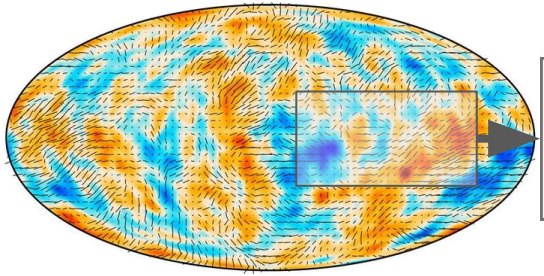
COSmological **M**icrowave **O**bservations **Cal**ibration source

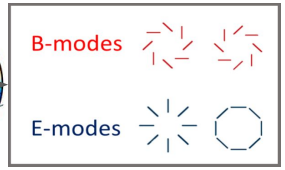
A. Ritacco (CNRS, LPSC institute, Grenoble)
on behalf of the COSMOCal international collaboration

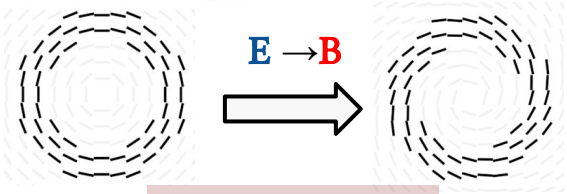
Outline

1. Scientific motivations
2. COSMOCal project overview
3. Proof of concept at 260 GHz and full tests
4. Proposal for space

