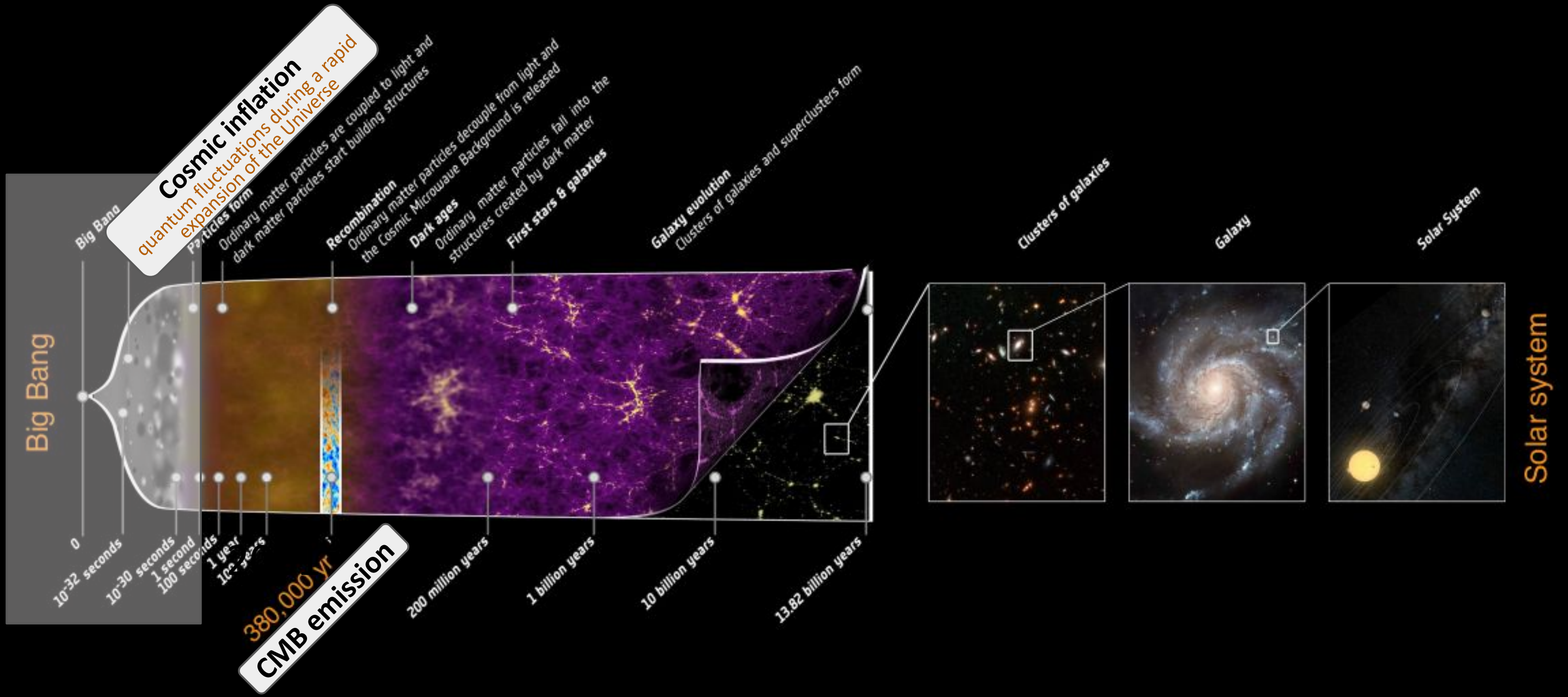
COSmological Microwave Observations Calibration source

COSMOCal web site

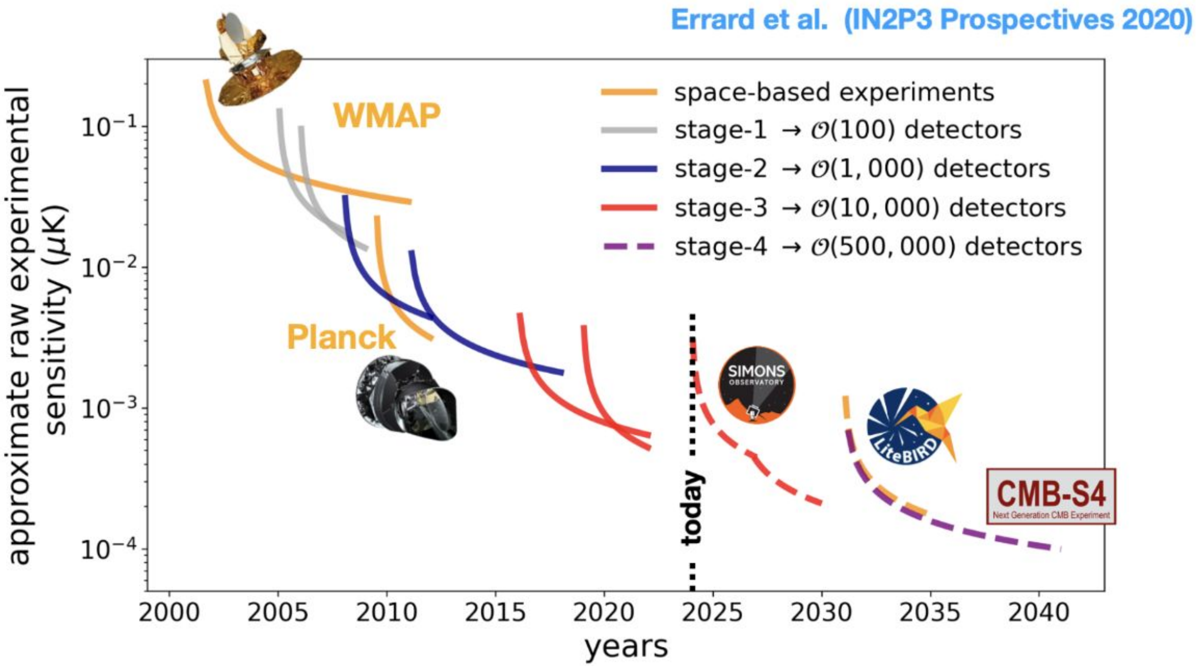
A. Ritacco (CNRS-LPSC)
on behalf of the COSMOCal international collaboration

