CMB systematics and calibration focus workshop

Report of Contributions

https://indico.ipmu.jp/e/380

Contribution ID: **2** Type: **not specified**

welcome + explain the conference style

Monday 30 November 2020 17:00 (10 minutes)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **3** Type: **not specified**

Planck review and lessons learned/A new model of dust foreground and new measurement of the Solar Dipole with Planck HFI data

Monday 30 November 2020 17:10 (25 minutes)

We use the constraints set by the solar dipole seen with high signal to noise by all bolometers (100 to 353 GHz) to set with high accuracy the zero level of the HFI dust maps. This improves significantly the dust removal residuals.

Presenter: Dr PUGET, Jean-Loup (Institut d'Astrophysique Spatiale)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **4** Type: **not specified**

Planck HFI lessons learned in systematics and calibration

Monday 30 November 2020 17:35 (25 minutes)

The Planck satellite has measured CMB anisotropies on the full sky with unprecedented accuracy allowing pour cent precision on the measurement of cosmological parameters. This accuracy required
important mitigation of systematic effects which for some of the dominant effects were not anticipated before launch. In this presentation I will focus on Planck High Frequency Instrument (HFI) systematic
effects, their constraints from flight data as well as ground measurement prior to launch. I will present the corrections applied to the data and their limitations. I will show the importance of housekeeping
data, of multiple observation redundancies, and of the use of the dipole as calibrator. I will emphasise in this talk the lessons learned for the preparation of future satellite missions and the design of the full analysis chain.

Presenter: Prof. PATANCHON, Guillaume (AstroParticle and Cosmology Laboratory)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **5** Type: **not specified**

Planck review and lessons learned: LFI systematics/calibration challenge

Monday 30 November 2020 18:00 (25 minutes)

In this presentation I review the lessons learned from measuring and analyzing the microwave polarized sky with Planck, to extract the information encoded in the cosmic microwave background (CMB). I focus, in particular, on the challenge to control instrumental effects and calibration at the sensitivity level. This is crucial especially on large angular scales, where the noise is small and the levels of foregrounds and long-term instrumental correlations compete with the CMB polarized signal. The main rule learned from our experience with Planck is simple: "know your instrument and know your sky". Using Planck data I show how the knowledge of the instruments and the measurement of the polarized sky over more than a decade in frequency have been key in the production of Planck scientific results in polarization.

Presenter: Prof. MENNELLA, Aniello (University of Milan - INFN)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **6** Type: **not specified**

BeyondPlanck: Systematics and degeneracies in CMB observations and the importance of global analysis

Monday 30 November 2020 18:25 (25 minutes)

I will summarize some of the main lessons learned from Planck regarding efficient identification and mitigation of systematic effects, which will be essential for future CMB B-mode experiments. I will in particular highlight the tight relationship between instrumental systematics and astrophysical modelling, and the importance of addressing both of these aspects jointly. The presentation will use the recent BeyondPlanck results as a concrete example of how this challenge may be addressed, but the main focus will be general and applicable to any CMB experiment and analysis pipeline.

Presenter: Prof. ERIKSEN, Hans Kristian (University of Oslo)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **7** Type: **not specified**

Free discussions

Monday 30 November 2020 18:50 (25 minutes)

Session Classification: 1. Planck Heritage on systematics and calibration

Contribution ID: **8** Type: **not specified**

Bandpass and polarization-angle calibration requirements for B-mode searches with the Simons Observatory

Monday 30 November 2020 20:45 (25 minutes)

I will discuss foreground and instrument systematic modeling for upcoming ground-based B-mode searches with the Simons Observatory (SO). I will begin by summarizing the power-spectrum domain foreground and systematic cleaning pipeline for SO. Using this framework we have quantified calibration requirements on bandpass and polarization angle systematics for the SO target of $\sigma_r \approx 10^{-3}$. We show that we can explicitly model and marginalize over systematic parameters to reduce biases on r, without incurring a large penalty on σ_r. The pipeline was validated on simulations and BICEP data. We then propagated these systematic requirements into instrument design choices for the HWP, sinuous antenna, and detector time constants.

Presenter: Dr ABITBOL, Max (University of Oxford)

Session Classification: 2. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **9** Type: **not specified**

CMB polarization map self-calibration

Monday 30 November 2020 19:55 (25 minutes)

Accurate cosmological parameters estimates using polarization data put stringent requirements on maps calibration, as highlighted in the recent results of the Planck collaboration. In this talk, I will present the new results of a paper where we point out that a model-dependent determination of polarization calibration parameters can be achieved by the joint fit of the TE and EE CMB power spectra, thanks to the different functional dependence of TE and EE on polarization efficiency corrections. This provides a valuable cross-check to the polarization efficiencies determined using other approaches. We demonstrate that, in LCDM, the combination of the TE and EE constrain polarization efficiency corrections with sub-percent uncertainty with Planck data and 2% uncertainty with SPTpol data. We find similar conclusions in common LCDM extensions that include sampling the sum of the neutrino masses , the number of relativistic species , or the amplitude of lensing. The uncertainties on cosmologi-cal parameters are minimally impacted when marginalizing over the polarization efficiency corrections, except for the uncertainty on the amplitude of the primordial scalar power spectrum, which increases by 20-50%. However, this information can be fully recovered by the addition of TT data. For current and future ground-based experiments, SPT-3G and CMB-S4, we forecast the cosmological parameter uncertainties to be minimally degraded when marginalizing over polarization efficiency corrections. In addition, CMB-S4 could constrain its polarization calibration at the level of ~ 0.2% by combining TE and EE, and reach ~ 0.06% by also including TT. (paper to be submitted)

Presenter: Dr GALLI, Silvia (IAP)

Session Classification: 2. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **10** Type: **not specified**

Polarization angle requirements

Monday 30 November 2020 20:20 (25 minutes)

A methodology to provide the polarization angle requirements for the different frequency channels of a given CMB B-mode experiment is presented. The component separation procedure used to separate the CMB from the foreground signals is considered in order to establish those requirements. In addition, it is also considered possible instrumental correlations among the different measured polarization angles coming from systematics in the optics, wafers… Requirements are calculated for different experimental configurations.

Presenter: Prof. MARTÍNEZ-GONZÁLEZ, Enrique (Instituto de Física de Cantabria (CSIC-UC))

Session Classification: 2. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **11** Type: **not specified**

Free discussions

Monday 30 November 2020 21:10 (25 minutes)

Session Classification: 2. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **12** Type: **not specified**

Welcome + explain the conference style

Tuesday 1 December 2020 08:00 (10 minutes)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **13** Type: **not specified**

Highlight from the Europe-Japan session

Tuesday 1 December 2020 08:10 (20 minutes)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **14** Type: **not specified**

Potential Systematic Errors in Space Missions

Tuesday 1 December 2020 08:30 (25 minutes)

Presenter: Prof. PAGE, Lyman (Princeton University)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **15** Type: **not specified**

The View from the Stratosphere: Systematics and calibration challenges of CMB ballooning

Tuesday 1 December 2020 08:55 (25 minutes)

Balloon-borne instruments have long played an important role in CMB observation. Their unique vantage point provides a nearly unobstructed view of the sky at millimeter wavelengths, largely free of the atmospheric fluctuations and absorption that constrain terrestrial observations. By deploying modern instruments to a space-like environment, they also provide a critical technological proving ground for future satellite missions. Alongside these advantages, balloon-borne instruments also provide a number of unique challenges. I will discuss some of the systematic and calibration challenges that face current and future balloon-borne experiments, with a particular focus on SPIDER: a targeted B-mode payload currently awaiting its second long-duration balloon flight from Antarctica.

