

LiteBIRD NASA Mission of Opportunity Phase A Study



Adrian Lee

University of California, Berkeley
Lawrence Berkeley National Lab

LiteBIRD working group

<u>JAXA</u> H. Fuke I. Kawano H. Matsuhara T. Matsumura K. Mitsuda T. Nishibori K. Nishijo A. Noda A. Okamoto S. Sakai Y. Sato K. Shinozaki H. Sugita Y. Takei M. Utsunomiya T. Wada N. Yamasaki T. Yoshida K. Yotsumoto	<u>Osaka Pref. U.</u> M. Inoue K. Kimura M. Kozu H. Ogawa N. Okada	<u>KEK</u> K. Hattori M. Hazumi (PI) M. Hasegawa N. Kimura K. Kohri H. Morii T. Nagasaki R. Nagata H. Nishino S. Oguri T. Okamura N. Sato T. Suzuki O. Tajima T. Tomaru M. Yoshida	<u>NAOJ</u> A. Dominjon J. Inatani K. Karatsu S. Kashima T. Nitta T. Noguchi S. Sekiguchi Y. Sekimoto S. Shu	<u>U. Tsukuba</u> M. Nagai	<u>APC Paris</u> R. Stompor	<u>UC Berkeley / LBNL</u> D. Barron J. Borrill Y. Chinone A. Cukierman T. de Haan N. Goeckner-wald P. Harvey C. Hill Y. Hori W. Holzapfel O. Jeong T. Kisner R. Keskitalo A. Kusaka A. Lee(US PI) E. Linder P. Richards U. Seljak B. Sherwin A. Suzuki P. Turin B. Westbrook N. Whitehorn
<u>Osaka U.</u> S. Kuromiya M. Nakajima S. Takakura K. Takano	<u>Okayama U.</u> H. Ishino A. Kibayashi Y. Kibe Y. Kida A. Okamoto Y. Yamada	<u>SOKENDAI</u> Y. Akiba Y. Inoue H. Ishitsuka Y. Segawa H. Watanabe	<u>Saitama U.</u> M. Naruse	<u>TIT</u> S. Matsuoka R. Chendra	<u>CU Boulder</u> N. Halverson	<u>UC San Diego</u> T. Elleflot B. Keating G. Rebeiz
	<u>NIFS</u> S. Takada		<u>NICT</u> Y. Uzawa	<u>Tohoku U.</u> M. Hattori T. Morishima	<u>McGill U.</u> M. Dobbs	
	<u>Kavli IPMU</u> N. Katayama H. Sugai		<u>Konan U.</u> I. Ohta	<u>Nagoya U.</u> K. Ichiki	<u>MPA</u> E. Komatsu	
			<u>U. Tokyo</u> N. Tomita	<u>Yokohama Natl. U.</u> T. Fujino F. Irie K. Mizukami S. Nakamura K. Natsume T. Yamashita	<u>NIST</u> G. Hilton J. Hubmayr	
			<u>Kansei Gakuin U.</u> S. Matsuura	<u>RIKEN</u> S. Mima C. Otani	<u>Stanford U.</u> S. Cho K. Irwin S. Kernasovskiy C.-L. Kuo D. Li T. Namikawa W. Ogburn	
				<u>ILP Paris</u> J. Errard	<u>Wisconsin</u> K. Arnold	

Team Experience: ABS, ACT, BICEP/KECK, BOOMERanG, DASI, EBEX, SPT, MAXIMA, POLARBEAR, Planck, Simons Array, QUIET, WMAP

Scope of the NASA MO Proposal (Cost Cap \$65M)

Low-Frequency
Telescope (LFT)

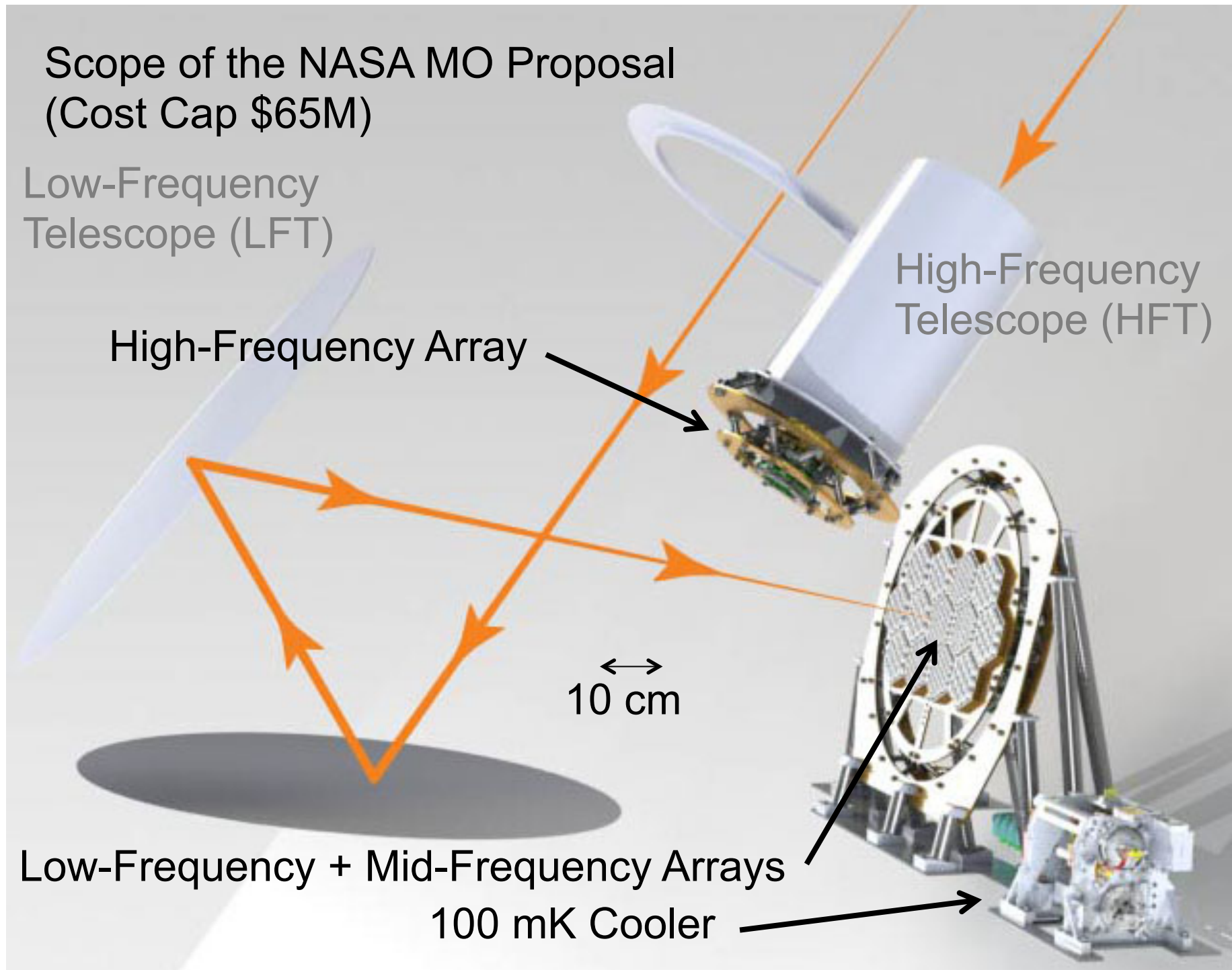
High-Frequency
Telescope (HFT)

