Data Analysis: Combination of CMB Datasets

Carlo Baccigalupi

SISSA

on behalf of the Italian CMB community

- Scientific Relevance

- Milestones

- Roles of the Italian Community

- Development & Implementation

From Bersanelli's Talk

Overview

- Scientific Relevance

    - Multi-Frequency Analysis

    - Cross-Correlation with Large Scale Structure (LSS)

- Milestones

    - Short Term (ST, 2016-2019)

    - Middle Term (MT, 2020-2025)

    - Long Term (LT, 2025+)

- Roles of the Italian Community
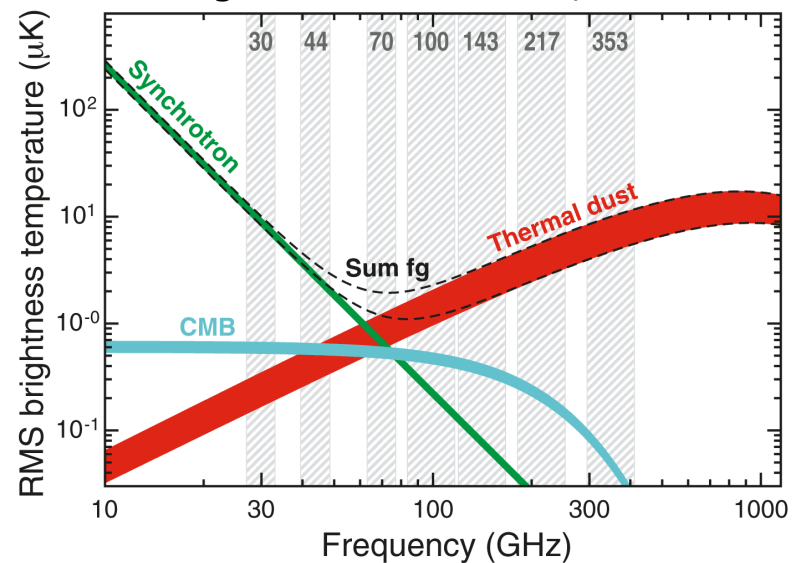
- Development & Implementation Plan

Status and Motivation. Planck 2015 confirms that polarized foregrounds are potentially comparable or dominant with respect to the B-mode signal from primordial GWs at any frequency, any location in the sky

Learing and Model Building (ST, MT): multi-frequency correlation of data for studying foregrounds

Data Analysis (all Terms): design of algorithms combining frequencies for foreground removal and characterization of uncertainties at large, intermediate and small angular scales

Support (ST): EU COMPET-5 2016-2019 grant (www.radioforegrounds.eu , Spain, UK, France, Italy)
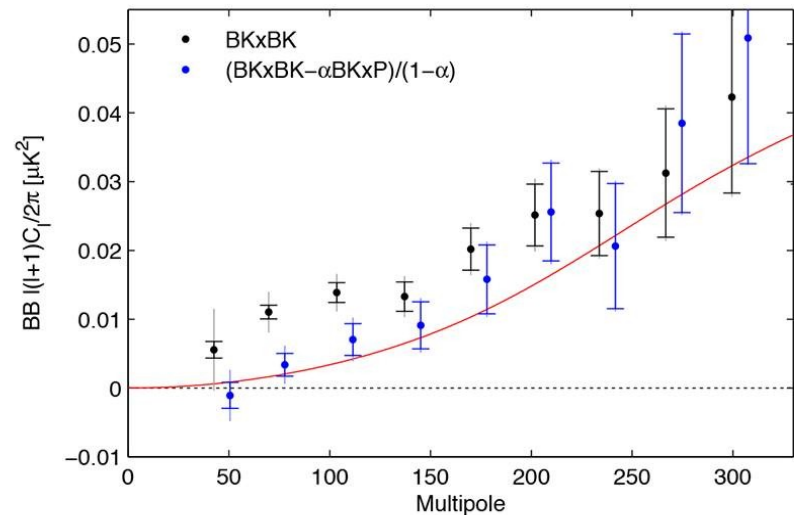
Figure from Planck X, 2015

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Figure from BICEP2×Keck×Planck (BKP), 2015

r≤0.07 (2σ) BKP 2016

Large Scales: CMB temperature changes while crossing evolving cosmological structures (Integrated Sachs-Wolfe, ISW)