Presenter: Prof. FILIPPINI, Jeff (University of Illinois Urbana-Champaign)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **16** Type: **not specified**

Systematics control and mitigation for BICEP/Keck deep polarization maps

Tuesday 1 December 2020 09:20 (25 minutes)

Small-aperture ground-based telescopes are a well-demonstrated method for achieving high sensitivity to degree-scale CMB polarization. Current and future experiments including BICEP Array, Simons Observatory, and CMB-S4 will all use similar designs in their effort to detect primordial gravitational waves. I will review the experience gained from the long-running BICEP/Keck program at the South Pole, focusing on design decisions and analysis techniques that mitigate instrumental systematics and enable the tightest constraints to date on B-mode polarization at degree scales.

Presenter: Prof. BISCHOFF, Colin (University of Cincinnati)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **17** Type: **not specified**

LiteBIRD systematics

Tuesday 1 December 2020 09:45 (25 minutes)

I will present a review of LiteBIRD systematics. LiteBIRD aims for measuring the tensor-to-scalar ratio, r, with an accuracy less than 0.001. Given the current sensitivity of the observation devices, the systematic effects yield the dominant contribution in the error of r. I will present an overview of the possible systematic sources, and the procedure to evaluate the effects and to give requirements. I also discuss possible mitigation of the systematic effects with the optimization of the scan strategy and the usage of the polarization modulation.

Presenter: Prof. ISHINO, Hirokazu (Okayama University)

Session Classification: 3. Review from the past to future challenges

Contribution ID: **18** Type: **not specified**

Beam-Related Systematic Error Suppression for the PIXIE Polarizing Fourier Transform Spectrometer

Tuesday 1 December 2020 10:30 (25 minutes)

The double differential nature of PIXIE's four-port measurement mitigates beam-related systematic errors common to the two-port systems used in most CMB measurements. Systematic errors coupling unpolarized temperature gradients to a false polarized signal cancel to first order for any individual detector. This common-mode cancellation is performed optically, prior to detection, and does not depend on the instrument calibration. Systematic errors coupling temperature to polarization cancel to second order when comparing signals from independent detectors. We describe the polarized beam patterns for PIXIE and assess the systematic error for measurements of CMB polarization.

Presenter: Dr KOGUT, Al (NASA GSFC)

Session Classification: 4. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **19** Type: **not specified**

Requirements for future CMB satellite missions: photometric and band-pass response calibration

Tuesday 1 December 2020 10:55 (25 minutes)

Future experiments, like the LiteBIRD space-borne mission, aim at measuring the CMB B-mode signal with high accuracy in order to measure the tensor-to-scalar ratio r at the 10^{−3} level. I will present a study of the photometric calibration and bandpass resolution requirements to minimize the leakage of polarized Galactic foreground signals into CMB polarization maps for a multi-frequency CMB experiment. I will show results for the LiteBIRD case and discuss them. Furthermore, following the Planck experience with CO line contamination, I will present an analysis to forecast this effect in LiteBIRD data, and eventually define mitigation strategies.

Presenter: Dr GHIGNA, Tommaso (Kavli IPMU/Univ. of Oxford)

Session Classification: 4. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **20** Type: **not specified**

Telescope baffling design that minimizes stray light systematics for ground-based experiments, the Simons Observatory case

Tuesday 1 December 2020 11:20 (25 minutes)

The Simons Observatory (SO) is a next generation Cosmic Microwave Background (CMB) experiment aimed to measure evidence of primordial gravitational waves and put constraints on the sum of the neutrino masses. SO is developing a high angular resolution 6 m class Large Aperture Telescope (LAT) for small angular scale measurements, and three wide field-of-view 0.42 m class Small Aperture Telescopes (SATs) for large angular scale measurements. In this talk, I will review the impact that stray light systematics have on high-sensitivity CMB polarization observations. I will discuss the telescope baffling design concepts utilized for ground-based CMB experiments, and describe the SO SAT baffling design currently under development. The SAT baffling is most effective in reducing systematics due to ground signal contamination that currently plague all ground-based CMB experiments.

Presenter: Dr MATSUDA, Fred (Kavli IPMU)

Session Classification: 4. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **21** Type: **not specified**

Polarization Modulator Signal Phase Variation: The Simons Observatory Case

Tuesday 1 December 2020 11:45 (25 minutes)

The Simons Observatory (SO), currently under construction, will deploy one large-aperture (6 m) and four small-aperture (42 cm) telescopes to the Chajnantor Plateau of the Atacama Desert in Chile in the coming years. The small-aperture telescopes feature continuously-rotating half-wave plates (CRHWP) at cryogenic stages in order to modulate incoming polarization from the sky. In this talk, I will review the effects of the transition-edge sensor bolometers, which comprise the detectors of the SO focal planes, on the modulated polarization signal. I will then discuss modeling and simulation of a particular systematic in the detectors, an unmodeled change in the phase delay due to detector time constant variations, and how this can affect recovery of polarization signals from the modulated data. I conclude with a discussion of limits set on detector performance as a result of studies of polarization angle calibration requirements in the context of SO.

Presenter: Dr CROWLEY, Kevin (University of California, Berkeley)

Session Classification: 4. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **22** Type: **not specified**

Free discussions

Tuesday 1 December 2020 12:10 (25 minutes)

Session Classification: 4. Systematics requirement toward the next generation CMB B-mode experiment

Contribution ID: **24** Type: **not specified**

Highlight from US-Japan session

Tuesday 1 December 2020 17:00 (20 minutes)

Session Classification: 5. methods: instrumentation 1

Contribution ID: **25** Type: **not specified**

A Q-Band Test-Source for UAV-Based Radiation Pattern Measurements

Tuesday 1 December 2020 17:20 (25 minutes)

In the last years, the Unmanned Aerial Vehicles (UAVs) produced significant innovations in in-situ antenna measurements. UAV-mounted radio-frequency generators have been initially exploited at low frequencies to characterize the radiation pattern of receiving antennas and arrays (e.g. HF radars, VHF radio telescopes), and up to the X-band for radar characterization. Within the Italian Large-Scale Polarization Explorer (LSPE) project, a UAV-mounted test source operating in the Q-band has been recently developed for the in-situ validation of the Strip instrument, which consists in a ground-based cluster of coherent polarimeters for polarization measurements of the microwave sky on large angular scales. The developed Q-band test-source is hereby presented. So far, tests of the UAV system have been performed in both laboratory environment and operative conditions.