Probing the inflation theory and beyond





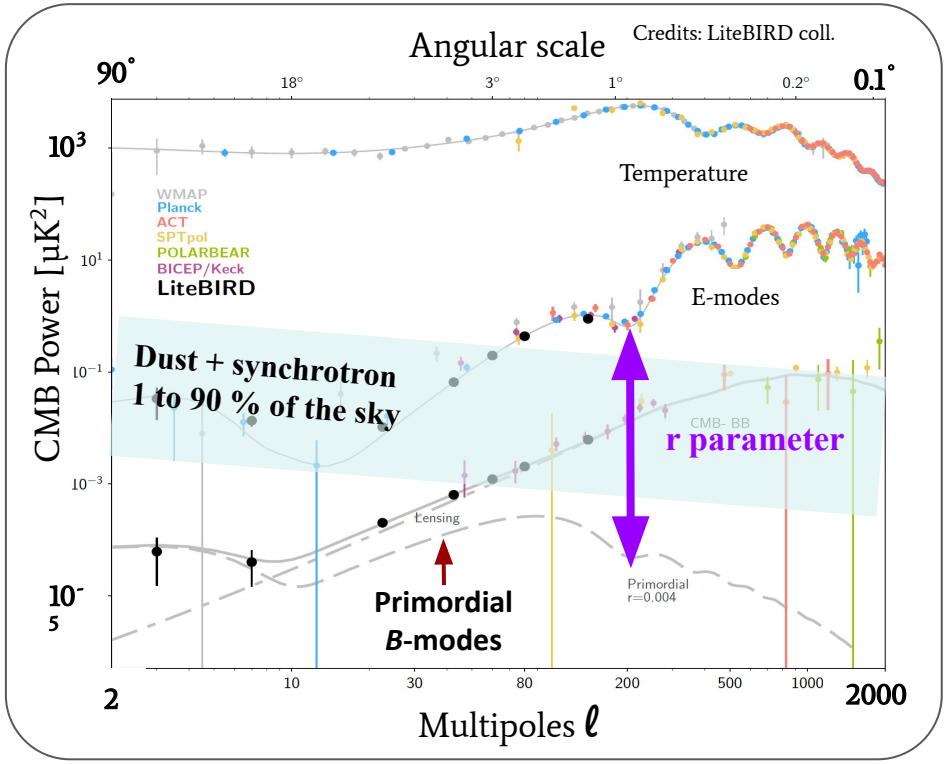


Leakage due to angle mis-calibration

Technical Challenges

- Sensitivity
- Systematics
- Calibration
- Foregrounds

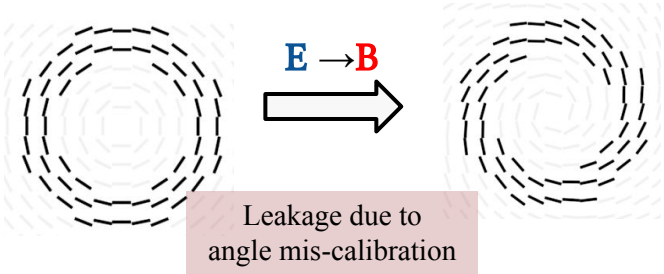
Primordial *B*-modes



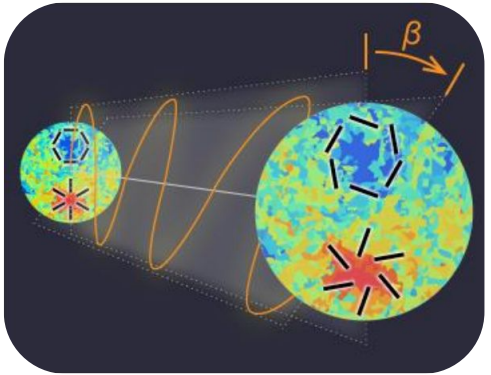
A SCIENCE CASE: the cosmic birefringence

Cosmic birefringence naturally convert *E*<->*B*

$$\begin{pmatrix} E_{\ell m} \\ B_{\ell m} \end{pmatrix}^{obs} = \begin{pmatrix} \cos(2\boldsymbol{\beta}) & -\sin(2\boldsymbol{\beta}) \\ \sin(2\boldsymbol{\beta}) & \cos(2\boldsymbol{\beta}) \end{pmatrix} \begin{pmatrix} E_{\ell m} \\ B_{\ell m} \end{pmatrix}$$



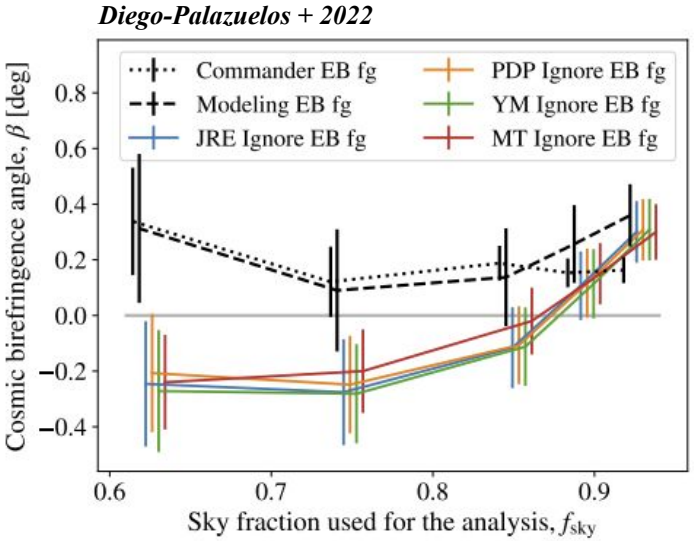
Leakage due to angle mis-calibration



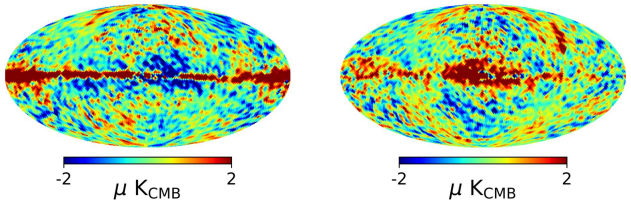
Minami, Yuto et al. 2018

Angle accuracy improval → Break the degeneracy between birefringence angle and CMB detectors orientation → **Insights into:**
- Fundamental particles
- Nature of dark matter
- Primordial magnetic fields

HINTs on Cosmic Birefringence from *Planck data*



Current foreground models lack of information



Dust EB decorrelation with freq. due to polarization angle

➡ **coupling between dust physics and magnetic fields.**

Ritacco *et al. A&A, 670, A163 (**2023**)*
*Vacher et al. A&A 672, A146 (**2023**)*

