CMB-S4 Collaboration Meeting Summer 2021 Fireslides

1. Yan-Chuan Cai
2. Omar Darwish
3. Valentina Fanfani
4. Fei Ge
5. Margaret Ikape
6. Tanveer Karim
7. Heather McCarrick
8. Elena Orlando
9. Srinivasan Raghunathan
10. Aritoki Suzuki

Cross-correlations and stacking using LSS and CMB

Yan-Chuan Cai (cai@roe.ac.uk)
University of Edinburgh

ISW and CMB lensing around superstructures

- Stacked CMB lensing and ISW signals around superstructures in the DESI Legacy Survey
  Hang, Alam, Cai & Peacock, arXiv:2105.11936, MNRAS accepted

- The lensing and temperature imprints of voids on the cosmic microwave background
  Cai, Neyrinck, Mao, Peacock, Szapudi, & Berlind, 2017MNRAS.466.3364C

- A Possible Cold Imprint of Voids on the Microwave Background Radiation
  Cai, Neyrinck, Szapudi, Cole & Frenk, 2014ApJ...786..110C

Intergalactic filaments with tSZ and CMB lensing

- Probing the missing baryons with the Sunyaev-Zel'dovich effect from filaments
  de Graaff, Cai, Heymans & Peacock, 2019A&A...624A..48D

CMB-LSS cross-correlations

- Galaxy clustering in the DESI Legacy Survey and its imprint on the CMB
  Hang, Alam, Peacock & Cai, 2021MNRAS.501.1481H

Omar Darwish

4th year PhD at DAMTP
Supervisor: Blake Sherwin

See also: 2004.01139, ACTxBOSS; 2007.08472, Density reconstruction

UNIVERSITY OF CAMBRIDGE

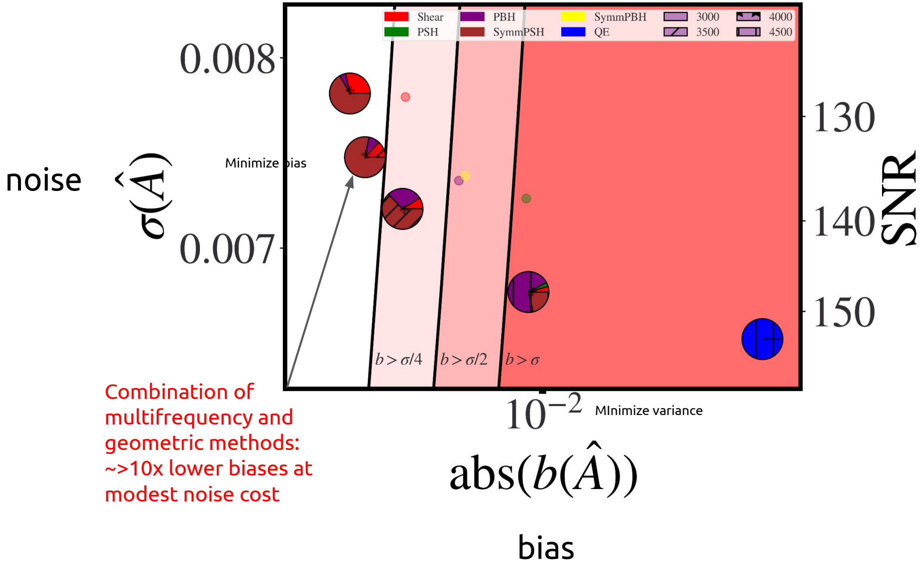
Optimization for reducing foregrounds in CMB Lensing analyses

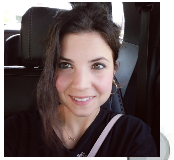
with Noah Sailer, Blake Sherwin, Simone Ferraro, Emmanuel Schaan

Key challenge in CMB lensing: 5-10% “foreground” biases from SZ, CIB in maps. Many mitigation methods developed: multifrequency component separation, shear-only estimation, estimator hardening...

Question: what is the combination of foreground mitigation methods that works best: i.e. maximises SNR, while minimising bias impact?

Optimal combination to be used in SO, and in a ~100 sigma ACT-unWISE cross-correlation (with Gerrit Farren), and ACT auto-spectrum analyses, and in future CMB-S4.





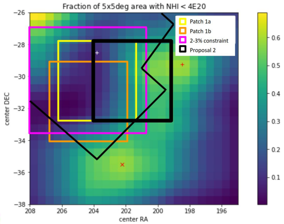
Valentina Fanfani - Second Year PhD Student in Physics and Astronomy

Contact: v.fanfani@campus.unimib.it - **Supervisors:** Federico Nati, Mario Zannoni

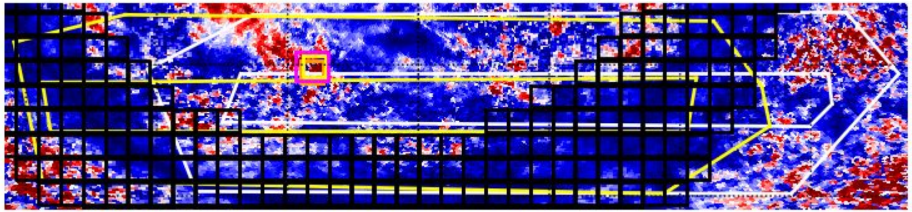
Research Interest: **Galactic Polarized Foregrounds for the CMB study**

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

Simulations for Patch Selection of CMB Dust Foreground



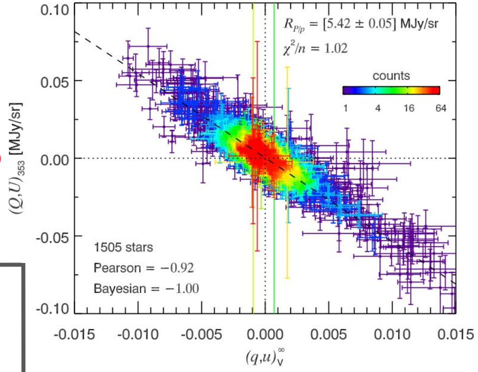
250 μm Polarization Fraction



Starlight polarization

Galactic Science Group

Leaders: *Susan Clark & Brandon Hensley*



Planck Collaboration, XII (2018)

