# CMB-S4 Spring Collaboration Meeting: Fireslides-II

1. Han **Aung**
2. Katie **Harrington**
3. Colin **Hill**
4. Selim **Hotinli**
5. Alec **Hryciuk**
6. Tony **Mroczkowski**
7. Sanjaykumar **Patil**
8. Noah **Sailer**
9. Ritoban Basu **Thakur**
10. Paul **Williams**

**11 May, 2022**

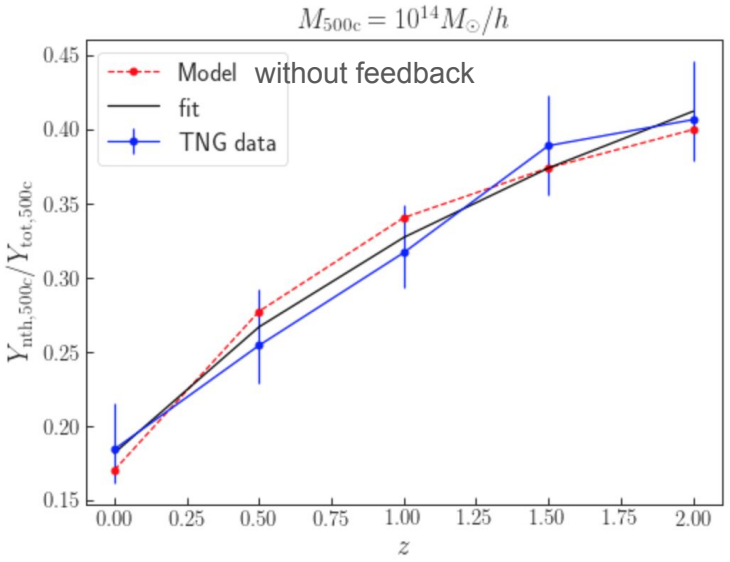
CMB-S4

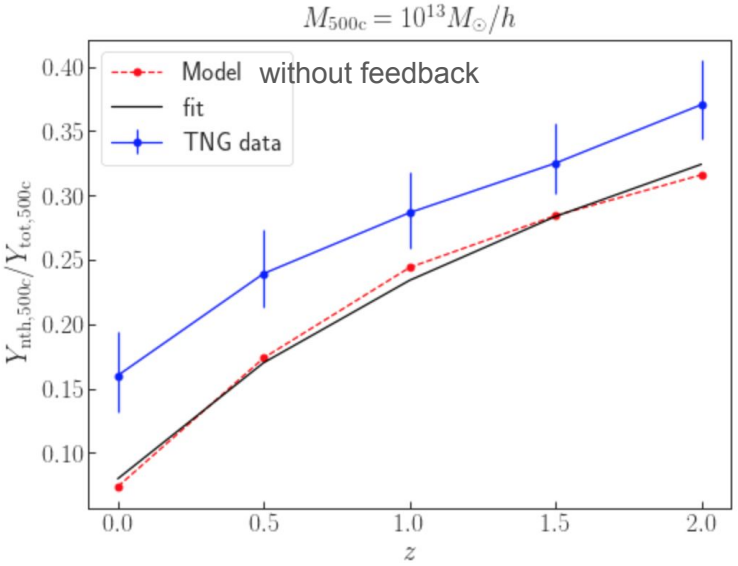
# Modeling the Sunyaev-Zeldovich Effect in Galaxy Clusters and Groups

Han Aung
Hebrew University of Jerusalem

Non-thermal pressure leads to hydrostatic mass bias in SZ measurements. We are modeling non-thermal pressure in clusters and groups:

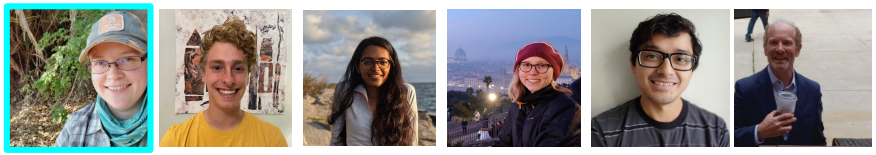
- Due to mass accretion history (Shi+14, Green+20)
- Due to feedback (Aung+ in prep)