Presenter: Dr PAONESSA, Fabio (National Research Council of Italy (CNR) - Institute of Electronics, Computer and Telecommunication Engineering (IEIIT))

Session Classification: 5. methods: instrumentation 1

Contribution ID: **26** Type: **not specified**

Calibration using Sparse Wire Grid

Tuesday 1 December 2020 17:45 (25 minutes)

A calibration for polarization responses (i.e. angle and gain) is an important subject for sucess of CMB polarization experiments. We (I and my colleagues) have developed calibration systems using sparse wire grid. Wires in ambient make a blackbody signal which is linearly polarized. Focal plane detectors measure the polarization signal when we set the wires in front of receiver or telescope aparture. The direction of polarization is parallel to the wire derection, and its intensity is proportional to the wire dencity. Thus far, this type calibration has been demonstrated in QUIET, ABS, POLARBEAR, and Simons Aarray experiments. In future, Small Aparture Telescopes in the Simons Observatory will regurally use this type calibrator towards the best systematic error control to date. In this presentation, I will review ideas/systems/experiences for each experiment.

Presenter: Prof. TAJIMA, Osamu (Kyoto University)

Session Classification: 5. methods: instrumentation 1

Contribution ID: **27** Type: **not specified**

B-mode forecast of CMB-Bharat

Tuesday 1 December 2020 18:10 (25 minutes)

The measurement of the primordial B-mode polarization in the cosmic microwave background (CMB) is a major challenge of future CMB experiments. However, as B-mode polarization is dominated by foregrounds at all scales and frequencies, the detectability of this cosmological signal solely depends on our ability to remove foregrounds. We present the of B-mode polarization forecast in the presence of galactic and extragalactic foregrounds and delensing in the context of the proposed CMB space mission, Exploring Cosmic History and Origins (ECHO) popularly known as 'CMB-Bharat'. We focus on, for the baseline design of ECHO, how polarised foreground can be controlled in recombination and reionization scales for more and more complex foreground models using both parametric (COMMANDER) and blind component separation approaches (NILC). In particular, we demonstrate, the impact of thermal dust, synchrotron, spinning dust, polarized extragalactic radio sources and delensing on tensor-to-scalar ratio r. In the presence of gravitational lensing and galactic diffuse emissions and point sources, the sensitivity is σ(r = 0) ~ 10^-3 . We find ECHO would detect the r = 10^-3 with 4σ accuracy after foreground cleaning in the presence of diffuse missions only. We demonstrate the detectability with 84 % delensing as well. Furthermore, we also demonstrate the significance level of reionization optical depth τ= 0.054 in recombination scale from E-mode polarization.

Presenter: ADAK, Debabrata (Senior Research Fellow at IUCAA)

Session Classification: 5. methods: instrumentation 1

Contribution ID: **28** Type: **not specified**

Laboratory Characterization of the Q & U Bolometric Interferometer for Cosmology (QUBIC)

Tuesday 1 December 2020 18:35 (25 minutes)

A prototype version of the Q & U Bolometric Interferometer for Cosmology (QUBIC) underwent a campaign of testing in the laboratory at Astroparticle Physics and Cosmology in Paris. Characterization of QUBIC includes the measurement of the synthesized beam, the measurement of interference fringes, and the measurement of polarization performance. A modulated and frequency tunable millimetre-wave source in the telescope far-field is used to simulate a point source. The QUBIC pointing is scanned across the point source to produce beam maps. Polarization modulation is measured using a rotating Half Wave Plate. The measured beam matches well to the theoretical simulations and gives QUBIC the ability to do spectro imaging. The polarization performance is excellent with less than 0.5% cross-polarization rejection. QUBIC has demonstrated the feasibility of Bolometric Interferometry, and verified the applicability of the key advantages to such a system including the minimization of systematic effects using self-calibration, and the possibility to do spectroimaging. This presentation is based on the paper https://arxiv.org/abs/2008.10056

Presenter: Dr TORCHINSKY, Steve (APC/Observatoire de Paris)

Session Classification: 5. methods: instrumentation 1

Contribution ID: **29** Type: **not specified**

LiteBIRD/MHFT Bread-Board testing

Tuesday 1 December 2020 19:20 (25 minutes)

We present the optical calibration strategy of the Medium-High Frequency Telescope on-board the LiteBIRD satellite, the JAXA's space mission targeting the detection of the imprint of primordial gravitational waves on the Cosmic Microwave Background.
For its purpose, LiteBIRD is endowed with unprecedent sensitivity, guaranteed by two independent instruments, the Low Frequency Telescope (LFT) and Medium-High Frequency Telescope (MHFT), which together accommodate more than 4000 bolometers in their focal planes, spanning a wide frequency range between 34 and 448 GHz.
Such a challenging goal implies tight control of systematic effects and a thorough understanding of the instruments, being the knowledge of the optical response one of the most critical aspects for high precision measurements.
Here we discuss the MHFT's optical calibration philosophy in the laboratory, focusing on its very first steps: the development of a Bread-Board model, a straightforward refractive optics capable of providing valuable clues on our modeling reliability, preferred measurement techniques and the accuracy achievable throughout the MHFT calibration process.

Presenter: Prof. FRANCESCHET, Cristian (Università degli Studi di Milano)

Session Classification: 6. methods: instrumentation 2

Contribution ID: **30** Type: **not specified**

Effect of Half-Wave Plate systematics on the estimate of r

Tuesday 1 December 2020 19:45 (25 minutes)

A rotating Half-Wave Plate (HWP) is included in the design of future CMB experiments, such as LiteBIRD. A realistic HWP is characterised by frequency-dependent non-idealities (i.e. efficiency, non-ideal phase
shift, cross-polarization) that are measured within a certain error. We simulate how uncertainties in the determination of the aforementioned non-idealities affect estimates of the tensor-to-scalar ratio r in a LiteBIRD-like experiment. By assuming a threshold on the acceptable level of bias Δr, we set requirements on the sensitivity that should be achieved with measurements of each non-ideal parameter.

Presenter: GIARDIELLO, Serena

Session Classification: 6. methods: instrumentation 2

Contribution ID: **31** Type: **not specified**

Characterization of the Optical System of the LSPE-STRIP Instrument

Tuesday 1 December 2020 20:10 (25 minutes)

We present the analysis of the optical system of the STRIP instrument, the ground-based telescope of the Large Scale Polarization (LSPE) experiment, which aims at polarization measurements of the Cosmic Microwave Background on large angular scales.
STRIP will observe the polarized emission from the "Observatorio del Teide"in Tenerife, starting in late 2021. The instrument consists of an array of forty-nine coherent polarimeters at 43 GHz (Q-band), coupled to a 1.5 m fully rotating crossed-Dragone telescope. An additional frequency channel with six-elements at 95 GHz (W-band) will be exploited as an atmospheric monitor.
We modelled and characterized the STRIP optics by means of electromagnetic simulations. The model includes the two nominal reflectors, forty-nine Q-band feedhorns, six W-band feedhorns, and the shielding structures. We present the results of the optical simulations of both main beam and sidelobes, including the effects of the infrared filters and the dielectric window of the cryostat. An analysis of the mirrors imperfections and deformations completes our understanding of the LSPE-STRIP optical response in its "real" configuration.
Accurate predictions of radiation patterns are essential both during the instrument development phase and for the extraction of robust data from the simulation pipeline because non-idealities in the optical system may introduce limitations in achieving high precision measurements, if not well understood and controlled. For these reasons, we used our results to simulate STRIP observations with its nominal scanning strategy.

