Observing low elevation sky and the CMB Cold Spot with BICEP3 at the South Pole

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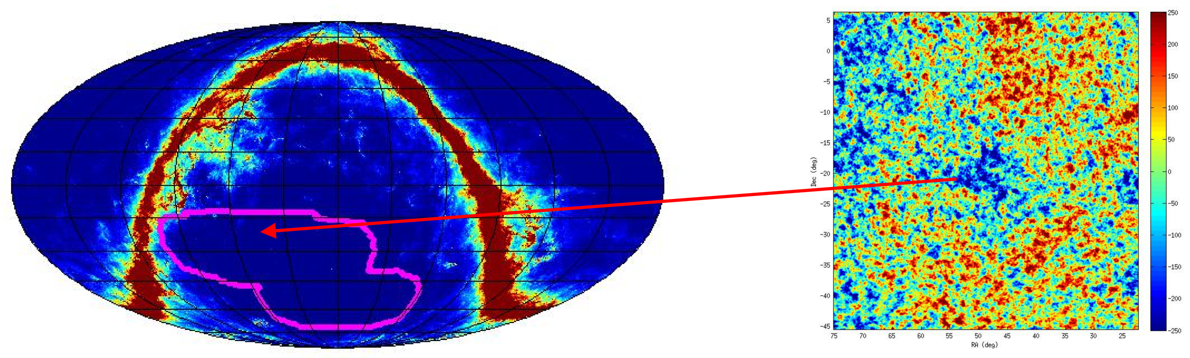
INTRODUCTION

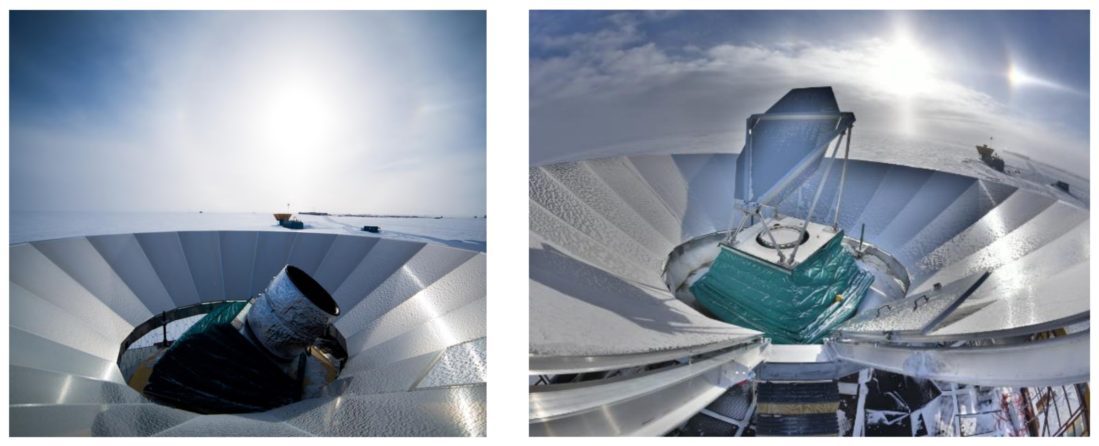
- BICEP3 is a 520 mm aperture on-axis refracting telescope at the South Pole which observes the polarization of the cosmic microwave background (CMB) at 95GHz to search for the B-mode signal from inflationary gravitational waves.
- The main target observation focuses on an observing field at a mid-elevation range at the South Pole.
- An extended sky coverage can be useful to understand non-isotropic non-Gaussian polarized foregrounds and to study other large-scale E-mode science cases.
- We have developed a low-elevation observation strategy to extend coverage of the Southern sky at the South Pole, where BICEP3 can quickly achieve degree-scale E-mode measurements over a large area. An interesting E-mode measurement is probing a potential polarization anomaly around the CMB Cold Spot, located at Galactic coordinates (210, -57) which in equatorial coordinates is (48.77, 19.58).