Primordial Universe probe
The Cosmic Microwave Background



Cosmologists are searching for the imprint on CMB polarization of primordial gravitational waves generated during cosmic inflation

The future of the CMB



Technical Challenges

↓

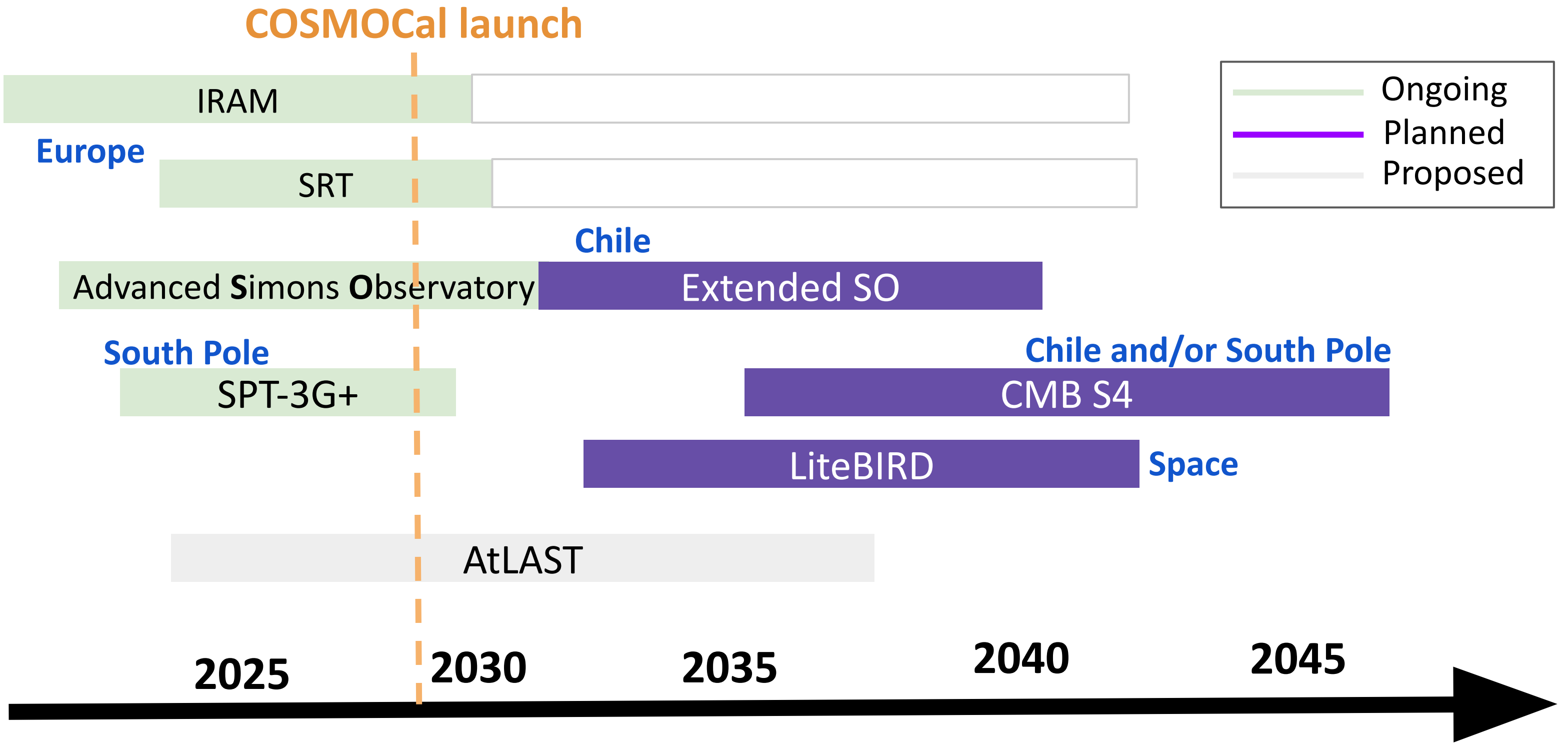
Sensitivity
Systematics
Calibration
Foregrounds

↓

Cosmic **M**icrowave **B**ackground **polarization**

Panorama of experiments of interest for the project

FREQUENCY RANGE 90 - 300 GHz



Space calibrator for microwave observatories worldwide

Absolute calibration of large aperture telescopes

Source in space to be in the far field!