Presenter: REALINI, Sabrina (Università degli Studi di Milano)

Session Classification: 6. methods: instrumentation 2

Contribution ID: **32** Type: **not specified**

The Effects of Instrumental Systematics on CMB Lensing Reconstruction

Tuesday 1 December 2020 20:35 (25 minutes)

The weak gravitational lensing of the CMB is an important cosmological tool that allows us to learn more about the structure, composition and evolution of the Universe. Upcoming CMB experiments, such as the Simons Observatory, will provide the most high-resolution and low-noise CMB measurements to date, from which we could reconstruct the lensing potential to unparalleled precision. To achieve this, the potential hindering of instrument systematics on the lensing reconstruction analysis must be considered, as these become more significant with low-noise CMB observations. In this talk, I will present our recent results regarding how various instrument systematics affect the CMB lensing reconstruction. Using simulations of temperature and polarization CMB maps for an SO-like instrument and scanning strategy, with the additions of systematics, we performed an optimal lensing reconstruction analysis to assess the significance of the resulting systematic-induced lensing biases. Specifically, we explored systematics relating to beam asymmetries and offsets, boresight pointing, gain drifts, gain calibration and electric crosstalk. I will show how these systematic effects bias the reconstructed lensing power spectrum and which effects may be a potential risk to future CMB experiments, and discuss possible mitigation strategies on the instrument level and in the analysis stage.

Presenter: MIRMELSTEIN, Mark (University of Sussex)

Session Classification: 6. methods: instrumentation 2

Contribution ID: **33** Type: **not specified**

Towards an Atacama Large Aperture Submillimeter Array (AtLAST)

Tuesday 1 December 2020 21:00 (25 minutes)

Astrophysical observations at (sub-)mm wavelengths (λ from ~300 μm to ~3mm) allow us to study the cold and dense material in the Universe, hence probing the formation of stars and planets, and the interstellar and circumgalactic medium of galaxies across all cosmic times. The current generation of 10-meter-class single dish telescopes has delivered some of the first surveys at (sub-)mm wavelengths, allowing us to go far beyond the previously optical-biased view of the Universe. Follow-up observations with interferometers then revealed in exquisite detail the morphology and kinematics of such (sub-)mm sources, enabling tests and revisions of theoretical models for the formation and evolution of planets, stars, and galaxies. However, it is now clear that without a transformative change in the capabilities of single-dish facilities in the 2030s, interferometers (like the ALMA observatory) will soon become source-starved. The current generation of 10-m class single dish telescopes, with their limited fields of view, spatial resolution, and sensitivity, can only reveal the 'tip of the iceberg' of the (sub-)mm source population, both for Galactic and extragalactic studies. These limitations cannot be compensated for by interferometers, which are all intrinsically affected by a low mapping speed and by the loss of diffuse extended signals.
The Atacama Large Aperture Submillimeter telescope (AtLAST) project is a concept for a 50 meter diameter single dish observatory to be built near the ALMA site. With its extremely large field of view (the goal is ~ 2 degrees), spatial resolution (up to ~1.5"at 350 μm), and sensitivity to both point sources and large-scale structures, AtLAST will be transformational for all fields of Astronomy in the 2030s. Here we will describe the recently approved EU Horizon2020 project to deliver a comprehensive design study for such a next-generation single-single dish facility. Beyond the EU, AtLAST would welcome an international consortium, and is beginning to garner broad support, with support from the Japanese 50-meter Large Submm Telescope community as well as many US Astro2020 decadal and Canadian Long Range Plan 2020 science case submissions.

Presenter: Dr MROCZKOWSKI, Tony (ESO)

Session Classification: 6. methods: instrumentation 2

Contribution ID: **34** Type: **not specified**

Free discussions

Tuesday 1 December 2020 21:25 (25 minutes)

Session Classification: 6. methods: instrumentation 2

Contribution ID: **35** Type: **not specified**

Highlight from Europe-Japan session

Wednesday 2 December 2020 08:00 (20 minutes)

Session Classification: 7. methods: instrumentation 3

Contribution ID: **36** Type: **not specified**

Drone-based polarization calibration source for mm-wave telescopes

Wednesday 2 December 2020 08:20 (25 minutes)

Experiments to measure the polarization of the CMB require an exquisite characterization and control of optical systematics to achieve their scientific goals. Relevant parameters are the polarized co- and cross-polar beam shape, absolute and relative polarization angle among detector pairs, polarization frequency dependence across the bandpass, and polarization properties of far sidelobes. In particular, the absolute polarization angle is important to detect cosmic birefringence and test alternative cosmological models. Unfortunately, there are only very few natural polarized sources that can be used to characterize and calibrate the polarized response of these telescopes, for which an artificial source becomes an appealing alternative. Using a ground based artificial source is usually incompatible with CMB telescopes because the resulting low elevation angle implies strong ground temperature contamination. Here we present the development of a polarized calibration source that can be mounted on a drone to illuminate telescopes at a distance and away from the ground loading. We have already shown that it is possible to lift a 4 kg payload at 5200 meters, in 10 minute flights, reaching the far-field of small aperture telescopes and entering the Fresnel regime for larger aperture telescopes. We implemented a 150 GHz coherent source, with a single selectable linear polarization, fixed frequency and electronic chopper at 10 Hz. The position of the source with respect to the telescope is measured in time to better than 2 cm precision, and angles better than 0.05 degrees, using a combined method based on differential GPS and optical photogrammetry. This allows us to match and synchronize the telescope's raw detector time streams to the source position and polarization angle in order to compensate the drone's movements. This source can be used to measure the polarized beam shape, relative and absolute polarization angles and map far sidelobes. We have performed the first successful measurements of polarized far sidelobes of the ACT telescopes in Cerro Toco, and the results will be included in this presentation.

Presenter: Prof. DÜNNER, Rolando (Pontificia Universidad Católica de Chile)

Session Classification: 7. methods: instrumentation 3

Contribution ID: **37** Type: **not specified**

A Compact Millimeter-Wavelength Fourier-Transform Spectrometer

Wednesday 2 December 2020 08:45 (25 minutes)

We have constructed a Fourier-transform spectrometer (FTS) operating between 50 and 330 GHz with minimum volume (355x260x64 mm) and weight (5.9 kg) while maximizing optical throughput (100 mm^2 sr) and optimizing the spectral resolution (4 GHz). This FTS is a modified polarizing Martin-Puplett interferometer with unobstructed input and output in which both input polarizations undergo interference. The instrument construction is simple, with mirrors milled on the box walls and one motorized stage as the single moving element. We have characterized the performance of the FTS and compared the measurements to an optical simulation. The instrument was used to characterize the end-to-end spectral response of a kilo-pixel radiometer constructed for the South Pole Telescope. The same FTS is also a prototype similar to the instrument designed for a NASA MIDEX mission (PIXIE) for measuring cosmic microwave background (CMB) B-modes and spectral distortion in space.

