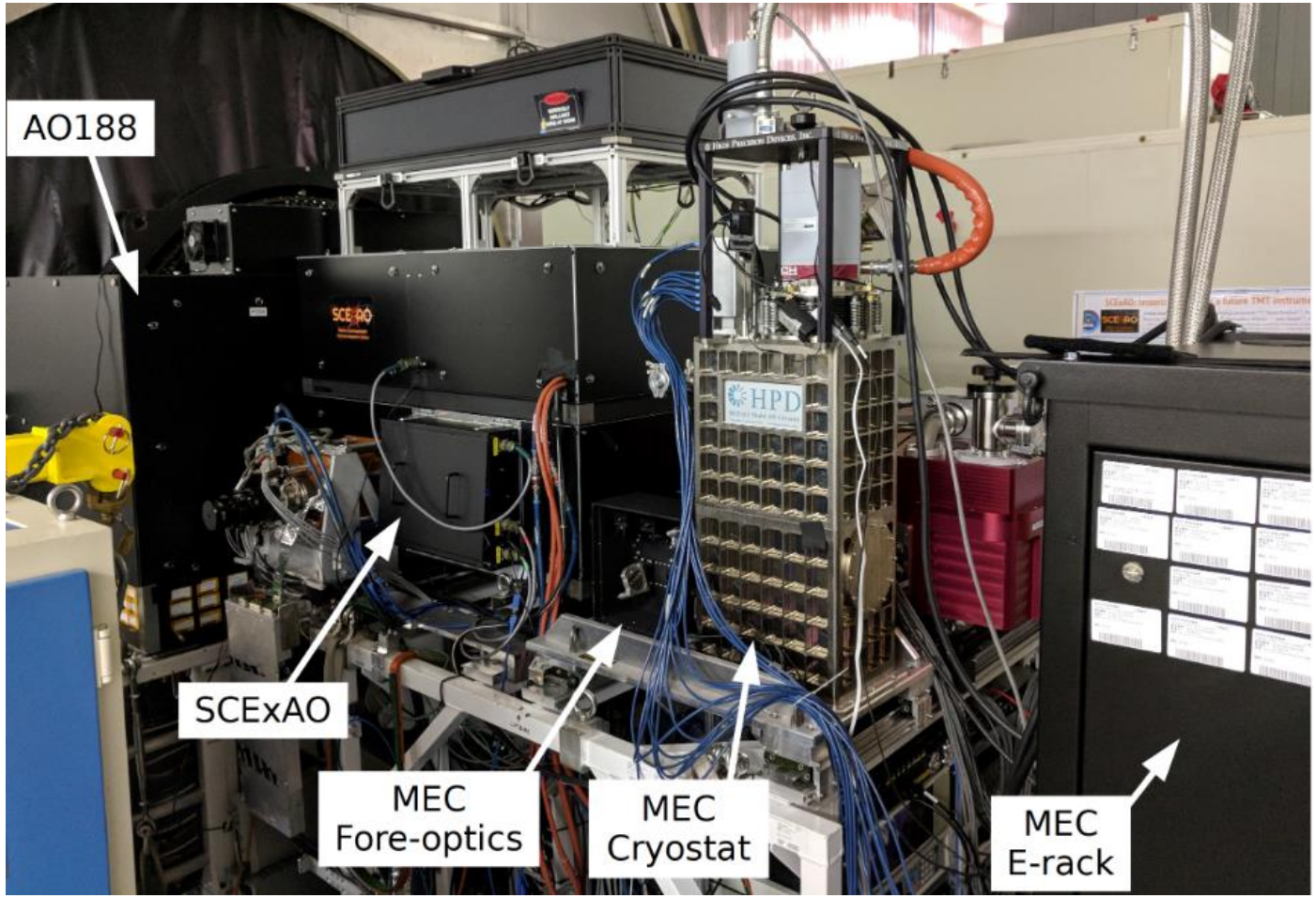
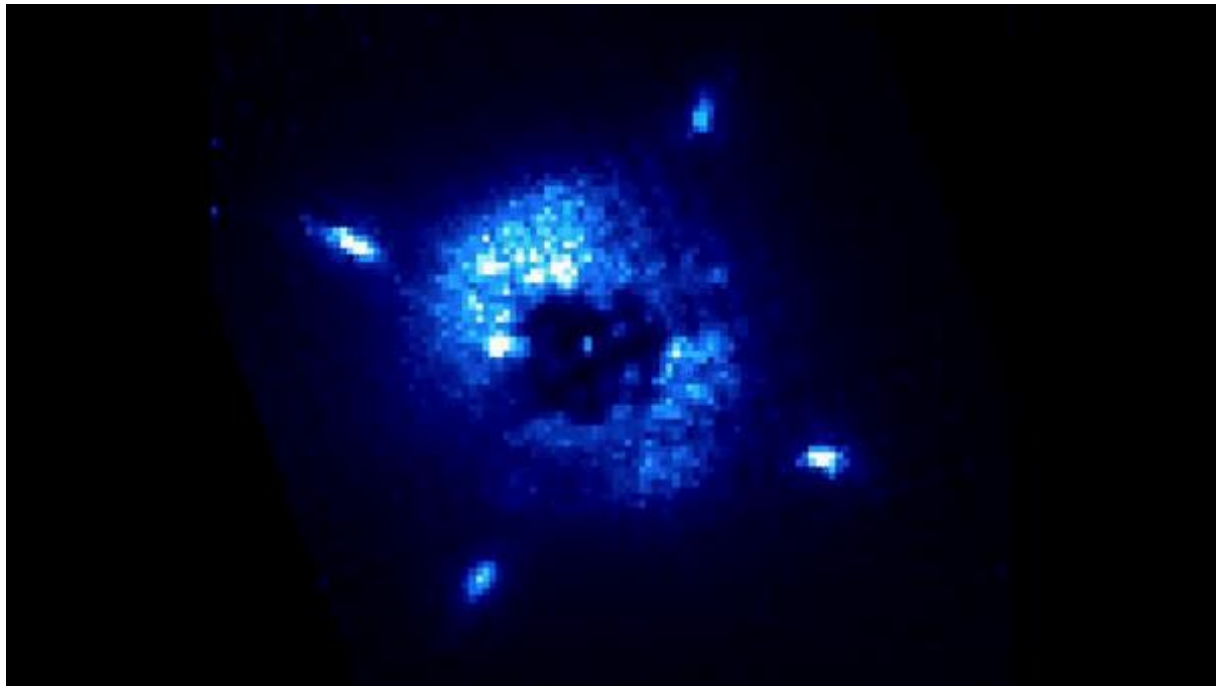
MKID Exoplanet Camera (MEC)