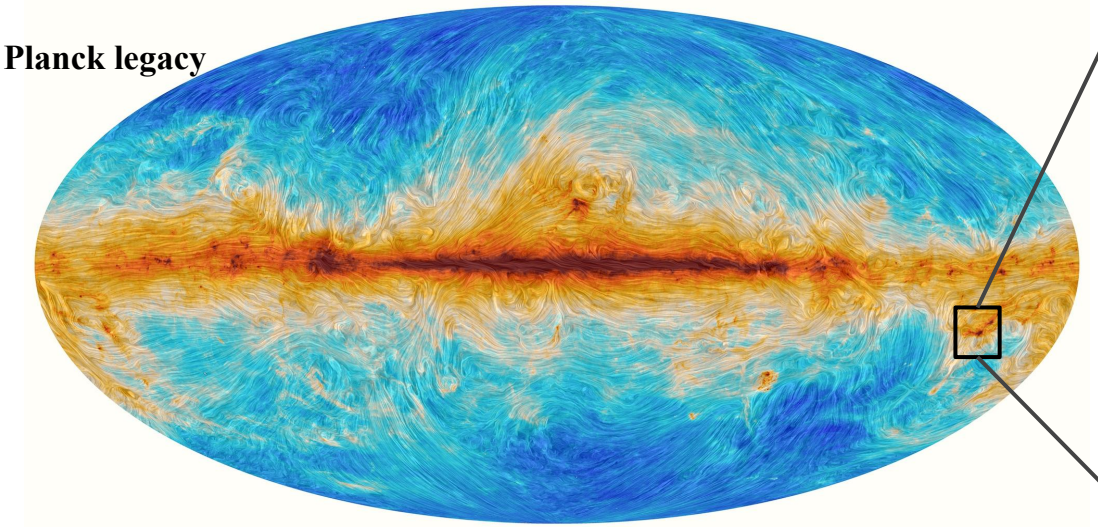
Boulanger's talk

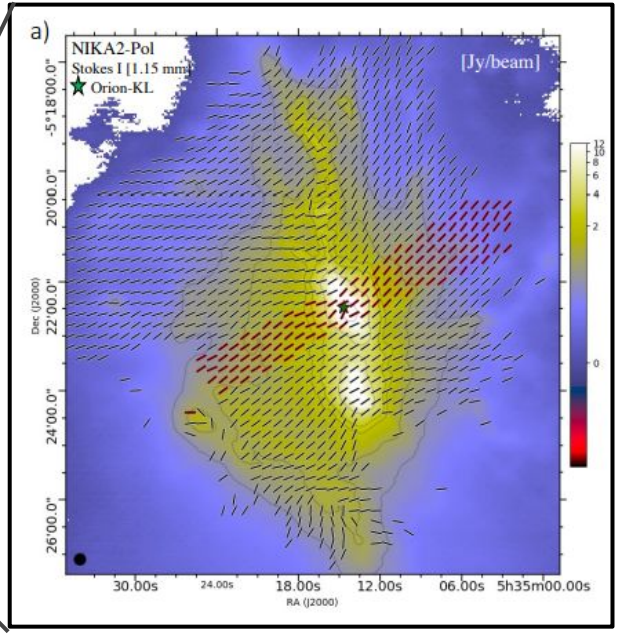
Accuracy in dust emission measurement and
absolute angle calibration is needed