CMB-S4 Next Generation CMB Experiment

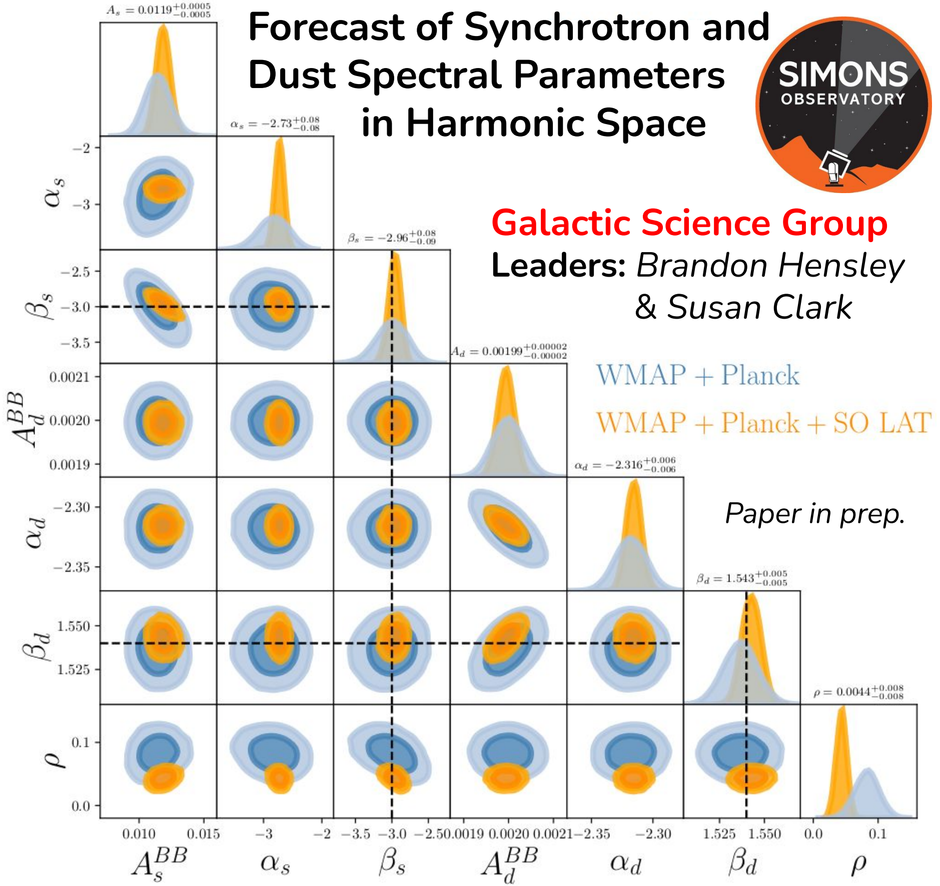
Sources Group

Forecast of Synchrotron and Dust Spectral Parameters in Harmonic Space

SIMONS OBSERVATORY

Galactic Science Group

Leaders: *Brandon Hensley & Susan Clark*



Paper in prep.

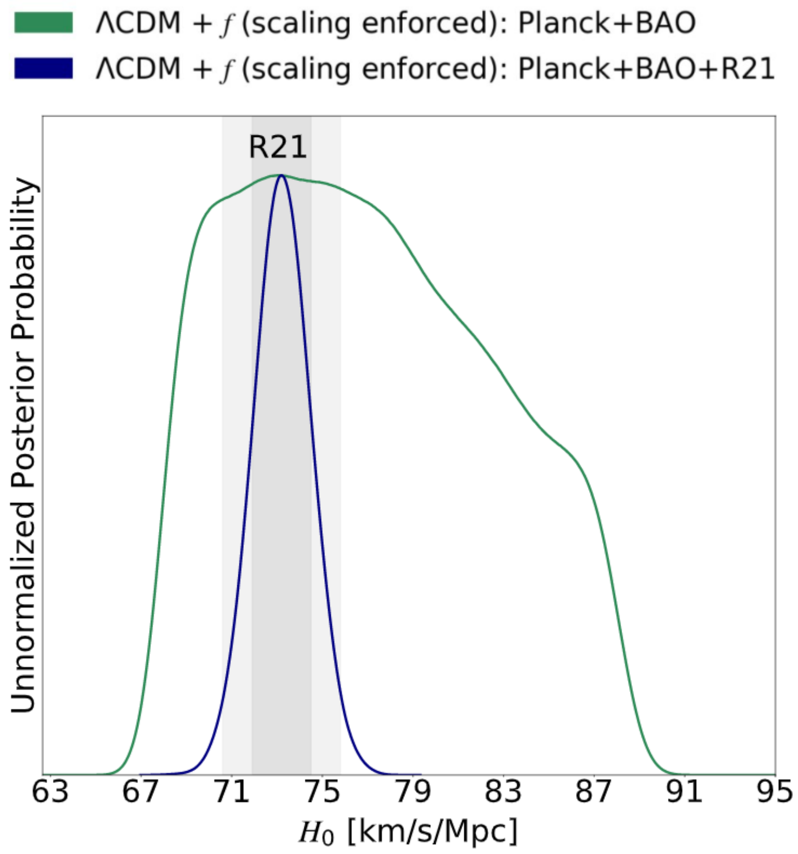
A Symmetry of Cosmological Observables, and a High Hubble Constant as an Indicator of a Mirror World Dark Sector

THE UNIVERSITY OF NEW MEXICO

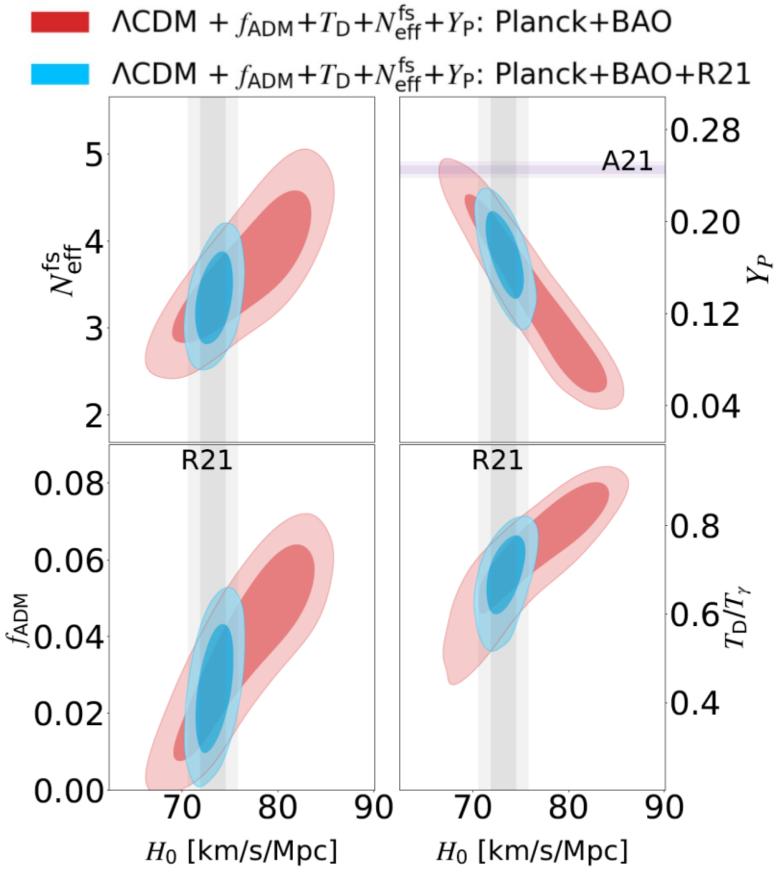
UCDAVIS

Francis-Yan Cyr-Racine, Fei Ge, Lloyd Knox

Symmetry Scaling: Gravitational Time Scales + Photon Scattering Time Scale



A cosmological model with a "mirror world" dark sector can exploit the symmetry and eliminate the H_0 tension.