- Z-J band Integral Field Unit (IFU)
  - 800 – 1400 nm
  - Visible to near-IR
- High-Contrast Exoplanet and Disk Imager
  - 20,400 pixel (140x146) array
- Commissioned March 19, 2018
- Designed to utilize SCExAO optical beam



MKID Exoplanet Camera (MEC)

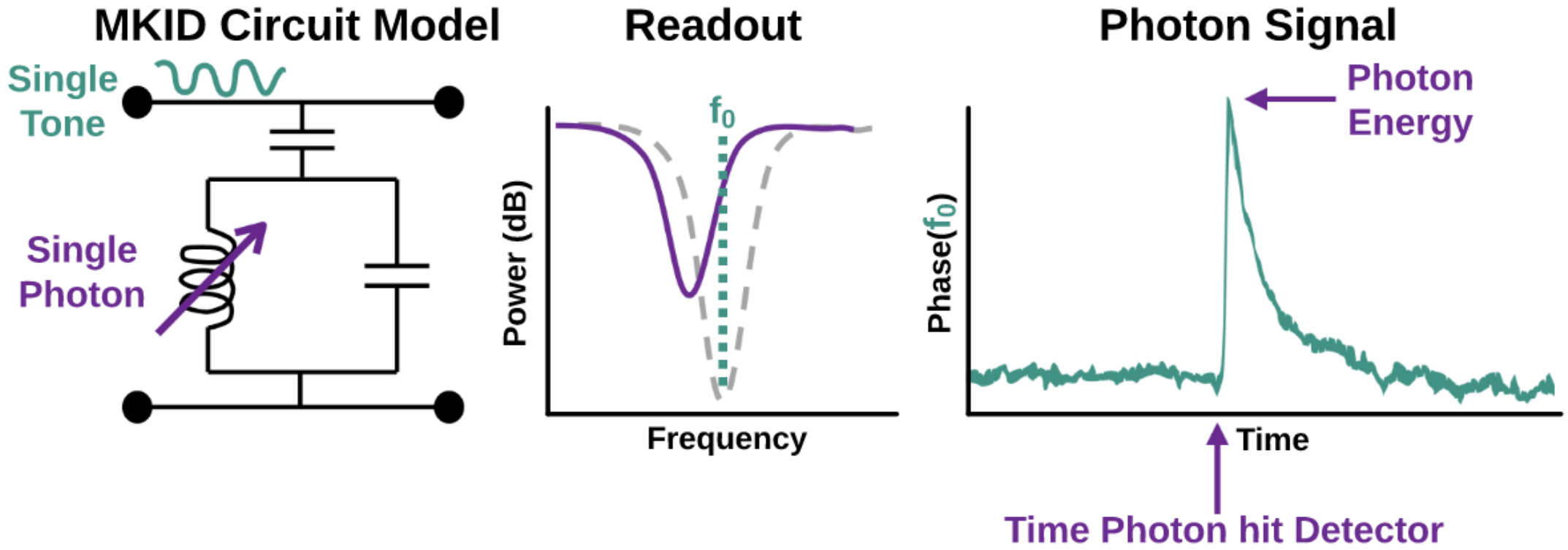
1. No Dark Current
2. No Read Noise
3. Cryogenic Operation
4. Small band gap for photon detection
5. Microsecond timing resolution between photon events
6. Stochastic Speckle Discrimination (Post-Processing)
    1. Detection of diffuse disks, brown dwarfs, close exoplanet companions
    2. Does not require PSF subtraction or polarization adjustments