Presenter: PAN, Zhaodi

Session Classification: 7. methods: instrumentation 3

Contribution ID: **38** Type: **not specified**

Broad Spectrum Noise Sources for Calibration of the BICEP/Keck CMB polarimeters

Wednesday 2 December 2020 09:10 (25 minutes)

The BICEP/Keck telescopes are a suite of CMB polarimeters located at the South Pole searching for evidence of inflationary gravitational waves. We invest much of our effort in acquiring high-fidelity calibrations of the optical performance to mitigate systematics in our results. To that end, we map far-field optical response using ground-based, non-thermal, finely-polarized Broad Spectrum Noise Sources (BSNS). We have so far constructed four BSNS's each operating at a different center frequency of 95GHz, 150GHz, 220GHz, and most recently 35GHz for use on the new BICEP Array receiver. In this presentation, I will discuss BSNS theory of operation, report on their performance, and discuss the various calibrations in which the BSNS's are used.

Presenter: Mr CORNELISON, James (Harvard University)

Session Classification: 7. methods: instrumentation 3

Contribution ID: **39** Type: **not specified**

Calibration of TES bolometer arrays with application to CLASS

Wednesday 2 December 2020 09:35 (25 minutes)

Calibrating raw detector time-ordered data (TOD) to a standard unit is often the first step in processing data sets acquired by large arrays of detectors over many months of observations. The calibration method must be accurate, to suppress systematic errors in the final results, and robust, to be applicable to a vast majority of observations.
The raw calibration method developed for the CLASS TES bolometer arrays relies on I-V curves acquired before every observing period. By binning the I-V curves over the entire observing season, we improve the calibration accuracy by a factor of 2 to ~4% error per detector TOD, while generating well-characterized calibration factors for 99.9% of the data.

Presenter: Dr APPEL, John (Johns Hopkins University)

Session Classification: 7. methods: instrumentation 3

Contribution ID: **40** Type: **not specified**

Far-sidelobe and Polarization Angle Measurement of LiteBIRD Low Frequency Telescope using a 1/4-scaled Model

Wednesday 2 December 2020 10:00 (25 minutes)

The LiteBIRD Low Frequency Telescope (LFT) is a crossed-Dragone telescope that observes 34-161 GHz with a field of view of 18 x 9 degrees. We developed a 1/4-scaled model of the LFT and measured its far-sidelobes and polarization angles at multiple positions on the focal plane at accordingly scaled wavelength. The near-field measurements were consistent with physical optics simulation down to -50 dB level, and showed that the far-sidelobes for two orthogonal polarization directions are consistent with each other down to -40 dB level. The compact antenna test range measurements determined the polarization position angle of the LFT with a resolution of less than 0.1 arcminutes, and showed that the angle varies by up to 1 degree at the edges of the focal plane.

Presenter: Mr TAKAKURA, Hayato (The University of Tokyo / Japan Aerospace Exploration Agency)

Session Classification: 7. methods: instrumentation 3

Contribution ID: **41** Type: **not specified**

Simulations of systematic effects arising from cosmic rays in the LiteBIRD space telescope, and effects on the measurements of CMB B modes.

Wednesday 2 December 2020 10:45 (25 minutes)

LiteBIRD is an upcoming JAXA-led cosmology space mission which has the scientific goal of measuring polarised CMB B-modes. LiteBIRD will fly at an L2 orbit, and thus will be subject to cosmic rays owing to the radiative environment. We present an end-to-end simulator for evaluating the effect of cosmic rays on the science outcomes of the LiteBIRD space mission, taking into account the projected cosmic ray flux during the mission duration, thermal and electrical response of the telescope's sub-Kelvin detectors, and its interaction with sky maps and the tensor-to-scalar ratio r. This simulator is an important tool for testing the sensitivity of mission outcomes on detector and wafer design, as well as sensitivity to variability of the radiative environment.

Presenter: Prof. STEVER, Samantha (Okayama University/Kavli IPMU)

Session Classification: 8. methods: instrumentation 4

Contribution ID: **42** Type: **not specified**

HWP development for LiteBIRD low-frequency telescope

Wednesday 2 December 2020 11:10 (25 minutes)

LiteBIRD low-frequency telescope (LFT) employs a polarization modulation unit (PMU) based on a continuously rotating half-wave plate (HWP) at the telescope aperture. The PMU significantly suppresses 1/f noise and mitigates differential systematics. Therefore, the control and calibration of PMU intrinsic systematics are critical to achieving the scientific goal of LiteBIRD. The LFT PMU consists of a 5 layer stacked sapphire achromatic HWP with sub-wavelength structure anti-reflection coating, and cryogenic contactless rotation mechanism based on superconducting magnetic bearing. LiteBIRD is in the conceptual design phase and we have developed the breadboard model (BBM) of the LFT PMU with an HWP diameter of 330 mm toward a demonstration model with a diameter of around 500 mm. We present BBM development status and summarize the PMU-specific systematics based on a Muller matrix formulation.

Presenter: Dr SAKURAI, Yuki (Kavli IPMU)

Session Classification: 8. methods: instrumentation 4

Contribution ID: **43** Type: **not specified**

A Cryogenic Half Wave Plate Rotator for the Simons Observatory Small Aperture Telescopes

Wednesday 2 December 2020 11:35 (25 minutes)

Located in the Atacama Desert of Chile, the Simons Observatory consists of one Large Aperture Telescope (LAT) and 3 Small Aperture Telescopes (SATs). The latter of these are optimized to observe the polarization in the CMB at large angular scales ($30 < \ell < 300$), and as such we require a high degree of stability in our observations. To accomplish this we employ rapidly rotating sapphire cryogenic half wave plates (CHWPs) in the optical chain of the SATs. This design uses a 550 mm diameter superconducting magnetic bearing (SMB) for contactless rotation, the largest such bearing used in a telescope to date. In this talk I will discuss the design considerations and initial performance of the CHWP rotation mechanism.

Presenter: Dr ASHTON, Peter (UC Berkeley / LBNL / Kavli IPMU)

Session Classification: 8. methods: instrumentation 4

Contribution ID: **44** Type: **not specified**

Impact of instrumental systematic effects on component separation and large scale B-modes measurements

Wednesday 2 December 2020 12:00 (25 minutes)

The next generation of CMB polarisation experiments needs to have sufficient sensitivity and frequency coverage to detect and characterise the primordial B-modes signal, and to distinguish it from foregrounds contamination. This requires the deployment of detectors arrays of many thousands of multichroic detectors, along with new technologies for polarisation modulation, antennas, readout, etc. This increased complexity will introduce new instrumental systematic effects, which need to be accounted for in instrument modelling and data analysis, in particular during the component separation step.

In this talk, I present a novel map-based framework for parametric component separation that allows to take into account a wide range of instrumental systematic effects, and forecast their impact on cosmological parameters estimation, in particular the tensor-to-scalar ratio r. I will detail the key steps of the framework, and introduce methods to model selected systematic effects in this context, such as frequency dependent polarisation angle, readout crosstalk and interplay of these effects with bandpasses. I will present early results that demonstrate the capabilities of the framework, and discuss prospects for future applications.