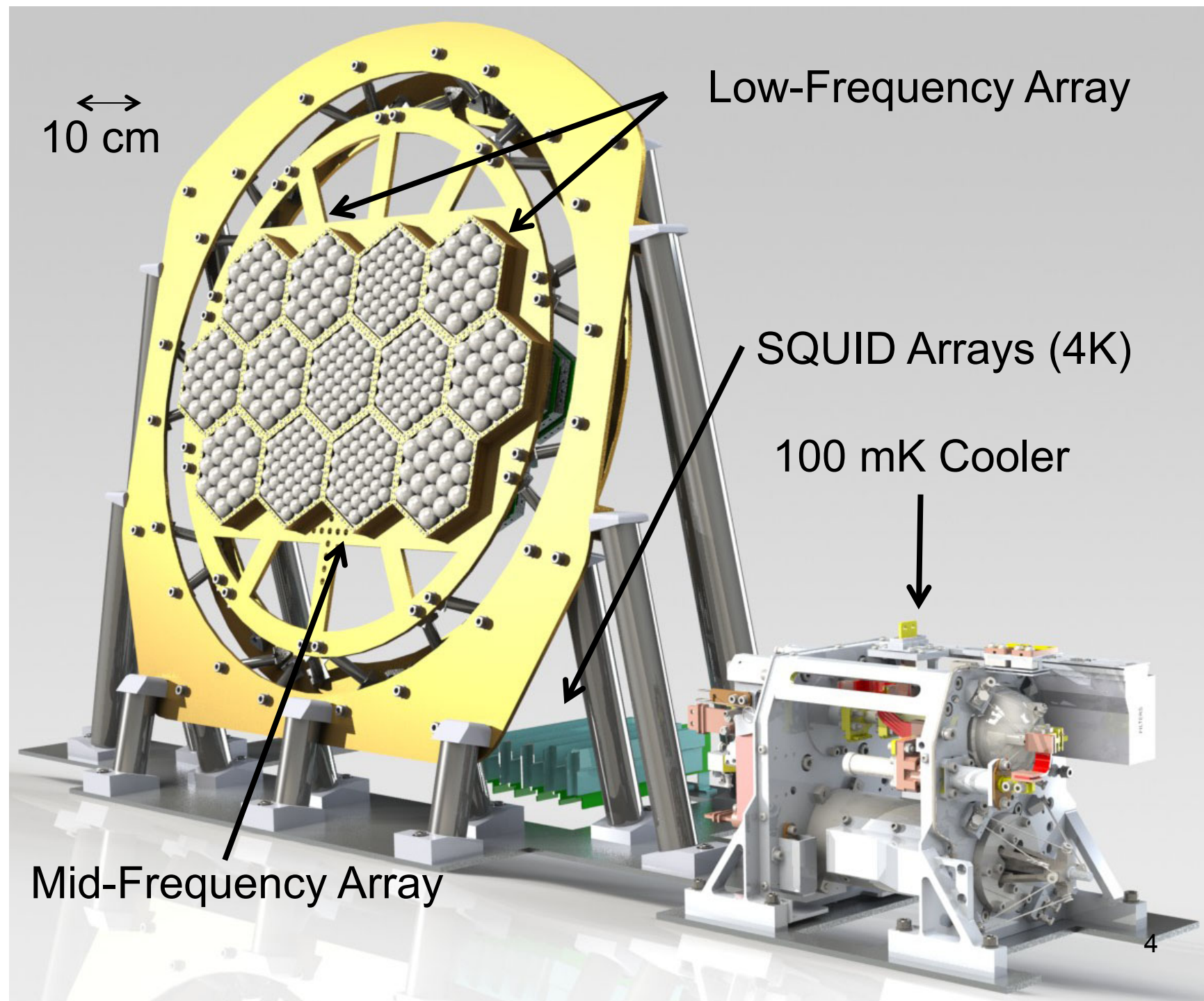
High-Frequency Array

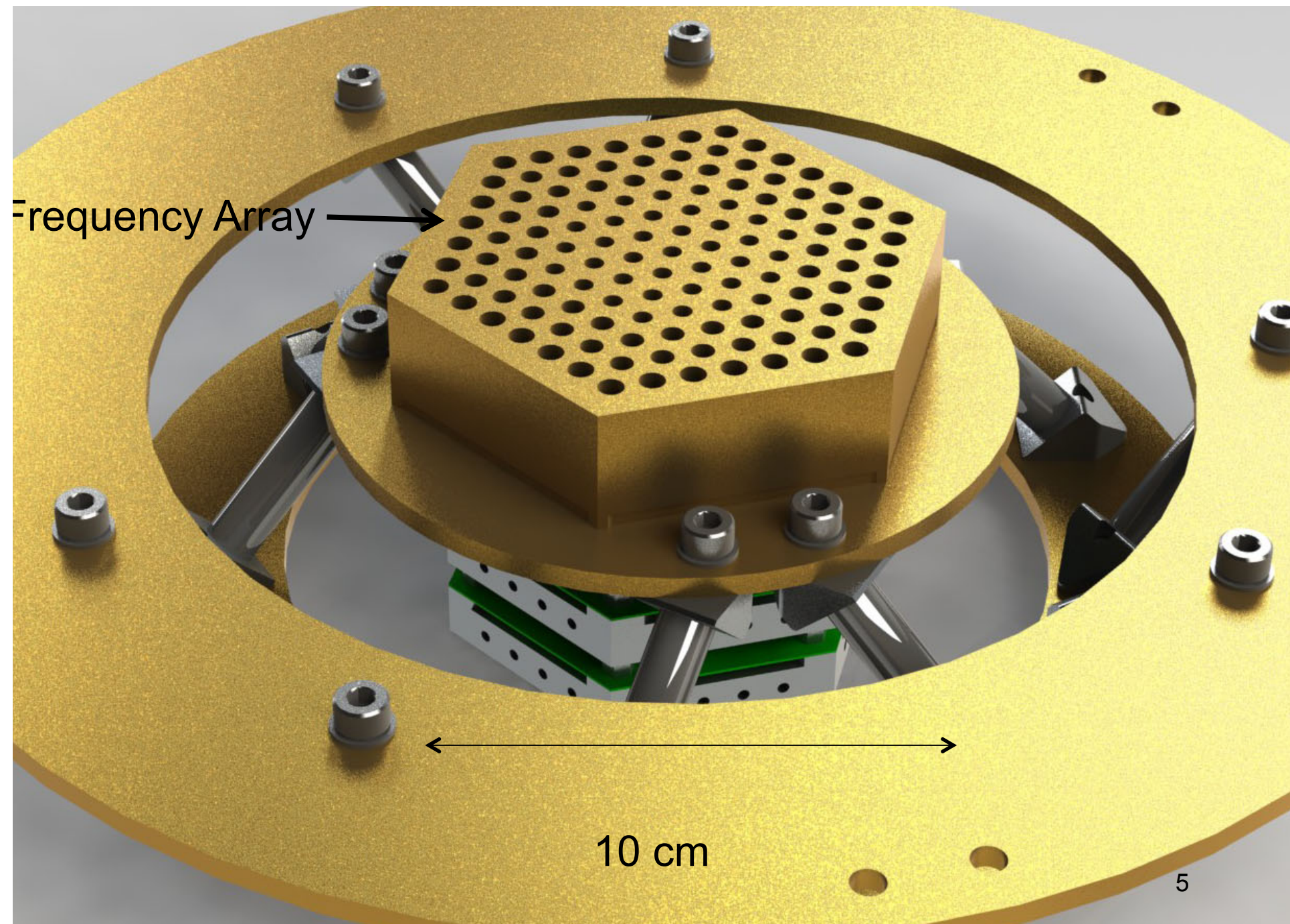
10 cm

Low-Frequency + Mid-Frequency Arrays