Source: NAOJ/SCExAO

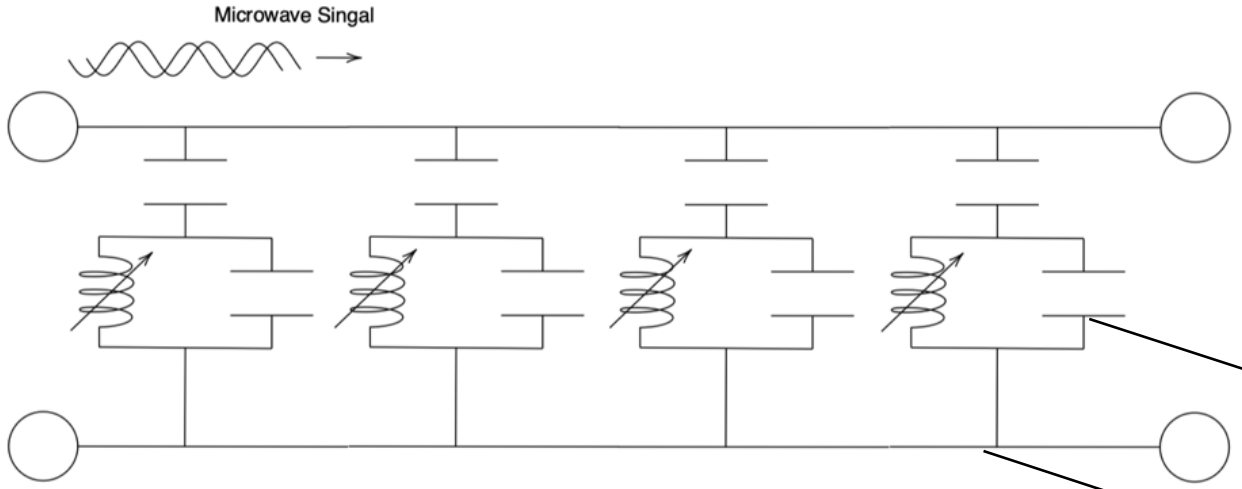
MKIDs (Microwave Kinetic Inductance Detectors)