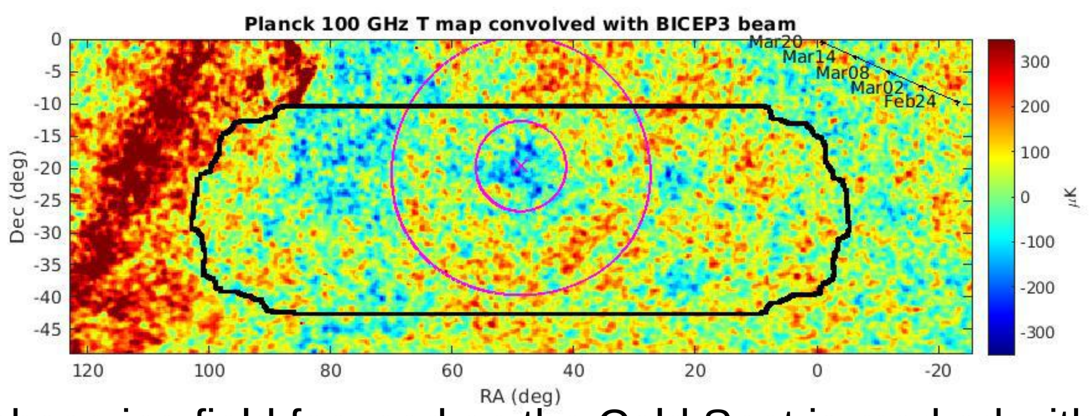
- Left figure shows the boundary of the tested low-elevation observing fields and the regular CMB observing field, marked on top of the Planck 353 GHz intensity map in equatorial coordinates. The observing fields overlap at one corner.
- Right figure shows the CMB component temperature map around the Cold Spot by Planck.

We present the observation and performance of BICEP3 at low elevation ranges we executed during austral summer seasons in 2018-19 and 2019-20.