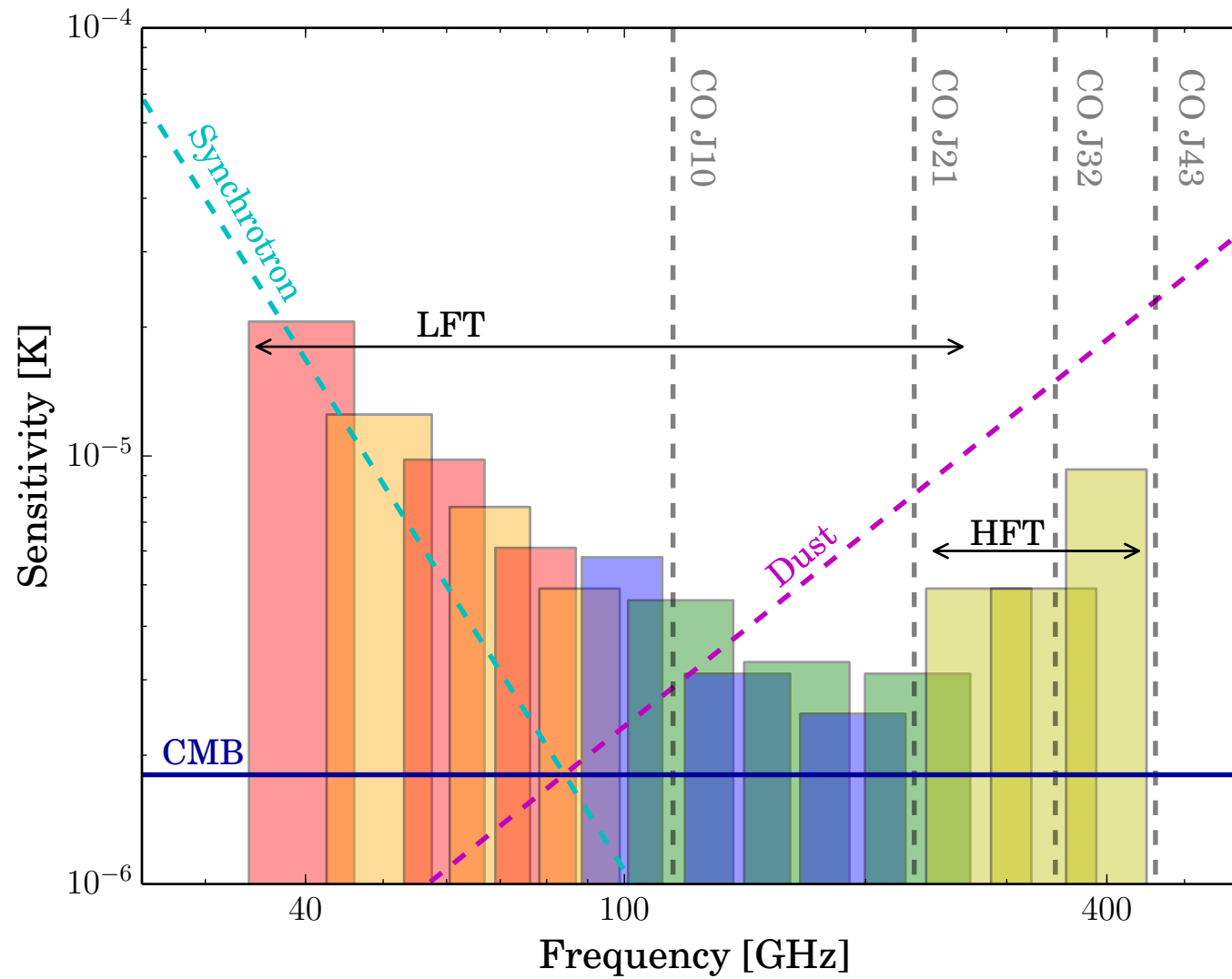
100 mK Cooler



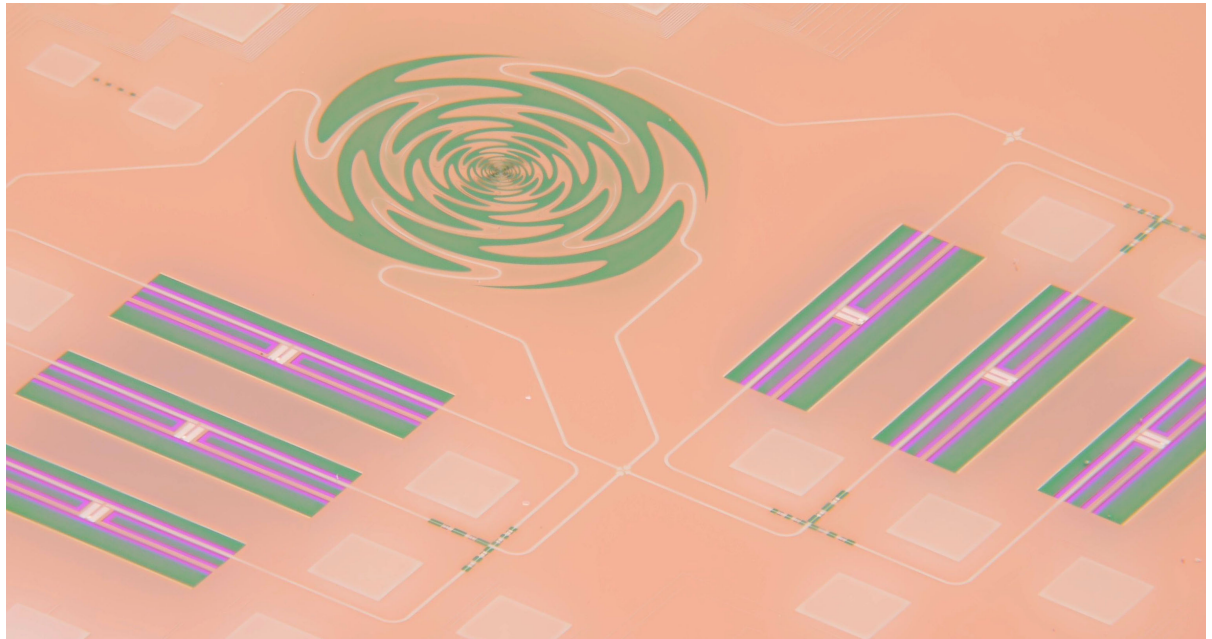
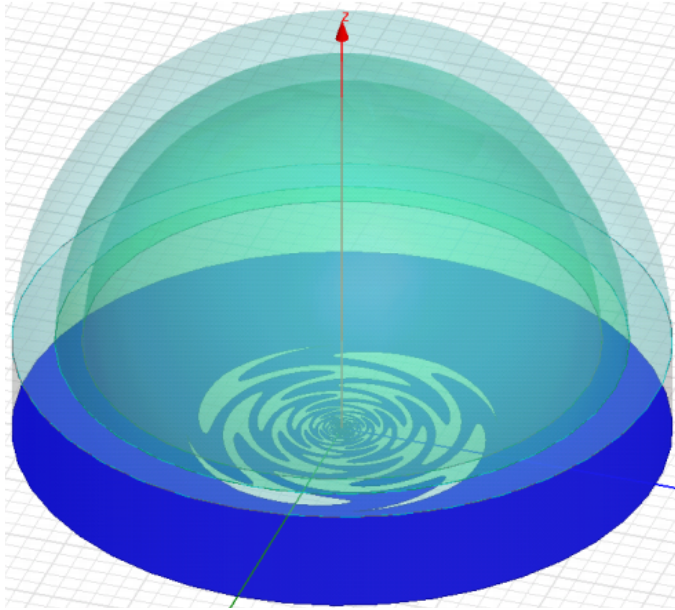