Intermediate Scales: Gravitational Lensing (GL) deflection by cosmological structures

Small scales: Point Source Populations, spectral distortion crossing Galaxy Clusters (Sunyaev-Zel-dovich, SZ)

Data Analysis: Simulation infrastructure, Cross-Correlation with LSS, de-Lensing of CMB B-mode spectrum

Impact: Dark Matter and Energy, Cluster and Source Catalogues, B-mode power spectrum measurement through de-Lensing

Multi-Probe Relevance: CMBXC WG within the Euclid Consortium

SIMULATION: COURTESY NIC GROUP, S. COLOMBI, IAP.

Scientific Relevance II/II:
Cross-Correlation with Large Scale Structure

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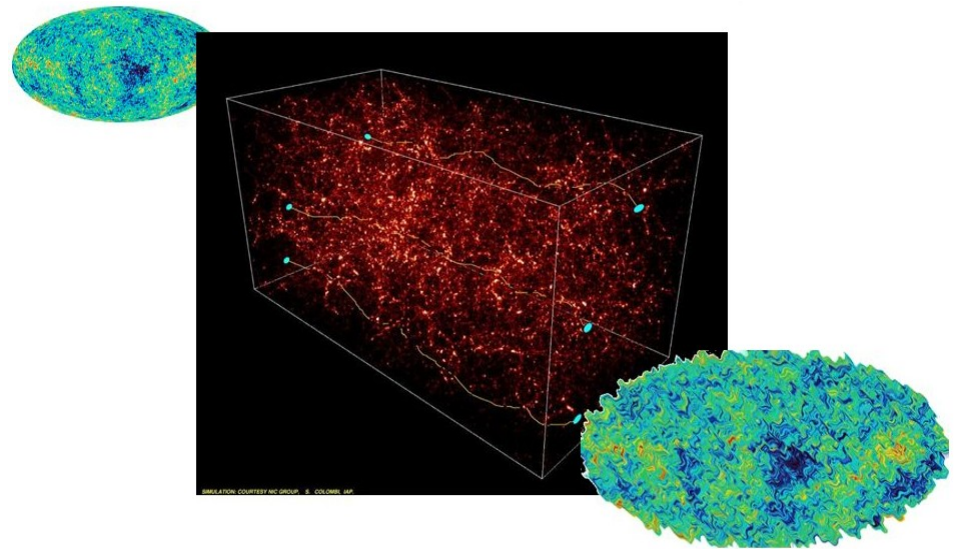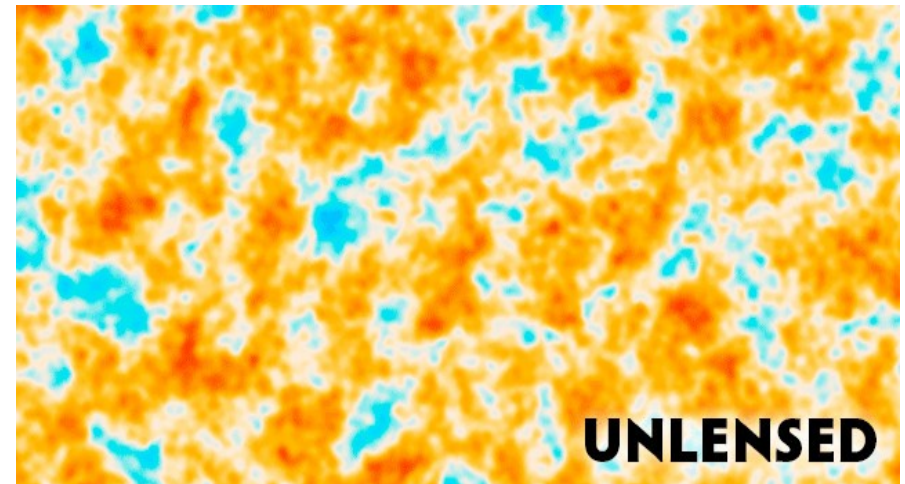
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UNLENSED