Magnetized dusty interstellar medium

H. Ajeddig & **NIKA2** Core team
EPJ Web of Conferences **257**, 00002

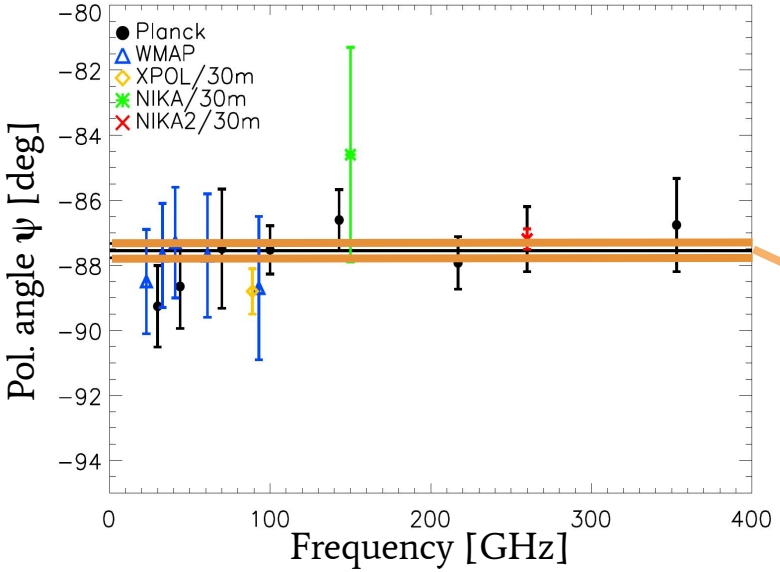
Planck legacy



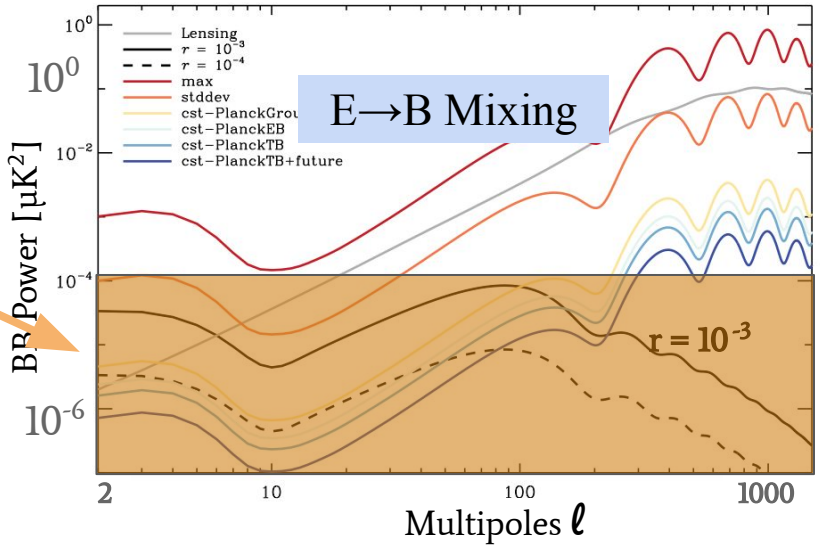


- ➔ ***Planck*** polarization observations had also a major **impact** on **Galactic astrophysics**
- ➔ **Ground based observations** deepen this **unique perspective** on dust and magnetic fields
- ➔ **Precise** measurements of **polarization angles** are also **essential** here

CRAB nebula: a sky calibrator for CMB experiments



Δψ



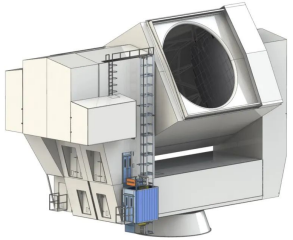
Ritacco et al. 2018 A&A, 616, A35
Aumont et al. A&A 2020
Ritacco et al., EPJ WC 257, 00042 (2022)

Absolute calibration must be improved!

Systematics effect control:

- Telescope's beam
- Leakage of I ->P
- Detectors cross-polarization

Absolute calibration for large aperture telescopes



Simons Observatory

SRT
Sardinia Radio Telescope

iram
Institut de Radioastronomie Millimétrique

Astrophysical reference sources (e.g. Crab nebula)

LiteBIRD

CMB-S4
Next Generation CMB Experiment

STRATEGY

- Calibration of large telescopes
- Observation of sky references

DELIVERABLE

Polarization maps of astrophysical references (in a large band)

FREQUENCY RANGE 90 - 300 GHz

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

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)
See his poster

2024

Full prototype's tests
See S. Savorgnano's talk.

2025-2026 …

Development of the space prototype

Dim-origines proposal (500 kEuro) submitted.