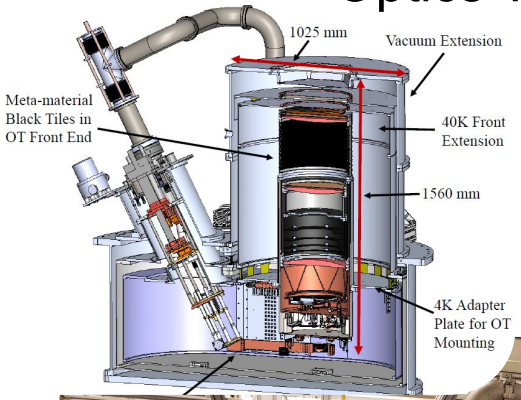


# SO Integration and Testing of LATR Optics Tubes

Katie Harrington



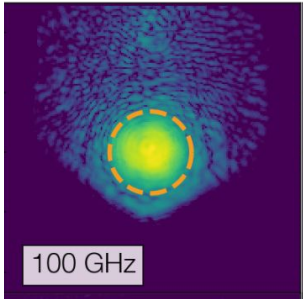


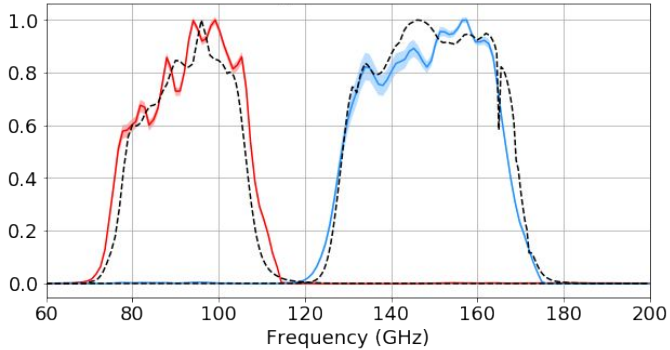

**System Engineering Driven Testing of LATR OTs.**

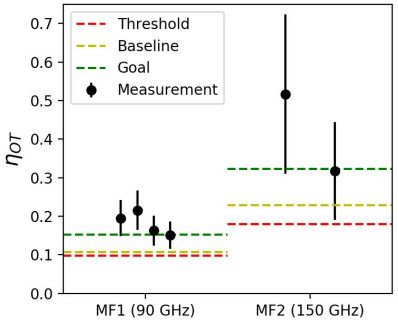
**Turned SAT into Single OT Tester**

Requirements Under Test:

- Beams
- Spill
- End-to-end Efficiency
- End-to-end Bandpasses
- Out-of-band Leakage
- Cross Polarization




**Verified MF OT will meet SO requirements for science goals.**

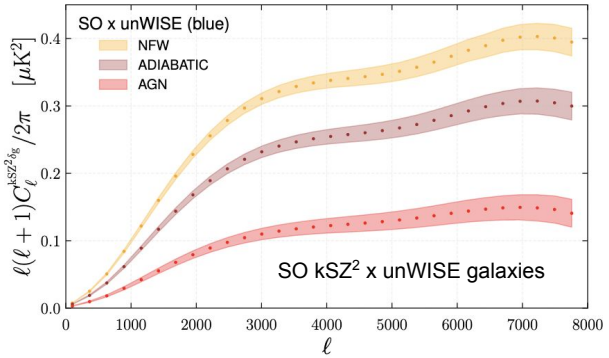
# Halo Model for Projected-Field kSZ Estimator

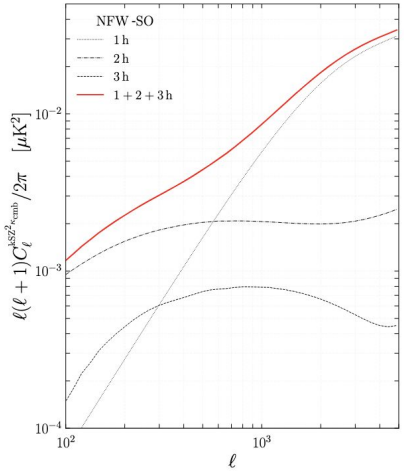
Boris Bolliet, Colin Hill, Simone Ferraro, Aleksandra Kusiak, Alex Krolewski (to appear)

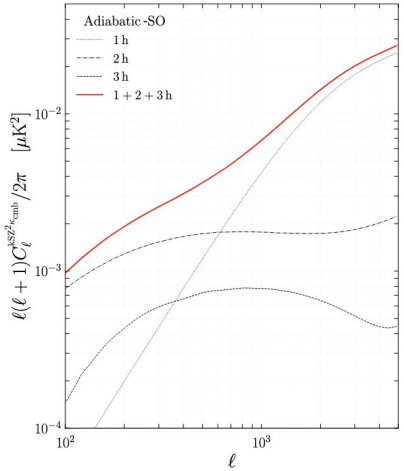
**Idea**: measure the <TTg> bispectrum due to kSZ effect by cross-correlating a foreground-cleaned, filtered, squared T map w/ LSS tracer map [Dore+04, DeDeo+05, Hill+16, Ferraro+16, Kusiak+21]

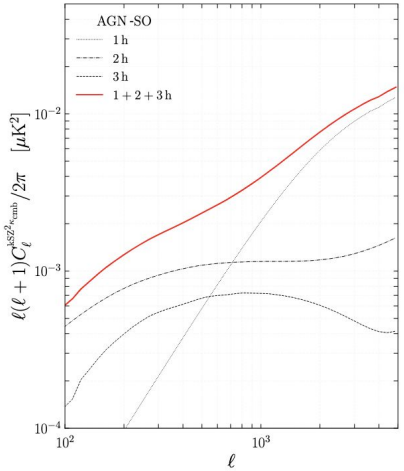
**Why?**: probe the distribution of baryons on small scales (→ feedback processes) and/or large-scale velocities

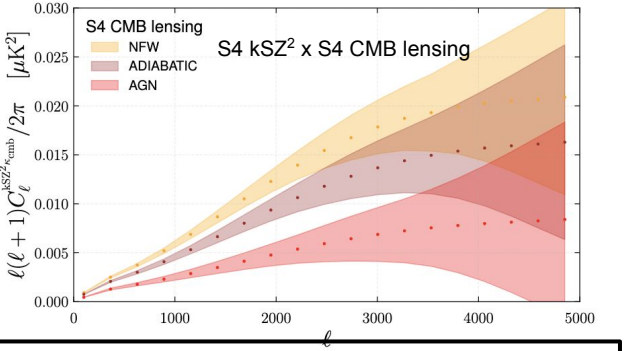
**What's new**: first detailed halo model calculation of this signal → can now study dependence on gas physics model/parameters