STRATEGY

- Calibration of large telescopes

Polarization Beams, efficiency, angle

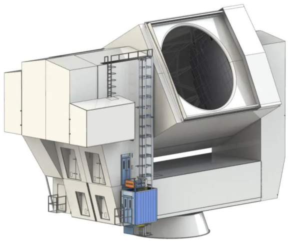
- Observation of sky references

DELIVERABLE

Polarization maps of astrophysical references

FREQUENCY RANGE 90 - 300 GHz

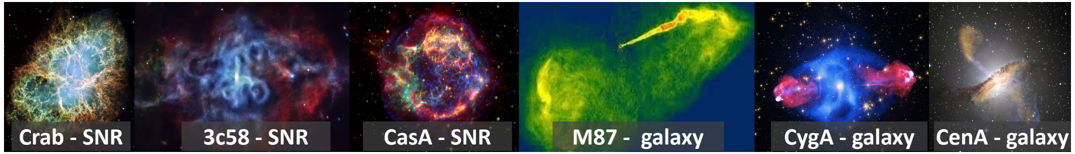
→ to provide also a reference for dust physics and foreground maps



Simons Observatory (Chile)

Sardinia Radio Telescope

SRT



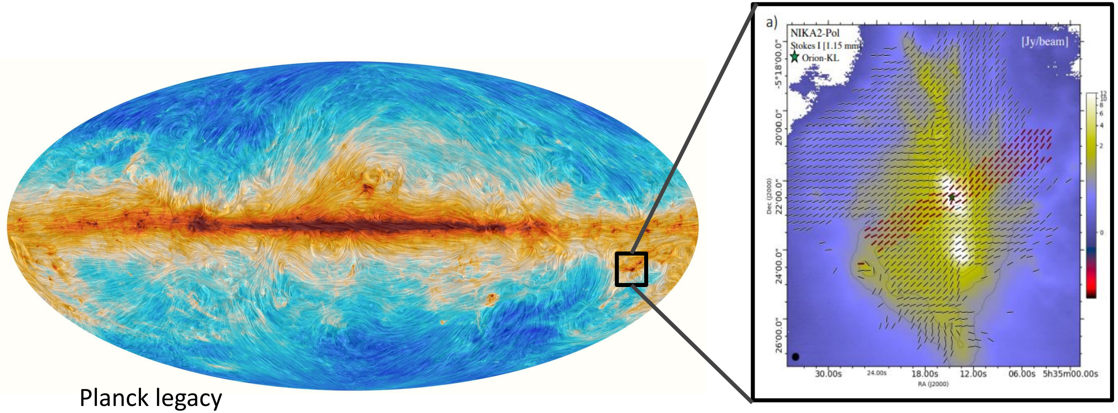
Space mission

Antarctica (?) & Chile

Impact on galactic astrophysics

Observations of dust polarization provide unique insights on
- Interstellar dust
- Cosmic magnetic fields

=> *These two physics are intertwined in the data. It is challenging to separate them.*



Planck legacy

*H. Ajeddig & **NIKA2** Core team*
*EPJWC **257**, 00002*

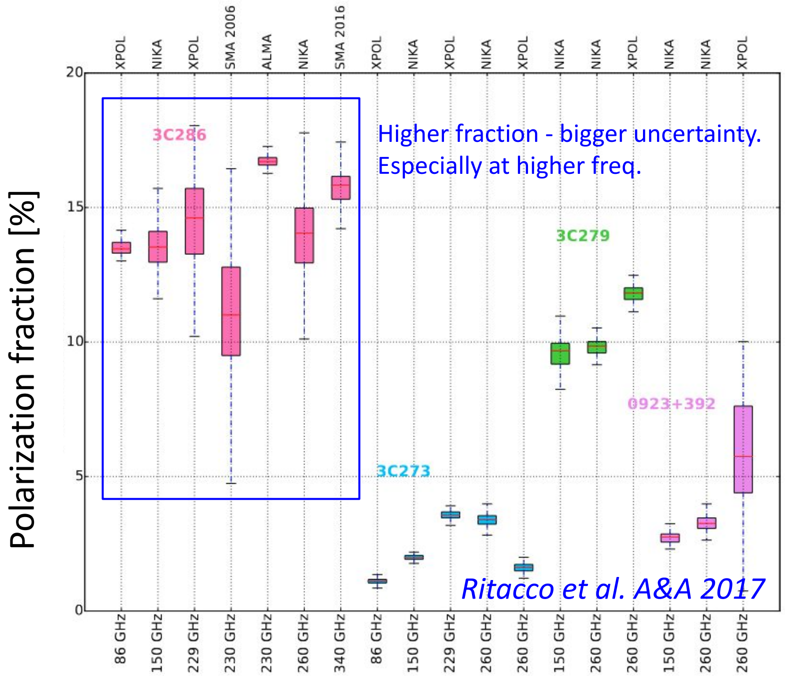
NIKA2/IRAM

Data interpretation rely on the modeling of the polarization fraction and angle
- Accurate measurements of their frequency dependence
- Combination of multi-scale data from small and large telescopes, and also interferometers