co-PIs:
F. Boulanger, A. Ritacco

2029

Expected launch

EUTELSAT GROUP

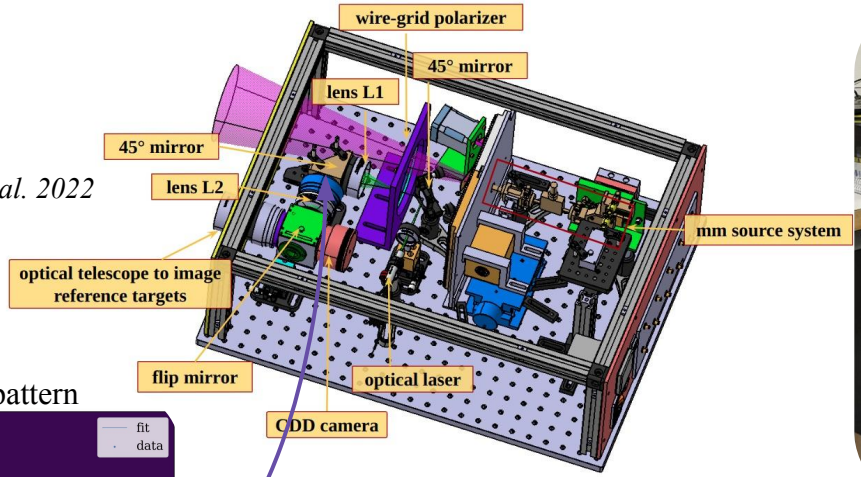
Funded so far by

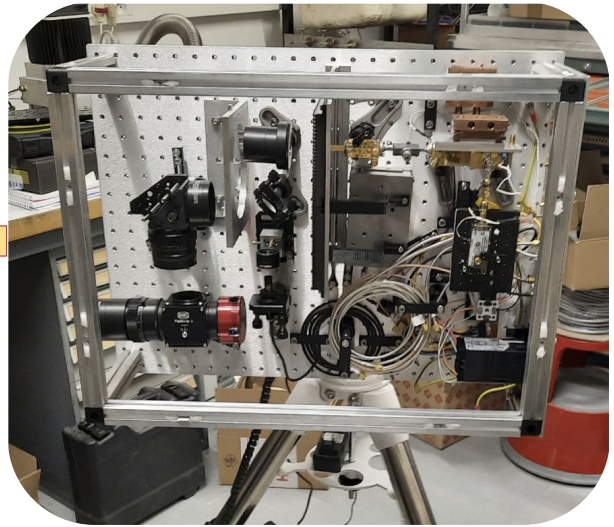
Built up an international collaboration

COSMOCal prototype @ 260 GHz

Ritacco, Bizzarri, Savorgnano et al. 2024 accepted PASP journal
https://arxiv.org/abs/2405.12135

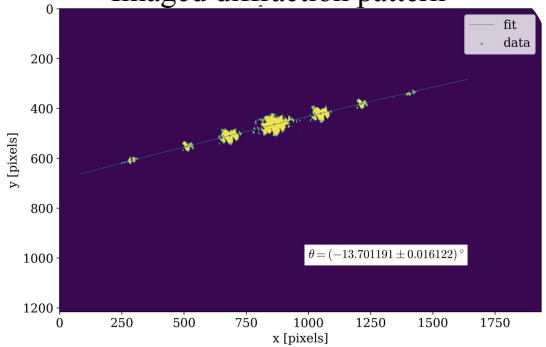
Concept inspired by
Johnson et al. 2015,
Nati et al. 2017, Coppi et al. 2022