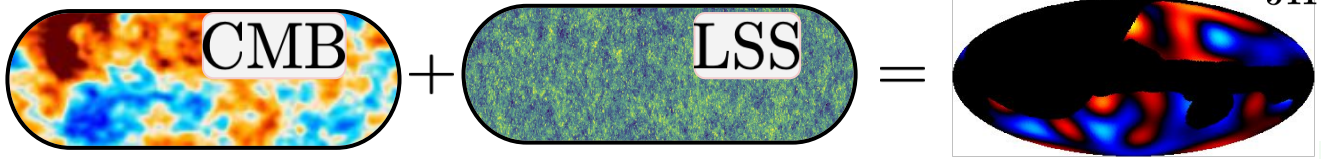

**SNR > 100 for CMB-S4 x unWISE/Rubin/Euclid**

https://github.com/borisbolliet/class_sz

# CMB-S4–LSS cross-correlations

CMB-S4 fireslide

Selim C. Hotinli
JHU Horizon Fellow




SCH et. al.

large-scale velocity (remote-dipole) reconstruction

non-Gaussianity: $\sigma(f_{\rm nl}) \lesssim 0.7$

addional degrees of freedom: $\sigma(\tau_{\rm nl}) \lesssim 0.5$

primordial isocurvature $\sigma(A_{\rm iso}) \lesssim 0.5$

kSZ-tomography: $\sim \int d\chi\, v_r \delta_e$ — 1812.03167 (PRL), 2006.03060 (PRD), 2108.02207 (PRD)

ML-tomography: $\sim \int d\chi\, v_\perp \nabla\Psi$ — 1908.08953 (PRD), 2012.09851 (PRD)

2205.03423 NK, GSP, MK, **SCH**

**ReCCO** tool for velocity tomography: 2111.11526 JC, RB, **SCH**, MJ, FM

large-scale remote-quadrupole reconstruction

primordial tensor fluctuations: $\sigma(r) \sim 0.1$

cosmic (late-time) birefringence: $\sigma(\alpha_{\rm reio}) \lesssim 0.5^\circ$

pSZ-tomography: $E/B \sim \int d\chi\, \pm q\ \delta_e$

2204.12503 SCH et. al.

NL, **SCH** (upcoming)

also → 2203.05728

CMB-S4 detection forecasts

kSZ effect SNR$\gtrsim$ 200

moving-lens effect SNR$\gtrsim$ 20*

kinetic pSZ effect SNR$\gtrsim$ 3

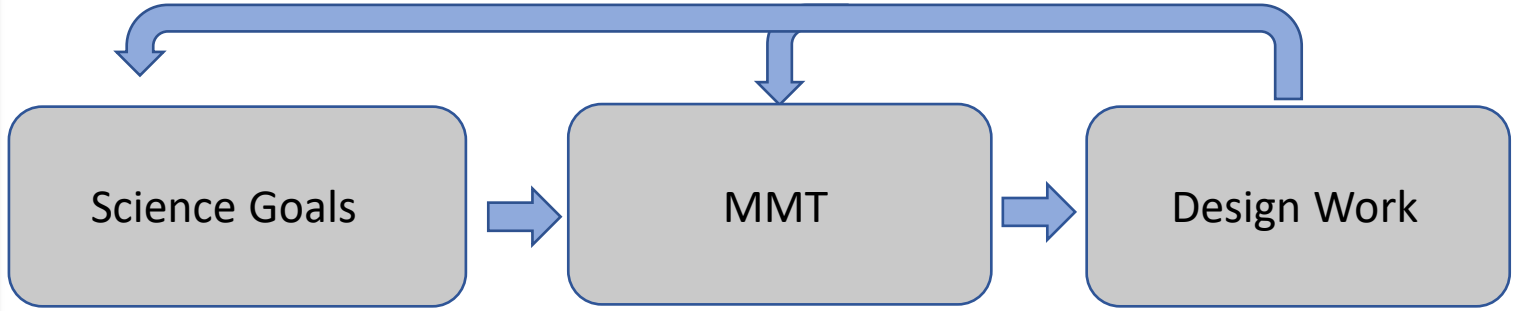
CMB-S4 delensing forecasts** see 2111.15036