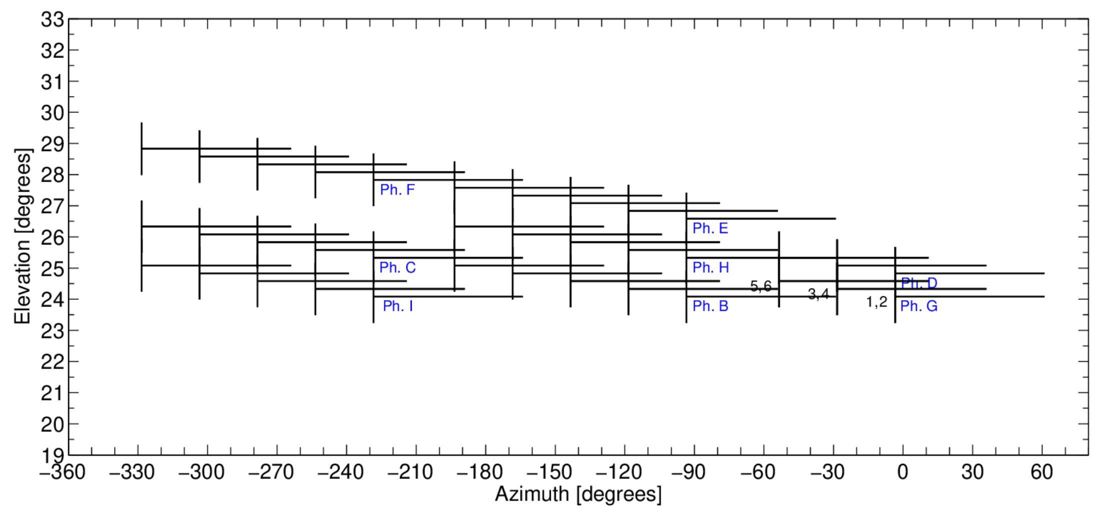
OBSERVATION



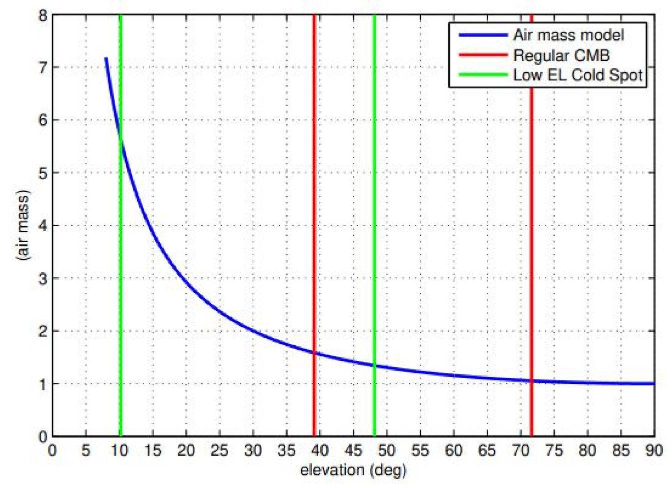
- Due to the constraint on operation imposed by the performance of the pulsetube cryocooler attached to the receiver, we do not tilt BICEP3 lower than 48° elevation. Instead, we use a flat mirror to redirect the beams to lower elevation. The mirror is originally used for beam characterization with a thermal source at far field. Note that the forebaffle could not fit with the current design.



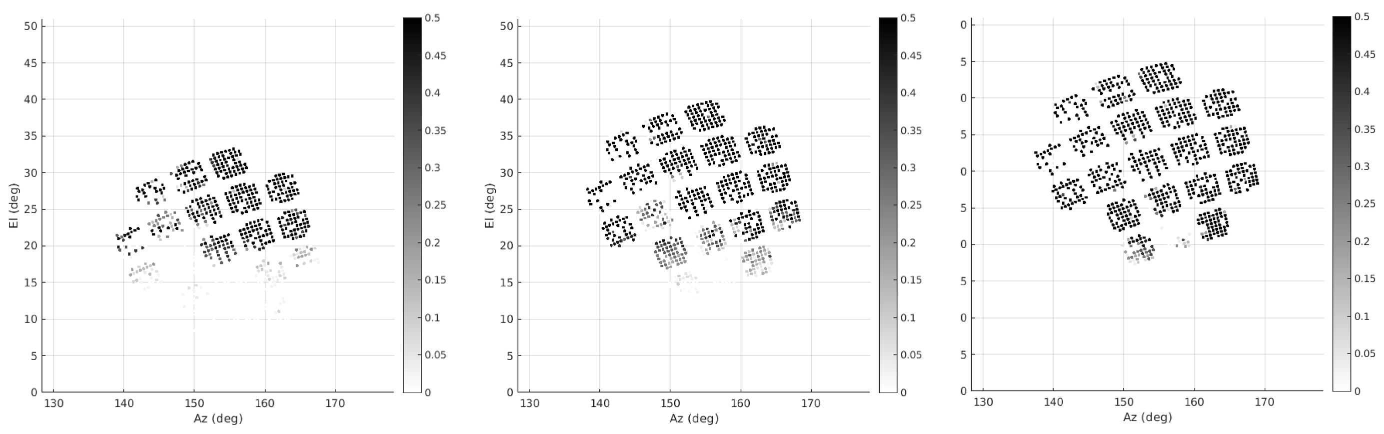
- An observing field focused on the Cold Spot is marked with black boundary. Deep map sensitivity within the outer magenta circle is needed to test polarization anomaly around the Cold Spot. We need to avoid the effects of the Sun whose path is marked with dates.



- Observing pattern of a three-day schedule at low elevation range in ground-based coordinates is shown. We included additional boresight elevation ranges from 17 deg to 34 deg.
- During the summer season in 2019-20, we focused the observing field on the Cold Spot.