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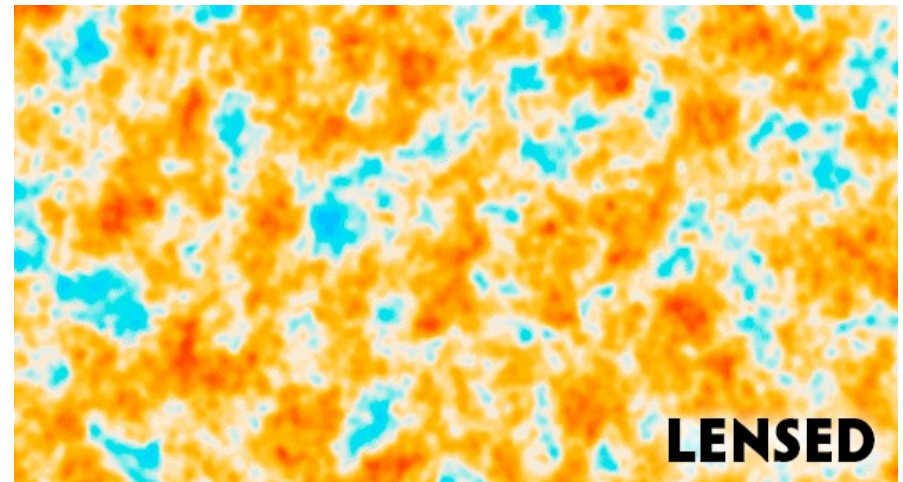
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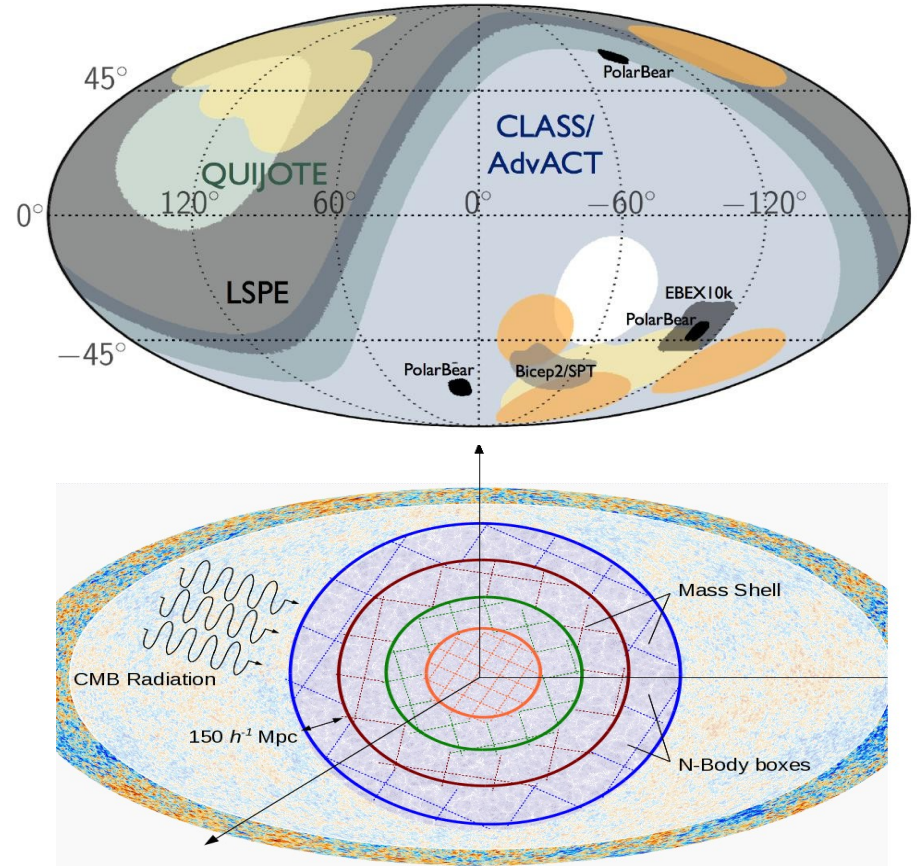**Multi-Probe Relevance**: CMBXC WG within the Euclid Consortium

LENSED

Figures from Krachmalnicoff et al., 2015, Calabrese et al., 2015

Cross-Correlation of CMB Data (LSPE×Planck×QUIJOTE×...) using the ASI supported Data Storage and Exploitation Facilities (ASDC, Planck-LFI DPC) for studying diffuse polarized foregrounds