15 Frequency Bands

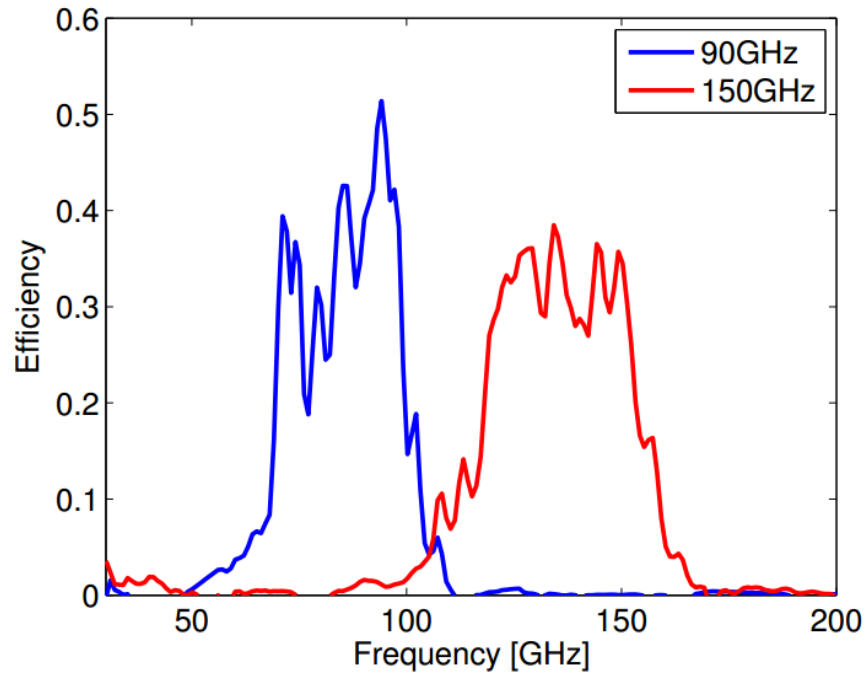


Low- and Mid-Frequency Arrays



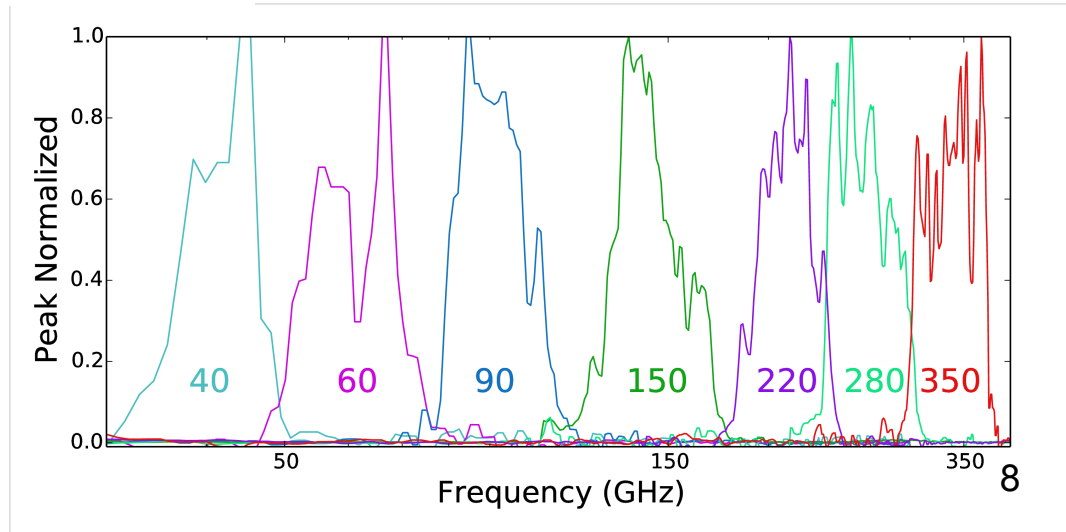
- Sinuous Antenna -> Broadband Trichroic Pixels
- 3:1 Bandwidth -> enables high band count within fixed field-of-view