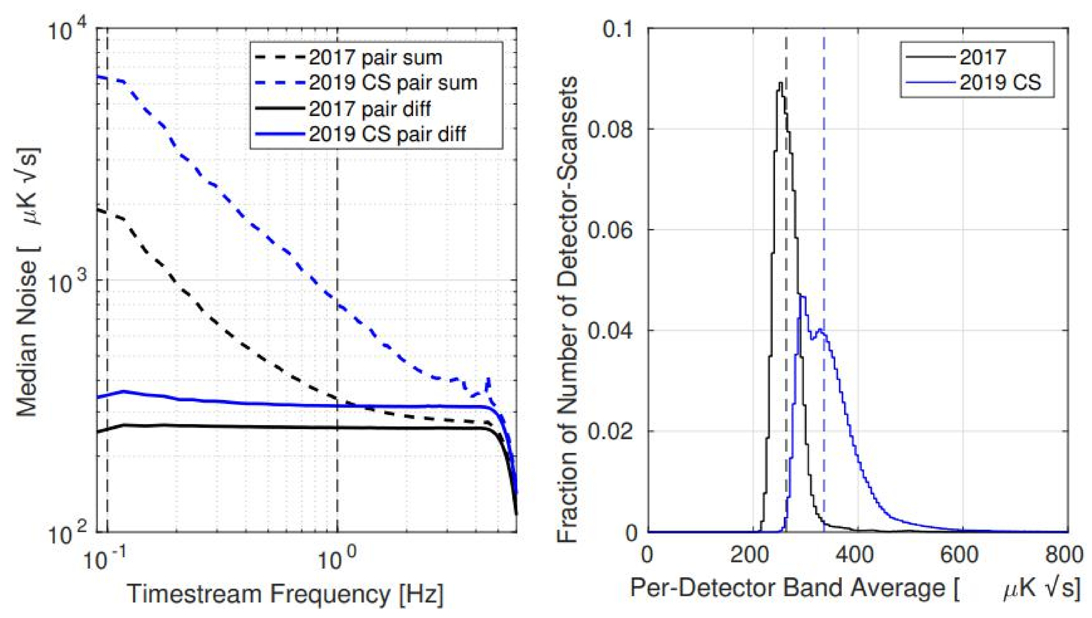


- The air mass model as csc(EL) is shown in blue. The elevation ranges for the presented low elevation schedules and the regular CMB schedules are marked with green and red vertical lines.
- We tune the TES bolometer bias points for each boresight orientation and elevation levels to keep the detectors at optimum negative electro-thermal feedback stage.
- Even with this retuning, detectors at the lowest elevations are still saturated over the safety margin chosen for regular CMB schedules due to atmospheric loading.