=> *Two essential keys that we are presently missing*

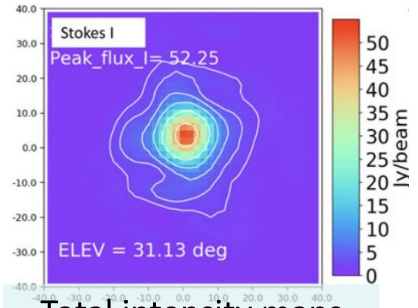
Calibration constraints for a large aperture telescope

Polarization efficiency

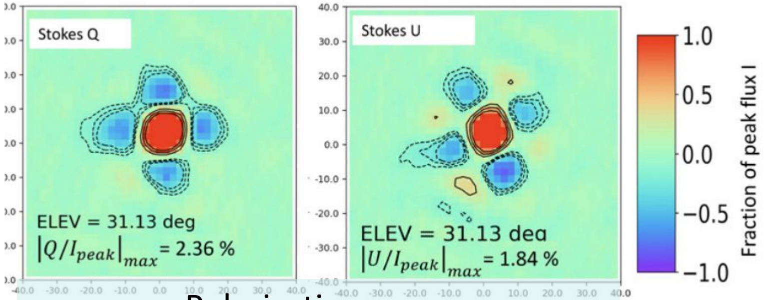


Quasars
Too variable and large uncertainty

Uranus observations/beam systematics



Total intensity maps



Polarization maps

Ajeddig +2020, 2022

COSMOCal timeline

2022

Development of the first prototype to work @ 260 GHz and be tested with NIKA2/30m.

2023

Tests of the components

L. Bizzarri's master thesis (defended in Sept. 2024)

2024

Full prototype's tests

Savorgnano PhD thesis (defense October 2025)