Cross-Correlation with LSS on existing Data and pre-launch Simulations (order of 10^6 CPU hours/year) within the Euclid Consortium in preparation to Data Analysis
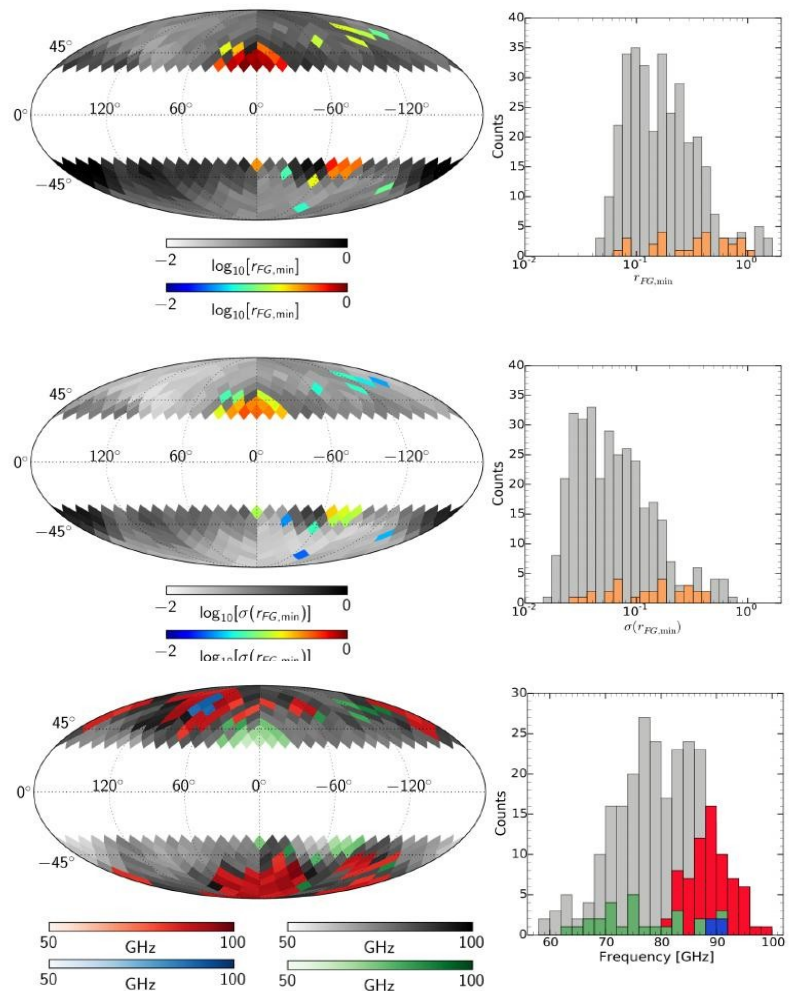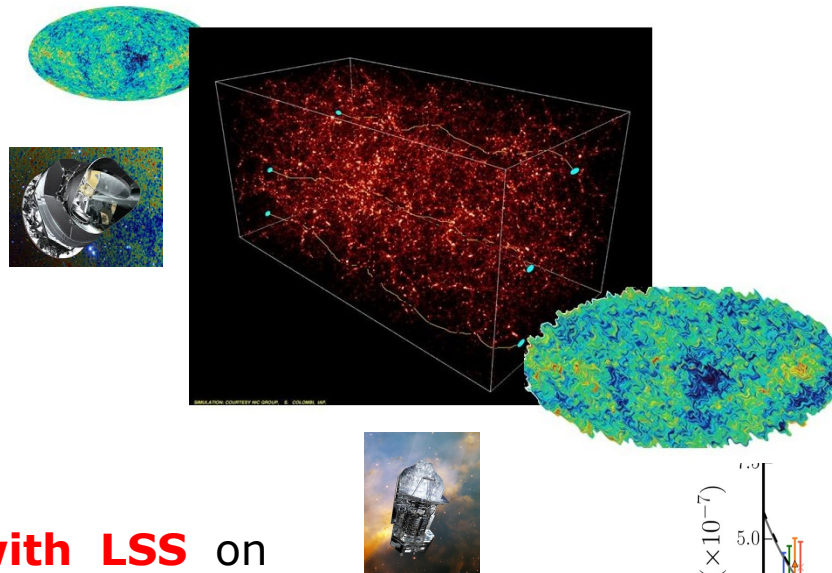
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Figure from Bianchini et al., 2016

herschel

planck

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SISSA

Mass Shell

CMB Radiation

150 h^{-1} Mpc

N-Body boxes

Lensing potential power spectrum per shell

Lensing Power

Multipole ℓ

z = 3.5994 (x 100)
z = 2.4393 (x 100)
z = 1.5718 (x 50)
z = 1.1188 (x 10)
z = 0.5843 (x 5)