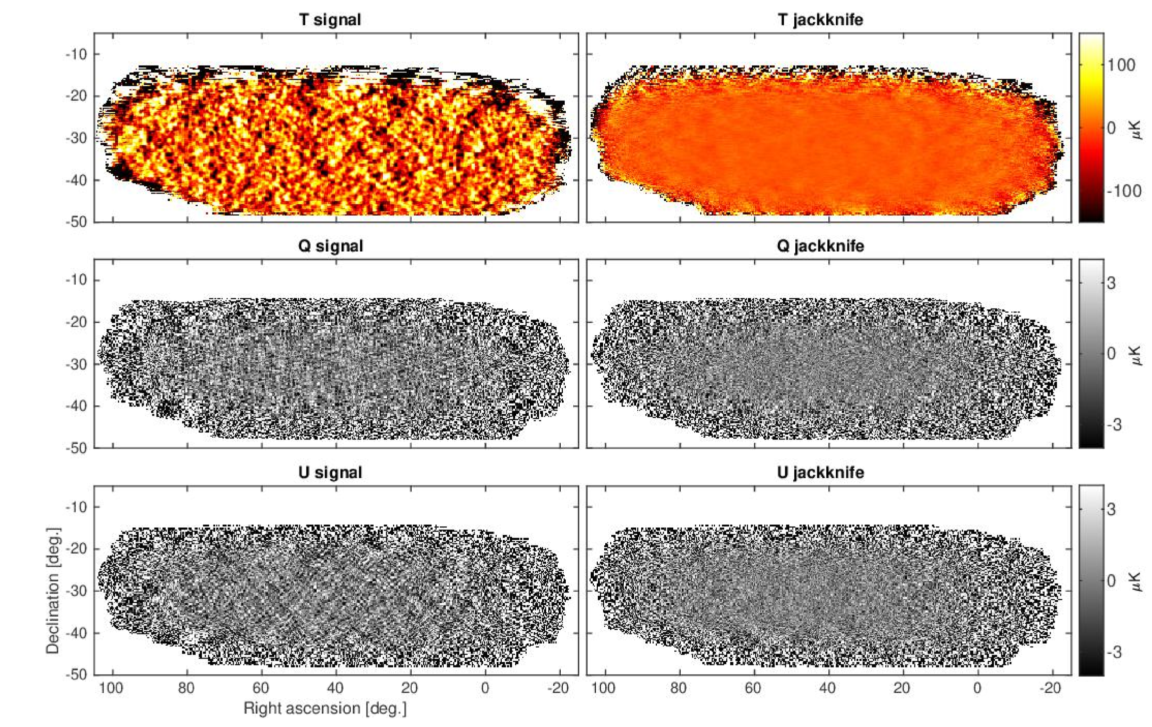


- The response rate after data quality cuts shows that we lose sensitivity from BICEP3 detectors below elevation of 15 deg.