2025-2026 …

Development of the space prototype

Phase A and EM model

Key point at CNES in April 25

2029-2030

Expected launch

Orbit 7.3° WEST
Visible from Europe el > 40°
Visible from Chile el ≃ 18.6°

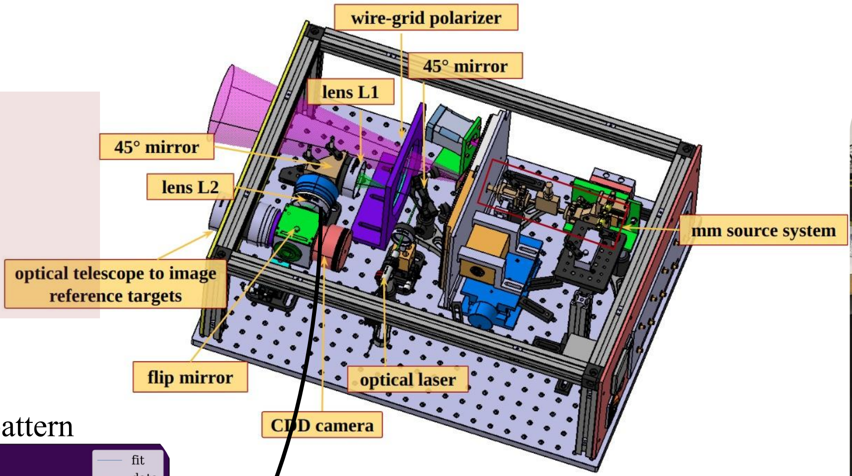
EUTELSAT GROUP

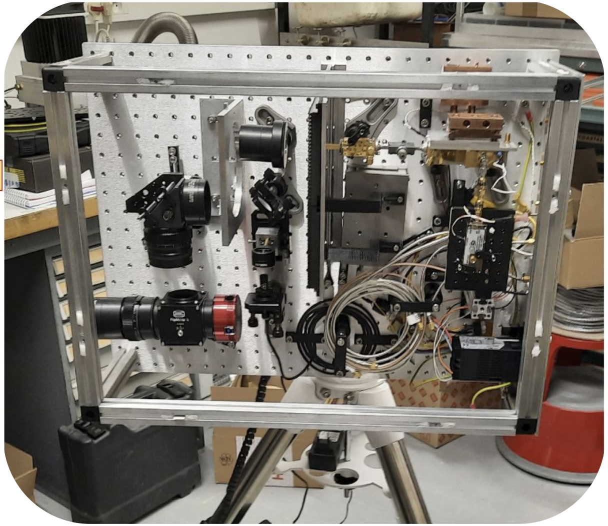
Funded so far by CENSUS, cnes, LPENS

Discussion with CNES are ongoing for funding and development

A prototype at 260 GHz for measurements at Pico Veleta

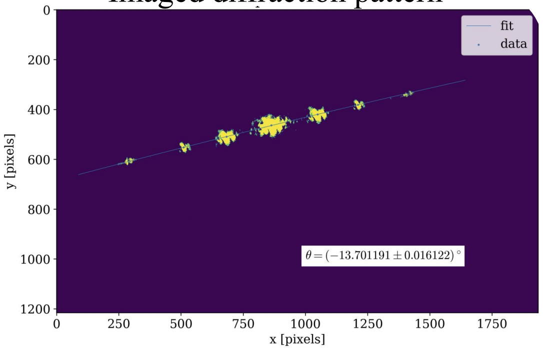
Requirement:
polarization angle
uncertainty 0.1 deg
Results: 0.06 deg.





Fully assembled

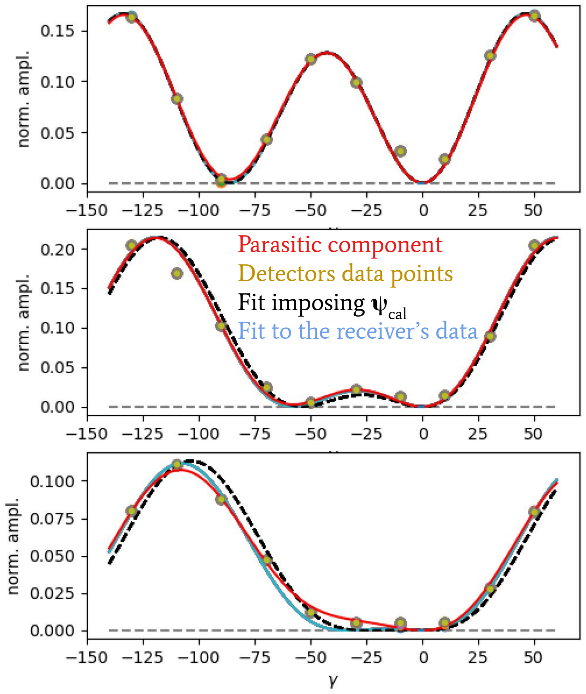
Imaged diffraction pattern



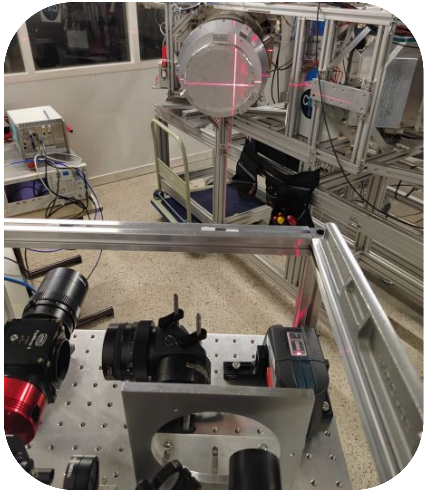
Concept inspired by
Johnson et al. 2015,
Nati et al. 2017, Coppi et al. 2022

A. Ritacco, L. Bizzarri, S. Savorgnano+2024 PASP

Laboratory measurements



A. Ritacco, L. Bizzarri, S. Savorgnano+2024 PASP



COSMOCal instrument in front of a cryostat containing KIDs detectors

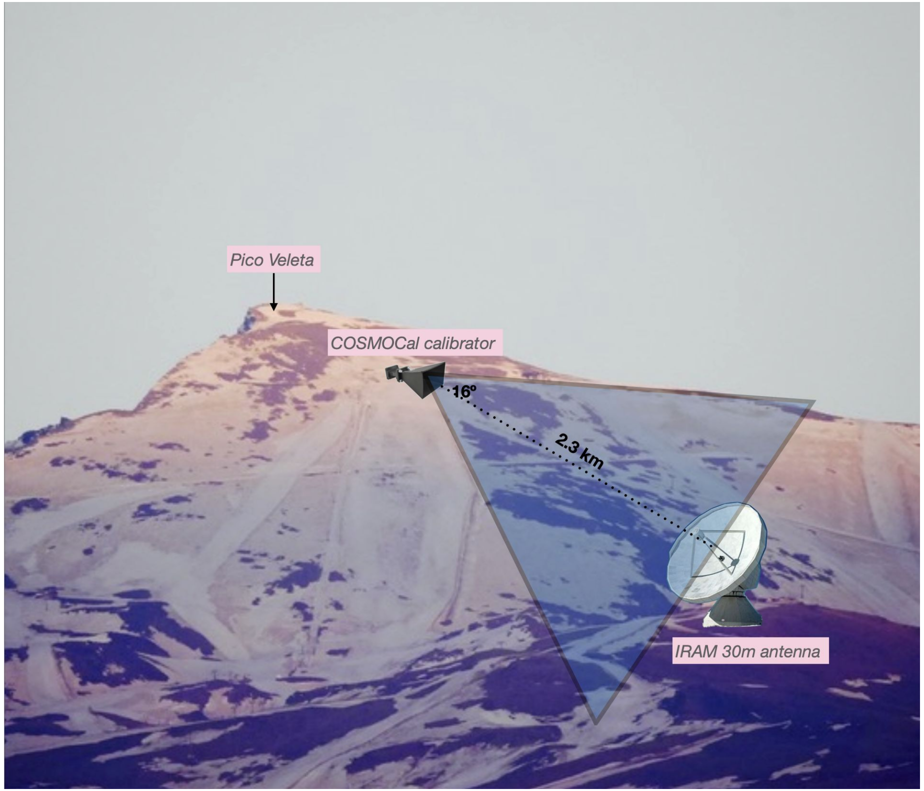
Recovered polarization angle ψ from measurements (yellow dots) with KIDs detectors