`github.com/selimhotinli/class_delens`

*also @ Sanjay's slide **also @ Cynthia's slide

# Map Multi Tool (MMT)

**A Tool for modeling systematics in the map domain**



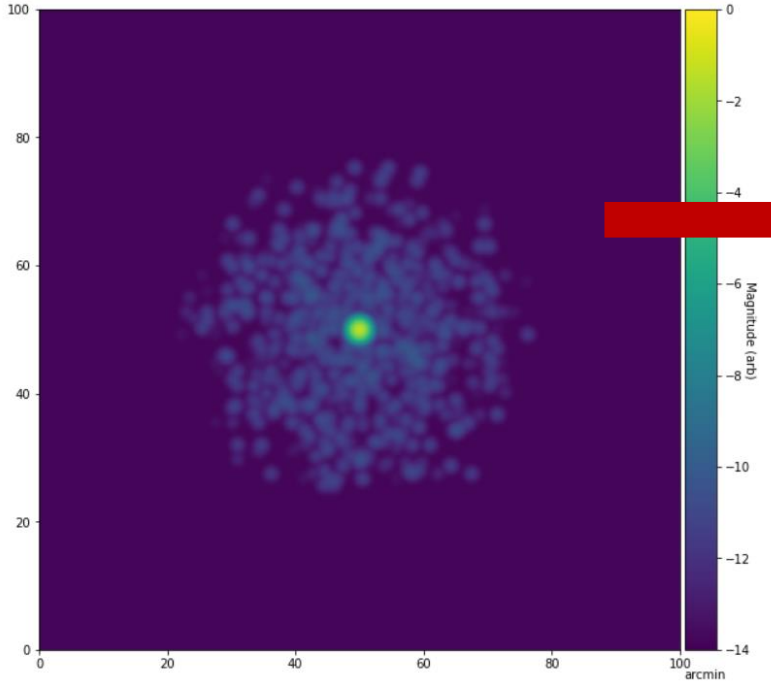

Alec Hryciuk

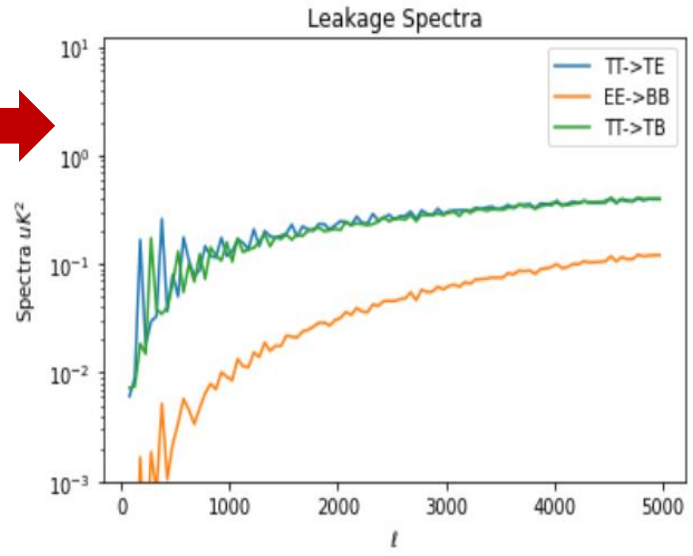
Ph. D. Student at University of Chicago

Working out 2 use cases with the Systematics WG

## Electrical Crosstalk

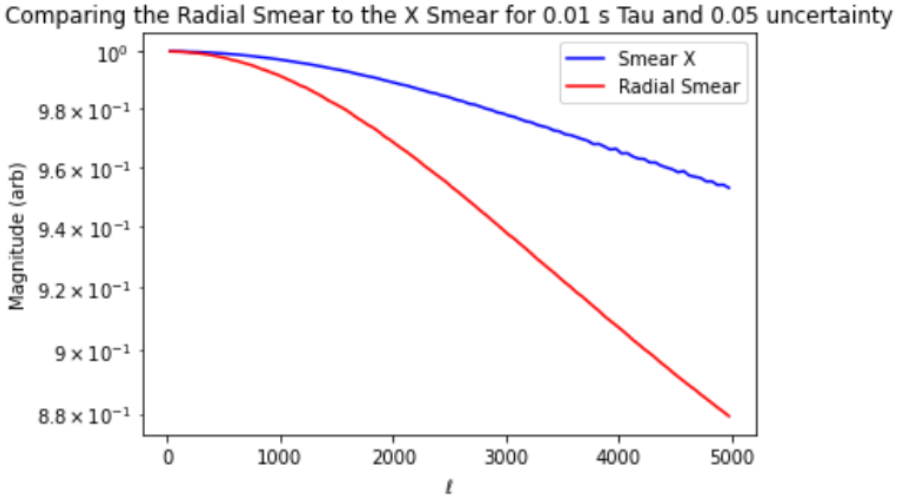
How much does detector-coupling affect high-ell science goals?




## Detector Time Constants

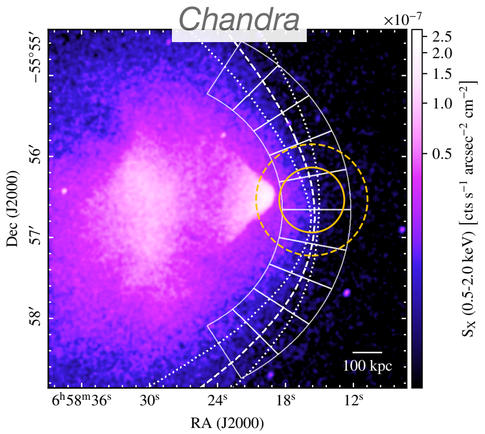
How well do time constants need to be measured to be on track for science goals?