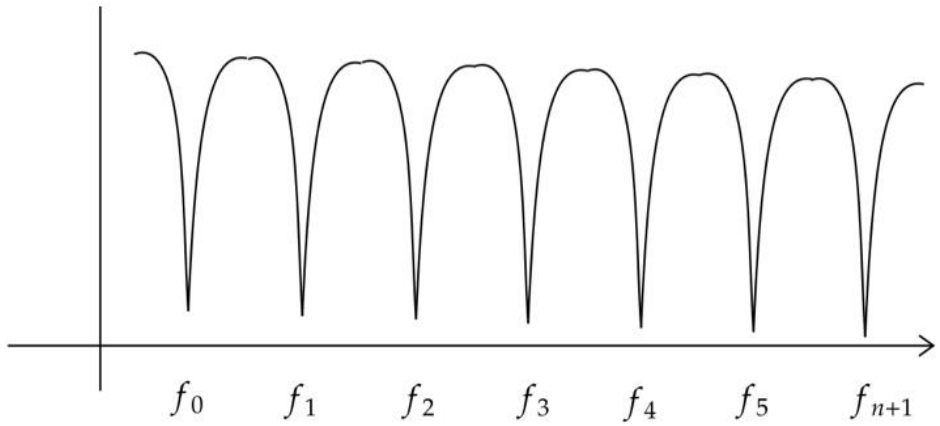
$$f_0 = \frac{1}{\sqrt{LC}}$$

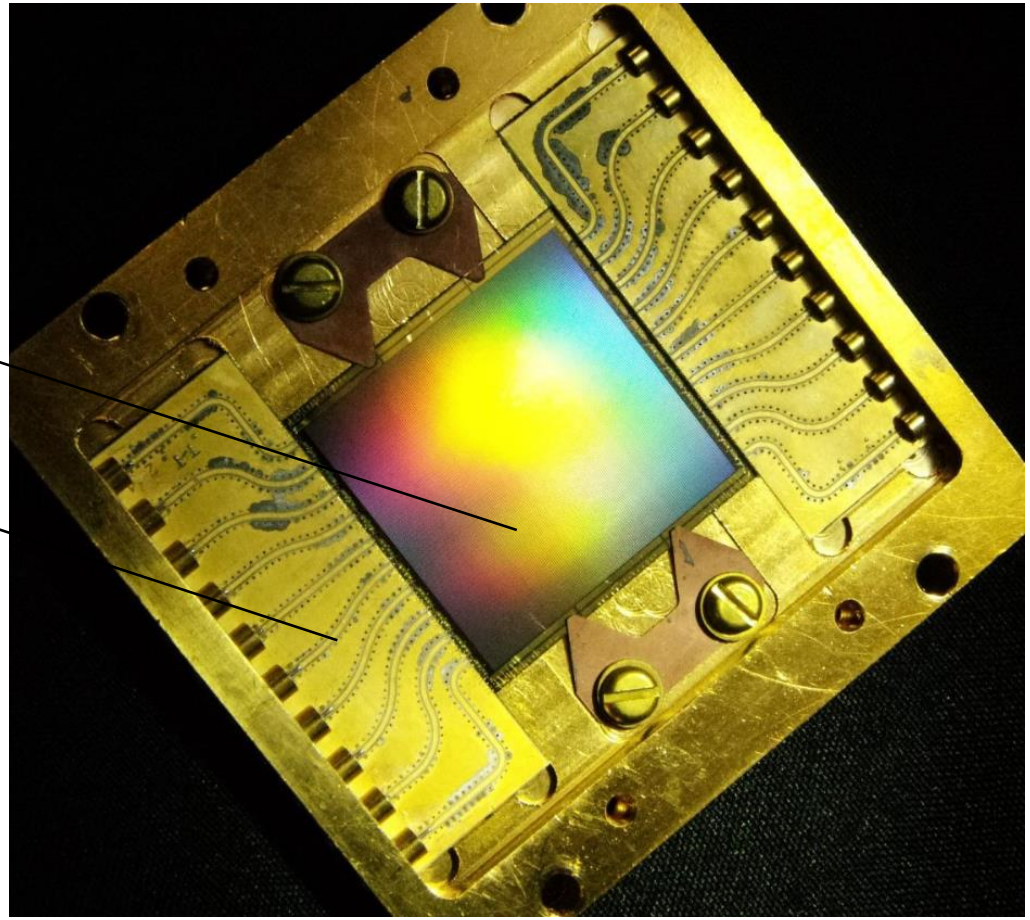


Source: Jennifer Smith, 2024, Doctoral Dissertation UCSB

MKID Array







MEC's Science Results

Discovery of a low mass companion around accelerating F5 Star HIP 5319

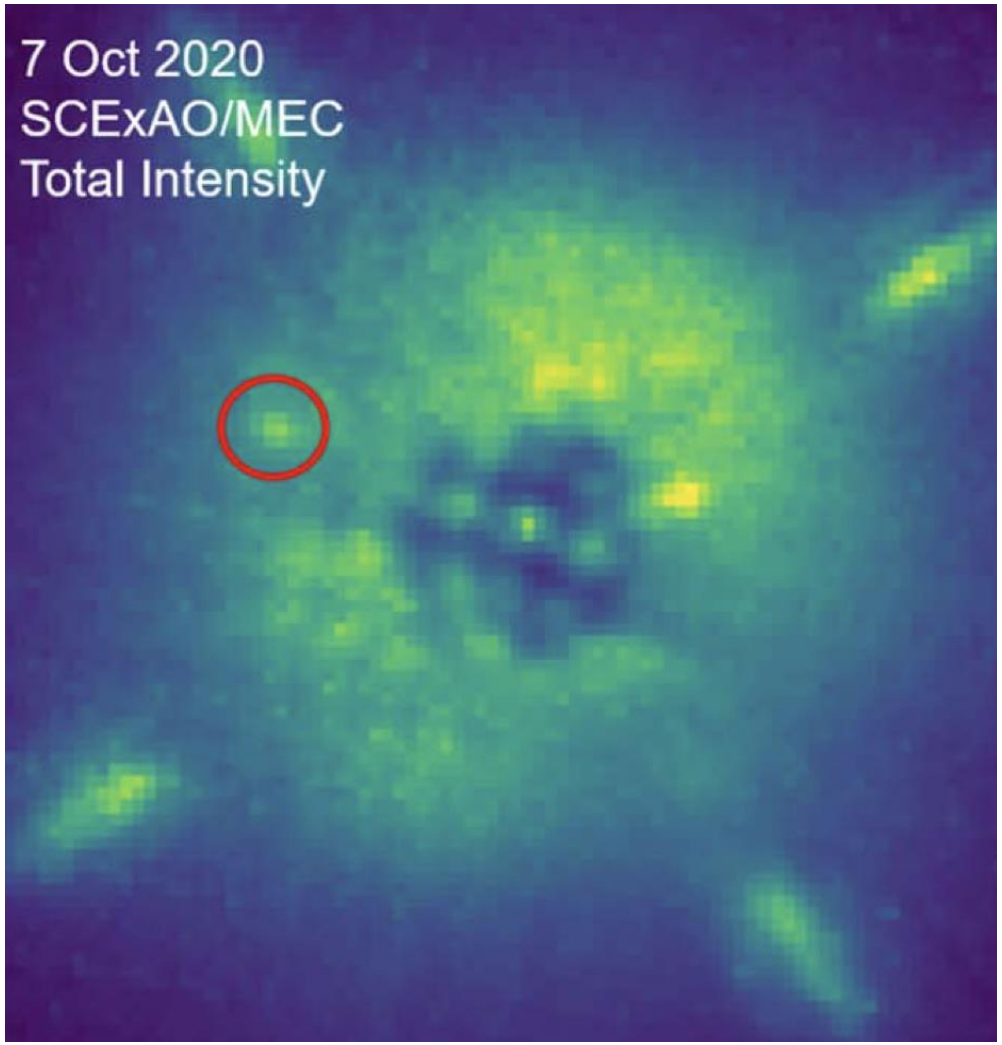
- Noah Swimmer *et al* 2022 *AJ* **164** 152