1) 4.3 ∓ 0.7 deg
2) 35.6 ∓ 0.9 deg
3) 63.8 ∓ 0.8 deg

Uncertainty dominated by a parasitic signal due to reflections in the lab

Independent measurements of ψ agree within 1-3 % in absolute value.

Measurements at Pico Veleta (Sierra Nevada, ES)



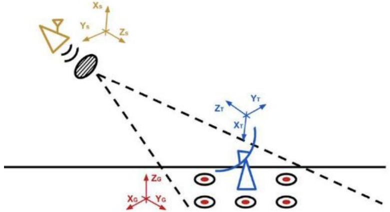
Goals:

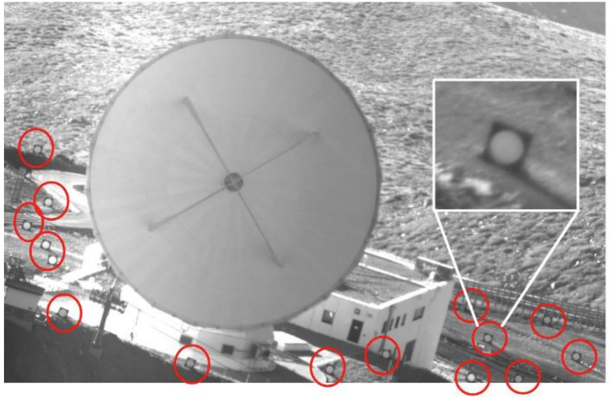
- Testing the interface with a mm telescope;
- Checking the response of cryogenics detectors and the whole optical chain;
- Gaining experience on photogrammetry.

Near field → large beam → radio alignement challenging

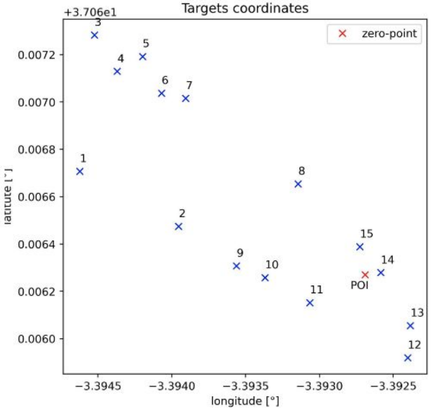
Photogrammetry

Photogrammetry is needed to retrieve the orientation of the calibrator with respect to the line of sight of the telescope.