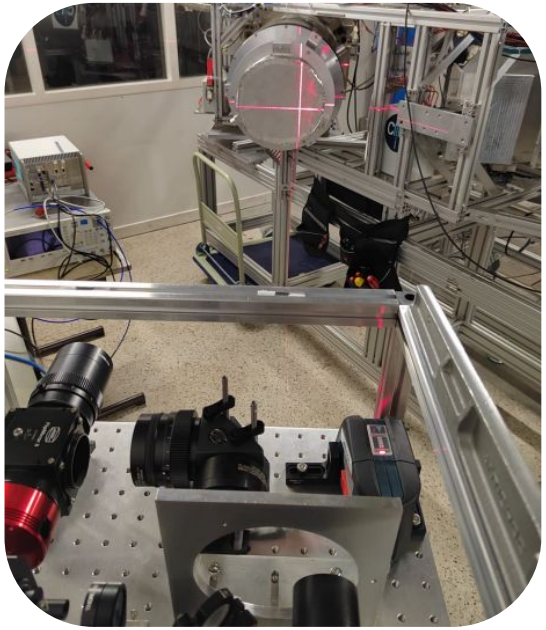
Fully assembled

Imaged diffraction pattern



see L. Bizzarri's poster

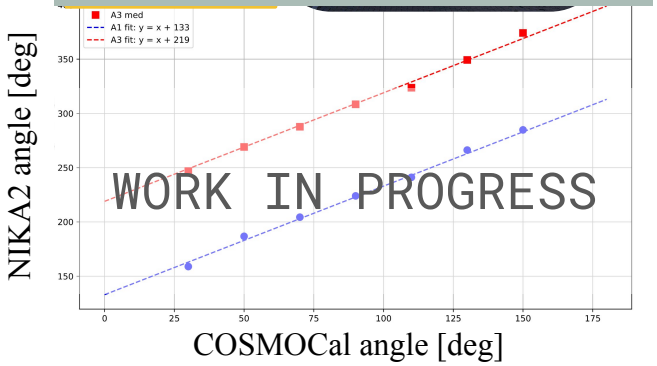
COSMOCal full tests



In laboratory tests
@ LPSC

Campaign at the telescope

Pioneering measurements with a large antenna



Goal: 0.1 deg.
Results: 0.06 deg.

Ritacco, Bizzarri, Savorgnano et al. 2024
accepted PASP journal
https://arxiv.org/abs/2405.12135

→ ***Savorgnano's talk***

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

Eutelsat partnership

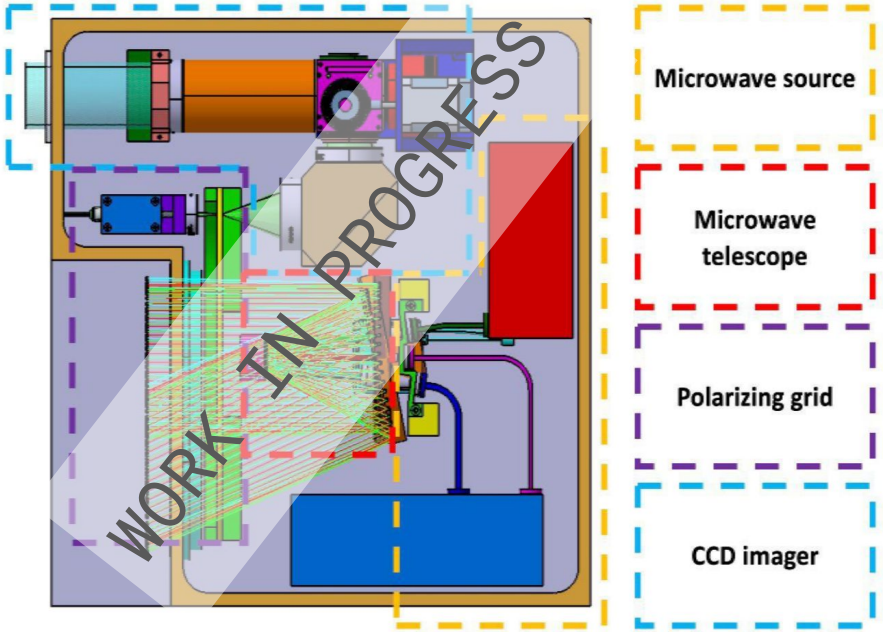
- Partnership initiated through CENSUS in February 2024.
- COSMOCal to be launched in 2029 on a platform of Eutelsat Group in GEO.
- Source visible from both Europe and Atacama.
- Payload design coordinated with engineers from Eutelsat Group.
- COSMOCal specifications to be included in Eutelsat's call for tender to be issued in 2025.
- Partnership opens a new perspective for space astrophysics.