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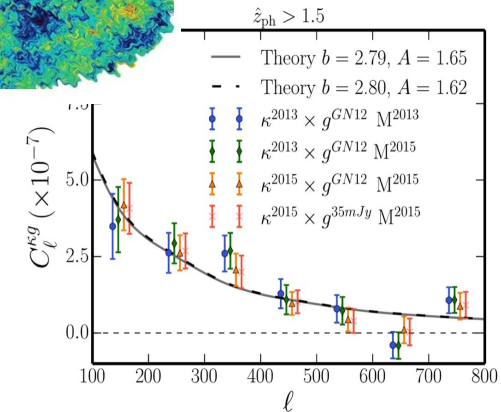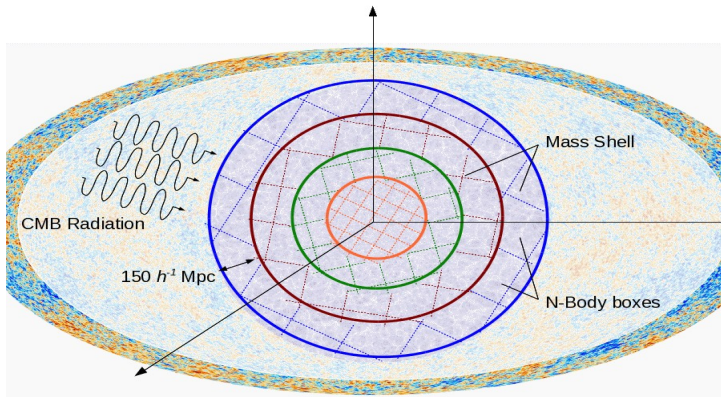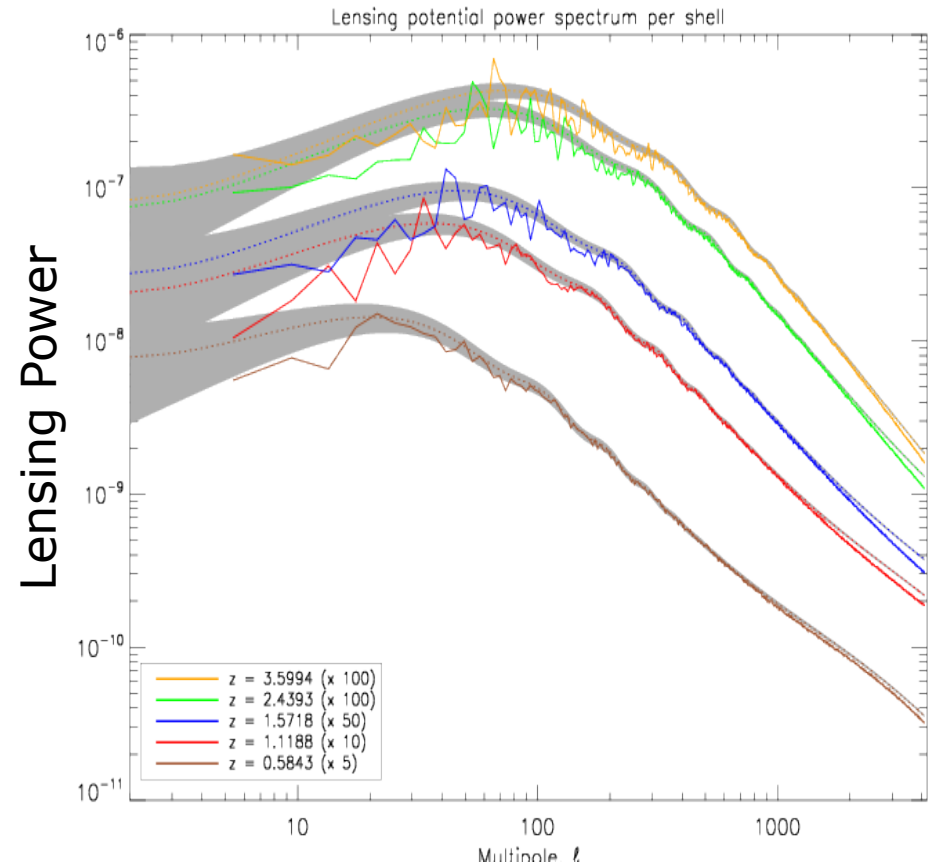
Figures from Calabrese et al., 2015