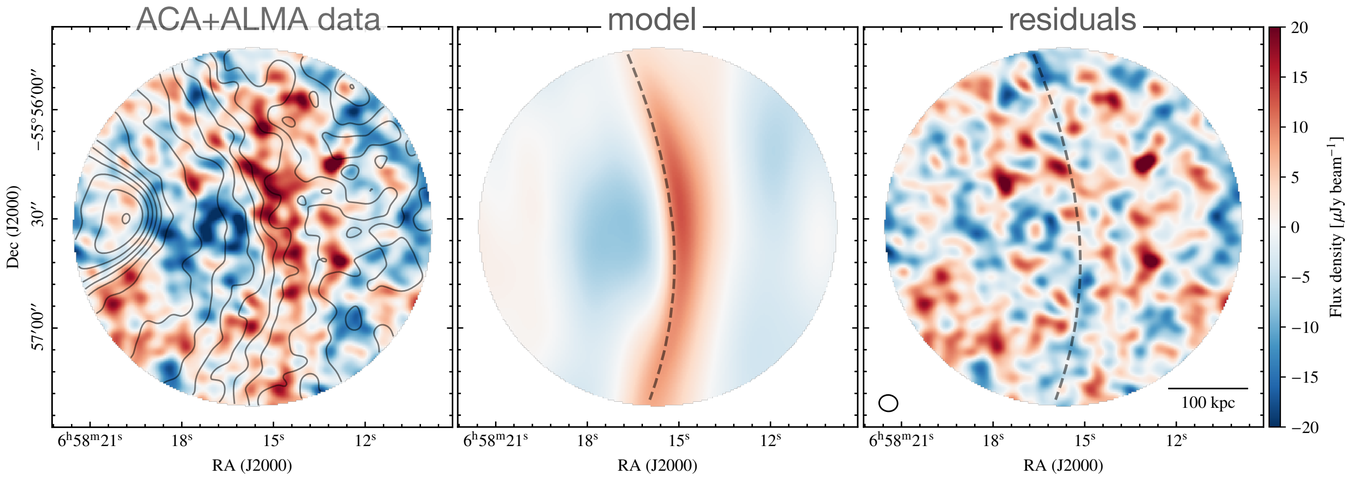
# Tony Mroczkowski

**mm/submm instrument scientist**
**European Southern Observatory**

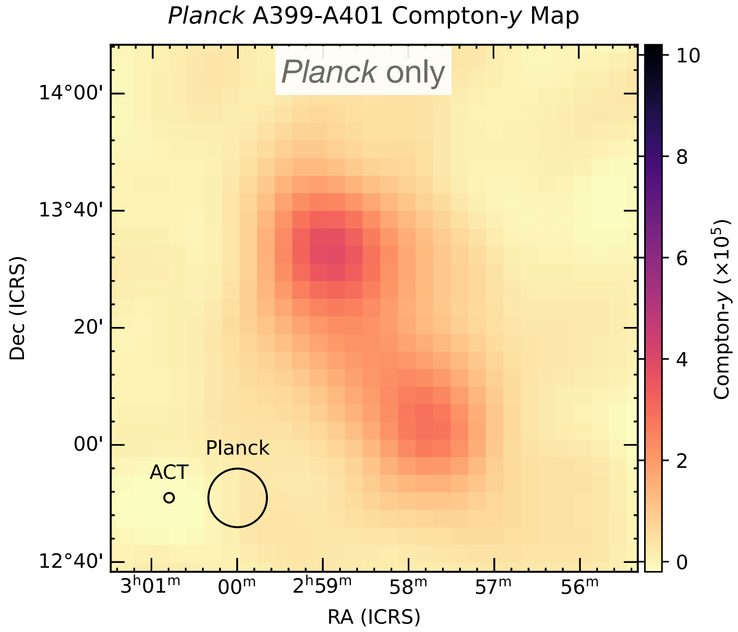
- I tend to do galaxy cluster astrophysics with the thermal and kinetic SZ effects
- I usually use subarcminute resolution instruments like MUSTANG-2 on the GBT and ALMA/ACA (see Bullet Cluster plots from Di Mascolo, Mroczkowski, et al. 2019)
- I am a vocal advocate for the Atacama Large Aperture Submm Telescope (the AtLAST 50-m, 2 deg FoV concept).
- Even ~6-meter telescopes can do astrophysics (see A399-A401 plots from Hincks et al. 2020)

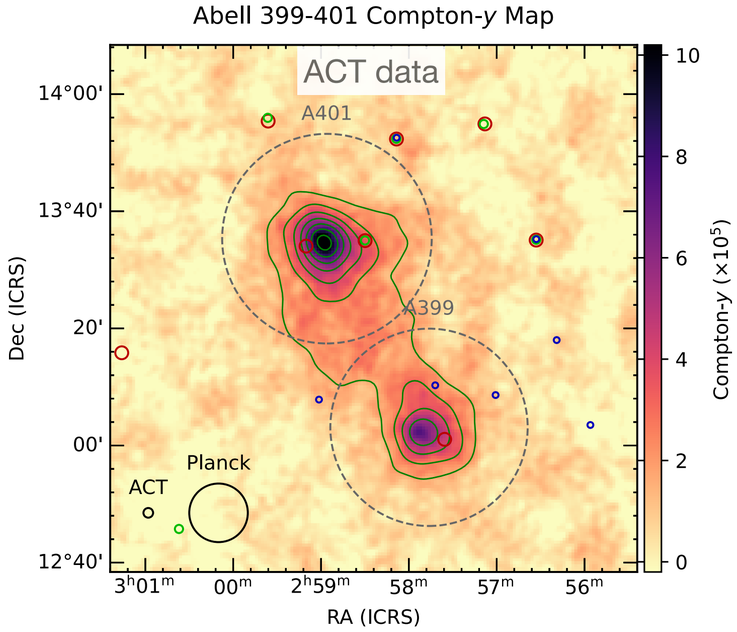


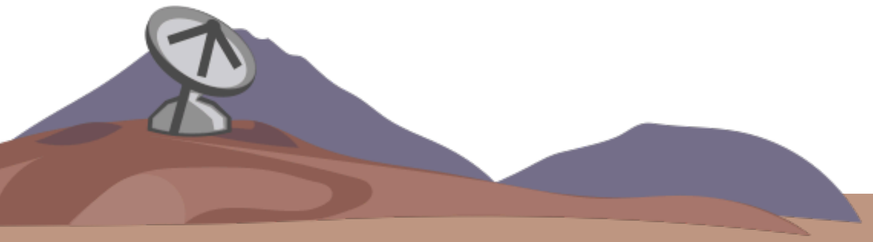

*Chandra* X-ray data
ALMA (ACA) field in yellow (dashed)




SZ constraints from ALMA+ACA Band 3 (~92 GHz; see Di Mascolo et al. 2019) on the shock are most consistent with adiabatic acceleration processes, challenging the canonical X-ray results for the Bullet (though see recent Russell et al. 2022 results on A2142).