Pixel Types

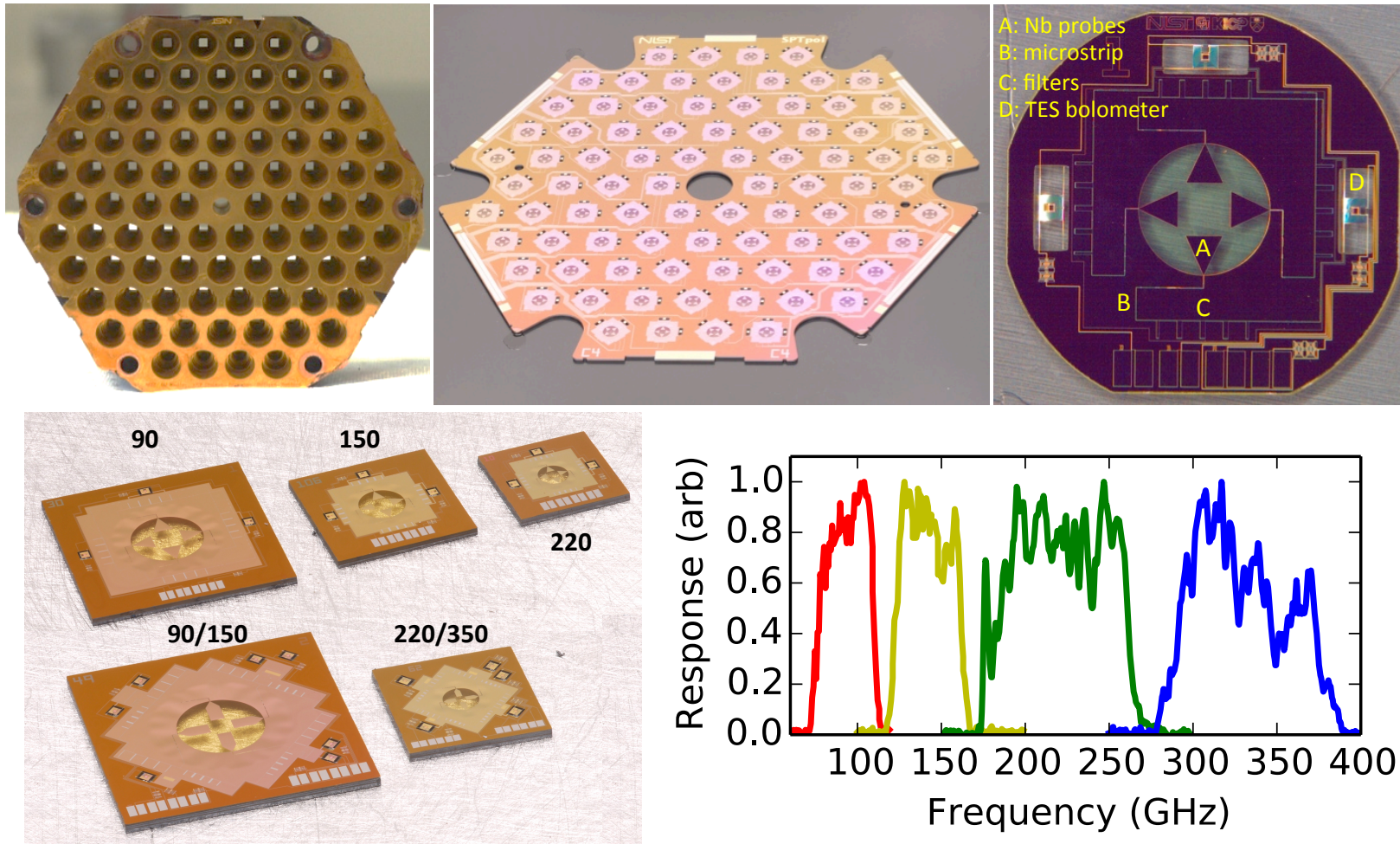


Sinuuous, 2-band pixel

Sinuuous, 3-band and 4-band pixels



High-Frequency Array



- Horn Coupled Array: Demonstrated performance at high frequency.

Detector Arrays

- Low-Frequency Array (40-89 GHz)
 - Fabrication: NIST
 - Module Design+Test: Colorado
- Mid-Frequency Array (100-235 GHz)
 - Fabrication: Berkeley (+Stanford personnel)
 - Module Design+Test: Berkeley
- High-Frequency Array (280-402 GHz)
 - Fabrication: NIST
 - Module Design+Test: Stanford

Detector Experience

- Berkeley
 - Past: APEX-SZ, SPT-SZ, POLARBEAR-1, EBEX, ASTE
 - Future: POLARBEAR-2 and Simons Array
- NIST/Stanford
 - Past: ABS, SCUBA-2, ACTPOL, SPT-POL, MUSTANG
 - Future: AdvACT, SPIDER

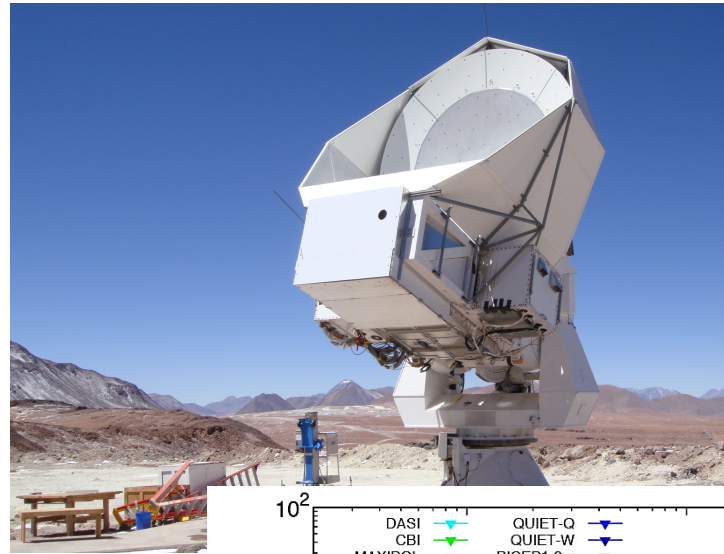
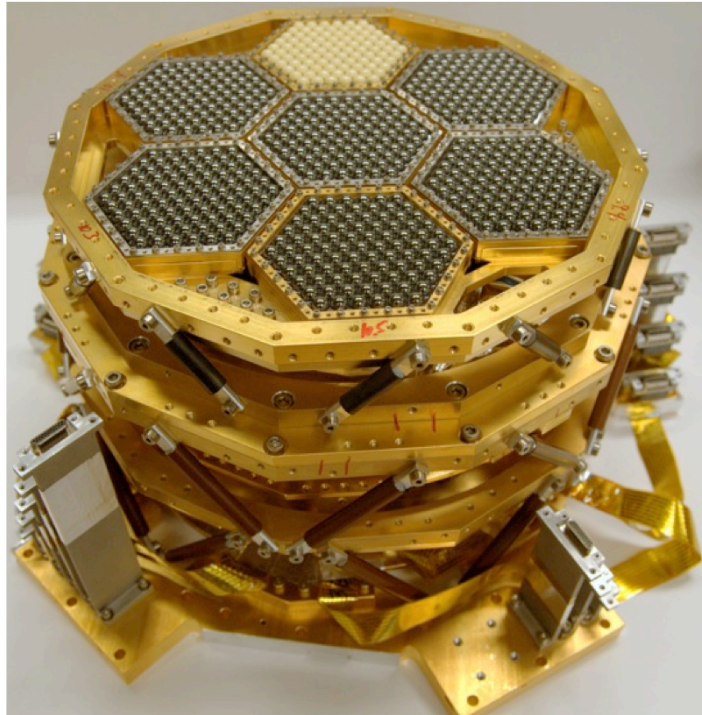