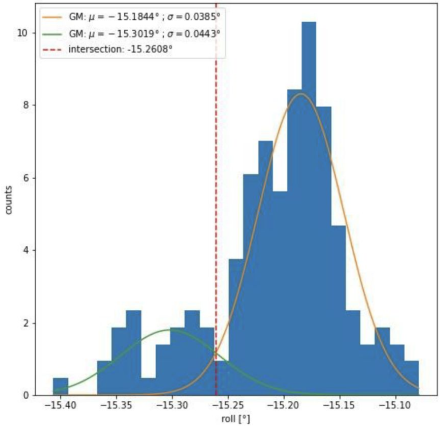




Ground references



From the main Gaussian we can estimate μ (roll)=15.1844° and σ(roll)=0.0385°

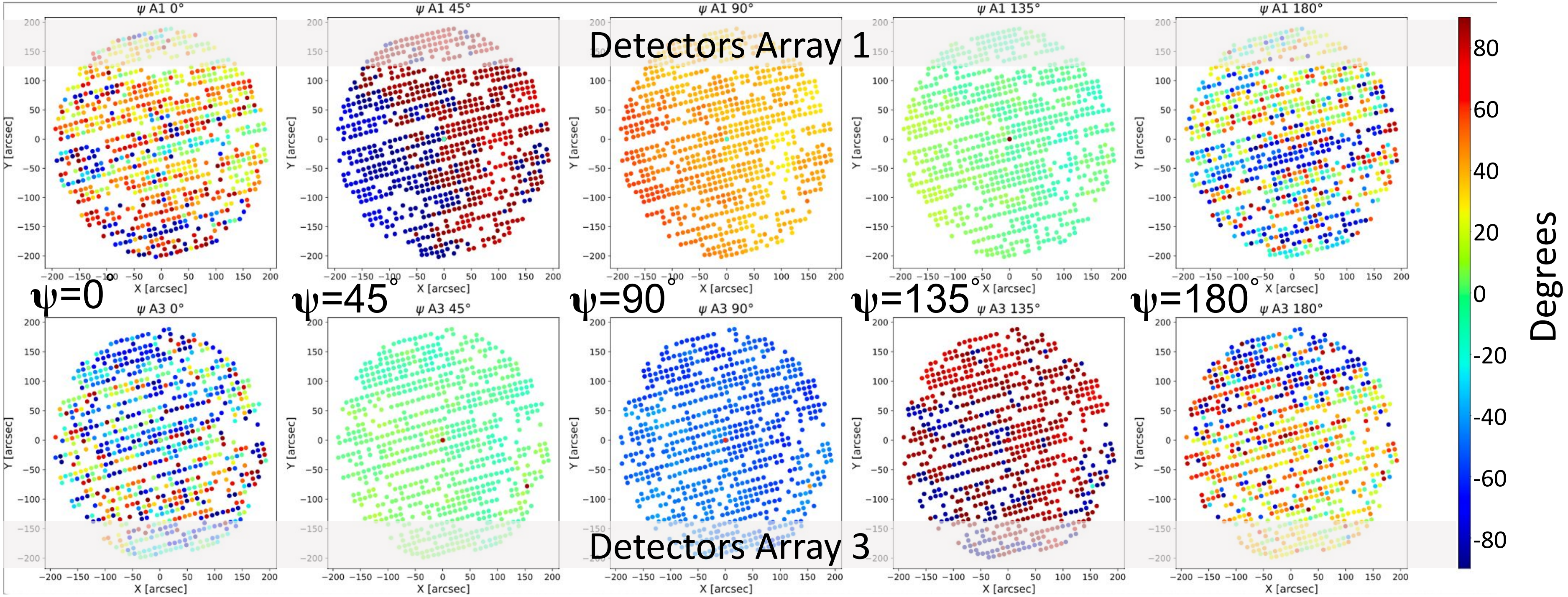


Difficult to identify the center of the targets.

Identification of targets

Credits: L. Bizzarri's master thesis

Polarization angle distribution over the two KIDs arrays of NIKA2/30m @260 GHz



Credits:
Savorgnano's PhD thesis

Alessia Ritacco

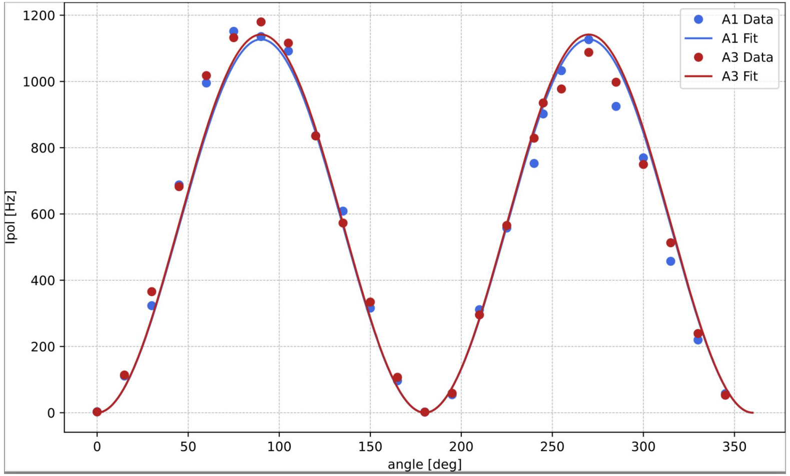
Notice that the 90 deg difference between the two arrays is expected by configuration.

Inhomogeneous distribution due to near field !!

Status of the data analysis

GEO orbit

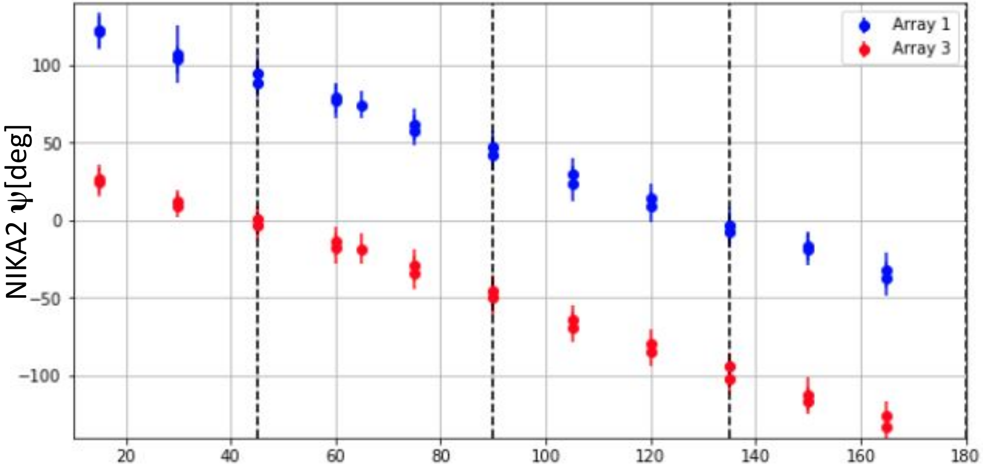
I_{pol}[Hz]



COSMOCal ψ[deg]

Malus law.