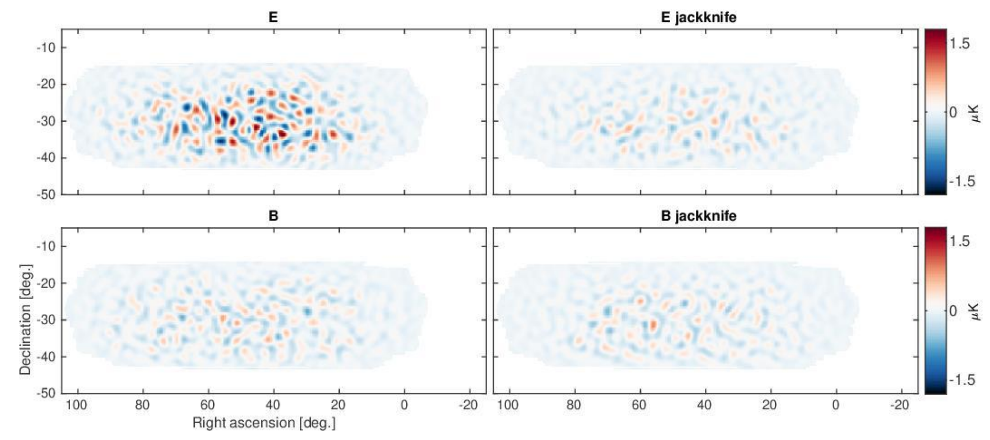
RESULTS



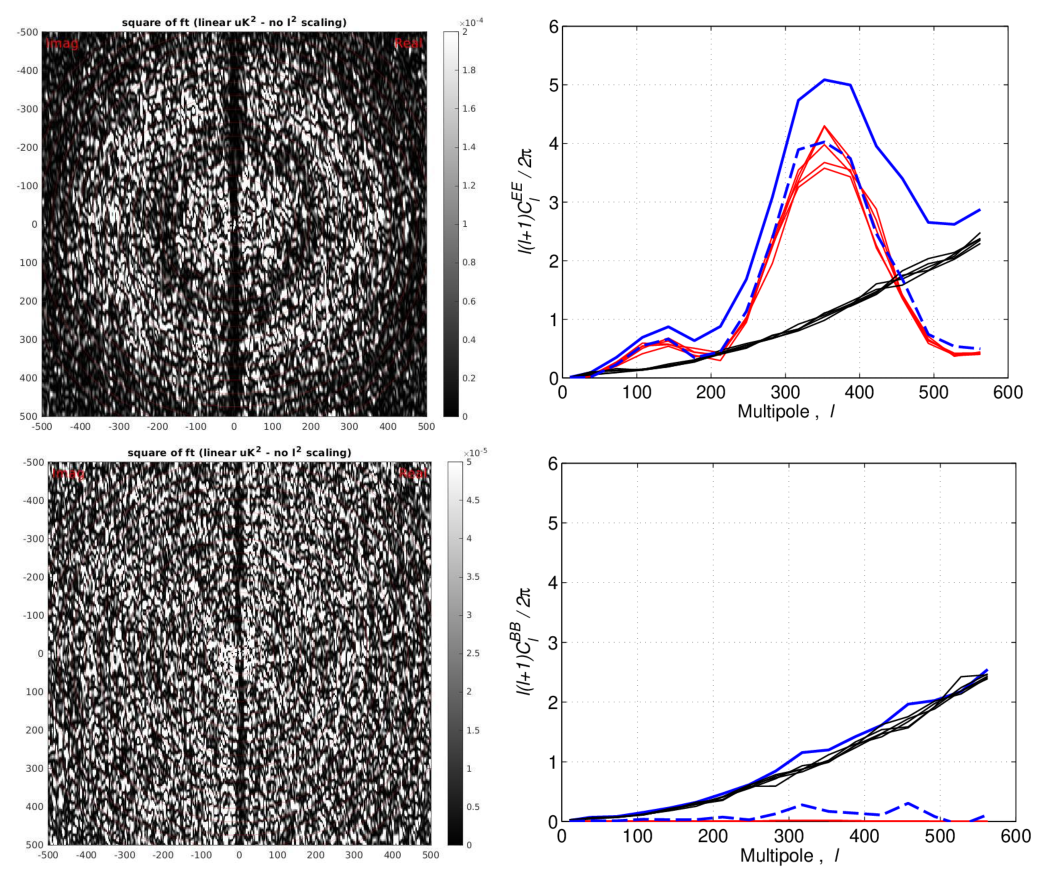
- *Left*: The median per-detector noise spectra for BICEP3 2017 season and 2019 Cold Spot data. *Right*: Histogram of per-detector per-scanset noise. The 2019 Cold Spot data has a median $335\mu K\sqrt{s}$, above the $265\mu K\sqrt{s}$ from 2017 data.



- Preliminary T, Q, and U maps from all usable low elevation schedules, with their scan-direction jackknife maps as noise proxy. Total usable integration time on source was 26 days.



- Preliminary E, and B maps from the Cold Spot schedules in 2019-20 summer season (18 days of usable integration time on source), with scan-direction jackknife maps as noise proxy. The maps are filtered to multipoles within $50 < \ell < 120$.



- 2D (left) and 1D (right) angular power spectra (APS) of the observed E-modes (top) and B-modes (bottom). For 1D APS, observed data is in solid blue, signal simulations are in red, noise realizations are in black, and noise-debiased observed data is in dashed blue. E-modes are measured with high signal-to-noise, while B-modes are dominated by noise.

CONCLUSIONS

- With a short (~1 month) observation campaign, BICEP3 could achieve map depth sensitive enough to show high signal-to-noise E-mode maps at a low elevation patch at the South Pole
- Remaining analysis tasks for the map data around the Cold Spot include probing potential systematics and utilizing partial noisy coverage around the Cold Spot.
- A design of baffling that can work with the flat mirror is being studied for potential future observation.
- BICEP3 has enormous potential for a wide variety of E-mode science applications at degree angular scales from the South Pole.

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