Euclid
Consortium

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Data Analysis: Foreground Removal for Stage III/IV sub-orbital Probes, Cross-Correlation between CMB lensing and Euclid Data, de-Lensing of the B-mode power spectra

Opportunities: synergy between ground-based observatories for low and intermediate frequencies, and high foreground monitor probes

Measurement of r to 10^{-2} level, measure of **Cross-Correlation** and constraints on the Dark Energy and Matter components

Covered CMB Fields
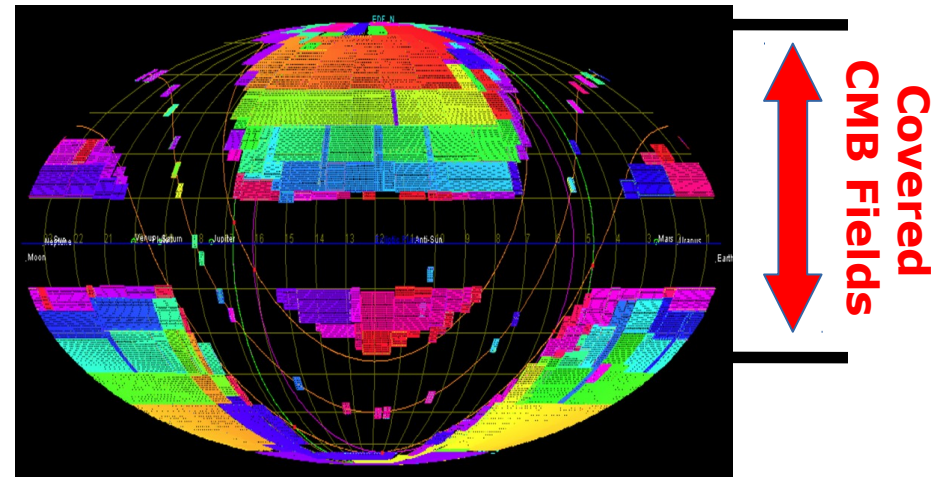
Milestones in the Long Term (2025+)

Probes from **Space (ESA/Jaxa/NASA)** and **ground (S4)**, see talks by deBernardis, Piacentini

SCENARIOS

B-modes from Cosmological Gravitational Waves **detected** previously, power spectrum reconstruction with **foreground cleaning and de-Lensing**, consolidation of **Euclid Legacy** through Cross-Correlation with CMB

OR

B-modes from Cosmological Gravitational Waves **undetected**, ultimate (**foreseen limiting sensitivity r~few×10⁻³**) detection attempt through **foreground cleaning and de-Lensing**, consolidation of **Euclid Legacy** through Cross-Correlation with CMB

Roles of the Italian Community, Short Term

Leading role in Planck (all groups)

Leading role in LSPE (Rome, Bologna, Ferrara, Genova, Milano, Trieste)

Data Reduction for QUBIC, PILOT (Rome, Milan)

Access to QUIJOTE Data for Polarized Foregrounds Study (SISSA, support from the EU RadioForegrounds Program)

Foreground Study/Removal in the **EBEX-IDS** (balloon-borne, NASA, proposed), **PolarBear and Simons Array** (ground-based, NSF+private foundation, ongoing) experiments (SISSA)

Responsability for **CMBXC** Simulation and Preparation for Data Analysis for the **Euclid Consortium** (Euclid Nodes)

From Bersanelli's Talk

Roles of the Italian Community, Middle Term

Exploitation of Data Reduction and Analysis in the ST through Combination/Cross-Correlation of CMB datasets, foreground study/modeling, design and application of Algorithms

Opportunity for **Leading Role in Missions of Opportunity** for Ground-Based Observation Facilities and High Frequency Foreground Monitoring