NIKA2 ψ[deg]



COSMOCal ψ[deg]

Credits:

Savorgnano's PhD thesis

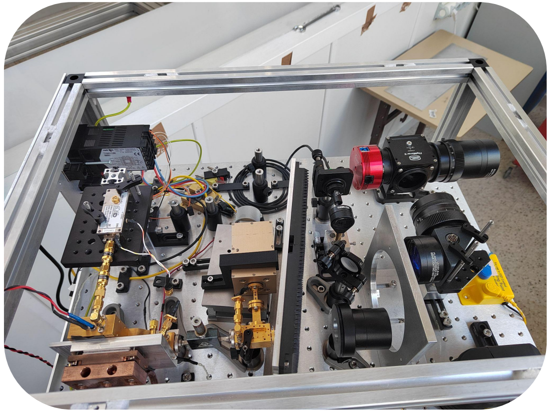
Uncertainties are computed as standard deviation.

Difficult to account for the per-pixel variation.

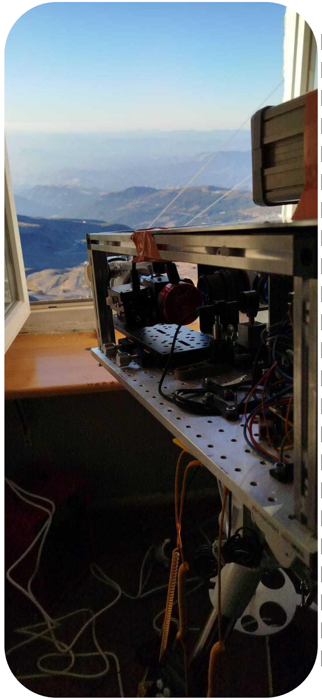
Work in progress

Big limitation: NEAR FIELD measurements.

From a laboratory prototype to a space payload



Laboratory and on-site measurements



IN SPACE

Microwave source

Microwave telescope

Polarizing grid

CDD imager

Gaining knowledge to establish requirements for space

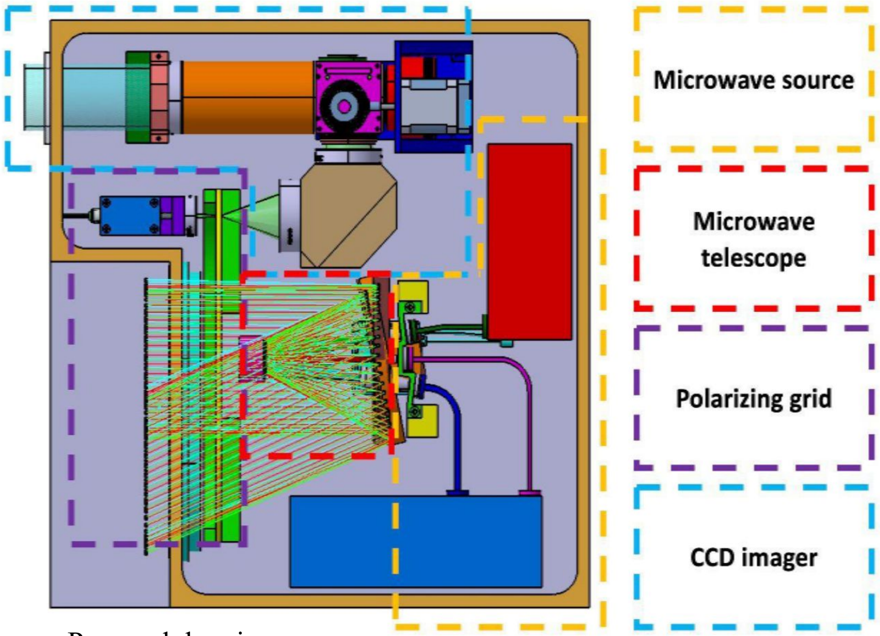
COSMOCal space payload

Frequency range: 90-300 GHz

1. Optical design to maximise the power towards ground telescopes
2. Thermo-mechanical design
3. Interface space platform
4. Multi-frequency
5. High signal power
6. Signal stability

….

Goal: visible from Chile !!



Proposal drawing

Conclusions

COSMOCal aims at providing a **model and instrument** independent method to calibrate polarization experiments within the frequency range 90-300 GHz.

- First prototype → essential to verify the methodology, understand the limitations and improve the design for space.
- Space payload: in the far field, multi-frequency, well adapted for specific telescopes on Earth.