# Transverse peculiar velocity detection

Sanjaykumar Patil, USC

Completed:

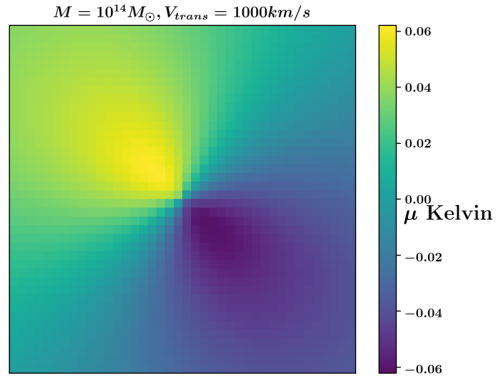
- Optimal filter to extract transverse velocity
- CMB cluster lensing
- ILC noise suppressing galactic and extra galactic noise

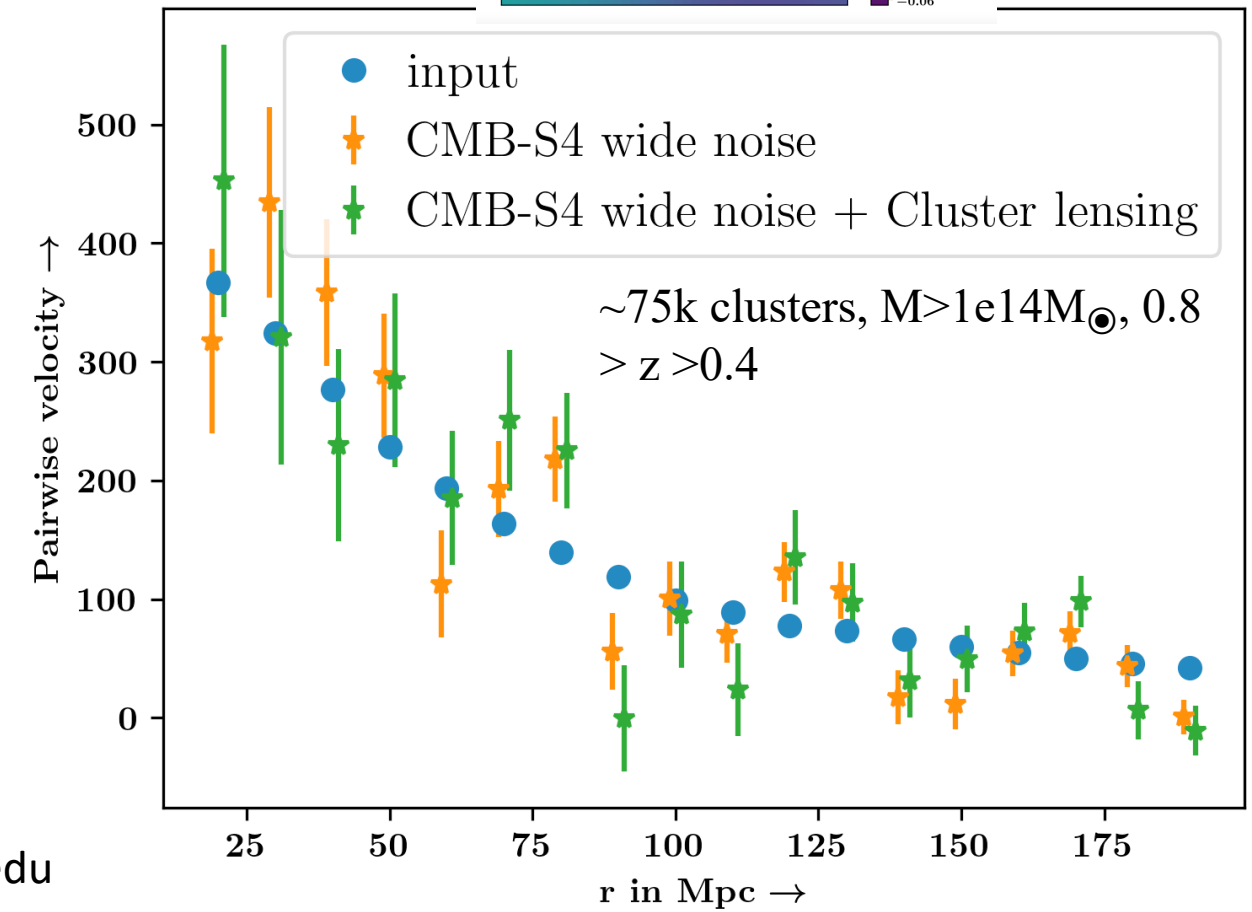
To do:

- Mass uncertainty
- Miscentering
- Cluster correlated noise
  - tSZ
  - kSZ

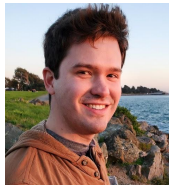
Oriented stacking to extract bulk transverse velocity (Selim is leading the project)