CMBXC Measurements for the **Euclid Consortium**

From Bersanelli's Talk

Roles of the Italian Community, Long Term

Leading role in the preparation of optimal design of the CORE (ESA/ESA+JAXA+NASA) satellite

Responsability for **CMBXC Cross-Correlation** with Euclid (Euclid nodes)

From Bersanelli's Talk

Development & Implementation

I. Plan for **High Education** targeted to transfer of expertises, Combination of CMB Datasets, to secure Data Analysis and Exploitation

II. ST: **Exploitation** of ASI supported experiments (LSPE×Planck×...) for Foreground Study, Foreground Cleaning Algorithm Development

III. ST: support to the selection of optimal design in the **Study for Mission of Opportunity for Ground-Based Observation Facilities High Frequency Foreground Monitoring** Instruments, complementary, and preparatory to future satellite missions

IV. Development of **CMB-LSS Cross-Correlation Estimators** application to **Euclid data** (ST,MT)

V. Application of **Foreground Cleaning Algorithms to Sub-orbital experiments**, application to Data, support to Simulations (ST, MT)

VI. Development of **De-Lensing** techniques for Sub-Orbital experiments, support to **Simulations, Application to Data** (MT)

VII. Transfer of expertise to **Satellite/Ground-Network LT projects**

Backup

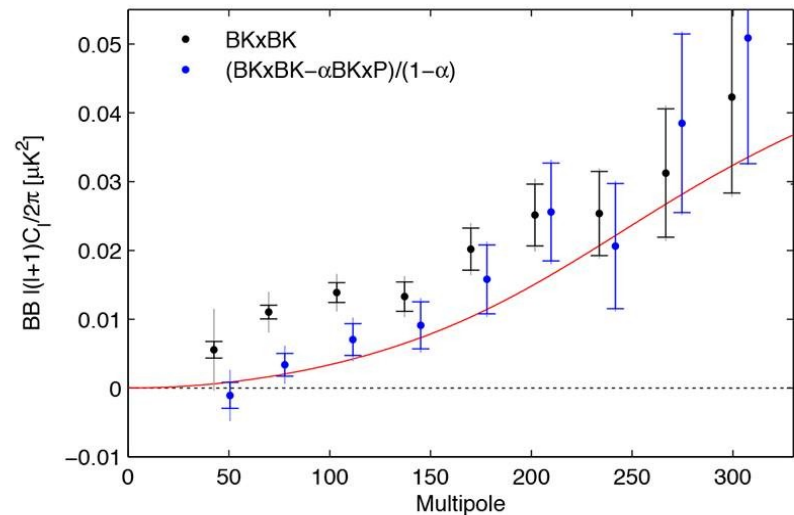# Scientific Relevance I/II: Multi-Frequency Analysis

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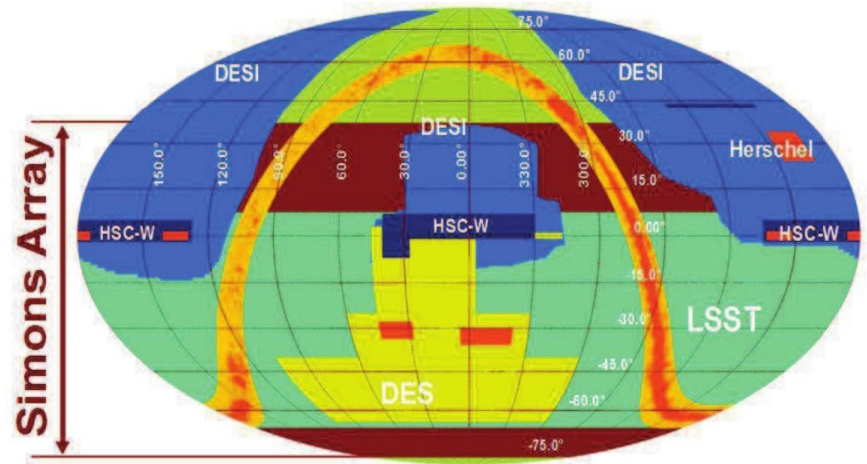Figure from BICEP2×Keck×Planck (BKP), 2015

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Conclusion

- Bla

- Bla

- Bla