NIST

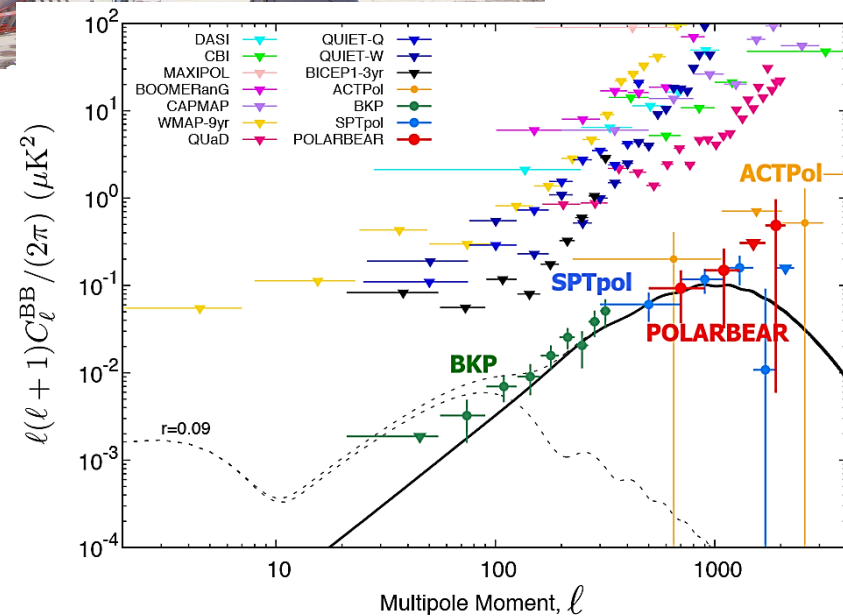


Berkeley

Detector Heritage: POLARBEAR-1



POLARBEAR 2014:
BB Measurement
dd detection using CMB alone

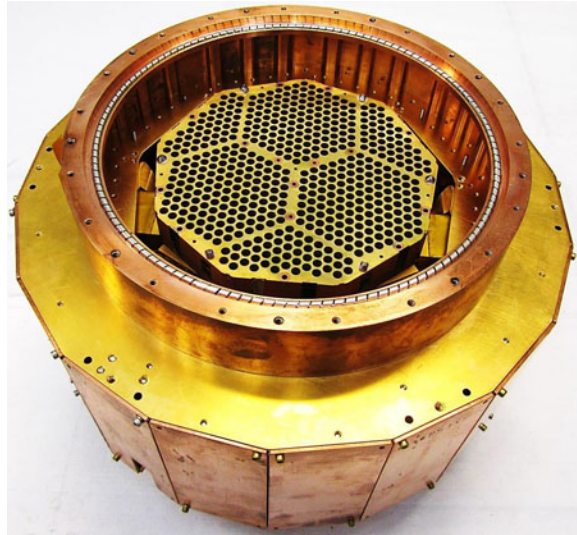


Detector Heritage: ACTPol and SPTPol

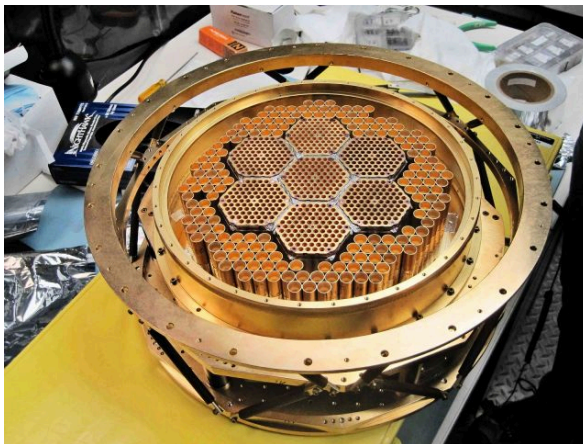
ACT



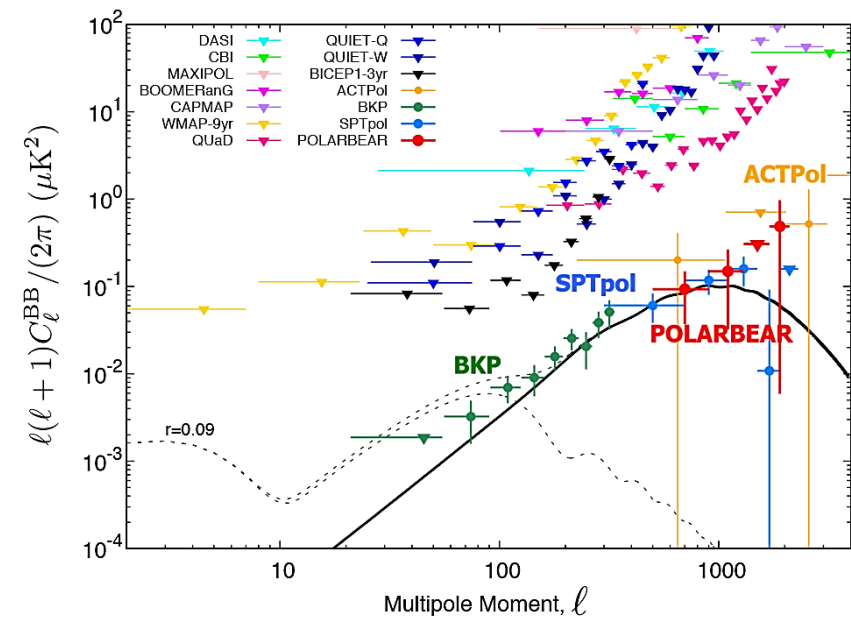
SPT



ACTPol

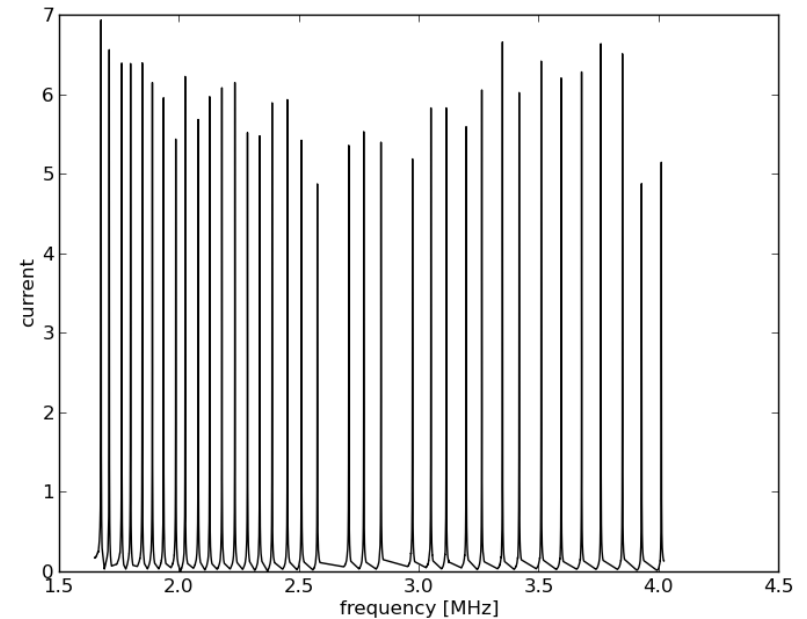
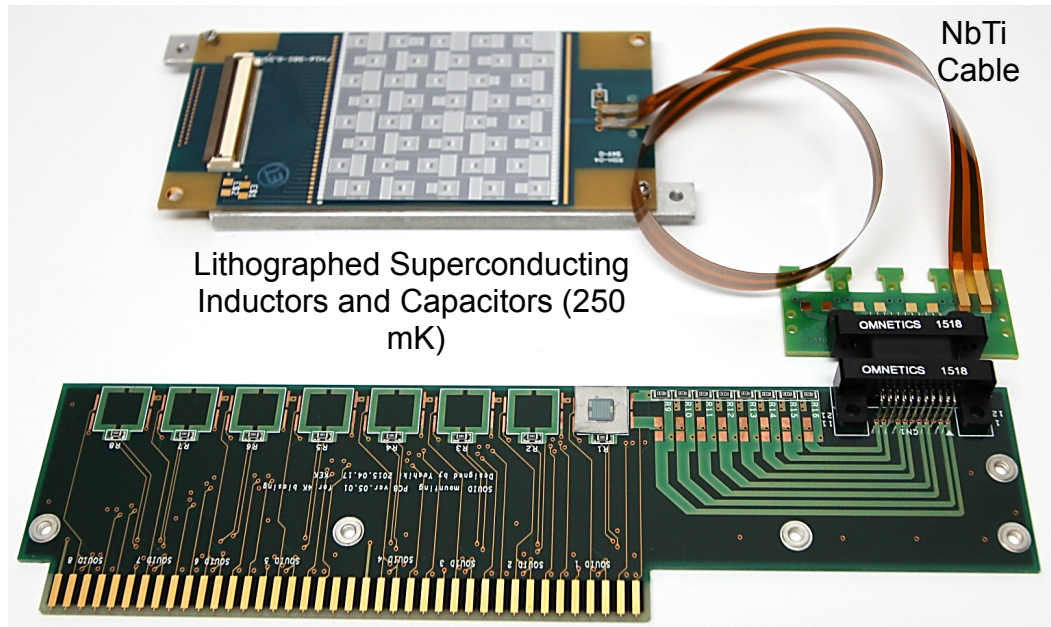