Presenter: Dr VERGÈS, Clara (Center for Astrophysics | Harvard & Smithsonian)

Session Classification: 8. methods: instrumentation 4

Contribution ID: **45** Type: **not specified**

Free discussions

Wednesday 2 December 2020 12:25 (25 minutes)

Session Classification: 8. methods: instrumentation 4

Contribution ID: **46** Type: **not specified**

Highlight from the US-Japan session

Wednesday 2 December 2020 17:00 (20 minutes)

Session Classification: 9. method: analysis 1

Contribution ID: **47** Type: **not specified**

Modeling optical systematics for the Simons Observatory Large Aperture Telescope

Wednesday 2 December 2020 17:20 (25 minutes)

In this talk I will discuss the optical modeling efforts used to inform the design of the Simons Observatory Large Aperture Telescope. I will present some general aspects of this new and exciting telescope design and review expected performance. I will discuss various techniques that we have used in the analysis of this telescope and compare those to similar work for past and current generation experiments. I will conclude by highlighting efforts that can help patch gaps in our current ability to model optical systems for future experiments searching for primordial B-mode polarization.

Presenter: Dr GUDMUNDSSON, Jon (Stockholm University)

Session Classification: 9. method: analysis 1

Contribution ID: **48** Type: **not specified**

Beam deconvolution with ArtDeco

Wednesday 2 December 2020 17:45 (25 minutes)

ArtDeco is beam-deconvolution code, designed for absolute CMB measurements.
Is has been successfully applied to beam analysis for the LFI instrument of the Planck mission up to multipole lmax=1500.

Given time-ordered data and known beam shapes as input, the code removes the effects of asymmetric beam shape, yielding as output a map with symmetrized effective beam.
In particular, the method can be used to correct for the beam-induced leakage of temperature signal into polarization. Further developments include applications to power-spectrum estimation. The methodology is based on efficient use of Wigner D-matrices.

We present briefly the algorithmic background, and discuss the computational requirements and the possibility af applying the methodology to future CMB experiments.

As a recent development, we discuss the possibility of combining beam-deconvolution with noise reduction and component separation within a Gibbs sampling framework (BeyondPlanck), and present preliminary simulation results.

References:
E. Keihänen and M. Reinecke. ArtDeco: a beam-deconvolution code for absolute cosmic microwave background measurements. Astronomy and Astrophysics, 548:A110, December 2012

E. Keihänen, K. Kiiveri, H. Kurki-Suonio, and M. Reinecke. Application of beam deconvolution to power spectrum estimation. MNRAS, 466:1348, 2017

Presenter: Dr KEIHÄNEN, Elina (University of Helsinki)

Session Classification: 9. method: analysis 1

Contribution ID: **49** Type: **not specified**

Controlling Beam Systematics in Next Generation CMB Experiments

Wednesday 2 December 2020 18:10 (25 minutes)

Future CMB experiments will require an unprecedented control of systematics in order to constrain the B-mode polarisation power spectrum. There are a plethora of different systematics which effect the measurements of the CMB, but in this talk we shall concentrate on the effects of beam systematics resulting from optical imperfections that can lead to contamination of the observed signals. One particular concern of these types of systematics is that they can result in mixing of signals of different "spin", causing leakage from the much larger spin-0 intensity signal to the spin-2 polarisation signal –in order to reach their desired sensitivity next generation experiments will need to understand and control this type of contamination. We will present a general overview of the effects of beam systematics, along with some of the ways they may be combatted both in the analysis pipeline and through instrument design and scan strategy.

Presenter: Mr MCCALLUM, Nialh (Jodrell Bank Centre for Astrophysics, University of Manchester)

Session Classification: 9. method: analysis 1

Contribution ID: **50** Type: **not specified**

Absolute calibration of next generation of CMB experiments through current and future observations of the Crab nebula

Wednesday 2 December 2020 18:35 (25 minutes)

One of the most powerful probes to understand the Universe's evolution is the Cosmic Microwave Background (CMB). Lately the search for the CMB polarization B-modes has become one of the main objectives of observational cosmology, leading to active instrumental developments and to a large number of CMB experiments. Nowadays, it is widely recognised that any unambiguous detection of the B-modes polarization pattern requires a detailed, multi-frequency study of foreground contamination levels; a very high control of the systematic effects deriving from the instrument itself and a very high accuracy in the reconstruction of the polarization direction (i.e. polarization angle).
In terms of instrumental systematic effects, one of the main challenges for future
ground-based, balloon-borne, and satellite CMB polarisation experiments is the accurate calibration of the absolute polarisation angle. Apart from the ground calibration an ideal sky calibrator is the Crab nebula (Tau A), which is the most intense polarized astrophysical object in the microwave sky at angular scales of a few arcminutes. Recent studies demonstrated that the polarization angle remains constant in the spectral range of 23-353 GHz, which is of interest for the calibration of CMB experiments. However the uncertainty associated with existing data does not allow yet to reach the sensitivity requirement for a clear detection of
the tensor-to-scalar ratio r, that is directly related to the energy scale of inflation. In order to improve the global uncertainty on the polarization angle we need to add new measurements through independent ground-based observations, using facilities like NIKA2 (Perotto et al. 2020), SCUBA2 (Graves et al. 2019) or SRT (Bolli et al. 2015). In this contribution I will give an overview on the recent measurements of the Crab nebula and discuss the current limitations to accomplish the sensitivity requirements of CMB experiments like LiteBIRD. In addition I will give a perspective on how to overcome these limitations by using state-of-art ground-based observations.

Presenter: Dr RITACCO, Alessia (Institut d'Astrophysique Spatiale (IAS), CNRS and Université Paris Sud, Orsay (FR); Département de Physique, Ecole Normale Supérieure, 24, rue Lhomond 75005 Paris, France)

Session Classification: 9. method: analysis 1

Contribution ID: **51** Type: **not specified**

Determination of the Systematics Related to Polarization Angle Uncertainty and Its Impact on r

Wednesday 2 December 2020 19:00 (25 minutes)

The new generation of CMB B-mode experiments will reach limits of sensitivity never achieved before in order to detect the elusive primordial B-mode signal. However, all these efforts will be futile if we lack a tight control of the systematics. Here, we focus on the systematic that arises from the uncertainty of the polarization angles calibration. Miscalibrated polarization angles induce a mixing of E and B modes which obscures the primordial B-mode signal. We introduce an iterative power-spectra maximum likelihood based method to calculate the polarization angles ($\bar{\alpha}$) from the multi-frequency signal. The basis behind this methodology grounds on nulling the C_ℓ^{EB} power-spectra. Two major assumptions are made: i) the rotation angles are small ($lesssim$6 deg), and, ii) the covariance matrix does not depend on $\bar{\alpha}$ (before the start of the iteration). With these assumptions we obtain an analytical linear system which leads to a very fast computational implementation. We show that with this methodology we are able to determine the rotation angle for each frequency with enough accuracy. In particular, this is proved by applying a parametric component separation technique to recover the CMB in three scenarios: i) signal without rotation angles, ii) signal with rotation angles, and iii) de-rotated signal with the estimation of $\bar{\alpha}$. We find that the systematic introduced by leftover polarization angles in the tensor-to-scalar ratio r are removed after the signal is corrected.