COSMOCal space payload

CHALLENGES

1. Optical design
2. Thermo-mechanical design
3. Interface space platform

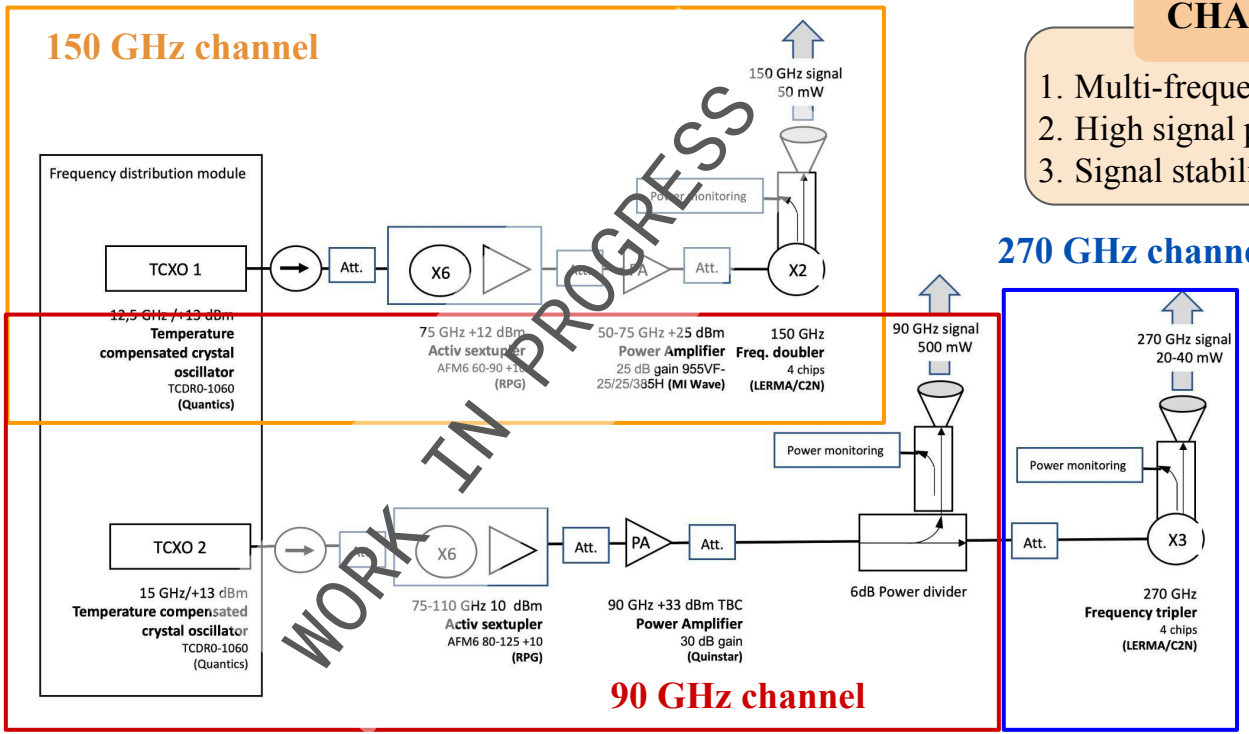
Lead: **P. Morfin (LPENS)**



Proposal drawing

This design aims to minimize the payload volume. A mechanism allows the source to be directed to Europe or Chile.

COSMOCal: microwave source



CHALLENGES

1. Multi-frequency
2. High signal power
3. Signal stability

Lead: **J. Treuttel** (Observatoire de Paris)

Based on JUICE-SWI instrument **space experiment**.
Maximise power.

Design of a **high-power** microwave source with **three frequency channels** (90, 150 & 270 GHz).

COSMOCal summary

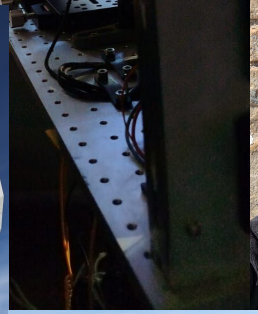
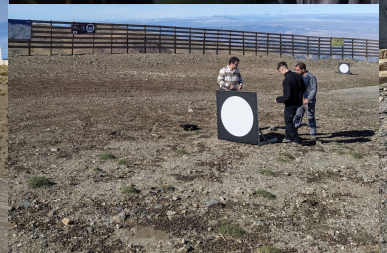
- Timely contribution to **paramount goals of observational cosmology**, in phase with the deployment of ambitious CMB experiments.
- Deeper perspective on **dust polarization** & the **physics of the magnetized ISM.**
- Training opportunities in space instrumentation, microwave technology, astrophysics and cosmology.
- Space proposal supported by a **proof-of-concept** instrument successfully tested with NIKA2 at the **IRAM 30m**. *Data analysis is ongoing on NIKA2 data.*
- **Cooperation between private and public entities** minimizing the proliferation of spacecraft in orbit around the Earth.





UGR station
Zeyas station




THANKS



OXFORD
ENGLAND