Discovery of a low mass companion to HIP 109427 at 6AU seperation

- Sarah Steiger *et al* 2021 *AJ* **162** 44

First SSD detection of protoplanetary diffuse disk AB Aurigae

- resolve structures in the disk within 0.3" without the use of any PSF subtraction or polarization
- Sarah Steiger, 2023, Doctoral Dissertation UCSB



Total intensity image of HIP 109427 B taken with SCExAO/MEC at Y and J band where the location of the companion has been circled in red (Steiger et al, 2021)

MEC Prime:
Upgrading MEC to Maximize its Science and Technical Capabilities

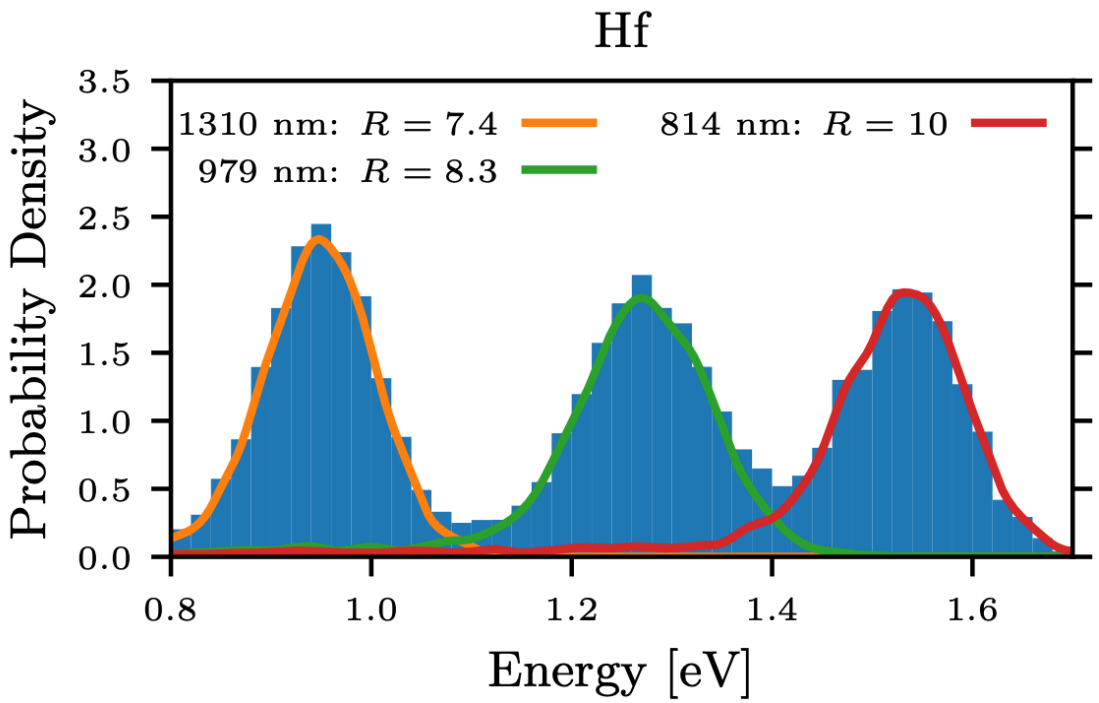
1. MKID Array
2. Generation 3 Room Temperature Readout
3. Data Processing Pipeline
4. Cryostat