Presenter: Mr DE LA HOZ, Elena (Instituto de Física de Cantabria (UC-CSIC))

Session Classification: 9. method: analysis 1

Contribution ID: **52** Type: **not specified**

B-mode delensing: progress and challenges

Wednesday 2 December 2020 19:45 (25 minutes)

Presenter: Dr SHERWIN, Blake (University of Cambridge)

Session Classification: 10. method: analysis 2

Contribution ID: **53** Type: **not specified**

Calibration strategy and mitigation of systematics effects in the QUIJOTE MFI wide survey

Wednesday 2 December 2020 20:10 (25 minutes)

I will review the current status of the QUIJOTE (Q-U-I JOint TEnerife) experiment, a project with the aim of characterising the polarisation of the Cosmic Microwave Background, and other galactic or extragalactic physical processes that emit in microwaves in the frequency range 10-42GHz, and at large angular scales (1 degree resolution). In particular, I will discuss the status of the wide survey carried out with the first QUIJOTE instrument (MFI), at 11, 13, 17 and 19GHz, and will present some of the challenges in our data processing pipeline: the calibration strategy of the experiment (including gain, polarization efficiency and polarization angle), beam modeling, RFI correction and the set of validation tests.

Presenter: J.A. , Rubiño-Martín

Session Classification: 10. method: analysis 2

Contribution ID: **54** Type: **not specified**

A Null test framework for B-mode measurements with POLARBEAR

Wednesday 2 December 2020 20:35 (25 minutes)

The POLARBEAR experiment has achieved B-mode measurements from degree angular scales to sub-degree angular scales for searching for primordial gravitational waves and measuring gravitational lensing effects of the large-scale structure. To achieve that, we implemented a blind analysis framework so-called "null test" in our analysis. In this talk, I explain our null test framework, which could optimize and validate data and analysis before the final power spectra were obtained.

Presenter: Dr CHINONE, Yuji (The University of Tokyo)

Session Classification: 10. method: analysis 2

Contribution ID: **55** Type: **not specified**

Paving the way towards a robust B-mode measurement

Wednesday 2 December 2020 21:00 (25 minutes)

The primary science goal of the vast majority of upcoming CMB experiments is the detection of B-modes sourced by primordial gravitational waves. While enhanced experimental sensitivity is essential to meet this target, diagnosing and removing sources of contamination that could potentially obscure the primordial B-mode signal will be equally important to claim a robust detection. This contamination can be of either cosmological origin (e.g cosmic polarization rotation induced by either primordial magnetic fields, or by the cosmological birefringence effect) or from uncontrolled instrument systematics. We apply the quadratic estimator (QE) technique to constrain or measure potential sources of contamination in CMB maps. Specifically we discuss the constraints that upcoming experiments including Simons Observatory and LiteBIRD will be able to place on anisotropic CPR. We also extend this QE cleaning formalism to efficiently reconstruct systematic effects, and perform blind cleaning on the CMB polarization maps. We specifically demonstrate the potential of this method by cleaning contamination sourced by differential detector gain from simulated maps with LiteBIRD like instrument characteristics.

Presenter: Mr WILLIAMS, Joel (Jodrell Bank Centre for Astrophysics - The University of Manchester)

Session Classification: 10. method: analysis 2

Contribution ID: **56** Type: **not specified**

A minimal power-spectrum-based moment expansion for CMB B-mode searches.

Wednesday 2 December 2020 21:25 (25 minutes)

The characterization and modelling of polarized foregrounds has become a critical issue in the quest for primordial B-modes. A typical method to proceed is to factorize and parametrize the spectral properties of foregrounds and their scale dependence (i.e. assuming that foreground spectra are well described everywhere by their sky-averaged spectrum). Since in reality foreground properties vary across the Galaxy, this assumption leads to inaccuracies in the model that manifest themselves as biases in the final cosmological parameters (in this case the tensor-to-scalar ratio). This is particularly relevant for surveys over large fractions of the sky, such as the Simons Observatory (SO), where the spectra should be modelled over a distribution of parameter values. Here we propose a method based on the existing "moment expansion" approach to address this issue in a power-spectrum-based analysis that is robust to other sources of instrumental uncertainty. Additionally, the method uses only a small set of parameters with simple physical interpretation, minimizing the impact of foreground uncertainties on the final B-mode constraints. We validate the method using SO-like simulated observations, recovering an unbiased estimate of the tensor-to-scalar ratio r with standard deviation $\sigma(r) \simeq 0.003$, compatible with official forecasts. When applying the method to the public \bicep{} data, we are able to recover constraints on r that follow closely those found by BICEP2/Keck Array in the presence of a scale-independent frequency decorrelation parameter.

Presenter: AZZONI, Susanna (University of Oxford / Kavli IPMU)

Session Classification: 10. method: analysis 2

Contribution ID: **57** Type: **not specified**

Free discussions

Wednesday 2 December 2020 21:50 (25 minutes)

Session Classification: 10. method: analysis 2

Contribution ID: **58** Type: **not specified**

Highlight from Europe-Japan session

Thursday 3 December 2020 08:00 (20 minutes)

Session Classification: 11. method: analysis 3

Contribution ID: **59** Type: **not specified**

Simultaneous determination of the cosmic birefringence and miscalibrated polarization angles

Thursday 3 December 2020 08:20 (25 minutes)

We show that the cosmic birefringence and miscalibrated polarization angles can be determined simultaneously by cosmic microwave background (CMB) experiments using the cross-correlation between E- and B-mode polarization data. This is possible because the polarization angles of the CMB are rotated by both the cosmic birefringence and miscalibration effects, whereas those of the Galactic foreground emission are rotated only by the latter. Our method does not require prior knowledge of the E- and B-mode power spectra of the foreground emission, but uses only the knowledge of the CMB polarization spectra. Specifically, we relate the observed EB correlation to the difference between the observed E- and B-mode spectra in the sky, and use different multipole dependences of the CMB (given by theory) and foreground spectra to derive the likelihood for the miscalibration angle α and the birefringence angle β. We show that a future satellite mission similar to LiteBIRD can determine β with a precision of 6 arcmin.

Presenter: Dr MINAMI, Yuto (KEK)

Session Classification: 11. method: analysis 3

Contribution ID: **60** Type: **not specified**

Analysis of Temperature-to-Polarization Leakage in BICEP3 and Keck Array CMB Data from 2016 to 2018

Thursday 3 December 2020 08:45 (25 minutes)

The BICEP/Keck (BK) experiment is a series of small-aperture refracting telescopes observing degree-scale Cosmic Microwave Background (CMB) polarization from the South Pole in search of a primordial B-mode signature. This B-mode signal arises from inflationary gravitational waves interacting with the CMB, and has amplitude parametrized by the tensor-to-scalar ratio r. As a pair differencing experiment, an important systematic that must be controlled is the differential beam response between the co-located, orthogonally polarized detectors. We use high-fidelity, in-situ measurements of the beam response to estimate the temperature-to-polarization (T—>P) leakage in our latest data including observations from 2016 through 2018. This includes three years of BICEP3 observing at 95 GHz, and multifrequency data from the Keck Array. Here we present measured per-detector far-field beam maps and differential beam mismatch for these receivers, as well as the preliminary results of "beam map simulations", which use these beam maps to observe a simulated temperature (no Q/U) sky to estimate T—>P leakage in our real data.