A mirror world dark sector to resolve H_0 tension: $\sim 3\%$ of total dark matter + $\sim 2K$ dark photons

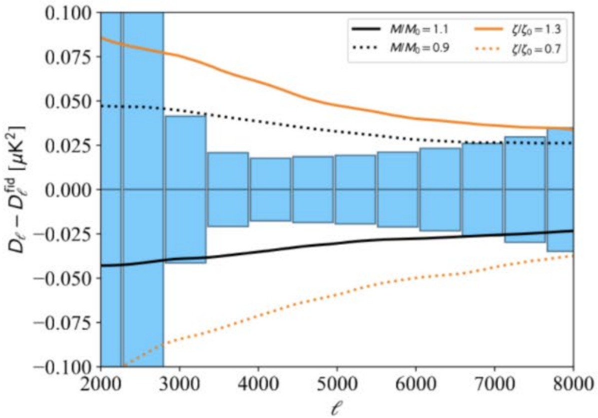
arXiv: 2107.13000

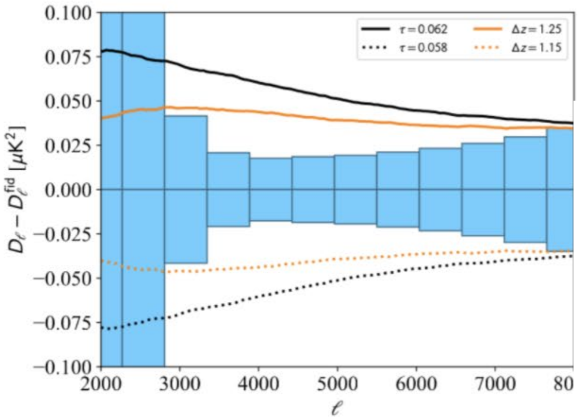
Mitigating the optical depth degeneracy using the Kinematic Sunyaev-Zel'dovich effect with CMB-S4

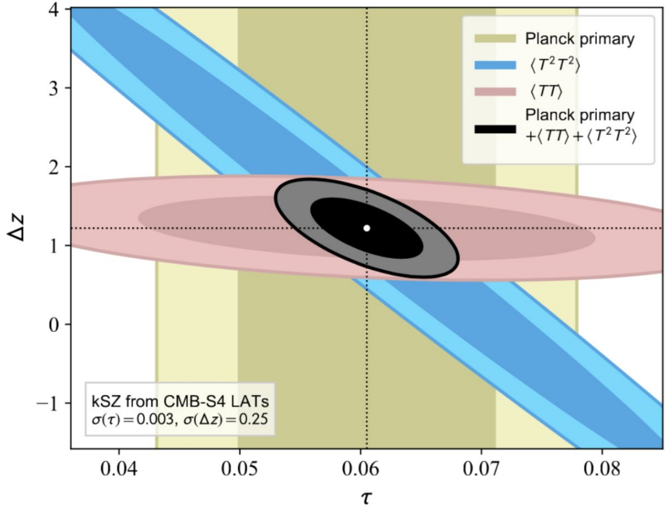
Margaret Ikape, PhD candidate, University of Toronto

ikape@astro.utoronto.ca

Renee Hlozek, Marcelo Alvarez, Simone Ferraro, J. Colin Hill







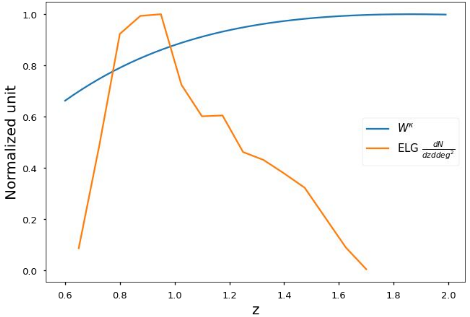
- Future work: get 2pt constraints on ACT likelihood

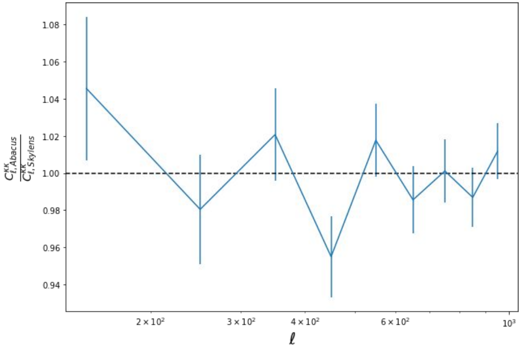
Read more on Arxiv: 2006.06594

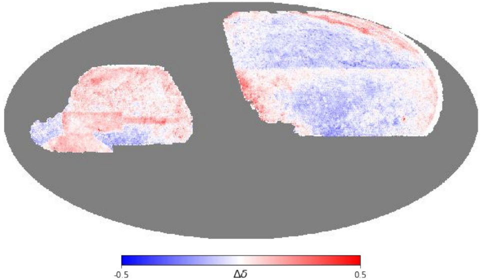
Cross-Correlation of CMB lensing with DESI Emission-Line Galaxies (ELGs) in Legacy Surveys

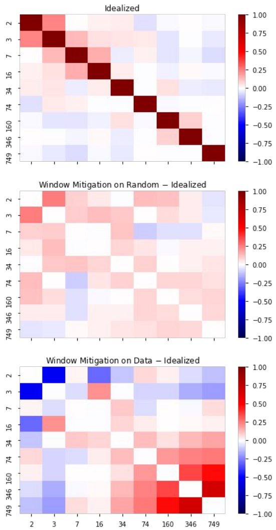
Tanveer Karim, Harvard University (5th Year PhD Student); Contact: tanveer.karim@cfa.harvard.edu
Advisor: Daniel Eisenstein
Collaboration with: Sukhdeep Singh, Mehdi Rezaie, Boryana Hadzhiyska

- Planck CMB lensing X Legacy Surveys DR9 ELGs to constrain linear bias, σ_8, Σm_ν
- Applicable for future CMB surveys X DESI
  - Forecast SNR of Planck CMB lensing X DESI ELGs ~46
- Validation with AbacusSummit
- Study impact of imaging systematics on covariance matrix