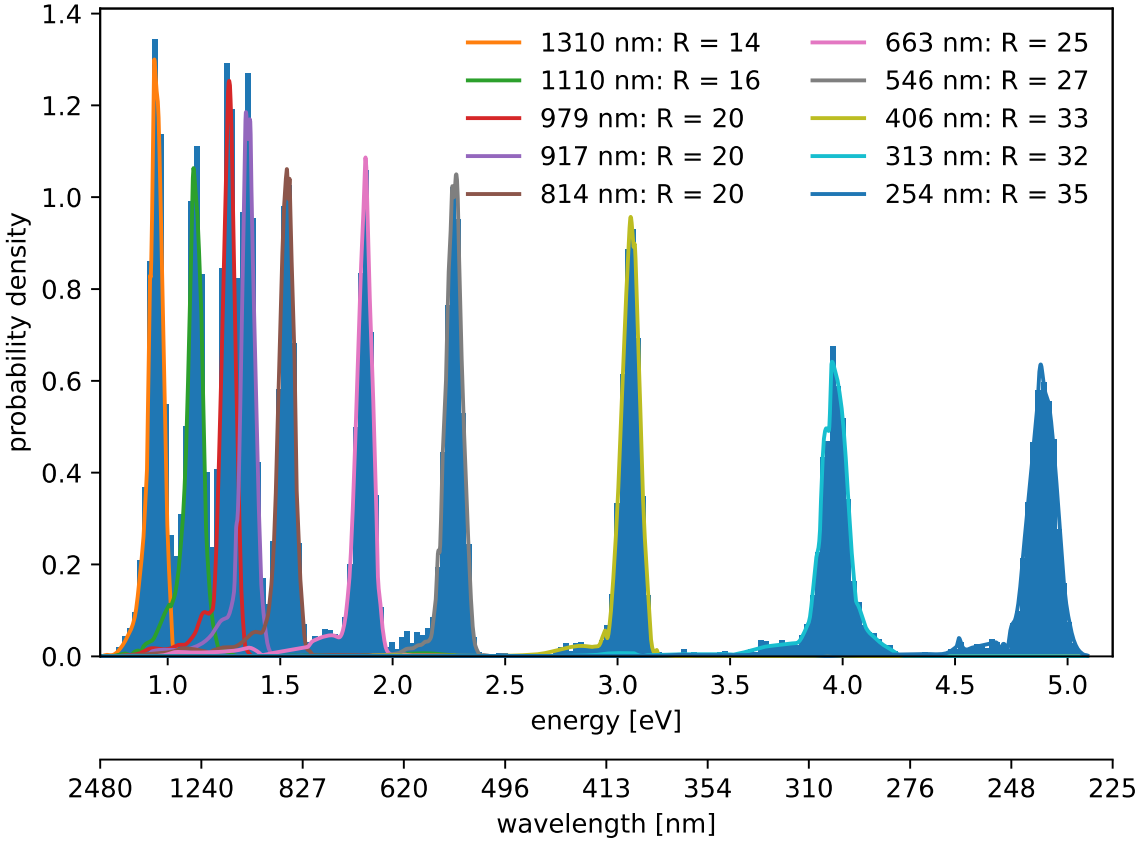
1. MEC Prime MKID Array

→ **double spectral resolution**

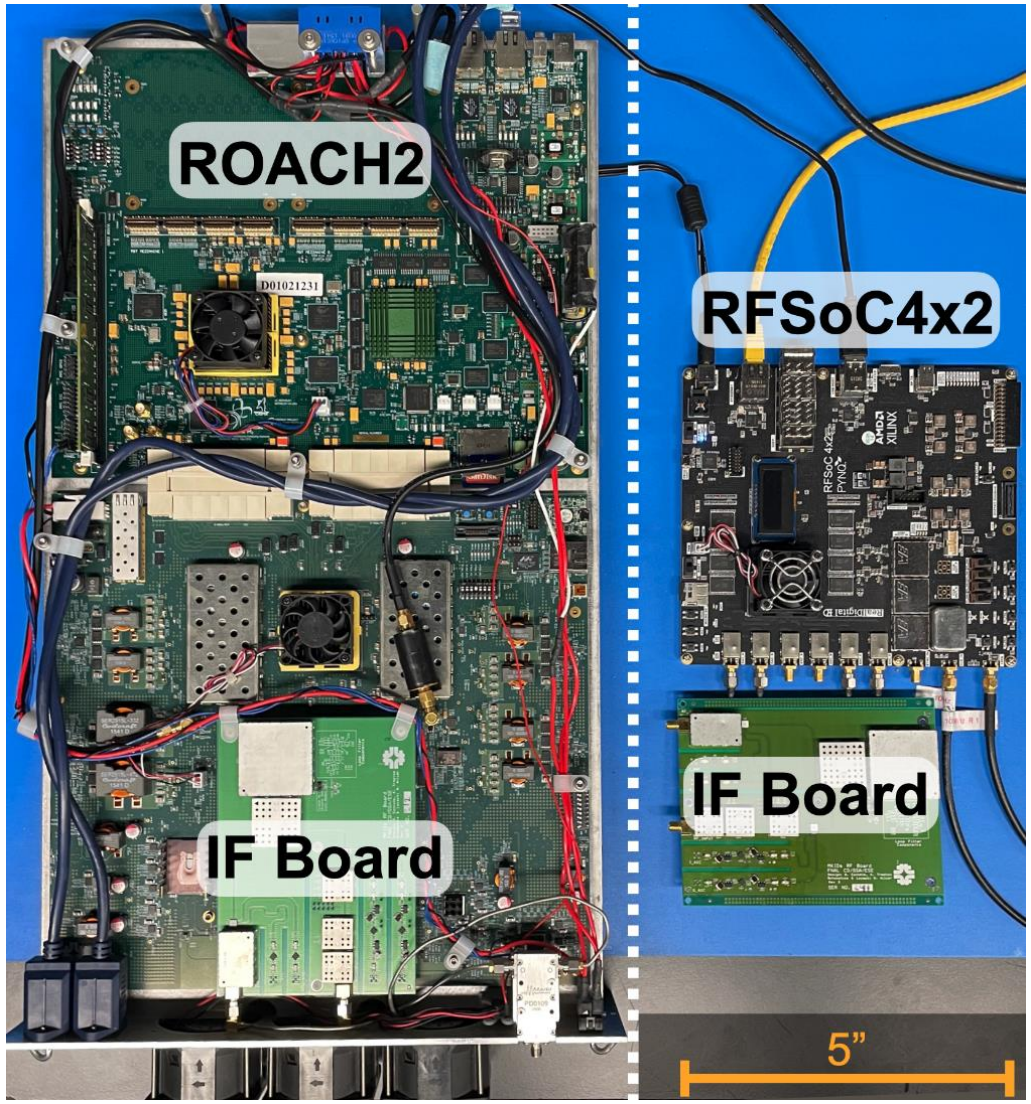
→ **double quantum efficiency (>70% entire passband)**