Presenter: ST GERMAINE, Tyler (Harvard University)

Session Classification: 11. method: analysis 3

Contribution ID: **61** Type: **not specified**

Systematics in delensing

Thursday 3 December 2020 09:10 (25 minutes)

In this talk, I will first present the systematics considered and their impact on the constraint on the tensor-to-scalar ratio r in delensing the BICEP/Keck data. Then, I will discuss systematics considerations for future delensing analyses.

Presenter: Dr WU, Kimmy

Session Classification: 11. method: analysis 3

Contribution ID: **62** Type: **not specified**

Optimizing the interplay of systematic effects and observing strategy in CMB space missions

Thursday 3 December 2020 09:35 (25 minutes)

CMB space missions are uniquely capable of probing the very largest angular scales for the primordial B-mode reionization bump which is the signal least susceptible to contamination from lensing.

A critical piece of this framework will necessarily be the ability of generating synthetic mission datasets of sufficient realism, both in their complexity and their size, to be truly representative of the dataset that would be gathered by a given mission conguration.

In this talk, we aim at outlining the studies that will be performed under the support of an APRA grant.

We firstly focus on showing preliminary results of simulations encoding systematic effects injected with the Time-Ordered Astrophysics Scalable Tools (TOAST) package, such as frequency bandpass mismatch, calibration errors, gain fluctuations, optical beam and Half-Wave plate imperfections.

On a second stage, we will focus on developing efficient mitigation algorithms by constructing, fitting and subtracting appropriate time-domain templates.

Finally, while the degree of any systematic effect will primarily depend on the instrument properties, the effectiveness of the mitigation strategies will mostly depend on the observing strategy. We, thus, aim at optimizing the survey with respect to these mitigations before attempting to quantify the systematics residuals and place requirements on instrument performance.

Presenter: Dr PUGLISI, Giuseppe (UC Berkeley)

Session Classification: 11. method: analysis 3

Contribution ID: **64** Type: **not specified**

Impacts of ice clouds in POLARBEAR

Thursday 3 December 2020 10:20 (25 minutes)

Atmospheric fluctuation is one of the sources of low-frequency noise in ground-based CMB experiments. Since atmospheric emissions are almost unpolarized, they do not directly increase the noise of polarization measurements as far as instruments are well-calibrated. Tropospheric ice clouds, however, scatter upwelling thermal radiations and produce polarized signals. In practice, most of the polarized bursts in the POLARBEAR data occur during cloudy observations. Cloud polarization is a critical noise since it is correlated among detectors and cannot be suppressed by the polarization modulation technique. In POLARBEAR, we apply data selection associated with polarized bursts and cut several percent of the data. We demonstrate example data and discuss impacts on the CMB measurements.

Presenter: Dr TAKAKURA, Satoru (Kavli IPMU)

Session Classification: 12. method: analysis 4

Contribution ID: **65** Type: **not specified**

Unified correction of the EB-leakage from masking and TOD filtering.

Thursday 3 December 2020 11:10 (25 minutes)

In a ground-based CMB experiment, the detection is contaminated by the atmosphere and ground emissions, and there are also temperature-to-polarization leakages. Thus, the time-ordered data (TOD) need to be filtered to reduce those contaminations. However, the filtering will inevitably remove some CMB signals and distort the rest. Especially, it causes additional E-to-B leakage and B-mode suppression that hinder the CMB B-mode detection. In this talk, I will divide the TOD filtering into several kinds from the simplest case to the general case, and show how to solve the E-to-B leakage problem in each case. The solution will include not only the E-to-B leakage but also the B-mode suppression corrections and will satisfy the minimum variance condition. Moreover, the solution works not only for the TOD filtering but also for any linear filtering in the pixel domain.

Presenter: Dr LIU, Hao (Anhui University)

Session Classification: 12. method: analysis 4

Contribution ID: **66** Type: **not specified**

Systematics diagnostics and self-calibration of CMB B-mode measurements with distortion fields for BICEP/Keck and LiteBIRD

Thursday 3 December 2020 10:45 (25 minutes)

Distortions in the primordial cosmic microwave background polarization can correspond to real or conjectured cosmological signals such as gravitational lensing, patchy reionization, and cosmic birefringence, but they can also arise from instrumental systematics such as detector gain fluctuation, differential gain, differential pointing, polarization angle rotation. The distortion fields generate E to B or T to B leakage that contaminates the primordial B-mode signal. These B-modes have unique $\langle EB \rangle$ and $\langle TB \rangle$ correlations that are zero in the primordial B-mode, which can be used to reconstruct the distortion fields. We demonstrate the method and sensitivity with realistic BICEP3 and Keck Array simulations and data, and show that the distortion fields, if existing, can be detected with EB and TB quadratic estimators before any spurious signal shows up in B-mode power spectra. We also give an outlook on applying this method to future space missions such as LiteBIRD.

Presenter: Mr YANG, Hung-I (Eric) (Stanford University)

Session Classification: 12. method: analysis 4

Contribution ID: **67** Type: **not specified**

Towards ending the partial-sky E-B ambiguity in CMB observations

Thursday 3 December 2020 11:35 (25 minutes)

A crucial problem for part-sky analysis of CMB polarization is the E-B leakage problem. Such leakage arises from the presence of ambiguous' modes that satisfy properties of both E and B modes. Solving this problem is critical for primordial polarization B mode detection in part-sky CMB polarization experiments. In this work we introduce a new method for reducing the leakage. We demonstrate that if we complement the E-mode information outside the observation patch with ancillary data from full-sky CMB observations, we can reduce and even effectively remove the E-to-B leakage. For this objective, we produce E-mode Stokes QU maps from Wiener filtered full-sky intensity and polarization CMB observations. We use these maps to fill the sky region that is not observed by the ground-based experiment of interest, and thus complement the part-sky Stokes QU maps. Since the E-mode information is now available on the full sky we see a significant reduction in the E-to-B leakage. We evaluate on simulated data sets the performance of our method for ashallow' fsky=8%, and a 'deep' fsky=2% northern hemisphere sky patch, with AliCPT-like properties, by combining those observations with Planck-like full sky polarization maps. We find that our method outperforms the standard and the pure-B method pseudo-C_\ell estimators for all of our simulations. Our new method gives unbiased estimates of the B-mode power spectrum with near-optimal errors. We also study the application of our method to the CMB-S4 experiment combined with LiteBIRD-like full sky data, and show that using signal-dominated full sky E-mode data we can eliminate the E-to-B leakage problem.

Presenter: Dr GHOSH, Shamik (University of Science and Technology of China)

Session Classification: 12. method: analysis 4

Contribution ID: **68** Type: **not specified**

Free discussions

Thursday 3 December 2020 12:00 (25 minutes)

Session Classification: 12. method: analysis 4

Contribution ID: **69** Type: **not specified**

Calibration insights from BeyondPlanck

Monday 30 November 2020 19:30 (25 minutes)

The BeyondPlanck collaboration recently published the results from mapping out the global Bayesian posterior of instrumental and observational parameters jointly for LFI time-ordered data. These results are the first of their kind, providing an unique new perspective on the calibration process, and in this talk I will share some of the things we learned, and how that can be applied to future experiments.

Presenter: Dr GJERLØW, Eirik (University of Oslo)

Session Classification: 2. Systematics requirement toward the next generation CMB B-mode experiment