Moving lens effect




CMB-S4 meeting 2022, email id: sanjayku@usc.edu




# Noah Sailer – UC Berkeley

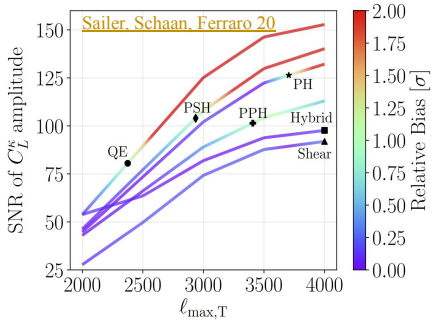
3rd year physics student

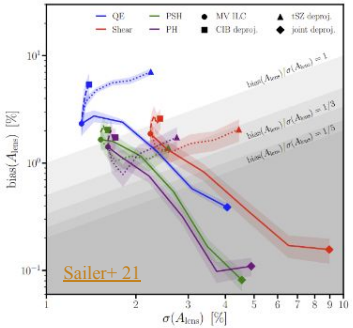
working w/ Martin White and Simone Ferraro

nsailer@berkeley.edu


## CMB lensing - optimal bias mitigation

- Two approaches to mitigating biases from extragalactic foregrounds
  - Geometric: bias-hardening
  - Multifrequency: modified ILC weights
- Future: biases from polarized (point) sources, galactic foregrounds




## DESI LRGs x ACT $\kappa$

- Cross-correlate DESI Luminous Red Galaxy sample (imaging) w/ ACT lensing
- Infer $\sigma_8(z)$ à la (effective) Lagrangian PT
- Current hints of low $\sigma_8(z)$ at $z \lesssim 0.5$
  - Systematics?

## Cross-correlations with future high-z surveys

- LPT-based Fisher forecasting (FishLSS)
  - galaxy and 21cm clustering, cross-correlations with CMB lensing
- Self-consistent forecasts for future LSS and CMB surveys (Euclid, MSE, MegaMapper, PUMA, S4, ...)
- Constraints on ΛCDM and extensions: EDE, neutrinos, primordial features, gravitational slip, etc.

Sailer, Castorina, Ferraro, White 21

Berkeley
UNIVERSITY OF CALIFORNIA

# Side Lobe mapping with BICEP-Keck Small Aperture Telescopes

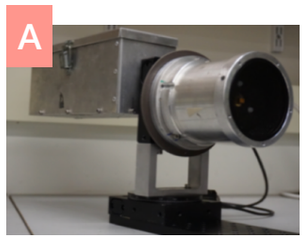
Ritoban Basu Thakur* (Caltech) on behalf of the BK collaboration

Small aperture telescopes (SATs) measure the polarized CMB at degree scales, probing the tensor-to-scalar ratio ($r$) and directly examining inflationary cosmology. BICEP-Keck SATs lead the limit on $r$ with the aim of reaching $\sigma(r) \sim 2\times10^{-3}$

Polarized differential beams at large angles, can limit $\sigma(r)$, e.g., via temperature-polarization leakage from ground, galaxy etc. Thus for CMB S4, it is important to perform Side Lobe (SL) studies. With BK SATs we are pursuing such SL measurements, which will inform CMB S4 SAT planning and development.

## BICEP3 FSL setup & map-making

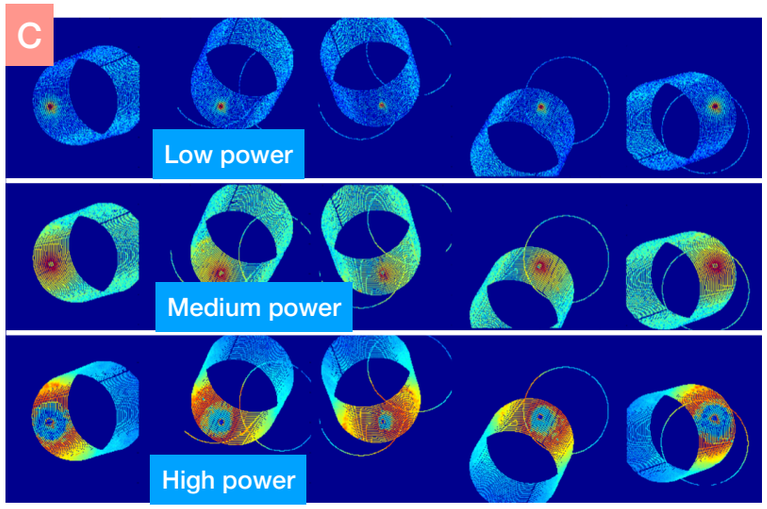
**Graphics credit: Giannakopoulos & Miller**

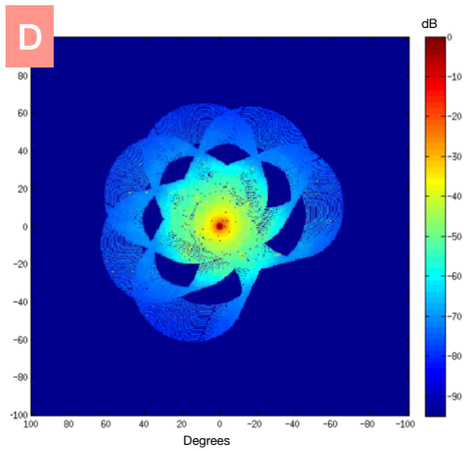




A) Polarized chopped calibration source. Source power is tunable B) Source on mast above BICEP3 ground shield.

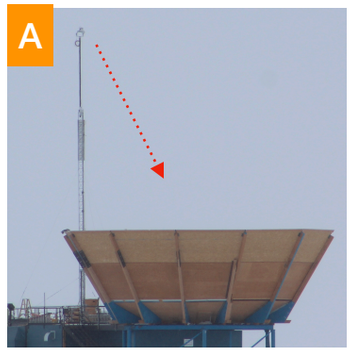
C) Per source power, detector-centric maps at 5 bore-sight rotations are shown. These are single detector examples. Bolometer behavior is non-linear (saturation effects) when staring at source with higher powers.