1. Sapphire/aTa/Hafnium
2. Hafnium airbridges
3. Parametric Amplification
4. Anti-reflection coating





2. Room Temperature Generation3 Readout



- Integrates all readout boards into a single CPU
- **10x less power usage** than current readout
- Room temperature system
  - Eliminates need to cryogenic insulation at the readout stage
- Incorporates **commercial off-the-shelf (COTS) components**

3. Data Processing Pipeline

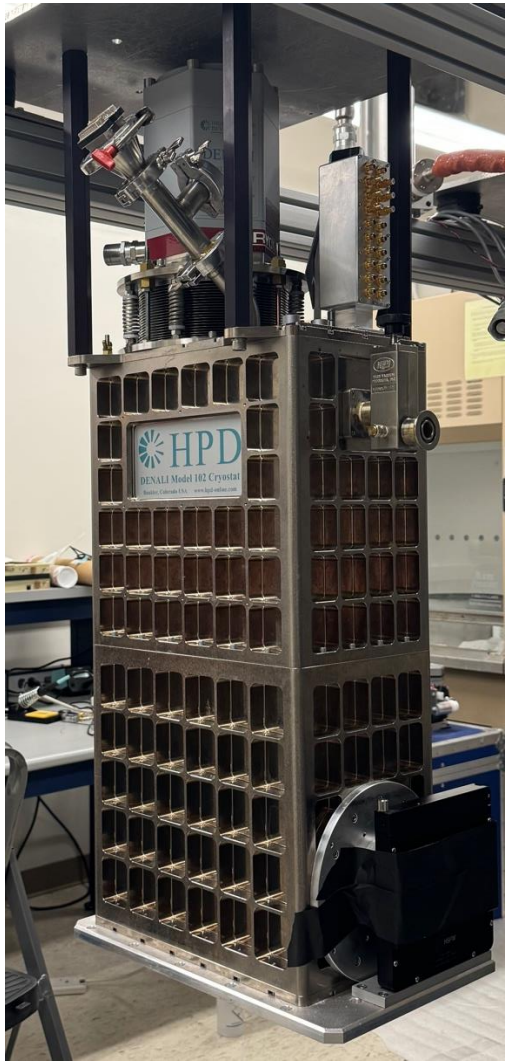
Currently:

- Open source releases
- Yields detailed fits files with preprogrammed user output options
  - High resolution images, movies, dithers, data cubes

In Progress:

- Improve pixel yield in wavelength calibration
- Optimize SSD method for consistent results
- Condense processing for low CPU usage
  - Will allow other users to run the pipeline without servers