SPTPol



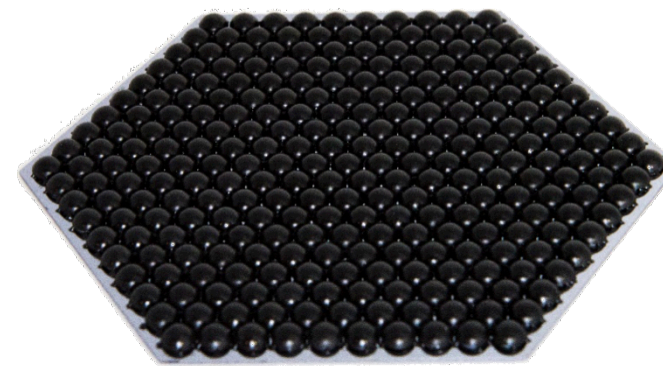
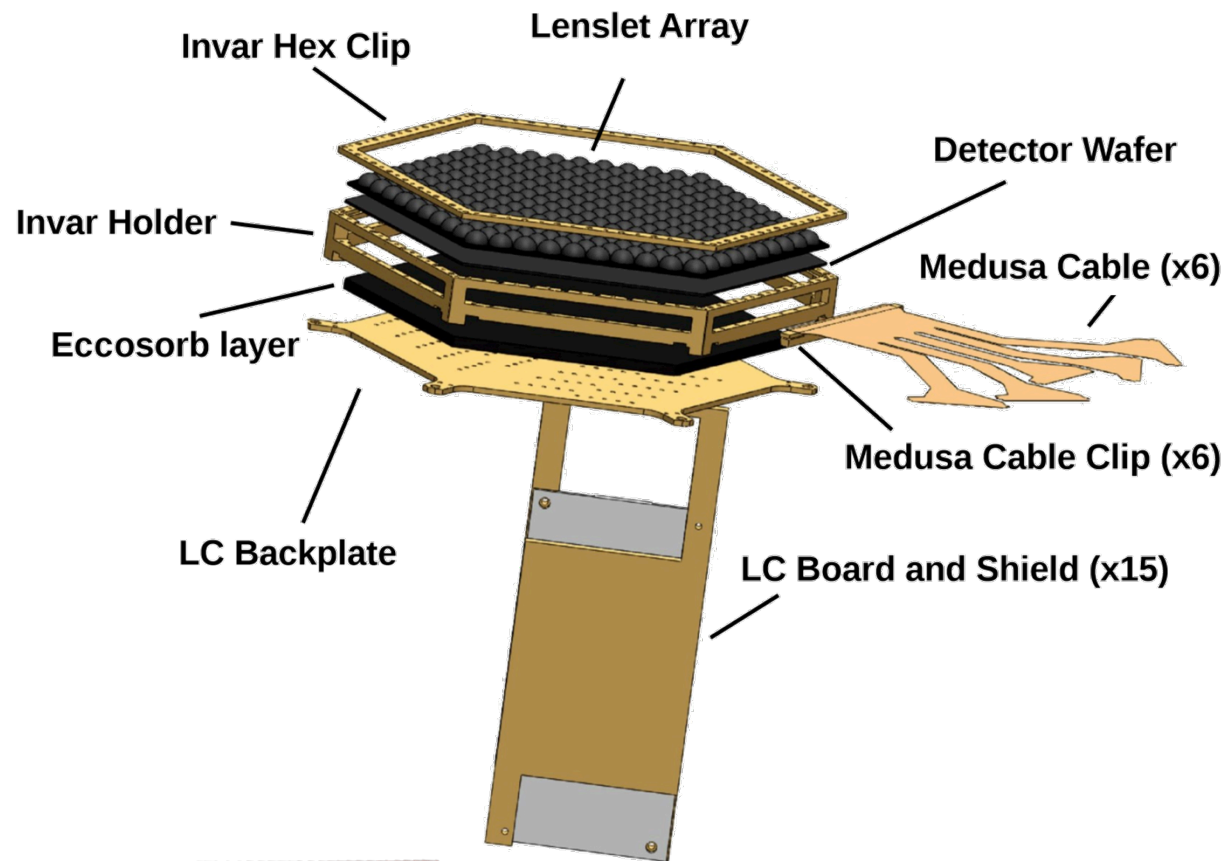
Detector Readout

Bolometer Readout

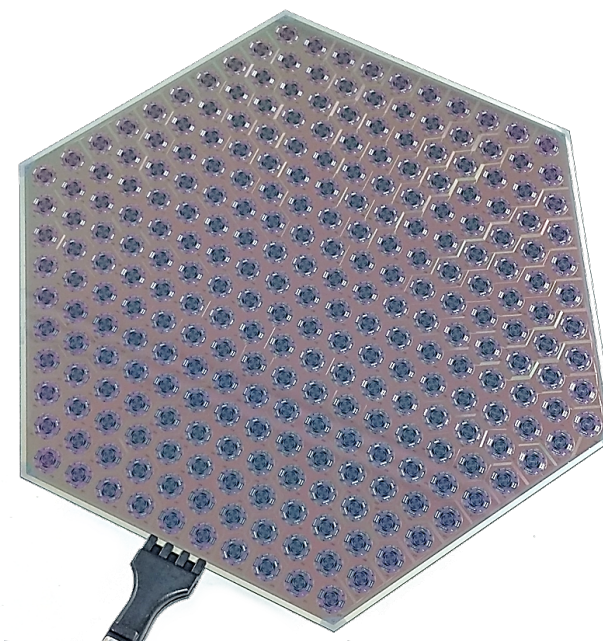


- Frequency-Domain Multiplexing (FDM)
 - SQUIDS (NIST/Stanford)
 - LC resonators (Berkeley)