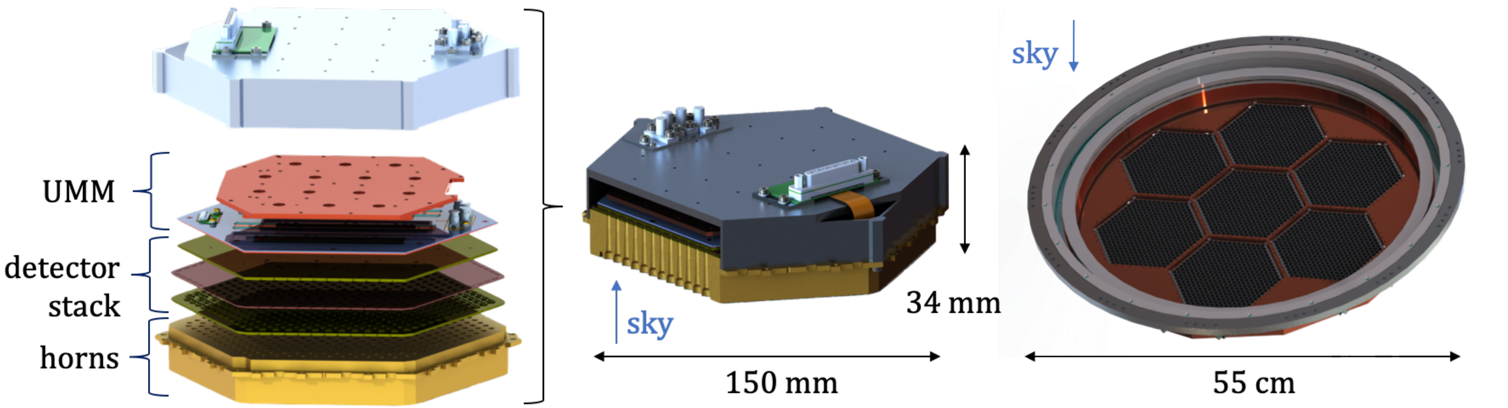


The Simons Observatory microwave SQUID multiplexing focal-plane modules

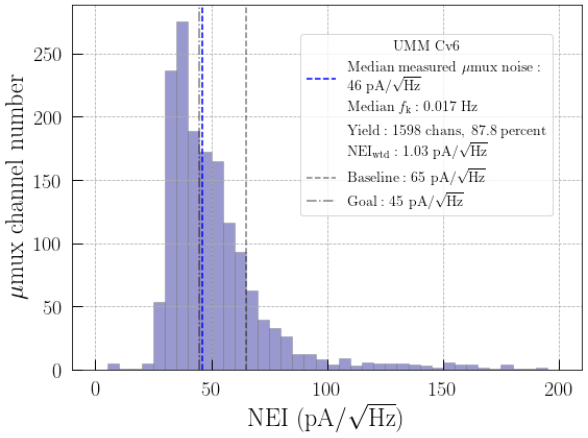
CMB-S4, Summer 2021 Collaboration Meeting

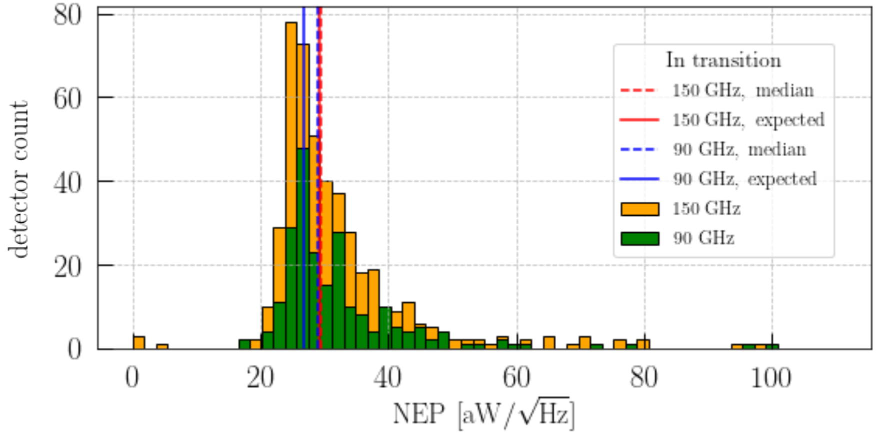
Heather McCarrick, Postdoc, Princeton University (hm8@princeton.edu)

- We recently posted a manuscript to arxiv (McCarrick et al. 2021, arxiv:2106.14797), which details the design of the Simons Observatory (SO) universal focal-plane modules (UFMs).
- The UFMs use microwave SQUID multiplexing (μmux) at a 1000 multiplexing factor for the readout of transition-edge sensor (TES) bolometer arrays. The 100 mK multiplexer is an integrated part of the UFM.
- The MF (90, 150 GHz) and UHF (220, 270 GHz) UFMs use the same design, which is also common to the three small aperture telescopes (SAT) and one large aperture telescope (LAT).
- We demonstrate the UFM functionality, at the full multiplexing factor. The UFM sensitivity is better than needed as outlined in the SO forecasting paper (SO Collaboration 2019, arxiv:1808.07445).
- SO is currently in the production stage of building and characterizing 49 UFMs, which will populate the receivers. First light is expected in 2022.



Figures showing the SO UFM design. The cold 2x1000 multiplexer is contained in the universal μmux module (UMM). The modules are compact and can be tessellated.

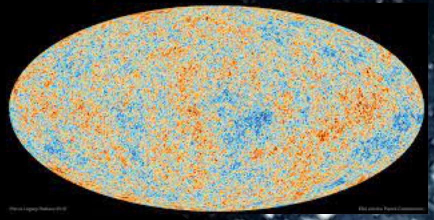




Left: Histogram of the cold multiplexer noise equivalent current (NEI). The median is 46 pA $Hz^{-1/2}$. *Right:* Histogram of the noise equivalent power (NEP) with the TES bolometers in-transition. The median for 90 and 150 GHz is within 10% of expectation and better than the SO requirement.

Foreground Synchrotron Emission Modeling

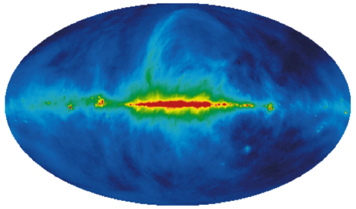
CMB and Synchrotron



Cosmic rays

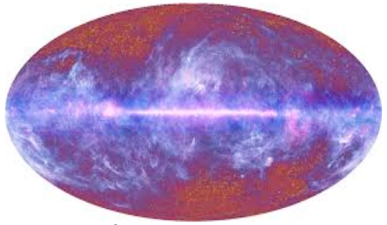
PROBLEM:
Synchrotron, Cosmic Rays & Magnetic Fields are not known

OUR SOLUTION:



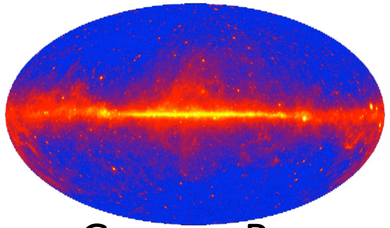
Radio Surveys

+



Microwaves

+



Gamma Rays

+

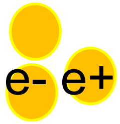
Cosmic Rays Measurements

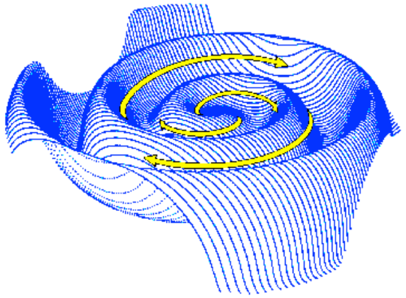
+

Our Cosmic-Ray Propagation Models →

RESULTS:

→





More details on the method and selected results:

Orlando & Strong (2013) MNRAS 436, 2127

Orlando (2018) MNRAS 475, 2724

Orlando (2019) Phys.Rev.D 99, 043007

CMB-S4 Workshop– Aug 2021

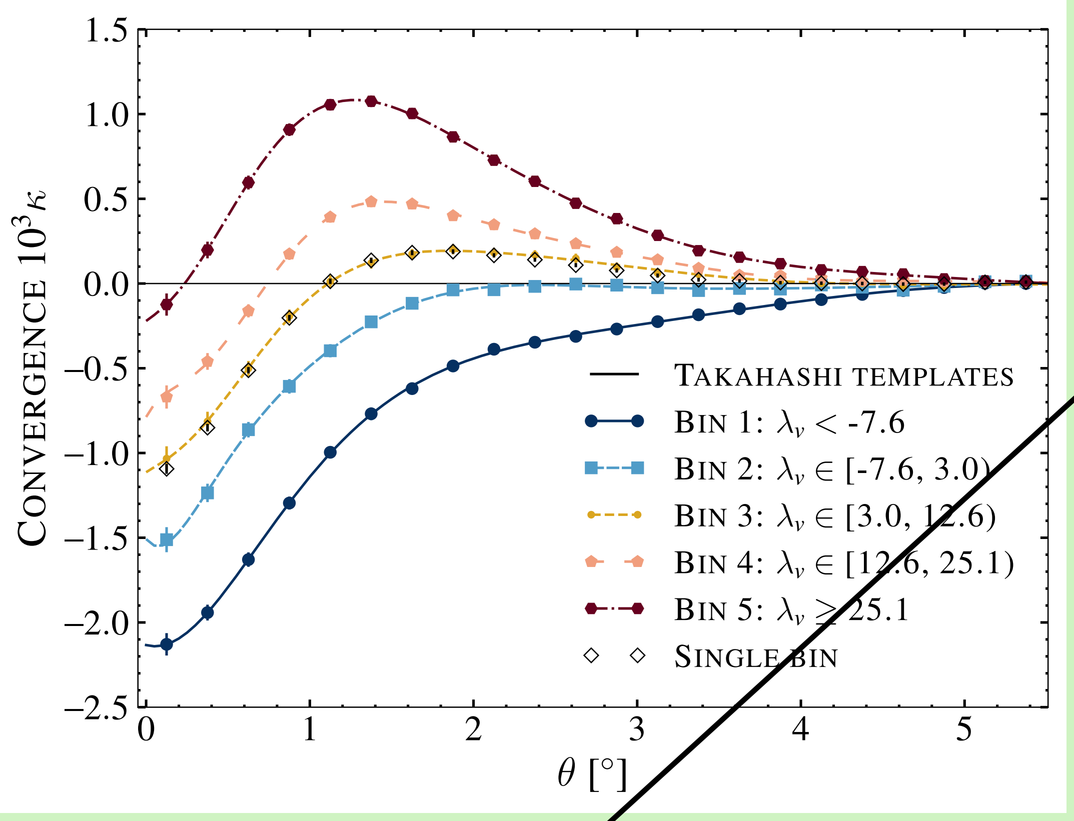
Elena Orlando – University of Trieste, Stanford University

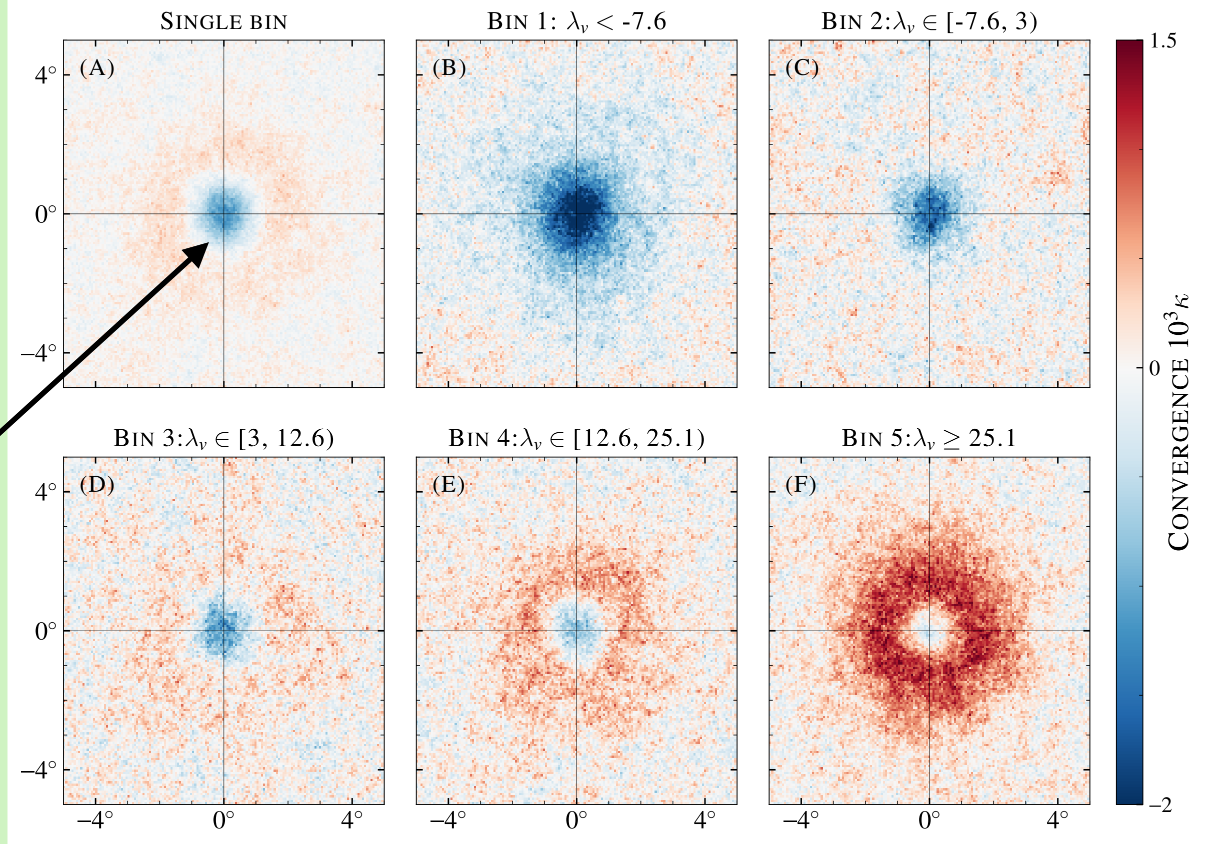
Combining lensing and thermal SZ effects to probe matter distribution in cosmic voids