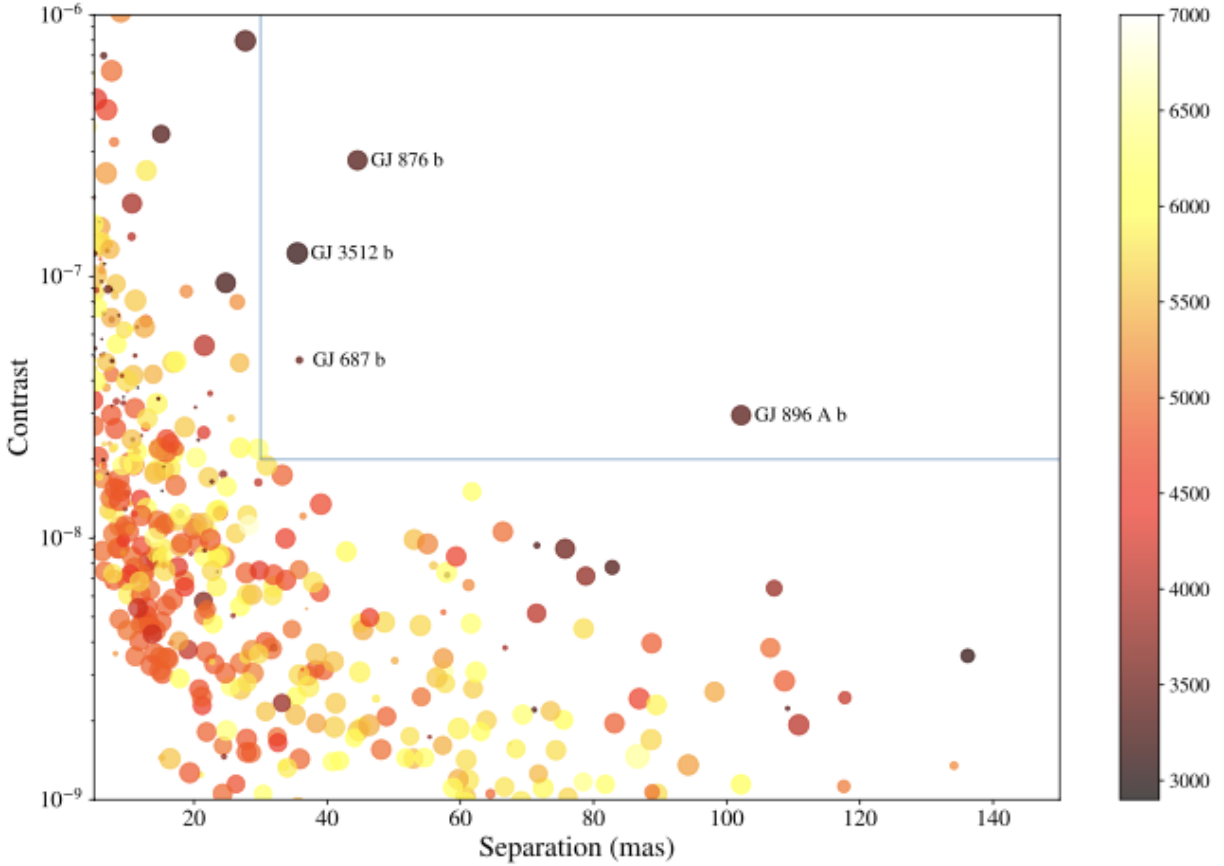
4. Cryostat



1. Extending cryostat 12 inches vertically
2. Simon Chase He3 absorption cooler
   - 50 μW of cooling power for 24 hours between
   - Achieves quantum limited performance
3. Travelling Wave Parametric Amplifiers at 300 mK stage
   - Reduce Johnson noise in readout chain
   - High gain over large bandwidth

Science Goals

- Develop low-noise NIR detector technology for future missions (HWO, TMT)
  - Increase high contrast imaging TRL
- Image first planet in fully reflected light
  - GJ 876b; 3.6 M_J gas giant orbiting a M4 dwarf near the habitable zone at a distance of 4.7 pc
    - Marcy *et al* 2001 *ApJ* **556** 296
  - GJ 896Ab; 2.3 M_J gas giant orbiting a M4 dwarf at a distance of 6.3 pc
    - Salvador Curiel *et al* 2022 *AJ* **164** 93



Estimated star to planet contrast ratio for currently known exoplanets.

MEC Prime Timeline

Q4 2024
- Retrieve MEC from Subaru
- Begin new MKID array fabrication

Q1-Q2 2025
- Write Gen3 readout software

Current Status

Q3-Q4 2025
- Finalize MKID array design
- Finalize Gen3 readout hardware and software

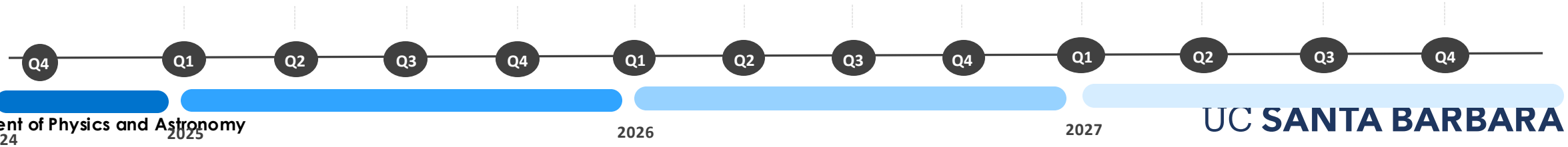
Q1-Q2 2026
- Gen3 readout integration and testing
- Finalize optical design

Q3 2026
- Return MEC Prime to Subaru

Q1 2027
MEC Prime commissioning

Q2 2027
First on-sky observations

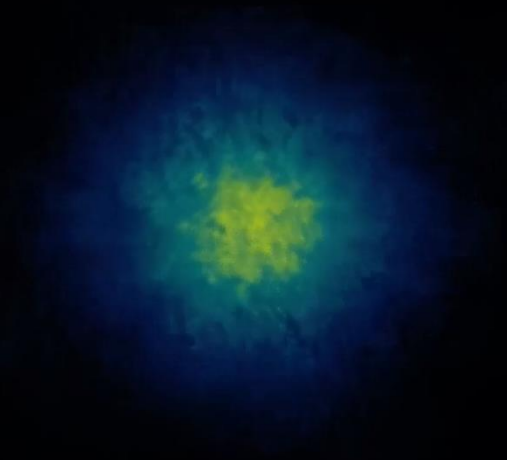
Q3 2027
First science data release



MEC Prime:

- **Double spectral resolution R $\rightarrow 30$**
- **Increased pixel yield**
- **Double quantum efficiency**
- Decreased readout weight, size, and power usage
- Improved cooling power and longevity
- **User friendly/Open-source capabilities** to invite new collaborators to use this powerful instrument

We are open to new collaborators on this project!



For more information:

https://web.physics.ucsb.edu/~bmazin/

https://github.com/MazinLab/MKIDPipeline

https://www.youtube.com/@ExperimentalAstrophysics

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