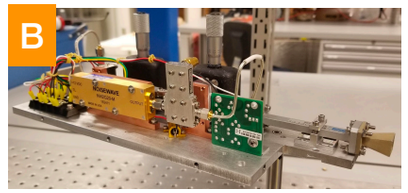


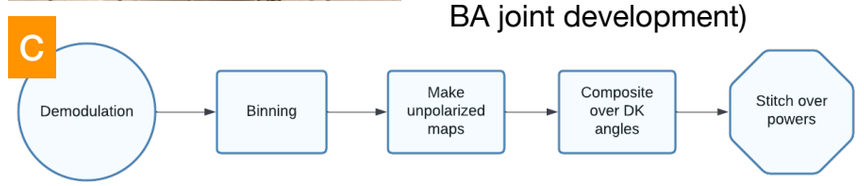

D) We composite the 5 maps, per power. And select regions in each, rejecting noise and saturation features.
A complete SL map is shown for a single 95 GHz detector.

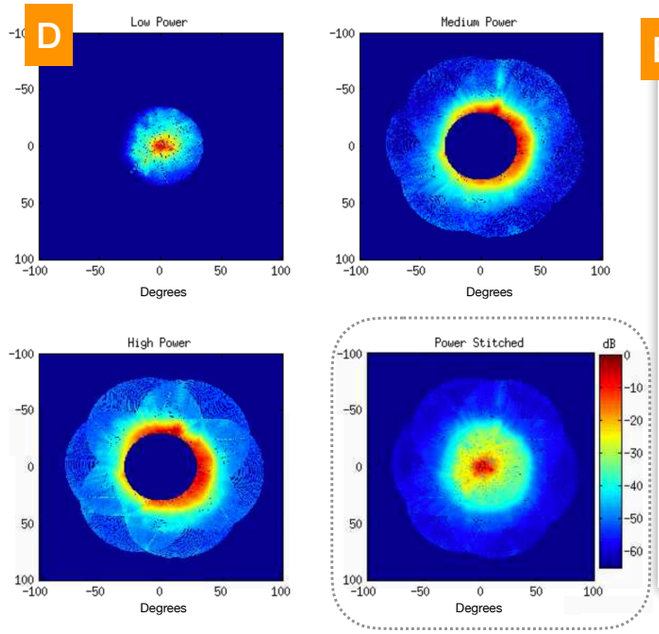
## BICEP Array (BA) FSL setup & map-making

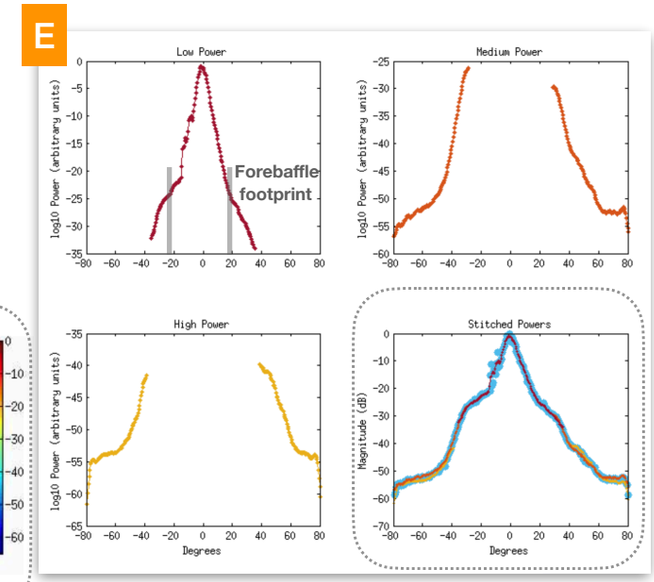



A) Source on mast above BA ground shield. B) Polarized chopped Ka-band amplified noise source with attenuators. C) Analysis flow chart for high signal-to-noise ratio maps (B3/BA joint development)




D) Low, medium and high power maps shown for one BA-1 detector @ 30 GHZ. The cut-outs in the medium/high-power maps remove saturated bolometer regions. The complete power stitched map is shown in the dashed box. E) SL beam map cross-sections shows that we characterize relative beams at < -50 dB at angles > 60 degrees (Far SL).

We demonstrate high fidelity SL map making with BK SATs. Main beams will be improved with standard far field beam measurements. These polarized beam maps will enable, (i) studying receiver characteristics in great detail, **informing CMB S4 SAT construction** (ii) Forward modeling Temperature to Polarization leakage, i.e., the **effect of polarized SL on $\sigma(r)$ as S4 SATs aim to reach $\sigma(r) \sim 5\times10^{-4}$**

***BK FSL team:*** *R. Basu Thakur* (Caltech), J. Cornelison (Harvard), C. Giannakopoulos (Cincinnati), O. Miller (Caltech), C. Verges (Harvard). Additional effort from E. Schoen (MIT/Caltech) and E. Yang (Stanford)*
**ritoban@caltech.edu*

# Paul Williams (Lawrence Berkeley National Lab)

- Postdoc working with Akito Kusaka
- I joined CMB-S4 in November 2021
- I’m working on the plan for SAT Cryostat Prototyping, including:
  - Prototyping schedule
  - Thermometry plan
  - Designing prototyping hardware
- During my PhD, I worked on BLAST-TNG
  - Sub-millimeter polarimeter (600 GHz - 1.2 THz)
  - Balloon-borne instrument, flew in January 2020 from McMurdo Station