Srinivasan Raghunathan *+ S. Nadathur, D. Nagai, K. Osato, B. Sherwin, N. Whitehorn*

Simulations

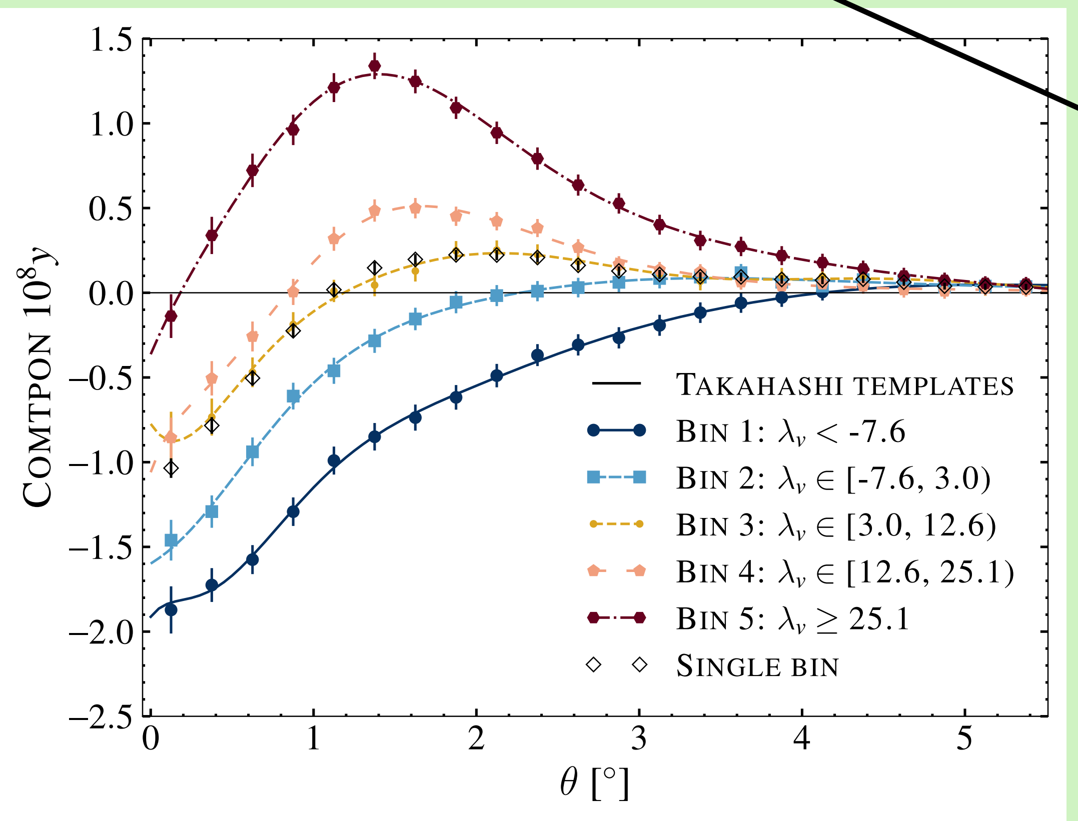
CMB lensing (Dark matter)

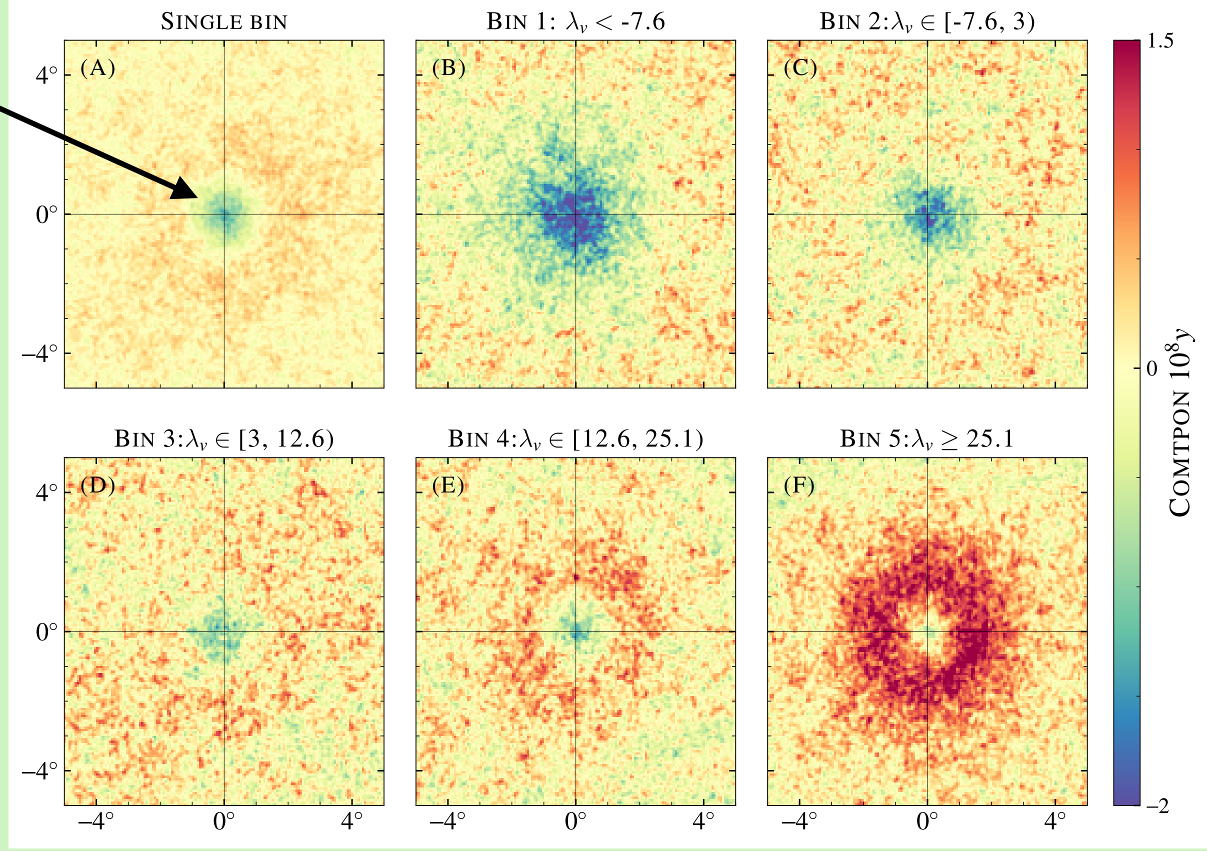




All voids vs grouping using $\lambda_v = \bar{\delta}_g \left(\frac{r_v}{1h^{-1}\mathrm{Mpc}}\right)^{1.2}$