Detector Module



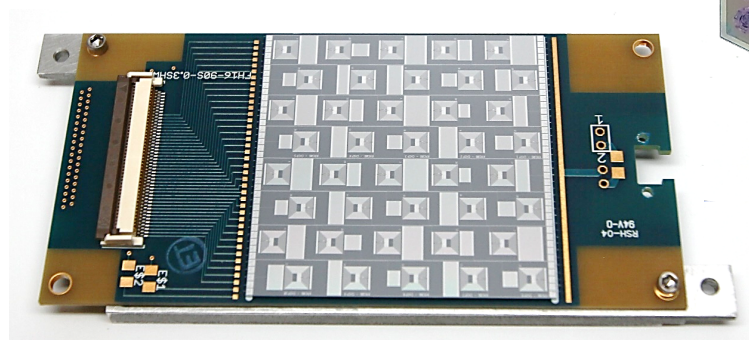
Lenslet Array



Detector Array



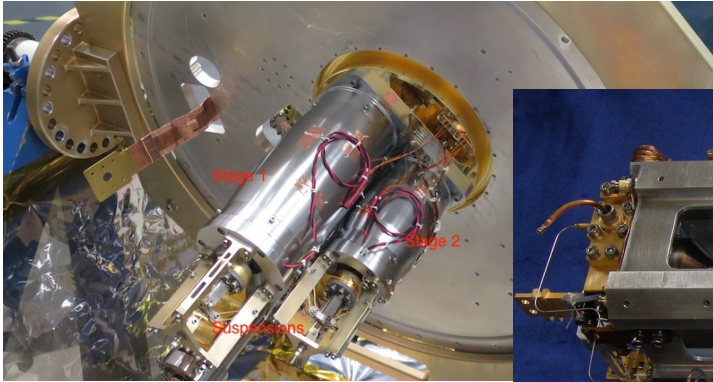
Flex Cable



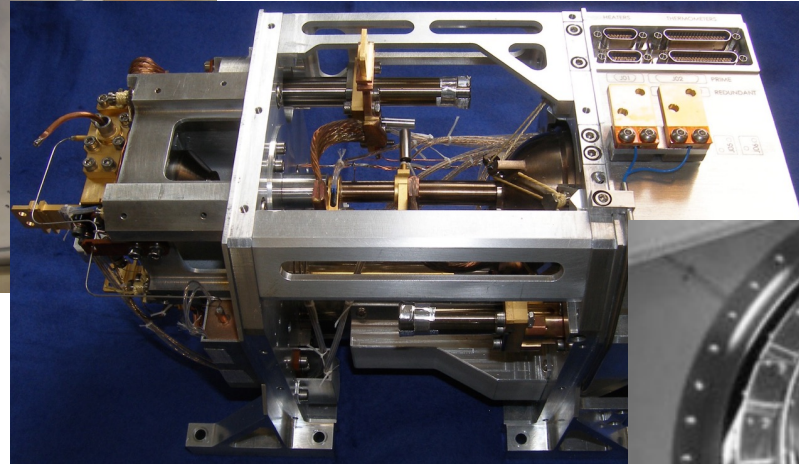
LC Board

100 mK Cooler

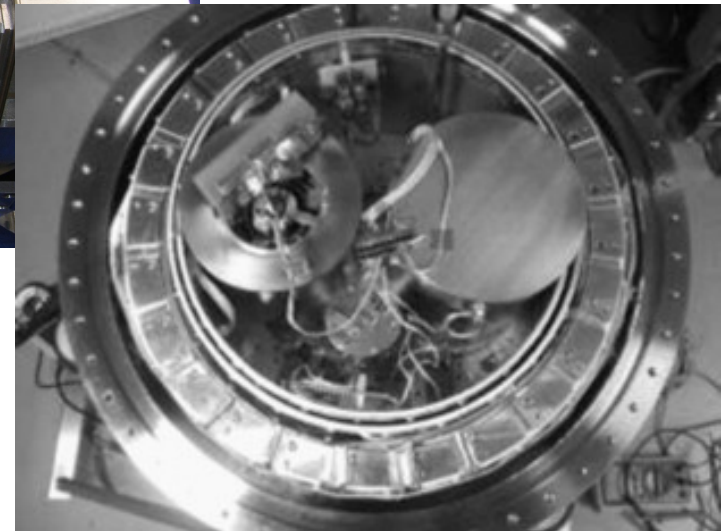
100 mK ADR Study



GSFC
(Astro-H)



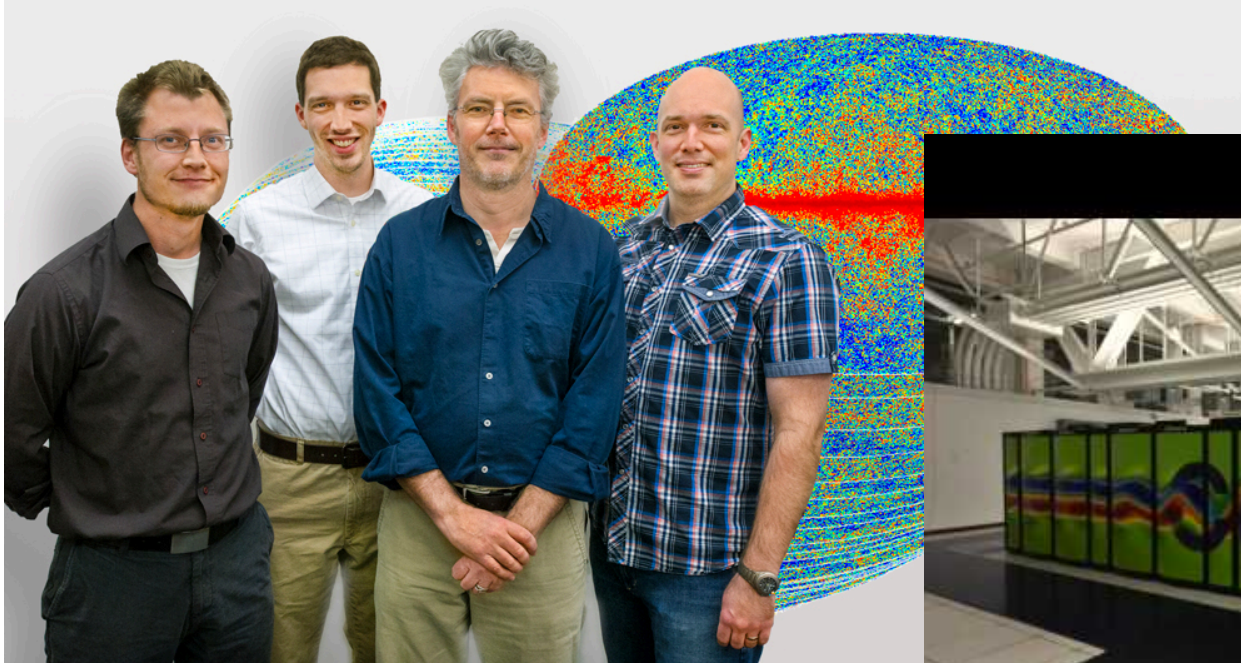
CEA
(SPICA-Safari)



SHI (Sumitomo)

- 100mK Cooler to be selected in Phase A
 - 3 ADRs discussed in MO proposal
 - Other candidates discussed (dilution)

Data Analysis



- Strong Experience in team including with WMAP and Planck
 - High Performance Computing at LBL

Conclusions

- Exciting Science!
 - Fingerprints of inflation
 - High energy physics from the Big Bang
 - Optical depth to reionization
- LiteBIRD
 - High Sensitivity
 - Robust to Foregrounds and Systematic Errors
 - Experienced Team in technology, instrumentation, and data analysis