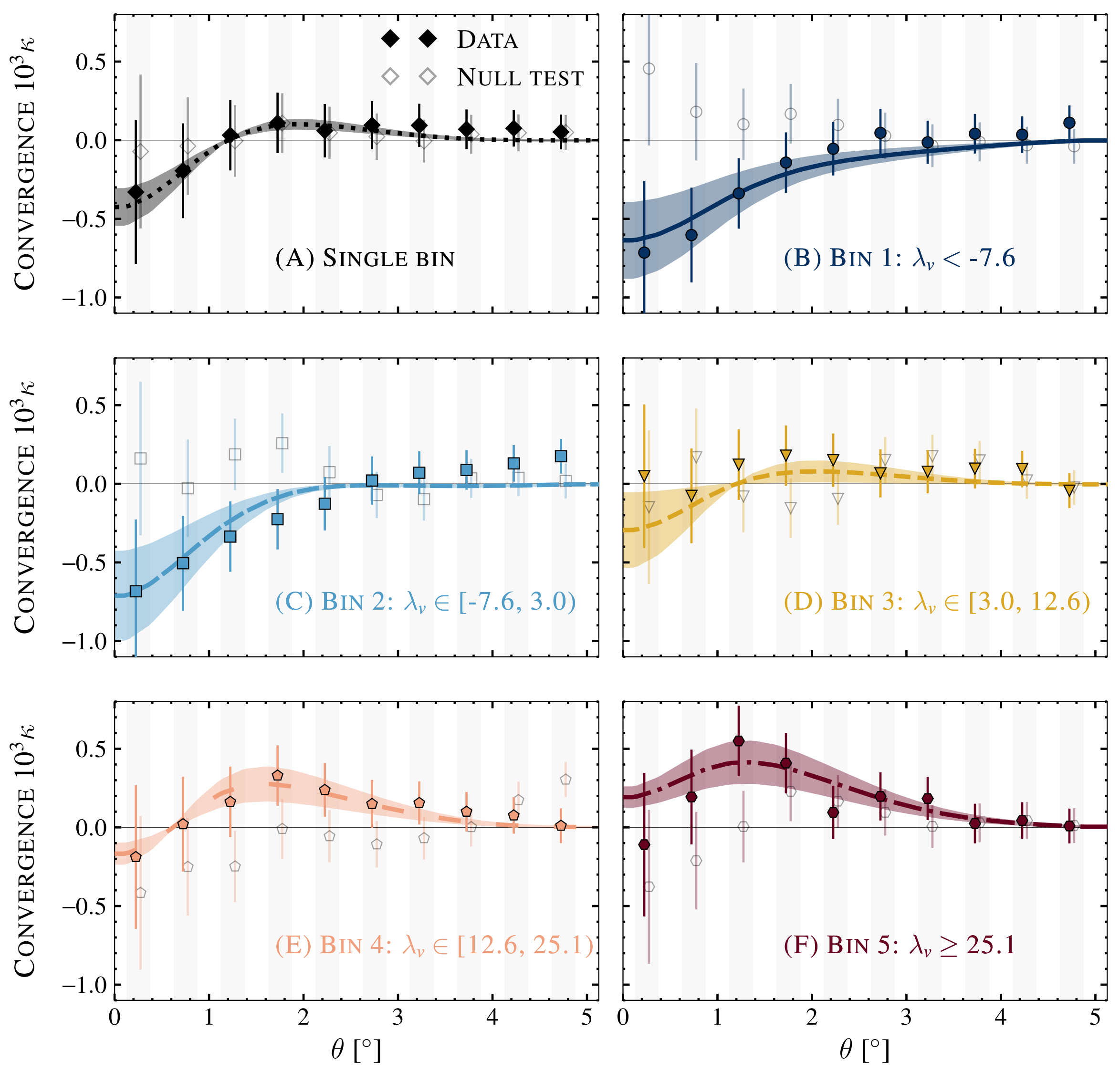
Compton-y (Baryons)





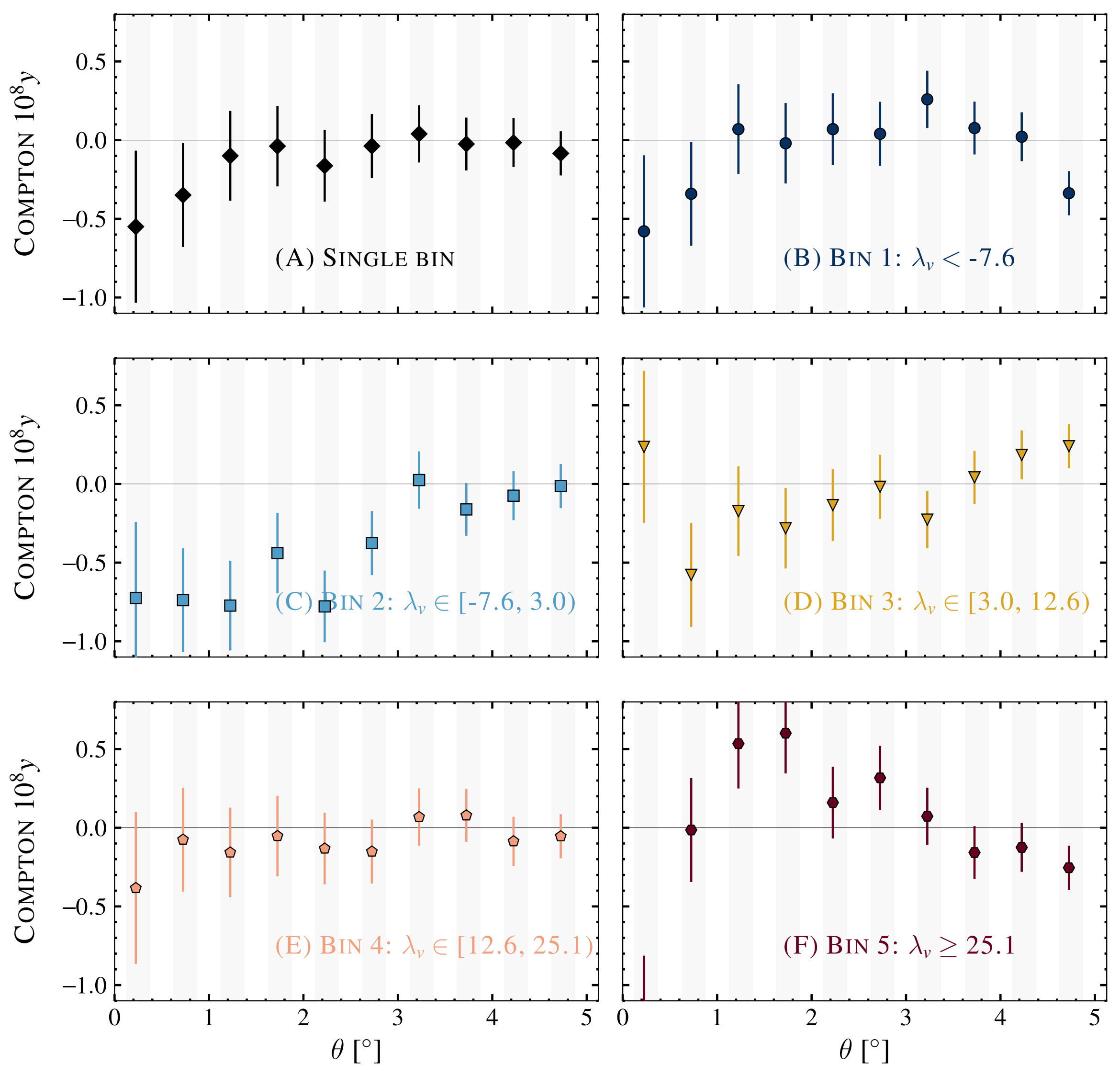
Planck lensing

Raghunathan, Nadathur, Sherwin, Whitehorn (2020), arXiv: 1911.08475.



Planck Compton-y

Preliminary, in preparation.



— Jointly use lensing and Compton-y to investigate how baryons trace dark matter —

Other references:

- CMB-lensing X Voids: Cai et al. 2016, arXiv: 1609.00301; Vielzeuf et al. 2021, arXiv: 1911.02951.
- Compton-y X Voids: Alonso et al. 2017, arXiv: 1709.01489.

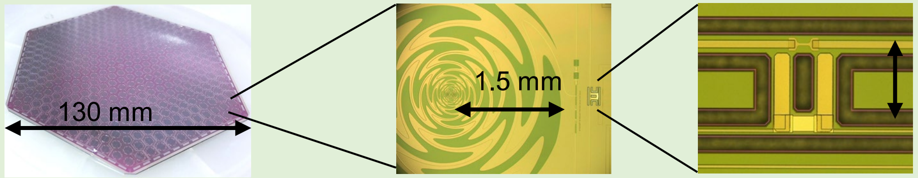
Recent developments of commercially fabricated horn antenna-coupled Transition Edge Sensor bolometer detectors for next generation Cosmic Microwave Background polarimetry experiments

Aritoki Suzuki[1] (asuzuki@lbl.gov), Elijah Kane[1,2], Adrian T. Lee[1,2], Tiffany Liu[1], Christopher Raum[2,3], Mario Renzullo[4], Patrick Truitt[4], John Vivalda[4], Benjamin Westbrook[2,3], Daniel Yohannes[4]

1. Physics Division, Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA
2. Physics Department, University of California, Berkeley, Berkeley CA 94720, USA
3. Radio Astronomy Laboratory, University of California, Berkeley, Berkeley CA 94720, USA
4. SeeQC Inc., Elmsford, NY, 10523, USA

Motivation

- Next generation Stage-IV ground based CMB experiment, CMB-S4, will make a definitive measurement of CMB polarization with O(500,000) detectors
- **Commercial micro-fabrication foundry's high fabrication throughput enables this order of magnitude increase in detector count**
- CMB-S4 recently **selected horn antenna-coupled TES bolometer detector** for the base line detector technology
- Seeqc have successfully fabricated sinuous antenna coupled TES detector arrays previously. We adapted most of the fabrication processes to fabricate horn coupled detector arrays



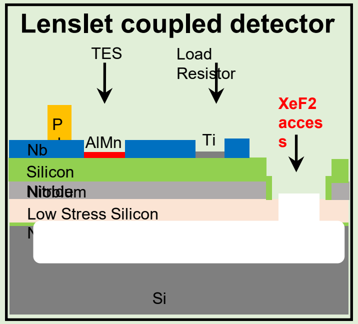
Sinuous antenna detector array **Pixel details** **XeF2 released TES bolometer**

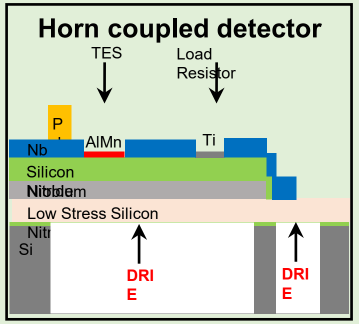
Commercial TES bolometer detector fabrication

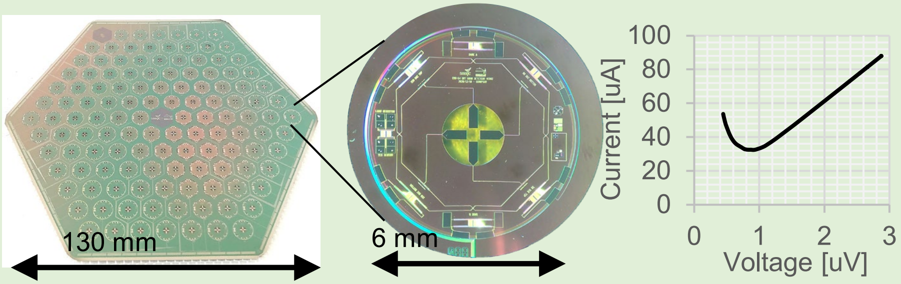
- Seeqc Inc. (https://seeqc.com/) is a company based in New York state that specializes in development and fabrication of superconductor electronics
- Engineers at Seeqc have extensive expertise and experience in superconducting microfabrication
- Seeqc Inc. recently procured DRIE etcher for through wafer fabrication process
- Every fabrication steps was done at Seeqc Inc.
- Seeqc also has multiple dilution refrigerators for cryogenic characterization of devices
- Seeqc uses industrial-scale fabrication method to increase throughput and reduce cost per wafer
- Commercial techniques for stringent quality assurance improve uniformity, repeatability, and yield by using high throughput fabrication and metrology equipment

Horn couple detector fabrication

- Fabrication steps for lenslet+sinuous antenna coupled detector and horn coupled detector are identical except for how silicon substrate is etched to release TES bolometer
  - Lenslet coupled detector: XeF2 etch
  - Horn coupled detector: DRIE etch
- We made two changes to the fabrication process:
  - Thicker low stress silicon nitride to survive DRIE process
  - Back side lithography for DRIE process
- We used stealth laser dicing technique offered by GDSI to dice large hexagonal arrays without breaking released membranes
- TES bolometers successfully operated
- **We fabricated prototype detector arrays for the CMB-S4 project**







Dual Tc TES bolometer

- We have also developed a design to achieve TES sensors with two different superconducting temperatures (Tc) without changing the fabrication process.
- We modified Tc using a superconducting proximity effect between Nb and AlMn alloy. TES material, AlMn alloy, sandwiched between Nb gaps (1 um ~ 4 um) to raise its Tc.
- Dual-Tc TES sensors are useful when same the detectors are required to operate under different incoming power.